REPORT

Downtown Redmond Link Extension Geotechnical Data Report

Submitted to:

Parametrix

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APPENDICES

1.0 INTRODUCTION

Golder Associates Inc. (Golder) prepared this Geotechnical Data Report (GDR) to summarize the geotechnical exploration program performed for the Sound Transit's Downtown Redmond Link Extension (DRLE) project. This GDR includes records of boreholes, results of in-situ and laboratory testing performed, and other supplementary information gathered to date.

1.1 Project Summary

The DRLE segment is a proposed 3.4 mile extension of Sound Transit's regional light rail system. Figure 1 shows the approximate vicinity of the project. The alignment begins near NE 40th Street in Redmond, Washington and extends north and east along the eastside of the State Route (SR) - 520 freeway. The alignment then turns east with the freeway, crossing the Sammamish River and descending into Marymoor Park, until reaching the Redmond Way Exit. At the Redmond Way Exit, the light rail alignment turns to the northwest, crosses under SR-520 and over Bear Creek, and then follows the Redmond Central Connector (RCC) alignment into downtown Redmond. The light rail alignment terminates at the proposed Downtown Redmond Station located at the north side of Redmond Town Center.

The current project adds two stations: the Southeast Redmond Station and the Downtown Redmond Station. The current design concept for the DRLE segment consists of a mix of at-grade and elevated track as well as several areas of cuts and fills.

1.2 Use of Report

This GDR presents the data from field explorations and in situ and laboratory testing of subsurface conditions at the specific locations and depths indicated using the means and methods described in this report. No other representation is made. This exploration plan was performed in general accordance with locally accepted geotechnical engineering practice to provide information for the area explored.

Subsurface conditions, such as those that may be interpreted from exploration records and test results included in this report, should not be construed as a guarantee or warranty of any subsurface conditions. Stratigraphic contacts depicted in the exploration records represent approximate boundaries between geologic deposits. There are possible variations in the subsurface conditions between the exploration areas and in groundwater conditions with time.

This report should be made available to prospective contractors for information or factual data only. No implications or recommendations are made in this report. It is the responsibility of the contractor to interpret the data presented in this report. The data are technical in nature and the contractor may wish to seek qualified help to interpret the data.

The scope of our services included limited review of regulatory records and environmental screening of soil samples for the purpose of protecting field personnel and the environment from potential contamination during drilling and for the disposal of investigation-derived waste (IDW). We did not perform detailed environmental assessments or evaluations regarding the presence or absence of hazardous or toxic materials in the soil, surface water, groundwater, or air, on or below the site.

2.0 GEOTECHNICAL EXPLORATION PROGRAM

2.1 Datums

All elevation values presented in this report are provided based on vertical datum NAVD88. Horizontal northing and easting values are presented in the DRLE project datum.

2.2 Existing Information

The records of historical boreholes and test pits shown on Figure 2 were provided in a separate document (Golder 2018).

2.3 Borehole Explorations

Golder boreholes were advanced with either hollow stem auger, mud rotary, or sonic drilling methods, depending on ground conditions. Drilling methods are indicated on the records of boreholes. Explorations in areas with a high density of buried utilities were generally air vacuumed to about 7½ feet below ground surface (bgs) to avoid unmarked utilities before continuing with planned drilling.

Standard penetration testing was conducted in accordance the Standard Penetration Test Method American Society for Testing and Materials (ASTM) D1586-11 using a 140-pound automatic hammer falling freely 30 inches, driving a 2-inch diameter split spoon. Standard penetration tests and sample collections were conducted as appropriate for ground conditions encountered, generally at 2.5-foot intervals until a depth of 15 bgs, then every 5 feet until depths explored. Modified California (3-inch O.D.) samplers were used when no sample recovery was obtained utilizing the standard split spoon sampler or when a larger samples were required (i.e. for archaeological screening). Thin-walled sampling tubes (Shelby tubes) were used selectively when soft-to-firm, fine-grained sediments were encountered. Soil samples were logged on site by either a Golder geotechnical engineer or geologist, then placed in plastic jars for transport to Golder's soil laboratory located in Redmond, Washington for additional review and third-party testing. Boreholes were backfilled with bentonite chips or bentonite grout and capped to match surface conditions in general accordance with Washington State Department of Ecology regulations. Piezometers were installed in selected boreholes. Waste and auger cuttings were drummed and sealed for offsite disposal by Golder's drilling subcontractors.

As part of the DRLE field investigation program from July 2017 to March 2018, a total of 42 exploratory boreholes were completed along the proposed alignment, as shown on Figure 2 and tabulated in Table 2-1. Golder's records of borehole explorations are presented in Appendix A.

2.4 Test Pit Explorations

Golder test pits were excavated in March 2018 with a rubber tracked mini excavator. Soil samples were logged on site by a Golder geologist and placed in plastic bags for transport to Golder's soil laboratory located in Redmond, Washington for additional review and third-party testing. Upon completion, test pits were backfilled with the excavated material and the backfilled material was tamped using the excavation equipment to minimize surface settlement to the extent possible.

As part of the DRLE field investigation program, a total of 5 test pits were completed along the proposed alignment, as shown on Figure 2 and tabulated in Table 2-1. Golder's records of test pits are presented in Appendix B.

2.5 Soil Classification

Soil classification for this project was based on ASTM D 2487-17, Standard Practice for Classification of Soils for Engineering Purposes, Unified Soil Classification System (USCS), and ASTM D 2488-17, Standard Practice for Description and Identification of Soils (Visual-Manual Procedures).

2.6 Test Pits Infiltration Testing

As part of the DRLE field investigation program, four small pilot infiltration tests (PIT) were completed at selected test pit locations. The records of the test pits are presented in Appendix B and PIT data are presented in Appendix C.

2.7 Suspension Logging

Global Geophysics, LLC conducted suspension logging in six boreholes: DRLE-G018, DRLE-G031, DRLE-G033, DRLE-G036, DRLE-G037, and DRLE-G037A along the DRLE alignment. The proposed objective of the geophysical investigation was to determine the shear wave velocity of the soil column below the ground surface. The suspension logging report is presented in Appendix D.

2.8 Pressuremeter Testing

In Situ Engineering conducted pressuremeter tests (PMT) during the advancement of two boreholes: DRLE-G018 and DRLE-G031. The purpose of the PMTs was to evaluate the in situ engineering properties (shear strength, limit pressure, and shear modulus) of materials encountered downhole. The pressuremeter testing report is presented in Appendix E.

2.9 Groundwater Monitoring

Thirteen (13) vibrating wire piezometers (VWP) and 1 standpipe piezometer were installed in selected boreholes and test pits as presented in Table 2-1. Piezometers were installed to monitor variations in groundwater levels during different times of the year along the proposed alignment. Groundwater data summary is presented in Table 2-2.

2.10 Slug Well Monitoring

Three slug wells were installed in selected boreholes (DRLE-G027, DRLE-G034, DRLE-G036) to monitor groundwater levels and to estimate the hydraulic conductivity of the soils near or below the groundwater table. Results from the slug testing are presented in Appendix F.

3.0 LABORATORY TESTING

Various laboratory tests were performed on selected soil samples collected during the DRLE field investigation program were tested at four different laboratories and are described in the following sections.

3.1 Soil Testing (Hayre McElroy and Associates, LLC)

Selected soil samples collected during the field investigation program were sent to Hayre McElroy and Associates, LLC (HMA) for soil testing including moisture content, grain size distribution, Atterberg limit, and organic content tests. Results of the soil testing completed by HMA are presented in Appendix G.

3.2 Soil Testing (HWA Geosciences Inc.)

Selected relatively undisturbed Shelby tube samples collected during the field investigation program were sent to HWA Geosciences Inc. (HWA) for soil testing including unconsolidated undrained triaxial and consolidation tests. Supplementary Atterberg limit tests were also performed. Results of the soil testing completed by HWA are presented in Appendix H.

3.3 Soil Testing (Golder Associates Ltd.)

Selected relatively undisturbed Shelby tube samples collected during the field investigation program were transported to Golder's laboratory in Burnaby, British Columbia for advanced soil testing. Cyclic direct simple shear (CycDSS), undrained triaxial, consolidation, and other supplementary testing completed at Golder's laboratory are presented in Appendix I.

Prior to CycDSS testing, all Shelby tubes were x-rayed (radiographic examination) by a third party (Acuren Group Inc.) to evaluate the quality of the samples obtained. Results from the X-Rays are presented in Appendix J.

3.4 Soil Testing – Resistivity and Corrosivity (HMA and Onsite Environmental Inc.)

Samples collected during the field investigation program were selected for resistivity and corrosion testing based on the locations of the proposed substations. The tests were conducted by HMA and Onsite Environmental Inc. and included soil resistivity, pH, concentration of chlorides, and redox potential tests. Results are presented in Appendix K.

3.5 Analytical Data (OnSite Environmental Inc.)

Soil cuttings from the upper 5 feet at borehole DRLE-G034 were drummed due to the results of photoionization detector (PID) readings conducted during the field investigation that indicated the potential presence of volatile organic compounds (VOCs). Samples were sent to OnSite Environmental Inc. for analytical testing. Results of the analytical data are presented in Appendix L.

4.0 SUPPLEMENTARY DATA

4.1 VWP Calibration Sheets

VWP calibrations sheets are presented in Appendix M.

4.2 Drill Rig Hammer Efficiencies

Energy calibration reports for the drill rigs used in the DRLE field investigation program are presented in Appendix N. Table N-1 in Appendix N summarizes the borehole, drill rig, hammer efficiency, and corresponding calibration report for reference.

5.0 CLOSING

This Geotechnical Data Report has been prepared for the exclusive use of Sound Transit and Parametrix. Use of this report by others or for another project is at the user's sole risk.

This report should not be construed as a warranty of subsurface conditions. Additional explorations should be completed in support of final design. Within the limitations of scope, schedule, and budget, these services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at this time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Signature Page

Golder Associates Inc.

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6.0 REFERENCES

American Society for Testing and Materials. 2011. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, ASTM D1586-11.

American Society for Testing and Materials. 2017. Standard Practice for Description and Identification of Soils (Visual-Manual Procedures), ASTM D2488-17.

American Society for Testing and Materials. 2017. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM D2487-17.

Golder Associates, Inc. (Golder). 2018. Draft Report. Historical Geotechnical Borehole Records. Submitted to Parametrix. May 25.

TABLES

Table 2-1: Summary of Boreholes and Test Pits

Borehole	Investigation Completion Date	Total Investigation Depth (ft)	Ground Surface Elevation (ft) NAVD88	Northing (ft) Project Datum	Easting (ft) Project Datum	Piezometer Installed?	Piezometer Depth (ft)	Well Installed?	Top of Screen (ft, bgs)	Bottom of screen (ft, bgs)	Seismic Casing Installed?	Pressuremeter Test?	Ecology Tag
DRLE-G001	8/29/2017	100.3	360.8	338867.7	1419712.4	x	-	x	-	-	x	x	-
DRLE-G002	2/13/2018	71.0	369.0	339256.7	1419540.2	VWP	65.0	x	-	-	x	x	BKL443
DRLE-G003	8/30/2017	100.3	371.9	339752.2	1419400.6	x	-	x	-	-	x	x	-
DRLE-G004	8/31/2017	76	366.5	340131.1	1419317.6	x	-	x	-	-	x	x	-
DRLE-G005	9/1/2017	76.3	360.9	340683.8	1419215.4	x	-	x	-	-	x	x	-
DRLE-G006	10/27/2017	61.5	370.7	341330.6	1419279.0	VWP	55.0	x	-	-	x	x	BKY360
DRLE-G007	10/30/2017	51.5	327.0	341739.0	1419201.8	x	-	x	-	-	x	x	-
DRLE-G008	10/31/2017	26.5	282.3	342505.2	1419307.0	x	-	x	-	-	x	x	-
DRLE-G010	9/8/2017	41.0	254.4	343344.5	1419663.2	x	-	x	-	-	x	x	-
DRLE-G011	11/1/2017	41.5	236.8	343826.5	1419758.9	x	-	x	-	-	x	x	-
DRLE-G012	11/2/2017	50.4	223.2	344114.5	1419863.5	x	-	x	-	-	x	x	-
DRLE-G013	11/3/2017	51.5	205.6	344452.1	1419988.4	VWP	45.0	x	-	-	x	x	BKY361
DRLE-G014	11/6/2017	51.3	179.6	344876.2	1420171.1	x	-	x	-	-	x	x	-
DRLE-G015	11/8/2017	101	110.0	345656.6	1421020.7	x	-	x	-	-	x	x	-
DRLE-G016	10/31/2017	101.5	82.7	345795.6	1421474.9	VWP	55.0	x	-	-	x	x	BKL754
DRLE-G017	11/3/2017	60.0	40.7	345808.6	1421706.1	x	-	x	-	-	x	x	-
DRLE-G017A	12/11/2017	240.1	45.2	345743.6	1421718.6	x	-	x	-	-	x	x	-
DRLE-G018	10/30/2017	220.0	40.7	345898.5	1422089.8	VWP	150.0	x	-	-	2.5" PVC	Yes	BKL759
DRLE-G019	7/25/2017	160.3	32.4	345926.9	1422451.4	x	-	x	-	-	x	x	-
DRLE-G020	8/3/2017	201.0	34.6	345946.4	1422844.3	VWP	78.0	x	-	-	x	x	No ID
DRLE-G021	7/20/2017	51.5	35.2	345945.6	1423212.7	x	-	x	-	-	x	x	-
DRLE-G022	7/27/2017	51.5	36.3	345935.5	1423624.4	VWP	47.0	x	-	-	x	x	No ID
DRLE-G023	7/19/2017	51.5	37.0	345926.5	1424001.7	x	-	x	-	-	x	x	-
DRLE-G023b	7/27/2017	6.5	36.9	345926.7	1423994.7	x	-	x	-	-	x	x	-
DRLE-G024	8/11/2017	51.5	40.7	345868.3	1424703.6	VWP	47.0	x	-	-	x	x	BKP465
DRLE-G025	8/9/2017	51.5	41.5	345844.1	1425111.6	x	-	x	-	-	x	x	-
DRLE-G027	9/5/2017	51.5	43.3	346002.0	1425965.7	VWP	48.0	2" PVC	15	25	x	x	BKX314
DRLE-G028	9/7/2017	51.5	41.9	346124.0	1426321.0	x	-	x	-	-	x	x	-
DRLE-G029	1/9/2017	101.5	47.8	346473.1	1426562.2	VWP	80.0	x	-	-	x	x	BKC322
DRLE-G031	9/24/2017	196.5	44.0	346834.4	1425996.7	VWP	80.0	x	-	-	2.5" PVC	Yes	BKP453
DRLE-G032	10/13/2017	236.3	43.8	346976.3	1425590.5	x	-	x	-	-	x	x	-
DRLE-G033	11/16/2017	231.5	43.9	347128.5	1425192.6	x	-	x	-	-	2.5" PVC	x	-
DRLE-G034	8/22/2017	111.5	44.1	347290.3	1424841.6	VWP	80.0	2" PVC	15	25	x	x	BKP464
DRLE-G034A	2/8/2018	145.0	44.2	347288.0	1424808.6	x	-	x	-	-	x	x	-
DRLE-G035	10/9/2017	205.0	42.9	347450.4	1424316.5	x	-	x	-	-	x	x	-
DRLE-G036	8/24/2017	68.0	44.1	347667.2	1423822.7	VWP	66.0	2" PVC	10	15	2.5" PVC	x	BKP463
DRLE-G036A	10/17/2017	240.5	43.8	347668.2	1423851.3	x	-	x	-	-	x	x	-
DRLE-G037	9/22/2017	246.8	43.3	347865.3	1423332.0	x	-	x	-	-	2.5" PVC	x	-
DRLE-G037A	2/13/2018	110.5	43.4	347859.3	1423350.0	x	-	x	-	-	2.5" PVC	x	-
DRLE-G038	1/11/2018	106.5	48.9	347106.2	1426095.9	x	-	x	-	-	x	x	-
DRLE-G044	10/11/2017	225.1	32.8	345911.3	1422286.5	x	-	x	-	-	x	x	-
DRLE-G045	10/5/2017	225	32.8	345921.4	1422639.3	x	-	x	-	-	x	x	-
DRLE-TP1	3/20/2018	10.0	43.8	347676.2	1423837.0	x	-	x	-	-	x	x	-
DRLE-TP2	3/22/2018	10.0	41.6	345908.3	1425663.0	x	-	x	-	-	x	x	-
DRLE-TP3A	3/21/2018	10.0	43.1	345420.4	1425641.3	x	-	x	-	-	x	x	-
DRLE-TP3B	3/23/2018	10.5	43.2	345425.1	1425643.9	SP	-	2" PVC	4	9.25	x	x	BKC148
DRLE-TP4	3/23/2018	10.5	46.8	346342.5	1426994.1	x	-	x	-	-	x	x	-

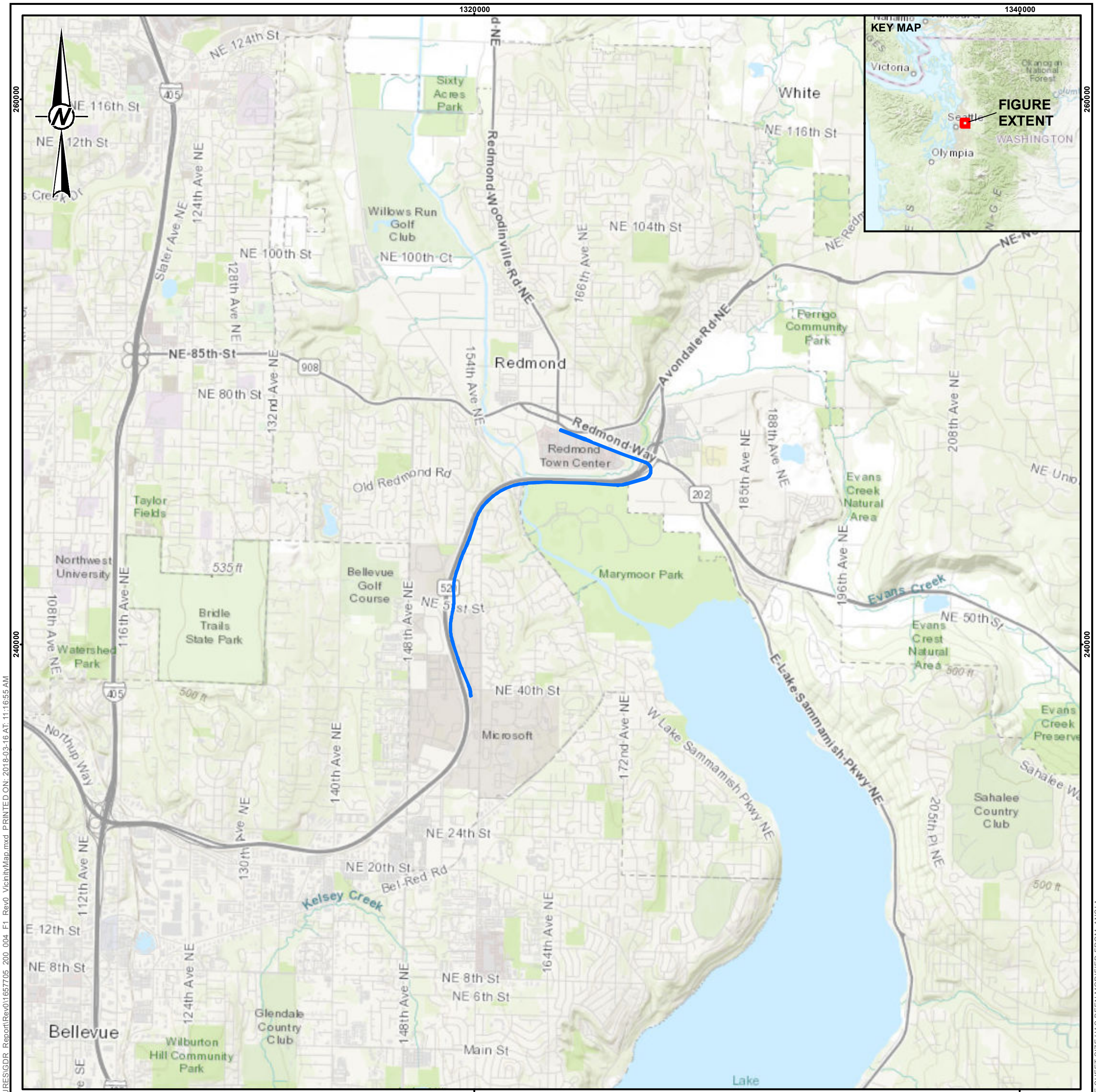
Notes:
1) x indicates "No"
2) VWP indicates Vibrating Wire Piezometer
3) SP indicates Standpipe Piezometer
4) Exploration coordinates provided by Parametrix
5) Coordinates provided on borehole and test pit logs are rounded

Table 2-2: Groundwater Data Summary

	Piezometer		Well		At Time of Drilling (ATD)	
Borehole	**Date of Reading**	**Measured/Calculated Ground Water Table (ft bgs)**	**Date of Reading**	**Measured Ground Water Table (ft bgs)**	**Date of Reading**	**Measured Ground Water Table (ft bgs)**
DRLE-G001					8/29/2017	64.0
DRLE-G002	3/4/2018 6/2/2018	61.4 57.5			2/15/2018	24.4
DRLE-G003					8/30/2017	75.0
DRLE-G004					8/31/2017	71.5
DRLE-G005					9/1/2017	63.8
DRLE-G006	3/4/2018 6/2/2018	43.8 43.3				
DRLE-G007					10/30/2017	22.3
DRLE-G008					Not observed	
DRLE-G010					Not observed	
DRLE-G011					Not observed	
DRLE-G012					11/2/2017	32.7
DRLE-G013	3/4/2018 6/2/2018	15.4 15.5				
DRLE-G014	11/6/2017	24.2				
DRLE-G015					Not observed	
DRLE-G016	11/16/2017 3/4/2018 6/2/2018	41.1 38.7 41.4				
DRLE-G017					Not observed	
DRLE-G017A					Not observed	
DRLE-G018	11/17/2017 3/4/2018 6/2/2018	86.6 85.8 See Note 1 89.1				
DRLE-G019					7/24/2017 7/25/2017 7/26/2017	8.8 7.4 7.5
DRLE-G020	9/28/2017 11/4/2017 11/17/2017 3/4/2018 6/2/2018	9.7 11.7 9.2 6.9 7.7			7/31/2017 8/1/2017 8/2/2017 8/3/2017	8.2 8.0 7.1 9.0
DRLE-G021					7/21/2017	7.3
DRLE-G022	9/28/2017 11/4/2017 11/17/2017 3/4/2018 6/2/2018	9.7 11.7 11.1 8.4 8.6			7/27/2017	9.3
DRLE-G023					7/20/2017	9.8
DRLE-G023b					Not observed	
DRLE-G024	10/3/2017 11/4/2017 11/17/2017 3/4/2018 6/2/2018	17.7 18.7 18.1 15.0 15.2				
DRLE-G025					8/9/2017	12.3
DRLE-G027	9/28/2017 11/17/2017 3/4/2018 6/2/2018	14.9 15.6 12.1 13.1	10/3/2017 11/17/2017 3/4/2018 6/2/2018	14.4 14.3 10.9 12.1	9/5/2017	14.2
DRLE-G028					9/7/2017	13.0
DRLE-G029	3/4/2018 6/2/2018	14.6 16.2				
DRLE-G031	9/28/2017 11/16/2017 3/4/2018 6/2/2018	15.4 16.8 13.2 14.4			9/20/2017	5.0
DRLE-G032					10/10/2017	12.7
DRLE-G033					Not observed	
DRLE-G034	9/28/2017 11/16/2017 3/4/2018 6/2/2018	17.2 20.6 17.0 15.9	10/3/2017 11/16/2017 3/4/2018 6/2/2018	20.5 21.2 17.6 17.8	8/18/2017 8/21/2017	9.0 17.7
DRLE-G034A					Not observed	
DRLE-G035					10/4/2017	21.4
DRLE-G036	9/28/2017 11/16/2017 3/4/2018 6/2/2018	18.4 21.5 18.3 17.5	10/3/2017 11/16/2017 3/4/2018 6/2/2018	Dry Dry 11.2 Dry	8/24/2017	10.0
DRLE-G036A					10/11/2017 10/13/2017 10/16/2017	5.9 4.0 31.7
DRLE-G037					9/13/2017	18.7
DRLE-G037A					Not observed	
DRLE-G038					1/10/2018	10.0
DRLE-G044					10/11/2017	11.0
DRLE-G045					10/3/2017	10.0
DRLE-TP1					Not observed	
DRLE-TP2					Not observed	
DRLE-TP3A					Not observed	
DRLE-TP3B			6/2/2018	Dry	Not observed	
DRLE-TP4					Not observed	

Notes:
1) VWP reading may be representing a different deep aquifer. For shallow groundwater conditions, refer to nearby boreholes
2) Refer to borehole records for drilling techniques

FIGURES



LEGEND

PROPOSED DRLE ALIGNMENT

0 1 2

1 " = 1 MI MILES

NOTE(S)

1. THE LOCATION OF ALL FEATURES SHOWN ARE APPROXIMATE.
2. THIS DRAWING IS FOR INFORMATION PURPOSES. IT IS INTENDED TO ASSIST IN SHOWING FEATURES DISCUSSED IN AN ATTACHED DOCUMENT. GOLDER ASSOCIATES INC., PARAMETRIX, AND SOUND TRANSIT CANNOT GUARANTEE THE ACCURACY AND CONTENT OF ELECTRONIC FILES. THE MASTER FILE IS STORED BY GOLDER ASSOCIATES INC. AND WILL SERVE AS THE OFFICIAL RECORD OF THIS COMMUNICATION.

REFERENCE(S)

1. SOUND TRANSIT (DRLE ALIGNMENT, VIA PARAMETRIX)
2. COORDINATE SYSTEM: NAD 1983 STATE PLANE WASHINGTON NORTH (FT)
3. SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, DELORME, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

CLIENT
SOUND TRANSIT

PROJECT
SOUND TRANSIT DOWNTOWN REDMOND LINK EXTENSION
KING COUNTY, WASHINGTON

TITLE
VICINITY MAP

CONSULTANT

GOLDER

Parametrix
ENGINEERING . PLANNING . ENVIRONMENTAL SCIENCES

SOUNDTRANSIT

YYYY-MM-DD	2018-03-16
DESIGNED	BVJ
PREPARED	BVJ
REVIEWED	CS
APPROVED	BB

PROJECT NO.	PHASE	REV.	FIGURE
1657705	200	0	1

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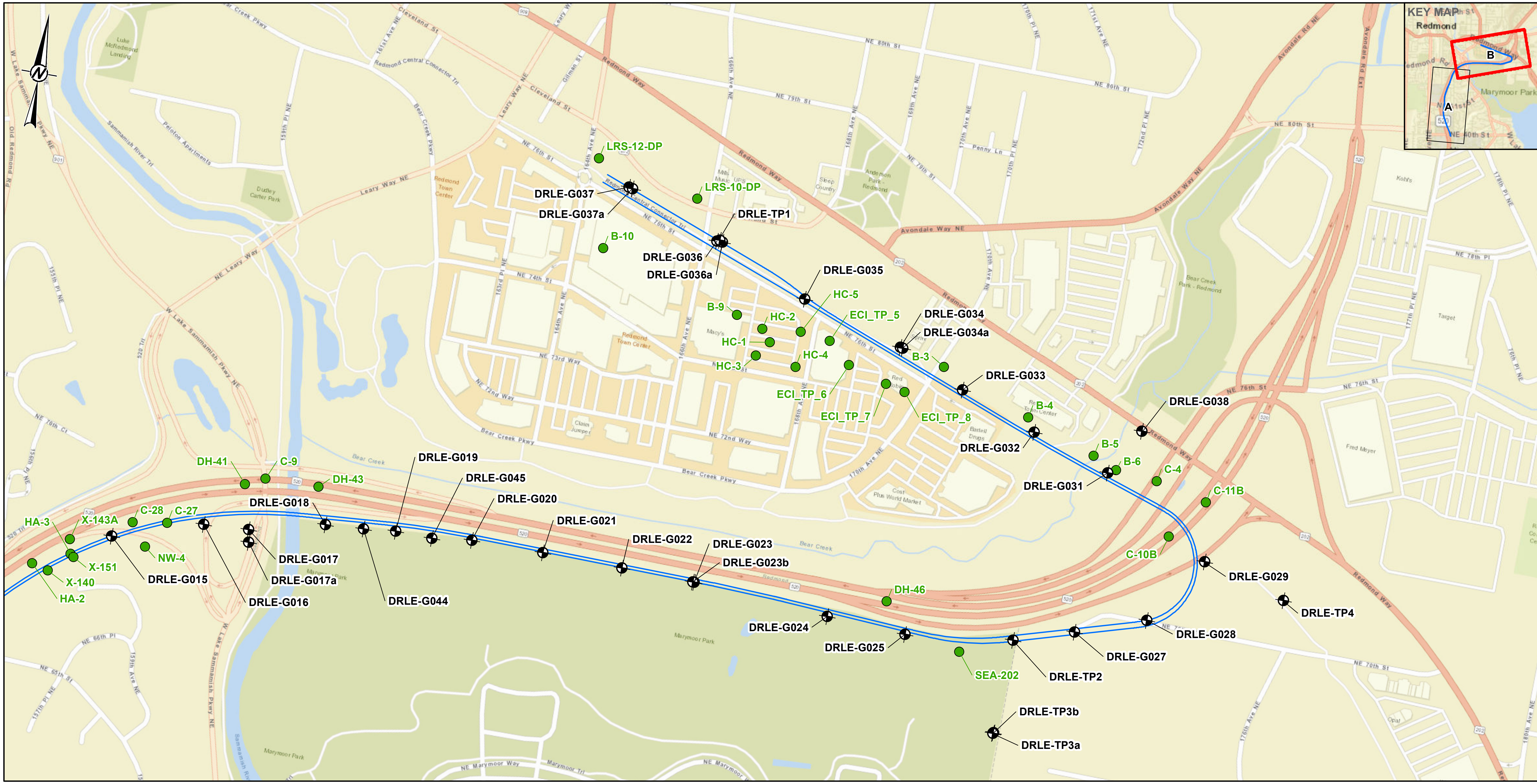

LEGEND

- DRILLED BOREHOLE/TEST PIT (CURRENT PHASE)
- HISTORICAL BOREHOLE/TEST PIT
- PROPOSED DRLE ALIGNMENT FIGURE
- PAGE INDEX

0 250 500 1,000

1 INCH = 500 FEET FEET

NOTE(S)

1. CURRENT BOREHOLES AND TEST PITS BY GOLDER. HISTORICAL BOREHOLES BY OTHERS.
2. HISTORICAL BOREHOLE/TEST PIT RECORDS ARE PROVIDED IN A SEPARATE DOCUMENT.
3. THE LOCATION OF ALL FEATURES SHOWN ARE APPROXIMATE.
4. THIS DRAWING IS FOR INFORMATION PURPOSES. IT IS INTENDED TO ASSIST IN SHOWING FEATURES DISCUSSED IN AN ATTACHED DOCUMENT. GOLDER ASSOCIATES INC., PARAMETRIX, AND SOUND TRANSIT CANNOT GUARANTEE THE ACCURACY AND CONTENT OF ELECTRONIC FILES. THE MASTER FILE IS STORED BY GOLDER ASSOCIATES INC. AND WILL SERVE AS THE OFFICIAL RECORD OF THIS COMMUNICATION.

REFERENCE(S)

1. GOLDER (CURRENT-PHASE DRILLED BOREHOLES)
2. SOUND TRANSIT (DRLE ALIGNMENT, VIA PARAMETRIX)
3. WASHINGTON DEPARTMENT OF NATURAL RESOURCES (HISTORICAL BOREHOLES)
4. WASHINGTON DEPARTMENT OF TRANSPORTATION (HISTORICAL BOREHOLES)
5. CITY OF REDMOND (HISTORICAL BOREHOLES)
6. MICROSOFT (HISTORICAL BOREHOLES)
7. COORDINATE SYSTEM: NAD 1983 STATE PLANE WASHINGTON NORTH (FT)
8. SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), TOMTOM, 2013

CLIENT
SOUND TRANSIT

PROJECT
SOUND TRANSIT DOWNTOWN REDMOND LINK EXTENSION
KING COUNTY, WASHINGTON

TITLE
SITE AND EXPLORATION PLAN

CONSULTANT
GOLDER
Parametrix
SOUNDTRANSIT

YYYY-MM-DD	2018-05-31
DESIGNED	BVJ
PREPARED	BVJ
REVIEWED	CS
APPROVED	BB

PROJECT NO.	PHASE	REV.	FIGURE
1657705	200	0	2B

PATH: G:\SoundTransit\RedmondLink\99_PROJECTS\1657705_RedmondLink\200\02_PRODUCTION\MXD\FIGURES\GDR_Report\Rev0\1657705_200_007_F2_Rev0_AllExplorations.mxd

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

APPENDIX A

RECORD OF BOREHOLES

STANDARD PRACTICE FOR CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (ASTM D 2487)

CRITERIA FOR ASSIGNING GROUP SYMBOLS AND NAMES			SOIL CLASSIFICATION GENERALIZED GROUP DESCRIPTIONS	
COARSE-GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS LESS THAN 5% FINES	GW	WELL-GRADED GRAVELS
			GP	POORLY-GRADED GRAVELS
		GRAVELS WITH FINES MORE THAN 12% FINES	GM	GRAVEL AND SILT MIXTURES
			GC	GRAVEL AND CLAY MIXTURES
	SANDS 50% OR MORE OF COARSE FRACTION PASSES NO. 4 SIEVE	CLEAN SANDS LESS THAN 5% FINES	SW	WELL-GRADED SANDS
			SP	NON- AND LOW-POORLY-GRADED SANDS
		SANDS WITH FINES MORE THAN 12% FINES	SM	SAND AND SILT MIXTURES
			SC	SAND AND CLAY MIXTURES
FINE-GRAINED SOILS 50% OR MORE PASSES THE NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50	INORGANIC	CL	LEAN CLAYS
			ML	SILTS AND ELASTIC SILTS
		ORGANIC	OL	LEAN ORGANIC CLAYS ORGANIC SILTS AND ELASTIC ORGANIC SILTS
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50	INORGANIC	CH	FAT CLAYS
			MH	ELASTIC SILTS
		ORGANIC	OH/OL	ORGANIC CLAYS AND SILTS
HIGHLY ORGANIC SOILS	PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR		PT	PEAT

BASED ON: ASTM D2487-06

SOIL CONSISTENCY

COHESIONLESS SOILS[a]	
DENSITY	N, blows/ft.[c]
VERY LOOSE	0 to 4
LOOSE	4 to 10
MEDIUM DENSE	10 to 30
DENSE	30 to 50
VERY DENSE	over 50

COHESIVE SOILS[b]	
CONSISTENCY	N, blows/ft.[c]
VERY SOFT	0 to 2
SOFT	2 to 4
FIRM	4 to 8
STIFF	8 to 15
VERY STIFF	15 to 30
HARD	over 30

(a) SOILS CONSISTING OF GRAVEL, SAND, AND SILT, EITHER SEPARATELY OR IN COMBINATION, POSSESSING NO CHARACTERISTICS OF PLASTICITY, AND EXHIBITING DRAINED BEHAVIOR.
(b) SOILS POSSESSING THE CHARACTERISTICS OF PLASTICITY, AND EXHIBITING UNDRAINED BEHAVIOR.
(c) REFER TO TEXT OF ASTM D 1586-84 FOR A DEFINITION OF N; IN NORMALLY CONSOLIDATED COHESIONLESS SOILS. RELATIVE DENSITY TERMS ARE BASED ON N VALUES CORRECTED FOR OVERBURDEN PRESSURES.
(d) UNDRAINED SHEAR STRENGTH = 1/2 UNCONFINED COMPRESSION STRENGTH.

COMPONENT DEFINITIONS BY GRADATION

COMPONENT	SIZE RANGE
BOULDERS	ABOVE 300 mm (12 in)
COBBLES	75 mm (3 in) to 300 mm (12 in)
GRAVEL	4.75 mm (No. 4) to 75 mm (3 in)
COARSE GRAVEL	19 mm (3/4 in) to 75 mm (3 in)
FINE GRAVEL	4.75 mm (No. 4) to 19 mm (3/4 in)
SAND	0.075mm (No. 200) to 4.75mm (No. 4)
COARSE SAND	2.0 mm (No. 10) to 4.75 mm (No. 4)
MEDIUM SAND	0.42 mm (No. 40) to 2.0 mm (No. 10)
FINE SAND	0.075 mm (No. 200) to 0.42 mm (No. 40)
SILT AND CLAY	SMALLER THAN 0.075mm (No. 200)

QUALITATIVE DESCRIPTIVE TERMINOLOGY FOR MOISTURE CONTENT

DRY	NO DISCERNIBLE MOISTURE PRESENT
MOIST	WILL MOISTEN THE HAND
WET	VISIBLE WATER PRESENT ON MATERIALS

DESCRIPTIVE TERMINOLOGY DENOTING COMPONENT PROPORTIONS

DESCRIPTIVE TERMS	RANGE OF PROPORTION
TRACE	0-5%
FEW	5-10%
LITTLE	15-25%
SOME	30-45%

SILT AND CLAY DESCRIPTIONS

DESCRIPTION	TYPICAL UNIFIED DESIGNATION
SILT	ML (NON-PLASTIC)
CLAYEY SILT	CL-ML (LOW PLASTICITY)
CLAY	CL
FAT CLAY	CH
ELASTIC SILT	MH
ORGANIC SOILS	OL, OH, Pt

SAMPLE TYPES

SYMBOL	DESCRIPTION
SS	2" O.D. SPLIT SPOON
BK	BULK
GB	GRAB SAMPLE
ST	SHELBY TUBE
MC	2 $\frac{1}{2}$" I.D. CAL. MOD. SAMPLER
HQ	DIAMOND ROCK CORE SAMPLE

MISCELLANEOUS LOG SYMBOLS

SYMBOL	DESCRIPTION
VWP	VIBRATING WIRE PIEZOMETER
ATD	AT TIME OF DRILLING
PI	PLASTICITY INDEX
▽	APPROX. GWT OBSERVED DURING DRILLING
▼	APPROX. GWT MEASURED AFTER WELL INSTALLATION

LOG AND SOIL CLASSIFICATION LEGEND

GOLDER

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: October 23, 2017 08:22
DRILLING END: October 30, 2017 00:00
COORDINATES: N: 345,899 E: 1,422,090

GS ELEV.: 38.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

BORING METHOD: Mud Rotary

Soil Profile

Depth (ft)	Description	Elev	USCS
40.0	(SP-SM), POORLY GRADED SAND WITH SILT, medium sand, few nonplastic fines, dark gray; medium dense to dense, wet *(continued)*	-1.6	SP-SM
50.0	(SM), SILTY SAND, fine to medium sand, little nonplastic fines, dark gray; medium dense to very dense, wet, thin seams of clean sand (SP) < 1/4 inch thick	-11.6	SM

Samples

BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop); REC / ATT (in); PENETRATION RESISTANCE BLOWS / ft (10, 20, 30, 40); WATER CONTENT (%) W_p — W — W_l (20, 40, 60, 80)

Sample Type & Number	Blows per 6 in	REC/ATT (in)	Penetration Resistance (blows/ft)
SS S-11	12-12-15 **(27)**	12/18	27
SS S-12	14-15-16 **(31)**	12/18	31
SS S-13	9-10-12 **(22)**	4/18	22
SS S-14	8-10-12 **(22)**	15/18	22
SS S-15	22-25-23 **(48)**	18/18	48
SS S-16	8-14-19 **(33)**	18/18	33
SS S-17	11-12-14 **(26)**	16/18	26

Notes / Water Levels

53.5: Successful pressuremeter test

55: Successful pressuremeter test

60: S-14: % Fines = 25

73: Successful pressuremeter test

74.5: Successful pressuremeter test

77.5: S-17: % Fines = 23; Drilling chatter from 77 to 82 ft, Possible gravel and cobbles present

ADDITIONAL LAB TESTING

Log continued on next page

DRILLING CO.: Holocene
DRILLER: Roddy Gilszth
DRILL RIG: CME-850, Track Mount

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G018

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: October 23, 2017 08:22
DRILLING END: October 30, 2017 00:00
COORDINATES: N: 345,899 E: 1,422,090

GS ELEV.: 38.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	SOIL PROFILE DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
80	Mud Rotary	80.0		-41.6							
			(SM), SILTY SAND, fine to medium sand, little nonplastic fines, dark gray; medium dense to very dense, wet, thin seams of clean sand (SP) < 1/4 inch thick *(continued)*		SM	SS S-18	25-30-34 (**64**)	14/18	>>		
		82.5	(CL-ML), SILTY CLAY WITH SAND, low plasticity fines, little fine to medium sand, dark gray; very stiff, moist, sand seams up to 3 inches thick	-44.1	CL-ML						
85						SS S-19	7-6-9 (**15**)	18/18	15	85.8 ft, 03/04/2018 VWP reading; 86.6 ft, 11/17/2017 VWP reading	
90						SS S-20	11-7-10 (**17**)	18/18	17	89.1 ft, 06/02/2018 VWP reading; 90: S-20: PI = 6	
95						SS S-21	6-7-9 (**16**)	18/18	16		
		97.0	(ML), SILT, nonplastic fines, trace fine sand, trace fine subrounded to subangular gravel, dark gray; very stiff to hard, wet	-58.6	ML						
100						SS S-22	11-11-12 (**23**)	18/18	23	100: S-22: PI = NP	
105						SS S-23	5-9-14 (**23**)	18/18	23		
110						SS S-24	9-18-19 (**37**)	18/18	37		
		112.5	(CH), FAT CLAY, high plasticity fines, few fine sand, dark gray; soft, moist, thin sand seams <1/4 thick	-74.1	CH						
115						SS S-25	1-2-4 (**6**)	18/18	6		
						ST ST-1		30/30			
120		120.0		-81.6						120: S-26: PI = 13	

Log continued on next page

DRILLING CO.: Holocene
DRILLER: Roddy Gilszth
DRILL RIG: CME-850, Track Mount

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

RECORD OF BOREHOLE DRLE-G018

PROJECT:	Downtown Redmond Link Extension	DRILLING START:	October 23, 2017 08:22	SHEET:	4 of 6
PROJECT NO.:	1657705	DRILLING END:	October 30, 2017 00:00	GS ELEV.:	38.4 feet
LOCATION:	Marymoor Park	COORDINATES:	N: 345,899 E: 1,422,090	TOC ELEV.:	na
				DATUM:	NAVD88/Project Datum

BORING METHOD: Mud Rotary

SOIL PROFILE

Depth (ft)	Description	Elev	USCS
120.0	(CL), LEAN CLAY, medium plasticity fines, few fine sand, dark gray; very soft to stiff, moist	-81.6	CL
122.0	(CL-ML), SILTY CLAY, low plasticity fines, few fine sand, dark gray; soft, moist	-83.6	CL-ML
127.5	(CL), LEAN CLAY, medium plasticity fines, few fine sand, dark gray; very soft to stiff, moist	-89.1	CL
142.5	(SM), SILTY SAND, medium sand, little nonplastic fines, trace subrounded to subangular gravel, dark gray; dense to very dense, wet	-104.1	SM
157.5	(CL), LEAN CLAY, low plasticity fines, some fine to medium sand, dark gray; stiff, moist	-119.1	CL

Log continued on next page

SAMPLES

Sample Type & Number	Blows per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	Penetration Resistance (Blows/ft)	Notes / Water Levels
SS S-26	0-0-0 **(0)**	16/18	0	
ST ST-2		30/30		
SS S-27	1-2-3 **(5)**	1/18	5	
SS S-28	4-6-8 **(14)**	18/18	14	130: S-28: PI = 18
ST ST-3		30/30		
SS S-29	4-6-4 **(10)**	1/18	10	
SS S-30	23-26-25 **(51)**	12/18	>>	
SS S-31	15-20-20 **(40)**	9/18	40	150: S-31: % Fines = 18; VWP installed
SS S-32	26-32-32 **(64)**	10/18	>>	
				160: S-33: PI = 18

DRILLING CO.:	Holocene	LOGGED:	Carly Schaeffer
DRILLER:	Roddy Gilszth	CHECKED:	Margaret Pryor
DRILL RIG:	CME-850, Track Mount	REVIEWED:	Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G018

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: October 23, 2017 08:22
DRILLING END: October 30, 2017 00:00
COORDINATES: N: 345,899 E: 1,422,090

GS ELEV.: 38.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
160	Mud Rotary	160.0	(CL), LEAN CLAY, low plasticity fines, some fine to medium sand, dark gray; stiff, moist *(continued)*	-121.6	CL	SS S-33	20-11-8 **(19)**	18/18	19		
		162.5	(CH), SANDY FAT CLAY, high plasticity fines, some fine to medium sand, dark gray, laminated; very stiff to hard, moist	-124.1	CH						
165						ST ST-4		30/30			
170						SS S-34	16-16-18 **(34)**	14/18	34	170: S-34: % Fines = 53	
175						SS S-35	10-13-24 **(37)**	18/18	37	175: S-35: PI = 52	
180						SS S-36	10-14-19 **(33)**	18/18	33		
185						SS S-37	14-15-27 **(42)**	16/18	42	185: S-37: % Fines = 61	
190						SS S-38	15-21-24 **(45)**	0/18	45	190: S-38: PI = 52	
195											
		197.5	(SM), SILTY SAND, fine sand, some nonplastic fines, trace fine subrounded gravel, dark gray; very dense, wet	-159.1	SM						
200											

Log continued on next page

DRILLING CO.: Holocene
DRILLER: Roddy Gilszth
DRILL RIG: CME-850, Track Mount

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

PROJECT:	Downtown Redmond Link Extension	DRILLING START:	October 23, 2017 08:22	SHEET:	6 of 6
PROJECT NO.:	1657705	DRILLING END:	October 30, 2017 00:00	GS ELEV.:	38.4 feet
LOCATION:	Marymoor Park	COORDINATES:	N: 345,899 E: 1,422,090	TOC ELEV.:	na
				DATUM:	NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	SOIL PROFILE: Depth	DESCRIPTION	Elev	USCS	GRAPHIC LOG	SAMPLES: SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC / ATT (in)	■ PENETRATION RESISTANCE BLOWS / ft (10, 20, 30, 40); WATER CONTENT (%) W_p — W — W_l (20, 40, 60, 80)	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
200	Mud Rotary	200.0	(SM), SILTY SAND, fine sand, some nonplastic fines, trace fine subrounded gravel, dark gray; very dense, wet *(continued)*	-161.6	SM		SS S-39	50/2" **(50/2")**	2 / 2	>>■	200.1 - 220: S-39: % Fines = 31; Drilling chatter	
205							SS S-40	50/1" **(50/1")**	1 / 1	>>■		
210												
215												
220		220.0	Bottom of borehole at 220.0 ft. Installed seismic casing and vibrating wire piezometer	-181.6								
225												
230												
235												
240												

01 - GOLDER - BOREHOLE RECORD - DF STD US LAB E-M.GDT - 6/28/18 08:40
C:\USERS\CSCHAEFFER\DESKTOP\DRLE LOGS.GPJ

DRILLING CO.:	Holocene	LOGGED:	Carly Schaeffer
DRILLER:	Roddy Gilszth	CHECKED:	Margaret Pryor
DRILL RIG:	CME-850, Track Mount	REVIEWED:	Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G019

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: North of Marymoor Park, South of 520

DRILLING START: July 21, 2017 09:02
DRILLING END: July 25, 2017 17:00
COORDINATES: N: 345,927 E: 1,422,451

GS ELEV.: 32.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

Boring method: Mud Rotary

Depth (ft)	Elev	Description	USCS	Sample Type & Number	Blows per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	Penetration Resistance (Blows/ft)	Notes / Water Levels
0.0	32.4	(ML), SILT, low plasticity fines, brown and white; stiff, moist to wet, few roots and wood fragments observed	ML	SS S-1	2-5-7 **(12)**	9/18	12	
2.0	30.4	(CL), LEAN CLAY, low plasticity fines, few fine sand, gray; soft, moist, few roots	CL	SS S-2	2-1-1 **(2)**	6/18	2	
4.5	27.9	(PT), PEAT, dark brown; very soft, wet	PT					4.5: Drilling mud loss
5.8	26.7	(GP), POORLY GRADED GRAVEL, fine to coarse subrounded to subangular gravel, trace medium to coarse sand, trace nonplastic fines, dark gray; medium dense to dense, wet	GP	SS S-3	0-3-10 **(13)**	8/18	13 (water content >>)	6: Drilling chatter
								∇ 7.5 ft, ATD
				SS S-4	30-21-19 **(40)**	8/18	40	
				SS S-5	24-21-18 **(39)**	2/18	39	
				SS S-6	21-17-16 **(33)**	10/18	33	
				SS S-7	8-10-17 **(27)**	0/18	27	15: S-7: % Fines < 1; 16: Drilling chatter
				SS S-8	19-19-19 **(38)**	8/18	38	
				SS S-9	11-14-14 **(28)**	0/18	28	
27.5	4.9	(SP), POORLY GRADED SAND, fine to medium sand, trace subrounded gravel, trace nonplastic fines, dark gray; medium dense to dense, wet	SP	SS S-10	19-18-14 **(32)**	9/18	32	
				SS S-11	15-14-16 **(30)**	14/18	30	
37.5	-5.1	(SM), SILTY SAND, fine to medium sand, little nonplastic fines, dark gray; medium dense to dense, wet	SM					40: S-12: % Fines = 30

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G019

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: North of Marymoor Park, South of 520

DRILLING START: July 21, 2017 09:02
DRILLING END: July 25, 2017 17:00
COORDINATES: N: 345,927 E: 1,422,451

GS ELEV.: 32.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
40	Mud Rotary	40.0	(SM), SILTY SAND, fine to medium sand, little nonplastic fines, dark gray; medium dense to dense, wet *(continued)*	-7.6	SM	SS S-12	8-9-11 **(20)**	16/18	20		
45						SS S-13	8-9-10 **(19)**	16/18	19		
50						SS S-14	3-6-22 **(28)**	18/18	28		
55						SS S-15	8-9-13 **(22)**	16/18	22		
60						SS S-16	10-11-10 **(21)**	16/18	21	60: S-16: % Fines = 16	
65						SS S-17	15-16-19 **(35)**	16/18	35		
70						SS S-18	8-10-18 **(28)**	15/18	28		
		72.5	(ML), SANDY SILT, nonplastic fines, some fine sand, dark gray; stiff to hard, wet	-40.1	ML						
75						SS S-19	1-3-5 **(8)**	18/18	8	75: S-19: PI = NP	
80											

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G019

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: North of Marymoor Park, South of 520

DRILLING START: July 21, 2017 09:02
DRILLING END: July 25, 2017 17:00
COORDINATES: N: 345,927 E: 1,422,451

SHEET: 3 of 5
GS ELEV.: 32.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
80	Mud Rotary	80.0	(ML), SANDY SILT, nonplastic fines, some fine sand, dark gray; stiff to hard, wet *(continued)*	-47.6	ML	SS S-20	5-14-17 **(31)**	14/18	31		
		84.0	(CL), SANDY LEAN CLAY, low plasticity fines, some fine sand, dark gray; medium stiff to very stiff, moist	-51.6	CL						
85						SS S-21	5-1-6 **(7)**	18/18	7	85: S-21: PI = 9	
90						SS S-22	7-4-11 **(15)**	18/18	15		
95						SS S-23	0-1-5 **(6)**	18/18	6	95: S-23: PI = 15	
100						SS S-24	2-0-6 **(6)**	18/18	6		
105						SS S-25	3-1-4 **(5)**	18/18	5	105: S-25: PI = 13	
110						SS S-26	4-0-2 **(2)**	18/18	2		
		113.0	(ML), SANDY SILT, nonplastic fines, some fine sand, dark gray; very soft to medium stiff, wet	-80.6	ML						
115						SS S-27	0-2-5 **(7)**	18/18	7	115: S-27: PI = NP	
120											

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G019

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: North of Marymoor Park, South of 520

DRILLING START: July 21, 2017 09:02
DRILLING END: July 25, 2017 17:00
COORDINATES: N: 345,927 E: 1,422,451

GS ELEV.: 32.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

Boring Method: Mud Rotary

Depth (ft)	Description	Elev	USCS	Sample Type & Number	Blows per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	Penetration Resistance (Blows/ft)	Notes / Water Levels
120.0	(ML), SANDY SILT, nonplastic fines, some fine sand, dark gray; very soft to medium stiff, wet *(continued)*	-87.6	ML	SS S-28	0-0-1 **(1)**	18/18	1	
122.0	(CL), SANDY LEAN CLAY, low plasticity fines, some fine sand, dark gray; medium stiff to hard, moist. Decreased sand content	-89.6	CL	ST ST-1		24/24		121.5: ST-1 Advanced at 400 psi. Dent in shelby tube 1 foot from bottom of tube.
				SS S-29	0-3-4 **(7)**	18/18	7	125: S-29: PI = 15
				ST ST-2		24/24		126.5: ST-2 Advanced at 300 psi; ST-2: PI = 21
				SS S-30	12-13-17 **(30)**	18/18	30	
132.5	(SC), CLAYEY SAND, fine sand, some medium plasticity fines, gray; medium dense, moist	-100.1	SC	SS S-31	4-4-13 **(17)**	18/18	17	135: S-31: % Fines = 35
137.5	(SP-SC), POORLY GRADED SAND WITH CLAY, fine to coarse sand, few medium plasticity fines, gray; dense to very dense, moist	-105.1	SP-SC	SS S-32	11-18-28 **(46)**	12/18	46	
	Decreased sand content			SS S-33	20-28-40 **(68)**	12/18	>>	
147.5	(CL), LEAN CLAY, low plasticity fines, gray; stiff, moist	-115.1	CL	SS S-34	3-2-8 **(10)**	18/18	10	
154.0	(SM), SILTY SAND, fine to coarse sand, little nonplastic fines, trace gravel, light gray; very dense, moist	-121.6	SM	SS S-35	32-38-38 **(76)**	12/18	>>	

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G019

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: North of Marymoor Park, South of 520

DRILLING START: July 21, 2017 09:02
DRILLING END: July 25, 2017 17:00
COORDINATES: N: 345,927 E: 1,422,451

GS ELEV.: 32.4 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	SOIL PROFILE: Depth	DESCRIPTION	Elev	USCS	GRAPHIC LOG	SAMPLES: SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC / ATT (in)	PENETRATION RESISTANCE BLOWS / ft (10 20 30 40); WATER CONTENT (%) W_p — W — W_l (20 40 60 80)	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
160		160.0		-127.6								
		160.3	Bottom of borehole at 160.3 ft. Backfilled with bentonite grout.	-127.9			SS S-36	100/4" (100/4")	2/4			
165												
170												
175												
180												
185												
190												
195												
200												

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G020

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 15:35
DRILLING END: August 3, 2017 10:25 N:
COORDINATES: 345,946 E: 1,422,844

SHEET: 1 of 6
GS ELEV.: 34.6 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

BORING METHOD: Mud Rotary

DEPTH (ft)	SOIL PROFILE: Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC / ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS
0	0.0	(ML), SILT WITH SAND, nonplastic fines, little fine sand, light brown, roots; stiff, moist	34.6	ML	SS S-1	3-4-5 **(9)**	4/18	9	
	2.0	(GW-GM), WELL GRADED GRAVEL WITH SILT AND SAND, fine to coarse subrounded to subangular gravel, some fine to coarse sand, little low plastic fines, gray and brown; medium dense to very dense, moist to wet	32.6	GW-GM					2: Drilling chatter
					SS S-2	7-9-12 **(21)**	7/18	21	
5					SS S-3	19-20-21 **(41)**	10/18	41	
					SS S-4	18-21-18 **(39)**	6/18	39	6.9 ft, 03/04/2018 VWP reading 7.2 ft, ATD 7.7 ft, 06/02/2018 VWP reading 9.2 ft, 11/17/2017 VWP reading 9.7 ft, 09/28/2017 VWP reading
10					SS S-5	12-7-6 **(13)**	7/18	13	10: S-5: % Fines = 5 11.7 ft, 11/04/2017 VWP reading
					SS S-6	20-16-13 **(29)**	8/18	29	
15					SS S-7	14-19-21 **(40)**	8/18	40	
20		Color change to gray			SS S-8	18-44-50 **(94)**	7/18	>>	
25					SS S-9	17-19-34 **(53)**	7/18	>>	25: Drilling chatter
30	30.0	(SM), SILTY SAND, fine to medium sand, little nonplastic fines, few coarse subrounded to subangular gravel, dark gray; medium dense, wet	4.6	SM	SS S-10	10-12-11 **(23)**	0/18	23	
35					SS S-11	13-10-13 **(23)**	12/18	23	35: S-11: % Fines = 20
40	40.0		-5.4						

Log continued on next page

DRILLING CO.: Holt Services
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G020

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 15:35
DRILLING END: August 3, 2017 10:25 N:
COORDINATES: 345,946 E: 1,422,844

SHEET: 2 of 6
GS ELEV.: 34.6 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

BORING METHOD: Mud Rotary

DEPTH (ft)	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS
40	40.0	(SP-SM), POORLY GRADED SAND WITH SILT, fine to medium sand, few nonplastic fines, dark gray; medium dense to very, wet	-5.4	SP-SM	SS S-12	9-14-20 **(34)**	0/18	34	
45					SS S-13	9-10-12 **(22)**	14/18	22	45: S-13: % Fines = 12
50					SS S-14	10-13-11 **(24)**	12/18	24	50: S-14: % Fines = 14
55					SS S-15	9-15-24 **(39)**	15/18	39	
60					SS S-16	9-11-13 **(24)**	0/18	24	
65					SS S-17	16-25-28 **(53)**	0/18	>>	
70					SS S-18	16-20-21 **(41)**	18/18	41	
75					SS S-19	8-12-15 **(27)**	14/18	27	
	77.5	(ML), SANDY SILT, nonplastic fines, some fine to medium sand, dark gray; very stiff to hard, wet	-42.9	ML					78: VWP Installed
80									

Log continued on next page

DRILLING CO.: Holt Services
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G020

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 15:35
DRILLING END: August 3, 2017 10:25
COORDINATES: N: 345,946 E: 1,422,844

GS ELEV.: 34.6 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

Boring method: Mud Rotary. Blows per 6 in: Automatic 140 lb Hammer, 30 inch drop.

Depth (ft)	Elev	Description	USCS	Sample Type & Number	Blows per 6 in	REC/ATT (in)	Penetration Resistance (Blows/ft)	Notes / Water Levels
80.0	-45.4	(ML), SANDY SILT, nonplastic fines, some fine to medium sand, dark gray; very stiff to hard, wet *(continued)*	ML	SS S-20	2-8-12 **(20)**	15/18	20	80: S-20: PI = NP; % Fines = 60
				SS S-21	13-22-28 **(50)**	13/18	50	
87.0	-52.4	(CL), SANDY LEAN CLAY, low plasticity fines, some fine to medium sand, dark gray; stiff, moist	CL	SS S-22	5-6-6 **(12)**	18/18	12	90: S-22: PI = 8
93.0	-58.4	(ML), SANDY SILT, nonplastic fines, some fine to medium sand, dark gray; very stiff, wet	ML	SS S-23	12-13-14 **(27)**	15/18	27	
				SS S-24	1-8-16 **(24)**	18/18	24	100: S-24: PI = NP; % Fines = 55
103.0	-68.4	(CL), SANDY LEAN CLAY, low plasticity fines, some fine to medium sand, dark gray; stiff, moist	CL	SS S-25	12-6-7 **(13)**	18/18	13	105: S-25: PI = 8; % Fines = 69
108.0	-73.4	(ML), SANDY SILT, low plasticity fines, some fine to medium sand, dark gray; medium stiff, wet	ML	SS S-26	2-1-6 **(7)**	18/18	7	110: S-26: PI = 4; % Fines = 85
112.5	-77.9	(CL), LEAN CLAY, low plasticity fines, few fine sand, dark gray; medium stiff to hard, moist, thin sand seams < 1/4 inch thick	CL	ST ST-1		24/24		
				SS S-27	0-2-5 **(7)**	18/18	7	
120								120: S-28: PI = 17

Log continued on next page

DRILLING CO.: Holt Services
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G020

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 15:35
DRILLING END: August 3, 2017 10:25
COORDINATES: N: 345,946 E: 1,422,844

GS ELEV.: 34.6 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
120	Mud Rotary	120.0	(CL), LEAN CLAY, low plasticity fines, few fine sand, dark gray; medium stiff to hard, moist, thin sand seams < 1/4 inch thick *(continued)*	-85.4	CL	SS S-28	0-1-5 **(6)**	18/18	6		
125						SS S-29	2-2-5 **(7)**	18/18	7		
130						SS S-30	11-27-21 **(48)**	3/18	48		
135						SS S-31	0-0-5 **(5)**	18/18	5	135: S-31: PI = 12	
140						SS S-32	0-3-8 **(11)**	18/18	11		
			Color change to gray								
145						SS S-33	0-0-5 **(5)**	18/18	5	145: S-33: PI = 14	
		147.5	(SM), SILTY SAND, fine to medium sand, some nonplastic fines, dark gray; medium dense, wet	-112.9	SM						
150						SS S-34	1-3-7 **(10)**	18/18	10	150: S-34: % Fines = 38	
155						SS S-35	8-8-11 **(19)**	18/18	19	155: S-35: % Fines = 23	
		157.5	(SP), POORLY GRADED SAND, fine to medium sand, trace nonplastic fines, gray; very dense, wet	-122.9	SP						
160											

Log continued on next page

DRILLING CO.: Holt Services
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G020

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 15:35
DRILLING END: August 3, 2017 10:25
COORDINATES: N: 345,946 E: 1,422,844

SHEET: 5 of 6
GS ELEV.: 34.6 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	WATER CONTENT (%)	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
160	Mud Rotary	160.0	(SP), POORLY GRADED SAND, fine to medium sand, trace nonplastic fines, gray; very dense, wet *(continued)*	-125.4	SP	SS S-36	29-32-27 **(59)**	15/18	>>			
		162.5	(CL), LEAN CLAY, medium plasticity fines, trace fine sand, gray; stiff to hard, moist	-127.9	CL							
165						SS S-37	0-3-9 **(12)**	18/18	12		165: S-37: PI = 19	
170						SS S-38	34-50/3" **(50/3")**	8/9	>>			
175						SS S-39	10-14-18 **(32)**	4/18	32			
180						SS S-40	0-2-11 **(13)**	18/18	13		180: S-40: PI = 14	
185						SS S-41	4-3-5 **(8)**	18/18	8			
						ST ST-2		12/12			186.5 - 188.5: Shelby Tube ST-2 Advanced with 600 psi of pressure.	
		187.5	(SM), SILTY SAND, fine to coarse sand, some nonplastic fines, few gravel, dark gray; very dense, wet	-152.9	SM							
190						SS S-42	30-48-38 **(86)**	12/18	>>		190: S-40: % Fines = 32	
195						SS S-43	100/2" **(100/2")**	2/2			195 - 200: Drilling chatter	
200												

Log continued on next page

DRILLING CO.: Holt Services
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G020

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 15:35
DRILLING END: August 3, 2017 10:25
COORDINATES: N: 345,946 E: 1,422,844

GS ELEV.: 34.6 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	GRAPHIC LOG	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC / ATT (in)	PENETRATION RESISTANCE BLOWS / ft (10 20 30 40); WATER CONTENT (%) W_p — W — W_l (20 40 60 80)	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
200		200.0		-165.4								
		201.0		-166.4	SM		SS S-44	85/5" (85/5")	1 / 5		201: Drilling chatter, possible cobbles/boulders.	
			Bottom of borehole at 201.0 ft. Installed vibrating wire piezometer									
205												
210												
215												
220												
225												
230												
235												
240												

DRILLING CO.: Holt Services
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G021

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 20, 2017 10:13
DRILLING END: July 20, 2017 16:26
COORDINATES: N: 345,946 E: 1,423,213

SHEET: 1 of 2
GS ELEV.: 35.2 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

Boring method: Mud Rotary. Blows per 6 in: Automatic 140 lb Hammer, 30 inch drop.

Depth (ft)	Elev	Description	USCS	Sample Type & Number	Blows per 6 in	REC/ATT (in)	Penetration Resistance (blows/ft)	Notes / Water Levels
0.0	35.2	(ML), SILT WITH SAND, nonplastic fines, brown and white; medium stiff, wet	ML	SS S-1	1-3-2 **(5)**	9/18	5	
2.0	33.2	(ML), SILT, low plasticity fines, trace fine to medium sand, light gray; soft, wet, trace roots	ML	SS S-2	1-2-2 **(4)**	9/18	4	2.5: S-2: PI = 8
3.5	31.7	(SP-SM), POORLY GRADED SAND WITH SILT, fine to medium sand, few nonplastic fines, dark gray; loose, wet, trace roots	SP-SM					∇ 5.0 ft, ATD (estimated based on soil conditions)
4.5	30.7	(SP), POORLY GRADED SAND, fine to medium sand, trace nonplastic fines, dark brown; medium dense, wet, trace roots	SP	SS S-3	0-6-13 **(19)**	4/18	19	
6.0	29.2	(PT), SANDY PEAT WITH GRAVEL, nonplastic fines, some fine to medium sand, little coarse subangular gravel, dark brown; stiff, wet	PT					
6.5	28.7	(SM), SILTY SAND WITH GRAVEL, fine to medium sand, some fine to coarse subrounded to subangular gravel, little nonplastic fines, gray-brown; dense, wet	SM	SS S-4	12-16-15 **(31)**	8/18	31	
9.5	25.7	(SP-SM), POORLY GRADED SAND WITH SILT AND GRAVEL, medium sand, some fine to coarse subrounded to subangular gravel, few nonplastic fines, dark gray; dense to very dense, wet Increased sand content (S-6)	SP-SM	SS S-5	7-21-22 **(43)**	4/18	43	
				SS S-6	14-11-12 **(23)**	8/18	23	12.5: S-6: % Fines = 7
				SS S-7	13-21-19 **(40)**	6/18	40	
				SS S-8	23-34-35 **(69)**	4/18	>>	
				SS S-9	15-20-29 **(49)**	8/18	49	
27.5	7.7	(GM), SILTY GRAVEL, fine to coarse subrounded to subangular gravel, some fine to medium sand, little nonplastic fines, dark gray; dense to very dense, wet	GM	SS S-10	15-17-23 **(40)**	12/18	40	
				SS S-11	18-21-22 **(43)**	8/18	43	40: Difficult drilling

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G021

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 20, 2017 10:13
DRILLING END: July 20, 2017 16:26
COORDINATES: N: 345,946 E: 1,423,213

GS ELEV.: 35.2 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
40	Mud Rotary	40.0	(GM), SILTY GRAVEL, fine to coarse subrounded to subangular gravel, some fine to medium sand, little nonplastic fines, dark gray; dense to very dense, wet *(continued)*	-4.8	GM	SS S-12	17-33-48 **(81)**	10/18	>>		
45	Mud Rotary	44.0	(SP), POORLY GRADED SAND, fine sand, trace low plasticity fines, dark gray; very dense, wet	-8.8	SP	SS S-13	17-30-33 **(63)**	7/18	>>		
50	Mud Rotary				SP	SS S-14	20-27-37 **(64)**	10/18	>>		
		51.5	Bottom of borehole at 51.5 ft. Backfilled with bentonite grout.	-16.3							

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G022

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 26, 2017 11:04
DRILLING END: July 27, 2017 10:00
COORDINATES: N: 345,936 E: 1,423,624

SHEET: 1 of 2
GS ELEV.: 36.3 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

BORING METHOD: Mud Rotary

DEPTH (ft)	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS
0	0.0	(ML), SANDY SILT, nonplastic fines, some fine to medium sand, white and light brown, roots; stiff to hard, moist	36.3	ML	SS S-1	2-4-6 **(10)**	7/18	10	
	3.0	(PT), PEAT, low plasticity fines, very dark brown, roots; hard, moist	33.3	PT	ST ST-1		24/24		
5	6.0	(GP), POORLY GRADED GRAVEL WITH SAND, fine to coarse subrounded to subangular gravel, few fine to coarse sand, trace nonplastic fines, gray; dense, moist to wet	30.3	GP	SS S-2	9-22-34 **(56)**	18/18	>>	6.5 - 12: Drilling chatter
					SS S-3	19-21-20 **(41)**	9/18	41	8.4 ft, 03/04/2018 VWP reading; 8.6 ft, 06/02/2018 VWP reading; 9.3 ft, ATD; 9.7 ft, 09/28/2017 VWP reading
10					SS S-4	10-18-13 **(31)**	2/18	31	10: S-4: % Fines = 3; 11.1 ft, 11/17/2017 VWP reading; 11.7 ft, 11/04/2017 VWP reading
					SS S-5	22-18-21 **(39)**	4/18	39	
15					SS S-6	13-16-17 **(33)**	8/18	33	
20					SS S-7	11-18-18 **(36)**	0/18	36	
25					SS S-8	15-16-18 **(34)**	9/18	34	
30					SS S-9	10-16-18 **(34)**	3/18	34	
	31.5	(SP-SM), POORLY GRADED SAND WITH SILT, fine to medium sand, few nonplastic fines, dark gray; medium dense, wet	4.8	SP-SM					
35					SS S-10	12-8-15 **(23)**	14/18	23	35: S-10: % Fines = 6
40									

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G022

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 26, 2017 11:04
DRILLING END: July 27, 2017 10:00
COORDINATES: N: 345,936 E: 1,423,624

SHEET: 2 of 2
GS ELEV.: 36.3 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	SOIL PROFILE DESCRIPTION	Elev	USCS	GRAPHIC LOG	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	■ PENETRATION RESISTANCE BLOWS / ft (10 20 30 40); WATER CONTENT (%) W_p —○W— W_l (20 40 60 80)	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
40	Mud Rotary	40.0	(SP-SM), POORLY GRADED SAND WITH SILT, fine to medium sand, few nonplastic fines, dark gray; medium dense, wet *(continued)*	-3.7	SP-SM		SS S-11	9-11-8 **(19)**	13/18	19		
		44.0	(SM), SILTY SAND WITH GRAVEL, fine to medium sand, little fine to coarse subrounded gravel, little nonplastic fines, dark gray; medium dense, wet	-7.7	SM							
45							SS S-12	8-11-10 **(21)**	14/18	21	45: S-12: % Fines = 14 47: VWP Installed	
50							SS S-13	9-10-10 **(20)**	14/18	20		
		51.5	Bottom of borehole at 51.5 ft. Installed vibrating wire piezometer	-15.2								
55												
60												
65												
70												
75												
80												

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G023

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 19, 2017 10:45
DRILLING END: July 19, 2017 16:59
COORDINATES: N: 345,927 E: 1,424,002

SHEET: 1 of 2
GS ELEV.: 37.0 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

BORING METHOD: Mud Rotary

SOIL PROFILE

Depth	Elev	DESCRIPTION	USCS
0.0	37.0	(ML), FILL: SANDY SILT, nonplastic fines, some fine to medium sand, brown to dark brown; very soft to soft, moist to wet	ML
4.5	32.5	(PT), FILL: PEAT, low plasticity fines, very dark brown, roots; very soft, moist	PT
7.5	29.5	(SP-SM), POORLY GRADED SAND WITH SILT AND GRAVEL, fine to medium sand, some fine subrounded to subangular gravel, few nonplastic fines, brown; medium dense, wet	SP-SM
9.0	28.0	(GP), POORLY GRADED GRAVEL WITH SAND, fine to coarse subrounded to subangular gravel, some fine to coarse sand, trace nonplastic fines, gray; medium dense to very dense, wet	GP
27.5	9.5	(SP-SM), POORLY GRADED SAND WITH SILT AND GRAVEL, fine to coarse sand, few fine to coarse subrounded gravel, few nonplastic fines, gray; medium dense, wet	SP-SM
32.5	4.5	(GP), POORLY GRADED GRAVEL WITH SAND, fine to coarse subrounded to subangular gravel, little fine to coarse sand, trace nonplastic fines, gray; very dense, wet	GP

SAMPLES

Blows per 6 in: Automatic 140 lb Hammer, 30 inch drop. REC/ATT (in).

Sample Type & Number	Blows per 6 in	(N)	REC/ATT (in)	Penetration Resistance (blows/ft)
SS S-1b	3-2-1	(3)	14/18	3
SS S-2	0-0-0	(0)	18/18	0
SS S-3	10-17-12	(29)	11/18	29
SS S-4	13-11-21	(32)	4/18	32
SS S-5	18-16-13	(29)	6/18	29
SS S-6	8-17-15	(32)	7/18	32
SS S-7	50-47-35	(82)	8/18	>>
SS S-8	30-30-29	(59)	0/18	>>
SS S-9	9-11-13	(24)	9/18	24
SS S-10	19-26-47	(73)	4/18	>>

PENETRATION RESISTANCE BLOWS / ft: 10 20 30 40
WATER CONTENT (%): W_p — W — W_l: 20 40 60 80

NOTES / WATER LEVELS

- 2.5: S-1: PI = NP
- 5: S-2: PI = NP
- 7.0 ft, ATD (estimated based on soil conditions)
- 7.5 - 40: Difficult drilling
- 20 - 40: Caving gravels
- 30: S-9: % Fines = 5

ADDITIONAL LAB TESTING

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G023

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 19, 2017 10:45
DRILLING END: July 19, 2017 16:59
COORDINATES: N: 345,927 E: 1,424,002

GS ELEV.: 37.0 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
40	Mud Rotary	40.0		-3.0	GP	SS S-11	5-25-39 **(64)**	0/18	>>		
		42.5	(SP), POORLY GRADED SAND WITH GRAVEL, fine to medium sand, little fine to coarse subrounded to subangular gravel, gray; dense to very dense, wet	-5.5	SP						
45						SS S-12	17-16-17 **(33)**	9/18	33		
50						SS S-13	17-26-33 **(59)**	2/18	>>		
		51.5	Bottom of borehole at 51.5 ft. Backfilled with bentonite grout.	-14.5							

DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G023B

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: July 27, 2017 00:00
DRILLING END: July 27, 2017 00:00
COORDINATES: N: 345,927 E: 1,423,995

SHEET: 1 of 1
GS ELEV.: 36.9 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	GRAPHIC LOG	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic Hammer, 30 inch drop)	REC / ATT (in)	PENETRATION RESISTANCE BLOWS / ft (10 20 30 40); WATER CONTENT (%) Wp —O W— Wl (20 40 60 80)	NOTES	ADDITIONAL LAB TESTING
0	Mud Rotary	0.0	(ML), SANDY SILT, nonplastic fines, some fine to medium sand, brown to dark brown; very soft to soft, wet	36.9	ML							
							ST ST-1		24/24		1.5: ST-1: PI = 80	
5											3.5: Sand at bottom of ST sample	
							ST ST-2		18/24		4: ST-2: PI = 73	
		6.5		30.4							6: Peat at bottom of ST sample	
			Bottom of borehole at 6.5 ft. Backfilled with bentonite grout.									

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40

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DRILLING CO.: Holt Services Inc
DRILLER: Larry Inselmore
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G024

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: August 10, 2017 08:02
DRILLING END: August 11, 2017 11:16
COORDINATES: N: 345,868 E: 1,424,704

SHEET: 1 of 2
GS ELEV.: 40.7 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS
0	Mud Rotary	0.0	(SP-SM), POORLY GRADED SAND WITH SILT, fine to medium sand, few nonplastic fines, brown; medium dense, moist, few roots	40.7	SP-SM	SS S-1	5-9-7 **(16)**	18/18	16	
		1.5	(ML), SILT WITH SAND, nonplastic fines, little medium sand, brown mottled gray; medium stiff to medium stiff, moist to wet	39.2	ML	SS S-2	6-7-6 **(13)**	8/18	13	2.5: S-2: PI = NP
5						SS S-3	3-5-9 **(14)**	12/18	14	
						SS S-4	2-2-4 **(6)**	10/18	6	7.5: S-4: PI = NP
10		9.5	(OL), ORGANIC SILT, low plasticity fines, gray; very soft, wet	31.2	OL	SS S-5	0-0-0 **(0)**	18/18	0	10: S-5A (10-10.75): PI = 16 10.75: S-5B (10.75-11.5): PI = NP
		10.8	(PT), PEAT, nonplastic fines, dark brown; wet	29.9	PT					
		12.0	(OH), ORGANIC SILT, high plasticity fines, gray; very soft, wet	28.7	OH	ST ST-1		24/36		12.5: S-6: PI = 53
15		15.0	(SP), POORLY GRADED SAND, fine to medium sand, trace nonplastic fines, dark gray; very loose, wet, trace wood fragments	25.7	SP	SS S-6	0-0-3 **(3)**	12/18	3	15.0 ft, 03/04/2018 VWP reading 15.2 ft, 06/02/2018 VWP reading 17.7 ft, 10/03/2017 VWP reading 18.1 ft, 11/17/2017 VWP reading 18.7 ft, 11/04/2017 VWP reading
20		19.0	(GP), POORLY GRADED GRAVEL WITH SAND, fine to coarse subrounded to subangular gravel, some fine to coarse sand, trace nonplastic fines, dark gray; medium dense to very dense, wet	21.7	GP	SS S-7	10-11-16 **(27)**	9/18	27	
25						SS S-8	28-30-24 **(54)**	0/18	>>	
30						SS S-9	16-19-19 **(38)**	11/18	38	
35						SS S-10	13-15-16 **(31)**	9/18	31	
40		40.0		0.7						

Log continued on next page

DRILLING CO.: Holt Services Inc
DRILLER: Abe Causland
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G024

PROJECT: Downtown Redmond Link Extension	DRILLING START: August 10, 2017 08:02	SHEET: 2 of 2	
PROJECT NO.: 1657705	DRILLING END: August 11, 2017 11:16	GS ELEV.: 40.7 feet	
LOCATION: Marymoor Park	COORDINATES: N: 345,868 E: 1,424,704	TOC ELEV.: na	
		DATUM: NAVD88/Project Datum	

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC / ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
40	Mud Rotary	40.0	(SP), POORLY GRADED SAND, medium sand, trace nonplastic fines, dark gray; dense to very dense, wet	0.7	SP	SS S-11	11-20-31 (**51**)	0 / 18	>>		
45						SS S-12	17-20-21 (**41**)	13 / 18	41		
										47: VWP Installed	
50		51.5		-10.8		SS S-13	11-18-23 (**41**)	13 / 18	41		
			Bottom of borehole at 51.5 ft. Installed vibrating wire piezometer								

DRILLING CO.: Holt Services Inc
DRILLER: Abe Causland
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

RECORD OF BOREHOLE DRLE-G025

PROJECT:	Downtown Redmond Link Extension	DRILLING START:	August 8, 2017 08:42	SHEET:	1 of 2
PROJECT NO.:	1657705	DRILLING END:	August 9, 2017 12:46	GS ELEV.:	41.5 feet
LOCATION:	Marymoor Park	COORDINATES:	N: 345,844 E: 1,425,112	TOC ELEV.:	na
				DATUM:	NAVD88/Project Datum

BORING METHOD: Mud Rotary

Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC/ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS
0.0	(ML), FILL: SILT WITH SAND, mostly nonplastic fines, little fine to medium sand, brown; moist	41.5	ML	GS GS-1				0 - 5: Hand augered
4.5	(SP), POORLY GRADED SAND, fine sand, trace nonplastic fines, dark gray; loose to medium dense, moist to wet	37.0	SP	SS S-1	5-7-9 **(16)**	14/18	16	7.0 ft, ATD (estimated based on soil conditions)
				SS S-2	4-2-0 **(2)**	6/18	2	
8.5	(OH), ORGANIC SILT, high plasticity fines, gray; soft, moist to wet, seams of wood/roots < 1/2 inch thick	33.0	OH	SS S-3	1-1-2 **(3)**	18/18	3	
				ST ST-1		24/24		12.5: ST-1 @ 12.5': PI = 113 13: ST-1 @ 13.0': PI = 101 13.5: ST-1 @ 13.5': PI = 159
14.0	(PT), PEAT, nonplastic fines, dark brown; very soft, wet	27.5	PT					
15.8	(GP), POORLY GRADED GRAVEL WITH SAND, fine to coarse subrounded to subangular gravel, some medium sand, dark gray; dense to very dense, wet	25.7	GP	SS S-4	0-3-14 **(17)**	14/18	17	15: S-4: PI = NP 17: Drilling chatter
				SS S-5	12-26-31 **(57)**	6/18	>>	
				SS S-6	18-25-22 **(47)**	9/18	47	25: Drilling chatter
				SS S-7	15-20-30 **(50)**	9/18	50	30: Drilling chatter
35.5	(SP), POORLY GRADED SAND, medium sand, trace nonplastic fines, dark gray; dense, wet	6.0	SP	SS S-8	15-15-20 **(35)**	14/18	35	

Log continued on next page

DRILLING CO.:	Holt Services Inc	LOGGED:	Carly Schaeffer
DRILLER:	Abe Causland	CHECKED:	Margaret Pryor
DRILL RIG:	Mobile B-54	REVIEWED:	Dave Findley

RECORD OF BOREHOLE DRLE-G025

PROJECT: Downtown Redmond Link Extension
PROJECT NO.: 1657705
LOCATION: Marymoor Park

DRILLING START: August 8, 2017 08:42
DRILLING END: August 9, 2017 12:46
COORDINATES: N: 345,844 E: 1,425,112

SHEET: 2 of 2
GS ELEV.: 41.5 feet
TOC ELEV.: na
DATUM: NAVD88/Project Datum

DEPTH (ft)	BORING METHOD	Depth	DESCRIPTION	Elev	USCS	SAMPLE TYPE & NUMBER	BLOWS per 6 in (Automatic 140 lb Hammer, 30 inch drop)	REC / ATT (in)	PENETRATION RESISTANCE BLOWS / ft	NOTES WATER LEVELS	ADDITIONAL LAB TESTING
40	Mud Rotary	40.0	(SP), POORLY GRADED SAND, medium sand, trace nonplastic fines, dark gray; dense, wet *(continued)*	1.5	SP	SS S-9	11-17-17 **(34)**	12/18	34		
45						SS S-10	10-18-16 **(34)**	13/18	34		
50		51.5		-10.0		SS S-11	14-18-18 **(36)**	13/18	36		
			Bottom of borehole at 51.5 ft. Backfilled with bentonite grout.								

DRILLING CO.: Holt Services Inc
DRILLER: Abe Causland
DRILL RIG: Mobile B-54

LOGGED: Carly Schaeffer
CHECKED: Margaret Pryor
REVIEWED: Dave Findley

Golder Associates

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APPENDIX B

RECORD OF TEST PITS

Golder Associates

RECORD OF TEST PIT LOG

TEST PIT NUMBER DRLE-TP3A

DATE: 3-21-18

PROJECT: ST Redmond Link

PROJECT No.: 1657705

LOCATION: Marymoor Park Velodrome, East

Northing: 345,420 **Easting:** 1,425,641

Datum: NAVD88/Project Datum

Elevation ft: 43.1 feet **Length x Width ft:** 4.0 x 3.5

Contractor: Kelly's Excavating (Pat Hill)

Logged By: J. Jamsgard

Equipment: TB138

Water Conditions:
Not observed

Surface Conditions:
Sod

DEPTH (ft)	Depth	SOIL PROFILE – DESCRIPTION	USCS	GRAPHIC LOG	SAMPLE TYPE & NUMBER	CONSISTENCY[1] OR DENSITY[2]	WATER CONTENT (%)	OTHER TESTS & NOTES
0	0.0							
	0.3	Sod						
		(SP), POORLY GRADED SAND, fine to medium sand, trace nonplastic fines, trace fine subrounded gravel, tan-gray, stratified, trace subrounded cobbles up to 6 inches in diameter; loose, moist; caving obsreved from about 3 feet below the ground surface.						
					GB S-1			S-1: %Fines = 2
5			SP			loose	moist	5 - 6: Iron Oxide Staining
								7 - 9: Lens of coarse sand and gravel
		Increased coarse sand content.						
					GB S-2			
10	10.0	Bottom of test pit at 10.0 ft. Backfilled with cuttings and tamped with bucket.						
15								

Notes: [1] See Legend Sheet for Definition of Terms, Symbols and Abbreviations
[2] Consistency or Density values are estimated based on excavation resistance and/or visual/manual assessment of samples

Checked: Margaret Pryor
Reviewed: David Findley

Golder Associates

RECORD OF TEST PIT LOG

TEST PIT NUMBER DRLE-TP3B

DATE: 3-23-18

PROJECT: ST Redmond Link

PROJECT No.: 1657705

LOCATION: Marymoor Park Velodrome, East

Northing: 345,425 **Easting:** 1,425,644

Datum: NAVD88/Project Datum

Elevation ft: 43.2 feet **Length x Width ft:** 4.5 x 3.5

Contractor: Kelly's Excavating (Pat Hill)

Logged By: C. Bloom

Equipment: TB138

Water Conditions:
Not observed

Surface Conditions:
Sod

DEPTH (ft)	Depth	SOIL PROFILE DESCRIPTION	USCS	GRAPHIC LOG	SAMPLE TYPE & NUMBER	CONSISTENCY[1] OR DENSITY[2]	WATER CONTENT (%)	OTHER TESTS & NOTES	WELL INSTALL.
0	0.0	Sod							Well Installation: Solid 2" PVC 0-4' bgs; Slotted 2" PVC 4-9.5', capped at 9.5'
	1.0	(SP), POORLY GRADED SAND, fine to coarse sand, trace fine to coarse subrounded gravel, light brown to light tan; non-cohesive, medium dense, moist; sand and gravel content coarsened with depth.	SP			compact	moist	1 - 2: Iron Oxide Staining	
5									
10	10.5	Bottom of test pit at 10.5 ft. Completed as well. Refer to diagram.							
15									

Notes: [1] See Legend Sheet for Definition of Terms, Symbols and Abbreviations
[2]Consistency or Density values are estimated based on excavation resistance and/or visual/manual assessment of samples

Checked: Margaret Pryor
Reviewed: David Findley

APPENDIX C

IN SITU TESTS – PILOT INFILTRATION TESTING (PIT)

Golder completed the excavation of five test pits at four locations for the purpose of evaluating stormwater infiltration potential. The location of the test pit infiltration sites are shown on Figure 2 and are summarized in Table 2-1. The logs of the test pits are contained in Appendix B. Laboratory tests on test pit samples included grain size analyses, the results of which are contained in Appendix G.

The infiltration tests were completed under the general guidance provided by the Washington State Department of Ecology (WSDOE) guidelines provided in Volume III – Hydrologic Analysis and Flow Control BMPs; Stormwater Management in Western Washington (August 2012)[1]. The method utilized was the Small-Scale Pilot Infiltration Test (PIT). The test pits excavated for the PIT were typically 3 feet wide, 4 feet long, and 3 to 4 feet below the existing ground surface. The recommended 6-hour presoak period was abbreviated on three of the four test pits (DRLE-TP1, DRLE-TP3a, and DRLE-TP4) because of very high inflow of water and difficulty in maintaining the 12 inches of presoak head. Typically, inflows for the presoak were on the order of 1,000 gallons in less than an hour. As such, the recommended 6-hour presoak period was terminated early. The actual infiltration testing consisted of a constant head test followed by a falling head test until the test pit was drained. After completion of each infiltration test, the test pit was deepened full depth (10 feet below existing ground) to evaluate the presence or absence of any lower permeable layer that could affect infiltration. The field data analysis results in an uncorrected infiltration rate in inches/hour, summarized in Table C1.

Table C1. Infiltration Rate Correction

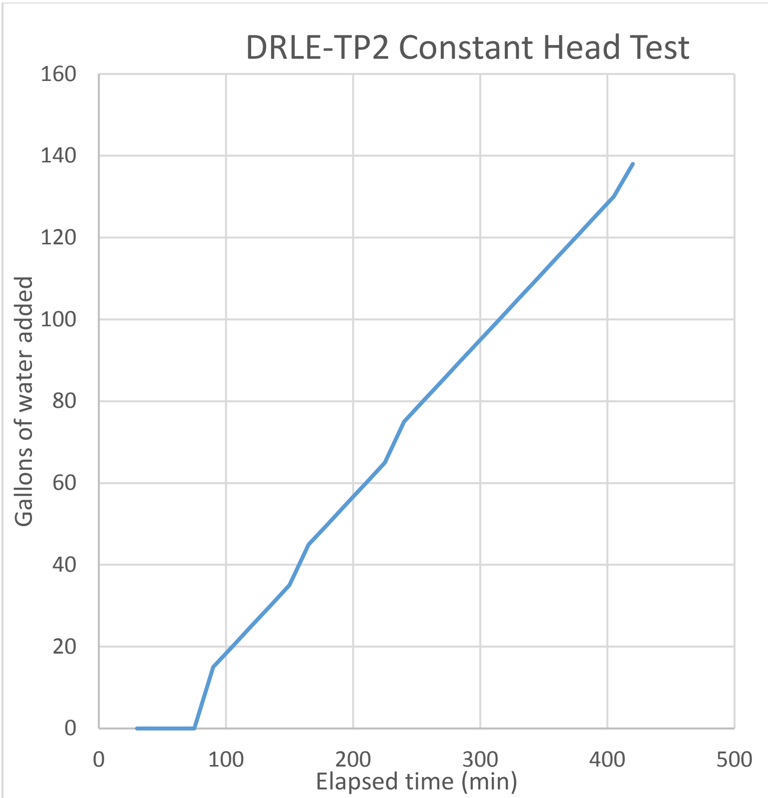
	TP-1	TP-2	TP-3A	TP-4
K_{field} (inches/hr)	49	2	74	71

The field data for each PIT is presented below.

[1] Washington State Department of Ecology. 2012. Stormwater Management Manual for Western Washington. Publication Number: 12-10-030. August.

Table C6. DRLE-TP2 Constant Head Test

Elapsed Time (min)	Gallons of water added	Rate (gpm)
15	0	0
30	0	0
45	0	0
60	0	0
75	0	0
90	15	1
105	5	0.33
120	5	0.33
135	5	0.33
150	5	0.33
165	10	0.67
180	5	0.33
195	5	0.33
210	5	0.33
225	5	0.33
240	10	0.67
255	5	0.33
270	5	0.33
285	5	0.33
300	5	0.33
315	5	0.33
330	5	0.33
345	5	0.33
360	5	0.33
375	5	0.33
390	5	0.33
405	5	0.33
420	8	0.53



DRLE-TP2 Constant Head Test
Gallons of water added
Elapsed time (min)
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500

Table C7. DRLE-TP2 Falling Head Test 1

Elapsed time (hr)	Head (in)	Rate (in/hr)
0	12	-
1	9.75	2.25
2	7.75	2
2.92	6	1.91

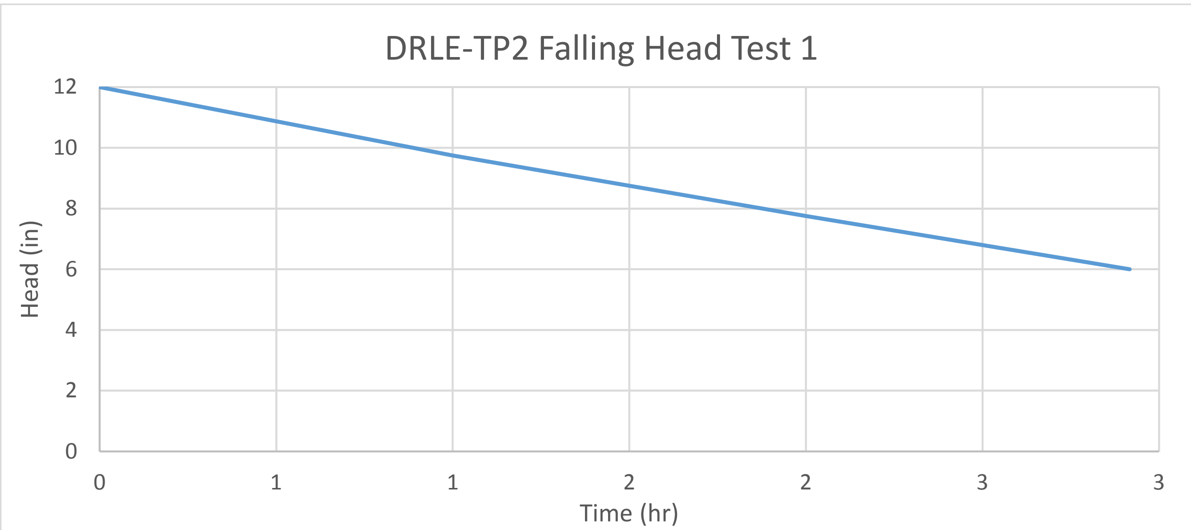


Table C8. DRLE-TP3A Constant Head Test

Elapsed Time (min)	Gallons of water added	Rate (gpm)
15	406	27.1
30	265	17.7
45	217	14.5
60	294	19.6
75	291	19.4
90	242	16.1

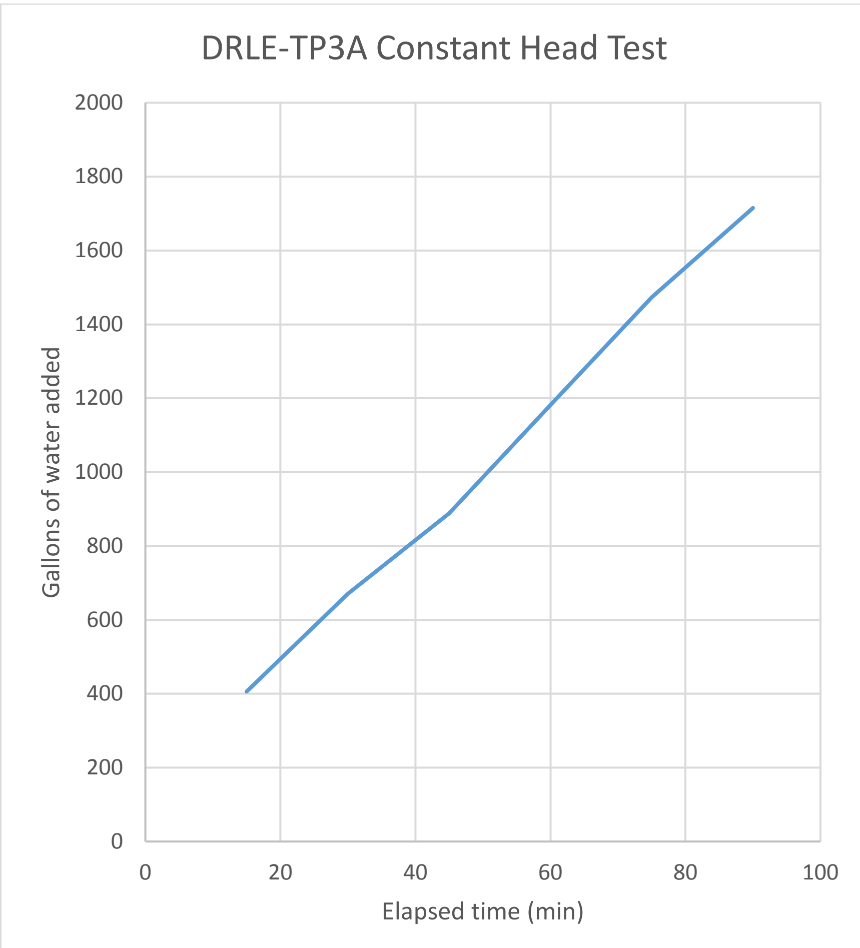


Table C9. DRLE-TP3A Falling Head Test 1

Elapsed Time (hr)	Head (in)	Rate (in/hr)
0	12	-
0.03	10	67.0
0.06	8	67.1
0.09	6	58.3
0.12	4	67.7
0.15	2	67.4

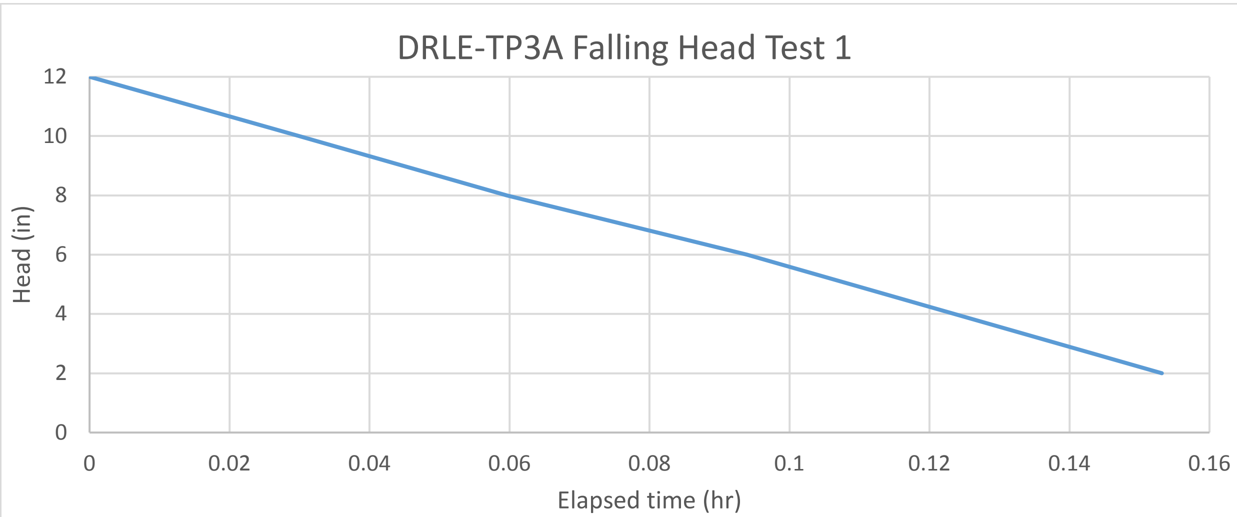


Table C10. DRLE-TP3A Falling Head Test 2

Elapsed Time (hr)	Head (in)	Rate (in/hr)
0	12	-
0.03	10	77.7
0.06	8	67.9
0.08	6	72.5
0.11	4	69.0
0.14	2	85.9

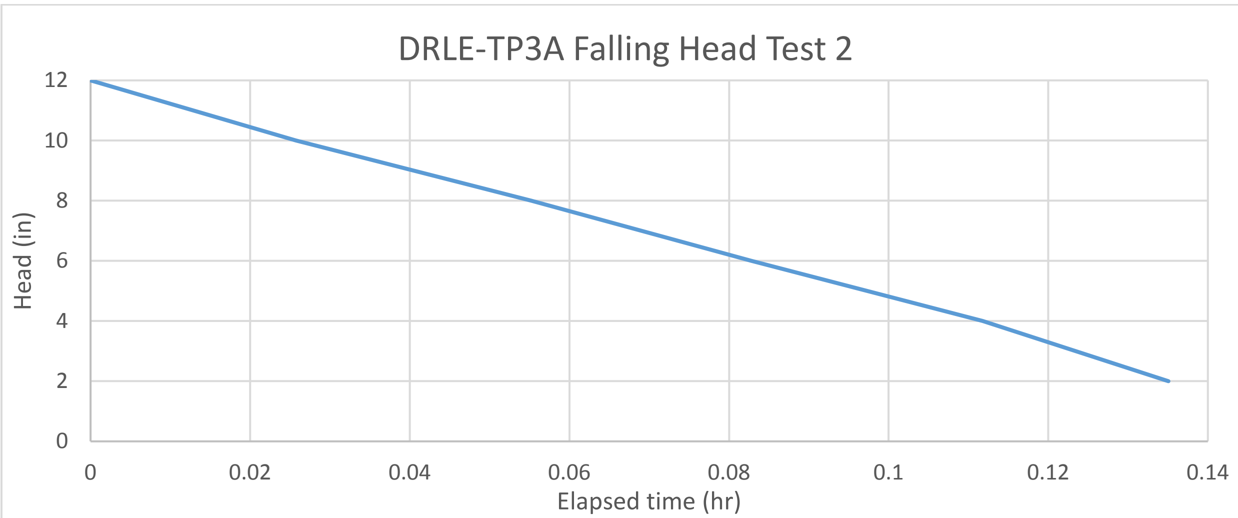
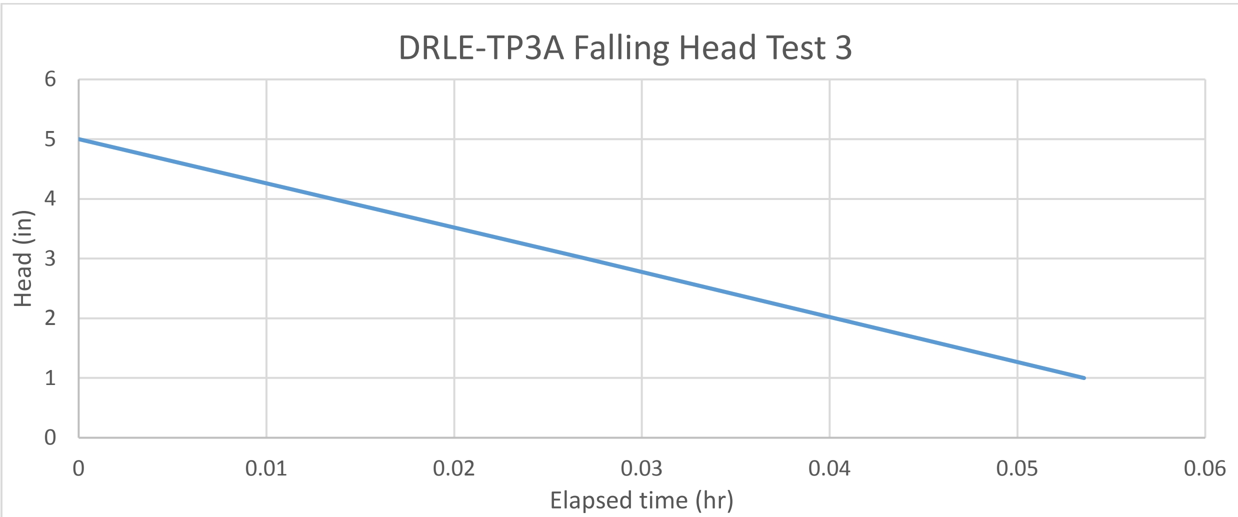


Table C11. DRLE-TP3A Falling Head Test 3

Elapsed Time (hr)	Head (in)	Rate (in/hr)
0	5	-
0.03	3	74.0
0.05	1	75.4



APPENDIX G

LABORATORY TESTS – SOIL TESTING (HAYRE MCELROY AND ASSOCIATES, LLC)

HMA Sample #	Sample #	Depth	Date Received	Date of Test	Tare #	Wt of Tare	Tare+ Wet	Tare+ Dry	Moisture %
054-138	G17-A S39	190'	12/13/2017	12/19/2017	G20	15.80	151.00	120.80	**28.8**
054-139	G17-A S40	200'	12/13/2017	12/19/2017	G14	15.70	124.90	97.20	**34.0**
054-140	G17-A S41	210'	12/13/2017	12/19/2017	B25	15.90	107.40	84.00	**34.4**
054-141	G17-A S42A	220'	12/13/2017	12/19/2017	A29	16.20	212.10	194.00	**10.2**
054-142	G17-A S43	230'	12/13/2017	12/19/2017	X7	192.90	434.80	409.00	**11.9**
8003-17	G018 S-1	2.5'-4'	11/3/2017	11/7/2017	G-16	15.8	274.1	189.6	**48.6**
8003-18	G018 S-2	5'-6.5'	11/3/2017	11/7/2017	B-4	15.9	374.3	265.4	**43.6**
8003-19	G018 S-3	7.5'-9'	11/3/2017	11/7/2017	F-71	15.9	333.9	251.3	**35.1**
8003-20	G018 S-4	9'-10.5'	11//3/2017	11/7/2017	G-24	15.9	281.1	177.2	**64.4**
8003-21	G018 S-5	10.5'-12'	11/3/2017	11/7/2017	G-25	15.7	360.0	257.4	**42.4**
8003-22	G018 S-6	12'-13.5'	11/3/2017	11/7/2017	G-20	15.8	284.3	215.5	**34.5**
8003-23	G018 S-7	21'-22.5'	11/3/2017	11/7/2017	AB22	15.7	125.3	122.7	**2.4**
8003-24	G018 S-11	40-41.5'	11/3/2017	11/7/2017	B-25	15.9	564.7	464.1	**22.4**
8003-25	G018 S-14	60-61.5	11/3/2017	11/7/2017	A-4	15.8	552.0	428.2	**30.0**
8003-27	G018 S-17	77.5'-79'	11/3/2017	11/7/2017	G-8	15.8	576.6	445.3	**30.6**
8003-28	G018 S-19	85'-86.5'	11/3/2017	11/7/2017	G-14	15.9	510.0	383.4	**34.4**
8003-29	G018 S-20	90'-91.5'	11/3/2017	11/7/2017	G-3	15.6	483.4	372.0	**31.3**
8003-30	G018 S-21	95'-96.5'	11/3/2017	11/7/2017	G-7	15.9	550.6	409.3	**35.9**
8003-31	G018 S-22	100'-101.5'	11/3/2017	11/7/2017	B-9	15.9	473.4	372.4	**28.3**
8003-32	G018 S-23	105'-106.5'	11/3/2017	11/7/2017	ABL3	16.0	564.9	431.8	**32.0**
8003-33	G018 S-25	115'-116.5'	11/3/2017	11/7/2017	G-1	15.7	452.2	333.6	**37.3**
8003-34	G018 S-26	120'-121.5'	11/3/2017	11/7/2017	A-21	15.9	392.4	293.1	**35.8**
8003-35	G018 S-27	125'-126.5'	11/3/2017	11/7/2017	X-7	193.3	246.1	235.4	**25.4**
8003-36	G018 S-28	130'-131.5'	11/3/2017	11/7/2017	X-8	194.1	621.5	512.8	**34.1**
8003-37	G018 S-29	140'-141.5'	11/3/2017	11/7/2017	A-44	190.1	223.0	213.6	**40.0**
8003-38	G018 S-31	150'-151.5'	11/3/2017	11/7/2017	X-6	196.2	695.7	619.2	**18.1**
8003-39	G018 S-33	160'-161.5'	11/3/2017	11/7/2017	X-9	231.2	624.2	515.9	**38.0**
8003-40	G018 S-34	170'-171.5'	11/3/2017	11/7/2017	X-5	198.3	581.7	486.7	**32.9**
8003-41	G018 S-35	175'-176.5'	11/3/2017	11/7/2017	9A	161.9	666.2	532.0	**36.3**
8003-42	G018 S-37	185'-186.5'	11/3/2017	11/7/2017	AB	157.6	592.9	487.3	**32.0**
8003-43	G018 S-38	190'-191.5'	11/3/2017	11/7/2017	AJ	164.9	612.2	507.9	**30.4**
8003-44	G018 S-39	200'-201.5'	11/3/2017	11/7/2017	A-7	16.4	211.1	190.9	**11.6**

HMA Sample #	Sample #	Depth	Date Received	Date of Test	Tare #	Wt of Tare	Tare+ Wet	Tare+ Dry	Moisture %
7992-1	G019 S-1	0'-1.5'	9/29/2017	10/3/2017	A-15	18.0	134.9	102.5	**38.3**
7992-2	G019 S-2	2.5'-4'	9/29/2017	10/3/2017	A-16	16.2	138.6	101.1	**44.2**
7992-3	G019 S-3	5'-6.5'	9/29/2017	10/3/2017	A-22	16.1	181.2	76.6	**172.9**
7992-4	G019 S-6	12.5'-14'	9/29/2017	10/3/2017	B-14	15.9	288.5	256.7	**13.2**
7992-5	G019 S-7	15'-16.5'	9/29/2017	10/3/2017	B-21	15.8	130.8	120.4	**9.9**
7992-6	G019 S-10	30'-31'.5"	9/29/2017	10/3/2017	A-2	16.9	311.6	267.6	**17.6**
7992-7	G019 S-12	40'-41.5'	9/29/2017	10/3/2017	A-9	16.4	326.1	258.1	**28.1**
7992-8	G019 S-14	50'-51.5'	9/29/2017	10/3/2017	B-5	16.20	222.10	174.20	**30.3**
7992-9	G019 S-16	60'-61.5'	9/29/2017	10/3/2017	B-3	16.60	308.80	244.4	**28.3**
7992-10	G019 S-18	70'-71.5'	9/29/2017	10/3/2017	B-8	16.2	274.50	218.40	**27.7**
7980-1	G019 S-19a	75'-76.5'	8/10/2017	8/11/2017	A-26	16.4	356.6	275.5	**31.3**
7980-2	G019 S-19b	75'-76.5'	8/10/2017	8/11/2017	A-191	16.2	371.9	287.5	**31.1**
7980-3	G019 S-21	85'-86.5'	8/10/2017	8/11/2017	B-4	16.6	445.9	335.6	**34.6**
7980-4	G019 S-23	95'-96.5'	8/10/2017	8/11/2017	A-19	16.0	470.9	346.2	**37.8**
7980-5	G019 S-25	105'-106.5'	8/10/2017	8/11/2017	A-13	16.1	421.1	321.6	**32.6**
7980-6	G019 S-27	115'-116.5'	8/10/2017	8/11/2017	AB23	16.0	461.2	370.3	**25.7**
7980-7	G019 S-29	125'-126.5'	8/10/2017	8/11/2017	B-9	15.8	480.6	368.6	**31.7**
7992-11	G019 S-31	135'-136'.5"	9/29/2017	10/3/2017	B-10	16.9	389.1	314.3	**25.2**
7992-12	G019 S-32	140'-141'.5"	9/29/2017	10/3/2017	For	16.0	387.8	322.10	**21.5**
7992-13	G019 S-35	155'-156.5'	929/2017	10/3/2017	A-29	16.0	551.8	478.2	**15.9**
7992-14	G020 S-1	0.0'-1.5'	9/29/2017	10/3/2017	B	16.0	55.7	51.8	**10.9**
7992-15	G020 S-2	2.5'-4'	9/29/2017	10/3/2017	A-10	16.2	316.0	290.4	**9.3**
7992-16	G020 S-4	7.5'-9'	9/29/2017	10/3/2017	A-7	16.3	289.6	263.6	**10.5**
7992-17	G020 S-5	10'-11.5'	9/29/2017	10/3/2017	B-1	15.9	405.5	370.40	**9.9**
7992-18	G020 S-7	15'-16.5'	9/29/2017	10/3/2017	B-26	15.9	387.9	356.8	**9.1**
7992-19	G020 S-11	35'-36.5'	9/29/2017	10/3/2017	B-17	16.6	384.6	321.7	**20.6**
7992-20	G020 S-13	45'-46.5'	9/29/2017	10/3/2017	A-23	16.4	279.2	227.4	**24.5**
7992-21	G020 S-14	50'-51.5'	9/29/2017	10/3/2017	B-6	16.1	398.1	320.1	**25.7**
7992-22	G020 S-16	60'-61.5'	9/29/2017	10/3/2017	B-2	16.1	566.5	455.3	**25.3**
7992-23	G020 S-19	75'-76.5'	9/29/2017	10/3/2017	A-12	16.4	427.6	340.8	**26.8**
7980-8	G020 S-20	80'-81.5'	8/10/2017	8/11/2017	zz	16.1	488.8	378.6	**30.4**
7980-8	G020 S-20	80'-81.5'	8/10/2017	8/11/2017	ZZ	16.10	488.80	378.60	**30.4**
7980-9	G020 S-22	90'-91.5'	8/10/2017	8/11/2017	B-192	15.7	509.7	383.4	**34.3**

HMA Sample #	Sample #	Depth	Date Received	Date of Test	Tare #	Wt of Tare	Tare+ Wet	Tare+ Dry	Moisture %
7980-9	G020 S-22	90'-91.5'	8/10/2017	8/11/2017	B-192	15.70	509.70	383.4	**34.3**
7980-10	G020 S-24	100'-101.5'	8/10/2017	8/11/2017	B-2	17.0	545.8	423.0	**30.2**
7980-10	G020 S-24	100'-101.5'	8/10/2017	8/11/2017	B-2	17.0	545.80	423.00	**30.2**
7980-11	G020 S-25	105'-106.5	8/10/2017	8/11/2017	B-3	15.8	496.4	378.7	**32.4**
7980-11	G020 S-25	105'-106.5'	8/10/2017	8/11/2017	B-3	15.8	496.4	378.7	**32.4**
7980-12	G020 S-26	110'-111.5'	8/10/2017	8/11/2017	A-1	16.1	413.1	312.7	**33.9**
7980-12	G020 S-26	110'-111.5'	8/10/2017	8/11/2017	A-1	16.1	413.1	312.70	**33.9**
7980-13	G020 S-28	120'-121.5'	8/10/2017	8/11/2017	A-27	16.0	457.4	344.4	**34.4**
7980-14	G020 S-31	135'-136.5'	8/10/2017	8/11/2017	B-28	16.6	447.1	344.4	**31.3**
7980-15	G020 S-33	145'-146.5'	8/10/2017	8/11/2017	A-31	15.8	401.3	315.1	**28.8**
7995-1	G020 S-34	150'-151.5'	10/17/2017	10/18/2017	B-18	15.8	343.8	285.5	**21.6**
7992-24	G020 S-35	155'-156.5'	9/29/2017	10/3/2017	B-19	16.1	631.0	522.6	**21.4**
7992-25	G020 S-36	160'-161.5'	9/29/2017	10/3/2017	A-14	15.8	450.4	383.2	**18.3**
7980-16	G020 S-37	165'-166.5'	8/10/2017	8/11/2017	A-3	16.1	400.2	307.5	**31.8**
7980-17	G020 S-40	180'-181.5'	8/10/2017	8/11/2017	B-27	15.7	278.9	223.80	**26.5**
7992-26	G021 S-1	0'-1.5'	9/29/2017	10/3/2017	A-4	16.4	183.6	136.7	**39.0**
7992-27	G021 S-2	2.5'-3.5'	9/29/2017	10/3/2017	B-18	15.8	278.1	206.5	**37.5**
7992-28	G021 S-3	5'-6'	9/29/2017	10/3/2017	A-18	15.9	115.7	88.5	**37.5**
7992-29	G021 S-4	7.5'-9'	9/29/2017	10/3/2017	A-17	16.0	282.3	258.4	**9.9**
7992-30	G021 S-6	12.5'-14'	9/29/2017	10/3/2017	B-20	17.60	404.60	364.00	**11.7**
7992-31	G021 S-8	20'-21.5	9/29/2017	10/3/2017	Ab-22	16.00	113.30	105.9	**8.2**
7992-32	G021 S-10	30'-31.5'	9/29/2017	10/3/2017	B-25	15.7	535.60	484.50	**10.9**
7992-33	G021 S-12	40'-41.5	9/29/2017	10/3/2017	C-1	16.0	482.8	438.7	**10.4**
7992-34	G022 S-1	0'1.5"	9/29/2017	10/3/2017	C-3	15.8	270.0	205.90	**33.7**
7992-35	G022 S-2	5'-6.5'	929/2017	10/3/2017	C-4	16.0	248.1	107.0	**155.1**
7992-36	G022 S-4	10'-11.5'	9/29/2017	10/3/2017	C-5	15.7	149.0	143.0	**4.7**
7992-37	G022 S-6	15'-16.5'	9/29/2017	10/3/2017	C-6	15.9	459.9	418.2	**10.4**
7992-38	G022 S-8	25'-26.5'	9/29/2017	10/3/2017	C-7	16.0	560.7	516.8	**8.8**
7992-39	G022 S-10	35'-36.5'	9/29/2017	10/3/2017	C-8	15.8	417.9	347.30	**21.3**
7992-40	G022 S-12	45'-46.5'	9/29/2017	10/3/2017	C-9	15.8	442.4	363.9	**22.6**
7992-41	G023 S-1	3.6'-4.0	9/29/2017	10/3/2017	C-10	15.8	232.1	181.3	**30.7**
7992-42	G023 S-2	5'-6.5'	9/29/2017	10/3/2017	C-11	15.8	329.8	140.5	**151.8**
7992-43	G023 S-6	15'-17.5'	9/29/2017	10/3/2017	C-12	15.9	488.5	445.9	**9.9**
7992-44	G023 S-9	30'-31.5'	9/29/2017	10/3/2017	C-13	15.8	385.9	341.9	**13.5**

HMA Sample #	Sample #	Depth	Date Received	Date of Test	Tare #	Wt of Tare	Tare+ Wet	Tare+ Dry	Moisture %
7995-2	G024 S-1	0.0'-1.5'	10/17/2017	10/18/2017	G-1	15.7	331.0	274.7	**21.7**
7995-3	G024 S-2	2.5'-4'	10/17/2017	10/18/2017	G-2	15.7	293.1	243.4	**21.8**
7995-4	G024 S-3	5'-6.5'	10/17/2017	10/18/2017	G-3	15.6	313.2	231.0	**38.2**
7995-5	G024 S-4	7.5'-9'	10/17/2017	10/18/2017	G-4	15.8	332.2	226.8	**50.0**
7995-6	G024 S-5A	10'-11'.5"	10/17/2017	10/18/2017	G-5	15.7	333.5	221.2	**54.6**
7995-7	G024 S-5B	10'-11'.5"	10/17/2017	10/18/2017	G-6	15.7	198.0	85.3	**161.9**
7995-8	G024 S-6	15.5'-17'	10/17/2017	10/18/2017	G-7	15.8	331.90	256.00	**31.6**
7995-9	G024 S-10	35'-36.5'	10/17/2017	10/18/2017	G-8	15.7	372.60	337.6	**10.9**
7995-10	G025 S-1	5'-6.5'	10/17/2017	10/18/2017	G-9	15.8	327.00	262.80	**26.0**
7995-11	G025 S-3	10'-11.5'	10/17/2017	10/18/2017	G-10	15.6	323.5	239.2	**37.7**
7995-12	G025 S-4A	15'-16.5'	10/17/2017	10/18/2017	G-11	15.6	260.1	93.00	**215.9**
7995-13	G025 S-6	25'-26.5'	10/17/2017	10/18/2017	G-12	15.7	360.9	329.0	**10.2**
7995-14	G027 S-1	2.5'-4.0'	10/17/2017	10/18/2017	G-13	15.6	308.5	303.4	**1.8**
7995-15	G027 S-3	7.5'-9.0'	10/17/2017	10/18/2017	G-14	15.7	349.8	336.4	**4.2**
7995-16	G027 S-4	10'-11.5'	10/17/2017	10/18/2017	G-15	15.7	561.0	535.4	**4.9**
7995-17	G027 S-5	12.5'-14.0'	10/17/2017	10/18/2017	G-16	15.6	354.8	332.60	**7.0**
7995-18	G027 S-6	15'-16.5'	10/17/2017	10/18/2017	G-17	15.8	305.8	276.7	**11.2**
7995-19	G027 S-7	20'-21.5'	10/17/2017	10/18/2017	G-18	15.8	257.5	220.5	**18.1**
7995-20	G027 S-9B	30.5'-31.5'	10/17/2017	10/18/2017	G-19	15.8	379.1	339.6	**12.2**
7995-21	G027 S-13	50'-51.5'	10/17/2017	10/18/2017	G-20	15.8	200.3	166.2	**22.7**
7995-23	G028 S-2	10'-11.5'	10/17/2017	10/18/2017	G-22	15.8	233.1	215.6	**8.8**
7995-24	G028 S-4	15'-16.5'	10/17/2017	10/18/2017	G-23	15.8	325.7	225.1	**48.1**
7995-22	G028 S-1	17.5'-9.0'	10/17/2017	10/18/2017	G-21	15.8	361.8	352.4	**2.8**
7995-25	G028 S-5	20'-21.5'	10/17/2017	10/18/2017	G-24	15.8	316.3	287.9	**10.4**
7995-26	G028 S-6	25'-26.5'	10/17/2017	10/18/2017	G-25	15.8	456.8	419.4	**9.3**
8023-5	G029 S1	5	2/19/2018	2/21/2018	5	16.1	453.3	406.4	**12.0**
8023-6	G029 S3	12.5	2/19/2018	2/21/2018	6	15.9	155.1	132.8	**19.1**
8023-7	G029 S5	20	2/19/2018	2/21/2018	7	15.8	243.5	217.7	**12.8**
8023-8	G029 S6	25	2/19/2018	2/21/2018	8	15.9	611.4	558.9	**9.7**
8023-9	G029 S8	35	2/19/2018	2/21/2018	9	15.8	93.5	84.2	**13.7**
8023-10	G029 S10	45	2/19/2018	2/21/2018	10	16.1	273.1	221.2	**25.3**
8023-11	G029 S11	50	2/19/2018	2/21/2018	11	15.8	481.7	400.0	**21.3**
8023-12	G029 S12	55	2/19/2018	2/21/2018	12	16.0	279.3	219.6	**29.3**

GRAIN SIZE DISTRIBUTION TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-4
Depth: 9'-10.5' **Sample Number:** 8003-20
Material Description: Silty Sand
Date: 11/10/2017
USCS Classification: SM
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 128.30
Tare Wt. = 15.90
Minus #200 from wash = 30.3%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
177.20	15.90	3/8"	0.00	0.00	100.0
		#4	3.10	0.00	98.1
		#10	7.60	0.00	93.4
		#40	31.80	0.00	73.7
		#100	28.80	0.00	55.8
		#200	24.60	0.00	40.5

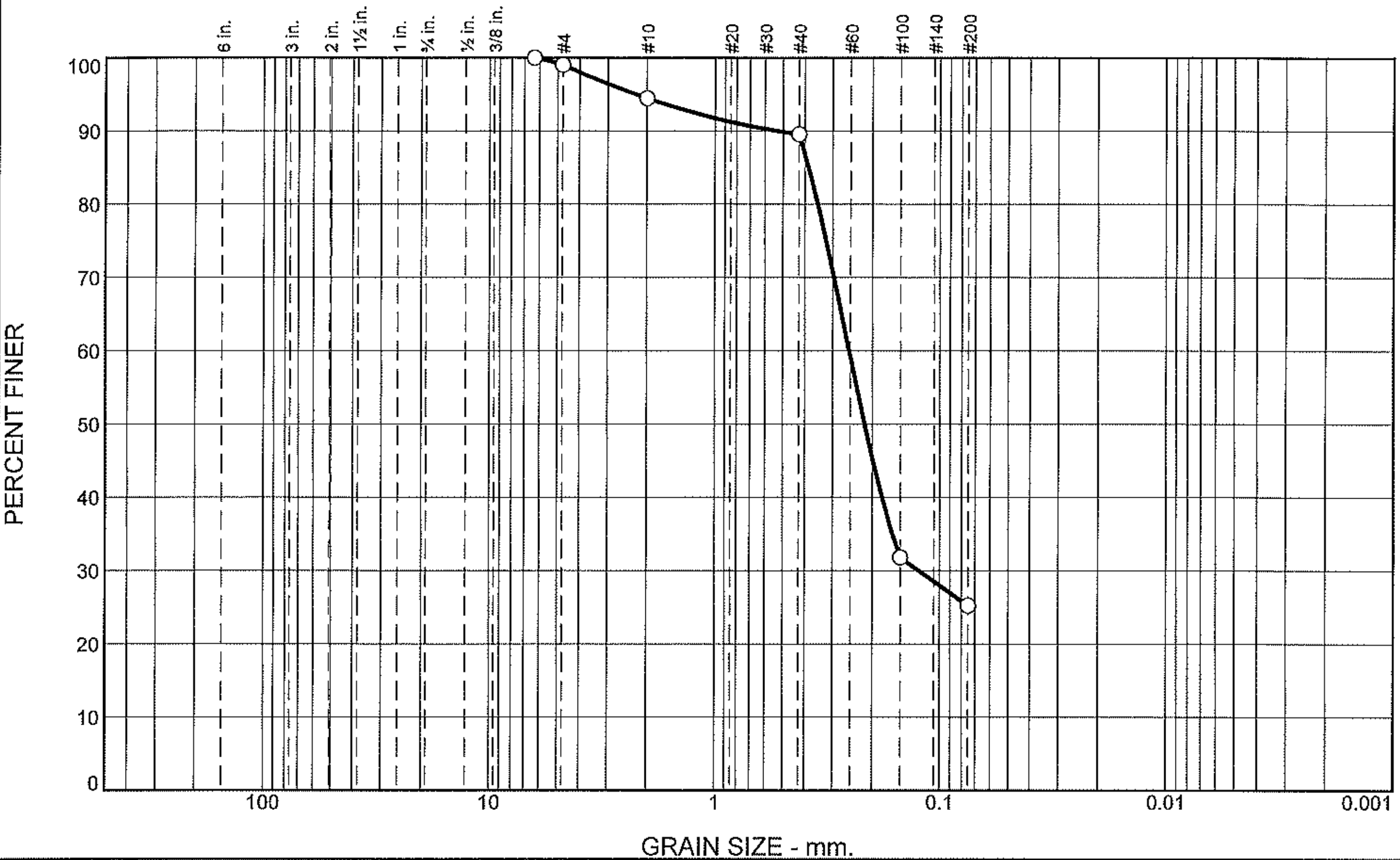
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	1.9	1.9	4.7	19.7	33.2	57.6			40.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
				0.1140	0.1865	0.6485	0.9294	1.4071	2.4963

Fineness Modulus
1.16

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.0	4.6	4.9	64.3	25.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/4"	100.0		
#4	99.0		
#10	94.4		
#40	89.5		
#100	31.8		
#200	25.2		

* (no specification provided)

Soil Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.5351 D_{85}= 0.3852 D_{60}= 0.2538
D_{50}= 0.2164 D_{30}= 0.1240 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G018 S-6
Sample Number: 8003-22 **Depth:** 12'-13.5' **Date:** 11/10/2017

Hayre McElroy & Associates, LLC
Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-6
Depth: 12'-13.5' **Sample Number:** 8003-22
Material Description: Silty Sand
Date: 11/10/2017
USCS Classification: SM
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 205.90
Tare Wt. = 15.80
Minus #200 from wash = 4.8%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
215.50	15.80	1/4"	0.00	0.00	100.0
		#4	2.00	0.00	99.0
		#10	9.10	0.00	94.4
		#40	9.80	0.00	89.5
		#100	115.30	0.00	31.8
		#200	13.10	0.00	25.2

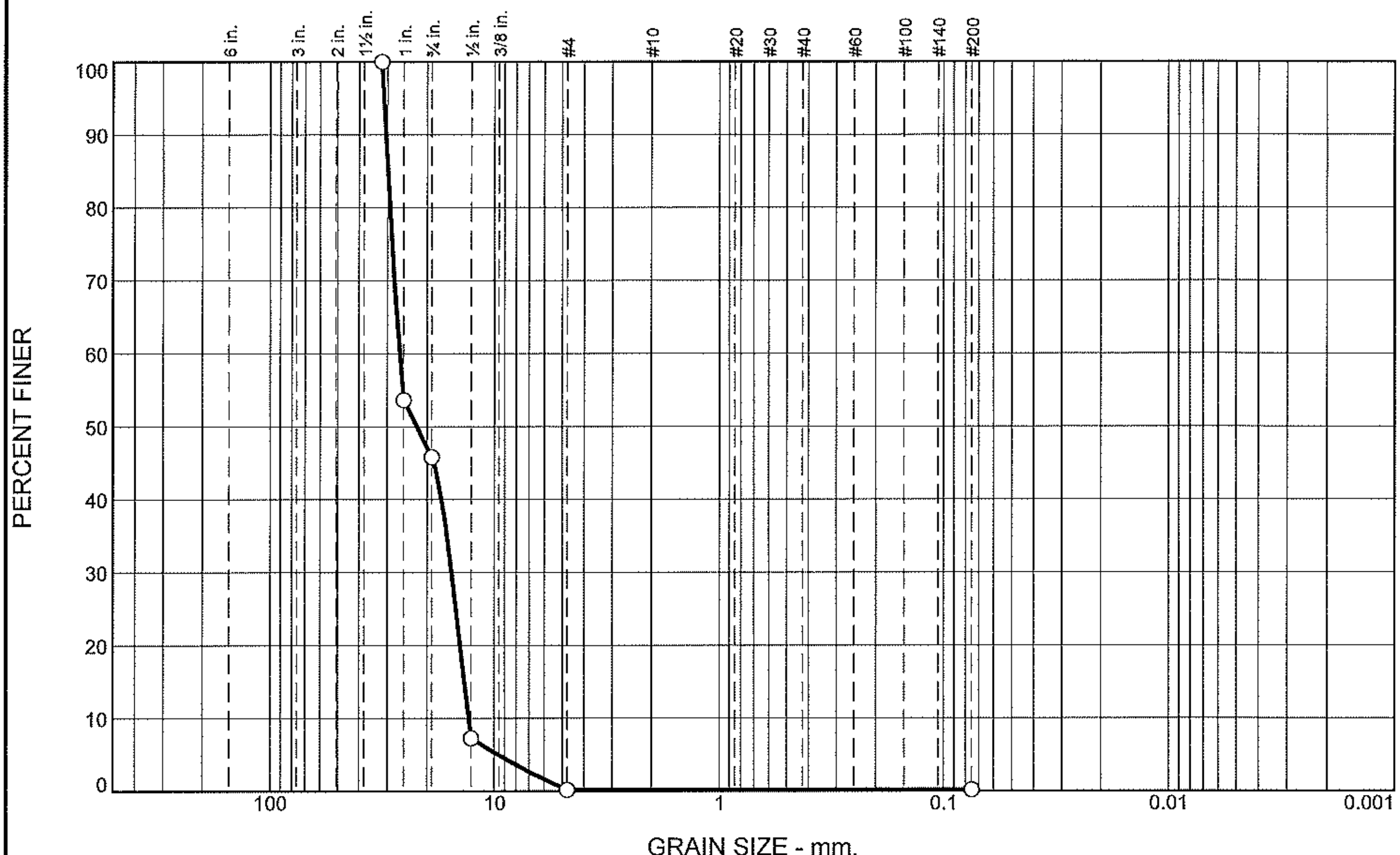
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	1.0	1.0	4.6	4.9	64.3	73.8			25.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
			0.1240	0.2164	0.2538	0.3507	0.3852	0.5351	2.2569

Fineness Modulus
1.21

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	54.2	45.6	0.0	0.0		0.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/4"	100.0		
1"	53.6		
3/4"	45.8		
1/2"	7.3		
#4	0.2		
#200	0.2		

* (no specification provided)

Soil Description

Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 30.5164 D_{85}= 29.9045 D_{60}= 26.5663
D_{50}= 22.2242 D_{30}= 15.5430 D_{15}= 13.6481
D_{10}= 13.0414 C_u= 2.04 C_c= 0.70

Classification

USCS= GP AASHTO=

Remarks

Location: G018 S-7
Sample Number: 8003-23 **Depth:** 21'-22.5' **Date:** 11/10/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-7
Depth: 21'-22.5'
Sample Number: 8003-23
Material Description: Gravel
Date: 11/10/2017
USCS Classification: GP
Tested by: SR
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 122.50
Tare Wt. = 15.70
Minus #200 from wash = 0.2%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
122.70	15.70	1 1/4"	0.00	0.00	100.0
		1"	49.60	0.00	53.6
		3/4"	8.40	0.00	45.8
		1/2"	41.20	0.00	7.3
		#4	7.60	0.00	0.2

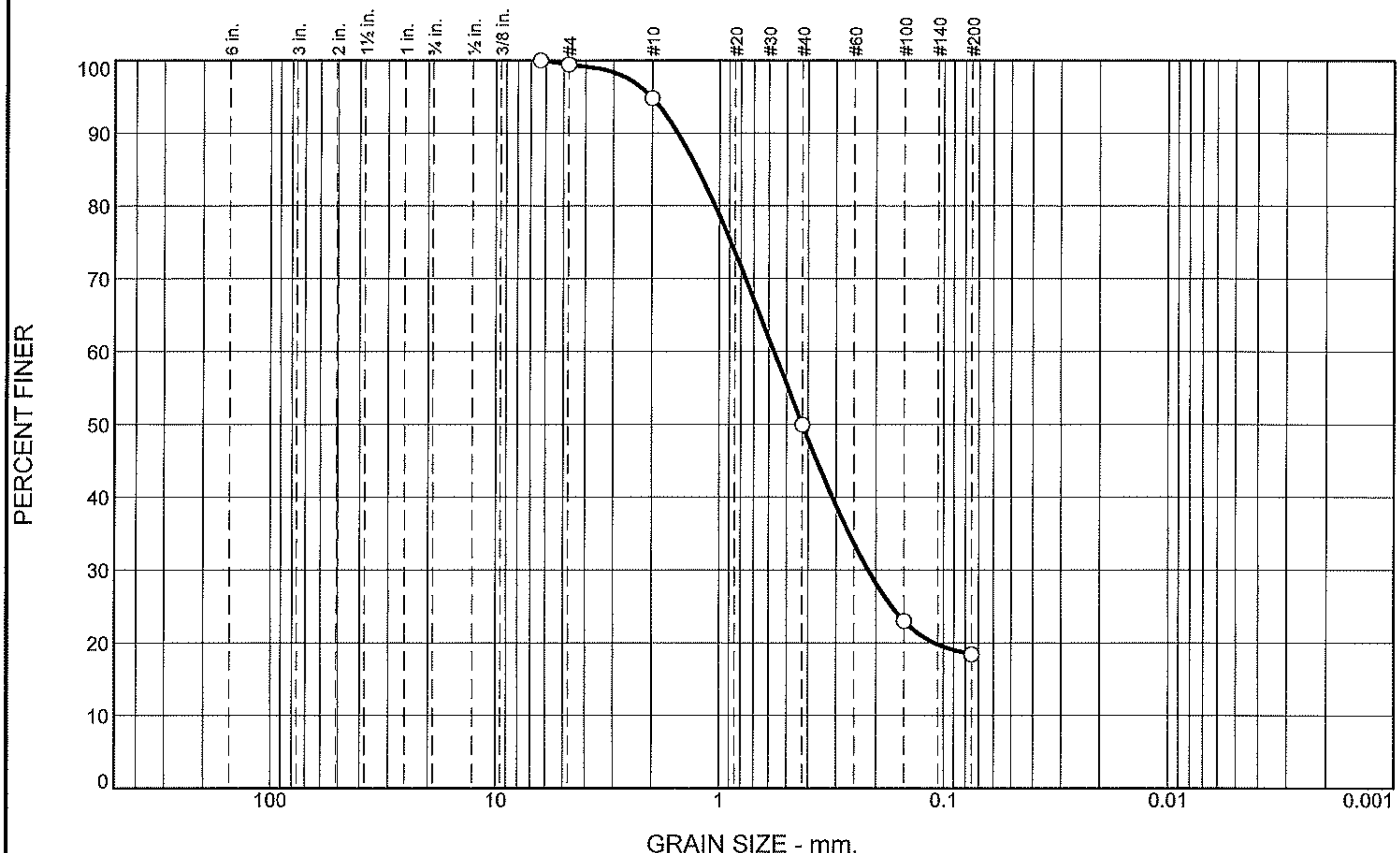
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	54.2	45.6	99.8	0.0	0.0		0.0			0.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
13.0414	13.6481	14.2513	15.5430	22.2242	26.5663	29.2879	29.9045	30.5164	31.1298

Fineness Modulus	C_u	C_c
7.48	2.04	0.70

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.6	4.6	44.9	31.5	18.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/4"	100.0		
#4	99.4		
#10	94.8		
#40	49.9		
#100	23.0		
#200	18.4		

* (no specification provided)

Soil Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.5347 D_{85}= 1.2486 D_{60}= 0.5698
D_{50}= 0.4259 D_{30}= 0.2168 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G018 S-31
Sample Number: 8003-38 **Depth:** 150'-151.5' **Date:** 11/10/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-31
Depth: 150'-151.5' **Sample Number:** 8003-38
Material Description: Silty Sand
Date: 11/10/2017
USCS Classification: SM
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 549.40
Tare Wt. = 196.20
Minus #200 from wash = 16.5%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
619.20	196.20	1/4"	0.00	0.00	100.0
		#4	2.40	0.00	99.4
		#10	19.60	0.00	94.8
		#40	189.80	0.00	49.9
		#100	114.00	0.00	23.0
		#200	19.30	0.00	18.4

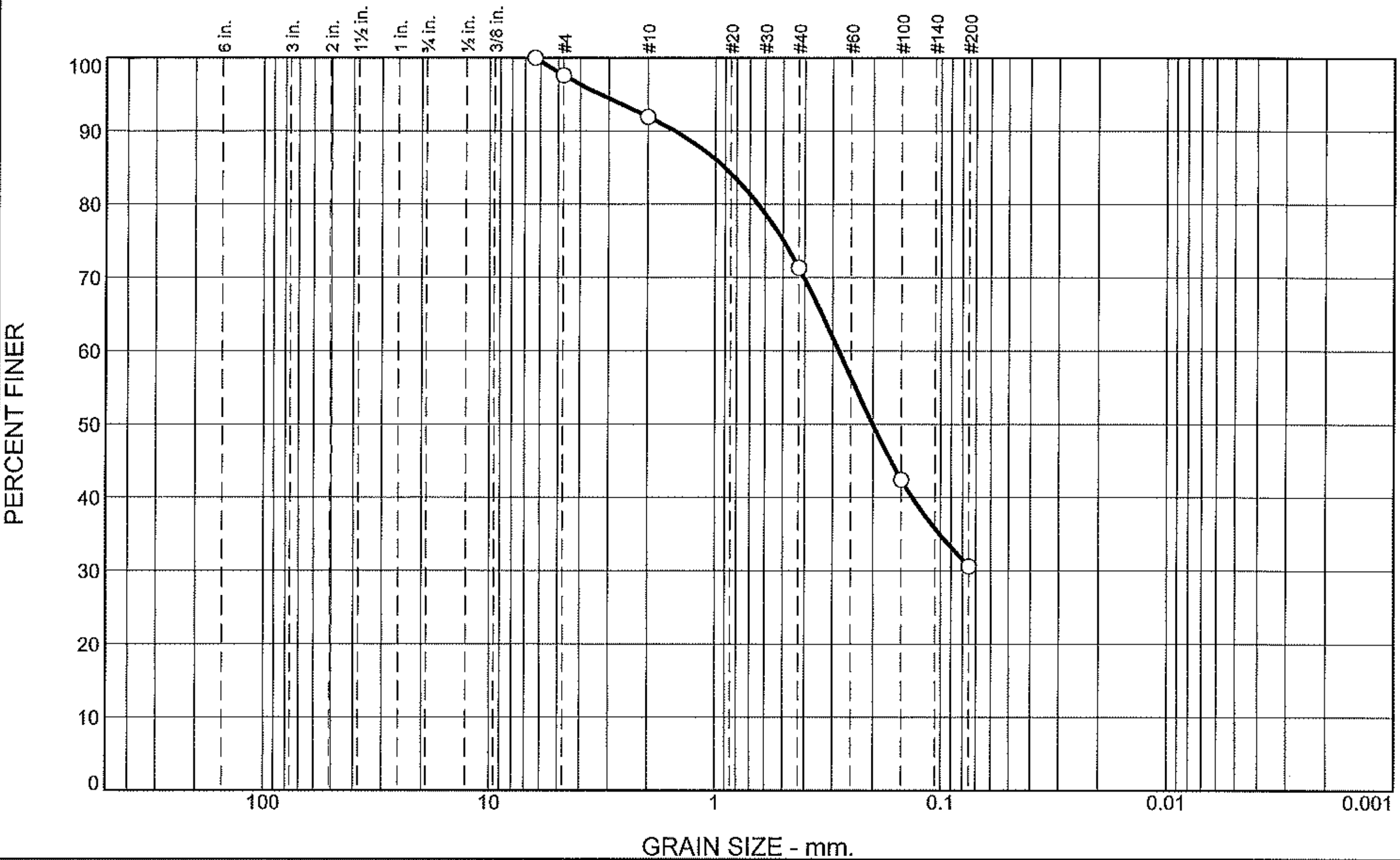
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.6	0.6	4.6	44.9	31.5	81.0			18.4

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
		0.1104	0.2168	0.4259	0.5698	1.0455	1.2486	1.5347	2.0291

Fineness Modulus
1.97

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	2.4	5.7	20.6	40.7	30.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/4"	100.0		
#4	97.6		
#10	91.9		
#40	71.3		
#100	42.4		
#200	30.6		

* (no specification provided)

Soil Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.5214 D_{85}= 0.9088 D_{60}= 0.2829
D_{50}= 0.2013 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G018 S-39
Sample Number: 8003-44 **Depth:** 200'-201.5' **Date:** 11/10/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-39
Depth: 200'-201.5'
Sample Number: 8003-44
Material Description: Silty Sand
Date: 11/10/2017
USCS Classification: SM
Tested by: SR
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 147.50
Tare Wt. = 16.40
Minus #200 from wash = 24.9%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
190.90	16.40	1/4"	0.00	0.00	100.0
		#4	4.20	0.00	97.6
		#10	9.90	0.00	91.9
		#40	35.90	0.00	71.3
		#100	50.50	0.00	42.4
		#200	20.60	0.00	30.6

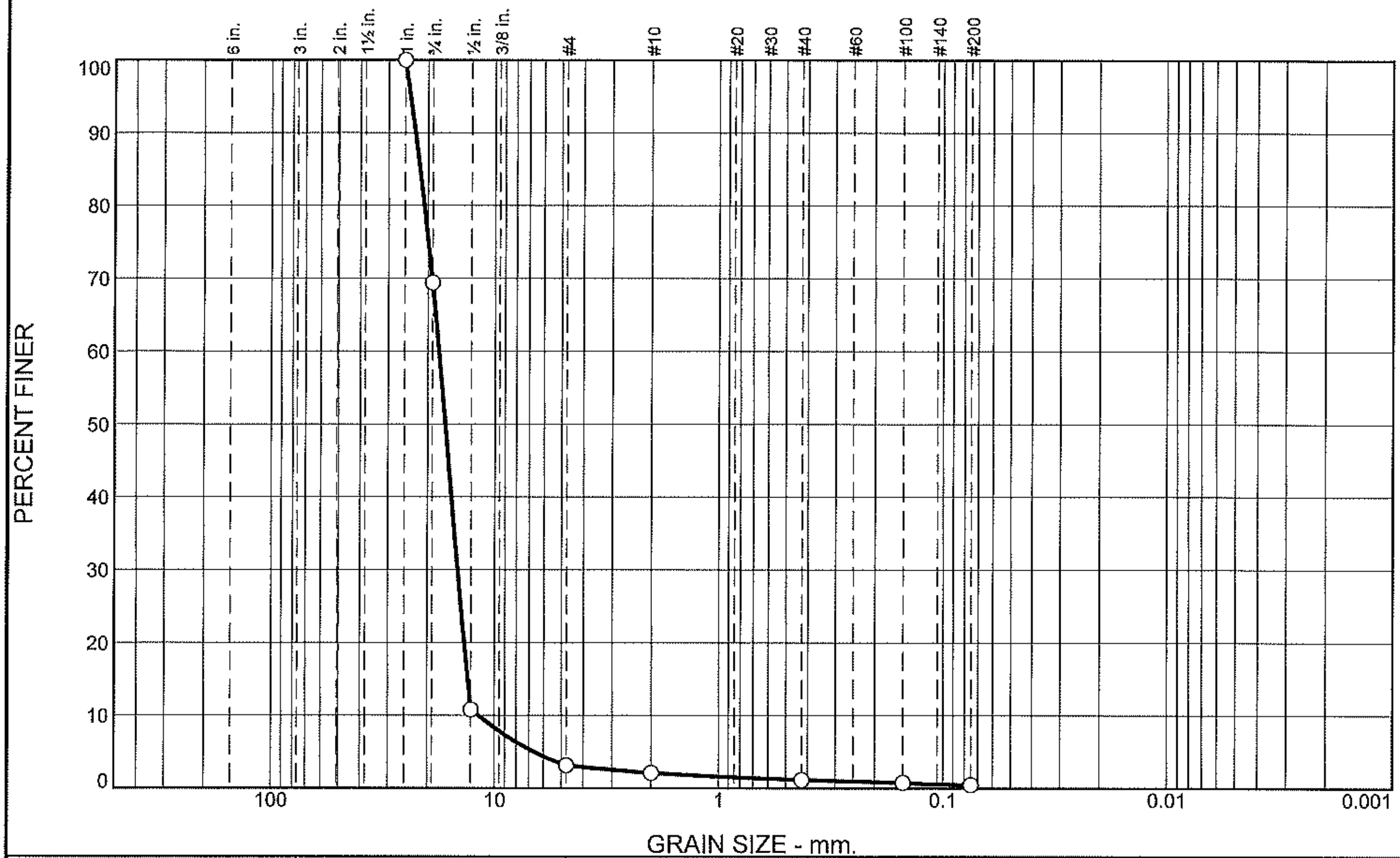
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	2.4	2.4	5.7	20.6	40.7	67.0			30.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
				0.2013	0.2829	0.6446	0.9088	1.5214	3.2723

Fineness Modulus
1.39

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	30.6	66.2	1.1	1.0	0.6	0.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	69.4		
1/2"	10.8		
#4	3.2		
#10	2.1		
#40	1.1		
#100	0.8		
#200	0.5		

* (no specification provided)

Soil Description

Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 22.8625 D_{85}= 21.7621 D_{60}= 17.8159
D_{50}= 16.6786 D_{30}= 14.6532 D_{15}= 13.1543
D_{10}= 11.8065 C_u= 1.51 C_c= 1.02

Classification

USCS= GP AASHTO=

Remarks

Location: G019 S-7
Sample Number: 7992-5 **Depth:** 15'-16.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC	**Client:** Golder Associates
	Project: ST-DRLE
Redmond, WA	**Project No:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/11/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-7
Depth: 15'-16.5'
Sample Number: 7992-5
Material Description: Gravel
Date: 10/5/2017
USCS Classification: GP
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 119.40
Tare Wt. = 15.80
Minus #200 from wash = 1.0%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
120.40	15.80	1"	0.00	0.00	100.0
		3/4"	32.00	0.00	69.4
		1/2"	61.30	0.00	10.8
		#4	8.00	0.00	3.2
		#10	1.10	0.00	2.1
		#40	1.00	0.00	1.1
		#100	0.40	0.00	0.8
		#200	0.30	0.00	0.5

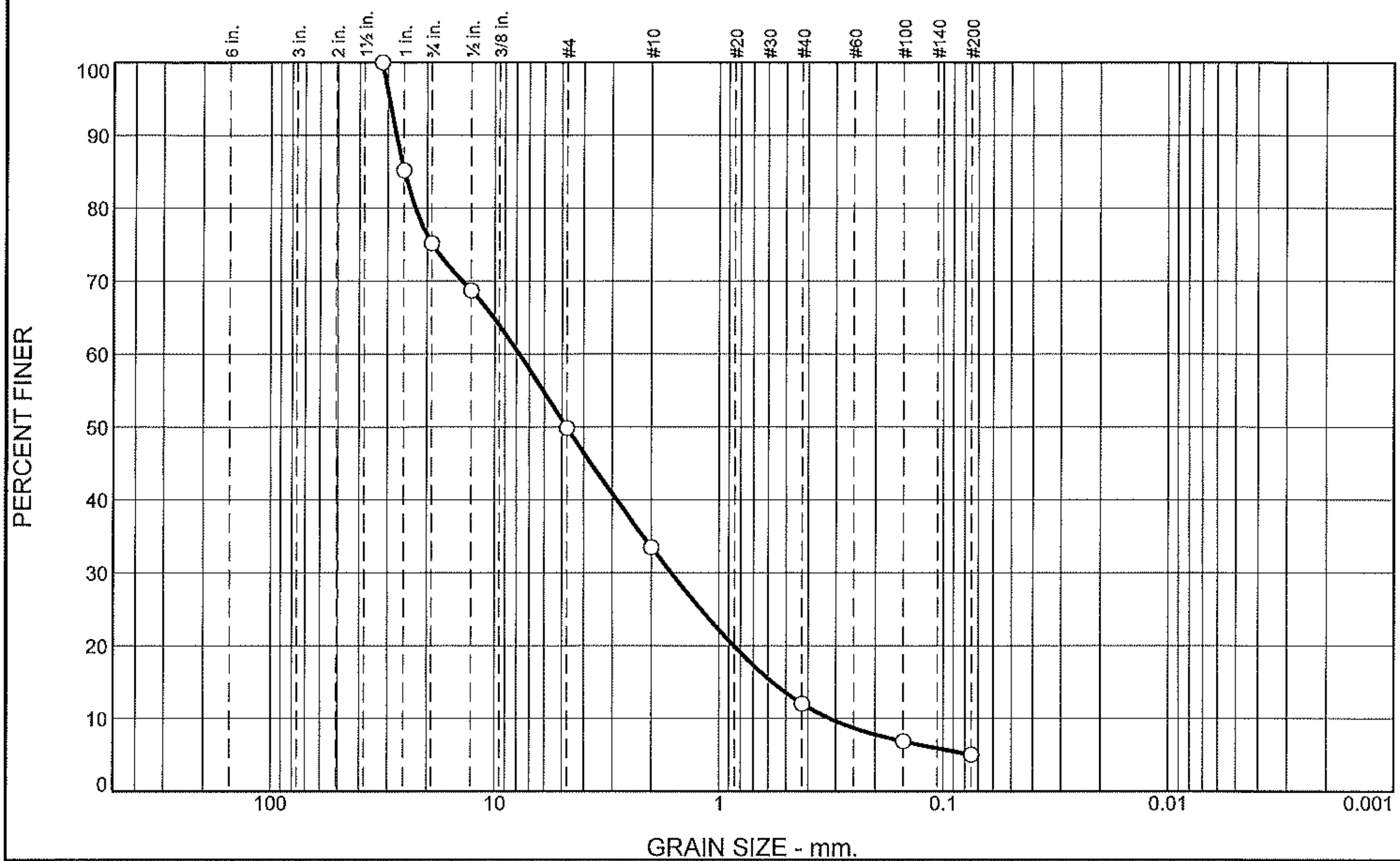
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	30.6	66.2	96.8	1.1	1.0	0.6	2.7			0.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
11.8065	13.1543	13.6668	14.6532	16.6786	17.8159	20.7803	21.7621	22.8625	24.0803

Fineness Modulus	C_u	C_c
7.12	1.51	1.02

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	24.8	25.4	16.3	21.5	7.0	5.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/4"	100.0		
1"	85.2		
3/4"	75.2		
1/2"	68.7		
#4	49.8		
#10	33.5		
#40	12.0		
#100	6.9		
#200	5.0		

* (no specification provided)

Soil Description

Gravel With Silt and Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 27.5310 D_{85}= 25.3095 D_{60}= 7.7882
D_{50}= 4.7863 D_{30}= 1.6354 D_{15}= 0.5761
D_{10}= 0.3193 C_u= 24.39 C_c= 1.08

Classification

USCS= GW-GM AASHTO=

Remarks

Location: G020 S-5
Sample Number: 7992-17 **Depth:** 10'-11.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/16/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-5
Depth: 10'-11.5' **Sample Number:** 7992-17
Material Description: Gravel With Silt and Sand
Date: 10/5/2017
USCS Classification: GW-GM
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 354.20
Tare Wt. = 15.90
Minus #200 from wash = 4.6%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
370.40	15.90	1 1/4"	0.00	0.00	100.0
		1"	52.50	0.00	85.2
		3/4"	35.50	0.00	75.2
		1/2"	23.10	0.00	68.7
		#4	66.70	0.00	49.8
		#10	58.00	0.00	33.5
		#40	76.00	0.00	12.0
		#100	18.30	0.00	6.9
		#200	6.60	0.00	5.0

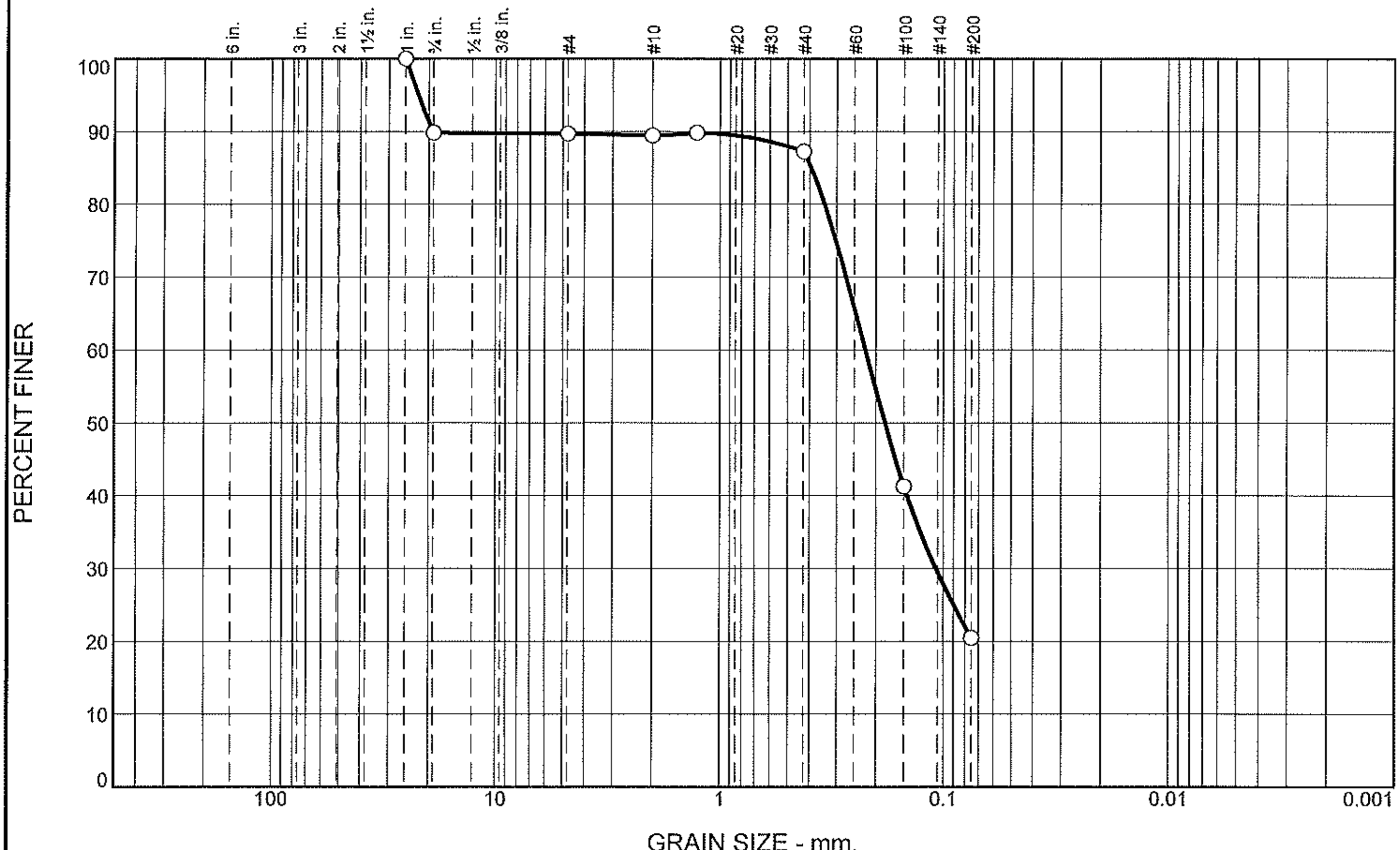
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	24.8	25.4	50.2	16.3	21.5	7.0	44.8			5.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.3193	0.5761	0.8600	1.6354	4.7863	7.7882	22.6107	25.3095	27.5310	29.6234

Fineness Modulus	C_u	C_c
5.18	24.39	1.08

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	10.2	0.1	0.3	2.1	66.8	20.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	89.8		
#4	89.7		
#10	89.4		
.1/2"	89.8		
#40	87.3		
#100	41.3		
#200	20.5		

* (no specification provided)

Soil Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 19.1790 D_{85}= 0.3933 D_{60}= 0.2232
D_{50}= 0.1824 D_{30}= 0.1081 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G020 S-11
Sample Number: 7992-19 **Depth:** 35'-36.5 **Date:** 10/5/2017

Hayre McElroy & Associates, LLC Redmond, WA	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/16/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-11
Depth: 35'-36.5
Sample Number: 7992-19
Material Description: Silty Sand
Date: 10/5/2017
USCS Classification: SM
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 273.00
Tare Wt. = 16.60
Minus #200 from wash = 16.0%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
321.70	16.60	1"	0.00	0.00	100.0
		3/4"	31.10	0.00	89.8
		.1/2"	0.00	0.00	89.8
		#4	0.40	0.00	89.7
		#10	0.80	0.00	89.4
		#40	6.60	0.00	87.3
		#100	140.30	0.00	41.3
		#200	63.50	0.00	20.5

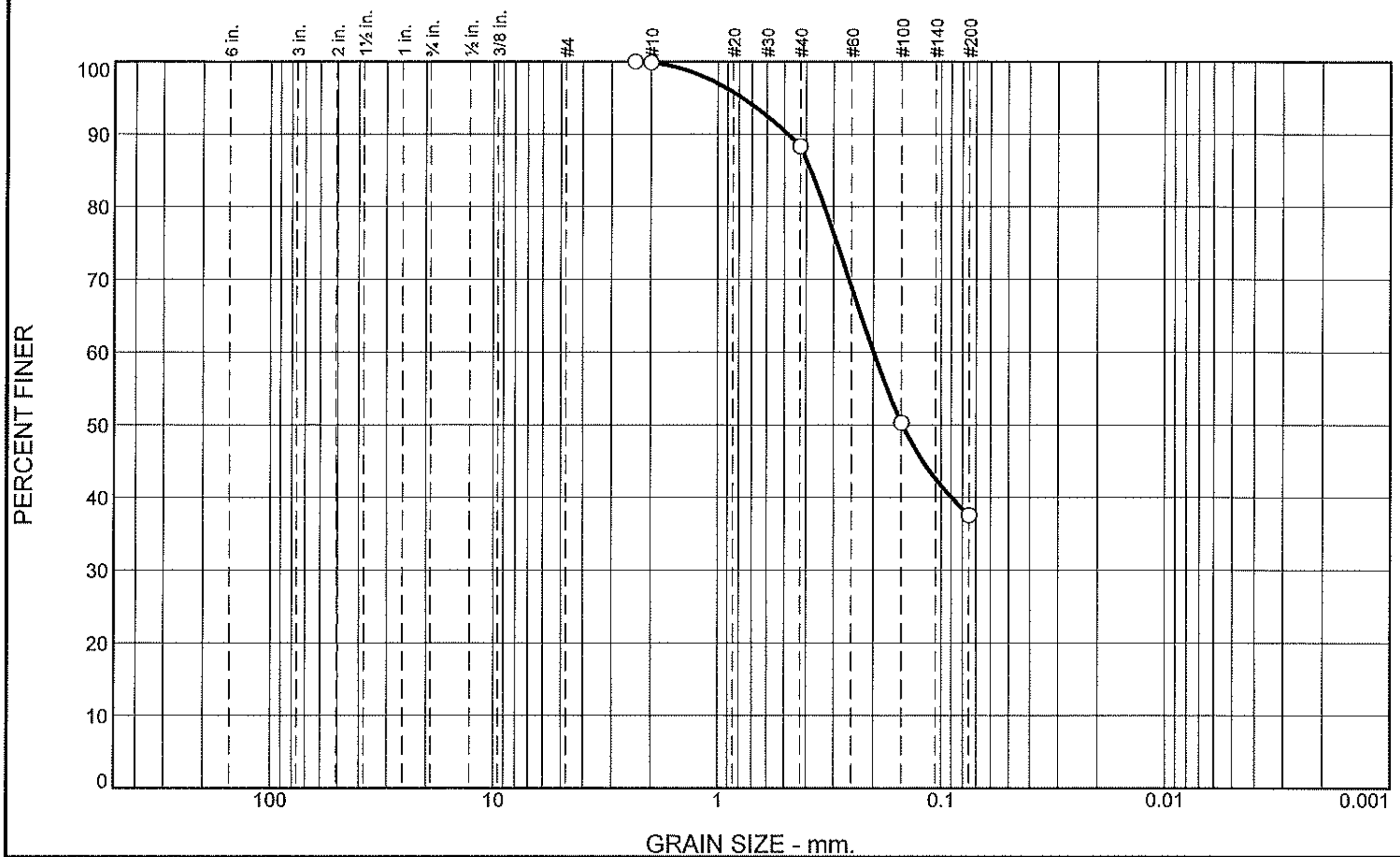
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	10.2	0.1	10.3	0.3	2.1	66.8	69.2			20.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
			0.1081	0.1824	0.2232	0.3422	0.3933	19.1790	22.2853

Fineness Modulus
1.47

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.1	11.6	50.7	37.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#8	100.0		
#10	99.9		
#40	88.3		
#100	50.3		
#200	37.6		

* (no specification provided)

Soil Description

SILTY SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.4843 D_{85}= 0.3816 D_{60}= 0.1996
D_{50}= 0.1485 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G020 S-34
Sample Number: 7995-1 **Depth:** 150'-151.5' **Date:** 10/21/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/26/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-34
Depth: 150'-151.5'
Sample Number: 7995-1
Material Description: SILTY SAND
Date: 10/21/2017
USCS Classification: SM
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 187.20
Tare Wt. = 15.80
Minus #200 from wash = 36.4%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
285.50	15.80	#8	0.00	0.00	100.0
		#10	0.40	0.00	99.9
		#40	31.10	0.00	88.3
		#100	102.60	0.00	50.3
		#200	34.30	0.00	37.6

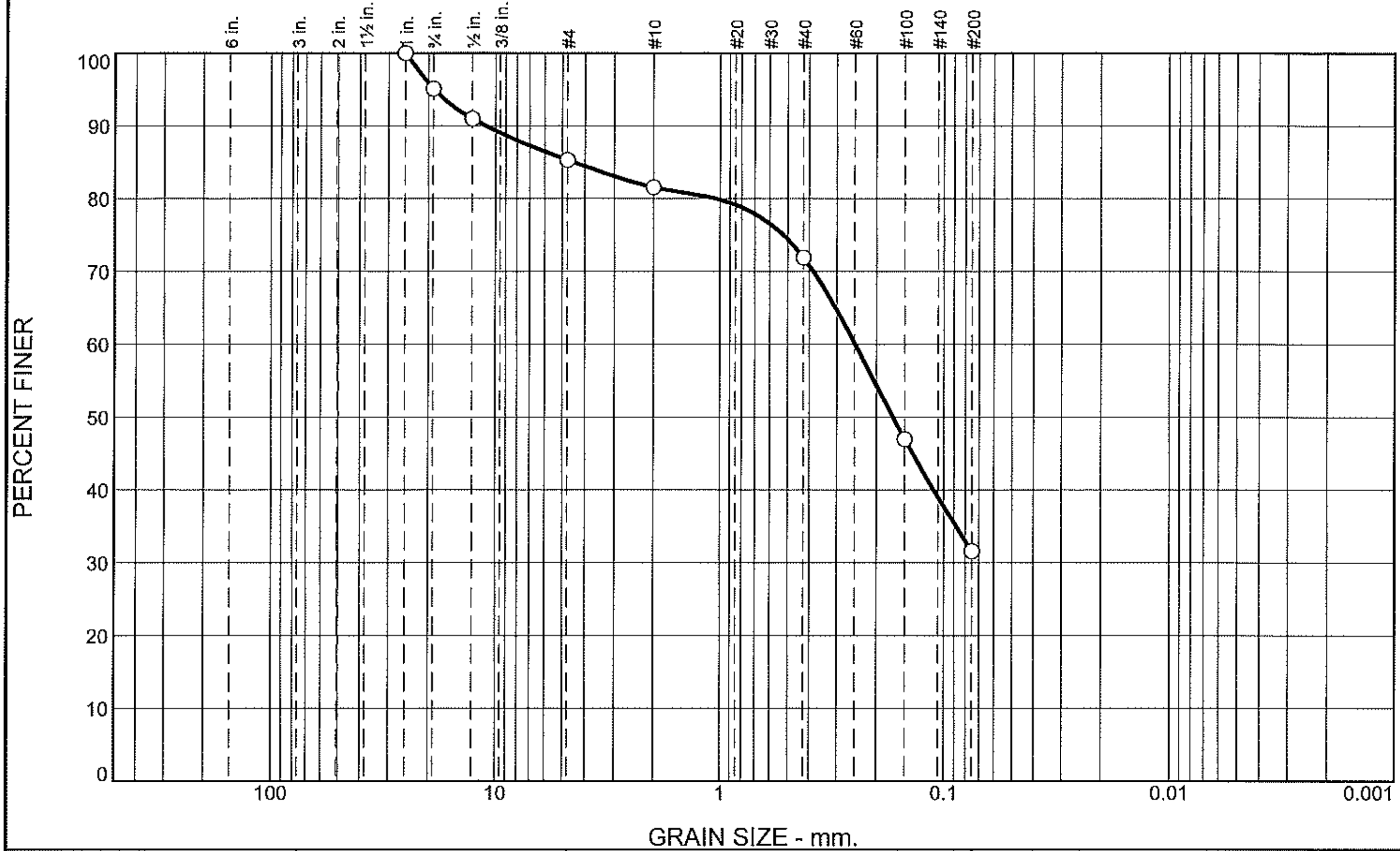
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.1	11.6	50.7	62.4			37.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
				0.1485	0.1996	0.3311	0.3816	0.4843	0.7777

Fineness Modulus
0.83

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.9	9.8	3.8	9.6	40.3	31.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	95.1		
1/2"	91.0		
#4	85.3		
#10	81.5		
#40	71.9		
#100	47.0		
#200	31.6		

* (no specification provided)

Soil Description

Silty Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 11.1016 D_{85}= 4.4857 D_{60}= 0.2488
D_{50}= 0.1692 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G020 S-42
Sample Number: 7992-45 **Depth:** 190'-191.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/11/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-42
Depth: 190'-191.5' **Sample Number:** 7992-45
Material Description: Silty Sand
Date: 10/5/2017
USCS Classification: SM
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 249.20
Tare Wt. = 16.70
Minus #200 from wash = 27.5%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
337.50	16.70	1"	0.00	0.00	100.0
		3/4"	15.80	0.00	95.1
		1/2"	13.20	0.00	91.0
		#4	18.20	0.00	85.3
		#10	12.00	0.00	81.5
		#40	31.00	0.00	71.9
		#100	79.90	0.00	47.0
		#200	49.40	0.00	31.6

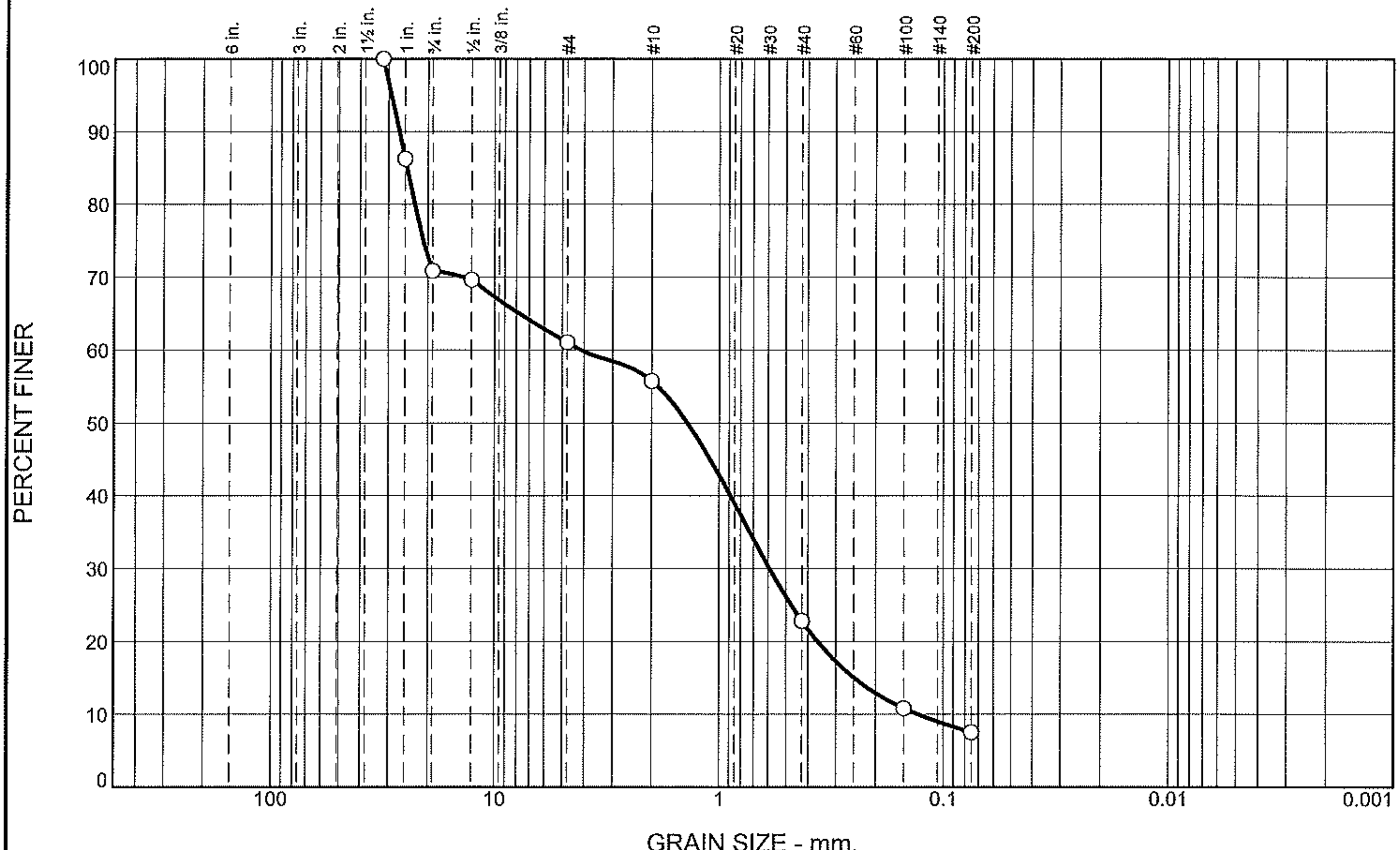
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	4.9	9.8	14.7	3.8	9.6	40.3	53.7			31.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
				0.1692	0.2488	1.0465	4.4857	11.1016	18.9506

Fineness Modulus
1.80

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	29.1	9.8	5.4	32.9	15.3	7.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/4"	100.0		
1"	86.3		
3/4"	70.9		
1/2"	69.6		
#4	61.1		
#10	55.7		
#40	22.8		
#100	10.9		
#200	7.5		

* (no specification provided)

Soil Description

Sand with Silt and Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 26.9668 D_{85}= 24.8989 D_{60}= 4.1483
D_{50}= 1.3852 D_{30}= 0.5924 D_{15}= 0.2491
D_{10}= 0.1292 C_u= 32.10 C_c= 0.65

Classification

USCS= SP-SM AASHTO=

Remarks

Location: G021 S-6
Sample Number: 7992-30 **Depth:** 12.5'-14' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/16/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G021 S-6
Depth: 12.5'-14' **Sample Number:** 7992-30
Material Description: Sand with Silt and Gravel
Date: 10/5/2017
USCS Classification: SP-SM
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 339.90
Tare Wt. = 17.60
Minus #200 from wash = 7.0%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
364.00	17.60	1 1/4"	0.00	0.00	100.0
		1"	47.60	0.00	86.3
		3/4"	53.30	0.00	70.9
		1/2"	4.40	0.00	69.6
		#4	29.60	0.00	61.1
		#10	18.40	0.00	55.7
		#40	114.10	0.00	22.8
		#100	41.40	0.00	10.9
		#200	11.50	0.00	7.5

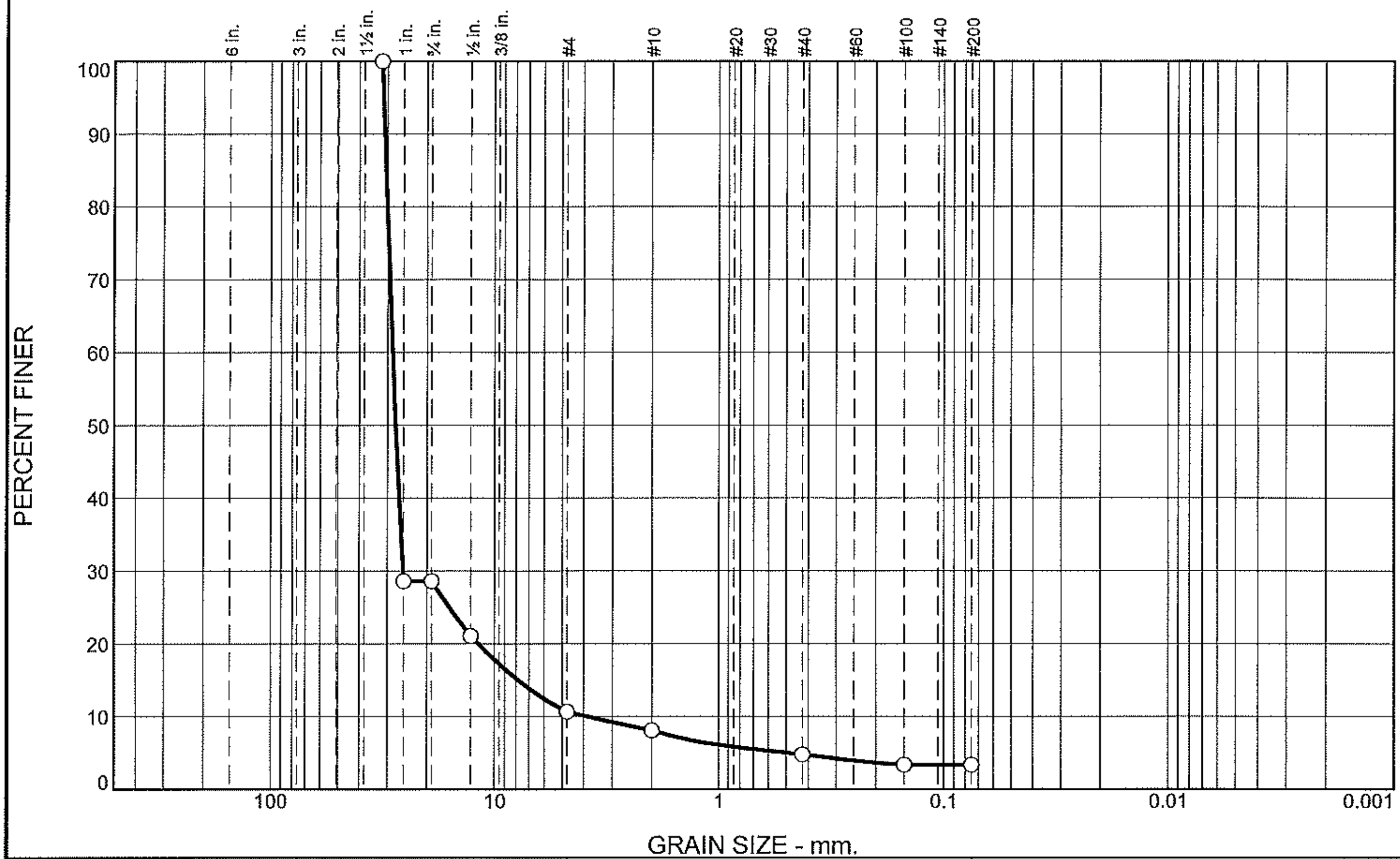
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	29.1	9.8	38.9	5.4	32.9	15.3	53.6			7.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.1292	0.2491	0.3625	0.5924	1.3852	4.1483	22.9804	24.8989	26.9668	29.2494

Fineness Modulus	C_u	C_c
4.39	32.10	0.65

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	71.4	17.9	2.6	3.3	1.4	3.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/4"	100.0		
1"	28.6		
3/4"	28.6		
1/2"	21.1		
#4	10.7		
#10	8.1		
#40	4.8		
#100	3.4		
#200	3.4		

* (no specification provided)

Soil Description

Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 30.9553 D_{85}= 30.5617 D_{60}= 28.5661
D_{50}= 27.7101 D_{30}= 25.6025 D_{15}= 7.8548
D_{10}= 3.8446 C_u= 7.43 C_c= 5.97

Classification

USCS= GP AASHTO=

Remarks

Location: G022 S-4
Sample Number: 7992-36 **Depth:** 10'-11.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

10/11/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G022 S-4
Depth: 10'-11.5' **Sample Number:** 7992-36
Material Description: Gravel
Date: 10/5/2017
USCS Classification: GP
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 140.50
Tare Wt. = 15.70
Minus #200 from wash = 2.0%

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
143.00	15.70	1 1/4"	0.00	0.00	100.0
		1"	90.90	0.00	28.6
		3/4"	0.00	0.00	28.6
		1/2"	9.60	0.00	21.1
		#4	13.20	0.00	10.7
		#10	3.30	0.00	8.1
		#40	4.20	0.00	4.8
		#100	1.80	0.00	3.4
		#200	0.00	0.00	3.4

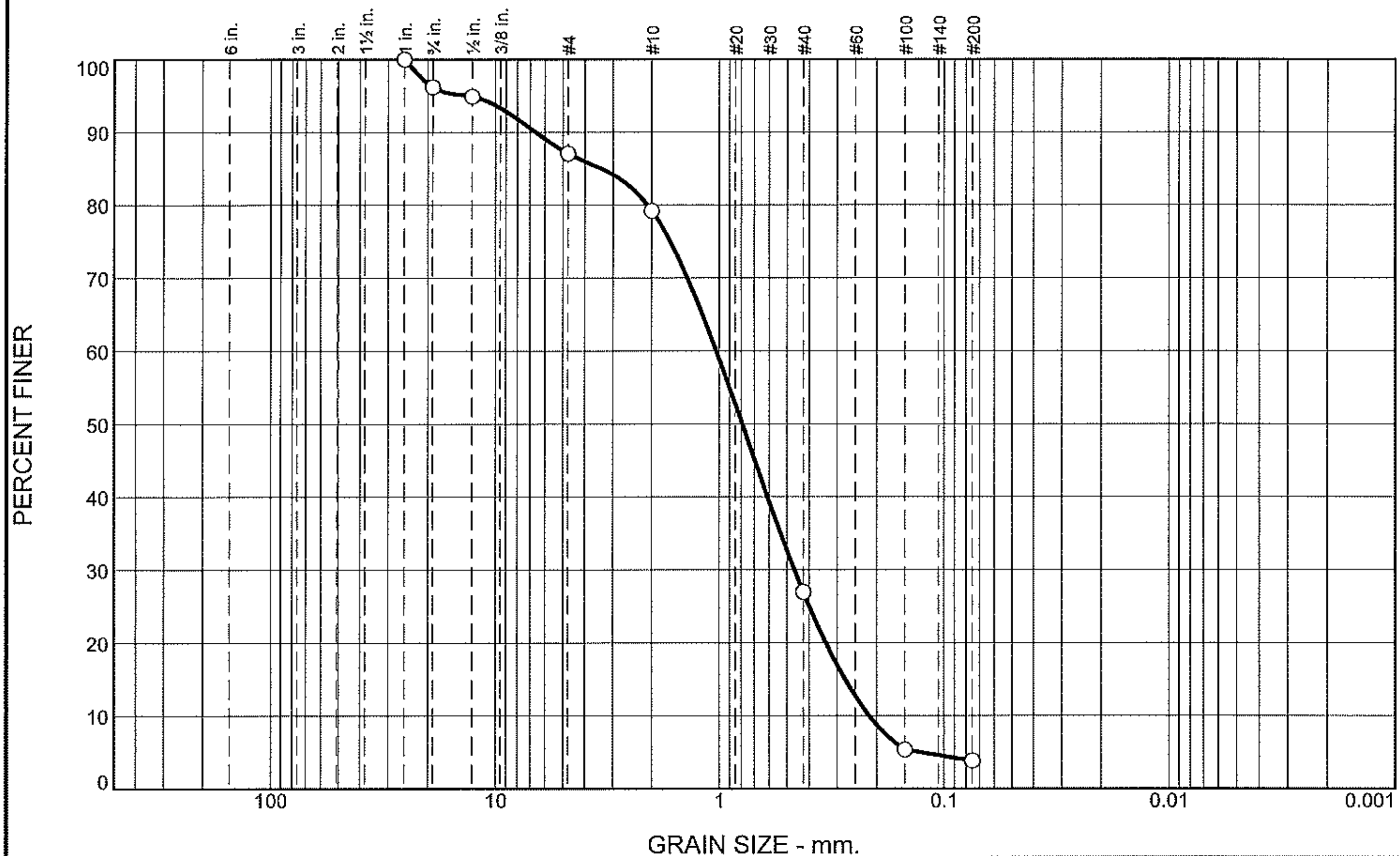
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	71.4	17.9	89.3	2.6	3.3	1.4	7.3			3.4

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
3.8446	7.8548	11.7961	25.6025	27.7101	28.5661	30.1688	30.5617	30.9553	31.3508

Fineness Modulus	C_u	C_c
7.16	7.43	5.97

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	3.8	9.2	7.8	52.3	23.1	3.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	96.2		
1/2"	94.9		
#4	87.0		
#10	79.2		
#40	26.9		
#100	5.3		
#200	3.8		

* (no specification provided)

Soil Description

SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 6.6416 D_{85}= 3.3943 D_{60}= 1.0322
D_{50}= 0.7922 D_{30}= 0.4653 D_{15}= 0.2774
D_{10}= 0.2165 C_u= 4.77 C_c= 0.97

Classification

USCS= SP AASHTO=

Remarks

Location: G028 S-1
Sample Number: 7995-22 **Depth:** 7.5'-9.0' **Date:** 10/21/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

4/4/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: DRLE-TP2 / S1
Depth: 3
Sample Number: 8041-2
Material Description: Silty SAND
Date: 4/4/2018
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 328.50
Tare Wt. = 16.14
Minus #200 from wash = 34.5%

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
492.77	16.14	0.00	1"	0.00	100.0
			3/4"	0.00	100.0
			3/8"	0.00	100.0
			#4	0.00	100.0
			#10	0.00	100.0
			#40	0.60	99.9
			#100	135.60	71.6
			#200	312.70	34.4

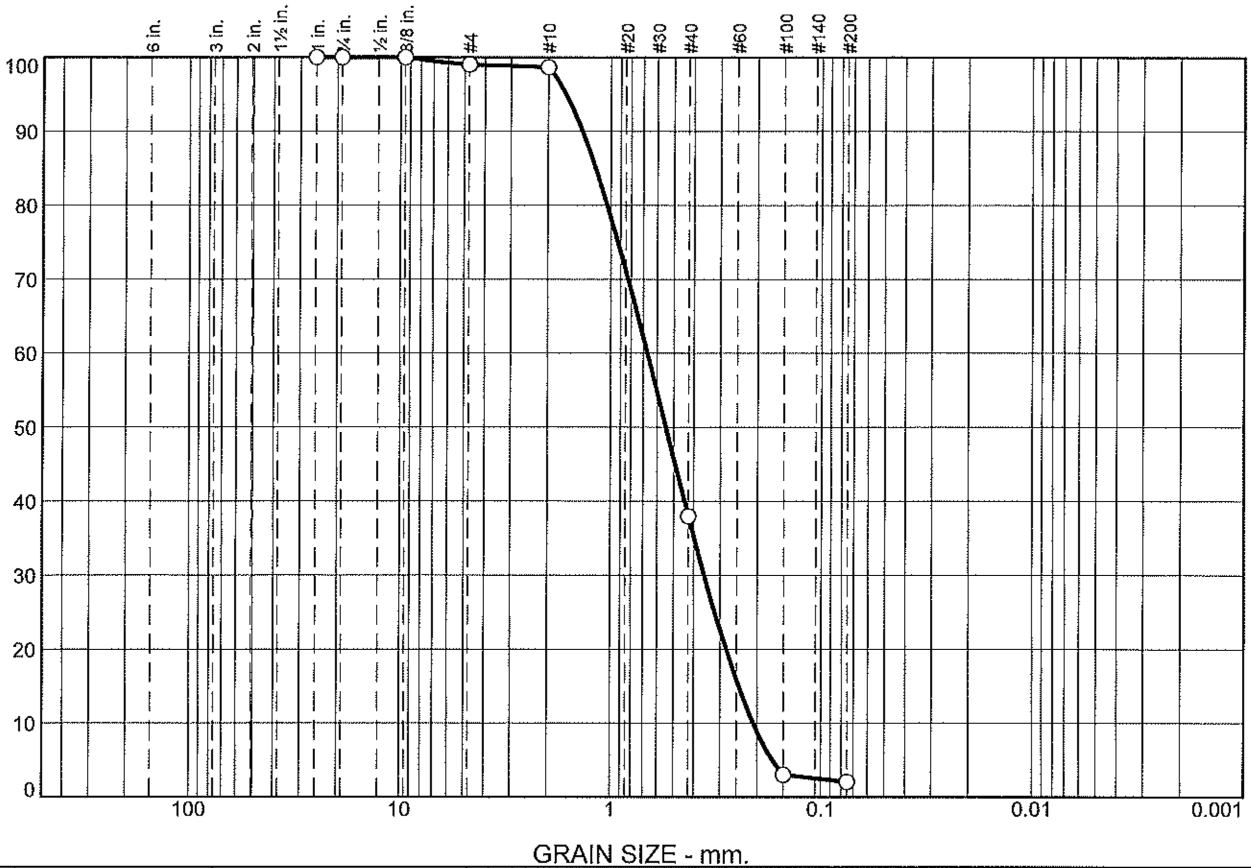
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	0.0	0.1	65.5	65.6			34.4

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
				0.0985	0.1184	0.1843	0.2127	0.2519	0.3118

Fineness Modulus
0.34

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	1.0	0.3	60.7	36.0	2.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1"	100.0		
3/4"	100.0		
3/8"	100.0		
#4	99.0		
#10	98.7		
#40	38.0		
#100	3.0		
#200	2.0		

* (no specification provided)

Soil Description

Poorly Graded SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 1.3740 D_{85}= 1.1873 D_{60}= 0.6702
D_{50}= 0.5458 D_{30}= 0.3570 D_{15}= 0.2445
D_{10}= 0.2085 C_u= 3.21 C_c= 0.91

Classification

USCS= SP AASHTO=

Remarks

Location: DRLE-TP3A / S1
Sample Number: 8041-3 **Depth:** 3 **Date:** 4/4/2018

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

4/4/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: DRLE-TP3A / S1
Depth: 3
Sample Number: 8041-3
Material Description: Poorly Graded SAND
Date: 4/4/2018
USCS Classification: SP
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 485.20
Tare Wt. = 15.94
Minus #200 from wash = 2.0%

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
494.68	15.94	0.00	1"	0.00	100.0
			3/4"	0.00	100.0
			3/8"	0.00	100.0
			#4	4.70	99.0
			#10	6.30	98.7
			#40	297.00	38.0
			#100	464.30	3.0
			#200	469.00	2.0

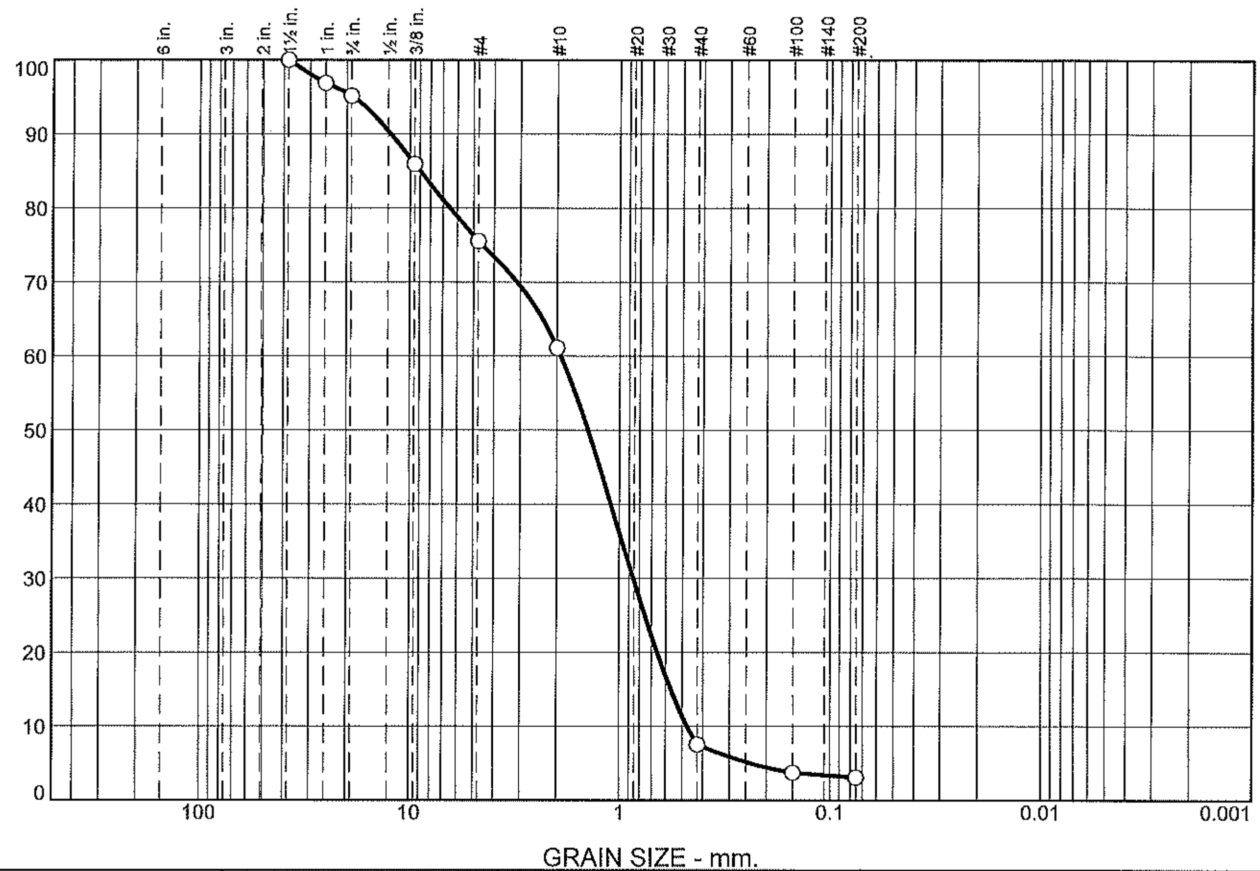
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	1.0	1.0	0.3	60.7	36.0	97.0			2.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.2085	0.2445	0.2806	0.3570	0.5458	0.6702	1.0436	1.1873	1.3740	1.6452

Fineness Modulus	C_u	C_c
2.37	3.21	0.91

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.8	19.7	14.4	53.5	4.5	3.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 1/2"	100.0		
1"	96.9		
3/4"	95.2		
3/8"	85.9		
#4	75.5		
#10	61.1		
#40	7.6		
#100	3.7		
#200	3.1		

* (no specification provided)

Soil Description

Poorly Graded SAND with Gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 12.3468 D_{85}= 8.9788 D_{60}= 1.9221
D_{50}= 1.4229 D_{30}= 0.8596 D_{15}= 0.5687
D_{10}= 0.4754 C_u= 4.04 C_c= 0.81

Classification

USCS= SP AASHTO=

Remarks

Location: DRLE-TP4 / S3
Sample Number: 8041-4 **Depth:** 3 **Date:** 4/4/2018

Hayre McElroy & Associates, LLC
Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

4/4/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: DRLE-TP4 / S3
Depth: 3
Sample Number: 8041-4
Material Description: Poorly Graded SAND with Gravel
Date: 4/4/2018
USCS Classification: SP
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 1374.10
Tare Wt. = 15.99
Minus #200 from wash = 2.7%

Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
1412.25	15.99	0.00	1 1/2"	0.00	100.0
			1"	43.30	96.9
			3/4"	67.50	95.2
			3/8"	196.30	85.9
			#4	341.50	75.5
			#10	543.10	61.1
			#40	1290.70	7.6
			#100	1344.00	3.7
			#200	1353.20	3.1

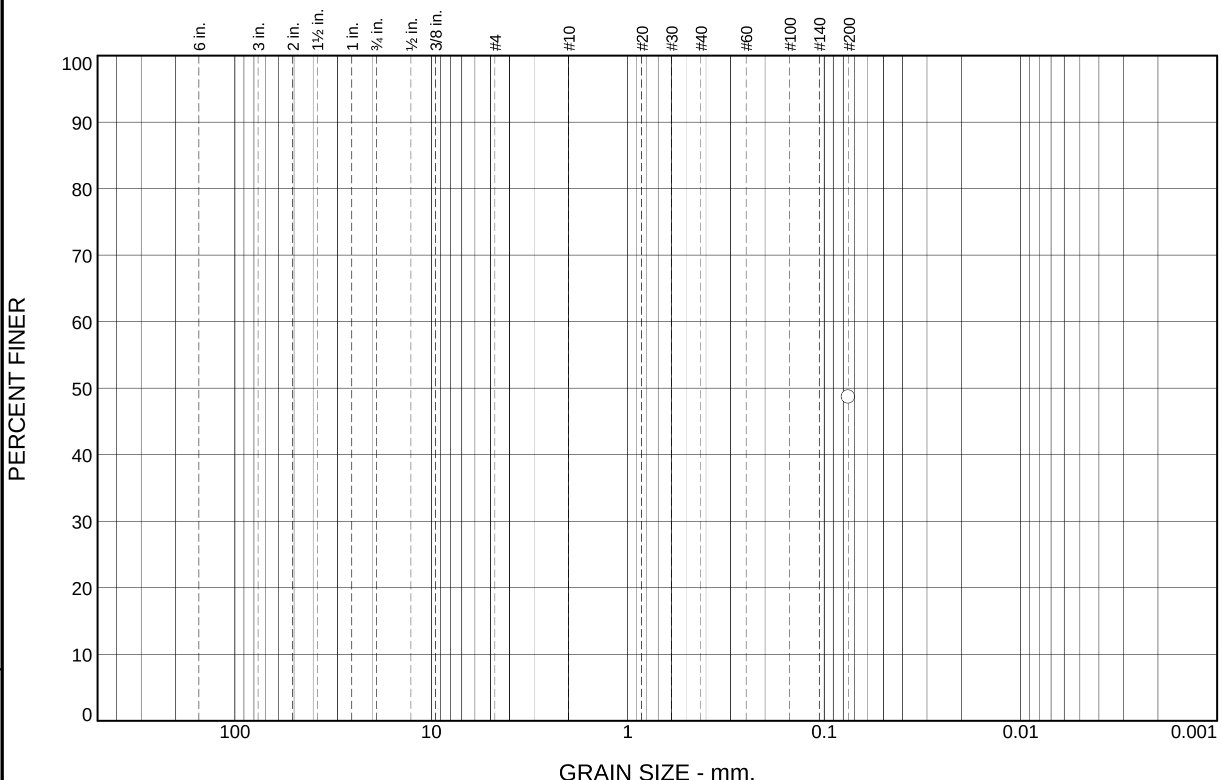
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	4.8	19.7	24.5	14.4	53.5	4.5	72.4			3.1

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.4754	0.5687	0.6605	0.8596	1.4229	1.9221	6.5084	8.9788	12.3468	18.6607

Fineness Modulus	C_u	C_c
4.09	4.04	0.81

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						48.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	48.6		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G1 / S5
Sample Number: 054-2 **Depth:** 10' **Date:** 12/19/2018

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G1 / S5
Depth: 10' **Sample Number:** 054-2
Material Description: Silty SAND
Date: 12/19/2018
USCS Classification: SM
Tested by: GD **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 215.36
Tare Wt. = 15.70
Minus #200 from wash = 48.6%

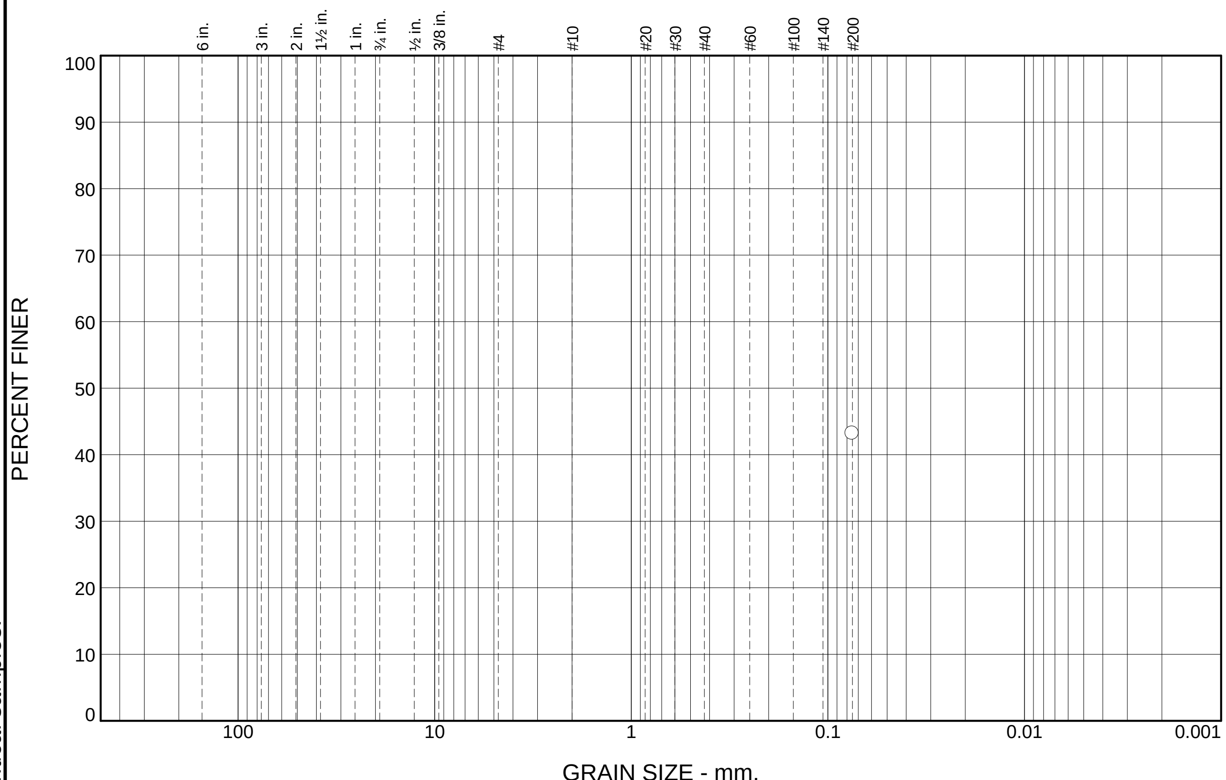
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
404.30	15.70	0.00	1"		
			3/4"		
			3/8"		
			#4		
			#10		
			#40		
			#100		
			#200		48.6

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										48.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						43.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	43.2		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G2 S3
Sample Number: 8023-1 **Depth:** 7.5' **Date:** 2/22/2018

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

2/22/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G2 S3
Depth: 7.5' **Sample Number:** 8023-1
Material Description: Silty SAND
Date: 2/22/2018
USCS Classification: SM
Tested by: GD **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 190.63
Tare Wt. = 16.01
Minus #200 from wash = 43.2%

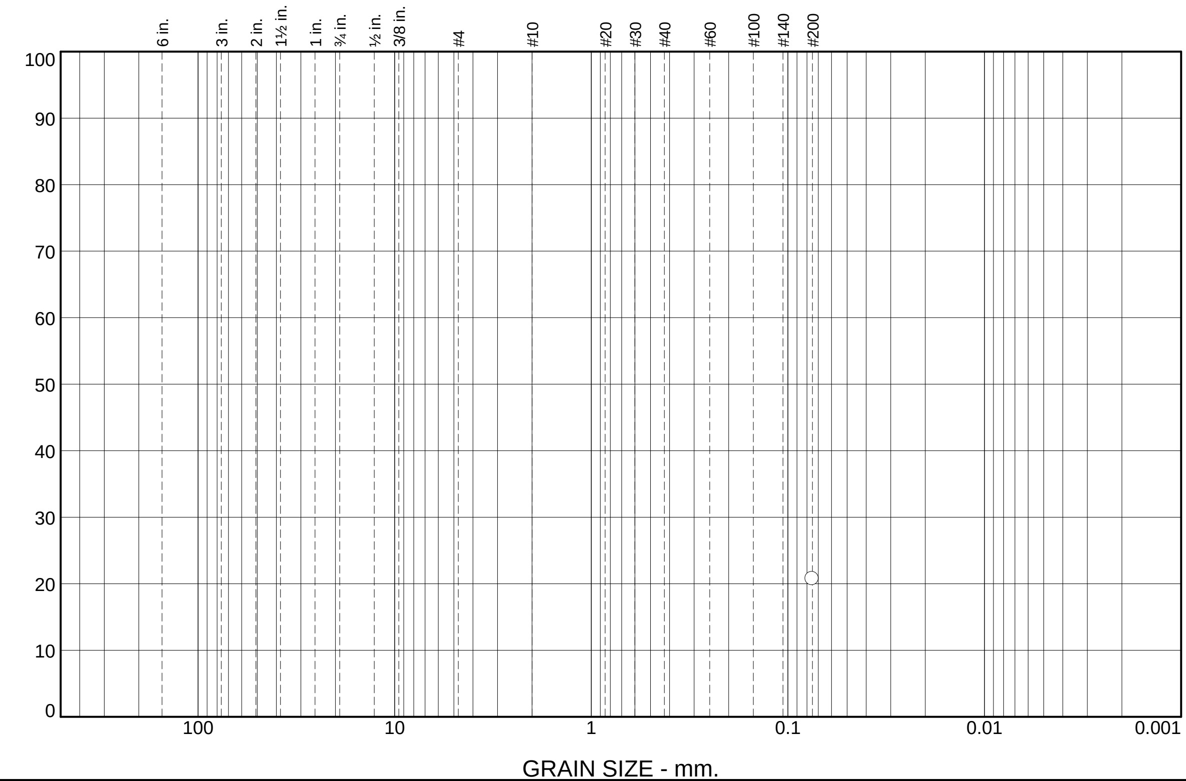
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
323.40	16.01	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										43.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						20.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	20.7		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G3 / S4
Sample Number: 054-8 **Depth:** 10' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G3 / S4
Depth: 10'
Sample Number: 054-8
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 173.02
Tare Wt. = 15.80
Minus #200 from wash = 20.7%

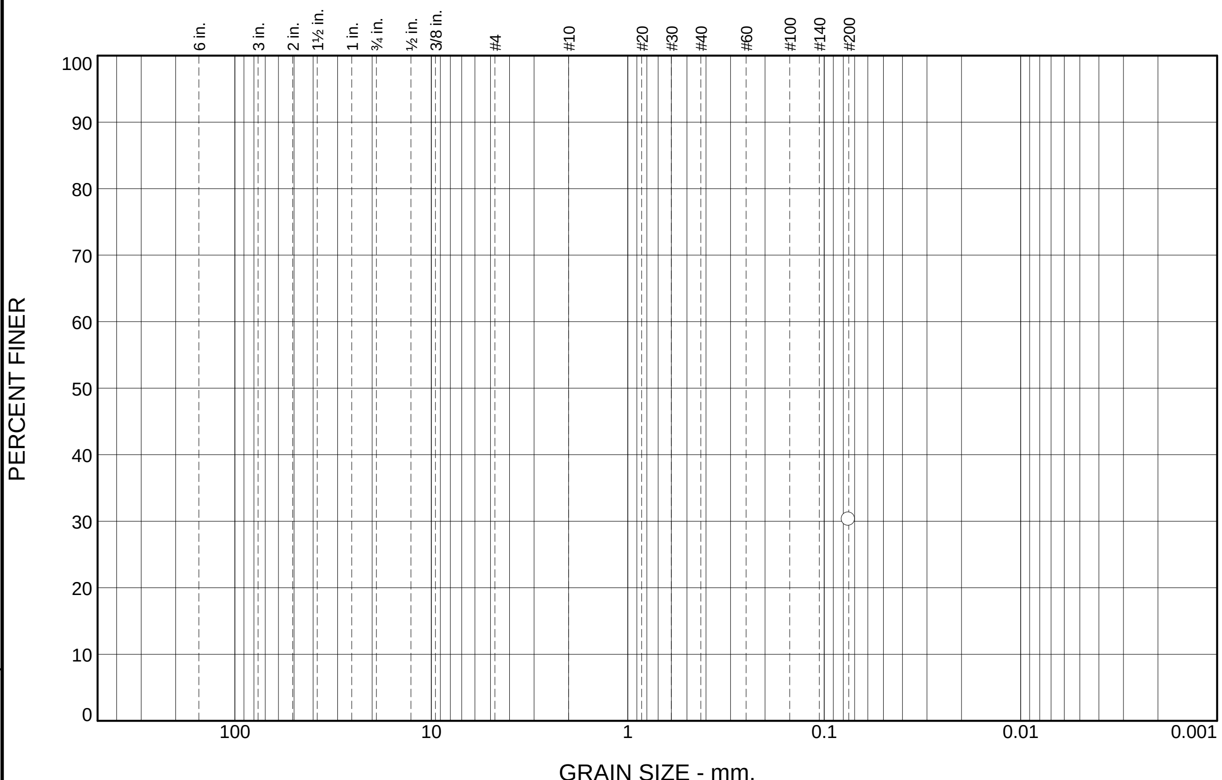
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
214.10	15.80	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										20.7

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						30.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	30.2		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G4 / S6
Sample Number: 054-15 **Depth:** 12.5' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G4 / S6
Depth: 12.5'
Sample Number: 054-15
Material Description: Silty SAND
Date: 12/22/2017
USCS Classification: SM
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 203.71
Tare Wt. = 16.10
Minus #200 from wash = 30.2%

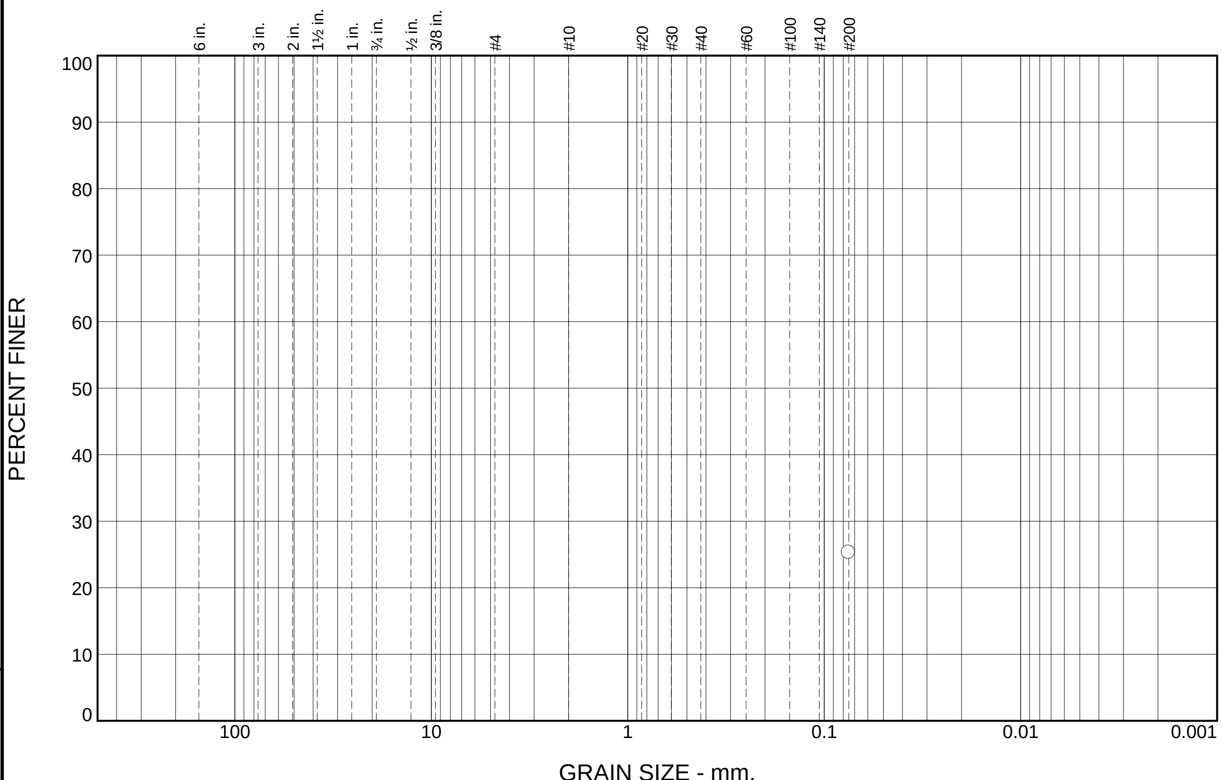
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
285.07	16.10	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										30.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						25.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	25.3		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G5 / S7
Sample Number: 054-21 **Depth:** 15' **Date:** 12/22/2017

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G5 / S7
Depth: 15'
Sample Number: 054-21
Material Description: Silty SAND
Date: 12/22/2017
USCS Classification: SM
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 251.78
Tare Wt. = 16.00
Minus #200 from wash = 25.3%

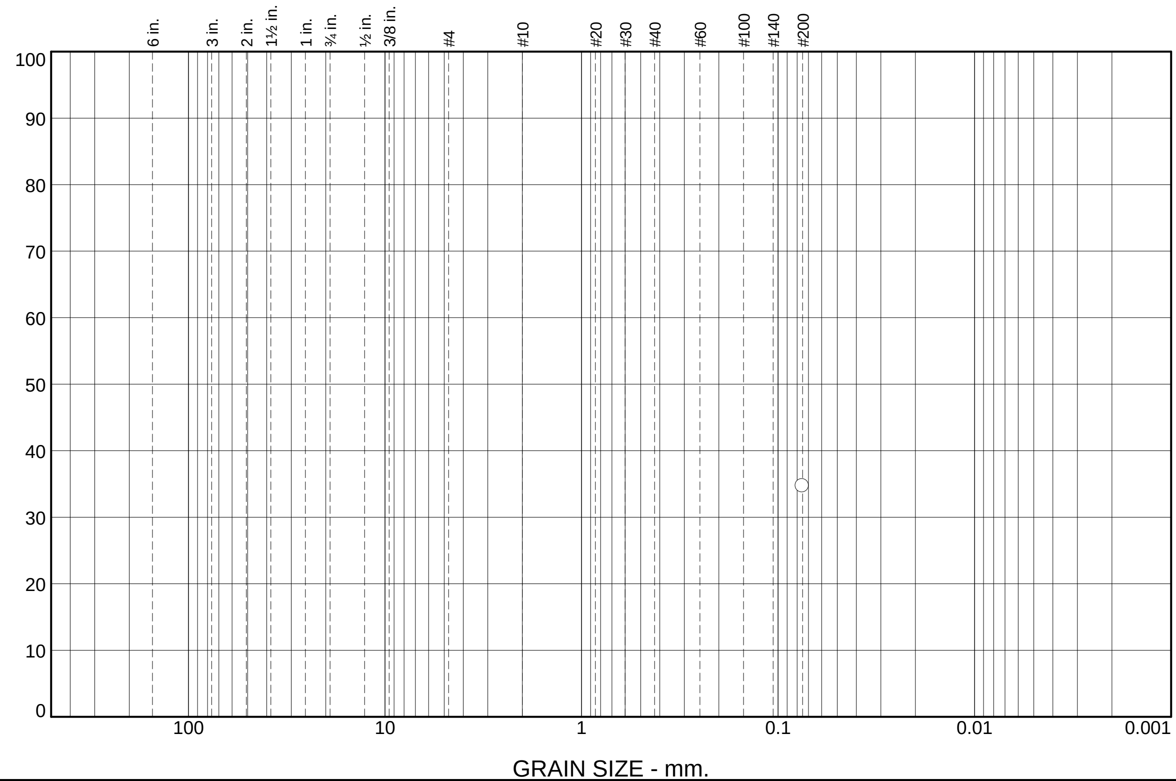
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
331.65	16.00	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										25.3

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						34.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	34.7		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G6 / S1
Sample Number: 054-25A **Depth:** 7.5' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G6 / S1
Depth: 7.5'
Sample Number: 054-25A
Material Description: Silty SAND
Date: 12/22/2017
USCS Classification: SM
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 198.72
Tare Wt. = 16.20
Minus #200 from wash = 34.7%

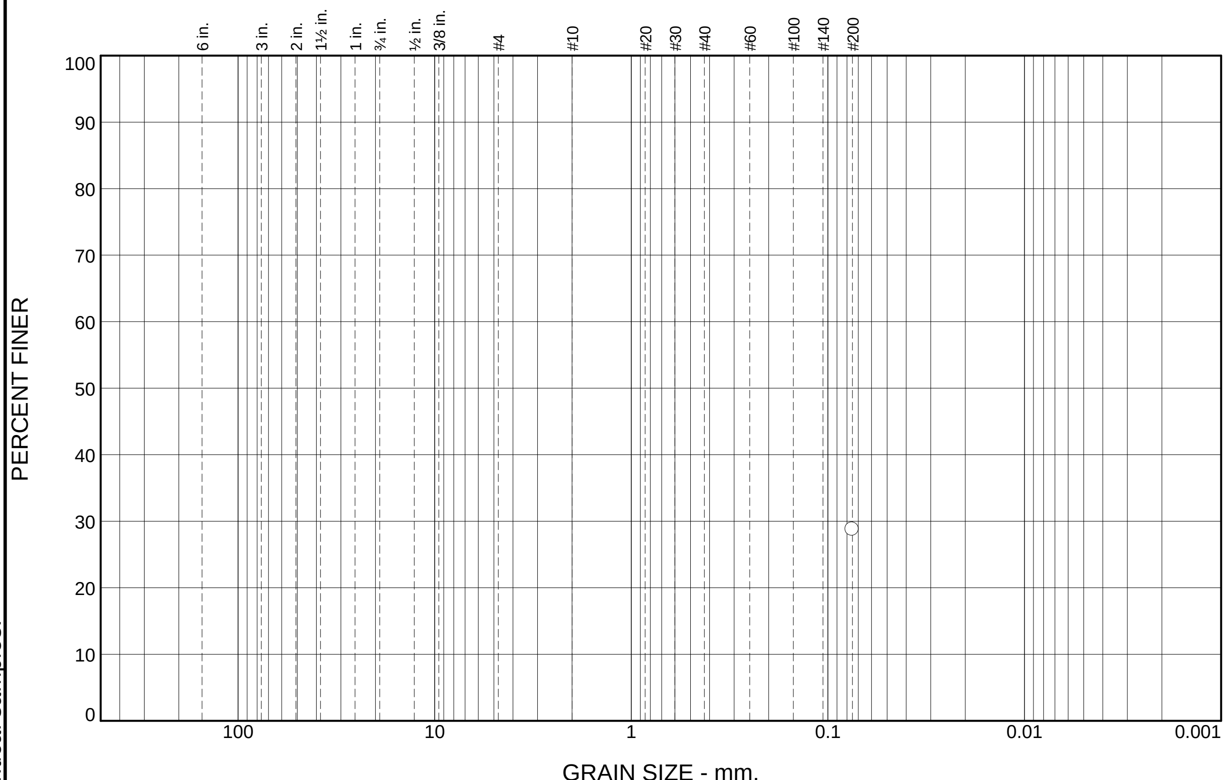
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
295.60	16.20	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										34.7

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						28.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	28.8		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G7 / S2
Sample Number: 054-29 **Depth:** 5' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G7 / S2
Depth: 5' **Sample Number:** 054-29
Material Description: Silty SAND
Date: 12/22/2017
USCS Classification: SM
Tested by: GD **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 139.44
Tare Wt. = 16.00
Minus #200 from wash = 28.8%

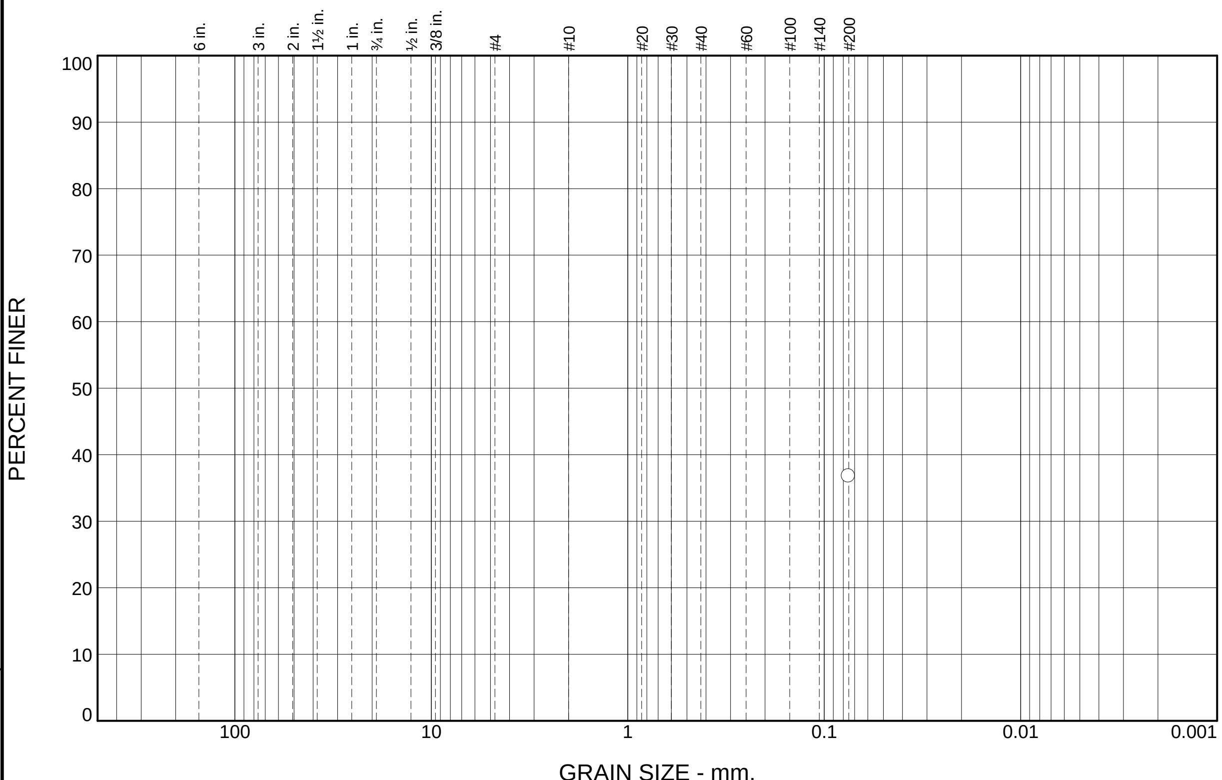
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
189.27	16.00	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										28.8

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						36.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	36.8		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G12 / S2
Sample Number: 054-45 **Depth:** 5' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G12 / S2
Depth: 5'
Sample Number: 054-45
Material Description: Silty SAND
Date: 12/22/2017
USCS Classification: SM
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 112.91
Tare Wt. = 16.10
Minus #200 from wash = 36.8%

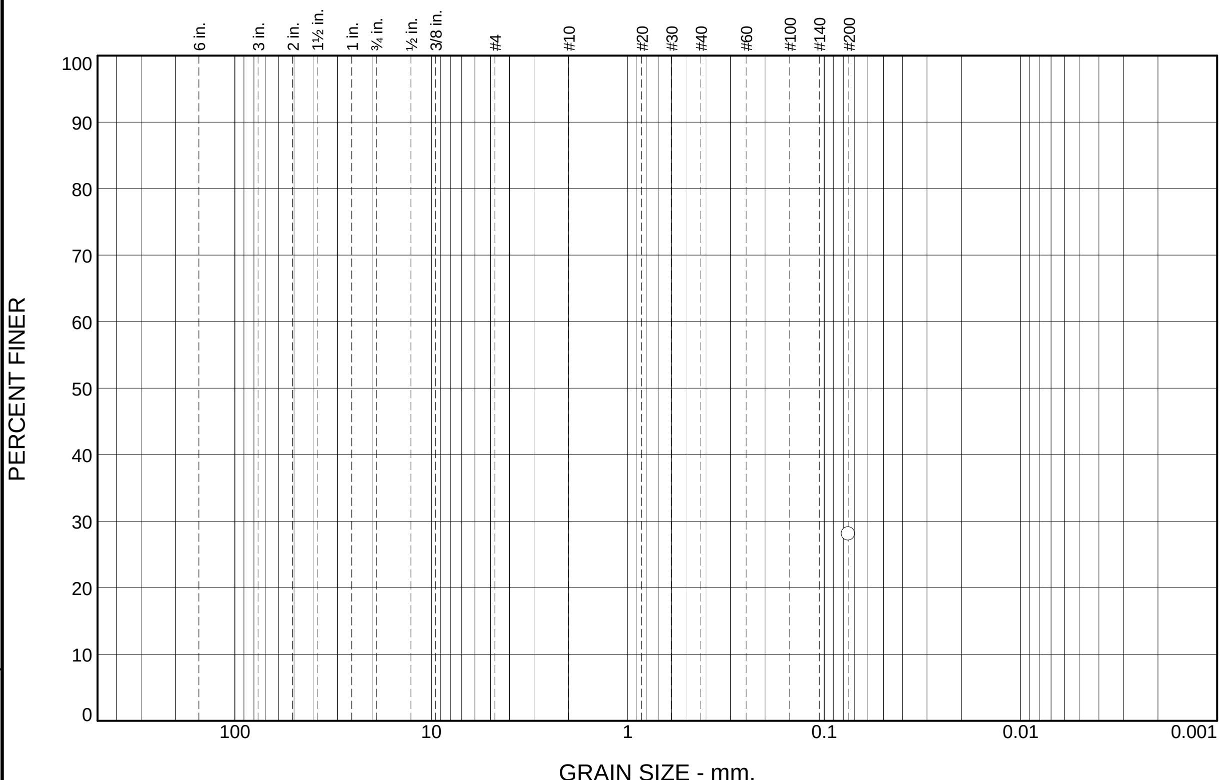
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
169.20	16.10	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										36.8

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						28.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	28.0		

* (no specification provided)

Soil Description

Silty SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SM AASHTO=

Remarks

Location: G13 / S2
Sample Number: 054-51 **Depth:** 5' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G13 / S2
Depth: 5'
Sample Number: 054-51
Material Description: Silty SAND
Date: 12/22/2017
USCS Classification: SM
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 91.17
Tare Wt. = 16.10
Minus #200 from wash = 28.0%

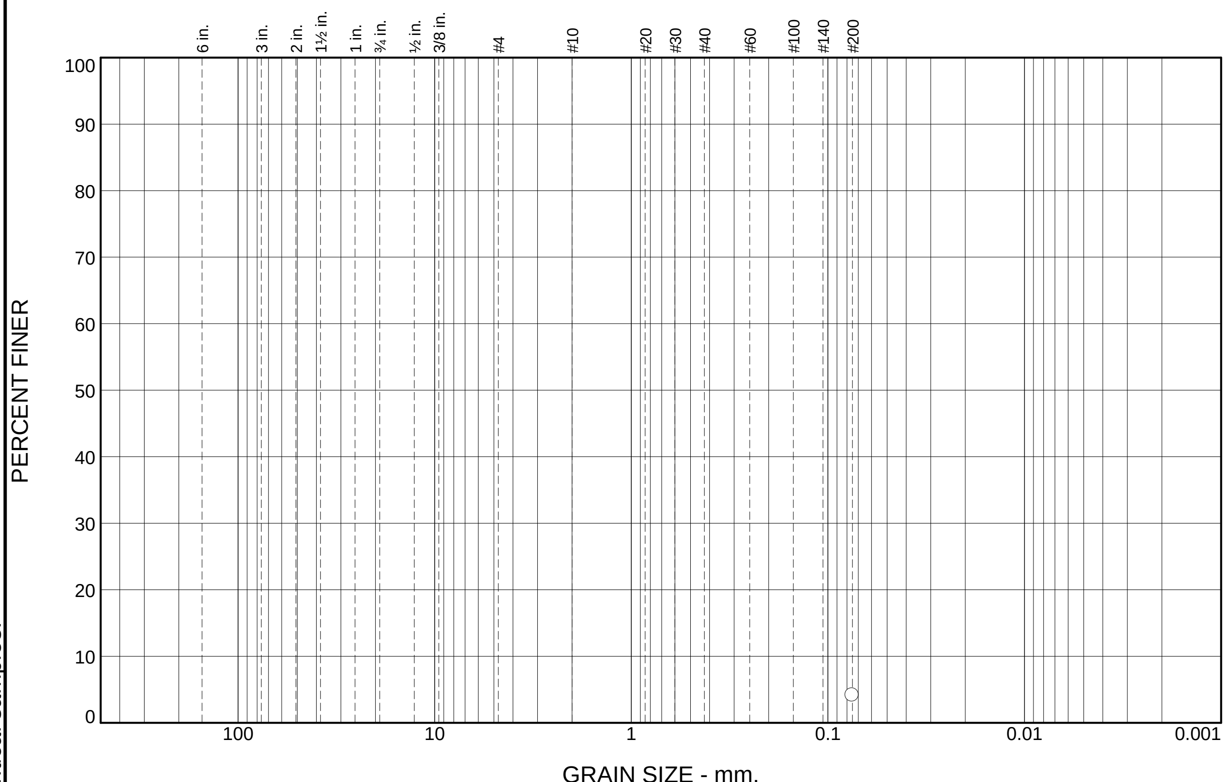
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
120.42	16.10	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										28.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						4.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	4.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G14 / S9
Sample Number: 054-57 **Depth:** 30' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G14 / S9
Depth: 30'
Sample Number: 054-57
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 269.74
Tare Wt. = 16.20
Minus #200 from wash = 4.1%

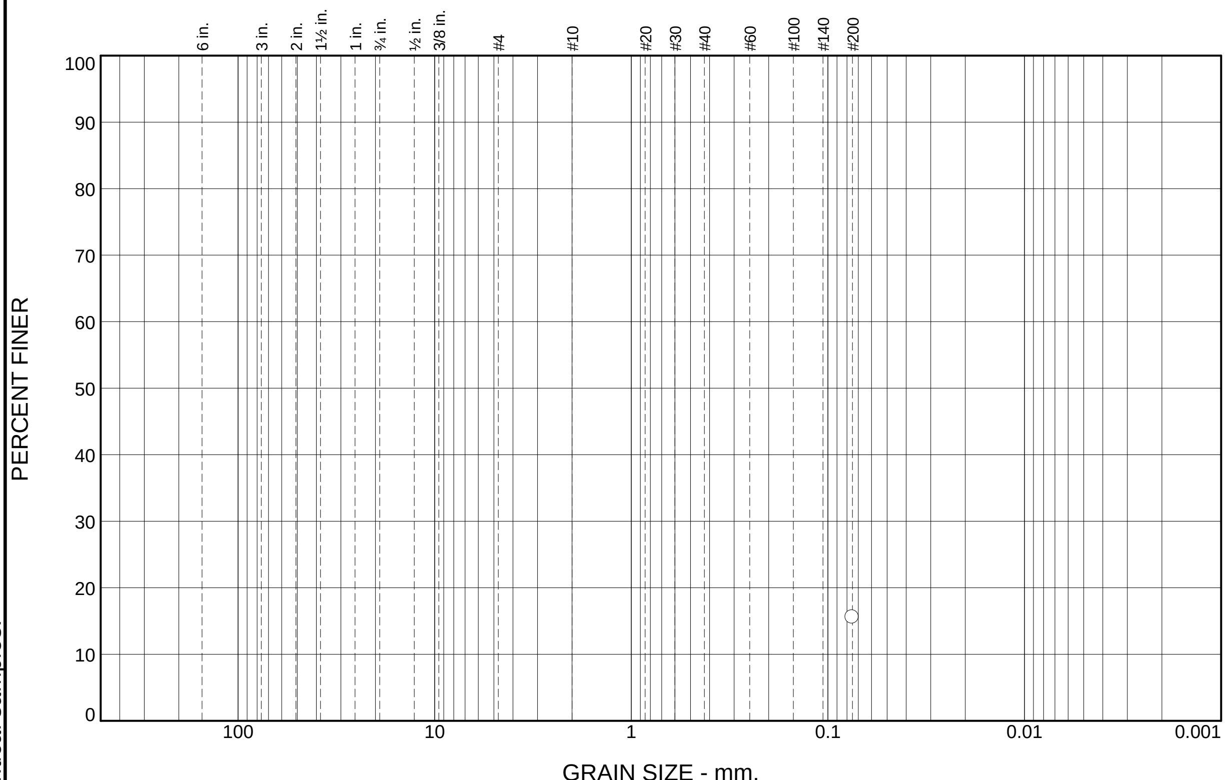
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
280.62	16.20	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										4.1

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						15.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	15.5		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G14 / S11
Sample Number: 054-58 **Depth:** 40' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G14 / S11
Depth: 40'
Sample Number: 054-58
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 191.12
Tare Wt. = 15.70
Minus #200 from wash = 15.5%

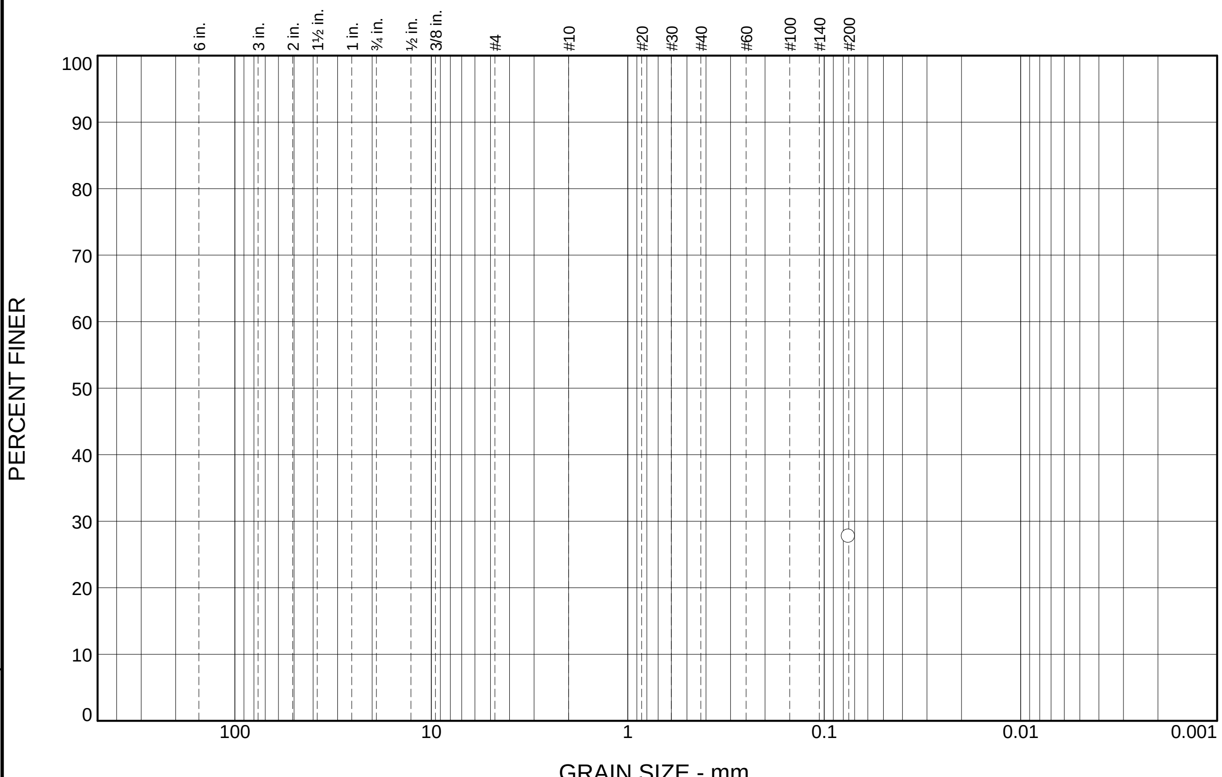
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
223.41	15.70	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										15.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						27.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	27.7		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G15 / S7
Sample Number: 054-61 **Depth:** 20' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G15 / S7
Depth: 20'
Sample Number: 054-61
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 232.39
Tare Wt. = 15.80
Minus #200 from wash = 27.7%

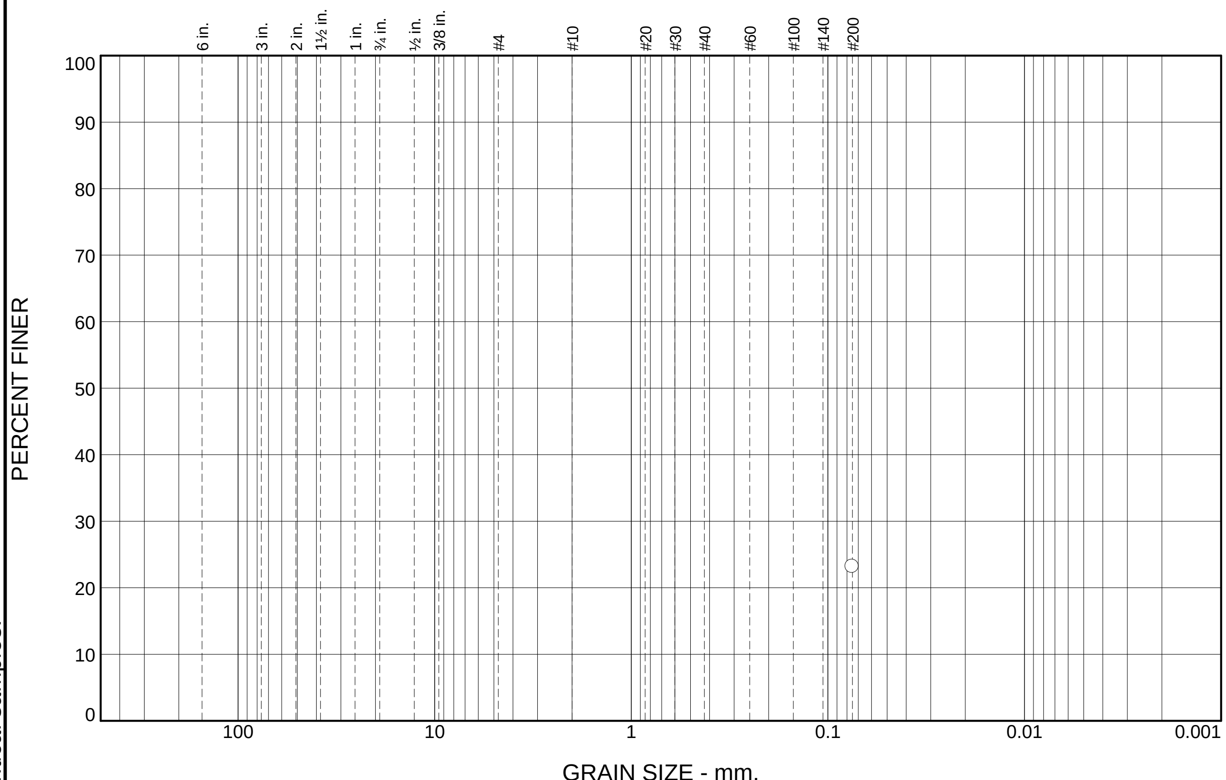
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
315.38	15.80	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										27.7

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						23.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	23.2		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G15 / S8
Sample Number: 054-62 **Depth:** 25' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G15 / S8
Depth: 25'
Sample Number: 054-62
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 192.44
Tare Wt. = 15.80
Minus #200 from wash = 23.2%

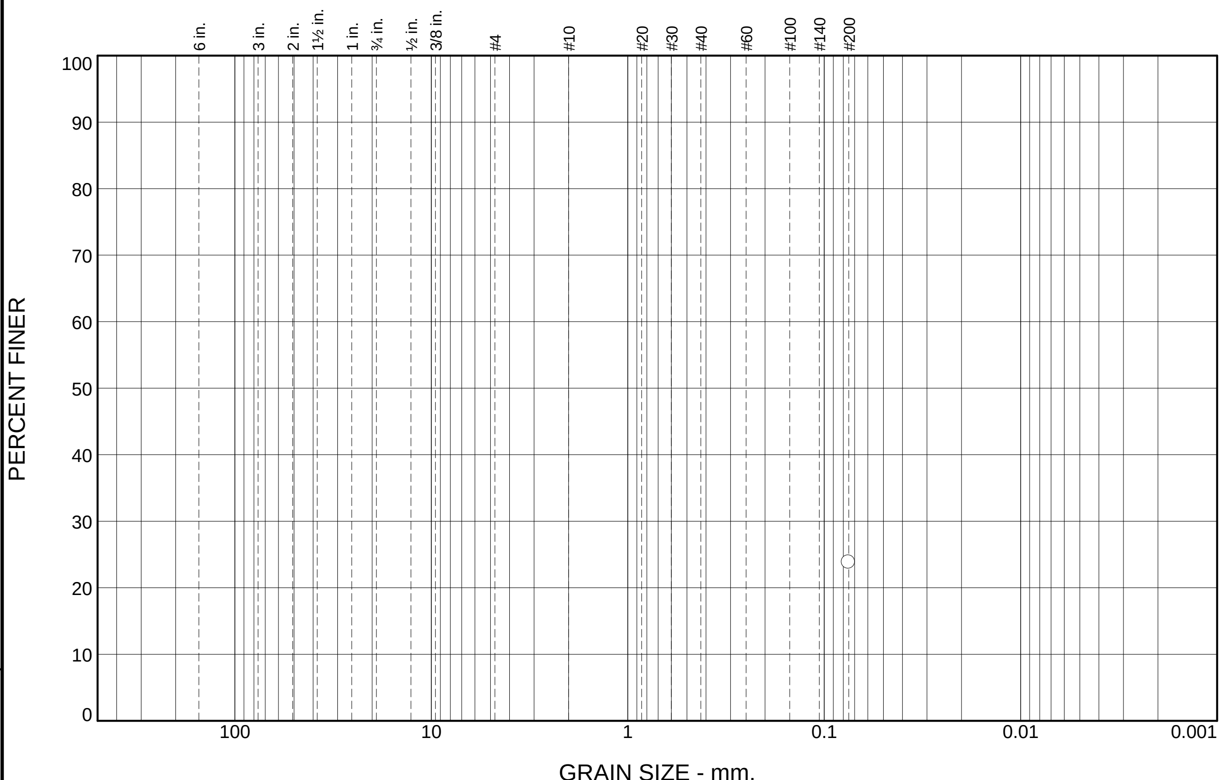
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
245.67	15.80	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										23.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						23.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	23.8		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G15 / S10
Sample Number: 054-63 **Depth:** 35' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G15 / S10
Depth: 35'
Sample Number: 054-63
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 132.32
Tare Wt. = 15.90
Minus #200 from wash = 23.8%

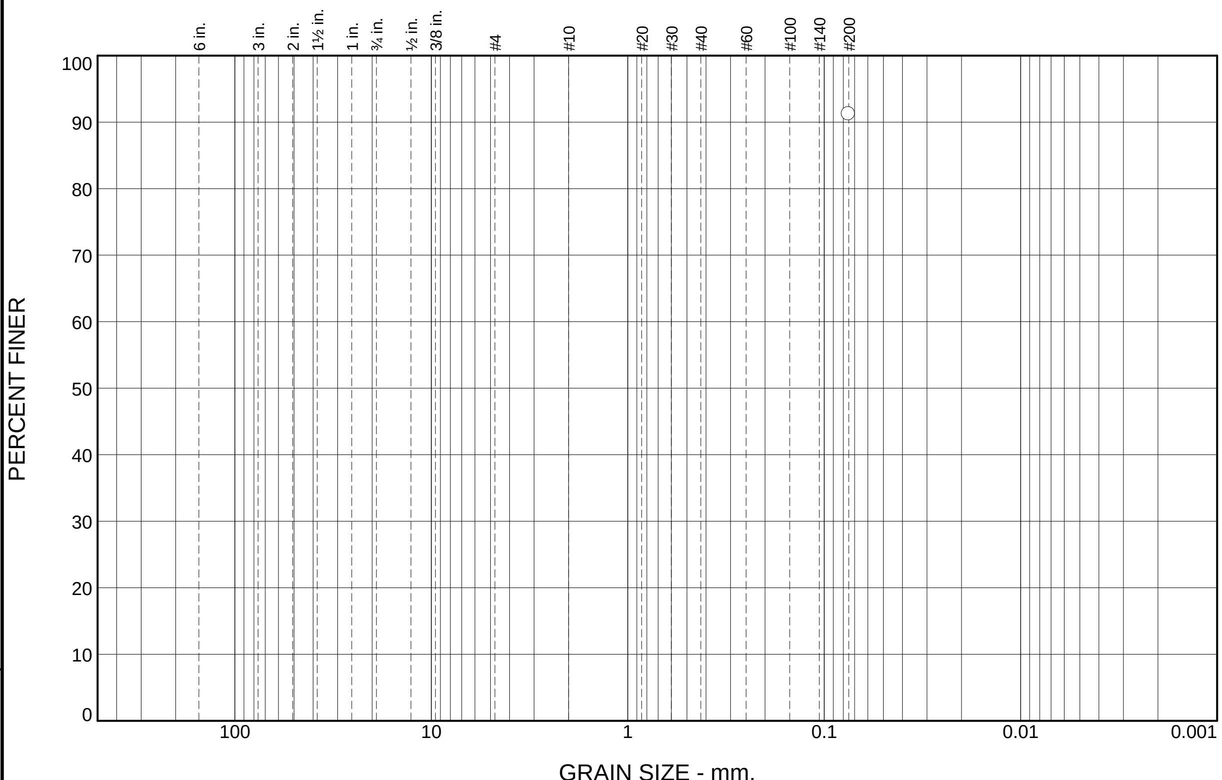
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
168.70	15.90	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										23.8

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						91.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	91.2		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G15 / S14
Sample Number: 054-66 **Depth:** 55' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G15 / S14
Depth: 55' **Sample Number:** 054-66
Date: 12/22/2017
Tested by: GD **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 29.94
Tare Wt. = 16.00
Minus #200 from wash = 91.2%

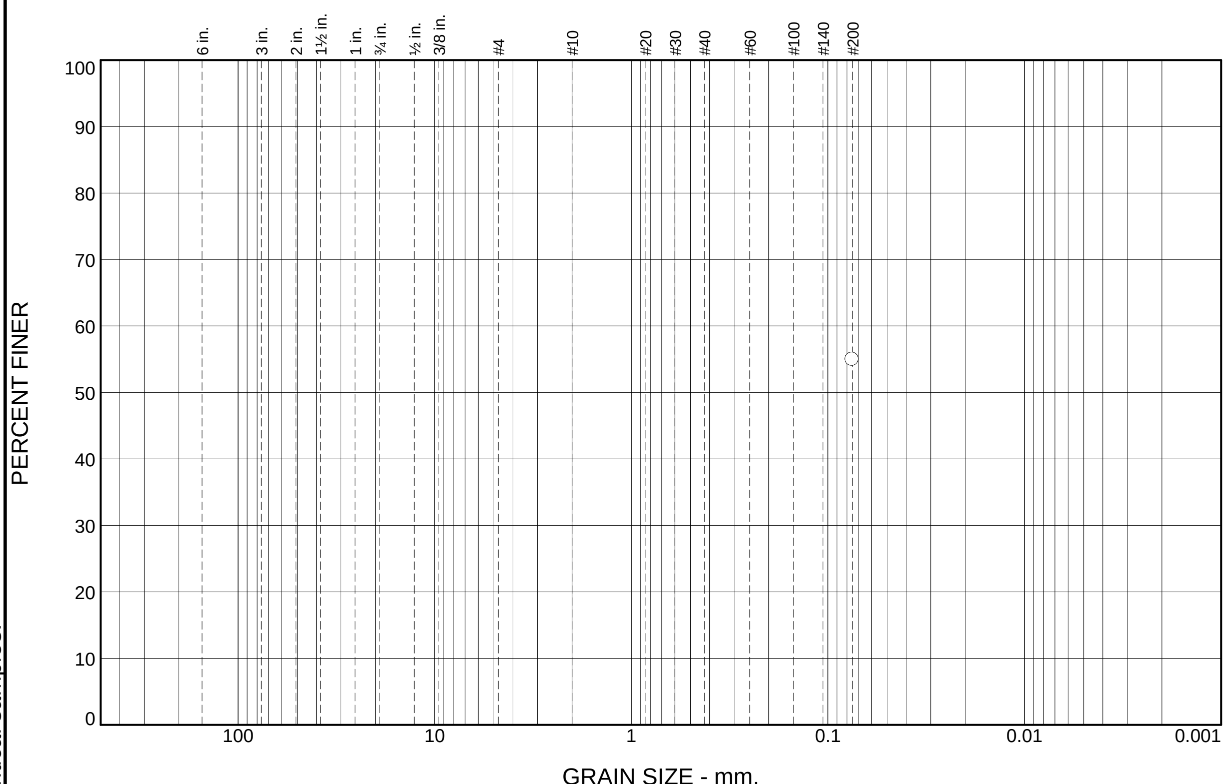
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
174.11	16.00	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										91.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						54.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	54.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G15 / S18
Sample Number: 054-69 **Depth:** 75' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G15 / S18
Depth: 75'
Sample Number: 054-69
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 68.86
Tare Wt. = 15.90
Minus #200 from wash = 54.9%

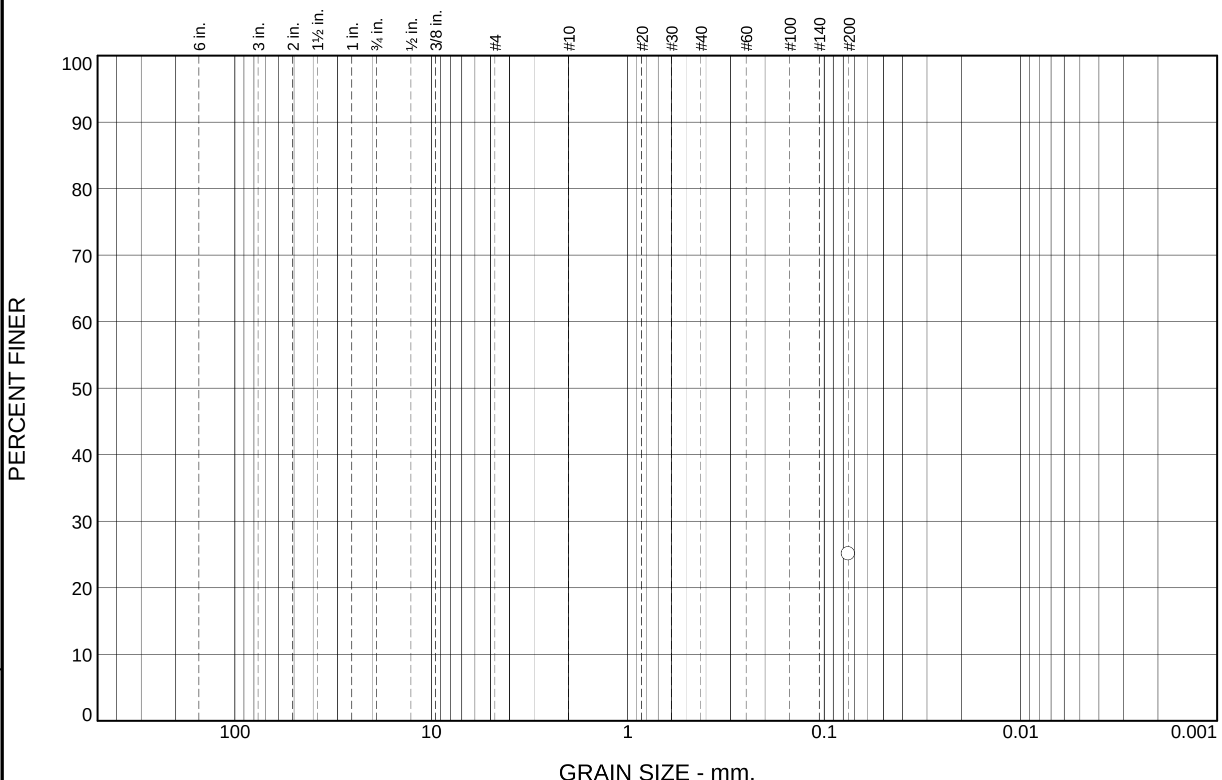
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
133.42	15.90	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										54.9

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						25.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	25.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G016 S-15
Sample Number: 8003-10 **Depth:** 60'-61.5' **Date:** 11/08/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G016 S-15
Depth: 60'-61.5' **Sample Number:** 8003-10
Date: 11/08/2017
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 285.60
Tare Wt. = 15.70
Minus #200 from wash = 25.0%

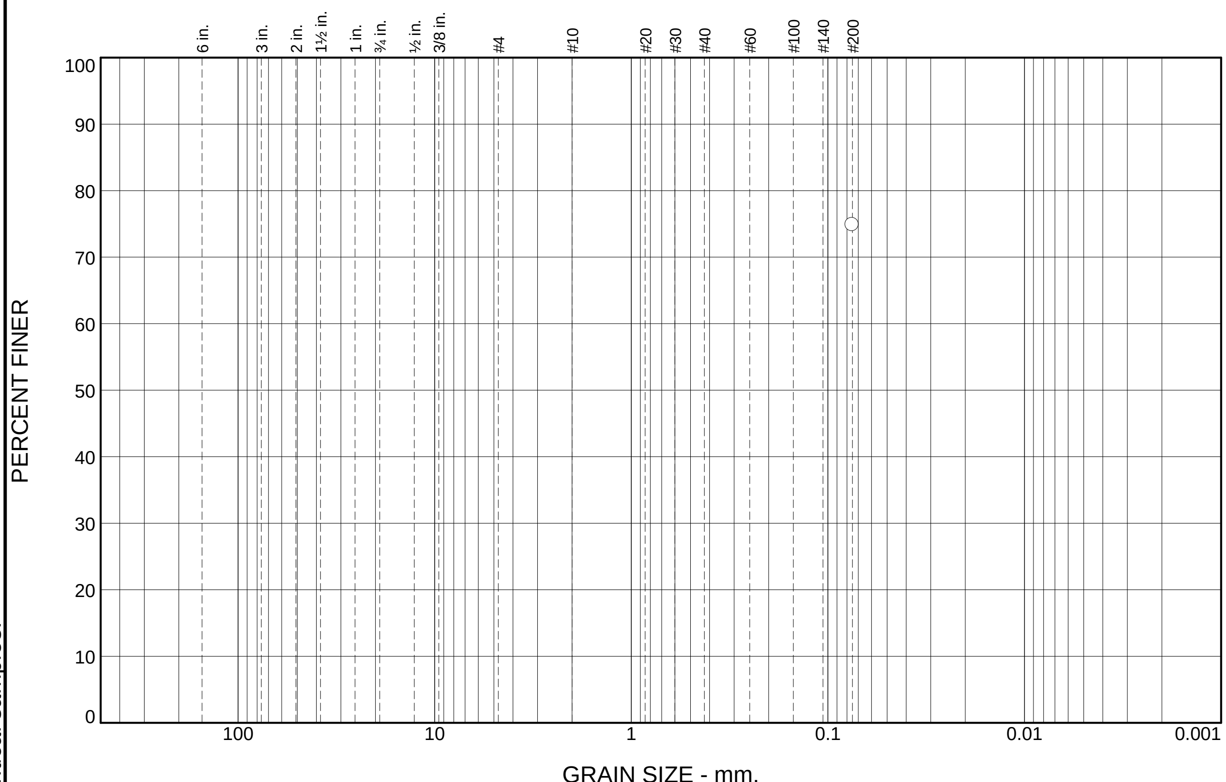
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
375.80	15.70	#200			25.0

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										25.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						74.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	74.8		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G016 S-17
Sample Number: 8003-12 **Depth:** 70'-71.5' **Date:** 11/08/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G016 S-17
Depth: 70'-71.5' **Sample Number:** 8003-12
Date: 11/08/2017
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 76.10
Tare Wt. = 15.70
Minus #200 from wash = 74.8%

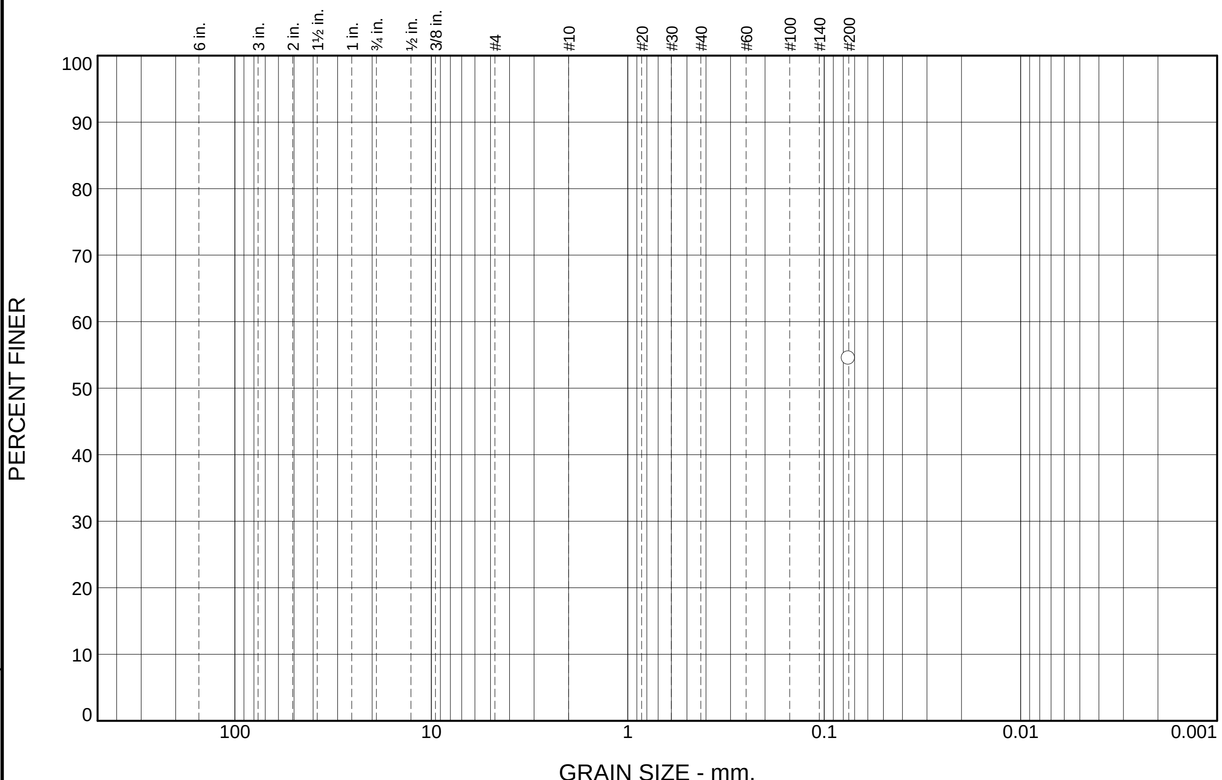
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
255.60	15.70	#200			74.8

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										74.8

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						54.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	54.5		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G016 S-22
Sample Number: 8003-16 **Depth:** 95'-96.5' **Date:** 11/08/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G016 S-22
Depth: 95'-96.5'
Sample Number: 8003-16
Date: 11/08/2017
Tested by: SR
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 151.60
Tare Wt. = 15.70
Minus #200 from wash = 54.5%

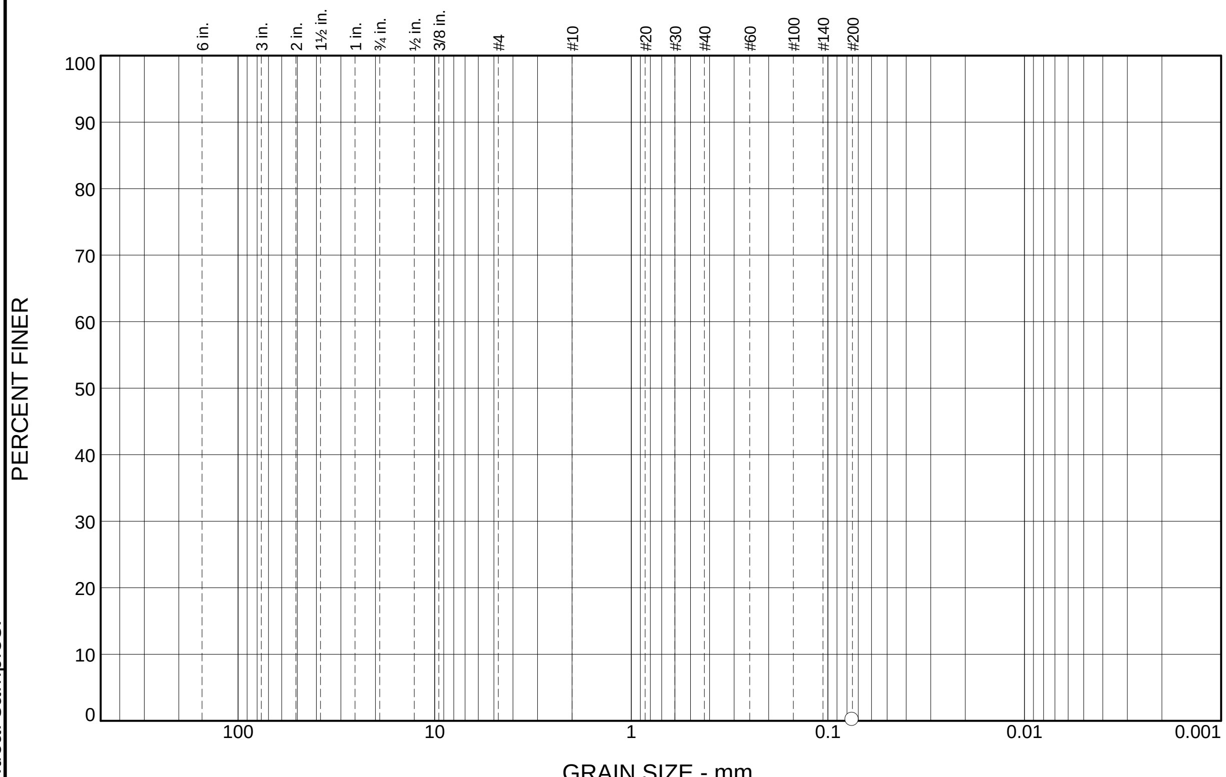
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
314.20	15.70	#200			54.5

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										54.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						0.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	0.2		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G17 / S8
Sample Number: 054-110 **Depth:** 30' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC
Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G17 / S8
Depth: 30'
Sample Number: 054-110
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 249.22
Tare Wt. = 15.80
Minus #200 from wash = 0.2%

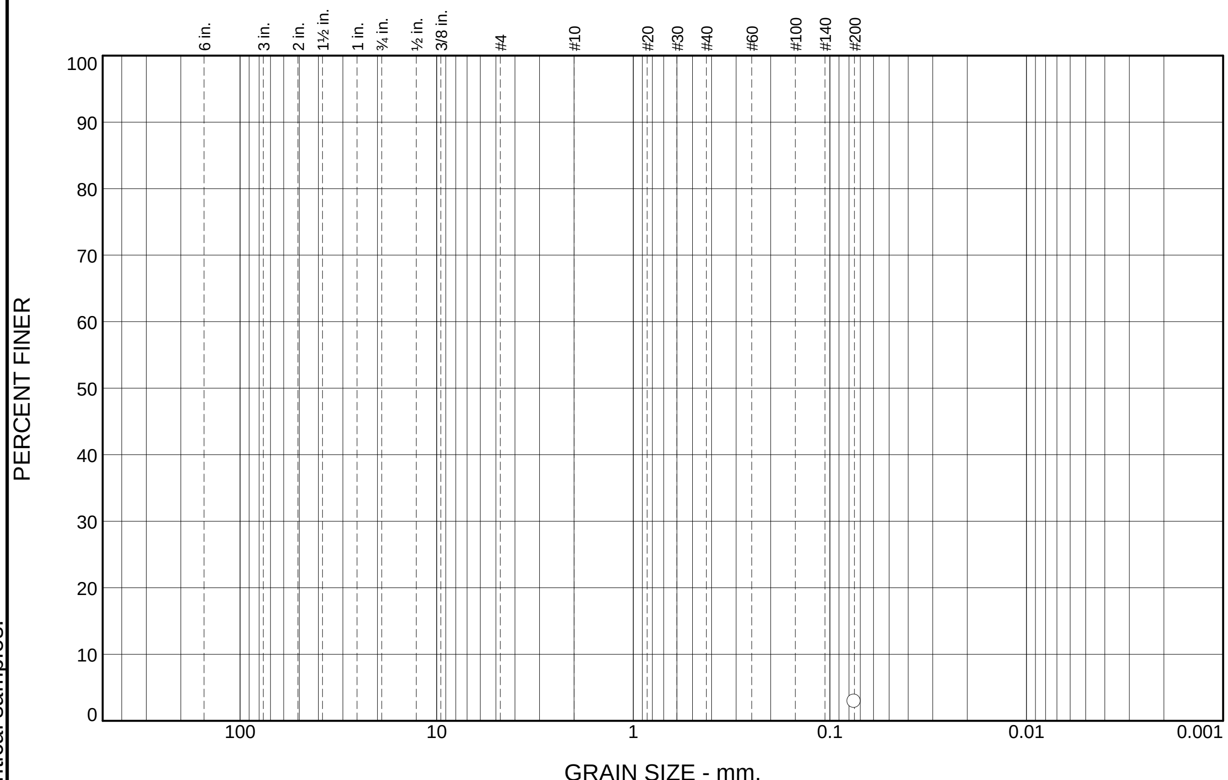
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
249.60	15.80	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										0.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						2.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	2.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G17A / S10
Sample Number: 054-119 **Depth:** 35' **Date:** 12/22/2017

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G17A / S10
Depth: 35'
Sample Number: 054-119
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 215.92
Tare Wt. = 15.80
Minus #200 from wash = 2.9%

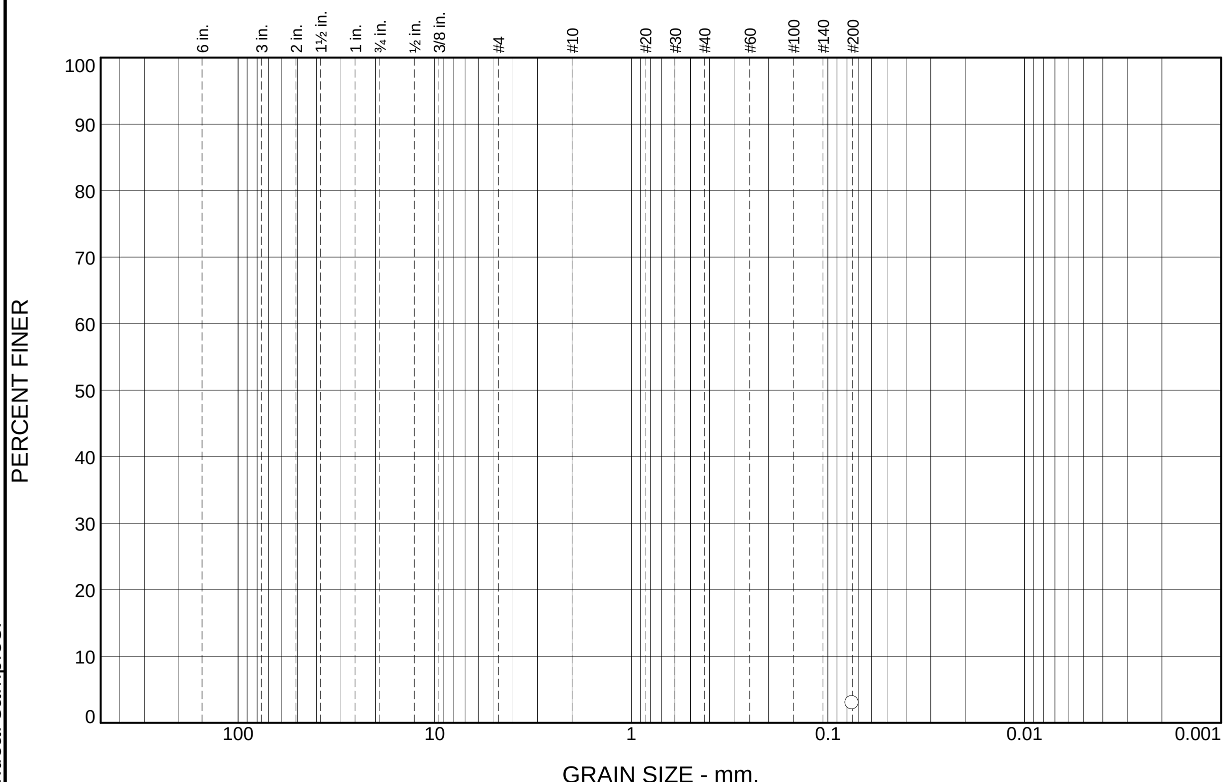
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
221.89	15.80	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										2.9

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						3.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	3.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G17A / S13
Sample Number: 054-121 **Depth:** 50' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No:** 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: GD **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G17A / S13
Depth: 50'
Sample Number: 054-121
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 345.19
Tare Wt. = 15.70
Minus #200 from wash = 3.0%

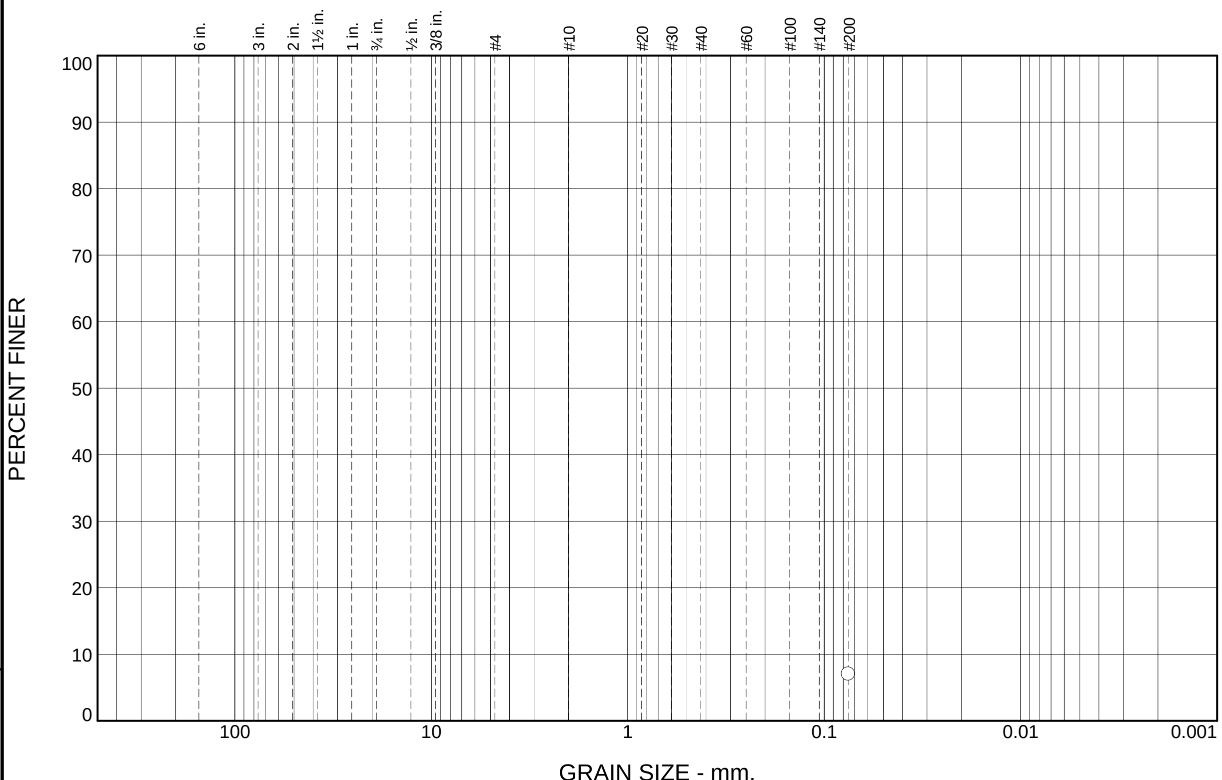
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
355.30	15.70	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										3.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						7.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	7.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G17A / S18
Sample Number: 054-124 **Depth:** 75' **Date:** 12/22/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No: 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G17A / S18
Depth: 75'
Sample Number: 054-124
Date: 12/22/2017
Tested by: GD
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 198.82
Tare Wt. = 15.80
Minus #200 from wash = 7.0%

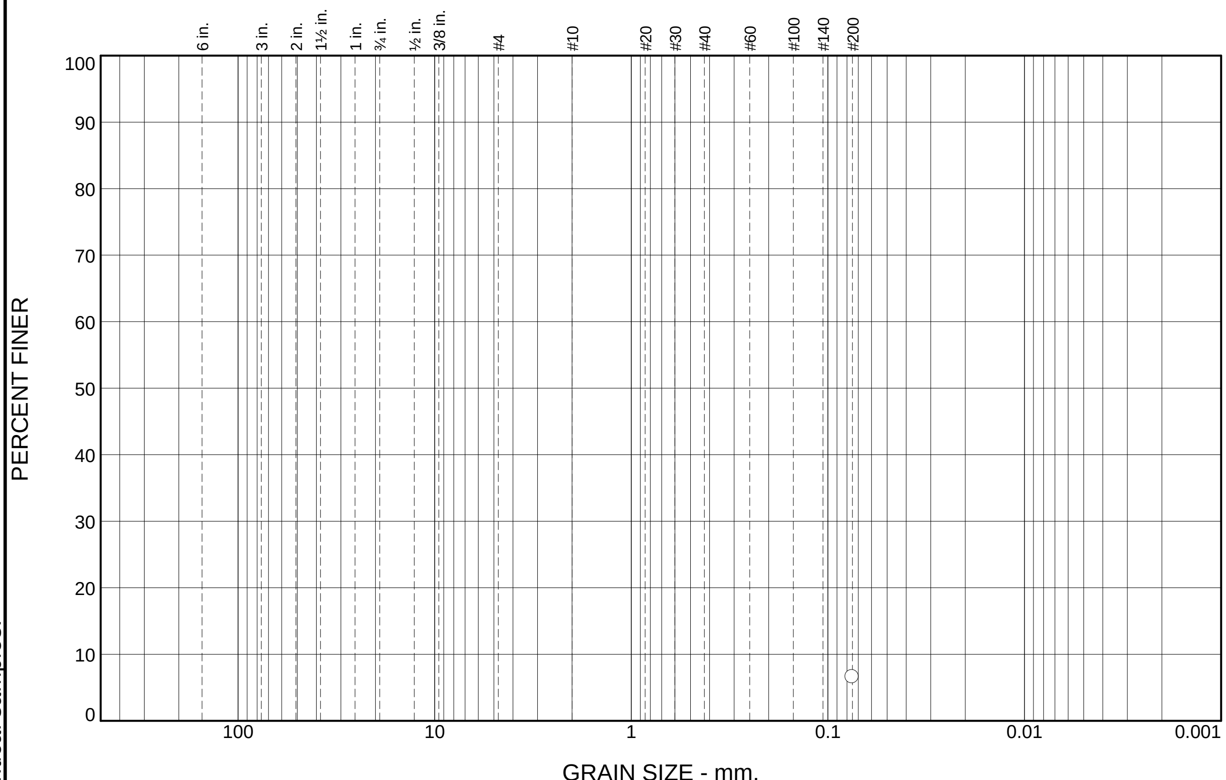
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer
212.57	15.80	0.00			

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										7.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						6.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	6.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G018 S-11
Sample Number: 8003-24 **Depth:** 40'-41.5' **Date:** 11/08/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-11
Depth: 40'-41.5' **Sample Number:** 8003-24
Date: 11/08/2017
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 434.70
Tare Wt. = 15.90
Minus #200 from wash = 6.6%

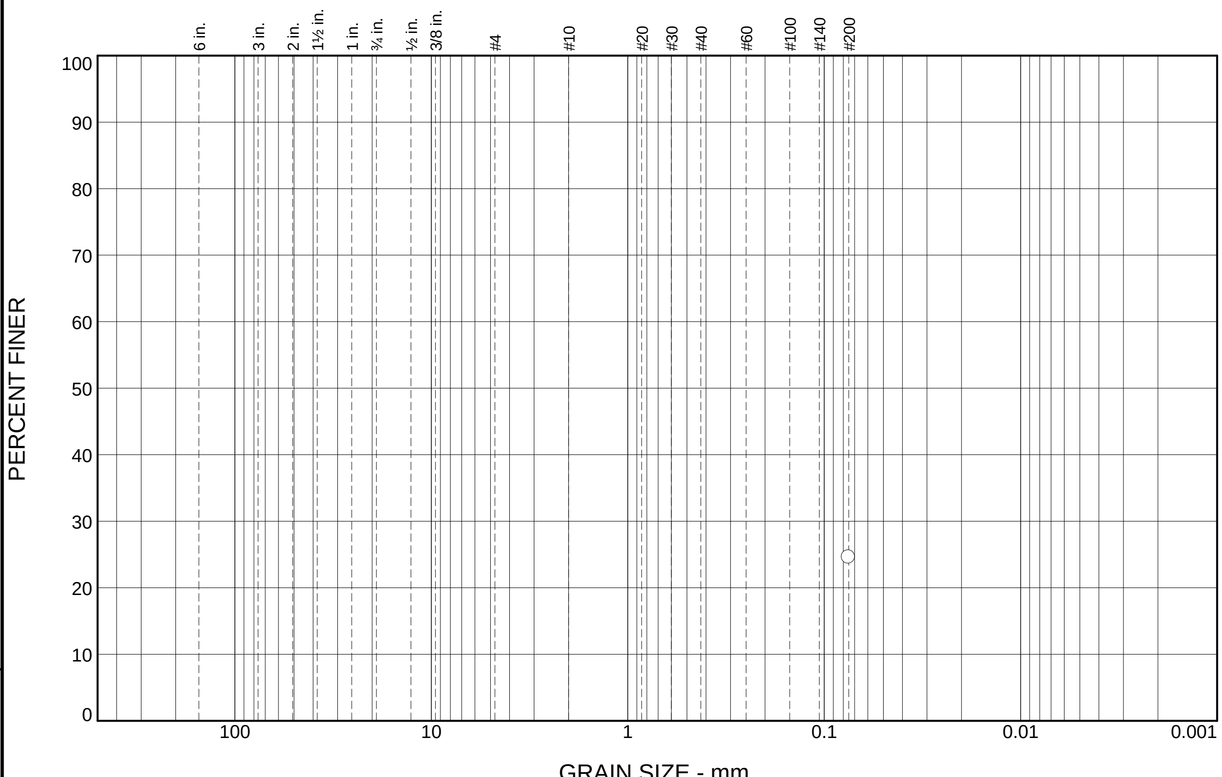
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
464.10	15.90	#200			6.6

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										6.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						24.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	24.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G018 S-14
Sample Number: 8003-25 **Depth:** 60'-61.5' **Date:** 11/08/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-14
Depth: 60'-61.5'
Sample Number: 8003-25
Date: 11/08/2017
Tested by: SR
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 326.80
Tare Wt. = 15.80
Minus #200 from wash = 24.6%

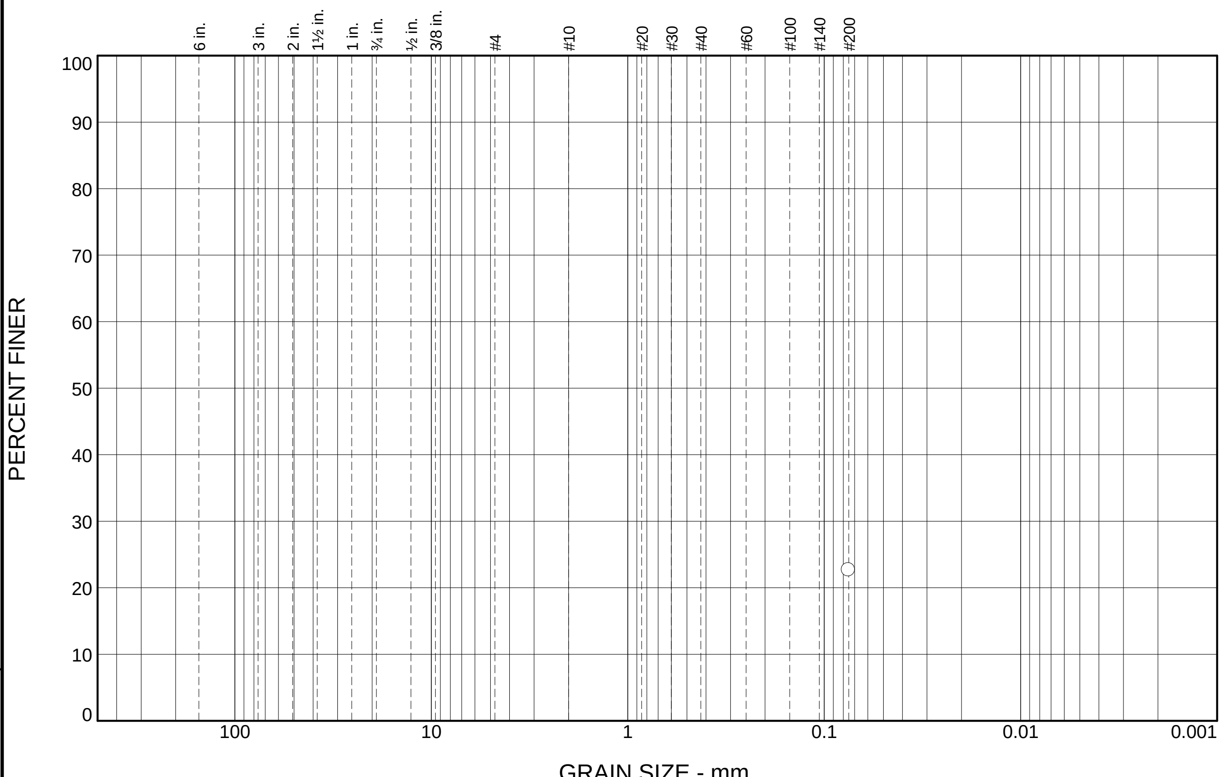
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
428.20	15.80	#200			24.6

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										24.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						22.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	22.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G018 S-17
Sample Number: 8003-27 **Depth:** 77.5'-79' **Date:** 11/8/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-17
Depth: 77.5'-79'
Sample Number: 8003-27
Date: 11/8/2017
Tested by: SR
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 348.10
Tare Wt. = 15.80
Minus #200 from wash = 22.6%

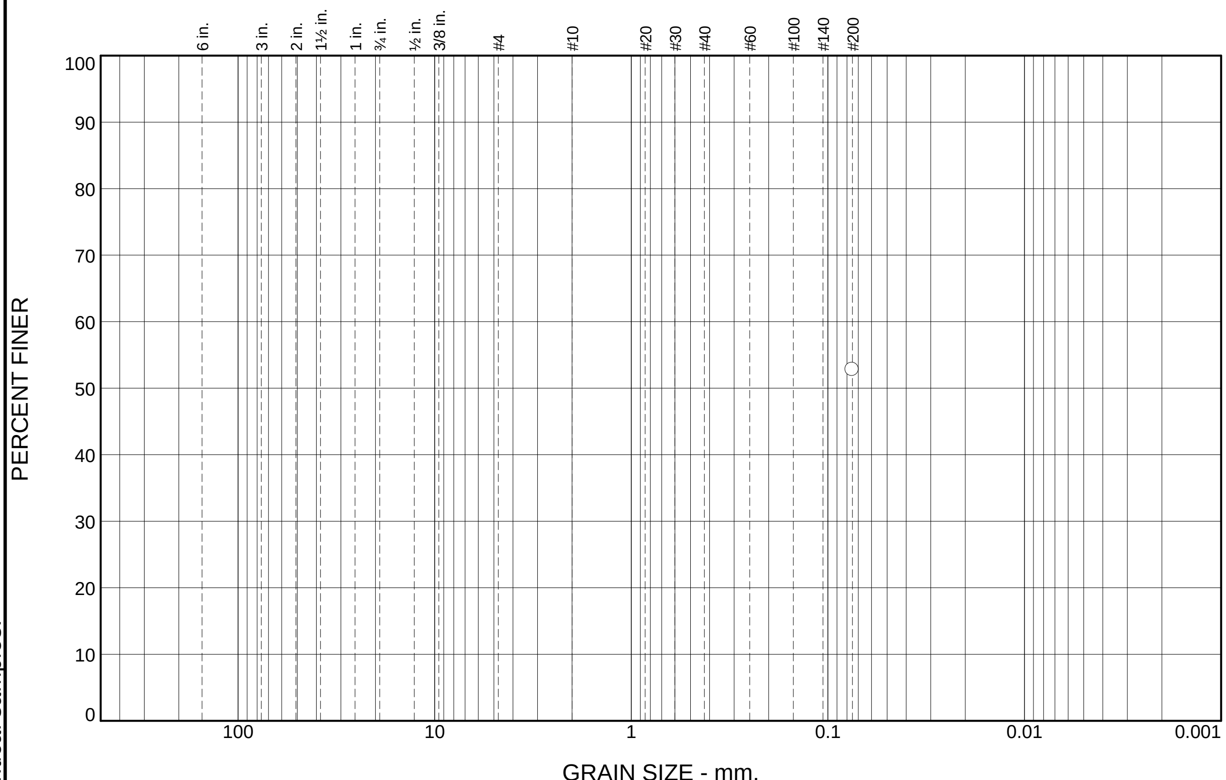
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
445.30	15.80	#200			22.6

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										22.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						52.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	52.8		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G018 S-34
Sample Number: 8003-40 **Depth:** 170'-171.5' **Date:** 11/8/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: SR **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-34
Depth: 170'-171.5'
Sample Number: 8003-40
Date: 11/8/2017
Tested by: SR
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 334.50
Tare Wt. = 198.30
Minus #200 from wash = 52.8%

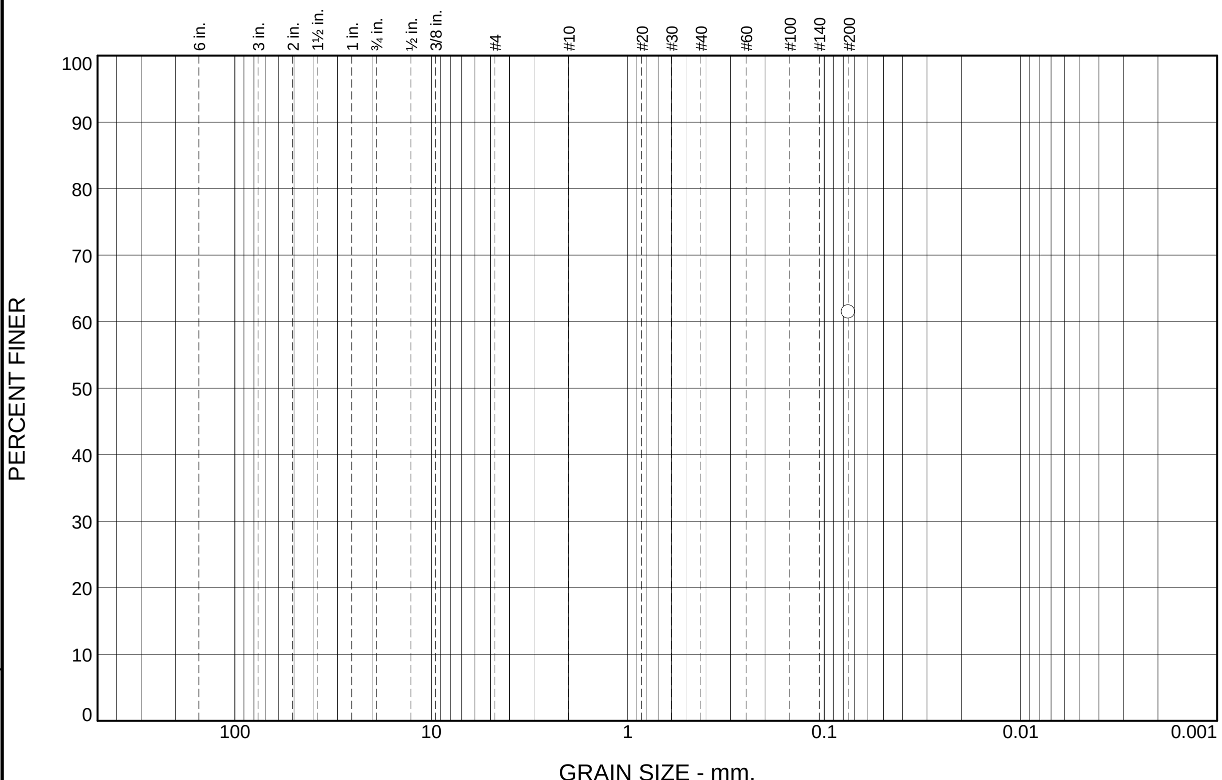
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
486.70	198.30	#200			52.8

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										52.8

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						61.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	61.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G018 S-37
Sample Number: 8003-42 **Depth:** 185'-186.5' **Date:** 11/8/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: SR **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-37
Depth: 185'-186.5' **Sample Number:** 8003-42
Date: 11/8/2017
Tested by: SR **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 284.80
Tare Wt. = 157.60
Minus #200 from wash = 61.4%

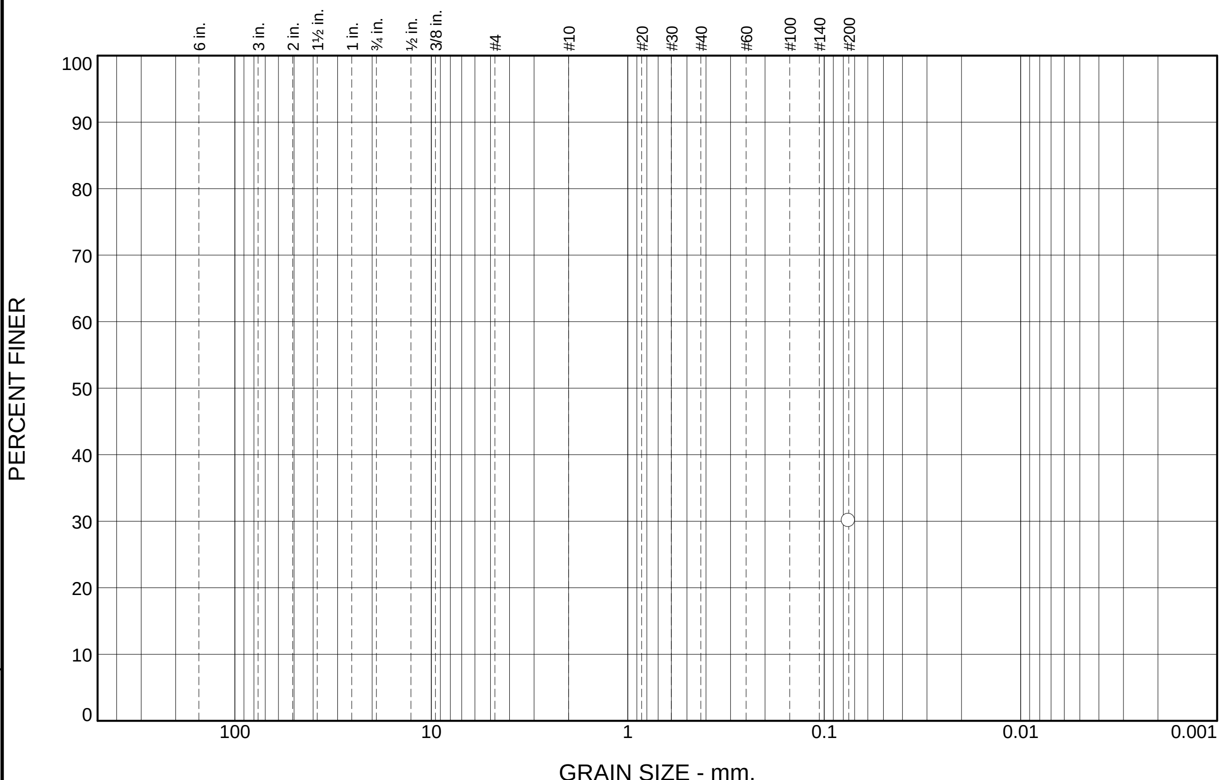
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
487.30	157.60	#200			61.4

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										61.4

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						30.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	30.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G019 S-12
Sample Number: 7992-7 **Depth:** 40'-41.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-12
Depth: 40'-41.5'
Sample Number: 7992-7
Date: 10/5/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 185.40
Tare Wt. = 16.40
Minus #200 from wash = 30.1%

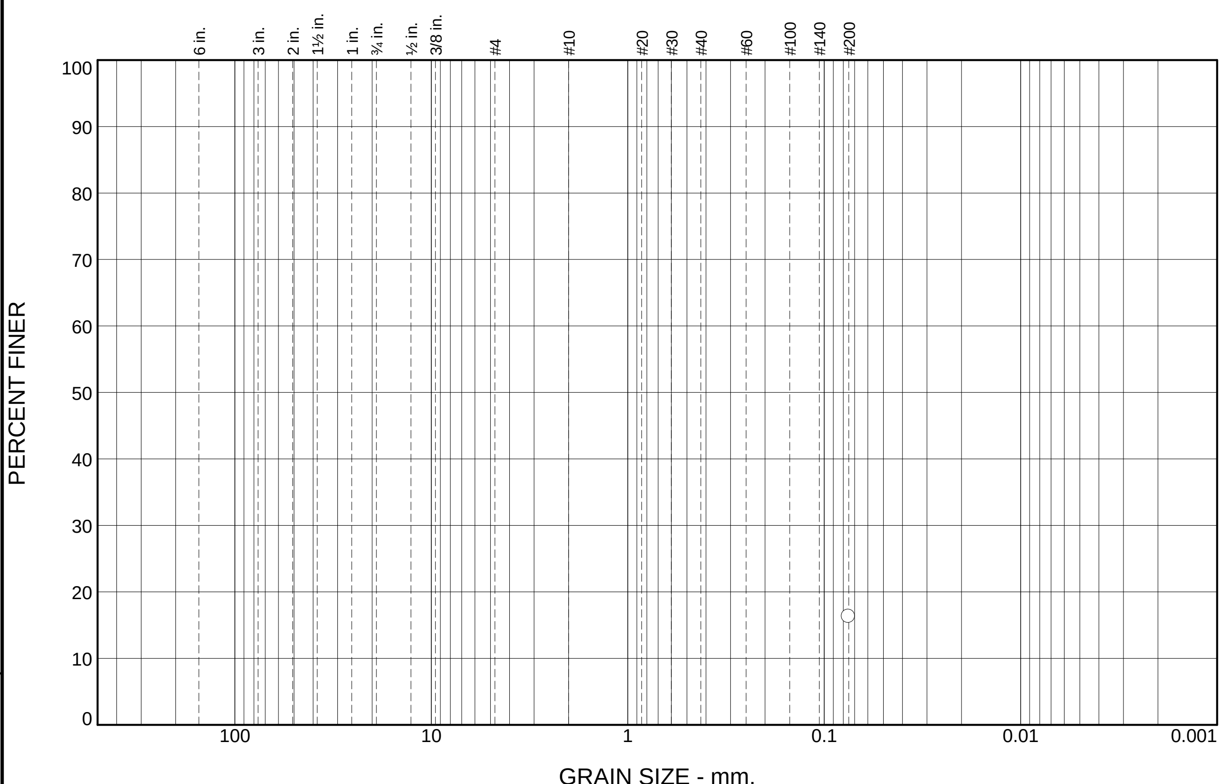
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
258.10	16.40	#200			30.1

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										30.1

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						16.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	16.3		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G019 S-16
Sample Number: 7992-9 **Depth:** 60'-61.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-16
Depth: 60'-61.5' **Sample Number:** 7992-9
Date: 10/5/2017
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 207.30
Tare Wt. = 16.60
Minus #200 from wash = 16.3%

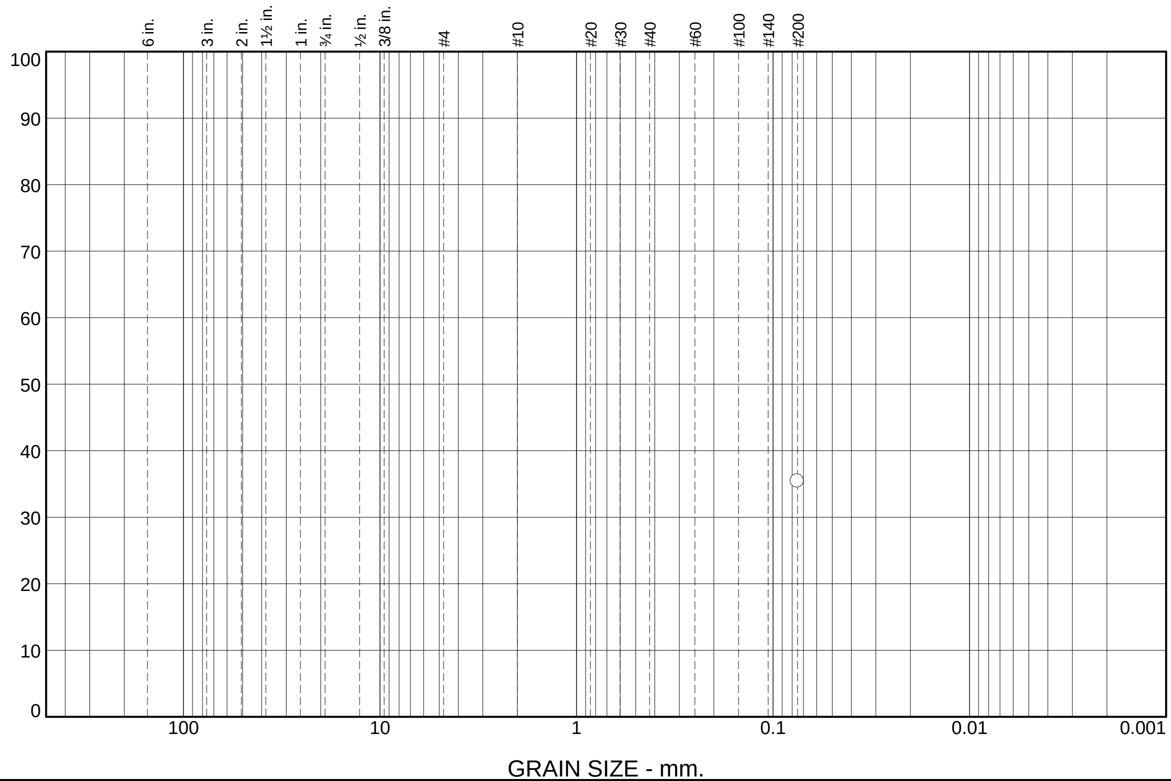
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
244.40	16.60	#200			16.3

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										16.3

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						35.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	35.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Location: G019 S-31
Sample Number: 7992-11 **Depth:** 135'-136.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-31
Depth: 135'-136.5'
Sample Number: 7992-11
Date: 10/5/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 209.00
Tare Wt. = 16.90
Minus #200 from wash = 35.4%

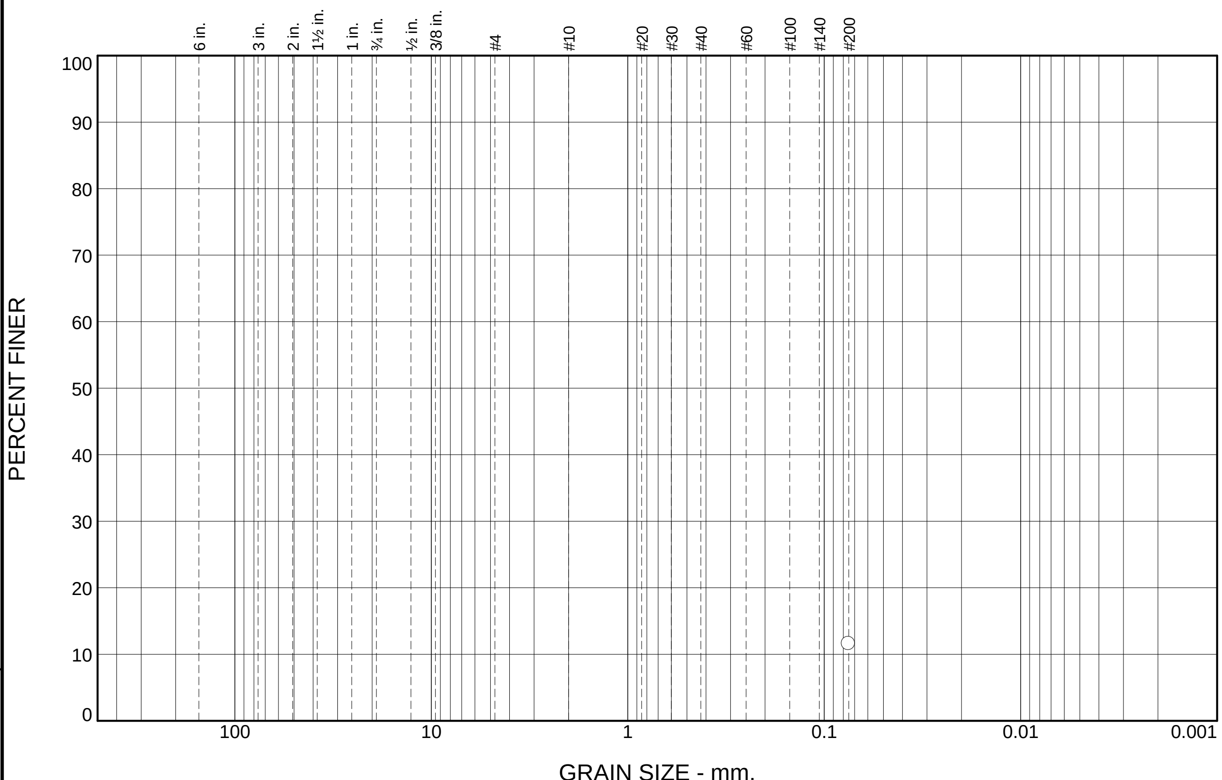
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
314.30	16.90	#200			35.4

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										35.4

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						11.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	11.6		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G020 S-13
Sample Number: 7992-20 **Depth:** 45'-46.5 **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-13
Depth: 45'-46.5
Sample Number: 7992-20
Date: 10/5/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 203.00
Tare Wt. = 16.40
Minus #200 from wash = 11.6%

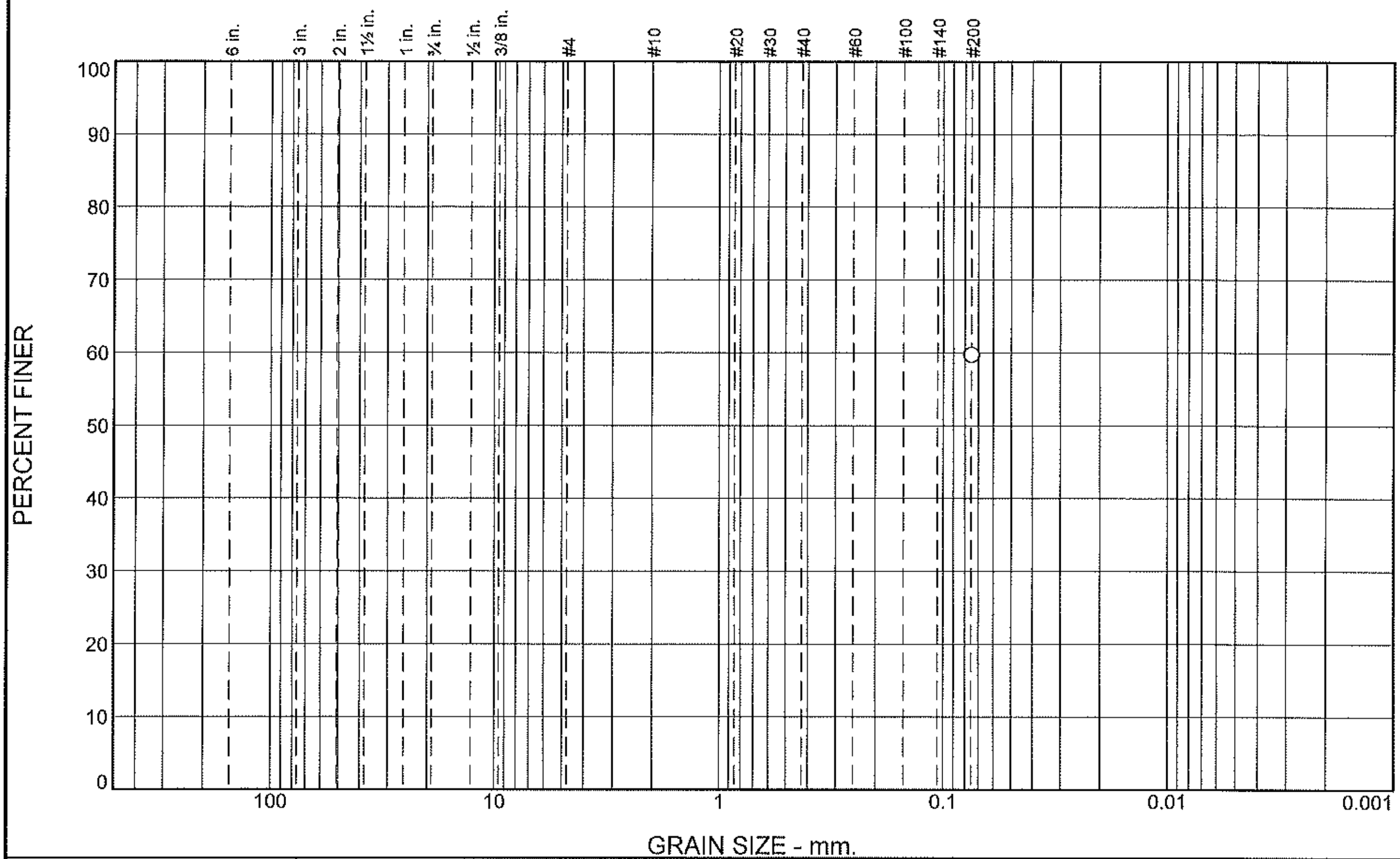
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
227.40	16.40	#200			11.6

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										11.6

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						59.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	59.7		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G020 S-20 80'-81.5'
Sample Number: 7980-8

Date: 08/12/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client:
Project: ST-DRLE
Project No: 1657705 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

8/14/2017

Project: ST-DRLE
Project Number: 1657705
Location: G020 S-20 80'-81.5'
Sample Number: 7980-8
Date: 08/12/2017
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 114.20
Tare Wt. = 16.10
Minus #200 from wash = 59.7%

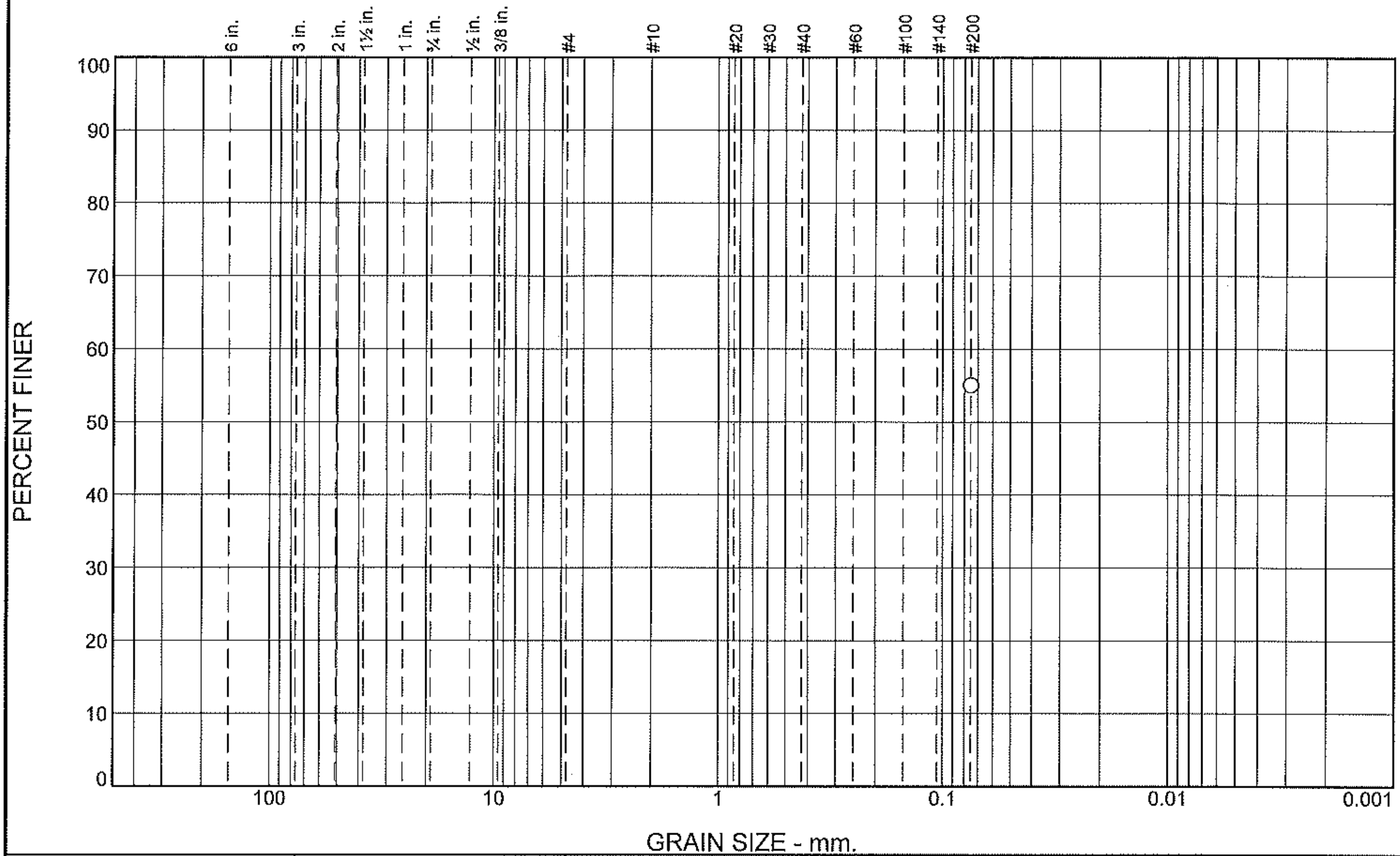
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
259.70	16.10	#200			59.7

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										59.7

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						55.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	55.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G020 S-24 100'-101.5'
Sample Number: 7980-10

Date: 08/12/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client:
Project: ST-DRLE

Project No: 1657705 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

8/14/2017

Project: ST-DRLE
Project Number: 1657705
Location: G020 S-24 100'-101.5'
Sample Number: 7980-10
Date: 08/12/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 130.90
Tare Wt. = 17.00
Minus #200 from wash = 55.1%

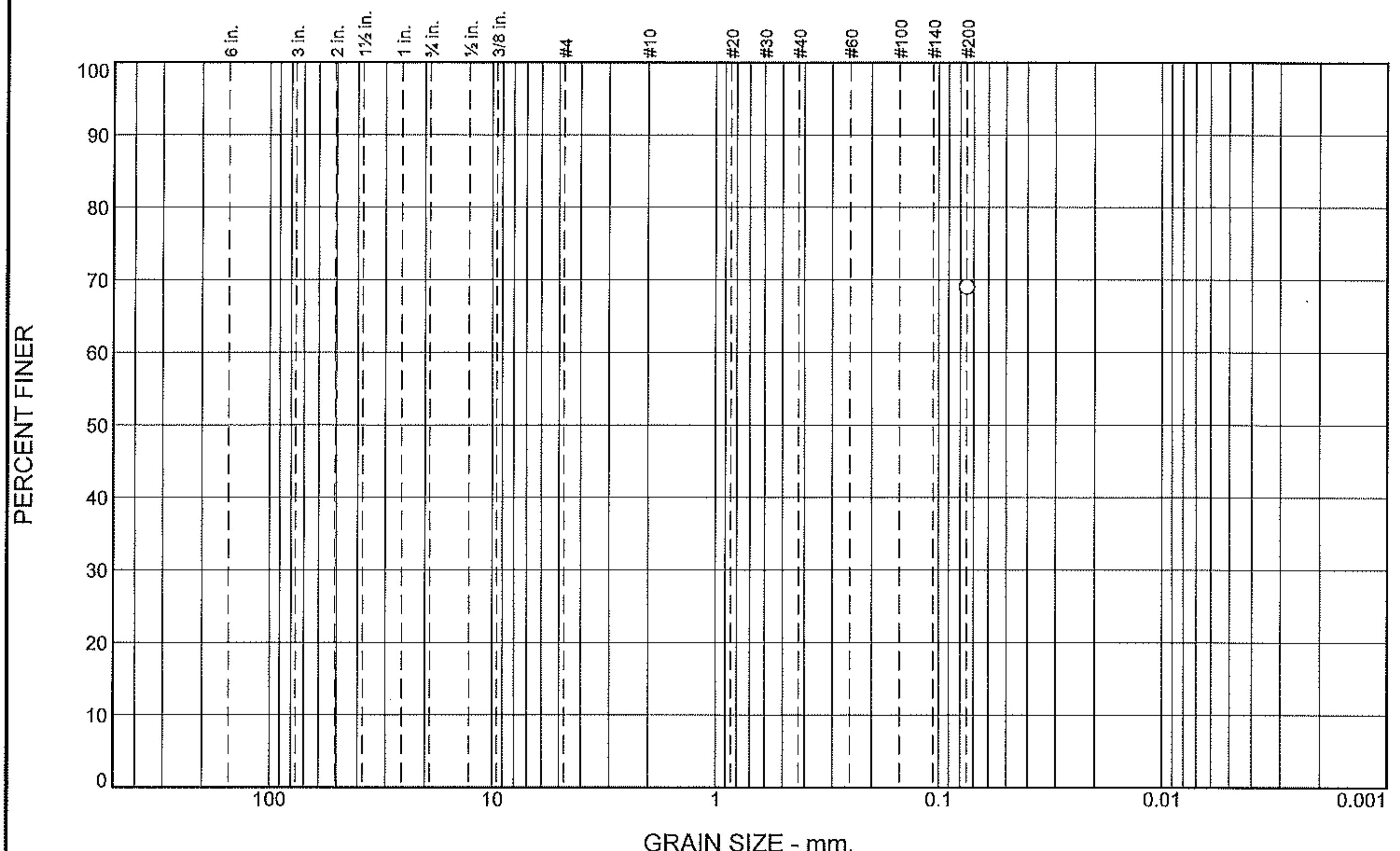
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
270.40	17.00	#200			55.1

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										55.1

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						69.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	69.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G020 S-25 105'-106.5'
Sample Number: 7980-11

Date: 08/12/2017

Hayre McElroy & Associates, LLC Redmond, WA	Client: Project: ST-DRLE Project No: 1657705 Figure

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

8/14/2017

Project: ST-DRLE
Project Number: 1657705
Location: G020 S-25 105'-106.5'
Sample Number: 7980-11
Date: 08/12/2017
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 81.50
Tare Wt. = 15.80
Minus #200 from wash = 69.1%

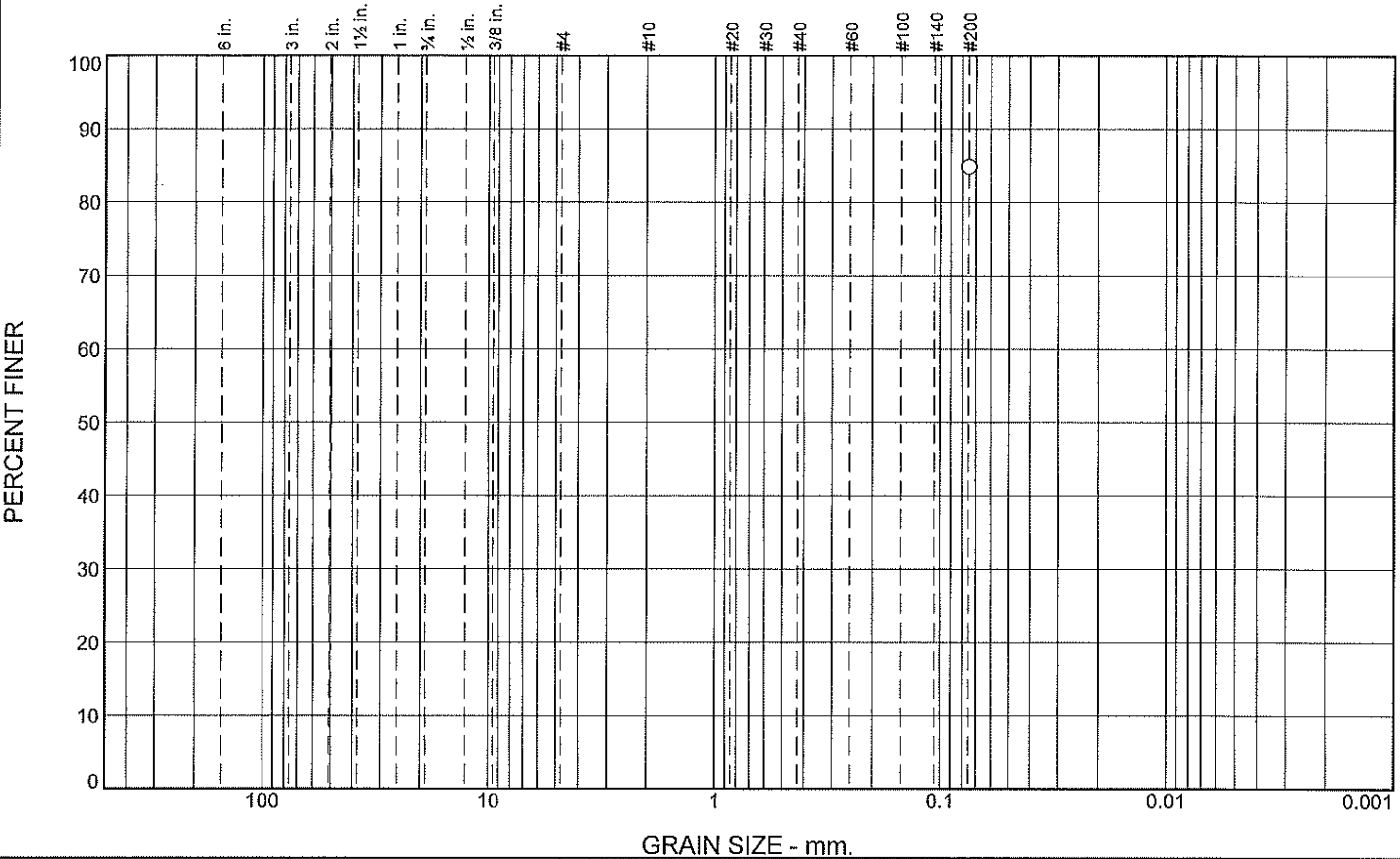
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
228.10	15.80	#200			69.1

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										69.1

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						84.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	84.9		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G020 S-26 110'-111.5'
Sample Number: 7980-12

Date: 08/14/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client:
Project: ST-DRLE
Project No: 1657705 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

8/15/2017

Project: ST-DRLE
Project Number: 1657705
Location: G020 S-26 110'-111.5'
Sample Number: 7980-12
Date: 08/14/2017
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): Dry Sample and Tare = 35.20
Tare Wt. = 16.10
Minus #200 from wash = 84.9%

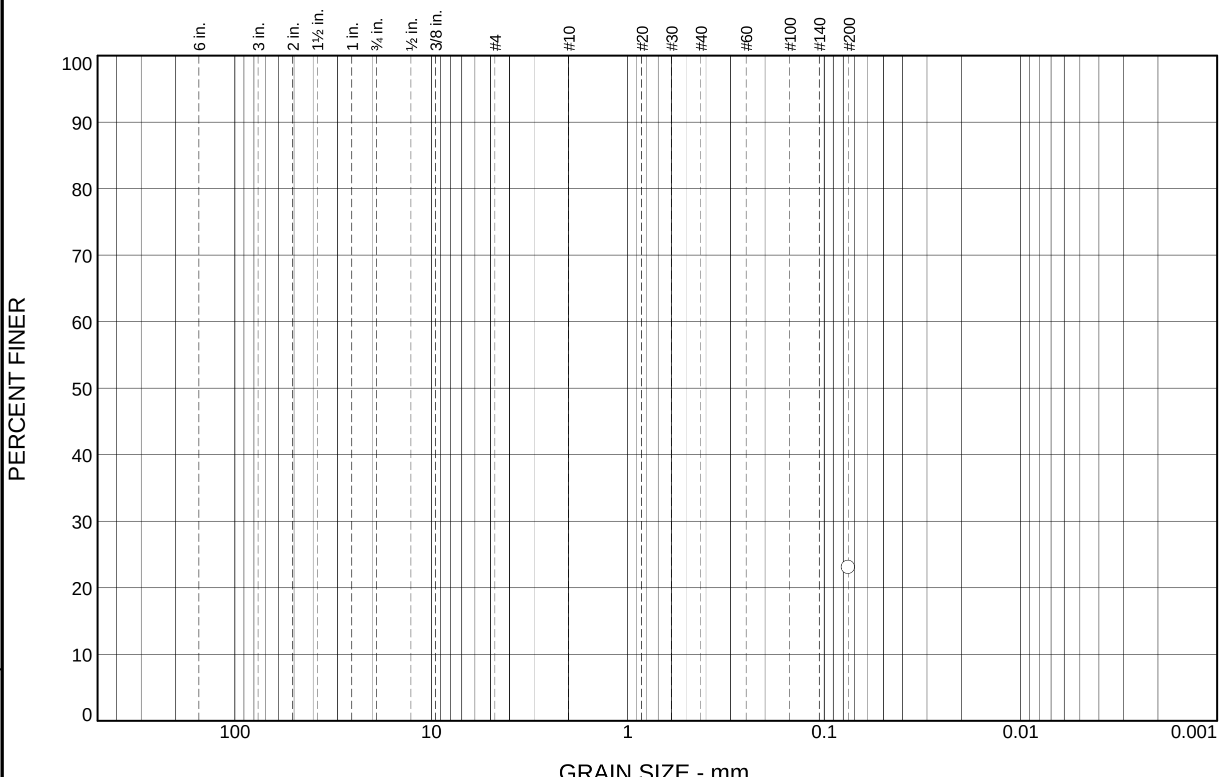
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
142.20	16.10	#200			84.9

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										84.9

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						23.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	23.0		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G020 S-35
Sample Number: 7992-24 **Depth:** 155'-156.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-35
Depth: 155'-156.5'
Sample Number: 7992-24
Date: 10/5/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 406.00
Tare Wt. = 16.10
Minus #200 from wash = 23.0%

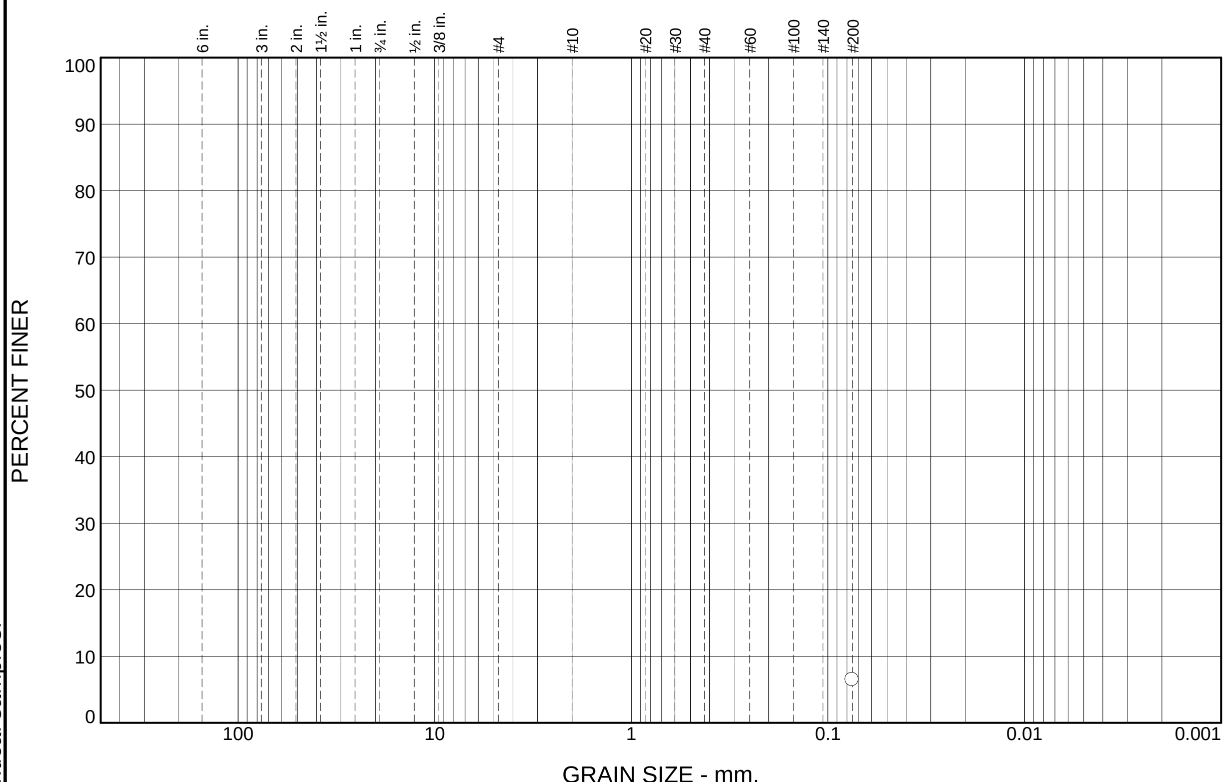
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
522.60	16.10	#200			23.0

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										23.0

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						6.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	6.5		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G022 S-10
Sample Number: 7992-39 **Depth:** 35'-36.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G022 S-10
Depth: 35'-36.5' **Sample Number:** 7992-39
Date: 10/5/2017
Tested by: BH **Checked by:** JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 325.90
Tare Wt. = 15.80
Minus #200 from wash = 6.5%

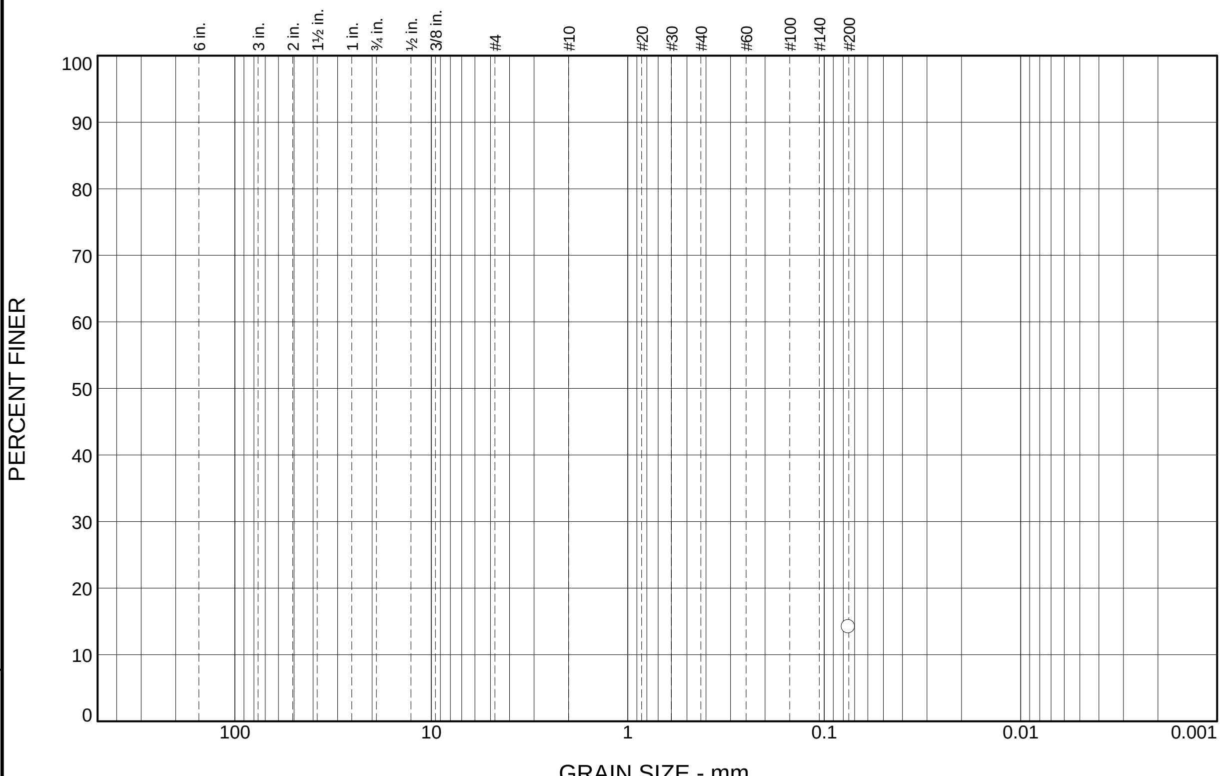
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
347.30	15.80	#200			6.5

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										6.5

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						14.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	14.2		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G022 S-12
Sample Number: 7992-40 **Depth:** 45'-46.5' **Date:** 10/5/2017

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G022 S-12
Depth: 45'-46.5'
Sample Number: 7992-40
Date: 10/5/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 314.60
Tare Wt. = 15.80
Minus #200 from wash = 14.2%

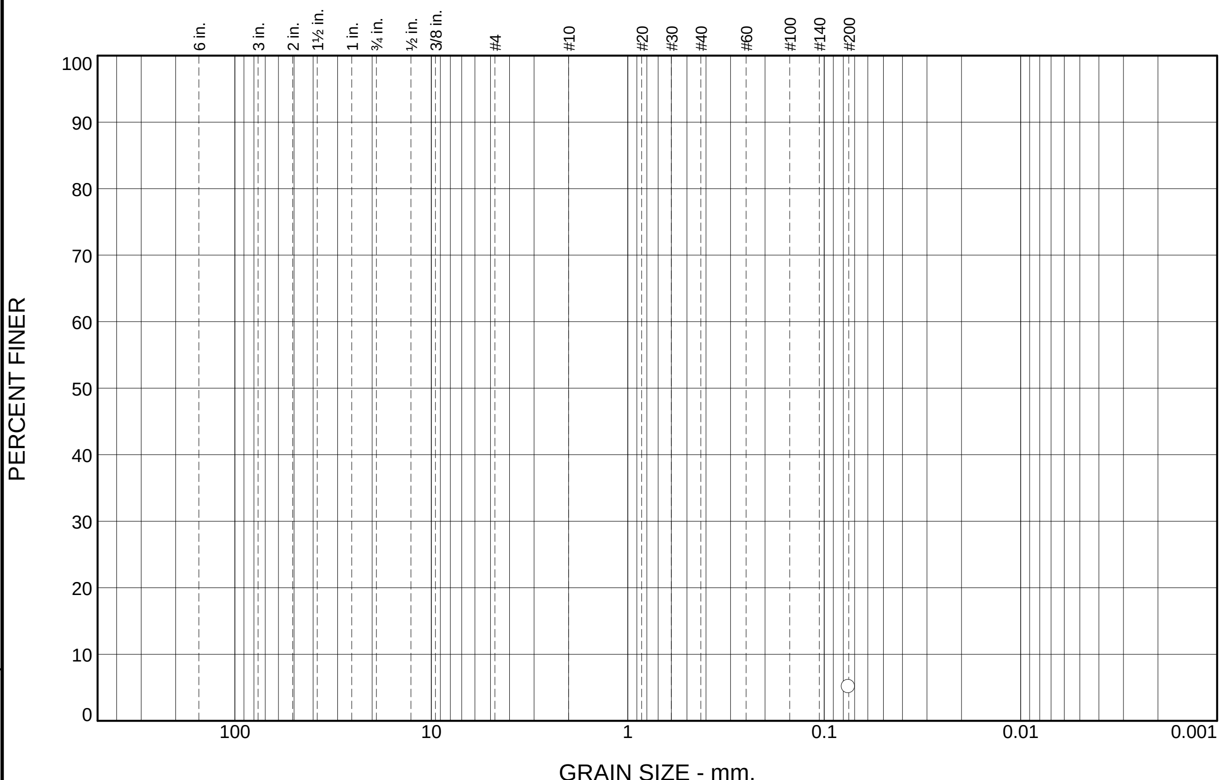
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
363.90	15.80	#200			14.2

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										14.2

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						5.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	5.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G023 S-9
Sample Number: 7992-44 **Depth:** 30'-31.5' **Date:** 10/5/2017

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: BH **Checked By:** JAM

GRAIN SIZE DISTRIBUTION TEST DATA

3/13/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G023 S-9
Depth: 30'-31.5'
Sample Number: 7992-44
Date: 10/5/2017
Tested by: BH
Checked by: JAM

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 325.30
Tare Wt. = 15.80
Minus #200 from wash = 5.1%

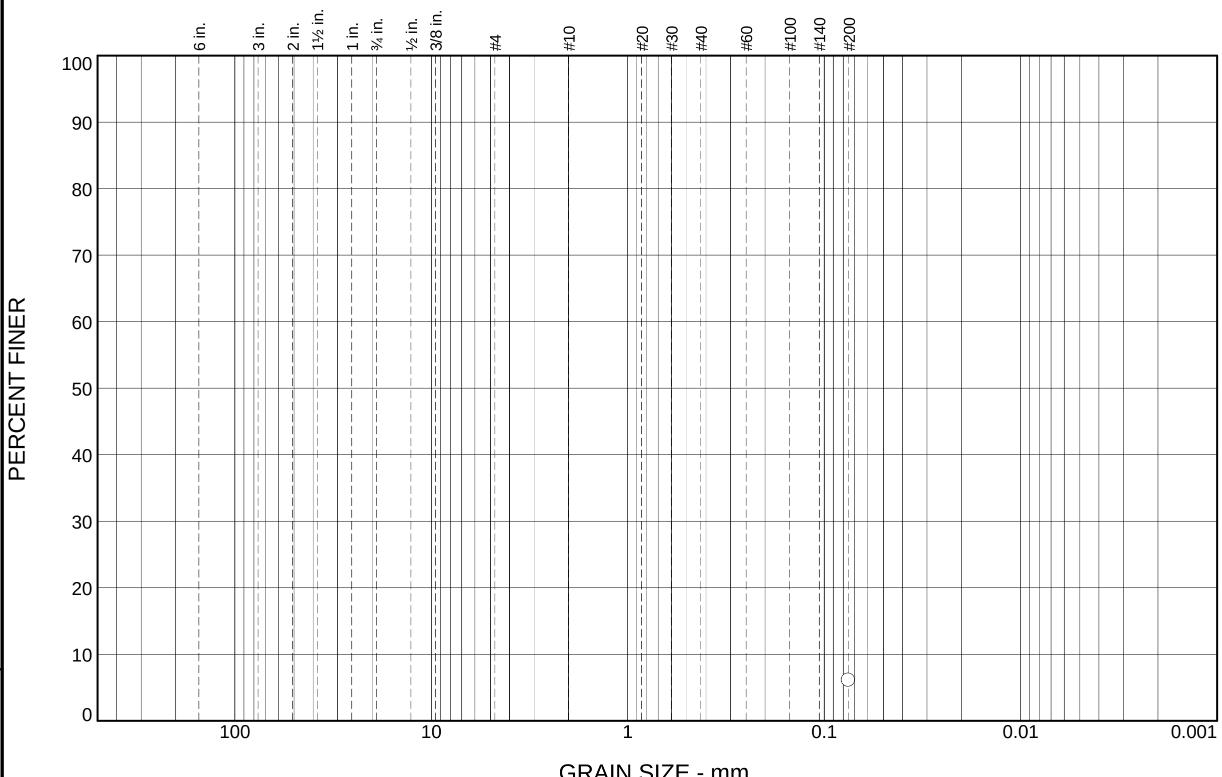
Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
341.90	15.80	#200			5.1

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
										5.1

D_{10}	D_{15}	D_{20}	D_{30}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
						6.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	6.1		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Location: G027 S-7
Sample Number: 7995-19 **Depth:** 20'-21.5' **Date:** 10/21/2017

Hayre McElroy & Associates, LLC

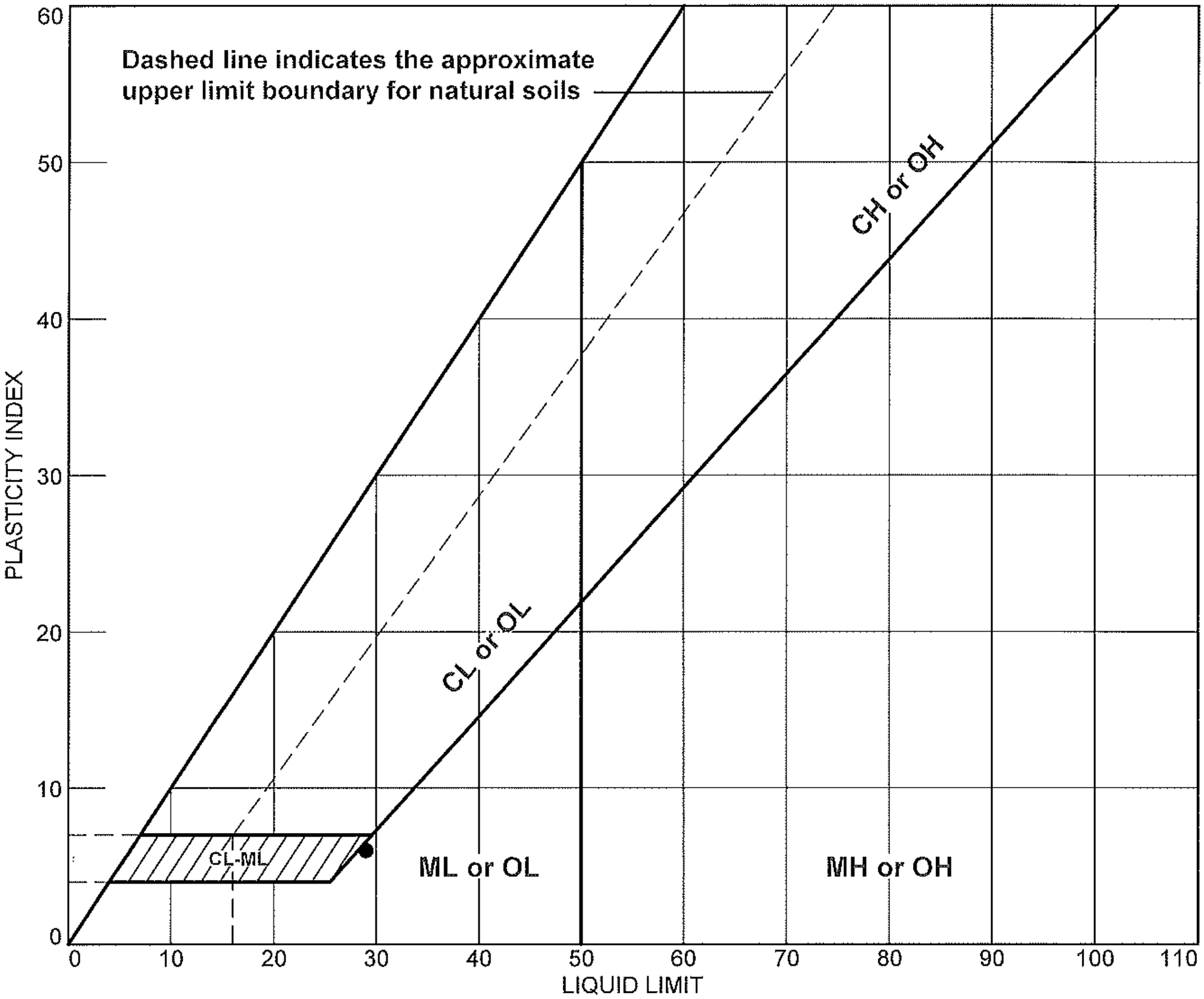
Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No: 1657705/17-940 **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Tested By: BH **Checked By:** JAM

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G7 / S5	054-32	12.5'	18.5	23	29	6	ML

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: GD **Checked By:** JAM

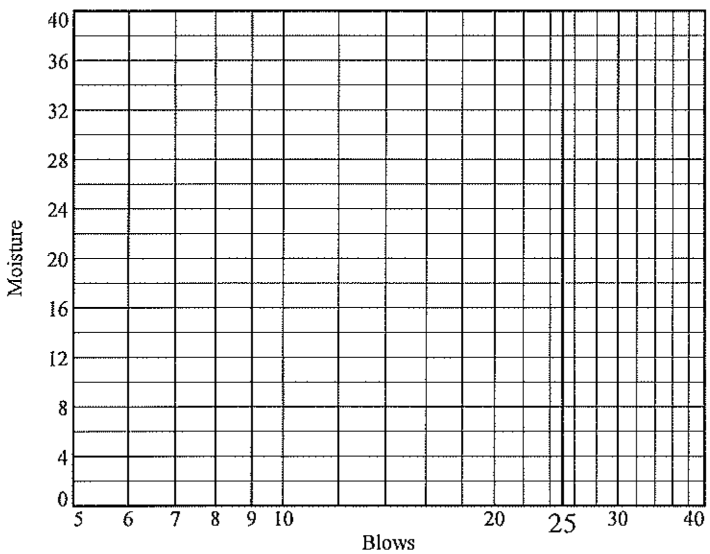
LIQUID AND PLASTIC LIMIT TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-2
Depth: 5'-6.5'
Sample Number: 8003-18
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 43.6

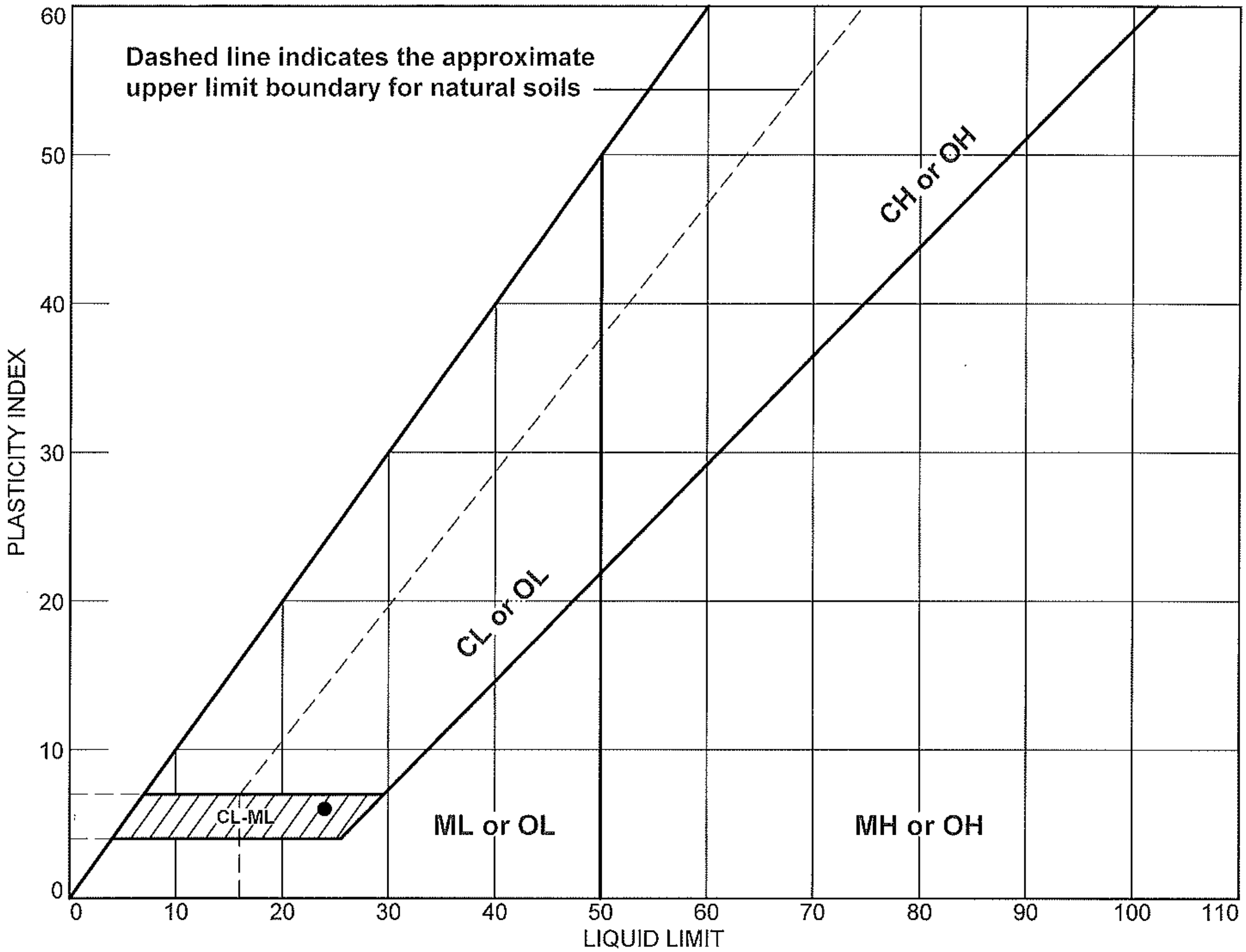
Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare				
Dry+Tare				
Tare				
Moisture				

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
374.3	265.4	15.9	43.6

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-20 90'-91.5'	8003-29	90'-91.5'	31.3	18	24	6	CL-ML

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

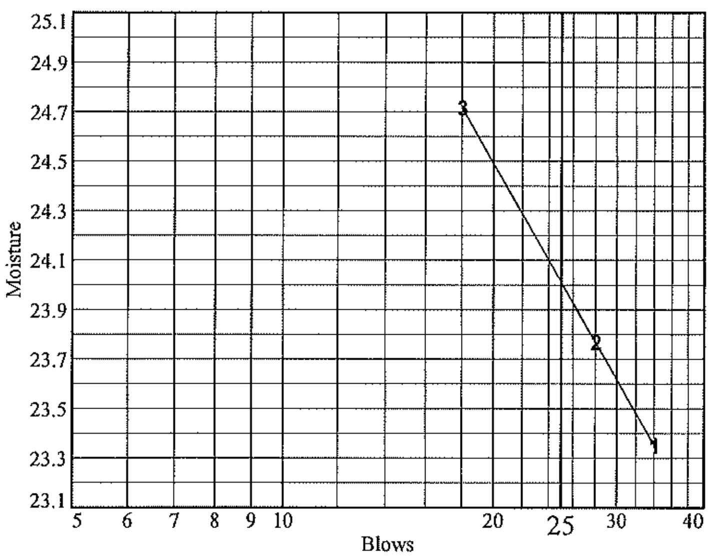
LIQUID AND PLASTIC LIMIT TEST DATA

11/16/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-20
Depth: 90'-91.5'
Sample Number: 8003-29
USCS: CL-ML
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	30.94	29.46	26.83			
Dry+Tare	27.68	26.42	24.21			
Tare	13.72	13.63	13.61			
# Blows	34	28	18			
Moisture	23.4	23.8	24.7			



Liquid Limit= 24
Plastic Limit= 18
Plasticity Index= 6
Natural Moisture= 31.3
Liquidity Index= 2.2

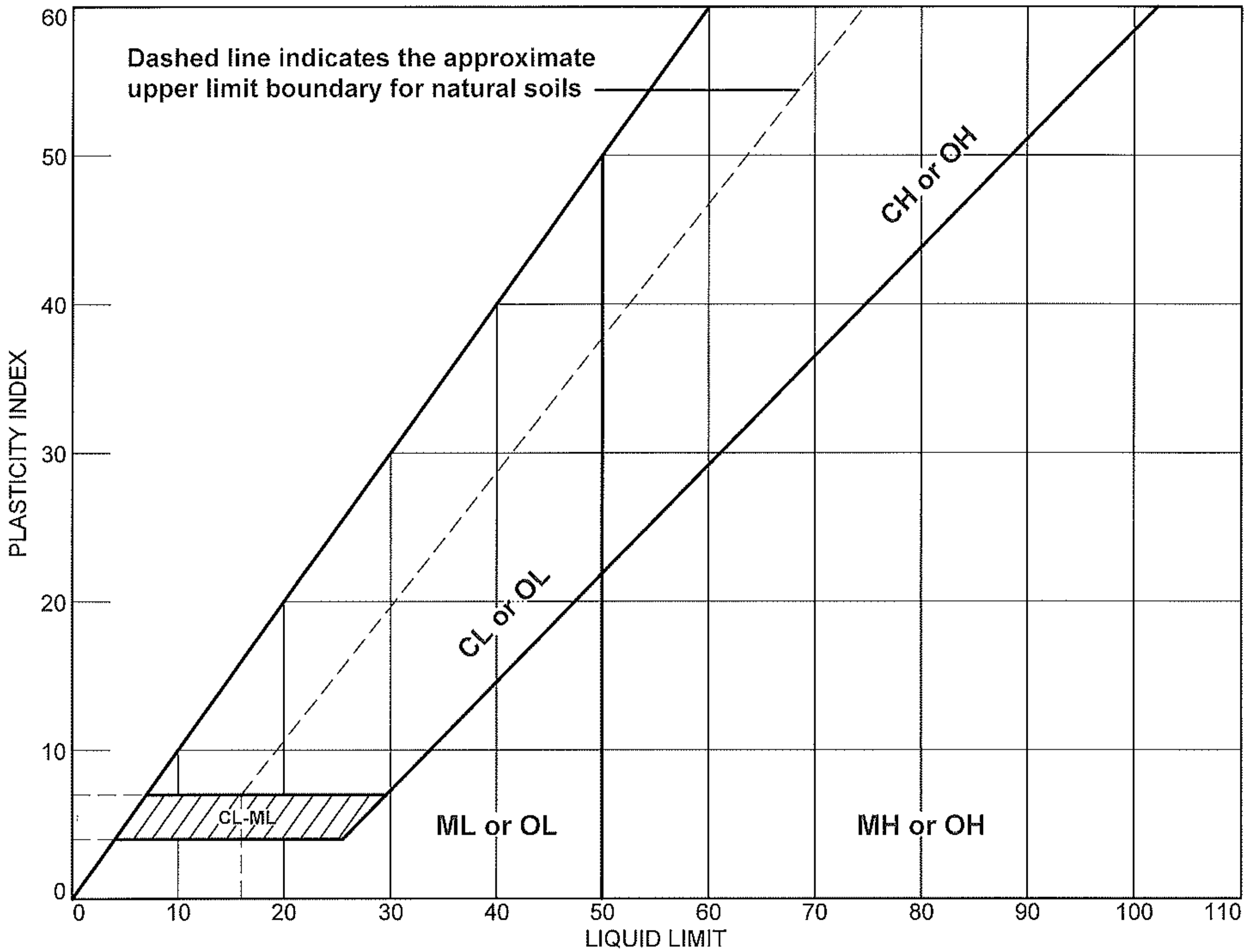
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.00	23.00	23.00		
Dry+Tare	21.59	21.59	21.59		
Tare	13.63	13.63	13.63		
Moisture	17.7	17.7	17.7		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
483.4	372.0	15.6	31.3

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-22 100'-101.5'	8003-31	100'-101.5'	28.3	NP	NV	NP	

Hayre McElroy & Associates, LLC Redmond, WA	Client: Golder Associates Project: ST-DRLE Project No.: 1657705/17-940 Figure

Tested By: BH Checked By: JAM

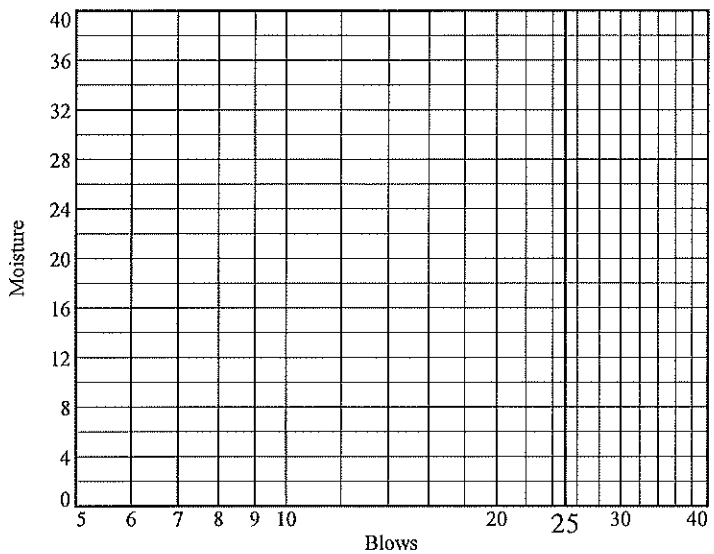
LIQUID AND PLASTIC LIMIT TEST DATA

11/14/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-22
Depth: 100'-101.5'
Sample Number: 8003-31
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 28.3

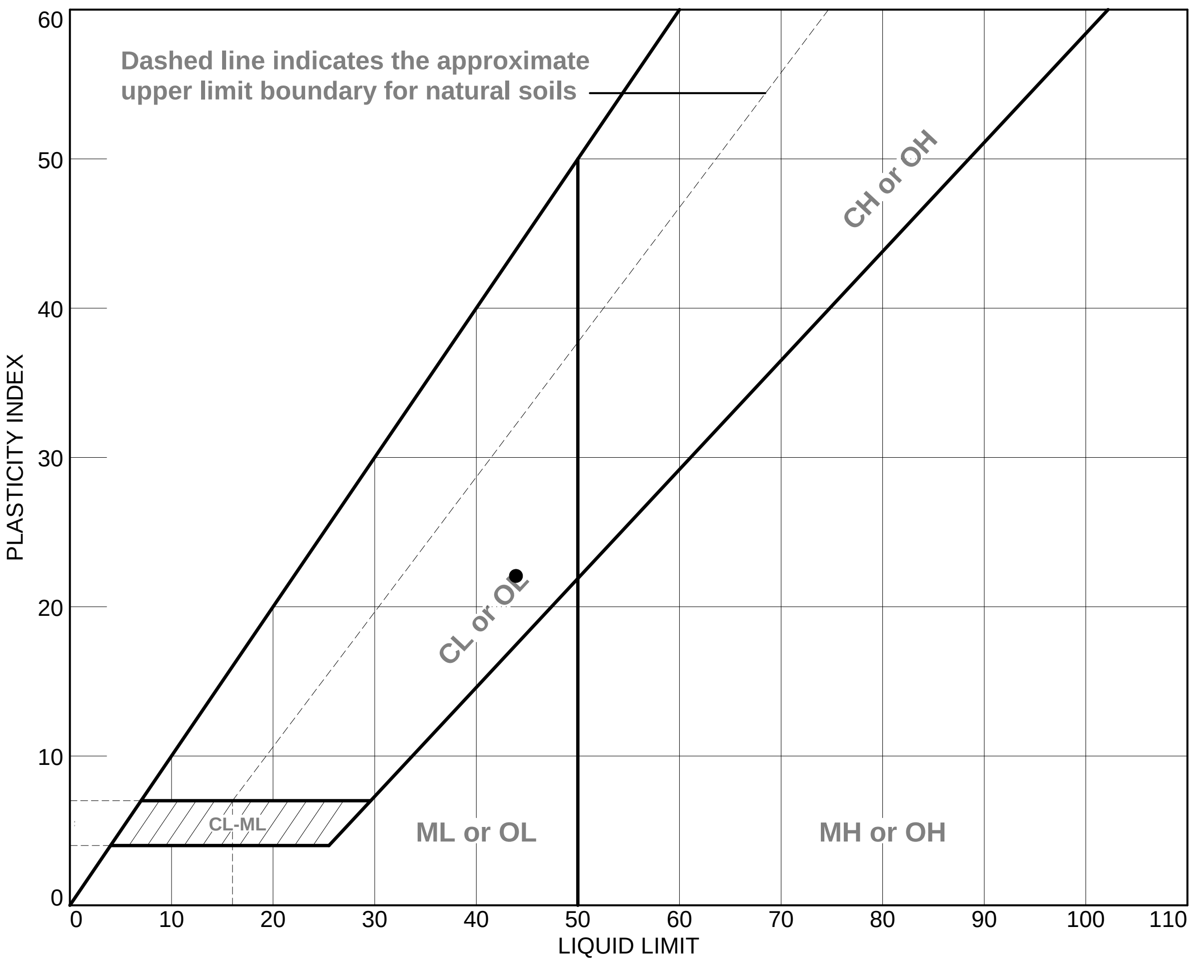
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
473.4	372.4	15.9	28.3

LIQUID AND PLASTIC LIMITS TEST REPORT



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SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-26 120'-121.5'	8003-34	120'-121.5'	35.8	22	44	22	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

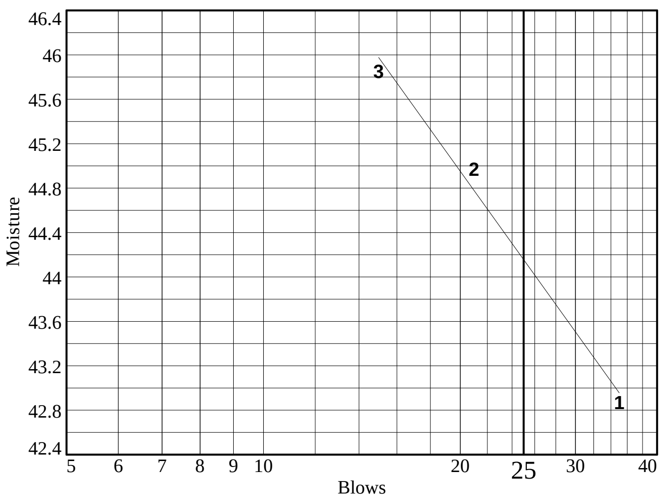
LIQUID AND PLASTIC LIMIT TEST DATA

3/14/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-26
Depth: 120'-121.5' **Sample Number:** 8003-34
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	21.14	23.32	24.06			
Dry+Tare	18.16	19.56	20.02			
Tare	11.21	11.20	11.21			
# Blows	35	21	15			
Moisture	42.9	45.0	45.9			

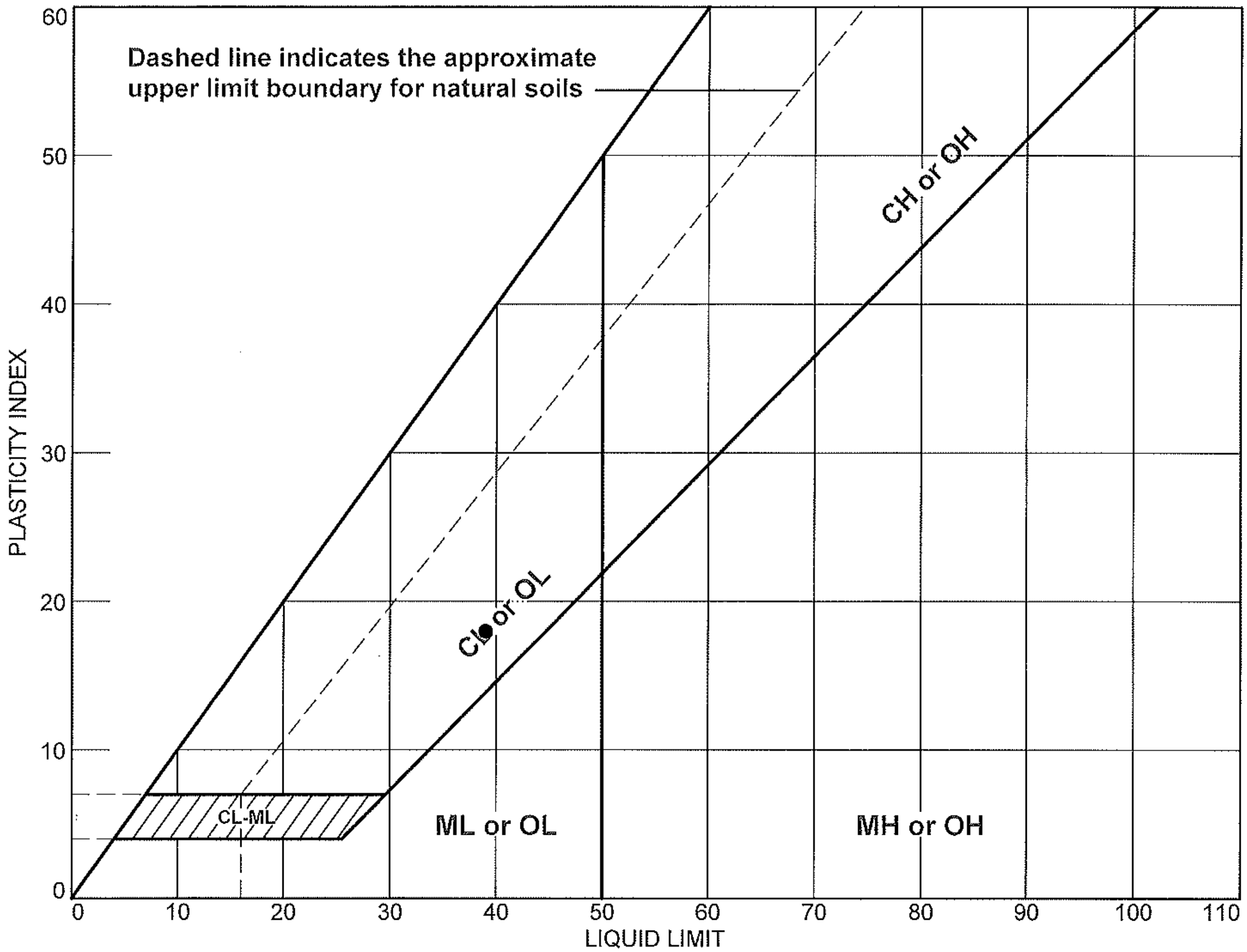


Liquid Limit= 44
Plastic Limit= 22
Plasticity Index= 22
Natural Moisture= 35.8
Liquidity Index= 0.6

Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	21.25				
Dry+Tare	19.45				
Tare	11.18				
Moisture	21.8				

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-28 130'-131.5'	8000-36	130'-131.5'	34.1	21	39	18	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

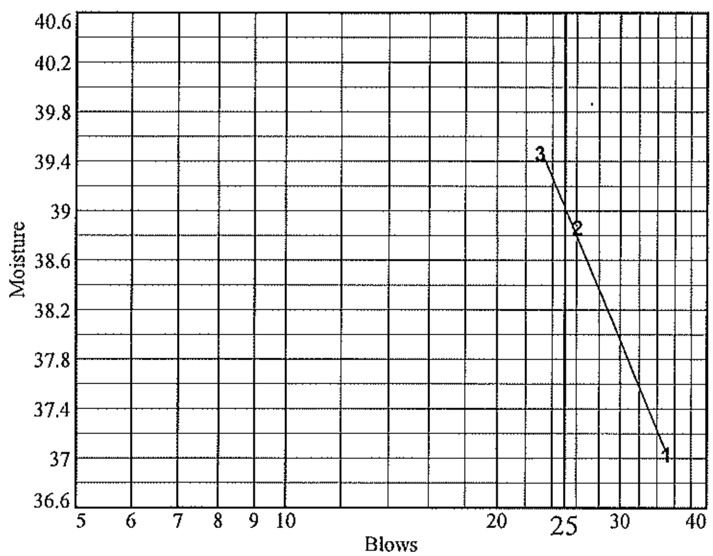
LIQUID AND PLASTIC LIMIT TEST DATA

11/15/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-28
Depth: 130'-131.5' **Sample Number:** 8000-36
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	23.55	29.06	27.36			
Dry+Tare	20.88	24.75	23.52			
Tare	13.67	13.66	13.79			
# Blows	35	26	23			
Moisture	37.0	38.9	39.5			



Liquid Limit= 39
Plastic Limit= 21
Plasticity Index= 18
Natural Moisture= 34.1
Liquidity Index= 0.7

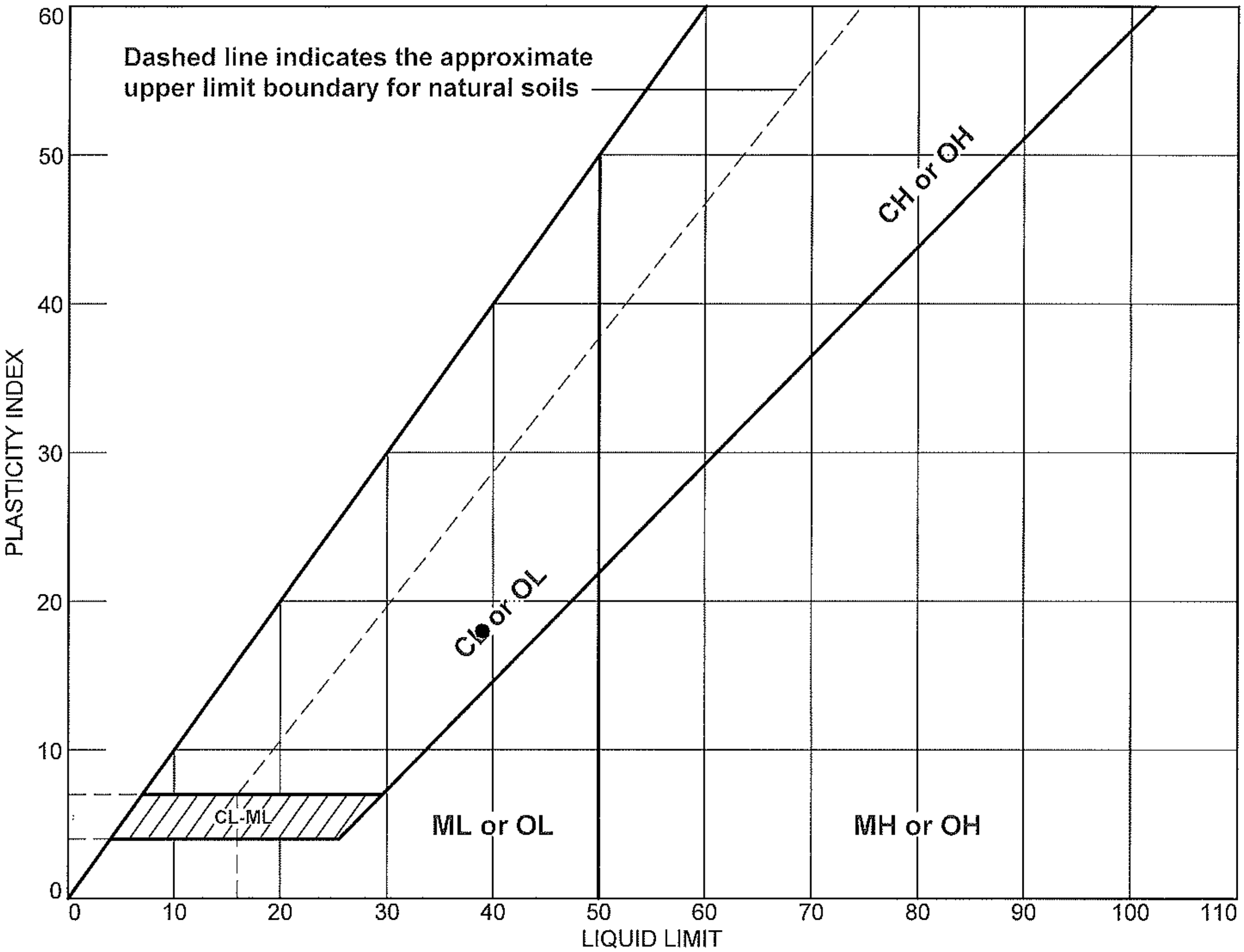
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.06	22.06	22.06		
Dry+Tare	20.59	20.59	20.59		
Tare	13.59	13.59	13.59		
Moisture	21.0	21.0	21.0		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
621.5	512.8	194.1	34.1

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-33 160'-161.5'	8003-39	160'-161.5'	38.0	21	39	18	CL

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

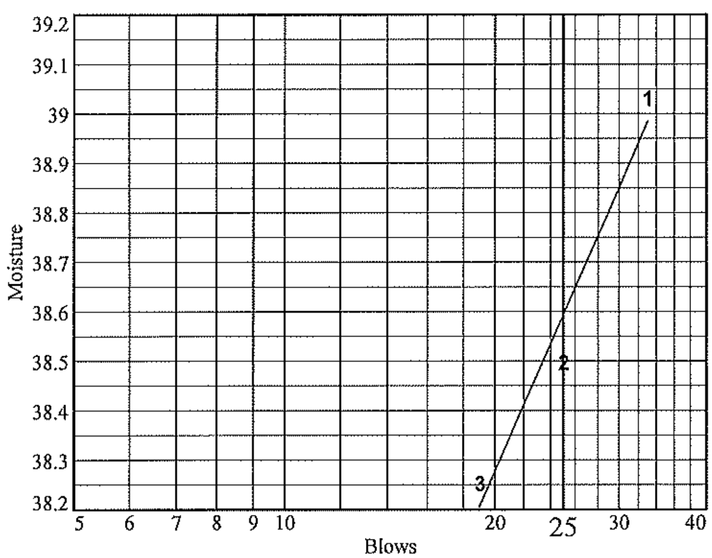
LIQUID AND PLASTIC LIMIT TEST DATA

11/15/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-33
Depth: 160'-161.5' **Sample Number:** 8003-39
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	27.27	28.44	27.27			
Dry+Tare	23.48	24.34	23.59			
Tare	13.77	13.69	13.97			
# Blows	33	25	19			
Moisture	39.0	38.5	38.3			



Liquid Limit= 39
Plastic Limit= 21
Plasticity Index= 18
Natural Moisture= 38.0
Liquidity Index= 0.9

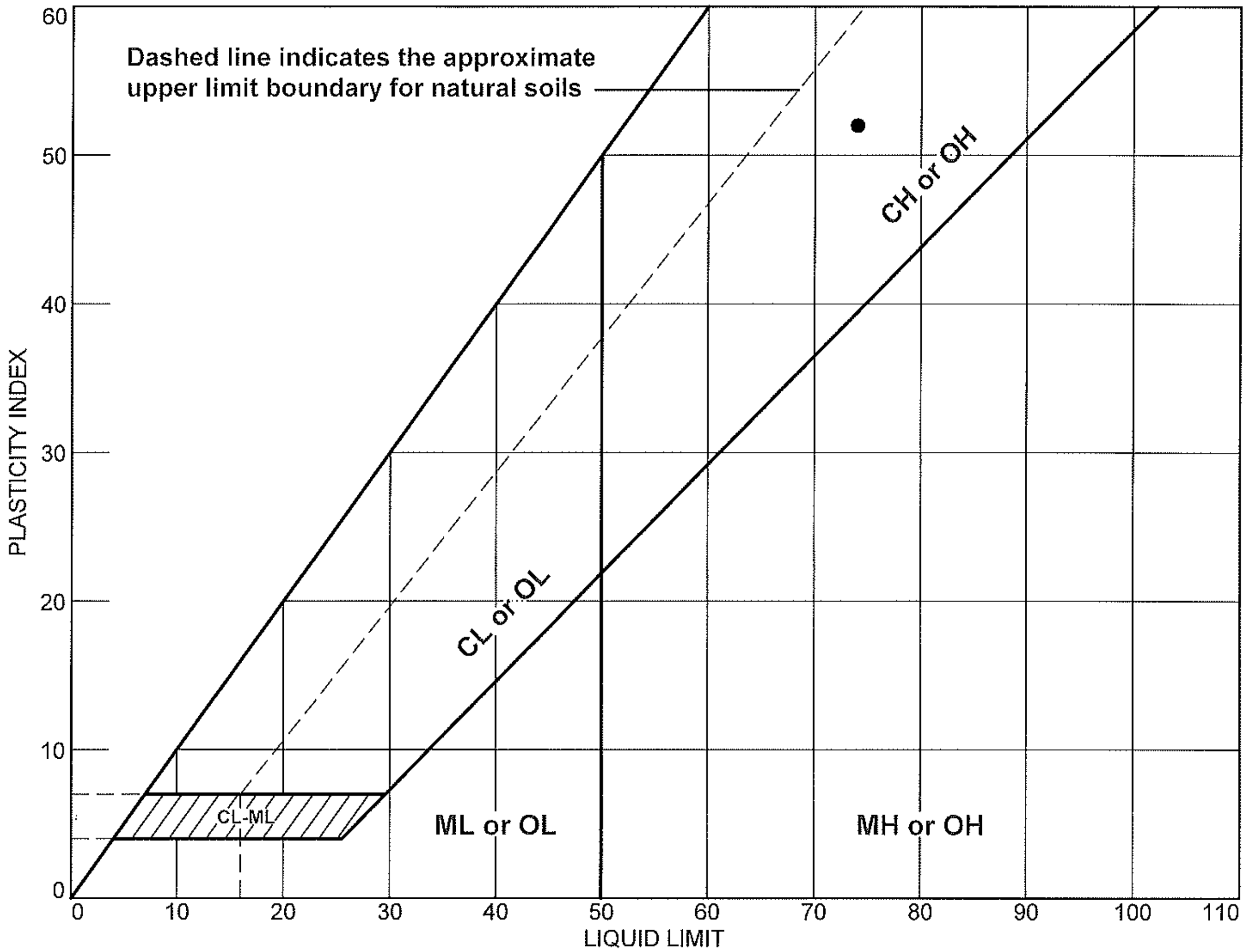
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.08	22.08	22.08		
Dry+Tare	20.65	20.65	20.65		
Tare	13.70	13.70	13.70		
Moisture	20.6	20.6	20.6		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
624.2	515.9	231.2	38.0

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-35 175'-176.5'	8003-41	175'-176.5'	36.3	22	74	52	CH

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

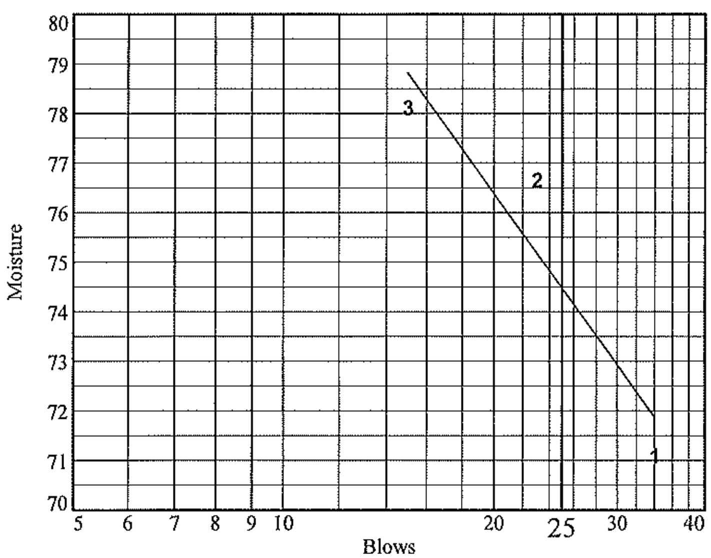
Tested By: BH **Checked By:** JAM

LIQUID AND PLASTIC LIMIT TEST DATA 11/16/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-35
Depth: 175'-176.5' **Sample Number:** 8003-41
USCS: CH
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	27.49	27.23	28.51			
Dry+Tare	20.70	20.30	20.94			
Tare	11.15	11.26	11.25			
# Blows	34	23	15			
Moisture	71.1	76.7	78.1			



Liquid Limit= 74
Plastic Limit= 22
Plasticity Index= 52
Natural Moisture= 36.3
Liquidity Index= 0.3

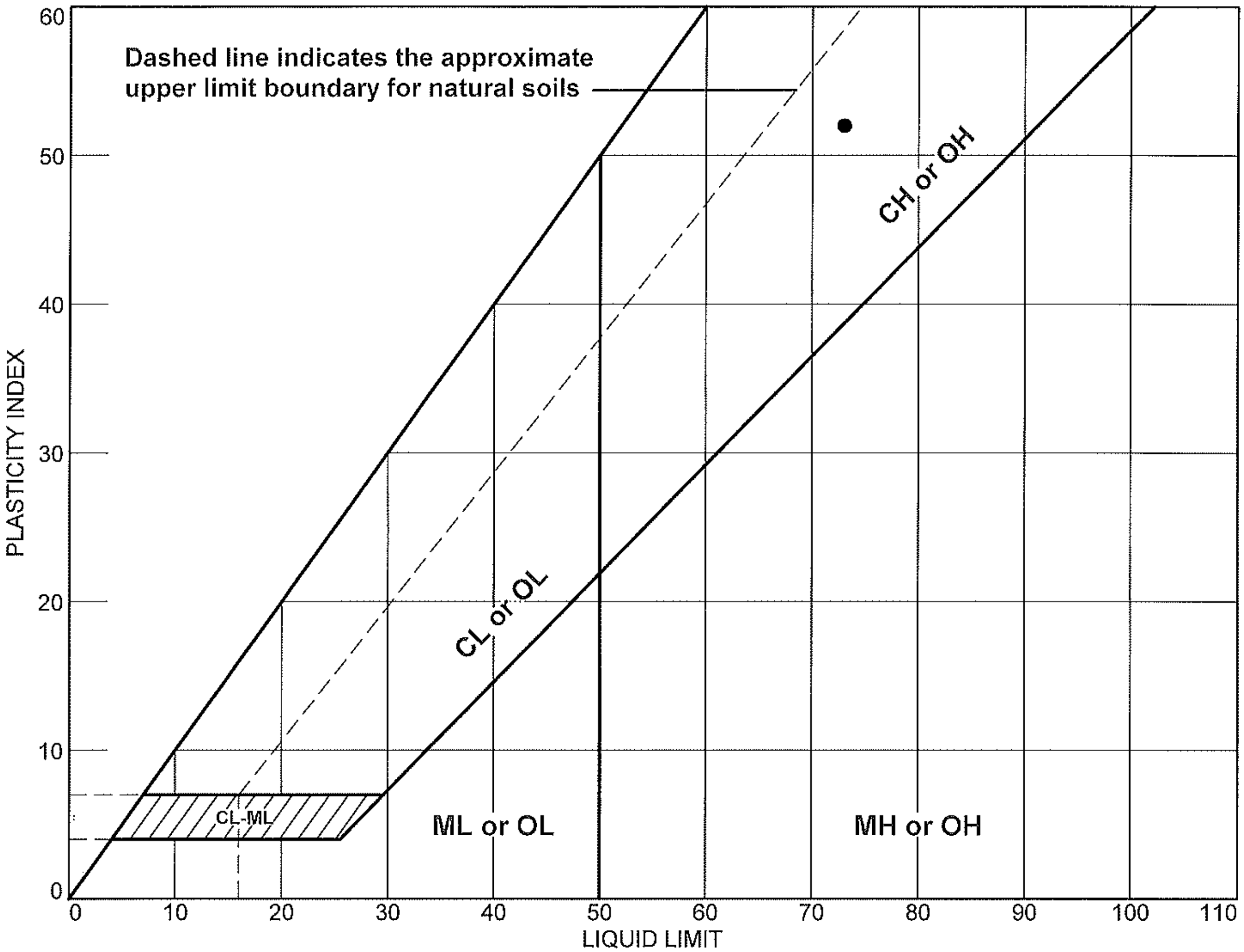
Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	21.12	21.12	21.12	
Dry+Tare	19.76	19.76	19.76	
Tare	13.71	13.71	13.71	
Moisture	22.5	22.5	22.5	

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
666.2	532.0	161.9	36.3

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G018 S-38 190'-191.5'	8003-43	190'-191.5'	30.4	21	73	52	CH

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates

Project: ST-DRLE

Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

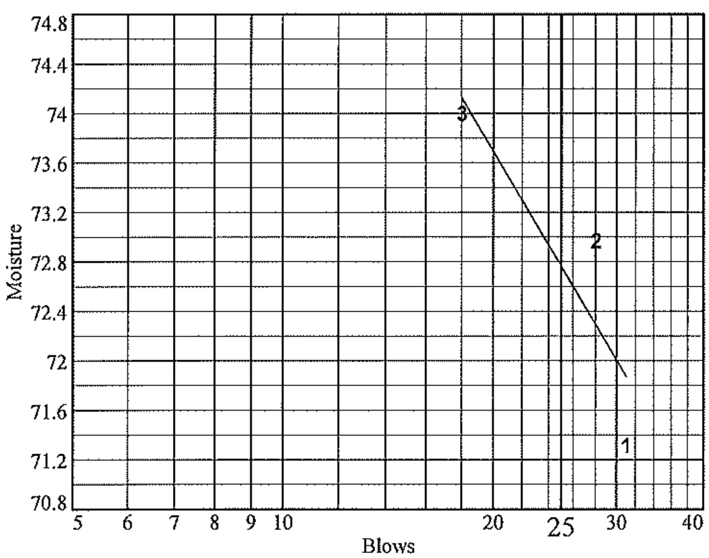
LIQUID AND PLASTIC LIMIT TEST DATA

11/16/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G018 S-38
Depth: 190'-191.5' **Sample Number:** 8003-43
USCS: CH
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	26.80	27.27	32.55			
Dry+Tare	20.31	20.52	23.47			
Tare	11.21	11.27	11.20			
# Blows	31	28	18			
Moisture	71.3	73.0	74.0			



Liquid Limit= 73
Plastic Limit= 21
Plasticity Index= 52
Natural Moisture= 30.4
Liquidity Index= 0.2

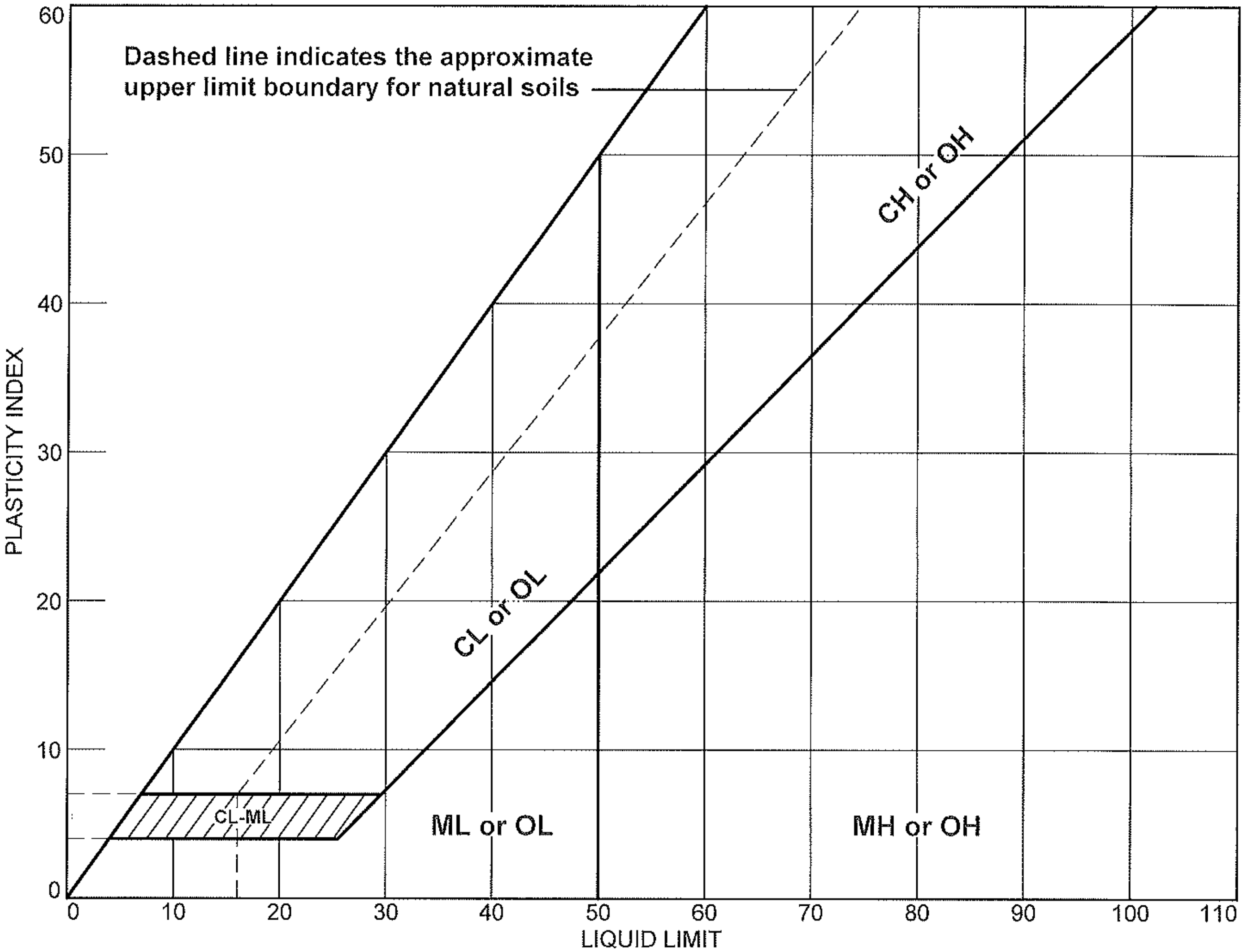
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	21.48	21.48	21.48		
Dry+Tare	20.13	20.13	20.13		
Tare	13.67	13.67	13.67		
Moisture	20.9	20.9	20.9		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
612.2	507.9	164.9	30.4

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G019 S-19a 75'-76.5'	7980-I	75'-76.5'	31.3	NP	NV	NP	

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

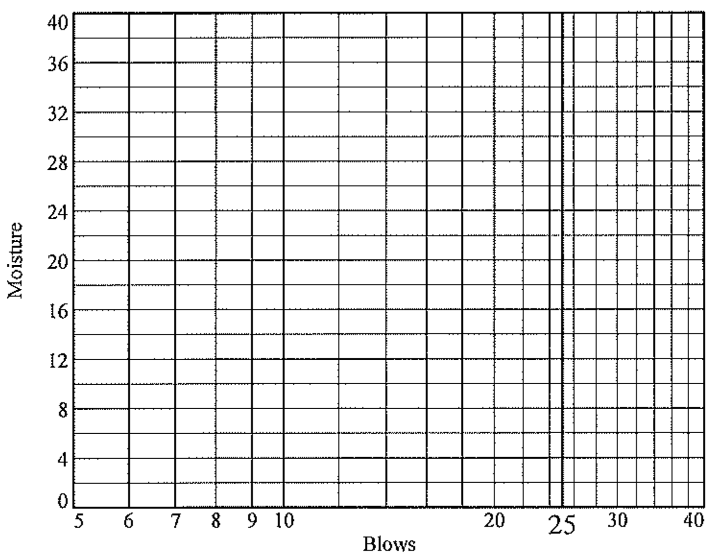
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-19a
Depth: 75'-76.5'
Sample Number: 7980-1
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 31.3

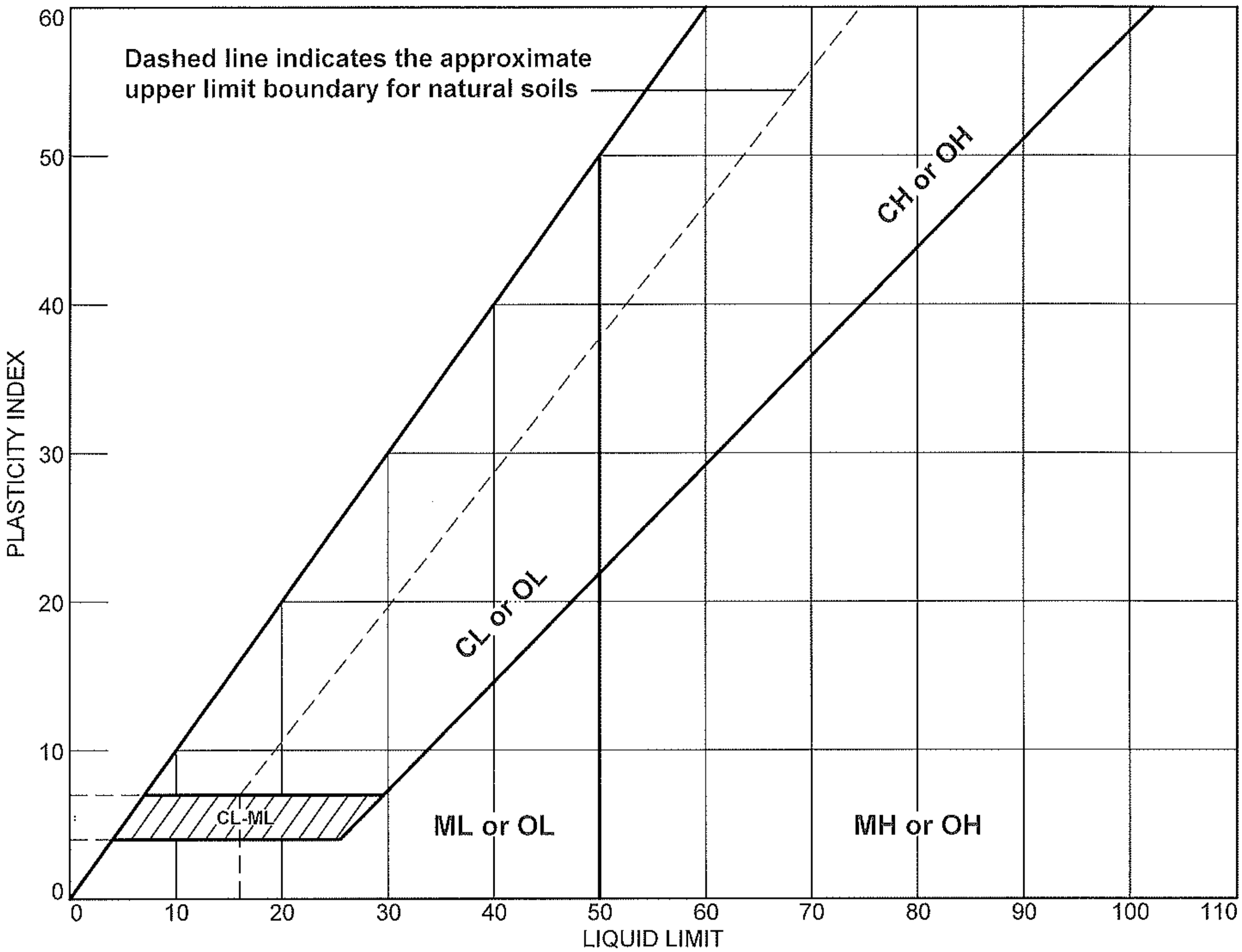
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
356.6	275.5	16.4	31.3

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G019 S-19b 75'-76'	7980-2	75'-76.5	31.1	NP	NV	NP	

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

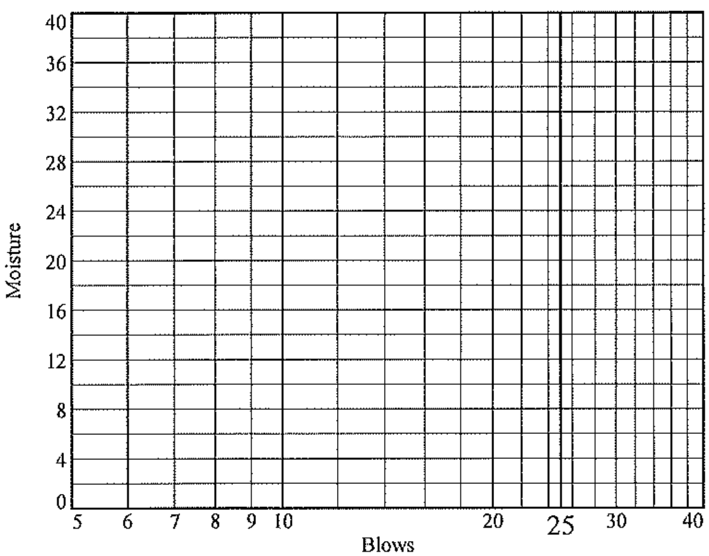
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-19b
Depth: 75'-76.5
Sample Number: 7980-2
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 31.1

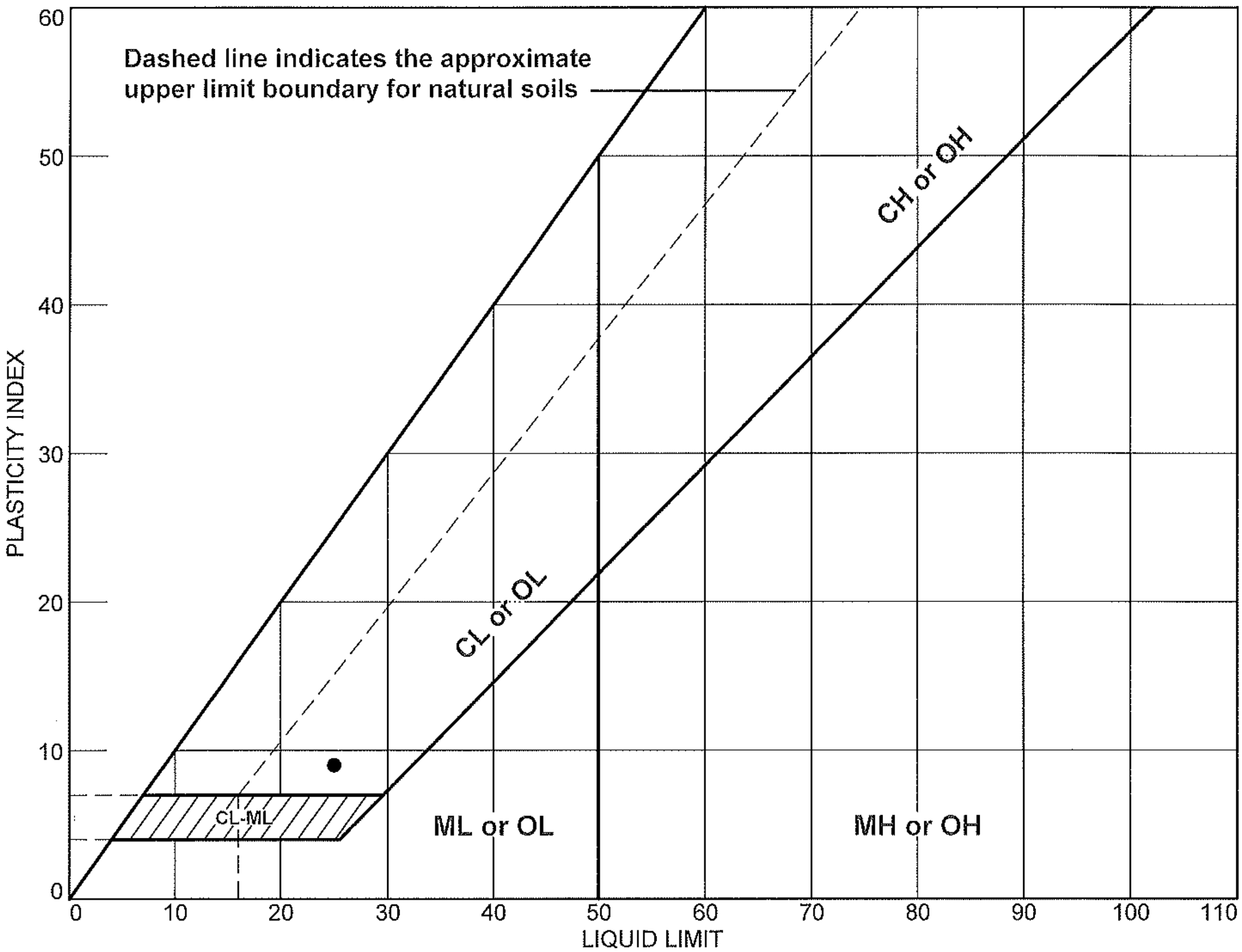
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
371.9	287.5	16.2	31.1

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G019 S-21 85'-86.5'	7980-3	85'-86.5'	34.6	16	25	9	CL

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

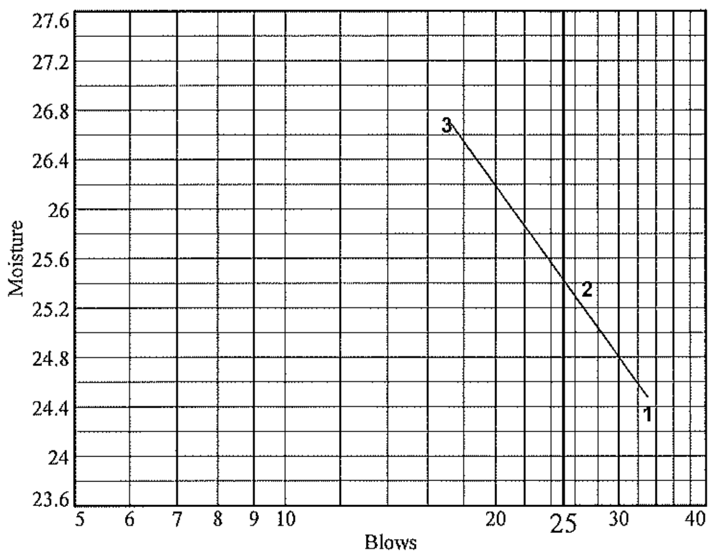
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-21
Depth: 85'-86.5'
Sample Number: 7980-3
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	32.18	29.60	28.44			
Dry+Tare	28.55	26.38	25.31			
Tare	13.64	13.68	13.58			
# Blows	33	27	17			
Moisture	24.3	25.4	26.7			



Liquid Limit= 25
Plastic Limit= 16
Plasticity Index= 9
Natural Moisture= 34.6
Liquidity Index= 2.1

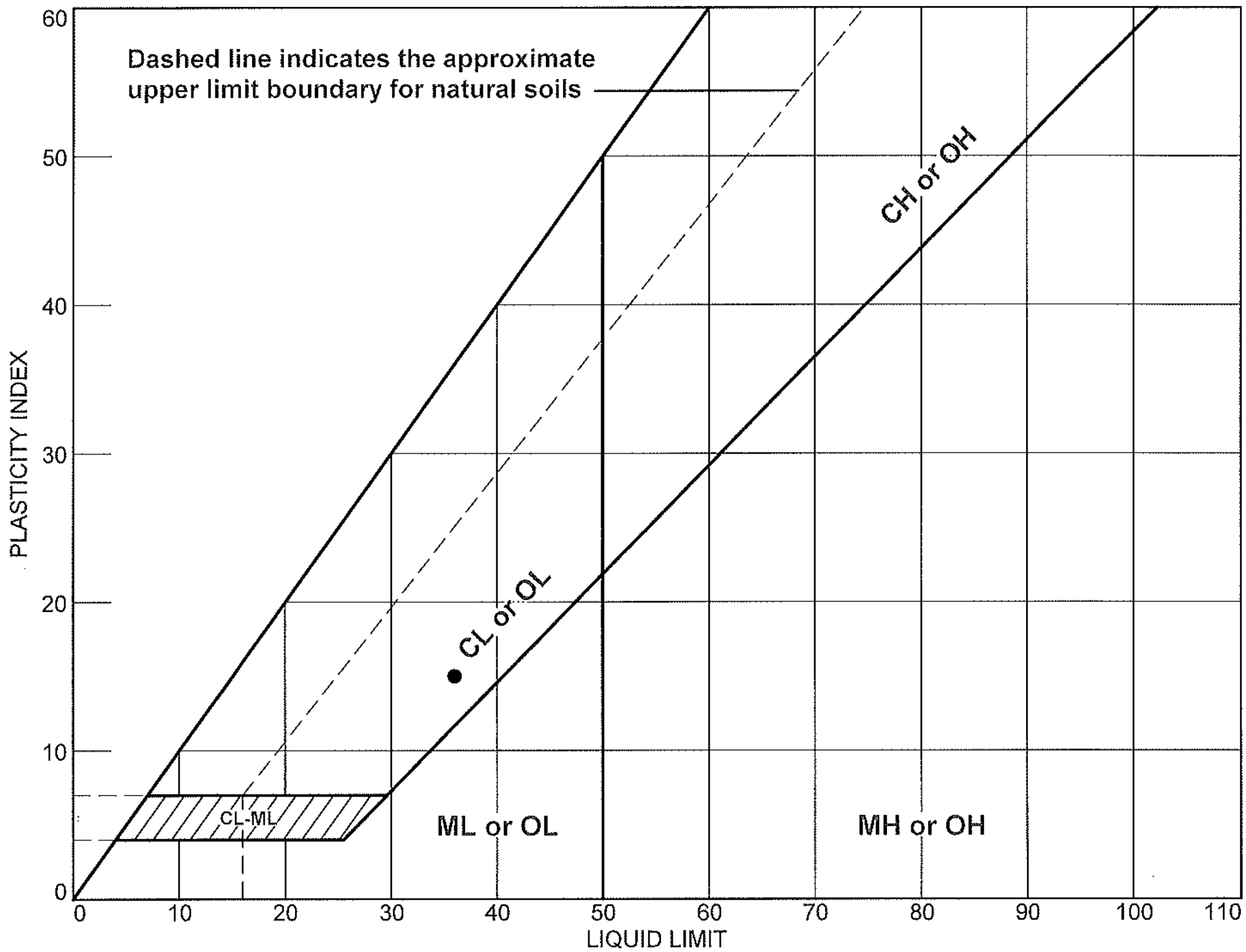
Plastic Limit Data

Run No.	1	2	3	4
Wet+Tare	23.55	23.55	23.55	
Dry+Tare	22.14	22.14	22.14	
Tare	13.54	13.54	13.54	
Moisture	16.4	16.4	16.4	

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
445.9	335.6	16.6	34.6

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G019 S-23 95'-96.5'	7980-4	95'-96.5'	37.8	21	36	15	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

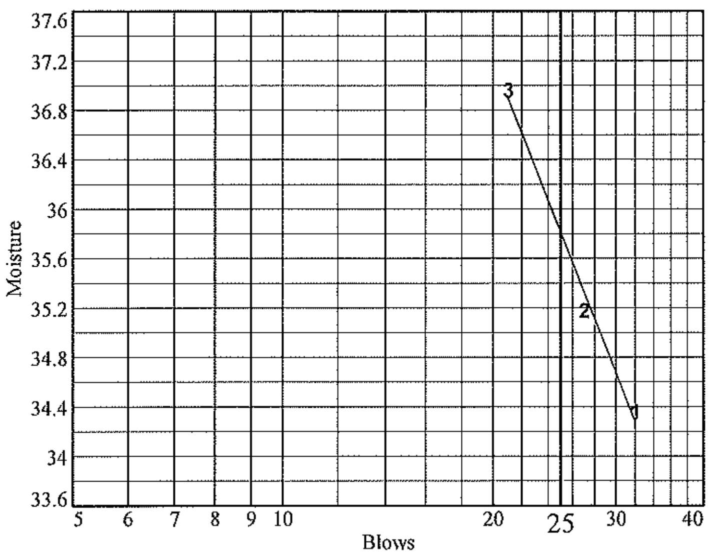
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-23
Depth: 95'-96.5' **Sample Number:** 7980-4
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	28.06	27.76	29.98			
Dry+Tare	24.39	24.08	25.57			
Tare	13.71	13.62	13.64			
# Blows	32	27	21			
Moisture	34.4	35.2	37.0			



Liquid Limit= 36
Plastic Limit= 21
Plasticity Index= 15
Natural Moisture= 37.8
Liquidity Index= 1.1

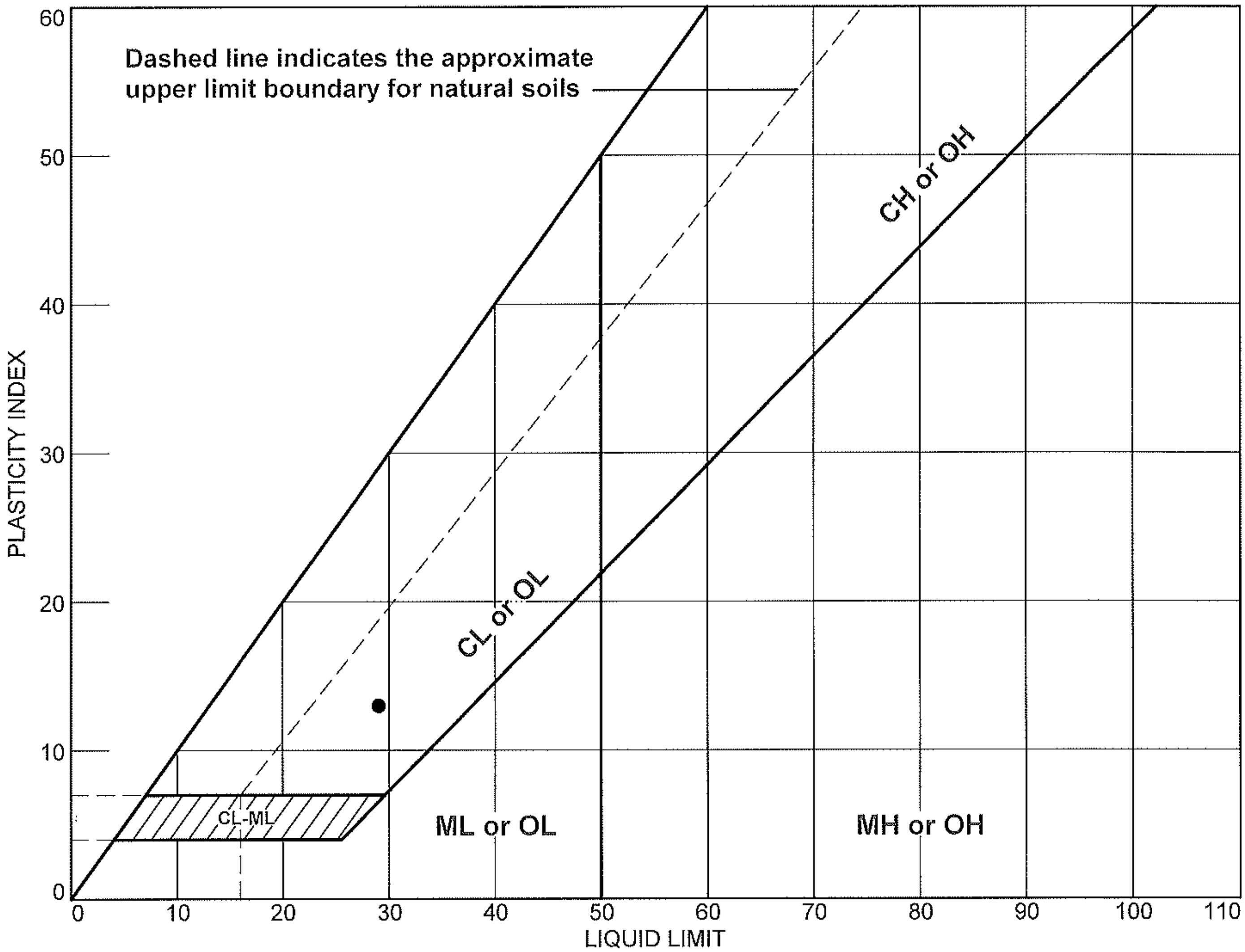
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.80	22.80	22.80		
Dry+Tare	21.22	21.22	21.22		
Tare	13.62	13.62	13.62		
Moisture	20.8	20.8	20.8		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
470.9	346.2	16.0	37.8

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G-019 S-25 105'-106.5'	7980-5	105'-106.5'	32.6	16	29	13	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

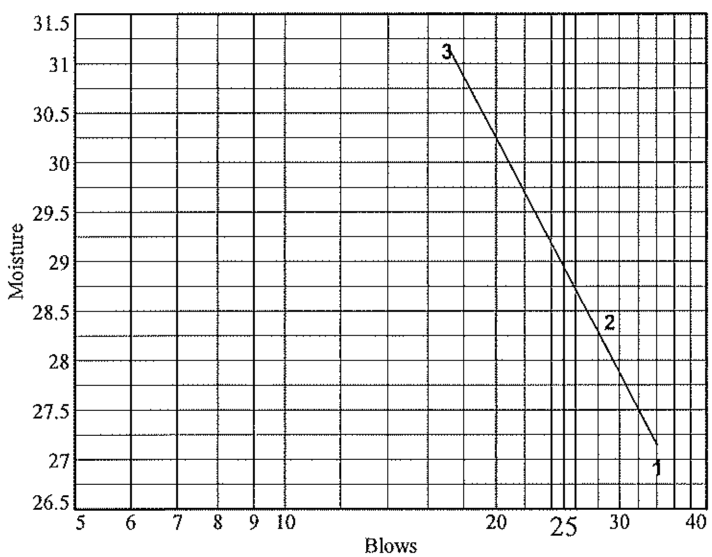
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-25
Depth: 105'-106.5'
Sample Number: 7980-5
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	33.23	31.79	28.79			
Dry+Tare	29.05	27.77	25.22			
Tare	13.52	13.61	13.75			
# Blows	34	29	17			
Moisture	26.9	28.4	31.1			



Liquid Limit= 29
Plastic Limit= 16
Plasticity Index= 13
Natural Moisture= 32.6
Liquidity Index= 1.3

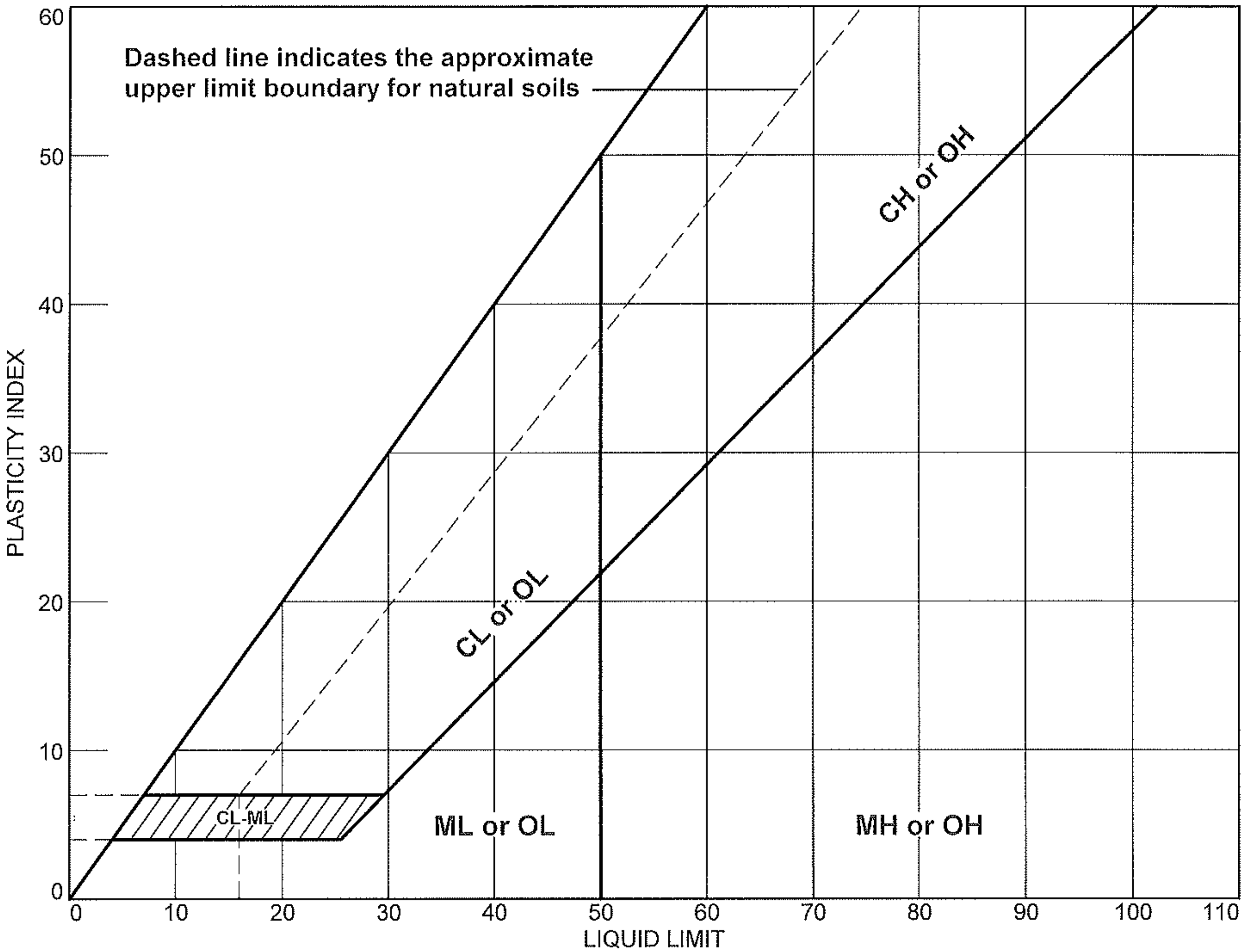
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.78	22.78	22.78		
Dry+Tare	21.50	21.50	21.50		
Tare	13.69	13.69	13.69		
Moisture	16.4	16.4	16.4		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
421.1	321.6	16.1	32.6

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G019 S-27 115'-116.5'	7980-6	115'-116.5'	25.7	NP	NV	NP	

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

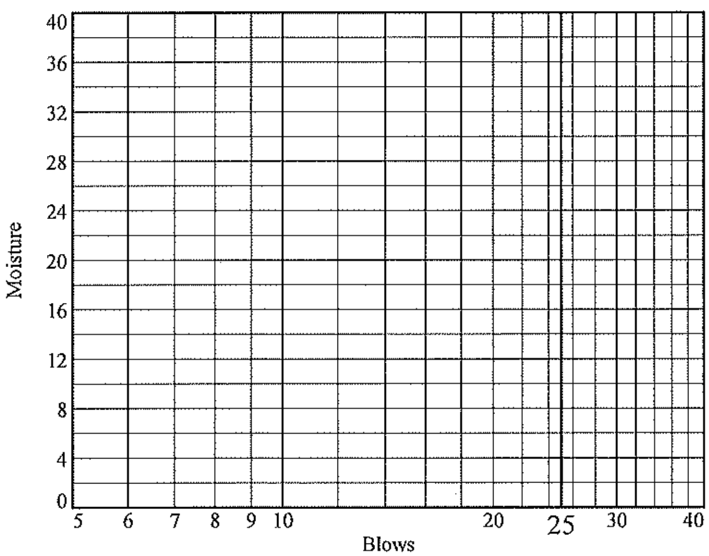
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-27
Depth: 115'-116.5'
Sample Number: 7980-6
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 25.7

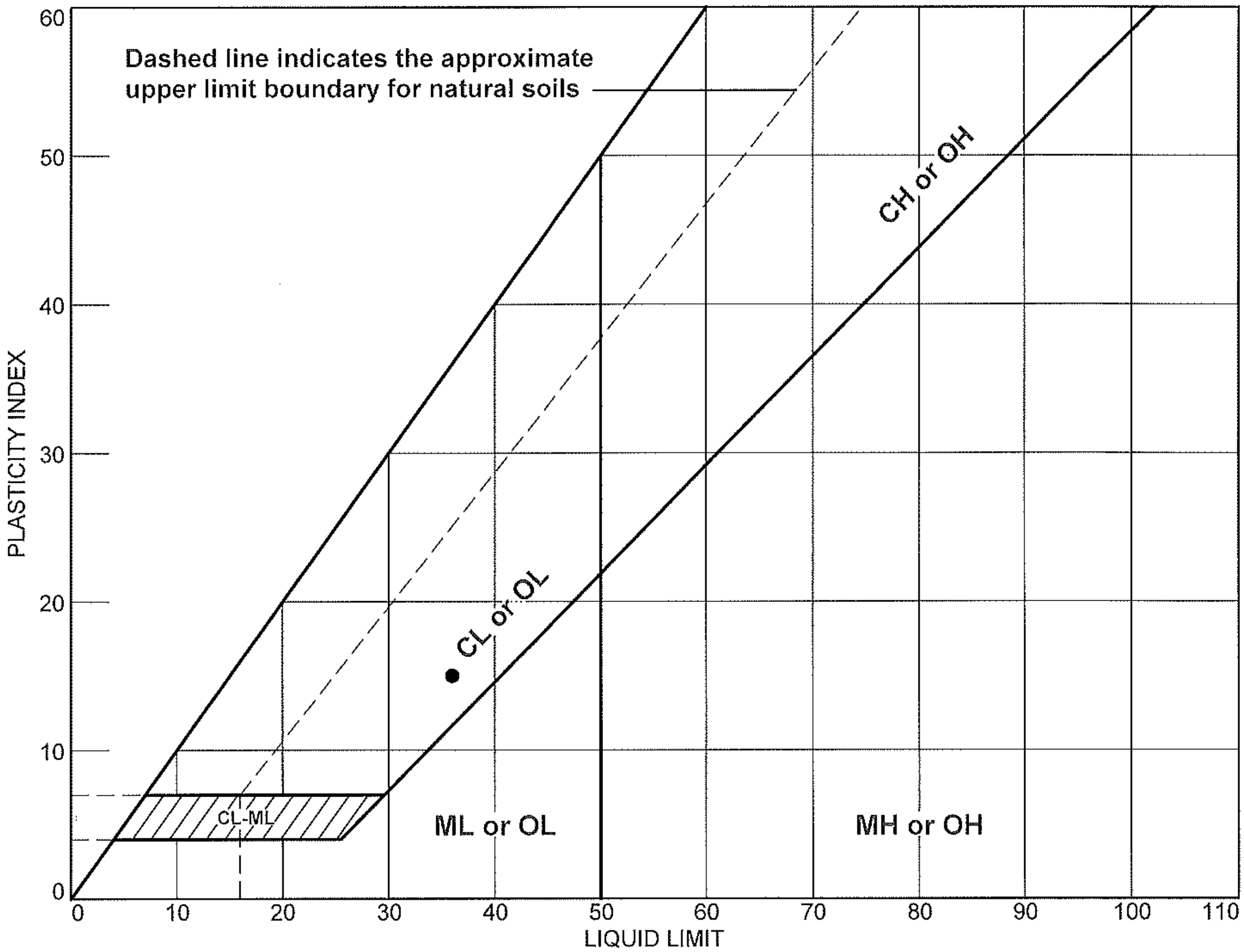
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
461.2	370.3	16.0	25.7

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G019 S-29 125'-126.5'	7980-7	125'-126.5'	31.7	21	36	15	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

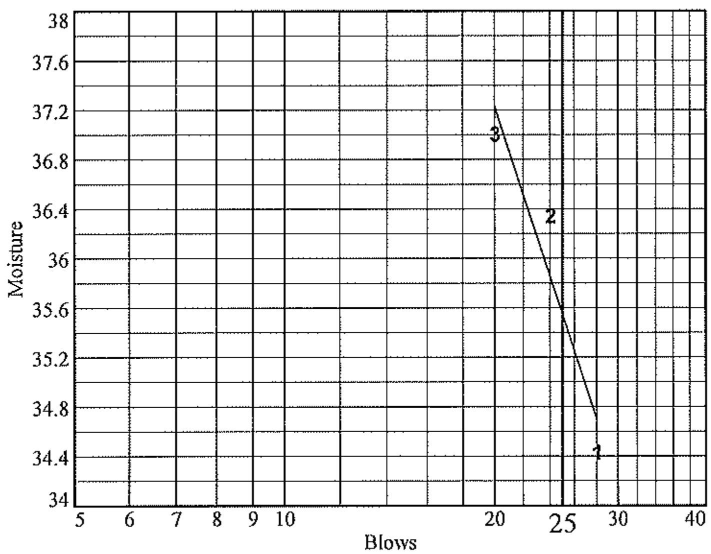
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G019 S-29
Depth: 125'-126.5'
Sample Number: 7980-7
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	32.39	28.94	25.89			
Dry+Tare	27.59	24.88	22.60			
Tare	13.65	13.71	13.71			
# Blows	28	24	20			
Moisture	34.4	36.3	37.0			



Liquid Limit= 36
Plastic Limit= 21
Plasticity Index= 15
Natural Moisture= 31.7
Liquidity Index= 0.7

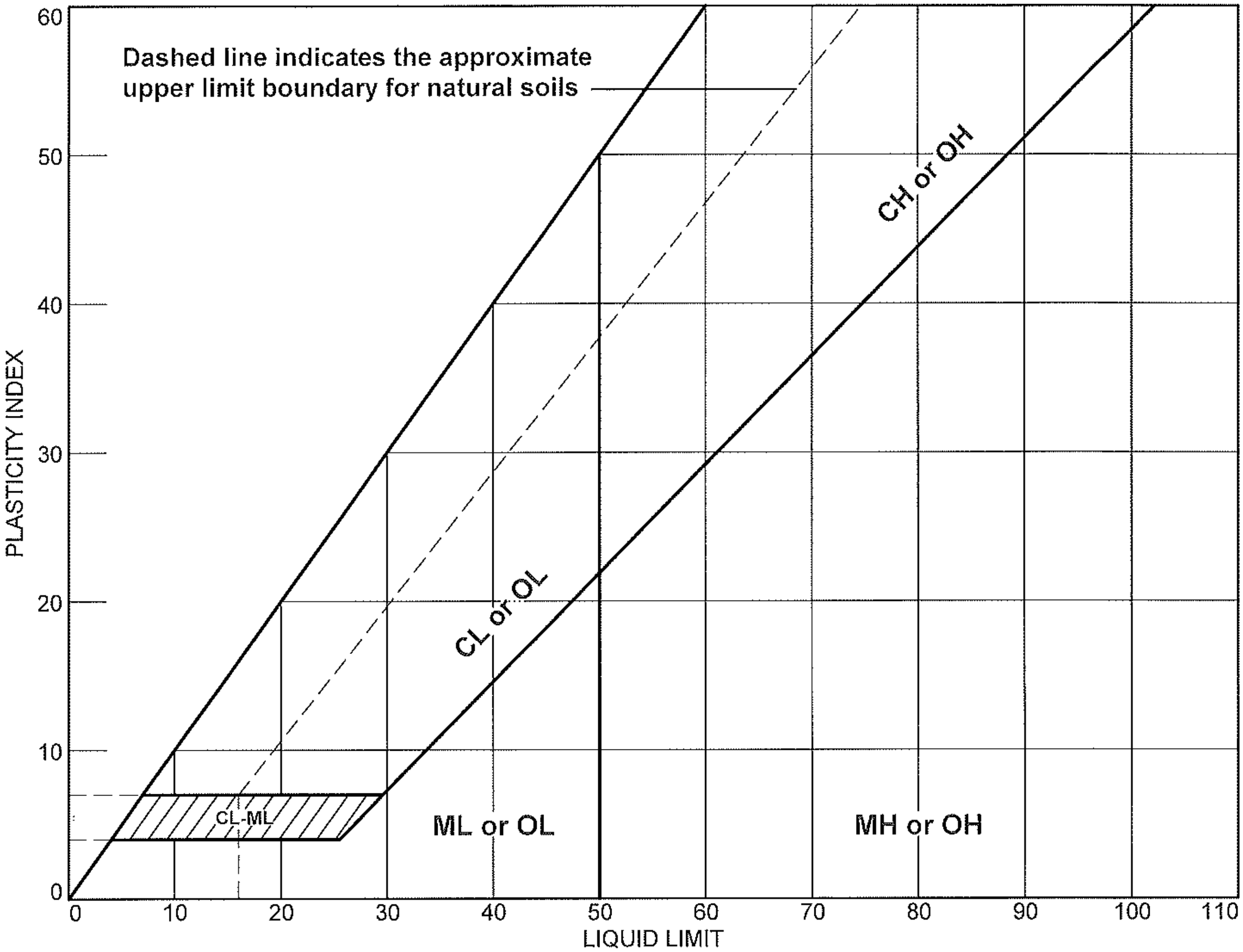
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.30	23.30	23.30		
Dry+Tare	21.62	21.62	21.62		
Tare	13.63	13.63	13.63		
Moisture	21.0	21.0	21.0		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
480.6	368.6	15.8	31.7

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-20 80'-81.5'	7980-8	80'-81.5'	30.4	NP	NV	NP	

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

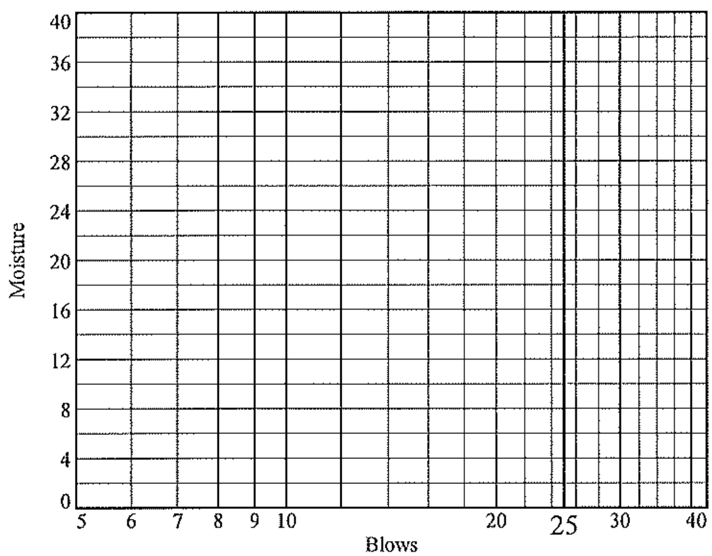
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-20
Depth: 80'-81.5'
Sample Number: 7980-8
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 30.4

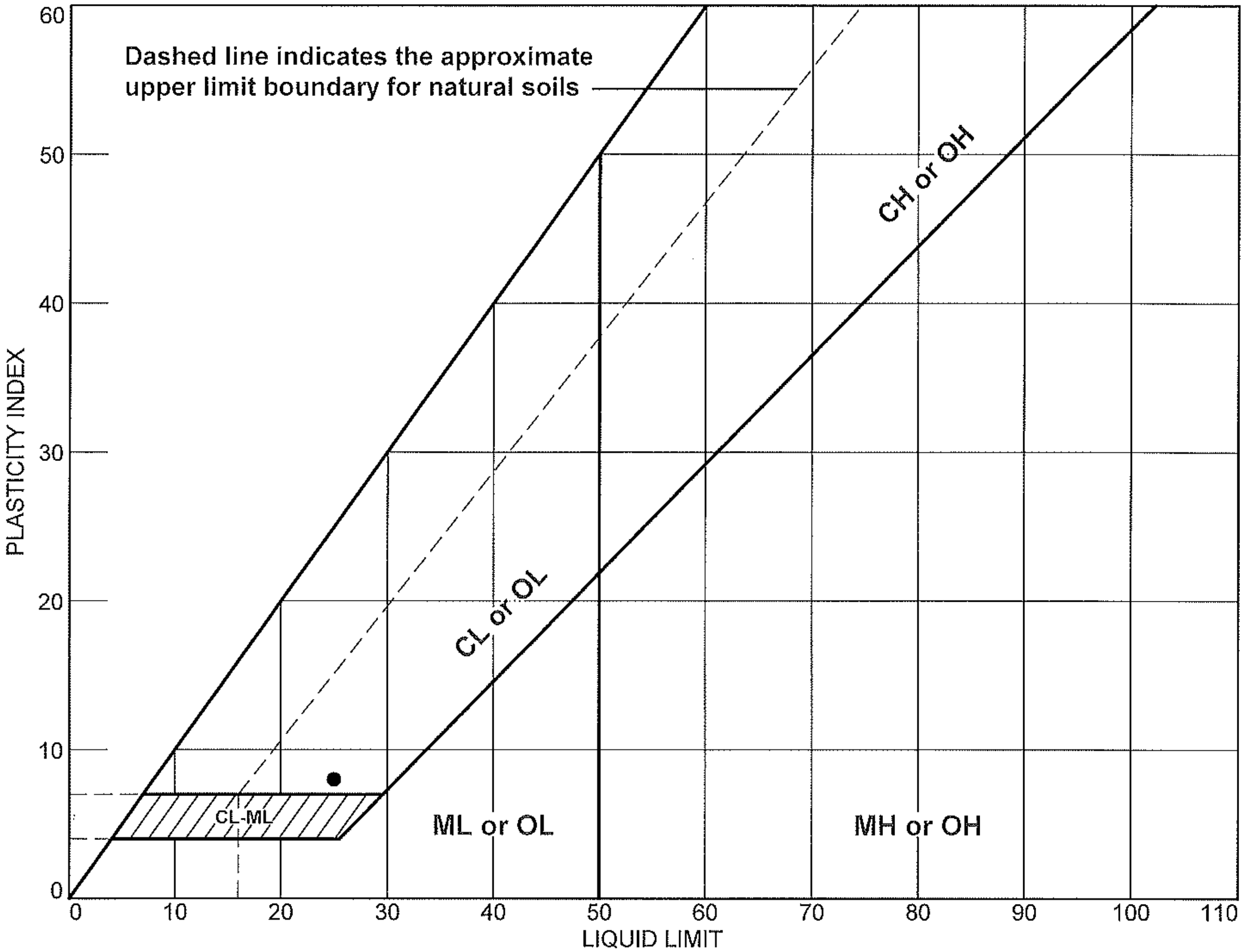
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
488.8	378.6	16.1	30.4

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-22 90'-91.5'	7980-9	90'-91.5'	34.3	17	25	8	CL

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

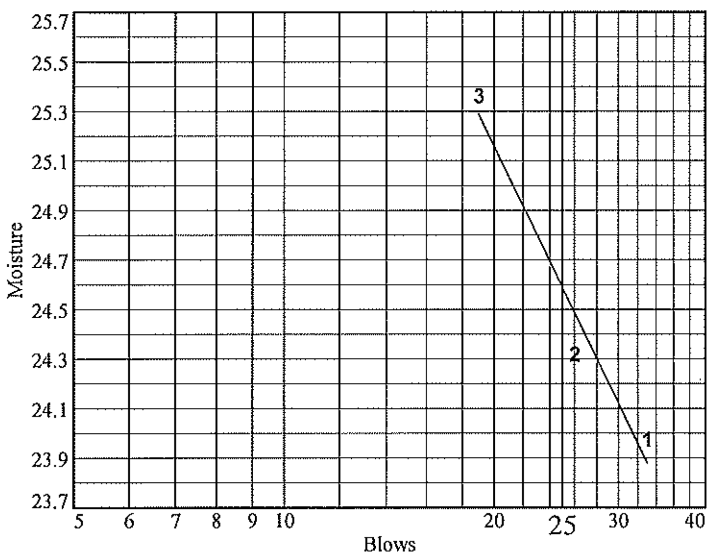
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-22
Depth: 90'-91.5' **Sample Number:** 7980-9
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	29.07	30.54	29.09			
Dry+Tare	26.08	27.23	25.96			
Tare	13.61	13.62	13.62			
# Blows	33	26	19			
Moisture	24.0	24.3	25.4			



Liquid Limit= 25
Plastic Limit= 17
Plasticity Index= 8
Natural Moisture= 34.3
Liquidity Index= 2.2

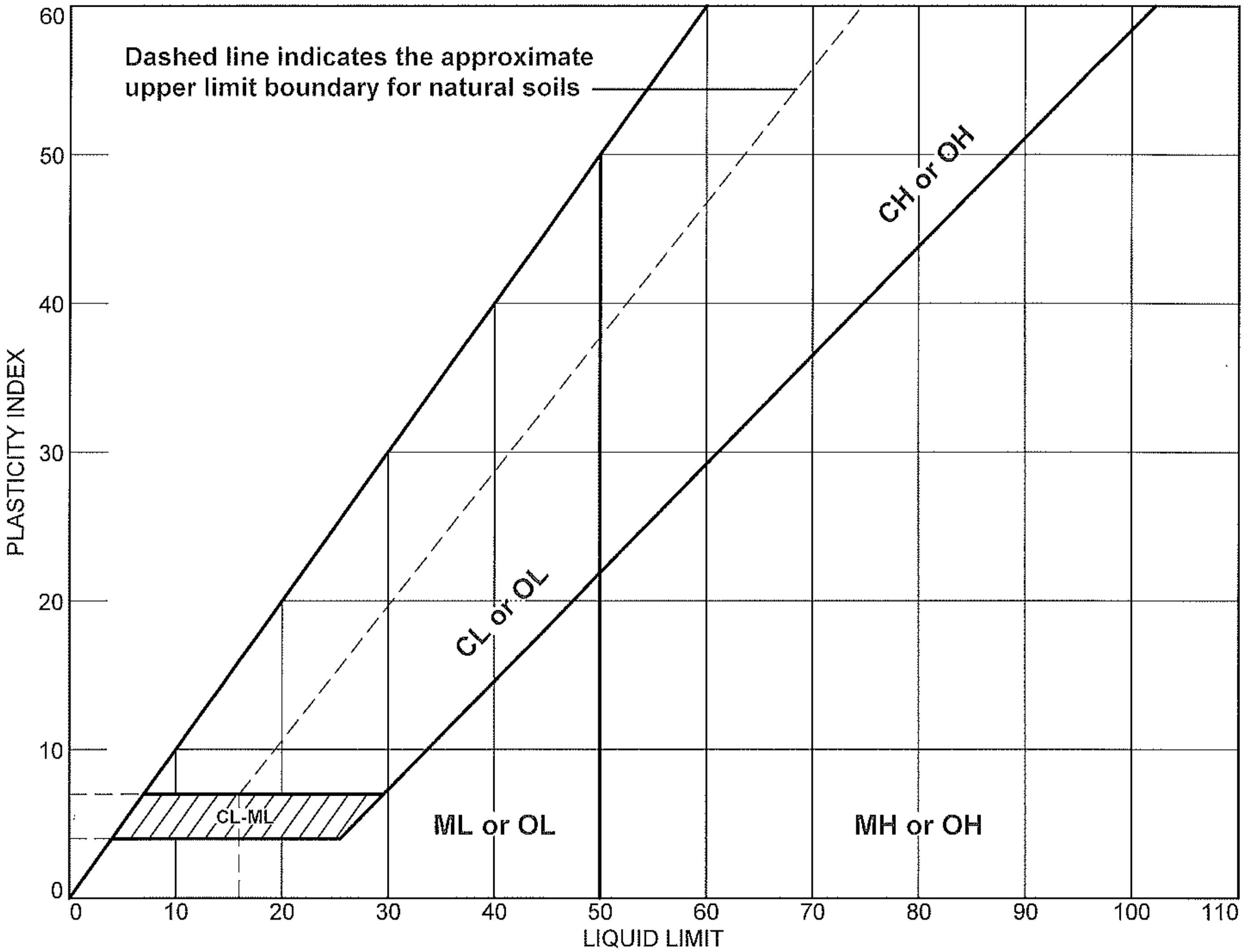
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.84	23.84	23.84		
Dry+Tare	22.39	22.39	22.39		
Tare	13.65	13.65	13.65		
Moisture	16.6	16.6	16.6		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
509.7	383.4	15.7	34.3

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-24 100'-101.5'	7980-10	100'-101.5'	30.2	NP	NV	NP	

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

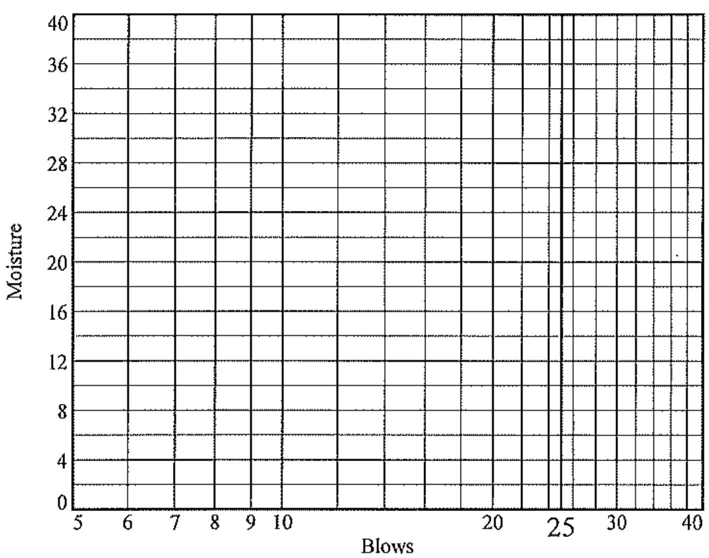
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-24
Depth: 100'-101.5'
Sample Number: 7980-10
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 30.2

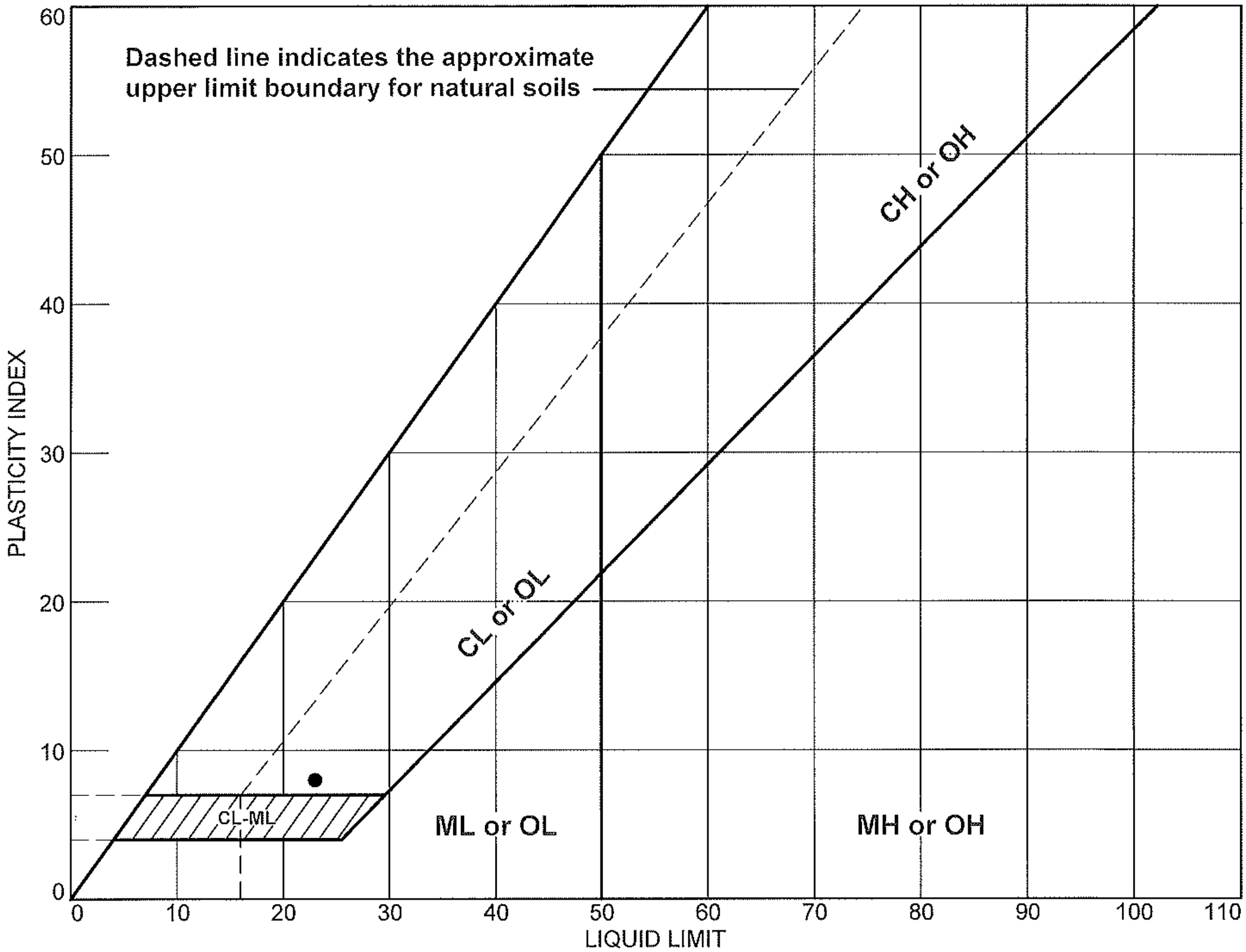
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
545.8	423.0	17.0	30.2

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-25 105'-106.5'	7920-11		32.4	15	23	8	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

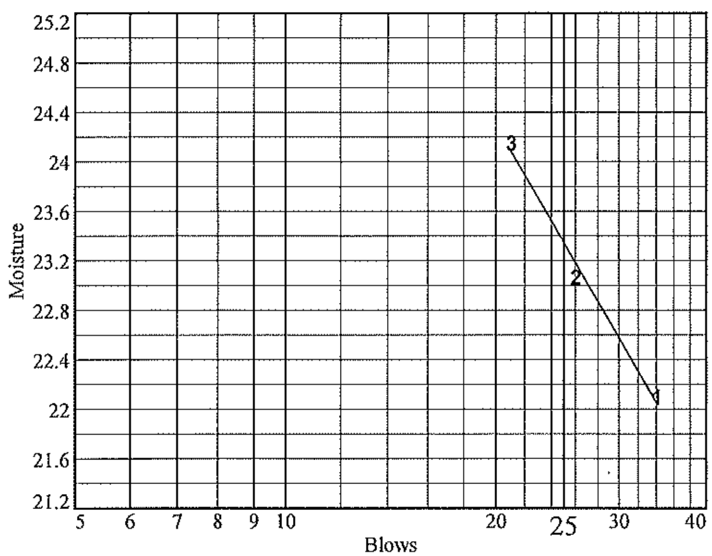
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-25
Sample Number: 7920-11
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	34.74	26.60	32.06			
Dry+Tare	30.91	24.15	28.49			
Tare	13.58	13.53	13.71			
# Blows	34	26	21			
Moisture	22.1	23.1	24.2			



Liquid Limit= 23
Plastic Limit= 15
Plasticity Index= 8
Natural Moisture= 32.4
Liquidity Index= 2.2

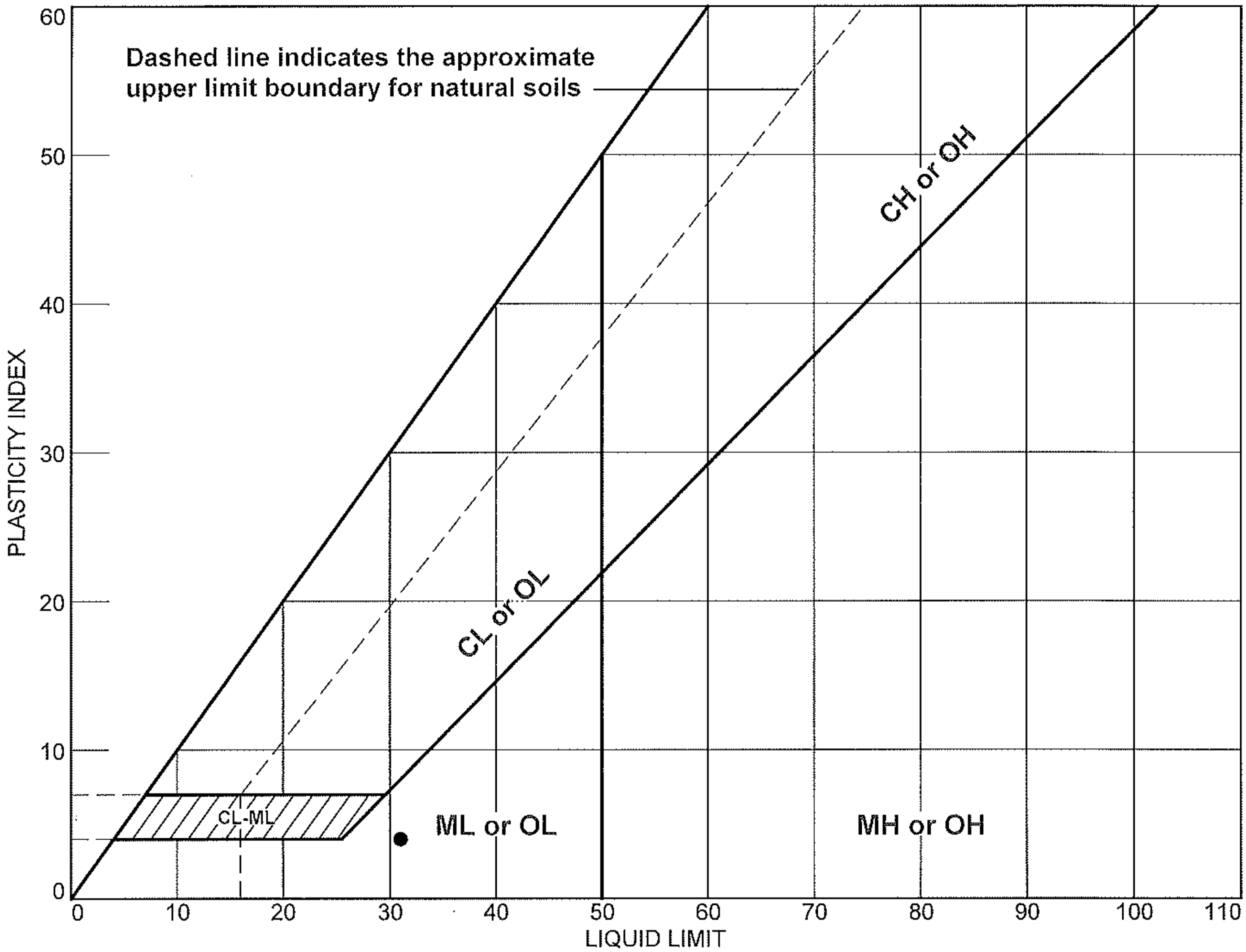
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.54	23.54	23.54		
Dry+Tare	22.25	22.25	22.25		
Tare	13.69	13.69	13.69		
Moisture	15.1	15.1	15.1		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
496.4	378.7	15.8	32.4

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-26 110'-111.5'	7980-12	110'-111.5'	33.9	27	31	4	ML

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

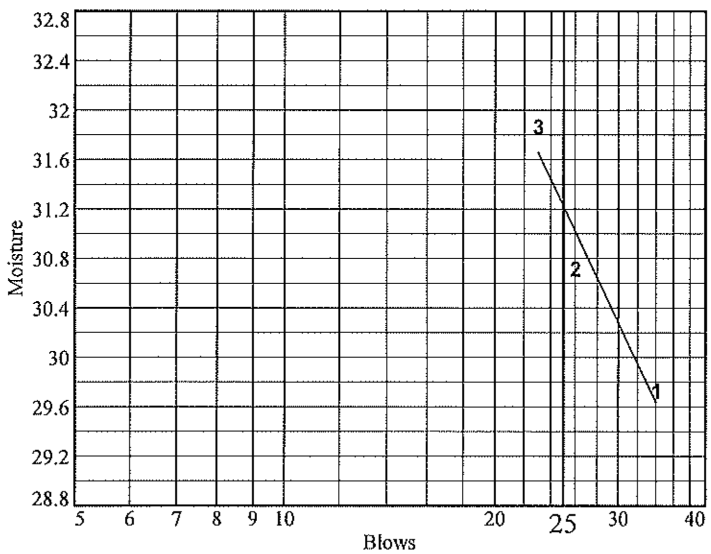
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-26
Depth: 110'-111.5' **Sample Number:** 7980-12
USCS: ML
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	30.05	29.24	27.91			
Dry+Tare	26.28	25.60	24.43			
Tare	13.60	13.75	13.51			
# Blows	34	26	23			
Moisture	29.7	30.7	31.9			



Liquid Limit= 31
Plastic Limit= 27
Plasticity Index= 4
Natural Moisture= 33.9
Liquidity Index= 1.7

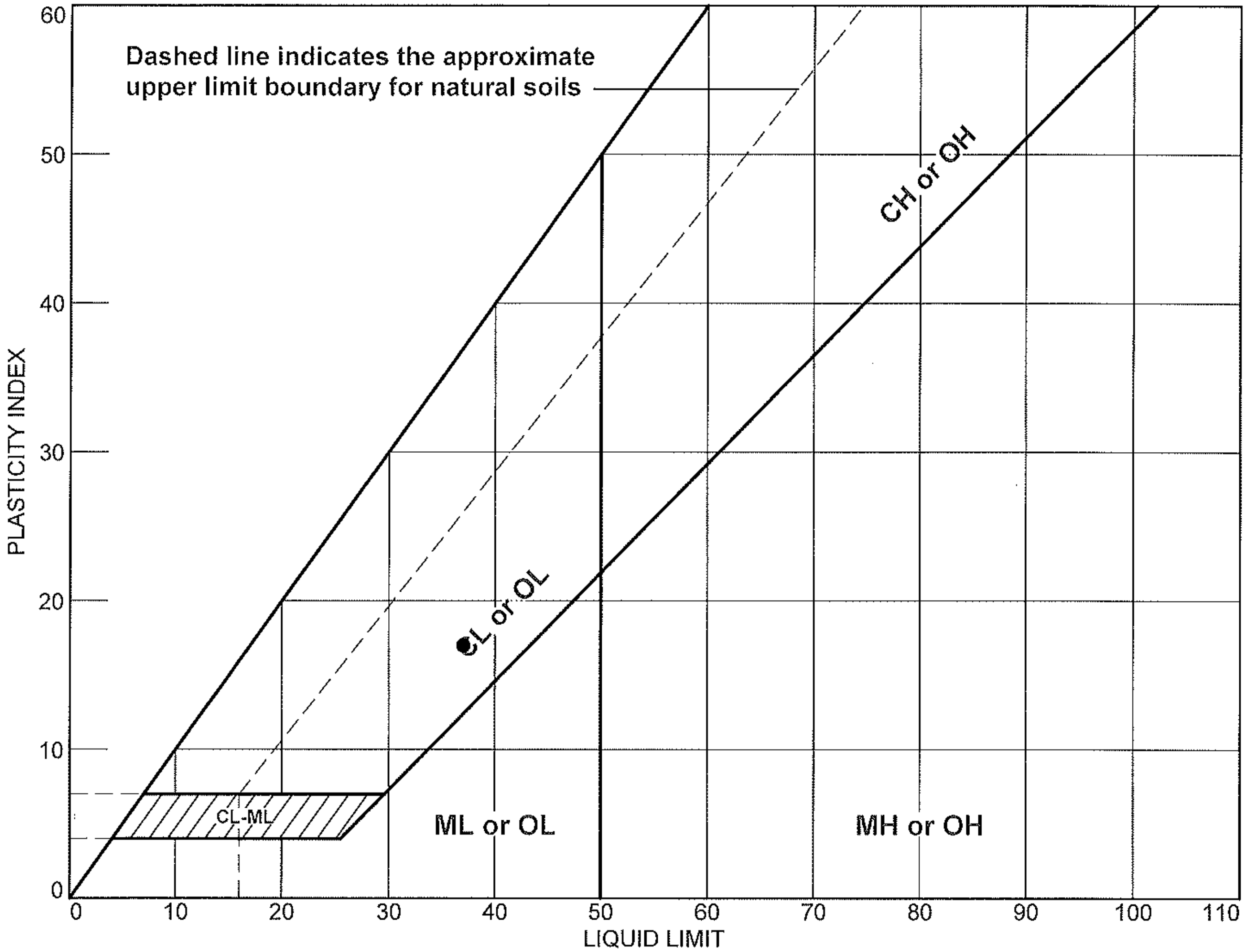
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.10	23.10	23.10		
Dry+Tare	21.07	21.07	21.07		
Tare	13.65	13.65	13.65		
Moisture	27.4	27.4	27.4		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
413.1	312.7	16.1	33.9

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-28 120'-121.5'	7980-13	120'-121.5'	34.4	20	37	17	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

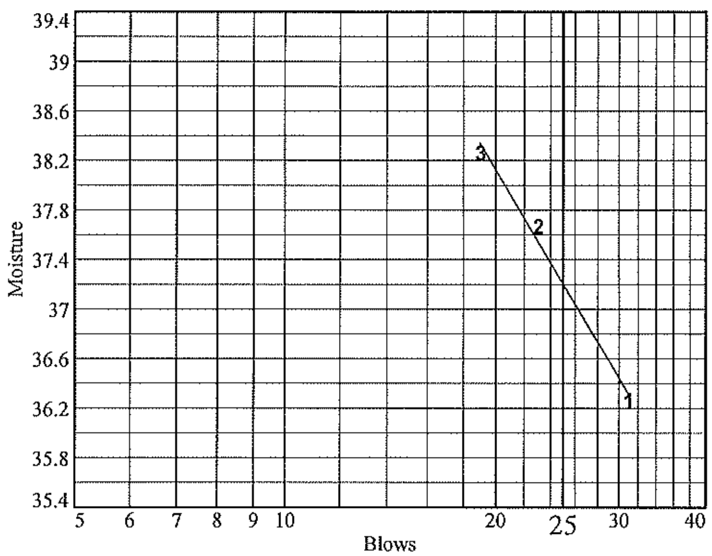
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 G-28
Depth: 120'-121.5'
Sample Number: 7980-13
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	30.90	27.70	29.62			
Dry+Tare	26.32	23.85	25.17			
Tare	13.69	13.63	13.54			
# Blows	31	23	19			
Moisture	36.3	37.7	38.3			



Liquid Limit= 37
Plastic Limit= 20
Plasticity Index= 17
Natural Moisture= 34.4
Liquidity Index= 0.8

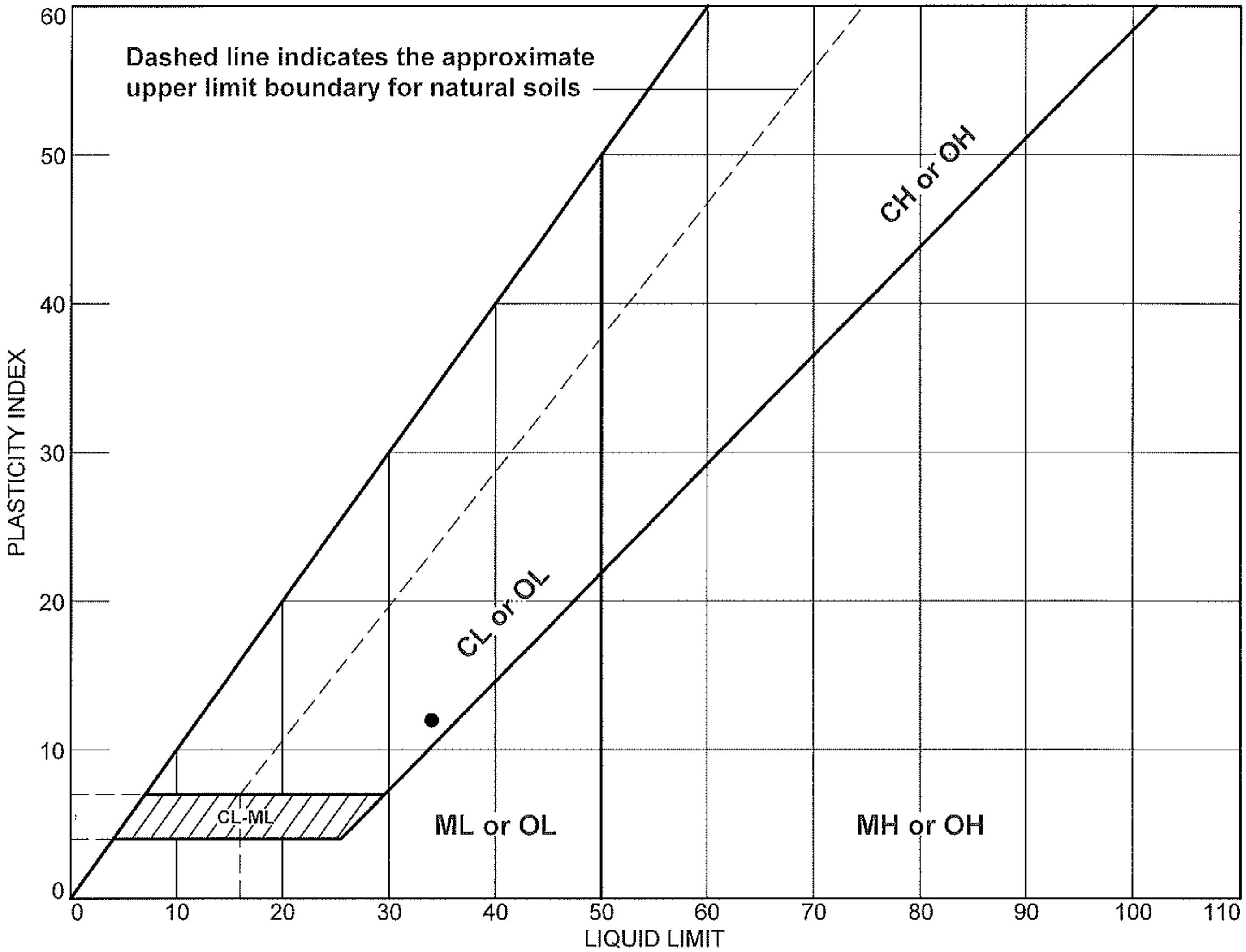
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	21.10	21.10	21.10		
Dry+Tare	19.83	19.83	19.83		
Tare	13.59	13.59	13.59		
Moisture	20.4	20.4	20.4		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
457.4	344.4	16.0	34.4

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-31 135'-136.5'	7980-14	135'-136.5'	31.3	22	34	12	CL

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

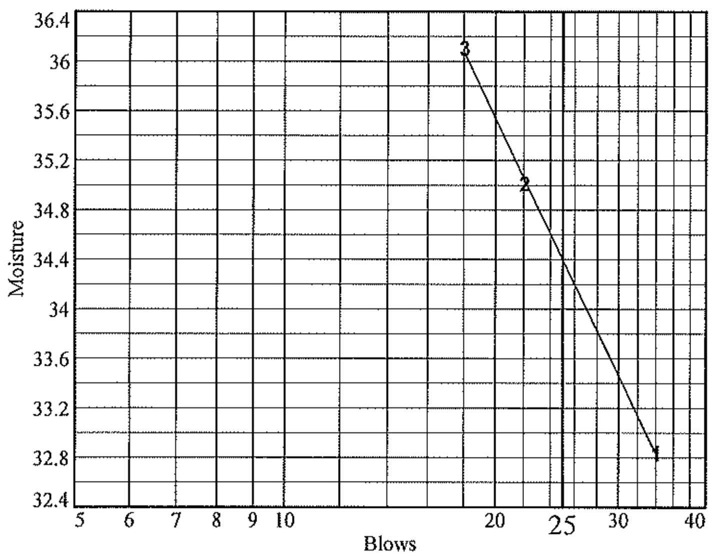
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-31
Depth: 135'-136.5' **Sample Number:** 7980-14
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	27.94	31.30	29.96			
Dry+Tare	24.39	26.72	25.62			
Tare	13.58	13.64	13.60			
# Blows	34	22	18			
Moisture	32.8	35.0	36.1			



Liquid Limit= 34
Plastic Limit= 22
Plasticity Index= 12
Natural Moisture= 31.3
Liquidity Index= 0.8

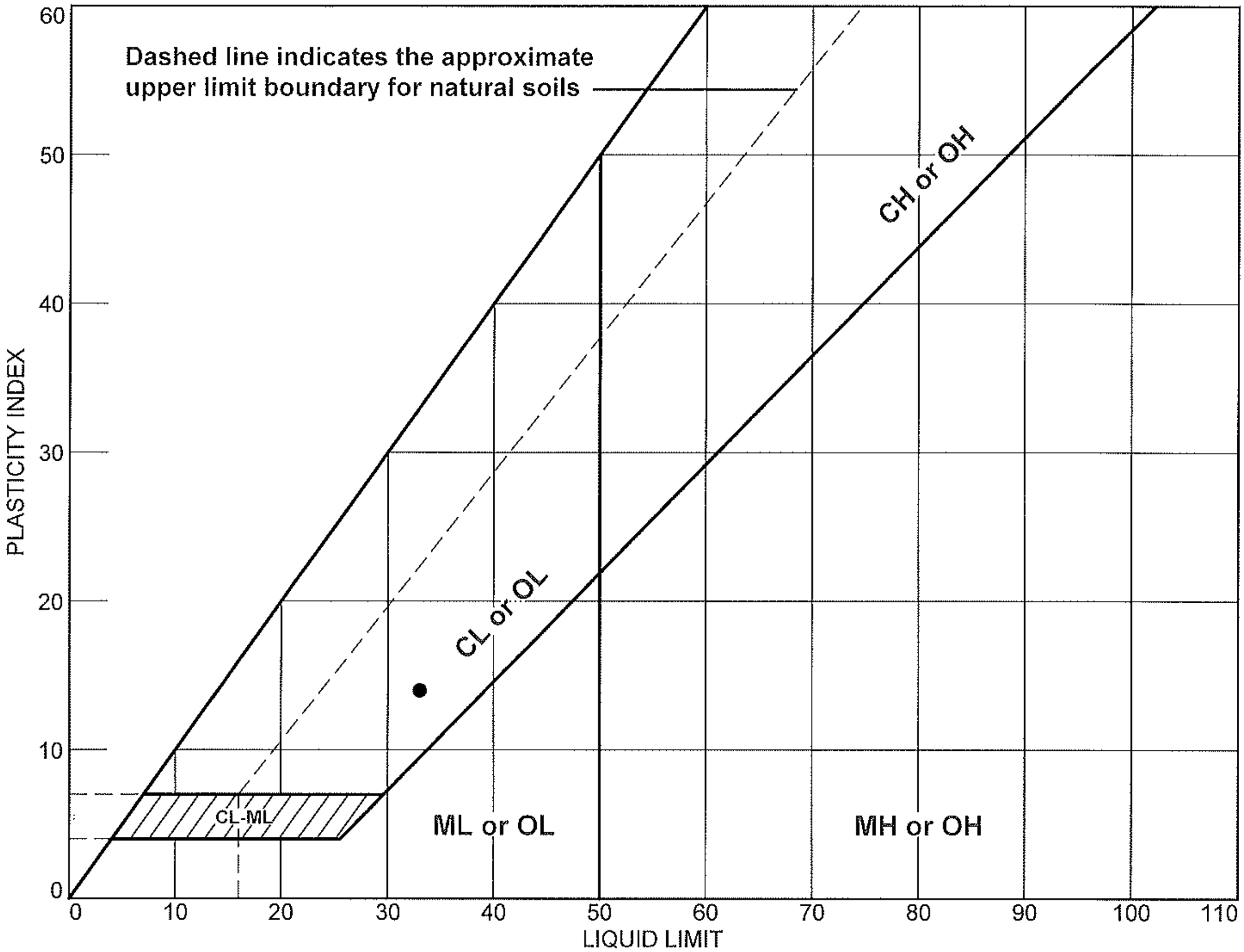
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.02	22.02	22.02		
Dry+Tare	20.52	20.52	20.52		
Tare	13.68	13.68	13.68		
Moisture	21.9	21.9	21.9		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
447.1	344.4	16.6	31.3

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-33 145'-146.5'	7980-15	145'-146.5'	28.8	19	33	14	CL

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

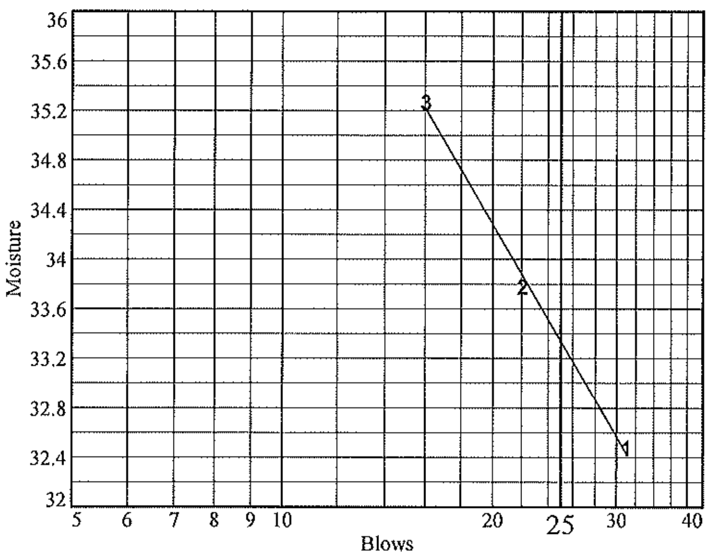
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-33
Depth: 145'-146.5' **Sample Number:** 7980-15
USCS: CL
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	28.60	31.51	30.26			
Dry+Tare	24.93	26.99	25.89			
Tare	13.63	13.61	13.5			
# Blows	31	22	16			
Moisture	32.5	33.8	35.3			



Liquid Limit= 33
Plastic Limit= 19
Plasticity Index= 14
Natural Moisture= 28.8
Liquidity Index= 0.7

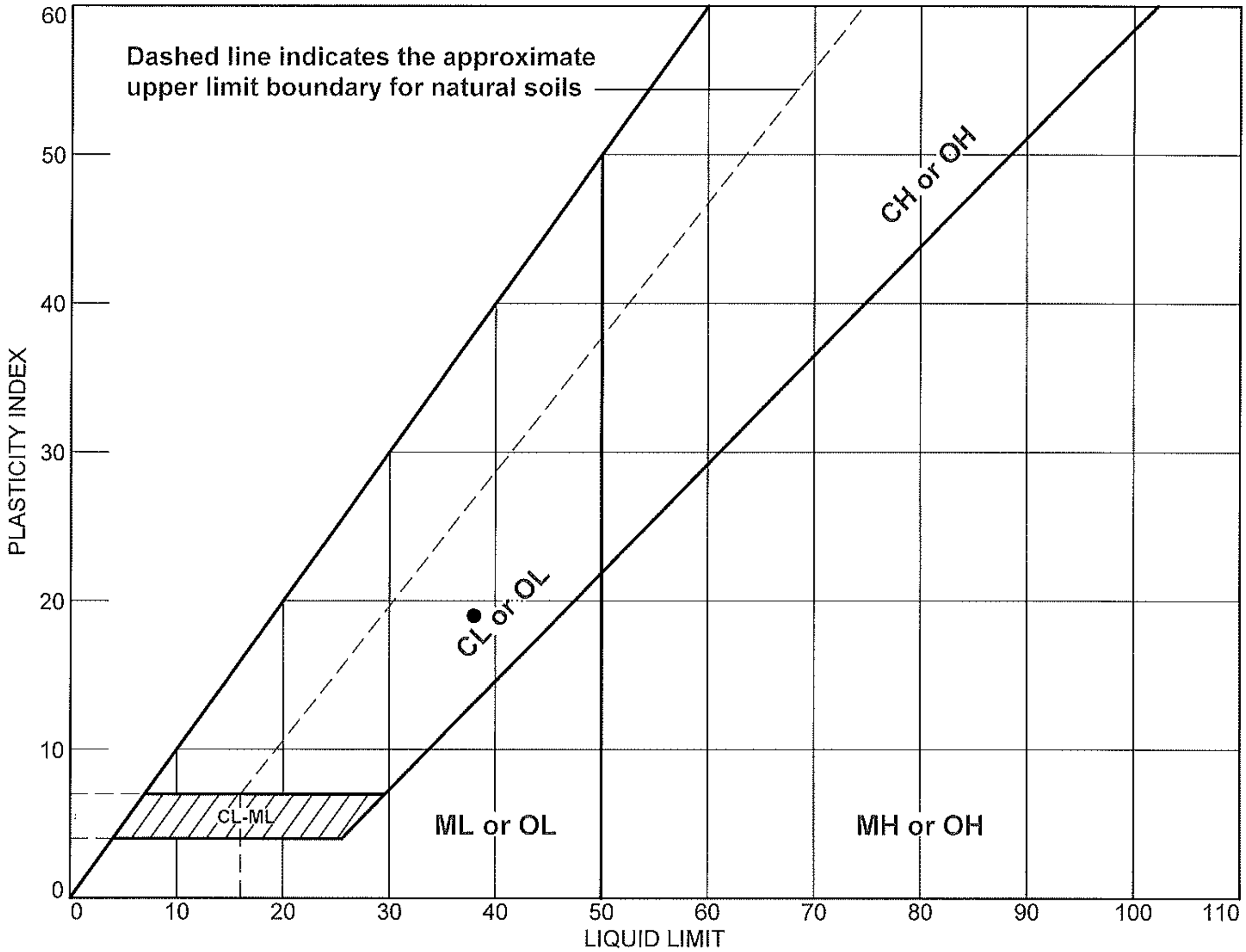
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.49	22.49	22.49		
Dry+Tare	21.08	21.08	21.08		
Tare	13.66	13.66	13.66		
Moisture	19.0	19.0	19.0		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
401.3	315.1	15.8	28.8

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-37 165'-166.5'	7980-16	165'-166.5'	31.8	19	38	19	CL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

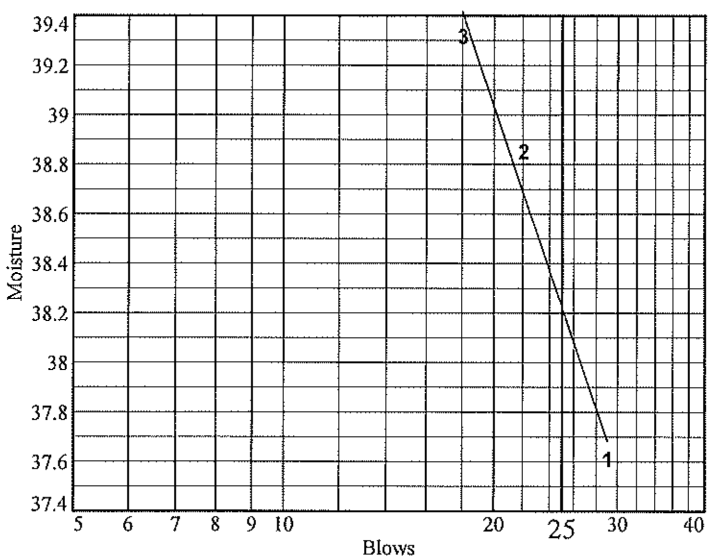
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-37
Depth: 165'-166.5'
Sample Number: 7980-16
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	28.85	30.96	30.07			
Dry+Tare	24.66	26.08	25.45			
Tare	13.52	13.52	13.70			
# Blows	29	22	18			
Moisture	37.6	38.9	39.3			



Liquid Limit= 38
Plastic Limit= 19
Plasticity Index= 19
Natural Moisture= 31.8
Liquidity Index= 0.7

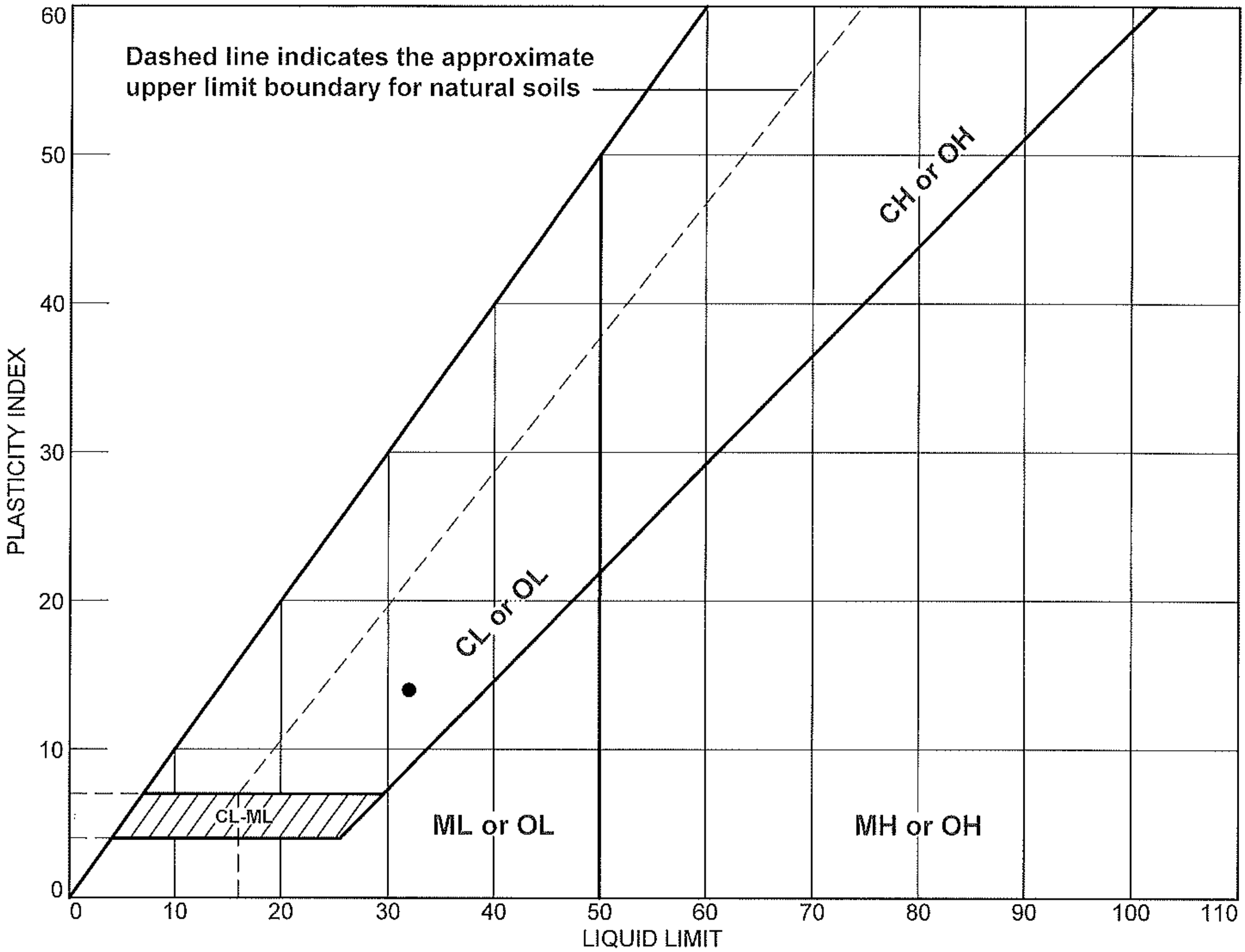
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.50	23.50	23.50		
Dry+Tare	21.90	21.90	21.90		
Tare	13.67	13.67	13.67		
Moisture	19.4	19.4	19.4		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
400.2	307.5	16.1	31.8

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G020 S-40 180'-181.5'	7980-17	180'-181.5'	26.5	18	32	14	CL

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

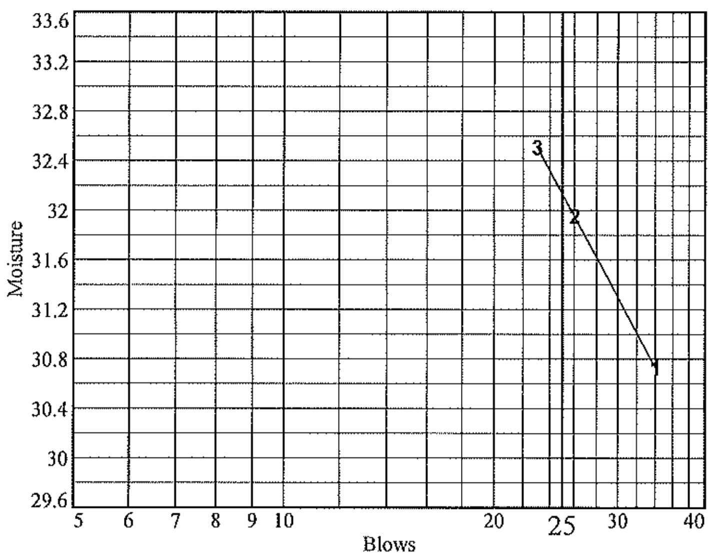
LIQUID AND PLASTIC LIMIT TEST DATA

8/23/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G020 S-40
Depth: 180'-181.5'
Sample Number: 7980-17
USCS: CL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	30.37	31.25	27.65			
Dry+Tare	26.43	27.00	24.22			
Tare	13.61	13.70	13.67			
# Blows	34	26	23			
Moisture	30.7	32.0	32.5			



Liquid Limit= 32
Plastic Limit= 18
Plasticity Index= 14
Natural Moisture= 26.5
Liquidity Index= 0.6

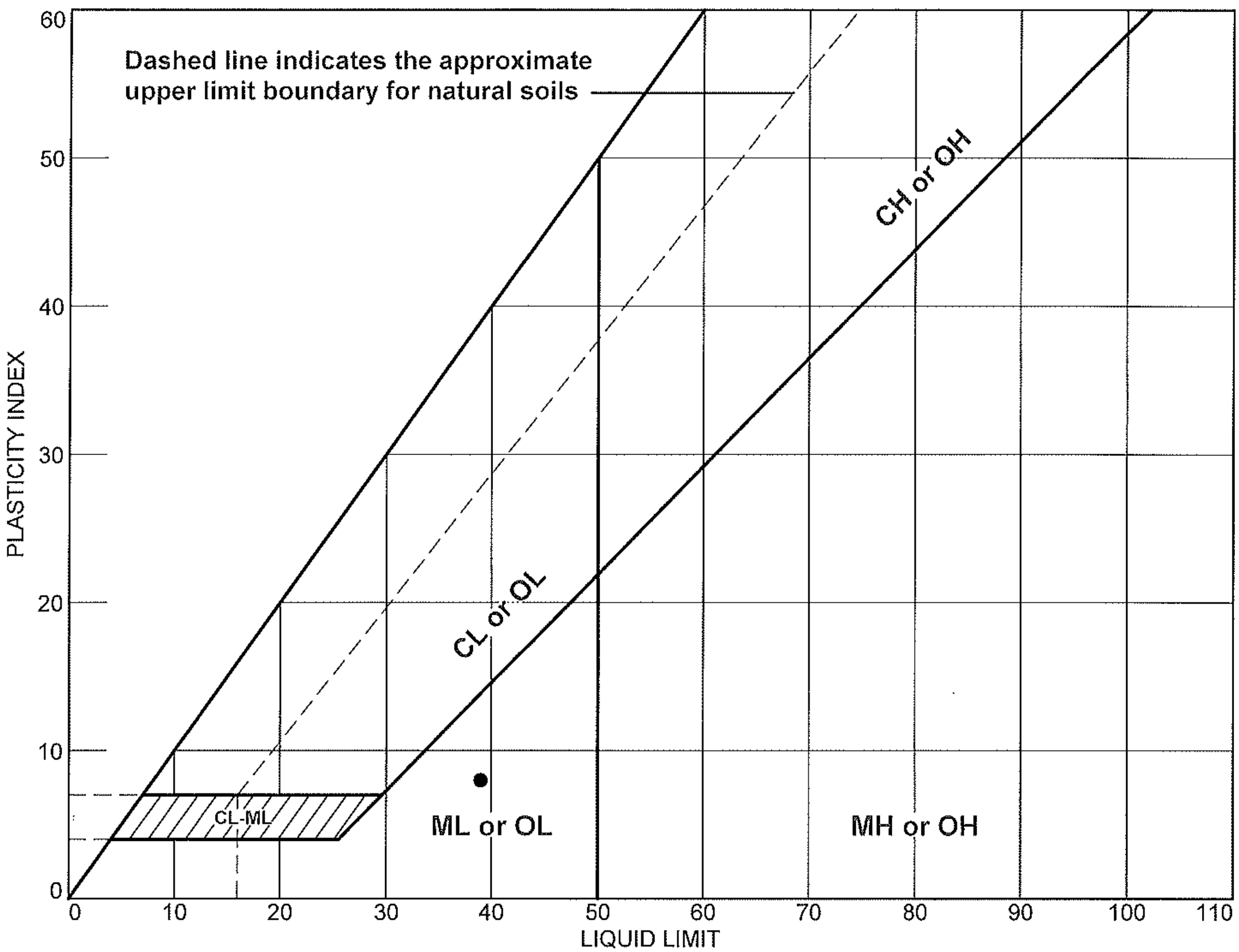
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	22.23	22.23	22.23		
Dry+Tare	20.95	20.95	20.95		
Tare	13.65	13.65	13.65		
Moisture	17.5	17.5	17.5		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
278.9	223.8	15.7	26.5

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G021 S-2 2.5'-3.5'	7992-27	2.5'-3.5'	37.5	31	39	8	ML

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

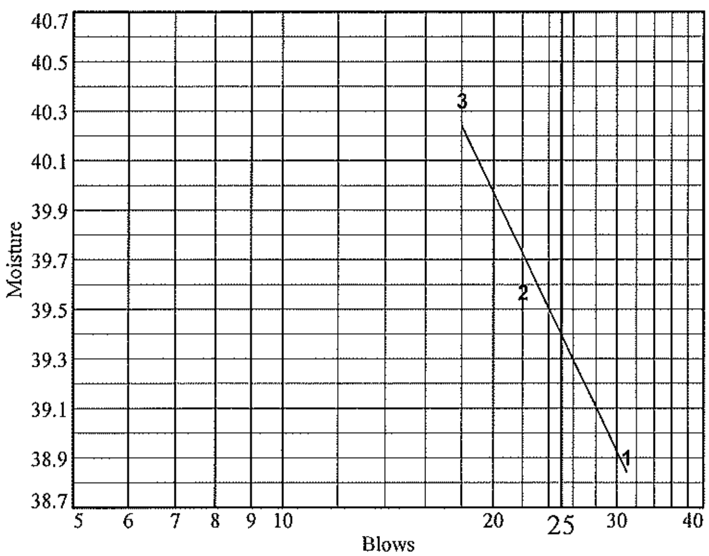
LIQUID AND PLASTIC LIMIT TEST DATA

10/11/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G021 S-2
Depth: 2.5'-3.5' **Sample Number:** 7992-27
USCS: ML
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	32.61	36.26	26.79			
Dry+Tare	27.30	29.85	23.03			
Tare	13.65	13.65	13.71			
# Blows	31	22	18			
Moisture	38.9	39.6	40.3			



Liquid Limit= 39
Plastic Limit= 31
Plasticity Index= 8
Natural Moisture= 37.5
Liquidity Index= 0.8

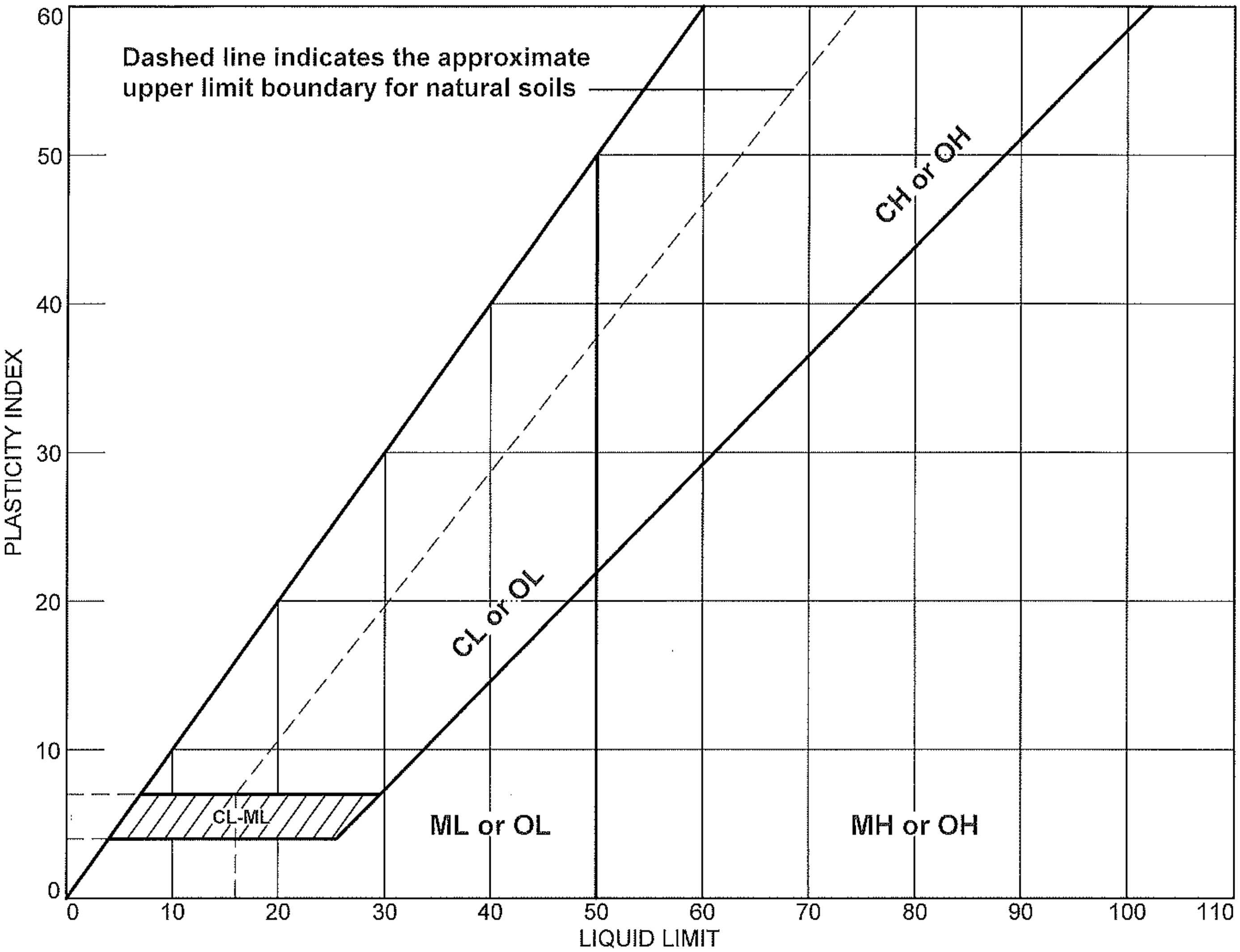
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	23.08	23.08	23.08		
Dry+Tare	20.83	20.83	20.83		
Tare	13.59	13.59	13.59		
Moisture	31.1	31.1	31.1		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
278.1	206.5	15.8	37.5

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G023 S-1 3.6'-4.0'	7992-41	3.6'-4.0'	30.7	NP	NV	NP	

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

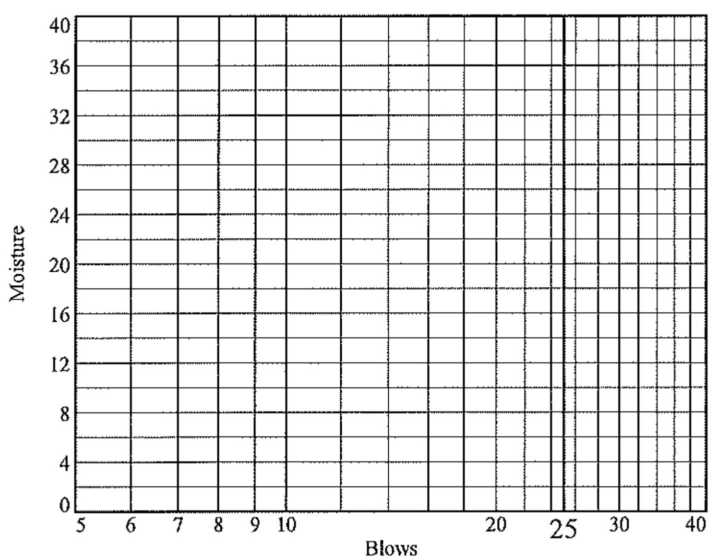
LIQUID AND PLASTIC LIMIT TEST DATA

10/11/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G023 S-1
Depth: 3.6'-4.0'
Sample Number: 7992-41
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 30.7

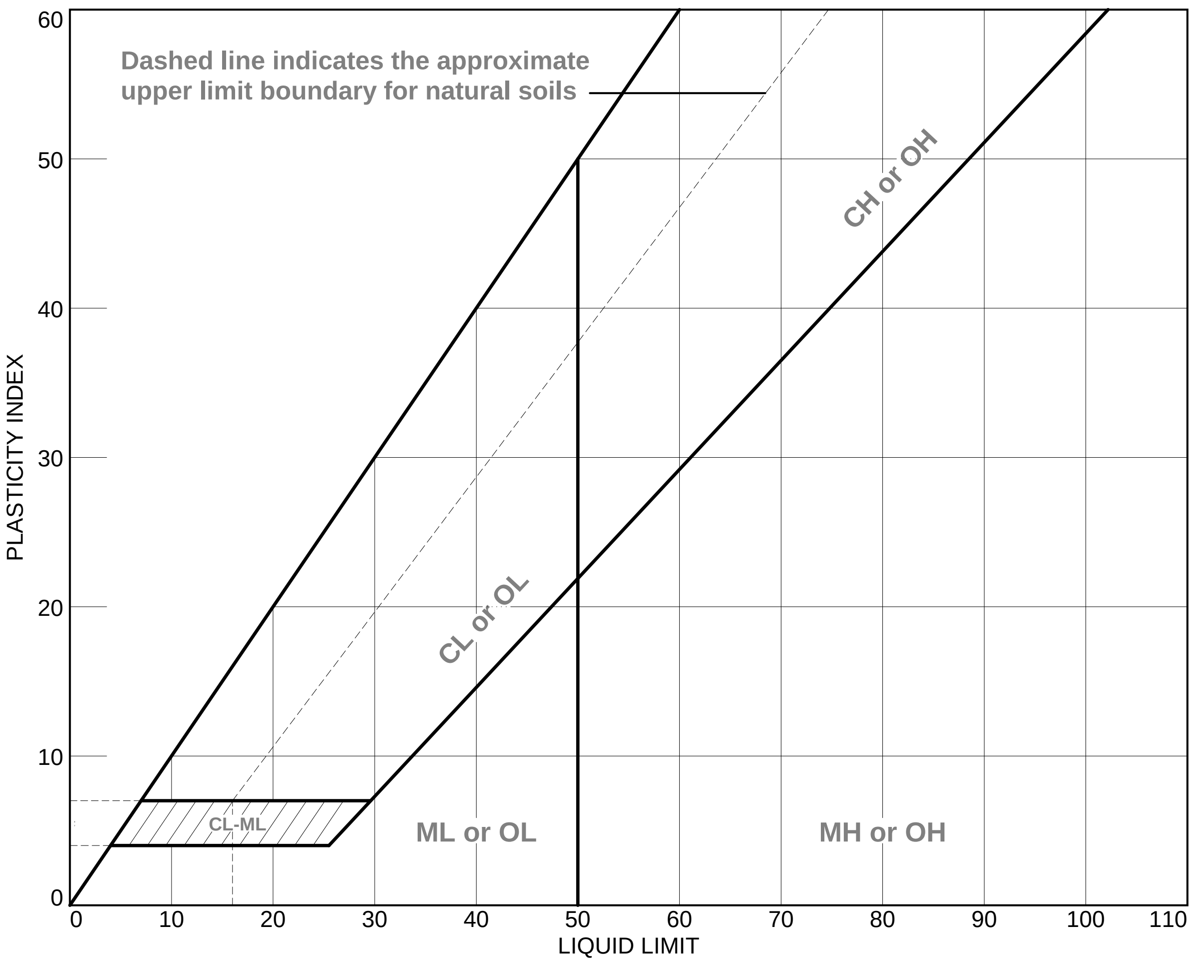
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
232.1	181.3	15.8	30.7

LIQUID AND PLASTIC LIMITS TEST REPORT



These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G023 S-2 5'-6.5'	7992-42	5'-6.5'	151.8		NV		PT

NV = No Value
Note: Indeterminate result due to peat structure preventing reliable test results.

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

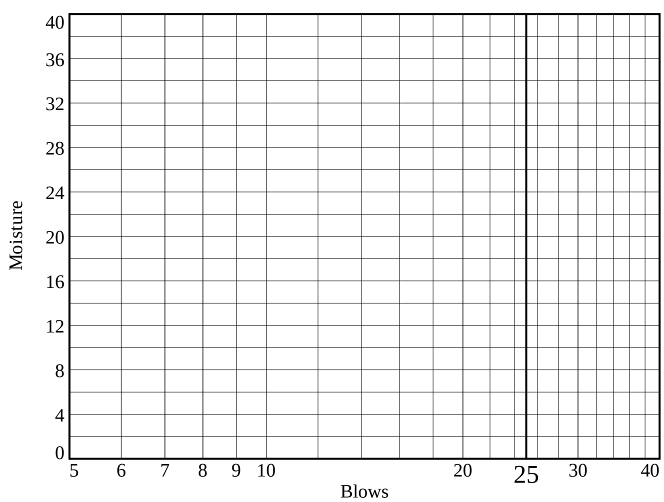
LIQUID AND PLASTIC LIMIT TEST DATA

3/12/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G023 S-2
Depth: 5'-6.5' **Sample Number:** 7992-42
Material Description: Peat
USCS: PT
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						

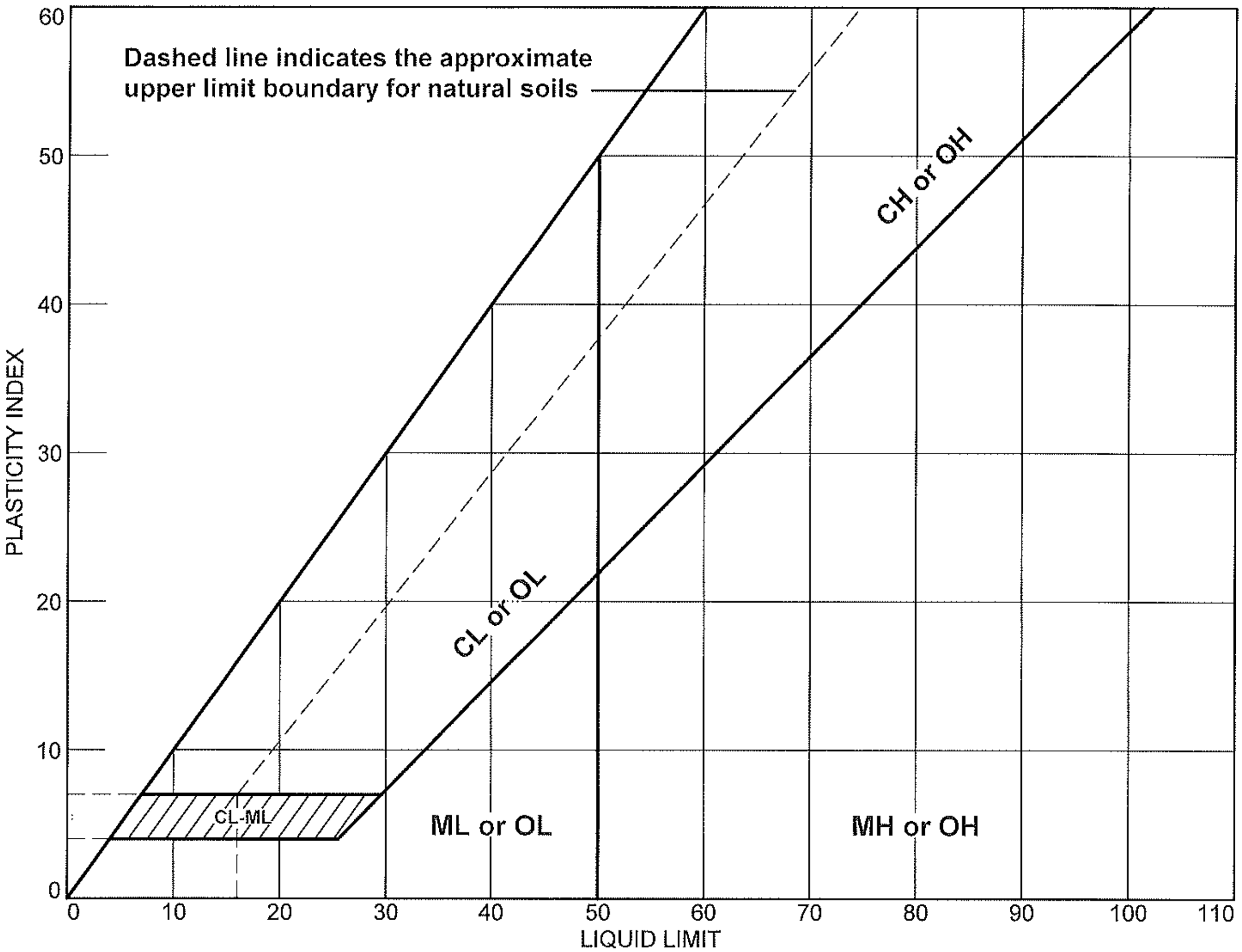


Liquid Limit= NV
Plastic Limit=
Plasticity Index=
Natural Moisture= 151.8

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
329.8	140.5	15.8	151.8

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G024 S-2 2.5'-4'	7995-3	2.5'-4'	21.8	NP	NV	NP	

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE

Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

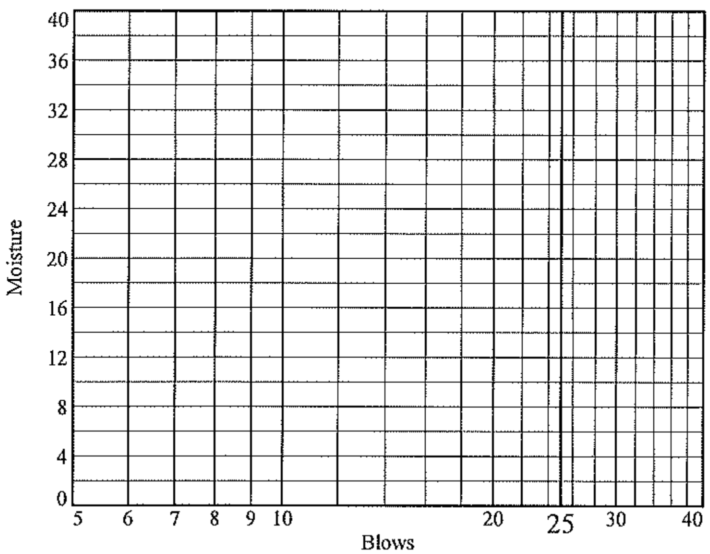
LIQUID AND PLASTIC LIMIT TEST DATA

10/26/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G024 S-2
Depth: 2.5'-4'
Sample Number: 7995-3
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						



Liquid Limit= NV
Plastic Limit= NP
Plasticity Index= NP
Natural Moisture= 21.8

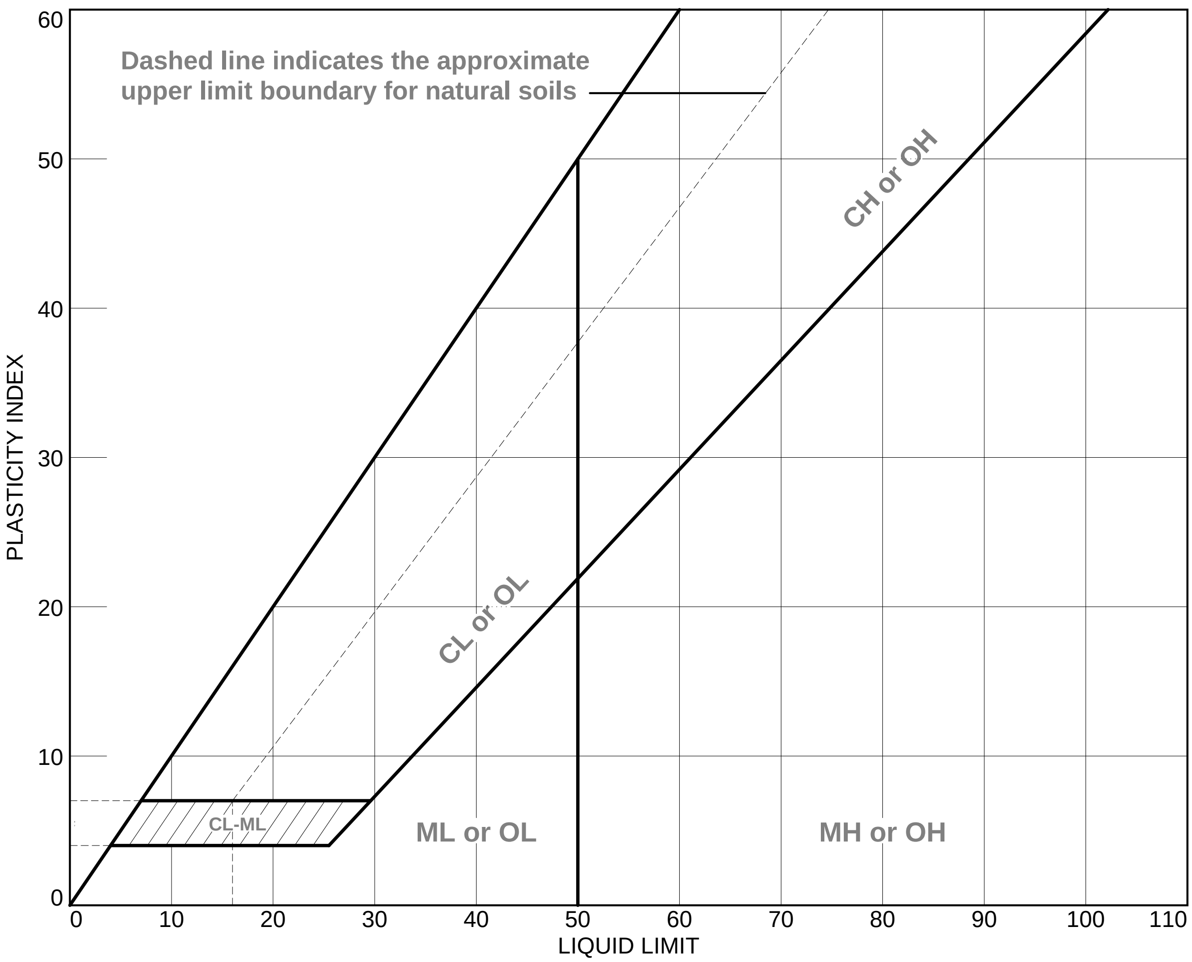
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare					
Dry+Tare					
Tare					
Moisture					

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
293.1	243.4	15.7	21.8

LIQUID AND PLASTIC LIMITS TEST REPORT



These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G024 S-4 7.5'-9'	7995-5	7.5'-9'	50.0		NV		

NV = No Value
Note: Indeterminate result due to organic structure preventing reliable test results.

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

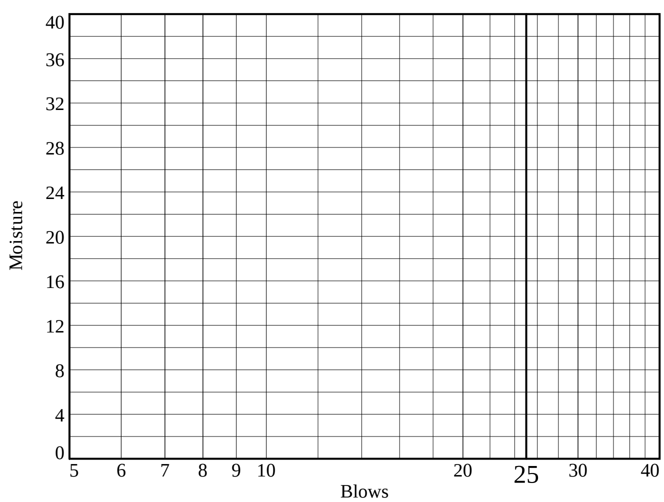
LIQUID AND PLASTIC LIMIT TEST DATA

3/12/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G024 S-4
Depth: 7.5'-9' **Sample Number:** 7995-5
Material Description: Silt with organics
USCS: NA
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						

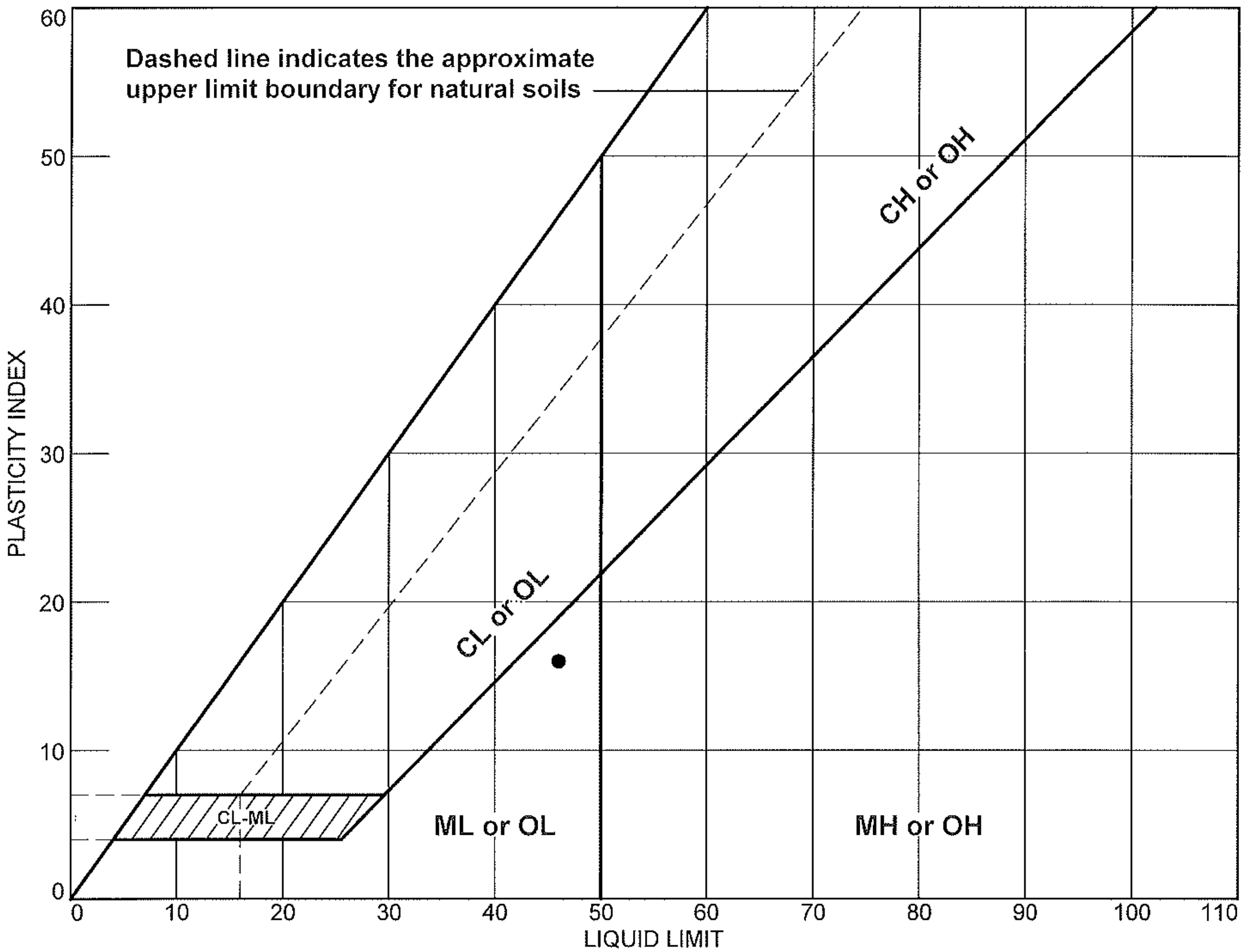


Liquid Limit= NV
Plastic Limit=
Plasticity Index=
Natural Moisture= 50.0

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
332.2	226.8	15.8	50.0

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G024 S-5A 10'-11.5'	7995-6	10'-11.5'	54.6	30	46	16	OL

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

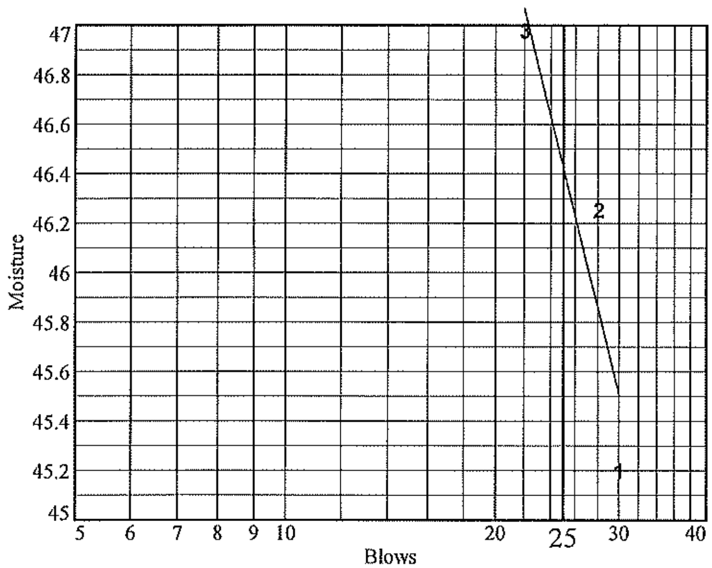
LIQUID AND PLASTIC LIMIT TEST DATA

10/26/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G024 S-5A
Depth: 10'-11.5'
Sample Number: 7995-6
USCS: OL
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	32.83	30.32	29.85			
Dry+Tare	26.85	25.01	24.64			
Tare	13.62	13.53	13.55			
# Blows	30	28	22			
Moisture	45.2	46.3	47.0			



Liquid Limit= 46
Plastic Limit= 30
Plasticity Index= 16
Natural Moisture= 54.6
Liquidity Index= 1.5

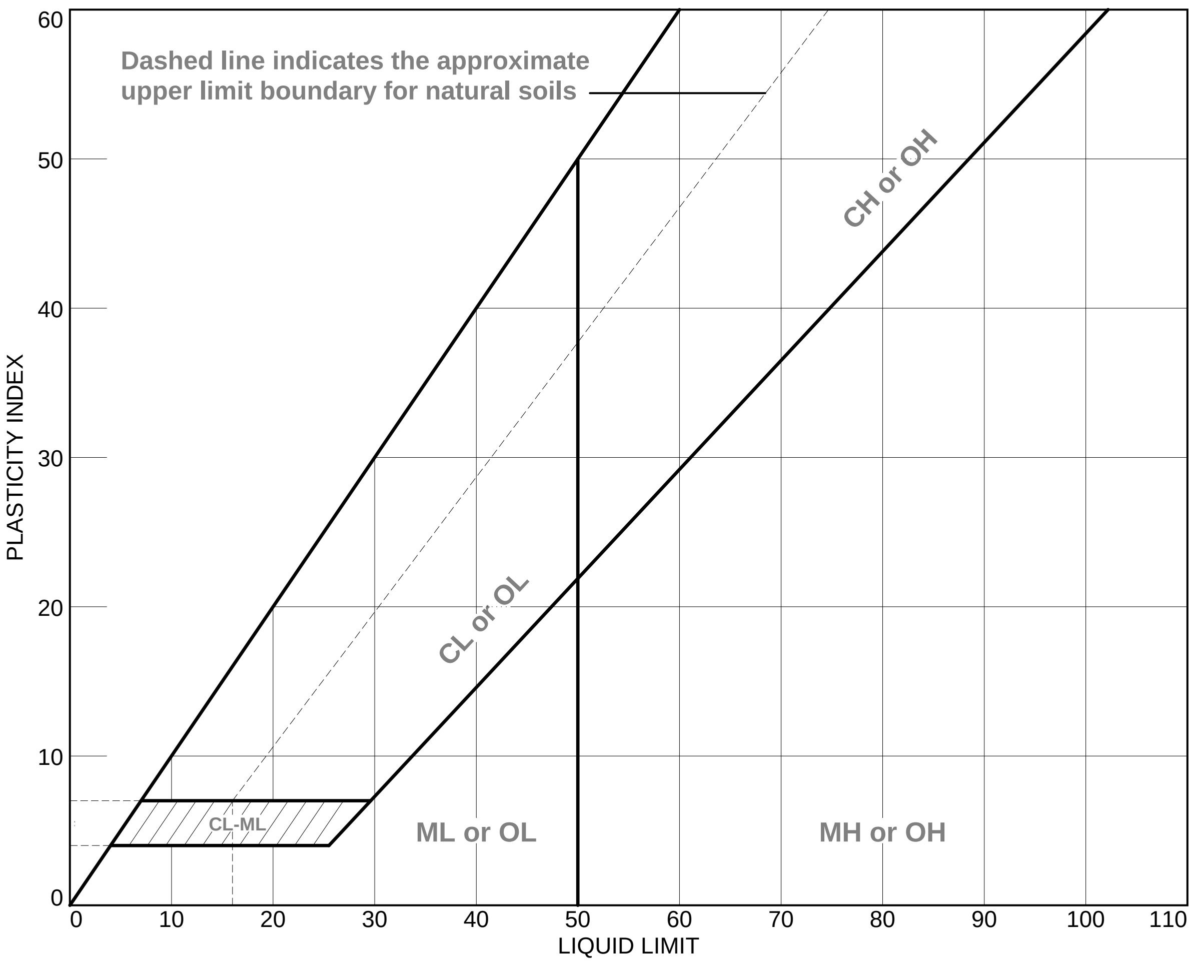
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	21.44	21.44	21.44		
Dry+Tare	19.67	19.67	19.67		
Tare	13.69	13.69	13.69		
Moisture	29.6	29.6	29.6		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
333.5	221.2	15.7	54.6

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G024 S5B 10'-11.5'	7995-7	10'-11.5'	161.9		NV		PT

NV = No Value
Note: Indeterminate result due to peat structure preventing reliable test results.

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

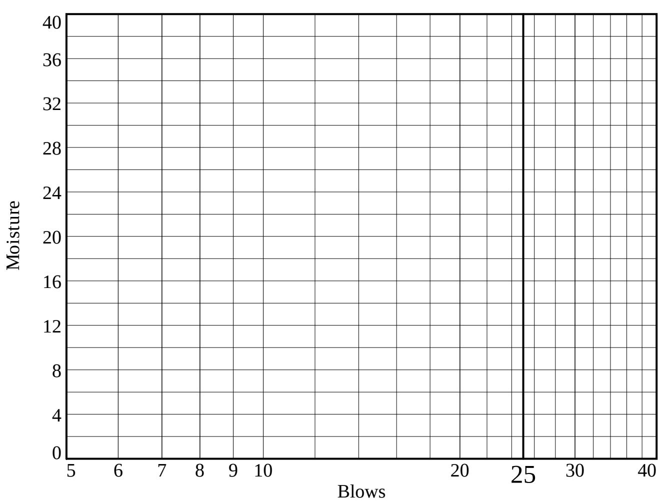
LIQUID AND PLASTIC LIMIT TEST DATA

3/12/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G024 S-5B
Depth: 10'-11.5'
Sample Number: 7995-7
Material Description: Peat
USCS: PT
Tested by: BH
Checked by: JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						

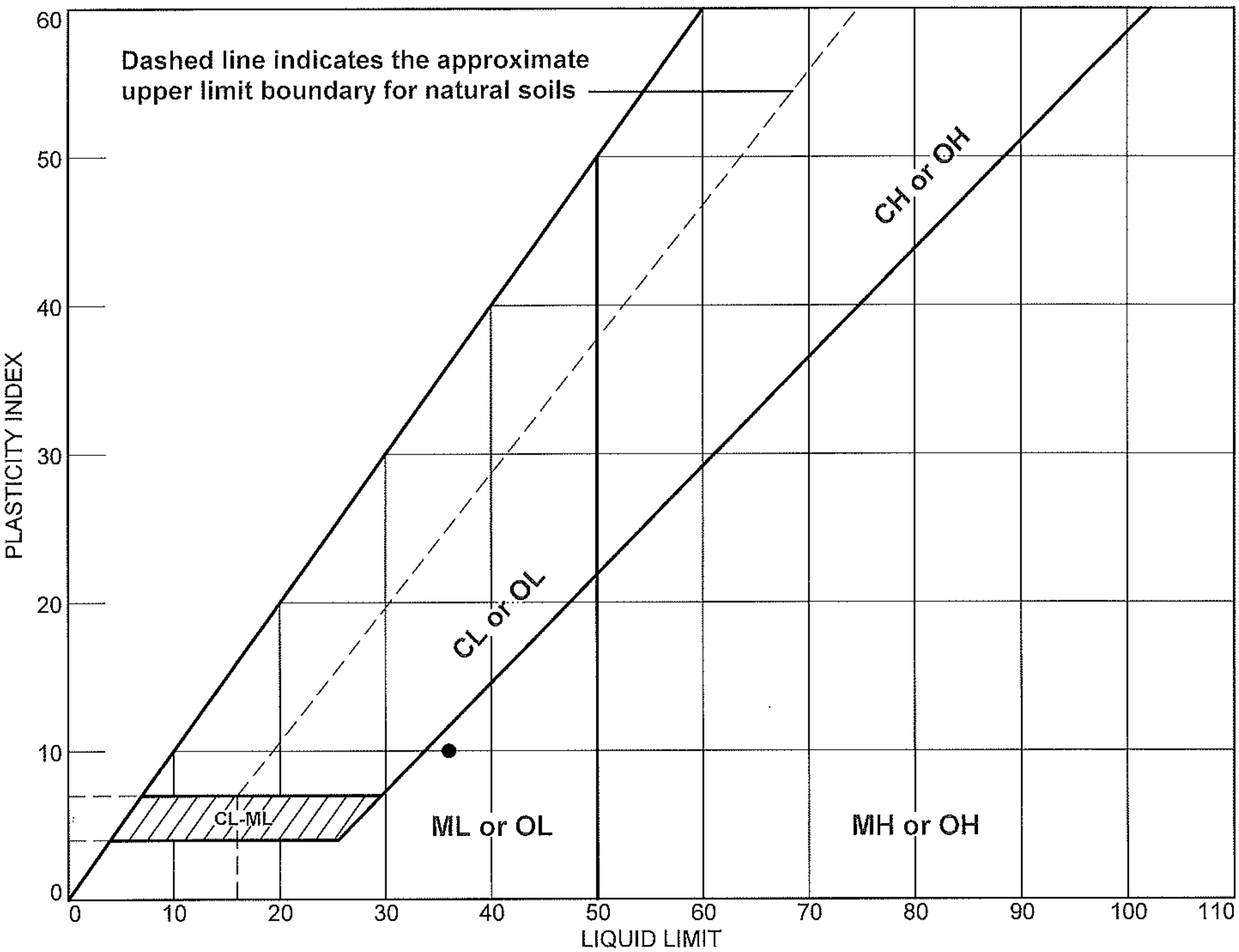


Liquid Limit= NV
Plastic Limit=
Plasticity Index=
Natural Moisture= 161.9

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
198.0	85.3	15.7	161.9

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G025 S-3 10'-11.5'	7995-11	10'-11.5'	37.7	26	36	10	ML

Hayre McElroy & Associates, LLC **Redmond, WA**	**Client:** Golder Associates **Project:** ST-DRLE **Project No.:** 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

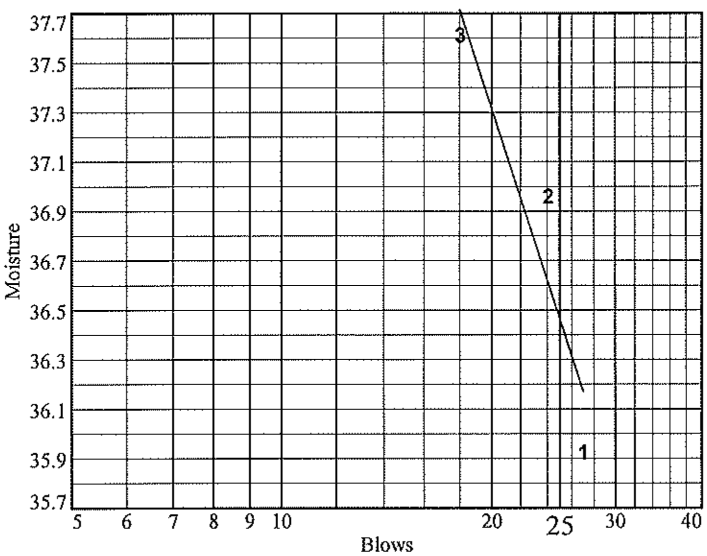
LIQUID AND PLASTIC LIMIT TEST DATA

10/26/2017

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G025 S-3
Depth: 10'-11.5' **Sample Number:** 7995-11
USCS: ML
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	33.62	30.55	31.66			
Dry+Tare	28.31	26.00	26.74			
Tare	13.53	13.69	13.66			
# Blows	27	24	18			
Moisture	35.9	37.0	37.6			



Liquid Limit= 36
Plastic Limit= 26
Plasticity Index= 10
Natural Moisture= 37.7
Liquidity Index= 1.2

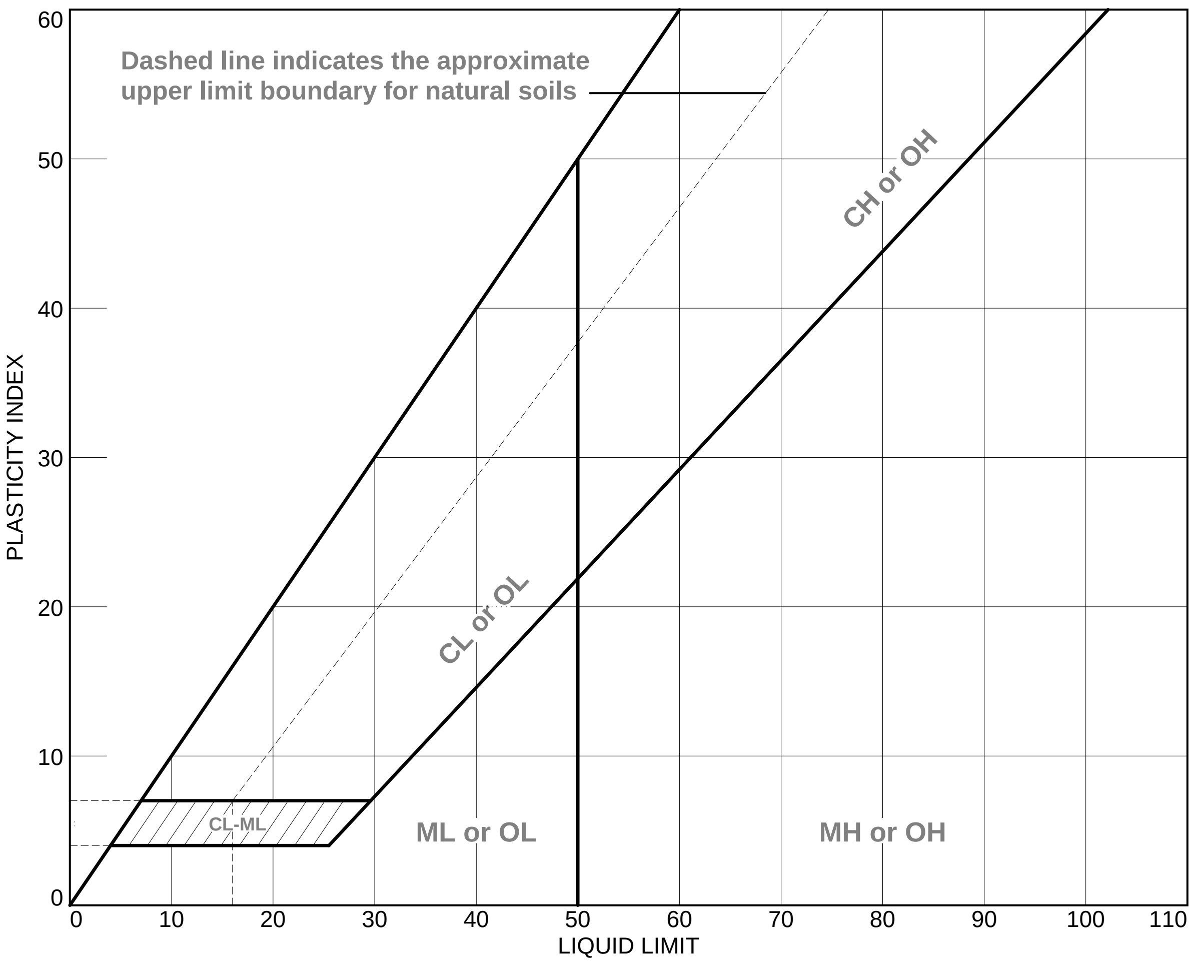
Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	20.92	20.92	20.92		
Dry+Tare	19.42	19.42	19.42		
Tare	13.69	13.69	13.69		
Moisture	26.2	26.2	26.2		

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
323.5	239.2	15.6	37.7

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA								
SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G025 S-4A 15'-16.5'	7995-12	15'-16.5'	215.9		NV		PT

NV = No Value
Note: Indeterminate result due to peat structure preventing reliable test results.

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicative of apparently identical samples.

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

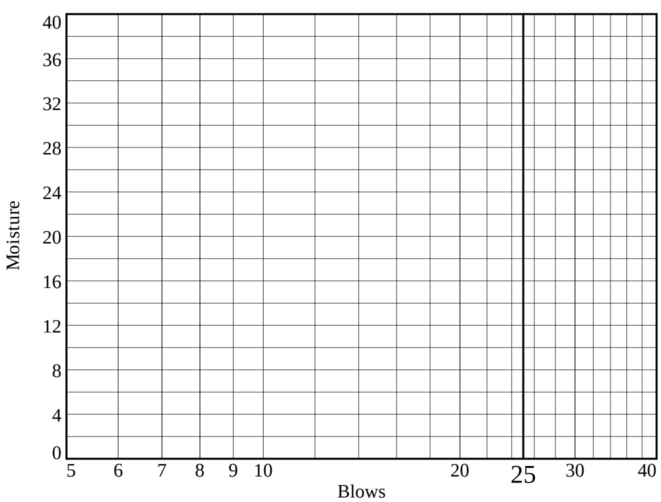
LIQUID AND PLASTIC LIMIT TEST DATA

3/12/2018

Client: Golder Associates
Project: ST-DRLE
Project Number: 1657705/17-940
Location: G025 S-4A
Depth: 15'-16.5' **Sample Number:** 7995-12
Material Description: Peat
USCS: NA
Tested by: BH **Checked by:** JAM

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare						
Dry+Tare						
Tare						
# Blows						
Moisture						

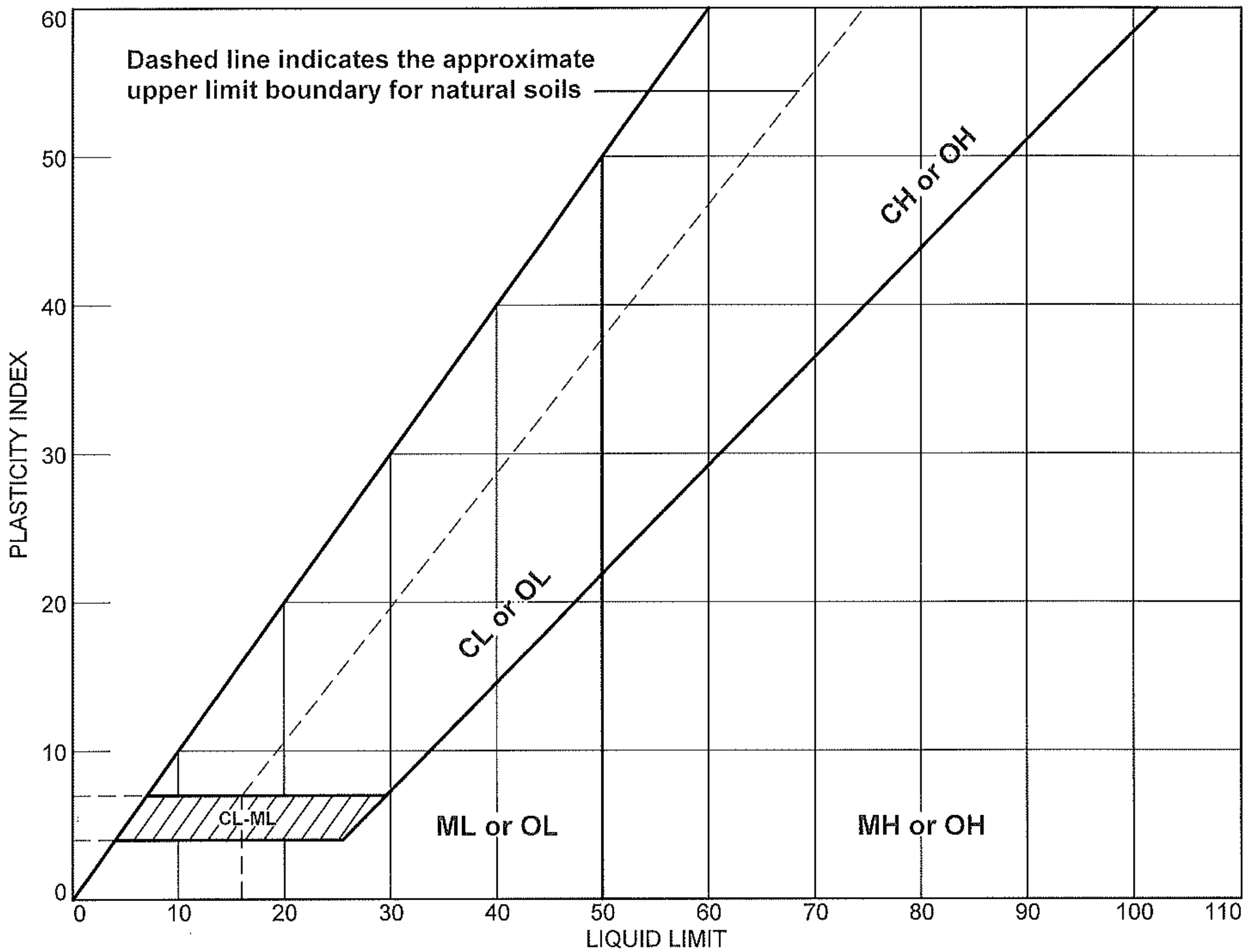


Liquid Limit= NV
Plastic Limit=
Plasticity Index=
Natural Moisture= 215.9

Natural Moisture Data

Wet+Tare	Dry+Tare	Tare	Moisture
260.1	93.0	15.6	215.9

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	G031 S-1 2.5'-4.0'	7995-28	2.5'-4.0'	14.3	NP	NV	NP	

Hayre McElroy & Associates, LLC

Redmond, WA

Client: Golder Associates
Project: ST-DRLE
Project No.: 1657705/17-940 **Figure**

Tested By: BH **Checked By:** JAM

hayremcelroy & associates, llc

ORGANIC CONTENT

ASTM D 2974

Project Name	ST-DRLE
Project Number	1657705
Date Tested	3/8/2018
HMA Lab #	G023 S2 5-6.5'
Material Description	Peat

Total Wet Wt + Tare	143.5 grams
Total Oven Dried Wt + Tare	128.4 grams
Wt of Tare	117.7 grams
Moisture Loss	15.1 grams
Moisture Content	140.7 %

BURN No.	Tare + Dry Weight
1	124.47
2	124.03
3	124.03
4	
5	

Total Oven Dried Wt + Tare	128.4 grams
Total Ash/Soil Wt + Tare	124.0 grams
Wt of Tare	117.7 grams
Ash Content	4.4 grams
Percentage Ash Content	**68.9 %**

APPENDIX H

LABORATORY TESTS – SOIL TESTING (HWA GEOSCIENCES INC.)

November 13, 2017
HWA Project No. 2012-095-23 T1200

Golder Associates Inc.
18300 Union Hill Road, Suite 200
Redmond, Washington 98052

Attention: Mr. Birkan Bayrak, Ph.D., P.E.

Subject: **SOIL LABORATORY TESTING REPORT**
Atterberg Limits, Consolidation and Triaxial Strength Testing
Sound Transit Redmond East Link Extension
Golder Project No. 1657705

Dear Mr. Bayrak;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the above referenced project. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE DESCRIPTION: The samples were delivered to our laboratory on October 25, 2017 by Golder Associates personnel. The samples were delivered in Shelby tubes designated with exploration ID, sample number and depth of sampling. The Shelby tubes were extruded and tests were ordered by the client based on photographic information. The samples were classified for engineering purposes in general accordance with ASTM D2487. The sample descriptions appear on the attached report Figures.

LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ATTERBERG LIMITS): Six selected samples were tested using method ASTM D 4318, multi-point method. The results are reported on the attached Liquid Limit, Plastic Limit, and Plasticity Index report, Figure 1.

UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION OF SOILS: The unconsolidated, undrained strength of the selected samples were tested in general accordance with method ASTM D2850 to determine the strength characteristics of the soil. Each sample was extruded from the sample tube and a representative section was cut from the sample. The sample ends were trimmed to obtain a cylindrical test sample with a length to diameter ratio between 2:1 and 2.5:1. The bulk density of the sample was determined by careful weighing and dimensional measurement of the trimmed sample. The confining stresses used are indicated on the test plots. The results are summarized and plotted graphically on the attached Unconsolidated Undrained Triaxial Compression Test for Cohesive Soils reports, Figures 2-7.

ONE DIMENSIONAL CONSOLIDATION PROPERTIES OF SOIL: The consolidation properties of selected soil samples were measured in general accordance with ASTM D2435. Saturation was maintained by inundation of the sample throughout the test. The samples were subjected to increasing increments of total stress, the duration of which was selected to exceed the time required for completion of primary consolidation as defined in the Standard, Method B. Unloading of the sample was carried out incrementally. According to the client's instructions, the samples were also subjected to a reloading cycle after the initial load-unload cycle. The test results are presented on the attached Figures 8-13.

CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report, except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

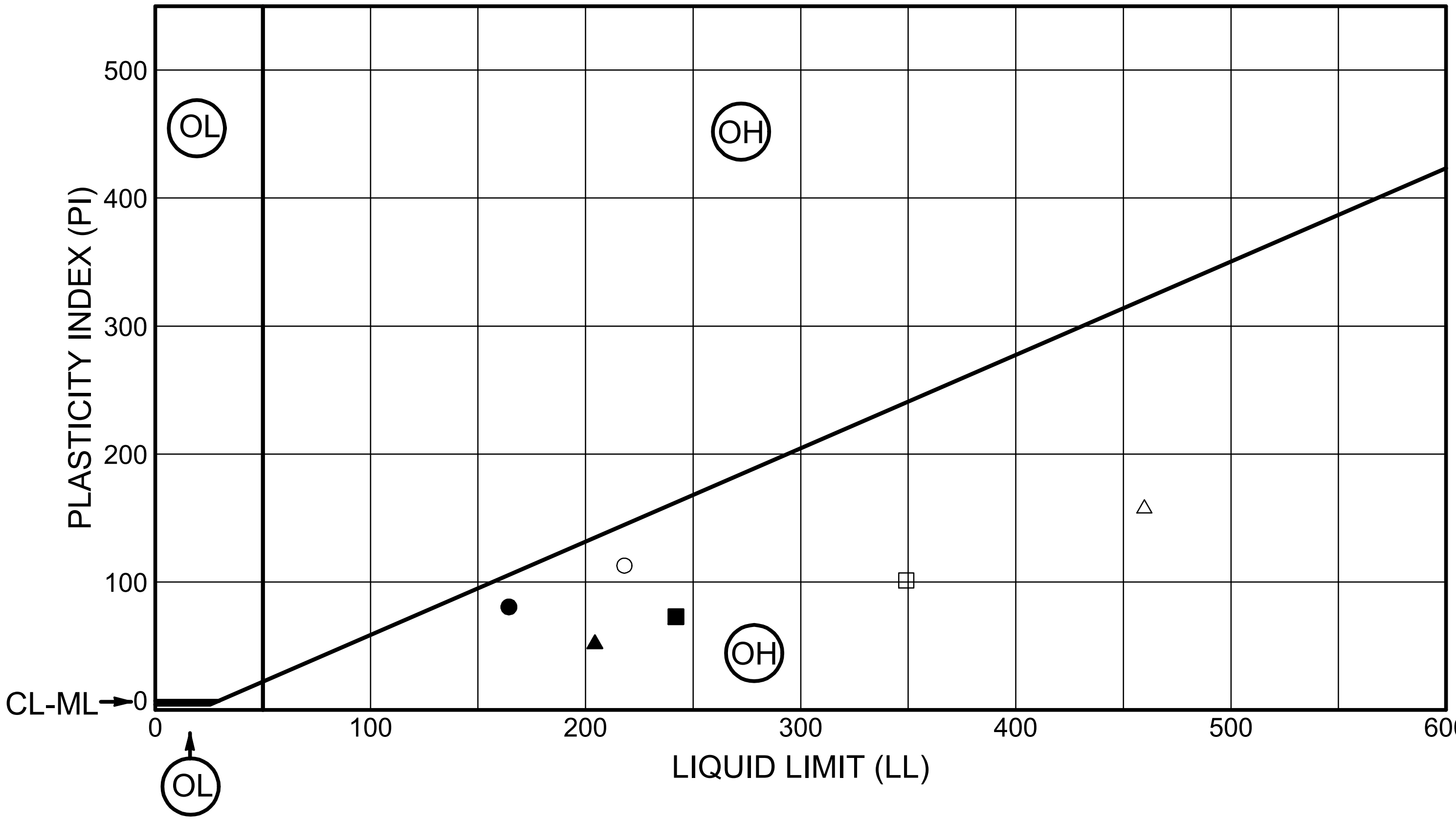
HWA GEOSCIENCES INC.

Daniel Walton
Laboratory Supervisor

Steven E. Greene, L.G., L.E.G.
Principal Engineering Geologist
Vice President

Attachments:

Figure 1	Liquid Limit, Plastic Limit and Plasticity Index of Soils
Figures 2-7	Unconsolidated-Undrained Compression Test for Cohesive Soils
Figures 8-13	One Dimensional Consolidation of Soils



SYMBOL	SAMPLE		DEPTH (ft)	CLASSIFICATION	% MC	LL	PL	PI	% Fines
●	G023B	UU-TX1	5.0 - 5.5	(OH) Very dark brown, organic SILT	163	164	84	80	
■	G023B	UU-TX2	5.5 - 6.0	(OH) Very dark brown, organic SILT	158	242	169	73	
▲	G024	UU-TX3	12.5 - 13.0	(OH) Dark brown, organic SILT	95	204	151	53	
○	G025	UU-TX4	12.5 - 13.0	(OH) Dark brown, organic SILT	189	218	105	113	
□	G025	UU-TX5	13.0 - 13.5	(OH) Very dark brown, organic SILT	313	349	248	101	
△	G025	UU-TX6	13.5 - 14.0	(OH) Dark brown, organic SILT	258	460	301	159	

HWA GEOSCIENCES INC.

MLT for Golder Associates Inc.
Redmond East Link Extension

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS METHOD ASTM D4318

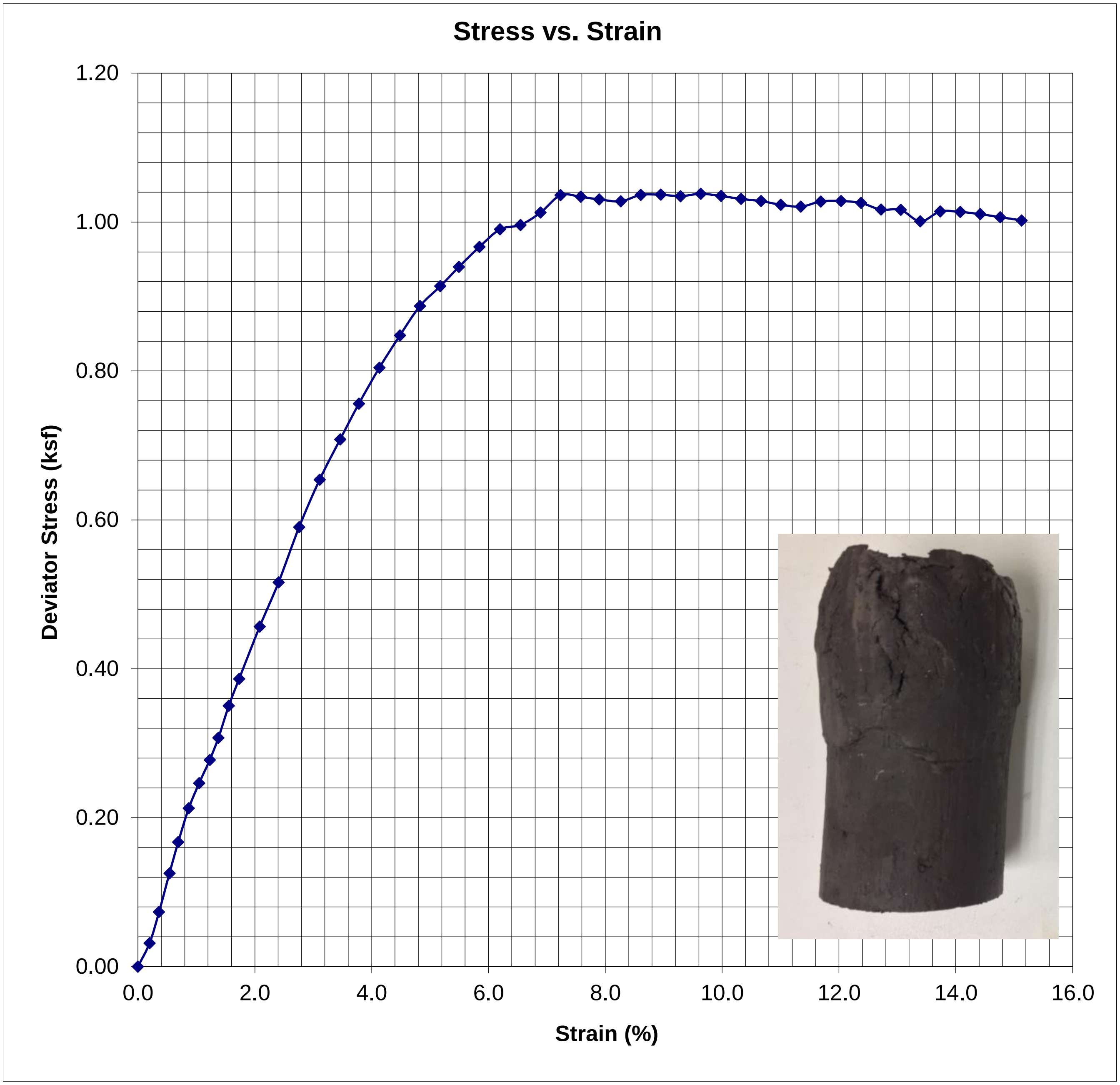
PROJECT NO.: 2012-095 T1200 FIGURE: 1

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Very dark brown, organic SILT (OH)		
Sample Point:	G023B		
Sample Number:	ST-2 (UU-TX1)	Initial Moisture Content (%):	163.1
Sample Depth:	5-5.5 feet	Wet Unit Weight (pcf):	85.7
Confining Stress (ksf):	0.60	Dry Unit Weight (pcf):	32.6
Strain Rate (%\min):	0.85	Total Peak Stress (ksf):	1.038

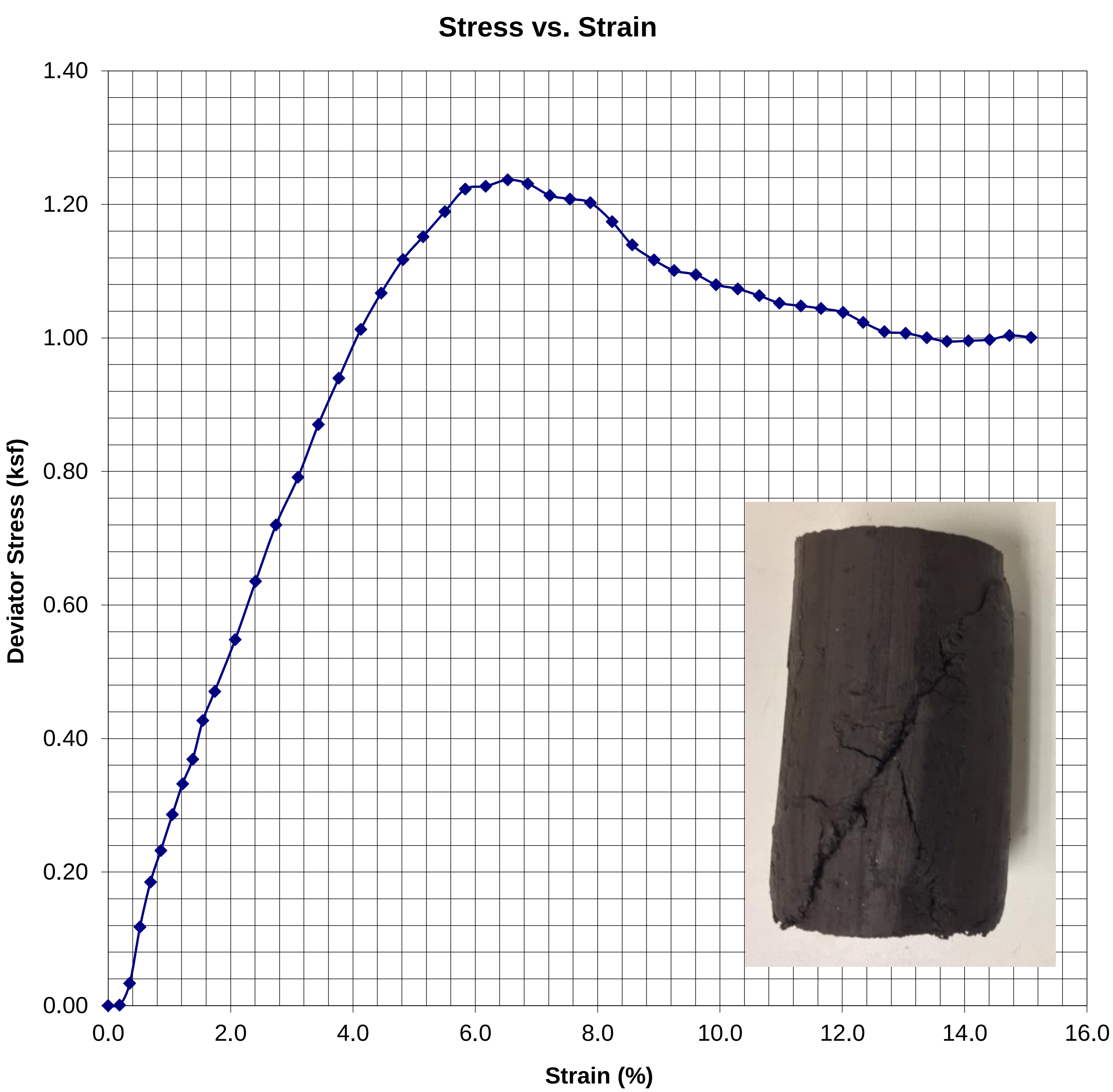
Figure No.: 2

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Very dark brown, organic SILT (OH)		
Sample Point:	G023B		
Sample Number:	ST-2 (UU-TX2)	Initial Moisture Content (%):	157.7
Sample Depth:	5.5-6.0 feet	Wet Unit Weight (pcf):	77.3
Confining Stress (ksf):	0.71	Dry Unit Weight (pcf):	30.0
Strain Rate (%\min):	0.85	Total Peak Stress (ksf):	1.237

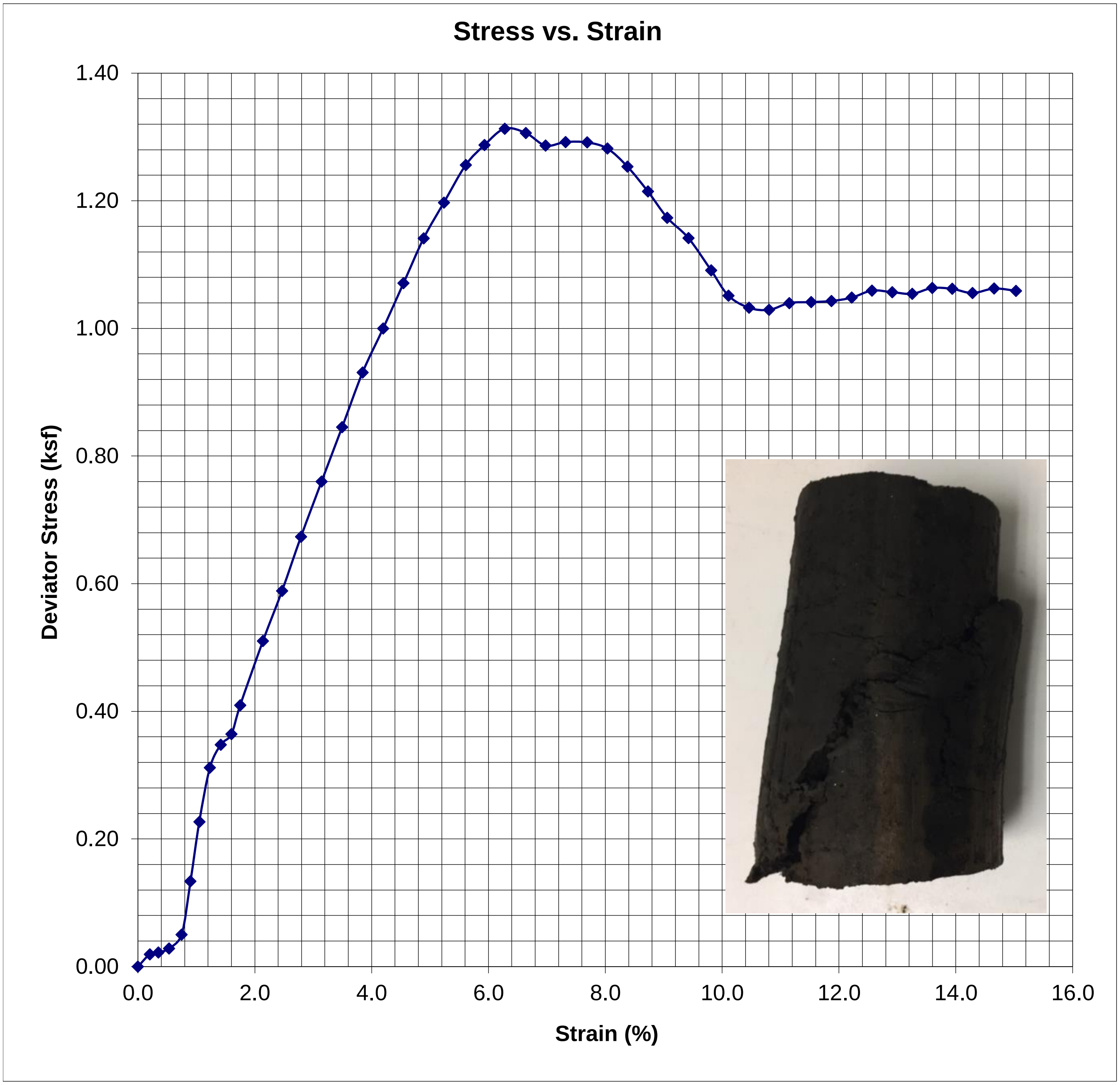
Figure No.: 3

HWA GeoSciences Inc. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Dark brown, organic SILT (OH)		
Sample Point:	G024		
Sample Number:	ST-1 (UU-TX3)	Initial Moisture Content (%):	94.6
Sample Depth:	12.5-13.0 feet	Wet Unit Weight (pcf):	79.5
Confining Stress (ksf):	1.50	Dry Unit Weight (pcf):	40.8
Strain Rate (%\min):	0.85	Total Peak Stress (ksf):	1.313

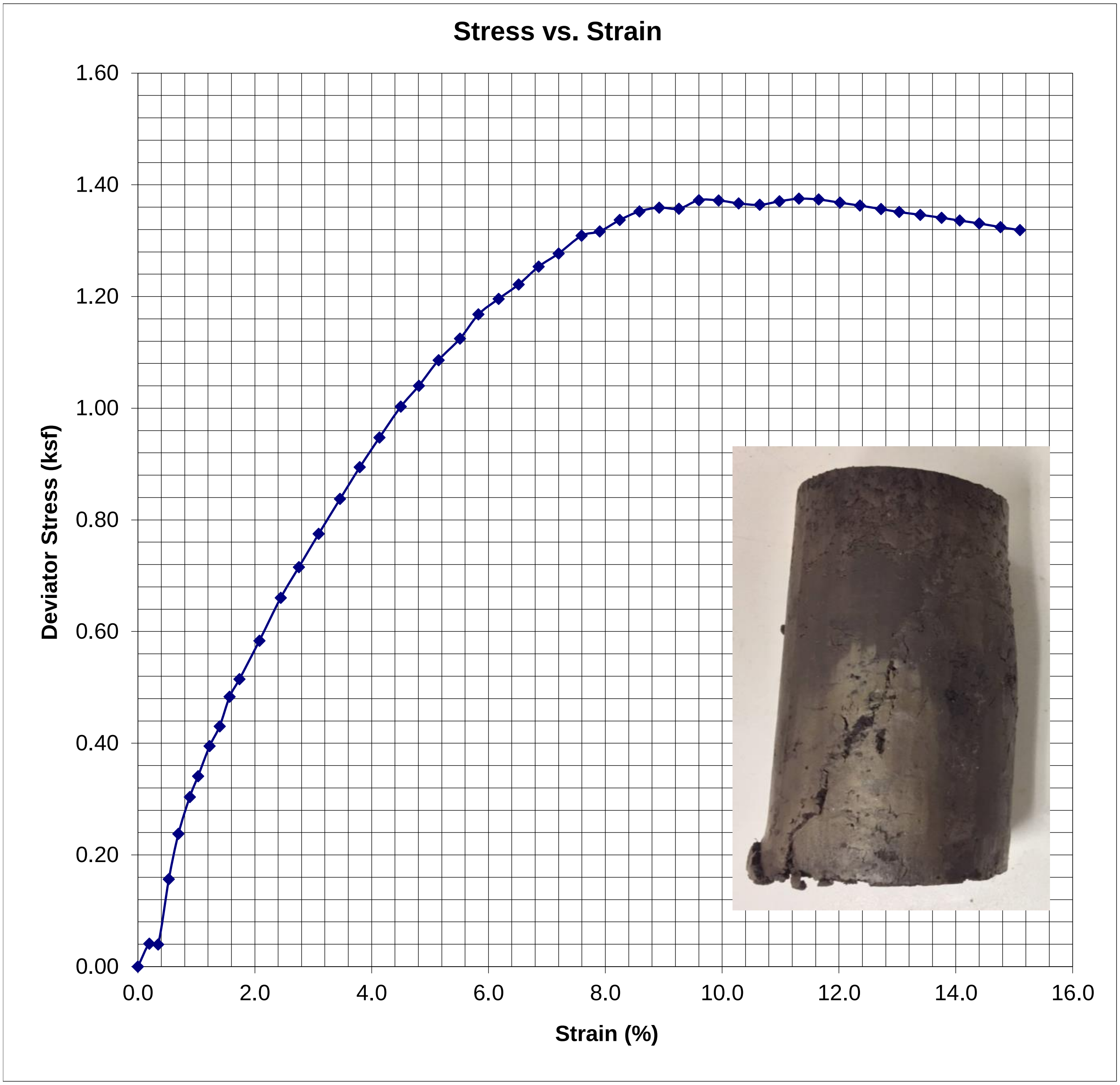
Figure No.: 4

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Dark brown, organic SILT (OH)		
Sample Point:	G025		
Sample Number:	ST-1 (UU-TX4)	Initial Moisture Content (%):	189.4
Sample Depth:	12.5-13.0 feet	Wet Unit Weight (pcf):	79.3
Confining Stress (ksf):	1.50	Dry Unit Weight (pcf):	27.4
Strain Rate (%\min):	0.85	Total Peak Stress (ksf):	1.375

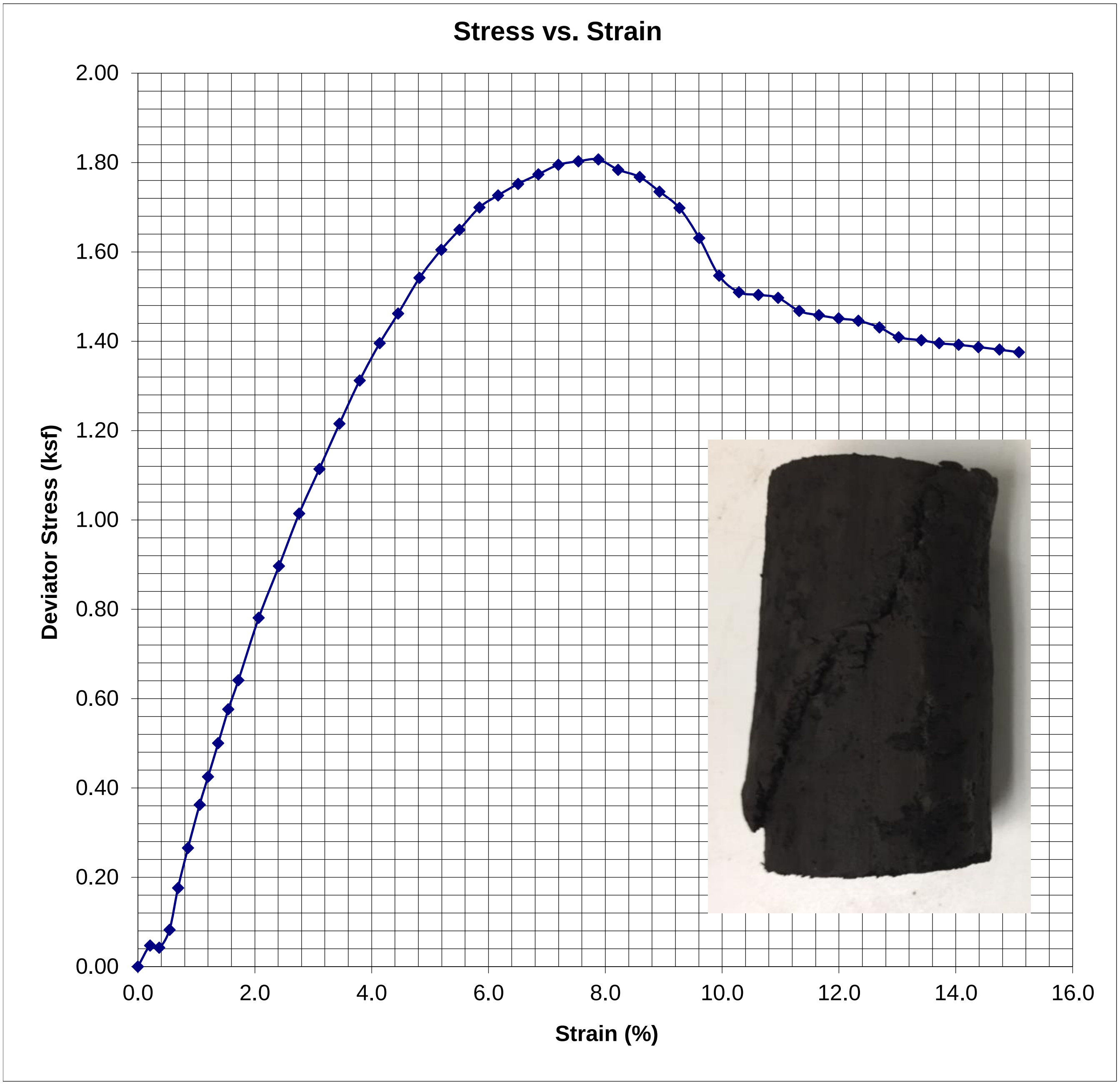
Figure No.: 5

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Very dark brown, organic SILT (OH)		
Sample Point:	G025		
Sample Number:	ST-1 (UU-TX5)	Initial Moisture Content (%):	312.7
Sample Depth:	13.0-13.5 feet	Wet Unit Weight (pcf):	71.0
Confining Stress (ksf):	1.60	Dry Unit Weight (pcf):	17.2
Strain Rate (%\min):	0.85	Total Peak Stress (ksf):	1.807

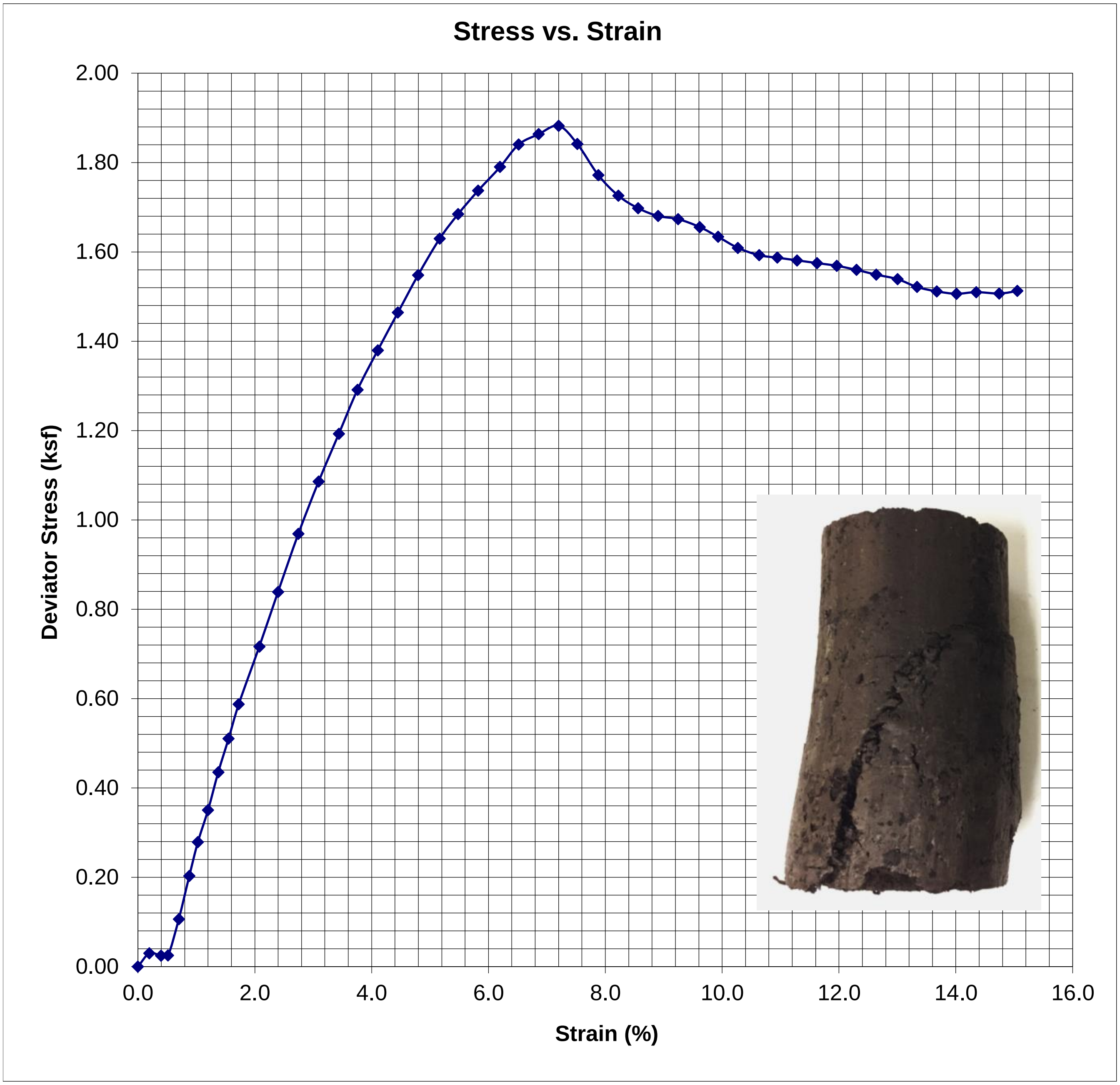
Figure No.: 6

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Very dark brown, organic SILT (OH)		
Sample Point:	G025		
Sample Number:	ST-1 (UU-TX6)	Initial Moisture Content (%):	257.7
Sample Depth:	13.5-14.0 feet	Wet Unit Weight (pcf):	70.0
Confining Stress (ksf):	1.70	Dry Unit Weight (pcf):	19.6
Strain Rate (%\min):	0.85	Total Peak Stress (ksf):	1.882

Figure No.: 7

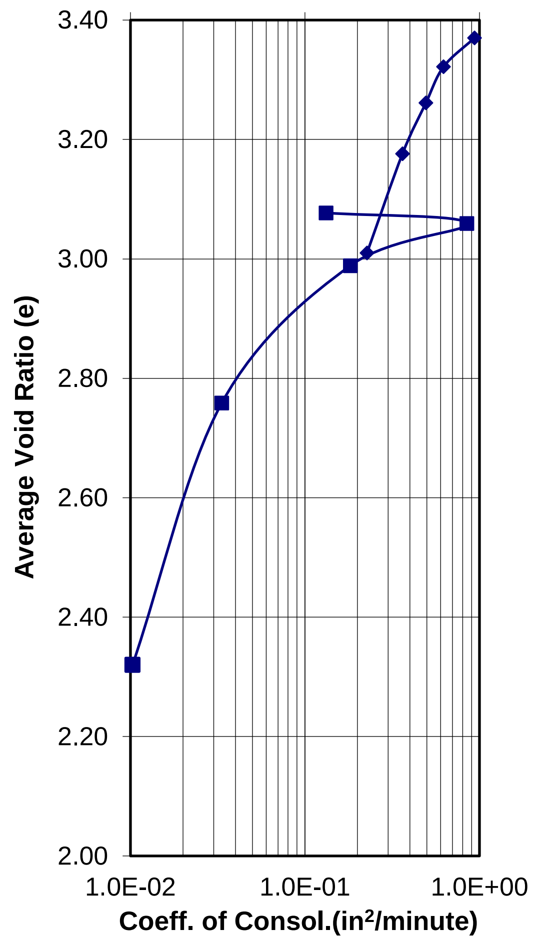
HWA GEOSCIENCES INC.

ONE DIMENSIONAL CONSOLIDATION
ASTM D 2435

Project Name: Golder-Redmond E. Link Ext.
Project Number: 2012-095 T1200
Borehole Number: G023B

Sample Number: ST-2 (Cons.-1)
Sample Depth: 6.0-6.5
Soil Description: Very dark brown, organic SILT (OH)

	Start	Finish	
Moisture Content	187.6	144.8	%
Saturation	96.9	100.4	%
Dry Density	24.0	30.8	pcf



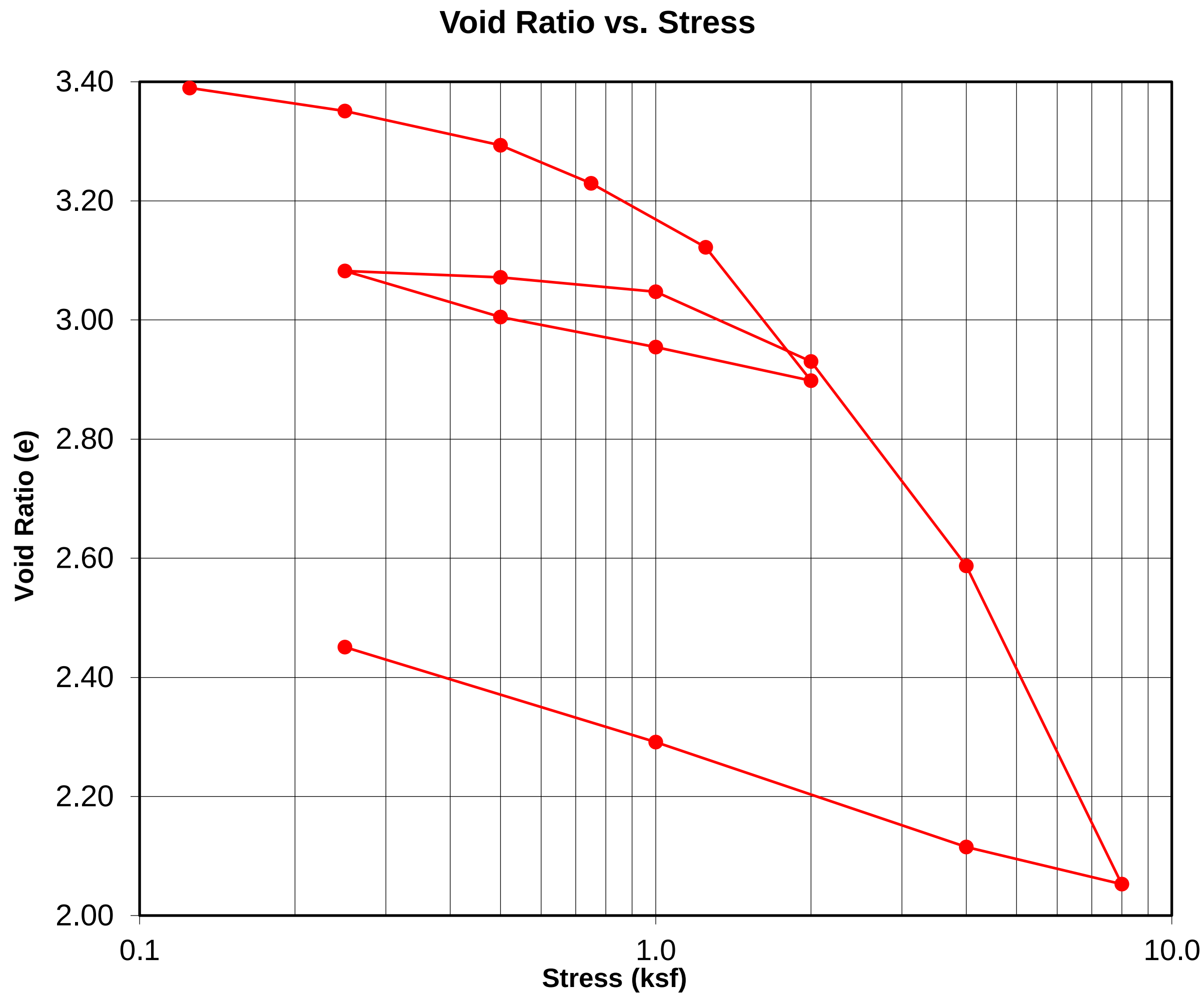
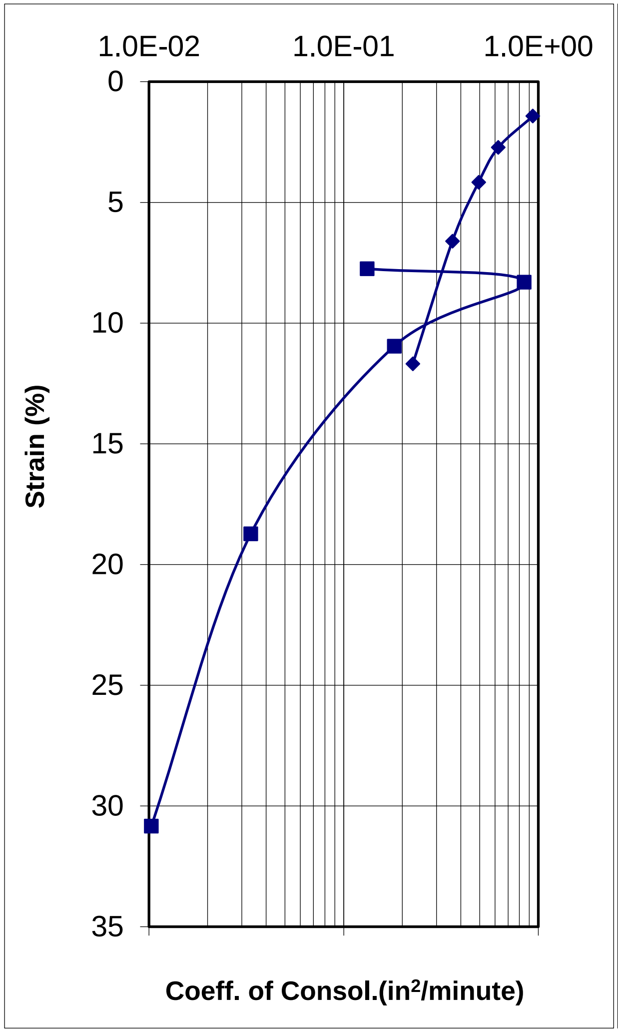


FIGURE 8

HWA GEOSCIENCES INC.

ONE DIMENSIONAL CONSOLIDATION
ASTM D 2435

					Start	Finish	
Project Name:	Golder-Redmond E. Link Ext.	Sample Number:	ST-2 (Cons.-1)	Moisture Content	187.6	144.8	%
Project Number:	2012-095 T1200	Sample Depth:	6.0-6.5	Saturation	96.9	100.4	%
Borehole Number:	G023B	Soil Description:	Very dark brown, organic SILT (OH)	Dry Density	24.0	30.8	pcf



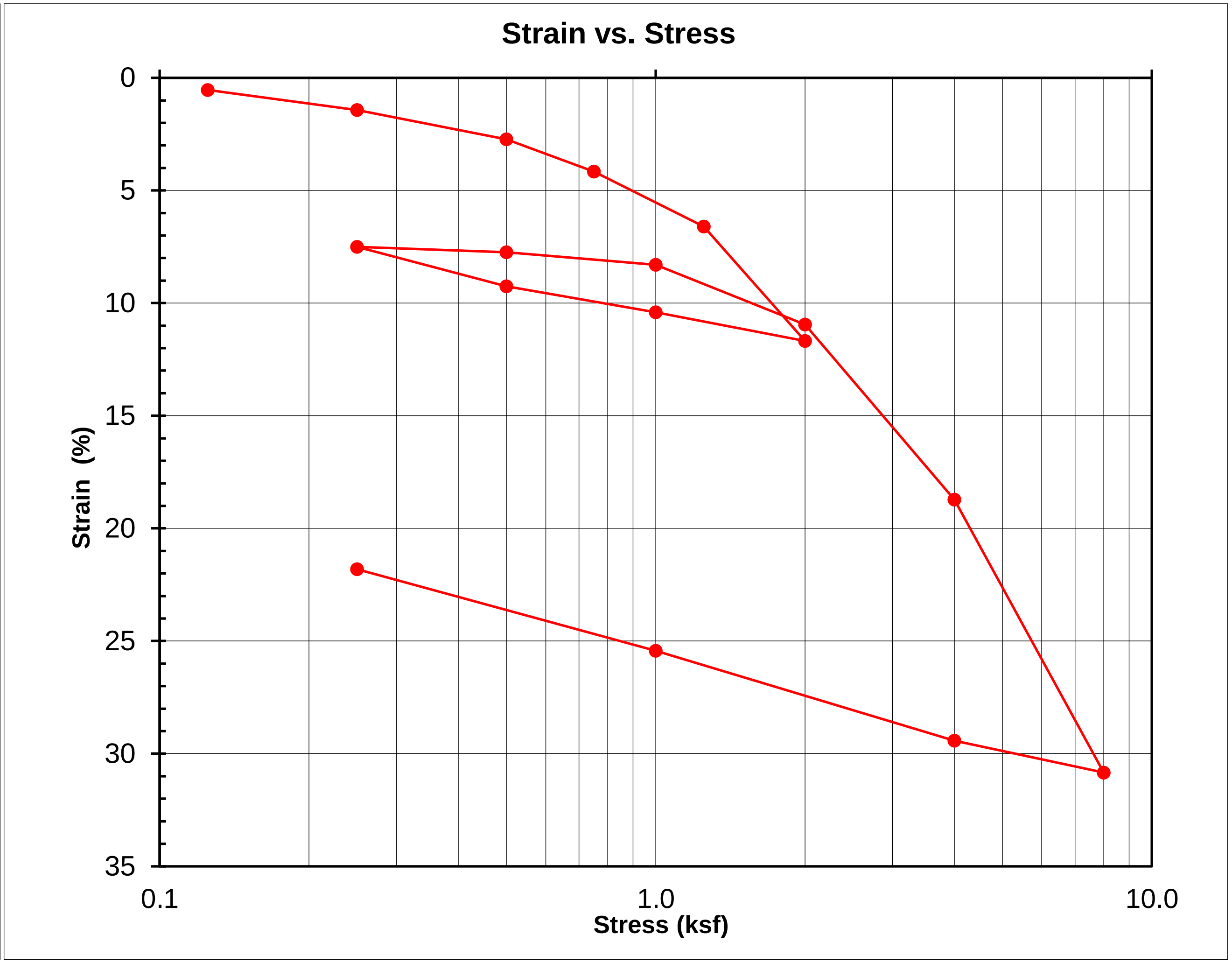
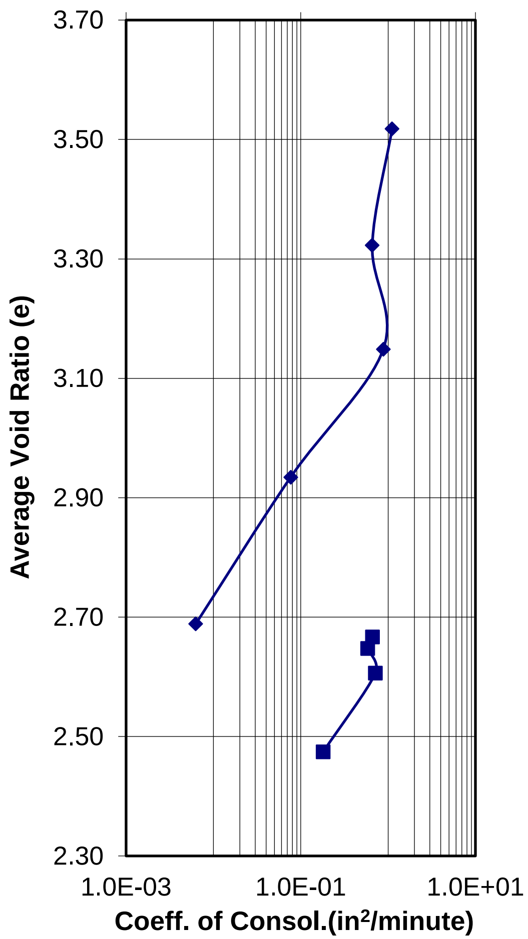


FIGURE 9

HWA GEOSCIENCES INC.

ONE DIMENSIONAL CONSOLIDATION
ASTM D 2435

Project Name:	Golder-Redmond E. Link Ext.	Sample Number:	ST-1 (Cons.-2)		Start	Finish	
Project Number:	2012-095 T1200	Sample Depth:	12.5-14.5	Moisture Content	133.8	136.8	%
Borehole Number:	G024	Soil Description:	Very dark brown, organic SILT (OH)	Saturation	90.9	100.1	%
				Dry Density	25.4	33.0	pcf



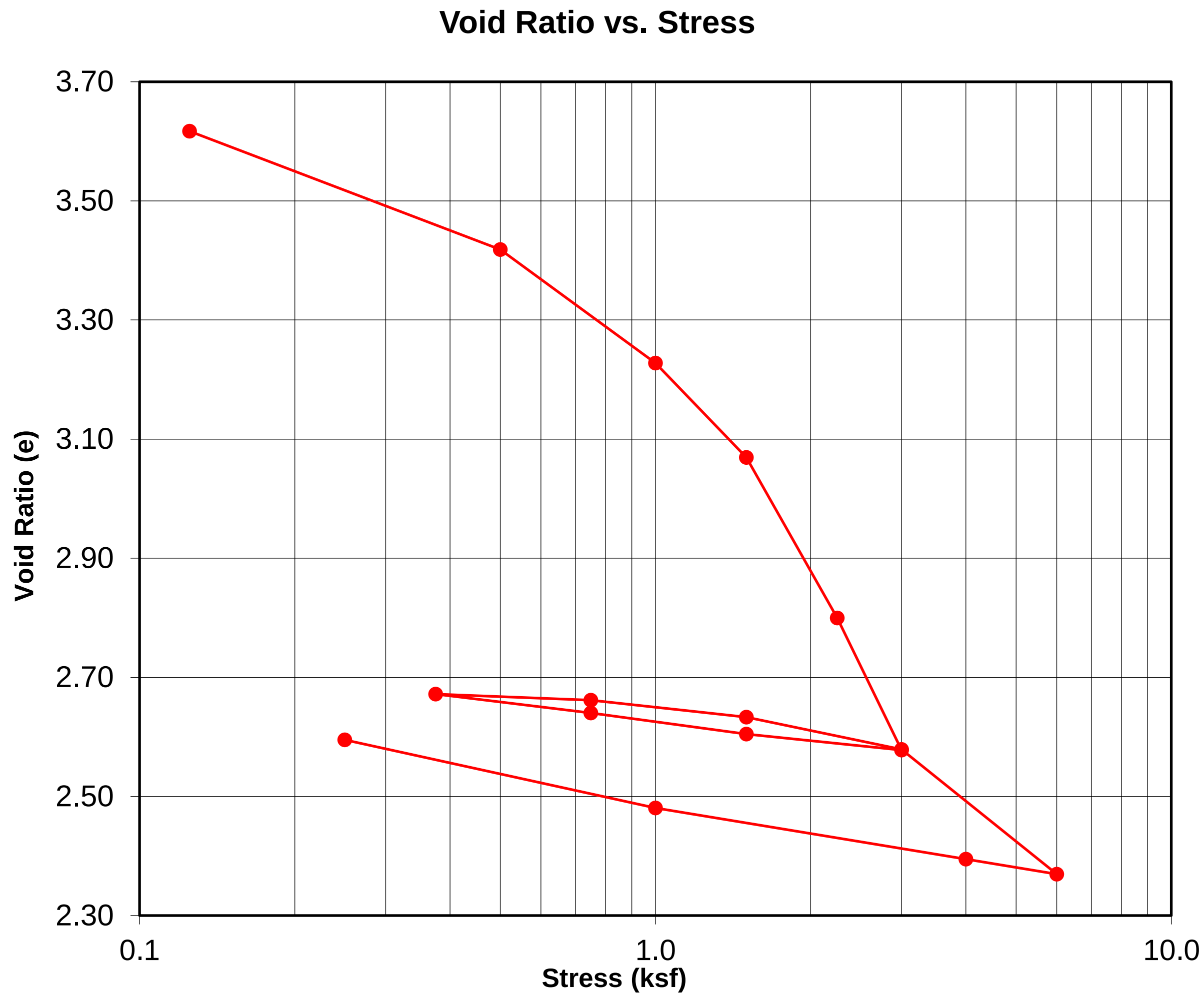


FIGURE 10

HWA GeoSciences Inc.

ONE DIMENSIONAL CONSOLIDATION
ASTM D 2435

					Start	Finish	
Project Name:	Golder-Redmond E. Link Ext.	Sample Number:	ST-1 (Cons.-2)	Moisture Content	133.8	136.8	%
Project Number:	2012-095 T1200	Sample Depth:	12.5-14.5	Saturation	90.9	100.1	%
Borehole Number:	G024	Soil Description:	Very dark brown, organic SILT (OH)	Dry Density	25.4	33.0	pcf

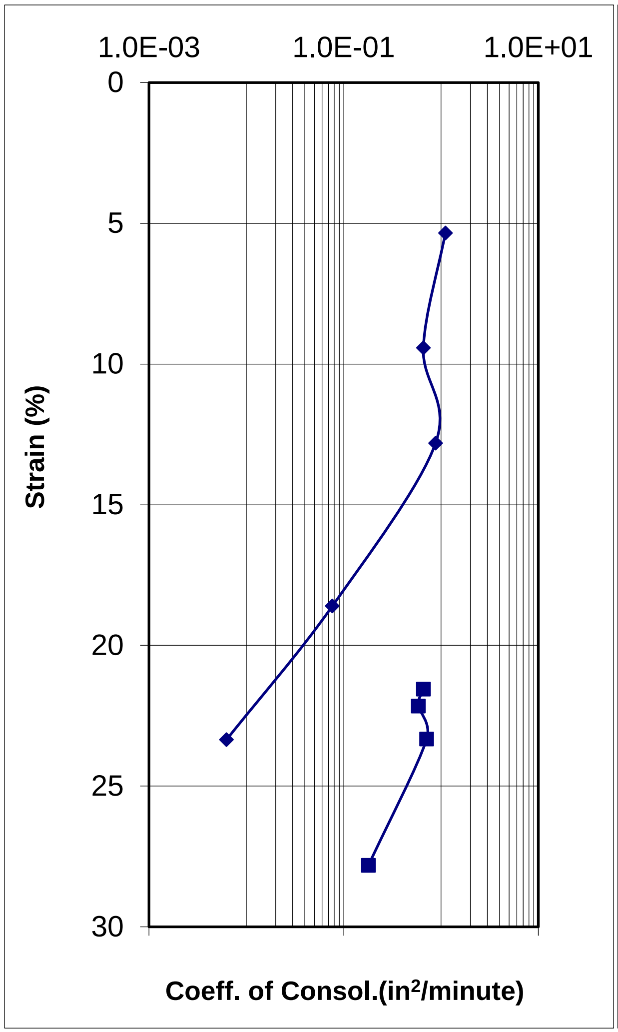
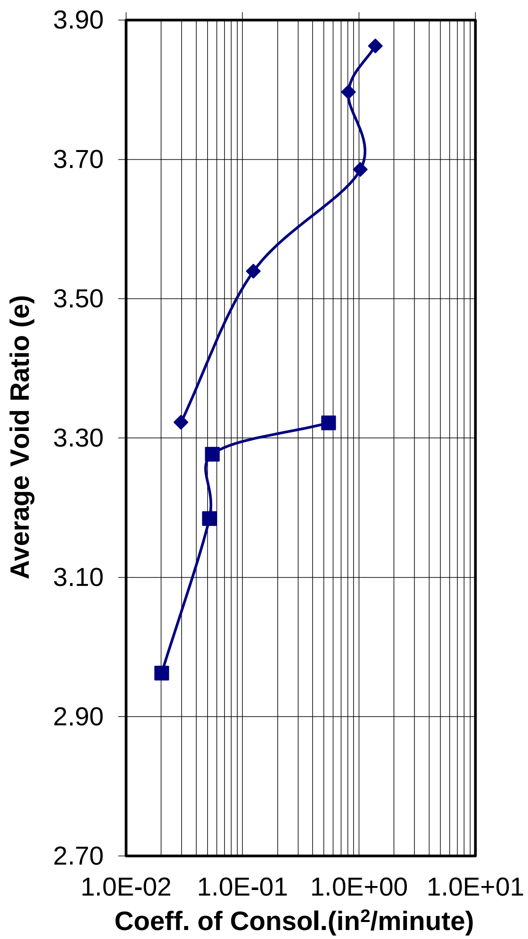


FIGURE 11

HWA GEOSCIENCES INC.

ONE DIMENSIONAL CONSOLIDATION
ASTM D 2435

						Start	Finish	
Project Name:	Golder-Redmond E. Link Ext.	Sample Number:	ST-1 (Cons.-3)		Moisture Content	379.1	321.4	%
Project Number:	2012-095 T1200	Sample Depth:	14.0-14.5		Saturation	102.0	98.5	%
Borehole Number:	G025	Soil Description:	Very dark brown, organic SILT (OH)		Dry Density	12.8	14.6	pcf



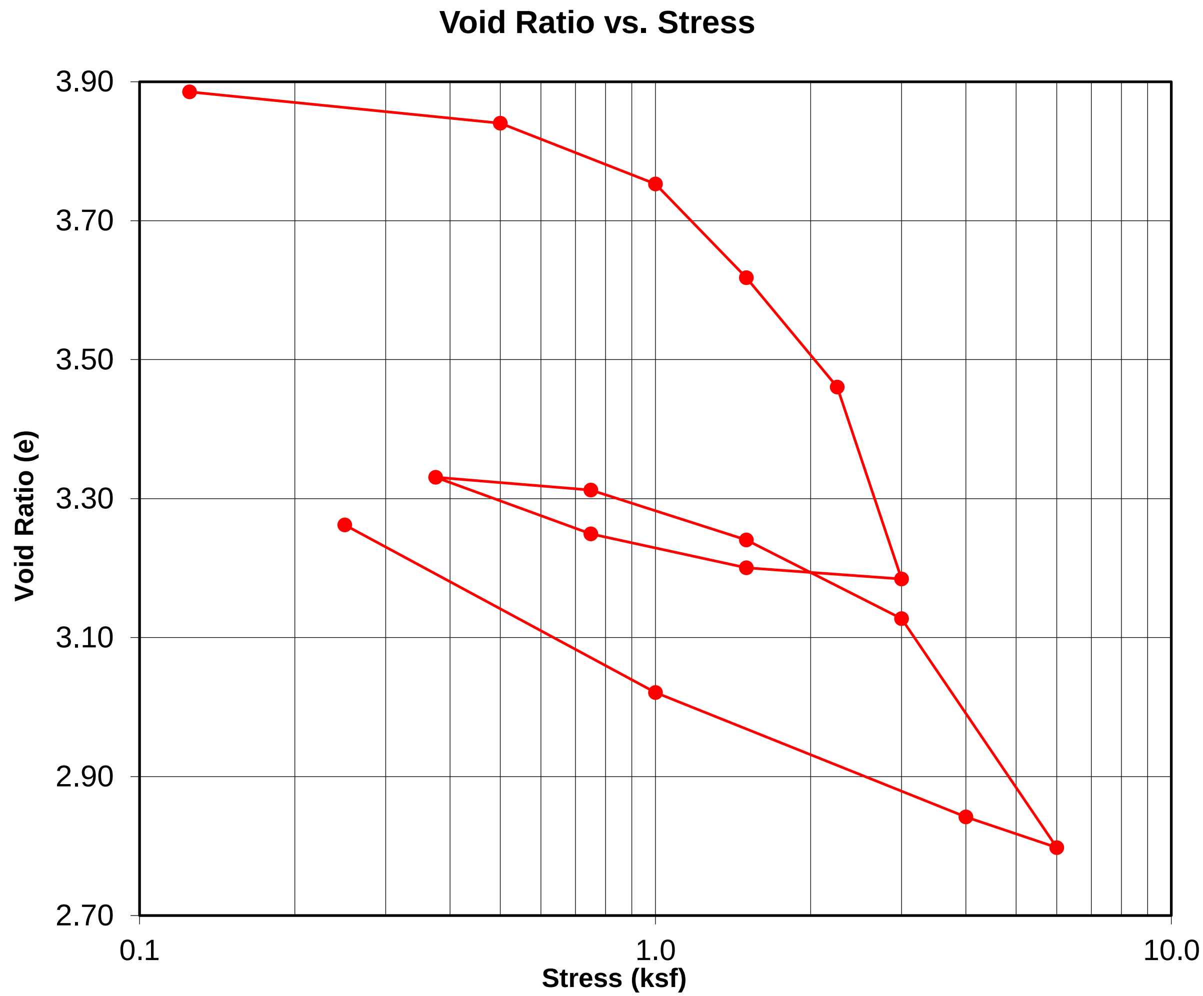


FIGURE 12

HWA GEOSCIENCES INC.

ONE DIMENSIONAL CONSOLIDATION
ASTM D 2435

					Start	Finish	
Project Name:	Golder-Redmond E. Link Ext.	Sample Number:	ST-1 (Cons.-3)	Moisture Content	379.1	321.4	%
Project Number:	2012-095 T1200	Sample Depth:	14.0-14.5	Saturation	102.0	98.5	%
Borehole Number:	G025	Soil Description:	Very dark brown, organic SILT (OH)	Dry Density	12.8	14.6	pcf

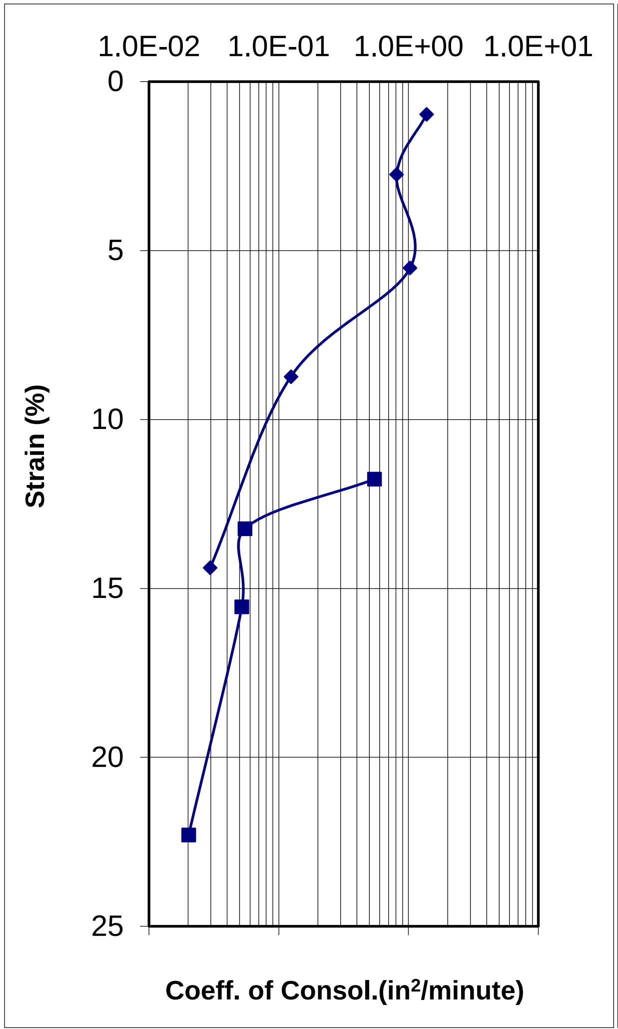


FIGURE 13

HWA GeoSciences Inc.
Geotechnical & Pavement Engineering • Hydrogeology • Geoenvironmental • Inspection & Testing

January 18, 2018
HWA Project No. 2012-095-23 T1200

Golder Associates Inc.
18300 Union Hill Road, Suite 200
Redmond, Washington 98052

Attention: Mr. Birkan Bayrak, Ph.D., P.E.

Subject: **Soil Laboratory Testing Report**
Atterberg Limits, Consolidation and Triaxial Strength Testing
Sound Transit Redmond East Link Extension
Golder Project No. 1657705

Dear Mr. Bayrak;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the above referenced project. Herein we present the results of our laboratory analyses, which are summarized on the attached Figures. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

Sample Description: The samples were delivered to our laboratory on January 11, 2018 by Golder Associates personnel. The samples were delivered in Shelby tubes designated with exploration ID, sample number and depth of sampling. The Shelby tubes were extruded and tests were ordered by the client based on photographic information. The samples were classified for engineering purposes in general accordance with ASTM D2487. The sample descriptions appear on the attached report Figures.

Liquid Limit, Plastic Limit, and Plasticity Index of Soils (Atterberg Limits): Two selected samples were tested in general accordance with ASTM D 4318, multi-point method. The results are reported on the attached Liquid Limit, Plastic Limit, and Plasticity Index report, Figure 1.

One Dimensional Consolidation Properties of Soil: The consolidation properties of selected soil samples were measured in general accordance with ASTM D2435. Saturation was maintained by inundation of the sample throughout the test. The samples were subjected to increasing increments of total stress, the duration of which was selected to exceed the time required for completion of primary consolidation as defined in the Standard, Method B. In accordance with the client's instructions, incremental unloading of the samples was not carried out. The test results are presented on the attached Figures 2-5.

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Bothell, WA 98021-7010
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UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION OF SOILS: The unconsolidated, undrained strength of the selected samples was tested in general accordance with method ASTM D2850 to determine the strength characteristics of the soil. Each sample was extruded from the sample tube and a representative section was cut from the sample. The sample ends were trimmed to obtain a cylindrical test sample with a length to diameter ratio between 2:1 and 2.5:1. The bulk density of the sample was determined by careful weighing and dimensional measurement of the trimmed sample. The confining stresses used are indicated on the test plots. The results are summarized and plotted graphically on the attached Unconsolidated Undrained Triaxial Compression Test for Cohesive Soils reports, Figures 6-9.

CLOSURE: Experience has shown that laboratory test values for soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested sample may represent. HWA also makes no warranty as to how representative either the sample tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance or variance that affect sample representativeness.

No copy should be made of this report, except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Daniel Walton
Laboratory Supervisor

Steven E. Greene, L.G., L.E.G.
Principal Engineering Geologist
Vice President

Attachments:

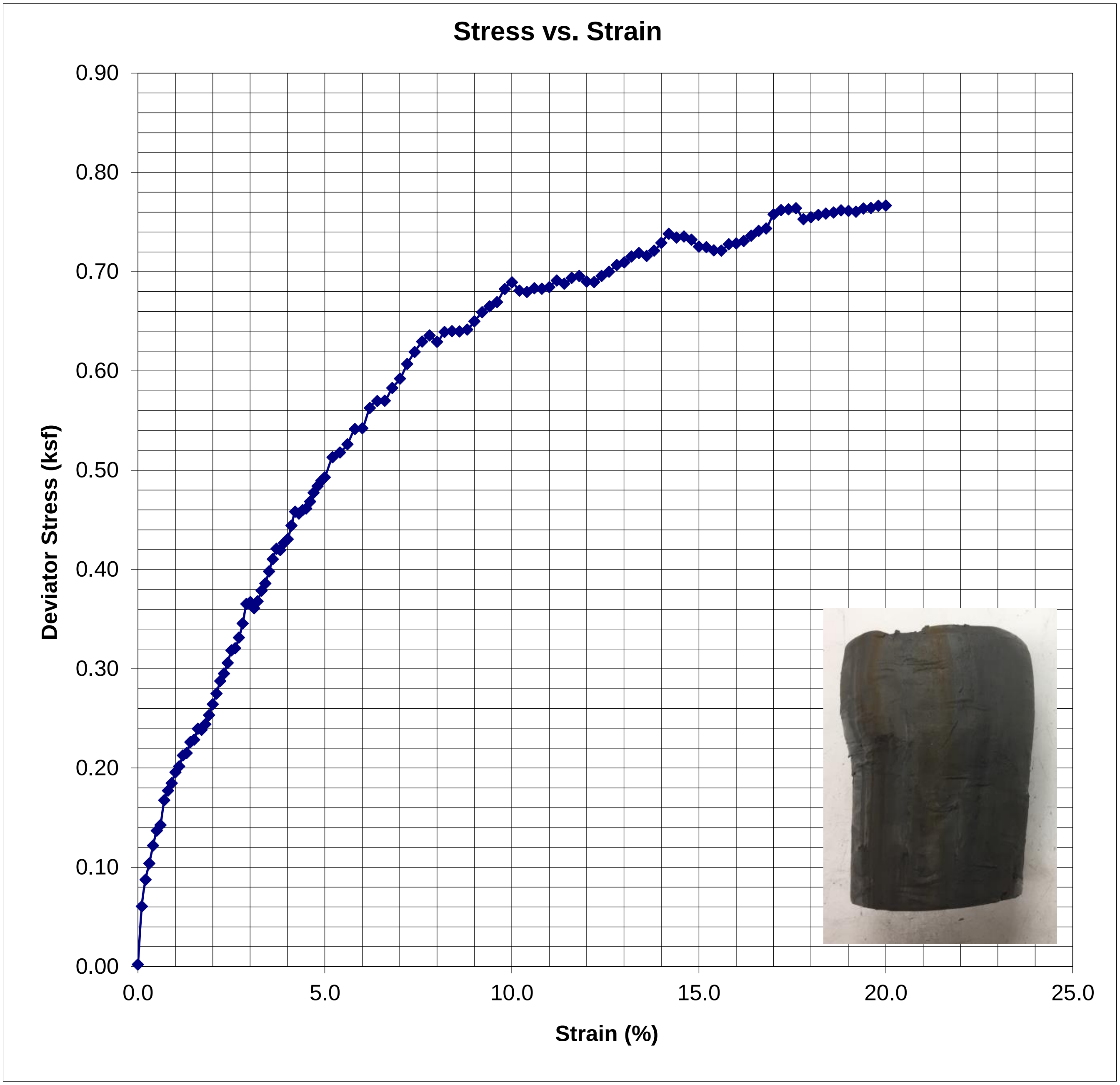
Figure 1	Liquid Limit, Plastic Limit and Plasticity Index of Soils
Figures 2-5	One Dimensional Consolidation of Soils
Figures 6-9	Unconsolidated-Undrained Compression Test for Cohesive Soils

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



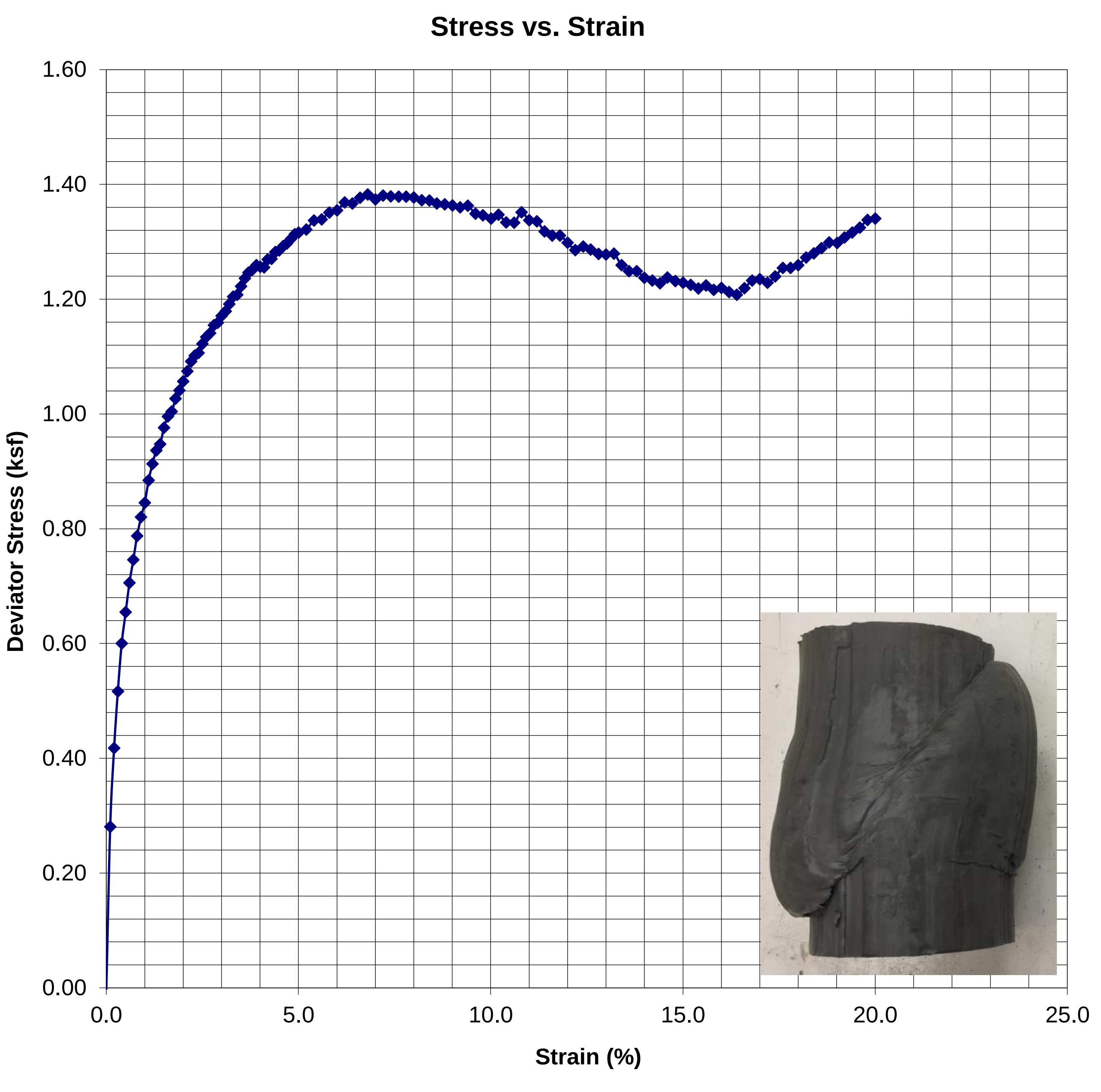
Soil Classification:	Dark gray, lean CLAY (CL)		
Sample Point:	G019		
Sample Number:	ST-2 (UU-TX7)	Initial Moisture Content (%):	37.0
Sample Depth:	126.5-128.5 feet	Wet Unit Weight (pcf):	116.3
Confining Stress (ksf):	15.50	Dry Unit Weight (pcf):	84.9
Strain Rate (%\min):	1.00	Total Peak Stress (ksf):	0.767
		Figure No.:	6

HWA GEOSCIENCES INC. Materials Testing Laboratory

Unconsolidated-Undrained Triaxial Compression Test for Cohesive Soils (ASTM D2850)

Client: Golder Associates, Inc. **Project Number:** 2012-095 T1200

Project Name: Redmond East Link Extension



Soil Classification:	Gray, lean CLAY (CL)		
Sample Point:	G019		
Sample Number:	ST-2 (UU-TX8)	Initial Moisture Content (%):	39.9
Sample Depth:	126.5-128.5 feet	Wet Unit Weight (pcf):	110.2
Confining Stress (ksf):	15.50	Dry Unit Weight (pcf):	78.8
Strain Rate (%\min):	1.00	Total Peak Stress (ksf):	1.382

Figure No.: 7

APPENDIX M

SUPPLEMENTARY DATA – VWP CALIBRATION SHEETS

DRLE-G018

VW Piezometer Calibration Certificate

Serial #: 1701362
Range : 700 kPa
Cable Length: 90 m
Date of Calibration: 4/21/2017

Part #: 52611036
Cable Part # : 50613524
Calibrated by: AM
Note:

ABC Calibration Factors

	A	B	C
kPa	-1.628864E-4	1.666454E-2	1.367978E+3
psi	-2.362468E-5	2.416987E-3	1.984084E+2

Pressure in kPa/psi $= (A \times Hz^2) + (B \times Hz) + C$, where Hz is frequency in Hertz.

TI Calibration Factors

	C0	C1	C2	C3	C4	C5
kPa	1.367340E+3	1.505272E-2	1.647148E-1	-1.626258E-4	2.801698E-5	-2.058106E-3
psi	1.983089E+2	2.183136E-3	2.388902E-2	-2.358605E-5	4.063376E-6	-2.984925E-4

Pressure in kPa/psi $= C0 + (C1 \times Hz) + (C2 \times T) + (C3 \times Hz^2) + (C4 \times Hz \times T) + (C5 \times T^2)$

Where Hz is the frequency reading in Hertz and T is the Thermistor reading in degrees C.
TI factors are calculated from temperatures at 5.0, 15.0 and 25.0 degrees C.
Applied pressure and temperature are NIST traceable.

Summary of Test Results at 15°C

Thermistor reading is 14.8 °C.

Applied Pressure is referenced to 1 atm. Calculated Pressure uses ABC Calibration factors.

Applied (kPa)	Equivalent (psi)	Frequency (Hz)	Calculated (kPa)	Calculated (psi)	Error (%FS)
0.0	0.00	2949.7	-0.1	-0.01	0.01
70.0	10.15	2874.3	70.2	10.18	-0.02
140.0	20.31	2797.3	140.0	20.31	0.00
210.0	30.46	2718.0	209.9	30.45	0.01
280.0	40.61	2636.2	279.9	40.60	0.01
350.0	50.76	2551.7	349.9	50.75	0.01
420.0	60.92	2464.1	420.0	60.92	0.00
490.0	71.07	2373.2	490.1	71.09	-0.02
560.0	81.22	2278.8	560.1	81.24	-0.01
630.0	91.37	2180.3	630.0	91.37	0.00
700.0	101.53	2077.0	699.9	101.51	0.01

DRLE-G020

GEOKON 48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-700 kPa

Date of Calibration: July 10, 2017

This calibration has been verified/validated as of 07/17/2017

Serial Number: 1724158

Temperature: 23.30 °C

Calibration Instruction: VW Pressure Transducers

Barometric Pressure: 993.8 mbar

Cable Length: 110 feet

Technician: Kathy Rogers

Applied Pressure (kPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8702	8702	8702	0.175	0.03	0.041	0.01
140.0	7901	7902	7902	139.9	-0.01	140.0	0.00
280.0	7101	7101	7101	279.7	-0.05	279.8	-0.02
420.0	6298	6298	6298	419.9	-0.02	420.0	0.00
560.0	5494	5495	5495	560.1	0.01	560.2	0.02
700.0	4693	4693	4693	700.1	0.01	699.9	-0.01

(kPa) Linear Gage Factor (G): -0.1746 (kPa/ digit)

Polynomial Gage factors: A: -8.063E-08 B: -0.1735 C: ______

Thermal Factor (K): -0.03237 (kPa/ °C)

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gage Factor (G): -0.02532 (psi/ digit)

Polynomial Gage Factors: A: -1.169E-08 B: -0.02516 C: ______

Thermal Factor (K): -0.004695 (psi/ °C)

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)$*

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$*

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8696 Temperature: 22.2 °C Barometer: 997.2 mbar

The above instrument was found to be in tolerance in all operating ranges

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1

DRLE-G022

GEOKON 48 Spencer St. Lebanon, NH 03766 USA

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-350 kPa

Date of Calibration: July 10, 2017

This calibration has been verified/validated as of 07/17/2017

Serial Number: 1724351

Temperature: 23.20 °C

Calibration Instruction: VW Pressure Transducers

Barometric Pressure: 993.8 mbar

Cable Length: 60 feet

Technician: Kathy Rogers

Applied Pressure (kPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8837	8838	8838	-0.165	-0.05	-0.117	-0.03
70.0	8200	8200	8200	70.15	0.04	70.20	0.06
140.0	7567	7567	7567	140.0	-0.01	140.0	0.00
210.0	6933	6933	6933	209.9	-0.03	210.0	-0.02
280.0	6299	6299	6299	279.8	-0.05	279.9	-0.03
350.0	5663	5663	5663	350.0	0.01	350.0	0.02

(kPa) Linear Gage Factor (G): -0.1103 (kPa/ digit)

Polynomial Gage factors: A: 1.759E-09 B: -0.1103 C: ________

Thermal Factor (K): -0.03869 (kPa/ °C)

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gage Factor (G): -0.01600 (psi/ digit)

Polynomial Gage Factors: A: 2.552E-10 B: -0.01600 C: ________

Thermal Factor (K): -0.005612 (psi/ °C)

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)^*$

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)^*$

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8835 Temperature: 21.9 °C Barometer: 997.2 mbar

The above instrument was found to be in tolerance in all operating ranges.
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1

DRLE-G024

GEOKON 48 Spencer St Lebanon, NH 03766 USA

Vibrating Wire Pressure Transducer Calibration Report

Model Number: 4500S-350 kPa

Date of Calibration: July 10, 2017

This calibration has been verified/validated as of 07/17/2017

Serial Number: 1724352

Temperature: 23.20 °C

Calibration Instruction: VW Pressure Transducers

Barometric Pressure: 993.8 mbar

Cable Length: 60 feet

Technician: Kelly Rogers

Applied Pressure (kPa)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Pressure (Linear)	Error Linear (%FS)	Calculated Pressure (Polynomial)	Error Polynomial (%FS)
0.0	8904	8905	8905	-0.054	-0.01	-0.168	-0.05
70.0	8250	8250	8250	70.23	0.06	70.28	0.08
140.0	7601	7601	7601	139.9	-0.03	140.1	0.01
210.0	6951	6951	6951	209.7	-0.08	209.9	-0.04
280.0	6298	6298	6298	279.8	-0.05	279.9	-0.03
350.0	5643	5643	5643	350.2	0.06	350.1	0.03

(kPa) Linear Gage Factor (G): -0.1074 (kPa/ digit)

Polynomial Gage factors: A: -9.792E-08 B: -0.1060 C: ______

Thermal Factor (K): -0.06684 (kPa/ °C)

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

(psi) Linear Gage Factor (G): -0.01558 (psi/ digit)

Polynomial Gage Factors: A: -1.42E-08 B: -0.01537 C: ______

Thermal Factor (K): -0.009694 (psi/ °C)

Calculate C by setting P=0 and R_1 = initial field zero reading into the polynomial equation

Calculated Pressures:

Linear, $P = G(R_1 - R_0) + K(T_1 - T_0) - (S_1 - S_0)$*

Polynomial, $P = AR_1^2 + BR_1 + C + K(T_1 - T_0) - (S_1 - S_0)$*

*Barometric pressures expressed in kPa or psi. Barometric compensation is not required with vented transducers.

Factory Zero Reading: 8900 Temperature: 21.1 °C Barometer: 997.2 mbar

The above instrument was found to be in tolerance in all operating ranges
The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1

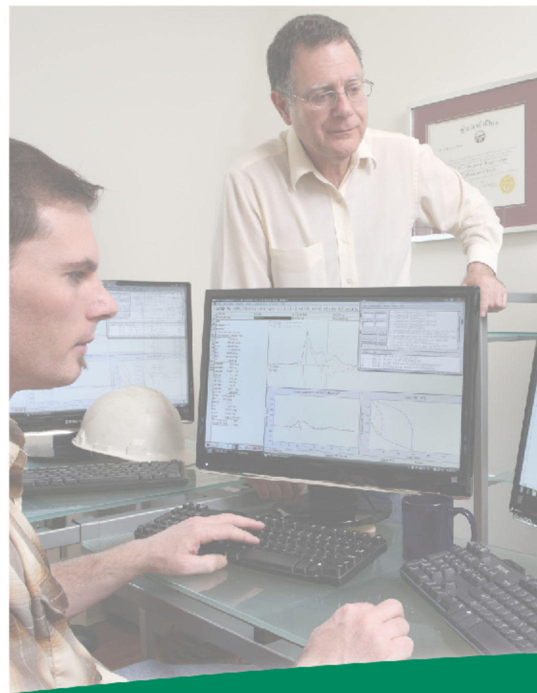
APPENDIX N

SUPPLEMENTARY DATA – DRILL RIG HAMMER EFFICIENCIES

Table N-1: Drill Rig Hammer Efficiencies

Borehole	Subcontractor	Rig Type	Rig Model	ETR	Reference
DRLE-G001	HOLT	Truck	CME-85	90	Report 3, pg 2
DRLE-G002	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G003	HOLT	Truck	CME-85	90	Report 3, pg 2
DRLE-G004	HOLT	Truck	CME-85	90	Report 3, pg 2
DRLE-G005	HOLT	Truck	CME-85	90	Report 3, pg 2
DRLE-G006	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G007	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G008	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G010	HOLT	Truck	Mobile B-59	98	Report 5, pg 3
DRLE-G011	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G012	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G013	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G014	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G015	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G016	Holocene	Truck	CME-850	86.1	Report 1, pg 4
DRLE-G017	Holocene	Track	CME-850	86.1	Report 1, pg 4
DRLE-G017A	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G018	Holocene	Track	CME-850	86.1	Report 1, pg 4
DRLE-G019	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G020	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G021	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G022	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G023	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G023b	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G024	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G025	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G027	HOLT	Truck	CME-85	90	Report 3, pg 2
DRLE-G028	HOLT	Truck	Mobile B-59	98	Report 5, pg 3
DRLE-G029	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G031	HOLT	Truck	Mobile B-58	83	Report 4, pg 2
DRLE-G032	HOLT	Truck	CME-85	90	Report 3, pg 2
DRLE-G033	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G034	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G034A	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G035	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G036	HOLT	Track	Mobile B-54	88.2	Report 6, pg4
DRLE-G036A	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G037	HOLT	Sonic	Terra Sonic CC 150	95	Report 5, pg 5
DRLE-G037A	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G038	Holocene	Truck	Mobile B-58	89.7	Report 2, pg 2
DRLE-G044	Holocene	Track	CME-850	86.1	Report 1, pg 4
DRLE-G045	Holocene	Track	CME-850	86.1	Report 1, pg 4

Report 1
Holocene CME 850



Job No. 176009-1

Report on: SPT Energy Calibration

Prepared for: Holocene Drilling, Inc.

By: Marty Bixler, P.E.
Anna Klesney

April 20, 2017

GRL Dynamic Measurements and Analyses
engineers, inc.

www.GRLengineers.com
info@GRLengineers.com

April 20, 2017

Jon M. Root
Holocene Drilling, Inc.
11412 62nd Ave E.
Puyallup, WA 98373

Re: Energy Measurement for Dynamic Penetrometers
Standard Penetration Tests (SPT)
Various locations, Washington GRL Job No. 176009-1

Dear Mr. Root:

This report transmits our findings from energy measurements and related data analysis conducted by GRL Engineers, Inc. (GRL) for your two drill rigs operating in Kent and Shelton, Washington. Two automatic hammer and penetrometer systems were monitored during Standard Penetration Tests. Dynamic testing summarized in this report was conducted on April 14 and 17, 2017.

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 the appended tables with the average and standard deviation provided in Appendix B together with representative plots of force and normalized velocity.

EQUIPMENT

Hammer and Penetrometer System

Energy measurements were recorded during standard penetration tests conducted for two automatic hammers and the following drill rig types and numbers.

Drill Rig Type	Drill Rig Number
Mobile B-59 (truck rig)	Holocene Rig #74
CME 850 (track rig)	Holocene Rig #31

Measurements were recorded for one boring location for each of the two drill rigs. Holocene Drilling, Inc. advanced the penetrometer to depths of approximately 10 and 15 feet, respectively, prior to energy measurements for the above tabulated rigs. The instrumented subassembly was connected to the top of the drill rod string and measurements recorded at intervals for several depths of data. Selected data is presented in this report.

Measurements were recorded for every blow required to advance the sampler typically 18 inches. Results are provided for the final 12 inches or less of the sampler advancement alone (i.e., excluding the initial 6 inches of advancement). Please refer to ASTM D4633 regarding recommendations on blow counts and instrumented drill rod lengths, as well as other details of the test method.

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

Drill Rod Area sq. inch	Outside Diameter Inch	Inside Diameter inch
1.44	2.63	2.25
Depth of Penetrometer feet	Drill Rod Section Lengths feet	Transducer to Penetrometer Length feet
A	A	A
10.0	13	15
20.0	23	25
35.0	38	40
B	B	B
15.0	16	18
45.0	46	48
50.0	51	53
55.0	56	58
60.0	61	63
70.0	71	73

* A (Mobile B-59 Number 74); B (CME 850 Number 31).

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, was used 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 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 the appended tables. 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., EFV or also referred to as EMX) 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.

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 relevant samples are presented herein.

The tables 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
- EFV – the maximum calculated energy (EMX) transferred to the rod top
- 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.

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

Summary of Results

I. Two automatic hammers were monitored during standard penetration tests conducted on April 14 and 17, 2017. The average energy transfer ratio calculated with the EFV method for the monitored sequences for the drill rigs are tabulated below together with the corresponding, average hammer operating rates.

Drill Rig	Energy Transfer Ratio percent	Operating Rate bpm
Mobile B-59 (Rig #74)	89.5	45.2
CME 850 (Rig #31)	86.1	42.8

II. The uncorrected N-values encountered during the sequences ranged from 28 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 the measurements and monitored depths meeting ASTM requirements are presented in the appended tables. The measured overall energy transfer ratios tabulated above for the respective drill rigs produce a respective N_{60} equivalent of roughly $1.49N_m$ and $1.43N_m$. Further corrections due to overburden stresses in the soil may be made prior to use of the N-values for design purposes.

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.

MARTY G. BIXLER
STATE OF WASHINGTON
51806
REGISTERED
PROFESSIONAL ENGINEER

Marty G. Bixler
4-20-17

Marty G. Bixler, P.E. (Washington #51806)
Senior Engineer

Anna M. Klesney

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

APPENDIX A
AN INTRODUCTION INTO SPT DYNAMIC PILE TESTING

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.

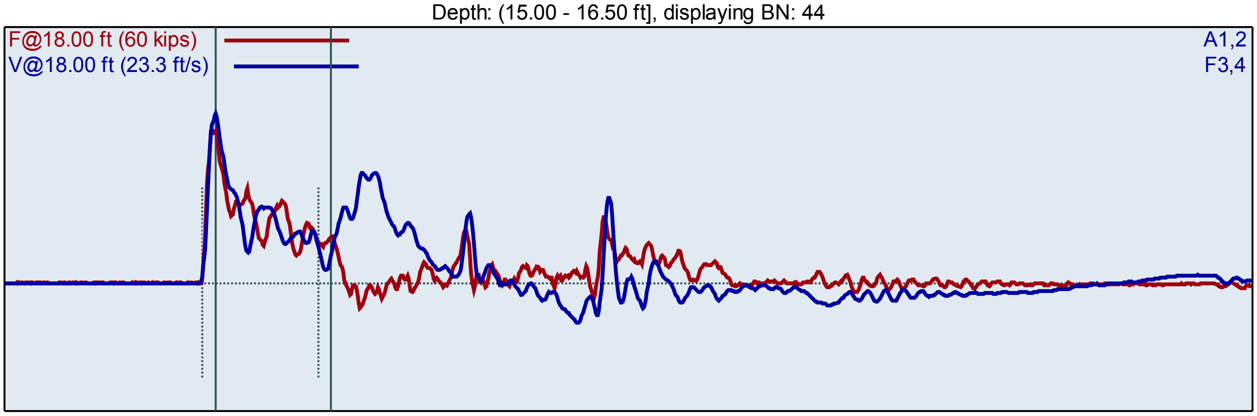
Appendix B

Results of SPT Rig Calibration

CME 850 #31 15
GRL-MGB Test date: 4/17/2017

AR: 1.44 in^2 SP: 0.492 k/ft3
LE: 18.00 ft EM: 30000 ksi
WS: 16807.9 ft/s

Depth: (15.00 - 16.50 ft], displaying BN: 44



FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute
EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	(%)
1	9	15.06	36	14.4	6.9	276.5	79.0
2	9	15.11	38	16.2	37.5	297.4	85.0
3	9	15.17	36	15.3	38.2	288.3	82.4
4	9	15.22	38	15.9	38.4	297.5	85.0
5	9	15.28	39	16.3	38.3	306.7	87.6
6	9	15.33	38	15.8	38.5	298.2	85.2
7	9	15.39	37	15.1	38.6	289.3	82.7
8	9	15.44	38	16.4	38.8	299.3	85.5
9	9	15.50	38	16.3	38.7	301.1	86.0
10	13	15.54	36	15.5	38.7	294.1	84.0
11	13	15.58	38	16.2	38.8	300.6	85.9
12	13	15.62	36	15.3	38.8	290.4	83.0
13	13	15.65	36	15.4	39.0	291.7	83.3
14	13	15.69	38	16.1	38.9	303.5	86.7
15	13	15.73	39	16.2	39.0	305.4	87.3
16	13	15.77	39	16.3	39.0	302.4	86.4
17	13	15.81	37	15.6	38.9	296.6	84.7
18	13	15.85	38	15.9	39.0	302.4	86.4
19	13	15.88	39	16.1	39.2	306.9	87.7
20	13	15.92	38	15.7	39.0	297.1	84.9
21	13	15.96	37	15.6	39.2	296.3	84.7
22	13	16.00	37	15.5	39.0	299.4	85.5
23	24	16.02	36	16.0	39.0	295.8	84.5
24	24	16.04	37	15.4	39.1	300.7	85.9
25	24	16.06	38	16.2	39.0	305.8	87.4
26	24	16.08	37	15.9	39.2	300.3	85.8
27	24	16.10	37	15.6	39.1	300.3	85.8
28	24	16.13	37	15.6	39.3	296.8	84.8
29	24	16.15	38	15.7	39.2	302.9	86.5
30	24	16.17	36	15.9	39.1	301.0	86.0
31	24	16.19	37	15.9	39.2	302.6	86.5
32	24	16.21	37	15.8	39.1	305.4	87.2
33	24	16.23	38	15.7	39.1	300.9	86.0

34	24	16.25	38	15.7	39.1	302.4	86.4
35	24	16.27	37	15.6	39.4	299.9	85.7
36	24	16.29	39	16.0	38.9	301.2	86.0
37	24	16.31	39	16.1	39.0	305.6	87.3
38	24	16.33	36	15.1	39.1	297.8	85.1
39	24	16.35	37	15.4	39.0	298.3	85.2
40	24	16.38	37	15.6	38.9	303.3	86.7
41	24	16.40	37	15.5	38.9	303.1	86.6
42	24	16.42	37	15.4	39.0	302.6	86.4
43	24	16.44	39	16.3	38.9	306.2	87.5
44	24	16.46	36	15.4	38.9	300.6	85.9
45	24	16.48	36	15.0	39.1	291.2	83.2
46	24	16.50	38	15.9	38.9	304.8	87.1
		Average	37	15.7	39.0	300.4	85.8
		Std Dev	1	0.3	0.1	4.2	1.2
		Maximum	39	16.3	39.4	306.9	87.7
		Minimum	36	15.0	38.7	290.4	83.0

N-value: 37

Sample Interval Time: 69.42 seconds.

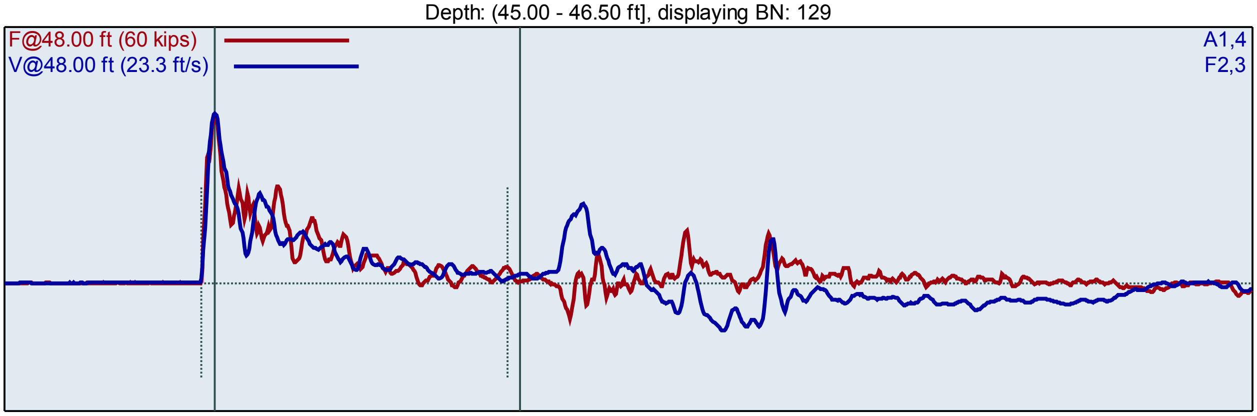
CME 850 #31
GRL-MGB

15
Test date: 4/17/2017

AR: 1.44 in^2
LE: 48.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (45.00 - 46.50 ft], displaying BN: 129



BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	(%)
47	16	45.03	35	13.8	19.6	277.9	79.4
48	16	45.06	35	14.8	40.5	297.5	85.0
49	16	45.09	35	14.6	41.2	299.1	85.5
50	16	45.13	37	14.8	41.6	301.7	86.2
51	16	45.16	37	14.5	41.6	300.6	85.9
52	16	45.19	38	15.0	41.6	298.6	85.3
53	16	45.22	37	14.4	41.8	289.4	82.7
54	16	45.25	39	14.9	41.8	300.4	85.8
55	16	45.28	37	14.5	42.0	287.1	82.0
56	16	45.31	37	15.0	41.8	294.0	84.0
57	16	45.34	38	14.6	41.9	287.8	82.2
58	16	45.38	38	14.6	41.8	293.0	83.7
59	16	45.41	36	14.3	41.9	279.6	79.9
60	16	45.44	37	14.2	42.0	281.8	80.5
61	16	45.47	38	14.4	41.7	289.5	82.7
62	16	45.50	39	14.7	42.0	291.4	83.2
63	33	45.52	37	14.1	41.6	293.0	83.7
64	33	45.53	37	14.0	41.9	285.4	81.5
65	33	45.55	39	14.6	41.9	300.1	85.7
66	33	45.56	38	14.4	41.8	288.3	82.4
67	33	45.58	36	13.9	42.0	280.8	80.2
68	33	45.59	36	14.5	41.7	302.4	86.4
69	33	45.61	36	14.0	41.9	288.0	82.3
70	33	45.62	38	14.5	41.9	296.9	84.8
71	33	45.64	38	14.6	41.7	296.8	84.8
72	33	45.65	37	14.7	41.9	294.3	84.1
73	33	45.67	36	14.3	41.7	287.6	82.2
74	33	45.68	36	14.1	42.0	283.3	81.0
75	33	45.70	36	14.2	41.9	289.4	82.7
76	33	45.71	36	14.2	42.0	287.5	82.1
77	33	45.73	38	14.8	41.7	307.6	87.9
78	33	45.74	37	14.4	41.9	292.0	83.4
79	33	45.76	36	14.1	42.1	285.4	81.6
80	33	45.77	35	14.1	41.9	286.1	81.8
81	33	45.79	35	13.8	42.0	282.3	80.7
82	33	45.80	37	14.0	41.7	287.2	82.1

83	33	45.82	37	14.0	42.1	285.6	81.6
84	33	45.83	35	13.8	41.9	287.1	82.0
85	33	45.85	37	14.1	42.0	289.5	82.7
86	33	45.86	36	14.1	41.9	289.8	82.8
87	33	45.88	39	14.8	41.7	298.8	85.4
88	33	45.89	36	13.7	42.2	284.7	81.3
89	33	45.91	35	13.7	41.7	288.5	82.4
90	33	45.92	37	14.2	42.1	292.8	83.6
91	33	45.94	37	14.2	42.1	291.5	83.3
92	33	45.95	36	14.2	41.9	293.1	83.8
93	33	45.97	35	13.9	41.8	286.1	81.7
94	33	45.98	34	13.8	42.1	286.1	81.7
95	33	46.00	34	13.7	42.0	282.2	80.6
96	36	46.01	37	15.0	42.0	297.8	85.1
97	36	46.03	34	13.5	42.0	282.3	80.7
98	36	46.04	35	13.8	42.1	283.9	81.1
99	36	46.06	37	14.6	42.0	295.1	84.3
100	36	46.07	36	14.0	42.0	287.7	82.2
101	36	46.08	36	14.1	42.2	291.0	83.2
102	36	46.10	37	14.2	42.0	295.1	84.3
103	36	46.11	37	14.3	42.0	290.0	82.9
104	36	46.13	36	14.2	41.7	291.4	83.2
105	36	46.14	37	15.0	41.8	300.6	85.9
106	36	46.15	35	13.8	42.0	281.7	80.5
107	36	46.17	37	14.6	42.1	296.7	84.8
108	36	46.18	35	13.8	41.9	286.5	81.9
109	36	46.19	36	14.0	42.0	288.9	82.5
110	36	46.21	36	13.8	42.0	286.1	81.7
111	36	46.22	38	14.7	41.9	297.1	84.9
112	36	46.24	36	13.7	42.0	285.2	81.5
113	36	46.25	35	13.5	42.0	284.7	81.3
114	36	46.26	36	14.0	42.0	288.1	82.3
115	36	46.28	36	13.7	41.8	283.1	80.9
116	36	46.29	38	14.6	41.9	297.0	84.9
117	36	46.31	35	13.7	42.1	284.3	81.2
118	36	46.32	37	14.4	41.9	294.9	84.3
119	36	46.33	36	13.9	42.0	286.7	81.9
120	36	46.35	36	14.1	41.9	289.0	82.6
121	36	46.36	35	13.9	42.1	287.1	82.0
122	36	46.38	35	13.8	42.1	283.9	81.1
123	36	46.39	35	13.6	41.9	282.1	80.6
124	36	46.40	35	14.1	42.0	290.6	83.0
125	36	46.42	35	14.1	42.0	291.4	83.3
126	36	46.43	36	14.0	42.0	291.5	83.3
127	36	46.44	35	13.9	42.0	289.9	82.8
128	36	46.46	35	13.8	42.0	288.2	82.3
129	36	46.47	39	15.5	42.2	314.0	89.7
130	36	46.49	37	16.5	42.0	310.3	88.7
131	36	46.50	36	15.9	41.9	310.9	88.8
		Average	36	14.2	41.9	290.7	83.0
		Std Dev	1	0.5	0.1	7.1	2.0
		Maximum	39	16.5	42.2	314.0	89.7
		Minimum	34	13.5	41.6	280.8	80.2

N-value: 69

Sample Interval Time: 120.31 seconds.

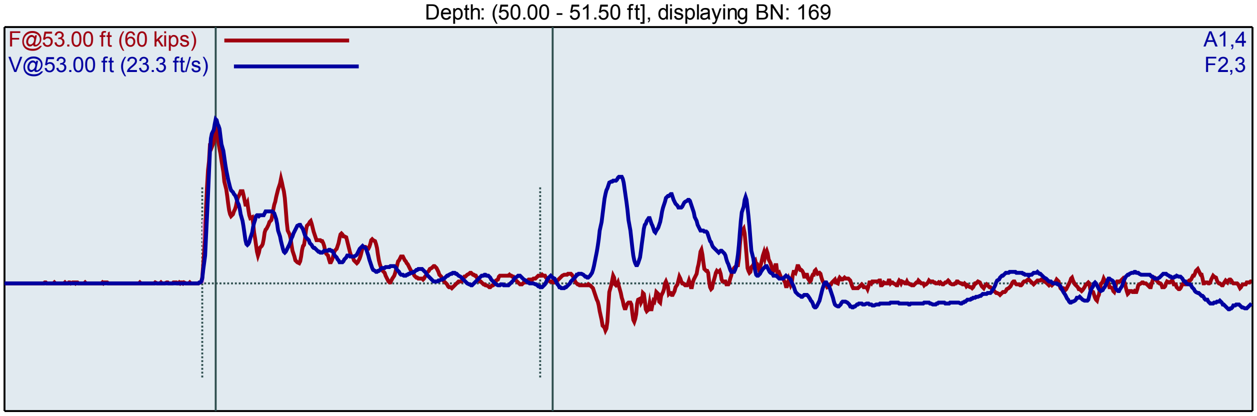
CME 850 #31
GRL-MGB

15
Test date: 4/17/2017

AR: 1.44 in^2
LE: 53.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (50.00 - 51.50 ft], displaying BN: 169



BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	(%)
132	12	50.04	36	14.2	1.9	290.2	82.9
133	12	50.08	37	15.1	44.1	299.9	85.7
134	12	50.13	35	14.3	44.5	293.9	84.0
135	12	50.17	37	15.2	45.2	301.3	86.1
136	12	50.21	37	14.7	45.2	295.9	84.5
137	12	50.25	36	14.6	45.5	292.4	83.5
138	12	50.29	38	14.9	45.4	301.9	86.2
139	12	50.33	38	15.5	45.3	307.1	87.7
140	12	50.38	36	14.7	45.4	288.8	82.5
141	12	50.42	38	15.1	45.4	298.6	85.3
142	12	50.46	38	15.3	45.4	306.5	87.6
143	12	50.50	36	14.8	45.6	298.6	85.3
144	11	50.55	37	15.0	45.3	300.8	86.0
145	11	50.59	35	14.5	45.5	288.5	82.4
146	11	50.64	37	15.2	45.5	306.2	87.5
147	11	50.68	39	15.9	45.5	315.1	90.0
148	11	50.73	38	15.1	45.5	305.2	87.2
149	11	50.77	38	15.4	45.5	307.0	87.7
150	11	50.82	37	15.5	45.8	306.0	87.4
151	11	50.86	36	14.8	45.6	295.6	84.5
152	11	50.91	37	15.1	45.6	301.0	86.0
153	11	50.95	37	15.2	45.6	303.3	86.7
154	11	51.00	37	15.2	45.6	307.2	87.8
155	17	51.03	37	15.2	45.8	305.6	87.3
156	17	51.06	37	15.0	45.7	298.0	85.1
157	17	51.09	37	15.2	45.7	305.5	87.3
158	17	51.12	37	15.2	45.7	304.1	86.9
159	17	51.15	37	15.4	45.6	307.4	87.8
160	17	51.18	37	15.3	45.6	303.2	86.6
161	17	51.21	36	14.9	45.6	301.2	86.0
162	17	51.24	37	15.0	45.6	304.7	87.0
163	17	51.26	37	14.9	45.6	305.0	87.1
164	17	51.29	37	15.1	45.8	307.3	87.8
165	17	51.32	38	15.4	45.6	306.0	87.4
166	17	51.35	38	15.5	45.9	302.6	86.5
167	17	51.38	37	15.0	45.7	299.3	85.5

168	17	51.41	37	15.3	45.7	304.9	87.1
169	17	51.44	37	14.9	45.8	300.2	85.8
170	17	51.47	35	15.4	45.8	304.7	87.1
171	17	51.50	38	16.2	45.9	312.4	89.3
		Average	37	15.2	45.7	303.9	86.8
		Std Dev	1	0.3	0.1	4.9	1.4
		Maximum	39	16.2	45.9	315.1	90.0
		Minimum	35	14.5	45.3	288.5	82.4

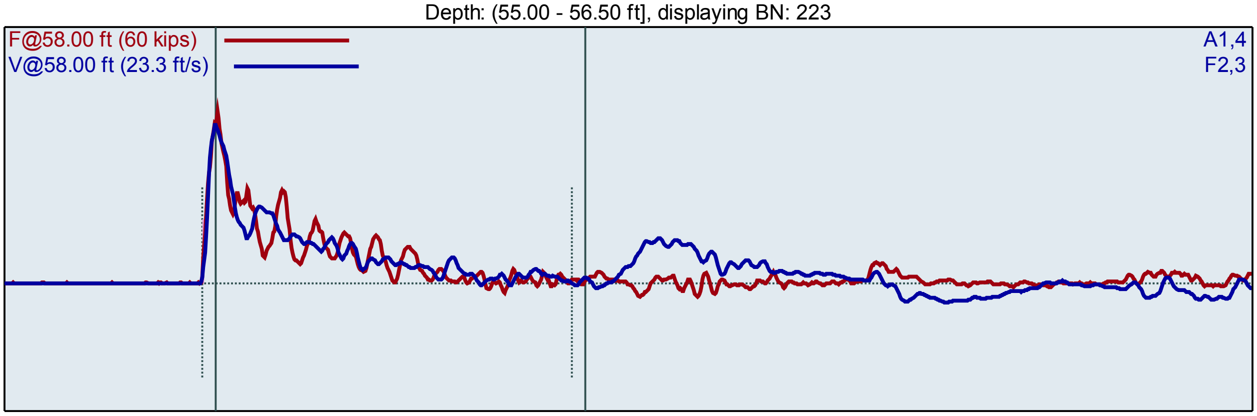
N-value: 28

Sample Interval Time: 51.39 seconds.

CME 850 #31 15
GRL-MGB Test date: 4/17/2017

AR: 1.44 in^2 SP: 0.492 k/ft3
LE: 58.00 ft EM: 30000 ksi
WS: 16807.9 ft/s

Depth: (55.00 - 56.50 ft], displaying BN: 223



BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	(%)
172	14	55.04	38	15.0	1.9	304.5	87.0
173	14	55.07	39	14.7	42.1	298.1	85.2
174	14	55.11	39	14.8	42.3	304.1	86.9
175	14	55.14	39	15.1	42.9	308.8	88.2
176	14	55.18	39	15.1	42.9	305.5	87.3
177	14	55.21	38	14.2	42.9	301.8	86.2
178	14	55.25	39	14.9	42.9	305.5	87.3
179	14	55.29	39	14.4	42.8	301.6	86.2
180	14	55.32	41	15.3	43.0	314.3	89.8
181	14	55.36	39	15.1	42.9	308.9	88.2
182	14	55.39	40	15.0	42.9	311.0	88.9
183	14	55.43	40	15.2	42.9	315.3	90.1
184	14	55.46	40	15.2	42.9	308.9	88.3
185	14	55.50	40	15.3	43.1	310.5	88.7
186	16	55.53	39	15.0	42.9	308.9	88.2
187	16	55.56	38	14.5	43.0	305.8	87.4
188	16	55.59	40	15.3	42.9	308.3	88.1
189	16	55.63	41	15.2	43.0	309.2	88.4
190	16	55.66	39	14.5	43.0	306.4	87.5
191	16	55.69	38	14.2	43.1	302.5	86.4
192	16	55.72	37	13.8	42.9	304.7	87.1
193	16	55.75	37	14.0	43.2	299.8	85.7
194	16	55.78	38	14.5	43.1	304.7	87.1
195	16	55.81	36	13.1	43.2	289.3	82.7
196	16	55.84	36	13.8	43.2	300.3	85.8
197	16	55.88	37	14.0	43.1	300.7	85.9
198	16	55.91	39	14.6	43.2	304.7	87.1
199	16	55.94	37	14.2	43.3	306.5	87.6
200	16	55.97	35	13.2	43.4	291.6	83.3
201	16	56.00	37	14.4	42.9	306.5	87.6
202	24	56.02	37	14.2	43.4	305.2	87.2
203	24	56.04	36	13.2	43.4	299.7	85.6
204	24	56.06	38	13.9	43.2	300.1	85.7
205	24	56.08	38	14.0	43.1	300.8	86.0
206	24	56.10	39	14.5	43.2	307.0	87.7
207	24	56.13	40	15.0	43.0	311.6	89.0

208	24	56.15	38	14.0	43.4	297.9	85.1
209	24	56.17	38	14.6	43.1	303.1	86.6
210	24	56.19	40	14.6	43.1	304.2	86.9
211	24	56.21	40	14.8	43.1	310.3	88.7
212	24	56.23	38	14.7	43.2	302.3	86.4
213	24	56.25	38	13.8	43.3	295.7	84.5
214	24	56.27	39	14.7	43.0	311.5	89.0
215	24	56.29	34	13.3	43.1	296.1	84.6
216	24	56.31	38	14.3	42.9	307.0	87.7
217	24	56.33	37	14.1	43.1	304.0	86.9
218	24	56.35	38	14.0	43.1	301.8	86.2
219	24	56.38	40	14.8	43.2	311.4	89.0
220	24	56.40	39	14.6	43.0	310.3	88.7
221	24	56.42	37	14.5	43.2	305.1	87.2
222	24	56.44	41	14.4	43.1	319.4	91.2
223	24	56.46	40	14.4	43.2	316.4	90.4
224	24	56.48	40	14.4	43.2	315.9	90.3
225	24	56.50	40	14.8	42.9	322.5	92.1
		Average	38	14.3	43.1	305.2	87.2
		Std Dev	1	0.5	0.1	6.7	1.9
		Maximum	41	15.3	43.4	322.5	92.1
		Minimum	34	13.1	42.9	289.3	82.7

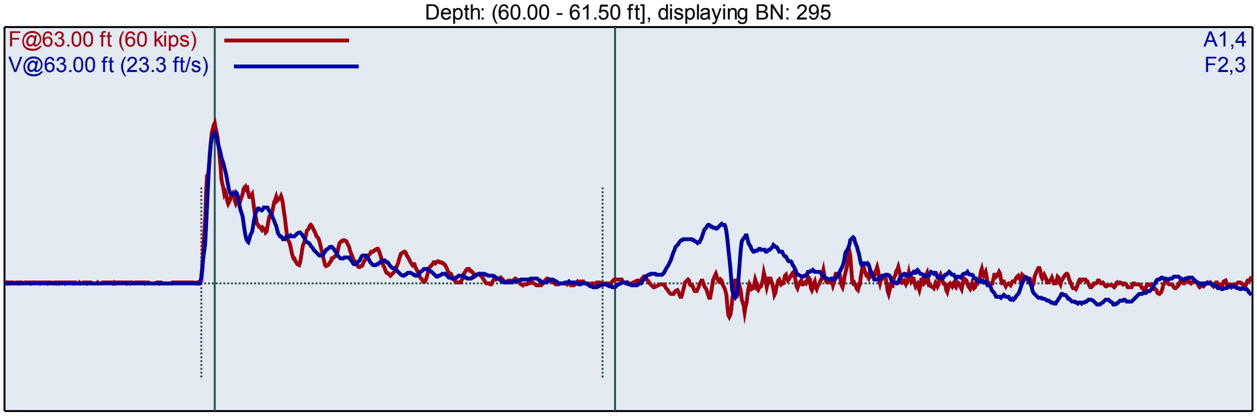
N-value: 40

Sample Interval Time: 73.87 seconds.

CME 850 #31 15
GRL-MGB Test date: 4/17/2017

AR: 1.44 in^2 SP: 0.492 k/ft3
LE: 63.00 ft EM: 30000 ksi
WS: 16807.9 ft/s

Depth: (60.00 - 61.50 ft], displaying BN: 295



BL#	BC /6"	LP ft	FMX kips	VMX ft/s	BPM bpm	EFV ft-lb	ETR (%)
226	31	60.02	36	14.8	1.9	305.8	87.4
227	31	60.03	39	14.5	48.7	319.3	91.2
228	31	60.05	37	14.4	49.8	301.6	86.2
229	31	60.06	38	14.4	44.3	305.1	87.2
230	31	60.08	38	14.6	44.1	303.9	86.8
231	31	60.10	37	14.6	44.1	300.2	85.8
232	31	60.11	38	14.8	44.1	311.3	89.0
233	31	60.13	36	14.4	44.2	298.0	85.1
234	31	60.15	37	14.6	44.3	302.3	86.4
235	31	60.16	38	14.7	44.3	310.9	88.8
236	31	60.18	36	15.3	44.1	311.5	89.0
237	31	60.19	38	16.2	44.2	313.6	89.6
238	31	60.21	39	15.1	44.3	310.0	88.6
239	31	60.23	35	16.5	44.2	307.6	87.9
240	31	60.24	36	15.9	44.3	311.7	89.1
241	31	60.26	36	15.7	44.3	307.9	88.0
242	31	60.27	35	15.7	44.5	310.1	88.6
243	31	60.29	35	16.1	44.2	309.1	88.3
244	31	60.31	36	15.7	44.4	302.7	86.5
245	31	60.32	35	15.6	44.6	304.1	86.9
246	31	60.34	33	15.7	44.6	303.4	86.7
247	31	60.35	34	15.6	44.6	303.9	86.8
248	31	60.37	32	15.5	44.5	295.0	84.3
249	31	60.39	32	14.4	44.7	290.3	83.0
250	31	60.40	30	15.3	44.3	296.0	84.6
251	31	60.42	34	15.6	44.8	307.1	87.7
252	31	60.44	36	14.8	44.5	300.6	85.9
253	31	60.45	34	15.5	44.6	301.2	86.0
254	31	60.47	34	15.2	44.5	299.6	85.6
255	31	60.48	30	15.1	44.7	296.5	84.7
256	31	60.50	34	15.8	44.3	303.1	86.6
257	23	60.52	35	14.6	44.7	298.0	85.2
258	23	60.54	38	14.7	44.6	303.6	86.7
259	23	60.57	37	13.5	44.6	298.0	85.1
260	23	60.59	35	13.9	44.6	298.1	85.2
261	23	60.61	35	13.5	44.7	299.1	85.5

262	23	60.63	39	14.3	44.7	312.7	89.3
263	23	60.65	38	14.3	44.5	305.2	87.2
264	23	60.67	40	14.4	44.6	310.8	88.8
265	23	60.70	39	14.5	44.6	309.9	88.5
266	23	60.72	39	14.5	44.6	308.1	88.0
267	23	60.74	39	14.5	44.5	310.5	88.7
268	23	60.76	36	13.6	44.5	301.1	86.0
269	23	60.78	39	14.3	44.4	306.1	87.5
270	23	60.80	37	13.8	44.5	305.6	87.3
271	23	60.83	36	14.0	44.3	304.0	86.8
272	23	60.85	39	14.5	44.4	308.5	88.2
273	23	60.87	38	14.2	44.5	305.5	87.3
274	23	60.89	36	13.4	44.6	300.4	85.8
275	23	60.91	38	14.1	44.3	305.6	87.3
276	23	60.93	38	14.1	44.5	307.6	87.9
277	23	60.96	39	14.4	44.5	314.9	90.0
278	23	60.98	38	14.1	44.5	305.1	87.2
279	23	61.00	38	14.1	44.4	308.4	88.1
280	18	61.03	36	13.7	44.4	301.4	86.1
281	18	61.06	39	14.4	44.6	308.1	88.0
282	18	61.08	38	14.1	44.5	305.6	87.3
283	18	61.11	38	14.1	44.5	307.9	88.0
284	18	61.14	39	14.5	44.6	308.1	88.0
285	18	61.17	37	14.0	44.6	304.2	86.9
286	18	61.19	38	14.0	44.5	304.6	87.0
287	18	61.22	36	13.4	44.6	298.7	85.4
288	18	61.25	37	14.0	44.3	306.4	87.5
289	18	61.28	37	13.8	44.5	305.6	87.3
290	18	61.31	36	13.4	44.5	298.0	85.2
291	18	61.33	40	14.3	44.5	308.4	88.1
292	18	61.36	37	13.8	44.6	304.4	87.0
293	18	61.39	36	13.2	44.3	299.9	85.7
294	18	61.42	37	13.4	44.7	300.7	85.9
295	18	61.44	37	13.7	44.5	301.6	86.2
296	18	61.47	37	12.8	44.4	293.3	83.8
297	18	61.50	39	14.7	44.5	322.2	92.1
		Average	38	14.0	44.5	305.0	87.1
		Std Dev	1	0.4	0.1	5.3	1.5
		Maximum	40	14.7	44.7	322.2	92.1
		Minimum	35	12.8	44.3	293.3	83.8

N-value: 41

Sample Interval Time: 95.50 seconds.

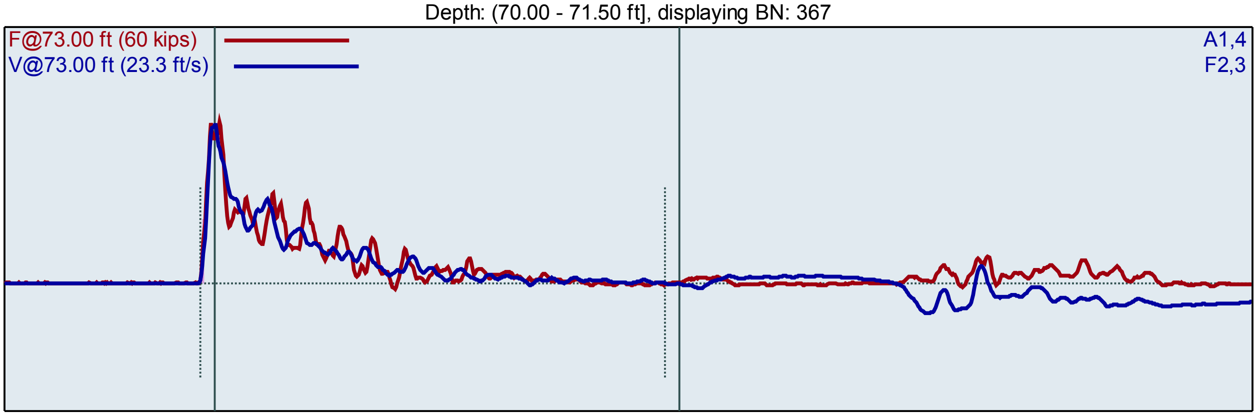
CME 850 #31
GRL-MGB

15
Test date: 4/17/2017

AR: 1.44 in^2
LE: 73.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (70.00 - 71.50 ft], displaying BN: 367



BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	(%)
298	16	70.03	37	15.9	1.9	319.8	91.4
299	16	70.06	36	15.6	47.6	314.8	89.9
300	16	70.09	37	16.0	48.7	317.6	90.7
301	16	70.13	37	16.3	44.6	314.3	89.8
302	16	70.16	36	15.8	43.4	312.6	89.3
303	16	70.19	36	16.6	43.3	313.9	89.7
304	16	70.22	36	15.7	43.4	311.3	88.9
305	16	70.25	36	16.1	43.4	309.5	88.4
306	16	70.28	36	16.4	43.4	312.3	89.2
307	16	70.31	36	16.0	43.4	312.3	89.2
308	16	70.34	35	15.7	43.5	308.5	88.1
309	16	70.38	36	16.6	43.4	315.1	90.0
310	16	70.41	36	16.4	43.5	317.6	90.7
311	16	70.44	36	16.6	43.5	319.9	91.4
312	16	70.47	36	16.4	43.4	316.3	90.4
313	16	70.50	36	16.0	43.4	314.8	89.9
314	24	70.52	35	16.0	43.5	315.0	90.0
315	24	70.54	36	16.8	43.6	320.2	91.5
316	24	70.56	36	16.4	43.4	320.5	91.6
317	24	70.58	36	16.4	43.6	317.5	90.7
318	24	70.60	36	16.5	43.4	318.7	91.0
319	24	70.63	37	16.7	43.4	315.6	90.2
320	24	70.65	36	16.3	43.4	317.9	90.8
321	24	70.67	37	16.7	43.4	321.0	91.7
322	24	70.69	35	15.9	43.6	313.8	89.7
323	24	70.71	35	15.8	43.6	307.5	87.8
324	24	70.73	35	15.5	43.5	313.4	89.5
325	24	70.75	35	15.3	43.5	307.1	87.7
326	24	70.77	34	15.2	43.7	301.9	86.3
327	24	70.79	35	15.3	43.6	307.0	87.7
328	24	70.81	34	14.5	43.7	301.3	86.1
329	24	70.83	34	15.2	43.4	305.5	87.3
330	24	70.85	34	14.8	43.5	303.6	86.8
331	24	70.88	34	15.5	43.4	307.6	87.9
332	24	70.90	35	15.6	43.6	307.0	87.7
333	24	70.92	35	15.1	43.6	307.5	87.9

334	24	70.94	35	15.5	43.4	308.9	88.3
335	24	70.96	33	15.3	43.7	307.9	88.0
336	24	70.98	35	15.9	43.6	314.1	89.7
337	24	71.00	34	15.1	43.7	309.3	88.4
338	32	71.02	33	14.8	43.6	309.3	88.4
339	32	71.03	34	14.6	43.6	310.2	88.6
340	32	71.05	35	14.6	43.7	306.2	87.5
341	32	71.06	34	15.1	43.7	307.8	87.9
342	32	71.08	35	14.7	43.5	308.1	88.0
343	32	71.09	36	15.1	43.8	311.3	88.9
344	32	71.11	36	14.1	43.6	305.4	87.2
345	32	71.13	36	15.7	43.7	312.7	89.3
346	32	71.14	35	14.6	43.5	308.0	88.0
347	32	71.16	35	14.5	43.8	306.8	87.7
348	32	71.17	37	15.1	43.7	311.1	88.9
349	32	71.19	34	14.2	43.8	304.9	87.1
350	32	71.20	34	14.2	43.9	300.0	85.7
351	32	71.22	36	14.1	43.6	306.2	87.5
352	32	71.23	35	14.2	43.8	304.5	87.0
353	32	71.25	35	12.6	43.7	289.4	82.7
354	32	71.27	35	14.2	43.5	309.6	88.5
355	32	71.28	35	14.2	43.7	307.0	87.7
356	32	71.30	36	14.0	43.5	304.7	87.0
357	32	71.31	36	13.3	43.6	299.1	85.4
358	32	71.33	36	14.1	43.5	306.0	87.4
359	32	71.34	36	13.1	43.8	298.6	85.3
360	32	71.36	36	13.4	43.8	307.5	87.9
361	32	71.38	35	13.2	43.5	306.5	87.6
362	32	71.39	36	13.1	43.5	297.3	84.9
363	32	71.41	35	14.1	43.5	304.5	87.0
364	32	71.42	36	14.3	43.6	311.3	88.9
365	32	71.44	38	14.5	43.7	308.8	88.2
366	32	71.45	39	15.0	43.3	318.9	91.1
367	32	71.47	38	14.4	43.7	310.2	88.6
368	32	71.48	38	15.8	43.8	321.0	91.7
369	32	71.50	36	15.6	43.5	315.9	90.3
		Average	35	14.9	43.6	308.9	88.3
		Std Dev	1	1.0	0.1	6.3	1.8
		Maximum	39	16.8	43.9	321.0	91.7
		Minimum	33	12.6	43.3	289.4	82.7

N-value: 56

Sample Interval Time: 97.50 seconds.

Summary of SPT Test Results

Project: CME 850 #31, Test Date: 4/17/2017

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute

EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

Instr. Length ft	Blows Applied /6"	Start Depth ft	Final Depth ft	**N Value**	**N60 Value**	Average FMX kips	Average VMX ft/s	Average BPM bpm	Average EFV ft-lb	Average ETR (%)
18.00	**9-13-24**	15.00	16.50	**37**	**53**	37	15.7	39.0	300.4	85.8
48.00	**16-33-36**	45.00	46.50	**69**	**99**	36	14.2	41.9	290.7	83.0
53.00	**12-11-17**	50.00	51.50	**28**	**40**	37	15.2	45.7	303.9	86.8
58.00	**14-16-24**	55.00	56.50	**40**	**57**	38	14.3	43.1	305.2	87.2
63.00	**31-23-18**	60.00	61.50	**41**	**58**	38	14.0	44.5	305.0	87.1
73.00	**16-24-32**	70.00	71.50	**56**	**80**	35	14.9	43.6	308.9	88.3
					Overall Average Values:	37	14.6	42.8	301.5	86.1
					Standard Deviation:	2	0.8	1.9	9.1	2.6
					Overall Maximum Value:	41	16.8	45.9	322.5	92.1
					Overall Minimum Value:	33	12.6	38.7	280.8	80.2

Report 2
Holocene Mobile B58

August 31, 2017

Re: Penetration Test Energy Measurements
Foremost Mobile B58, Mobil Autohammer
Borehole HPG09, July 14, 2017
Bellevue, Washington

RMDT Job No. 17F37

This letter presents energy transfer measurements made during Penetration Tests for the drill holes and drill rig referenced above. Robert Miner Dynamic Testing, Inc. (RMDT) made dynamic measurements with a Pile Driving Analyzer® as a hammer advanced the NW rod during sampling with a split spoon sampler.

The purpose of RMDT's testing was the measurement of energy transferred to the drill rods. Measurements were made on a section of NW gauge rod at the top of the drill rod. Strain gages and accelerometers on the rod were connected to a Pile Driving Analyzer® (PDA) which generally processed acceleration and strain measurements from each hammer blow and stored both the measurements and computed results. Measurements and data processing generally followed the ASTM D 4633-16 standard. Energy transfer past the gage location, EFV, was computed by the PDA using force and velocity records as follows:

$$EFV = \int_a^b F(t)\ v(t)\ dt$$

The value "a" corresponds to the start of the record which is when the energy transfer begins and *"b"* is the time at which energy transferred to the rod reaches a maximum value. Appendix A contains more information on our measurement equipment and methods of analysis. The EFV energy calculation is identical to the EMX energy result discussed in Appendix A. The EFV and EMX values apply to the sensor location near the top of the rod.

TEST DETAILS

On the morning of July 14, 2017, a boring was advances at your project site referenced above. The drill rig was a truck mounted B58 unit manufactured by Foremost Mobile; this rig was identified as Truck #92 with Washington State Licence number C93096E. The Penetration Test hammer was a Mobile chain-drive automatic hammer equipped with a 140 lb ram. Sampling rods were NW gage with J threads. We collected data for sample starting depths of 40, 45, 50, 55 and 60 ft.

Mailing Address: P.O. Box 340, Manchester, WA, 98353, USA **Phone:** 360-871-5480
Location: 2288 Colchester Dr. E., Ste A, Manchester, WA, 98353 **Fax:** 360-871-5483

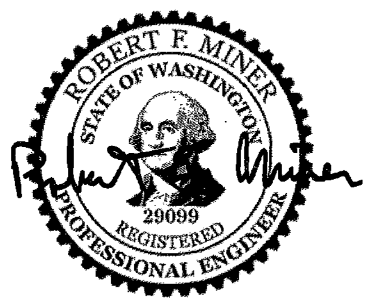
RESULTS

Sampling at each depth ended with penetration rates exceeding 50 blows for 6 inches and in some cases this occurred within the first of the standard three 6-inch intervals. For this circumstance we judged that the transfer energy may be characterized best by considering results for all hammer blows. One attached figure presents a graphical summary of pertinent results, and Appendix B contains the results for each hammer blow. The results for each hammer blow include the measured energy transfer, EFV, the computed transfer efficiency, ETR, and the hammer blow rate, BPM.

Energy measurements must be divided by the theoretical free fall energy of the hammer to obtain an efficiency. A 140 lb ram raised 30 inches above an impact surface has 350 lb-ft of potential energy. Thus, the transfer energy results for sampling with the 140 lb ram may be divided by 350 lb-ft to yield the ratio of the delivered energy to the nominal potential energy. This efficiency ratio, ETR, is plotted on the attached graphical summary and given numerically for each blows in Appendix 8. Within the five sample intervals we monitored the ETR result was relatively consistent and the overall average was 89.7 percent.

It was a pleasure to assist you and to participate on this project.. Please do not hesitate to contact us if you or other project participants have any questions about this report.

Sincerely,

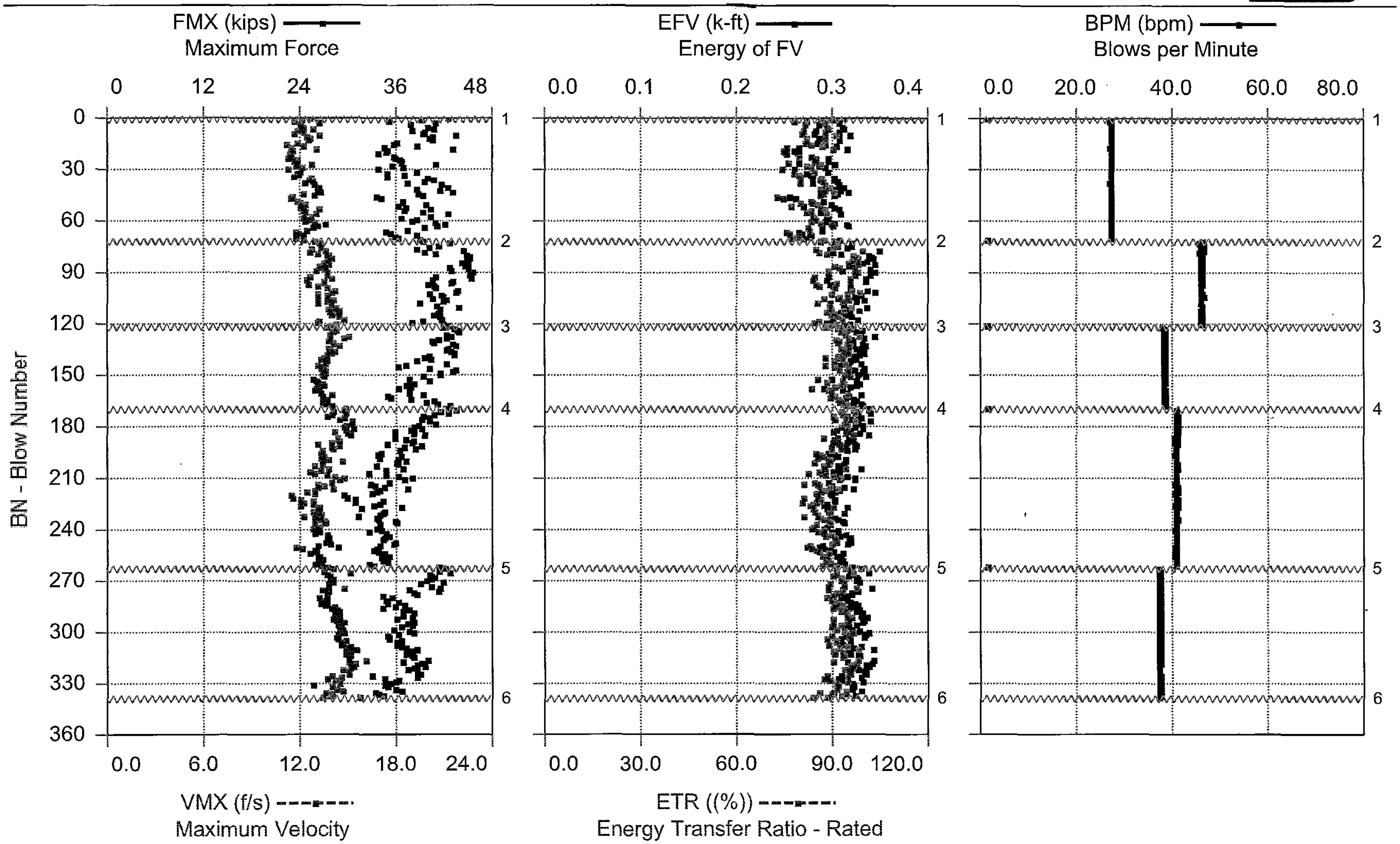


Robert Miner, P.E.

Robert Miner Dynamic Testing, Inc.

August 31, 2017

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2016.1.56.3 - Case Method & iCAP® Results
Printed: 31-August-2017 Test started: 14-July-2017



1 - Begin Sample at 40 ft.
2 - Begin Sample at 45 ft.
3 - Begin Sample at 50 ft.
4 - Begin Sample at 55 ft.
5 - Begin Sample at 60 ft.
6 - End of testing.

APPENDIX A
AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

BACKGROUND

Modern procedures of design and construction control require verification of bearing capacity and integrity of deep foundations during preconstruction test programs and also production installation. Dynamic pile testing methods meet this need economically and reliably, and therefore, form an important part of a quality assurance program when deep foundations are executed. Several dynamic pile testing methods exist; they have different benefits and limitations and different requirements for proper execution.

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 (such as that of a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. The method is therefore 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 an evaluation of various quantities based on closed form solutions of the wave equation, a partial differential equation describing the motion of a rod under the effect of an impact. Conveniently, measurements and analyses are done by a single piece of equipment: the Pile Driving Analyzer® (PDA). However, for bearing capacity evaluations an important additional method is CAPWAP® which performs a much more rigorous analysis of the dynamic records than the simpler Case Method.

A related analysis method is the "Wave Equation Analysis" which calculates a relationship between bearing capacity and pile stress and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data.

The following description deals primarily with the Case Method or "High Strain Test" Method of pile testing, however, for the sake of completeness, the "Low Strain Test" performed with the Pile Integrity Test™ (PIT), mainly for pile integrity evaluation, will also be described.

RESULTS FROM DYNAMIC TESTING

There are two main objectives of high strain dynamic pile testing:

- *Dynamic Pile Monitoring* and
- *Dynamic Load Testing.*

Dynamic pile monitoring is conducted during the installation of impact driven piles to achieve a safe and economical pile installation. Dynamic load testing, on the other hand, has as its primary goal the assessment of pile bearing capacity. It is applicable to both cast *insitu* piles or drilled shafts and impact driven piles during restrike.

Dynamic Pile Monitoring

During pile installation, the sensors attached to the pile measure pile top force and velocity. A PDA conditions and processes these signals and calculates or evaluates:

- Bearing capacity at the time of testing, including an assessment of shaft resistance development and driving resistance. This information supports formulation of a driving criterion.
- Dynamic pile stresses, axial and averaged over the pile cross section, both tensile and compressive, during pile driving to limit the potential of damage either near the pile top or along its length. Bending stresses can be evaluated at the point of sensor attachment.
- Pile integrity assessment by the PDA is based on the recognition of certain wave reflections from along the pile. If detected early enough, a pile may be saved from complete destruction. On the other hand, once damage is recognized measures can be taken to prevent reoccurrence.
- Hammer performance parameters including the energy transferred to the pile, the hammer speed in blows per minute and the stroke of open ended diesel hammers.

Dynamic Pile Load Testing

Bearing capacity testing of either driven piles or drilled shafts applies the same basic measurement approach of dynamic pile monitoring. However, the test is done independent of the pile installation process and therefore a pile driving hammer or other dynamic loading device may not be available. If a special ram has to be mobilized then its weight should be between 0.8 and 2% of the test load (e.g. between 4 and 10 tons for a 500 ton test load) to assure sufficient soil resistance activation.

For a successful test, it most important that the test is conducted after a sufficient waiting time following pile installation for soil properties approaching their long term condition or concrete to properly set. During testing, PDA results of pile/shaft stresses and transferred energy are used to maintain safe stresses and assure sufficient resistance activation. For safe and sufficient testing of drilled shafts, ram energies are often increased from blow to blow until the test capacity has been activated. On the other hand, restrike tests on driven piles may require a warm hammer so that the very first blow produces a complete resistance activation. Data must be evaluated by CAPWAP for bearing capacity.

After the dynamic load test has been conducted with sufficient energy and safe stresses, the CAPWAP analysis provides the following results:

- Bearing capacity i.e. the mobilized capacity present at the time of testing
- Resistance distribution including shaft resistance and end bearing components
- Stresses in pile or shaft calculated for both the static load application and the dynamic test. These stresses are averages over the cross section and do not include bending effects or nonuniform contact stresses, e.g. when the pile toe is on uneven rock.
- Shaft impedance vs depth; this is an estimate of the shaft shape if it differs substantially from the planned profile
- Dynamic soil parameters for shaft and toe, i.e. damping factors and quakes (related to the dynamic stiffness of the resistance at the pile/soil interface.)

MEASUREMENTS

PDA

The basis for the results calculated by the PDA are pile top strain and acceleration measurements which are converted to force and velocity records, respectively. The PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. Using closed form Case Method solutions, based on the one-dimensional linear wave equation, the PDA calculates the results described in the analytical solutions section below.

HPA

The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. For this unit to be applicable, the ram must be visible. The impact velocity results can be automatically processed with a PC or recorded on a strip chart.

Saximeter™

For open end diesel hammers, the time between two impacts indicates the magnitude of the ram fall height or stroke. This information is not only measured and calculated by the PDA but also by the convenient, hand-held Saximeter.

PIT

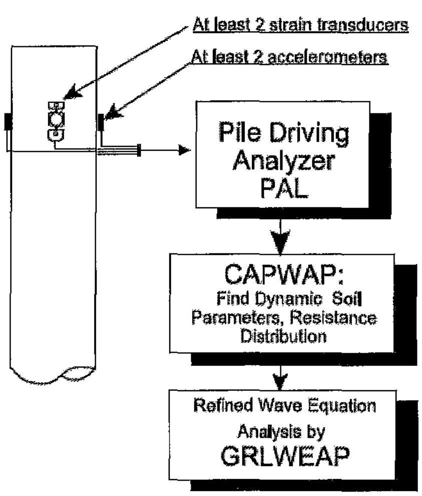
The Pile Integrity Tester™ (PIT) can be used to evaluate defects in concrete piles or shafts which may have occurred during driving or casting. Also timber piles of limited length can be tested in that manner. This so-called "Low Strain Method" or "Pulse-Echo Method" of integrity testing requires only the measurement of acceleration at the pile top. The stress wave producing impact is then generated by a small hand-held hammer and the records interpreted in the time domain. PIT also supports the so-called "Transient Response Method" which requires the additional measurement of the hammer force and an analysis in the frequency domain. This method may also be used to evaluate the unknown length of deep foundations under existing structures.

ANALYTICAL SOLUTIONS
BEARING CAPACITY

Wave Equation

GRL has written the GRLWEAP™ program which calculates a relationship between bearing capacity, pile stress and blow count. This relationship is often called the "bearing graph." Once the blow count is known from pile installation logs, the bearing graph yields the bearing capacity. This approach requires no measurements and therefore can be performed during the design stage of a project, for example for the selection of hammer, cushion and pile size.

After dynamic pile monitoring and/or dynamic load testing has been performed, the "Refined Wave Equation Analysis" or RWEA (see schematic below) is often performed by inputting the PDA and CAPWAP calculated parameters. Then the bearing graph from the RWEA is the basis for a safe and sufficient driving criteria.



Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil resistance is

$$R(t) = \tfrac{1}{2}\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

- t = a point in time after impact
- t_2 = time $t + 2L/c$
- L = pile length below gages
- c = $(E/\rho)^{1/2}$ is the speed of the stress wave
- ρ = pile mass density
- Z = EA/c is the pile impedance
- E = elastic modulus of the pile (ρc^2)
- A = pile cross sectional area

The total soil resistance consists of a dynamic (R_d) and a static (R_s) component. The static component is therefore

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2.

There are a number of ways in which Eq. 1 through 3 can be evaluated. Most commonly, t_2 is set to that time at which the static resistance becomes maximum. The result is the so-called **RMX** capacity. Damping factors for RMX typically range between 0.5 for coarse grained materials to 1.0 for clays. The **RSP** capacity (this method is most commonly referred to in the literature, yet it is not very frequently used) requires damping factors between 0.1 for sand and 1.0 for clay. Another capacity, **RA2**, determines the capacity at a time when the pile is essentially at rest and thus damping is small; RA2

therefore requires no damping parameter. In any event, the proper Case Method and its associated damping parameter is most conveniently found after a CAPWAP analysis has been performed.

The static resistance calculated by Case Method or CAPWAP is the mobilized resistance at the time of testing. Consideration therefore has to be given to soil setup or relaxation effects and whether or not a sufficient set has been achieved under the test loading that would correspond to a full activation of the ultimate soil resistance.

The PDA also calculates an estimate of shaft resistance as the difference between force and velocity times impedance at the time immediately prior to the return of the stress wave from the pile toe. This shaft resistance is not reduced by damping effects and is therefore called the total shaft resistance **SFT**. A correction for damping effects produces the static shaft resistance estimate, **SFR**.

The Case Method solution is simple enough to be evaluated "in real time," i.e. between hammer blows, using the PDA. It is therefore possible to calculate all relevant results for all hammer blows and plot these results as a function of depth or blow number. This is done in the PDAPLOT program.

CAPWAP

The CAse Pile Wave Analysis Program combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the shaft resistance, end bearing, damping factors and soil stiffnesses. The method iteratively calculates a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

During pile monitoring, it is important that compressive stress maxima at pile top and toe and tensile stress maxima somewhere along the pile be calculated for each hammer blow.

At the pile top (location of sensors) both the maximum compression stress, **CSX**, and the maximum stress from individual strain transducers, **CSI**, are directly obtained from the measurements. Note that CSI is greater than or equal to CSX and the difference between CSI and CSX is a measure of bending in the plane of the strain transducers. Note also that all stresses calculated for locations below the sensors are averaged over the pile cross section and therefore do not include components from either bending or eccentric soil resistance effects.

The PDA calculates the compressive stress at the pile bottom, **CSB**, assuming (a) a uniform pile and (b) that the pile toe force is the maximum value of the total resistance R(t) minus the total shaft resistance, SFT. Again, for this stress estimation uniform resistance force are assumed (e.g. not a sloping rock.)

For concrete piles, the maximum tension stress, **TSX**, is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by finding the maximum tension wave (either traveling upward, W_U, or downward, W_d) and reducing it by the minimum compressive wave traveling in opposite direction.

$$W_u = \tfrac{1}{2}[F(t) - Zv(t)] \tag{4}$$

$$W_d = \tfrac{1}{2}[F(t) + Zv(t)] \tag{5}$$

CAPWAP also calculates tensile and compressive stresses along the pile and, in general, more accurately than the PDA. In fact, for non-uniform piles or piles with joints, cracks or other discontinuities, the closed form solutions from the PDA may be in error.

PILE INTEGRITY

High Strain Tests (PDA)

Stress waves in a pile are reflected wherever the pile impedance, $Z = EA/c = \rho cA = A\sqrt{(E\ \rho)}$, changes. Therefore, the pile impedance is a measure of the quality of the pile material (E, ρ, c) and the size of its cross section (A). The reflected waves arrive at the pile top at a time which is greater the farther away from the pile top the reflection occurs. The

magnitude of the change of the upward traveling wave (calculated from the measured force and velocity, Eq. 4) indicates the extent of the cross sectional change. Thus, with β_i (**BTA**) being a relative integrity factor which is unity for no impedance change and zero for the pile end, the following is calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \qquad (6)$$

with

$$\alpha_i = ½(W_{UR} - W_{UD})/(W_{Di} - W_{UR}) \qquad (7)$$

where

- W_{UR} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.
- W_{UD} is the upwards traveling wave due to the damage reflection.
- W_{Di} is the maximum downward traveling wave due to impact.

It can be shown that this formulation is quite accurate as long as individual reflections from different pile impedance changes have no overlapping effects on the stress wave reflections.

Without rigorous derivation, it has been proposed to consider as slight damage when β is above 0.8 and a serious damage when β is less than 0.6.

Low Strain Tests (PIT)

The pile top is struck with a held hand hammer and the resulting pile top velocity is measured, displayed and interpreted for signs of wave reflections. In general, a comparison of the reflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the reflection. PIT records can also be interpreted by the β-Method. However, low strain tests do not activate much resistance which simplifies Eq. 7 since W_{UR} is then equal to zero.

For drilled shafts and PIT records that clearly show a toe reflection, an approximate shaft profile can be calculated from low strain records using the PITSTOP program's PROFILE routine.

HAMMER PERFORMANCE

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

$$E(t) = {}_o\int^t F(t)v(t)\,dt \qquad (8a)$$

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

$$e_T = EMX/E_R \qquad (8b)$$

where

- E_R is the manufacturer's rated energy value.

Both Saximeter and PDA calculate the stroke (**STK**) of an open end diesel hammer using

$$STK = (g/8)\,T_B^2 - h_L \qquad (9)$$

where

- g is the earth's gravitational acceleration,
- T_B is the time between two hammer blows,
- h_L is a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

DETERMINATION OF WAVE SPEED

An important facet of dynamic pile testing is an assessment of pile material properties. Since in general force is determined from strain by multiplication with elastic modulus, E, and cross sectional area, A, the dynamic elastic modulus has to be determined for pile materials other than steel. In general, the records measured by the PDA clearly indicate a pile toe reflection as long as pile penetration per blow is greater than 1 mm or .04 inches. The time between the onset of the force and velocity records at impact and the onset of the reflection from the toe (usually apparent by a local maximum of the wave up curve) is the so-called wave travel time, T. Dividing 2L (L is here the length of the pile below sensors) by T leads to the stress wave speed in the pile:

$$c = 2L/T \qquad (10)$$

The elastic modulus of the pile material is related to the wave speed according to the linear elastic wave equation theory by

$$E = c^2\rho \qquad (11)$$

Since the mass density of the pile material, ρ, is usually well known (an exception is timber for which samples should be weighed), the elastic modulus is easily found from the wave speed. Note, however, that this is a dynamic modulus which is generally higher than the static one and that the wave speed depends to some degree on the strain level of the stress wave. For example, experience shows that the wave speed from PIT is roughly 5% higher than the wave speed observed during a high strain test.

Other Notes:

- If the pile material is nonuniform then the wave speed c, according to Eq. 10, is an average wave speed and does not necessarily reflect the pile material properties of the location where the strain sensors are attached to the pile top. For example, pile driving often causes fine tension cracks some distance below the top of concrete piles. Then the average c is slower than that at the pile top. It is therefore recommended to determine E in the beginning of pile driving and not adjust it when the average c changes.

- If the pile has such a high resistance that there is no clear indication of a toe reflection then the wave speed of the pile material must be determined either by assumption or by taking a sample of the concrete and measuring its wave speed in a simple free column test. Another possibility is to use the proportionality relationship, discussed under "DATA QUALITY CHECKS" to find c as the ratio between the measured velocity and measured strain.

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 PDA or PIT 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 certain relationships.

Proportionality

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 pile, force and velocity measured at the pile top are proportional

$$F = v\,Z = v\,(EA/c) \qquad (12a)$$

This relationship can also be expressed in terms of stress

$$\sigma = v\,(E/c) \qquad (12b)$$

or strain

$$\varepsilon = v / c \qquad (12c)$$

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.

Measurements are always taken at opposite sides of the pile as a means of calculating the average force and velocity in the pile. The velocity on the two sides of the pile is very similar even when high bending exists. Thus, an independent check of the velocity measurements is easy and simple.

Strain measurements may differ greatly between the two sides of the pile when bending exists. It is even possible that tension is measured on one side while very high compression exists on the other side of the pile. In extreme cases, bending might be so high that it leads to a nonlinear stress distribution. The averaging of the two strain signals does then not lead to the average pile force and proportionality will not be achieved.

When testing drilled shafts, measurements of strain may also be affected by local concrete quality variations. It is then often necessary to use four strain transducers spaced at 90 degrees around the pile for an improved strain data quality. The use of four transducers is also recommended for large pile

diameters, particularly when it is difficult to mount the sensors at least two pile widths or diameters below the pile top.

LIMITATIONS, ADDITIONAL CONSIDERATIONS

Mobilization of capacity

Estimates of pile capacity from dynamic testing indicate the **mobilized pile capacity at the time of testing**. At very high blow counts (low set per blow), dynamic test methods tend to produce lower bound capacity estimates as not all resistance (particularly at and near the toe) is fully activated.

Time dependent soil resistance effects

Static pile capacity from dynamic method calculations provide an estimate of the axial pile capacity. Increases and decreases in the pile capacity with time typically occur (soil setup/relaxation). Therefore, **restrike testing usually yields a better indication of long term pile capacity than a test at the end of pile driving**. Often a wait period of one or two days between end of driving and restrike is satisfactory for a realistic prediction of pile capacity but this waiting time depends, among other factors, on the permeability of the soil.

(A) Soil setup

Because excess positive pore pressures often develop during pile driving in fine grained soil (clays, silts or even fine sands), the capacity of a pile at the time of driving may often be less than the long term pile capacity. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and thus the pile capacity at the time of driving. As these pore pressures dissipate, the soil resistance acting on the pile increases as does the axial pile capacity. This phenomena is routinely called soil setup or soil freeze.

(B) Relaxation

Relaxation (capacity reduction with time) has been observed for piles driven into weathered shale, and may take several days to fully develop. Pile capacity estimates based upon initial driving or short term restrike tests can significantly overpredict long term pile capacity. Therefore, piles driven into shale should be tested after a minimum one week wait either statically or dynamically (with particular emphasis than on the first few blows). Relaxation has also been observed for displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe. Again, restrike tests should be used, with great emphasis on early blows.

Capacity results for open pile profiles

Larger diameter open ended pipe piles (or H-piles which do not bear on rock) may behave differently under dynamic and static loading conditions. Under dynamic loads the soil inside the pile or between its flanges may slip and produce internal friction while under static loads the plug may move with the pile, thereby creating end bearing over the full pile cross section. As a result both friction and end bearing components may be different under static and dynamic conditions.

CAPWAP Analysis Results

A portion of the soil resistance calculated on an individual soil segment in a CAPWAP analysis can usually be shifted up or down the shaft one soil segment without significantly altering the match quality. Therefore, use of the CAPWAP resistance distribution for uplift, downdrag, scour, or other geotechnical considerations should be made with an understanding of these analysis limitations.

Stresses

PDA and CAPWAP calculated stresses are average values over the cross section. Additional allowance has to be made for bending or non-uniform contact stresses. To prevent damage it is therefore important to maintain good hammer-pile alignment and to protect the pile toes using appropriate devices or an increased cross sectional area.

In the United States is has become generally acceptable to limit the dynamic installation stresses of driven piles to the following levels:

90% of yield strength for steel piles

85% of the concrete compressive strength - after subtraction of the effective prestress - for concrete piles in compression

100% of effective prestress plus ½ of the concrete's tension strength for prestressed piles in tension

70% of the reinforcement strength for regularly reinforced concrete piles in tension

300% of the static design allowable stress for timber

Note that the dynamic stresses may either be directly measured at the pile top by the PDA or calculated by the PDA for other locations along the pile based on the pile top measurements.

Additional design considerations

Numerous factors have to be considered in pile foundation design. Some of these considerations include

- additional pile loading from downdrag or negative skin friction,
- lateral and uplift loading requirements
- effective stress changes (due to changes in water table, excavations, fills or other changes in overburden),
- long term settlements in general and settlement from underlying weaker layers and/or pile group effects,

These factors have not been evaluated by GRL and have not been considered in the interpretation of the dynamic testing results. The foundation designer should determine if these or any other considerations are applicable to this project and the foundation design.

Wave equation analysis results

The results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Although attempts have been made to base the analysis on the best available information, actual field conditions may vary and therefore stresses and blow counts may differ from the predictions reported. Capacity predictions derived from wave equation analyses should use restrike information. However, because of the uncertainties associated with restrike blow counts and restrike hammer energies, correlations of such results with static test capacities with have often displayed considerable scatter.

As for PDA and CAPWAP, the theory on which GRLWEAP is based is the one-dimensional wave equation. For that reason, stress predictions by the wave equation analysis can only be averages over the pile cross section. Thus, bending stresses or stress concentrations due to non-uniform impact or uneven soil or rock resistance are not considered in these results. Stress maxima calculated by the wave equation are usually subjected to the same limits as those measured directly or calculated from measurements by the PDA.

Appendix B

Summary of Case Method Field Results

NW-J, AUTO HAMMER
OP: RMDT
Date: 14-July-2017

AR: 1.42 in²
LE: 48.40 ft
WS: 16,807.9 f/s

SP: 0.492 k/ft³
EM: 30,000 ksi
JC: 0.35 []

FMX: Maximum Force
VMX: Maximum Velocity
EFV: Energy of FV

ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute
AMX: Maximum Acceleration

BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
1	AV1	43	12.7	0.31	89.6	1.9	2,409
2	AV1	39	12.2	0.30	86.7	27.4	2,259
3	AV1	35	11.7	0.28	78.6	27.3	2,206
4	AV1	41	13.2	0.31	88.2	27.5	2,582
5	AV1	38	12.1	0.29	82.0	27.4	2,330
6	AV1	40	12.4	0.31	89.0	27.5	2,410
7	AV1	41	12.9	0.31	89.4	27.4	2,493
8	AV1	38	11.9	0.28	81.3	27.5	2,269
9	AV1	40	12.3	0.31	88.0	27.4	2,391
10	AV1	39	11.7	0.28	80.8	27.4	2,298
11	AV1	44	13.2	0.32	91.4	27.5	2,567
12	AV1	41	12.5	0.31	88.4	27.5	2,429
13	AV1	40	12.7	0.29	82.2	27.5	2,577
14	AV1	41	12.6	0.31	88.3	27.4	2,395
15	AV1	36	11.9	0.29	81.8	27.5	2,056
16	AV1	36	11.3	0.29	83.9	27.4	2,184
17	AV1	39	12.3	0.31	87.5	27.5	2,220
18	AV1	35	11.5	0.27	76.2	27.3	2,132
19	AV1	43	13.1	0.32	90.6	27.6	2,568
20	AV1	35	11.6	0.26	75.1	27.4	2,054
21	AV1	35	11.5	0.26	75.7	27.5	2,225
22	AV1	34	11.5	0.27	76.1	27.5	1,974
23	AV1	36	11.5	0.28	79.8	27.5	2,136
24	AV1	36	11.3	0.30	85.1	27.5	2,337
25	AV1	37	11.9	0.30	85.1	27.6	2,236
26	AV1	37	11.8	0.30	85.0	27.5	2,292
27	AV1	37	12.0	0.27	76.4	27.4	2,330
28	AV1	41	12.8	0.30	86.7	27.7	2,583
29	AV1	36	11.8	0.29	82.2	27.5	2,226
30	AV1	37	12.2	0.29	83.9	27.5	2,275
31	AV1	34	11.3	0.26	74.8	27.5	1,943
32	AV1	39	12.2	0.30	84.8	27.5	2,373
33	AV1	35	12.0	0.28	78.7	27.6	2,131
34	AV1	37	12.1	0.28	80.1	27.5	2,299
35	AV1	35	11.7	0.28	80.4	27.5	2,333
36	AV1	40	12.8	0.30	87.0	27.6	2,560
37	AV1	41	12.7	0.30	86.6	27.5	2,630
38	AV1	40	12.9	0.31	87.8	27.5	2,541
39	AV1	38	12.4	0.28	80.5	27.3	2,410
40	AV1	42	13.0	0.31	88.3	27.6	2,553
41	AV1	43	13.3	0.31	89.8	27.5	2,683
42	AV1	39	13.2	0.30	86.8	27.5	2,709
43	AV1	42	13.2	0.31	88.4	27.5	2,588
44	AV1	43	13.3	0.32	91.0	27.5	2,853
45	AV1	39	12.3	0.31	87.7	27.5	2,567
46	AV1	40	13.0	0.30	86.7	27.6	2,556
47	AV1	34	11.7	0.26	73.3	27.4	2,134

NW-J, AUTO HAMMER
OP: RMDT Date: 14-July-2017

BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
48	AV1	34	11.6	0.26	75.1	27.5	1,994
49	AV1	37	11.9	0.29	83.7	27.6	2,246
50	AV1	37	12.1	0.28	80.4	27.5	2,256
51	AV1	40	12.5	0.30	85.9	27.4	2,537
52	AV1	36	12.3	0.27	77.5	27.5	2,539
53	AV1	37	12.1	0.30	86.7	27.5	2,416
54	AV1	41	13.3	0.31	88.4	27.6	2,725
55	AV1	37	12.3	0.29	84.1	27.5	2,421
56	AV1	39	12.4	0.29	82.6	27.6	2,477
57	AV1	43	13.1	0.31	88.7	27.5	2,713
58	AV1	40	12.8	0.30	84.5	27.5	2,837
59	AV1	37	12.3	0.30	85.0	27.5	2,330
60	AV1	39	12.7	0.30	85.1	27.6	2,584
61	AV1	38	12.4	0.29	84.0	27.5	2,470
62	AV1	41	13.0	0.30	87.0	27.6	2,769
63	AV1	42	13.7	0.32	90.3	27.5	2,951
64	AV1	41	13.2	0.32	90.9	27.6	2,891
65	AV1	40	12.9	0.29	83.0	27.5	2,666
66	AV1	38	12.5	0.29	83.3	27.6	2,424
67	AV1	35	11.9	0.27	76.1	27.4	2,138
68	AV1	35	12.0	0.27	77.0	27.5	2,228
69	AV1	39	12.4	0.28	79.9	27.5	2,502
70	AV1	36	12.3	0.28	79.5	27.6	2,278
71	AV1	36	11.8	0.27	77.6	27.5	2,523
72	AV1	39	12.3	0.31	88.0	1.9	2,271
73	AV1	40	13.0	0.30	86.6	46.5	2,542
74	AV1	43	13.3	0.32	91.9	45.9	2,762
75	AV1	42	13.4	0.32	92.0	46.8	2,860
76	AV1	40	13.3	0.32	90.6	46.4	2,706
77	AV1	39	12.8	0.30	85.3	46.2	2,591
78	AV1	44	13.7	0.35	100.0	46.9	3,020
79	AV1	40	12.7	0.30	86.4	46.0	2,529
80	AV1	41	13.2	0.31	88.6	46.2	2,729
81	AV1	45	13.8	0.34	96.9	46.4	3,035
82	AV1	45	13.7	0.34	97.9	46.6	2,835
83	AV1	45	14.1	0.34	98.3	46.4	2,586
84	AV1	45	13.7	0.34	96.6	46.4	2,608
85	AV1	44	13.6	0.33	95.3	46.5	2,638
86	AV1	45	13.9	0.34	98.6	46.3	2,907
87	AV1	45	13.3	0.32	91.1	46.4	2,552
88	AV1	43	13.4	0.32	92.6	46.6	2,660
89	AV1	45	13.7	0.34	97.6	46.6	2,685
90	AV1	43	13.1	0.31	89.2	46.5	2,432
91	AV1	46	13.7	0.34	98.6	46.3	2,863
92	AV1	45	13.8	0.34	97.6	46.5	2,891
93	AV1	41	12.7	0.30	84.8	46.4	2,520
94	AV1	45	14.1	0.34	96.0	46.5	2,945
95	AV1	41	12.6	0.30	84.4	46.4	2,232
96	AV1	43	13.6	0.34	95.9	46.5	2,945
97	AV1	43	13.5	0.32	91.5	46.5	2,606
98	AV1	40	12.6	0.30	85.2	46.6	2,194
99	AV1	41	13.2	0.30	86.4	46.2	2,525
100	AV1	41	13.7	0.32	91.3	46.4	2,644

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BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
101	AV1	44	14.3	0.34	96.4	46.4	2,954
102	AV1	44	14.1	0.35	98.9	46.4	2,914
103	AV1	40	13.2	0.32	90.4	46.5	2,483
104	AV1	42	13.7	0.33	94.8	46.2	2,672
105	AV1	42	13.8	0.32	92.8	47.0	2,478
106	AV1	41	13.2	0.31	87.9	46.3	2,588
107	AV1	42	14.1	0.33	95.5	46.3	2,963
108	AV1	42	13.8	0.33	93.4	46.4	2,630
109	AV1	39	13.2	0.30	85.6	46.2	2,481
110	AV1	41	14.1	0.31	89.5	46.7	2,514
111	AV1	44	14.4	0.34	96.5	46.7	2,837
112	AV1	42	13.9	0.32	90.4	46.6	2,654
113	AV1	42	14.6	0.33	94.0	46.2	2,903
114	AV1	42	13.9	0.31	88.6	46.5	2,441
115	AV1	41	14.4	0.32	91.2	46.5	2,625
116	AV1	41	14.1	0.32	90.1	46.4	2,587
117	AV1	42	14.5	0.32	92.0	46.5	2,593
118	AV1	42	14.8	0.33	93.5	46.3	2,833
119	AV1	40	13.3	0.30	86.3	46.5	2,237
120	AV1	38	13.2	0.30	84.7	46.3	2,530
121	AV1	42	14.4	0.32	91.6	46.7	2,738
122	AV1	43	14.1	0.31	89.6	1.9	2,768
123	AV1	42	13.8	0.31	88.1	38.3	2,876
124	AV1	43	14.1	0.32	92.2	38.8	2,800
125	AV1	44	14.3	0.33	94.9	38.7	2,757
126	AV1	44	14.2	0.33	93.0	38.6	2,915
127	AV1	42	14.0	0.33	94.7	38.8	2,915
128	AV1	43	15.1	0.35	98.8	38.8	3,114
129	AV1	42	14.9	0.33	95.7	38.6	3,043
130	AV1	42	14.0	0.32	91.8	38.6	3,034
131	AV1	41	13.9	0.32	92.4	38.7	2,782
132	AV1	41	14.2	0.32	92.3	38.6	2,788
133	AV1	43	14.1	0.33	95.2	38.7	2,759
134	AV1	44	14.6	0.34	96.1	38.7	2,902
135	AV1	43	13.8	0.33	93.2	38.6	2,893
136	AV1	42	14.0	0.33	94.3	38.8	3,008
137	AV1	43	14.3	0.33	95.5	38.6	3,310
138	AV1	43	14.1	0.33	95.5	38.7	2,771
139	AV1	43	13.8	0.33	94.0	38.6	2,915
140	AV1	40	13.7	0.32	92.1	38.7	2,789
141	AV1	40	13.6	0.31	88.4	38.7	2,742
142	AV1	41	13.4	0.33	93.4	38.7	2,808
143	AV1	39	13.7	0.32	91.3	38.5	2,987
144	AV1	42	13.7	0.33	94.7	38.8	2,699
145	AV1	37	13.2	0.31	88.1	38.6	2,518
146	AV1	36	13.5	0.32	90.9	38.7	2,626
147	AV1	40	13.4	0.33	95.4	38.6	2,700
148	AV1	44	13.6	0.32	92.8	38.6	3,163
149	AV1	43	13.6	0.33	95.1	38.7	3,120
150	AV1	42	13.7	0.33	95.6	38.7	2,920
151	AV1	42	13.5	0.33	93.9	38.7	2,971
152	AV1	40	13.6	0.34	95.9	38.6	2,771
153	AV1	38	12.9	0.30	85.9	38.7	2,265

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BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
154	AV1	40	13.1	0.33	93.4	38.6	2,858
155	AV1	38	13.2	0.31	88.9	38.7	2,386
156	AV1	38	13.4	0.33	94.0	38.6	2,772
157	AV1	37	13.6	0.33	93.1	38.6	2,740
158	AV1	38	13.3	0.32	91.2	38.6	2,656
159	AV1	36	13.1	0.29	83.7	38.6	2,425
160	AV1	38	13.0	0.31	89.2	38.7	2,507
161	AV1	38	13.3	0.32	90.4	38.6	2,871
162	AV1	40	14.0	0.33	94.8	38.8	2,917
163	AV1	35	13.5	0.32	91.0	38.7	2,280
164	AV1	35	13.5	0.31	89.8	38.6	2,651
165	AV1	38	13.8	0.32	92.2	38.7	2,780
166	AV1	41	13.8	0.33	93.2	38.6	2,921
167	AV1	40	13.4	0.32	92.4	38.7	2,913
168	AV1	41	13.7	0.33	94.6	38.8	2,909
169	AV1	43	14.0	0.33	94.9	38.7	3,063
170	AV1	43	14.9	0.34	96.8	1.9	2,823
171	AV1	44	14.8	0.34	96.9	41.0	2,767
172	AV1	42	14.2	0.33	93.2	41.1	2,453
173	AV1	43	15.0	0.34	97.6	41.0	2,875
174	AV1	41	14.1	0.33	93.8	41.0	2,466
175	AV1	39	13.8	0.32	90.6	41.4	2,433
176	AV1	40	14.8	0.33	94.6	41.0	2,968
177	AV1	39	14.6	0.32	91.4	41.0	2,781
178	AV1	40	15.3	0.34	97.5	41.3	2,971
179	AV1	41	15.3	0.33	93.8	41.1	2,841
180	AV1	39	15.0	0.33	95.1	41.0	2,913
181	AV1	38	14.8	0.33	92.9	41.4	2,992
182	AV1	39	15.5	0.33	95.1	41.0	2,888
183	AV1	38	15.0	0.32	91.4	41.1	2,929
184	AV1	36	14.2	0.32	90.4	41.2	2,666
185	AV1	38	15.0	0.33	94.3	41.3	2,796
186	AV1	40	15.2	0.34	97.0	41.1	2,915
187	AV1	36	14.5	0.31	87.8	40.9	2,669
188	AV1	38	14.5	0.32	91.1	41.4	2,734
189	AV1	38	14.5	0.32	92.2	41.2	2,842
190	AV1	38	14.1	0.32	90.5	40.9	2,901
191	AV1	35	13.2	0.32	92.6	41.3	2,515
192	AV1	39	14.6	0.33	93.1	41.1	3,037
193	AV1	37	14.0	0.32	90.3	41.1	2,642
194	AV1	39	14.2	0.33	92.9	41.2	2,676
195	AV1	37	13.5	0.32	90.4	41.2	2,576
196	AV1	34	13.4	0.30	85.1	41.1	2,500
197	AV1	34	13.4	0.30	86.7	40.9	2,485
198	AV1	37	13.6	0.31	87.7	41.1	2,613
199	AV1	34	13.3	0.30	85.9	41.2	2,414
200	AV1	36	13.9	0.31	89.8	41.0	2,688
201	AV1	37	14.7	0.31	89.9	41.2	2,714
202	AV1	36	13.5	0.30	85.0	41.2	2,579
203	AV1	36	13.5	0.31	89.4	41.3	2,566
204	AV1	34	13.0	0.31	87.8	41.0	2,422
205	AV1	37	13.9	0.33	94.5	41.3	2,619
206	AV1	35	13.4	0.31	88.4	41.0	2,491

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BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
207	AV1	35	12.7	0.30	86.3	41.0	2,538
208	AV1	33	13.0	0.29	83.1	41.1	2,416
209	AV1	35	13.7	0.31	88.0	41.2	2,509
210	AV1	37	14.3	0.32	90.5	41.1	2,646
211	AV1	38	14.8	0.33	93.0	41.2	2,846
212	AV1	37	14.6	0.32	92.7	41.1	2,678
213	AV1	35	14.1	0.30	85.0	41.2	2,540
214	AV1	33	13.2	0.29	81.6	40.9	2,354
215	AV1	34	13.6	0.30	86.1	41.1	2,562
216	AV1	35	13.2	0.31	89.5	41.3	2,500
217	AV1	38	14.1	0.32	92.3	41.2	2,745
218	AV1	34	13.0	0.31	88.1	41.0	2,526
219	AV1	34	12.5	0.30	86.7	41.4	2,348
220	AV1	33	13.0	0.30	85.4	40.9	2,464
221	AV1	30	11.6	0.30	86.0	41.1	2,058
222	AV1	30	11.7	0.29	81.6	41.0	2,082
223	AV1	31	12.1	0.30	86.8	41.3	2,160
224	AV1	34	12.9	0.30	87.0	41.0	2,454
225	AV1	31	12.3	0.28	81.2	41.3	2,146
226	AV1	34	12.9	0.30	84.3	41.3	2,261
227	AV1	33	12.2	0.29	83.5	40.7	2,204
228	AV1	37	13.3	0.32	90.6	41.3	2,568
229	AV1	32	13.2	0.30	84.3	41.2	2,175
230	AV1	35	12.9	0.30	84.7	41.1	2,444
231	AV1	35	13.3	0.31	89.7	41.1	2,595
232	AV1	34	13.4	0.30	85.6	41.1	2,499
233	AV1	31	12.3	0.29	81.5	41.1	2,088
234	AV1	34	13.0	0.30	86.6	41.0	2,418
235	AV1	34	13.1	0.31	87.8	41.3	2,495
236	AV1	36	13.6	0.31	89.0	41.0	2,635
237	AV1	36	13.7	0.31	89.7	41.1	2,679
238	AV1	34	13.0	0.30	85.3	41.2	2,440
239	AV1	34	13.3	0.30	84.4	41.1	2,484
240	AV1	34	12.9	0.29	83.8	41.0	2,229
241	AV1	34	13.2	0.31	87.8	40.9	2,494
242	AV1	33	13.3	0.30	85.9	41.0	2,431
243	AV1	35	13.0	0.31	87.7	41.2	2,499
244	AV1	35	13.7	0.32	90.2	41.2	2,683
245	AV1	35	13.8	0.31	88.1	41.0	2,687
246	AV1	35	13.8	0.32	91.4	41.0	2,659
247	AV1	34	13.8	0.32	91.1	41.1	2,582
248	AV1	36	13.7	0.32	91.6	41.1	2,726
249	AV1	36	14.0	0.32	90.3	41.2	2,785
250	AV1	34	13.2	0.29	83.3	41.1	2,383
251	AV1	29	11.9	0.29	82.2	40.8	2,175
252	AV1	34	12.2	0.29	83.8	41.1	2,270
253	AV1	33	13.0	0.30	85.5	40.8	2,433
254	AV1	34	13.1	0.30	86.3	41.2	2,401
255	AV1	35	12.7	0.31	89.2	41.0	2,342
256	AV1	35	13.3	0.31	87.4	40.7	2,547
257	AV1	34	13.2	0.31	88.3	41.2	2,644
258	AV1	35	13.4	0.31	88.6	41.1	2,591
259	AV1	34	13.3	0.31	89.3	41.1	2,496

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BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
260	AV1	35	13.3	0.31	88.2	41.0	2,404
261	AV1	33	13.0	0.31	89.5	41.0	2,457
262	AV1	33	13.4	0.31	87.4	41.0	2,572
263	AV1	41	13.7	0.32	91.9	1.9	2,661
264	AV1	42	14.2	0.33	94.4	37.6	2,907
265	AV1	42	13.6	0.32	91.9	37.8	2,936
266	AV1	43	15.2	0.34	97.0	37.9	3,115
267	AV1	40	13.8	0.32	91.5	37.7	2,804
268	AV1	40	14.0	0.32	90.8	37.7	2,901
269	AV1	41	14.0	0.33	93.2	37.7	2,733
270	AV1	41	14.2	0.33	93.5	37.8	2,726
271	AV1	40	14.1	0.33	93.1	38.0	2,880
272	AV1	42	14.2	0.33	94.2	37.6	2,990
273	AV1	39	13.9	0.31	89.6	37.6	2,987
274	AV1	41	13.8	0.31	89.4	37.8	2,978
275	AV1	42	14.8	0.34	97.9	37.9	3,136
276	AV1	38	13.5	0.31	89.1	37.7	2,962
277	AV1	42	13.9	0.33	93.5	37.7	3,139
278	AV1	38	13.8	0.32	91.8	37.9	2,781
279	AV1	39	13.8	0.32	92.0	37.8	3,131
280	AV1	34	13.8	0.32	90.6	37.8	2,685
281	AV1	36	13.3	0.31	88.5	37.7	2,772
282	AV1	35	13.5	0.32	90.3	37.7	2,746
283	AV1	36	13.8	0.32	91.4	37.8	2,732
284	AV1	35	13.4	0.32	92.7	37.8	2,614
285	AV1	37	13.6	0.33	93.7	37.8	2,797
286	AV1	36	14.2	0.32	92.2	37.7	2,708
287	AV1	35	14.1	0.32	90.9	37.8	2,591
288	AV1	38	14.4	0.33	94.0	37.7	2,784
289	AV1	37	14.5	0.33	93.1	37.8	2,875
290	AV1	38	14.3	0.33	95.1	37.7	2,978
291	AV1	37	14.5	0.33	94.8	37.8	3,215
292	AV1	38	14.4	0.34	96.4	37.7	3,056
293	AV1	36	14.2	0.32	90.9	37.7	2,712
294	AV1	38	14.4	0.33	95.5	37.8	2,976
295	AV1	38	14.8	0.33	95.1	37.7	3,050
296	AV1	38	14.6	0.32	90.8	37.7	2,976
297	AV1	38	14.4	0.33	93.1	37.8	3,155
298	AV1	37	14.5	0.32	90.1	37.7	2,722
299	AV1	36	14.7	0.32	91.8	37.7	2,780
300	AV1	38	14.5	0.33	94.2	37.8	2,737
301	AV1	38	14.8	0.34	97.1	37.8	3,176
302	AV1	36	14.4	0.34	95.9	37.7	3,066
303	AV1	35	14.4	0.32	90.1	37.7	2,751
304	AV1	35	14.3	0.33	95.3	37.8	3,002
305	AV1	35	14.5	0.31	88.8	37.7	2,816
306	AV1	37	15.0	0.32	91.5	37.8	2,775
307	AV1	36	14.7	0.32	91.5	37.7	2,764
308	AV1	36	14.6	0.31	89.1	37.7	2,974
309	AV1	37	15.2	0.33	94.8	37.8	2,830
310	AV1	37	15.0	0.32	92.5	37.7	3,076
311	AV1	39	15.6	0.34	98.2	37.9	3,150
312	AV1	38	14.9	0.32	90.8	37.6	3,000

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BL#	TYPE	FMX	VMX	EFV	ETR	BPM	AMX
		kips	f/s	k-ft	(%)	bpm	g's
313	AV1	38	15.2	0.33	93.7	37.7	2,952
314	AV1	38	14.9	0.32	91.2	37.8	2,874
315	AV1	38	15.2	0.33	94.2	37.7	3,079
316	AV1	38	15.2	0.33	93.6	37.8	2,932
317	AV1	40	16.2	0.34	98.5	37.7	3,064
318	AV1	37	15.1	0.32	90.6	37.8	2,789
319	AV1	39	15.5	0.34	97.7	37.8	3,245
320	AV1	39	15.4	0.34	96.0	37.7	2,854
321	AV1	40	15.4	0.34	97.1	37.7	3,188
322	AV1	38	15.2	0.34	96.2	37.7	3,262
323	AV1	38	14.7	0.33	93.9	37.7	3,117
324	AV1	39	15.1	0.33	95.6	37.7	3,090
325	AV1	39	15.1	0.34	96.1	37.7	3,215
326	AV1	33	14.1	0.31	88.7	37.8	2,614
327	AV1	39	14.6	0.33	94.8	37.7	3,026
328	AV1	35	13.8	0.31	87.7	37.7	2,489
329	AV1	36	14.3	0.31	89.8	37.7	2,667
330	AV1	36	14.5	0.33	95.1	37.8	3,049
331	AV1	36	14.5	0.32	91.8	37.7	2,658
332	AV1	35	12.9	0.32	92.3	37.9	2,467
333	AV1	35	14.1	0.32	92.2	37.7	2,516
334	AV1	36	14.3	0.32	91.7	37.7	2,816
335	AV1	37	14.8	0.33	94.6	37.8	2,844
336	AV1	34	13.7	0.30	86.3	37.7	2,505
337	AV1	34	14.0	0.32	90.2	37.6	2,462
338	AV1	35	13.9	0.33	93.0	37.9	2,474
339	AV1	32	13.4	0.30	84.3	37.7	2,301
Average		38	13.5	0.31	89.7	37.4	2,651

Total number of blows analyzed: 339

BL# Comments

1 Begin Sample at 40 ft.
72 Begin Sample at 45 ft.
122 Begin Sample at 50 ft.
170 Begin Sample at 55 ft.
263 Begin Sample at 60 ft.
339 End of testing.

Time Summary

Drive 2 minutes 32 seconds 9:25 AM - 9:28 AM (7/14/2017) BN 1 - 71
Stop 21 minutes 44 seconds 9:28 AM - 9:49 AM
Drive 1 minute 3 seconds 9:49 AM - 9:51 AM BN 72 - 121
Stop 14 minutes 1 second 9:51 AM - 10:05 AM
Drive 1 minute 12 seconds 10:05 AM - 10:06 AM BN 122 - 169
Stop 15 minutes 55 seconds 10:06 AM - 10:22 AM
Drive 2 minutes 14 seconds 10:22 AM - 10:24 AM BN 170 - 262
Stop 15 minutes 44 seconds 10:24 AM - 10:40 AM
Drive 2 minutes 0 second 10:40 AM - 10:42 AM BN 263 - 339

Total time [01:16:28] = (Driving [00:09:03] + Stop [01:07:25])

Report 3
Holt CME-85

July 2, 2013

Mr. Dale Abernathy
Holt Services, Inc.
13000 Lakeholme Road Sw
Lakewood, WA 98498

Re: Penetration Test Energy Measurements
Bore Hole: E340-B-07A, July 1, 2013
Truck Mounted CME Rig No. 7, 140lb ram, NW-J Rod
Bellevue, Washington RMDT Job No. 13F36

Dear Mr. Abernathy,

This letter presents energy transfer measurements made during Standard Penetration Tests for the drill hole and drill rig referenced above. Robert Miner Dynamic Testing, Inc. (RMDT) made dynamic measurements with a Pile Driving Analyzer® as a hammer advanced the NW rod during sampling with a split spoon sampler.

The purpose of RMDT's testing was the measurement of energy transferred to the drill rods. Measurements were made on a section of NW gauge rod at the top of the drill rod. Strain gages and accelerometers on the rod were connected to a Pile Driving Analyzer® (PDA) which generally processed acceleration and strain measurements from each hammer blow and stored both the measurements and computed results. Measurements and data processing generally followed the ASTM D 4633-10 standard. Energy transfer past the gage location, EFV, was computed by the PDA using force and velocity records as follows:

$$EFV = \int_a^b F(t)\, v(t)\, dt$$

The value "a" corresponds to the start of the record which is when the energy transfer begins and *"b"* is the time at which energy transferred to the rod reaches a maximum value. Appendix A contains more information on our measurement equipment and methods of analysis. The EFV energy calculation is identical to the EMX energy result discussed in Appendix A. The EFV and EMX values apply to the sensor location near the top of the rod.

TEST DETAILS

Testing occurred on July 1, 2013. Boring E340-B-07A was advanced in the maintenance yard for the Microsoft Connector Buses in Bellevue, Washington. NW size rod was used to advance a split spoon sampler. The automatic hammer in use during our testing was manufactured by Central Mine Equipment (CME) and was reported to use a 140 lb ram. The drill rig was a truck-mounted CME-85 and referred to as Rig No. 7 by the operator.

RESULTS

A summary of testing and monitoring results is given in Table 1. The tabulated results include the starting sample depth, the penetration resistance, the number of hammers blows in our data set, measured energy transfer, EFV, the computed transfer efficiency, ETR, and the hammer blow rate, BPM. Appendix B contains detailed numeric results for each individual test.

Energy measurements must be divided by the theoretical free fall energy of the hammer to obtain an efficiency. A 140 lb ram raised 30 inches above an impact surface has 350 lb-ft of potential energy. Thus, the transfer energy results for sampling with the 140 ram may be divided by 350 lb-ft to yield the ratio of the delivered energy to the nominal potential energy. This efficiency ratio, ETR, is given for each sample interval as a percent efficiency.

Table 1. Summary of Test Details and Results for the 140-lb ram and Split Spoon Sampler

Sample Name and Sample Start Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
Sample 1, 15ft	48/1ft	48	298	85	46
Sample 2, 20ft	58/1ft	58	306	87	46
Sample 3, 30ft	89/1ft	89	317	91	47
Sample 4, 40ft	81/1ft	81	316	90	47
Sample 5, 50ft	50/6in	49	325	93	45
Sample 6, 60ft	57/6in	57	321	92	46
Average for Split Spoon samples:			**314**	**90**	**46**

Six sample returns were monitored while the 140 lb ram and standard split spoon sampler were in use. The overall average ETR and hammer blow rate was 90 percent and 46 blows per minute, respectively.

It was a pleasure to assist you and to participate on this project with the staff of Holt Services, Inc. Please do not hesitate to contact us if you or your client have any questions about this report.

Sincerely,

Andrew Banas
Staff Engineer
Robert Miner Dynamic Testing, Inc.

APPENDIX A
AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

BACKGROUND

Modern procedures of design and construction control require verification of bearing capacity and integrity of deep foundations during preconstruction test programs and also production installation. Dynamic pile testing methods meet this need economically and reliably, and therefore, form an important part of a quality assurance program when deep foundations are executed. Several dynamic pile testing methods exist; they have different benefits and limitations and different requirements for proper execution.

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 (such as that of a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. The method is therefore 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 an evaluation of various quantities based on closed form solutions of the wave equation, a partial differential equation describing the motion of a rod under the effect of an impact. Conveniently, measurements and analyses are done by a single piece of equipment: the Pile Driving Analyzer® (PDA). However, for bearing capacity evaluations an important additional method is CAPWAP® which performs a much more rigorous analysis of the dynamic records than the simpler Case Method.

A related analysis method is the "Wave Equation Analysis" which calculates a relationship between bearing capacity and pile stress and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data.

The following description deals primarily with the Case Method or "High Strain Test" Method of pile testing, however, for the sake of completeness, the "Low Strain Test" performed with the Pile Integrity Test™ (PIT), mainly for pile integrity evaluation, will also be described.

RESULTS FROM DYNAMIC TESTING

There are two main objectives of high strain dynamic pile testing:

- *Dynamic Pile Monitoring* and
- *Dynamic Load Testing*.

Dynamic pile monitoring is conducted during the installation of impact driven piles to achieve a safe and economical pile installation. Dynamic load testing, on the other hand, has as its primary goal the assessment of pile bearing capacity. It is applicable to both cast *insitu* piles or drilled shafts and impact driven piles during restrike.

Dynamic Pile Monitoring

During pile installation, the sensors attached to the pile measure pile top force and velocity. A PDA conditions and processes these signals and calculates or evaluates:

- Bearing capacity at the time of testing, including an assessment of shaft resistance development and driving resistance. This information supports formulation of a driving criterion.

- Dynamic pile stresses, axial and averaged over the pile cross section, both tensile and compressive, during pile driving to limit the potential of damage either near the pile top or along its length. Bending stresses can be evaluated at the point of sensor attachment.

- Pile integrity assessment by the PDA is based on the recognition of certain wave reflections from along the pile. If detected early enough, a pile may be saved from complete destruction. On the other hand, once damage is recognized measures can be taken to prevent reoccurrence.

- Hammer performance parameters including the energy transferred to the pile, the hammer speed in blows per minute and the stroke of open ended diesel hammers.

Dynamic Pile Load Testing

Bearing capacity testing of either driven piles or drilled shafts applies the same basic measurement approach of dynamic pile monitoring. However, the test is done independent of the pile installation process and therefore a pile driving hammer or other dynamic loading device may not be available. If a special ram has to be mobilized then its weight should be between 0.8 and 2% of the test load (e.g. between 4 and 10 tons for a 500 ton test load) to assure sufficient soil resistance activation.

For a successful test, it most important that the test is conducted after a sufficient waiting time following pile installation for soil properties approaching their long term condition or concrete to properly set. During testing, PDA results of pile/shaft stresses and transferred energy are used to maintain safe stresses and assure sufficient resistance activation. For safe and sufficient testing of drilled shafts, ram energies are often increased from blow to blow until the test capacity has been activated. On the other hand, restrike tests on driven piles may require a warm hammer so that the very first blow produces a complete resistance activation. Data must be evaluated by CAPWAP for bearing capacity.

After the dynamic load test has been conducted with sufficient energy and safe stresses, the CAPWAP analysis provides the following results:

- Bearing capacity i.e. the mobilized capacity present at the time of testing

- Resistance distribution including shaft resistance and end bearing components

- Stresses in pile or shaft calculated for both the static load application and the dynamic test. These stresses are averages over the cross section and do not include bending effects or nonuniform contact stresses, e.g. when the pile toe is on uneven rock.

- Shaft impedance vs depth; this is an estimate of the shaft shape if it differs substantially from the planned profile

- Dynamic soil parameters for shaft and toe, i.e. damping factors and quakes (related to the dynamic stiffness of the resistance at the pile/soil interface.)

MEASUREMENTS

PDA

The basis for the results calculated by the PDA are pile top strain and acceleration measurements which are converted to force and velocity records, respectively. The PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. Using closed form Case Method solutions, based on the one-dimensional linear wave equation, the PDA calculates the results described in the analytical solutions section below.

HPA

The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. For this unit to be applicable, the ram must be visible. The impact velocity results can be automatically processed with a PC or recorded on a strip chart.

Saximeter™

For open end diesel hammers, the time between two impacts indicates the magnitude of the ram fall height or stroke. This information is not only measured and calculated by the PDA but also by the convenient, hand-held Saximeter.

PIT

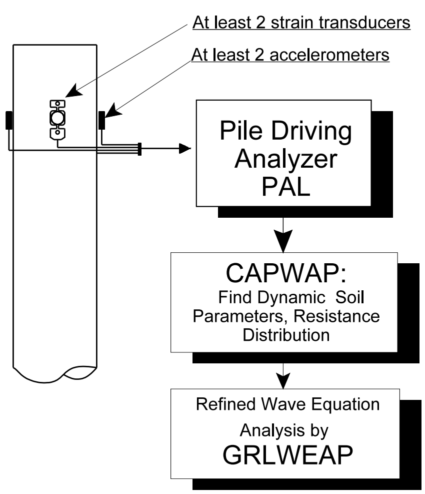
The Pile Integrity Tester™ (PIT) can be used to evaluate defects in concrete piles or shafts which may have occurred during driving or casting. Also timber piles of limited length can be tested in that manner. This so-called "Low Strain Method" or “Pulse-Echo Method” of integrity testing requires only the measurement of acceleration at the pile top. The stress wave producing impact is then generated by a small hand-held hammer and the records interpreted in the time domain. PIT also supports the so-called “Transient Response Method” which requires the additional measurement of the hammer force and an analysis in the frequency domain. This method may also be used to evaluate the unknown length of deep foundations under existing structures.

ANALYTICAL SOLUTIONS
BEARING CAPACITY

Wave Equation

GRL has written the GRLWEAP™ program which calculates a relationship between bearing capacity, pile stress and blow count. This relationship is often called the “bearing graph.” Once the blow count is known from pile installation logs, the bearing graph yields the bearing capacity. This approach requires no measurements and therefore can be performed during the design stage of a project, for example for the selection of hammer, cushion and pile size.

After dynamic pile monitoring and/or dynamic load testing has been performed, the “Refined Wave Equation Analysis” or RWEA (see schematic below) is often performed by inputting the PDA and CAPWAP calculated parameters. Then the bearing graph from the RWEA is the basis for a safe and sufficient driving criteria.



Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil resistance is

$$R(t) = \tfrac{1}{2}\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

t = a point in time after impact
t_2 = time $t + 2L/c$
L = pile length below gages
c = $(E/\rho)^{1/2}$ is the speed of the stress wave
ρ = pile mass density
Z = EA/c is the pile impedance
E = elastic modulus of the pile (ρc^2)
A = pile cross sectional area

The total soil resistance consists of a dynamic (R_d) and a static (R_s) component. The static component is therefore

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2.

There are a number of ways in which Eq. 1 through 3 can be evaluated. Most commonly, t_2 is set to that time at which the static resistance becomes maximum. The result is the so-called **RMX** capacity. Damping factors for RMX typically range between 0.5 for coarse grained materials to 1.0 for clays. The **RSP** capacity (this method is most commonly referred to in the literature, yet it is not very frequently used) requires damping factors between 0.1 for sand and 1.0 for clay. Another capacity, **RA2**, determines the capacity at a time when the pile is essentially at rest and thus damping is small; RA2

therefore requires no damping parameter. In any event, the proper Case Method and its associated damping parameter is most conveniently found after a CAPWAP analysis has been performed.

The static resistance calculated by Case Method or CAPWAP is the mobilized resistance at the time of testing. Consideration therefore has to be given to soil setup or relaxation effects and whether or not a sufficient set has been achieved under the test loading that would correspond to a full activation of the ultimate soil resistance.

The PDA also calculates an estimate of shaft resistance as the difference between force and velocity times impedance at the time immediately prior to the return of the stress wave from the pile toe. This shaft resistance is not reduced by damping effects and is therefore called the total shaft resistance **SFT**. A correction for damping effects produces the static shaft resistance estimate, **SFR**.

The Case Method solution is simple enough to be evaluated "in real time," i.e. between hammer blows, using the PDA. It is therefore possible to calculate all relevant results for all hammer blows and plot these results as a function of depth or blow number. This is done in the PDAPLOT program.

CAPWAP

The CAse Pile Wave Analysis Program combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the shaft resistance, end bearing, damping factors and soil stiffnesses. The method iteratively calculates a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

During pile monitoring, it is important that compressive stress maxima at pile top and toe and tensile stress maxima somewhere along the pile be calculated for each hammer blow.

At the pile top (location of sensors) both the maximum compression stress, **CSX**, and the maximum stress from individual strain transducers, **CSI**, are directly obtained from the measurements. Note that CSI is greater than or equal to CSX and the difference between CSI and CSX is a measure of bending in the plane of the strain transducers. Note also that all stresses calculated for locations below the sensors are averaged over the pile cross section and therefore do not include components from either bending or eccentric soil resistance effects.

The PDA calculates the compressive stress at the pile bottom, **CSB**, assuming (a) a uniform pile and (b) that the pile toe force is the maximum value of the total resistance R(t) minus the total shaft resistance, SFT. Again, for this stress estimation uniform resistance force are assumed (e.g. not a sloping rock.)

For concrete piles, the maximum tension stress, **TSX**, is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by finding the maximum tension wave (either traveling upward, W_U, or downward, W_d) and reducing it by the minimum compressive wave traveling in opposite direction.

$$W_u = \tfrac{1}{2}[F(t) - Zv(t)] \tag{4}$$

$$W_d = \tfrac{1}{2}[F(t) + Zv(t)] \tag{5}$$

CAPWAP also calculates tensile and compressive stresses along the pile and, in general, more accurately than the PDA. In fact, for non-uniform piles or piles with joints, cracks or other discontinuities, the closed form solutions from the PDA may be in error.

PILE INTEGRITY

High Strain Tests (PDA)

Stress waves in a pile are reflected wherever the pile impedance, $Z = EA/c = \rho c A = A\sqrt{(E\rho)}$, changes. Therefore, the pile impedance is a measure of the quality of the pile material (E, ρ, c) and the size of its cross section (A). The reflected waves arrive at the pile top at a time which is greater the farther away from the pile top the reflection occurs. The

magnitude of the change of the upward traveling wave (calculated from the measured force and velocity, Eq. 4) indicates the extent of the cross sectional change. Thus, with β_i (**BTA**) being a relative integrity factor which is unity for no impedance change and zero for the pile end, the following is calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \qquad (6)$$

with

$$\alpha_i = ½(W_{UR} - W_{UD})/(W_{Di} - W_{UR}) \qquad (7)$$

where

- W_{UR} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.
- W_{UD} is the upwards traveling wave due to the damage reflection.
- W_{Di} is the maximum downward traveling wave due to impact.

It can be shown that this formulation is quite accurate as long as individual reflections from different pile impedance changes have no overlapping effects on the stress wave reflections.

Without rigorous derivation, it has been proposed to consider as slight damage when β is above 0.8 and a serious damage when β is less than 0.6.

Low Strain Tests (PIT)

The pile top is struck with a held hand hammer and the resulting pile top velocity is measured, displayed and interpreted for signs of wave reflections. In general, a comparison of the reflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the reflection. PIT records can also be interpreted by the β-Method. However, low strain tests do not activate much resistance which simplifies Eq. 7 since W_{UR} is then equal to zero.

For drilled shafts and PIT records that clearly show a toe reflection, an approximate shaft profile can be calculated from low strain records using the PITSTOP program's PROFILE routine.

HAMMER PERFORMANCE

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

$$E(t) = {}_o\int^t F(t)v(t)\,dt \qquad (8a)$$

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

$$e_T = EMX/E_R \qquad (8b)$$

where

- E_R is the manufacturer's rated energy value.

Both Saximeter and PDA calculate the stroke (**STK**) of an open end diesel hammer using

$$STK = (g/8)\,T_B^2 - h_L \qquad (9)$$

where

- g is the earth's gravitational acceleration,
- T_B is the time between two hammer blows,
- h_L is a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

DETERMINATION OF WAVE SPEED

An important facet of dynamic pile testing is an assessment of pile material properties. Since in general force is determined from strain by multiplication with elastic modulus, E, and cross sectional area, A, the dynamic elastic modulus has to be determined for pile materials other than steel. In general, the records measured by the PDA clearly indicate a pile toe reflection as long as pile penetration per blow is greater than 1 mm or .04 inches. The time between the onset of the force and velocity records at impact and the onset of the reflection from the toe (usually apparent by a local maximum of the wave up curve) is the so-called wave travel time, T. Dividing 2L (L is here the length of the pile below sensors) by T leads to the stress wave speed in the pile:

$$c = 2L/T \qquad (10)$$

The elastic modulus of the pile material is related to the wave speed according to the linear elastic wave equation theory by

$$E = c^2\rho \qquad (11)$$

Since the mass density of the pile material, ρ, is usually well known (an exception is timber for which samples should be weighed), the elastic modulus is easily found from the wave speed. Note, however, that this is a dynamic modulus which is generally higher than the static one and that the wave speed depends to some degree on the strain level of the stress wave. For example, experience shows that the wave speed from PIT is roughly 5% higher than the wave speed observed during a high strain test.

Other Notes:

- If the pile material is nonuniform then the wave speed c, according to Eq. 10, is an average wave speed and does not necessarily reflect the pile material properties of the location where the strain sensors are attached to the pile top. For example, pile driving often causes fine tension cracks some distance below the top of concrete piles. Then the average c is slower than that at the pile top. It is therefore recommended to determine E in the beginning of pile driving and not adjust it when the average c changes.

- If the pile has such a high resistance that there is no clear indication of a toe reflection then the wave speed of the pile material must be determined either by assumption or by taking a sample of the concrete and measuring its wave speed in a simple free column test. Another possibility is to use the proportionality relationship, discussed under “DATA QUALITY CHECKS” to find c as the ratio between the measured velocity and measured strain.

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 PDA or PIT 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 certain relationships.

Proportionality

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 pile, force and velocity measured at the pile top are proportional

$$F = v\,Z = v\,(EA/c) \qquad (12a)$$

This relationship can also be expressed in terms of stress

$$\sigma = v\,(E/c) \qquad (12b)$$

or strain

$$\epsilon = v\,/\,c \qquad (12c)$$

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.

Measurements are always taken at opposite sides of the pile as a means of calculating the average force and velocity in the pile. The velocity on the two sides of the pile is very similar even when high bending exists. Thus, an independent check of the velocity measurements is easy and simple.

Strain measurements may differ greatly between the two sides of the pile when bending exists. It is even possible that tension is measured on one side while very high compression exists on the other side of the pile. In extreme cases, bending might be so high that it leads to a nonlinear stress distribution. The averaging of the two strain signals does then not lead to the average pile force and proportionality will not be achieved.

When testing drilled shafts, measurements of strain may also be affected by local concrete quality variations. It is then often necessary to use four strain transducers spaced at 90 degrees around the pile for an improved strain data quality. The use of four transducers is also recommended for large pile

diameters, particularly when it is difficult to mount the sensors at least two pile widths or diameters below the pile top.

LIMITATIONS, ADDITIONAL CONSIDERATIONS

Mobilization of capacity

Estimates of pile capacity from dynamic testing indicate the **mobilized pile capacity at the time of testing**. At very high blow counts (low set per blow), dynamic test methods tend to produce lower bound capacity estimates as not all resistance (particularly at and near the toe) is fully activated.

Time dependent soil resistance effects

Static pile capacity from dynamic method calculations provide an estimate of the axial pile capacity. Increases and decreases in the pile capacity with time typically occur (soil setup/relaxation). Therefore, **restrike testing usually yields a better indication of long term pile capacity than a test at the end of pile driving**. Often a wait period of one or two days between end of driving and restrike is satisfactory for a realistic prediction of pile capacity but this waiting time depends, among other factors, on the permeability of the soil.

(A) Soil setup

Because excess positive pore pressures often develop during pile driving in fine grained soil (clays, silts or even fine sands), the capacity of a pile at the time of driving may often be less than the long term pile capacity. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and thus the pile capacity at the time of driving. As these pore pressures dissipate, the soil resistance acting on the pile increases as does the axial pile capacity. This phenomena is routinely called soil setup or soil freeze.

(*B) Relaxation*

Relaxation (capacity reduction with time) has been observed for piles driven into weathered shale, and may take several days to fully develop. Pile capacity estimates based upon initial driving or short term restrike tests can significantly overpredict long term pile capacity. Therefore, piles driven into shale should be tested after a minimum one week wait either statically or dynamically (with particular emphasis than on the first few blows). Relaxation has also been observed for displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe. Again, restrike tests should be used, with great emphasis on early blows.

Capacity results for open pile profiles

Larger diameter open ended pipe piles (or H-piles which do not bear on rock) may behave differently under dynamic and static loading conditions. Under dynamic loads the soil inside the pile or between its flanges may slip and produce internal friction while under static loads the plug may move with the pile, thereby creating end bearing over the full pile cross section. As a result both friction and end bearing components may be different under static and dynamic conditions.

CAPWAP Analysis Results

A portion of the soil resistance calculated on an individual soil segment in a CAPWAP analysis can usually be shifted up or down the shaft one soil segment without significantly altering the match quality. Therefore, use of the CAPWAP resistance distribution for uplift, downdrag, scour, or other geotechnical considerations should be made with an understanding of these analysis limitations.

Stresses

PDA and CAPWAP calculated stresses are average values over the cross section. Additional allowance has to be made for bending or non-uniform contact stresses. To prevent damage it is therefore important to maintain good hammer-pile alignment and to protect the pile toes using appropriate devices or an increased cross sectional area.

In the United States is has become generally acceptable to limit the dynamic installation stresses of driven piles to the following levels:

90% of yield strength for steel piles

85% of the concrete compressive strength - after subtraction of the effective prestress - for concrete piles in compression

100% of effective prestress plus ½ of the concrete's tension strength for prestressed piles in tension

70% of the reinforcement strength for regularly reinforced concrete piles in tension

300% of the static design allowable stress for timber

Note that the dynamic stresses may either be directly measured at the pile top by the PDA or calculated by the PDA for other locations along the pile based on the pile top measurements.

Additional design considerations

Numerous factors have to be considered in pile foundation design. Some of these considerations include

- additional pile loading from downdrag or negative skin friction,
- lateral and uplift loading requirements
- effective stress changes (due to changes in water table, excavations, fills or other changes in overburden),
- long term settlements in general and settlement from underlying weaker layers and/or pile group effects,

These factors have not been evaluated by GRL and have not been considered in the interpretation of the dynamic testing results. The foundation designer should determine if these or any other considerations are applicable to this project and the foundation design.

Wave equation analysis results

The results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Although attempts have been made to base the analysis on the best available information, actual field conditions may vary and therefore stresses and blow counts may differ from the predictions reported. Capacity predictions derived from wave equation analyses should use restrike information. However, because of the uncertainties associated with restrike blow counts and restrike hammer energies, correlations of such results with static test capacities with have often displayed considerable scatter.

As for PDA and CAPWAP, the theory on which GRLWEAP is based is the one-dimensional wave equation. For that reason, stress predictions by the wave equation analysis can only be averages over the pile cross section. Thus, bending stresses or stress concentrations due to non-uniform impact or uneven soil or rock resistance are not considered in these results. Stress maxima calculated by the wave equation are usually subjected to the same limits as those measured directly or calculated from measurements by the PDA.

Appendix B

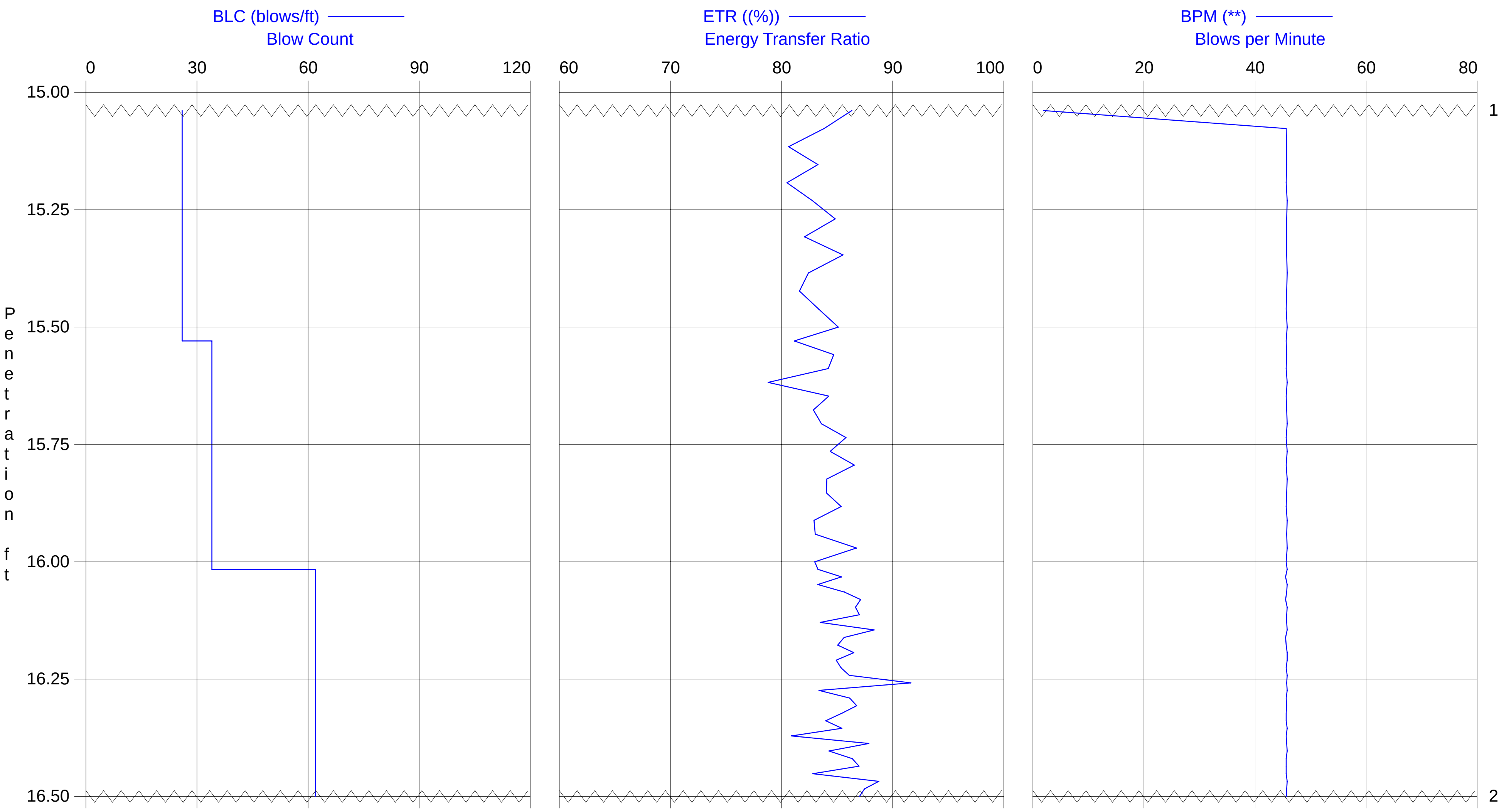
Summary of Case Method Field Results

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 2-Jul-2013

Test date: 1-Jul-2013

HOLT, SPT RIG 7 - SAMPLE 1, 15 FT -BH E340-B-07A



1 - Start of test on 7/1/2013 at 10:58:11 AM

2 - End of test on 7/1/2013 at 10:59:30 AM

HOLT, SPT RIG 7 - SAMPLE 1, 15 FT BH E340-B-07A
OP: RMDT Test date: 1-Jul-2013

AR: 1.42 in^2 SP: 0.492 k/ft3
LE: 19.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
EFV: Energy of FV
ETR: Energy Transfer Ratio
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
RAU: Auto Capacity End Bearing Piles

BL#	BLC	CSI	CSX	EFV	ETR	BPM	FMX	VMX	RAT	RAU
	bl/ft	ksi	ksi	k-ft	(%)	**	kips	f/s	[]	kips
14	34	29.0	28.4	0.284	81.1	45.6	40	13.8	1.2	3
15	34	29.4	28.8	0.296	84.7	45.7	41	15.1	1.2	4
16	34	29.2	28.7	0.295	84.2	45.6	41	14.6	1.2	0
17	34	28.4	28.0	0.276	78.8	45.8	40	13.7	1.2	5
18	34	29.4	28.8	0.295	84.2	45.6	41	14.6	1.2	4
19	34	29.0	28.2	0.290	82.9	45.7	40	13.7	1.2	4
20	34	28.8	28.3	0.293	83.6	45.8	40	14.0	1.2	3
21	34	29.2	28.5	0.300	85.8	45.6	40	14.7	1.2	0
22	34	29.0	28.2	0.295	84.4	45.8	40	14.5	1.2	0
23	34	29.6	28.9	0.303	86.5	45.6	41	15.4	1.2	4
24	34	29.1	28.4	0.294	84.1	45.8	40	14.5	1.2	0
25	34	29.3	28.5	0.294	84.0	45.7	40	14.8	1.2	5
26	34	29.2	28.5	0.299	85.4	45.6	40	15.0	1.1	1
27	34	28.1	27.6	0.290	82.9	45.8	39	14.2	1.4	4
28	34	28.8	27.9	0.291	83.0	45.7	40	13.4	2.7	0
29	34	29.1	28.4	0.304	86.7	45.8	40	15.9	2.7	4
30	34	28.8	28.1	0.290	83.0	45.6	40	14.2	2.7	6
31	62	29.3	28.4	0.291	83.3	45.8	40	13.9	2.7	0
32	62	28.5	27.9	0.299	85.4	45.5	40	15.2	2.7	5
33	62	29.0	28.2	0.291	83.3	45.8	40	13.9	2.7	5
34	62	29.3	28.2	0.300	85.7	45.7	40	14.1	2.7	8
35	62	29.3	28.5	0.305	87.1	45.5	40	15.0	2.7	8
36	62	29.0	28.1	0.303	86.7	45.8	40	14.3	2.7	4
37	62	29.4	28.5	0.305	87.0	45.7	40	14.8	2.7	7
38	62	28.5	27.6	0.292	83.5	45.7	39	13.8	2.7	3
39	62	29.5	28.7	0.309	88.3	45.8	41	15.8	2.7	5
40	62	29.0	28.1	0.300	85.6	45.5	40	14.3	2.7	8
41	62	28.9	28.1	0.298	85.1	45.6	40	15.2	2.7	8
42	62	31.5	29.9	0.303	86.5	45.8	42	15.0	2.7	3
43	62	28.2	27.7	0.297	84.9	45.8	39	14.6	2.7	7
44	62	29.4	28.3	0.299	85.3	45.6	40	13.9	2.7	7
45	62	29.0	28.0	0.301	86.1	45.8	40	14.4	2.7	8
46	62	28.9	28.3	0.321	91.6	45.7	40	16.1	2.7	5
47	62	30.8	29.2	0.292	83.4	45.8	41	14.1	2.7	5
48	62	29.5	28.4	0.301	86.1	45.6	40	15.2	2.7	10
49	62	29.1	28.3	0.304	86.8	45.7	40	15.1	2.7	4
50	62	28.4	27.9	0.299	85.5	45.6	40	14.6	2.7	9
51	62	30.3	28.6	0.294	84.0	45.6	41	14.6	2.7	7
52	62	28.9	28.2	0.299	85.4	45.8	40	15.3	2.7	7
53	62	29.0	27.9	0.283	80.9	45.6	40	12.8	2.7	7
54	62	30.0	28.8	0.308	87.9	45.7	41	15.7	2.7	8
55	62	29.2	27.8	0.295	84.3	45.8	39	13.5	2.7	3
56	62	29.1	28.0	0.302	86.4	45.6	40	14.2	2.7	6
57	62	28.4	27.8	0.304	87.0	45.6	40	15.5	2.7	7
58	62	29.0	28.1	0.290	82.8	45.6	40	13.0	2.7	7
59	62	29.4	28.6	0.311	88.8	45.8	41	15.0	2.7	6
60	62	29.4	28.3	0.306	87.5	45.7	40	14.7	2.7	6
61	62	29.0	27.9	0.305	87.0	45.7	40	14.3	2.7	7
Average		29.1	28.3	0.298	85.1	45.7	40	14.5	2.2	5
Std. Dev.		0.6	0.4	0.008	2.2	0.1	1	0.7	0.7	3
Maximum		31.5	29.9	0.321	91.6	45.8	42	16.1	2.7	10

Total number of blows analyzed: 48

BL#	Comments
1	Start of test on 7/1/2013 at 10:58:11 AM
61	End of test on 7/1/2013 at 10:59:30 AM

Time Summary

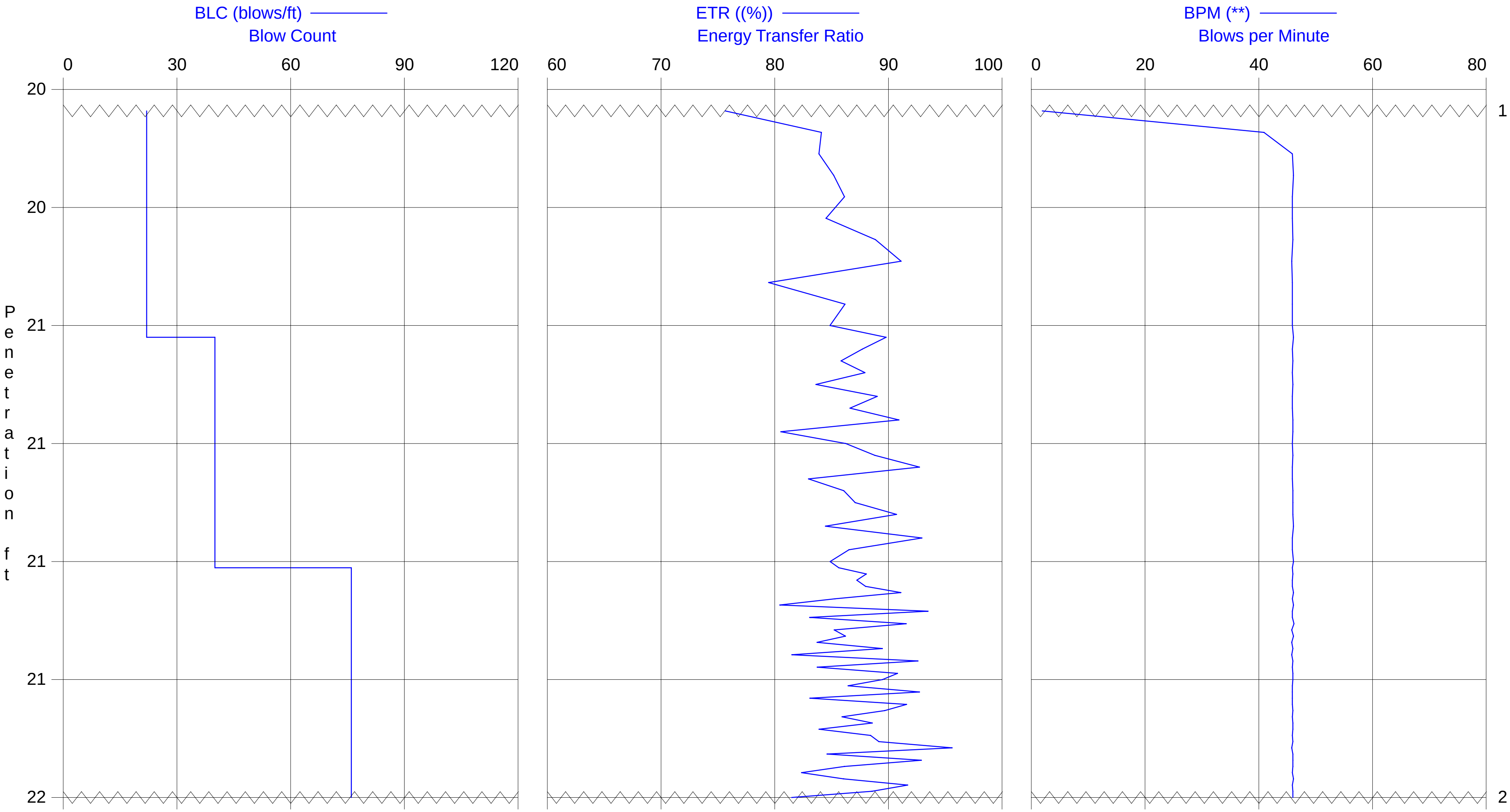
Drive 1 minute 19 seconds 10:58:11 AM - 10:59:30 AM (7/1/2013) BN 1 - 61

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 2-Jul-2013

Test date: 1-Jul-2013

HOLT, SPT RIG 7 - SAMPLE 2, 20 FT -BH E340-B-07A



1 - Start of test on 7/1/2013 at 11:09:34 AM

2 - End of test on 7/1/2013 at 11:11:03 AM

HOLT, SPT RIG 7 - SAMPLE 2, 20 FT BH E340-B-07A
OP: RMDT Test date: 1-Jul-2013

AR: 1.42 in^2 SP: 0.492 k/ft3
LE: 24.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
EFV: Energy of FV
ETR: Energy Transfer Ratio
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
RAU: Auto Capacity End Bearing Piles

BL#	BLC	CSI	CSX	EFV	ETR	BPM	FMX	VMX	RAT	RAU
	bl/ft	ksi	ksi	k-ft	(%)	**	kips	f/s	[]	kips
12	40	31.6	29.9	0.314	89.8	46.1	42	15.2	1.1	0
13	40	30.9	29.6	0.307	87.7	45.9	42	14.3	1.1	0
14	40	29.7	28.6	0.300	85.8	46.0	41	14.7	1.1	3
15	40	29.8	28.7	0.308	87.9	45.9	41	14.8	1.1	0
16	40	29.3	28.3	0.293	83.6	46.0	40	13.4	1.1	0
17	40	31.7	30.3	0.312	89.0	45.9	43	15.0	1.1	0
18	40	29.9	28.7	0.303	86.6	45.9	41	13.6	1.1	0
19	40	30.3	29.1	0.318	90.9	46.0	41	15.5	1.1	0
20	40	28.6	27.6	0.282	80.5	46.0	39	12.4	1.1	0
21	40	30.1	29.0	0.302	86.3	45.9	41	14.5	1.1	0
22	40	30.9	29.7	0.311	88.8	46.0	42	14.7	1.1	0
23	40	31.2	29.6	0.325	92.7	45.9	42	16.2	1.1	1
24	40	29.9	28.7	0.290	83.0	45.9	41	12.7	1.1	1
25	40	28.9	27.9	0.301	86.1	46.0	40	14.7	1.2	1
26	40	30.0	28.9	0.305	87.1	46.0	41	14.3	1.1	3
27	40	29.5	28.3	0.317	90.7	46.0	40	15.3	1.2	4
28	40	29.4	28.4	0.296	84.5	46.1	40	13.5	1.1	1
29	40	30.0	28.9	0.325	92.9	45.9	41	15.7	1.1	3
30	40	30.2	29.1	0.303	86.5	45.9	41	14.3	1.1	3
31	40	30.2	29.0	0.297	84.9	46.1	41	14.2	1.1	6
32	76	29.3	28.3	0.300	85.6	45.9	40	14.7	1.2	4
33	76	30.5	29.4	0.308	88.1	46.0	42	14.8	1.1	4
34	76	30.4	29.4	0.305	87.2	45.9	42	14.6	1.1	13
35	76	30.3	29.1	0.308	88.0	45.9	41	15.0	1.2	5
36	76	30.1	29.0	0.319	91.1	46.1	41	15.5	1.1	7
37	76	30.0	29.0	0.299	85.3	45.9	41	13.8	1.1	5
38	76	28.7	27.6	0.282	80.5	46.1	39	12.3	1.2	7
39	76	30.3	29.2	0.327	93.5	45.9	42	16.4	1.1	7
40	76	30.2	29.1	0.291	83.1	45.9	41	13.1	1.1	7
41	76	31.8	30.1	0.320	91.6	46.2	43	16.2	1.1	12
42	76	30.7	29.2	0.298	85.2	45.8	41	14.0	1.2	14
43	76	31.1	29.5	0.302	86.2	46.1	42	14.5	1.1	12
44	76	28.9	28.0	0.293	83.7	45.8	40	13.4	1.2	10
45	76	30.8	29.4	0.313	89.5	46.0	42	15.6	1.1	8
46	76	28.8	27.8	0.285	81.5	45.8	39	13.0	1.2	10
47	76	30.3	29.3	0.324	92.6	46.0	42	16.3	1.1	15
48	76	29.9	28.9	0.293	83.7	45.9	41	13.0	1.1	9
49	76	31.4	29.7	0.318	90.8	46.0	42	15.8	1.1	10
50	76	29.5	28.5	0.313	89.5	46.0	40	15.0	1.1	10
51	76	30.6	29.4	0.303	86.4	45.9	42	13.3	1.1	9
52	76	29.7	28.7	0.325	92.7	45.9	41	16.2	1.2	11
53	76	29.5	28.5	0.291	83.1	45.9	40	12.4	1.2	8
54	76	30.8	29.7	0.321	91.6	45.9	42	15.2	1.1	9
55	76	30.4	29.3	0.314	89.7	46.0	42	15.1	1.1	10
56	76	29.3	28.2	0.301	85.9	45.9	40	13.8	1.2	12
57	76	29.4	28.5	0.310	88.6	46.0	40	14.4	1.2	9
58	76	28.8	28.1	0.294	83.9	46.0	40	14.1	1.2	7
59	76	30.3	29.3	0.310	88.4	45.9	42	14.6	1.1	11
60	76	30.1	29.1	0.312	89.2	46.0	41	14.3	1.1	11
61	76	30.4	29.4	0.335	95.6	45.8	42	16.5	1.1	15
62	76	29.9	28.7	0.296	84.6	46.0	41	12.7	1.1	11
63	76	31.3	29.8	0.325	92.9	46.0	42	15.6	1.1	12
64	76	28.9	28.0	0.301	86.1	46.0	40	13.5	1.1	9
65	76	28.6	28.0	0.288	82.4	45.9	40	14.1	1.2	12
66	76	29.6	28.7	0.301	86.0	46.1	41	14.2	1.2	14
67	76	30.4	29.5	0.321	91.7	45.9	42	14.9	1.1	14
68	76	30.7	29.8	0.310	88.6	46.0	42	14.4	1.1	13
69	76	28.7	28.0	0.285	81.5	46.0	40	13.3	1.2	15
Average		30.0	28.9	0.306	87.4	46.0	41	14.5	1.2	7
Std. Dev.		0.8	0.6	0.012	3.6	0.1	1	1.1	0.0	5
Maximum		31.8	30.3	0.335	95.6	46.2	43	16.5	1.2	15

Total number of blows analyzed: 58

BL#	Comments
1	Start of test on 7/1/2013 at 11:09:34 AM

BL#	Comments
69	End of test on 7/1/2013 at 11:11:03 AM

Time Summary

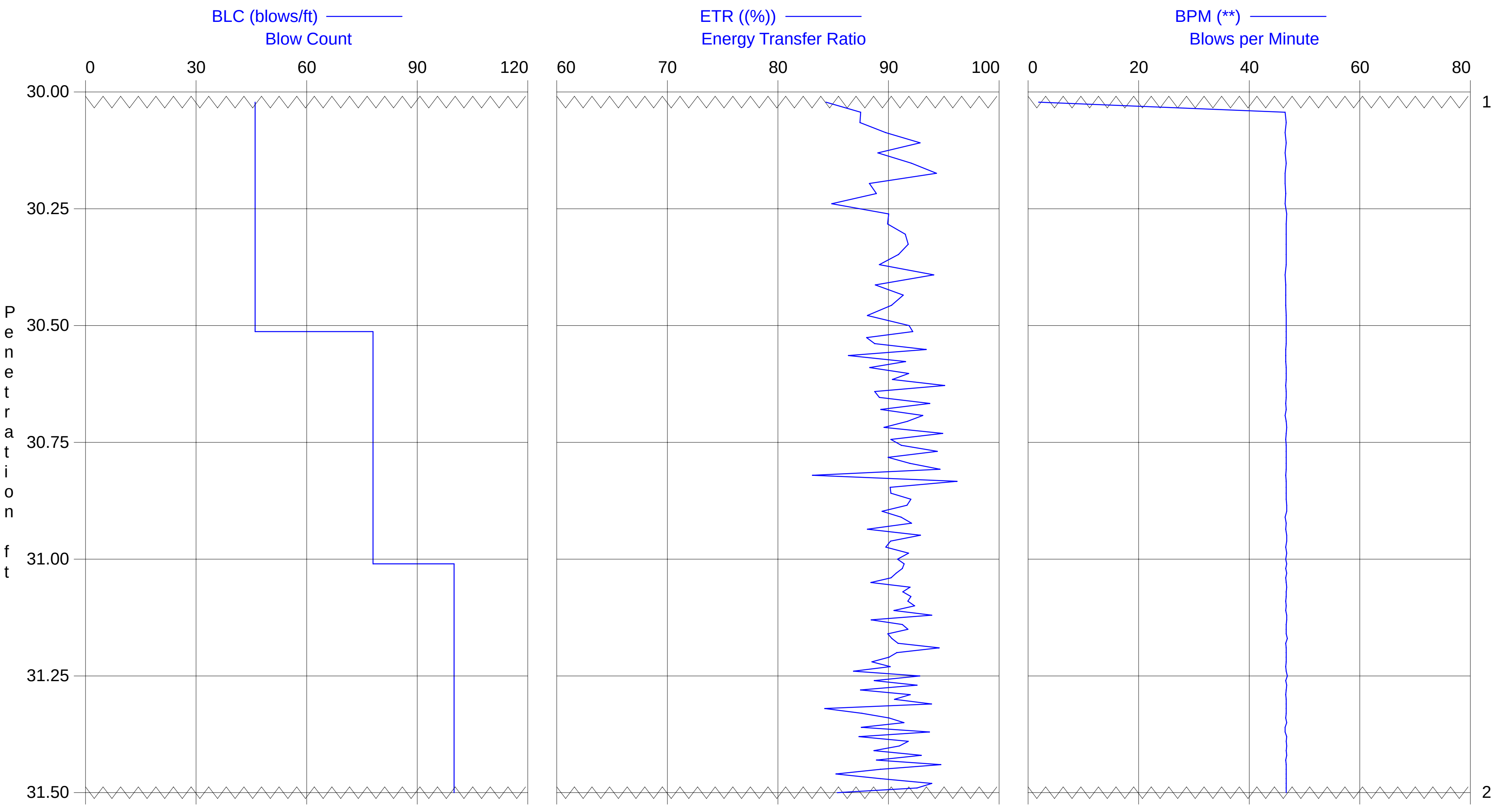
Drive	1 minute 29 seconds	11:09:34 AM - 11:11:03 AM (7/1/2013) BN 1 - 69

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 2-Jul-2013

Test date: 1-Jul-2013

HOLT, SPT RIG 7 - SAMPLE 3, 30 FT -BH E340-B-07A



1 - Start of test on 7/1/2013 at 11:33:06 AM

2 - End of test on 7/1/2013 at 11:35:29 AM

HOLT, SPT RIG 7 - SAMPLE 3, 30 FT
OP: RMDT

BH E340-B-07A
Test date: 1-Jul-2013

AR: 1.42 in^2
LE: 34.00 ft
WS: 16,807.9 f/s

SP: 0.492 k/ft3
EM: 30,000 ksi
JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
EFV: Energy of FV
ETR: Energy Transfer Ratio
BPM: Blows per Minute

FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
RAU: Auto Capacity End Bearing Piles

BL#	BLC	CSI	CSX	EFV	ETR	BPM	FMX	VMX	RAT	RAU
	bl/ft	ksi	ksi	k-ft	(%)	**	kips	f/s	[]	kips
24	78	31.0	29.9	0.323	92.2	46.7	42	15.3	1.1	4
26	78	29.8	29.0	0.311	88.8	46.7	41	14.5	1.1	5
28	78	30.4	29.6	0.302	86.4	46.6	42	13.7	1.1	4
30	78	30.7	29.8	0.309	88.3	46.7	42	13.8	1.1	2
32	78	31.3	30.2	0.316	90.3	46.7	43	14.9	0.9	11
34	78	30.4	29.6	0.311	88.8	46.7	42	14.2	1.1	12
36	78	31.4	30.2	0.328	93.7	46.6	43	16.0	1.1	13
38	78	31.9	30.5	0.326	93.1	46.5	43	15.4	1.1	13
40	78	31.2	30.1	0.314	89.6	46.8	43	14.5	1.1	11
42	78	31.3	30.3	0.316	90.2	46.6	43	14.5	1.1	14
44	78	31.5	30.4	0.330	94.4	46.7	43	15.6	1.1	11
46	78	32.0	30.9	0.322	91.9	46.7	44	14.7	1.1	12
48	78	30.2	29.0	0.291	83.1	46.6	41	13.0	1.1	13
50	78	32.3	30.8	0.316	90.2	46.7	44	14.2	1.1	11
52	78	31.6	30.4	0.322	92.0	46.7	43	14.9	1.1	11
54	78	31.4	30.6	0.313	89.4	46.8	43	14.3	1.1	11
56	78	31.6	30.3	0.322	92.1	46.7	43	15.1	1.1	12
58	78	33.5	31.4	0.325	92.9	46.8	45	15.3	1.1	13
60	78	31.9	30.8	0.314	89.8	46.6	44	14.0	0.9	10
62	78	31.8	30.7	0.318	90.8	46.6	44	14.4	1.1	12
64	100	31.0	30.0	0.319	91.2	46.6	43	15.1	1.1	12
66	100	30.9	30.0	0.316	90.2	46.6	43	14.5	1.1	12
68	100	33.2	31.1	0.322	91.9	46.8	44	15.0	0.9	14
70	100	31.1	30.0	0.322	92.0	46.7	43	15.0	1.1	14
72	100	32.2	31.1	0.323	92.4	46.7	44	14.9	0.9	13
74	100	31.2	30.4	0.329	93.9	46.8	43	15.5	1.1	12
76	100	31.8	30.6	0.319	91.3	46.7	43	14.7	1.1	9
78	100	30.8	29.7	0.315	89.9	46.7	42	14.7	1.1	12
80	100	32.3	30.8	0.318	90.9	46.6	44	14.8	0.9	9
82	100	31.2	30.2	0.318	90.8	46.7	43	14.4	1.1	10
84	100	30.6	29.8	0.310	88.5	46.7	42	14.0	1.1	14
86	100	31.0	29.6	0.304	86.8	46.7	42	14.2	1.1	10
88	100	31.5	30.0	0.310	88.7	46.6	43	14.1	1.1	11
90	100	31.3	30.3	0.306	87.5	46.7	43	13.3	1.1	14
92	100	31.5	30.3	0.317	90.5	46.7	43	14.5	1.1	15
94	100	30.8	29.3	0.295	84.2	46.7	42	13.0	1.1	14
96	100	31.3	30.1	0.315	90.1	46.6	43	14.4	1.1	18
98	100	30.6	29.4	0.306	87.5	46.5	42	14.2	1.9	21
100	100	31.2	30.2	0.306	87.3	46.8	43	13.5	1.1	23
102	100	31.0	29.9	0.318	91.0	46.8	42	14.5	1.8	16
104	100	32.1	30.4	0.325	93.0	46.8	43	15.4	1.8	19
106	100	32.0	30.7	0.332	94.7	46.7	44	15.6	1.8	18
108	100	30.3	28.8	0.298	85.2	46.7	41	13.7	1.9	18
110	100	32.6	30.6	0.329	93.9	46.7	43	15.3	1.7	21
112	100	30.5	29.2	0.299	85.4	46.7	41	13.9	1.8	23
Average		31.6	30.3	0.317	90.7	46.7	43	14.7	1.2	13
Std. Dev.		0.8	0.6	0.009	2.5	0.1	1	0.7	0.3	4
Maximum		33.5	31.4	0.337	96.2	46.9	45	16.3	1.9	23

Total number of blows analyzed: 89

BL#	Comments
1	Start of test on 7/1/2013 at 11:33:06 AM
112	End of test on 7/1/2013 at 11:35:29 AM

Time Summary

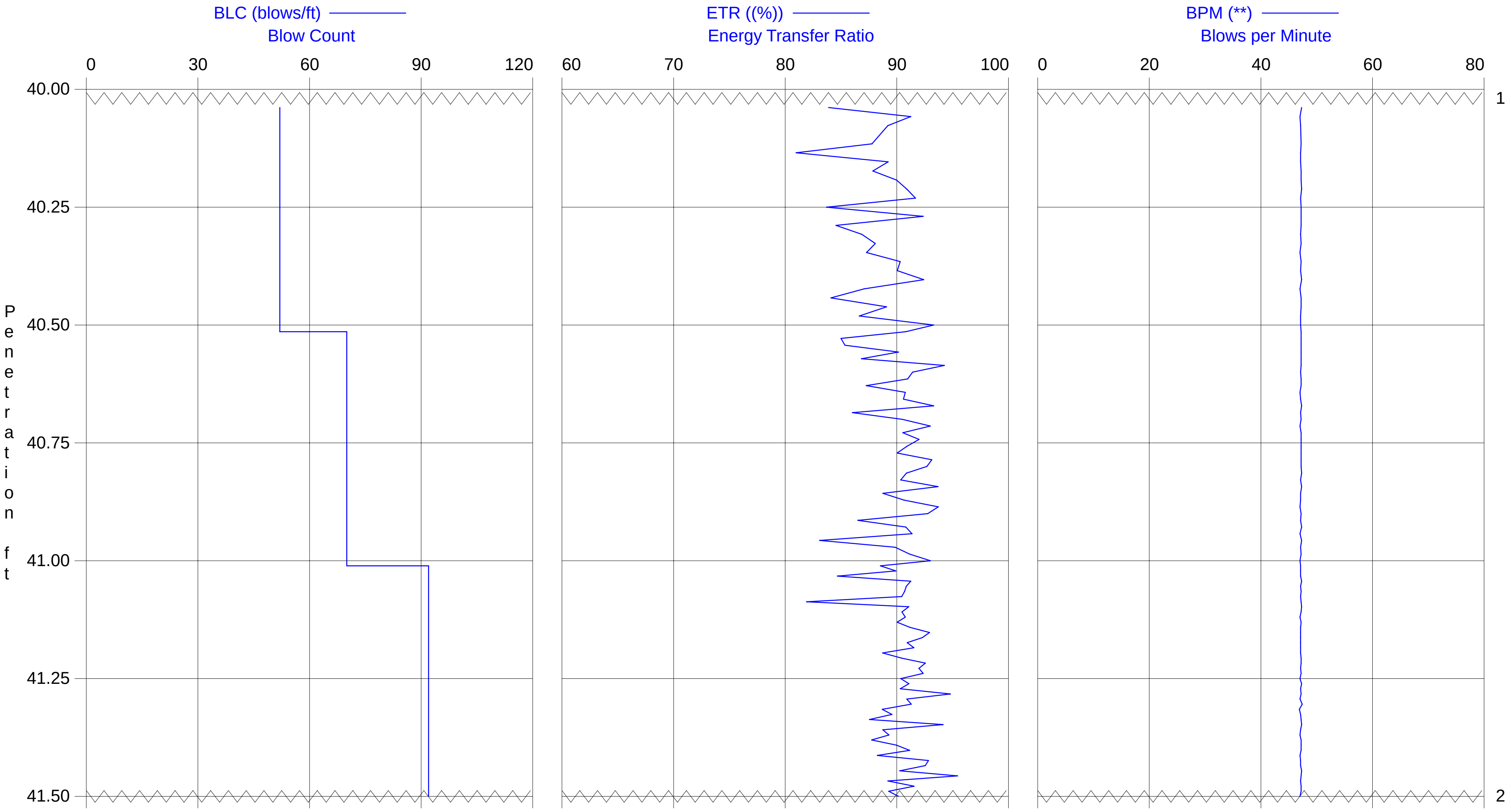
Drive 2 minutes 23 seconds 11:33:06 AM - 11:35:29 AM (7/1/2013) BN 1 - 112

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 2-Jul-2013

Test date: 1-Jul-2013

HOLT, SPT RIG 7 - SAMPLE 4, 40 FT -BH E340-B-07A



1 - Start of test on 7/1/2013 at 12:04:57 PM

2 - End of test on 7/1/2013 at 12:07:13 PM

HOLT, SPT RIG 7 - SAMPLE 4, 40 FT BH E340-B-07A
OP: RMDT Test date: 1-Jul-2013

AR: 1.42 in^2 SP: 0.492 k/ft3
LE: 44.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
EFV: Energy of FV
ETR: Energy Transfer Ratio
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
RAU: Auto Capacity End Bearing Piles

BL#	BLC	CSI	CSX	EFV	ETR	BPM	FMX	VMX	RAT	RAU
	bl/ft	ksi	ksi	k-ft	(%)	**	kips	f/s	[]	kips
27	70	30.3	29.8	0.318	90.8	47.2	42	15.0	0.7	10
29	70	28.2	27.3	0.299	85.4	47.2	39	13.5	1.0	7
31	70	29.6	29.0	0.304	86.8	47.2	41	13.9	0.7	12
33	70	30.2	29.9	0.320	91.4	47.1	42	14.6	0.9	11
35	70	29.4	29.0	0.305	87.3	47.2	41	13.7	0.9	11
37	70	29.4	29.3	0.317	90.6	47.1	42	14.2	0.9	12
39	70	29.3	28.4	0.301	86.0	47.1	40	14.3	1.1	5
41	70	30.2	29.8	0.326	93.0	47.0	42	15.1	0.9	11
43	70	31.0	30.2	0.322	92.0	47.2	43	14.3	0.4	12
45	70	29.9	29.6	0.315	90.0	47.2	42	14.0	0.7	9
47	70	32.5	30.6	0.324	92.7	47.2	43	14.5	0.9	12
49	70	30.3	29.7	0.316	90.3	47.1	42	14.1	0.9	12
51	70	29.3	29.0	0.311	88.8	47.1	41	13.6	0.7	9
53	70	32.2	31.2	0.328	93.7	47.0	44	14.9	0.4	8
55	70	29.5	28.5	0.303	86.5	47.1	40	13.5	0.7	7
57	70	30.2	29.5	0.320	91.4	47.0	42	14.6	0.9	9
59	70	30.0	29.3	0.314	89.8	47.1	42	14.3	0.9	11
61	70	30.5	29.6	0.326	93.0	47.0	42	14.5	0.9	13
63	92	30.1	29.2	0.315	89.9	47.1	41	13.9	1.1	14
65	92	32.1	30.8	0.319	91.2	47.3	44	14.2	0.4	12
67	92	30.7	29.7	0.317	90.7	47.2	42	14.1	0.4	11
69	92	28.6	27.5	0.287	81.9	47.2	39	13.2	1.1	6
71	92	30.8	29.5	0.317	90.5	47.2	42	14.1	0.7	13
73	92	29.8	29.1	0.315	90.0	47.2	41	14.0	0.7	11
75	92	30.1	29.3	0.325	92.9	47.1	42	14.8	0.9	8
77	92	30.1	29.1	0.318	90.9	47.1	41	14.6	0.9	9
79	92	29.2	28.9	0.311	88.7	47.1	41	14.4	0.7	13
81	92	31.9	30.7	0.324	92.6	47.2	44	14.8	0.4	9
83	92	32.0	30.8	0.323	92.4	47.2	44	14.7	0.4	12
85	92	30.5	29.5	0.319	91.1	47.3	42	14.3	0.5	6
87	92	32.4	31.2	0.332	94.8	47.2	44	15.2	0.4	8
89	92	29.2	28.6	0.320	91.3	47.4	41	14.5	0.7	9
91	92	31.7	30.7	0.313	89.6	47.1	44	14.4	0.7	9
93	92	30.9	29.8	0.330	94.2	47.3	42	15.1	0.9	11
95	92	32.4	31.1	0.313	89.3	47.0	44	13.9	0.7	10
97	92	29.6	28.8	0.315	90.0	47.2	41	14.2	0.9	12
99	92	29.2	28.9	0.309	88.3	47.0	41	13.8	0.7	13
101	92	29.7	28.9	0.324	92.5	47.1	41	14.9	0.9	14
103	92	30.7	29.6	0.334	95.5	47.2	42	15.4	0.9	13
105	92	29.4	28.5	0.320	91.6	47.2	40	14.7	0.9	13
107	92	29.5	28.8	0.316	90.2	47.0	41	14.1	0.9	13
Average		30.3	29.5	0.316	90.4	47.2	42	14.3	0.8	10
Std. Dev.		1.1	0.9	0.009	2.5	0.1	1	0.5	0.2	2
Maximum		32.5	31.2	0.334	95.5	47.4	44	15.4	1.1	14

Total number of blows analyzed: 81

BL#	Comments
1	Start of test on 7/1/2013 at 12:04:57 PM
107	End of test on 7/1/2013 at 12:07:13 PM

Time Summary

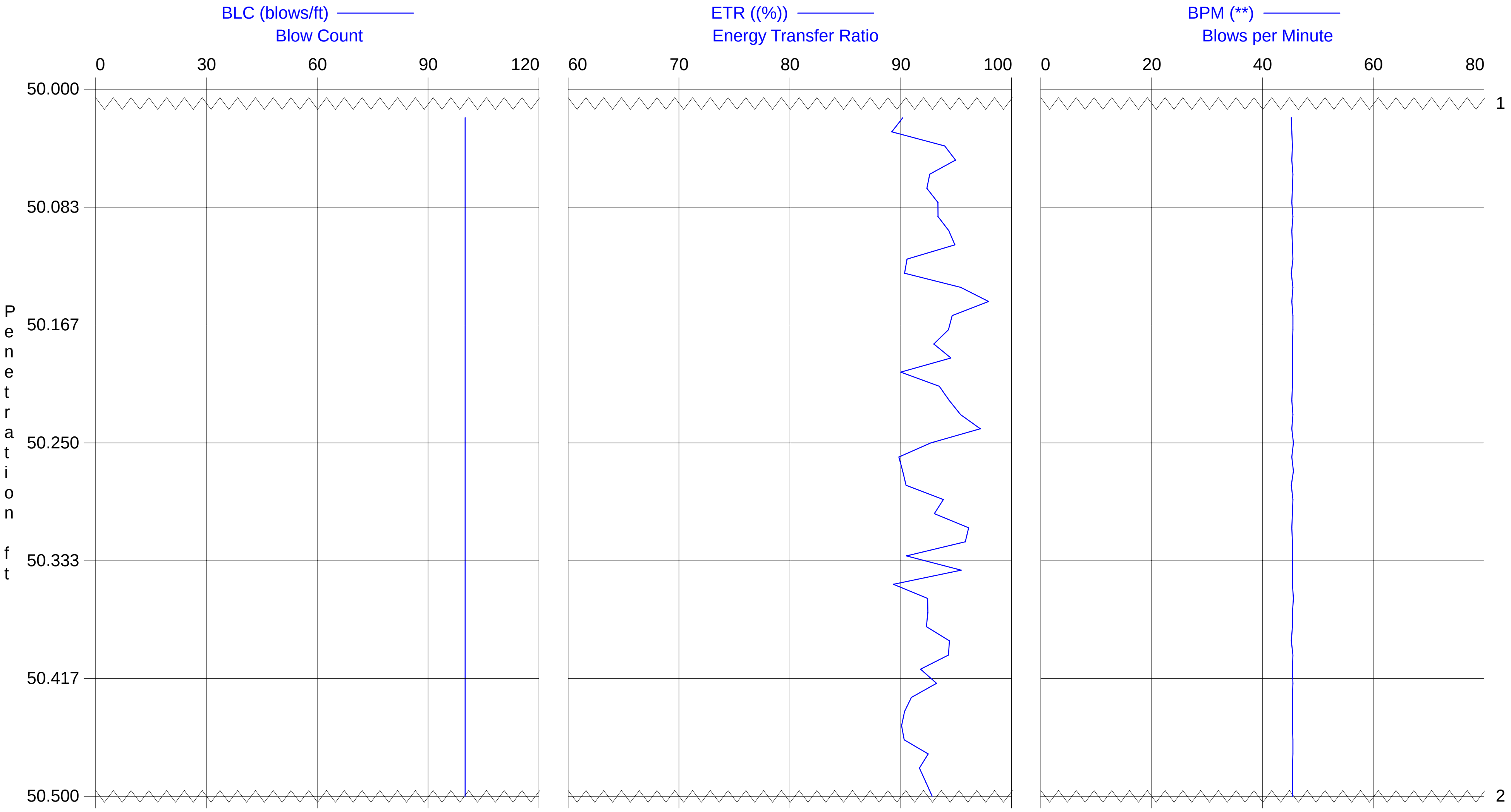
Drive 2 minutes 16 seconds 12:04:57 PM - 12:07:13 PM (7/1/2013) BN 1 - 107

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 2-Jul-2013

Test date: 1-Jul-2013

HOLT, SPT RIG 7 - SAMPLE 5, 50 FT -BH E340-B-07A



1 - Start of test on 7/1/2013 at 12:32:13 PM

2 - End of test on 7/1/2013 at 12:33:17 PM

HOLT, SPT RIG 7 - SAMPLE 5, 50 FT
OP: RMDT

BH E340-B-07A
Test date: 1-Jul-2013

AR: 1.42 in^2
LE: 54.00 ft
WS: 16,807.9 f/s

SP: 0.492 k/ft3
EM: 30,000 ksi
JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
EFV: Energy of FV
ETR: Energy Transfer Ratio
BPM: Blows per Minute

FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
RAU: Auto Capacity End Bearing Piles

BL#	BLC	CSI	CSX	EFV	ETR	BPM	FMX	VMX	RAT	RAU
	bl/ft	ksi	ksi	k-ft	(%)	**	kips	f/s	[]	kips
2	100	29.9	29.6	0.316	90.2	45.2	42	14.6	1.1	9
3	100	29.7	29.5	0.312	89.2	45.3	42	14.4	0.5	6
4	100	30.0	29.5	0.329	94.0	45.4	42	14.4	0.6	12
5	100	30.8	30.5	0.332	95.0	45.3	43	14.9	0.6	7
6	100	29.6	29.2	0.324	92.6	45.5	41	14.9	1.0	8
7	100	29.7	29.3	0.323	92.4	45.4	42	14.3	0.6	9
8	100	30.1	30.0	0.327	93.4	45.3	43	14.9	0.8	10
9	100	29.2	29.1	0.327	93.4	45.5	41	14.7	0.6	12
10	100	29.7	29.6	0.330	94.3	45.3	42	15.0	0.6	12
11	100	30.7	30.4	0.332	94.9	45.4	43	15.3	0.5	13
12	100	29.7	29.7	0.317	90.6	45.5	42	14.4	0.6	12
13	100	29.0	28.6	0.316	90.3	45.2	41	14.4	0.6	10
14	100	31.9	31.4	0.334	95.4	45.5	45	15.5	0.5	15
15	100	30.3	30.2	0.343	97.9	45.3	43	14.8	0.6	10
16	100	29.3	29.2	0.331	94.6	45.5	41	14.8	0.6	12
17	100	30.6	30.2	0.330	94.3	45.5	43	15.3	0.7	12
18	100	29.5	29.1	0.325	93.0	45.4	41	14.5	0.6	11
19	100	30.2	30.0	0.331	94.5	45.4	43	15.2	0.6	14
20	100	28.9	28.6	0.315	90.0	45.4	41	14.7	0.7	15
21	100	29.1	28.7	0.327	93.5	45.4	41	14.6	0.6	11
22	100	29.5	29.5	0.330	94.4	45.3	42	15.1	0.6	14
23	100	32.1	31.4	0.334	95.4	45.5	45	15.6	0.4	13
24	100	32.0	31.3	0.340	97.2	45.3	44	15.5	0.5	16
25	100	29.6	29.5	0.325	92.7	45.6	42	15.1	0.7	15
26	100	28.8	28.2	0.314	89.8	45.3	40	14.2	0.6	11
27	100	28.9	28.4	0.316	90.2	45.6	40	14.6	0.6	11
28	100	28.8	28.4	0.317	90.5	45.2	40	14.7	0.8	11
29	100	29.0	28.9	0.328	93.8	45.5	41	14.8	0.7	10
30	100	29.3	29.2	0.326	93.0	45.4	42	15.1	0.6	13
31	100	31.5	31.1	0.336	96.1	45.3	44	15.2	0.6	16
32	100	30.4	30.0	0.335	95.8	45.4	43	15.5	0.7	20
33	100	29.7	29.2	0.317	90.5	45.4	41	14.1	0.6	12
34	100	30.5	30.3	0.334	95.5	45.4	43	14.9	0.7	15
35	100	29.5	29.0	0.313	89.3	45.4	41	14.3	0.8	13
36	100	30.5	30.5	0.324	92.4	45.6	43	14.9	0.5	16
37	100	29.9	29.3	0.324	92.5	45.4	42	15.1	0.7	15
38	100	29.5	29.0	0.323	92.3	45.4	41	14.4	0.5	16
39	100	29.5	28.8	0.330	94.4	45.2	41	15.2	0.5	20
40	100	32.1	30.4	0.330	94.3	45.5	43	14.4	0.5	16
41	100	29.3	28.6	0.321	91.8	45.4	41	14.5	0.6	18
42	100	29.5	29.3	0.326	93.2	45.5	42	14.2	0.6	14
43	100	29.7	29.6	0.318	91.0	45.4	42	15.1	0.6	19
44	100	28.8	28.6	0.316	90.3	45.4	41	14.2	0.6	16
45	100	28.1	28.1	0.315	90.1	45.4	40	13.9	0.6	16
46	100	29.2	28.5	0.316	90.3	45.5	40	14.5	0.5	13
47	100	31.2	29.7	0.324	92.5	45.5	42	14.9	0.5	16
48	100	30.2	29.7	0.321	91.7	45.4	42	13.9	1.0	16
49	100	30.5	29.9	0.323	92.3	45.4	42	14.3	0.7	16
50	100	29.8	29.3	0.325	92.8	45.4	42	14.5	0.5	15
Average		29.9	29.5	0.325	92.9	45.4	42	14.7	0.6	13
Std. Dev.		0.9	0.8	0.007	2.1	0.1	1	0.4	0.1	3
Maximum		32.1	31.4	0.343	97.9	45.6	45	15.6	1.1	20

Total number of blows analyzed: 49

BL#	Comments
1	Start of test on 7/1/2013 at 12:32:13 PM
50	End of test on 7/1/2013 at 12:33:17 PM

Time Summary

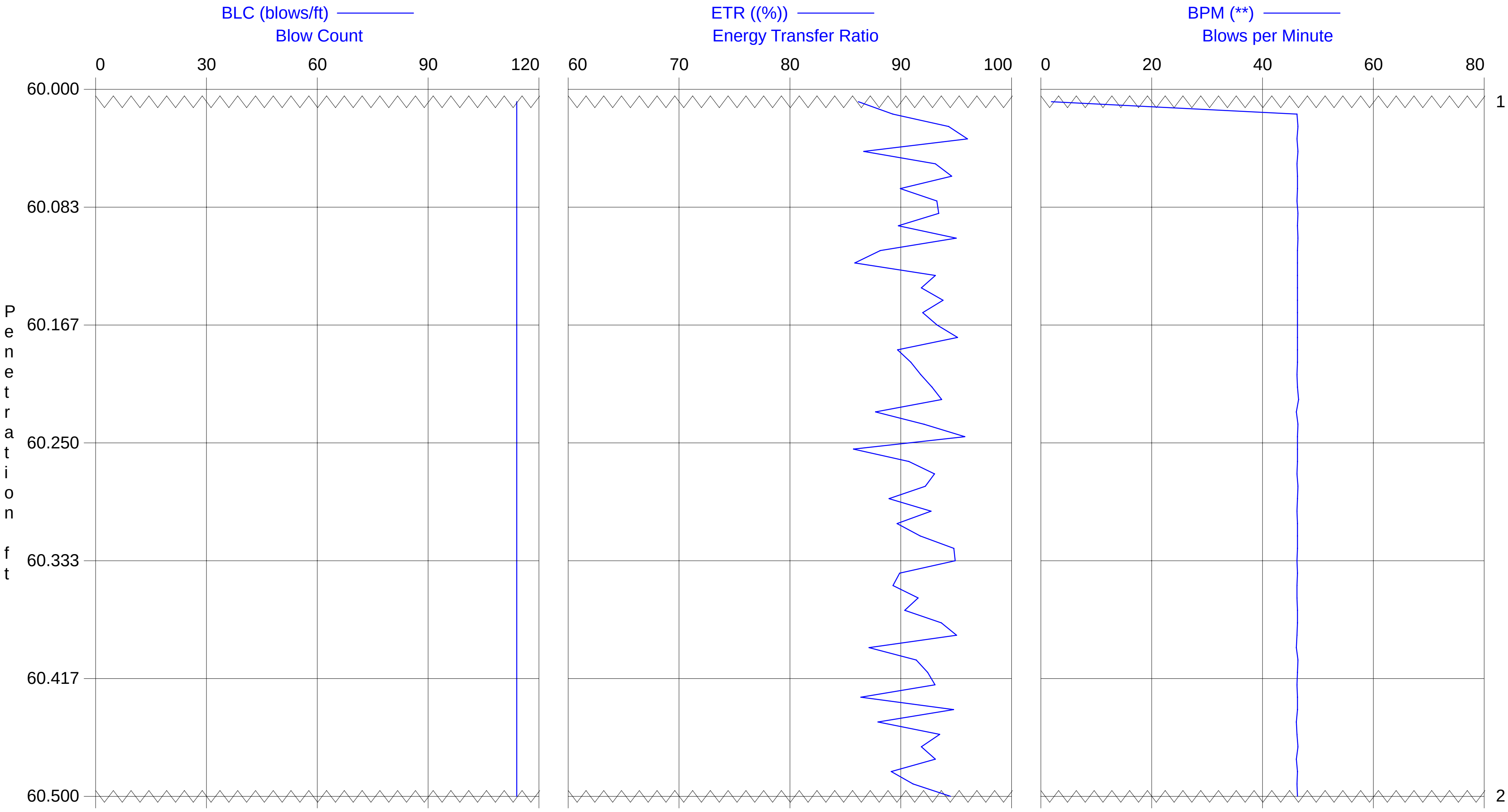
Drive 1 minute 4 seconds 12:32:13 PM - 12:33:17 PM (7/1/2013) BN 1 - 50

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 2-Jul-2013

Test date: 1-Jul-2013

HOLT, SPT RIG 7 - SAMPLE 6, 60 FT -BH E340-B-07A



1 - Start of test on 7/1/2013 at 1:05:07 PM

2 - End of test on 7/1/2013 at 1:06:20 PM

HOLT, SPT RIG 7 - SAMPLE 6, 60 FT BH E340-B-07A
OP: RMDT Test date: 1-Jul-2013

AR: 1.42 in^2 SP: 0.492 k/ft3
LE: 64.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
EFV: Energy of FV
ETR: Energy Transfer Ratio
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
RAU: Auto Capacity End Bearing Piles

BL#	BLC	CSI	CSX	EFV	ETR	BPM	FMX	VMX	RAT	RAU
	bl/ft	ksi	ksi	k-ft	(%)	**	kips	f/s	[]	kips
1	114	29.5	28.6	0.302	86.2	1.9	41	14.3	0.6	0
2	114	30.3	29.1	0.313	89.3	46.2	41	13.8	0.6	0
3	114	33.6	31.9	0.330	94.3	46.4	45	15.3	0.5	0
4	114	32.8	31.2	0.336	96.0	46.2	44	15.6	0.5	4
5	114	30.2	28.9	0.303	86.7	46.4	41	13.5	0.6	4
6	114	33.0	30.8	0.326	93.1	46.2	44	14.8	0.5	2
7	114	34.2	31.8	0.331	94.6	46.3	45	16.0	0.5	4
8	114	31.3	29.7	0.315	90.0	46.3	42	14.0	0.6	6
9	114	31.6	30.1	0.326	93.3	46.2	43	14.9	0.6	9
10	114	32.7	31.0	0.327	93.4	46.4	44	14.4	0.5	12
11	114	30.1	29.2	0.314	89.8	46.3	41	14.5	0.6	11
12	114	33.3	31.4	0.333	95.0	46.4	45	15.3	0.5	10
13	114	30.6	29.2	0.309	88.2	46.3	42	13.8	0.5	9
14	114	30.6	29.2	0.300	85.9	46.3	41	13.6	0.6	9
15	114	30.8	29.3	0.326	93.1	46.3	42	14.9	0.5	15
16	114	30.6	29.4	0.322	91.9	46.3	42	13.7	0.6	12
17	114	32.9	30.4	0.328	93.8	46.3	43	15.0	0.5	12
18	114	30.8	29.6	0.322	92.0	46.3	42	14.2	0.6	12
19	114	32.3	30.7	0.326	93.3	46.3	44	15.8	0.5	10
20	114	33.4	31.8	0.333	95.1	46.3	45	15.3	0.5	8
21	114	31.6	30.1	0.314	89.7	46.3	43	14.3	0.5	9
22	114	30.5	29.5	0.318	90.9	46.3	42	14.6	0.5	10
23	114	31.4	30.3	0.321	91.8	46.2	43	14.5	0.5	12
24	114	32.9	31.0	0.325	92.8	46.3	44	15.1	0.5	13
25	114	31.2	29.6	0.328	93.7	46.5	42	15.4	0.6	11
26	114	31.2	29.6	0.307	87.7	46.1	42	12.9	0.6	14
27	114	29.9	29.0	0.322	92.1	46.4	41	14.0	0.6	11
28	114	32.1	30.1	0.335	95.8	46.3	43	15.7	0.6	12
29	114	29.5	29.0	0.300	85.7	46.3	41	13.1	0.5	18
30	114	30.9	29.7	0.318	90.7	46.3	42	15.1	0.5	12
31	114	31.8	30.3	0.326	93.0	46.2	43	15.5	0.5	15
32	114	30.8	29.5	0.323	92.2	46.4	42	14.5	0.5	10
33	114	30.0	29.1	0.311	88.9	46.3	41	14.2	0.5	12
34	114	32.8	31.3	0.325	92.7	46.2	44	14.9	0.5	11
35	114	30.4	29.4	0.314	89.7	46.3	42	14.5	0.6	11
36	114	32.0	30.6	0.321	91.8	46.3	43	15.0	0.5	14
37	114	33.1	31.6	0.332	94.8	46.3	45	15.6	0.5	12
38	114	32.9	31.3	0.332	94.9	46.2	44	16.0	0.5	16
39	114	32.4	30.2	0.315	89.9	46.3	43	13.8	0.5	23
40	114	30.0	29.1	0.313	89.3	46.2	41	14.1	0.6	27
41	114	31.1	29.2	0.320	91.6	46.2	42	14.8	0.5	26
42	114	30.0	29.0	0.316	90.4	46.3	41	14.1	0.6	26
43	114	31.7	29.6	0.328	93.7	46.3	42	14.8	0.5	15
44	114	31.2	29.7	0.333	95.0	46.2	42	15.6	0.5	17
45	114	30.7	29.4	0.305	87.1	46.1	42	13.0	0.6	14
46	114	30.8	29.7	0.320	91.4	46.4	42	14.4	0.6	14
47	114	31.0	30.3	0.324	92.4	46.3	43	14.4	0.5	14
48	114	31.5	30.2	0.326	93.1	46.2	43	15.1	0.6	16
49	114	30.4	29.6	0.302	86.4	46.3	42	13.1	0.6	14
50	114	32.0	30.6	0.332	94.8	46.3	43	15.3	0.5	15
51	114	31.5	30.4	0.308	87.9	46.1	43	13.7	0.6	16
52	114	33.4	31.9	0.327	93.5	46.2	45	15.2	0.5	23
53	114	31.3	30.1	0.321	91.9	46.4	43	14.9	0.5	15
54	114	31.8	30.5	0.326	93.1	46.1	43	14.9	0.6	13
55	114	31.3	30.2	0.312	89.1	46.3	43	13.6	0.5	13
56	114	31.3	30.3	0.319	91.1	46.2	43	14.3	0.6	13
57	114	32.1	30.9	0.331	94.5	46.3	44	15.8	0.5	15
Average		31.5	30.1	0.321	91.6	45.5	43	14.6	0.5	12
Std. Dev.		1.1	0.9	0.010	2.7	5.8	1	0.8	0.1	6
Maximum		34.2	31.9	0.336	96.0	46.5	45	16.0	0.6	27

Total number of blows analyzed: 57

BL#	Comments
1	Start of test on 7/1/2013 at 1:05:07 PM
57	End of test on 7/1/2013 at 1:06:20 PM

HOLT, SPT RIG 7 - SAMPLE 6, 60 FT
OP: RMDT
BH E340-B-07A
Test date: 1-Jul-2013

Time Summary

Drive	1 minute 13 seconds	1:05:07 PM - 1:06:20 PM (7/1/2013) BN 1 - 57

Report 4
Holt Mobile B-58

September 26, 2017

Mr. Dale Abernathy
Holt Services, Inc.
10621 Todd Rd. East
Edgewood, WA 98372

Re: Penetration Test Energy Measurements
Mobile B-58 Rig No. 17, Mobile Auto Hammer
Bore Hole: Yard Test Hole, August 25, 2017
Holt Services Yard, Edgewood, Washington

RMDT Job No. 17F39

Dear Mr. Abernathy,

This letter presents energy transfer measurements made during Standard Penetration Tests for the drill hole and drill rig referenced above. Robert Miner Dynamic Testing, Inc. (RMDT) made dynamic measurements with a Pile Driving Analyzer® as a hammer advanced the NW rod during sampling with a split spoon sampler.

The purpose of RMDT's testing was the measurement of energy transferred to the drill rods. Measurements were made on a section of NW gauge rod at the top of the drill string. Strain gages and accelerometers on the rod were connected to a Pile Driving Analyzer® (PDA) which generally processed acceleration and strain measurements from each hammer blow and stored both the measurements and computed results. Measurements and data processing generally followed the ASTM D 4633-16 standard. Energy transfer past the gage location, EFV, was computed by the PDA using force and velocity records as follows:

$$EFV = \int_a^b F(t)\, v(t)\, dt$$

The value "a" corresponds to the start of the record which is when the energy transfer begins and *"b"* is the time at which energy transferred to the rod reaches a maximum value. Appendix A contains more information on our measurement equipment and methods of analysis. The EFV energy calculation is identical to the EMX energy result discussed in Appendix A. The EFV and EMX values apply to the sensor location near the top of the rod.

TEST DETAILS

On August 25, 2017, a single boring was advanced at the maintenance yard of Holt Services in Edgewood, Washington. The drill rig used during sampling was a truck mounted Mobile B-58 auger unit manufactured by Mobile Drill International and referred to as Rig 17 by the operator. The B-58 unit drilled to six predetermined depth intervals ranging from 20 to 50 ft below ground surface. The rod used to advance the spoon at each sample depth had a diameter matching that of NW rod. The automatic hammer in use during our testing was manufactured by Mobile Dill International and appeared to use a chain drive powered by a hydraulic motor, with the ram and chain drive enclosed within an outer casing.

RESULTS

A summary of testing and monitoring results is given in Table 1. The tabulated results include the starting sample depth, the penetration resistance, the number of hammers blows in our data set, measured energy transfer, EFV, the computed transfer efficiency, ETR, and the hammer blow rate, BPM. Appendix B contains detailed numeric results for each individual test.

Energy measurements must be divided by the theoretical free fall energy of the hammer to obtain an efficiency. A 140 lb ram raised 30 inches above an impact surface has 350 lb-ft of potential energy. Thus, the transfer energy results for sampling with the 140 lb ram may be divided by 350 lb-ft to yield the ratio of the delivered energy to the nominal potential energy. This efficiency ratio, ETR, is given for each sample interval as a percent efficiency.

Table 1. Summary of Test Details and Results for the 140-lb ram and Split Spoon Sampler

Sample Name and Sample Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
20 ft Sample	30/1 ft	30	289	83	28
25 ft Sample	25/1 ft	25	288	82	29
30 ft Sample	33/1 ft	33	288	82	32
35 ft Sample	27/1 ft	27	290	83	32
40 ft Sample	23/1 ft	23	291	83	32
50 ft Sample	50/3 in	49	285	82	32
Average for Split Spoon samples:			**289**	**83**	**31**

Six sample returns were monitored while the 140 lb ram and standard split spoon sampler were in use. The overall average ETR and hammer blow rate was 83 percent and 31 blows per minute, respectively.

It was a pleasure to assist you and to participate on this project with the staff of Holt Services Inc. Please do not hesitate to contact us if you or other project participants have any questions about this report.

Sincerely,

September 26, 2017

Andrew J. Banas, P.E.

Robert Miner Dynamic Testing, Inc.

APPENDIX A
AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

BACKGROUND

Modern procedures of design and construction control require verification of bearing capacity and integrity of deep foundations during preconstruction test programs and also production installation. Dynamic pile testing methods meet this need economically and reliably, and therefore, form an important part of a quality assurance program when deep foundations are executed. Several dynamic pile testing methods exist; they have different benefits and limitations and different requirements for proper execution.

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 (such as that of a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. The method is therefore 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 an evaluation of various quantities based on closed form solutions of the wave equation, a partial differential equation describing the motion of a rod under the effect of an impact. Conveniently, measurements and analyses are done by a single piece of equipment: the Pile Driving Analyzer® (PDA). However, for bearing capacity evaluations an important additional method is CAPWAP® which performs a much more rigorous analysis of the dynamic records than the simpler Case Method.

A related analysis method is the “Wave Equation Analysis” which calculates a relationship between bearing capacity and pile stress and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data.

The following description deals primarily with the Case Method or “High Strain Test” Method of pile testing, however, for the sake of completeness, the “Low Strain Test” performed with the Pile Integrity Test™ (PIT), mainly for pile integrity evaluation, will also be described.

RESULTS FROM DYNAMIC TESTING

There are two main objectives of high strain dynamic pile testing:

- *Dynamic Pile Monitoring* and
- *Dynamic Load Testing*.

Dynamic pile monitoring is conducted during the installation of impact driven piles to achieve a safe and economical pile installation. Dynamic load testing, on the other hand, has as its primary goal the assessment of pile bearing capacity. It is applicable to both cast *insitu* piles or drilled shafts and impact driven piles during restrike.

Dynamic Pile Monitoring

During pile installation, the sensors attached to the pile measure pile top force and velocity. A PDA conditions and processes these signals and calculates or evaluates:

- Bearing capacity at the time of testing, including an assessment of shaft resistance development and driving resistance. This information supports formulation of a driving criterion.

- Dynamic pile stresses, axial and averaged over the pile cross section, both tensile and compressive, during pile driving to limit the potential of damage either near the pile top or along its length. Bending stresses can be evaluated at the point of sensor attachment.

- Pile integrity assessment by the PDA is based on the recognition of certain wave reflections from along the pile. If detected early enough, a pile may be saved from complete destruction. On the other hand, once damage is recognized measures can be taken to prevent reoccurrence.

- Hammer performance parameters including the energy transferred to the pile, the hammer speed in blows per minute and the stroke of open ended diesel hammers.

Dynamic Pile Load Testing

Bearing capacity testing of either driven piles or drilled shafts applies the same basic measurement approach of dynamic pile monitoring. However, the test is done independent of the pile installation process and therefore a pile driving hammer or other dynamic loading device may not be available. If a special ram has to be mobilized then its weight should be between 0.8 and 2% of the test load (e.g. between 4 and 10 tons for a 500 ton test load) to assure sufficient soil resistance activation.

For a successful test, it most important that the test is conducted after a sufficient waiting time following pile installation for soil properties approaching their long term condition or concrete to properly set. During testing, PDA results of pile/shaft stresses and transferred energy are used to maintain safe stresses and assure sufficient resistance activation. For safe and sufficient testing of drilled shafts, ram energies are often increased from blow to blow until the test capacity has been activated. On the other hand, restrike tests on driven piles may require a warm hammer so that the very first blow produces a complete resistance activation. Data must be evaluated by CAPWAP for bearing capacity.

After the dynamic load test has been conducted with sufficient energy and safe stresses, the CAPWAP analysis provides the following results:

- Bearing capacity i.e. the mobilized capacity present at the time of testing

- Resistance distribution including shaft resistance and end bearing components

- Stresses in pile or shaft calculated for both the static load application and the dynamic test. These stresses are averages over the cross section and do not include bending effects or nonuniform contact stresses, e.g. when the pile toe is on uneven rock.

- Shaft impedance vs depth; this is an estimate of the shaft shape if it differs substantially from the planned profile

- Dynamic soil parameters for shaft and toe, i.e. damping factors and quakes (related to the dynamic stiffness of the resistance at the pile/soil interface.)

MEASUREMENTS

PDA

The basis for the results calculated by the PDA are pile top strain and acceleration measurements which are converted to force and velocity records, respectively. The PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. Using closed form Case Method solutions, based on the one-dimensional linear wave equation, the PDA calculates the results described in the analytical solutions section below.

HPA

The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. For this unit to be applicable, the ram must be visible. The impact velocity results can be automatically processed with a PC or recorded on a strip chart.

Saximeter™

For open end diesel hammers, the time between two impacts indicates the magnitude of the ram fall height or stroke. This information is not only measured and calculated by the PDA but also by the convenient, hand-held Saximeter.

PIT

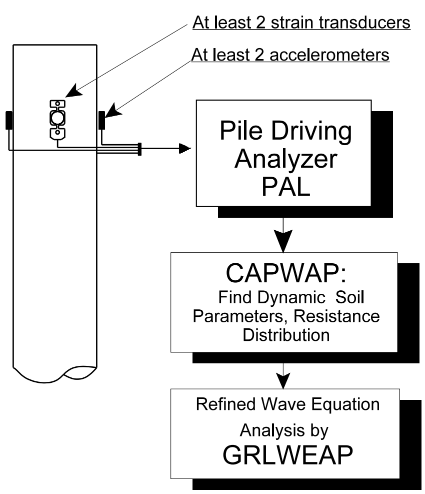
The Pile Integrity Tester™ (PIT) can be used to evaluate defects in concrete piles or shafts which may have occurred during driving or casting. Also timber piles of limited length can be tested in that manner. This so-called "Low Strain Method" or “Pulse-Echo Method” of integrity testing requires only the measurement of acceleration at the pile top. The stress wave producing impact is then generated by a small hand-held hammer and the records interpreted in the time domain. PIT also supports the so-called “Transient Response Method” which requires the additional measurement of the hammer force and an analysis in the frequency domain. This method may also be used to evaluate the unknown length of deep foundations under existing structures.

ANALYTICAL SOLUTIONS
BEARING CAPACITY

Wave Equation

GRL has written the GRLWEAP™ program which calculates a relationship between bearing capacity, pile stress and blow count. This relationship is often called the “bearing graph.” Once the blow count is known from pile installation logs, the bearing graph yields the bearing capacity. This approach requires no measurements and therefore can be performed during the design stage of a project, for example for the selection of hammer, cushion and pile size.

After dynamic pile monitoring and/or dynamic load testing has been performed, the “Refined Wave Equation Analysis” or RWEA (see schematic below) is often performed by inputting the PDA and CAPWAP calculated parameters. Then the bearing graph from the RWEA is the basis for a safe and sufficient driving criteria.



Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil resistance is

$$R(t) = \tfrac{1}{2}\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

t = a point in time after impact
t_2 = time $t + 2L/c$
L = pile length below gages
c = $(E/\rho)^{1/2}$ is the speed of the stress wave
ρ = pile mass density
Z = EA/c is the pile impedance
E = elastic modulus of the pile ($\rho\, c^2$)
A = pile cross sectional area

The total soil resistance consists of a dynamic (R_d) and a static (R_s) component. The static component is therefore

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2.

There are a number of ways in which Eq. 1 through 3 can be evaluated. Most commonly, t_2 is set to that time at which the static resistance becomes maximum. The result is the so-called **RMX** capacity. Damping factors for RMX typically range between 0.5 for coarse grained materials to 1.0 for clays. The **RSP** capacity (this method is most commonly referred to in the literature, yet it is not very frequently used) requires damping factors between 0.1 for sand and 1.0 for clay. Another capacity, **RA2**, determines the capacity at a time when the pile is essentially at rest and thus damping is small; RA2

therefore requires no damping parameter. In any event, the proper Case Method and its associated damping parameter is most conveniently found after a CAPWAP analysis has been performed.

The static resistance calculated by Case Method or CAPWAP is the mobilized resistance at the time of testing. Consideration therefore has to be given to soil setup or relaxation effects and whether or not a sufficient set has been achieved under the test loading that would correspond to a full activation of the ultimate soil resistance.

The PDA also calculates an estimate of shaft resistance as the difference between force and velocity times impedance at the time immediately prior to the return of the stress wave from the pile toe. This shaft resistance is not reduced by damping effects and is therefore called the total shaft resistance **SFT**. A correction for damping effects produces the static shaft resistance estimate, **SFR**.

The Case Method solution is simple enough to be evaluated "in real time," i.e. between hammer blows, using the PDA. It is therefore possible to calculate all relevant results for all hammer blows and plot these results as a function of depth or blow number. This is done in the PDAPLOT program.

CAPWAP

The CAse Pile Wave Analysis Program combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the shaft resistance, end bearing, damping factors and soil stiffnesses. The method iteratively calculates a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

During pile monitoring, it is important that compressive stress maxima at pile top and toe and tensile stress maxima somewhere along the pile be calculated for each hammer blow.

At the pile top (location of sensors) both the maximum compression stress, **CSX**, and the maximum stress from individual strain transducers, **CSI**, are directly obtained from the measurements. Note that CSI is greater than or equal to CSX and the difference between CSI and CSX is a measure of bending in the plane of the strain transducers. Note also that all stresses calculated for locations below the sensors are averaged over the pile cross section and therefore do not include components from either bending or eccentric soil resistance effects.

The PDA calculates the compressive stress at the pile bottom, **CSB**, assuming (a) a uniform pile and (b) that the pile toe force is the maximum value of the total resistance R(t) minus the total shaft resistance, SFT. Again, for this stress estimation uniform resistance force are assumed (e.g. not a sloping rock.)

For concrete piles, the maximum tension stress, **TSX**, is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by finding the maximum tension wave (either traveling upward, W_U, or downward, W_d) and reducing it by the minimum compressive wave traveling in opposite direction.

$$W_u = ½[F(t) - Zv(t)] \tag{4}$$

$$W_d = ½[F(t) + Zv(t)] \tag{5}$$

CAPWAP also calculates tensile and compressive stresses along the pile and, in general, more accurately than the PDA. In fact, for non-uniform piles or piles with joints, cracks or other discontinuities, the closed form solutions from the PDA may be in error.

PILE INTEGRITY

High Strain Tests (PDA)

Stress waves in a pile are reflected wherever the pile impedance, $Z = EA/c = \rho cA = A\sqrt{(E\,\rho)}$, changes. Therefore, the pile impedance is a measure of the quality of the pile material (E, ρ, c) and the size of its cross section (A). The reflected waves arrive at the pile top at a time which is greater the farther away from the pile top the reflection occurs. The

magnitude of the change of the upward traveling wave (calculated from the measured force and velocity, Eq. 4) indicates the extent of the cross sectional change. Thus, with β_i (**BTA**) being a relative integrity factor which is unity for no impedance change and zero for the pile end, the following is calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \qquad (6)$$

with

$$\alpha_i = ½(W_{UR} - W_{UD})/(W_{Di} - W_{UR}) \qquad (7)$$

where

W_{UR} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.

W_{UD} is the upwards traveling wave due to the damage reflection.

W_{Di} is the maximum downward traveling wave due to impact.

It can be shown that this formulation is quite accurate as long as individual reflections from different pile impedance changes have no overlapping effects on the stress wave reflections.

Without rigorous derivation, it has been proposed to consider as slight damage when β is above 0.8 and a serious damage when β is less than 0.6.

Low Strain Tests (PIT)

The pile top is struck with a held hand hammer and the resulting pile top velocity is measured, displayed and interpreted for signs of wave reflections. In general, a comparison of the reflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the reflection. PIT records can also be interpreted by the β-Method. However, low strain tests do not activate much resistance which simplifies Eq. 7 since W_{UR} is then equal to zero.

For drilled shafts and PIT records that clearly show a toe reflection, an approximate shaft profile can be calculated from low strain records using the PITSTOP program's PROFILE routine.

HAMMER PERFORMANCE

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

$$E(t) = {}_o\int^t F(t)v(t)\,dt \qquad (8a)$$

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

$$e_T = EMX/E_R \qquad (8b)$$

where

E_R is the manufacturer's rated energy value.

Both Saximeter and PDA calculate the stroke (**STK**) of an open end diesel hammer using

$$STK = (g/8)\,T_B^{\,2} - h_L \qquad (9)$$

where

g is the earth's gravitational acceleration,
T_B is the time between two hammer blows,
h_L is a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

DETERMINATION OF WAVE SPEED

An important facet of dynamic pile testing is an assessment of pile material properties. Since in general force is determined from strain by multiplication with elastic modulus, E, and cross sectional area, A, the dynamic elastic modulus has to be determined for pile materials other than steel. In general, the records measured by the PDA clearly indicate a pile toe reflection as long as pile penetration per blow is greater than 1 mm or .04 inches. The time between the onset of the force and velocity records at impact and the onset of the reflection from the toe (usually apparent by a local maximum of the wave up curve) is the so-called wave travel time, T. Dividing 2L (L is here the length of the pile below sensors) by T leads to the stress wave speed in the pile:

$$c = 2L/T \qquad (10)$$

The elastic modulus of the pile material is related to the wave speed according to the linear elastic wave equation theory by

$$E = c^2 \rho \qquad (11)$$

Since the mass density of the pile material, ρ, is usually well known (an exception is timber for which samples should be weighed), the elastic modulus is easily found from the wave speed. Note, however, that this is a dynamic modulus which is generally higher than the static one and that the wave speed depends to some degree on the strain level of the stress wave. For example, experience shows that the wave speed from PIT is roughly 5% higher than the wave speed observed during a high strain test.

Other Notes:

- If the pile material is nonuniform then the wave speed c, according to Eq. 10, is an average wave speed and does not necessarily reflect the pile material properties of the location where the strain sensors are attached to the pile top. For example, pile driving often causes fine tension cracks some distance below the top of concrete piles. Then the average c is slower than that at the pile top. It is therefore recommended to determine E in the beginning of pile driving and not adjust it when the average c changes.

- If the pile has such a high resistance that there is no clear indication of a toe reflection then the wave speed of the pile material must be determined either by assumption or by taking a sample of the concrete and measuring its wave speed in a simple free column test. Another possibility is to use the proportionality relationship, discussed under "DATA QUALITY CHECKS" to find c as the ratio between the measured velocity and measured strain.

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 PDA or PIT 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 certain relationships.

Proportionality

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 pile, force and velocity measured at the pile top are proportional

$$F = v\,Z = v\,(EA/c) \qquad (12a)$$

This relationship can also be expressed in terms of stress

$$\sigma = v\,(E/c) \qquad (12b)$$

or strain

$$\epsilon = v / c \qquad (12c)$$

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.

Measurements are always taken at opposite sides of the pile as a means of calculating the average force and velocity in the pile. The velocity on the two sides of the pile is very similar even when high bending exists. Thus, an independent check of the velocity measurements is easy and simple.

Strain measurements may differ greatly between the two sides of the pile when bending exists. It is even possible that tension is measured on one side while very high compression exists on the other side of the pile. In extreme cases, bending might be so high that it leads to a nonlinear stress distribution. The averaging of the two strain signals does then not lead to the average pile force and proportionality will not be achieved.

When testing drilled shafts, measurements of strain may also be affected by local concrete quality variations. It is then often necessary to use four strain transducers spaced at 90 degrees around the pile for an improved strain data quality. The use of four transducers is also recommended for large pile

diameters, particularly when it is difficult to mount the sensors at least two pile widths or diameters below the pile top.

LIMITATIONS, ADDITIONAL CONSIDERATIONS

Mobilization of capacity

Estimates of pile capacity from dynamic testing indicate the **mobilized pile capacity at the time of testing**. At very high blow counts (low set per blow), dynamic test methods tend to produce lower bound capacity estimates as not all resistance (particularly at and near the toe) is fully activated.

Time dependent soil resistance effects

Static pile capacity from dynamic method calculations provide an estimate of the axial pile capacity. Increases and decreases in the pile capacity with time typically occur (soil setup/relaxation). Therefore, **restrike testing usually yields a better indication of long term pile capacity than a test at the end of pile driving**. Often a wait period of one or two days between end of driving and restrike is satisfactory for a realistic prediction of pile capacity but this waiting time depends, among other factors, on the permeability of the soil.

(A) Soil setup

Because excess positive pore pressures often develop during pile driving in fine grained soil (clays, silts or even fine sands), the capacity of a pile at the time of driving may often be less than the long term pile capacity. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and thus the pile capacity at the time of driving. As these pore pressures dissipate, the soil resistance acting on the pile increases as does the axial pile capacity. This phenomena is routinely called soil setup or soil freeze.

(*B) Relaxation*

Relaxation (capacity reduction with time) has been observed for piles driven into weathered shale, and may take several days to fully develop. Pile capacity estimates based upon initial driving or short term restrike tests can significantly overpredict long term pile capacity. Therefore, piles driven into shale should be tested after a minimum one week wait either statically or dynamically (with particular emphasis than on the first few blows). Relaxation has also been observed for displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe. Again, restrike tests should be used, with great emphasis on early blows.

Capacity results for open pile profiles

Larger diameter open ended pipe piles (or H-piles which do not bear on rock) may behave differently under dynamic and static loading conditions. Under dynamic loads the soil inside the pile or between its flanges may slip and produce internal friction while under static loads the plug may move with the pile, thereby creating end bearing over the full pile cross section. As a result both friction and end bearing components may be different under static and dynamic conditions.

CAPWAP Analysis Results

A portion of the soil resistance calculated on an individual soil segment in a CAPWAP analysis can usually be shifted up or down the shaft one soil segment without significantly altering the match quality. Therefore, use of the CAPWAP resistance distribution for uplift, downdrag, scour, or other geotechnical considerations should be made with an understanding of these analysis limitations.

Stresses

PDA and CAPWAP calculated stresses are average values over the cross section. Additional allowance has to be made for bending or non-uniform contact stresses. To prevent damage it is therefore important to maintain good hammer-pile alignment and to protect the pile toes using appropriate devices or an increased cross sectional area.

In the United States is has become generally acceptable to limit the dynamic installation stresses of driven piles to the following levels:

90% of yield strength for steel piles

85% of the concrete compressive strength - after subtraction of the effective prestress - for concrete piles in compression

100% of effective prestress plus ½ of the concrete's tension strength for prestressed piles in tension

70% of the reinforcement strength for regularly reinforced concrete piles in tension

300% of the static design allowable stress for timber

Note that the dynamic stresses may either be directly measured at the pile top by the PDA or calculated by the PDA for other locations along the pile based on the pile top measurements.

Additional design considerations

Numerous factors have to be considered in pile foundation design. Some of these considerations include

- additional pile loading from downdrag or negative skin friction,
- lateral and uplift loading requirements
- effective stress changes (due to changes in water table, excavations, fills or other changes in overburden),
- long term settlements in general and settlement from underlying weaker layers and/or pile group effects,

These factors have not been evaluated by GRL and have not been considered in the interpretation of the dynamic testing results. The foundation designer should determine if these or any other considerations are applicable to this project and the foundation design.

Wave equation analysis results

The results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Although attempts have been made to base the analysis on the best available information, actual field conditions may vary and therefore stresses and blow counts may differ from the predictions reported. Capacity predictions derived from wave equation analyses should use restrike information. However, because of the uncertainties associated with restrike blow counts and restrike hammer energies, correlations of such results with static test capacities with have often displayed considerable scatter.

As for PDA and CAPWAP, the theory on which GRLWEAP is based is the one-dimensional wave equation. For that reason, stress predictions by the wave equation analysis can only be averages over the pile cross section. Thus, bending stresses or stress concentrations due to non-uniform impact or uneven soil or rock resistance are not considered in these results. Stress maxima calculated by the wave equation are usually subjected to the same limits as those measured directly or calculated from measurements by the PDA.

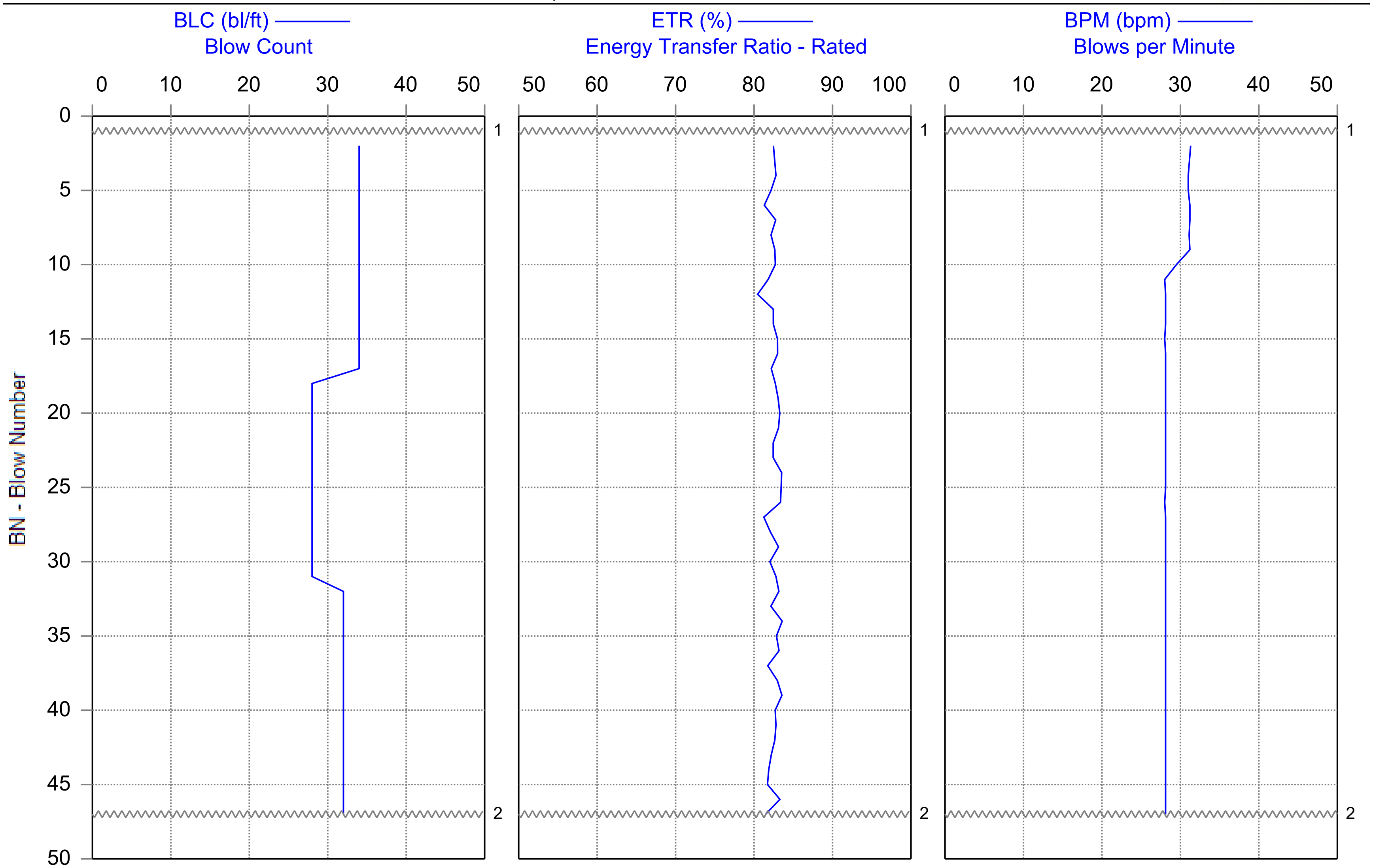
Appendix B

Summary of Case Method Results

Pile Dynamics, Inc. - PDIPLOT2 Ver 2016.2.57.6 - Case Method & iCAP® Results

Printed: 25-September-2017 Test started: 25-August-2017

HOLT DRILLING, RIG 17 - 20.0 FT SAMPLE



1 - Start of test on 8/25/2017 at 12:56 PM

2 - End of test on 8/25/2017 at 12:58 PM

HOLT DRILLING, RIG 17 - 20.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

AR: 1.40 in² SP: 0.492 k/ft³
LE: 26.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35 []

EFV: Energy of FV CSX: Max Measured Compr. Stress
ETR: Energy Transfer Ratio - Rated DMX: Maximum Displacement
BPM: Blows per Minute RAT: SPT Length Ratio
FMX: Maximum Force DFN: Final Displacement
VMX: Maximum Velocity

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	DMX	RAT	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	in	[]	in
18	20.54	28	289.5	82.7	28.1	43	14.5	30.7	0.47	0.8	0.43
19	20.57	28	290.7	83.1	28.1	43	14.5	30.5	0.47	0.8	0.43
20	20.61	28	291.4	83.3	28.1	43	14.4	30.9	0.47	0.8	0.43
21	20.64	28	290.9	83.1	28.1	43	14.5	31.1	0.47	0.8	0.43
22	20.68	28	288.5	82.4	28.1	43	14.5	31.0	0.47	0.8	0.43
23	20.71	28	288.5	82.4	28.1	43	14.5	31.1	0.47	0.8	0.43
24	20.75	28	292.3	83.5	28.1	43	14.6	31.0	0.47	0.8	0.43
25	20.79	28	292.1	83.5	28.1	43	14.6	30.8	0.48	0.8	0.43
26	20.82	28	291.8	83.4	28.0	43	14.6	30.8	0.49	0.8	0.43
27	20.86	28	284.3	81.2	28.1	43	14.4	31.0	0.46	0.8	0.43
28	20.89	28	287.3	82.1	28.1	44	14.5	31.2	0.47	0.8	0.43
29	20.93	28	290.9	83.1	28.1	44	14.6	31.2	0.48	0.8	0.43
30	20.96	28	287.0	82.0	28.1	43	14.5	30.5	0.48	0.8	0.43
31	21.00	28	289.8	82.8	28.1	43	14.6	31.0	0.48	0.8	0.43
32	21.03	32	291.1	83.2	28.1	43	14.6	31.0	0.49	0.8	0.38
33	21.06	32	287.5	82.1	28.1	44	14.5	31.2	0.50	1.1	0.38
34	21.09	32	292.5	83.6	28.1	43	14.6	31.0	0.49	0.8	0.38
35	21.13	32	290.0	82.8	28.1	44	14.5	31.2	0.49	0.8	0.38
36	21.16	32	291.1	83.2	28.1	43	14.6	31.0	0.50	0.8	0.38
37	21.19	32	286.1	81.7	28.1	43	14.4	30.9	0.52	1.1	0.38
38	21.22	32	290.4	83.0	28.1	43	14.6	30.8	0.52	0.8	0.38
39	21.25	32	292.4	83.5	28.1	44	14.7	31.2	0.53	0.8	0.38
40	21.28	32	289.4	82.7	28.1	43	14.6	30.8	0.51	1.1	0.38
41	21.31	32	289.7	82.8	28.1	44	14.6	31.1	0.54	1.1	0.38
42	21.34	32	289.2	82.6	28.1	42	14.4	29.9	0.53	1.1	0.38
43	21.38	32	287.6	82.2	28.1	43	14.5	30.9	0.51	1.1	0.38
44	21.41	32	286.5	81.9	28.1	43	14.4	30.8	0.52	1.1	0.38
45	21.44	32	286.0	81.7	28.1	43	14.5	30.7	0.53	1.1	0.38
46	21.47	32	291.5	83.3	28.1	43	14.6	30.7	0.53	1.1	0.38
47	21.50	32	285.2	81.5	28.1	43	14.4	30.7	0.56	1.1	0.38
		Average	289.4	82.7	28.1	43	14.5	30.9	0.50	0.9	0.40
		Std. Dev.	2.3	0.6	0.0	0	0.1	0.3	0.03	0.2	0.03
		Maximum	292.5	83.6	28.1	44	14.7	31.2	0.56	1.1	0.43
		Minimum	284.3	81.2	28.0	42	14.4	29.9	0.46	0.8	0.38

Total number of blows analyzed: 30

BL# Sensors

2-47 F1: [328NWJ2] 220.6 (1.00); F2: [328NWJ2] 220.6 (1.00); A1: [K2449] 340.0 (1.00); A2: [K3258] 337.0 (1.00)

BL# Comments

1 Start of test on 8/25/2017 at 12:56 PM

47 End of test on 8/25/2017 at 12:58 PM

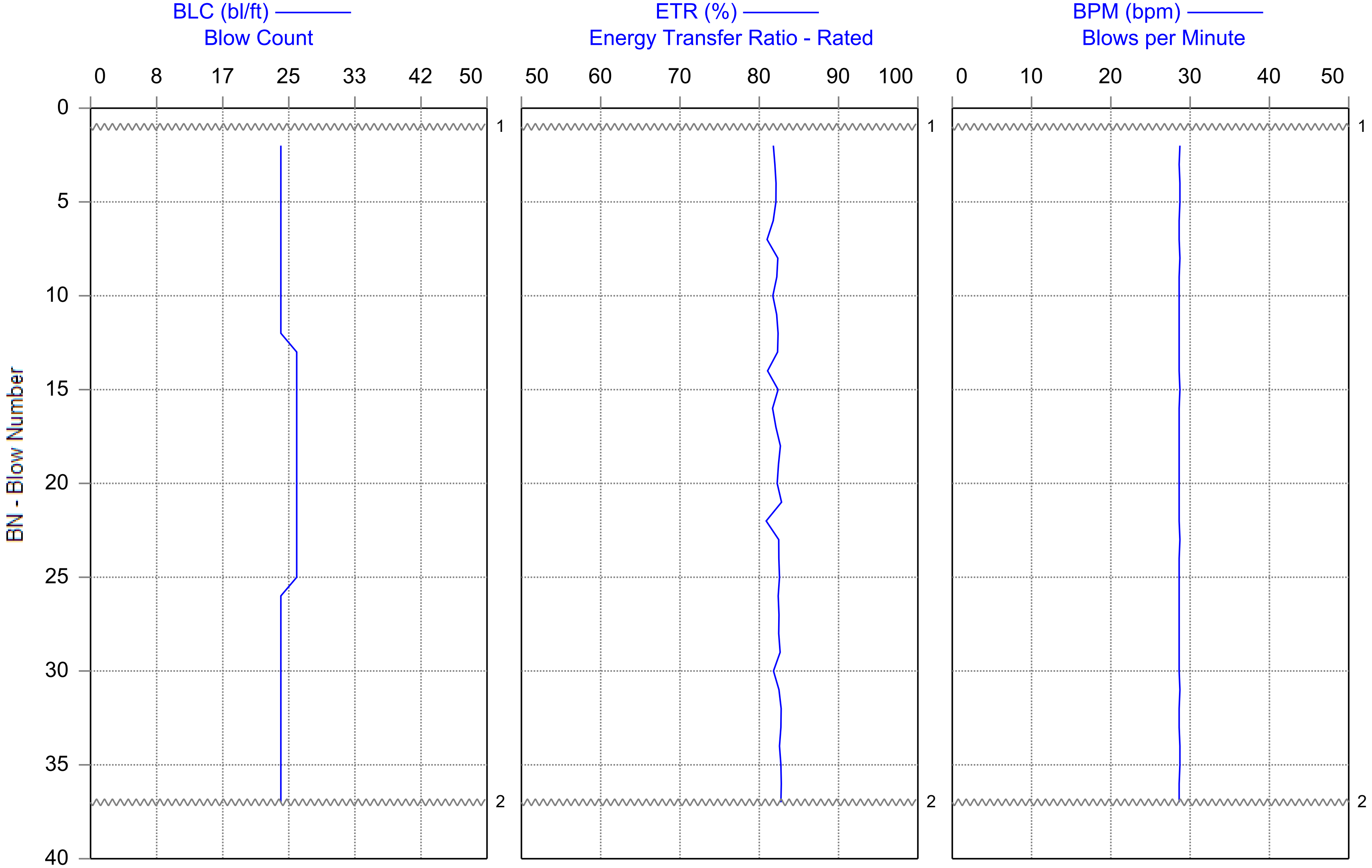
Time Summary

Drive 2 minutes 3 seconds 12:56 PM - 12:58 PM BN 1 - 47

Pile Dynamics, Inc. - PDIPLOT2 Ver 2016.2.57.6 - Case Method & iCAP® Results

Printed: 25-September-2017 Test started: 25-August-2017

HOLT DRILLING, RIG 17 - 25.0 FT SAMPLE



1 - Start of test on 8/25/2017 at 1:09 PM

2 - End of test on 8/25/2017 at 1:10 PM

HOLT DRILLING, RIG 17 - 25.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

AR: 1.40 in² SP: 0.492 k/ft³
LE: 31.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35 []

EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
CSX: Max Measured Compr. Stress
DMX: Maximum Displacement
RAT: SPT Length Ratio
DFN: Final Displacement

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	DMX	RAT	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	in	[]	in
13	25.54	26	288.1	82.3	28.6	41	13.8	29.6	0.57	0.8	0.46
14	25.58	26	283.6	81.0	28.6	42	14.0	30.3	0.55	0.8	0.46
15	25.62	26	288.3	82.4	28.7	42	14.0	30.2	0.57	0.8	0.46
16	25.65	26	285.8	81.7	28.6	41	13.8	29.6	0.55	0.8	0.46
17	25.69	26	287.3	82.1	28.6	42	13.9	29.7	0.55	0.8	0.46
18	25.73	26	289.3	82.7	28.6	43	14.0	30.6	0.56	0.8	0.46
19	25.77	26	288.5	82.4	28.6	42	13.9	30.0	0.55	0.8	0.46
20	25.81	26	287.9	82.3	28.6	42	13.9	29.9	0.55	0.8	0.46
21	25.85	26	289.8	82.8	28.6	43	14.1	30.4	0.56	0.8	0.46
22	25.88	26	283.0	80.9	28.6	42	14.0	30.0	0.56	0.8	0.46
23	25.92	26	288.6	82.4	28.7	42	14.0	30.2	0.57	0.8	0.46
24	25.96	26	288.6	82.5	28.6	43	14.1	30.6	0.59	0.8	0.46
25	26.00	26	288.9	82.5	28.6	43	14.0	30.5	0.59	0.8	0.46
26	26.04	24	288.3	82.4	28.6	43	14.0	30.6	0.60	0.8	0.50
27	26.08	24	288.7	82.5	28.6	43	14.1	30.6	0.62	0.8	0.50
28	26.13	24	288.6	82.4	28.6	42	13.9	30.1	0.58	0.8	0.50
29	26.17	24	289.2	82.6	28.6	42	14.0	30.2	0.63	0.8	0.50
30	26.21	24	286.2	81.8	28.6	42	13.9	30.0	0.64	0.8	0.50
31	26.25	24	288.7	82.5	28.7	43	14.1	30.7	0.66	0.8	0.50
32	26.29	24	289.6	82.8	28.6	42	14.0	30.3	0.66	0.8	0.50
33	26.33	24	289.5	82.7	28.6	42	14.0	30.0	0.67	0.8	0.50
34	26.38	24	288.9	82.5	28.7	42	14.0	30.1	0.64	0.8	0.50
35	26.42	24	289.5	82.7	28.7	43	14.1	30.8	0.65	0.8	0.50
36	26.46	24	289.7	82.8	28.6	43	14.1	30.4	0.65	0.8	0.50
37	26.50	24	289.5	82.7	28.6	42	14.0	29.9	0.64	0.8	0.50
		Average	288.2	82.3	28.6	42	14.0	30.2	0.60	0.8	0.48
		Std. Dev.	1.7	0.5	0.0	0	0.1	0.3	0.04	0.0	0.02
		Maximum	289.8	82.8	28.7	43	14.1	30.8	0.67	0.8	0.50
		Minimum	283.0	80.9	28.6	41	13.8	29.6	0.55	0.8	0.46

Total number of blows analyzed: 25

BL# Sensors

2-37 F1: [328NWJ2] 220.6 (1.00); F2: [328NWJ2] 220.6 (1.00); A1: [K2449] 340.0 (1.00);
A2: [K3258] 337.0 (1.00)

BL# Comments

1 Start of test on 8/25/2017 at 1:09 PM
37 End of test on 8/25/2017 at 1:10 PM

HOLT DRILLING, RIG 17 - 25.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

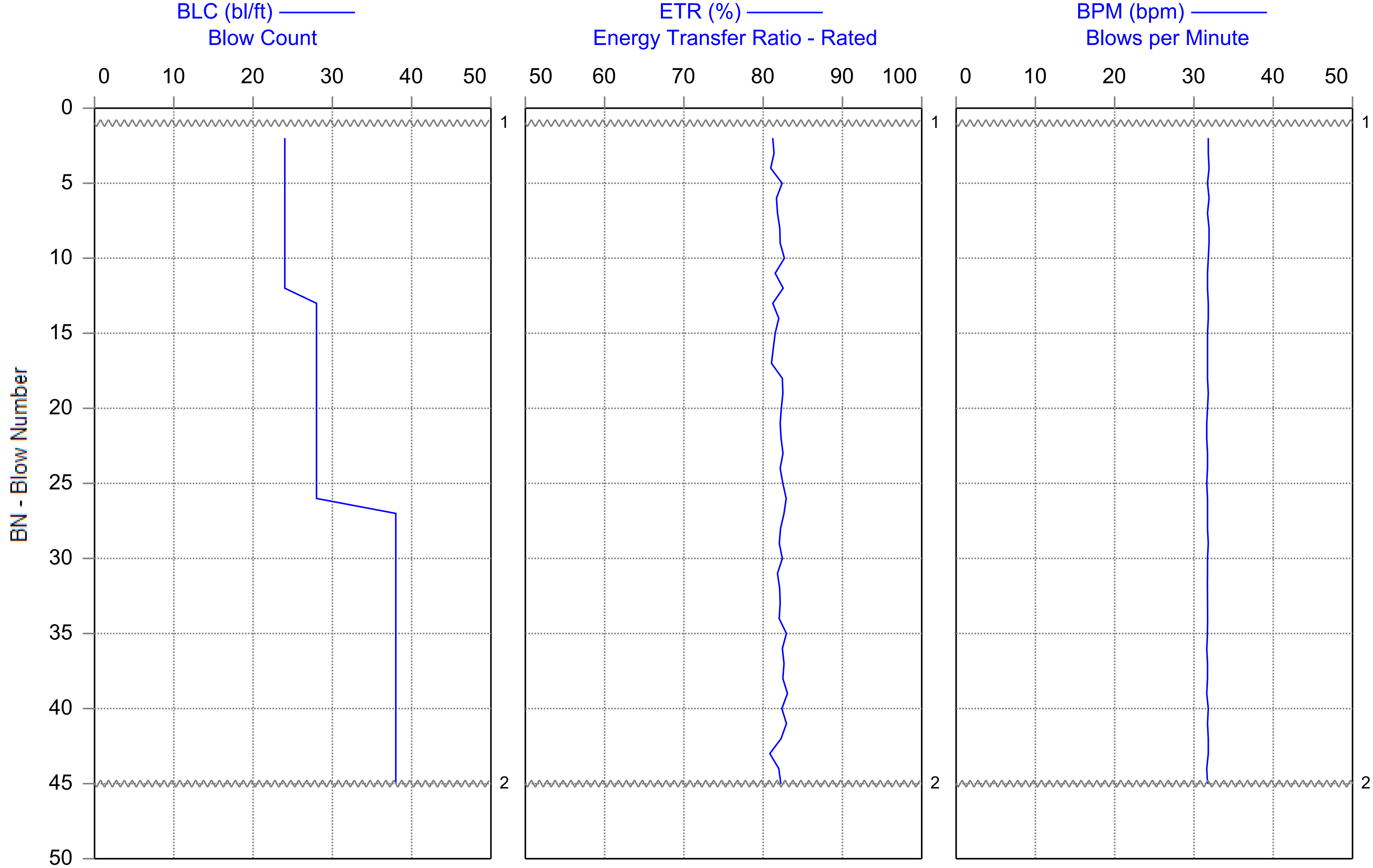
Time Summary

Drive 1 minute 15 seconds 1:09 PM - 1:10 PM BN 1 - 37

Pile Dynamics, Inc. - PDIPLOT2 Ver 2016.2.57.6 - Case Method & iCAP® Results

Printed: 25-September-2017 Test started: 25-August-2017

HOLT DRILLING, RIG 17 - 30.0 FT SAMPLE



1 - Start of test on 8/25/2017 at 1:21 PM

2 - End of test on 8/25/2017 at 1:23 PM

HOLT DRILLING, RIG 17 - 30.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

AR: 1.40 in² SP: 0.492 k/ft³
LE: 36.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35 []

EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
CSX: Max Measured Compr. Stress
DMX: Maximum Displacement
RAT: SPT Length Ratio
DFN: Final Displacement

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	DMX	RAT	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	in	[]	in
13	30.54	28	284.2	81.2	31.8	40	13.6	28.9	0.54	0.8	0.43
14	30.57	28	286.9	82.0	31.8	41	13.7	28.9	0.54	0.8	0.43
15	30.61	28	285.3	81.5	31.7	41	13.8	29.5	0.52	0.8	0.43
16	30.64	28	284.4	81.3	31.7	42	13.8	29.8	0.51	0.8	0.43
17	30.68	28	283.7	81.0	31.7	41	13.9	29.2	0.51	0.8	0.43
18	30.71	28	288.4	82.4	31.7	41	13.9	29.6	0.51	0.8	0.43
19	30.75	28	288.7	82.5	31.8	41	13.8	29.3	0.50	0.8	0.43
20	30.79	28	288.0	82.3	31.7	41	13.8	29.2	0.49	0.8	0.43
21	30.82	28	287.5	82.1	31.6	41	13.9	29.4	0.49	0.8	0.43
22	30.86	28	287.9	82.3	31.6	41	13.8	29.4	0.48	0.8	0.43
23	30.89	28	288.7	82.5	31.7	41	13.9	29.6	0.47	0.8	0.43
24	30.93	28	287.5	82.1	31.7	41	13.9	29.5	0.46	0.8	0.43
25	30.96	28	288.7	82.5	31.6	42	13.9	30.0	0.46	0.8	0.43
26	31.00	28	290.2	82.9	31.7	41	13.9	29.5	0.45	0.8	0.43
27	31.03	38	289.2	82.6	31.7	42	13.9	29.7	0.43	0.8	0.31
28	31.05	38	287.7	82.2	31.7	41	13.8	29.3	0.42	0.8	0.32
29	31.08	38	287.1	82.0	31.8	41	13.8	29.3	0.41	0.8	0.31
30	31.11	38	288.5	82.4	31.7	41	13.9	29.6	0.42	0.8	0.32
31	31.13	38	286.3	81.8	31.7	41	13.8	29.3	0.41	0.8	0.31
32	31.16	38	287.2	82.1	31.7	41	13.9	29.6	0.41	0.8	0.31
33	31.18	38	287.5	82.1	31.7	41	13.9	29.4	0.41	0.8	0.31
34	31.21	38	287.1	82.0	31.7	41	13.9	29.4	0.40	0.8	0.31
35	31.24	38	290.3	82.9	31.7	42	14.0	29.7	0.41	0.8	0.31
36	31.26	38	288.5	82.4	31.6	41	13.8	29.2	0.40	0.8	0.31
37	31.29	38	289.2	82.6	31.7	42	13.9	29.8	0.40	0.8	0.31
38	31.32	38	288.7	82.5	31.7	41	13.9	29.2	0.41	0.8	0.31
39	31.34	38	290.7	83.1	31.6	41	13.9	29.3	0.41	0.8	0.32
40	31.37	38	288.2	82.4	31.8	41	13.9	29.2	0.41	0.8	0.31
41	31.39	38	290.2	82.9	31.7	41	13.9	29.4	0.41	0.8	0.31
42	31.42	38	287.9	82.3	31.8	42	13.9	29.7	0.41	0.8	0.31
43	31.45	38	282.9	80.8	31.8	41	13.9	29.3	0.40	0.8	0.31
44	31.47	38	286.9	82.0	31.6	42	14.0	30.3	0.41	0.8	0.31
45	31.50	38	287.8	82.2	31.7	42	14.0	29.9	0.41	0.8	0.31
		Average	287.6	82.2	31.7	41	13.9	29.5	0.45	0.8	0.36
		Std. Dev.	1.8	0.5	0.1	0	0.1	0.3	0.05	0.0	0.06
		Maximum	290.7	83.1	31.8	42	14.0	30.3	0.54	0.8	0.43
		Minimum	282.9	80.8	31.6	40	13.6	28.9	0.40	0.8	0.31

Total number of blows analyzed: 33

BL# Sensors

2-45 F1: [328NWJ2] 220.6 (1.00); F2: [328NWJ2] 220.6 (1.00); A1: [K2449] 340.0 (1.00);
A2: [K3258] 337.0 (1.00)

BL#	Comments
1	Start of test on 8/25/2017 at 1:21 PM
45	End of test on 8/25/2017 at 1:23 PM

Time Summary

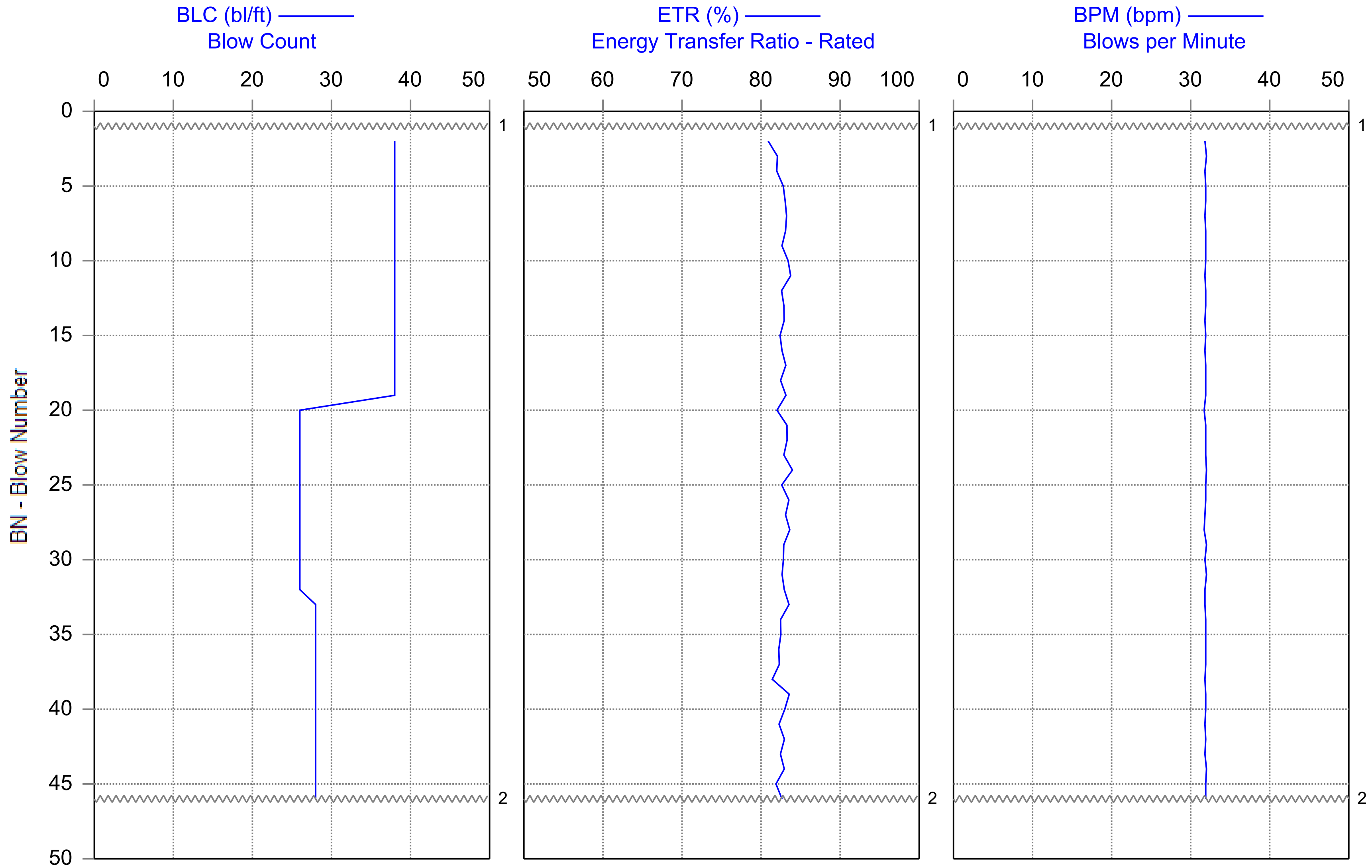
Drive 1 minute 23 seconds 1:21 PM - 1:23 PM BN 1 - 45

Pile Dynamics, Inc. - PDIPLOT2 Ver 2016.2.57.6 - Case Method & iCAP® Results

Printed: 25-September-2017

Test started: 25-August-2017

HOLT DRILLING, RIG 17 - 35.0 FT SAMPLE



1 - Start of test on 8/25/2017 at 1:31 PM

2 - End of test on 8/25/2017 at 1:33 PM

HOLT DRILLING, RIG 17 - 35.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

AR: 1.40 in² SP: 0.492 k/ft³
LE: 41.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35 []

EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
CSX: Max Measured Compr. Stress
RAT: SPT Length Ratio
DMX: Maximum Displacement
DFN: Final Displacement

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	RAT	DMX	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	[]	in	in
20	35.54	26	287.1	82.0	31.7	41	14.2	29.2	0.9	0.56	0.46
21	35.58	26	291.4	83.3	31.9	41	14.3	29.5	0.6	0.57	0.46
22	35.62	26	291.5	83.3	31.9	41	14.2	29.4	0.6	0.56	0.46
23	35.65	26	290.1	82.9	31.9	41	14.3	29.3	0.6	0.57	0.46
24	35.69	26	293.9	84.0	32.0	41	14.3	29.4	0.9	0.59	0.46
25	35.73	26	289.1	82.6	31.9	41	14.2	29.2	0.6	0.56	0.46
26	35.77	26	292.3	83.5	31.9	41	14.3	29.2	0.6	0.56	0.46
27	35.81	26	290.8	83.1	31.8	41	14.3	29.1	0.6	0.55	0.46
28	35.85	26	292.7	83.6	31.7	41	14.3	29.4	0.6	0.58	0.46
29	35.88	26	290.0	82.9	32.0	41	14.3	29.0	0.6	0.56	0.46
30	35.92	26	289.8	82.8	31.8	42	14.3	29.9	0.6	0.58	0.46
31	35.96	26	289.3	82.7	32.0	40	14.3	28.9	0.6	0.55	0.46
32	36.00	26	290.3	82.9	31.8	41	14.3	29.2	0.6	0.54	0.46
33	36.04	28	292.4	83.5	31.8	41	14.3	29.5	0.6	0.53	0.43
34	36.07	28	288.6	82.5	31.9	41	14.2	29.0	0.6	0.52	0.43
35	36.11	28	288.7	82.5	31.9	41	14.2	29.6	0.9	0.53	0.43
36	36.14	28	287.8	82.2	31.9	42	14.2	29.8	0.9	0.52	0.43
37	36.18	28	288.0	82.3	31.9	42	14.2	30.0	0.9	0.54	0.43
38	36.21	28	284.9	81.4	31.8	40	14.1	28.9	0.9	0.51	0.43
39	36.25	28	292.5	83.6	31.9	42	14.3	30.0	0.6	0.51	0.43
40	36.29	28	290.5	83.0	31.9	41	14.3	29.2	0.6	0.51	0.43
41	36.32	28	287.9	82.3	31.8	40	14.3	28.8	0.9	0.49	0.43
42	36.36	28	290.3	82.9	31.9	42	14.3	29.8	0.6	0.50	0.43
43	36.39	28	288.5	82.4	31.8	40	14.3	28.8	0.9	0.48	0.43
44	36.43	28	290.3	82.9	32.0	41	14.4	29.4	0.6	0.49	0.43
45	36.46	28	286.6	81.9	31.9	41	14.3	29.2	0.9	0.52	0.43
46	36.50	28	289.2	82.6	31.9	41	14.3	29.1	0.9	0.51	0.43
		Average	289.8	82.8	31.9	41	14.3	29.3	0.7	0.54	0.44
		Std. Dev.	2.0	0.6	0.1	0	0.1	0.3	0.1	0.03	0.02
		Maximum	293.9	84.0	32.0	42	14.4	30.0	0.9	0.59	0.46
		Minimum	284.9	81.4	31.7	40	14.1	28.8	0.6	0.48	0.43

Total number of blows analyzed: 27

BL# Sensors

2-46 F1: [328NWJ2] 220.6 (1.00); F2: [328NWJ2] 220.6 (1.00); A1: [K2449] 340.0 (1.00);
A2: [K3258] 337.0 (1.00)

BL# Comments

1 Start of test on 8/25/2017 at 1:31 PM
46 End of test on 8/25/2017 at 1:33 PM

HOLT DRILLING, RIG 17 - 35.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

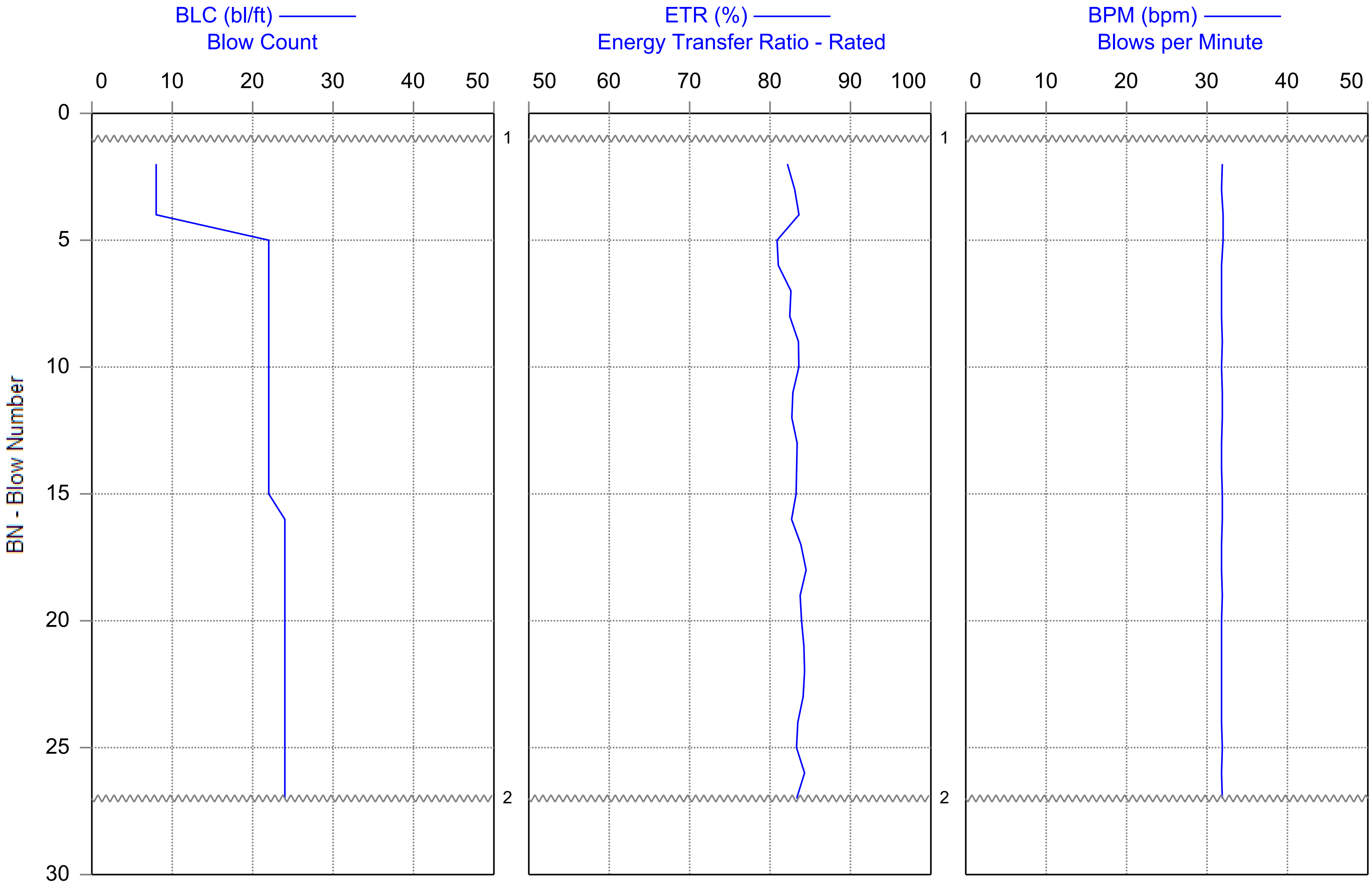
Time Summary

Drive 1 minute 24 seconds 1:31 PM - 1:33 PM BN 1 - 46

Pile Dynamics, Inc. - PDIPLOT2 Ver 2016.2.57.6 - Case Method & iCAP® Results

Printed: 25-September-2017 Test started: 25-August-2017

HOLT DRILLING, RIG 17 - 40.0 FT SAMPLE



1 - Start of test on 8/25/2017 at 1:42 PM

2 - End of test on 8/25/2017 at 1:42 PM

HOLT DRILLING, RIG 17 - 40.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

AR:	1.40 in²	SP:	0.492 k/ft³
LE:	46.00 ft	EM:	30,000 ksi
WS:	16,807.9 f/s	JC:	0.35 []

EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
CSX: Max Measured Compr. Stress
RAT: SPT Length Ratio
DMX: Maximum Displacement
DFN: Final Displacement

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	RAT	DMX	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	[]	in	in
5	40.55	22	283.1	80.9	32.0	42	14.4	29.9	0.4	0.69	0.54
6	40.59	22	283.6	81.0	31.8	42	14.4	29.7	0.4	0.66	0.54
7	40.64	22	289.1	82.6	31.8	42	14.4	29.9	0.4	0.65	0.54
8	40.68	22	288.6	82.4	31.8	42	14.4	30.3	0.4	0.64	0.54
9	40.73	22	292.3	83.5	31.9	42	14.5	30.3	0.4	0.61	0.54
10	40.77	22	292.5	83.6	31.8	43	14.5	30.5	0.4	0.60	0.54
11	40.82	22	289.9	82.8	31.9	42	14.3	30.3	0.4	0.60	0.54
12	40.86	22	289.5	82.7	31.9	42	14.3	30.2	0.4	0.58	0.54
13	40.91	22	291.8	83.4	31.8	43	14.4	30.5	0.4	0.59	0.54
14	40.95	22	291.5	83.3	31.8	43	14.3	30.4	0.9	0.58	0.54
15	41.00	22	291.3	83.2	31.9	42	14.3	30.2	0.9	0.59	0.54
16	41.04	24	289.4	82.7	31.9	42	14.1	30.1	0.9	0.55	0.50
17	41.08	24	293.4	83.8	31.8	43	14.4	30.4	0.4	0.56	0.50
18	41.13	24	295.7	84.5	31.8	43	14.4	30.5	0.9	0.56	0.50
19	41.17	24	293.1	83.7	31.9	43	14.4	30.4	0.4	0.54	0.50
20	41.21	24	293.7	83.9	31.8	43	14.4	30.5	0.9	0.54	0.50
21	41.25	24	294.7	84.2	31.8	43	14.4	30.5	0.4	0.53	0.50
22	41.29	24	295.0	84.3	31.8	43	14.4	30.5	0.4	0.56	0.50
23	41.33	24	294.4	84.1	31.8	42	14.4	30.3	0.4	0.52	0.50
24	41.38	24	292.0	83.4	31.8	43	14.4	30.4	0.7	0.53	0.50
25	41.42	24	291.5	83.3	31.9	42	14.2	30.1	0.4	0.54	0.50
26	41.46	24	295.0	84.3	31.8	42	14.4	30.3	0.4	0.56	0.50
27	41.50	24	291.6	83.3	31.9	42	14.4	30.2	0.4	0.53	0.50
		Average	291.4	83.3	31.8	42	14.4	30.3	0.5	0.58	0.52
		Std. Dev.	3.2	0.9	0.1	0	0.1	0.2	0.2	0.05	0.02
		Maximum	295.7	84.5	32.0	43	14.5	30.5	0.9	0.69	0.54
		Minimum	283.1	80.9	31.8	42	14.1	29.7	0.4	0.52	0.50

Total number of blows analyzed: 23

BL# Sensors

2-27 F1: [328NWJ2] 220.6 (1.00); F2: [328NWJ2] 220.6 (1.00); A1: [K2449] 340.0 (1.00); A2: [K3258] 337.0 (1.00)

BL# Comments

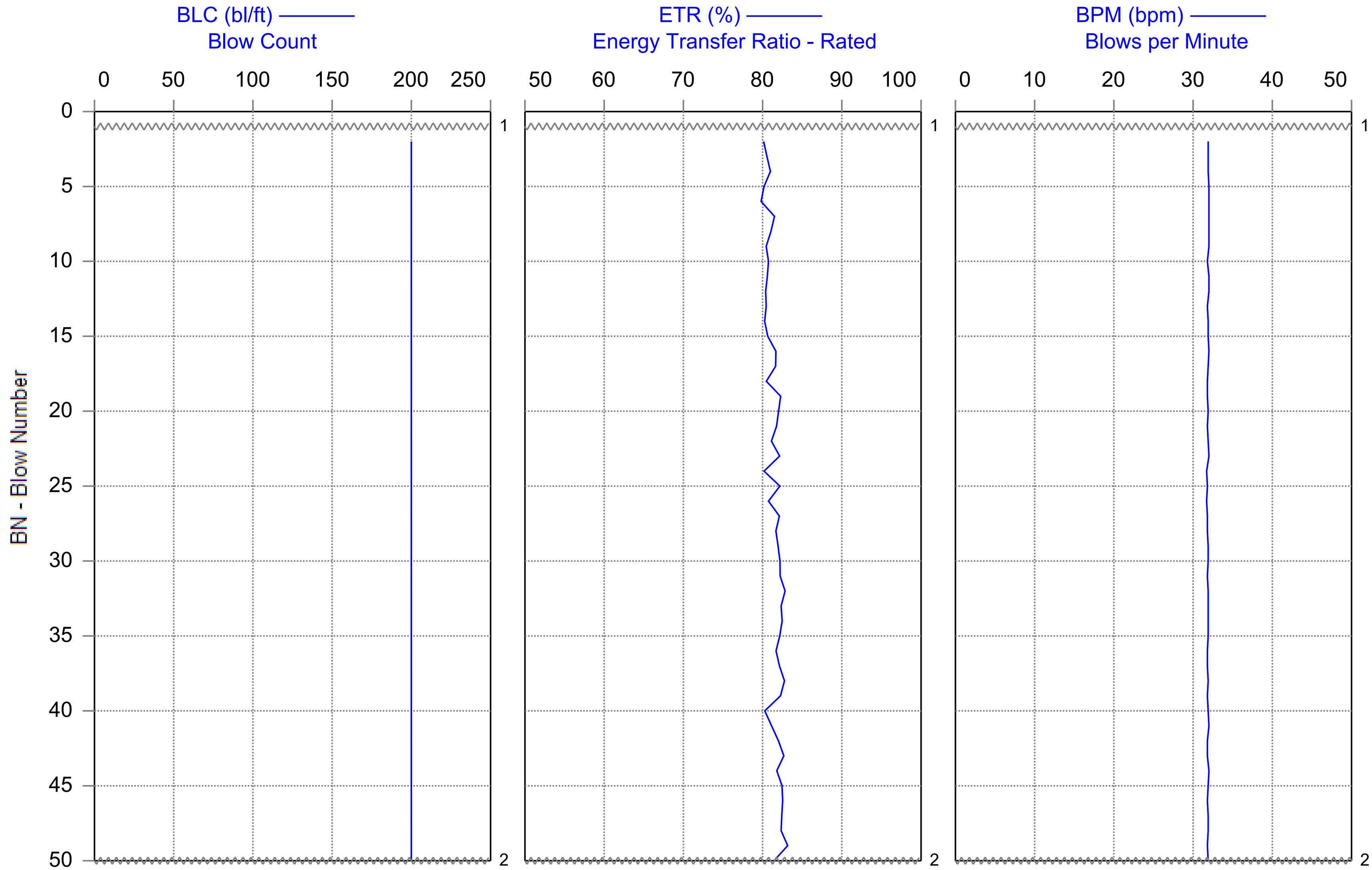
1 Start of test on 8/25/2017 at 1:42 PM
27 End of test on 8/25/2017 at 1:42 PM

Time Summary

Drive 48 seconds 1:42 PM - 1:42 PM BN 1 - 27

Pile Dynamics, Inc. - PDIPLOT2 Ver 2016.2.57.6 - Case Method & iCAP® Results
Printed: 25-September-2017 Test started: 25-August-2017

HOLT DRILLING, RIG 17 - 50.0 FT SAMPLE



1 - Start of test on 8/25/2017 at 1:59 PM
2 - End of test on 8/25/2017 at 2:00 PM

HOLT DRILLING, RIG 17 - 50.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

AR: 1.40 in² SP: 0.492 k/ft³
LE: 56.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35 []

EFV: Energy of FV
ETR: Energy Transfer Ratio - Rated
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
CSX: Max Measured Compr. Stress
RAT: SPT Length Ratio
DMX: Maximum Displacement
DFN: Final Displacement

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	RAT	DMX	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	[]	in	in
2	50.01	200	280.4	80.1	31.9	42	14.1	30.2	0.4	0.27	0.06
3	50.02	200	281.9	80.5	31.9	43	14.2	30.5	0.9	0.27	0.06
4	50.02	200	283.4	81.0	31.9	43	14.2	30.5	0.4	0.27	0.06
5	50.03	200	280.6	80.2	32.0	43	14.2	30.4	0.6	0.28	0.05
6	50.03	200	279.3	79.8	32.0	42	14.0	30.2	0.6	0.32	0.06
7	50.04	200	285.2	81.5	32.0	43	14.3	30.6	0.4	0.29	0.06
8	50.04	200	283.7	81.0	32.0	42	14.2	30.1	0.4	0.27	0.06
9	50.05	200	281.6	80.5	32.0	42	14.1	30.0	0.4	0.25	0.06
10	50.05	200	282.6	80.7	31.8	42	14.1	29.9	0.6	0.27	0.06
11	50.06	200	282.1	80.6	32.0	42	14.2	30.3	0.4	0.24	0.07
12	50.06	200	281.3	80.4	32.0	42	14.1	30.1	0.6	0.27	-0.03
13	50.07	200	281.6	80.4	31.8	42	14.1	30.2	0.4	0.25	0.06
14	50.07	200	280.9	80.3	31.9	42	14.1	30.0	0.4	0.23	0.06
15	50.08	200	282.2	80.6	31.9	42	14.1	30.0	0.4	0.22	0.06
16	50.08	200	285.8	81.7	32.0	42	14.2	30.0	0.7	0.23	0.06
17	50.09	200	285.7	81.6	31.9	42	14.2	30.2	0.7	0.22	0.06
18	50.09	200	281.6	80.5	31.8	42	14.0	29.8	0.7	0.22	0.06
19	50.10	200	287.9	82.3	31.8	42	14.1	30.0	0.7	0.23	0.06
20	50.10	200	287.0	82.0	31.9	42	14.1	30.0	0.7	0.23	0.06
21	50.11	200	286.1	81.7	31.8	42	14.0	30.1	0.4	0.23	0.06
22	50.11	200	283.9	81.1	31.9	42	14.0	29.9	0.4	0.23	0.06
23	50.12	200	287.5	82.1	32.0	42	14.0	30.0	0.7	0.23	0.06
24	50.12	200	280.6	80.2	31.7	41	13.7	29.5	0.7	0.23	0.06
25	50.13	200	287.6	82.2	31.8	42	14.0	29.9	0.4	0.23	0.06
26	50.13	200	282.6	80.7	31.7	41	13.8	29.5	0.7	0.23	0.06
27	50.14	200	287.4	82.1	31.8	42	13.9	30.0	0.7	0.23	0.06
28	50.14	200	285.9	81.7	31.8	42	13.9	29.9	0.7	0.23	0.06
29	50.15	200	286.8	82.0	31.9	42	14.0	29.9	0.7	0.23	0.06
30	50.15	200	287.6	82.2	31.9	42	14.0	29.8	0.7	0.23	0.06
31	50.16	200	287.7	82.2	31.8	42	14.1	29.8	0.7	0.25	0.06
32	50.16	200	289.9	82.8	31.9	42	14.0	29.9	0.7	0.27	0.06
33	50.17	200	288.1	82.3	31.9	42	14.0	29.7	0.7	0.25	0.06
34	50.17	200	288.6	82.5	31.9	42	14.1	29.8	0.7	0.25	0.06
35	50.18	200	287.5	82.2	31.9	42	13.9	29.9	0.7	0.25	0.06
36	50.18	200	285.9	81.7	31.8	41	14.2	29.4	0.4	0.26	0.06
37	50.19	200	287.4	82.1	31.8	40	14.2	28.8	0.5	0.26	0.06
38	50.19	200	289.6	82.8	31.9	42	14.3	29.7	0.4	0.25	0.06
39	50.20	200	287.9	82.2	31.8	42	14.2	29.8	0.4	0.25	0.06
40	50.20	200	280.9	80.3	31.9	41	13.9	29.5	0.7	0.25	0.06
41	50.21	200	284.0	81.1	32.0	42	14.1	29.8	0.6	0.25	0.06
42	50.21	200	287.0	82.0	31.8	42	14.2	30.2	0.4	0.25	0.06
43	50.22	200	289.3	82.7	31.8	43	14.2	30.5	0.4	0.25	0.06
44	50.22	200	286.2	81.8	32.0	43	14.1	30.4	0.6	0.25	0.06
45	50.23	200	288.6	82.4	31.9	43	14.3	30.4	0.4	0.25	0.06
46	50.23	200	288.8	82.5	31.8	43	14.2	30.4	0.4	0.25	0.06

HOLT DRILLING, RIG 17 - 50.0 FT SAMPLE RIG NO 17, MOBILE 140 LB SPT
OP: RMDT Date: 25-August-2017

BL#	Depth	BLC	EFV	ETR	BPM	FMX	VMX	CSX	RAT	DMX	DFN
	ft	bl/ft	k-ft	(%)	bpm	kips	f/s	ksi	[]	in	in
47	50.24	200	288.4	82.4	31.9	42	14.1	30.3	0.4	0.24	0.06
48	50.24	200	288.2	82.3	31.9	42	14.0	30.3	0.7	0.24	0.06
49	50.25	200	291.1	83.2	31.8	43	14.2	30.4	0.4	0.25	0.06
50	50.25	200	285.0	81.4	31.9	42	13.8	30.0	0.7	0.25	0.06
		Average	285.3	81.5	31.9	42	14.1	30.0	0.5	0.25	0.06
		Std. Dev.	3.1	0.9	0.1	0	0.1	0.3	0.2	0.02	0.01
		Maximum	291.1	83.2	32.0	43	14.3	30.6	0.9	0.32	0.07
		Minimum	279.3	79.8	31.7	40	13.7	28.8	0.4	0.22	-0.03

Total number of blows analyzed: 49

BL# Sensors

2-50 F1: [328NWJ2] 220.6 (1.00); F2: [328NWJ2] 220.6 (1.00); A1: [K2449] 340.0 (1.00); A2: [K3258] 337.0 (1.00)

BL# Comments

1 Start of test on 8/25/2017 at 1:59 PM
50 End of test on 8/25/2017 at 2:00 PM

Time Summary

Drive 1 minute 32 seconds 1:59 PM - 2:00 PM BN 1 - 50

Report 5
Holt TerraSonic CC150

May 9, 2013

Mr. Dale Abernathy
Holt Services, Inc.
13000 Lakeholme Road Sw
Lakewood, WA 98498

Re: Penetration Test Energy Measurements
Rig B2177GW, 140lb and 300 lb ram, NW-J, November 1, 2012
Landa Track Rig Model L-10-T, 140 lb ram, NW-J, April 17, 2013
Tera-Sonic CC-150, 140 lb ram, AW-J, April 19, 2013
King and Pierce County, Washington

RMDT Job No. 12F53

Dear Mr. Abernathy,

This letter presents energy transfer measurements made during Penetration Tests for the drill rigs referenced above. Robert Miner Dynamic Testing, Inc. (RMDT) made dynamic measurements with a Pile Driving Analyzer® as a hammer advanced the NW or AW rod during soil sampling.

The purpose of RMDT's testing was the measurement of energy transferred to the drill rods. Measurements were made on a sections of NW or AW gauge rod at the top of the drill rod. Strain gages and accelerometers on the rod were connected to a Pile Driving Analyzer® (PDA) which generally processed acceleration and strain measurements from each hammer blow and stored both the measurements and computed results. Measurements and data processing generally followed the ASTM D 4633-10 standard. Energy transfer past the gage location, EFV, was computed by the PDA using force and velocity records as follows:

$$EFV = \int_a^b F(t)\ v(t)\ dt$$

The value "a" corresponds to the start of the record which is when the energy transfer begins and *"b"* is the time at which energy transferred to the rod reaches a maximum value. Appendix A contains more information on our measurement equipment and methods of analysis. The EFV energy calculation is identical to the EMX energy result discussed in Appendix A. The EFV and EMX values apply to the sensor location near the top of the rod.

TEST DETAILS

Rig B2177GW, November 1, 2012

Testing occurred on November 1, 2012. Boring B59 was advanced at the Holt Services Yard located in Lakewood. Washington. The drill rig was a Model B59 manufactured by Mobile Drill International (Mobile). The automatic hammer in use during our testing was also manufactured

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Location: 2288 Colchester Dr. E., Ste A, Manchester, WA, 98353 **Fax:** 360-871-5483

by Mobile and was reported to use either a 140 lb or a 300 lb ram. A 140 lb and 300 lb ram were used to advance a standard split spoon and a 3" O.D. split spoon sampler, respectively. NW size rod was used during all testing.

Track Rig Model L-10-T, April 17, 2013

Testing occurred on April 17, 2013. Boring E330-B28 was advanced along the proposed Sound Transit East Link Lightrail Line near 116th Ave NE and NE 8th St in Bellevue, Washington. The drill rig was a track-mounted Landa Drilling Services, Inc. Limited Access Rig (SN:130115). The automatic hammer in use during our testing was reported to use a 140 lb ram to advance a standard split spoon sampler. NW size rod was used during all testing

Terra-Sonic CC150 Track Rig, April 19, 2013

Testing occurred on April 19, 2013. Boring E340-B12 was advanced along the proposed Sound Transit East Link Lightrail Line near 124th Ave NE and NE 14th St in Bellevue, Washington. The drill rig was a track-mounted Terra-Sonic Rig. The automatic hammer in use during our testing was a Mobile self compensating autohammer and was reported to use a 140 lb ram to advance a standard split spoon sampler. AW size rod was used during all testing.

RESULTS

Summaries of the results for tests conducted at each of the three test sites (and ram weights) are given in Tables 1 through 4. The tabulated results include the starting sample depth, the penetration resistance, the number of hammers blows in our data set, measured energy transfer, EFV, the computed transfer efficiency, ETR, and the hammer blow rate, BPM. Appendix B contains detailed numeric results for each individual test.

Energy measurements must be divided by the theoretical free fall energy of the hammer to obtain an efficiency. A 140 lb ram raised 30 inches above an impact surface has 350 lb-ft of potential energy. A 300 lb ram raised 30 inches above an impact surface has 750 lb-ft of potential energy. Thus, the transfer energy results for sampling with the 140 and 300 lb rams may be divided by 350 and 750 lb-ft, respectively, to yield the ratio of the delivered energy to the nominal potential energy. This efficiency ratio, ETR, is given for each sample interval as a percent efficiency.

Rig B2177GW, November 1, 2012

Five sample returns were monitored while a 140 lb ram and standard split spoon sampler were in use. The overall average ETR was 98 percent and the average hammer blow rate was 22 blows per minute.

Table 1. Summary of Test Details and Results for Rig B2177GW using a 140-lb ram and Split Spoon Sampler, November 1, 2012

Sample Name and Start Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
20 ft	7/1 ft	7	300	86	24
35 ft	6/1 ft	6	354	101	21
40 ft	4/1 ft	4	353	101	22
55 ft	5/1 ft	5	354	101	22
65 ft	19/1 ft	19	356	102	22
		Average:	**343**	**98**	**22**

For this drilling rig on November 1, 2012 five sample intervals were monitored while a 300 lb ram and a 3" O.D. split spoon sampler were used. For the 300 lb ram the average ETR values within the sample intervals ranged from 99 to 103 percent. The overall average ETR was 101 percent and the average hammer blow rate was 23 blows per minute.

Table 2. Summary of Test Details and Results for Rig B2177GW using a 300-lb ram and 3"O.D. Sampler, November 1, 2012

Sample Name and Start Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
25 ft	12/1 ft	12	739	99	25
30 ft	6/1 ft	6	738	98	24
45 ft	3/1 ft	3	769	103	21
50 ft	3/1 ft	3	770	103	23
60 ft	3/1 ft	3	759	101	20
		Average:	**755**	**101**	**23**

Track Rig Model L-10-T, April 17, 2013

Six sample returns were monitored while the 140 lb ram and standard split spoon sampler were in use. For the 140 lb ram the average ETR values within the sample intervals ranged from 83 to 90 percent. The overall average ETR value was 87 percent. The hammer strike rate was reduced after Sample 50 ft was recorded to determine if the hammer strike rate (BPM) influenced the recorded transfer energy (EFV). Test results reported only modest variations to the calculated EFV at hammer strike rates between 24 and 49 BPM.

Table 3. Summary of Test Details and Results for Rig L-10-T using a 140-lb ram and Standard Split Spoon Sampler, April 17, 2013

Sample Name and Start Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
35 ft	50/6 in	49	296	85	48
40 ft	50/6 in	50	307	88	46
45 ft	75/1 ft	75	308	88	49
50 ft	66/1 ft	66	315	90	49
55 ft	50/4 in	40	292	83	24
60 ft	50/6 in	50	311	89	25
		Average:	**305**	**87**	**40**

Terra-Sonic CC150 Track Rig

Three sample returns were monitored while the 140 lb ram and standard split spoon sampler were in use before artesian pressures forced drilling to halt for the day. The overall average ETR and hammer blow rate was 95 percent and 46 blows per minute, respectively.

Table 4. Summary of Test Details and Results for Terra-Sonic CC150 Track Rig using a 140-lb ram and Standard Split Spoon Sampler, April 19, 2013

Sample Name and Start Depth	Penetration Resistance (Blow/Set)	Number of Blows in Data Set	Average Transfer Energy EFV (lb-ft)	Average Transfer Efficiency ETR (percent)	Average Hammer Blow Rate BPM (blow/min)
20 ft	30/1 ft	30	339	97	44
30 ft	50/4 in	50	325	93	47
45 ft	50/6 in	44	338	97	48
		Average:	**334**	**95**	**46**

It was a pleasure to assist you and to participate on this project with the staff of Holt Services, Inc. Please do not hesitate to contact us if you or your client have any questions about this report.

Sincerely,

Andrew Banas

Andrew Banas
Staff Engineer
Robert Miner Dynamic Testing, Inc.

Robert J. Miner

Robert Miner
President

Appendix B

Summary of Case Method Field Results

APPENDIX A
AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

BACKGROUND

Modern procedures of design and construction control require verification of bearing capacity and integrity of deep foundations during preconstruction test programs and also production installation. Dynamic pile testing methods meet this need economically and reliably, and therefore, form an important part of a quality assurance program when deep foundations are executed. Several dynamic pile testing methods exist; they have different benefits and limitations and different requirements for proper execution.

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 (such as that of a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. The method is therefore 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 an evaluation of various quantities based on closed form solutions of the wave equation, a partial differential equation describing the motion of a rod under the effect of an impact. Conveniently, measurements and analyses are done by a single piece of equipment: the Pile Driving Analyzer® (PDA). However, for bearing capacity evaluations an important additional method is CAPWAP® which performs a much more rigorous analysis of the dynamic records than the simpler Case Method.

A related analysis method is the “Wave Equation Analysis” which calculates a relationship between bearing capacity and pile stress and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data.

The following description deals primarily with the Case Method or “High Strain Test” Method of pile testing, however, for the sake of completeness, the “Low Strain Test” performed with the Pile Integrity Test™ (PIT), mainly for pile integrity evaluation, will also be described.

RESULTS FROM DYNAMIC TESTING

There are two main objectives of high strain dynamic pile testing:

- *Dynamic Pile Monitoring* and
- *Dynamic Load Testing*.

Dynamic pile monitoring is conducted during the installation of impact driven piles to achieve a safe and economical pile installation. Dynamic load testing, on the other hand, has as its primary goal the assessment of pile bearing capacity. It is applicable to both cast *insitu* piles or drilled shafts and impact driven piles during restrike.

Dynamic Pile Monitoring

During pile installation, the sensors attached to the pile measure pile top force and velocity. A PDA conditions and processes these signals and calculates or evaluates:

- <u>Bearing capacity</u> at the time of testing, including an assessment of shaft resistance development and driving resistance. This information supports formulation of a driving criterion.

- <u>Dynamic pile stresses</u>, axial and averaged over the pile cross section, both tensile and compressive, during pile driving to limit the potential of damage either near the pile top or along its length. Bending stresses can be evaluated at the point of sensor attachment.

- <u>Pile integrity</u> assessment by the PDA is based on the recognition of certain wave reflections from along the pile. If detected early enough, a pile may be saved from complete destruction. On the other hand, once damage is recognized measures can be taken to prevent reoccurrence.

- <u>Hammer performance</u> parameters including the energy transferred to the pile, the hammer speed in blows per minute and the stroke of open ended diesel hammers.

Dynamic Pile Load Testing

Bearing capacity testing of either driven piles or drilled shafts applies the same basic measurement approach of dynamic pile monitoring. However, the test is done independent of the pile installation process and therefore a pile driving hammer or other dynamic loading device may not be available. If a special ram has to be mobilized then its weight should be between 0.8 and 2% of the test load (e.g. between 4 and 10 tons for a 500 ton test load) to assure sufficient soil resistance activation.

For a successful test, it most important that the test is conducted after a sufficient waiting time following pile installation for soil properties approaching their long term condition or concrete to properly set. During testing, PDA results of pile/shaft stresses and transferred energy are used to maintain safe stresses and assure sufficient resistance activation. For safe and sufficient testing of drilled shafts, ram energies are often increased from blow to blow until the test capacity has been activated. On the other hand, restrike tests on driven piles may require a warm hammer so that the very first blow produces a complete resistance activation. Data must be evaluated by CAPWAP for bearing capacity.

After the dynamic load test has been conducted with sufficient energy and safe stresses, the CAPWAP analysis provides the following results:

- Bearing capacity i.e. the mobilized capacity present at the time of testing

- Resistance distribution including shaft resistance and end bearing components

- Stresses in pile or shaft calculated for both the static load application and the dynamic test. These stresses are averages over the cross section and do not include bending effects or nonuniform contact stresses, e.g. when the pile toe is on uneven rock.

- Shaft impedance vs depth; this is an estimate of the shaft shape if it differs substantially from the planned profile

- Dynamic soil parameters for shaft and toe, i.e. damping factors and quakes (related to the dynamic stiffness of the resistance at the pile/soil interface.)

MEASUREMENTS

PDA

The basis for the results calculated by the PDA are pile top strain and acceleration measurements which are converted to force and velocity records, respectively. The PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. Using closed form Case Method solutions, based on the one-dimensional linear wave equation, the PDA calculates the results described in the analytical solutions section below.

HPA

The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. For this unit to be applicable, the ram must be visible. The impact velocity results can be automatically processed with a PC or recorded on a strip chart.

Saximeter™

For open end diesel hammers, the time between two impacts indicates the magnitude of the ram fall height or stroke. This information is not only measured and calculated by the PDA but also by the convenient, hand-held Saximeter.

PIT

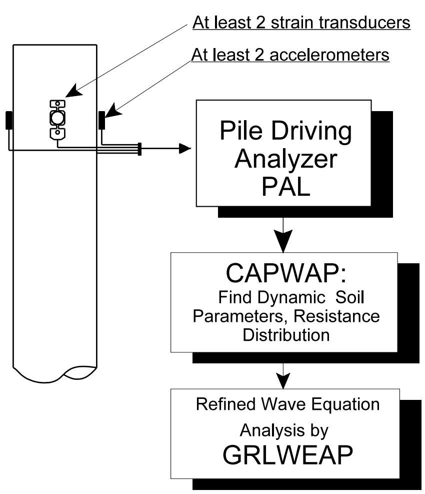
The Pile Integrity Tester™ (PIT) can be used to evaluate defects in concrete piles or shafts which may have occurred during driving or casting. Also timber piles of limited length can be tested in that manner. This so-called "Low Strain Method" or “Pulse-Echo Method” of integrity testing requires only the measurement of acceleration at the pile top. The stress wave producing impact is then generated by a small hand-held hammer and the records interpreted in the time domain. PIT also supports the so-called “Transient Response Method” which requires the additional measurement of the hammer force and an analysis in the frequency domain. This method may also be used to evaluate the unknown length of deep foundations under existing structures.

ANALYTICAL SOLUTIONS
BEARING CAPACITY

Wave Equation

GRL has written the GRLWEAP™ program which calculates a relationship between bearing capacity, pile stress and blow count. This relationship is often called the "bearing graph." Once the blow count is known from pile installation logs, the bearing graph yields the bearing capacity. This approach requires no measurements and therefore can be performed during the design stage of a project, for example for the selection of hammer, cushion and pile size.

After dynamic pile monitoring and/or dynamic load testing has been performed, the "Refined Wave Equation Analysis" or RWEA (see schematic below) is often performed by inputting the PDA and CAPWAP calculated parameters. Then the bearing graph from the RWEA is the basis for a safe and sufficient driving criteria.



Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil resistance is

$$R(t) = ½\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

t	=	a point in time after impact
t_2	=	time t + 2L/c
L	=	pile length below gages
c	=	$(E/\rho)^{½}$ is the speed of the stress wave
ρ	=	pile mass density
Z	=	EA/c is the pile impedance
E	=	elastic modulus of the pile (ρc^2)
A	=	pile cross sectional area

The total soil resistance consists of a dynamic (R_d) and a static (R_s) component. The static component is therefore

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2.

There are a number of ways in which Eq. 1 through 3 can be evaluated. Most commonly, t_2 is set to that time at which the static resistance becomes maximum. The result is the so-called **RMX** capacity. Damping factors for RMX typically range between 0.5 for coarse grained materials to 1.0 for clays. The **RSP** capacity (this method is most commonly referred to in the literature, yet it is not very frequently used) requires damping factors between 0.1 for sand and 1.0 for clay. Another capacity, **RA2**, determines the capacity at a time when the pile is essentially at rest and thus damping is small; RA2

therefore requires no damping parameter. In any event, the proper Case Method and its associated damping parameter is most conveniently found after a CAPWAP analysis has been performed.

The static resistance calculated by Case Method or CAPWAP is the mobilized resistance at the time of testing. Consideration therefore has to be given to soil setup or relaxation effects and whether or not a sufficient set has been achieved under the test loading that would correspond to a full activation of the ultimate soil resistance.

The PDA also calculates an estimate of shaft resistance as the difference between force and velocity times impedance at the time immediately prior to the return of the stress wave from the pile toe. This shaft resistance is not reduced by damping effects and is therefore called the total shaft resistance **SFT**. A correction for damping effects produces the static shaft resistance estimate, **SFR**.

The Case Method solution is simple enough to be evaluated "in real time," i.e. between hammer blows, using the PDA. It is therefore possible to calculate all relevant results for all hammer blows and plot these results as a function of depth or blow number. This is done in the PDAPLOT program.

CAPWAP

The CAse Pile Wave Analysis Program combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the shaft resistance, end bearing, damping factors and soil stiffnesses. The method iteratively calculates a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

During pile monitoring, it is important that compressive stress maxima at pile top and toe and tensile stress maxima somewhere along the pile be calculated for each hammer blow.

At the pile top (location of sensors) both the maximum compression stress, **CSX**, and the maximum stress from individual strain transducers, **CSI**, are directly obtained from the measurements. Note that CSI is greater than or equal to CSX and the difference between CSI and CSX is a measure of bending in the plane of the strain transducers. Note also that all stresses calculated for locations below the sensors are averaged over the pile cross section and therefore do not include components from either bending or eccentric soil resistance effects.

The PDA calculates the compressive stress at the pile bottom, **CSB**, assuming (a) a uniform pile and (b) that the pile toe force is the maximum value of the total resistance R(t) minus the total shaft resistance, SFT. Again, for this stress estimation uniform resistance force are assumed (e.g. not a sloping rock.)

For concrete piles, the maximum tension stress, **TSX**, is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by finding the maximum tension wave (either traveling upward, W_U, or downward, W_d) and reducing it by the minimum compressive wave traveling in opposite direction.

$$W_u = \tfrac{1}{2}[F(t) - Zv(t)] \qquad (4)$$

$$W_d = \tfrac{1}{2}[F(t) + Zv(t)] \qquad (5)$$

CAPWAP also calculates tensile and compressive stresses along the pile and, in general, more accurately than the PDA. In fact, for non-uniform piles or piles with joints, cracks or other discontinuities, the closed form solutions from the PDA may be in error.

PILE INTEGRITY

High Strain Tests (PDA)

Stress waves in a pile are reflected wherever the pile impedance, $Z = EA/c = \rho cA = A\,\sqrt{(E\,\rho)}$, changes. Therefore, the pile impedance is a measure of the quality of the pile material (E, ρ, c) and the size of its cross section (A). The reflected waves arrive at the pile top at a time which is greater the farther away from the pile top the reflection occurs. The

magnitude of the change of the upward traveling wave (calculated from the measured force and velocity, Eq. 4) indicates the extent of the cross sectional change. Thus, with β_i (**BTA**) being a relative integrity factor which is unity for no impedance change and zero for the pile end, the following is calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \quad (6)$$

with

$$\alpha_i = \tfrac{1}{2}(W_{UR} - W_{UD})/(W_{Di} - W_{UR}) \quad (7)$$

where

- W_{UR} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.
- W_{UD} is the upwards traveling wave due to the damage reflection.
- W_{Di} is the maximum downward traveling wave due to impact.

It can be shown that this formulation is quite accurate as long as individual reflections from different pile impedance changes have no overlapping effects on the stress wave reflections.

Without rigorous derivation, it has been proposed to consider as slight damage when β is above 0.8 and a serious damage when β is less than 0.6.

Low Strain Tests (PIT)

The pile top is struck with a held hand hammer and the resulting pile top velocity is measured, displayed and interpreted for signs of wave reflections. In general, a comparison of the reflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the reflection. PIT records can also be interpreted by the β-Method. However, low strain tests do not activate much resistance which simplifies Eq. 7 since W_{UR} is then equal to zero.

For drilled shafts and PIT records that clearly show a toe reflection, an approximate shaft profile can be calculated from low strain records using the PITSTOP program's PROFILE routine.

HAMMER PERFORMANCE

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

$$E(t) = \int_o^t F(t)v(t)\, dt \quad (8a)$$

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

$$e_T = EMX/E_R \quad (8b)$$

where

E_R is the manufacturer's rated energy value.

Both Saximeter and PDA calculate the stroke (**STK**) of an open end diesel hammer using

$$STK = (g/8)\, T_B^2 - h_L \quad (9)$$

where

- g is the earth's gravitational acceleration,
- T_B is the time between two hammer blows,
- h_L is a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

DETERMINATION OF WAVE SPEED

An important facet of dynamic pile testing is an assessment of pile material properties. Since in general force is determined from strain by multiplication with elastic modulus, E, and cross sectional area, A, the dynamic elastic modulus has to be determined for pile materials other than steel. In general, the records measured by the PDA clearly indicate a pile toe reflection as long as pile penetration per blow is greater than 1 mm or .04 inches. The time between the onset of the force and velocity records at impact and the onset of the reflection from the toe (usually apparent by a local maximum of the wave up curve) is the so-called wave travel time, T. Dividing 2L (L is here the length of the pile below sensors) by T leads to the stress wave speed in the pile:

$$c = 2L/T \quad (10)$$

The elastic modulus of the pile material is related to the wave speed according to the linear elastic wave equation theory by

$$E = c^2 \rho \qquad (11)$$

Since the mass density of the pile material, ρ, is usually well known (an exception is timber for which samples should be weighed), the elastic modulus is easily found from the wave speed. Note, however, that this is a dynamic modulus which is generally higher than the static one and that the wave speed depends to some degree on the strain level of the stress wave. For example, experience shows that the wave speed from PIT is roughly 5% higher than the wave speed observed during a high strain test.

Other Notes:

- If the pile material is nonuniform then the wave speed c, according to Eq. 10, is an average wave speed and does not necessarily reflect the pile material properties of the location where the strain sensors are attached to the pile top. For example, pile driving often causes fine tension cracks some distance below the top of concrete piles. Then the average c is slower than that at the pile top. It is therefore recommended to determine E in the beginning of pile driving and not adjust it when the average c changes.

- If the pile has such a high resistance that there is no clear indication of a toe reflection then the wave speed of the pile material must be determined either by assumption or by taking a sample of the concrete and measuring its wave speed in a simple free column test. Another possibility is to use the proportionality relationship, discussed under "DATA QUALITY CHECKS" to find c as the ratio between the measured velocity and measured strain.

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 PDA or PIT 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 certain relationships.

Proportionality

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 pile, force and velocity measured at the pile top are proportional

$$F = v\,Z = v\,(EA/c) \qquad (12a)$$

This relationship can also be expressed in terms of stress

$$\sigma = v\,(E/c) \qquad (12b)$$

or strain

$$\epsilon = v / c \qquad (12c)$$

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.

Measurements are always taken at opposite sides of the pile as a means of calculating the average force and velocity in the pile. The velocity on the two sides of the pile is very similar even when high bending exists. Thus, an independent check of the velocity measurements is easy and simple.

Strain measurements may differ greatly between the two sides of the pile when bending exists. It is even possible that tension is measured on one side while very high compression exists on the other side of the pile. In extreme cases, bending might be so high that it leads to a nonlinear stress distribution. The averaging of the two strain signals does then not lead to the average pile force and proportionality will not be achieved.

When testing drilled shafts, measurements of strain may also be affected by local concrete quality variations. It is then often necessary to use four strain transducers spaced at 90 degrees around the pile for an improved strain data quality. The use of four transducers is also recommended for large pile

diameters, particularly when it is difficult to mount the sensors at least two pile widths or diameters below the pile top.

LIMITATIONS, ADDITIONAL CONSIDERATIONS

Mobilization of capacity

Estimates of pile capacity from dynamic testing indicate the **mobilized pile capacity at the time of testing**. At very high blow counts (low set per blow), dynamic test methods tend to produce lower bound capacity estimates as not all resistance (particularly at and near the toe) is fully activated.

Time dependent soil resistance effects

Static pile capacity from dynamic method calculations provide an estimate of the axial pile capacity. Increases and decreases in the pile capacity with time typically occur (soil setup/relaxation). Therefore, **restrike testing usually yields a better indication of long term pile capacity than a test at the end of pile driving**. Often a wait period of one or two days between end of driving and restrike is satisfactory for a realistic prediction of pile capacity but this waiting time depends, among other factors, on the permeability of the soil.

(A) Soil setup

Because excess positive pore pressures often develop during pile driving in fine grained soil (clays, silts or even fine sands), the capacity of a pile at the time of driving may often be less than the long term pile capacity. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and thus the pile capacity at the time of driving. As these pore pressures dissipate, the soil resistance acting on the pile increases as does the axial pile capacity. This phenomena is routinely called soil setup or soil freeze.

(*B) Relaxation*

Relaxation (capacity reduction with time) has been observed for piles driven into weathered shale, and may take several days to fully develop. Pile capacity estimates based upon initial driving or short term restrike tests can significantly overpredict long term pile capacity. Therefore, piles driven into shale should be tested after a minimum one week wait either statically or dynamically (with particular emphasis than on the first few blows). Relaxation has also been observed for displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe. Again, restrike tests should be used, with great emphasis on early blows.

Capacity results for open pile profiles

Larger diameter open ended pipe piles (or H-piles which do not bear on rock) may behave differently under dynamic and static loading conditions. Under dynamic loads the soil inside the pile or between its flanges may slip and produce internal friction while under static loads the plug may move with the pile, thereby creating end bearing over the full pile cross section. As a result both friction and end bearing components may be different under static and dynamic conditions.

CAPWAP Analysis Results

A portion of the soil resistance calculated on an individual soil segment in a CAPWAP analysis can usually be shifted up or down the shaft one soil segment without significantly altering the match quality. Therefore, use of the CAPWAP resistance distribution for uplift, downdrag, scour, or other geotechnical considerations should be made with an understanding of these analysis limitations.

Stresses

PDA and CAPWAP calculated stresses are average values over the cross section. Additional allowance has to be made for bending or non-uniform contact stresses. To prevent damage it is therefore important to maintain good hammer-pile alignment and to protect the pile toes using appropriate devices or an increased cross sectional area.

In the United States is has become generally acceptable to limit the dynamic installation stresses of driven piles to the following levels:

90% of yield strength for steel piles

85% of the concrete compressive strength - after subtraction of the effective prestress - for concrete piles in compression

100% of effective prestress plus ½ of the concrete's tension strength for prestressed piles in tension

70% of the reinforcement strength for regularly reinforced concrete piles in tension

300% of the static design allowable stress for timber

Note that the dynamic stresses may either be directly measured at the pile top by the PDA or calculated by the PDA for other locations along the pile based on the pile top measurements.

Additional design considerations

Numerous factors have to be considered in pile foundation design. Some of these considerations include

- additional pile loading from downdrag or negative skin friction,
- lateral and uplift loading requirements
- effective stress changes (due to changes in water table, excavations, fills or other changes in overburden),
- long term settlements in general and settlement from underlying weaker layers and/or pile group effects,

These factors have not been evaluated by GRL and have not been considered in the interpretation of the dynamic testing results. The foundation designer should determine if these or any other considerations are applicable to this project and the foundation design.

Wave equation analysis results

The results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Although attempts have been made to base the analysis on the best available information, actual field conditions may vary and therefore stresses and blow counts may differ from the predictions reported. Capacity predictions derived from wave equation analyses should use restrike information. However, because of the uncertainties associated with restrike blow counts and restrike hammer energies, correlations of such results with static test capacities with have often displayed considerable scatter.

As for PDA and CAPWAP, the theory on which GRLWEAP is based is the one-dimensional wave equation. For that reason, stress predictions by the wave equation analysis can only be averages over the pile cross section. Thus, bending stresses or stress concentrations due to non-uniform impact or uneven soil or rock resistance are not considered in these results. Stress maxima calculated by the wave equation are usually subjected to the same limits as those measured directly or calculated from measurements by the PDA.

Appendix B

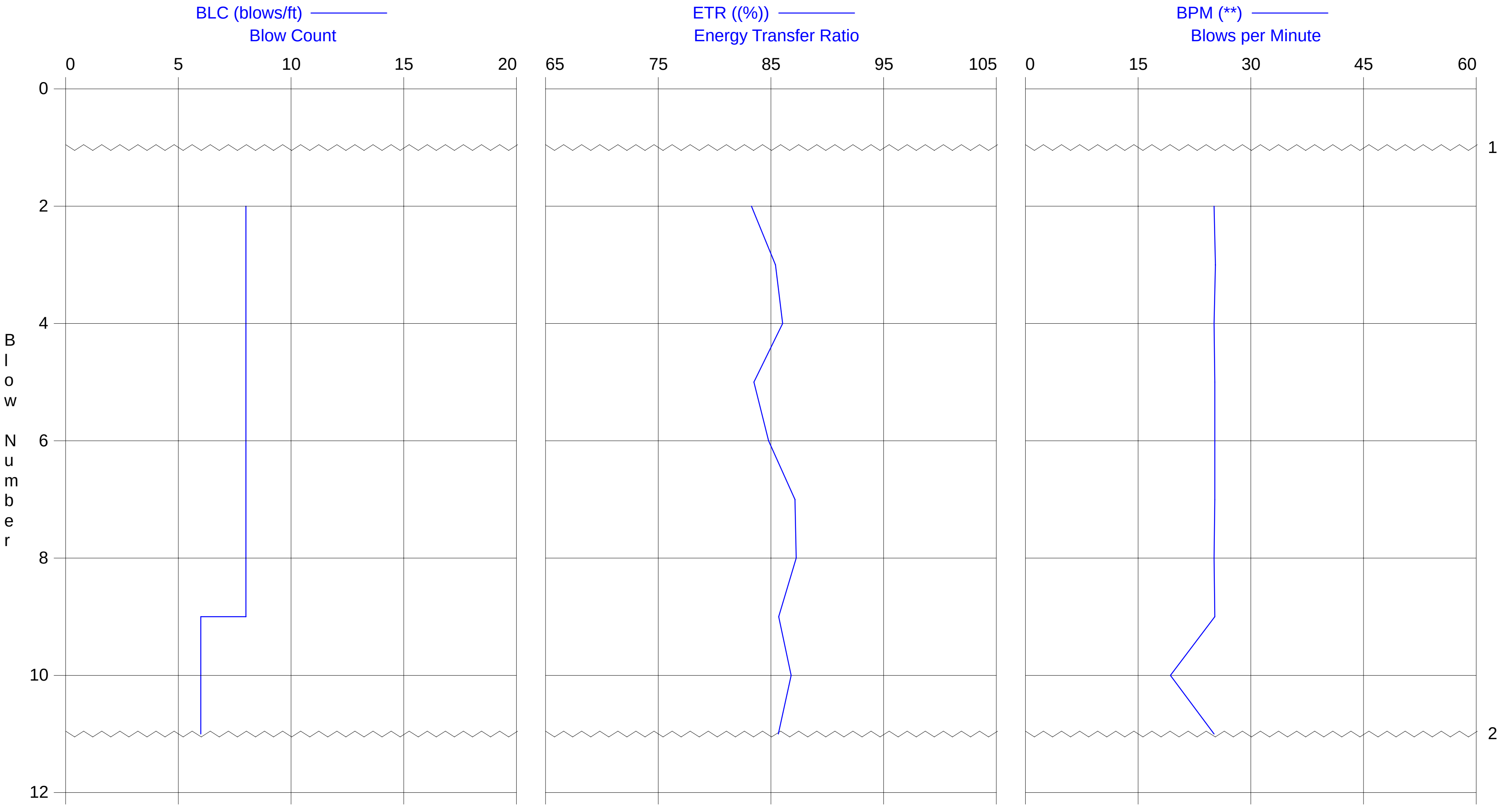
Summary of Case Method Field Results

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 1-Nov-2012

HOLT SERVICES - 20 FT, B59 -NWJ



1 - Start of test on 11/1/2012 at 9:18:43 AM

2 - End of test on 11/1/2012 at 9:19:08 AM

HOLT SERVICES - 20 FT, B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 23.40 ft EM: 29,869 ksi
WS: 16,771.1 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
5	20.63	8	29.3	27.9	83.5	0.292	25.2	40	15.3	1.1
6	20.75	8	29.2	28.0	84.8	0.297	25.2	40	16.6	1.1
7	20.88	8	28.4	27.4	87.1	0.305	25.2	39	16.2	1.1
8	21.00	8	30.2	28.4	87.2	0.305	25.1	41	16.7	1.1
9	21.17	6	30.4	28.4	85.7	0.300	25.2	41	16.3	1.1
10	21.33	6	28.1	27.5	86.8	0.304	19.3	39	16.8	1.1
11	21.50	6	29.7	28.2	85.7	0.300	25.1	40	15.8	1.1
		Average	29.3	28.0	85.8	0.300	24.3	40	16.2	1.1
		Std. Dev.	0.8	0.4	1.3	0.004	2.1	1	0.5	0.0
		Maximum	30.4	28.4	87.2	0.305	25.2	41	16.8	1.1
		Minimum	28.1	27.4	83.5	0.292	19.3	39	15.3	1.1

Total number of blows analyzed: 7

BL#	depth (ft)	Comments
1	20.13	Start of test on 11/1/2012 at 9:18:43 AM
11	21.50	End of test on 11/1/2012 at 9:19:08 AM

Time Summary

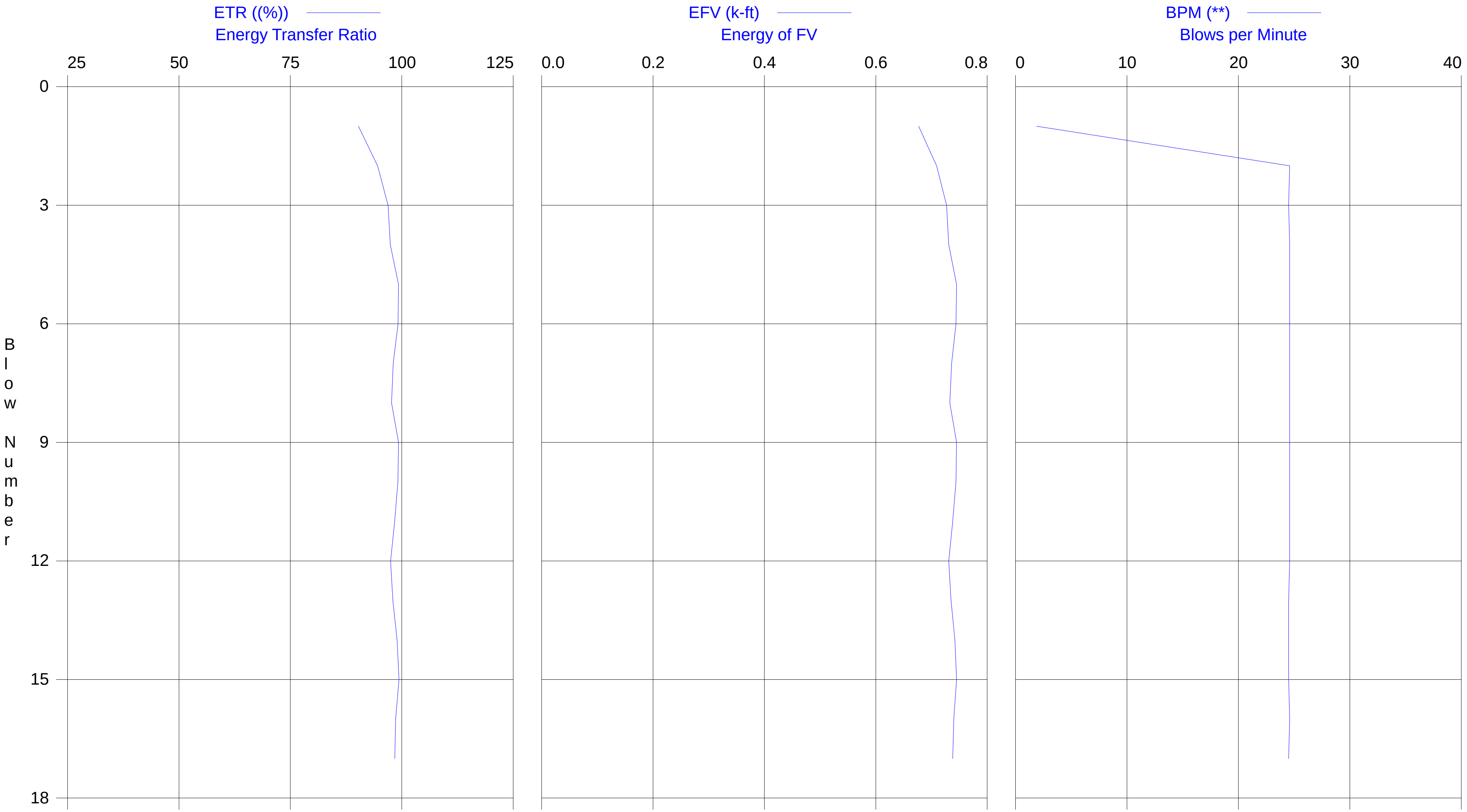
Drive 25 seconds 9:18:43 AM - 9:19:08 AM (11/1/2012) BN 1 - 11

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 25 FT B59 ·NWJ



HOLT SERVICES - 25 FT B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 30.40 ft EM: 29,869 ksi
WS: 16,771.1 f/s JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
6	10	99.2	0.744	24.6	43	16.2	2,531	25	0.813	1.1
7	10	98.1	0.736	24.6	43	16.4	2,487	26	0.806	1.1
8	10	97.7	0.733	24.6	44	16.4	2,541	27	0.808	1.1
9	10	99.3	0.745	24.6	43	16.3	2,388	26	0.812	1.1
10	10	99.1	0.744	24.6	43	16.3	2,360	24	0.808	1.1
11	14	98.4	0.738	24.6	43	16.3	2,395	26	0.807	1.1
12	14	97.5	0.731	24.6	43	16.4	2,434	25	0.803	1.1
13	14	98.0	0.735	24.5	43	16.7	2,727	25	0.806	1.1
14	14	98.9	0.742	24.5	43	16.6	2,624	26	0.806	1.1
15	14	99.4	0.745	24.5	43	16.7	2,658	25	0.810	1.1
16	14	98.6	0.740	24.6	43	16.6	2,646	26	0.806	1.1
17	14	98.4	0.738	24.5	42	16.5	2,606	26	0.802	1.1
Average		98.5	0.739	24.6	43	16.4	2,533	26	0.807	1.1
Maximum		99.4	0.745	24.6	44	16.7	2,727	27	0.813	1.1
@ Blow#		15	9	6	8	15	13	8	6	10

Total number of blows analyzed: 12

Time Summary

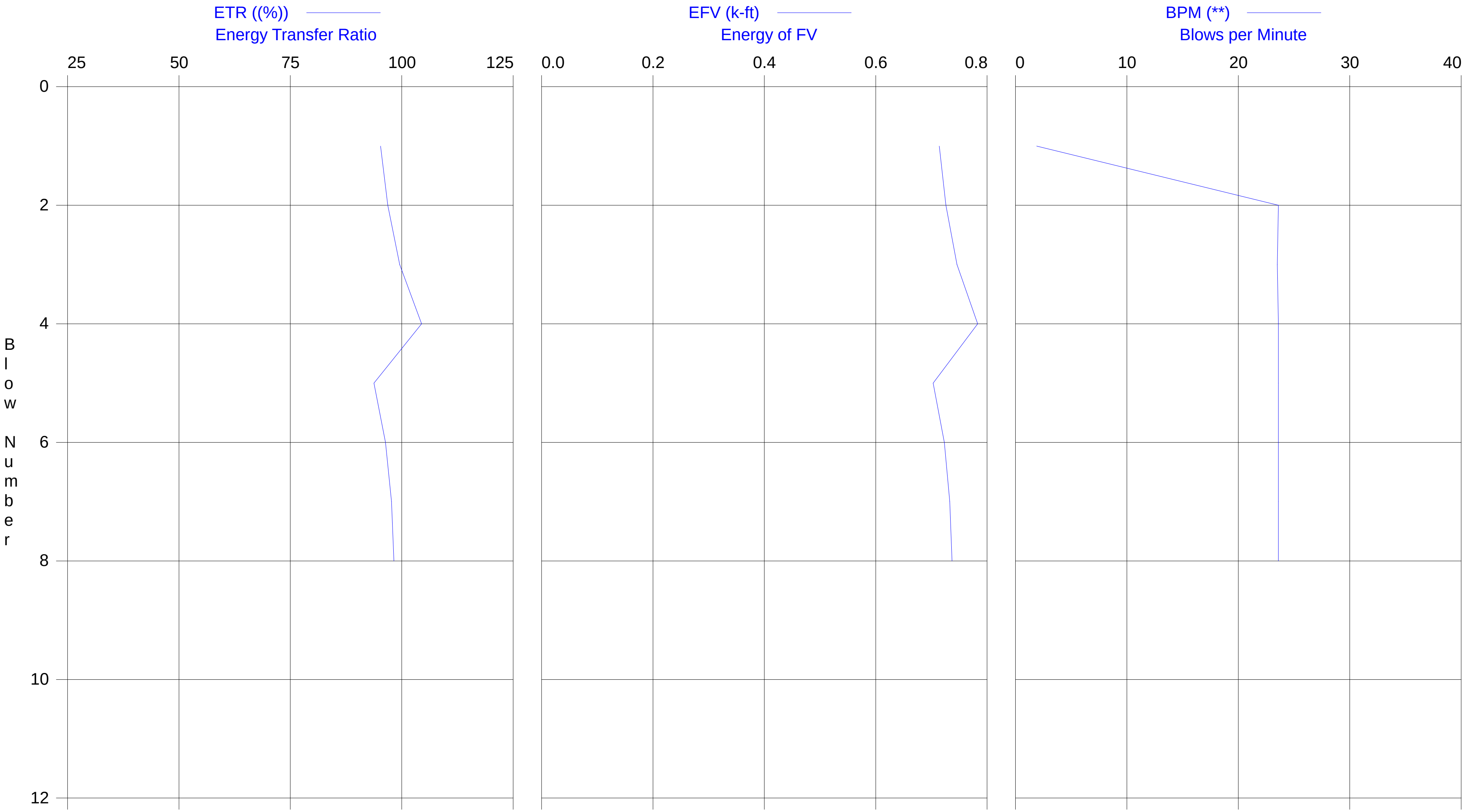
Drive 39 seconds 10:03:13 - 10:03:52 (11/1/2012) BN 1 - 17

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 30 FT B59 NWJ



Case Method Results PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

HOLT SERVICES - 30 FT B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 35.40 ft EM: 29,869 ksi
WS: 16,771.1 f/s JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
3	4	99.5	0.746	23.5	40	17.4	2,801	23	0.819	1.1
4	4	104.5	0.783	23.6	41	17.7	2,966	26	0.832	1.1
5	8	93.8	0.703	23.6	40	17.6	2,811	26	0.835	1.1
6	8	96.4	0.723	23.6	41	17.5	2,811	27	0.830	1.1
7	8	97.7	0.733	23.6	40	17.8	2,827	26	0.825	1.1
8	8	98.2	0.737	23.6	40	17.4	2,842	28	0.822	1.1
Average		98.3	0.738	23.6	40	17.5	2,843	26	0.827	1.1
Maximum		104.5	0.783	23.6	41	17.8	2,966	28	0.835	1.1
@ Blow#		4	4	4	6	7	4	8	5	8

Total number of blows analyzed: 6

Time Summary

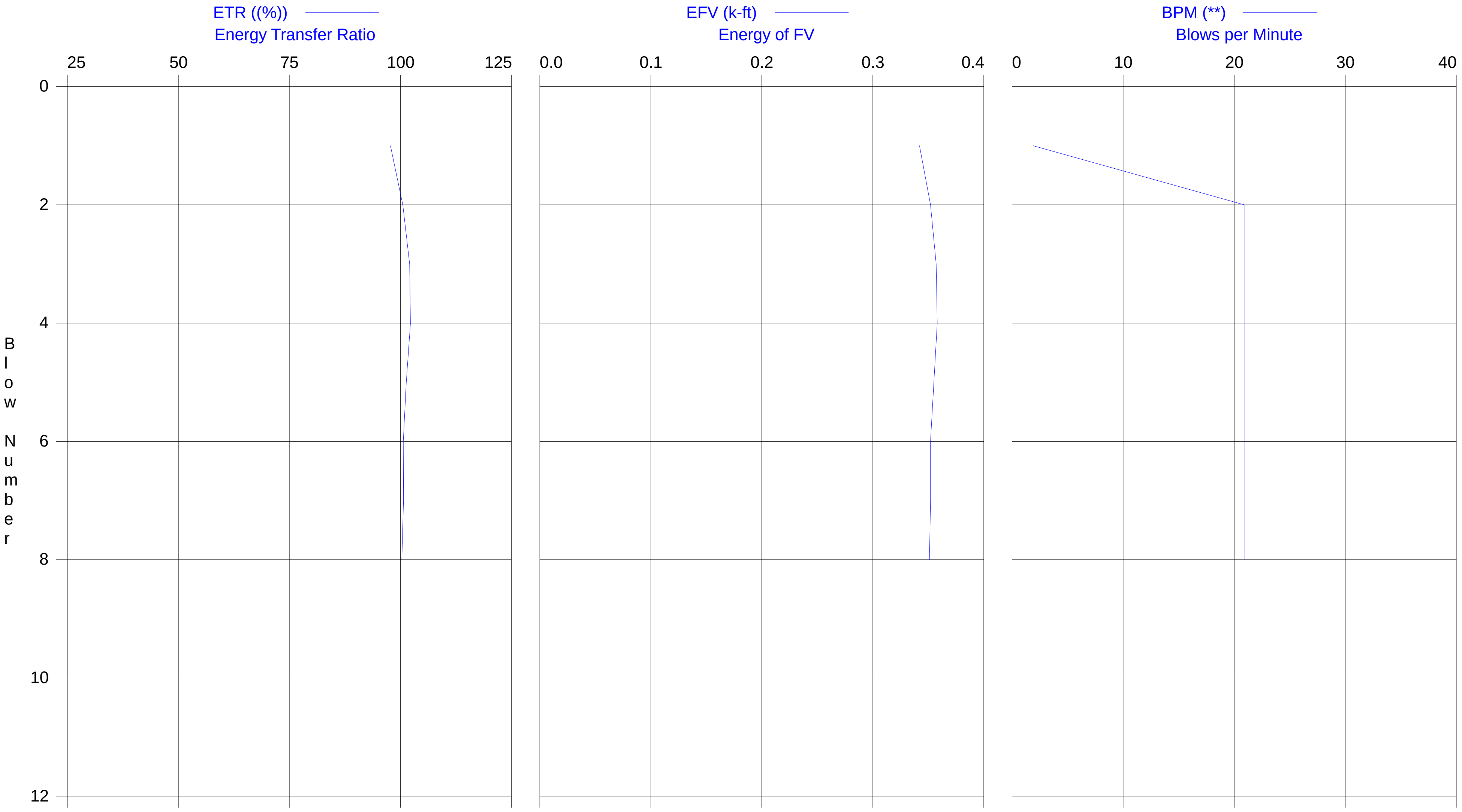
Drive 18 seconds 10:21:04 - 10:21:22 (11/1/2012) BN 1 - 8

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 35 FT B59 NWJ



HOLT SERVICES - 35 FT B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2
LE: 40.40 ft
WS: 16,771.1 f/s

SP: 0.492 k/ft3
EM: 29,869 ksi
JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
3	4	102.1	0.357	20.9	41	15.5	2,358	22	0.398	1.1
4	4	102.2	0.358	20.9	41	15.9	2,467	22	0.383	0.8
5	8	101.3	0.355	20.9	40	15.8	2,461	23	0.384	0.8
6	8	100.7	0.352	20.9	41	15.5	2,364	23	0.383	0.8
7	8	100.7	0.352	20.9	40	15.6	2,440	24	0.382	0.8
8	8	100.3	0.351	20.9	40	15.4	2,386	23	0.394	1.1
Average		101.2	0.354	20.9	41	15.6	2,413	23	0.387	0.9
Maximum		102.2	0.358	20.9	41	15.9	2,467	24	0.398	1.1
@ Blow#		4	4	3	3	4	4	7	3	3

Total number of blows analyzed: 6

Time Summary

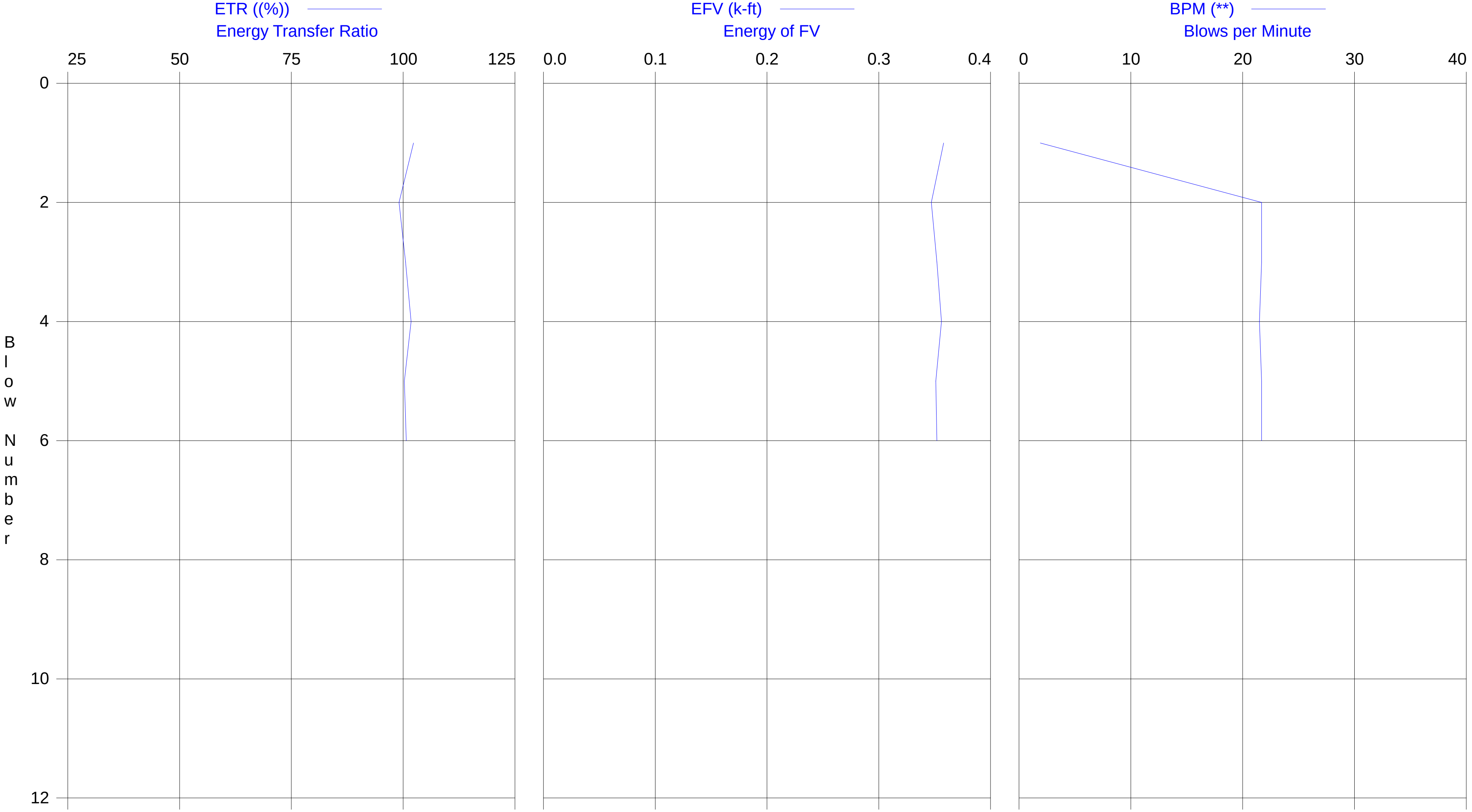
Drive 20 seconds 11:08:09 - 11:08:29 (11/1/2012) BN 1 - 8

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 40 FT B59 NWJ



HOLT SERVICES - 40 FT B59
OP: RMDT

NWJ
Test date: 1-Nov-2012

AR: 1.43 in^2
LE: 45.40 ft
WS: 16,771.1 f/s

SP: 0.492 k/ft3
EM: 29,869 ksi
JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
3	4	100.5	0.352	21.7	40	16.0	2,799	26	0.402	1.1
4	4	101.8	0.356	21.5	39	16.4	2,745	28	0.397	1.1
5	4	100.3	0.351	21.7	39	15.9	2,747	28	0.395	1.1
6	4	100.7	0.352	21.7	39	15.9	2,557	24	0.397	1.1
Average		100.8	0.353	21.6	39	16.1	2,712	27	0.398	1.1
Maximum		101.8	0.356	21.7	40	16.4	2,799	28	0.402	1.1
@ Blow#		4	4	3	3	4	3	5	3	6

Total number of blows analyzed: 4

Time Summary

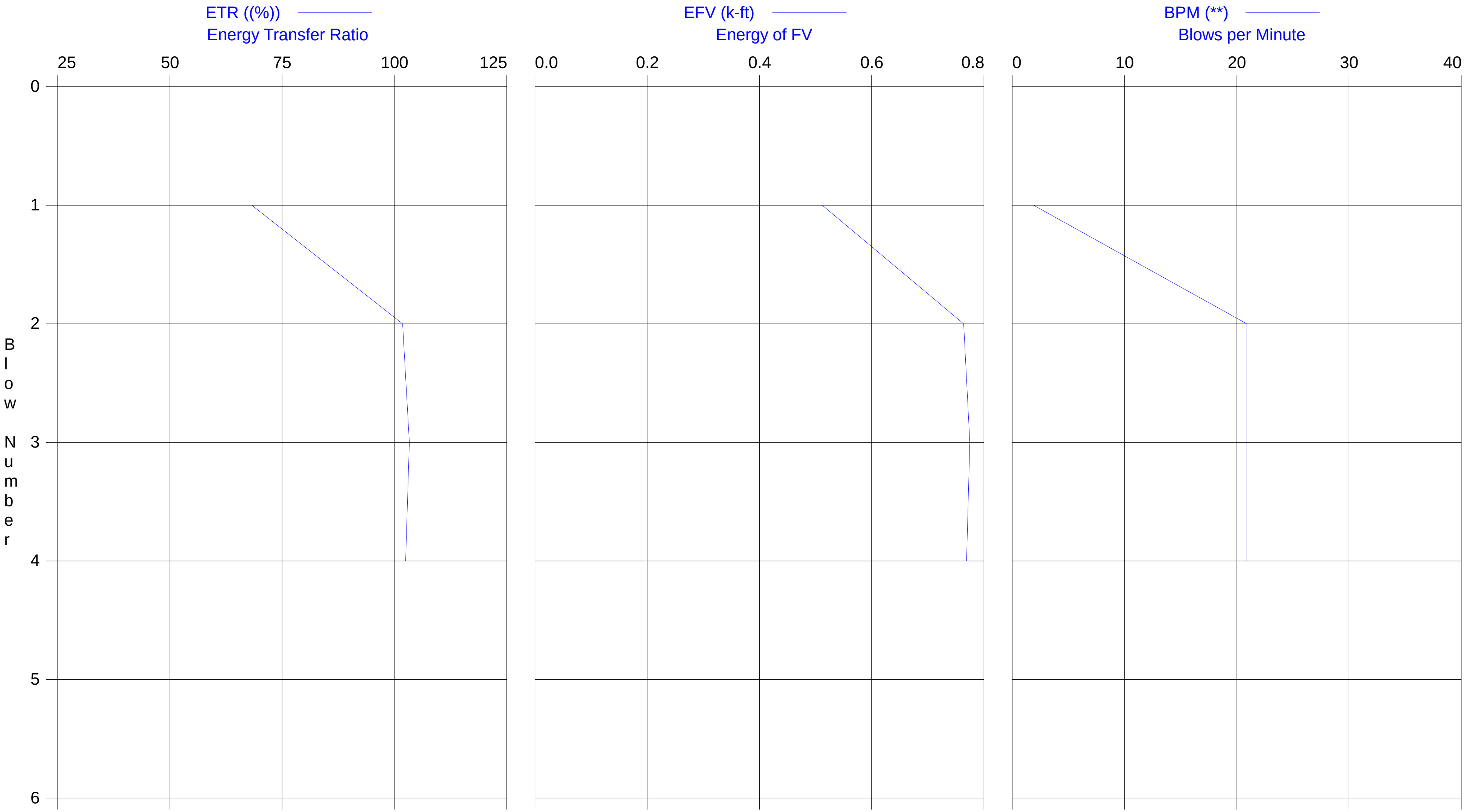
Drive 14 seconds 11:17:40 - 11:17:54 (11/1/2012) BN 1 - 6

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 45 FT, B59 -NWJ



HOLT SERVICES - 45 FT, B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2
LE: 50.40 ft
WS: 16,771.1 f/s

SP: 0.492 k/ft3
EM: 29,869 ksi
JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
2	2	101.8	0.764	20.9	40	17.3	2,409	33	0.841	1.1
3	2	103.3	0.775	20.9	40	16.3	2,358	36	0.845	1.1
4	2	102.5	0.769	20.9	40	16.5	2,433	39	0.847	1.1
Average		102.6	0.769	20.9	40	16.7	2,400	36	0.844	1.1
Maximum		103.3	0.775	20.9	40	17.3	2,433	39	0.847	1.1
@ Blow#		3	3	2	4	2	4	4	4	2

Total number of blows analyzed: 3

Time Summary

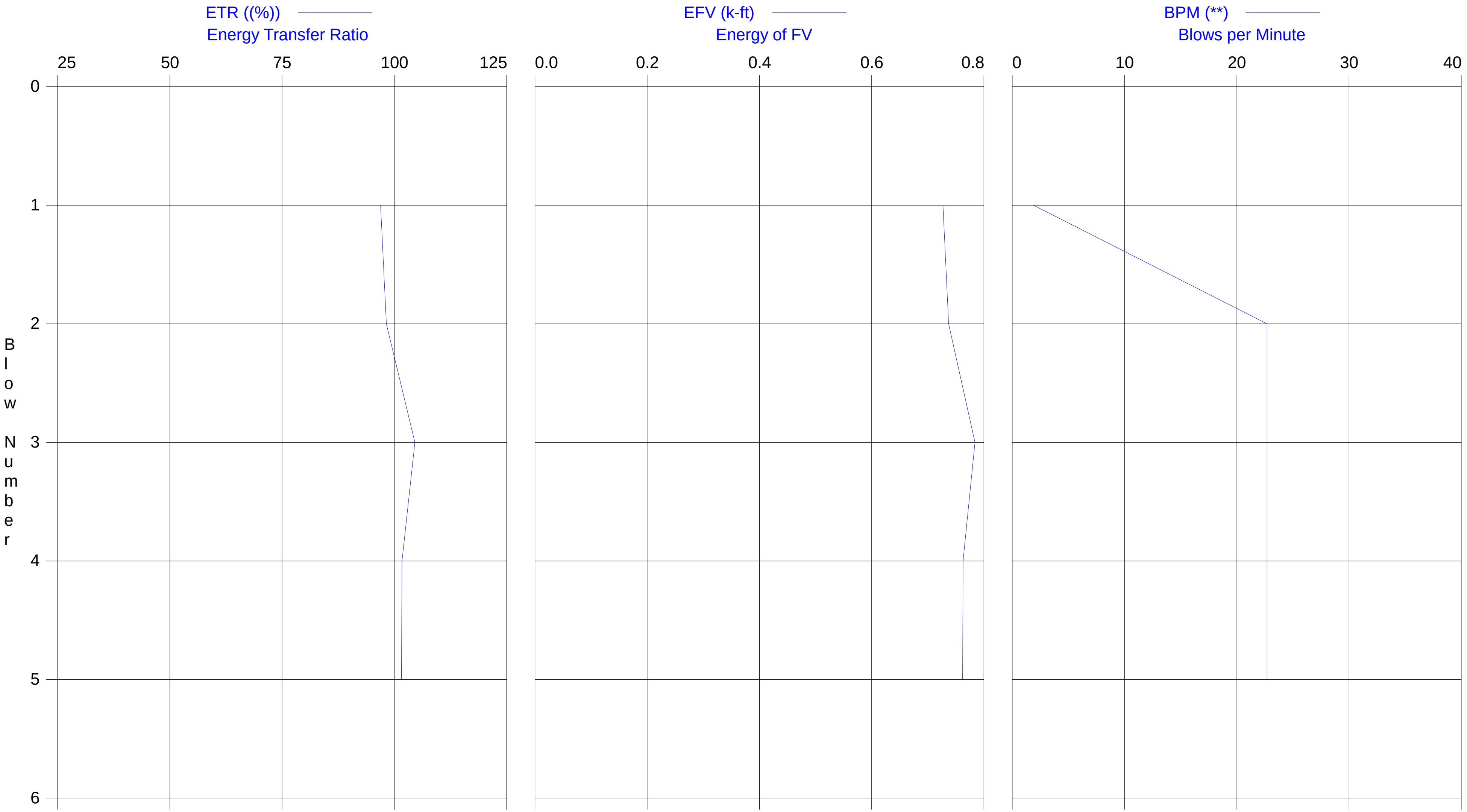
Drive 9 seconds 11:43:57 - 11:44:06 (11/1/2012) BN 1 - 4

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 50 FT, B59 -NWJ



HOLT SERVICES - 50 FT, B59
OP: RMDT

NWJ
Test date: 1-Nov-2012

AR: 1.43 in^2
LE: 55.40 ft
WS: 16,771.1 f/s

SP: 0.492 k/ft3
EM: 29,869 ksi
JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity

AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
3	0	104.6	0.784	22.7	41	16.7	2,977	35	0.889	1.1
4	4	101.7	0.763	22.7	43	16.5	2,924	38	0.894	1.1
5	4	101.6	0.762	22.7	42	16.5	2,916	36	0.888	1.1
Average		102.6	0.770	22.7	42	16.6	2,939	36	0.890	1.1
Maximum		104.6	0.784	22.7	43	16.7	2,977	38	0.894	1.1
@ Blow#		3	3	3	4	3	3	4	4	4

Total number of blows analyzed: 3

Time Summary

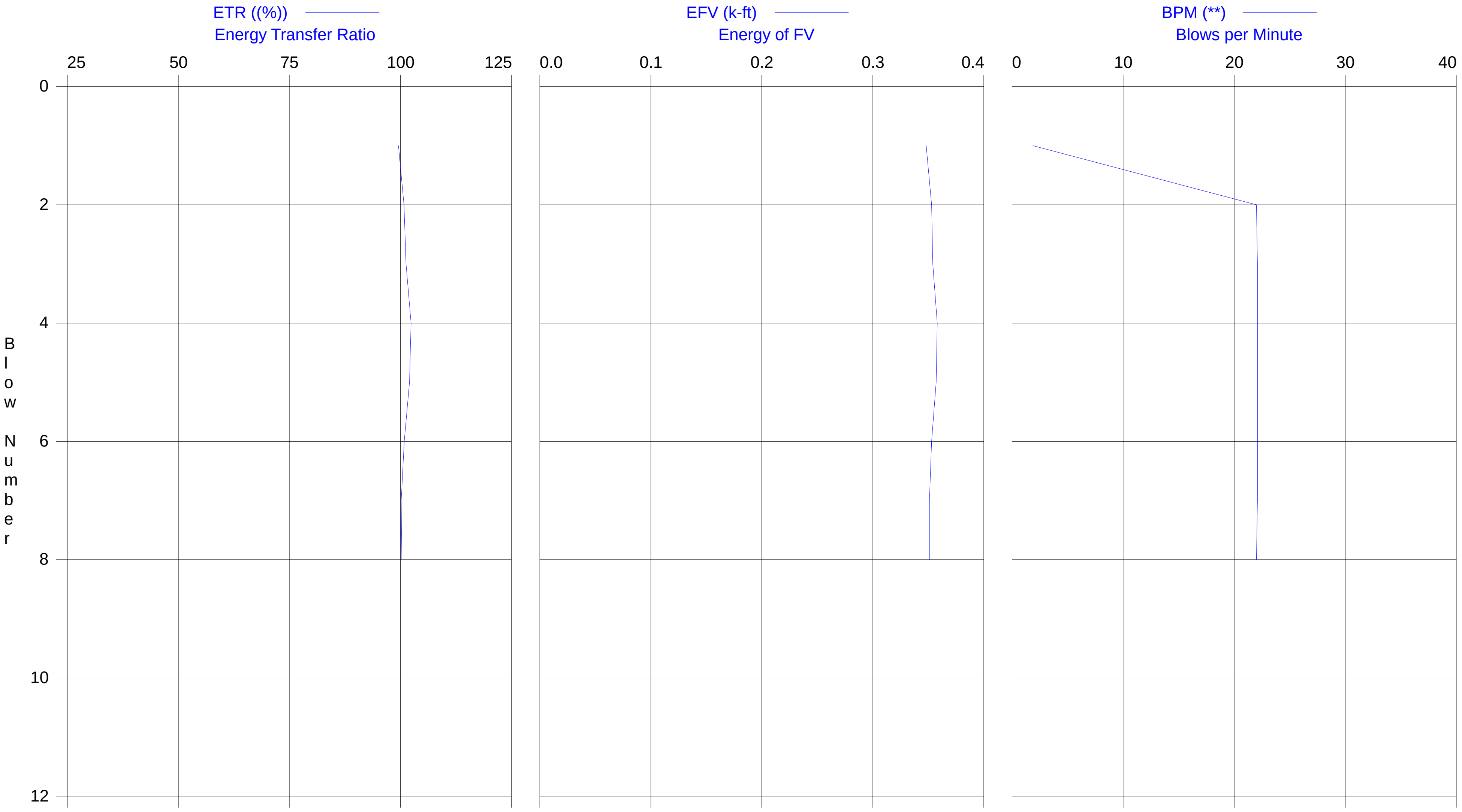
Drive 10 seconds 11:55:44 - 11:55:54 (11/1/2012) BN 1 - 5

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 55 FT, B59 -NWJ



Case Method Results PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

HOLT SERVICES - 55 FT, B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 60.40 ft EM: 29,869 ksi
WS: 16,771.1 f/s JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
4	4	102.4	0.358	22.1	39	15.9	2,496	18	0.389	0.7
5	4	102.1	0.357	22.1	39	15.9	2,505	15	0.390	0.7
6	6	100.9	0.353	22.1	39	15.9	2,609	19	0.386	0.7
7	6	100.2	0.351	22.1	39	15.9	2,422	17	0.384	0.7
8	6	100.3	0.351	22.0	38	15.8	2,422	13	0.377	0.7
Average		101.2	0.354	22.1	39	15.9	2,491	16	0.385	0.7
Maximum		102.4	0.358	22.1	39	15.9	2,609	19	0.390	0.7
@ Blow#		4	4	4	6	5	6	6	5	8

Total number of blows analyzed: 5

Time Summary

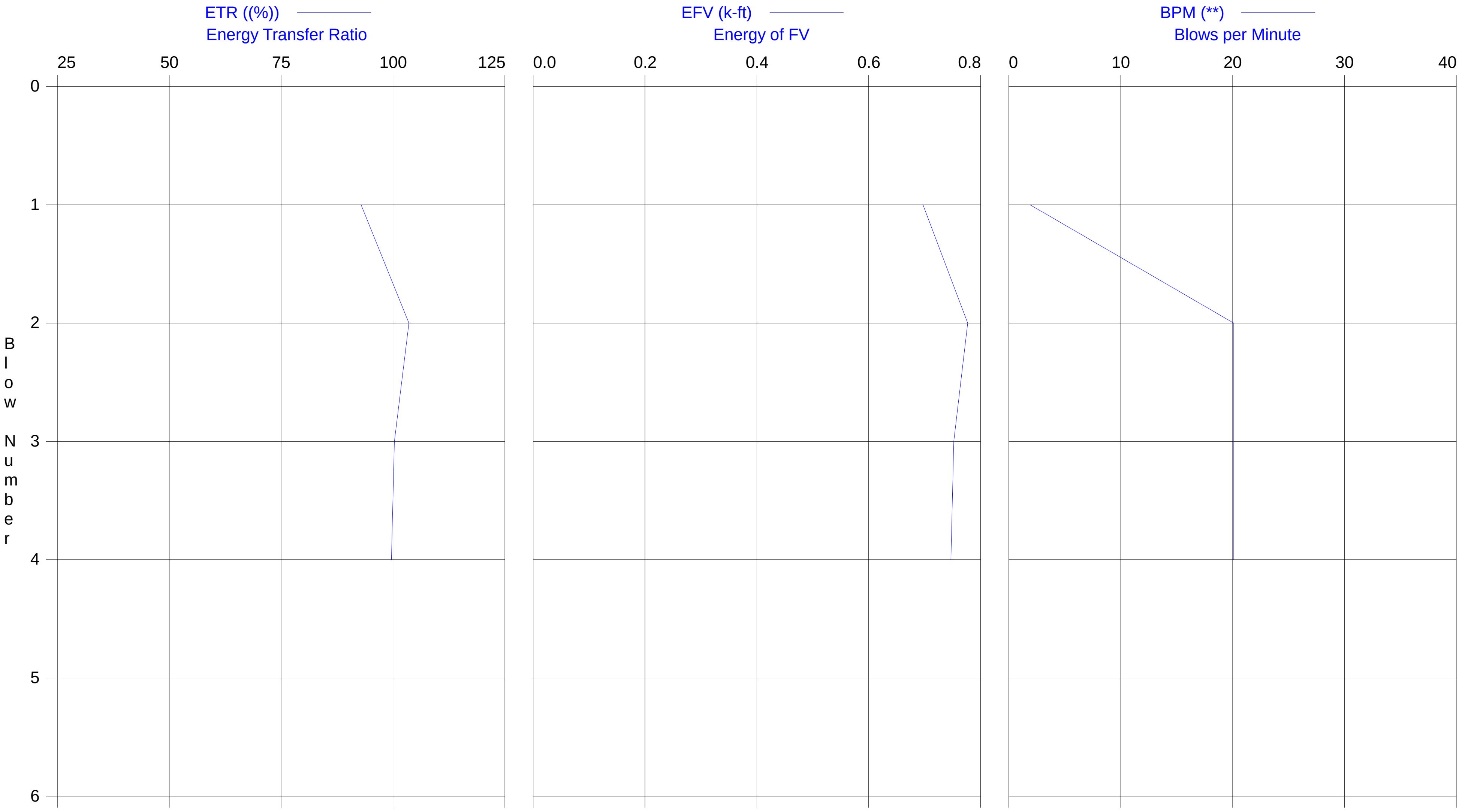
Drive 19 seconds 12:19:01 - 12:19:20 (11/1/2012) BN 1 - 8

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 60 FT, B59 -NWJ



HOLT SERVICES - 60 FT, B59
OP: RMDT

NWJ
Test date: 1-Nov-2012

AR: 1.43 in^2
LE: 65.40 ft
WS: 16,771.1 f/s

SP: 0.492 k/ft3
EM: 29,869 ksi
JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity

AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
2	2	103.6	0.777	20.1	43	16.6	2,808	33	0.858	1.1
3	4	100.3	0.752	20.1	43	16.6	2,932	36	0.868	1.1
4	4	99.6	0.747	20.1	42	16.4	2,753	35	0.857	1.1
Average		101.2	0.759	20.1	43	16.5	2,831	34	0.861	1.1
Maximum		103.6	0.777	20.1	43	16.6	2,932	36	0.868	1.1
@ Blow#		2	2	2	2	2	3	3	3	2

Total number of blows analyzed: 3

Time Summary

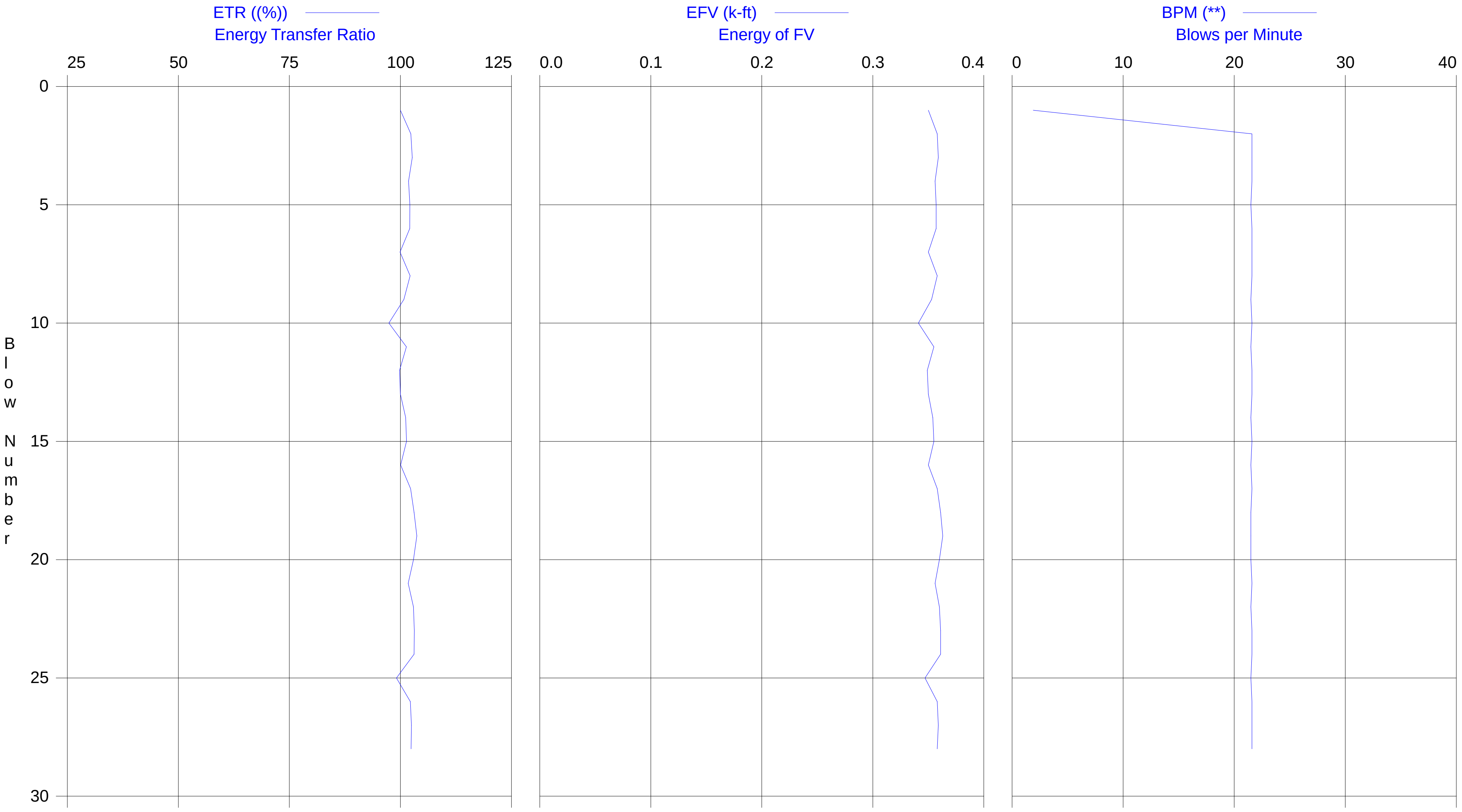
Drive 9 seconds 12:38:36 - 12:38:45 (11/1/2012) BN 1 - 4

Robert Miner Dynamic Testing, Inc. - Case Method Results

PDIPLOT Ver. 2010.2 - Printed: 1-Nov-2012

Test date: 1-Nov-2012

HOLT SERVICES - 65 FT, B59 -NWJ



HOLT SERVICES - 65 FT, B59 NWJ
OP: RMDT Test date: 1-Nov-2012

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 70.40 ft EM: 29,869 ksi
WS: 16,771.1 f/s JC: 0.35

ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
AMX: Maximum Acceleration
SFT: Skin friction total
EF2: Energy of F^2
RAT: SPT Length Ratio

BL#	BLC	ETR	EFV	BPM	FMX	VMX	AMX	SFT	EF2	RAT
	bl/ft	(%)	k-ft	**	kips	f/s	g's	kips	k-ft	[]
10	26	97.4	0.341	21.6	37	13.9	1,849	14	0.363	0.6
11	26	101.4	0.355	21.5	39	14.7	2,041	17	0.376	0.6
12	26	99.8	0.349	21.6	38	14.4	1,922	16	0.373	0.8
13	26	100.0	0.350	21.6	38	14.2	1,813	13	0.370	0.6
14	26	101.2	0.354	21.5	38	14.4	1,903	17	0.372	0.6
15	26	101.4	0.355	21.6	38	14.7	1,935	15	0.377	0.6
16	26	100.1	0.350	21.5	37	13.7	1,692	14	0.372	0.8
17	26	102.3	0.358	21.6	39	14.9	2,093	18	0.379	0.8
18	26	103.1	0.361	21.5	39	15.1	1,979	17	0.385	0.8
19	26	103.7	0.363	21.5	39	15.2	2,020	17	0.384	0.6
20	26	102.9	0.360	21.5	39	15.0	2,039	19	0.385	0.8
21	26	101.8	0.356	21.6	39	14.8	1,952	19	0.385	0.6
22	26	103.0	0.360	21.5	39	15.0	2,034	19	0.387	0.8
23	12	103.1	0.361	21.6	40	15.0	2,009	18	0.389	0.8
24	12	103.1	0.361	21.6	39	15.0	2,004	19	0.387	0.8
25	12	99.1	0.347	21.5	36	14.2	1,634	14	0.362	0.8
26	12	102.2	0.358	21.6	37	14.6	1,878	18	0.375	0.8
27	12	102.5	0.359	21.6	38	14.9	1,959	17	0.377	0.8
28	12	102.4	0.358	21.6	37	14.6	1,963	19	0.378	0.8
Average		101.6	0.356	21.6	38	14.7	1,933	17	0.378	0.7
Maximum		103.7	0.363	21.6	40	15.2	2,093	19	0.389	0.8
@ Blow#		19	19	10	23	19	17	22	23	26

Total number of blows analyzed: 19

Time Summary

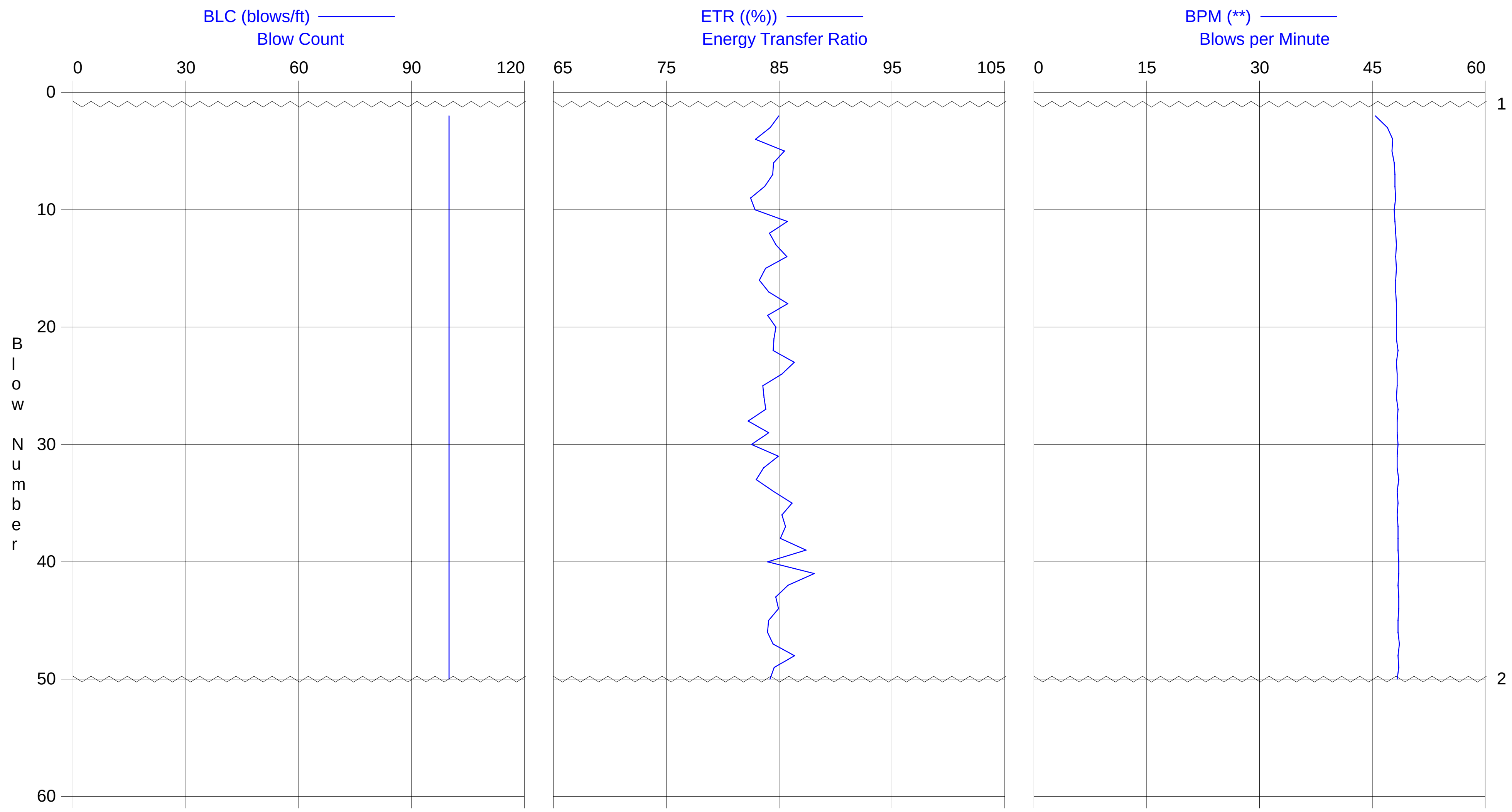
Drive 1 minute 15 seconds 12:59:21 - 13:00:36 (11/1/2012) BN 1 - 28

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 17-Apr-2013

HOLT SERVICES, SOUND TRANSIT - SAMPLE 35 FT BHE330-B28



1 - Start of test on 4/17/2013 at 9:28:14 AM

2 - End of test on 4/17/2013 at 9:29:14 AM

HOLT SERVICES, SOUND TRANSIT - SAMPLE 35 FT BHE330-B28
OP: RMDT Test date: 17-Apr-2013

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 39.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
2	35.02	100	30.1	29.7	85.0	0.297	45.4	43	13.6	1.1
3	35.03	100	30.9	30.3	84.2	0.295	47.0	43	13.9	1.1
4	35.04	100	30.6	29.9	82.9	0.290	47.7	43	14.0	1.1
5	35.05	100	30.7	30.3	85.5	0.299	47.6	43	14.1	1.1
6	35.06	100	31.1	30.6	84.5	0.296	47.9	44	14.1	1.1
7	35.07	100	30.9	30.2	84.4	0.295	48.0	43	14.5	1.1
8	35.08	100	30.8	30.1	83.7	0.293	48.0	43	14.3	1.1
9	35.09	100	30.2	29.7	82.5	0.289	48.1	43	14.1	1.1
10	35.10	100	30.6	30.1	82.9	0.290	47.9	43	14.3	1.1
11	35.11	100	30.6	30.4	85.7	0.300	48.0	43	14.7	1.1
12	35.12	100	29.8	29.4	84.1	0.295	48.1	42	14.3	0.7
13	35.13	100	30.7	30.3	84.7	0.297	48.2	43	14.5	1.1
14	35.14	100	30.5	30.3	85.7	0.300	48.1	43	14.5	0.9
15	35.15	100	30.4	30.1	83.8	0.293	48.2	43	14.2	1.1
16	35.16	100	30.3	30.1	83.2	0.291	48.1	43	14.0	1.1
17	35.17	100	30.6	30.5	84.1	0.294	48.1	44	14.6	1.1
18	35.18	100	30.9	30.7	85.8	0.300	48.2	44	14.6	0.7
19	35.19	100	30.6	30.2	84.0	0.294	48.2	43	14.9	1.1
20	35.20	100	30.6	30.4	84.7	0.296	48.2	43	14.8	0.7
21	35.21	100	30.7	30.5	84.5	0.296	48.2	44	15.0	1.1
22	35.22	100	30.0	29.6	84.5	0.296	48.4	42	14.5	1.1
23	35.23	100	30.5	30.1	86.3	0.302	48.2	43	15.0	1.1
24	35.24	100	30.4	30.4	85.3	0.298	48.3	43	14.9	1.1
25	35.25	100	30.3	30.3	83.6	0.292	48.3	43	14.3	1.1
26	35.26	100	30.0	29.9	83.7	0.293	48.2	43	15.4	1.1
27	35.27	100	29.6	29.1	83.8	0.293	48.4	42	14.8	1.1
28	35.28	100	29.8	29.5	82.3	0.288	48.3	42	15.0	0.7
29	35.29	100	29.8	29.6	84.1	0.294	48.3	42	15.1	1.1
30	35.30	100	29.1	28.7	82.6	0.289	48.4	41	15.0	1.1
31	35.31	100	29.6	29.5	84.9	0.297	48.3	42	15.1	1.0
32	35.32	100	29.8	29.5	83.6	0.293	48.3	42	14.9	0.9
33	35.33	100	30.1	29.6	83.0	0.290	48.5	42	15.0	1.1
34	35.34	100	30.1	29.9	84.5	0.296	48.3	43	14.7	1.1
35	35.35	100	31.2	31.1	86.2	0.302	48.4	44	15.5	0.7
36	35.36	100	30.6	30.5	85.2	0.298	48.3	44	15.6	1.1
37	35.37	100	29.8	29.8	85.6	0.299	48.4	43	15.6	0.7
38	35.38	100	30.5	30.1	85.1	0.298	48.4	43	14.9	1.1
39	35.39	100	31.4	31.3	87.4	0.306	48.4	45	15.6	1.1
40	35.40	100	29.6	29.4	84.0	0.294	48.5	42	14.6	1.1
41	35.41	100	31.6	31.6	88.1	0.308	48.5	45	15.9	1.1
42	35.42	100	31.3	31.2	85.8	0.300	48.4	45	15.4	1.1
43	35.43	100	30.7	30.2	84.7	0.296	48.5	43	14.9	1.1
44	35.44	100	31.5	31.4	84.9	0.297	48.5	45	15.2	1.1
45	35.45	100	30.3	30.0	84.1	0.294	48.4	43	14.8	1.1
46	35.46	100	30.4	30.4	84.0	0.294	48.4	43	15.1	0.9
47	35.47	100	30.4	30.2	84.5	0.296	48.6	43	15.0	1.1
48	35.48	100	31.5	31.3	86.4	0.302	48.4	45	15.6	1.1
49	35.49	100	31.5	31.2	84.6	0.296	48.5	45	15.3	0.7
50	35.50	100	30.0	29.7	84.2	0.295	48.3	42	14.7	1.1
		Average	30.5	30.2	84.5	0.296	48.2	43	14.8	1.0
		Std. Dev.	0.6	0.6	1.2	0.004	0.5	1	0.5	0.1
		Maximum	31.6	31.6	88.1	0.308	48.6	45	15.9	1.1
		Minimum	29.1	28.7	82.3	0.288	45.4	41	13.6	0.7

Total number of blows analyzed: 49

BL#	depth (ft)	Comments
1	35.01	Start of test on 4/17/2013 at 9:28:14 AM
50	35.50	End of test on 4/17/2013 at 9:29:14 AM

Time Summary

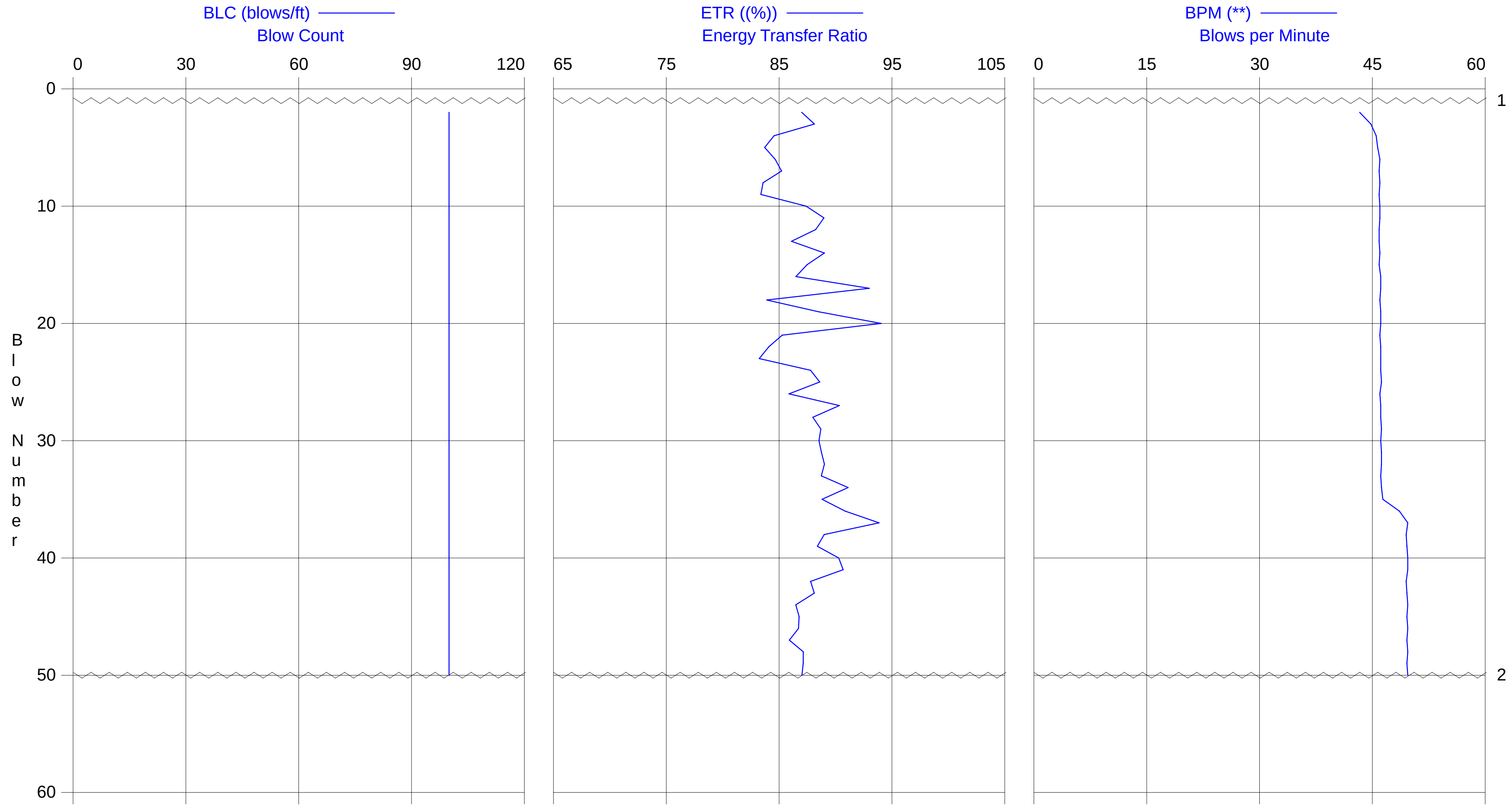
Drive 1 minute 9:28:14 AM - 9:29:14 AM (4/17/2013) BN 1 - 50

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 17-Apr-2013

HOLT SERVICES, SOUND TRANSIT - SAMPLE 40 FT BH:330-B28



1 - Start of test on 4/17/2013 at 11:18:01 AM

2 - End of test on 4/17/2013 at 11:19:04 AM

HOLT SERVICES, SOUND TRANSIT - SAMPLE 40 FT BH:330-B28
OP: RMDT Test date: 17-Apr-2013

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 44.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
2	40.02	100	30.0	29.4	87.0	0.305	43.3	42.1	14.3	0.9
3	40.03	100	30.7	30.6	88.1	0.308	44.8	43.7	16.1	0.8
4	40.04	100	32.3	31.7	84.5	0.296	45.5	45.4	14.3	0.6
5	40.05	100	30.7	30.2	83.7	0.293	45.7	43.1	14.8	0.8
6	40.06	100	32.9	32.9	84.6	0.296	46.0	47.0	14.2	0.6
7	40.07	100	33.0	32.7	85.2	0.298	45.9	46.8	15.4	0.6
8	40.08	100	31.0	30.4	83.6	0.293	46.0	43.6	14.0	0.6
9	40.09	100	30.6	30.0	83.4	0.292	45.9	43.0	14.5	1.1
10	40.10	100	33.6	33.6	87.4	0.306	46.0	48.0	16.2	0.6
11	40.11	100	33.4	33.0	89.0	0.311	46.0	47.3	16.4	0.6
12	40.12	100	34.4	33.9	88.2	0.309	45.9	48.6	15.4	0.8
13	40.13	100	32.9	32.8	86.1	0.301	45.9	47.0	16.0	0.6
14	40.14	100	32.0	31.9	89.0	0.312	46.0	45.6	16.8	0.6
15	40.15	100	34.4	34.0	87.5	0.306	45.9	48.6	15.6	0.8
16	40.16	100	33.7	33.3	86.5	0.303	46.1	47.7	15.9	0.7
17	40.17	100	31.8	31.5	93.0	0.326	46.1	45.1	17.0	0.4
18	40.18	100	33.7	33.5	83.9	0.294	46.0	47.9	14.8	0.6
19	40.19	100	33.9	33.5	88.5	0.310	46.1	47.9	15.8	0.6
20	40.20	100	33.2	32.4	94.0	0.329	46.1	46.3	17.2	0.8
21	40.21	100	31.7	31.5	85.3	0.298	46.0	45.1	15.9	0.6
22	40.22	100	32.0	32.0	84.1	0.294	46.1	45.7	15.2	0.6
23	40.23	100	30.6	30.4	83.2	0.291	46.1	43.5	16.3	0.9
24	40.24	100	30.4	30.2	87.8	0.307	46.1	43.2	16.1	0.6
25	40.25	100	33.3	32.9	88.6	0.310	46.2	47.1	16.2	0.6
26	40.26	100	30.1	29.5	85.9	0.301	46.0	42.2	16.1	0.9
27	40.27	100	33.8	33.2	90.3	0.316	46.1	47.5	16.5	0.6
28	40.28	100	32.3	31.8	88.0	0.308	46.1	45.5	17.1	0.6
29	40.29	100	33.0	32.7	88.7	0.310	46.2	46.8	16.9	0.6
30	40.30	100	31.0	30.6	88.5	0.310	46.1	43.8	17.2	0.6
31	40.31	100	33.4	32.9	88.8	0.311	46.2	47.0	16.5	0.8
32	40.32	100	33.6	33.1	89.0	0.312	46.2	47.3	16.5	0.6
33	40.33	100	32.6	32.0	88.7	0.311	46.1	45.8	17.0	0.6
34	40.34	100	33.0	32.4	91.1	0.319	46.2	46.3	17.7	0.6
35	40.35	100	33.8	33.0	88.8	0.311	46.4	47.2	17.0	0.6
36	40.36	100	33.0	32.3	90.9	0.318	48.6	46.2	18.0	0.6
37	40.37	100	33.2	32.3	93.9	0.329	49.7	46.2	17.1	0.9
38	40.38	100	32.7	32.2	89.0	0.311	49.5	46.1	16.4	0.7
39	40.39	100	31.3	31.1	88.4	0.309	49.6	44.6	16.7	0.9
40	40.40	100	32.2	32.2	90.3	0.316	49.7	46.0	16.6	0.8
41	40.41	100	31.8	31.8	90.7	0.317	49.7	45.5	16.3	0.8
42	40.42	100	31.4	31.0	87.8	0.307	49.5	44.4	16.0	0.9
43	40.43	100	31.1	31.0	88.1	0.308	49.6	44.4	16.2	1.1
44	40.44	100	32.1	31.6	86.5	0.303	49.7	45.2	15.3	0.7
45	40.45	100	31.6	31.2	86.8	0.304	49.6	44.6	16.2	0.6
46	40.46	100	29.6	29.6	86.7	0.304	49.7	42.3	16.4	0.7
47	40.47	100	29.5	29.1	85.9	0.301	49.6	41.7	16.2	0.7
48	40.48	100	30.8	30.7	87.2	0.305	49.7	44.0	16.1	0.9
49	40.49	100	31.6	31.6	87.1	0.305	49.6	45.1	16.1	0.9
50	40.50	100	31.7	31.3	87.0	0.305	49.7	44.8	15.5	0.8
		Average	32.2	31.8	87.7	0.307	47.0	45.5	16.1	0.7
		Std. Dev.	1.3	1.2	2.5	0.009	1.7	1.8	0.9	0.1
		Maximum	34.4	34.0	94.0	0.329	49.7	48.6	18.0	1.1
		Minimum	29.5	29.1	83.2	0.291	43.3	41.7	14.0	0.4

Total number of blows analyzed: 49

BL#	depth (ft)	Comments
1	40.01	Start of test on 4/17/2013 at 11:18:01 AM
50	40.50	End of test on 4/17/2013 at 11:19:04 AM

Time Summary

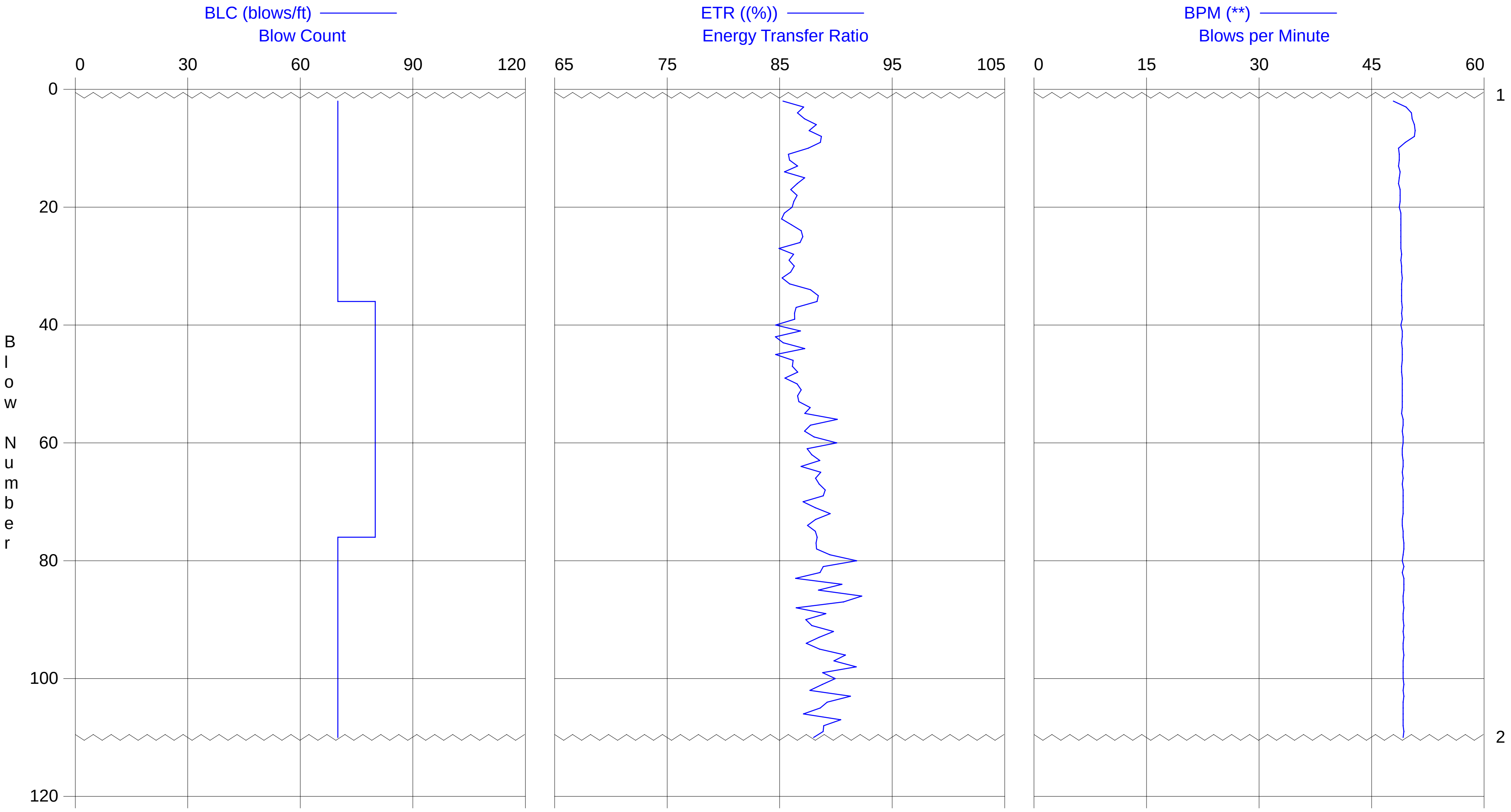
Drive 1 minute 3 seconds 11:18:01 AM - 11:19:04 AM (4/17/2013) BN 1 - 50

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 17-Apr-2013

HOLT SERVICES, SOUND TRANSIT - SAMPLE 45 FT BH:E330-B28



1 - Start of test on 4/17/2013 at 12:52:45 PM

2 - End of test on 4/17/2013 at 12:54:58 PM

HOLT SERVICES, SOUND TRANSIT - SAMPLE 45 FT BH:E330-B28
OP: RMDT Test date: 17-Apr-2013

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 49.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
36	45.51	80	31.3	31.3	88.3	0.309	49.0	44.7	15.7	1.0
37	45.53	80	31.9	31.7	86.5	0.303	49.1	45.4	15.0	1.0
38	45.54	80	31.7	31.2	86.3	0.302	49.0	44.6	15.0	1.1
39	45.55	80	30.5	30.1	86.3	0.302	49.1	43.1	14.8	1.0
40	45.56	80	31.5	31.3	84.7	0.296	48.9	44.8	15.0	1.0
41	45.58	80	32.4	32.1	86.8	0.304	49.1	45.9	14.9	1.0
42	45.59	80	32.1	31.5	84.6	0.296	49.1	45.0	14.7	1.1
43	45.60	80	31.4	31.1	85.3	0.299	49.0	44.5	15.1	1.1
44	45.61	80	31.5	31.1	87.2	0.305	49.1	44.5	15.3	1.0
45	45.63	80	31.3	31.2	84.6	0.296	49.1	44.6	15.4	1.1
46	45.64	80	31.6	31.4	86.2	0.302	49.1	45.0	15.0	1.1
47	45.65	80	30.9	30.4	86.1	0.301	49.0	43.5	15.1	1.0
48	45.66	80	32.6	32.4	86.6	0.303	49.0	46.4	14.9	1.1
49	45.68	80	30.8	30.4	85.5	0.299	49.1	43.5	15.2	1.0
50	45.69	80	31.9	31.8	86.5	0.303	49.1	45.4	15.1	1.1
51	45.70	80	31.4	30.9	86.9	0.304	49.1	44.2	14.8	0.9
52	45.71	80	31.7	31.1	86.6	0.303	49.1	44.5	14.8	1.0
53	45.73	80	31.8	31.2	86.7	0.303	49.1	44.6	15.0	1.0
54	45.74	80	31.3	30.9	87.7	0.307	49.1	44.2	15.5	1.1
55	45.75	80	30.7	30.6	87.2	0.305	49.0	43.7	15.4	1.0
56	45.76	80	30.5	30.4	90.1	0.315	49.2	43.5	15.6	1.1
57	45.78	80	30.9	30.4	87.7	0.307	49.2	43.4	15.6	1.0
58	45.79	80	31.9	31.3	87.2	0.305	49.1	44.8	15.1	1.0
59	45.80	80	29.5	29.4	88.1	0.308	49.2	42.0	16.1	1.0
60	45.81	80	29.3	29.3	90.1	0.315	49.2	42.0	16.3	1.0
61	45.83	80	31.2	30.5	87.4	0.306	49.1	43.6	15.8	0.9
62	45.84	80	32.0	31.7	87.9	0.307	49.1	45.4	15.8	1.1
63	45.85	80	31.2	31.2	88.6	0.310	49.2	44.6	16.4	1.1
64	45.86	80	31.3	31.0	86.9	0.304	49.2	44.4	15.9	1.1
65	45.88	80	31.3	31.3	88.6	0.310	49.1	44.7	16.0	1.1
66	45.89	80	31.7	31.0	88.2	0.309	49.2	44.4	15.8	1.0
67	45.90	80	30.0	29.7	88.5	0.310	49.1	42.5	16.1	1.0
68	45.91	80	31.8	31.7	89.0	0.312	49.2	45.4	16.4	1.1
69	45.93	80	30.9	30.7	88.9	0.311	49.2	43.9	16.3	1.1
70	45.94	80	32.0	31.9	87.1	0.305	49.2	45.7	15.9	1.0
71	45.95	80	30.9	30.6	88.2	0.309	49.2	43.8	16.5	1.1
72	45.96	80	30.6	30.0	89.5	0.313	49.2	43.0	16.4	1.0
73	45.98	80	31.3	31.3	88.2	0.309	49.1	44.7	15.9	1.1
74	45.99	80	31.4	31.1	87.5	0.306	49.1	44.4	15.8	1.1
75	46.00	80	30.2	30.1	88.2	0.309	49.2	43.1	16.4	1.1
76	46.01	70	30.6	30.5	88.3	0.309	49.2	43.7	16.4	1.0
77	46.03	70	30.4	29.8	88.2	0.309	49.3	42.6	16.3	1.0
78	46.04	70	30.1	29.6	88.3	0.309	49.3	42.4	16.5	1.0
79	46.06	70	32.1	31.7	89.5	0.313	49.2	45.4	16.3	1.0
80	46.07	70	29.5	29.3	91.8	0.321	49.1	41.9	17.1	1.0
81	46.09	70	30.0	29.4	88.9	0.311	49.3	42.1	16.7	1.0
82	46.10	70	31.6	31.3	88.6	0.310	49.1	44.8	16.2	1.0
83	46.11	70	29.3	28.8	86.4	0.302	49.3	41.2	16.7	1.0
84	46.13	70	30.9	30.9	90.5	0.317	49.3	44.2	16.6	1.0
85	46.14	70	31.8	31.6	88.4	0.310	49.3	45.2	16.3	1.0
86	46.16	70	31.4	31.0	92.3	0.323	49.2	44.4	16.9	1.0
87	46.17	70	32.5	32.0	90.7	0.317	49.2	45.8	16.6	1.0
88	46.19	70	31.1	30.6	86.5	0.303	49.3	43.7	16.4	1.0
89	46.20	70	31.6	31.3	89.1	0.312	49.2	44.8	16.3	1.0
90	46.21	70	31.5	31.2	87.3	0.306	49.2	44.7	16.4	1.0
91	46.23	70	30.3	30.0	87.9	0.308	49.3	42.9	16.8	1.0
92	46.24	70	31.6	31.3	89.8	0.314	49.2	44.8	16.2	1.0
93	46.26	70	30.4	29.7	88.5	0.310	49.3	42.5	16.6	1.0
94	46.27	70	29.7	29.5	87.4	0.306	49.2	42.2	16.3	1.0
95	46.29	70	32.3	32.1	88.5	0.310	49.2	45.9	15.7	1.1
96	46.30	70	31.7	31.6	90.8	0.318	49.3	45.2	17.0	1.1
97	46.31	70	32.0	31.9	89.8	0.314	49.2	45.6	16.5	1.0
98	46.33	70	29.3	29.2	91.8	0.321	49.2	41.8	17.0	1.0
99	46.34	70	31.7	31.0	88.8	0.311	49.2	44.4	16.1	1.0
100	46.36	70	30.1	29.7	89.9	0.315	49.2	42.4	16.8	1.0
101	46.37	70	29.2	28.8	88.8	0.311	49.3	41.2	16.7	1.0

HOLT SERVICES, SOUND TRANSIT - SAMPLE 45 FT BH:E330-B28
OP: RMDT Test date: 17-Apr-2013

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
102	46.39	70	30.7	30.2	87.7	0.307	49.2	43.3	16.1	1.0
103	46.40	70	29.7	29.6	91.3	0.320	49.3	42.3	16.7	1.0
104	46.41	70	31.7	31.3	89.2	0.312	49.2	44.8	16.5	1.0
105	46.43	70	31.2	30.5	88.6	0.310	49.2	43.7	16.3	1.0
106	46.44	70	31.5	31.2	87.1	0.305	49.2	44.7	16.1	1.0
107	46.46	70	31.8	31.5	90.4	0.317	49.2	45.0	16.2	1.0
108	46.47	70	31.1	30.7	88.9	0.311	49.2	43.9	16.5	1.0
109	46.49	70	32.3	32.0	88.9	0.311	49.3	45.8	16.0	1.0
110	46.50	70	31.1	30.4	88.0	0.308	49.2	43.4	16.3	1.0
		Average	31.1	30.8	88.1	0.308	49.2	44.1	16.0	1.0
		Std. Dev.	0.8	0.8	1.6	0.006	0.1	1.2	0.6	0.0
		Maximum	32.6	32.4	92.3	0.323	49.3	46.4	17.1	1.1
		Minimum	29.2	28.8	84.6	0.296	48.9	41.2	14.7	0.9

Total number of blows analyzed: 75

BL#	depth (ft)	Comments
1	45.01	Start of test on 4/17/2013 at 12:52:45 PM
110	46.50	End of test on 4/17/2013 at 12:54:58 PM

Time Summary

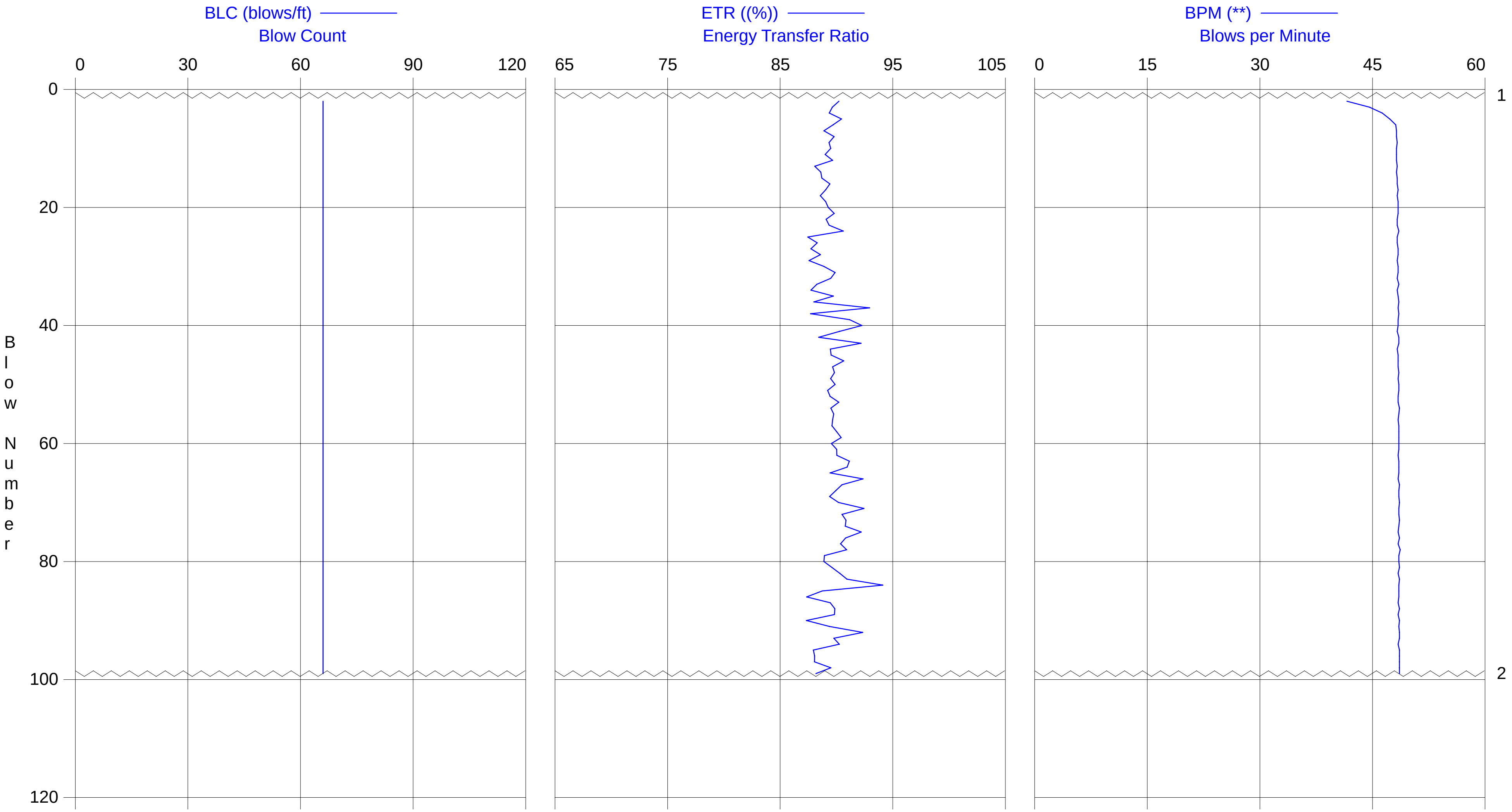
Drive 2 minutes 13 seconds 12:52:45 PM - 12:54:58 PM (4/17/2013) BN 1 - 110

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 17-Apr-2013

HOLT SERVICES, SOUND TRANSIT - SAMPLE 50 FT BH:E330-B28



1 - Start of test on 4/17/2013 at 1:16:29 PM

2 - End of test on 4/17/2013 at 1:18:30 PM

HOLT SERVICES, SOUND TRANSIT - SAMPLE 50 FT BH:E330-B28
OP: RMDT Test date: 17-Apr-2013

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 54.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
34	50.52	66	29.9	29.9	87.7	0.307	48.3	42.7	18.1	0.7
35	50.53	66	28.5	28.4	89.7	0.314	48.4	40.6	17.9	0.6
36	50.55	66	32.1	32.1	88.0	0.308	48.5	45.9	18.6	0.5
37	50.56	66	29.5	29.4	92.9	0.325	48.4	42.1	19.1	0.7
38	50.58	66	30.5	30.5	87.7	0.307	48.5	43.7	18.1	0.5
39	50.59	66	33.2	33.2	91.2	0.319	48.4	47.4	18.2	0.5
40	50.61	66	31.7	31.6	92.3	0.323	48.4	45.2	19.0	0.5
41	50.62	66	30.8	30.6	90.2	0.316	48.3	43.7	18.0	0.7
42	50.64	66	30.5	30.3	88.4	0.309	48.5	43.3	19.0	0.7
43	50.65	66	29.0	28.5	92.2	0.323	48.5	40.8	19.1	0.7
44	50.67	66	30.4	30.3	89.5	0.313	48.3	43.3	18.4	0.5
45	50.68	66	28.8	28.5	89.5	0.313	48.4	40.7	18.0	0.7
46	50.70	66	33.5	33.2	90.7	0.317	48.4	47.6	18.1	0.5
47	50.71	66	30.4	30.3	89.6	0.314	48.4	43.4	18.8	0.5
48	50.73	66	29.2	29.2	89.8	0.314	48.5	41.7	18.1	1.1
49	50.74	66	29.5	29.1	89.5	0.313	48.4	41.7	18.4	0.7
50	50.76	66	30.6	30.3	89.9	0.315	48.5	43.3	18.3	0.5
51	50.77	66	31.5	31.4	89.2	0.312	48.5	45.0	18.2	0.9
52	50.79	66	29.5	28.2	89.4	0.313	48.4	40.4	17.6	0.7
53	50.80	66	29.5	29.0	90.2	0.316	48.4	41.5	18.5	0.7
54	50.82	66	29.6	29.5	89.5	0.313	48.6	42.2	17.9	0.7
55	50.83	66	29.1	28.6	89.7	0.314	48.5	41.0	18.4	0.7
56	50.85	66	31.0	30.7	89.7	0.314	48.4	44.0	17.5	0.7
57	50.86	66	30.4	30.0	89.6	0.314	48.5	42.9	18.1	0.7
58	50.88	66	31.5	31.3	90.0	0.315	48.5	44.8	18.1	0.5
59	50.89	66	30.9	30.8	90.4	0.316	48.5	44.1	18.4	0.7
60	50.91	66	28.8	28.5	89.6	0.313	48.5	40.8	17.9	1.0
61	50.92	66	29.4	29.3	90.0	0.315	48.5	41.9	18.2	0.7
62	50.94	66	29.0	28.7	90.0	0.315	48.4	41.1	18.2	0.8
63	50.96	66	30.3	30.1	91.1	0.319	48.5	43.1	18.9	0.9
64	50.97	66	32.4	32.0	90.9	0.318	48.5	45.8	18.8	0.5
65	50.99	66	30.6	30.3	89.4	0.313	48.5	43.3	18.3	0.8
66	51.00	66	29.9	29.6	92.3	0.323	48.4	42.4	19.0	0.7
67	51.02	66	31.2	31.0	90.5	0.317	48.6	44.4	17.8	0.5
68	51.03	66	30.0	29.7	89.9	0.315	48.5	42.5	18.2	0.7
69	51.05	66	30.1	29.7	89.4	0.313	48.5	42.5	17.7	0.7
70	51.06	66	31.5	31.4	90.2	0.316	48.6	44.9	18.8	0.5
71	51.08	66	30.1	29.9	92.4	0.324	48.5	42.8	19.1	0.7
72	51.09	66	28.9	28.6	90.5	0.317	48.5	40.9	18.0	0.7
73	51.11	66	31.2	30.9	90.8	0.318	48.6	44.2	18.3	0.7
74	51.12	66	29.0	28.8	90.8	0.318	48.5	41.2	18.2	0.7
75	51.14	66	30.4	30.0	92.2	0.323	48.4	42.9	19.5	0.7
76	51.15	66	30.2	30.1	90.8	0.318	48.6	43.1	18.4	0.9
77	51.17	66	28.7	28.2	90.4	0.316	48.4	40.3	18.5	0.7
78	51.18	66	31.1	30.9	90.9	0.318	48.7	44.1	18.6	0.7
79	51.20	66	30.5	30.3	88.9	0.311	48.5	43.4	18.0	0.7
80	51.21	66	30.5	30.2	88.9	0.311	48.5	43.2	18.2	0.7
81	51.23	66	30.6	30.2	89.6	0.314	48.6	43.2	18.1	0.7
82	51.24	66	31.0	30.7	90.3	0.316	48.4	43.9	18.1	0.7
83	51.26	66	32.2	32.1	90.9	0.318	48.6	45.9	18.4	0.5
84	51.27	66	29.4	29.0	94.1	0.329	48.5	41.5	19.3	0.7
85	51.29	66	30.7	30.3	88.7	0.311	48.5	43.3	17.7	0.7
86	51.30	66	30.9	30.4	87.4	0.306	48.5	43.5	17.4	0.7
87	51.32	66	31.3	31.1	89.4	0.313	48.4	44.5	18.1	0.5
88	51.33	66	30.4	30.0	89.9	0.314	48.6	43.0	18.3	0.7
89	51.35	66	31.7	31.3	89.8	0.314	48.4	44.8	17.8	0.5
90	51.36	66	29.4	29.0	87.3	0.306	48.6	41.4	17.7	0.7
91	51.38	66	29.5	29.2	89.4	0.313	48.5	41.8	18.5	0.7
92	51.39	66	30.0	29.7	92.3	0.323	48.6	42.5	19.7	0.7
93	51.41	66	29.1	28.7	89.8	0.314	48.6	41.0	19.0	0.7
94	51.42	66	28.8	28.5	90.2	0.316	48.4	40.7	18.4	0.7
95	51.44	66	29.2	29.0	88.0	0.308	48.6	41.6	18.5	0.7
96	51.46	66	29.1	28.7	88.1	0.308	48.6	41.1	17.9	0.9
97	51.47	66	29.1	29.1	88.0	0.308	48.6	41.7	18.4	0.7
98	51.49	66	28.8	28.5	89.5	0.313	48.6	40.8	18.9	0.7
99	51.50	66	30.7	30.2	88.2	0.309	48.6	43.2	18.4	0.5

HOLT SERVICES, SOUND TRANSIT - SAMPLE 50 FT BH:E330-B28
OP: RMDT Test date: 17-Apr-2013

	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
Average	30.3	30.0	90.0	0.315	48.5	42.9	18.4	0.7
Std. Dev.	1.1	1.2	1.4	0.005	0.1	1.7	0.5	0.1
Maximum	33.5	33.2	94.1	0.329	48.7	47.6	19.7	1.1
Minimum	28.5	28.2	87.3	0.306	48.3	40.3	17.4	0.5

Total number of blows analyzed: 66

BL#	depth (ft)	Comments
1	50.02	Start of test on 4/17/2013 at 1:16:29 PM
99	51.50	End of test on 4/17/2013 at 1:18:30 PM

Time Summary

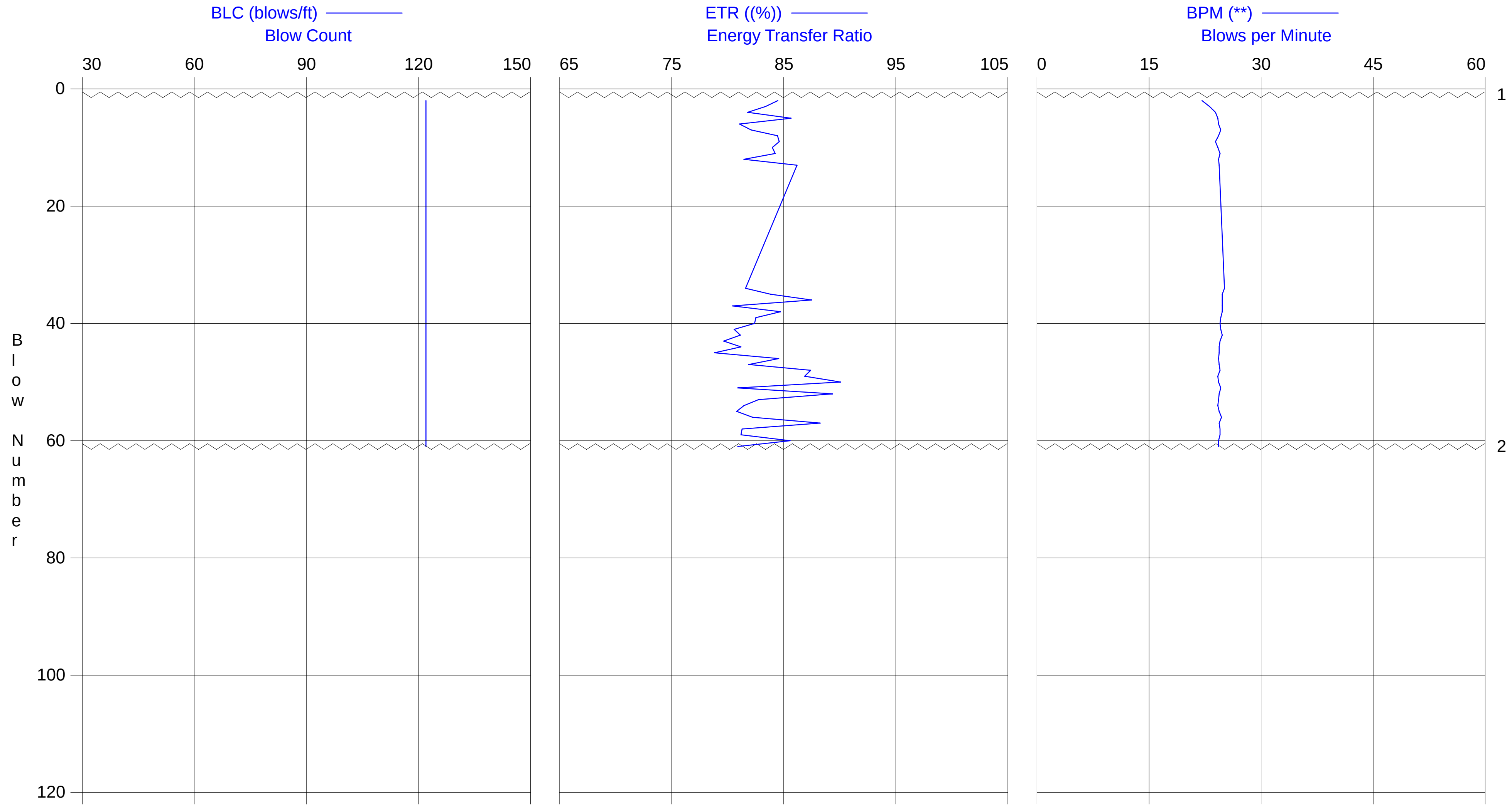
Drive	2 minutes 1 second	1:16:29 PM - 1:18:30 PM (4/17/2013) BN 1 - 99

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 17-Apr-2013

HOLT SERVICES, SOUND TRANSIT - SAMPLE 55 FT BH:E330-B28



1 - Start of test on 4/17/2013 at 2:05:19 PM

2 - End of test on 4/17/2013 at 2:08:52 PM

HOLT SERVICES, SOUND TRANSIT - SAMPLE 55 FT BH:E330-B28
OP: RMDT Test date: 17-Apr-2013

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 59.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
2	55.02	122	29.0	28.2	84.5	0.296	22.1	40.3	14.6	0.8
3	55.03	122	30.0	29.2	83.4	0.292	23.1	41.8	14.7	0.8
4	55.03	122	29.7	29.2	81.8	0.286	23.9	41.8	14.9	0.8
5	55.04	122	30.3	29.6	85.7	0.300	24.2	42.3	14.7	0.8
6	55.05	122	29.2	28.5	81.0	0.284	24.3	40.8	15.2	0.7
7	55.06	122	29.9	28.8	82.1	0.287	24.6	41.3	15.4	0.7
8	55.07	122	30.5	29.3	84.4	0.296	24.3	41.9	15.0	0.7
9	55.07	122	29.4	28.4	84.6	0.296	23.9	40.7	14.7	0.9
10	55.08	122	30.4	29.4	84.0	0.294	24.2	42.0	14.7	0.7
11	55.09	122	30.4	29.3	84.2	0.295	24.5	41.9	14.2	0.9
12	55.10	122	29.6	28.9	81.5	0.285	24.3	41.3	14.7	0.9
13	55.11	122	31.5	30.5	86.2	0.302	24.4	43.6	14.7	1.0
34	55.28	122	28.6	28.0	81.6	0.286	25.1	40.1	14.2	0.8
35	55.29	122	29.3	29.0	83.8	0.293	24.8	41.5	14.0	0.8
36	55.30	122	31.3	30.9	87.5	0.306	24.8	44.3	14.7	0.7
37	55.30	122	28.4	28.0	80.4	0.282	24.8	40.0	14.0	0.7
38	55.31	122	30.1	29.7	84.7	0.297	24.8	42.5	14.2	0.9
39	55.32	122	29.1	28.7	82.5	0.289	24.6	41.1	14.0	0.8
40	55.33	122	29.0	28.7	82.4	0.288	24.5	41.0	14.2	0.8
41	55.34	122	29.0	28.3	80.6	0.282	24.6	40.5	13.9	0.9
42	55.34	122	28.8	28.1	81.1	0.284	24.8	40.2	13.8	0.9
43	55.35	122	28.5	28.1	79.6	0.279	24.5	40.2	13.8	0.8
44	55.36	122	28.7	27.9	81.2	0.284	24.4	39.9	14.0	1.0
45	55.37	122	28.9	28.3	78.8	0.276	24.4	40.5	13.7	0.9
46	55.38	122	29.6	29.5	84.6	0.296	24.3	42.1	14.3	0.7
47	55.39	122	29.5	29.0	81.9	0.287	24.4	41.4	13.9	0.8
48	55.39	122	32.1	31.8	87.4	0.306	24.5	45.5	15.1	0.7
49	55.40	122	30.9	30.8	86.9	0.304	24.2	44.1	14.7	0.7
50	55.41	122	32.5	32.4	90.1	0.315	24.3	46.4	15.6	0.7
51	55.42	122	28.7	28.5	80.9	0.283	24.6	40.7	14.4	0.9
52	55.43	122	33.2	33.1	89.4	0.313	24.4	47.4	15.9	0.6
53	55.43	122	29.6	29.3	82.7	0.290	24.3	41.9	14.5	0.9
54	55.44	122	29.3	29.0	81.5	0.285	24.2	41.4	14.4	0.9
55	55.45	122	29.4	28.8	80.8	0.283	24.4	41.2	14.1	0.9
56	55.46	122	29.3	29.0	82.2	0.288	24.7	41.5	14.4	0.9
57	55.47	122	32.3	32.3	88.3	0.309	24.4	46.1	16.2	0.7
58	55.48	122	28.6	28.1	81.3	0.284	24.5	40.3	13.9	0.9
59	55.48	122	29.3	28.9	81.2	0.284	24.5	41.3	14.5	0.7
60	55.49	122	30.8	30.5	85.6	0.300	24.3	43.6	14.8	0.7
61	55.50	122	29.1	28.4	80.9	0.283	24.3	40.6	14.8	0.9
		Average	29.8	29.3	83.3	0.292	24.4	41.9	14.5	0.8
		Std. Dev.	1.2	1.3	2.7	0.009	0.5	1.8	0.6	0.1
		Maximum	33.2	33.1	90.1	0.315	25.1	47.4	16.2	1.0
		Minimum	28.4	27.9	78.8	0.276	22.1	39.9	13.7	0.6

Total number of blows analyzed: 40

BL#	depth (ft)	Comments
1	55.01	Start of test on 4/17/2013 at 2:05:19 PM
61	55.50	End of test on 4/17/2013 at 2:08:52 PM

Time Summary

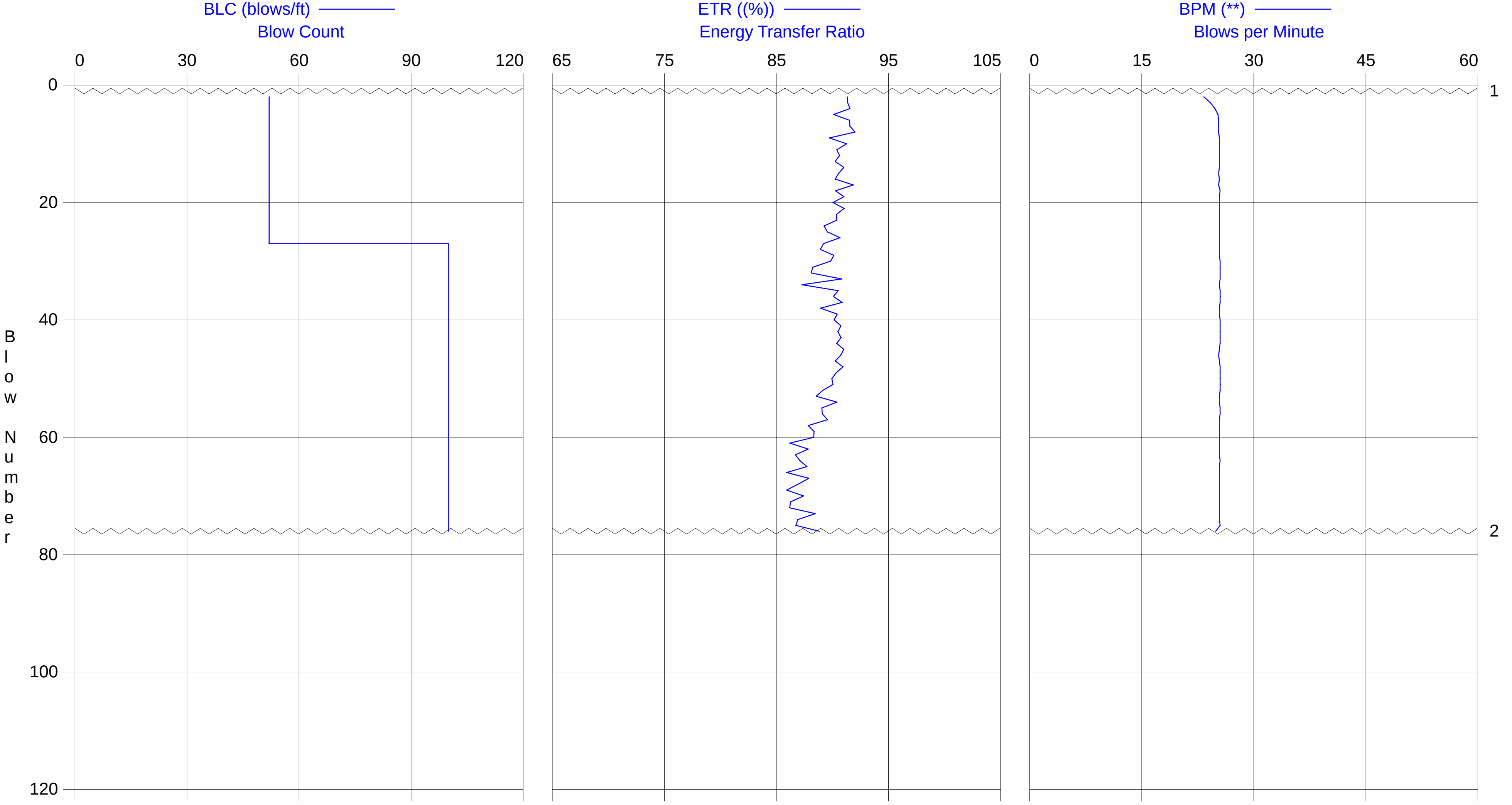
Drive 3 minutes 33 seconds 2:05:19 PM - 2:08:52 PM (4/17/2013) BN 1 - 61

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 17-Apr-2013

HOLT SERVICES, SOUND TRANSIT - SAMPLE 60 FT BH:E330-B28



1 - Start of test on 4/17/2013 at 2:36:38 PM

2 - End of test on 4/17/2013 at 2:39:35 PM

HOLT SERVICES, SOUND TRANSIT - SAMPLE 60 FT BH:E330-B28
OP: RMDT Test date: 17-Apr-2013

AR: 1.43 in^2 SP: 0.492 k/ft3
LE: 64.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
27	60.51	100	30.1	29.6	89.2	0.312	25.4	42	16.2	0.6
28	60.52	100	30.1	29.6	88.9	0.311	25.4	42	16.3	0.6
29	60.53	100	30.1	29.7	90.1	0.315	25.4	42	16.3	0.6
30	60.54	100	30.3	29.7	89.8	0.314	25.5	42	16.3	0.5
31	60.55	100	30.3	29.6	88.2	0.309	25.5	42	16.1	0.6
32	60.56	100	30.2	29.7	88.1	0.308	25.5	42	16.0	0.6
33	60.57	100	30.3	29.8	90.8	0.318	25.5	43	16.4	0.5
34	60.58	100	30.1	29.6	87.3	0.306	25.4	42	16.0	0.6
35	60.59	100	30.0	29.5	90.5	0.317	25.5	42	16.4	0.5
36	60.60	100	29.7	29.2	90.1	0.315	25.5	42	16.4	0.6
37	60.61	100	30.0	29.5	90.9	0.318	25.5	42	16.5	0.5
38	60.62	100	30.0	29.6	88.9	0.311	25.4	42	16.2	0.5
39	60.63	100	30.0	29.5	90.4	0.316	25.4	42	16.4	0.5
40	60.64	100	29.8	29.4	90.2	0.316	25.5	42	16.4	0.6
41	60.65	100	30.0	29.4	90.7	0.318	25.5	42	16.5	0.5
42	60.66	100	29.7	29.2	90.5	0.317	25.5	42	16.2	0.5
43	60.67	100	29.6	29.1	90.8	0.318	25.5	42	16.2	0.5
44	60.68	100	29.7	29.2	90.4	0.316	25.5	42	16.2	0.5
45	60.69	100	29.8	29.2	91.0	0.319	25.4	42	16.3	0.5
46	60.70	100	29.4	28.9	90.7	0.318	25.3	41	16.2	0.5
47	60.71	100	29.5	28.9	90.2	0.316	25.4	41	16.2	0.5
48	60.72	100	29.7	29.3	90.9	0.318	25.5	42	16.0	0.5
49	60.73	100	29.6	29.0	90.3	0.316	25.5	42	16.4	0.6
50	60.74	100	29.4	28.9	89.9	0.315	25.5	41	16.2	0.6
51	60.75	100	29.4	28.9	90.0	0.315	25.5	41	16.1	0.6
52	60.76	100	29.4	28.7	89.1	0.312	25.5	41	16.0	0.6
53	60.77	100	29.3	28.9	88.6	0.310	25.4	41	15.9	0.6
54	60.78	100	29.3	28.8	90.4	0.316	25.4	41	16.1	0.6
55	60.79	100	29.2	28.7	89.1	0.312	25.5	41	16.0	0.6
56	60.80	100	29.4	29.0	89.1	0.312	25.5	41	15.8	0.6
57	60.81	100	29.5	29.0	89.6	0.313	25.4	41	16.1	0.6
58	60.82	100	29.2	28.7	87.8	0.307	25.4	41	16.0	0.6
59	60.83	100	29.4	28.8	88.4	0.309	25.4	41	15.9	0.6
60	60.84	100	29.0	28.5	88.3	0.309	25.4	41	16.0	0.6
61	60.85	100	29.4	28.9	86.2	0.302	25.4	41	15.5	0.6
62	60.86	100	29.8	29.2	87.8	0.307	25.4	42	15.6	0.6
63	60.87	100	29.6	29.0	86.7	0.303	25.4	41	15.5	0.6
64	60.88	100	28.5	28.0	87.1	0.305	25.5	40	15.9	0.6
65	60.89	100	28.6	28.1	87.7	0.307	25.4	40	15.8	0.6
66	60.90	100	28.4	27.8	85.9	0.301	25.4	40	15.9	0.6
67	60.91	100	28.7	28.1	87.9	0.308	25.4	40	16.1	0.6
68	60.92	100	28.2	27.7	86.9	0.304	25.4	40	16.3	0.6
69	60.93	100	27.8	27.4	85.9	0.301	25.4	39	16.5	0.6
70	60.94	100	28.3	27.8	87.4	0.306	25.4	40	16.5	0.6
71	60.95	100	28.0	27.5	86.3	0.302	25.4	39	16.6	0.6
72	60.96	100	27.3	26.7	86.2	0.302	25.4	38	16.7	0.6
73	60.97	100	27.7	27.0	88.5	0.310	25.4	39	17.1	0.6
74	60.98	100	27.2	26.6	86.9	0.304	25.4	38	17.1	0.6
75	60.99	100	27.4	26.8	86.7	0.304	25.5	38	17.0	0.6
76	61.00	100	27.3	26.7	88.8	0.311	24.9	38	17.4	0.6
		Average	29.3	28.7	88.9	0.311	25.4	41	16.2	0.6
		Std. Dev.	0.9	0.9	1.6	0.005	0.1	1	0.4	0.1
		Maximum	30.3	29.8	91.0	0.319	25.5	43	17.4	0.6
		Minimum	27.2	26.6	85.9	0.301	24.9	38	15.5	0.5

Total number of blows analyzed: 50

BL#	depth (ft)	Comments
1	60.02	Start of test on 4/17/2013 at 2:36:38 PM
76	61.00	End of test on 4/17/2013 at 2:39:35 PM

Time Summary

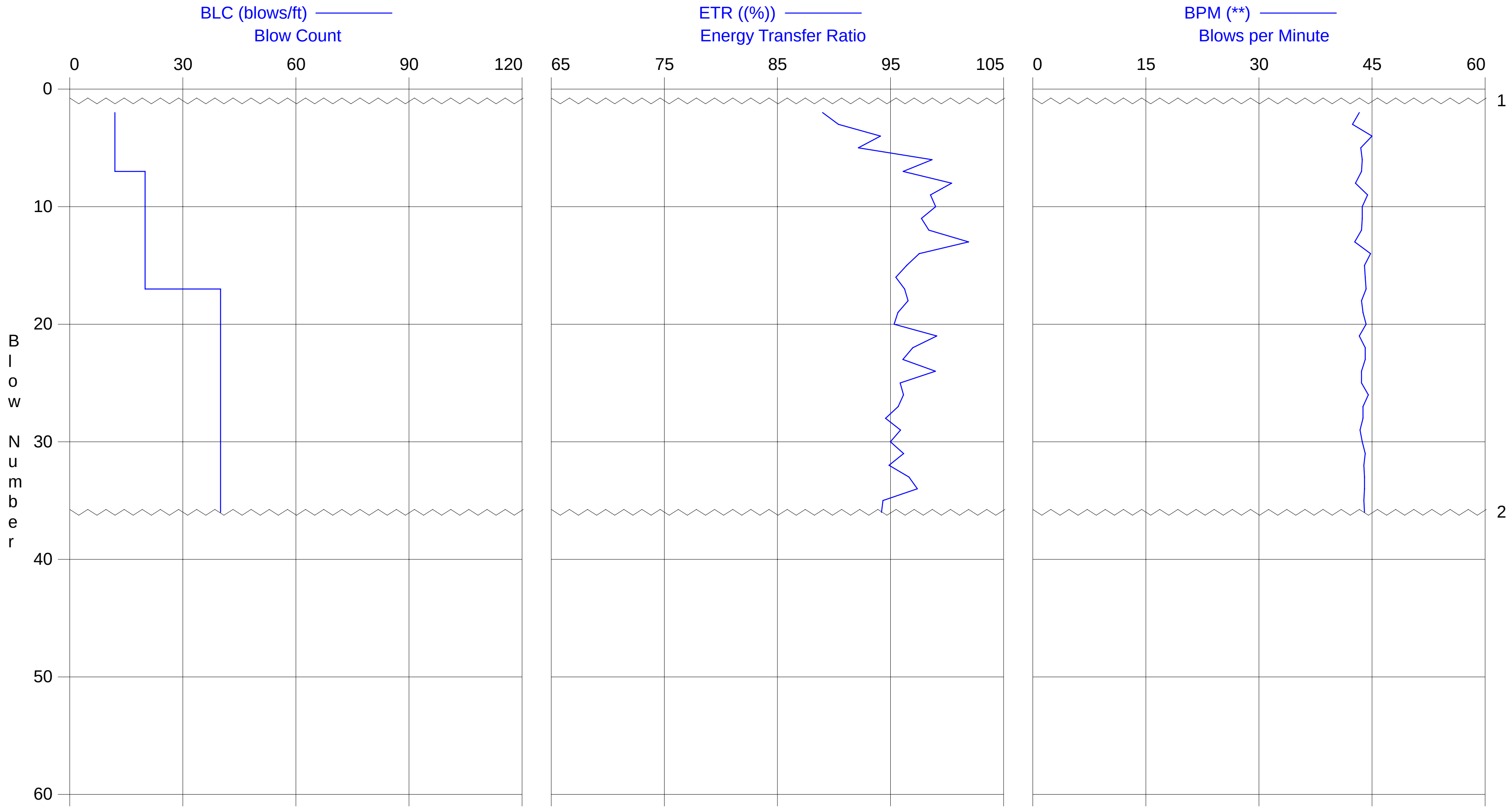
Drive 2 minutes 57 seconds 2:36:38 PM - 2:39:35 PM (4/17/2013) BN 1 - 76

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 19-Apr-2013

HOLT SERVICES, SONIC - SAMPLE 20 FT E340-B-12, 140LB MOBILE AUTO



1 - Start of test on 4/19/2013 at 10:59:50 AM

2 - End of test on 4/19/2013 at 11:00:38 AM

HOLT SERVICES, SONIC - SAMPLE 20 FT E340-B-12, 140LB MOBILE AUTO
OP: RMDT Test date: 19-Apr-2013

AR: 1.20 in^2 SP: 0.492 k/ft3
LE: 23.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
7	20.55	20	23.7	21.9	96.1	0.336	43.6	26	13.6	1.1
8	20.60	20	23.4	21.6	100.4	0.351	42.8	26	13.5	1.1
9	20.65	20	23.7	22.2	98.5	0.345	44.4	27	13.5	1.1
10	20.70	20	24.0	22.3	99.0	0.346	43.7	27	13.5	1.1
11	20.75	20	23.4	21.9	97.7	0.342	43.7	26	13.5	1.1
12	20.80	20	23.3	21.6	98.4	0.344	43.6	26	13.5	1.1
13	20.85	20	23.4	21.7	101.9	0.357	42.7	26	13.9	1.1
14	20.90	20	22.8	20.9	97.5	0.341	44.8	25	13.8	1.1
15	20.95	20	22.3	20.6	96.4	0.338	44.0	25	12.9	1.1
16	21.00	20	22.2	20.6	95.5	0.334	44.1	25	12.8	1.1
17	21.03	40	22.1	20.4	96.2	0.337	44.2	24	13.1	1.1
18	21.05	40	22.3	20.4	96.6	0.338	43.6	25	13.2	1.1
19	21.08	40	22.8	21.1	95.7	0.335	43.8	25	13.4	1.1
20	21.10	40	22.6	21.2	95.3	0.334	44.2	25	13.5	1.1
21	21.13	40	22.2	20.7	99.1	0.347	43.3	25	13.9	1.1
22	21.15	40	22.5	20.8	97.0	0.339	44.1	25	14.4	1.1
23	21.18	40	22.6	21.5	96.1	0.336	44.1	26	14.3	1.1
24	21.20	40	22.6	21.4	99.0	0.346	43.6	26	14.5	1.1
25	21.23	40	23.1	21.6	95.9	0.335	43.6	26	14.1	1.1
26	21.25	40	22.3	20.8	96.1	0.336	44.5	25	13.6	1.1
27	21.28	40	22.3	20.9	95.7	0.335	43.8	25	14.4	1.1
28	21.30	40	23.0	21.1	94.6	0.331	43.8	25	14.4	1.1
29	21.33	40	22.9	21.3	95.9	0.336	43.4	26	13.7	1.1
30	21.35	40	22.9	21.1	95.0	0.332	43.7	25	14.5	1.1
31	21.38	40	22.2	20.5	96.2	0.337	44.1	25	14.2	1.1
32	21.40	40	22.5	20.6	94.9	0.332	43.9	25	14.6	1.1
33	21.43	40	22.8	20.8	96.6	0.338	44.0	25	15.0	1.1
34	21.45	40	22.7	21.0	97.4	0.341	44.0	25	15.4	1.1
35	21.48	40	22.7	20.9	94.3	0.330	43.9	25	14.3	1.1
36	21.50	40	22.0	20.6	94.2	0.330	44.0	25	14.5	1.1
		Average	22.8	21.1	96.8	0.339	43.8	25	13.9	1.1
		Std. Dev.	0.5	0.5	1.8	0.006	0.4	1	0.6	0.0
		Maximum	24.0	22.3	101.9	0.357	44.8	27	15.4	1.1
		Minimum	22.0	20.4	94.2	0.330	42.7	24	12.8	1.1

Total number of blows analyzed: 30

BL#	depth (ft)	Comments
1	20.08	Start of test on 4/19/2013 at 10:59:50 AM
36	21.50	End of test on 4/19/2013 at 11:00:38 AM

Time Summary

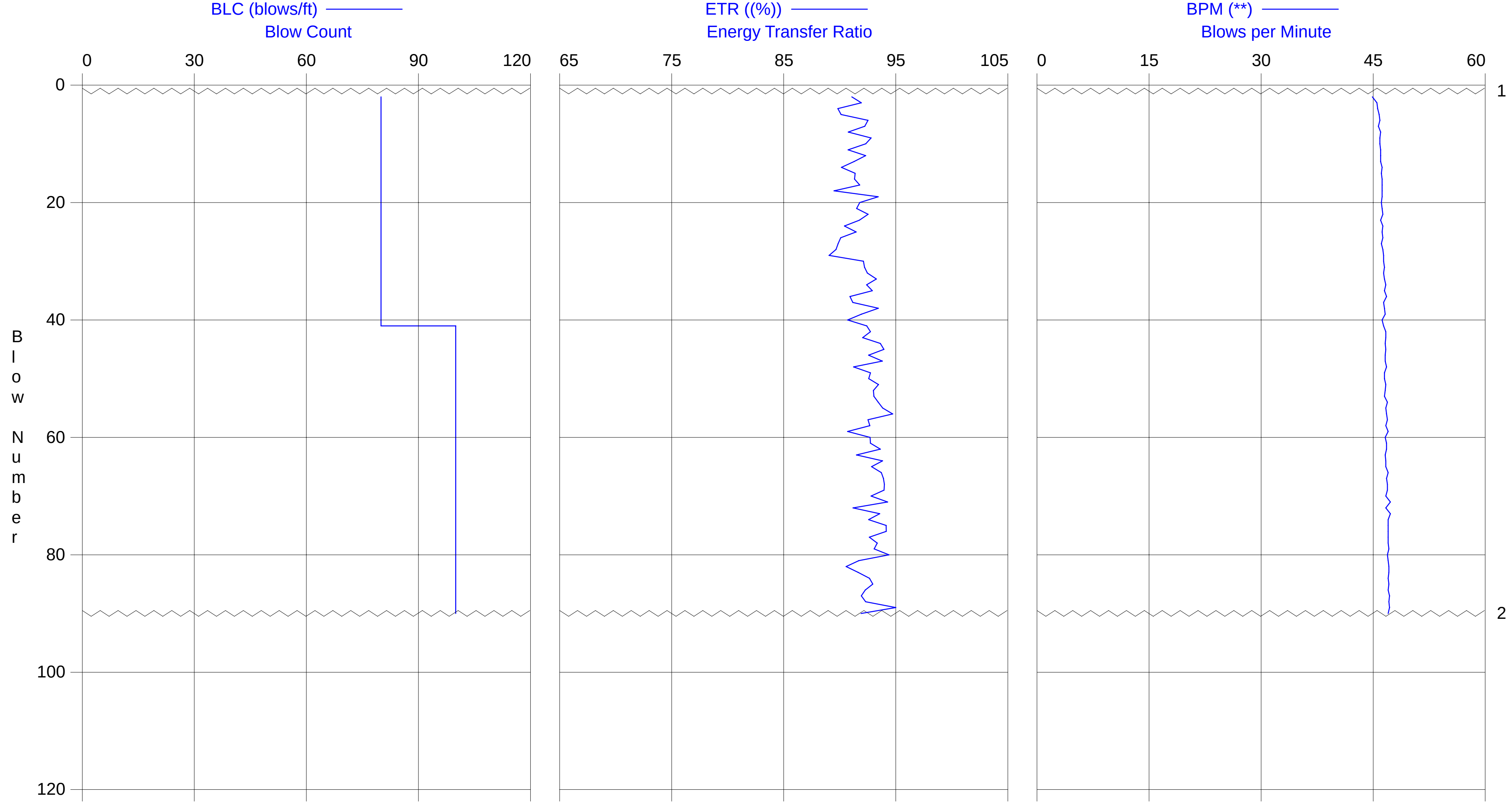
Drive 48 seconds 10:59:50 AM - 11:00:38 AM (4/19/2013) BN 1 - 36

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 19-Apr-2013

HOLT SERVICES, SONIC - SAMPLE 30 FT E340-B-12, 140LB MOBILE AUTO



1 - Start of test on 4/19/2013 at 11:37:49 AM

2 - End of test on 4/19/2013 at 11:39:43 AM

HOLT SERVICES, SONIC - SAMPLE 30 FT E340-B-12, 140LB MOBILE AUTO
OP: RMDT Test date: 19-Apr-2013

AR: 1.20 in^2 SP: 0.492 k/ft3
LE: 33.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress BPM: Blows per Minute
CSX: Max Measured Compr. Stress FMX: Maximum Force
ETR: Energy Transfer Ratio VMX: Maximum Velocity
EFV: Energy of FV RAT: SPT Length Ratio

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]
41	30.51	100	24.8	24.4	92.4	0.323	46.4	29	14.7	1.1
42	30.52	100	24.5	24.0	92.7	0.325	46.7	29	14.6	1.1
43	30.53	100	24.5	24.1	92.0	0.322	46.7	29	14.0	1.1
44	30.54	100	24.5	24.4	93.6	0.328	46.6	29	14.6	1.1
45	30.55	100	25.0	24.5	93.9	0.329	46.7	29	14.4	1.1
46	30.56	100	25.2	24.7	92.6	0.324	46.6	30	13.7	1.1
47	30.57	100	25.7	25.1	93.8	0.328	46.6	30	14.0	1.1
48	30.58	100	25.1	24.7	91.2	0.319	46.8	30	13.8	1.1
49	30.59	100	24.9	24.4	92.7	0.325	46.5	29	14.0	1.1
50	30.60	100	24.1	23.9	92.6	0.324	46.5	29	14.7	1.1
51	30.61	100	24.7	24.4	93.5	0.327	46.7	29	14.5	1.1
52	30.62	100	24.6	24.5	93.0	0.326	46.6	29	14.7	1.1
53	30.63	100	24.9	24.7	93.0	0.326	46.5	30	14.4	1.1
54	30.64	100	24.9	24.5	93.4	0.327	46.9	29	14.8	1.1
55	30.65	100	25.5	25.0	93.8	0.328	46.7	30	14.1	1.1
56	30.66	100	25.8	25.3	94.7	0.332	46.8	30	14.6	1.1
57	30.67	100	26.0	25.2	92.5	0.324	46.9	30	14.1	1.1
58	30.68	100	24.7	24.1	92.7	0.324	46.7	29	14.3	1.1
59	30.69	100	24.3	23.9	90.7	0.317	47.0	29	14.3	1.1
60	30.70	100	24.8	24.6	92.7	0.324	46.6	30	14.6	1.1
61	30.71	100	25.2	24.9	92.7	0.325	46.8	30	14.7	1.1
62	30.72	100	24.8	23.6	93.6	0.328	46.8	28	14.4	1.1
63	30.73	100	24.6	24.1	91.5	0.320	46.6	29	14.4	1.1
64	30.74	100	25.2	25.0	93.8	0.328	46.7	30	14.6	1.1
65	30.75	100	25.8	25.0	92.8	0.325	46.7	30	14.3	1.1
66	30.76	100	24.7	24.3	93.7	0.328	47.0	29	14.7	1.1
67	30.77	100	24.9	24.2	93.9	0.329	46.8	29	14.5	1.1
68	30.78	100	23.7	23.3	94.0	0.329	46.9	28	15.0	1.1
69	30.79	100	25.3	24.9	94.0	0.329	46.9	30	14.4	1.1
70	30.80	100	25.6	24.5	92.8	0.325	46.7	29	15.0	1.1
71	30.81	100	26.5	25.2	94.3	0.330	47.3	30	14.8	1.1
72	30.82	100	26.5	25.1	91.2	0.319	46.7	30	14.6	1.1
73	30.83	100	27.6	26.2	93.6	0.327	47.3	31	14.2	1.1
74	30.84	100	27.4	26.7	92.6	0.324	47.0	32	15.1	1.1
75	30.85	100	28.0	27.1	94.1	0.329	47.0	33	14.6	1.1
76	30.86	100	27.6	27.2	94.2	0.330	47.0	33	14.6	1.1
77	30.87	100	28.2	27.6	92.6	0.324	47.0	33	14.4	1.1
78	30.88	100	28.7	28.3	93.3	0.327	47.0	34	14.5	1.1
79	30.89	100	29.7	28.6	93.1	0.326	47.1	34	15.7	1.1
80	30.90	100	28.2	27.7	94.4	0.330	46.9	33	14.9	1.1
81	30.91	100	29.9	28.7	91.7	0.321	47.0	34	15.2	1.1
82	30.92	100	28.5	27.9	90.6	0.317	47.1	34	14.9	1.1
83	30.93	100	29.5	28.5	91.6	0.321	47.1	34	15.0	1.1
84	30.94	100	30.4	28.6	92.7	0.324	47.0	34	15.2	1.1
85	30.95	100	28.4	27.5	92.9	0.325	47.1	33	14.7	1.1
86	30.96	100	28.5	28.1	92.3	0.323	47.0	34	14.6	1.1
87	30.97	100	28.5	28.2	91.9	0.322	47.2	34	15.0	1.1
88	30.98	100	29.2	28.4	92.3	0.323	47.1	34	14.7	1.1
89	30.99	100	28.9	28.4	95.0	0.332	47.2	34	14.8	1.1
90	31.00	100	30.3	28.6	91.9	0.322	47.0	34	15.2	1.1
		Average	26.4	25.7	92.9	0.325	46.9	31	14.6	1.1
		Std. Dev.	1.9	1.7	1.0	0.004	0.2	2	0.4	0.0
		Maximum	30.4	28.7	95.0	0.332	47.3	34	15.7	1.1
		Minimum	23.7	23.3	90.6	0.317	46.4	28	13.7	1.1

Total number of blows analyzed: 50

BL#	depth (ft)	Comments
1	30.01	Start of test on 4/19/2013 at 11:37:49 AM
90	31.00	End of test on 4/19/2013 at 11:39:43 AM

Time Summary

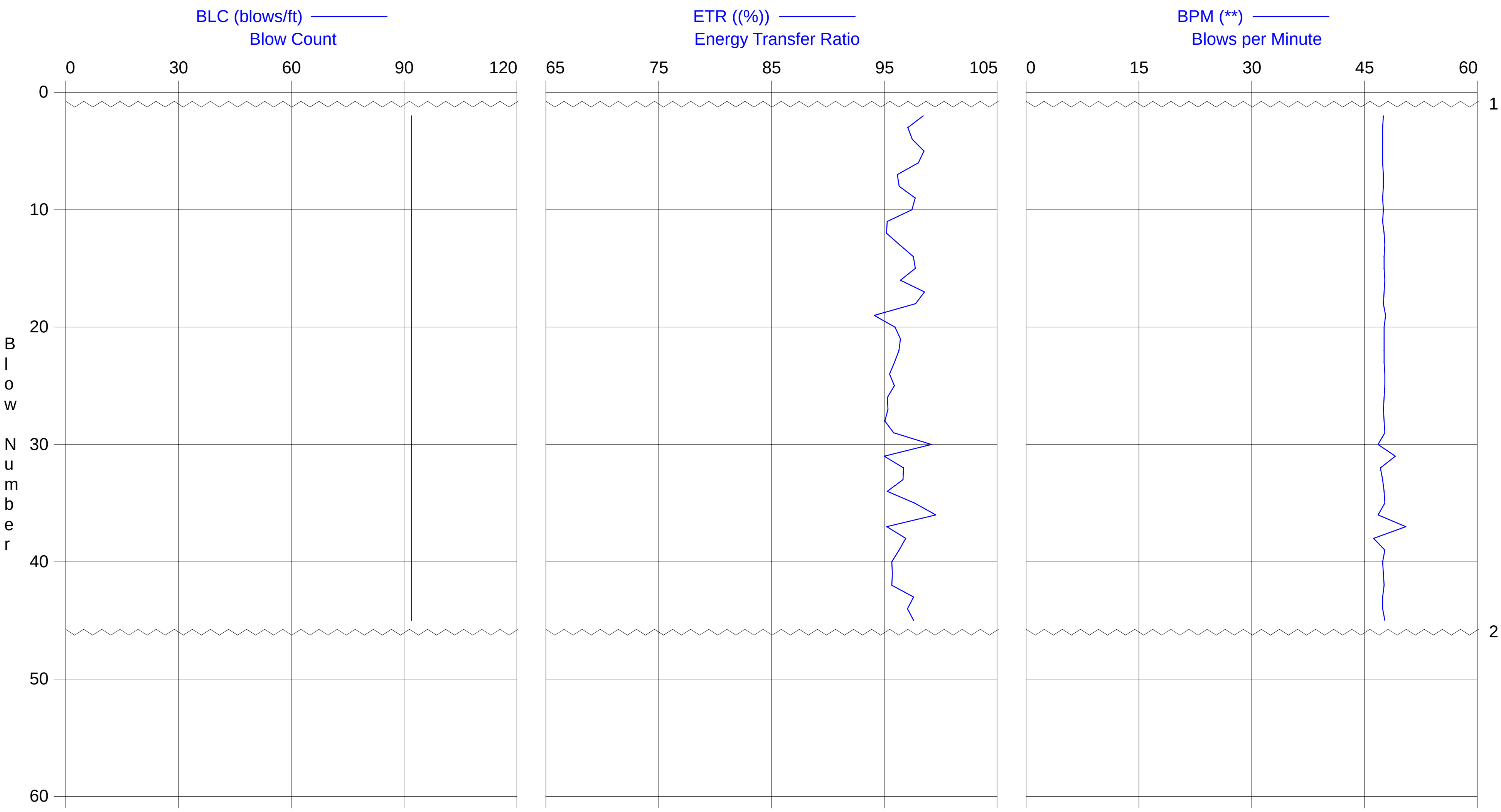
Drive 1 minute 54 seconds 11:37:49 AM - 11:39:43 AM (4/19/2013) BN 1 - 90

Robert Miner Dynamic Testing, Inc. - Case Method & iCAP® Results

PDIPLOT Ver. 2012.2 - Printed: 26-Apr-2013

Test date: 19-Apr-2013

HOLT SERVICES, SONIC - SAMPLE 45 FT E340-B-12, 140LB MOBILE AUTO



1 - Start of test on 4/19/2013 at 1:57:55 PM

2 - End of test on 4/19/2013 at 1:58:55 PM

HOLT SERVICES, SONIC - SAMPLE 45 FT E340-B-12, 140LB MOBILE AUTO
OP: RMDT Test date: 19-Apr-2013

AR: 1.20 in^2 SP: 0.492 k/ft3
LE: 48.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.35

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
ETR: Energy Transfer Ratio
EFV: Energy of FV
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RAT: SPT Length Ratio
CSB: Compression Stress at Bottom

BL#	depth	BLC	CSI	CSX	ETR	EFV	BPM	FMX	VMX	RAT	CSB
	ft	bl/ft	ksi	ksi	(%)	k-ft	**	kips	f/s	[]	ksi
2	45.02	92	23.4	23.0	98.4	0.345	47.5	28	15.4	1.1	23.0
3	45.03	92	24.2	23.9	97.1	0.340	47.4	29	15.9	1.1	24.3
4	45.04	92	22.8	22.4	97.5	0.341	47.4	27	15.9	1.1	23.6
5	45.05	92	23.7	23.7	98.5	0.345	47.4	28	15.9	1.1	22.8
6	45.07	92	23.2	22.6	98.0	0.343	47.4	27	15.9	1.1	24.1
7	45.08	92	22.8	22.1	96.2	0.337	47.5	26	15.7	1.1	22.5
8	45.09	92	23.1	22.9	96.3	0.337	47.5	27	15.9	1.1	23.7
9	45.10	92	24.1	23.0	97.7	0.342	47.4	28	15.6	1.1	22.7
10	45.11	92	22.7	21.8	97.5	0.341	47.5	26	15.6	1.1	23.4
11	45.12	92	22.9	22.0	95.3	0.333	47.4	26	15.4	1.1	22.5
12	45.13	92	23.6	23.0	95.2	0.333	47.6	28	15.5	1.1	20.4
13	45.14	92	23.9	23.5	96.4	0.337	47.7	28	15.1	1.1	19.7
14	45.15	92	23.5	23.4	97.6	0.342	47.6	28	14.9	1.1	20.1
15	45.16	92	22.5	22.3	97.8	0.342	47.6	27	15.4	1.1	21.4
16	45.17	92	24.5	23.8	96.4	0.338	47.7	29	15.2	1.1	21.5
17	45.18	92	23.8	23.5	98.6	0.345	47.6	28	15.0	1.1	21.4
18	45.20	92	22.6	22.3	97.8	0.342	47.5	27	15.2	1.1	23.0
19	45.21	92	22.3	21.8	94.1	0.329	47.8	26	15.3	1.1	23.6
20	45.22	92	23.1	23.0	96.0	0.336	47.6	28	15.2	1.1	23.5
21	45.23	92	23.6	23.1	96.4	0.337	47.6	28	15.3	1.1	23.1
22	45.24	92	23.0	22.9	96.3	0.337	47.6	27	14.7	1.1	23.5
23	45.25	92	24.0	23.4	95.9	0.336	47.6	28	15.5	1.1	24.0
24	45.26	92	24.1	23.5	95.5	0.334	47.7	28	15.4	1.1	24.0
25	45.27	92	23.7	23.3	95.9	0.336	47.7	28	15.3	1.1	23.5
26	45.28	92	24.7	23.1	95.3	0.333	47.6	28	15.4	1.1	24.1
27	45.29	92	23.3	22.4	95.3	0.334	47.5	27	14.7	1.1	24.0
28	45.30	92	22.3	21.9	95.1	0.333	47.6	26	14.7	1.1	22.9
29	45.32	92	22.1	21.8	95.8	0.335	47.7	26	15.3	1.1	23.8
30	45.33	92	23.7	23.1	99.2	0.347	46.8	28	15.6	1.1	24.8
31	45.34	92	24.7	23.7	95.0	0.332	49.1	28	14.6	1.1	22.7
32	45.35	92	22.6	22.5	96.7	0.338	47.1	27	14.6	1.1	23.7
33	45.36	92	21.9	21.6	96.7	0.338	47.4	26	14.4	1.1	24.1
34	45.37	92	24.0	23.3	95.3	0.333	47.6	28	14.9	1.1	25.8
35	45.38	92	24.1	23.7	97.7	0.342	47.7	28	14.3	1.1	23.3
36	45.39	92	23.8	23.2	99.6	0.349	46.8	28	14.5	1.1	23.2
37	45.40	92	22.8	22.6	95.2	0.333	50.5	27	14.2	1.1	22.2
38	45.41	92	22.2	21.9	96.9	0.339	46.2	26	14.5	1.1	22.8
39	45.42	92	22.0	21.9	96.3	0.337	47.7	26	14.5	1.1	21.5
40	45.43	92	23.3	22.7	95.7	0.335	47.4	27	14.7	1.1	22.6
41	45.45	92	22.4	22.3	95.7	0.335	47.5	27	14.6	1.1	21.2
42	45.46	92	22.8	22.3	95.7	0.335	47.6	27	15.3	1.1	22.7
43	45.47	92	22.8	22.5	97.6	0.342	47.4	27	15.1	1.1	21.3
44	45.48	92	22.5	22.1	97.1	0.340	47.4	26	15.3	1.1	22.7
45	45.49	92	22.4	22.2	97.6	0.342	47.7	27	15.1	1.1	21.7
		Average	23.2	22.7	96.6	0.338	47.6	27	15.1	1.1	22.9
		Std. Dev.	0.7	0.6	1.2	0.004	0.6	1	0.5	0.0	1.2
		Maximum	24.7	23.9	99.6	0.349	50.5	29	15.9	1.1	25.8
		Minimum	21.9	21.6	94.1	0.329	46.2	26	14.2	1.1	19.7

Total number of blows analyzed: 44

BL#	depth (ft)	Comments
1	45.01	Start of test on 4/19/2013 at 1:57:55 PM
46	45.50	End of test on 4/19/2013 at 1:58:55 PM

Time Summary

Drive 1 minute 1:57:55 PM - 1:58:55 PM (4/19/2013) BN 1 - 46

Report 6
Holt Mobile B-54

Job No. 186004-1

Report on:
Dynamic Energy Measurements
SPT Rig Calibration Project
Portland, Oregon

Prepared for Holt Services, Inc.
By Marty Bixler and Diego Campos

March 20, 2018

GRL engineers, inc.
Dynamic Measurements and Analyses

March 20, 2018

Dale Smith
Holt Services, Inc.
10621 Todd Road, E
Edgewood, WA 98372

Re: Energy Measurement for Dynamic Penetrometers
Standard Penetration Tests (SPT)
Portland, Oregon GRL Job No. 186004-1

Dear Mr. Smith:

This report transmits our findings from energy measurements and related data analysis conducted by GRL Engineers, Inc. (GRL) for your Mobile B-54 track-rig operating in Portland, Oregon. One automatic hammer and penetrometer system was monitored during Standard Penetration Tests. Dynamic testing summarized in this report was conducted on March 19, 2018.

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 the appended tables with the average and standard deviation provided in Appendix B together with representative plots of force and normalized velocity.

EQUIPMENT

Hammer and Penetrometer System

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

Drill Rig Type
Mobile B-54 Track-rig #9
SN 2010009

Measurements were recorded for two boring locations; B3 and B4. Holt Services, Inc. advanced the penetrometer to depths of approximately 16½ feet at each boring location with relatively little resistance, and then encountered relatively high resistance conditions. The instrumented subassembly was connected to the top of the drill rod string and measurements recorded at intervals for several depths of data. Selected data presented in this report is from depths of approximately 20 and 23 feet for boring B3 and a depth of approximately 20 feet for boring B4.

Measurements were recorded for each blow required to advance the sampler. Results are provided for typically 12 inches (or less when refusal conditions were encountered) of the sampler advancement (i.e., excluding the initial 6 inches of advancement when the penetrometer was able to advance the full 18 inches) for the averaging of results. Please refer to ASTM D4633 regarding recommendations on blow counts and instrumented drill rod lengths, as well as other details of the test method.

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

Drill Rod Area sq. inch	Outside Diameter Inch	Inside Diameter inch
1.45	2.63	2.25

Note that these are the rod size dimensions for the instrumented section used for the testing, as well as the drill rod string. A split spoon sampler was used as the penetrometer.

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, was used 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 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 the appended tables. 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:

$$EFV = \int_{b}^{a} F(t)v(t)dt$$

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., 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.

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 relevant samples are presented herein.

The tables 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
- EFV – the maximum calculated energy (EMX) transferred to the rod top
- 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.

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

Summary of Results

I. The automatic hammer was monitored during standard penetration tests conducted on March 19, 2018. The average energy transfer ratio calculated with the EFV method for the monitored sequences for the drill rigs are tabulated below together with the corresponding, average hammer operating rates.

Drill Rig	Energy Transfer Ratio percent	Operating Rate bpm
Mobile B-54 Rig #9	**88.2**	41.5

Please note the first two samples obtained from the rig obtained transfer efficiencies of 85.4 and 89.5 percent, and the third sample had a transfer efficiency of 89.6 percent.

II. The uncorrected N-values encountered during the sequences ranged from 80 to 94.

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 the measurements and monitored depths meeting ASTM requirements are presented in the appended tables. The measured overall energy transfer ratio tabulated above for the drill rig produce an N_{60} equivalent of roughly $1.47N_m$. Further corrections due to overburden stresses in the soil may be made prior to use of the N-values for design purposes.

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.

REGISTERED PROFESSIONAL ENGINEER
89606PE
Marty G. Bixler 3-20-18
OREGON
SEP 9, 2014
MARTY G. BIXLER
RENEWAL DATE: 12-31-19

Diego Campos

Marty G. Bixler, P.E. (Oregon #89606)
Senior Engineer

Diego Campos, E.I.
Staff Engineer

APPENDIX A
AN INTRODUCTION INTO SPT DYNAMIC PILE 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.

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

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.

Appendix B

Results of SPT Rig Calibration

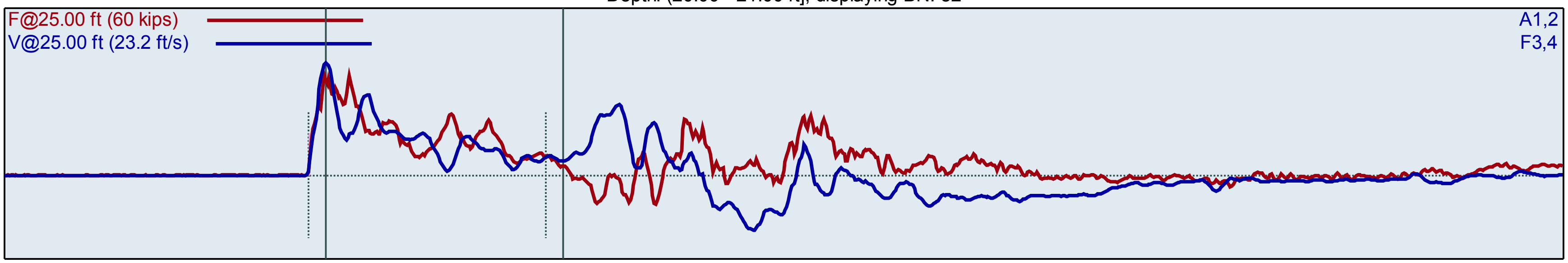
MOBILE B-54 RIG 9
GRL-MGB

20-B3
Test date: 3/19/2018

AR: 1.45 in^2
LE: 25.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (20.00 - 21.00 ft], displaying BN: 82



F3 : [292NWJ] 215.95 PDICAL (1) FF1
F4 : [292NWJ-2] 216.67 PDICAL (1) FF1

A1 (PR): [K4422] 400 mv/6.4v/5000g (1) VF1
A2 (PR): [K4981] 322 mv/6.4v/5000g (1) VF1

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute

EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	%
1	34	20.01	38	13.9	52.9	293.7	83.9
2	34	20.03	37	11.8	48.4	286.5	81.9
3	34	20.04	34	11.4	46.6	280.5	80.1
4	34	20.06	34	11.1	43.8	284.7	81.3
5	34	20.07	34	12.7	43.2	292.6	83.6
6	34	20.09	34	12.4	43.3	295.9	84.5
7	34	20.10	37	13.9	43.4	299.0	85.4
8	34	20.12	36	14.1	43.3	293.3	83.8
9	34	20.13	35	14.1	43.5	293.7	83.9
10	34	20.15	35	14.2	42.9	293.3	83.8
11	34	20.16	35	14.2	43.0	292.2	83.5
12	34	20.18	36	14.7	42.8	302.5	86.4
13	34	20.19	34	14.5	42.9	286.2	81.8
14	34	20.21	35	14.6	43.0	305.4	87.3
15	34	20.22	33	14.8	43.0	292.3	83.5

16	34	20.24	35	15.1	42.8	298.6	85.3
17	34	20.25	35	15.1	42.5	303.9	86.8
18	34	20.26	34	15.1	42.4	301.6	86.2
19	34	20.28	35	15.2	42.3	303.9	86.8
20	34	20.29	34	15.4	42.4	296.5	84.7
21	34	20.31	35	15.2	42.2	307.2	87.8
22	34	20.32	35	15.2	42.3	302.6	86.5
23	34	20.34	35	15.2	42.4	305.1	87.2
24	34	20.35	34	15.4	42.1	303.9	86.8
25	34	20.37	36	15.0	41.9	309.8	88.5
26	34	20.38	35	15.3	42.0	302.9	86.5
27	34	20.40	35	15.3	41.8	301.9	86.3
28	34	20.41	34	15.5	41.8	303.9	86.8
29	34	20.43	35	15.6	41.6	303.6	86.7
30	34	20.44	33	16.0	41.9	306.0	87.4
31	34	20.46	34	15.5	41.5	298.6	85.3
32	34	20.47	35	15.6	41.5	310.1	88.6
33	34	20.49	34	15.5	41.7	310.8	88.8
34	34	20.50	35	15.4	41.6	310.1	88.6
35	94	20.51	34	15.6	41.6	303.3	86.7
36	94	20.52	33	15.6	41.4	290.9	83.1
37	94	20.53	35	15.6	41.9	308.0	88.0
38	94	20.54	35	15.7	41.3	294.5	84.2
39	94	20.55	34	15.8	41.4	307.0	87.7
40	94	20.56	35	15.1	41.7	310.5	88.7
41	94	20.57	35	15.8	41.2	306.3	87.5
42	94	20.58	35	15.5	41.3	302.7	86.5
43	94	20.59	35	15.6	41.3	299.5	85.6
44	94	20.60	35	15.8	41.3	298.8	85.4
45	94	20.61	35	15.8	41.2	296.6	84.7
46	94	20.62	35	15.7	41.0	299.7	85.6
47	94	20.63	34	16.4	41.0	300.4	85.8
48	94	20.64	34	16.2	41.2	302.1	86.3
49	94	20.65	35	15.4	41.4	305.4	87.3
50	94	20.66	35	15.3	41.0	298.4	85.3
51	94	20.67	34	15.6	41.1	299.4	85.5
52	94	20.68	35	15.7	41.3	303.8	86.8
53	94	20.69	35	15.3	41.0	297.0	84.9
54	94	20.70	35	15.6	41.0	298.2	85.2
55	94	20.71	35	15.3	41.0	297.7	85.1
56	94	20.72	34	15.5	40.8	298.7	85.4
57	94	20.73	35	15.5	41.2	300.4	85.8
58	94	20.74	34	15.1	40.8	291.6	83.3

59	94	20.75	35	15.6	40.9	301.4	86.1
60	94	20.76	34	15.5	41.0	296.3	84.7
61	94	20.77	33	15.0	2.4	294.1	84.0
62	94	20.78	35	15.7	42.6	295.1	84.3
63	94	20.79	33	15.4	40.6	295.5	84.4
64	94	20.80	34	15.6	41.0	295.8	84.5
65	94	20.81	35	15.5	40.9	294.7	84.2
66	94	20.82	34	15.6	40.9	292.6	83.6
67	94	20.83	34	15.6	40.9	292.7	83.6
68	94	20.84	35	15.7	40.7	303.6	86.7
69	94	20.85	35	15.8	41.0	294.3	84.1
70	94	20.86	34	15.7	41.1	288.6	82.4
71	94	20.87	34	15.9	40.5	293.1	83.7
72	94	20.88	34	15.5	41.0	292.5	83.6
73	94	20.89	35	15.5	41.0	299.8	85.7
74	94	20.90	35	16.0	41.0	295.6	84.5
75	94	20.91	35	15.9	41.0	294.7	84.2
76	94	20.92	36	15.9	40.8	299.8	85.7
77	94	20.93	36	15.9	40.6	296.5	84.7
78	94	20.94	36	15.8	40.8	304.4	87.0
79	94	20.95	35	15.8	41.0	297.2	84.9
80	94	20.96	35	15.8	41.2	297.7	85.1
81	94	20.97	36	16.0	40.7	299.7	85.6
82	94	20.98	36	15.6	41.0	298.7	85.3
83	94	20.99	35	16.0	41.1	292.8	83.7
84	94	21.00	37	15.9	41.1	302.2	86.3
		Average	35	15.2	41.4	298.7	85.4
		Std Dev	1	1.0	4.6	6.1	1.7
		Maximum	38	16.4	52.9	310.8	88.8
		Minimum	33	11.1	2.4	280.5	80.1

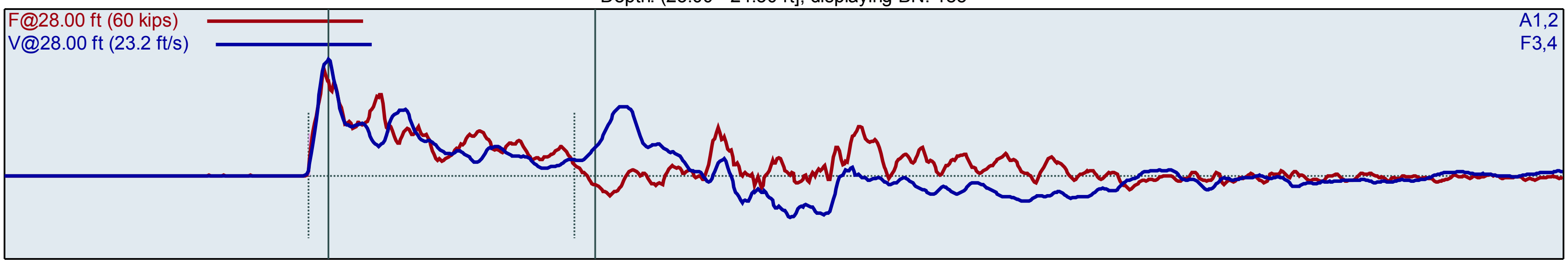
N-value: 84

Sample Interval Time: 143.07 seconds.

MOBILE B-54 RIG 9 20-B3
GRL-MGB Test date: 3/19/2018

AR: 1.45 in^2 SP: 0.492 k/ft3
LE: 28.00 ft EM: 30000 ksi
WS: 16807.9 ft/s

Depth: (23.00 - 24.50 ft], displaying BN: 185



F3 : [292NWJ] 215.95 PDICAL (1) FF1
F4 : [292NWJ-2] 216.67 PDICAL (1) FF1

A1 (PR): [K4422] 400 mv/6.4v/5000g (1) VF1
A2 (PR): [K4981] 322 mv/6.4v/5000g (1) VF1

BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	%
85	23	23.02	35	15.6	53.8	305.9	87.4
86	23	23.04	34	15.8	46.5	313.2	89.5
87	23	23.07	35	15.6	44.8	304.7	87.0
88	23	23.09	35	15.8	43.8	313.4	89.5
89	23	23.11	34	15.5	43.2	306.1	87.5
90	23	23.13	36	15.8	43.5	309.6	88.5
91	23	23.15	36	15.6	43.4	306.8	87.7
92	23	23.17	35	15.7	43.0	310.9	88.8
93	23	23.20	35	15.7	43.0	312.7	89.3
94	23	23.22	36	15.8	42.7	316.4	90.4
95	23	23.24	37	15.8	42.9	314.5	89.9
96	23	23.26	36	15.9	42.8	312.2	89.2
97	23	23.28	37	15.7	42.5	311.6	89.0
98	23	23.30	35	15.7	42.5	313.5	89.6
99	23	23.33	35	15.6	42.5	306.8	87.6
100	23	23.35	39	16.0	42.7	316.0	90.3
101	23	23.37	34	15.4	42.2	299.2	85.5
102	23	23.39	35	15.5	42.5	306.2	87.5

103	23	23.41	35	15.7	42.3	310.1	88.6
104	23	23.43	37	15.9	42.3	310.9	88.8
105	23	23.46	37	15.8	41.8	303.7	86.8
106	23	23.48	36	15.8	42.3	310.3	88.7
107	23	23.50	38	16.3	41.9	314.3	89.8
108	34	23.51	37	16.0	42.1	313.9	89.7
109	34	23.53	38	16.1	41.8	315.6	90.2
110	34	23.54	36	15.9	42.0	310.3	88.6
111	34	23.56	37	15.9	41.9	309.6	88.5
112	34	23.57	38	15.8	42.0	308.6	88.2
113	34	23.59	35	15.8	41.7	320.1	91.4
114	34	23.60	36	15.9	41.7	315.7	90.2
115	34	23.62	36	15.7	41.9	309.7	88.5
116	34	23.63	34	15.6	41.7	313.3	89.5
117	34	23.65	37	15.7	41.5	311.5	89.0
118	34	23.66	34	15.6	41.7	314.6	89.9
119	34	23.68	38	15.9	41.7	316.8	90.5
120	34	23.69	37	15.7	41.5	318.1	90.9
121	34	23.71	36	15.7	41.7	315.4	90.1
122	34	23.72	35	15.6	41.4	314.7	89.9
123	34	23.74	37	15.7	41.8	316.0	90.3
124	34	23.75	38	15.8	41.7	315.4	90.1
125	34	23.76	38	16.0	41.5	316.6	90.5
126	34	23.78	37	15.8	41.6	313.0	89.4
127	34	23.79	35	15.6	41.4	309.6	88.4
128	34	23.81	36	15.3	41.2	314.0	89.7
129	34	23.82	35	15.5	41.6	316.4	90.4
130	34	23.84	38	15.6	41.3	312.4	89.3
131	34	23.85	37	15.5	41.6	310.7	88.8
132	34	23.87	37	15.8	41.5	315.0	90.0
133	34	23.88	39	15.9	41.4	312.9	89.4
134	34	23.90	37	15.7	41.4	312.8	89.4
135	34	23.91	38	15.9	41.4	318.0	90.9
136	34	23.93	39	15.8	41.2	311.9	89.1
137	34	23.94	38	15.7	41.5	315.5	90.1
138	34	23.96	35	15.6	41.4	317.2	90.6
139	34	23.97	39	15.9	41.2	318.5	91.0
140	34	23.99	36	15.8	41.4	307.8	87.9
141	34	24.00	37	15.7	41.5	305.2	87.2
142	46	24.01	36	15.7	41.1	309.5	88.4
143	46	24.02	38	15.8	41.0	313.8	89.7
144	46	24.03	35	15.6	41.5	314.4	89.8
145	46	24.04	36	15.6	41.5	304.5	87.0

146	46	24.05	37	15.8	41.6	310.0	88.6
147	46	24.07	36	15.5	41.3	302.2	86.3
148	46	24.08	38	16.1	41.3	317.0	90.6
149	46	24.09	39	16.1	41.3	319.3	91.2
150	46	24.10	38	16.0	41.4	313.7	89.6
151	46	24.11	34	15.6	41.3	308.1	88.0
152	46	24.12	39	16.1	41.4	319.9	91.4
153	46	24.13	40	15.8	41.4	315.6	90.2
154	46	24.14	34	15.5	40.9	318.7	91.1
155	46	24.15	34	15.5	41.2	309.1	88.3
156	46	24.16	36	15.6	41.7	320.3	91.5
157	46	24.17	35	15.6	41.5	307.6	87.9
158	46	24.18	36	15.8	41.4	307.0	87.7
159	46	24.20	36	15.7	41.1	308.7	88.2
160	46	24.21	36	15.8	41.1	311.6	89.0
161	46	24.22	37	15.8	40.9	318.6	91.0
162	46	24.23	34	14.8	41.3	309.3	88.4
163	46	24.24	34	14.9	41.1	309.8	88.5
164	46	24.25	34	15.2	41.1	315.0	90.0
165	46	24.26	34	14.8	41.2	303.2	86.6
166	46	24.27	34	14.7	41.2	304.0	86.9
167	46	24.28	34	15.0	40.8	314.4	89.8
168	46	24.29	35	15.4	41.1	319.5	91.3
169	46	24.30	35	15.6	41.0	318.8	91.1
170	46	24.32	34	15.2	41.0	308.9	88.3
171	46	24.33	36	15.3	41.0	315.1	90.0
172	46	24.34	36	16.0	41.4	313.1	89.5
173	46	24.35	36	16.0	41.4	310.4	88.7
174	46	24.36	36	16.0	41.0	311.7	89.1
175	46	24.37	38	16.1	41.2	321.1	91.7
176	46	24.38	37	16.0	41.4	310.3	88.6
177	46	24.39	35	15.8	41.2	309.1	88.3
178	46	24.40	37	16.1	41.1	312.0	89.2
179	46	24.41	36	16.0	41.3	309.6	88.5
180	46	24.42	37	16.2	41.5	320.2	91.5
181	46	24.43	37	16.0	41.0	308.3	88.1
182	46	24.45	37	16.2	41.3	321.0	91.7
183	46	24.46	36	16.0	41.5	310.5	88.7
184	46	24.47	36	16.0	41.4	309.6	88.4
185	46	24.48	38	16.2	41.2	315.2	90.1
186	46	24.49	36	16.0	41.1	307.7	87.9
187	46	24.50	39	16.3	41.2	323.0	92.3

Average	36	15.7	41.4	313.1	89.5
Std Dev	1	0.3	0.3	4.6	1.3
Maximum	40	16.3	42.1	323.0	92.3
Minimum	34	14.7	40.8	302.2	86.3
	N-value: 80				

Sample Interval Time: 146.78 seconds.

Summary of SPT Test Results

Project: MOBILE B-54 RIG 9, Test Date: 3/19/2018

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute
EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

Instr. Length ft	Blows Applied /6"	Start Depth ft	Final Depth ft	**N Value**	**N60 Value**	Average FMX kips	Average VMX ft/s	Average BPM bpm	Average EFV ft-lb	Average ETR %
25.00	**34-94**	20.00	21.00	**94**	**136**	35	15.2	41.4	298.7	85.4
28.00	**23-34-46**	23.00	24.50	**80**	**116**	36	15.7	41.4	313.1	89.5
					Overall Average Values:	36	15.5	41.4	305.7	87.4
					Standard Deviation:	1	0.8	3.3	9.0	2.6
					Overall Maximum Value:	40	16.4	52.9	323.0	92.3
					Overall Minimum Value:	33	11.1	2.4	280.5	80.1

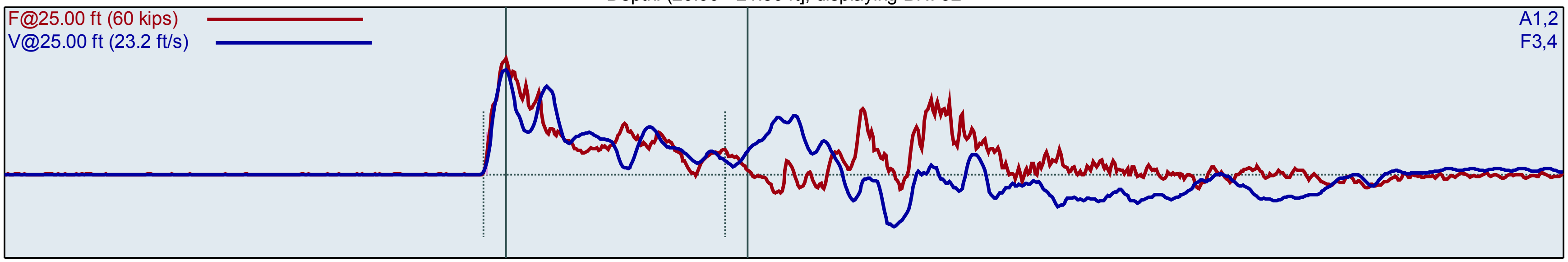
MOBILE B-54 RIG 9
GRL-MGB

20-B4
Test date: 3/19/2018

AR: 1.45 in^2
LE: 25.00 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

Depth: (20.00 - 21.50 ft], displaying BN: 92



F3 : [292NWJ] 215.95 PDICAL (1) FF1
F4 : [292NWJ-2] 216.67 PDICAL (1) FF1

A1 (PR): [K4422] 400 mv/6.4v/5000g (1) VF1
A2 (PR): [K4981] 322 mv/6.4v/5000g (1) VF1

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute

EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

BL#	BC	LP	FMX	VMX	BPM	EFV	ETR
	/6"	ft	kips	ft/s	bpm	ft-lb	%
1	0	20.01	43	15.2	53.8	310.8	88.8
2	0	20.02	42	14.3	46.3	312.3	89.2
3	0	20.03	45	14.7	43.7	321.6	91.9
4	0	20.05	42	14.4	43.0	299.7	85.6
5	0	20.06	41	14.9	42.9	309.4	88.4
6	0	20.07	41	15.2	42.9	302.4	86.4
7	0	20.08	37	15.1	42.9	296.3	84.7
8	0	20.09	40	15.5	42.7	312.1	89.2
9	0	20.10	39	15.9	42.7	305.6	87.3
10	0	20.11	37	15.4	42.3	298.2	85.2
11	0	20.13	41	15.5	42.6	312.1	89.2
12	0	20.14	40	15.7	42.1	309.6	88.4
13	0	20.15	42	15.3	42.4	311.8	89.1
14	0	20.16	40	14.7	42.4	305.6	87.3
15	0	20.17	42	14.7	42.2	307.1	87.8

16	0	20.18	40	15.1	42.4	304.7	87.1
17	0	20.19	40	15.0	41.9	304.9	87.1
18	0	20.20	40	16.3	42.1	309.8	88.5
19	0	20.22	41	15.7	42.1	316.2	90.3
20	0	20.23	37	15.8	41.7	307.0	87.7
21	0	20.24	39	16.2	42.1	312.0	89.1
22	0	20.25	42	15.8	42.0	316.1	90.3
23	0	20.26	40	16.0	41.9	313.5	89.6
24	0	20.27	40	15.5	41.7	318.1	90.9
25	0	20.28	41	16.0	41.9	318.5	91.0
26	0	20.30	41	15.5	41.7	314.5	89.9
27	0	20.31	40	15.7	41.6	313.6	89.6
28	0	20.32	39	15.7	41.7	312.1	89.2
29	0	20.33	41	15.7	41.9	320.1	91.5
30	0	20.34	40	15.9	41.8	315.0	90.0
31	0	20.35	40	15.6	41.8	316.9	90.5
32	0	20.36	41	15.7	41.8	317.9	90.8
33	0	20.38	40	16.2	41.7	319.5	91.3
34	0	20.39	39	16.0	41.9	318.1	90.9
35	0	20.40	41	15.5	41.6	316.0	90.3
36	0	20.41	38	15.9	41.7	313.0	89.4
37	0	20.42	38	16.1	41.9	317.6	90.7
38	0	20.43	41	15.7	41.7	319.7	91.3
39	0	20.44	42	15.1	41.6	319.5	91.3
40	0	20.45	40	15.5	41.5	313.8	89.7
41	0	20.47	41	15.5	41.5	317.1	90.6
42	0	20.48	41	15.6	41.4	319.4	91.2
43	0	20.49	39	16.1	41.6	317.0	90.6
44	0	20.50	40	15.8	41.4	317.9	90.8
45	44	20.51	40	16.0	41.4	319.9	91.4
46	44	20.52	40	16.2	41.6	318.2	90.9
47	44	20.53	41	16.1	41.6	322.2	92.1
48	44	20.54	40	15.8	41.5	313.0	89.4
49	44	20.55	41	15.7	41.5	319.1	91.2
50	44	20.56	40	15.4	41.6	311.1	88.9
51	44	20.57	41	15.4	41.2	308.3	88.1
52	44	20.58	41	14.5	41.2	310.8	88.8
53	44	20.59	42	14.8	41.3	316.9	90.5
54	44	20.60	41	14.8	41.3	315.1	90.0
55	44	20.61	41	14.7	41.3	319.3	91.2
56	44	20.62	40	14.0	41.4	308.8	88.2
57	44	20.63	42	15.0	41.0	317.3	90.6
58	44	20.64	41	14.6	41.4	315.0	90.0

59	44	20.65	40	14.8	41.3	314.9	90.0
60	44	20.66	40	14.5	41.1	305.9	87.4
61	44	20.67	41	14.6	41.1	309.2	88.3
62	44	20.68	41	14.4	41.2	308.3	88.1
63	44	20.69	41	14.8	41.1	315.9	90.3
64	44	20.70	41	14.7	41.1	307.6	87.9
65	44	20.71	41	14.7	41.3	310.8	88.8
66	44	20.72	41	14.6	41.1	307.7	87.9
67	44	20.73	41	14.7	40.7	308.7	88.2
68	44	20.74	41	14.6	40.9	308.4	88.1
69	44	20.75	41	14.8	41.1	311.8	89.1
70	44	20.76	42	14.6	41.3	307.3	87.8
71	44	20.77	41	14.5	41.2	306.2	87.5
72	44	20.78	42	14.9	41.1	312.3	89.2
73	44	20.79	40	14.7	41.3	319.5	91.3
74	44	20.80	41	14.8	41.1	307.2	87.8
75	44	20.81	41	14.7	41.0	315.8	90.2
76	44	20.82	40	14.7	41.2	317.4	90.7
77	44	20.83	41	14.8	41.2	320.6	91.6
78	44	20.84	41	14.8	41.2	318.9	91.1
79	44	20.85	41	14.4	41.1	314.0	89.7
80	44	20.86	41	14.5	41.1	317.3	90.7
81	44	20.87	41	14.6	41.2	318.5	91.0
82	44	20.88	41	14.4	41.0	320.5	91.6
83	44	20.89	41	14.4	40.9	315.3	90.1
84	44	20.90	41	14.3	41.2	313.3	89.5
85	44	20.91	41	14.5	41.0	314.7	89.9
86	44	20.92	41	14.7	41.2	320.9	91.7
87	44	20.93	41	14.7	41.2	316.9	90.5
88	44	20.94	41	14.6	41.1	314.9	90.0
89	44	20.95	42	14.7	41.1	320.6	91.6
90	44	20.96	40	14.8	41.4	316.9	90.6
91	44	20.97	41	14.4	41.3	308.5	88.1
92	44	20.98	42	14.5	41.5	317.7	90.8
93	44	20.99	42	14.6	41.1	316.5	90.4
94	44	21.00	41	14.6	41.3	319.6	91.3
		Average	41	15.1	41.8	313.5	89.6
		Std Dev	1	0.6	1.4	5.5	1.6
		Maximum	45	16.3	53.8	322.2	92.1
		Minimum	37	14.0	40.7	296.3	84.7

N-value: 94

Sample Interval Time: 134.04 seconds.

Summary of SPT Test Results

Project: MOBILE B-54 RIG 9, Test Date: 3/19/2018

FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute
EFV: Maximum Energy
ETR: Energy Transfer Ratio - Rated

Instr. Length ft	Blows Applied /6"	Start Depth ft	Final Depth ft	**N Value**	**N60 Value**	Average FMX kips	Average VMX ft/s	Average BPM bpm	Average EFV ft-lb	Average ETR %
25.00	**0-44-50**	20.00	21.50	**94**	**140**	41	15.1	41.8	313.5	89.6
					Overall Average Values:	41	15.1	41.8	313.5	89.6
					Standard Deviation:	1	0.6	1.4	5.5	1.6
					Overall Maximum Value:	45	16.3	53.8	322.2	92.1
					Overall Minimum Value:	37	14.0	40.7	296.3	84.7

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