SEISMIC STABILITY EVALUATIONS OF CHESBRO, LENIHAN, STEVENS CREEK, AND UVAS DAMS (SSE2)

PHASE A: STEVENS CREEK AND LENIHAN DAMS

LENIHAN DAM

SITE INVESTIGATIONS AND LABORATORY TESTING DATA REPORT

(REPORT No. LN-2)

Prepared for

SANTA CLARA VALLEY WATER DISTRICT
5750 Almaden Expressway
San Jose, CA 95118

February 2012

TERRA / GeoPentech
a Joint Venture

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1.1 GENERAL

In May 2010, the Santa Clara Valley Water District (District) retained Terra / GeoPentech (TGP), a joint venture of Terra Engineers, Inc. and GeoPentech, Inc., to complete seismic stability evaluations of Chesbro, Lenihan, Stevens Creek and Uvas Dams. These evaluations were required by the Division of Safety of Dams (DSOD) as part of their Phase III screening process of the State's dams located in highly seismic environments. The evaluations are also a vital part of the District's Dam Safety Program (SCVWD, 2005). Phase A of the project includes work on Stevens Creek and Lenihan Dams and has a planned completion date of 2012. Phase B of the project includes work on Chesbro and Uvas Dams and is scheduled to begin in 2012 and to finish by the end of 2013. The general scope of the project consists of the field, laboratory, and office studies required to evaluate the seismic stability of the four referenced dams.

This report documents the site investigation and laboratory testing program conducted at Lenihan Dam in support of the seismic stability evaluation of the dam. This is a data report, and as such the report describes the work that was done and presents the results of the site investigations and laboratory testing. Interpretation of these results and development of parameters for the seismic stability evaluation is the subject of a separate future report on Site Characterization (Terra / GeoPentech, 2012).

1.2 PURPOSE AND SCOPE OF FIELD EXPLORATIONS AND LABORATORY TESTING

Our initial review of the large amount of geotechnical data available for Lenihan Dam (Terra / GeoPentech, 2010) led us to conclude that:

1. there appeared to be sufficient information available to define the geometry of the dam and its foundation; and
2. a detailed review and thorough evaluation of the available data on the properties of the various zones of the embankment (as indicated by the construction records, field investigations and laboratory tests completed to date) may provide much of the information necessary to support the engineering analyses.

Thus, with the approval of the District and DSOD, we proceeded with an interim site characterization at the dam that was based on the data available from the dam construction records and the field investigations and laboratory tests completed by others over time; performed preliminary engineering analyses using this interim site characterization to identify what supplemental field and laboratory data were necessary to reduce the uncertainties in the seismic stability analyses of the dam; and prepared a work plan for site investigations and laboratory testing that was focused on filling data gaps identified by the preliminary analyses. The results of the interim site characterization and preliminary engineering analyses, and the scope of the recommended site investigations and laboratory testing are documented in our Work Plan (Terra / GeoPentech, 2011).

Specifically, our review of the existing field and laboratory geotechnical data, and the use of these data for the preliminary engineering analyses, indicated the following:

1. The dam is founded on Franciscan Complex bedrock; i.e. for practical purposes, all of the alluvial and colluvial soils were removed prior to placement and compaction of the dam embankment materials.
2. The undrained shear strength and stress-strain behavior of the various embankment zones of the dam, and the variation of shear strengths within each of the zones, are required for the dynamic deformation analyses and are not well defined, particularly for direct simple shear loading conditions.
3. The small strain stiffness of the embankment materials, as indicated by the shear wave velocity of the embankment materials, is required for the dynamic deformation analyses and the available data are inconsistent.
4. The Franciscan Complex bedrock includes both soft and hard rock and the difference in shear wave velocities between the soft and hard rock is not well defined and may influence the input ground motions.

Item 1 above is a very significant finding because it eliminates the potential for liquefaction of foundation soils. However, the absence of poor foundation soils makes the detailed characterization of the compacted clayey embankment soils more critical than would be the case if liquefaction of foundation soils were a concern, because the performance of the dam is now likely to be controlled by the properties of the embankment materials rather than being dominated by the liquefaction of the foundation soils.

Our approach for obtaining the data required for Item 2 was to collect intact samples of embankment materials with a 4-inch diameter Pitcher Barrel Sampler in mud rotary borings and to test these samples in the laboratory using undrained shear strength tests with pore pressure measurements for triaxial compression and direct simple shear loading conditions. The laboratory engineering property tests were complemented by measurements of grain size, water content, and Atterberg Limits. Cone Penetrometer Test (CPT) probes were completed at potential locations of mud rotary boreholes before these boreholes were drilled, and the data from these CPT probes were used to finalize the boring locations and identify depths within the mud rotary borings where the presence of gravel in the embankment appeared to be less likely. These depths were targeted for obtaining good quality Pitcher Barrel samples. This is an important role for the use of the CPT data because the experience from past geotechnical investigations is that the gravel content of the embankment materials made obtaining good quality Pitcher Barrel samples very difficult.

Our approach for obtaining shear wave velocity measurements within the embankment soils and underlying bedrock, to provide the data required for Items 3 and 4, was to perform OYO P-S Borehole Suspension Logging in the mud rotary borings. In addition, downhole geophysical logging using the "seismic cone" was performed as part of the CPT sounding work to provide additional measurements of shear wave velocity.

The originally recommended scope of the field investigations documented in the Work Plan (Terra / GeoPentech, 2011) included two mud rotary borings and ten CPT probes. It also included Multisource Spectral Analysis of Surface Wave (MSASW) geophysical survey lines to evaluate the variation of shear wave velocity along survey lines that cross boundaries between soft and hard rock within the Franciscan Complex. However, after review and discussion of the proposed program with DSOD, the program was modified as follows:

1. The number of mud rotary borings was increased from two to three;
2. The number of CPT probes was reduced from ten to four; and
3. The MSASW lines were eliminated.

1.3 ORGANIZATION OF REPORT

This report contains three sections in addition to this introduction, and four appendices. Section 2 describes the site investigations and Section 3 describes the laboratory testing program. Section 4 is a list of references. The appendices contain the logs of the CPT probes and borings (Appendices A and B), the results of the down-hole geophysical logging (Appendix C), and the laboratory test results (Appendix D).

2.1 GENERAL

The field explorations included the following:

1. Four CPT probes;
2. Drilling of three mud rotary borings with collection of SPT and Pitcher Barrel samples; and
3. OYO down-hole geophysical logging in each of the three mud rotary borings.

The CPT soundings at potential locations of mud rotary boreholes were completed before the mud rotary boreholes were drilled and the data from these CPT soundings were used to check conditions at the boring locations and identify depths within the mud rotary borings where the presence of gravel in the embankment appeared to be less likely. These depths were targeted for obtaining good quality Pitcher Barrel samples. In recognition of the difficulty in obtaining good quality intact soil samples in gravelly soils, we collected a relatively large number of Pitcher Barrel samples and x-rayed the sample tubes to help identify which of the tubes would more likely provide samples suitable for laboratory testing.

The locations of the borings and CPTs are shown in plan on Figure 1. As shown on this figure, two borings and three CPT probes were performed on the crest of the dam and one boring and one CPT probe were completed from the bike path on the downstream slope of the dam. The plan locations and ground surface elevations at the locations of the borings and CPT probes were surveyed by TGP and the plan locations (based on California State Plane Coordinate System) and ground surface elevations [based on North American Vertical Datum of 1988 (NAVD 88)], are summarized below.

Exploration Number	California State Plane Coordinates, feet		Elevation, feet
LD-B-101	N 1,899,274	E 6,127,954	673.0
LD-B-102	N 1,899,428	E 6,127,942	626.7
LD-B-103	N 1,899,268	E 6,127,636	672.7
LD-CPT-101	N 1,899,273	E 6,127,942	673.0
LD-CPT-102	N 1,899,432	E 6,127,934	626.6
LD-CPT-103	N 1,899,264	E 6,127,626	672.7
LD-CPT-104	N 1,899,257	E 6,127,762	672.6
LD-CPT-104B	N 1,899,256	E 6,127,767	672.6

2.2 CONE PENETROMETER TEST PROBES

Four CPT probes were completed by Gregg Drilling & Testing on June 14, 2011 at the locations shown on Figure 1: three on the crest of the dam (LD-CPT-101, LD-CPT-103, and LD-CPT-104) and one on the downstream slope (LD-CPT-102). Richard Harlan, CEG of TGP supervised the field operations.

Gregg Drilling & Testing completed the CPT probes using an integrated electronic cone system. The soundings were conducted using a 20-ton capacity cone with a tip area of 15 cm^2 and a friction sleeve area of 225 cm^2. The cone takes measurements of cone bearing, sleeve friction and penetration pore water pressure at 5-cm intervals during penetration to provide a nearly continuous log.

The logs of the CPT probes are summarized in the report by Gregg Drilling & Testing that is included in Appendix A. All the CPT probes were extended to refusal which was encountered slightly above or below the bottom of the embankment. LD-CPT-101 on the crest encountered an abandoned water line at a depth of 3.5 feet; thus, the hole was moved 9 feet west and 4 feet north (i.e., downstream) of the original location and the CPT probe was extended to slightly above the depth of the dam foundation based on the as-built drawings. LD-CPT-104, also on the crest, encountered refusal at a depth of 34 feet in the embankment; the rig was moved 5 feet east and the CPT probe was able to reach the foundation rock at that new location.

In addition to the CPT soundings, measurements of downhole shear wave velocity were made using the "seismic cone" at intervals of about 10 feet of penetration in all the CPT probes except for LD-CPT-102 on the downstream slope. The slope of the bike path at this location was such that the striking bar could not come in contact with the ground surface once the CPT rig was leveled.

The CPT test results were used to establish target locations for Pitcher Barrel Sampling for the mud rotary borings that followed completion of the CPT probes. Figure 2 illustrates the procedure that was used. The cone tip resistance measurements were made every 10 cm and rolling median tip resistances over a one-foot long sampling interval and over a five-foot long sampling interval were computed and plotted at 10-cm intervals. By visually comparing the median value of the tip resistance over the 5-foot sampling interval to the median value of the tip resistance over a 1-foot sampling interval, it was possible to locate zones where the median tip resistances over the two sampling intervals were similar. These zones should represent zones where the presence of gravel has relatively little influence on the tip resistance, or zones where there is little gravel present.

2.3 MUD ROTARY BORINGS AND DOWN-HOLE GEOPHYSICAL LOGGING

As shown on Figure 1, mud rotary borings LD-B-101 and LD-B-103 were completed on the dam crest and mud rotary boring LD-B-102 was completed on the downstream slope from the bike path. The borings were made by Pitcher Drilling. LD-B-101 and LD-B-102 were completed during the period from June 17 to 24, 2011 using two Fraste Multidrill Model XL drill rigs, one truck-mounted on the crest and the other track-mounted on the bike path. The work was supervised in the field by Richard Harlan, CEG with the assistance of Andrew Dinsick, PE, both of TGP. Because of drill rig availability, the third boring, LD-B-203, could not be completed until July 18 to 20, 2011 and was performed under the supervision of Richard Harlan, CEG.

Disturbed samples were obtained using the Standard Penetration Test (SPT) and intact samples were obtained using 4-inch diameter Pitcher Barrel samples. As discussed above, the results of the CPT probes were used to target sampling locations for the Pitcher Barrel sampler by identifying depths within the mud rotary borings where the presence of gravel in the embankment appeared to be less likely.

Upon completion of drilling, each boring was logged by GeoVision using OYO P-S suspension logging equipment. The depth of geophysical logging extended about 54 feet and 97 feet into the Franciscan Complex bedrock at LD-B-101 and LD-B-103, respectively. The original plan was to also extend the geophysical logging 50 feet into bedrock at LD-B-102; however, the borehole had to be terminated in the drain material at the base of the dam because total fluid loss was encountered in that zone. After this event, the depth of geophysical logging into rock was extended at LD-B-103 beyond the planned 50 feet at the request of DSOD.

The boring logs for the mud rotary borings are contained in Appendix B and the report by GeoVision on the OYO P-S Suspension logging is included as Appendix C.

3.1 PURPOSE OF GEOTECHNICAL LABORATORY TESTING

The primary purpose of the laboratory testing program was to measure the undrained shear strength of the embankment materials and to determine their undrained stress-strain behavior for use in the dynamic deformation analyses. The program included triaxial and direct simple shear undrained strength tests with pore pressure measurements on specimens of embankment materials selected from the intact Pitcher Barrel samples. These tests were distributed in the Upper Core, Lower Core and Downstream Shell based on a close look at the results of the preliminary deformation analyses and the measurements made in Cone Penetrometer Test (CPT) soundings adjacent to the mud rotary borings. The final selection and number of samples tested was controlled by the condition and length of the samples as observed during sample extrusion, and by the amount of gravel present. Robert Kirby, PE of TGP observed the extrusion of all Pitcher Barrel samples and selected the specimens for engineering property tests. DSOD personnel were also present during the processing of some of the samples. The triaxial tests were conducted on 8-inch high by 4-inch diameter specimens and did not require trimming. The direct simple shear tests and consolidation tests were conducted on trimmed 1-inch high by 2.6-inch diameter specimens, and these tests were completed on specimens with little or no gravel content.

The laboratory engineering property tests were complemented by measurements of grain size, water content, and Atterberg Limits on all the samples tested. In addition to these tests, physical and index property tests were also completed on a number of samples obtained using the split spoon sampler. The purpose of the additional physical and index property tests was to evaluate how representative the samples used for strength testing were, compared to the average conditions within each of the embankment zones.

3.2 SCOPE OF LABORATORY TESTING

The laboratory testing included the following:

7	Consolidated Undrained Triaxial Compression (CIU') Tests with Pore Pressure Measurements
4	Consolidated Undrained Direct Simple Shear (DSS) Tests
4	Consolidation Tests
47	Water Content Tests
1	Moisture/Density Test
22	Grain Size Analyses
20	Atterberg Limits
3	Specific Gravity Tests

A total of 30 Pitcher Barrel samples were collected in the three mud-rotary borings. X-rays of these samples were taken to assess sample disturbance and to aid in the selection of the best samples for engineering property testing.

Duplicate specimens were selected from four of the seven samples chosen for CIU' testing and DSS tests were completed on these specimens. Additional specimens were selected from the same samples for one-dimensional consolidation tests. The samples used for the CIU' and DSS tests were consolidated to near the estimated maximum in-situ effective stress prior to shearing.

The results of all the laboratory tests are contained in Appendix D. Photographs of the triaxial specimens after testing are also included in this appendix.

Santa Clara Valley Water District (SCVWD), 2005 (May), Dam Safety Program Report, prepared by Water Utility Operations Division – Infrastructure Planning Unit.

Terra / GeoPentech, 2010 (November 24), Technical Memorandum SSE2-TM-1LN, Initial Review of Available Data for Lenihan Dam.

Terra / GeoPentech, 2011 (April), Seismic Stability Evaluations of Chesbro, Lenihan, Stevens Creek, and Uvas Dams, Phase A: Stevens Creek and Lenihan Dams, Lenihan Dam, Work Plan for Site Investigations and Laboratory Testing (Report No. LN-1), prepared for Santa Clara Valley Water District.

Terra / GeoPentech, 2012 (to be issued), Seismic Stability Evaluations of Chesbro, Lenihan, Stevens Creek, and Uvas Dams, Phase A: Stevens Creek and Lenihan Dams, Lenihan Dam, Site Characterization, Material Properties, and Ground Motions (Report No. LN-3), prepared for Santa Clara Valley Water District.

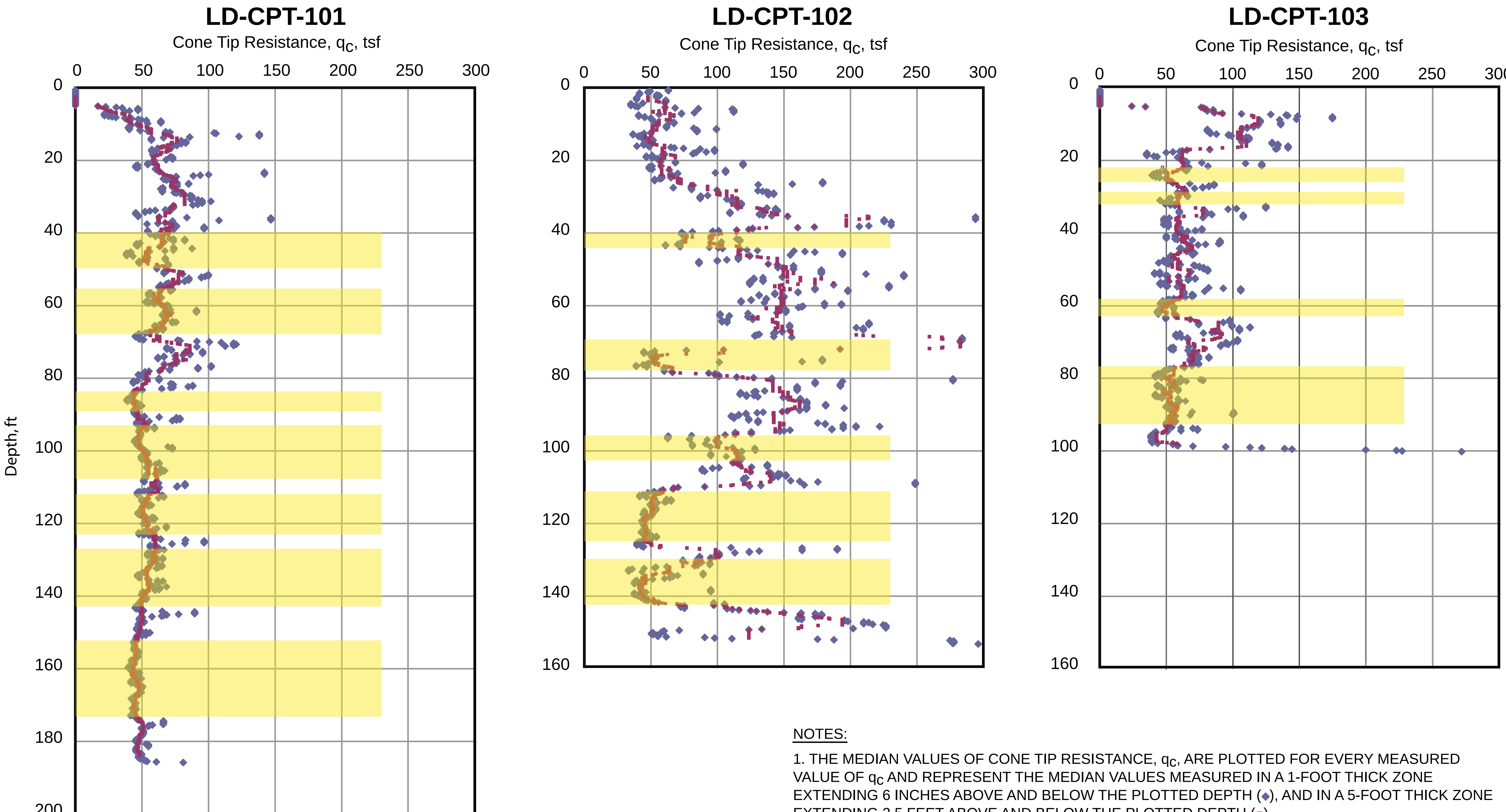
FIGURES

TERRA / GeoPentech
a Joint Venture

PLAN LOCATIONS OF FIELD EXPLORATIONS
LENIHAN DAM
SEISMIC STABILITY EVALUATIONS (SSE2)

Figure
1

Rev. 0 09/30/2011 SSE2-R-2LN



LEGEND

- ◆ Rolling 1-ft Median
- ■ Rolling 5-ft Median

NOTES:

1. THE MEDIAN VALUES OF CONE TIP RESISTANCE, q_c, ARE PLOTTED FOR EVERY MEASURED VALUE OF q_c AND REPRESENT THE MEDIAN VALUES MEASURED IN A 1-FOOT THICK ZONE EXTENDING 6 INCHES ABOVE AND BELOW THE PLOTTED DEPTH (◆), AND IN A 5-FOOT THICK ZONE EXTENDING 2.5 FEET ABOVE AND BELOW THE PLOTTED DEPTH (■).
2. TARGET SAMPLING ZONES WERE SELECTED WHERE THE DIFFERENCES BETWEEN THE MEDIAN VALUES OF q_c APPEARED TO BE RELATIVELY SMALL.
3. TARGET SAMPLING ZONES WITHIN THE EMBANKMENT MATERIALS ARE SHADED YELLOW.

TERRA / GeoPentech a Joint Venture	USE OF CPT DATA TO TARGET SAMPLING LOCATIONS - LENIHAN DAM SEISMIC STABILITY EVALUATIONS (SSE2)	Figure 2

Rev. 0 09/30/2011 SSE2-R-2LN

APPENDIX A

CONTENTS

Report by Gregg Drilling & Testing, Inc. dated June 15, 2011.

GREGG DRILLING & TESTING, INC.
GEOTECHNICAL AND ENVIRONMENTAL INVESTIGATION SERVICES

June 15, 2011

Terra Engineers
Attn: Bob Kirby

Subject: CPT Site Investigation
Lenihan Dam
California
GREGG Project Number: 11-081Ma

Dear Mr. Kirby:

The following report presents the results of GREGG Drilling & Testing's Cone Penetration Test investigation for the above referenced site. The following testing services were performed:

1	Cone Penetration Tests	(CPTU)	☒
2	Pore Pressure Dissipation Tests	(PPD)	☐
3	Seismic Cone Penetration Tests	(SCPTU)	☒
4	UVOST Laser Induced Fluorescence	(UVOST)	☐
5	Groundwater Sampling	(GWS)	☐
6	Soil Sampling	(SS)	☐
7	Vapor Sampling	(VS)	☐
8	Pressuremeter Testing	(PMT)	☐
9	Vane Shear Testing	(VST)	☐
10	Dilatometer Testing	(DMT)	☐

A list of reference papers providing additional background on the specific tests conducted is provided in the bibliography following the text of the report. If you would like a copy of any of these publications or should you have any questions or comments regarding the contents of this report, please do not hesitate to contact our office at (925) 313-5800.

Sincerely,
GREGG Drilling & Testing, Inc.

Mary Walden
Operations Manager

950 Howe Rd • Martinez, California 94553 • (925) 313-5800 • FAX (925) 313-0302
OTHER OFFICES: LOS ANGELES • HOUSTON
www.greggdrilling.com

Cone Penetration Test Sounding Summary

-Table 1-

CPT Sounding Identification	Date	Termination Depth (Feet)	Depth of Groundwater Samples (Feet)	Depth of Soil Samples (Feet)	Depth of Pore Pressure Dissipation Tests (Feet)
LD-CPT-101	6/14/11	186	-	-	-
LD-CPT-102	6/14/11	154	-	-	-
LD-CPT-103	6/13/11	100	-	-	-
LD-CPT-104	6/13/11	35	-	-	-
LD-CPT-104B	6/13/11	145	-	-	-

Bibliography

Lunne, T., Robertson, P.K. and Powell, J.J.M., "Cone Penetration Testing in Geotechnical Practice" E & FN Spon. ISBN 0 419 23750, 1997

Roberston, P.K., "Soil Classification using the Cone Penetration Test", Canadian Geotechnical Journal, Vol. 27, 1990 pp. 151-158.

Mayne, P.W., "NHI (2002) Manual on Subsurface Investigations: Geotechnical Site Characterization", available through www.ce.gatech.edu/~geosys/Faculty/Mayne/papers/index.html, Section 5.3, pp. 107-112.

Robertson, P.K., R.G. Campanella, D. Gillespie and A. Rice, "Seismic CPT to Measure In-Situ Shear Wave Velocity", Journal of Geotechnical Engineering ASCE, Vol. 112, No. 8, 1986 pp. 791-803.

Robertson, P.K., Sully, J., Woeller, D.J., Lunne, T., Powell, J.J.M., and Gillespie, D.J., "Guidelines for Estimating Consolidation Parameters in Soils from Piezocone Tests", Canadian Geotechnical Journal, Vol. 29, No. 4, August 1992, pp. 539-550.

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Campanella, R.G. and I. Weemees, "Development and Use of An Electrical Resistivity Cone for Groundwater Contamination Studies", Canadian Geotechnical Journal, Vol. 27 No. 5, 1990 pp. 557-567.

DeGroot, D.J. and A.J. Lutenegger, "Reliability of Soil Gas Sampling and Characterization Techniques", International Site Characterization Conference - Atlanta, 1998.

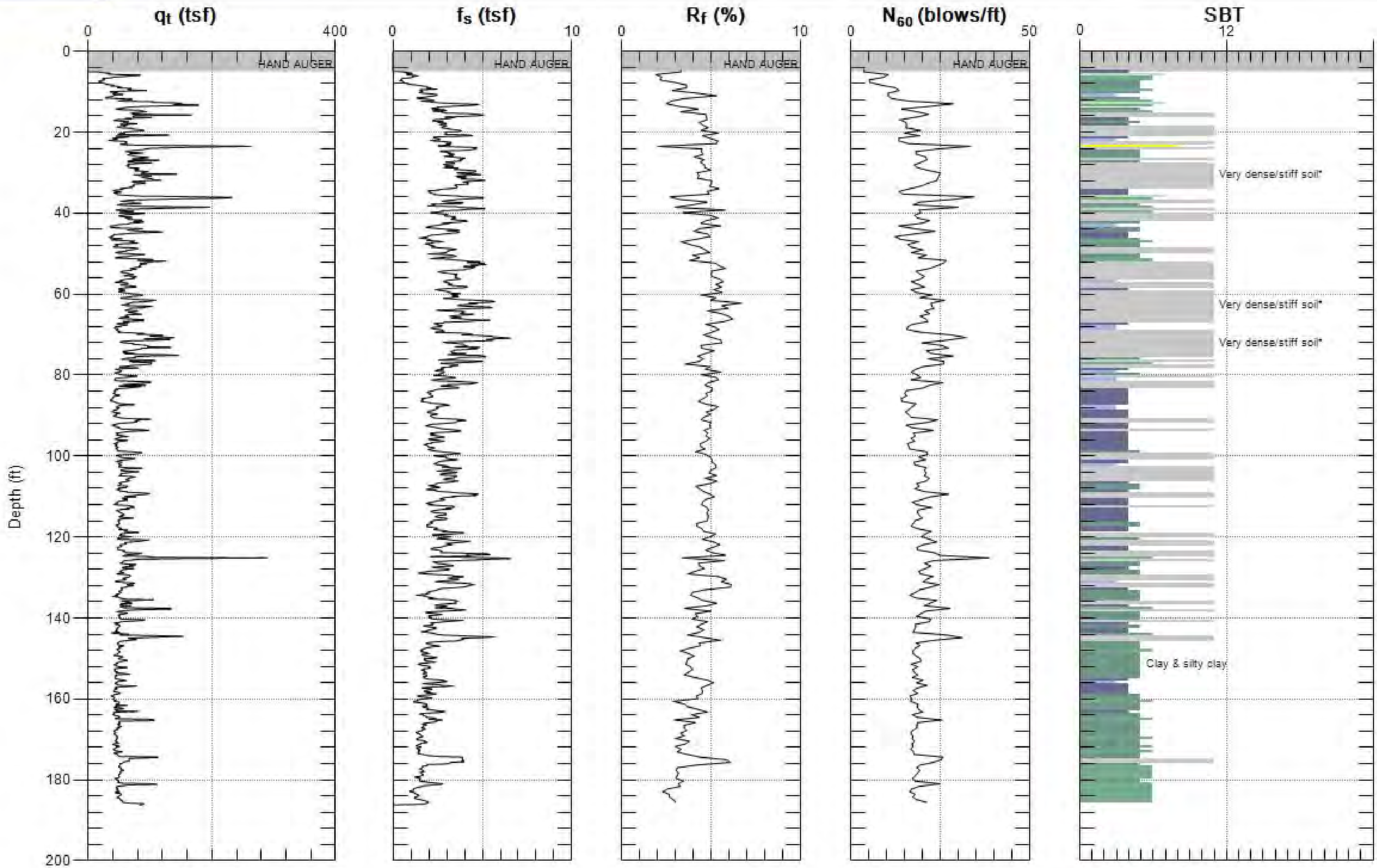
Woeller, D.J., P.K. Robertson, T.J. Boyd and Dave Thomas, "Detection of Polyaromatic Hydrocarbon Contaminants Using the UVIF-CPT", 53rd Canadian Geotechnical Conference Montreal, QC October pp. 733-739, 2000.

Zemo, D.A., T.A. Delfino, J.D. Gallinatti, V.A. Baker and L.R. Hilpert, "Field Comparison of Analytical Results from Discrete-Depth Groundwater Samplers" BAT EnviroProbe and QED HydroPunch, Sixth national Outdoor Action Conference, Las Vegas, Nevada Proceedings, 1992, pp 299-312.

Copies of ASTM Standards are available through www.astm.org

GREGG TERRA ENGINEERS

Site: LENIHAN DAM | Engineer: B.KIRBY
Sounding: LD-CPT-101 | Date: 6/14/2011 07:15



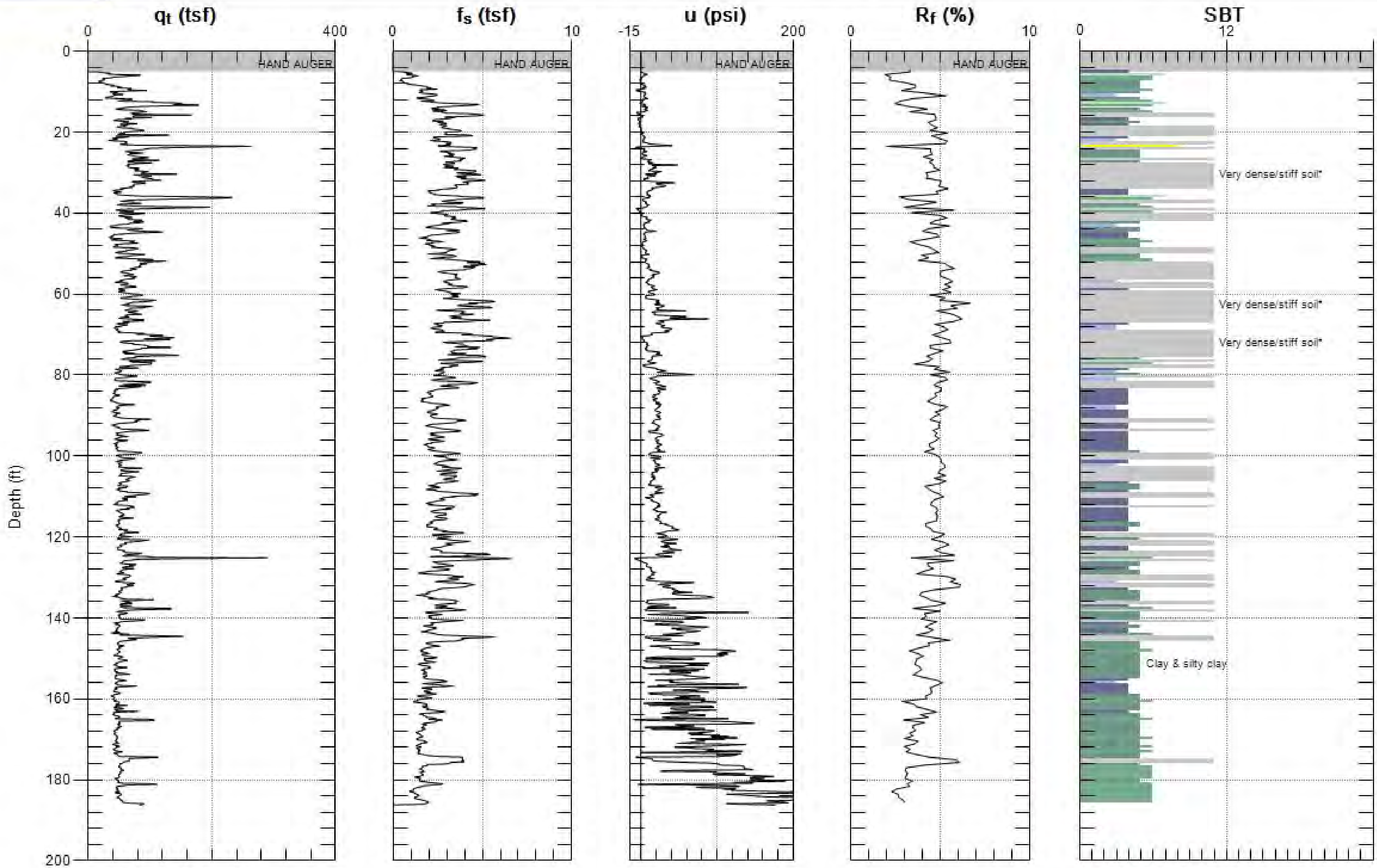
Max. Depth: 186.352 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

TERRA ENGINEERS

Site: LENIHAN DAM
Sounding: LD-CPT-101
Engineer: B.KIRBY
Date: 6/14/2011 07:15



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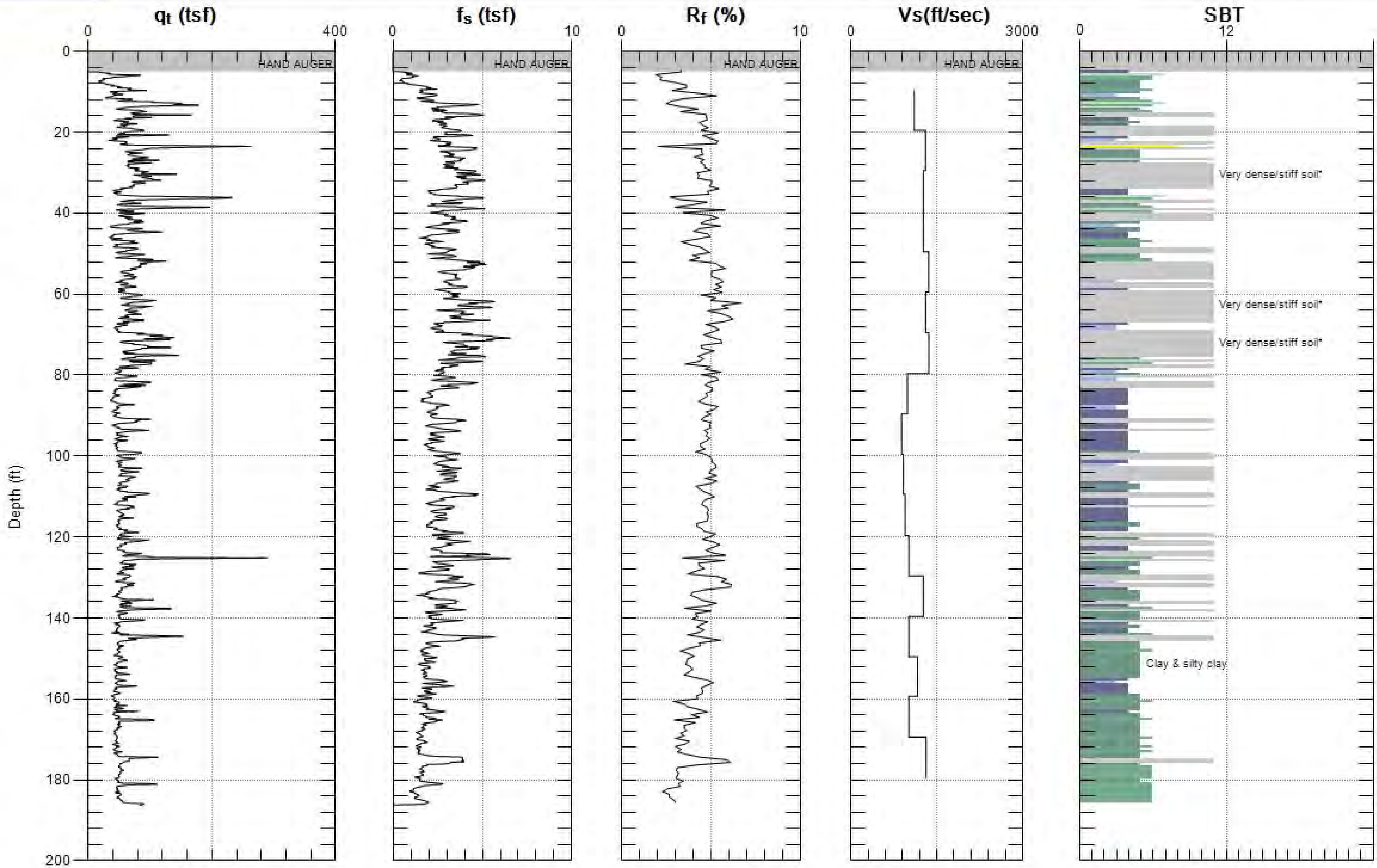
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG TERRA ENGINEERS

Site: LENIHAN DAM
Sounding: LD-CPT-101

Engineer: B.KIRBY
Date: 6/14/2011 07:15



Max. Depth: 186.352 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Shear Wave Velocity Calculations

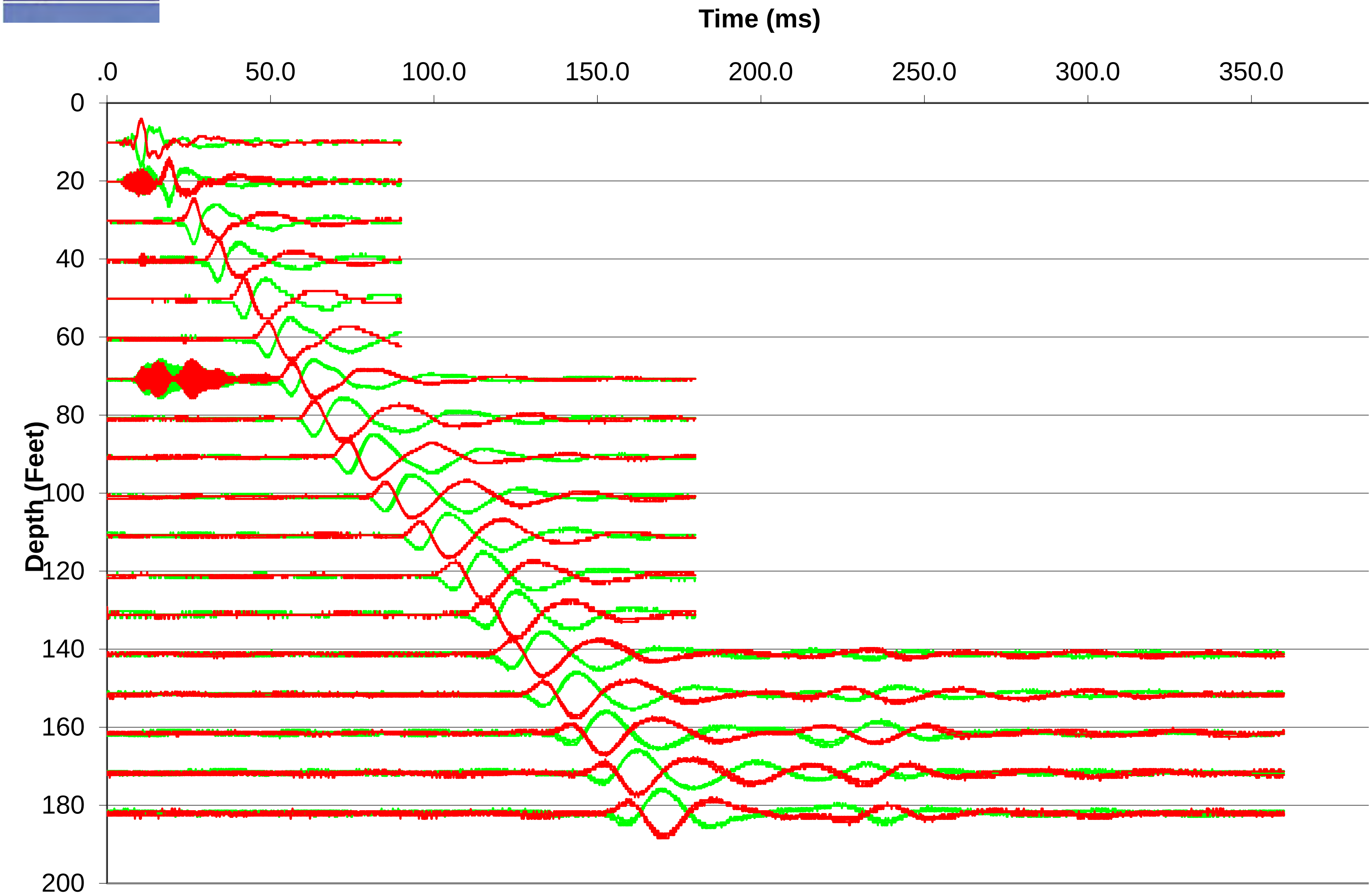
LENIHAN DAM
LD-CPT-101

Geophone Offset: 0.66 Feet
Source Offset: 1.67 Feet

06/14/11

Test Depth (Feet)	Geophone Depth (Feet)	Waveform Ray Path (Feet)	Incremental Distance (Feet)	Characteristic Arrival Time (ms)	Incremental Time Interval (ms)	Interval Velocity (Ft/Sec)	Interval Depth (Feet)
10.17	9.51	9.66	9.66	12.0500			
20.18	19.52	19.59	9.93	21.0500	9.0000	1103.6	14.51
30.18	29.52	29.57	9.98	28.7000	7.6500	1304.9	24.52
40.19	39.53	39.57	9.99	36.6000	7.9000	1265.1	34.53
50.20	49.54	49.56	10.00	44.5000	7.9000	1265.7	44.53
60.20	59.54	59.57	10.00	51.8500	7.3500	1360.8	54.54
70.21	69.55	69.57	10.00	59.5000	7.6500	1307.6	64.55
80.22	79.56	79.57	10.00	66.8500	7.3500	1361.1	74.55
90.22	89.56	89.58	10.00	77.0000	10.1500	985.7	84.56
100.23	99.57	99.58	10.00	88.3000	11.3000	885.4	94.57
110.07	109.41	109.42	9.84	99.0500	10.7500	915.5	104.49
120.24	119.58	119.59	10.17	109.8000	10.7500	946.0	114.50
130.25	129.59	129.60	10.01	119.7000	9.9000	1010.7	124.59
140.26	139.60	139.61	10.01	127.6000	7.9000	1266.6	134.59
150.26	149.60	149.61	10.01	137.5000	9.9000	1010.7	144.60
160.10	159.44	159.45	9.84	145.9500	8.4500	1164.7	154.52
170.11	169.45	169.46	10.01	155.8500	9.9000	1010.7	164.45
180.12	179.46	179.47	10.01	163.4500	7.6000	1316.6	174.45

Waveforms for Sounding LD-CPT-101



GREGG **TERRA ENGINEERS**

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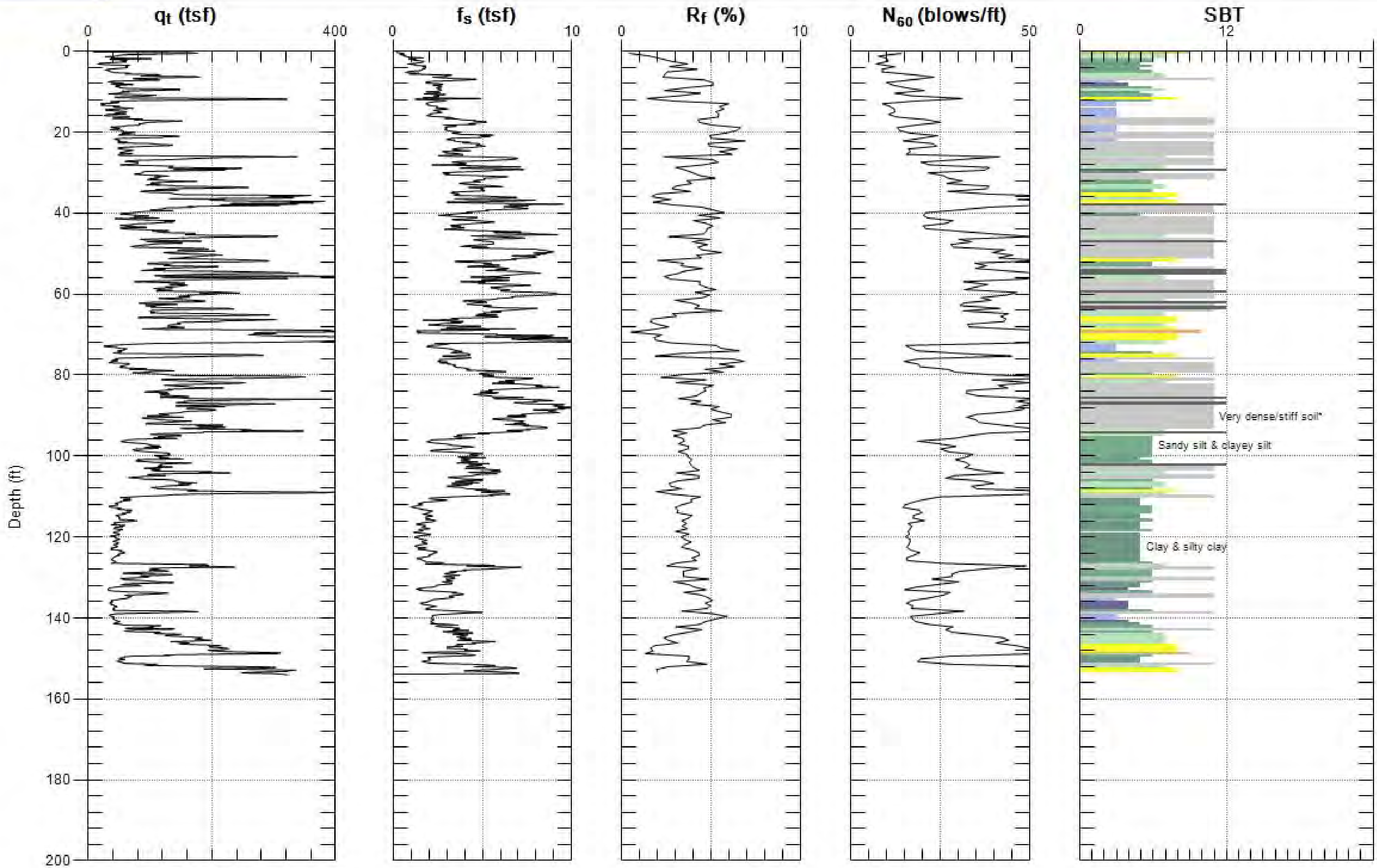
Sounding: LD-CPT-102 | Date: 6/14/2011 01:21



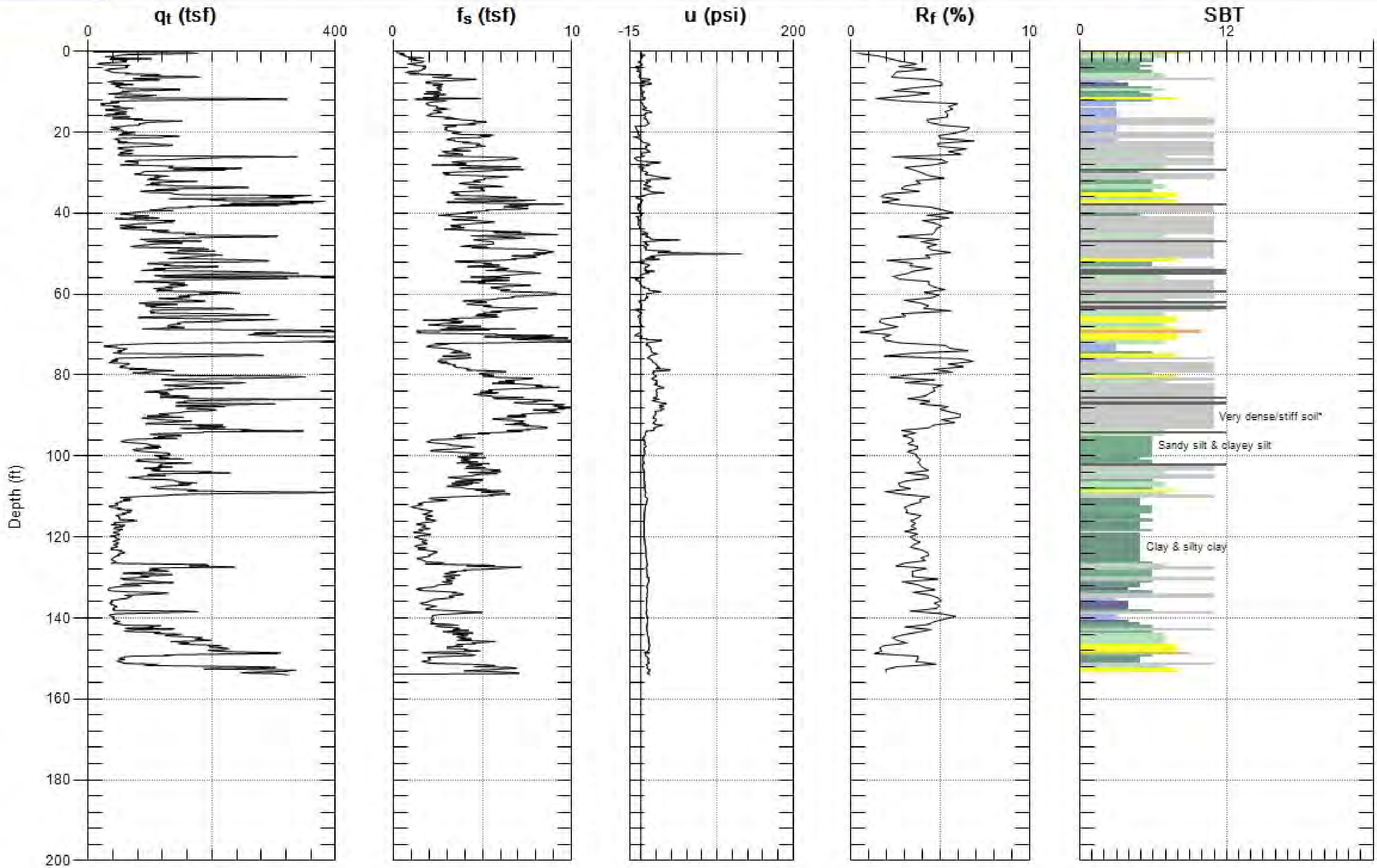
Max. Depth: 154.035 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

TERRA ENGINEERS

Site: LENIHAN DAM | Engineer: B.KIRBY

Sounding: LD-CPT-102 | Date: 6/14/2011 01:21



Max. Depth: 154.035 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

TERRA ENGINEERS

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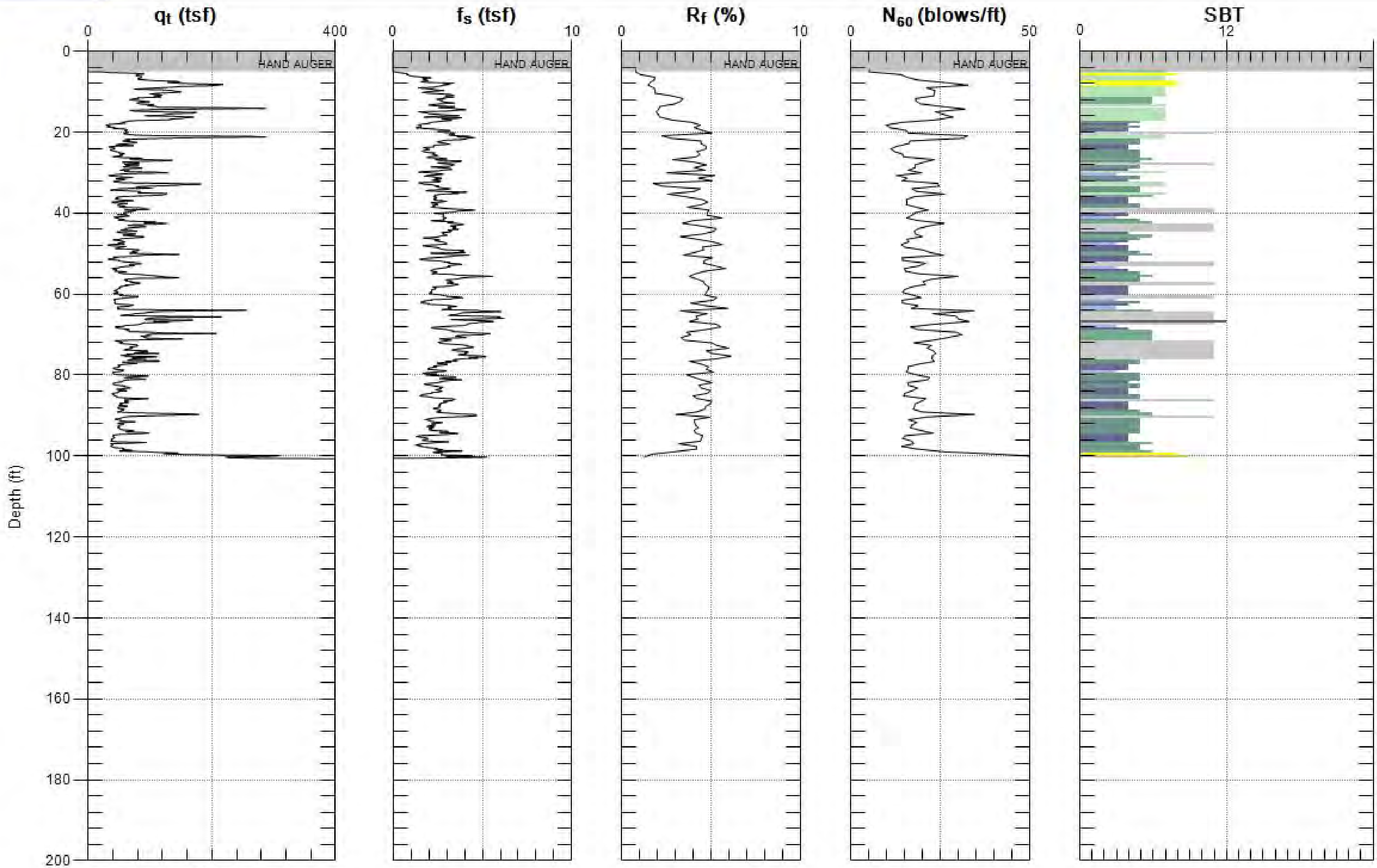
Engineer: B.KIRBY | Date: 6/13/2011 09:27



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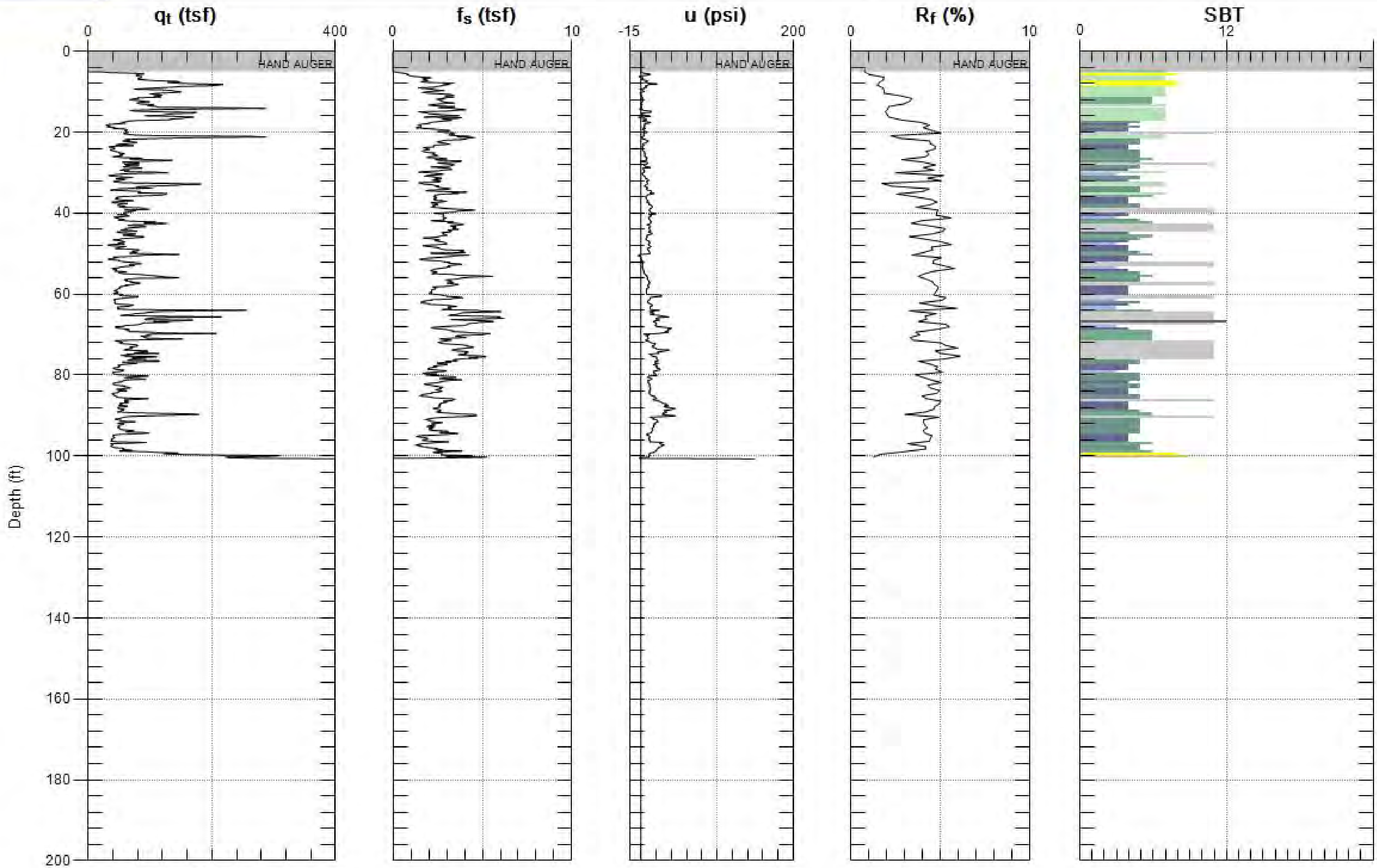
SBT: Soil Behavior Type (Robertson 1990)

TERRA ENGINEERS

Site: LENIHAN DAM
Sounding: LD-CPT-103
Engineer: B.KIRBY
Date: 6/13/2011 09:27



Max. Depth: 100.722 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

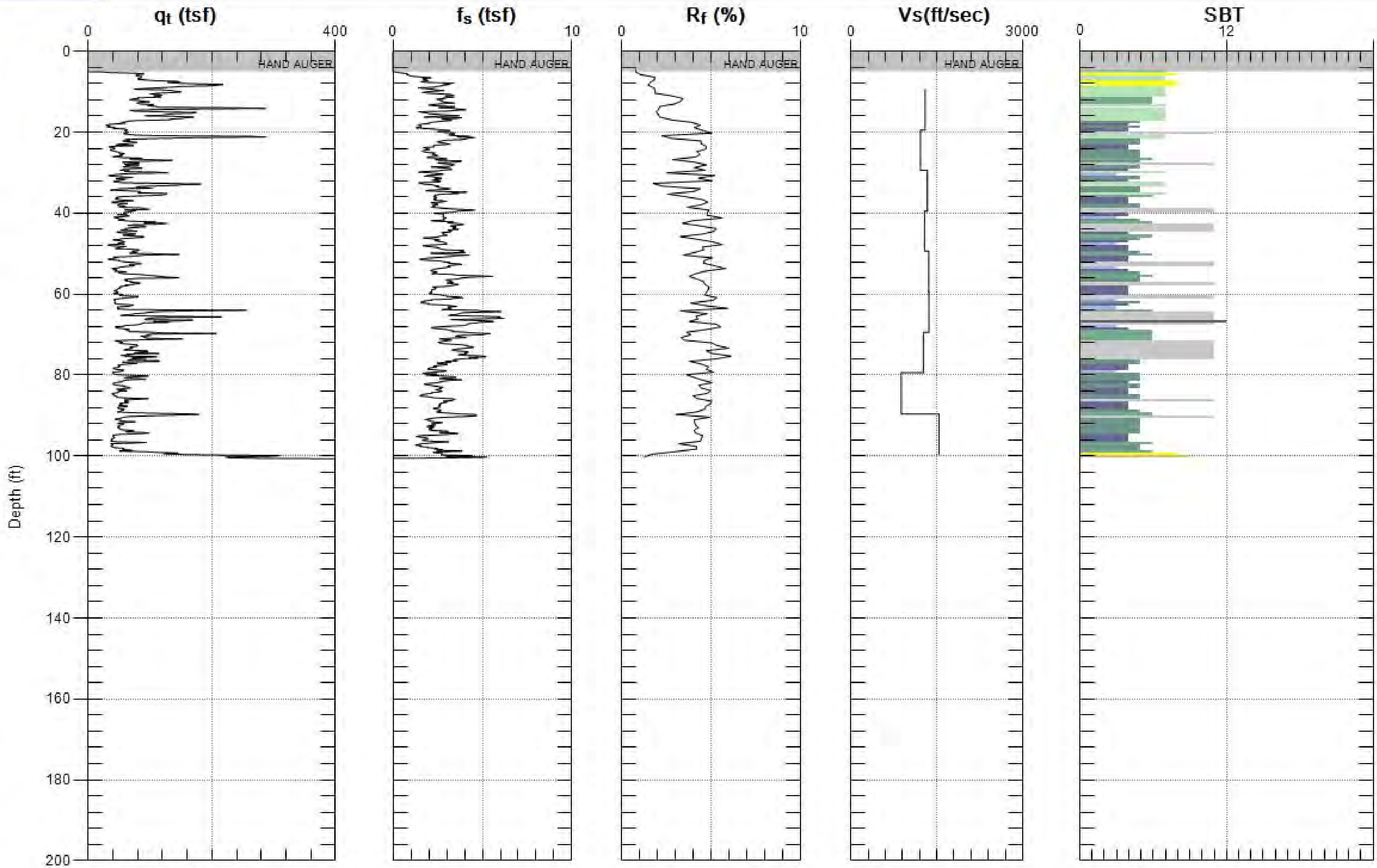
GREGG **TERRA ENGINEERS**

Site: LENIHAN DAM

Sounding: LD-CPT-103

Engineer: B.KIRBY

Date: 6/13/2011 09:27



Max. Depth: 100.722 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

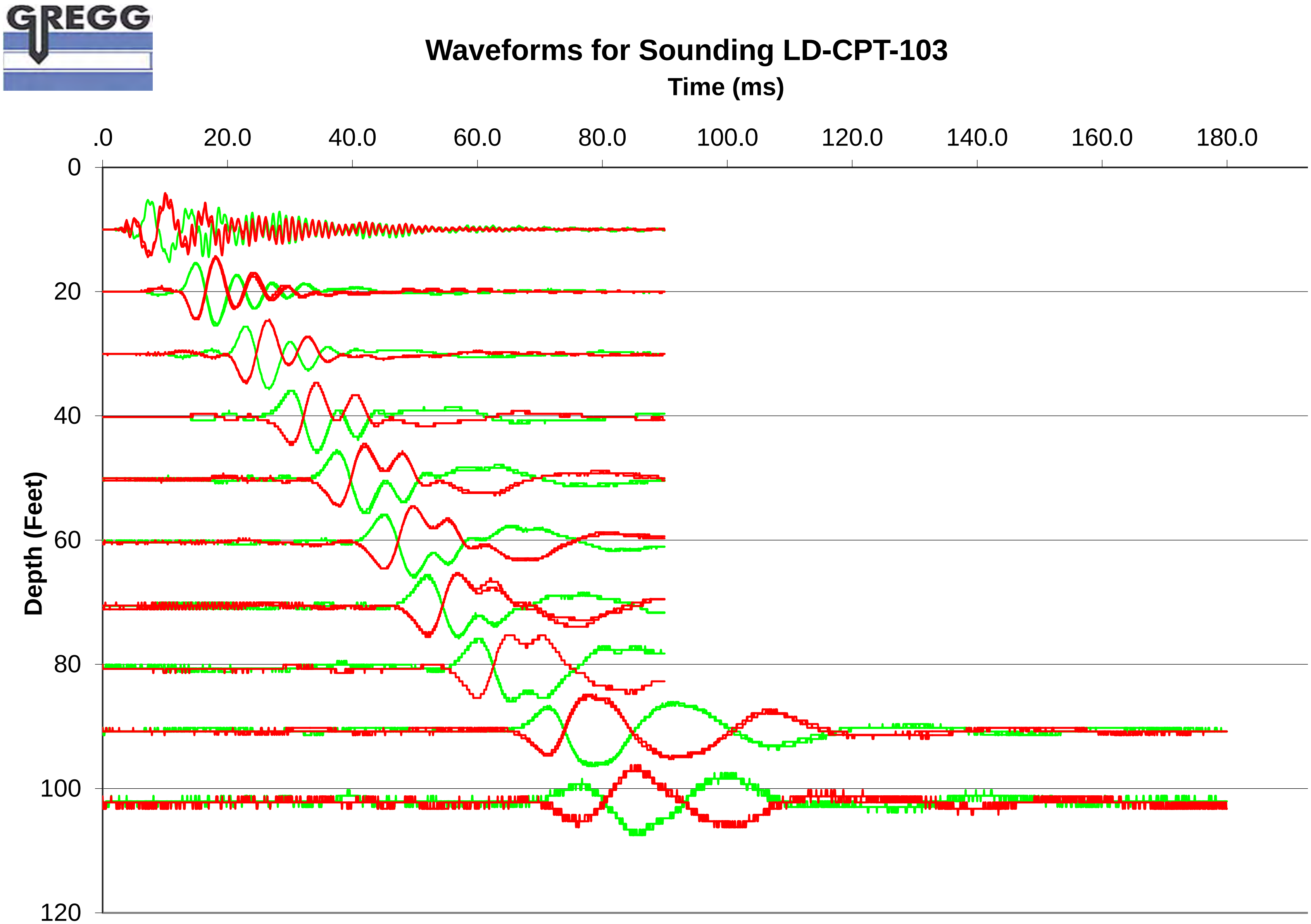
Shear Wave Velocity Calculations

LENIHAN DAM
LD-CPT-103

Geophone Offset: 0.66 Feet
Source Offset: 1.67 Feet

06/13/11

Test Depth (Feet)	Geophone Depth (Feet)	Waveform Ray Path (Feet)	Incremental Distance (Feet)	Characteristic Arrival Time (ms)	Incremental Time Interval (ms)	Interval Velocity (Ft/Sec)	Interval Depth (Feet)
10.01	9.35	9.49	9.49	8.7000			
20.01	19.35	19.42	9.93	16.3500	7.6500	1298.1	14.35
30.02	29.36	29.41	9.98	24.5500	8.2000	1217.3	24.36
40.19	39.53	39.57	10.16	32.1500	7.6000	1336.6	34.44
50.03	49.37	49.40	9.84	39.8000	7.6500	1285.7	44.45
60.04	59.38	59.40	10.00	47.1500	7.3500	1360.8	54.38
70.05	69.39	69.41	10.00	54.5000	7.3500	1361.0	64.38
80.05	79.39	79.41	10.00	62.4000	7.9000	1266.3	74.39
90.22	89.56	89.58	10.17	73.9500	11.5500	880.4	84.48
100.23	99.57	99.58	10.00	80.4500	6.5000	1539.2	94.57


Waveforms for Sounding LD-CPT-103
Time (ms)
.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
Depth (Feet)
0
20
40
60
80
100
120

GREGG

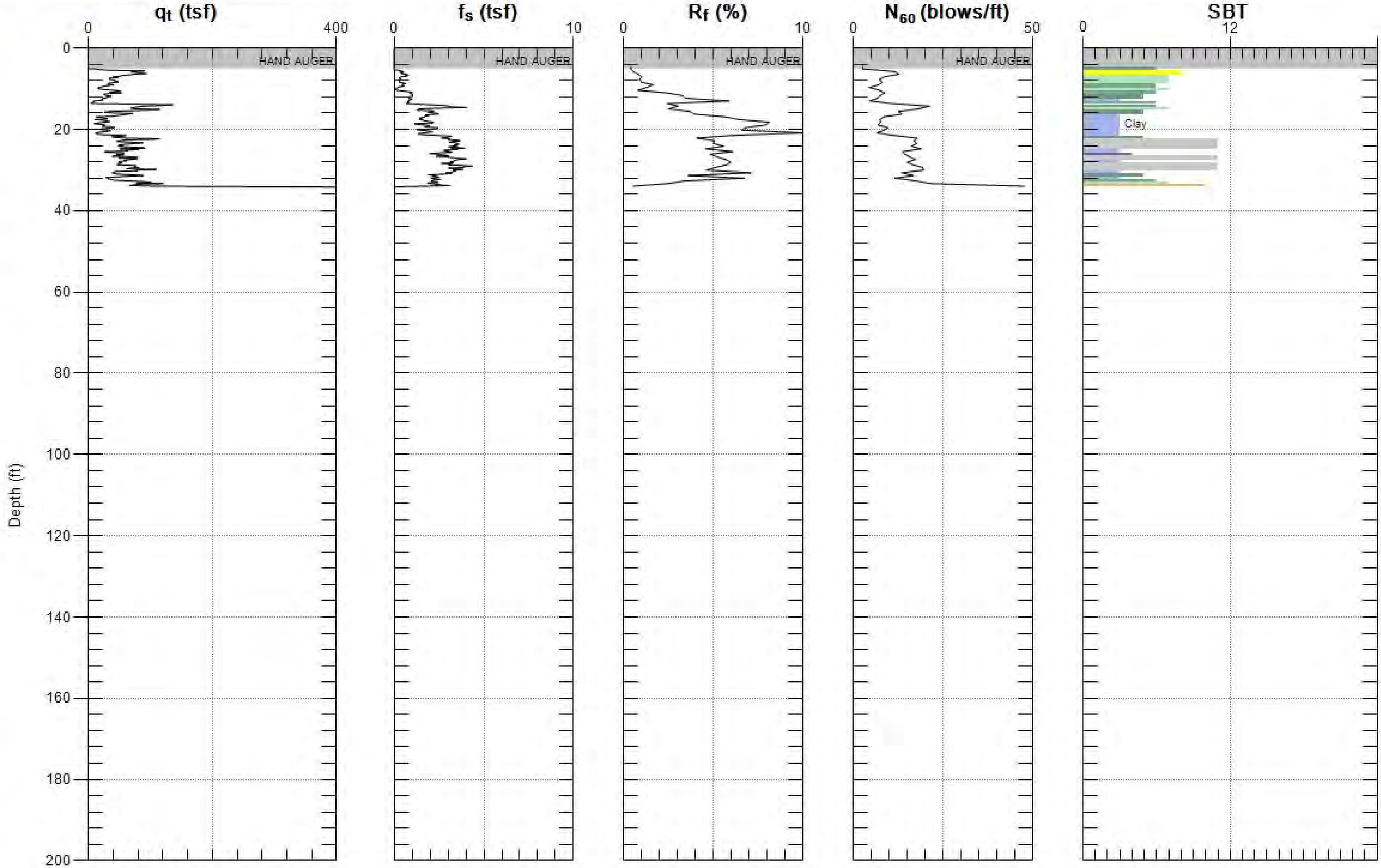
TERRA ENGINEERS

Site: LENIHAN DAM

Sounding: LD-CPT-104

Engineer: B.KIRBY

Date: 6/13/2011 01:24



Max. Depth: 34.285 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

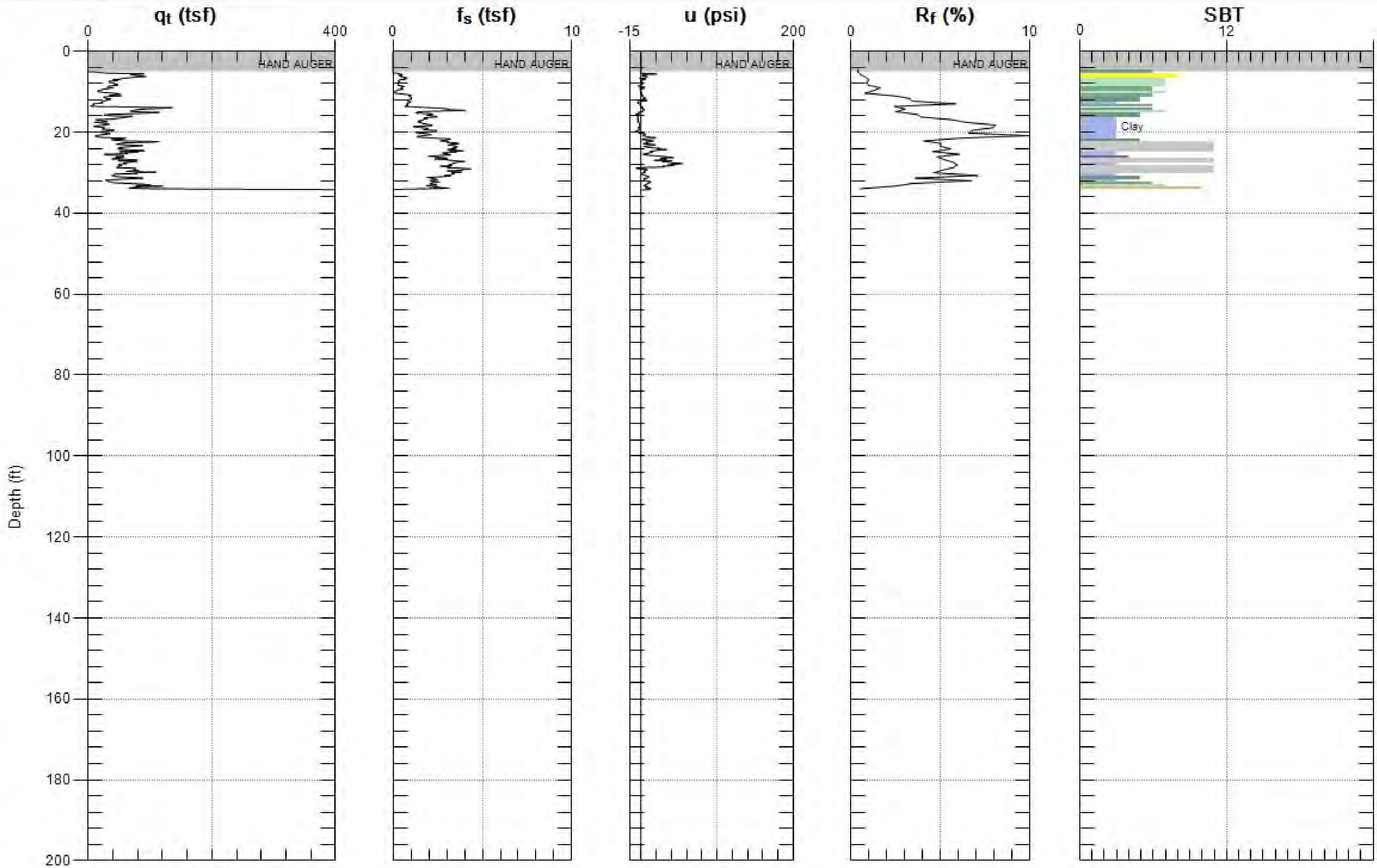
GREGG TERRA ENGINEERS

Site: LENIHAN DAM

Sounding: LD-CPT-104

Engineer: B.KIRBY

Date: 6/13/2011 01:24



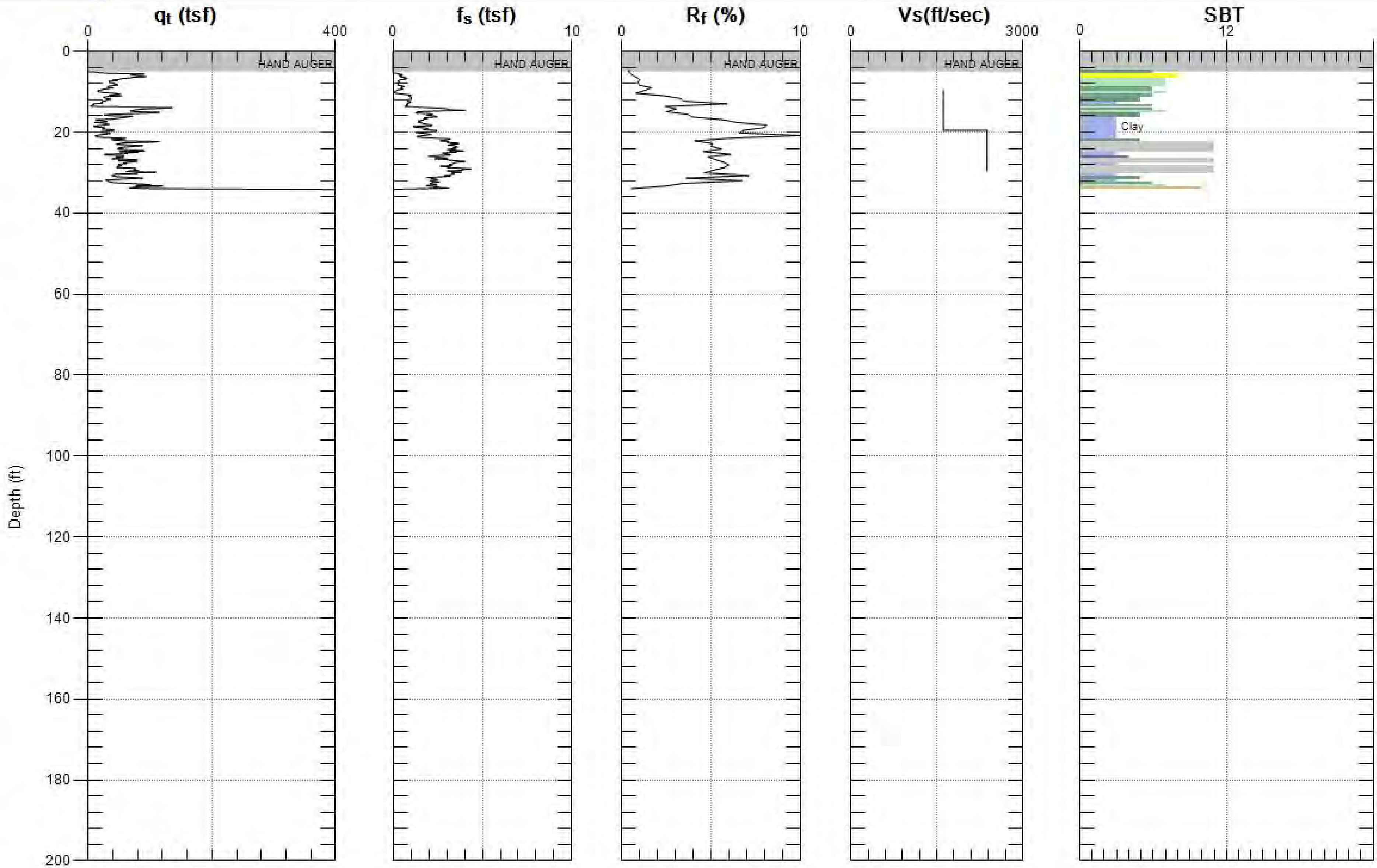
Max. Depth: 34.285 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

TERRA ENGINEERS

Site: LENIHAN DAM
Sounding: LD-CPT-104
Engineer: B.KIRBY
Date: 6/13/2011 01:24



Max. Depth: 34.285 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

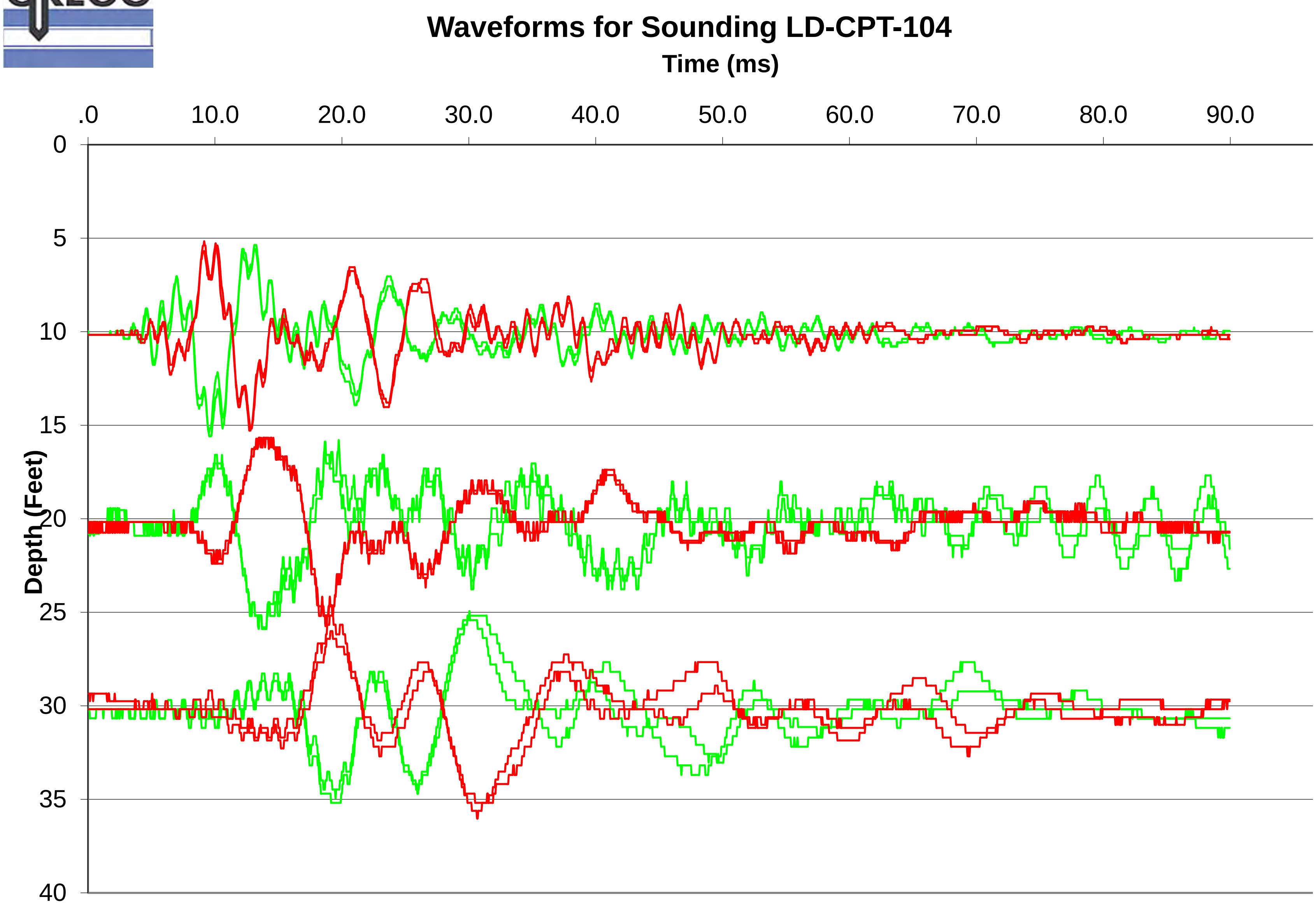
Shear Wave Velocity Calculations

LENIHAN DAM
LD-CPT-104

Geophone Offset: 0.66 Feet
Source Offset: 1.67 Feet

06/13/11

Test Depth (Feet)	Geophone Depth (Feet)	Waveform Ray Path (Feet)	Incremental Distance (Feet)	Characteristic Arrival Time (ms)	Incremental Time Interval (ms)	Interval Velocity (Ft/Sec)	Interval Depth (Feet)
10.17	9.51	9.66	9.66	11.3000			
20.18	19.52	19.59	9.93	17.4500	6.1500	1615.0	14.51
30.18	29.52	29.57	9.98	21.6500	4.2000	2376.8	24.52

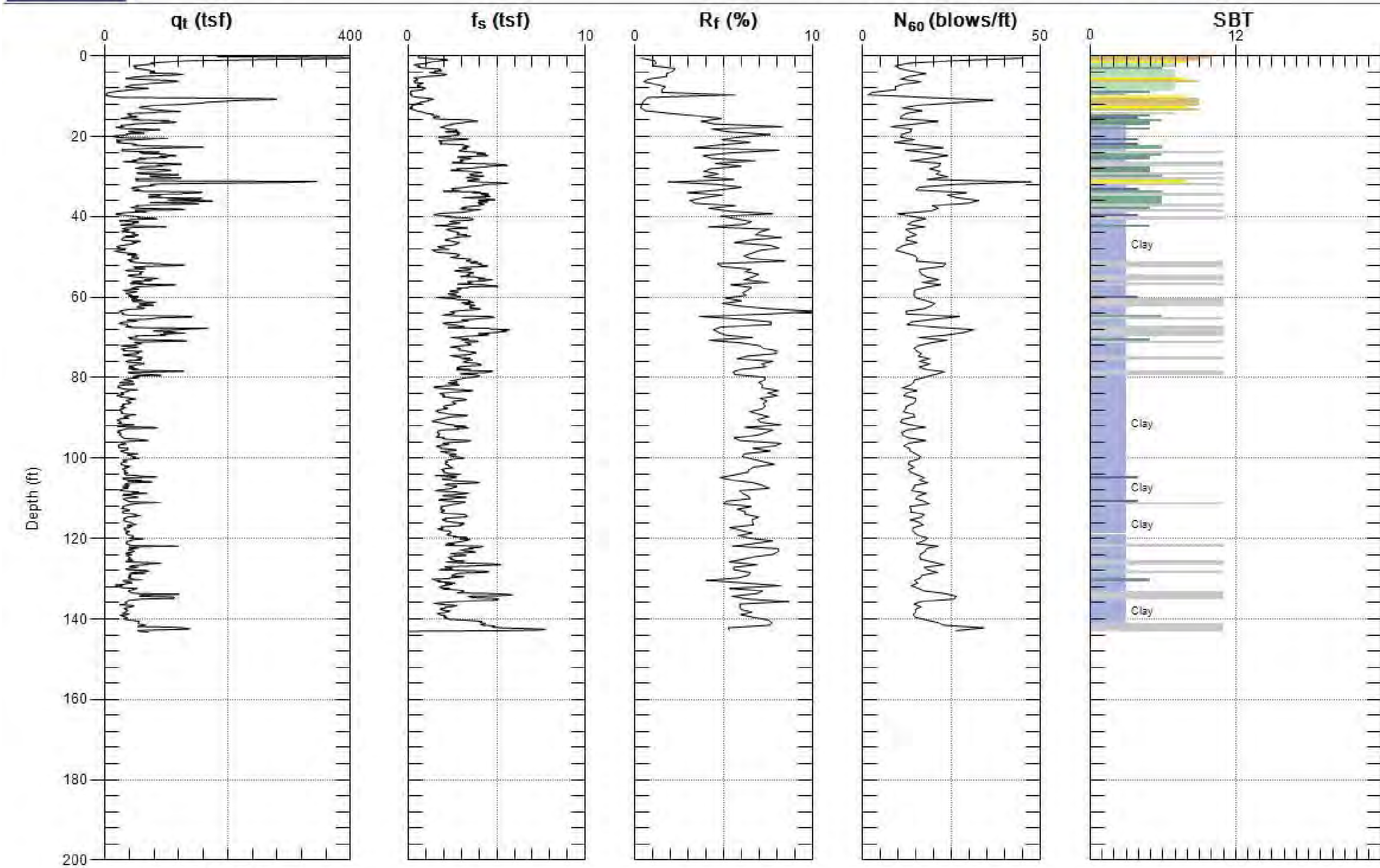

Waveforms for Sounding LD-CPT-104
Time (ms)
.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
0
5
10
15
20
25
30
35
40
Depth (Feet)

GREGG

TERRA ENGINEERS

Site: LENIHAN DAM
Sounding: LD-CPT-104B

Engineer: B.KIRBY
Date: 6/13/2011 02:21



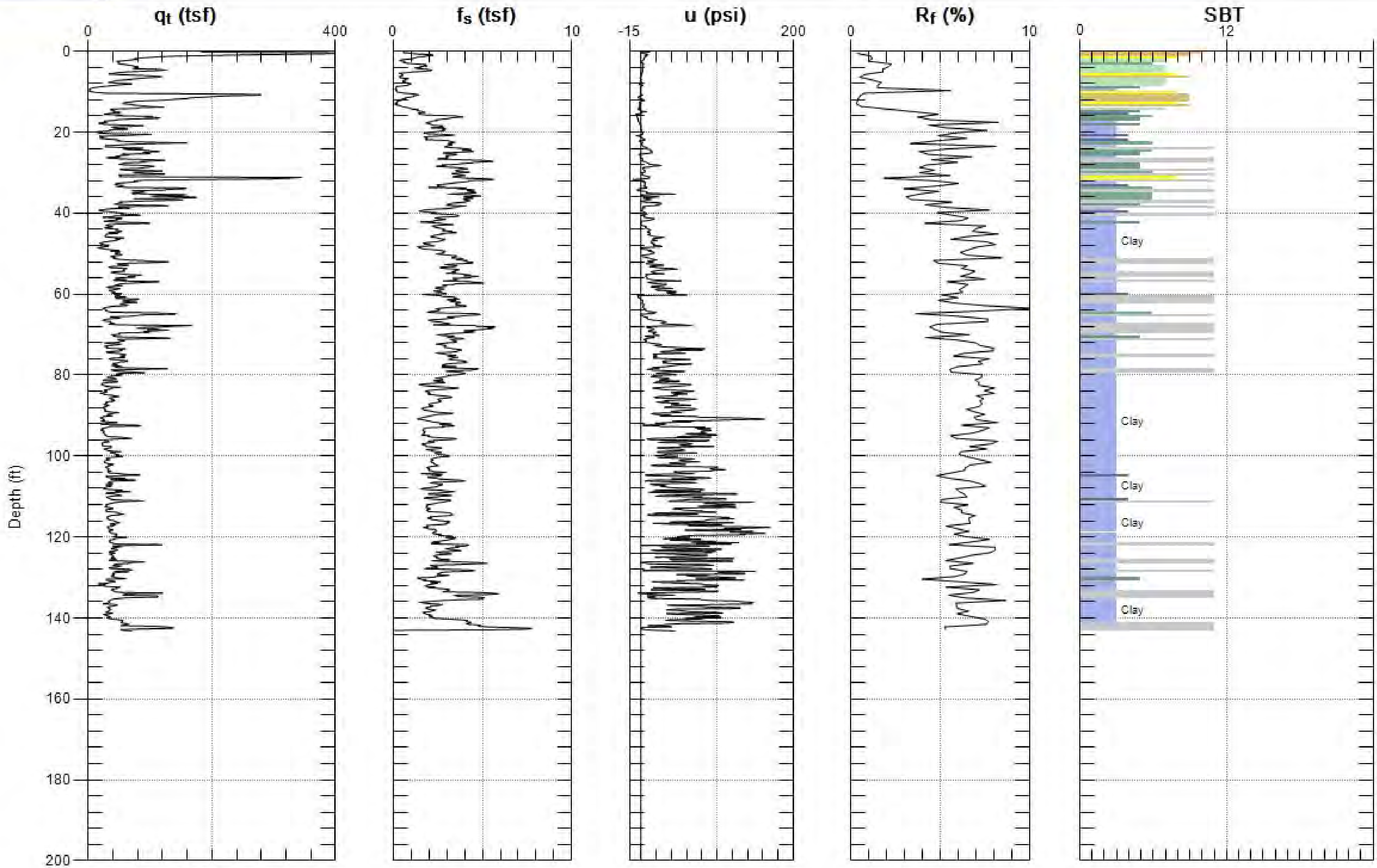
Max. Depth: 143.209 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **TERRA ENGINEERS**

Site: LENIHAN DAM **Engineer: B.KIRBY**

Sounding: LD-CPT-104B **Date: 6/13/2011 02:21**

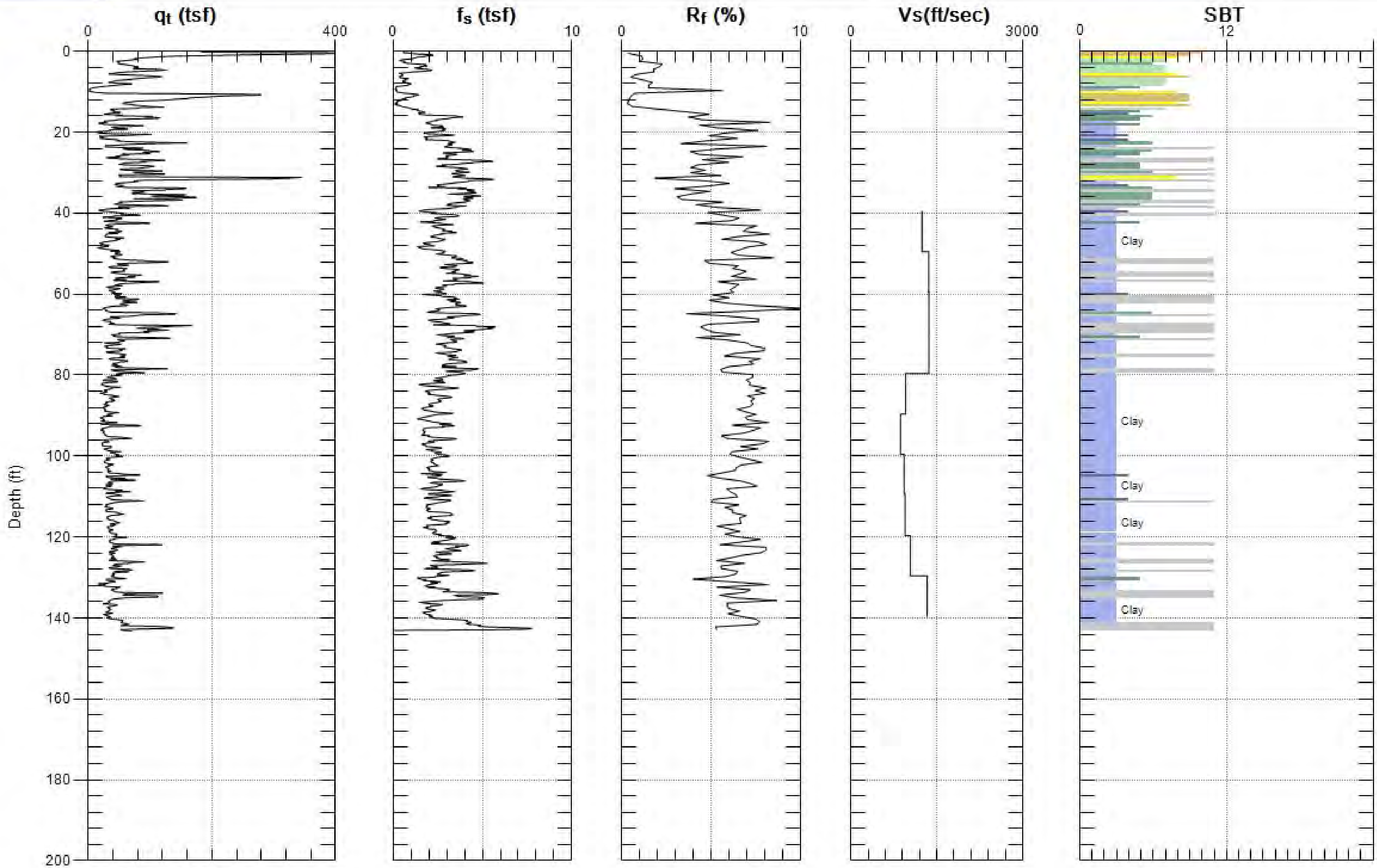


Max. Depth: 143.209 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG **TERRA ENGINEERS**

Site: LENIHAN DAM **Engineer: B.KIRBY**
Sounding: LD-CPT-104B **Date: 6/13/2011 02:21**



Max. Depth: 143.209 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

GREGG

Shear Wave Velocity Calculations

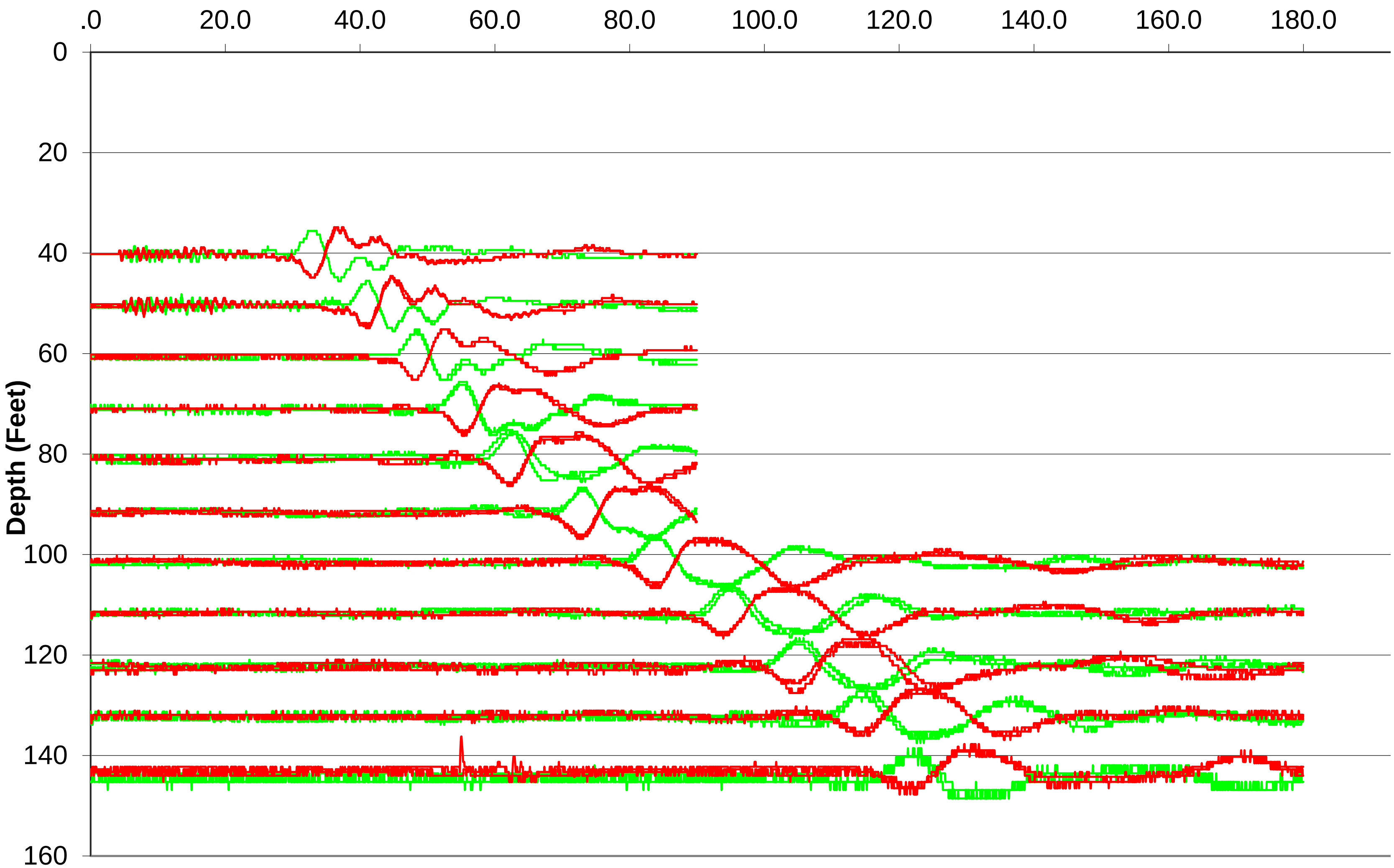
LENIHAN DAM
LD-CPT-104B

Geophone Offset: 0.66 Feet
Source Offset: 1.67 Feet

06/13/11

Test Depth (Feet)	Geophone Depth (Feet)	Waveform Ray Path (Feet)	Incremental Distance (Feet)	Characteristic Arrival Time (ms)	Incremental Time Interval (ms)	Interval Velocity (Ft/Sec)	Interval Depth (Feet)
40.19	39.53	39.57	39.57	34.8500			
50.20	49.54	49.56	10.00	42.9000	8.0500	1242.2	44.53
60.20	59.54	59.57	10.00	50.2500	7.3500	1360.8	54.54
70.21	69.55	69.57	10.00	57.6000	7.3500	1361.0	64.55
80.22	79.56	79.57	10.00	64.9500	7.3500	1361.1	74.55
90.22	89.56	89.58	10.00	75.4000	10.4500	957.4	84.56
100.23	99.57	99.58	10.00	86.9500	11.5500	866.2	94.57
110.07	109.41	109.42	9.84	97.5500	10.6000	928.4	104.49
120.24	119.58	119.59	10.17	108.3000	10.7500	946.0	114.50
130.25	129.59	129.60	10.01	117.9000	9.6000	1042.3	124.59
140.26	139.60	139.61	10.01	125.4000	7.5000	1334.1	134.59

Waveforms for Sounding LD-CPT-104B



APPENDIX B

CONTENTS

Figures

SANTA CLARA VALLEY WATER DISTRICT
SEISMIC SAFETY EVALUATIONS (SSE2)

Key to Log of Boring

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows/6 in. or Pressure, psi	SAMPLES: Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

COLUMN DESCRIPTIONS

1 **Elevation:** Elevation in feet referenced to specified datum.

2 **Depth:** Depth in feet below the ground surface.

3 **Sample Type:** Type of soil or rock sample collected at depth interval shown; sampler symbols are explained below.

4 **Sample Number:** Sample identification number.

5 **Blows/6 in. or Pressure:** Number of blows required to advance drive sampler each 6-inch drive interval, or distance noted, using a 140-lb hammer dropped 30 inches; or pull down pressure in psi to advance Pitcher or Shelby sampler.

6 **Recovery:** Length in feet of material recovered in sampler.

7 **Graphic Log:** Graphic depiction of subsurface material encountered. Typical symbols are given below; variations on these symbols are used to indicate secondary soil components.

8 **Material Description:** Description of material encountered; in addition to soil or rock classification, may include color, moisture, relative density/consistency, particle size, and plasticity for soil; texture, weathering, strength, and hardness of bedrock.

9 **% Gravel:** Percent of soil by weight retained on the No. 4 sieve as determined per ASTM Method D422.

10 **% Fines:** Percent of soil by weight passing the No. 200 sieve as determined per ASTM Method D422.

11 **Liquid Limit:** Liquid Limit (LL) of soil specimen passing the No. 40 sieve as determined per ASTM Method D4318.

12 **Plasticity Index:** Plasticity Index (PI=LL-PL) of soil specimen passing No. 40 sieve as determined per ASTM Method D4318.

13 **Moisture Content:** Moisture content, as a percentage of dry weight of specimen, determined per ASTM Method D2216.

14 **Dry Unit Weight:** Dry weight per unit volume of soil, reported in pounds per cubic foot, determined per ASTM Method D2937.

15 **Field Notes and Other Tests:** Comments and observations regarding drilling or sampling made by driller or field personnel. Lab test results other than those listed in columnar format may be recorded using abbreviations below.

TYPICAL MATERIAL GRAPHIC SYMBOLS

- POORLY GRADED SAND (SP)
- SILT (ML)
- LEAN CLAY (CL)
- POORLY GRADED GRAVEL (GP)
- WELL-GRADED SAND with SILT (SW-SM)
- SANDY SILT (ML)
- SILTY CLAY (CL-ML)
- WELL-GRADED GRAVEL (GW)
- SILTY SAND (SM)
- SILTY, CLAYEY SAND (SC-SM)
- CLAYEY SAND (SC)
- SILTY GRAVEL (GM)
- SANDSTONE
- SHALE
- Interbedded SANDSTONE and SHALE
- CHERT

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (SPT) split spoon
- HQ rock core barrel
- Shelby Tube (fixed-head, thin-walled)
- Modified California (2.4-inch-ID, 3-inch-OD)
- Pitcher Barrel (lined with Shelby tube)
- Bulk sample collected from auger cuttings

OTHER GRAPHIC SYMBOLS

- First water encountered at time of drilling and sampling
- Static water level measured at specified time after drilling
- Change in material properties within a lithologic unit
- ——— Inferred contact between soil strata or gradational change

OTHER LABORATORY TEST ABBREVIATIONS

CONS One-Dimensional Consolidation Test
DSS Direct Simple Shear Test
Gs Specific Gravity
TX-CIU Isotropically Consolidated Undrained Triaxial Test

GENERAL NOTES

1. Soil classifications are based on the Unified Soil Classification System. Descriptions and stratum lines are interpretive; actual lithologic changes may be gradual. Field descriptions may have been modified to reflect results of lab tests.

2. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced. They are not warranted to be representative of subsurface conditions at other locations or times.

Figure B-1

SANTA CLARA VALLEY WATER DISTRICT
SEISMIC SAFETY EVALUATIONS (SSE2)

Log of Boring LD-B-101

Date(s) Drilled	6/17/11 - 6/23/11; grouted 6/24/11	Logged By	R. Harlan	Checked By	R. Kirby
Drilling Method	Mud Rotary	Drill Bit Size/Type	5-7/8-in. tricone and drag bits, 3-7/8-in. tricone bit, HQ core bit	Total Depth of Borehole	258.0 feet
Drill Rig Type	Fraste Multidrill XL	Drilling Contractor	Pitcher Drilling	Surveyed Ground Surface Elevation	673.0 feet
Groundwater Level(s)	Not determined	Sampling Method	Modified California, SPT, Pitcher Barrel (3-in. and 4-in.), HQ core	Hammer Data	Automatic hammer; 140 lbs / 30-inch drop
Borehole Location	Approx. Station 15+80, dam crest, 11 ft U/S of centerline	Borehole Completion	Cement-bentonite grout slurry via tremie		

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	0						Asphalt (5 inches) over Road Base (6 inches)							Start drilling at 08:00 on 6/17/11 with 6-1/2-in. trash barrel to 3.5 ft. Set 6-in. casing to 4 ft.
							EMBANKMENT / UPPER CORE CLAYEY SAND WITH GRAVEL (SC), moderate yellowish brown, medium dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 1-1/2 inches, occasional gravel to 2+ inches.							
670														Drill with 5-7/8-in. tricone bit and bentonite-based drill fluid below 3.5 ft.
	5	SPT	SP-1	6 9 7	1.1							10.5		
665							Becomes dark yellowish brown to grayish brown							
							Increased gravel content (GC?)							Drill chatter 9-10.5 ft.
	10	SPT	SP-2	8 11 9	0.1									Poor recovery in SPT; gravel fragment jammed in shoe.
660														
	15	SPT	SP-3	12 14 14	0.7		Becomes mostly dark greenish gray, occasional pockets of moderate and dark yellowish brown		30	31	15	14.1		
655														Full drill fluid return.
	20	PB	PB-1	400 1000	1.2									Pitcher Barrel at 20 ft (4-in. used for all PB samples unless otherwise noted). Pull down pressure recorded in psi. Tip slightly dented.
650														
	25	SPT	SP-4	11 15 19	0.9		Becomes dense	22	42	33	17	17.2		
645														
	30													

Log of Boring LD-B-101

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	Material Description	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	Field Notes and Other Tests
	30	MC	MC-1	22 30 45	0.3	CLAYEY SAND WITH GRAVEL (SC), dark greenish gray with occasional pockets of moderate and dark yellowish brown, dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 2 inches [Embankment / Upper Core] (continued)					10.2		Modified California (3-in. OD) at 30 ft; sample retained in plastic bag.
640													
	35	SPT	SP-5	6 12 34	1.1	Becomes medium dense; Moderate yellowish brown; Coarse gravel or cobbles					11.9		Chattery, rough drilling 36.2-37.0 ft. Smoother drilling at 37 ft.
635													
	40	SPT	SP-6	8 12 14	1.0								
630													Driller reports softer drilling 43-45 ft.
	45	PB	PB-2	1000 700	1.5	Increased gravel content (GC?); Becomes mixed moderate yellowish brown and medium gray	15	47	34	15	16.5	117	Pitcher Barrel hanging up on sidewalls. Pull tube, ream hole with empty barrel, then with tricone prior to sampling at 45 ft. Chattery sampling to 46 ft; tip slightly shredded.
625													
	50	SPT	SP-7	10 14 18	0.2	Becomes dense					6.4		Poor recovery in SPT; 1-1/2-in. gravel wedged in shoe.
620													
	55	MC	MC-2	16 23 33	1.0	Becomes mostly dark greenish gray with minor yellowish brown mottling	25	32	33	17	12.1		Retain liner sample 55.3-55.8 ft.
615													Continued full fluid return.
	60	PB	PB-3	1000 1100	1.9	Becomes mixed reddish brown and yellowish brown							Pitcher Barrel tip slightly shredded.
610													
	65												

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	65	SPT	SP-8	10 15 21	1.5	Mixed reddish brown and olive gray, minor gravel							
605						Increased gravel and cobbles (GC?)							Very rough drilling 67-68 ft.
						CLAYEY SAND WITH GRAVEL (SC), mixed reddish brown and yellowish brown, dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 2 inches [Embankment / Upper Core] (continued)							
	70	SPT	SP-9	13 21 19	1.2	Becomes mostly olive gray mixed with yellowish brown and reddish brown		27	32	15	12.1		
600						Becomes mostly moderate brown with yellowish brown and reddish brown mottling							Continued full fluid return.
	75	MC	MC-3	20 26 32	1.0		26	35	37	21	11.9		Retain liner sample 75.3-75.8 ft.
													End for 6/17/11 at 17:50. Resume drilling at 07:30 on 6/20/11. Fluid level at 13 ft bgs prior to start of drilling.
595													
	80	SPT	SP-10	12 15 16	0.5								
590						**LOWER CORE** FAT CLAY (CH), dark gray, very stiff to hard, high plasticity, minor fine- to coarse-grained sand and gravel to 1 inch; locally higher concentrations of sand and gravel (shale fragments)							
	85												Attempt Pitcher Barrel at 85 ft. Tube falls off; must overdrill with barrel to recover.
585		PB	PB-4	600	1.6		1	92			21.0	101	DSS
											23.0	103	CONS
				1000		Localized gravelly zone (GC)	51	45	70	48	20.0	109	TX-CIU
	90												Switch to 5-7/8-in. drag bit at 89.5 ft.
580													
	95	SPT	SP-11	10 12 18	1.2						28.9		
575						Becomes hard							
	100												

Report: TGP SSE2 SOIL+LAB; File: SCVWD_LENIHAN.GPJ; 10/3/2011

TERRA / GeoPentech
a Joint Venture

Elevation, feet	Depth, feet	Sample Type	Sample Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
			SP-12	7 13 20	1.1		FAT CLAY (CH), dark gray, hard, high plasticity, minor fine- to coarse-grained sand and gravel to 1 inch; locally higher concentrations of sand and gravel (shale fragments) [Lower Core] (continued)		81	59	37			
570			PB-5	0 500	1.9									Sample with 3-in. Pitcher Barrel at 102 ft.
	105													
							Becomes dark yellowish brown mixed or mottled with light brown and dark gray							
565							Gravelly zone (GC?); 3-inch cobble in top of PB-6							Chattery, rough drilling 108-110.3 ft.
	110		PB-6	400 1500	1.2									Return to 4-in. Pitcher Barrel 110.3 ft; refusal at 111.8 ft, tip dented.
			SP-13	10 14 18	1.2		Increased fine- to coarse-grained sand and fine gravel					27.3		
560														
	115													Continued full fluid return.
555							Gravelly zone (GC?)							Chattery, rough drilling 117.5-119.5 ft.
	120		PB-7	500 1000	1.9		SANDY FAT CLAY WITH GRAVEL (CH), hard, high plasticity fines, ~15-25% fine- to coarse-grained sand and gravel to 3/4 inch							Pitcher Barrel tip badly dented; sample may be grooved.
550			SP-14	8 14 20	1.5		FAT CLAY (CH), mostly dark gray with minor light brown to yellowish brown mottling, hard, high plasticity, minor fine- to coarse-grained sand and fine gravel (shale fragments)							End for 6/20/11 at 17:25. Resume drilling at 07:40 on 6/21/11. Fluid level at 7 ft bgs prior to start of drilling. Chattery drilling 125-126 ft and at 129.5 ft.
	125						Gravelly zone (GC?)							
545							Narrow gravelly zone							
	130		PB-8	800 1300	1.9			0	94			24.1	99	Pitcher Barrel tip dented. DSS
												24.2	102	CONS
							Becomes mostly dark yellowish brown with yellowish orange, gray, and reddish brown mottling	18	63	63	42	21.5	107	TX-CIU, Gs=2.77
540			SP-15	10 17 23	1.3		SANDY LEAN to FAT CLAY WITH GRAVEL (CL/CH), medium to high plasticity, ~20-40% fine- to coarse-grained sand and fine gravel to 3/4 inch					27.3		
	135						FAT CLAY (CH), hard, high plasticity [see next sheet]							

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
							Gravelly zone (GC?)							Chattery drilling 135-135.5 ft.
							FAT CLAY (CH), mostly dark yellowish brown with yellowish orange, gray, and reddish brown mottling, hard, high plasticity, minor fine- to coarse-grained sand and fine gravel (shale fragments) [Lower Core]							
535														
							Gravelly zone (GC?)							Chattery zones 138.5-139 ft and 139.5-140.5 ft.
	140						Gravelly zone (GC?)							
			PB-9	1100	2.0									Pitcher Barrel tip slightly dented.
530			SP-16	12 15 28	1.2		CLAYEY GRAVEL (GC) layer 3 inches thick, moderate brown, gravel-size fragments of very weak shale							Switch to 5-7/8-in. tricone bit at 142.5 ft.
	145													
525														
	150		PB-10	300 800	2.3									Gravelly at end of Pitcher Barrel run; tip slightly dented.
							CLAYEY GRAVEL (GC), fine to coarse gravel to 1 inch							
520			SP-17	11 16 23	1.5							24.7		
	155													
							Gravelly zone (GC?)							Chattery drilling 155.5-156 ft.
515														Continued full fluid return.
	160		PB-11	300 800	1.5									
							Several fine to coarse gravel pieces to 1 inch							
510			SP-18	11 19 23	1.5									
	165													
505							Zone of coarse gravel or cobbles (GC?)							Rough drill chatter 168-168.5 ft.
	170													

Elevation, feet	Depth, feet	Samples: Type / Number	Blows/6 in. or Pressure, psi	Recovery, feet	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
		PB-12	300	1.9	FAT CLAY (CH), mostly dark yellowish brown with yellowish orange, gray, and reddish brown mottling, hard, high plasticity, minor fine- to coarse-grained sand and fine gravel (shale fragments) [Lower Core] (continued)	2	80			27.3	93	DSS
										37.1	81	CONS
			600			27	51	57	38	20.5	108	TX-CIU, Gs=2.69
500		SP-19	10 16 21	1.5						28.6		
												End for 6/21/11 at 18:00. Resume drilling at 07:45 on 6/22/11. Fluid level at 7 ft bgs prior start of to drilling.
	175											
495												
	180	PB-13	300 800	1.2								Pitcher Barrel tip slightly dented.
					← Several hard, fine to coarse, rounded gravel to 2 inches							
490		SP-20	9 14 22	1.5								
	185											Continued full fluid return.
485												
	190	PB-14	100 800	1.0								Pitcher Barrel tip slightly dented.
480		SP-21	13 21 33	1.1	**FOUNDATION / FRANCISCAN COMPLEX** SANDY LEAN CLAY WITH GRAVEL (CL), dark yellowish brown and light brown, very stiff to hard, medium plasticity fines; deeply weathered shale (melange matrix) or possibly lowermost embankment fill							Drill with 5-in. claw bit below 192.2 ft.
					SHALE, olive gray and black, deeply weathered, friable, low hardness, crushed (melange matrix), includes some harder blocks							
	195	SP-22	50/4"	0								Drill without sampling below 196.3 ft.
475												
	200											
					SANDSTONE, medium dark gray, fine-grained, little weathered, strong, hard, closely to locally intensely fractured, probably some mechanical breakage (based on recovered core below 210 ft)							Very slow, consistently hard drilling 201-203 ft (20 min/ft).
470												Switch to 3-7/8 in. tricone at 203.5 ft.
	205											

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
465							SANDSTONE, medium dark gray, fine-grained, little weathered, strong, hard, closely to locally intensely fractured [Foundation / Franciscan Complex] (continued)							Continued hard, slow drilling with 3-7/8-in. tricone; drill 206-210 ft in 40 min. Mostly hard, moderate gray sandstone cuttings in return.
	210		Run 1		2.0									Trip rods, switch to HQ core. Run 1 RQD=0% End for 6/22/11 at 17:00. Resume at 0814 on 6/23/11; thin drill fluid before start of coring.
460			Run 2		1.0		SHALE, dark gray, clayey, probably sheared, occasional blocks of harder sandstone							Run 2 RQD=0%
	215		Run 3		0									Run 3 no recovery due to washing out of probable shale. Switch back to 3-7/8-in. tricone. Drill 215-220 ft in 21 min.
455	220						SANDSTONE with lesser SHALE							Drill 220-230 ft in 106 min. Slow drilling; increased hard sandstone cuttings. Occasional very slight fluid losses below 220 ft; typically full fluid return.
450	225													
445	230						SHALE with lesser SANDSTONE							Faster drilling below 229 ft, with intermittent slower, harder drilling. Drill 230-240 ft in 57 min.
440	235													
435	240													

SANTA CLARA VALLEY WATER DISTRICT
SEISMIC SAFETY EVALUATIONS (SSE2)

Log of Boring LD-B-101

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
							SHALE with lesser SANDSTONE [Foundation / Franciscan Complex] (continued)							Drill 240-250 ft in 45 min.
430														Continued full fluid return with occasional very slight losses.
	245													
425														
	250													Drill 250-257 ft in 30 min.
420														
	255													
415							**Bottom of boring at 258.0 feet**							Terminate hole at 14:15 on 6/23/11. Conduct OYO P-wave and S-wave survey on 6/23/11. Backfill hole with grout via tremie on 6/24/11.
	260													
410														
	265													
405														
	270													
400														
	275													

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SANTA CLARA VALLEY WATER DISTRICT
SEISMIC SAFETY EVALUATIONS (SSE2)

Log of Boring LD-B-102

Date(s) Drilled	**6/20/11 - 6/22/11; grouted 6/23/11**	Logged By	**A. Dinsick / R. Harlan**	Checked By	**R. Kirby**
Drilling Method	**Mud Rotary**	Drill Bit Size/Type	**5-7/8-in. and 4-7/8-in. tricone bits; HQ core bit**	Total Depth of Borehole	**137.0 feet**
Drill Rig Type	**Fraste Multidrill XL**	Drilling Contractor	**Pitcher Drilling**	Surveyed Ground Surface Elevation	**626.7 feet**
Groundwater Level(s)	**Not determined (taped dry to 137 ft)**	Sampling Method	**SPT, 4-in. Pitcher Barrel, HQ core**	Hammer Data	**Automatic hammer; 140 lbs / 30-inch drop**
Borehole Location	**Approx. Station 15+80, D/S slope on bike path**	Borehole Completion	**Bentonite pellets 133-137 ft; cement-bentonite grout via tremie to surface**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	0						Asphalt (2 inches) over Road Base (8 inches)							Start drilling at 09:10 on 6/20/11 with 6-1/2-in. trash barrel to 4 ft. Stand by 09:30 to 10:30 while drill crew set 5 ft of 6-in. casing, set up mud tank, performed maintenance on rig. Drill with 5-7/8-in. tricone bit and bentonite-based drill fluid below 4 ft. A. Dinsick logging.
625							**DOWNSTREAM SHELL** CLAYEY GRAVEL WITH SAND (GC), olive gray with yellowish brown mottling, medium dense, fine to coarse gravel, fine-grained sand, ~20-40% medium plasticity fines							
	5		SP-1	4 8 8	1.5							7.1		
620														
	10		SP-2	8 9 10	1.2		Becomes gray to dark gray with reddish brown clayey matrix, ~50-60% fine to coarse angular gravel to 1-1/2 inches, ~15-30% medium plasticity fines							
615														
	15		SP-3	5 6 8	1.3		CLAYEY SAND WITH GRAVEL (SC), reddish brown to olive gray, medium dense, fine- to coarse-grained sand, ~20-45% medium plasticity fines, ~10-40% fine gravel consisting of friable and decomposing shale fragments	20	32	33	16	13.6		
610														
	20		SP-4	7 11 11	1.5		Becomes olive gray to dark greenish gray							Reach 20 ft at 11:00.
605														
	25		SP-5	9 13 18	1.2		Becomes olive gray with reddish brown mottling, dense					14.2		
600														
	30		SP-6	7 15	1.2		4-inch reddish brown layer with coarse angular gravel	36	23	30	14	10.7		

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	30	SPT	SP-6	15	1.2	CLAYEY SAND WITH GRAVEL (SC), olive gray with reddish brown mottling, dense, fine- to coarse-grained sand, ~20-45% medium plasticity fines, ~10-40% fine gravel consisting of friable and decomposing shale fragments [Downstream Shell] (continued)							
595													
						CLAYEY GRAVEL WITH SAND (GC), olive gray with reddish brown mottling, dense, fine to coarse gravel, fine- to coarse-grained sand, ~30-45% medium plasticity fines							Drill to 36 ft at 11:30. Stand by for Pitcher Barrel until 13:10.
	35	Pitcher Barrel	PB-1		1.5								
590						Becomes reddish brown with yellowish brown mottling	54	30	46	29	10.4	131	TX-CIU
						CLAYEY GRAVEL WITH SAND to CLAYEY SAND WITH GRAVEL (GC/SC), reddish brown with yellowish brown mottling, dense, fine to coarse gravel to 1 inch consisting mostly of angular hard shale, fine- to coarse-grained sand, ~20-40% medium plasticity fines							Significant rod chatter at 38 ft.
	40												
585													
		Pitcher Barrel	PB-2		2.0								
	45												Harder drilling.
		SPT	SP-7	12 19 25	1.5		39	24	33	15	12.0		
580													
	50	SPT	SP-8	15 22 29	1.2								
575													
						Gravel mostly friable and decomposed shale fragments							
	55	SPT	SP-9	14 16 28	1.2		41	21			7.6		Insufficient sample for Atterberg test.
570													
	60	Pitcher Barrel	PB-3		0.7	Becomes moderate yellowish brown with occasional reddish brown zones							Pitcher Barrel refusal at 61 ft due to clay plugging fluid path or bent tube.
565													
		SPT	SP-10	15 23	NA	4-inch layer of angular gravel							
	65												

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	65		SP-10	23	NA		CLAYEY GRAVEL WITH SAND to CLAYEY SAND WITH GRAVEL (GC/SC), moderate yellowish brown with occasional reddish brown zones, dense, fine to coarse gravel consisting mostly of friable and decomposing shale fragments, fine- to coarse-grained sand, ~20-40% medium plasticity fines [Downstream Shell] (continued)							
560														
							Becomes medium dense							
	70		SP-11	13 15 14	0.2									Poor recovery in SPT likely due to gravel blockage. End for 6/20/11 at 17:15. Resume drilling at 08:55 on 6/21/11. Fluid level at 6 ft bgs prior to start of drilling. Significant chatter at 71 ft. Extremely hard drilling at 73 ft. Greenstone or sandstone fragments in return.
555														
	75						Increased gravel							
550														Easier drilling at 77 ft.
							Becomes olive gray to dark greenish gray, very dense, with angular intact pieces of hard greenstone or sandstone							
	80		PB-4		2.5									
545			SP-12	22 25 32	0.7			43	17	30	15	6.0		
	85													
540														
							Becomes dark gray to olive gray							
	90		PB-5		2.0									
535			SP-13	41 32 32	NA							11.7		
	95													Rig chatter increases at 94.5 ft.
530														
														Drill to 99 ft at 13:45.
			PB-6		2.5		Becomes dark gray, with ~20-35% medium to high plasticity fines, occasional friable shale fragments							
	100													

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
			PB-6		2.5	CLAYEY GRAVEL WITH SAND to CLAYEY SAND WITH GRAVEL (GC/SC), dark gray, very dense, fine to coarse angular gravel consisting of hard pieces of greenstone or sandstone and minor friable shale fragments, fine- to coarse-grained sand, ~20-35% medium to high plasticity fines [Downstream Shell] (continued)	56	19	41	25	10.1	131	TX-CIU
525			SP-14	33 30 40	NA								
	105												
520													Rig chatter increases at 108 ft.
	110		PB-7		2.0								
515			SP-15	15 20 28	NA	Becomes dark gray with reddish brown mottling, dense, with mostly fine gravel, 20-35% medium plasticity fines					11.2		End for 6/21/11 at 17:15. Resume drilling at 08:30 on 6/22/11. Fluid level at 6 ft bgs prior to start of drilling. R. Harlan logging. Smoother drilling at 115 ft; clayey cuttings in return. Chattery drilling at 117-119 ft. Smoother drilling at 119 ft.
	115												
510													
	120		SP-16	13 20 17	0.9								Intermittent rough chatter 120-128 ft.
505						Occasional zones of CLAYEY GRAVEL (GC) and cobbles (based on drill action)							Pitcher Barrel tip slightly shredded.
	125		PB-8	700	2.1								
500			SP-17	15 24 25	1.1						10.8		Switch to 4-7/8-in. tricone. Smoother drilling 128-132 ft.
	130												
495						CLAYEY GRAVEL WITH SAND (GC), dark gray and dark yellowish brown, dense(?), fine to coarse gravel and cobbles, fine- to coarse-grained sand, plastic fines							Rough chatter 132-136 ft. Losing some drill fluid at 133.5 ft.
	135		SP-18	15 16	0.6								

Elevation, feet	Depth, feet	Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
		SPT	SP-18	50/5"	0.6		**DRAIN (ZONE 3)** WELL-GRADED GRAVEL, COBBLES, AND BOULDERS (GW?), gray, strong, hard sandstone blocks (9-inch piece of solid HQ core) and black, strong shale blocks (3-inch angular cobble above sandstone in core)							SPT refusal at 135.4 ft; rods bouncing. Total fluid loss; thicken mud and tricone to 136 ft. Switch to HQ core at 136 ft. Retain solid piece of core 136.0-136.8 ft. Total fluid loss at 137 ft. Terminate hole at 12:50 on 6/22/11. Backfill with bentonite pellets 133-137 ft, refill hole with drill fluid, and shut down for day. After conducting OYO P-wave and S-wave survey on 6/23/11, backfill hole 137 ft to surface with grout via tremie.
490		Core	Run 1		0.9									
							Bottom of boring at 137.0 feet							
	140													
485														
	145													
480														
	150													
475														
	155													
470														
	160													
465														
	165													
460														
	170													

SANTA CLARA VALLEY WATER DISTRICT
SEISMIC SAFETY EVALUATIONS (SSE2)

Log of Boring LD-B-103

Date(s) Drilled	7/18/11 - 7/19/11; grouted 7/20/11	Logged By	R. Harlan	Checked By	R. Kirby
Drilling Method	Mud Rotary	Drill Bit Size/Type	5-7/8-in. and 3-7/8-in. tricone bits; 4-7/8-in. drag bit	Total Depth of Borehole	208.7 feet
Drill Rig Type	Fraste Multidrill XL	Drilling Contractor	Pitcher Drilling	Surveyed Ground Surface Elevation	672.7 feet
Groundwater Level(s)	Not determined	Sampling Method	SPT, 4-in. Pitcher Barrel	Hammer Data	Automatic hammer; 140 lbs / 30-inch drop
Borehole Location	Approx. Station 12+50, dam crest centerline	Borehole Completion	Cement-bentonite grout slurry via tremie		

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	0					**EMBANKMENT** WELL-GRADED GRAVEL WITH CLAY AND SAND (GW-GC), light brown, dry, fine to coarse gravel to 3 inches (gravel pull-out area north of road)							Start drilling at 07:25 on 7/18/11 with 6-1/2-in. trash barrel to 2.5 ft. Set 6-in. casing to 3 ft.
670						**UPPER CORE** SANDY LEAN CLAY WITH GRAVEL (CL), moderate yellowish brown, stiff, medium plasticity, ~20-40% fine- to coarse-grained sand and fine to coarse gravel to 2 inches							Drill with 5-7/8-in. tricone bit and bentonite-based drill fluid below 3 ft.
	5	SPT	SP-1	5 5 6	1.3	2-inch layer of yellowish gray, fine-grained sand (SP)	15	65	48	27	14.8		
665						CLAYEY SAND WITH GRAVEL (SC), moderate yellowish brown, medium dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 2 inches							Full drill fluid return.
	10												
660		Pitcher Barrel	PB-1	250 500	2.2	Increased coarse gravel, possibly some cobbles (GC?)							Pitcher Barrel at 1 ft (4-in. used for all PB samples). Pull down pressure recorded in psi. Rough advance at 13.4 ft; tip dented. Rough drilling 13.4-14 ft; slight fluid loss through gravel zone. Thicken drill mud. Full fluid return below 14 ft.
	15					Becomes mixed moderate and dark yellowish brown and dark gray							
655		SPT	SP-2	9 10 8	0.4								Poor recovery in SPT; gravel wedged in shoe.
	20												
650		Pitcher Barrel	PB-2	140 400	2.1	4-inch cobble with dark gray plastic (GC)							Pitcher Barrel tip dented and bevelled.
	25	SPT	SP-3	8 10 9	1.5	CLAYEY SAND (SC), dark greenish gray, medium dense, fine- to medium-grained sand, medium plasticity fines, minor coarse-grained sand and gravel					19.1		
645						CLAYEY SAND WITH GRAVEL (SC), olive gray with yellowish brown and yellowish orange mottling, medium dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 2 inches							
	30												

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Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/6 in. or Pressure, psi	Samples: Recovery, feet	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	30	Pitcher Barrel	PB-3	550 400 400	2.1	CLAYEY SAND WITH GRAVEL (SC), olive gray with yellowish brown and yellowish orange mottling, medium dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 2 inches [Upper Core] (continued)							Pitcher Barrel tip dented.
640													
						Become moderate yellowish brown							
	35	Split Spoon	SP-4	5 12 15	1.3	Become olive gray with yellowish brown mottling							
635													Continued full fluid return.
	40	Pitcher Barrel	PB-4	350 400 350 400	2.1								Pitcher Barrel tip dented.
630													
	45	Split Spoon	SP-5	6 8 14	1.3						13.6		
625													
						SANDY LEAN CLAY (CL), olive gray with yellowish brown mottling, medium plasticity, ~30-40% fine- to coarse-grained sand, few to locally some gravel							
	50					Increased coarse gravel, possibly some cobbles (GC?)							Rough drill chatter 49.5-50.3 ft.
		Pitcher Barrel	PB-5	125 200 480	2.2		7	59			11.4 13.4	122 118	DSS CONS
620							38	28	39	22	13.8	123	TX-CIU, Gs=2.75
		Split Spoon	SP-6	8 8 14	1.1	CLAYEY SAND WITH GRAVEL (SC), olive gray with yellowish brown mottling, medium dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 2 inches	14	38	30	15	14.9		
	55												
615													
		Pitcher Barrel	PB-6	300	2.5	CLAYEY GRAVEL WITH SAND (GC), brownish gray, dense, fine to coarse gravel, fine- to coarse-grained sand, ~20% medium plasticity fines							
	60						52	19	40	23	14.4	122	TX-CIU
		Split Spoon	SP-7	18 17 19	1.2	SANDY SILT (ML), brownish gray, very stiff, low plasticity fines, fine-grained sand, some roots (moderately organic)					18.7		Silt appears softer than stiffness indicated by blows.
						CLAYEY SAND WITH GRAVEL (SC), dark yellowish brown with yellowish orange and olive gray mottling, dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 1 inch							
610													
	65												

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
	65						CLAYEY SAND WITH GRAVEL (SC), dark yellowish brown with yellowish orange and olive gray mottling, dense, fine- to coarse-grained sand, medium plasticity fines, ~20-40% fine to coarse gravel to 1 inch [Upper Core] (continued)							
							Becomes medium dense							
605		Pitcher Barrel	PB-7	250 300	0.8									Pitcher Barrel tip badly dented; recovered 10-in. very disturbed sample, not retained.
	70													
600		Split Spoon	SP-8	6 11 14	1.3									
	75													
595		Pitcher Barrel	PB-8	300 600 900	2.2		**LOWER CORE** FAT CLAY (CH), dark gray, very stiff, high plasticity, minor fine- to coarse-grained sand and gravel, including fragments of weak, low hardness, dark gray shale to 2 inches							Pitcher Barrel tip dented.
	80	Split Spoon	SP-9	8 12 17	1.0							22.2		
590														Continued full fluid return.
	85													
585		Pitcher Barrel	PB-9	300 800	2.2		2-inch fragment of weak, low hardness, dark gray shale packed tight within fat clay							
	90						Increased sand and fine gravel (GC?)							Switch to 4-7/8-in. drag bit at 88.5 ft. Fine to coarse sand and rock fragments in return 89-90 ft.
580		Split Spoon	SP-10	8 12 16	1.5									
	95						Gravely zone; several fine gravel-size hard sandstone fragments within fat clay at 97.1 ft							Chattery drilling 96.1-97 ft.
575		Split Spoon	SP-11	8 11 14	1.5							24.0		End for 7/18/11 at 16:40. Resume drilling at 07:15 on 7/19/11. Fluid level at 10 ft bgs prior to start of drilling.
							FOUNDATION / FRANCISCAN COMPLEX LEAN to FAT CLAY (CL/CH), dark yellowish brown with yellowish orange mottling; probably deeply weathered shale							
	100													

Report: TGP SSE2 SOIL+LAB; File: SCVWD_LENIHAN.GPJ; 10/3/2011

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
							SHALE, black, little weathered, friable to weak, low hardness, crushed and clayey (melange matrix) with occasional angular hard shale fragments, minor calcite veining							Harder, chattery drilling at 99.9 ft.
570		◩	SP-12	60/4"	0.3									SPT refusal at 102.3 ft; rods bouncing. Drill without sampling below 102.3 ft.
	105													Rougher drilling at 106.3 ft.
565							SANDSTONE(?); inferred from harder drilling; possibly block of harder, less fractured shale							Distinctly slower drilling, increased pull-down pressure 107.5-112.7 ft.
	110													
560							Softer zone, possibly crushed shale							Faster drilling 112.7-113.3 ft, harder 113.3-114.1 ft, then faster 114.1-119.5 ft.
							SHALE, black, crushed							
	115													
555														Continued full fluid return.
	120						Harder, less fractured							Add rod at 119 ft. Harder, slower drilling at 119.5 ft; black hard shale cuttings.
550							CHERT block, light green, hard							Very slow drilling 122-123 ft; light green hard cuttings.
	125													Drill 119-129 ft in 15 min. Much faster drilling below 123 ft.
545														
	130						Harder, less fractured							Much harder drilling 129.8-132.3 ft.
540														Softer drilling 132.3-134 ft.
							Hard							Harder drilling 134-134.5 ft, much faster 134.5-137.2 ft.
	135													

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
							SHALE, black, mostly crushed, occasional hard blocks [Foundation / Franciscan Complex] (continued)							Continue drilling with 4-7/8-in. drag bit.
535							Hard							Slower drilling 137.2-138 ft. Drill 129-139 ft in 15 min.
	140													Very fast drilling 138-153.5 ft.
530														
	145													
525														Drill 139-149 ft in 6 min.
	150													
520														Alternating harder and softer drilling 153.5-157.7 ft.
	155						Crushed with harder blocks							
515							Hard blocks of greenish gray SANDSTONE and red CHERT							Much slower drilling 157.7-158.5 ft; graywacke sandstone and chert cuttings. Drill 149-159 ft in 14 min.
	160													
510							Crushed with harder blocks							
	165													Very fast drilling 164-166 ft, slow 166-166.6 ft, then very fast 166.6-169 ft.
							Hard block							
							Predominantly crushed, with localized harder blocks smaller than 1 foot diameter							
505														Drill 159-169 ft in 7 min.
	170													

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
							SHALE, black, mostly crushed, localized harder blocks smaller than 1 inch [Foundation / Franciscan Complex] (continued)							
500														Continued full fluid return.
	175													
495														Drill 169-179 ft in 11 min.
	180													
490														
							SANDSTONE, greenish gray, hard							Very hard, very slow drilling at 183.1 ft; refusing drag bit at 183.3 ft. Trip rods and switch to 3-7/8-in. tricone bit.
	185													
							SHALE, black, crushed							Slow drilling 183.3-185.7 ft; sandstone cuttings.
485							SANDSTONE, greenish gray, hard							Faster advance 185.7-187 ft, then slow drilling 187-189 ft (sandstone cuttings).
	190						SANDSTONE and SHALE, varying amounts of sandstone, hard shale, and clayey crushed shale, minor localized blocks of red and green chert, rare weathered zones with orange iron oxide-stained clay							Somewhat faster drilling below 189 ft, with continued hard gray sandstone cuttings, varying amounts of black hard shale, gray clay, and minor green and red chert.
480														
	195													
475														
	200						SANDSTONE block, hard							Very slow drilling 199.1-200.3 ft.
470														Note: Overall slower drill penetration rates below 183 ft due to using tricone bit (vs. drag bit above 183 ft).
	205													

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/6 in. or Pressure, psi	Recovery, feet	Graphic Log	MATERIAL DESCRIPTION	% Gravel (>#4)	% Fines (<#200)	Liquid Limit	Plasticity Index	Moisture Content, %	Dry Unit Weight, pcf	FIELD NOTES AND OTHER TESTS
465							SANDSTONE and SHALE, varying amounts of sandstone, hard shale, and clayey crushed shale [Foundation / Franciscan Complex] (continued) SANDSTONE block, hard							Drill 199-208.7 ft in 30 min. Slower drilling below 206 ft.
	210						**Bottom of boring at 208.7 feet**							Tricone bit breaks apart at 208.7 ft; attempts to fish rollers from hole are unsuccessful. Terminate hole at 13:00 on 7/19/11. Conduct OYO P-wave and S-wave survey on 7/19/11. Backfill hole with grout via tremie on 7/20/11.
460														
	215													
455														
	220													
450														
	225													
445														
	230													
440														
	235													
435														
	240													

APPENDIX C

CONTENTS

Report by GEOVision Geophysical Services dated August 8, 2011.

LENIHAN DAM

BORINGS LD-B-101, LD-B-102 AND LD-B-103

SUSPENSION PS VELOCITIES

Report 11038-02 Rev 0

August 8, 2011

LENIHAN DAM
BORINGS LD-B-101, LD-B-102 AND LD-B-103
SUSPENSION PS VELOCITIES

Report 11038-02 Rev 0

August 8, 2011

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INTRODUCTION

Boring geophysical measurements were collected in three uncased borings located at Lenihan Dam, near Los Gatos, California. Geophysical data acquisition was performed on June 23 and July 19, 2011 by Robert Steller of **GEO***Vision*. Data analysis and report preparation was performed by Robert Steller and reviewed by John Diehl of **GEO***Vision*. The work was performed for Terra Engineers, Inc. (Terra). Robert Kirby served as the point of contact for Terra.

This report describes the field measurements, data analysis, and results of this work.

SCOPE OF WORK

This report presents the results of boring geophysical measurements collected on June 23 and July 19, 2011, in three uncased borings, as detailed below. The purpose of these studies was to supplement stratigraphic information obtained during Terra's soil and rock sampling program and to acquire shear wave velocities and compressional wave velocities as a function of depth.

BORING	DATES LOGGED	ELEVATION [1] (FEET)	COORDINATES (FEET) [1]	
			NORTHING	EASTING
LD-B-101	6/23/2011	672.958	1899274.3	6127953.6
LD-B-102	6/23/2011	626.705	1899428.1	6127942.1
LD-B-103	7/19/2011	672.708	1899268.02	6127635.65

[1] Coordinates provided by Terra, in California State Plane

Table 1. Boring locations and logging dates

The OYO Suspension PS Logging System (Suspension System) was used to obtain in-situ horizontal shear (S_H) and compressional (P) wave velocity measurements at 1.6 foot intervals. Measurements followed **GEO***Vision* Procedure for P-S Suspension Seismic Velocity Logging, revision 1.5. The acquired data was analyzed and a profile of velocity versus depth was produced for both compressional and horizontally polarized shear waves.

A detailed reference for the suspension PS velocity measurement techniques used in this study is:

> Guidelines for Determining Design Basis Ground Motions, Report TR-102293, Electric Power Research Institute, Palo Alto, California, November 1993, Sections 7 and 8.

INSTRUMENTATION

Suspension Instrumentation

Suspension soil velocity measurements were performed below the surface casing using the Suspension PS logging system, manufactured by OYO Corporation, and their subsidiary, Robertson Geologging. This system directly determines the average velocity of a 3.3-foot high segment of the soil column surrounding the boring of interest by measuring the elapsed time between arrivals of a wave propagating upward through the soil column. The receivers that detect the wave, and the source that generates the wave, are moved as a unit in the boring producing relatively constant amplitude signals at all depths.

The suspension system probe consists of a combined reversible polarity solenoid horizontal shear-wave source (S_H) and compressional-wave source (P), joined to two biaxial receivers by a flexible isolation cylinder, as shown in Figure 1. The separation of the two receivers is 3.3 feet, allowing average wave velocity in the region between the receivers to be determined by inversion of the wave travel time between the two receivers. The total length of the probe as used in these surveys is 21 feet, with the center point of the receiver pair 12.5 feet above the bottom end of the probe.

The probe receives control signals from, and sends the digitized receiver signals to, instrumentation on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a 3.28-foot circumference sheave fitted with a digital rotary encoder.

The entire probe is suspended in the boring by the cable, therefore, source motion is not coupled directly to the boring walls; rather, the source motion creates a horizontally propagating impulsive pressure wave in the fluid filling the boring and surrounding the source. This pressure wave is converted to P and S_H-waves in the surrounding soil and rock as it impinges upon the wall of the boring. These waves propagate through the soil and rock surrounding the boring, in turn causing a pressure wave to be generated in the fluid surrounding the receivers as the soil waves pass their location. Separation of the P and S_H-waves at the receivers is performed using the following steps:

1. Orientation of the horizontal receivers is maintained parallel to the axis of the source, maximizing the amplitude of the recorded S_H -wave signals.
2. At each depth, S_H-wave signals are recorded with the source actuated in opposite directions, producing S_H-wave signals of opposite polarity, providing a characteristic S_H-wave signature distinct from the P-wave signal.
3. The 7.0-foot separation of source and receiver 1 permits the P-wave signal to pass and damp significantly before the slower S_H-wave signal arrives at the receiver. In faster soils or rock, the isolation cylinder is extended to allow greater separation of the P- and S_H-wave signals.
4. In saturated soils, the received P-wave signal is typically of much higher frequency than the received S_H-wave signal, permitting additional separation of the two signals by low pass filtering.
5. Direct arrival of the original pressure pulse in the fluid is not detected at the receivers because the wavelength of the pressure pulse in fluid is significantly greater than the dimension of the fluid annulus surrounding the probe (meter versus centimeter scale), preventing significant energy transmission through the fluid medium.

In operation, a distinct, repeatable pattern of impulses is generated at each depth as follows:

1. The source is fired in one direction producing dominantly horizontal shear with some vertical compression, and the signals from the horizontal receivers situated parallel to the axis of motion of the source are recorded.
2. The source is fired again in the opposite direction and the horizontal receiver signals are recorded.
3. The source is fired again and the vertical receiver signals are recorded. The repeated source pattern facilitates the picking of the P and S_H-wave arrivals; reversal of the source changes the polarity of the S_H-wave pattern but not the P-wave pattern.

The data from each receiver during each source activation is recorded as a different channel on the recording system. The Suspension PS system has six channels (two simultaneous recording channels), each with a 1024 sample record. The recorded data are displayed as six channels with a common time scale. Data are stored on disk for further processing. Up to 8 sampling sequences can be summed to improve the signal to noise ratio of the signals.

Review of the displayed data on the recorder or computer screen allows the operator to set the gains, filters, delay time, pulse length (energy), sample rate, and summing number to optimize the quality of the data before recording. Verification of the calibration of the Suspension PS digital recorder is performed every twelve months using a NIST traceable frequency source and counter, as outlined in Appendix B.

MEASUREMENT PROCEDURES

Suspension Measurement Procedures

The borings were logged while filled with bentonite or polymer based drilling mud. Measurements followed the **GEO***Vision* Procedure for P-S Suspension Seismic Velocity Logging, revision 1.5. The probe was positioned with the mid-point of the receivers at ground level, and the depth value was set to zero, in order to reference all depths to ground level. The probe was lowered to the bottom of the boring, stopping at 1.6 foot intervals to collect data, as summarized in Table 2.

At each measurement depth the measurement sequence of two opposite horizontal records and one vertical record was performed, and the gains were adjusted as required. The data from each depth were viewed on the computer display, checked, and recorded on disk before moving to the next depth.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring.

BORING NUMBER	TOOL AND RUN NUMBER	DEPTH RANGE (FEET)	OPEN HOLE (FEET)	DEPTH TO BOTTOM OF CASING (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
LD-B-101	SUSPENSION 1	6.6 – 246.1	258.6	4.0	1.6	6/23/2011
LD-B-102	SUSPENSION 1	13.1 – 119.4	131.9	11.5	1.6	6/23/2011
LD-B-103	SUSPENSION 1	4.9 – 195.2	207.7	3.0	1.6	7/19/2011

- PROBE DID NOT TOUCH BOTTOM OF BORING

Table 2. Logging dates and depth ranges

DATA ANALYSIS

Suspension Analysis

Using the proprietary OYO program PSLOG.EXE version 1.0, the recorded digital waveforms were analyzed to locate the most prominent first minima, first maxima, or first break on the vertical axis records, indicating the arrival of P-wave energy. The difference in travel time between receiver 1 and receiver 2 (R1-R2) arrivals was used to calculate the P-wave velocity for that 3.3-foot segment of the soil column. When observable, P-wave arrivals on the horizontal axis records were used to verify the velocities determined from the vertical axis data. The time picks were then transferred into an EXCEL template (EXCEL version 2003 SP2) to complete the velocity calculations based upon the arrival time picks made in PSLOG.

The P-wave velocity over the 7.0-foot interval from source to receiver 1 (S-R1) was also picked using PSLOG, and calculated and plotted in EXCEL, for quality assurance of the velocity derived from the travel time between receivers. In this analysis, the depth values as recorded were increased by 5.2 feet to correspond to the mid-point of the 7.0-foot S-R1 interval. Travel times were obtained by picking the first break of the P-wave signal at receiver 1 and subtracting 4 milliseconds, the calculated and experimentally verified delay from source trigger pulse (beginning of record) to source impact. This delay corresponds to the duration of acceleration of the solenoid before impact.

As with the P-wave records, using PSLOG, the recorded digital waveforms were analyzed to locate the presence of clear S_H-wave pulses, as indicated by the presence of opposite polarity pulses on each pair of horizontal records. Ideally, the S_H-wave signals from the 'normal' and 'reverse' source pulses are very nearly inverted images of each other. Digital FFT - IFFT lowpass filtering was used to remove the higher frequency P-wave signal from the S_H-wave signal. Different filter cutoffs were used to separate P- and S_H-waves at different depths, ranging from 600 Hz in the slowest zones to 4000 Hz in the regions of highest velocity. At each depth, the filter frequency was selected to be at least twice the fundamental frequency of the S_H-wave signal being filtered.

Generally, the first maxima were picked for the 'normal' signals and the first minima for the 'reverse' signals, although other points on the waveform were used if the first pulse was distorted. The absolute arrival time of the 'normal' and 'reverse' signals may vary by +/- 0.2 milliseconds, due to differences in the actuation time of the solenoid source caused by constant mechanical bias in the source or by boring inclination. This variation does not affect the R1-R2 velocity determinations, as the differential time is measured between arrivals of waves created by the same source actuation. The final velocity value is the average of the values obtained from the 'normal' and 'reverse' source actuations.

As with the P-wave data, S_H-wave velocity calculated from the travel time over the 7.0-foot interval from source to receiver 1 was calculated and plotted for verification of the velocity derived from the travel time between receivers. In this analysis, the depth values were increased by 5.2 feet to correspond to the mid-point of the 7.0-foot S-R1 interval. Travel times were obtained by picking the first break of the S_H-wave signal at the near receiver and subtracting 4 milliseconds, the calculated and experimentally verified delay from the beginning of the record at the source trigger pulse to source impact. These data and analysis were reviewed by John Diehl as a component of **GEO***Vision*'s in-house QA-QC program.

Figure 2 shows an example of R1 - R2 measurements on a sample filtered suspension record. In Figure 2, the time difference over the 3.3-foot interval of 1.88 milliseconds for the horizontal signals is equivalent to an S_H-wave velocity of 1745 feet/second. Whenever possible, time differences were determined from several phase points on the S_H-waveform records to verify the data obtained from the first arrival of the S_H-wave pulse. Figure 3 displays the same record before filtering of the S_H-waveform record with a 1400 Hz FFT - IFFT digital lowpass filter, illustrating the presence of higher frequency P-wave energy at the beginning of the record, and distortion of the lower frequency S_H-wave by residual P-wave signal.

RESULTS

Suspension Results

Suspension R1-R2 P- and S_H-wave velocities are plotted in Figures 4, 5 and 6. The suspension velocity data presented in these figures are presented in Tables 3, 4 and 5. These plots and data are included in the EXCEL analysis files accompanying this report.

P- and S_H-wave velocity data from R1-R2 analysis and quality assurance analysis of S-R1 data are plotted together in Figures A-1, A-2 and A-3 to aid in visual comparison. It should be noted that R1-R2 data are an average velocity over a 3.3-foot segment of the soil column; S-R1 data are an average over 7.0 feet, creating a significant smoothing relative to the R1-R2 plots. S-R1 data are presented in Tables A-1, A-2 and A-3 and included in the EXCEL analysis files.

Calibration procedures and records for the suspension PS measurement system are presented in Appendix B.

SUMMARY

Discussion of Suspension Results

Suspension PS velocity data are ideally collected in uncased fluid filled borings, drilled with rotary mud (rotary wash) methods. These borings were ideal for collection of suspension PS velocity data.

Suspension PS velocity data quality is judged based upon 5 criteria:

1. Consistent data between receiver to receiver (R1 – R2) and source to receiver (S – R1) data.
2. Consistent relationship between P-wave and S_H -wave (excluding transition to saturated soils)
3. Consistency between data from adjacent depth intervals.
4. Clarity of P-wave and S_H-wave onset, as well as damping of later oscillations.
5. Consistency of profile between adjacent borings, if available.

These data show good correlation between R1 – R2 and S – R1 data, as well as good correlation between P-wave and S_H-wave velocities, though there is scatter in the P-wave data near the botttom of the dam embankment, probably caused by variable water content. P-wave and S_H-wave onsets are generally clear, and later oscillations are well damped.

Quality Assurance

These boring geophysical measurements were performed using industry-standard or better methods for measurements and analyses. All work was performed under **GEO***Vision* quality assurance procedures, which include:

- Use of NIST-traceable calibrations, where applicable, for field and laboratory instrumentation
- Use of standard field data logs
- Use of independent verification of velocity data by comparison of receiver-to-receiver and source-to-receiver velocities
- Independent review of calculations and results by a registered professional engineer, geologist, or geophysicist.

Suspension Data Reliability

P- and S_H-wave velocity measurement using the Suspension Method gives average velocities over a 3.3-foot interval of depth. This high resolution results in the scatter of values shown in the graphs. Individual measurements are very reliable with estimated precision of +/- 5%. Standardized field procedures and quality assurance checks contribute to the reliability of these data.

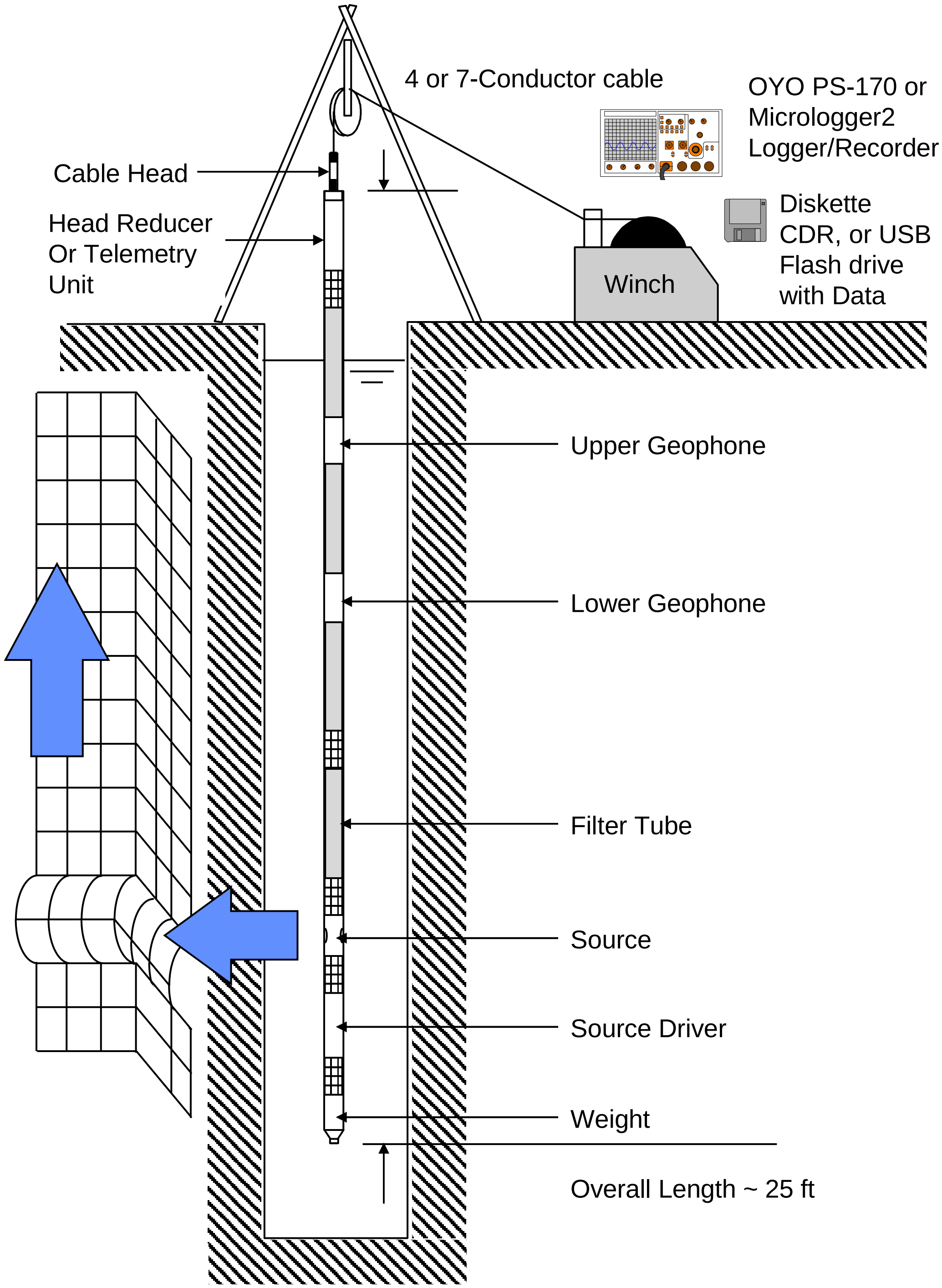

Figure 1: Concept illustration of P-S logging system

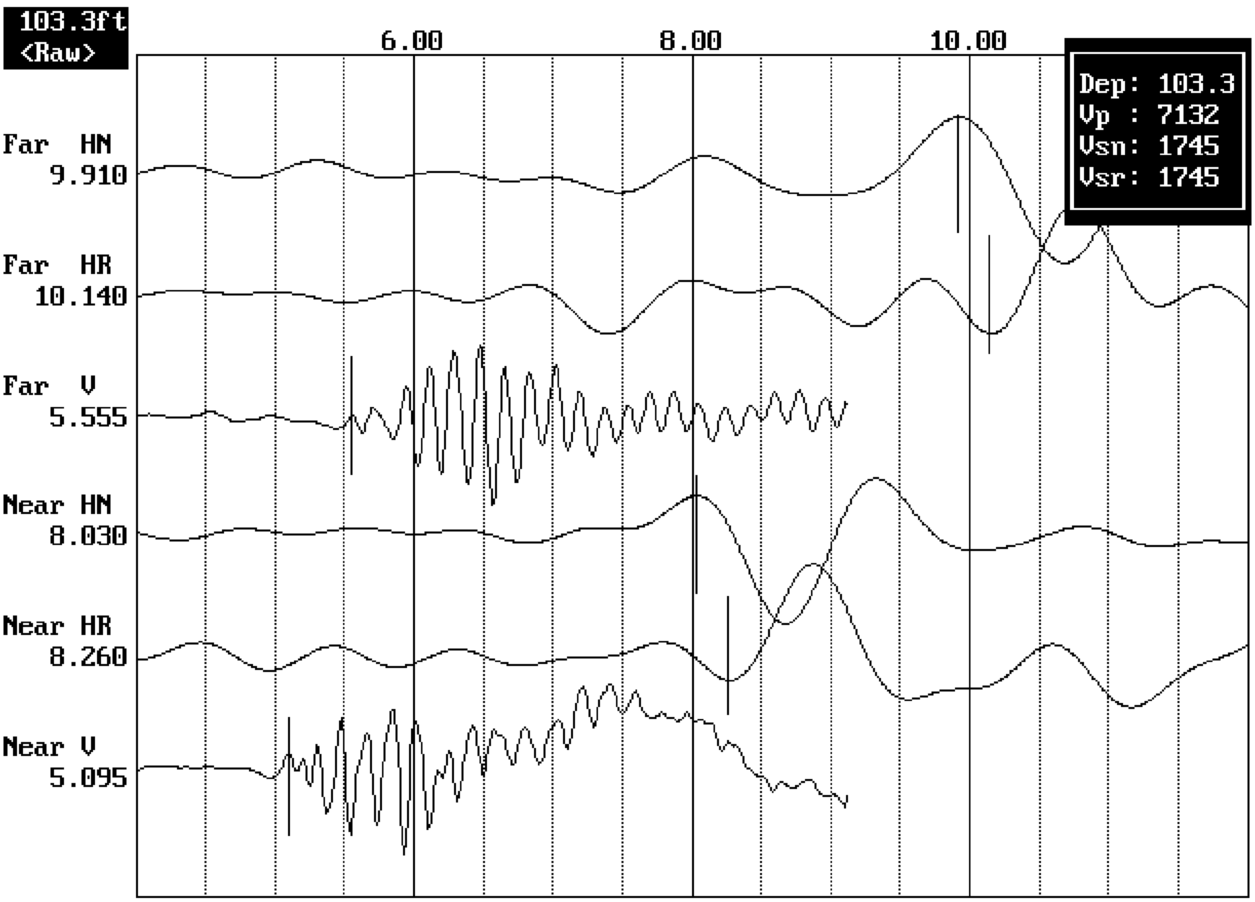

Figure 2: Example of filtered (1400 Hz lowpass) record

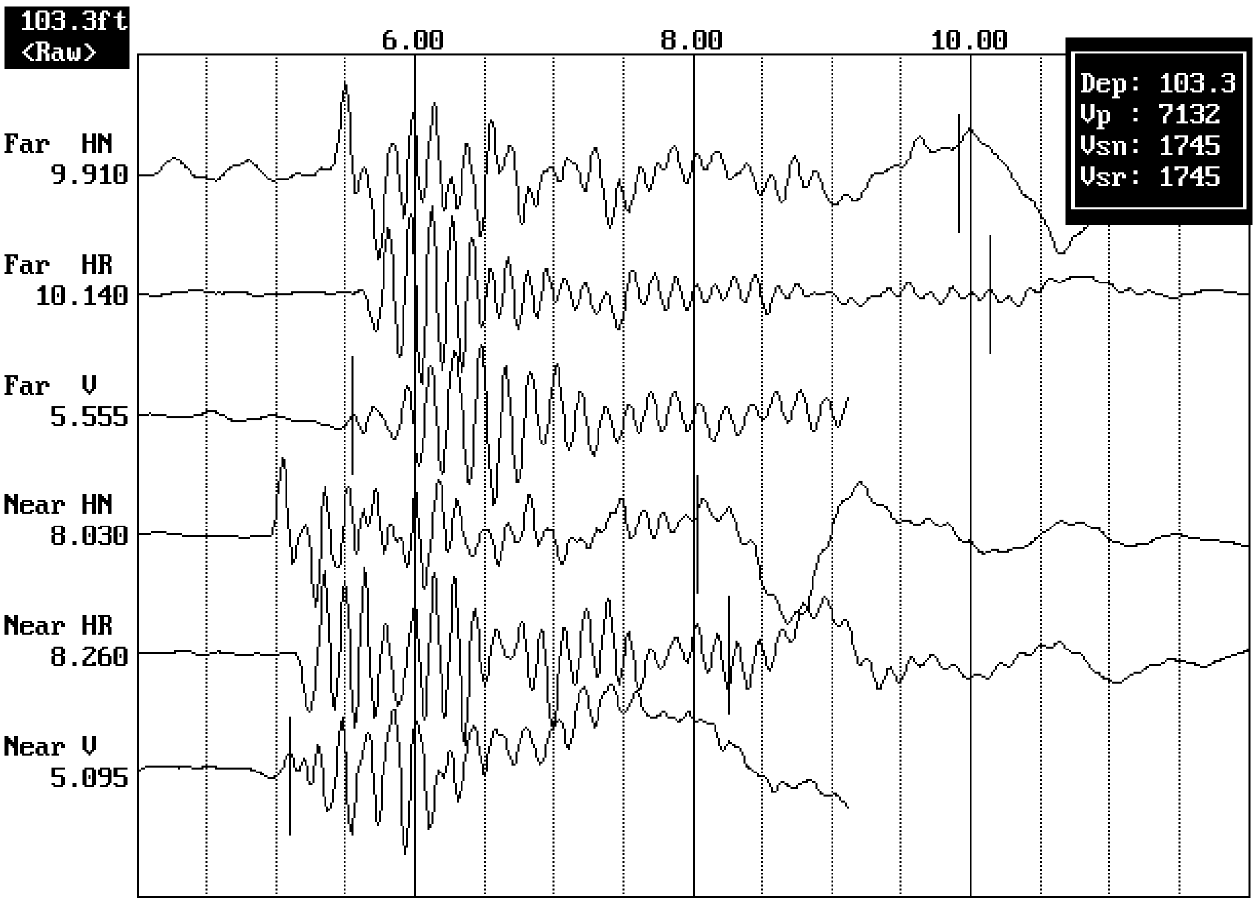

Figure 3. Example of unfiltered record

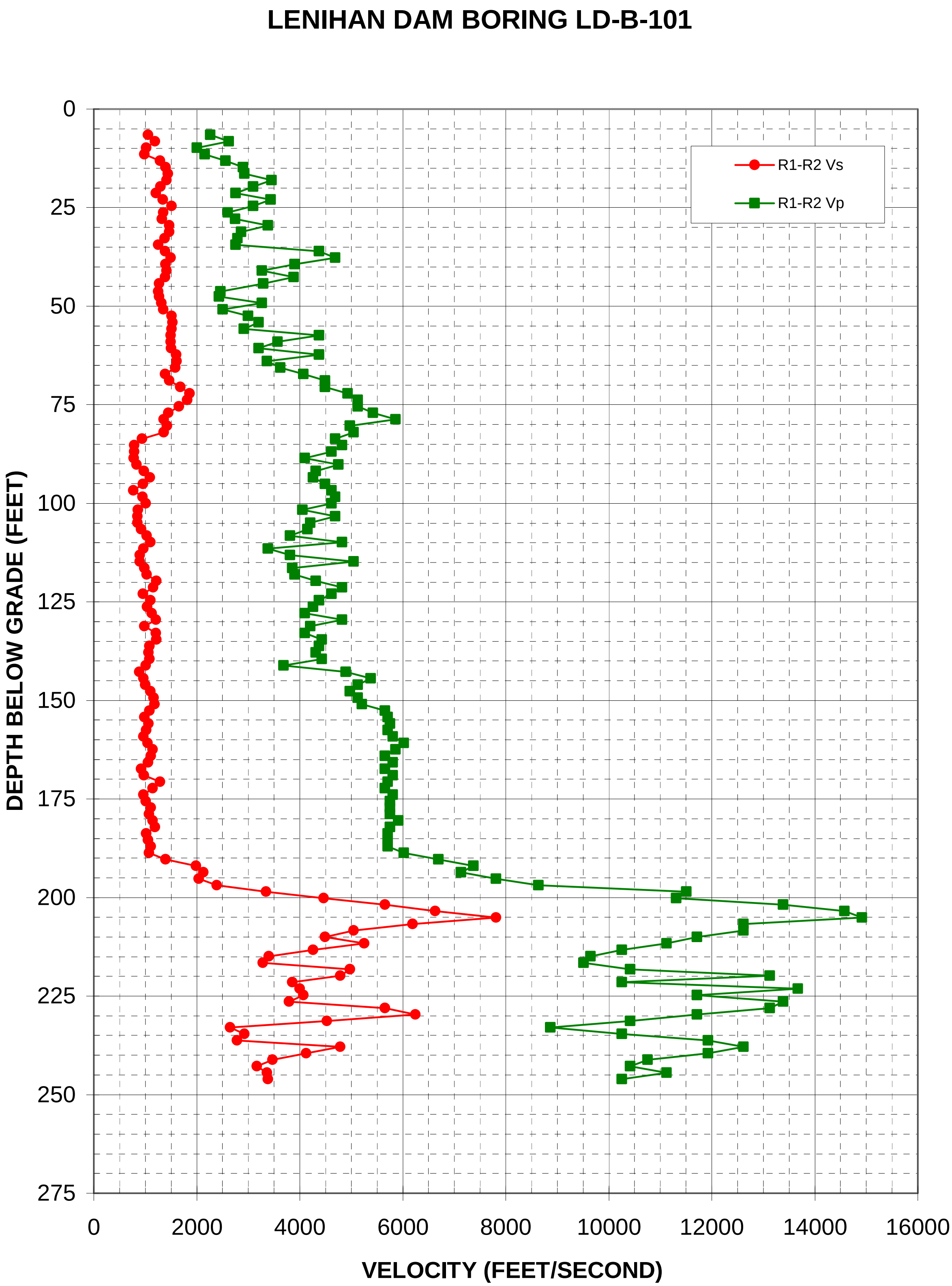

Figure 4: Boring LD-B-101, Suspension R1-R2 P- and S_H-wave velocities

Depth (feet)	V_s (feet/sec)	V_p (feet/sec)
6.6	1055	2263
8.2	1189	2625
9.8	1022	2001
11.5	985	2158
13.1	1287	2563
14.8	1396	2903
16.4	1439	2929
18.0	1414	3454
19.7	1297	3095
21.3	1211	2757
23.0	1339	3435
24.6	1512	3095
26.2	1350	2604
27.9	1320	2745
29.5	1465	3382
31.2	1471	2865
32.8	1376	2792
34.4	1250	2757
36.1	1387	4374
37.7	1495	4687
39.4	1399	3906
41.0	1411	3265
42.7	1384	3883
44.3	1272	3297
46.3	1250	2458
47.6	1267	2430
49.2	1318	3265
50.9	1350	2504
52.5	1508	2996
54.1	1526	3201
55.8	1508	2916
57.4	1498	4374
59.1	1498	3566
60.7	1505	3201
62.3	1604	4374
64.0	1612	3365
65.6	1585	3625
67.3	1384	4076
68.9	1468	4494
70.5	1678	4494
72.2	1864	4934
73.8	1818	5126
75.5	1653	5126
77.1	1445	5423
78.7	1356	5859
80.4	1426	4971
82.0	1361	5047
83.7	940	4687
85.3	787	4825
86.9	785	4621

Depth (feet)	V_s (feet/sec)	V_p (feet/sec)
88.6	779	4101
90.2	835	4755
91.9	979	4317
93.5	1094	4261
95.1	959	4494
96.8	774	4621
98.4	948	4687
100.1	1009	4621
101.7	859	4050
103.3	852	4687
105.0	850	4206
106.6	922	4153
108.3	1028	3815
109.9	1105	4825
111.5	962	3382
113.2	894	3815
114.8	896	5047
116.5	982	3860
118.1	1032	3906
119.8	1215	4317
121.4	1151	4825
123.0	954	4621
124.7	1097	4374
126.3	1038	4261
128.0	1124	4101
129.6	1206	4825
131.2	982	4206
132.9	1206	4101
134.5	1215	4434
136.2	1083	4374
137.8	1062	4317
139.4	1079	4434
141.1	1013	3686
142.7	884	4897
144.4	968	5378
146.0	1006	5126
147.6	1105	4971
149.3	1163	5126
150.9	1184	5208
152.6	1079	5657
154.2	982	5706
155.8	1069	5756
157.5	1022	5706
159.1	971	5807
160.8	1045	6020
162.4	1143	5859
164.0	1112	5657
165.7	1055	5807
167.3	922	5657
169.0	976	5807

Depth (feet)	V_s (feet/sec)	V_p (feet/sec)
170.6	1292	5706
172.2	1147	5657
173.9	968	5807
175.5	1009	5756
177.2	1108	5756
178.8	1076	5756
180.4	1143	5911
182.1	1189	5756
183.7	1022	5706
185.4	1055	5706
187.0	1107	5706
188.6	1077	6020
190.3	1396	6696
191.9	1982	7373
193.6	2130	7132
195.2	2038	7812
196.9	2386	8634
198.5	3348	11512
200.1	4464	11313
201.8	5657	13391
203.4	6628	14582
205.1	7812	14913
206.7	6190	12619
208.3	5047	12619
210.0	4494	11717
211.6	5249	11121
213.3	4261	10253
214.9	3400	9650
216.5	3281	9510
218.2	4971	10415
219.8	4790	13123
221.5	3860	10253
223.1	4001	13670
224.7	4076	11717
226.4	3793	13391
228.0	5657	13123
229.7	6249	11717
231.3	4525	10415
232.9	2646	8867
234.6	2929	10253
236.2	2780	11930
237.9	4790	12619
239.5	4127	11930
241.1	3472	10757
242.8	3170	10415
244.4	3365	11121
246.1	3382	10253

Table 3. Boring LD-B-101, Suspension R1-R2 depths and P- and S_H-wave velocities

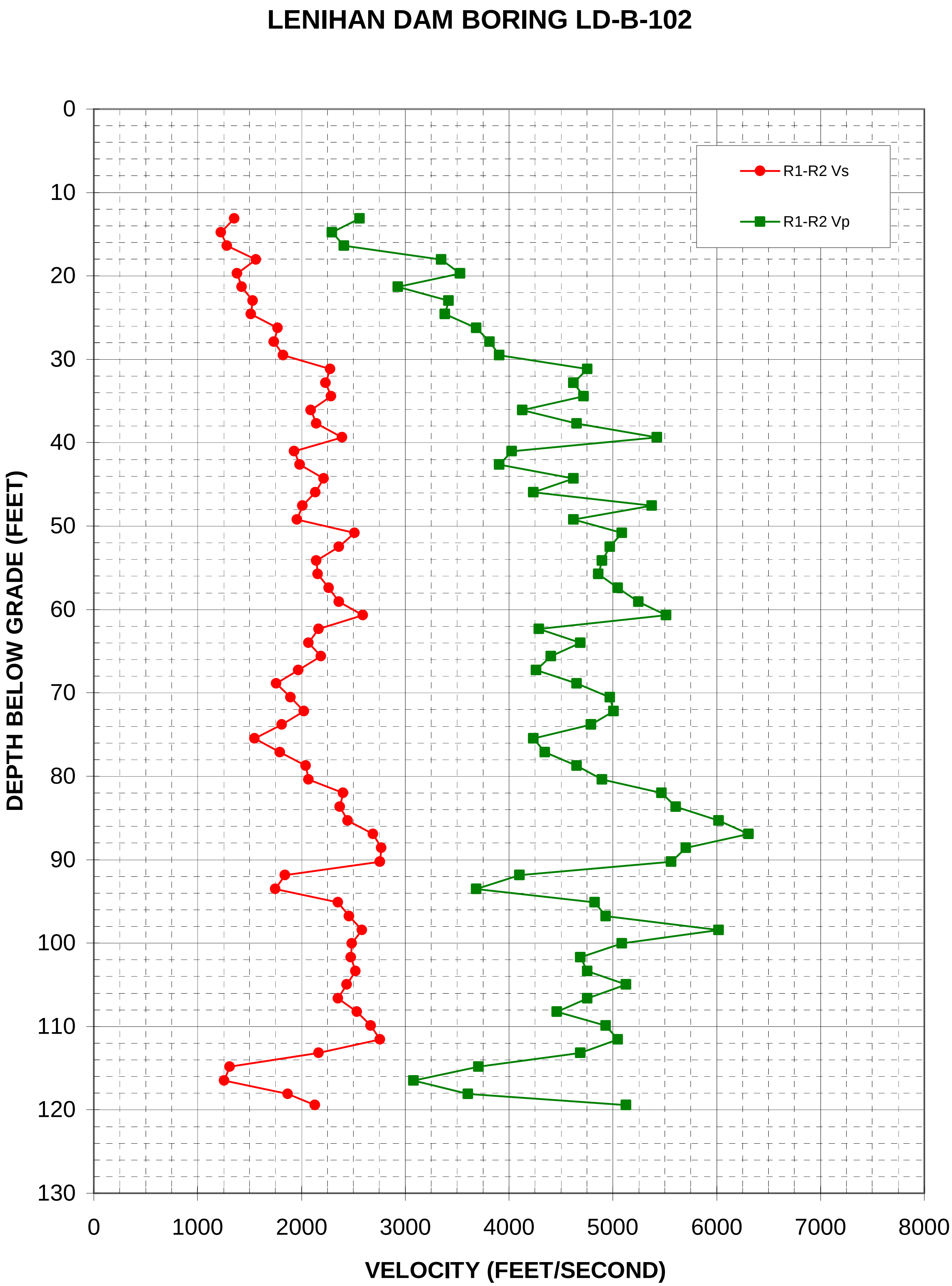

Figure 5: Boring LD-B-102, Suspension R1-R2 P- and S_H-wave velocities