

Technical Memorandum

Date: February 7, 2019 Project: FR18161290

To: Mr. David Vang,
Westlands Water District cc: Mr. Antonio Solorio and
Ms. Katarina Campbell,
Westlands Water District

From: Messrs. William Slowik and David Bean, *WS KB*
Wood Environment & Infrastructure Solutions, Inc.

Subject: Cone Penetration Test Investigation Results and Recommendations
Cantua Creek and Arroyo Pasajero Sites, Fresno County, California

Wood Environment & Infrastructure Solutions, Inc. (Wood), is pleased to provide Westlands Water District (WWD) with this technical memorandum detailing cone penetration test (CPT) results and recommendations for the Cantua Creek and Arroyo Pasajero sites located in Fresno County, California. In accordance with Wood's November 8, 2018, *Work Plan for Soil Borings for Basin Feasibility Investigation* (Work Plan), CPT borings were advanced to obtain subsurface data to determine if the underlying soils can support percolation basins for surface water recharge of the groundwater table.

CPT is a widely accepted method for determining soil stratigraphy and involves hydraulically pushing a cone-tipped measuring device into the ground at a constant rate, approximately 1 inch per second. The cone-tipped device remains in communication with a computer by a cable threaded through hollow-steel rods. The cone-tipped device is fitted with pressure transducers that record tip stress and sleeve stress readings, usually measured in tons per square foot (tsf). The readings correlate to 1 of 12 different soil behavioural types (SBTs). Refusal, or the inability to push the device further into the soil, can occur when the CPT computer detects deflection of the downhole tooling (rod flex) or the cone tip stress exceeds a predetermined tsf value. Once the CPT reaches the target depth, or refusal, the cone tip and steel rods are withdrawn from the borehole.

Percolation Basin Desired Lithology

Aside from the availability of a water source, soil type is the most important determining factor in whether a site is suitable for percolating surface water through the unsaturated vadose zone to the water table. In general, water percolates slowly through fine-grained soils and more rapidly as grain size increases. This is primarily due to the physical properties of clayey or fine-grained soils and their tendency to hold onto water more tightly than sandy- or coarse-grained soils.

Some of the least desirable soils for siting a percolation basin are any that contain an appreciable amount of clayey or very stiff fine-grained soils within the vadose zone. If the extent of clayey or fine-grained soils at a potential percolation basin site is limited and at or near the surface, the soils can be removed by excavation. Extensive intervals of clayey, fine-grained soils at intervals below about 10 feet below ground surface (bgs) quickly become cost prohibitive to remove. In addition to fine-grained soils, semi-consolidated sediments such as hardpan can present a barrier to percolation.

The most desirable SBT's for percolating large volumes of water to the water table are sandy or gravelly, coarse-grained soils (Attachment A; SBT 6 and 7). Coarse-grained soils have much greater permeability/hydraulic conductivity rates compared to fine-grained soils. If the vadose zone is comprised of coarse-grained materials, the percolation rate can be relatively high. In addition, a thick vadose will have a greater storage capacity than a thin vadose zone. As water percolates from a basin, it starts to build a groundwater mound in the vadose zone beneath the basin. When the groundwater mound reaches the bottom of the basin, the vadose zone is then saturated, and the percolation rate decreases to the rate that groundwater can move laterally away from the groundwater mound. The lateral movement of groundwater in the saturated zone is typically much slower than the vertical movement of water through the vadose zone. Hence, a thick, coarse-grained vadose zone will have a higher percolation rate and greater storage capacity than a thin, fine-grained vadose zone.

Pre-field Logistics

Wood obtained boring permits from the Fresno County Environmental Health Department (one permit required per parcel), marked all CPT boring locations, and notified Underground Service Alert (USA) prior to drilling activities. Wood prepared site-specific health and safety plans that were included in the Work Plan. While marking boring locations at the Cantua Creek site, Wood met with a representative of Shell Pipeline to identify their subsurface asset and maintain setback of at least 50 feet from the active petroleum product line. Additional site-specific information regarding site details, boring location rationale, and objectives is available in the Work Plan.

Investigation and Findings – Cantua Creek Site

On November 15 and 16, 2018, under the direction of Wood, Kehoe Testing & Engineering (Kehoe) of Huntington Beach, California, advanced nine CPT borings at the locations identified on Figure 1. Kehoe deployed a Vertek CPT Sound (SND) mounted to a 30-ton, 10-wheel truck chassis to obtain the lithologic data. In general, the CPT borings were cleared to 5 feet bgs using a hand auger to avoid striking any unmarked subsurface assets before powered equipment was advanced. CPT borings were abandoned with Portland cement emplaced from the bottom of each borehole to the top.

Three of the CPT borings (CPT-3, CPT-7, and CPT-9) reached the target depth of 100 feet bgs, while the other six borings encountered refusal at depths ranging from 57 to 92 feet bgs. Refusal encountered in borings CPT-4, CPT-5, and CPT-6, located on the western portion of the property, likely occurred when the CPT reached bedrock at the foot slope of the adjacent Diablo Range.

Generally, the upper 35 feet of the Cantua Creek site was characterized by coarser-grained soils, ranging from silt to silty sand to gravelly sand with some interbedded intervals of clay and very stiff, fine-grained soils, 1 to 3 feet thick. The CPT also detected intervals of these very stiff, fine-grained soils ranging in thickness from 4 to over 10 feet, between 35 feet bgs and the total depth explored. CPT boring logs as generated by the Vertek CPT SND are provided in Attachment A.

Investigation and Findings – Arroyo Pasajero Site

Between November 26 and 29, 2018, Wood directed Kehoe to advance 15 CPT borings at the Arroyo Pasajero site (Figure 2). The CPT borings were cleared to 5 feet bgs using a hand auger before powered equipment was advanced to avoid striking any unmarked subsurface assets. The CPT borings were abandoned with Portland cement emplaced from the bottom to the top of each borehole.



Nine of the 15 CPT borings proposed at the Arroyo Pasajero site reached the target depth of 100 feet bgs. The other six borings encountered refusal at depths ranging from 75 to 94 feet bgs. With the exception of boring AP-CPT-2, extensive intervals of clay and silty clay (fine-grained) soils were encountered in the upper 35 feet across the investigation area. These fine-grained soils were encountered as shallow as 5 feet bgs and ranged in thickness from 8 to 29 feet. The thickest intervals of clayey soils in the upper 35 feet were encountered along the northern portion of the site in borings AP-CPT-4, AP-CPT-7, AP-CPT-9, AP-CPT-13, and AP-CPT-14. The upper 35 feet of AP-CPT-2 that was installed closest to Los Gatos Creek was found to contain siltier soils.

Below a depth of 35 feet bgs, extensive intervals of coarse-grained soils including sands and gravelly sands were encountered. Intervals of finer grained soils including very stiff fine-grained soils were still encountered below 35 feet bgs and frequently found interbedded between the larger sand units. CPT boring logs as generated by the Vertek CPT SND are provided in Attachment A.

Conclusions and Recommendations

At the Cantua Creek site, very stiff, fine-grained soils were encountered during the CPT investigation in each boring below a depth of 50 feet and intervals of these presumed low permeability soils exceeded 5 feet thick in every boring. In addition, subsurface conditions encountered at the Cantua Creek site indicate the likely presence of bedrock from the adjacent Diablo Range. Refusal was encountered as shallow as 57 feet bgs and although the target depth of 100 feet was achieved in some of the CPT borings, consolidated sediments of the Diablo Range are likely present a short distance below this depth. This will present a significant barrier to surface water percolation to the water table. Based on the observed lithology, no additional work, including the proposed and funded exploratory boring, is recommended for the Cantua Creek site.

At the Arroyo Pasajero site, the predominantly clayey soils encountered in the upper 35 feet are presumed to have very low hydraulic conductivity. This low permeability layer is not quite as extensive on the western side of the property; however, in no instance does it appear to be less than 8 feet thick or become more permeable until a depth of at least 23 feet bgs. Below a depth of 35 feet, coarse-grained soils are encountered but are interbedded with finer, less permeable soils. Although the Arroyo Pasajero site has significant barriers to percolating surface water to the water table in the form of clayey, fine-grained soils, WWD may be able to recharge the groundwater table with surplus surface water using dry wells. The dry wells would be installed and cased through the presumed low permeability soils and into the coarse-grained, more permeable soils encountered below 35 feet.

Wood recommends advancing six geotechnical soil borings to approximately 45 feet bgs at the locations shown on Figure 2. The borings will be advanced for the purpose of obtaining soil samples for hydraulic conductivity, sieve analysis, moisture density, and Number 200 sieve wash soil physical characteristic tests for the distinct fine-and coarse-grained intervals.

One deep exploratory boring was proposed for the Arroyo Pasajero site. Since soils encountered at the Arroyo Pasajero site are not favourable for a percolation basin, funding for the deep exploratory boring may be better utilized towards a dry well pilot test to determine percolation rate. Dry wells will allow for water to be introduced directly into more permeable intervals of the vadose zone. Wood will review the results of the geotechnical investigation and present the findings to WWD prior to approval of the pilot test or installation of the exploratory boring.



Attachments: Figure 1 – Site Map with CPT Boring Locations – Cantua Creek
 Figure 2 – Site Map with CPT and Proposed Boring Locations – Arroyo Pasajero
 Attachment A - CPT Reports from Kehoe Testing & Engineering, Inc.

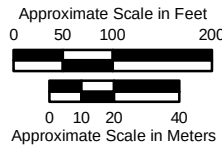




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Explanation

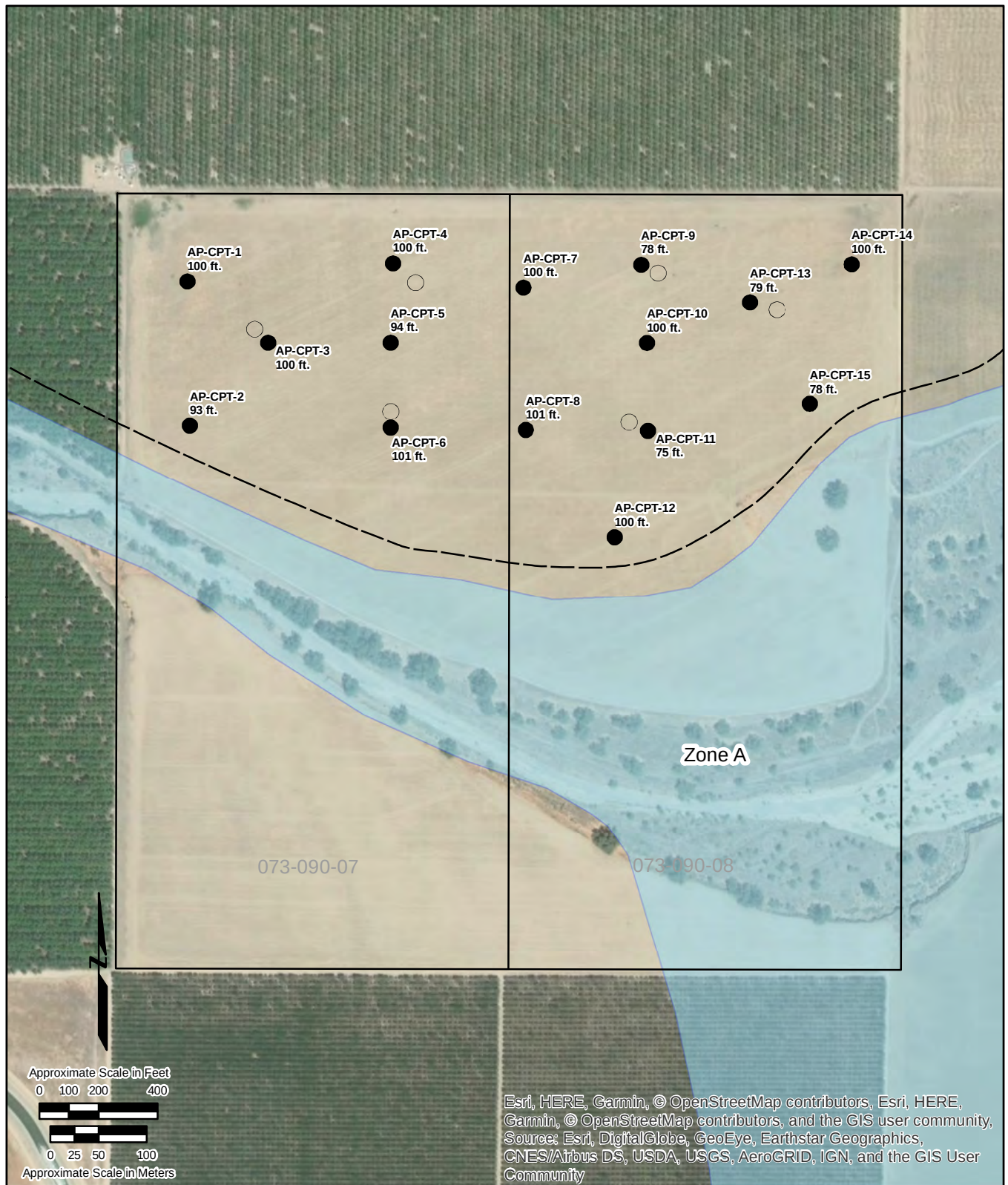
- Cone Penetrometer Test boring location¹
 - Parcel boundary
 - - Pipeline safety zone
 - 20 inch crude oil pipeline (Shell)
- 045-090-17S Fresno County Assessor's parcel number
- Note:**
1) Maximum borehole depth in feet below ground surface.



Site Map with Cone Penetrometer Test Boring Locations
Cantua Creek
Fresno County, California

By: SCM	Date: 12/14/2018	Project No.: FR18161290
wood.		Figure 1

Date: 12/14/2018 Printed by: elizabeth.chapman
 Path: N:_FR_projects\FR18161290\gis\maps\2018\Percolation_Basin_Feasibility_Investigation\fig02_SiteMap_ArroyoPasajero.mxd



Explanation

- Cone Penetrometer Test boring location¹
- Proposed geotechnical boring location
- Parcel boundary
- - - 100 foot buffer from Zone A
- FEMA 100 year flood hazard area

073-090-007 Fresno County Assessor's parcel number

Note:

1) Maximum borehole depth in feet below ground surface.

Site Map with Cone Penetrometer Test and Proposed Boring Locations

Arroyo Pasajero
 Fresno County, California

By: SCM

Date: 12/14/2018

Project No.: FR18161290

wood.

Figure

2



Attachment A
CPT Reports from
Kehoe Testing & Engineering, Inc.

SUMMARY OF CONE PENETRATION TEST DATA

Project:

**Cantua Creek Site
November 15 - 16
Arroyo Pasajero Site
November 26 - 29**

Prepared for:

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- 3. FIELD EQUIPMENT & PROCEDURES**
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APPENDIX

- CPT Plots
- CPT Classification/Soil Behavior Chart
- CPT Data Files (sent via email)

SUMMARY OF CONE PENETRATION TEST DATA

1. INTRODUCTION

This report presents the results of a Cone Penetration Test (CPT) program carried out for the Cantua Creek and Arroyo Pasajero sites located near Coalinga, California. The work was performed by Kehoe Testing & Engineering (KTE) on November 15-16 & 26-29, 2018. The scope of work was performed as directed by Wood Group personnel.

2. SUMMARY OF FIELD WORK

The fieldwork consisted of performing CPT soundings at 24 locations to determine the soil lithology.

LOCATION	DEPTH OF CPT (ft)	COMMENTS/NOTES:
CPT-1	88	Refusal
CPT-2	92	Refusal
CPT-3	100	
CPT-4	72	Refusal
CPT-5	86	Refusal
CPT-6	57	Refusal
CPT-7	100	
CPT-8	82	Refusal
CPT-9	100	
AP-CPT-1	100	
AP-CPT-2	93	Refusal
AP-CPT-3	100	
AP-CPT-4	100	
AP-CPT-5	94	Refusal
AP-CPT-6	100	

LOCATION	DEPTH OF CPT (ft)	COMMENTS/NOTES:
AP-CPT-7	100	
AP-CPT-8	100	
AP-CPT-9	100	Refusal
AP-CPT-10	100	
AP-CPT-11	75	Refusal
AP-CPT-12	100	
AP-CPT-13	79	Refusal
AP-CPT-14	100	
AP-CPT-15	78	Refusal

TABLE 2.1 - Summary of CPT Soundings

3. FIELD EQUIPMENT & PROCEDURES

The CPT soundings were carried out by **KTE** using an integrated electronic cone system manufactured by Vertek. The CPT soundings were performed in accordance with ASTM standards (D5778). The cone penetrometers were pushed using a 30-ton CPT rig. The cone used during the program was a 15 cm² cone and recorded the following parameters at approximately 2.5 cm depth intervals:

- Cone Resistance (qc)
- Sleeve Friction (fs)
- Dynamic Pore Pressure (u)
- Inclination
- Penetration Speed

The above parameters were recorded and viewed in real time using a laptop computer. Data is stored at the KTE office for up to 2 years for future analysis and reference. A complete set of baseline readings was taken prior to each sounding to determine temperature shifts and any zero load offsets. Monitoring base line readings ensures that the cone electronics are operating properly.

4. CONE PENETRATION TEST DATA & INTERPRETATION

The Cone Penetration Test data is presented in graphical form in the attached Appendix. These plots were generated using the CPeT-IT program. Penetration depths are referenced to ground surface. The soil classification on the CPT plots is derived from the attached CPT Classification Chart (Robertson) and presents major soil lithologic changes. The stratigraphic interpretation is based on relationships between cone resistance (qc), sleeve friction (fs), and penetration pore pressure (u). The friction ratio (Rf), which is sleeve friction divided by cone resistance, is a calculated parameter that is used along with cone resistance to infer soil behavior type. Generally, cohesive soils (clays) have high friction ratios, low cone resistance and generate excess pore water pressures. Cohesionless soils (sands) have lower friction ratios, high cone bearing and generate little (or negative) excess pore water pressures.

The CPT data files have also been provided. These files can be imported in CPeT-IT (software by GeoLogismiki) and other programs to calculate various geotechnical parameters.

It should be noted that it is not always possible to clearly identify a soil type based on q_c , f_s and u . In these situations, experience, judgement and an assessment of the pore pressure data should be used to infer the soil behavior type.

If you have any questions regarding this information, please do not hesitate to call our office at (714) 901-7270.

Sincerely,

KEHOE TESTING & ENGINEERING

Steven P. Kehoe

Steven P. Kehoe
President

12/04/18-kk-9655-5

APPENDIX

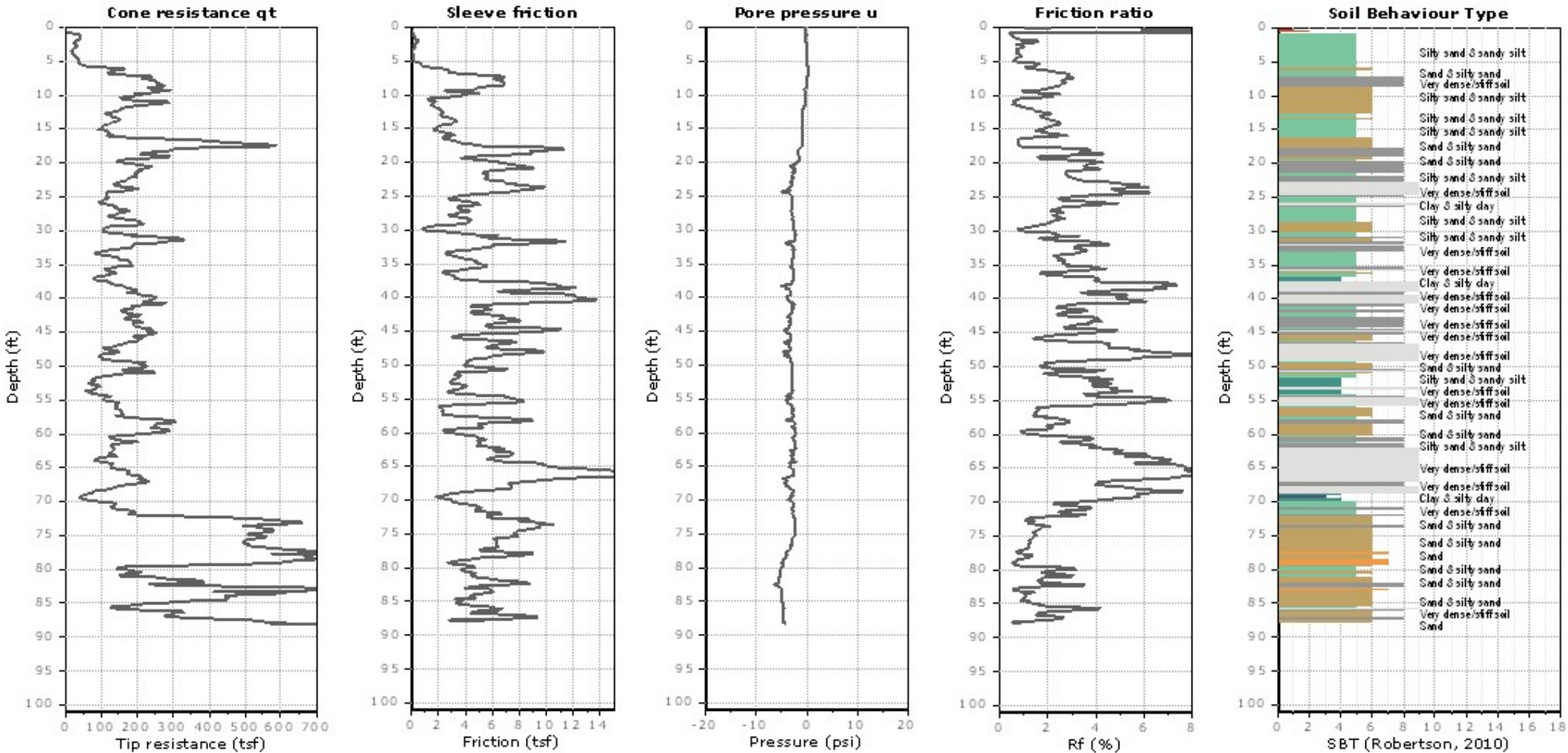


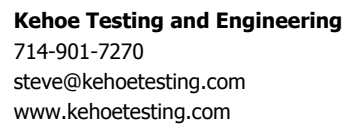
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Project: Wood Group
Location: Coalinga, CA

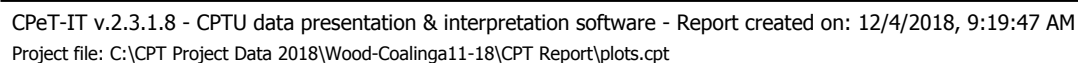
CPT-1

Total depth: 88.39 ft, Date: 11/15/2018
Cone Type: Vertek





CPT-2
Total depth: 92.59 ft, Date: 11/15/2018
Cone Type: Vertek

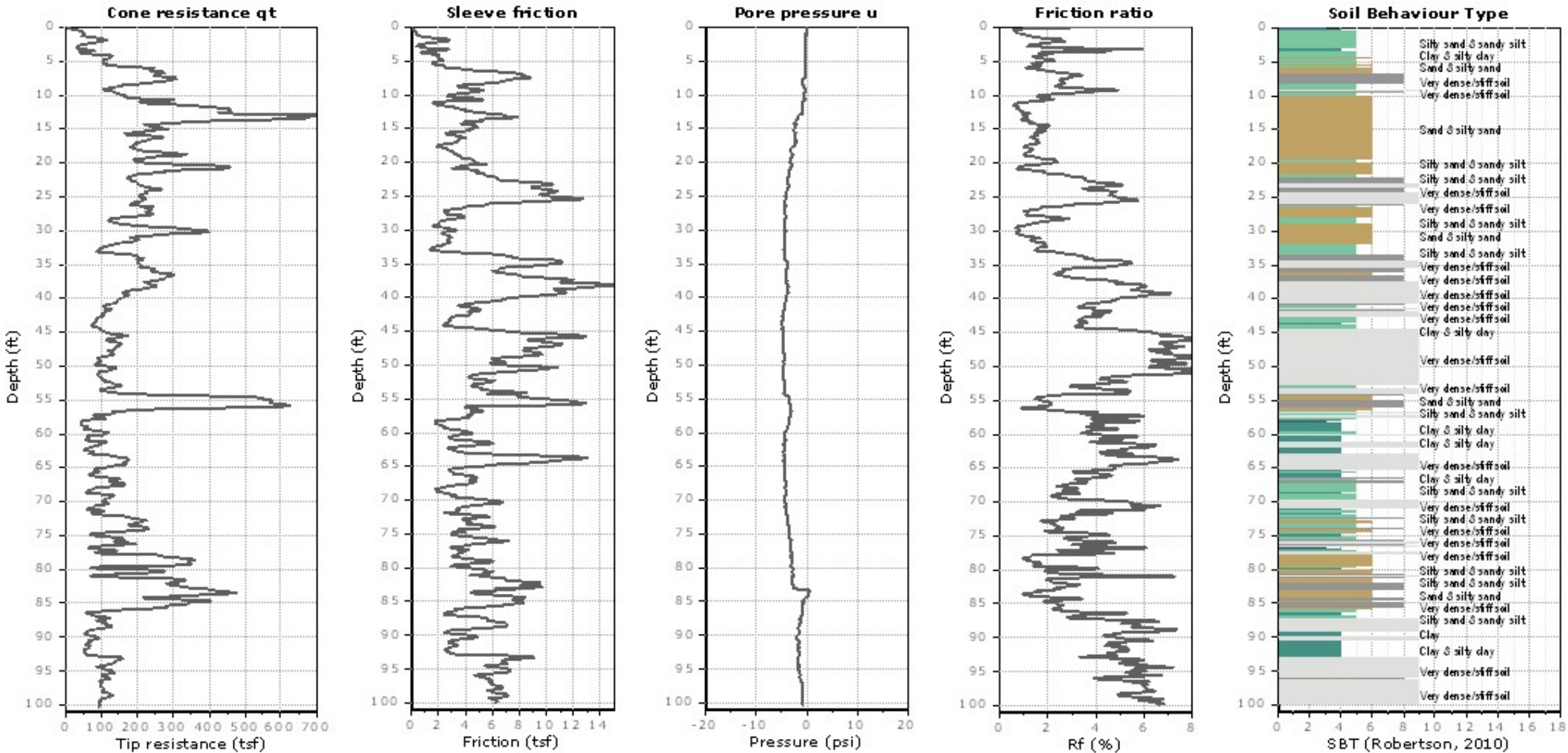




Project: Wood Group
Location: Coalinga, CA

CPT-3

Total depth: 100.33 ft, Date: 11/15/2018
Cone Type: Vertek





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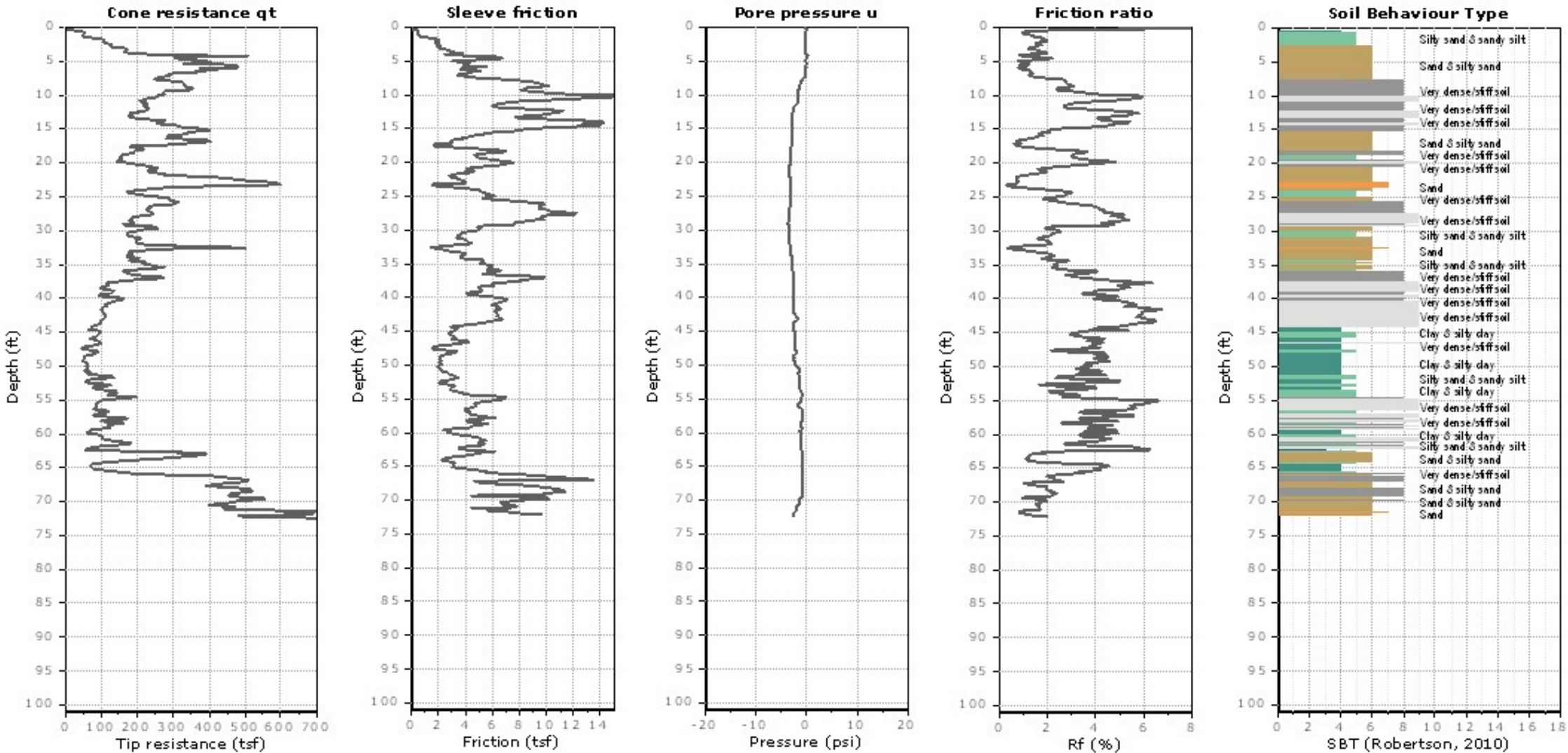
Project: Wood Group

Location: Coalinga, CA

CPT-4

Total depth: 72.51 ft, Date: 11/16/2018

Cone Type: Vertek



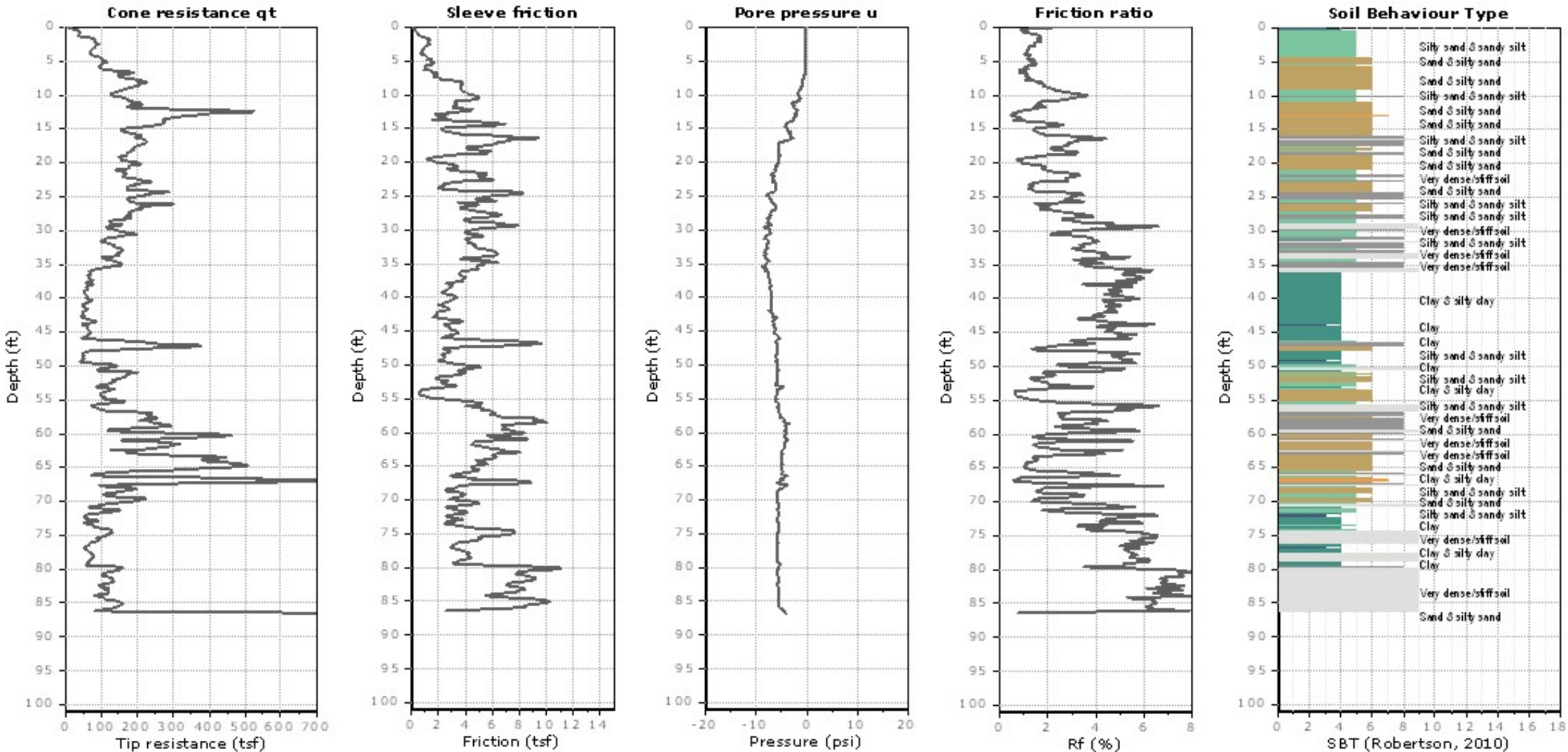


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Project: Wood Group
Location: Coalinga, CA

CPT-5

Total depth: 86.82 ft, Date: 11/15/2018
Cone Type: Vertek





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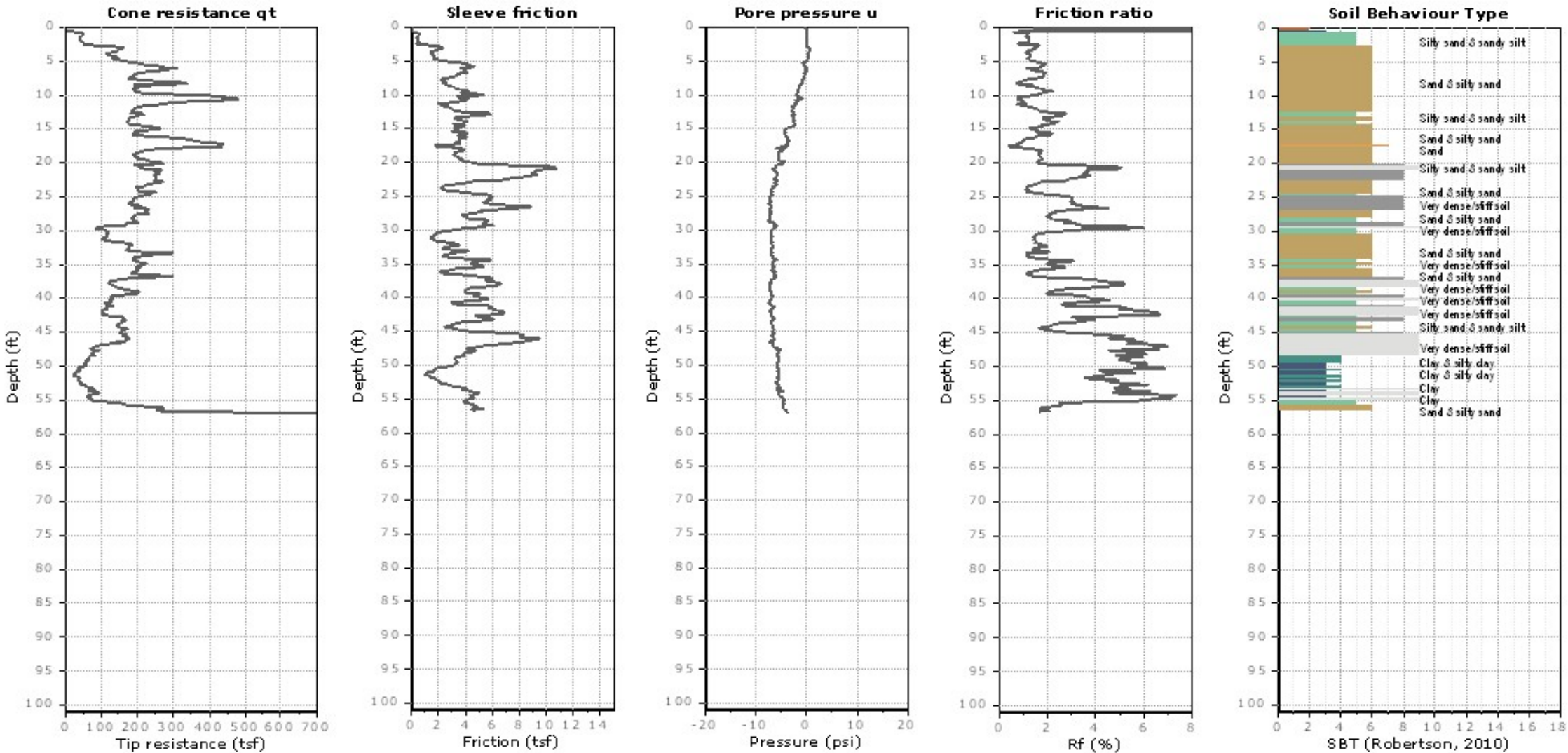
Project: Wood Group

Location: Coalinga, CA

CPT-6

Total depth: 57.10 ft, Date: 11/16/2018

Cone Type: Vertek





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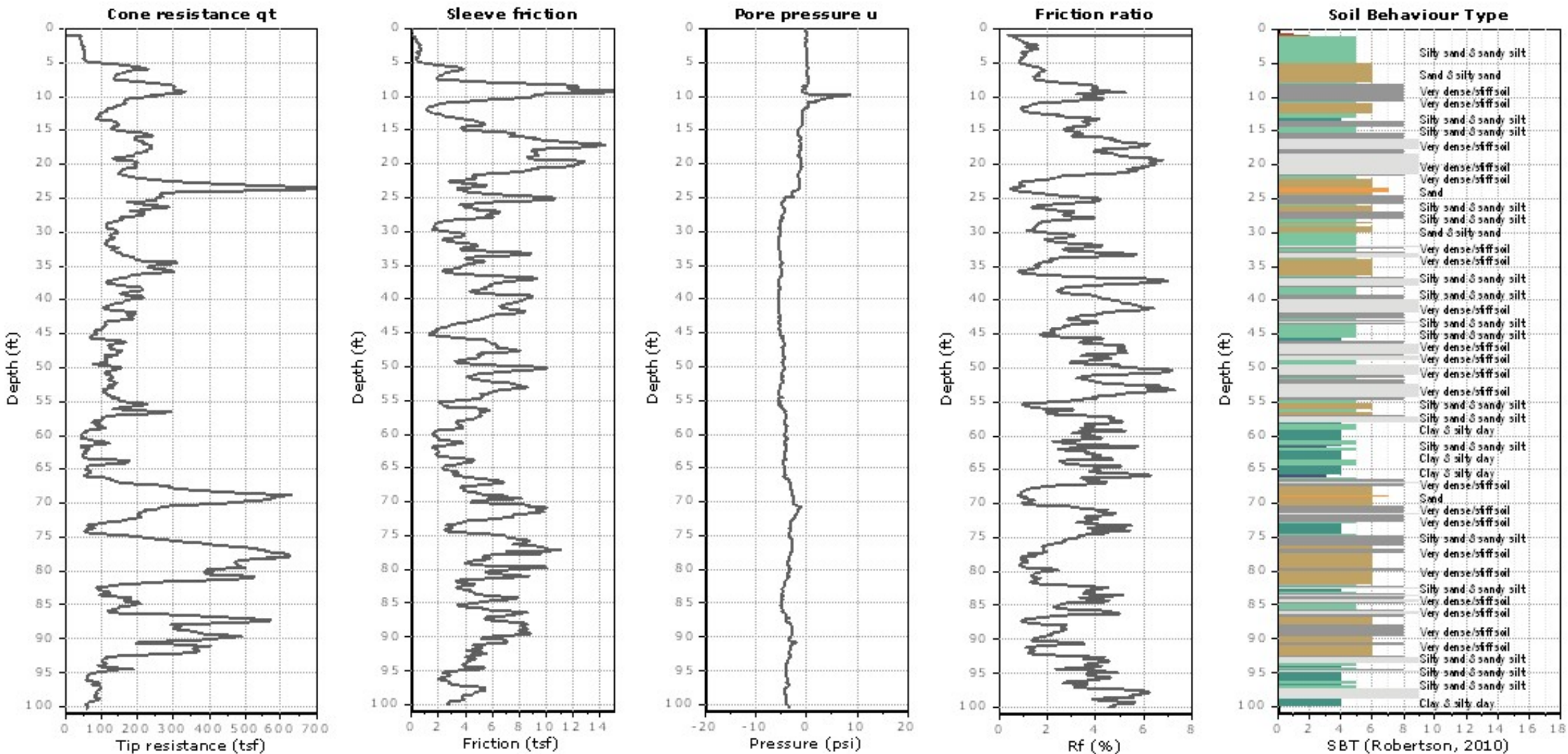
Project: Wood Group

Location: Coalinga, CA

CPT-7

Total depth: 100.42 ft, Date: 11/16/2018

Cone Type: Vertek





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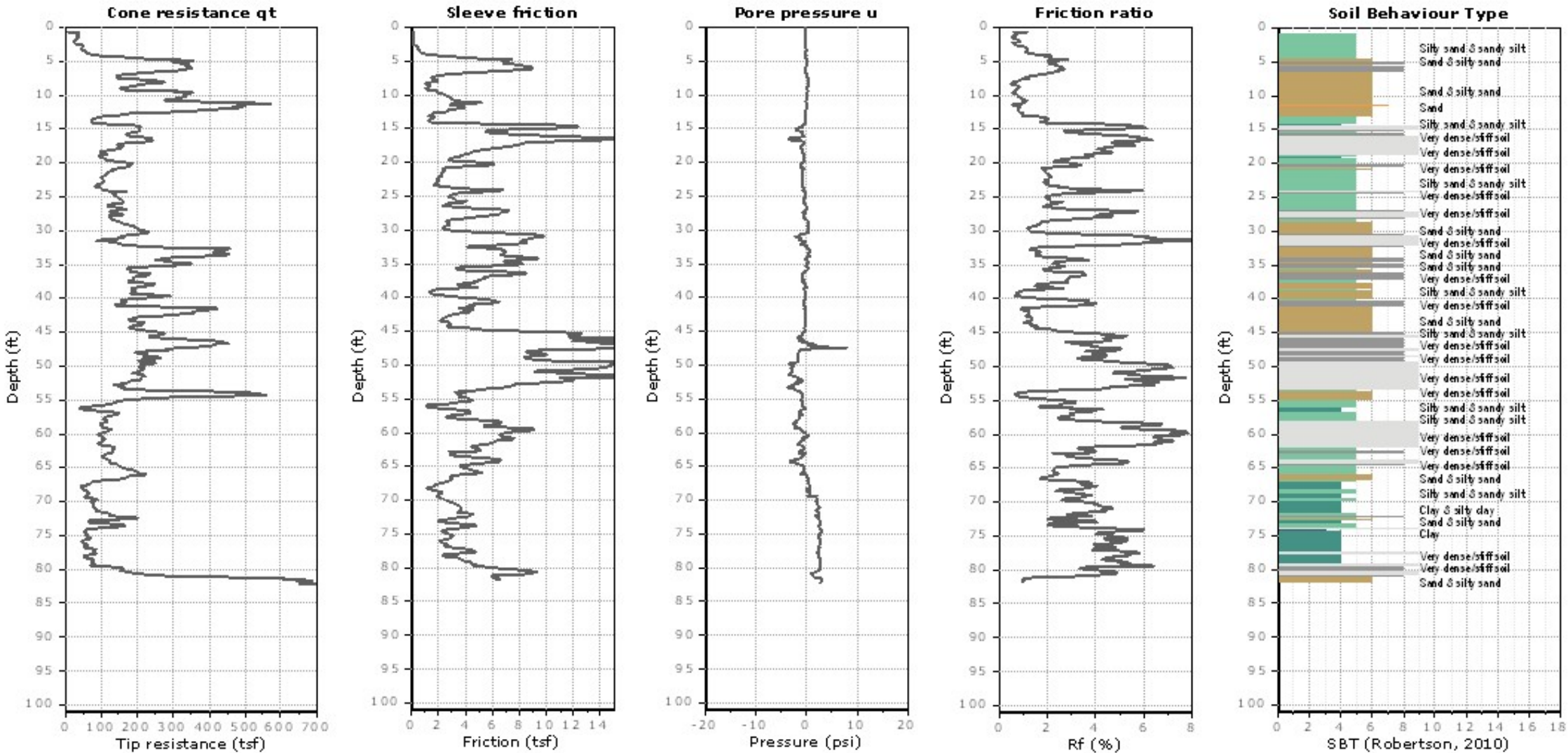
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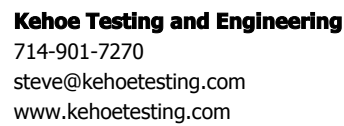
Location: Coalinga, CA

CPT-8

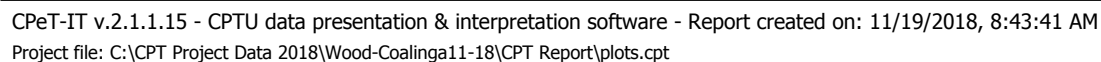
Total depth: 82.29 ft, Date: 11/16/2018

Cone Type: Vertek





CPT-9
Total depth: 100.36 ft, Date: 11/16/2018
Cone Type: Vertek



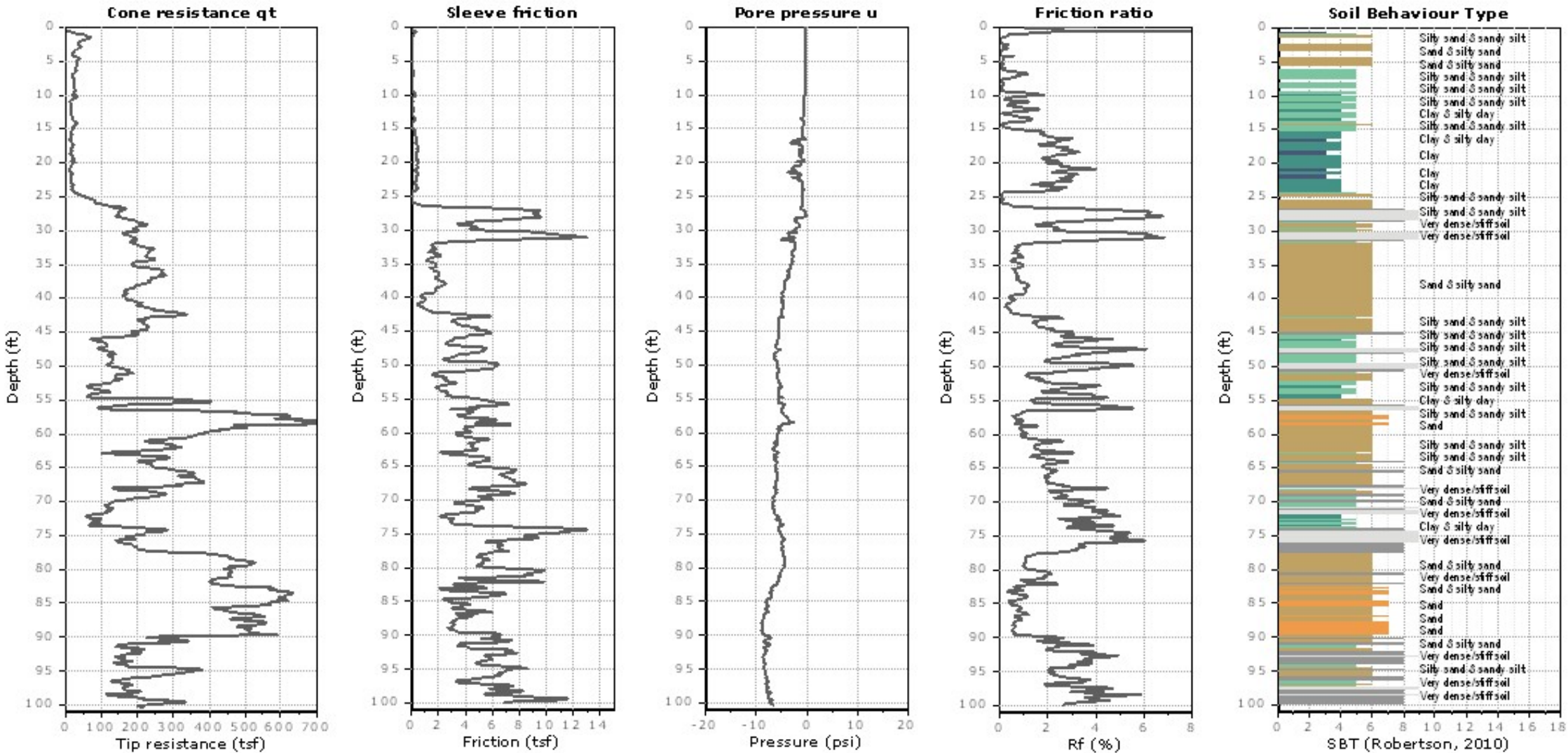


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AP-CPT-1

Total depth: 100.35 ft, Date: 11/26/2018
Cone Type: Vertek

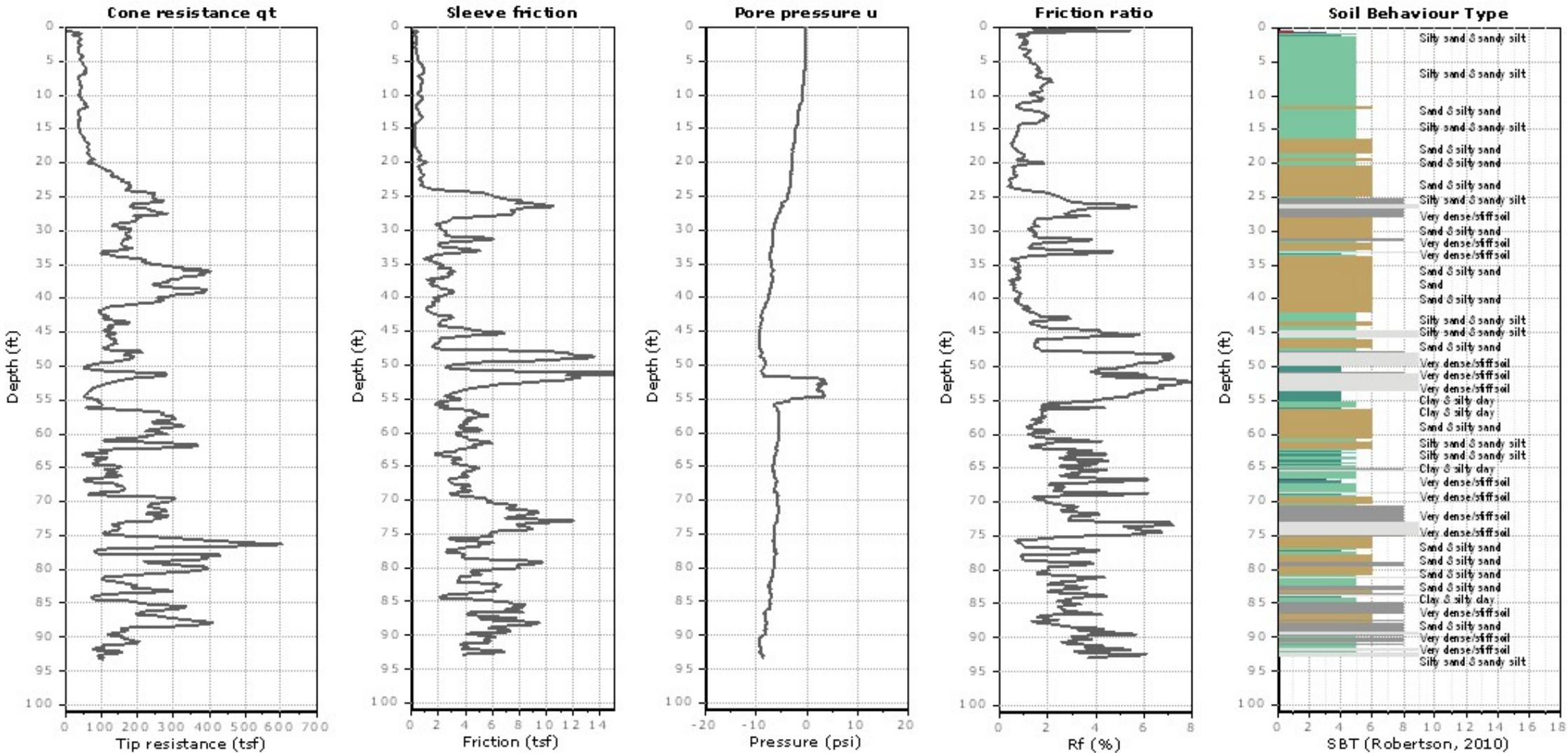




Project: Wood Group
Location: Coalinga, CA

AP-CPT-2

Total depth: 93.40 ft, Date: 11/27/2018
Cone Type: Vertek



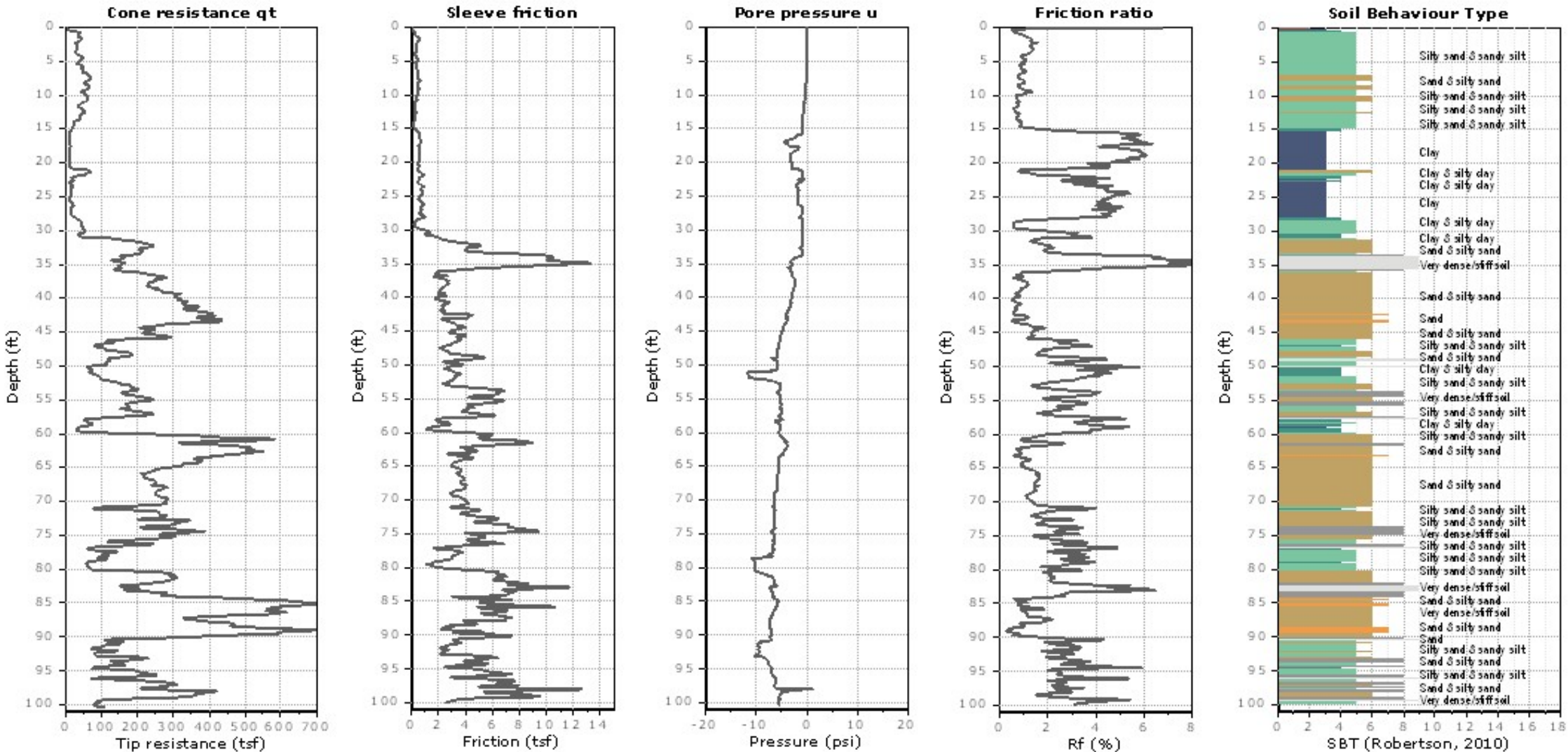


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AP-CPT-3

Total depth: 100.41 ft, Date: 11/27/2018
Cone Type: Vertek



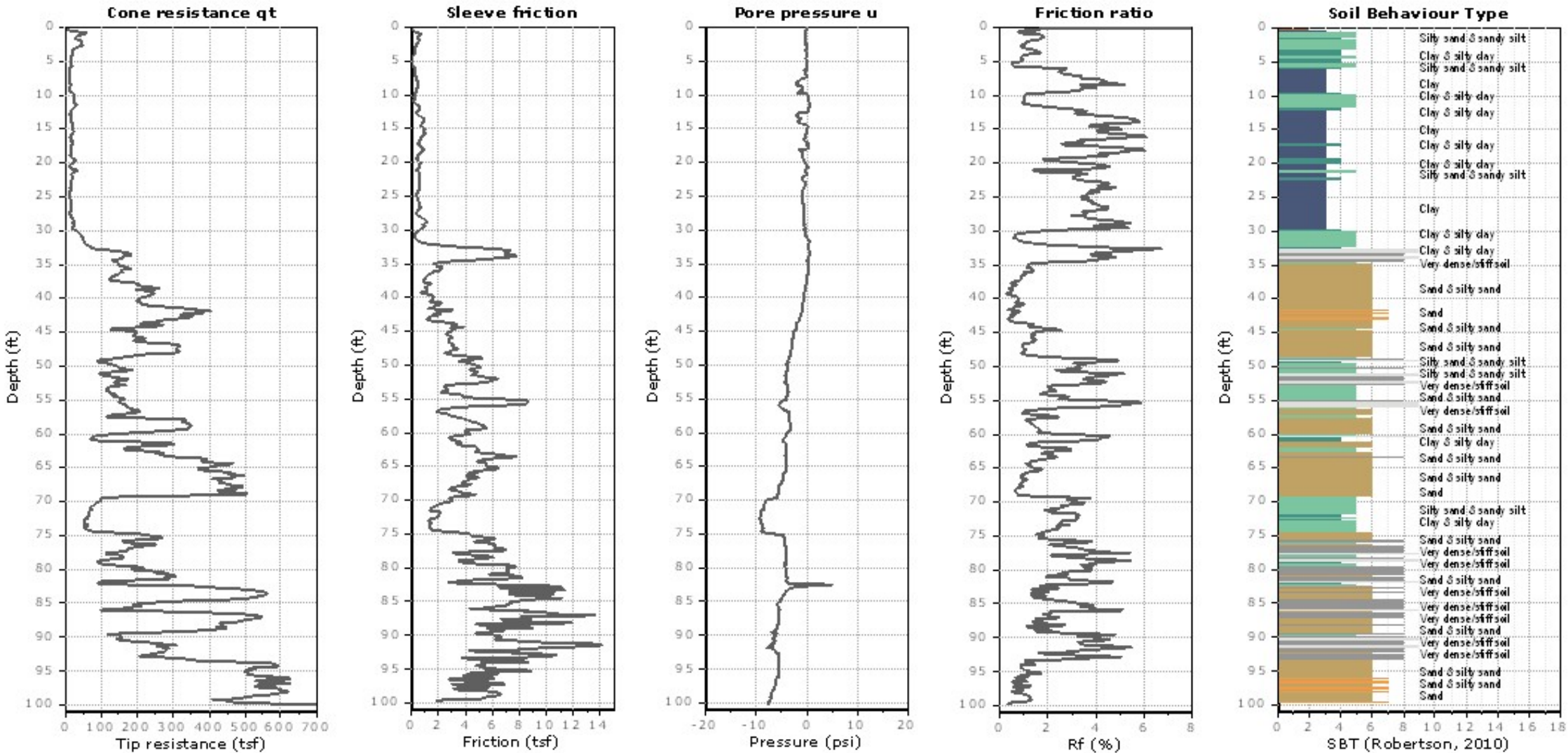


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Project: Wood Group
Location: Coalinga, CA

AP-CPT-4

Total depth: 100.20 ft, Date: 11/27/2018
Cone Type: Vertek



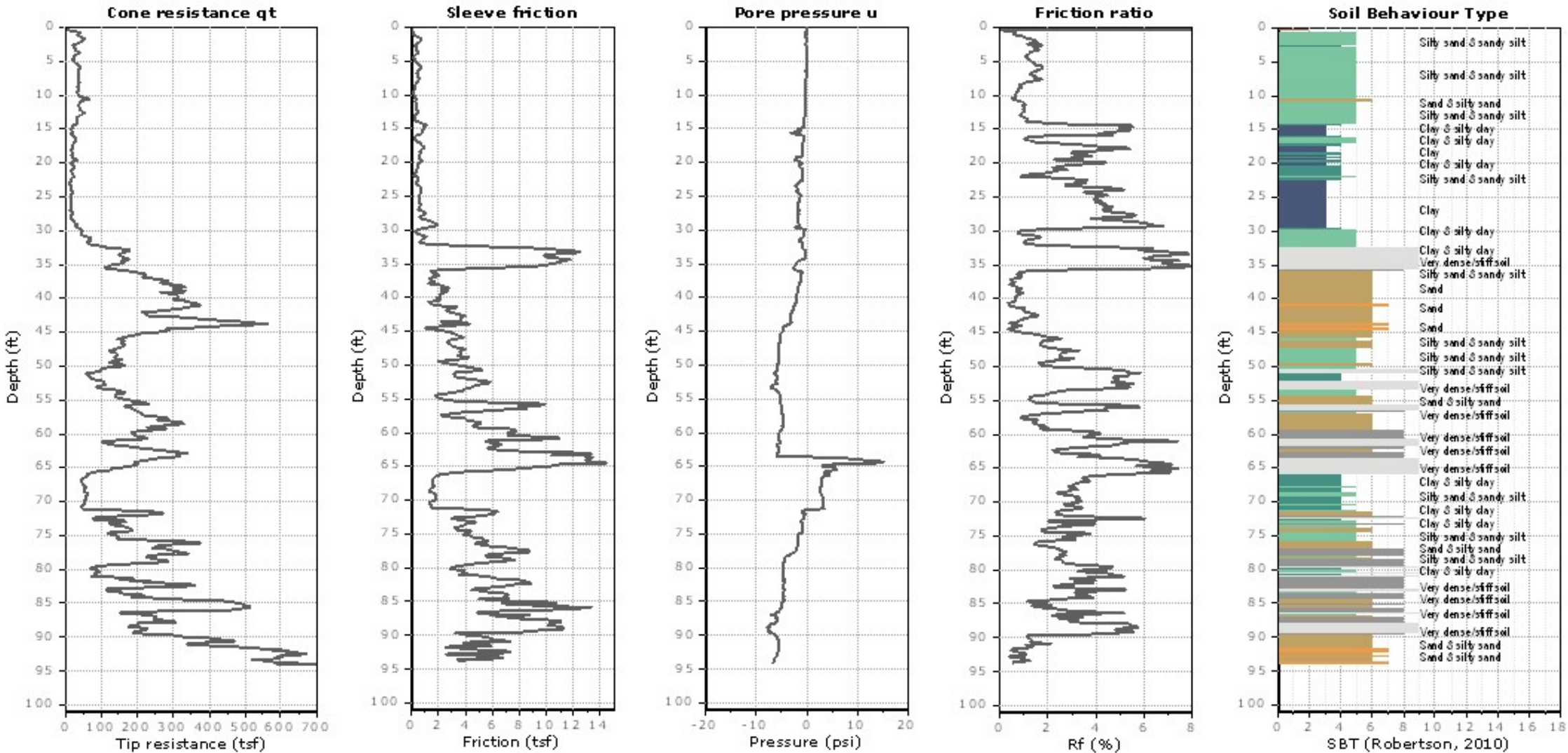


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Project: Wood Group
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AP-CPT-5

Total depth: 94.29 ft, Date: 11/27/2018
Cone Type: Vertek



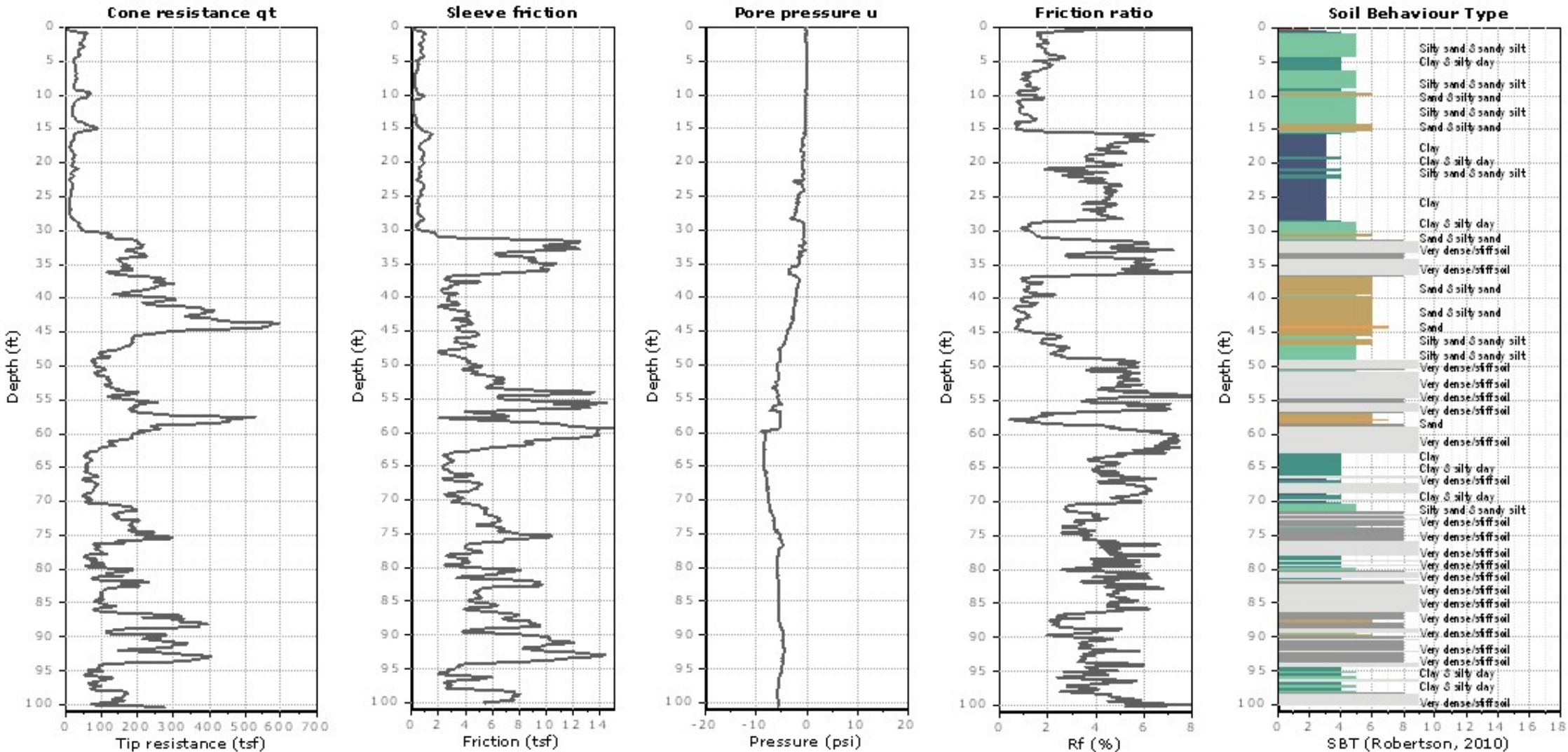


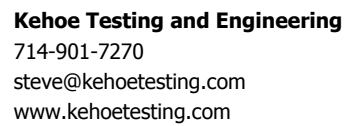
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Location: Coalinga, CA

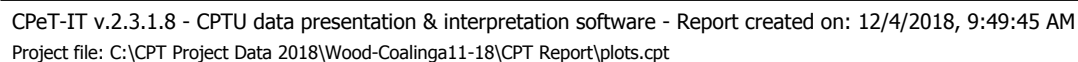
AP-CPT-6

Total depth: 100.54 ft, Date: 11/27/2018
Cone Type: Vertek





AP-CPT-7
Total depth: 100.46 ft, Date: 11/28/2018
Cone Type: Vertek



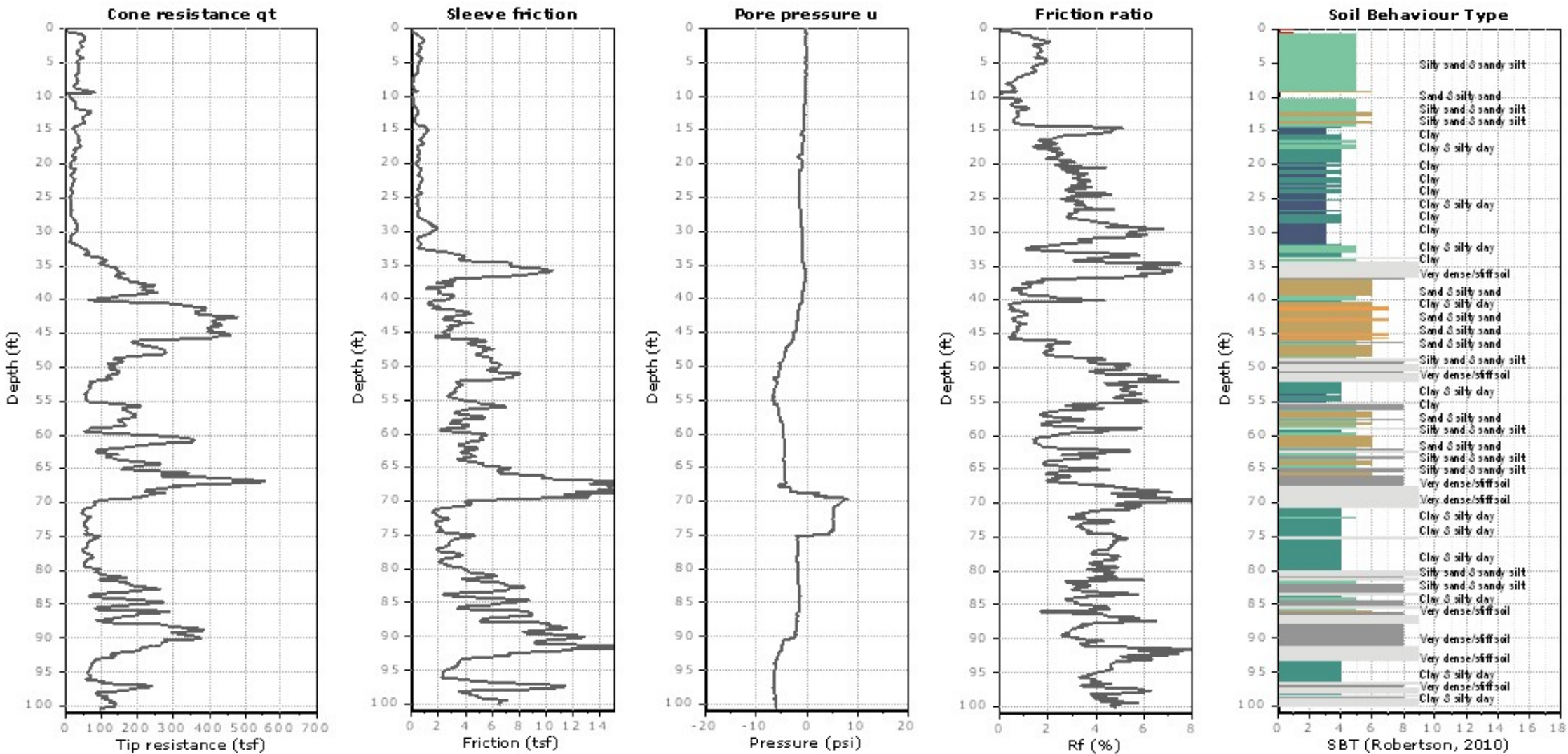


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Project: Wood Group
Location: Coalinga, CA

AP-CPT-8

Total depth: 100.53 ft, Date: 11/28/2018
Cone Type: Vertek

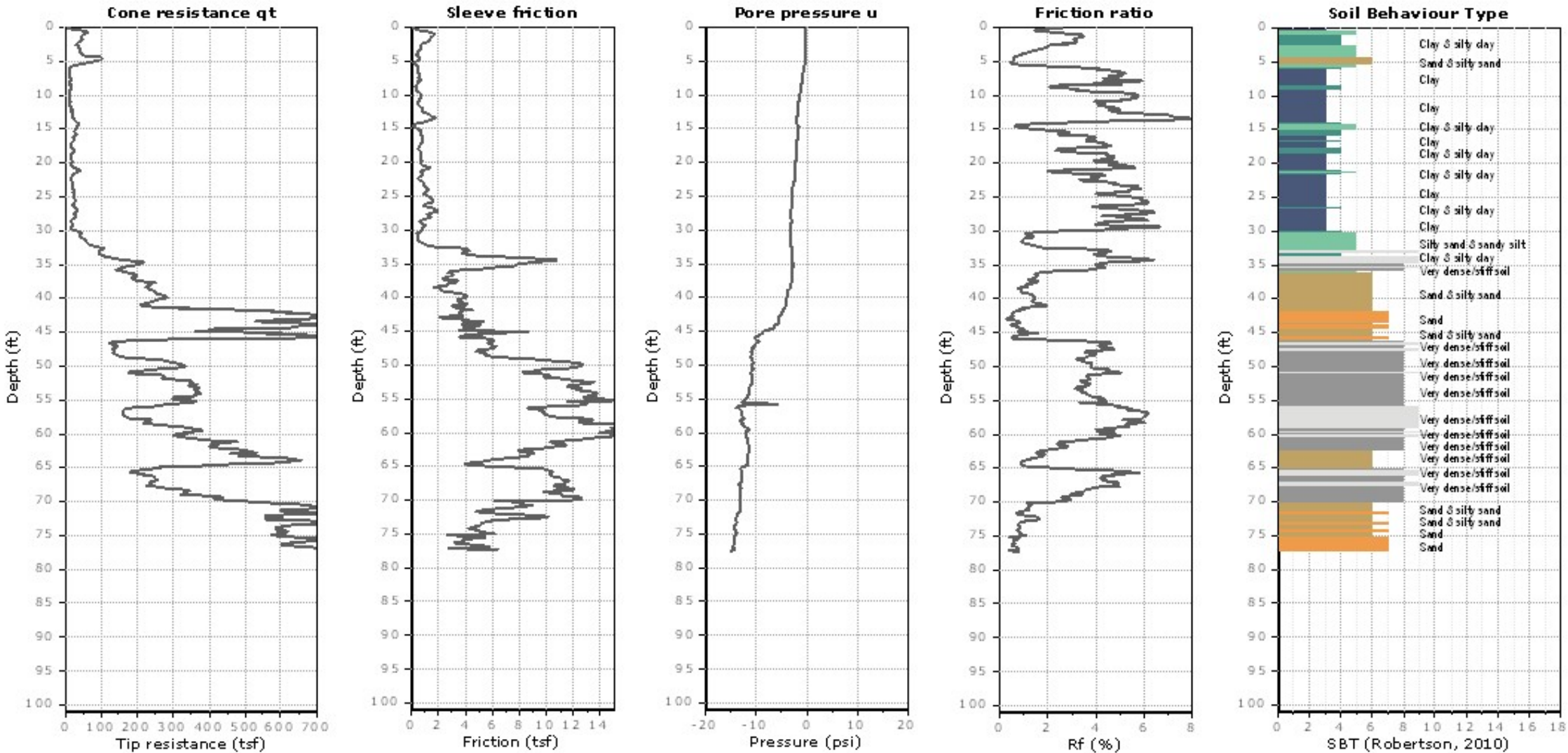




Project: Wood Group
Location: Coalinga, CA

AP-CPT-9

Total depth: 77.76 ft, Date: 11/29/2018
Cone Type: Vertek



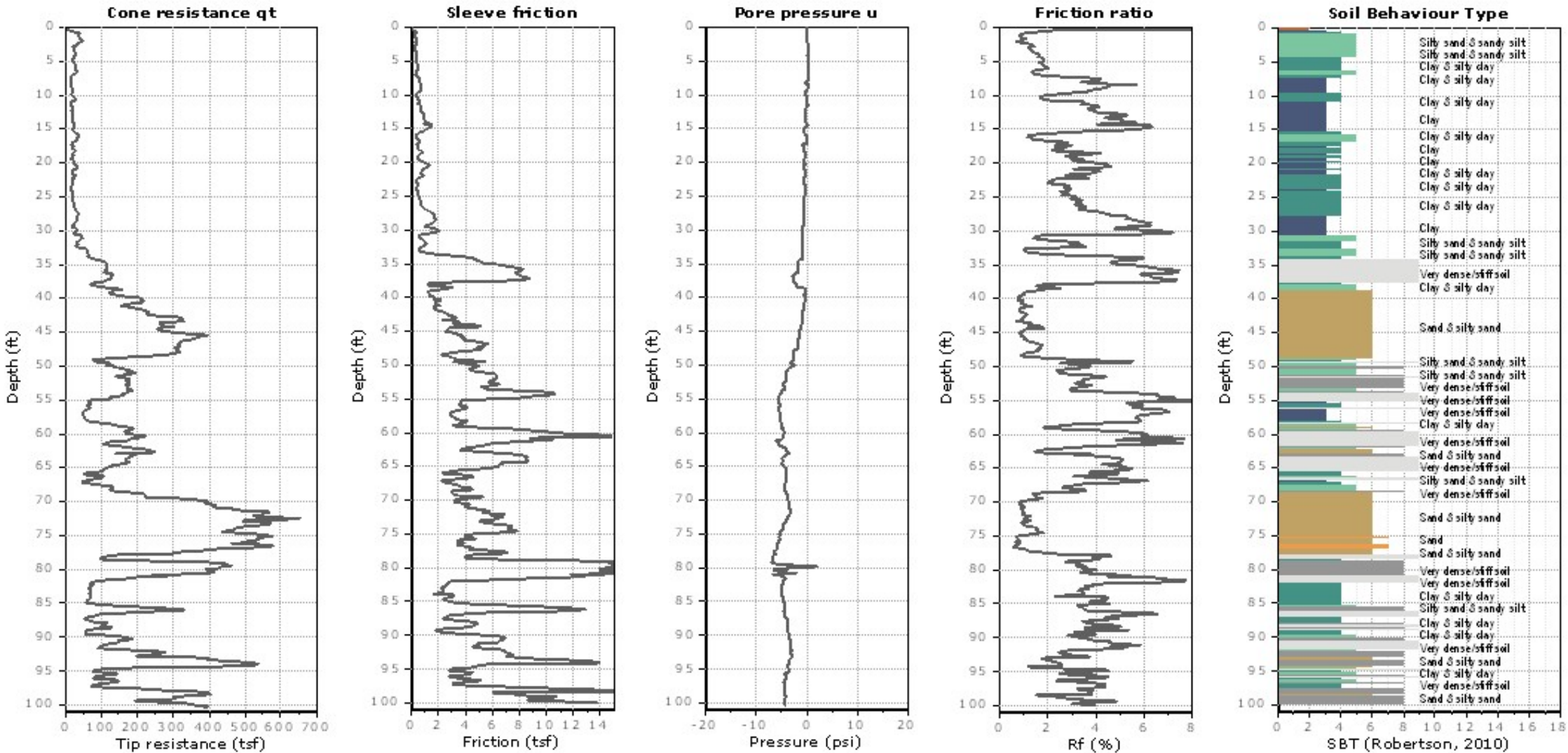


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Project: Wood Group
Location: Coalinga, CA

AP-CPT-10

Total depth: 100.40 ft, Date: 11/28/2018
Cone Type: Vertek



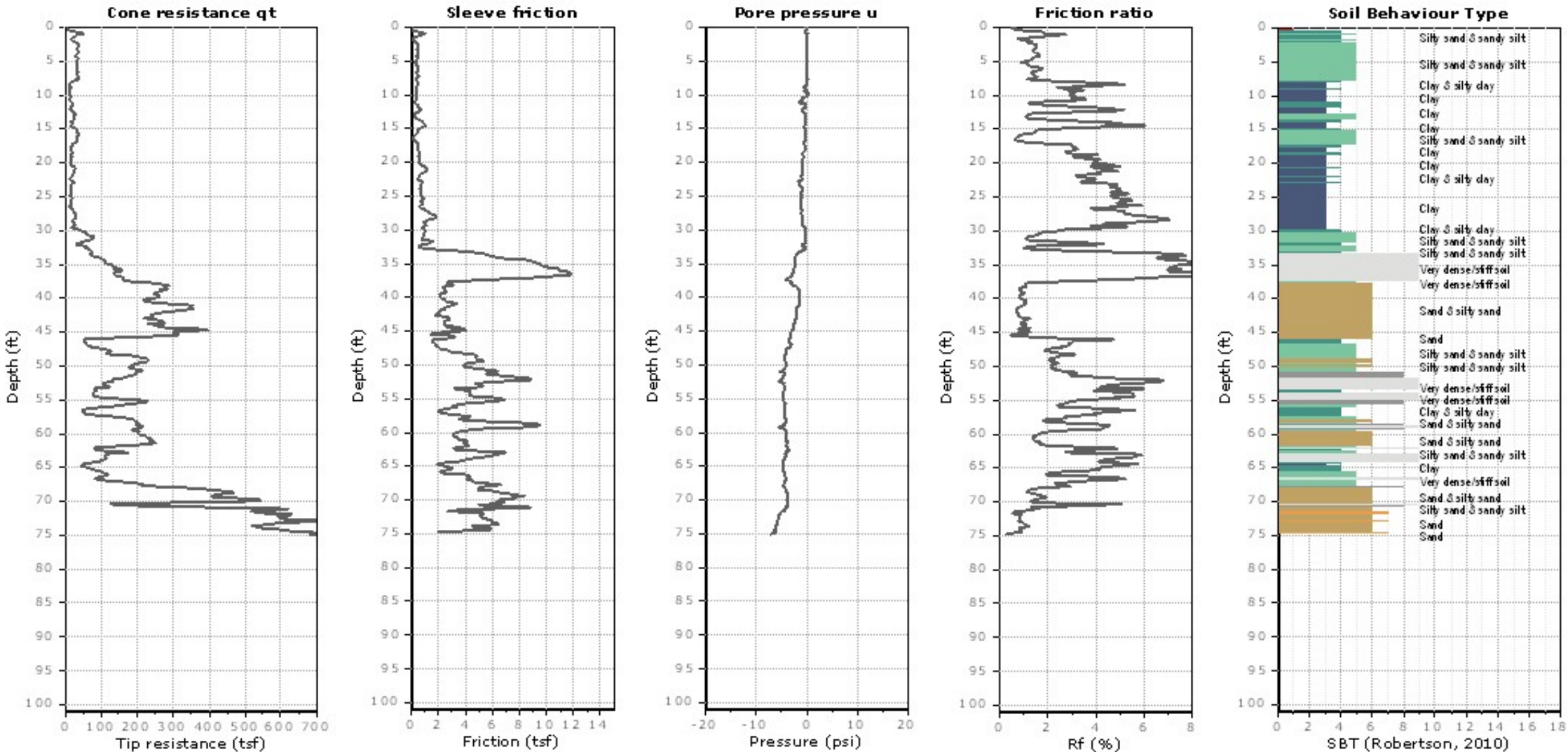


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Project: Wood Group
Location: Coalinga, CA

AP-CPT-11

Total depth: 75.20 ft, Date: 11/28/2018
Cone Type: Vertek



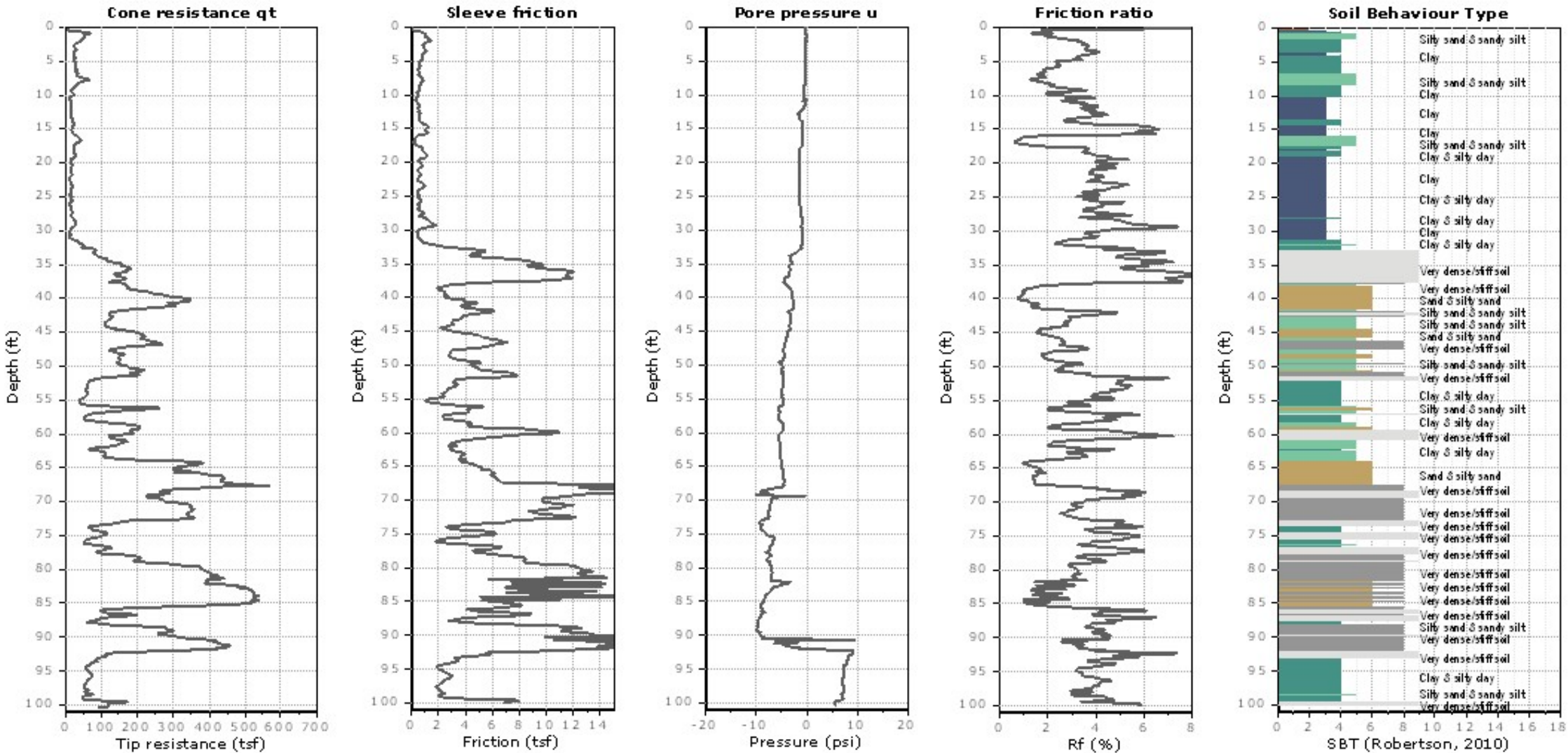


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Project: Wood Group
Location: Coalinga, CA

AP-CPT-12

Total depth: 100.48 ft, Date: 11/28/2018
Cone Type: Vertek



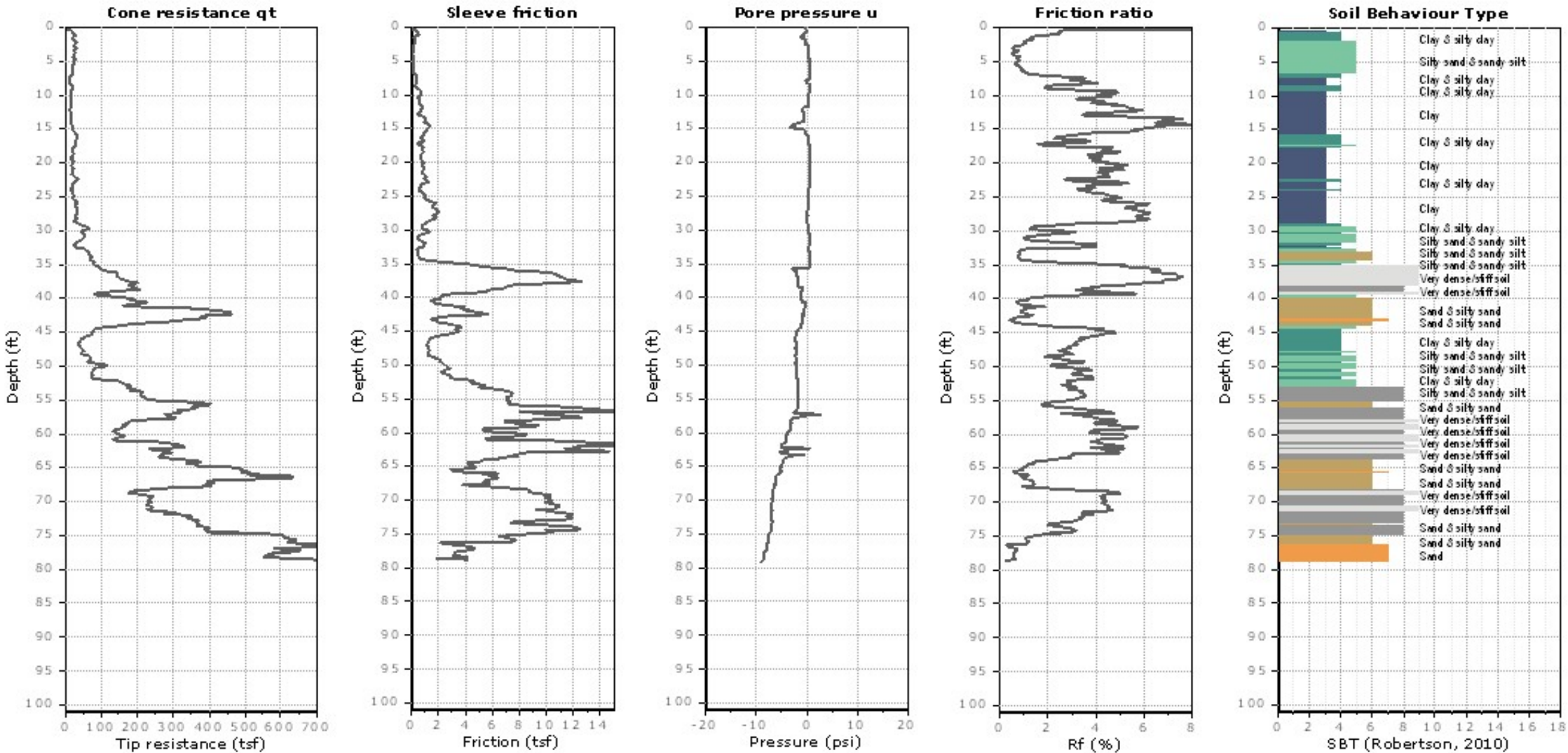


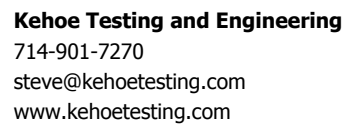
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Project: Wood Group
Location: Coalinga, CA

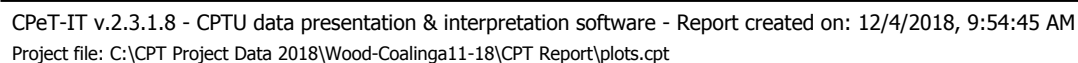
AP-CPT-13

Total depth: 79.21 ft, Date: 11/29/2018
Cone Type: Vertek





AP-CPT-14
Total depth: 100.46 ft, Date: 11/29/2018
Cone Type: Vertek



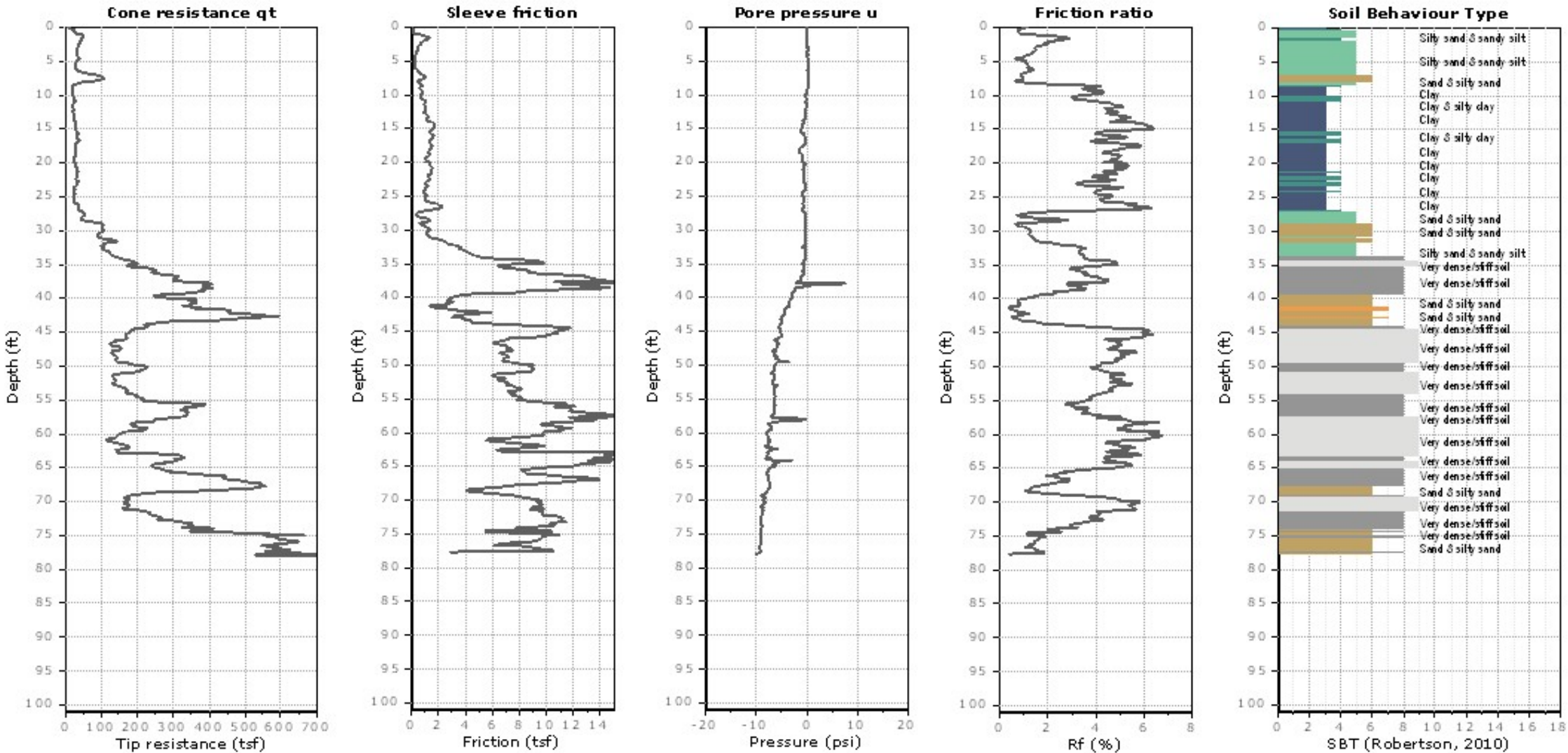


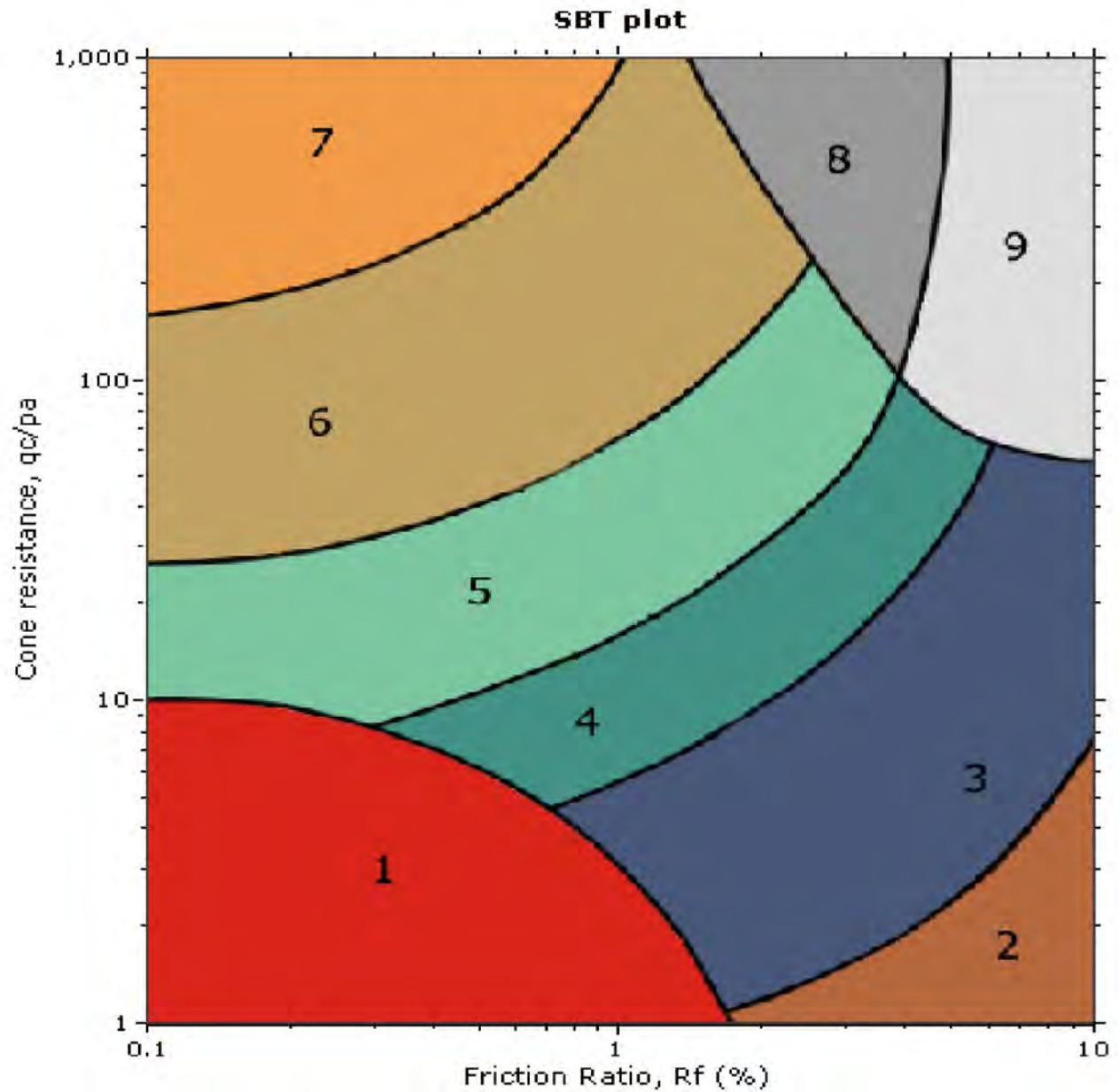
Kehoe Testing and Engineering
714-901-7270
steve@kehoetesting.com
www.kehoetesting.com

Project: Wood Group
Location: Coalinga, CA

AP-CPT-15

Total depth: 78.16 ft, Date: 11/29/2018
Cone Type: Vertek





SBT legend

- | | | |
|---|---|---|
| ■ 1. Sensitive fine grained | ■ 4. Clayey silt to silty clay | ■ 7. Gravelly sand to sand |
| ■ 2. Organic material | ■ 5. Silty sand to sandy silt | ■ 8. Very stiff sand to clayey sand |
| ■ 3. Clay to silty clay | ■ 6. Clean sand to silty sand | ■ 9. Very stiff fine grained |