Prepared for
Silicon Valley Clean Water

April 3, 2017

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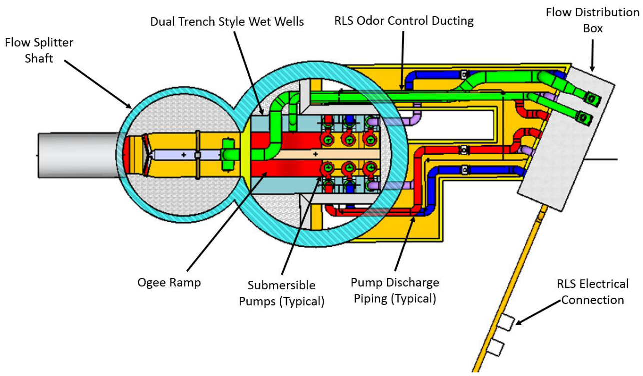
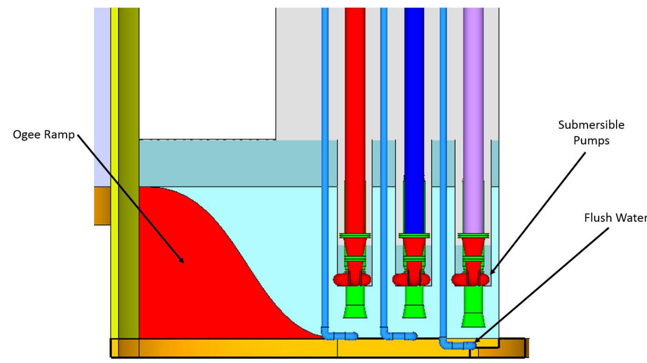
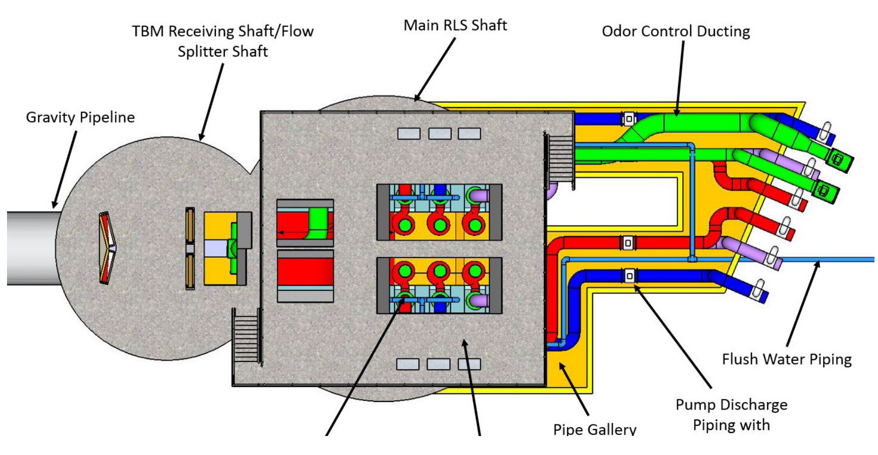




Receiving Lift Station - Project Planning Report



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SVCW Conveyance System Program
Receiving Lift Station
Project Planning Report

Prepared for

Silicon Valley Clean Water
Redwood City, CA

April 3, 2017

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Silicon Valley Clean Water
Redwood City, CA
April 3, 2017

3/31/17

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List of Abbreviations

AACE	American Association of Cost Engineering
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ADWF	Average Dry Weather Flow
ANSI	American National Standards Institute
AWWA	American Water Works Association
BC	Brown and Caldwell
BIIS	Bair Island Inlet Structure
BPS	Belmont Pump Station
Caltrans	State of California Department of Transportation
CCO	contract change order
CDFW	California Department of Fish and Wildlife
CFGC	California Fish and Game Code
CFM	cubic feet per minute
CIP	Capital Improvements Program
CRR	California Ridgeway Rail
CSMP	Conveyance System Master Plan
dB	decibel
dBA	A-weighted decibel
e.g.,	example
EIR	Environmental Impact Report
ESA	Environmental Site Assessment
etc.	etcetera
FA	foul air
FEF	flow equalization facility
FoP	front of plant
ft	feet
ft/s	feet per second
GDR	Geotechnical Data Report
H_2S	hydrogen sulfide
HDPE	High Density Polyethylene
HI	Hydraulic Institute
HMI	human machine interface
HP	horsepower
HVAC	heating, ventilation, and air conditioning
ID	Inside Diameter
JPA	Joint Powers Authority
kWh	kilowatt hour
LCC	lifecycle cost
LEL	lower explosive limit
L_{eq}	Equivalent Noise Level
MBTA	Migratory Bird Treaty Act
mgd	million gallons per day
MIC	microbiologically influenced corrosion
MPPS	Menlo Park Pump Station
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
P&IDs	process and instrumentation diagrams
PDWF	peak dry weather flow
PG&E	Pacific Gas and Electric Company
PLC	Programmable Logic Controller
POR	Preferred Operating Range
ppm	parts per million
PVC	polyvinyl chloride
PWWF	peak wet weather flow
RCPS	Redwood City Pump Station
RLS	Receiving Lift Station
RSB	Redwood Shores Bayfront
Regional Board	Regional Water Quality Control Board
SCADA	Supervisory Control and Data Acquisition
SCPS	San Carlos Pump Station
SMHM	Salt Marsh Harvest Mouse
SMWS	Salt Marsh Wandering Shrew
SRF	State Revolving Fund
SVCW	Silicon Valley Clean Water
TBM	tunnel boring machine
TDH	total dynamic head
TM	Technical Memorandum
US-101	U.S. Highway 101
USFWS	United States Fish and Wildlife Service
UST	underground storage tank
VFD	variable frequency drive
WBSD	West Bay Sanitary District
WSEL	water surface elevation
WWTP	wastewater treatment plant
YBM	Young Bay Mud

Executive Summary

The Receiving Lift Station (RLS) is a new pumping station that will lift flow from a gravity pipeline that transports wastewater from the "Member Agencies" (City of Belmont, City of San Carlos, City of Redwood City and West Bay Sanitary District) to a new Headworks at the Silicon Valley Clean Water (SVCW) Wastewater Treatment Plant (WWTP). The RLS will be located at the WWTP adjacent to the new Headworks. This RLS Project Planning Report presents current thinking regarding the RLS Project, which is one of several projects included in an overall Capital Improvements Program (CIP) being executed by SVCW. This report is intended to describe the RLS Project, and is not meant to be a preliminary or final design. A progressive design build entity will review this information as background and then work collaboratively with SVCW to develop additional concepts, preliminary design, a final design, and construct the RLS Project.

The RLS Project Planning Report discusses the RLS Project's background and purpose, setting, compiled data and assumptions, project specific analyses completed to date, the selected RLS Project description, cost estimate, schedule and next steps for progressing the design.

Background

The SVCW conveyance system transports raw wastewater from its Member Agencies to the SVCW WWTP. Four pump stations convey flow to the SVCW WWTP through the conveyance system force main: Belmont Pump Station (BPS), San Carlos Pump Station (SCPS), Redwood City Pump Station (RCPS), and Menlo Park Pump Station (MPPS). These pump stations and force mains will require upgrades since the pump stations are at the end of their useful lives and cannot meet the 2030 projected flows. An analysis was conducted to identify alternatives to improve the conveyance system that may reduce impacts to residents, businesses and other facilities. The alternatives analysis identified over 140 combinations of pipeline alignments and pump station locations that included different construction methods and modes of operation (e.g., gravity and pressure conveyance and configuration and location of conveyance storage).

The proposed Wastewater Conveyance System and Treatment Reliability Improvement Project, hereinafter referred to as the proposed Conveyance System Project, consists of the replacement/rehabilitation or repurposing of existing pump stations, improvements to the existing WWTP, and replacing portions of the existing force main pipeline with a deep gravity pipeline and new force mains. The proposed Conveyance System Project is characterized by major conveyance components including installing a new gravity pipeline, RLS, flow diversion facilities, influent connector pipes, and the replacement, rehabilitation or re-purposing of the four pump stations. Figure ES-1 shows a schematic of the proposed Conveyance System Project.

Figure ES-1. Schematic diagram of proposed Conveyance System Project

(Source: Kennedy/Jenks Consultants)

Recommended RLS Project

The proposed Conveyance System Project includes upgrades and improvements at many of SVCW's existing conveyance facilities, and also involves construction of new facilities. This Project Planning Report is focused on the design efforts to date at RLS, which is one component of the proposed Conveyance System Project. The RLS would be a deep, submersible pump station to pump the incoming wastewater from the gravity pipeline to an elevation sufficient to flow through the newly constructed Headworks Facility and additional WWTP processes. The RLS would be located on the SVCW property that currently holds the existing 10-acre ornamental pond area. The structure housing the RLS would extend approximately 10 feet above grade and approximately 93 feet below grade. The proposed RLS (Figure ES-2) will consist of the following major components:

- Connection to the gravity pipeline, including use of the Tunnel Boring Machine (TBM) retrieval shaft as the Flow Splitter Shaft.
- Two trench-style wet wells with submersible pumps within the Main RLS Shaft
- Pipe gallery for pump discharge piping, odor control ducts, flow meters and flush water piping.
- Flushing lines located at the sluice gates and stop logs and at each pump intake
- Flow Distribution Box at the pump discharge to feed into the Headworks
- Odor control systems located in the Headworks Facility
- Electrical facilities located in the Headworks Facility

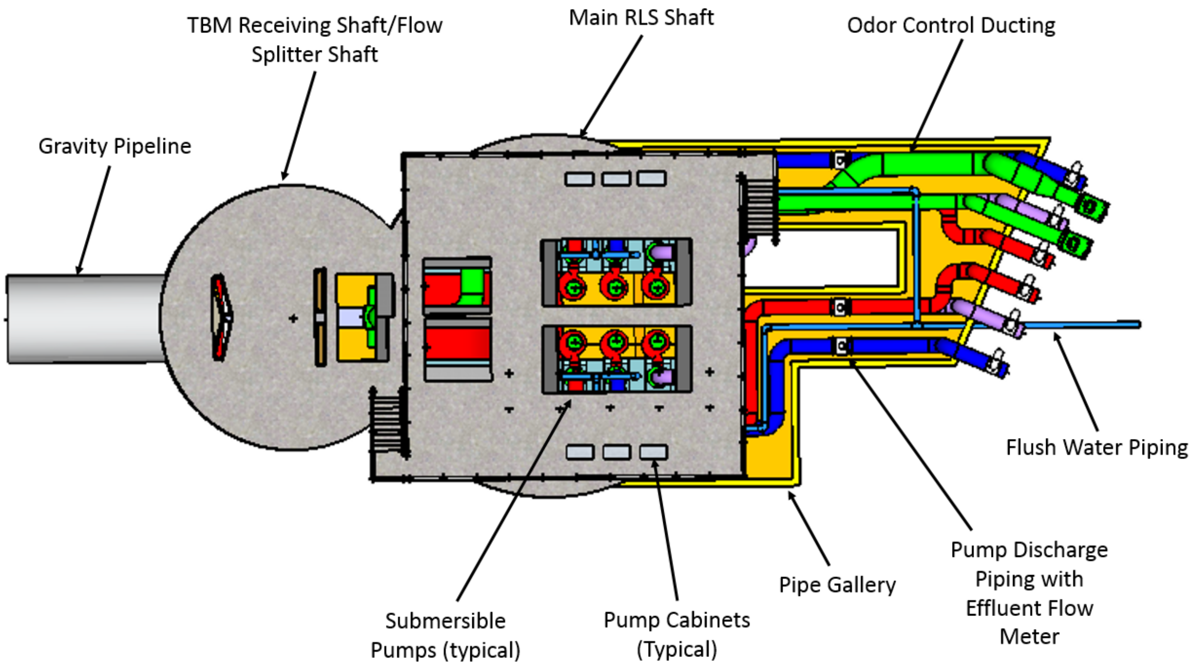

Figure ES-2. Overall RLS layout – plan view

The RLS would have a minimum redundant pumping capacity of 75 million gallons per day (mgd) at maximum total dynamic head (TDH). Each wet well could consist of three submersible non-clog pumps: three 15 mgd pumps in each wet well, for a total of six 15 mgd pumps. The combination of five 15 mgd pumps operating would convey 75 mgd with the sixth 15 mgd pump as a standby.

Project Schedule and Budget

The schedule of work for the RLS was developed as part of the proposed Conveyance System Project schedule. The RLS is currently proposed to be designed and constructed as a design build project with the additional Front of Plant (FoP) improvements. Currently, design development for the RLS and other FoP improvements is scheduled to begin in October 2017. Construction is scheduled to start for all FoP improvements including the RLS in December 2018 and will be complete in July 2022.

Brown and Caldwell (BC) developed a Class 3 cost estimate [as defined by the American Association of Cost Engineering International (AACE)] for the RLS in April 2016. The capital costs were originally developed in 2016 dollars, but were escalated to 2020, which is the midpoint year of construction. Table ES-1 summarizes the construction costs, contingency and soft costs, 2016 capital costs, and escalated capital costs for the RLS.

Table ES-1. RLS capital cost	
	Total Net Cost
Total Construction Cost[1]	$10.2 M
Contingency and Soft Cost Subtotal (25% and 43% of Construction Cost)	$2.5 M $4.4 M
2016 Capital Cost	$17.1 M
2020 Capital Cost	$20.0 M
Market Fluctuation Ranges[2]	$19.4 M – $21.8 M

1. *The RLS capital cost does not include construction costs for the pump station shaft, as that is included in the gravity tunnel project.*
2. *Market fluctuations developed by SVCW. Source: SVCW Conveyance System Construction Cost Analysis, Front of Plant, Revision Date: April 22, 2015, Revision 28b.*

Outstanding Issues to Carry into Subsequent Design

Several items will need further refinement and coordination with SVCW. These items include, but are not limited to:

- Hydraulic model and pump selection refinement that will affect the overall wet well dimensions, available pump manufacturers, number of pumps on variable frequency drives (VFDs) and number and size of the pumps.
- Equipment removal and maintenance access
- Odor control sizing
- Architectural features to match the surrounding area
- Alignment and grade of incoming gravity pipeline
- Alternative configuration of the shafts and sizing as well as structural improvements needed to convert the shafts into permanent structures
- Alternative RLS configurations other than self-cleaning trench style wet wells
- Alternative shaft corrosion protection approaches
- Alternative pipe discharge locations including above ground
- Alternative building configurations for RLS electrical, Headworks, and odor control.

Section 1

Introduction

This Project Planning Report discusses the RLS Project, which is a new pump station that will lift flow from a gravity pipeline that transports wastewater from the Member Agencies to a new Headworks at the SVCW WWTP. The RLS will be located at the WWTP adjacent to the new Headworks. The RLS Project is one component of the proposed Conveyance System Project; other related projects are discussed in separate Project Planning Reports.

The RLS Project Planning Report is intended to describe the RLS Project developed for and as generally presented in the Draft Environmental Impact Report (Draft EIR; SVCW, 2016). It is not meant to be a preliminary or final design, and it is not intended to be prescriptive to a progressive design build entity. A progressive design build entity will review this information as background and then work collaboratively with SVCW to develop additional alternative concepts, preliminary design, a final design and then construct the RLS Project. Alternative concepts may be developed that vary from the concepts contained in the planning reports. These new concepts will be considered and evaluated as alternatives. If the final RLS Project varies significantly from the concepts shown in these planning reports, additional California Environmental Quality Act (CEQA) review may be required. The level and timing of this possible CEQA review will be considered as the concepts are evaluated. Project Planning Reports for the other elements of the proposed Conveyance System Project have been prepared as separate documents. The Project Planning Report discusses the following topics:

- **Section 1 – Introduction:** The proposed Conveyance System and RLS Project's background and purpose.
- **Section 2 – Setting:** The RLS Project's setting including physical, institutional and interproject setting.
- **Section 3 – Compiled Data and Assumptions:** Compiled data and assumptions including planning and design parameters and assumptions and a summary of field investigations.
- **Section 4 – Project Specific Analyses:** RLS Project specific analyses including alternatives analysis, siting evaluation and hydraulic analysis.
- **Section 5 – Selected Project Description:** Selected RLS Project description including a written description of the recommended RLS Project alternative, major components, conceptual drawings, process and instrumentation drawings, design criteria, major equipment, useful life of the RLS Project, equipment replacement frequency, site layout, energy, constructability, construction sequencing and additional design considerations.
- **Section 6 – Cost Estimate and Schedule:** Cost estimate and schedule including life cycle costs and a planning level schedule for design and construction.
- **Section 7 – Outstanding Project Issues:** Next steps for preliminary design including a description of unresolved issues, further field investigation, description of additional analyses, decisions required from SVCW staff or management and items critical to interproject coordination.

1.1 Background

1.1.1 SVCW is a wastewater utility in San Mateo County

SVCW is a Joint Powers Authority (JPA) that owns and operates a regional WWTP at the eastern end of Redwood Shores, within Redwood City, and related wastewater pumping and transmission facilities. SVCW treats the majority of the wastewater generated from the mid-peninsula of San Mateo County south of the San Mateo Bridge. The JPA members include the cities of Belmont, Redwood City, and San Carlos, and the West Bay Sanitary District (WBSD) (which provides sanitary sewer collection services to the cities of Menlo Park, Portola Valley, and portions of Atherton, Woodside, East Palo Alto, and unincorporated areas of San Mateo County).

The individual members of the JPA own and operate the sanitary sewer collection systems within their respective jurisdictions. WBSD also owns the existing flow equalization facility (FEF) that is leased to SVCW and used to store wastewater during wet weather conditions. SVCW owns and operates the WWTP and the sanitary sewer force main and pump stations that convey the wastewater from the member agency connections to the treatment plant.

1.1.2 Existing conveyance system

SVCW's existing conveyance system assets include four pump stations, one for each of the four member agencies, a wet weather booster station located in the SCPS, an Influent Lift Station (ILS) located at the WWTP, and an approximately nine-mile-long force main. SVCW leases from the WBSD a FEF, which is an integral part of SVCW's existing conveyance system.

1.1.3 History of SVCW and the conveyance system

To understand the need for the proposed Wastewater Conveyance System and Treatment Reliability Improvement Project (the proposed Conveyance System Project) it is useful to know the history of SVCW, the assumptions used during the original design of the conveyance system, why the various components were built, and why at different times. This description of the history of SVCW will illustrate that the conveyance system is being operated in a manner different than its original design intent and, now, beyond its useful life.

Until the mid-1960's the mid-peninsula cities had their own wastewater treatment plants. Redwood City Sanitary District owned and operated the Redwood City Sewage Treatment Facility. Belmont and San Carlos owned and operated the Belmont/San Carlos Joint Sewage Treatment Facility. The developer of Redwood Shores (Mobil Land) owned the Redwood Shores Treatment Plant and it was operated by Redwood City Sanitary District. The Redwood City and Belmont/San Carlos plants separately discharged effluent to San Francisco Bay. The Redwood Shores Plant consisted of oxidation ponds and had no discharge as all the wastewater was evaporated. The level of treatment provided by these three plants and the locations of their outfalls could not meet the new stricter wastewater treatment and disposal regulations being imposed and developed at the state (Porter-Cologne Act, 1969) and federal (Clean Water Act, 1972) levels.

The Regional Water Quality Control Board (Regional Board) ordered a 10-to-1 dilution requirement for San Francisco Bay discharges. With encouragement from the Regional Board, in June 1969, the three cities formed the Strategic Consolidation Sewerage Plan Joint Powers Authority (SCSP JPA) for the purpose of addressing the new water quality regulations on a regional basis. To meet the 10-to-1 dilution requirement as soon as possible, the SCSP JPA would build connecting pipelines and a deep-water outfall for discharging the effluent from the existing three small treatment plants in advance of constructing the regional treatment plant. The site of the regional treatment plant needed to be decided so design of the new outfall could begin. After considering several sites, the SCSP JPA selected the Redwood Shores Plant site at the mouth of Steinberger Slough for the regional plant.

The pipeline consisted of six miles of reinforced concrete pipe that connected the treatment plants to the deep-water outfall located at the mouth of Steinberger Slough[1]. This new conveyance system was designed as a low pressure force main. In 1969 designs were completed for the pipeline as well as for the RCPS and the SCPS. These pump stations were built adjacent to the respective individual treatment plants. The pump stations, pipeline, and deep water outfall were put into service in 1971. The outfall, pipeline, and the Redwood City Pumping Plant (renamed Redwood City Pump Station) are still in use today.

Concurrent with the SCSP JPA improvement plans, Belmont's capital plans anticipated needing a new pump station and a pipeline that would connect it to the Belmont/San Carlos Joint Plant until the regional plant was operational. By the time the regional plant was operational and the Belmont/San Carlos Joint Plant closed, Belmont would also need a direct connection to the new SCSP force main. Design for a new pump station and direct connection force main on the west side of U.S. Highway 101 (US-101) finished in 1973. The force main consisted of two segments. The first was from the new BPS to the point of the future connection to the 54-inch force main. This section was 1,200 feet of 24-inch welded steel pipe, lined and coated with cement mortar. The second segment was downstream of the future connection point and terminated at the San Carlos/Belmont Joint Plant. In this segment the pipe size was reduced to 20-inches and the material changed to asbestos cement pipe. This change in size and material was likely due to the City wanting to reduce costs for this segment that would be used for less than 10 years.

In the mid-1970's, in response to Regional Board direction, the service area for the regional plant originally envisioned by the SCSP JPA expanded to include the West Bay Sanitary District (WBSD) service area. In November 1975, the members of the SCSP JPA and WBSD (previously named Menlo Park Sanitary District) founded South Bayside System Authority (SBSA, renamed in 2014 to Silicon Valley Clean Water) JPA as the successor to the Strategic Consolidation Sewerage Plan JPA.

The addition of the WBSD service area necessitated expanding the conveyance system to connect WBSD. Design of a 2.7-mile-long 33-inch diameter reinforced concrete pipe force main between the RCPS and the future Menlo Park Pump Station (MPPS) site was completed in 1976. The pipe was put into service when the regional plant became operational in 1982. The addition of WBSD to the system required that a booster pump station be added to the force main system, as the additional WBSD flows were not anticipated in the original force main head loss and pressure calculations.

The five segments of the existing force main, with year built, are described in Table 1-1.

[1] It should be noted that reinforced concrete pipe was the pipe of choice when the pipeline was designed in the early 1970's. High density polyethylene (HDPE) pipe was not available in large diameters at that time. The highly corrosive nature of the Redwood Shores saline soils made steel a poor candidate for this alignment.

Table 1-1. Existing force main location, size and length

Segment	Location	Pipe Inside Diameter (ID) (in)	Year Built and Material	Age of Pipeline (years)	Length[1]	
					Lineal Feet	Miles
1	Between MPPS and RCPS	33	1977 RCP	40	14,450	2.74
2	Between RCPS and SCPS	48	1971 RCP	46	12,950	2.45
3	Between the SCPS and Belmont "T"	54	1971 RCP	46	3,550	0.67
4	Between the Belmont Pump Station (BPS) and Belmont "T"	24	1974 WSCL/C[2]	43	1,150	0.22
5	Between Belmont "T" and SBSA WWTP	54	1971 RCP	46	15,500	2.94
				Total Force Main	47,600	9.0

Source: Based on Table 6.1 of the SVCW Conveyance System Master Plan (Winzler & Kelly, 2011).

1. *Lengths are rounded to the nearest 50 feet and tenth of a mile.*
2. *WSCL/C = welded steel, cement mortar lined and coated. Construction date estimated based on design drawings being completed in February 1973.*

In anticipation of higher flows and the higher water surface elevation of the regional WWTP, SBSA modified existing pump stations or built new one(s). The (1971) Redwood City and the (1974) BPSs were enlarged. A new SCPS replaced the 1971 SCPS. The MPPS was a new pump station that was subsequently modified in 1990 as part of WBSD's flow equalization project. Table 1-2 provides a summary of dates related to the pump stations.

Table 1-2. Age of existing pump stations

Pump Station	Existing Pump Station Operational	Enlarged, New or Modified	Years in Service
MPPS	1982	1990	35
RCPS	1971	1982	46
SCPS	--	1982 (new)	35
BPS	1974[1]	1982	43

1. *1974 is based on the date of the force main design drawings.*

Design of SBSA's regional WWTP was completed in December 1977 and the new plant became operational in 1982. When the regional WWTP plant was put into service, the four smaller plants were decommissioned and the new and upgraded pump stations began to pump wastewater to the regional plant.

1.2 Reasons the Project is Needed

The proposed Conveyance System Project is necessary to eliminate ongoing reliability concerns and accommodate changes in wastewater flowrates. Replacement of the conveyance system is SVCW's highest priority due to its age and continual state of failure. The existing SVCW conveyance system components are beyond their useful life. The American Society of Civil Engineers (ASCE) published a report entitled "Failure to Act" (ASCE, 2011) with the purpose "to provide an objective analysis of the economic implications for the United States of its continued underinvestment in infrastructure." Table 1-3 lists the useful life for force mains and pump stations used in the ASCE report.

Table 1-3. Useful lives of wastewater pump stations and force mains

Component	Useful Life (years)
Force Mains	25
Pumping Stations – Concrete Structures	50
Pumping Stations – Mechanical or Electrical	15

Source: Table 5 of Failure to Act, the economic impact of current investment trends in water and wastewater treatment infrastructure (American Society of Civil Engineers, 2011).

1.2.1 Force mains

SVCW's 46-year-old concrete force main is in poor condition and needs to be replaced. The pipeline suffers from several problems caused by the soils in which it is installed and the sewage characteristics. Problems have compounded, resulting in a history of numerous leaks. These leaks range from minor to the occasional catastrophic failure. Leaks require repairs along streets and in backyards and sometimes within biologically sensitive environments.

One section of the original force main that had the most leaks was replaced in 2015 with a fused-jointed high density polyethylene (HDPE) pipe. This was a 1.7-mile long portion of the 48-inch diameter force main from the RCPS to the north end of Inner Bair Island. The proposed Conveyance System Project will replace the remaining original force main that begins where the 48-inch replacement project ended (the north end of Inner Bair Island) and terminates at the WWTP.

Much of the existing force main is buried in young bay mud (YBM) soils that are poorly suited to the existing pipeline material and joint system. YBM has two main problems: it is expansive and corrosive. Expansive soils are weak, unstable, have high shrink-swell potential, and settle over time. The pipeline consists of 12-foot-long reinforced concrete pipe sections that are connected to each other with single non-restrained "O-ring" joints. The YBM soil does not provide sufficient support for the reinforced concrete pipe and its joints. This results in pipe movement and separation at the joints and is the cause of the majority of the leak events.

The bay mud soil is highly corrosive to buried steel and concrete that comes into direct contact with the soil. The pipe is also subjected to microbiologically influenced corrosion (MIC) from sewer gases inside the pipe. Internal and external corrosion of the concrete and reinforcing steel leads to more significant leaks. When surges in flow occur (such as during a power outage) the resulting pressure and vacuum surge conditions have broken the weakened pipeline resulting in major sewage spills. These types of leaks tend to be catastrophic with the potential of uncontrollable discharge of untreated wastewater to the environment.

The frequency of pipeline leaks is expected to increase as the pipe ages, given the current poor condition of the pipelines, continued movement of weak soils, and acceleration of the internal and external corrosion.

In addition to the problems related to the soil, the existing pipeline was designed as a low-pressure force main pipeline and not for typical force main pressures. When WBSD was added to the conveyance system and as wet weather flows have risen, flows in the force main have grown higher than the original design anticipated. When the WBSD flows were added, a booster pump station, and later a FEF, were added to the system.

With Herculean efforts, SVCW maintains pressures and surges in the conveyance system to within the force main's pressure limits, though this approach comes with significant risk. SVCW must carefully manage the flow in the pipeline to minimize leaks by opening and closing valves, turning on and off pumps (including the booster and influent lift pumps), diverting flow to storage, and backing up sewage in member agency collection systems. During wet weather events, wastewater flows from the WBSD collection system are diverted to the WBSD flow equalization facilities. When flows subside, the WBSD wastewater is pumped from the FEF through the MPPS and to the WWTP. Sometimes these pressure management efforts require using all available pumps and valves leaving limited or no backup equipment.

The reasons provided for replacing the pipelines are corroborated by industry accepted guidelines of useful life. The 46-years is well beyond a typical force main's lifespan of 25 years.

1.2.2 Pump stations

All five pump stations, the four member agency pump stations and the ILS, are in varying states of condition, ranging from poor to very poor. Despite system-wide repairs and regular maintenance, the pump stations are in need of replacement to provide safe and reliable operation and to accommodate the future projected flows through the system. Each pump station is at least 35 to 46 years old, well beyond the 15-year useful life for the mechanical and electrical components, and approaching the life of the concrete structure. In most instances the condition of the equipment has degraded to the extent that the systems require extensive maintenance to ensure functionality and reliability. To keep the pump stations operational, SVCW is spending millions of dollars to replace various pump station components, such as control systems, pumps, and valves. These components will not be used after the proposed Conveyance System Project is completed.

The solution to the current conveyance system problems SVCW is facing is to replace the original pipeline with a new pipeline that is designed for local soils conditions and system flows, and to replace or rehabilitate the pump stations. The conveyance pipeline and the pumping system improvements are interconnected and need to be planned, designed, and constructed in tandem.

1.2.3 Headworks

The proposed Conveyance System Project also includes construction of a Headworks to house screening and grit removal facilities. This process will be the first step in treatment. It removes rags, sand, grit, and debris that damage pumps and other process equipment.

The original SVCW wastewater treatment facility was built with no Headworks. The plant's current partial screening and grit removal processes continue to allow excessive downstream grit and unscreened material that cause premature wear on equipment and result in high maintenance and repair costs. Large debris and inorganic solids such as rags that are not removed by the existing screening equipment are removed manually. Manual removal of rags is labor intensive and places plant personnel in challenging work environments. SVCW recently installed new digester mix pumps, rotary screen presses, and gravity belt thickeners. This new equipment is very susceptible to damage caused by rags and debris. Without the Headworks, this new equipment will experience the same premature wear as the older equipment.

SVCW's decision to install screening and grit removal facilities was made for purposes of protecting its employees, addressing the continued high costs for labor and equipment damage, and increase the reliability of the overall treatment process. Effective screening of incoming wastewater will save both operation and maintenance costs and improve SVCW's operational capabilities.

1.3 Proposed Conveyance System Project Overview

The proposed Conveyance System Project proposes a combination of rehabilitating, repurposing, and decommissioning existing SVCW conveyance system assets, and the construction of replacement assets. Brief summaries of the major components included in the proposed Conveyance System Project are provided in the following paragraphs.

1.3.1 Pipelines

A 15-foot outside diameter tunnel will be built using a TBM to connect the recently constructed 48-inch replacement force main (located at the northern end of Inner Bair Island) to the WWTP. The distance between top of the tunnel and the ground surface will range from 20 to 52 feet. Inside this tunnel will be a new 11-foot inside diameter gravity pipeline. This new gravity pipeline will replace the remaining portion of the 48-inch and the entire existing 54-inch force main pipelines. The BPS would be connected to the new gravity pipeline by rehabilitating the existing 24-inch pipeline and a portion of the 54-inch pipeline. The 33-inch force main pipeline that connects the MPPS to the RCPS would remain as it exists.

1.3.2 Pump stations

The MPPS and the BPS will be rehabilitated and remain as part of the proposed Conveyance System Project. A new pump station will be built on the existing RCPS site and the existing pump station building will be repurposed to house auxiliary equipment that supports the new RCPS. The SCPS will no longer be needed and will be decommissioned. Portions of the SCPS building and yard will be repurposed to house odor control and ancillary equipment needed by other elements of the proposed Conveyance System Project. At the downstream end of the gravity pipeline, a new deep pump station (called the RLS) will be built to pump the wastewater from about 60 feet below grade to the new Headworks.

1.3.3 Headworks

A Headworks Facility will be constructed downstream of the receiving lift station to provide coarse screening and grit removal from the raw wastewater. This is a new treatment process being added to the WWTP treatment train. Two new large-diameter pipes will be built to connect the Headworks to the existing primary treatment process. Odor control facilities for the RLS and Headworks will be installed adjacent to the Headworks Facility.

1.4 Planning and Design History of the Conveyance System Project

SVCW completed a Conveyance System Master Plan (CSMP) in August 2011 (Winzler & Kelly, 2011) to plan and program the projects required for improving its conveyance system. The recommended approach at the time was to replace the existing force main with a new force main, and to rehabilitate or replace the pump stations. Chapter 7 of the CSMP developed conceptual-level requirements for the replacement and rehabilitation of the SVCW pump stations that served as the baseline for the pump station predesign. The CSMP also identified several items that required further refinement to be completed during the design phases of the project.

Following completion of the CSMP, BC started the preliminary design of the conveyance system pump stations in 2012. An Administrative Draft of the Conveyance System Predesign Report was completed in May 2014 (Brown and Caldwell, 2014). The proposed project at that time consisted of the following key elements, and is shown in Figure 1-1.

- Pipe Modifications:
  - Rehabilitation or replacement of the Segment 1 force main between MPPS and RCPS shown as PS1 and PS2 in Figure 1-1, respectively
  - Replacement of the Segment 2 with a new 48-inch diameter force main
  - Installation of a 36-inch gravity line to convey flow from the Belmont Connection Point to SCPS, shown as PS3 in Figure 1-1
  - Replacement of the Segment 3 force main with a 63-inch force main
- Pump Station Modifications:
  - New pump station at MPPS called PS1 in predesign
  - New pump station at RCPS called PS2 in predesign
  - New pump station at SCPS called PS3 in predesign
  - Elimination of BPS. BPS replaced with a connection from the Belmont Collection System to the 36-inch gravity line.

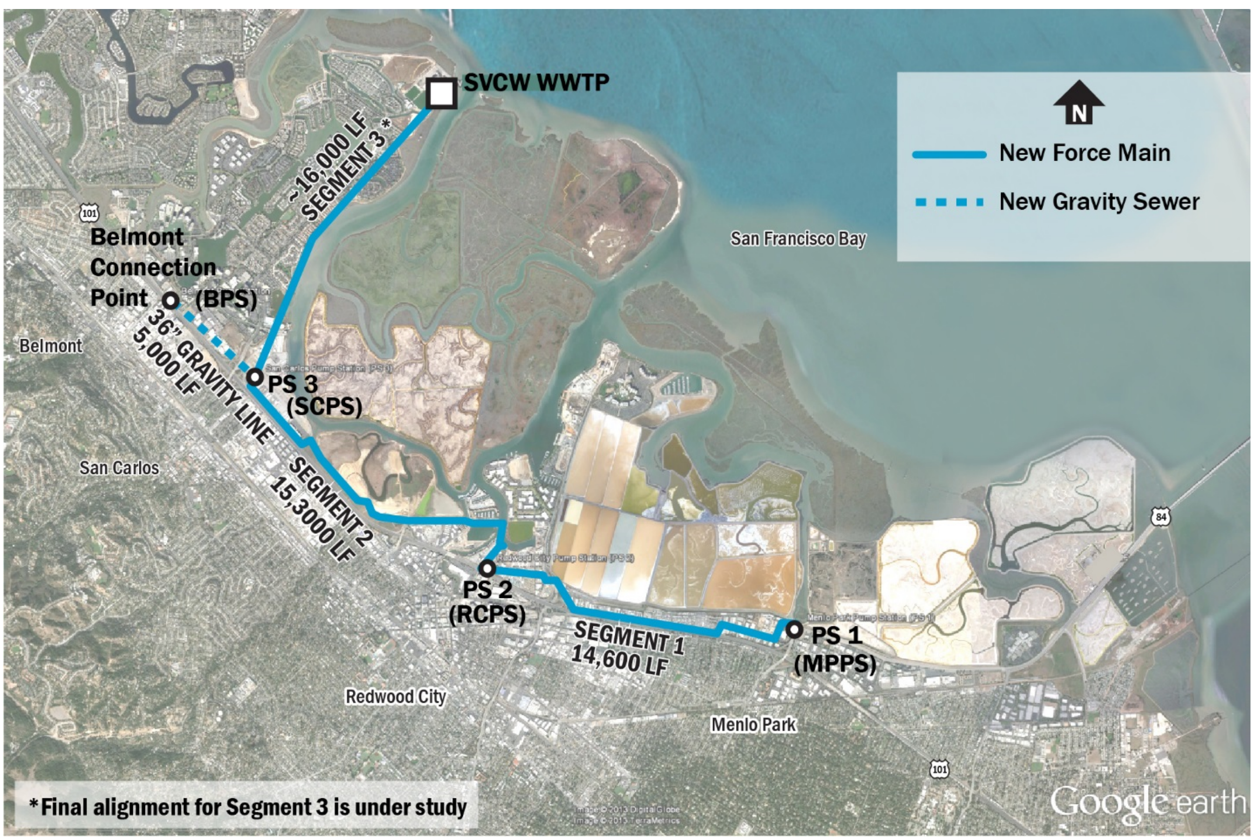

Figure 1-1. May 2014 Predesign proposed SVCW conveyance system

Following submittal of the Administration Draft of the Conveyance System Predesign Report in 2014 (Brown and Caldwell, 2014), SVCW decided to place the design of the Conveyance System on hold in order to evaluate gravity pipeline alternatives, which could be used in lieu of a force main in the San Carlos and Redwood Shores areas. The alternatives that were evaluated consisted of varying combinations of pump stations, gravity pipeline, and force mains to convey wastewater from SVCW's Member Agencies to the WWTP. SVCW performed a success versus risk analysis of the alternatives and selected the proposed Conveyance System Project described in Section 1.3. On May 14, 2015, the SVCW Board of Commissioners approved the proposed Conveyance System Project and granted permission to proceed with CEQA documentation and conceptual design.

BC began conceptual design of the pump stations in 2015 to support the development of Draft EIR that is required for CEQA documentation of the proposed Conveyance System Project. The Draft EIR was submitted in November 2016, and this Project Planning Report summarizes the conceptual design as of that date. The proposed Conveyance System Project is displayed in Figure 1-2. The key elements of the proposed Conveyance System Project are described in Section 1.3.

Figure 1-2. Schematic diagram of the proposed project

(Source: Kennedy/Jenks Consultants)

Table 1-4 summarizes major changes that have occurred between 2014 preliminary design of the conveyance pump stations and the proposed Conveyance System Project as of November 2016.

Table 1-4. Pre-design vs. proposed Conveyance System Project elements comparison		
Pre-design Project element	Pre-design (2014)	Proposed Conveyance System Project (2016)
Pipes		
Segment 1 Force Main	• Replacement or rehabilitation of Segment 1 force main.	• No changes to Segment 1 force main under current project. Rehabilitation to occur in the future.
Segment 2 Force Main	• Replacement of Segment 2 force main with new 48-inch force main.	• Part of Segment 2 replaced with 48-inch force main, segment labeled as “Airport Segment Alignment” in Figure 1-2 will be replaced with gravity pipeline.
Segment 3 Force Main	• Replacement of Segment 3 force main with new 63-inch force main.	• Segment 3 will be completely replaced with gravity pipeline.
36-inch Gravity Line	• New 36-inch gravity line from BPS to SCPS. BPS flows to be pumped by SCPS.	• The 36-inch gravity line will no longer be installed. Existing 24-inch and 54-inch force mains will be rehabilitated and convey flow from BPS to the gravity tunnel.
Pump Stations		
MPPS (PS1)	• MPPS will be a new pump station called PS1.	• MPPS will be rehabilitated, but the name will not be changed.
RCPS (PS2)	• RCPS will be a new pump station called PS2.	• RCPS will be a new pump station, but the name will not be changed.
SCPS (PS3)	• SCPS will be a new pump station called PS3.	• SCPS will be repurposed to contain odor control facilities for the gravity pipeline.
BPS	• BPS will be eliminated. A connection will be made from the Belmont collection system for conveyance to SCPS.	• BPS will be rehabilitated and convey flow to the gravity pipeline at the old SCPS site.
RLS (Non-predesign item)	• Does not exist as part of pre-design.	• New RLS will be constructed to convey flow from the gravity tunnel into the new WWTP Headworks.

1.5 Project Purpose

This section discusses the RLS Project objectives and the expected benefits of the RLS Project.

1.5.1 Objectives

The objectives of the RLS Project are:

- Provide major upgrades and improvements to maintain long-term operation of the pump station and conveyance system. The current conveyance system requires frequent hands-on maintenance and is experiencing ongoing operational challenges.
- Allow RLS to handle future Year 2030 flows from the Member Agencies for conveyance to the new Headworks Facility
- Provide ability to lift flow from the gravity pipeline for conveyance to the new Headworks Facility

1.5.2 Benefits

The benefits of the RLS Project support the proposed Conveyance System Project objectives:

- Easier, more efficient and effective operation and maintenance (O&M) of facilities.
- Improved safety with better access to operate and maintain facilities
- Lower impact on residences and businesses
- Ability of the RLS to handle current and future projected flows
- Allows force main rehabilitation between MPPS and RCPS to be deferred to a later date by reducing the overall conveyance system pressure
- Allows MPPS to be rehabilitated, instead of requiring a new pump station, with a reduction in pump size due to double pumping of wet weather flows at RCPS and reducing the overall conveyance system pressure.
- Allows the BPS to be rehabilitated and the SCPS to be repurposed, without necessitating construction of a brand new pump station, by conveying flow by gravity from SCPS.

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Section 2

Setting

The following section describes the area where the RLS is proposed to be located, adjacent facilities and other features (hydrologic, geologic, topographic, etc.) that impact the RLS Project.

2.1 Physical Setting

The WWTP is located at the east end of the Redwood Shores peninsula, and serves all of the SVCW Member Agencies. As part of the conveyance system upgrade, several improvements are proposed at the site near the front entrance to the WWTP where an ornamental pond currently exists along Radio Road. These Front-of-Plant (FoP) improvements include construction of the RLS, among other facilities. The following sections discuss the constraints at the WWTP/RLS site that will impact the design and construction of the new facilities and considerations as the design is progressed.

2.1.1 Existing site

The proposed RLS will be located within the 22-acre SVCW WWTP site (Figure 2-1). The RLS site has limited available area, and the 10-acre ornamental pond was identified as the only available space for the proposed RLS and other WWTP improvements.

Figure 2-1. RLS site

The existing SVCW WWTP is accessible by a secured gate. A perimeter fence is located around the existing WWTP site. The new FoP, including RLS, storm water pump station, and Headworks Facilities, will also need to be secured by a perimeter acoustic protective wall with access from Radio Road.

2.1.2 Site features and considerations

The FoP area will be graded to elevations required to provide access to new facilities and provide adequate site slope for drainage. The final surface grade around new facilities is anticipated to be approximately at Elevation 103 ft [National Geodetic Vertical Datum 1929 (NGVD29) +100 ft]. Structures will be placed approximately six inches above the finished grade to allow for positive drainage away from the structures and reduce ponding. Fill will be imported to raise the subgrade to an elevation that achieves site final grades when final pavement section thickness is added. Areas where no current improvements will be occurring will be graded to an approximate elevation of 101 ft (NGVD29+100 ft).

2.1.3 Existing utilities

Utilities such as local water, sanitary sewer, storm water sewer and electrical currently service the WWTP. No known utilities are currently located beneath the 10-acre ornamental pond. New utilities will be needed to service the RLS and other FoP facilities.

2.2 Institutional Setting

The entire WWTP property, including the FoP improvement area, is zoned as Redwood Shores Bayfront (RSB) District. Per Article 28 of the Redwood City code, public or private wastewater treatment plants in conjunction with the O&M of the existing SBSA facility (currently known as SVCW) are permitted within RSB designated areas.

SVCW, as a public agency JPA, is not subject to certain local land-use plans, policies and regulations (i.e., zoning and building codes, general plans, specific plans, and other planning and building laws), including those of its Member Agencies, under the doctrine of "intergovernmental immunity" which effectively means that a public agency implementing its basic mission and purpose does not need to obtain land use or other entitlements from other public agencies. Nevertheless, in the exercise of its discretion and in the interest of working cooperatively with local jurisdictions, the guidelines in the Redwood City General Plan will be considered with regards to the RLS above grade structure and landscaping.

2.2.1 Current and future nearby development plans

There are no known future development plans in the vicinity of the RLS. The surrounding area is built out with residential and commercial developments.

2.3 Interproject Setting

As shown in Figure 2-2, the MPPS is located at the southernmost point of the SVCW conveyance system. An existing 2.7-mile, 33-inch force main connects the MPPS to the RCPS. The force main that connects the two pump stations will remain during the proposed Conveyance System Project improvements. As part of the proposed Conveyance System Project improvements, MPPS will be rehabilitated and RCPS will become a new pump station.

Figure 2-2. SVCW existing conveyance system

Between the RCPS and the existing SCPS, is a 2.5-mile, 48-inch force main pipeline. The southern portion of this force main, between the RCPS and the northern end of Inner Bair Island, was replaced in 2015 and will be incorporated into the proposed Conveyance System Project. The remaining 0.8 miles of the existing 48-inch pipeline runs from Inner Bair Island to the SCPS. This remaining section of the 48-inch force main pipeline will be replaced by the gravity pipeline that will extend to and terminate at the Bair Island Inlet Structure (BIIS) on the very northern part of Inner Bair Island. RCPS will convey flows to the BIIS for conveyance to the SVCW WWTP via a new approximately 17,500 ft long large diameter gravity pipeline. The inside diameter of the gravity pipeline will be finalized during subsequent design.

The RLS will be located in the receiving shaft at the end of the gravity pipeline. The purpose of the RLS is to lift wastewater at the downstream end of the gravity pipeline and convey it to the Headworks for preliminary treatment.

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Section 3

Compiled Data and Assumptions

This section summarizes the data compiled as of January 2017 and assumptions for the RLS design, such as flow data, planning parameters and previous studies such as the contaminated and hazardous materials survey, geotechnical investigations, corrosivity investigations and noise regulations investigation.

3.1 Flow Data

The existing and future design flows as of January 25, 2017 are summarized in Table 3-1. The projected peak wet weather flow (PWWF) rates for each Member Agency are based on a single ten-year 24-hour storm event occurring over the entire service area with a coincident time of concentration for each Member Agency pump station and connection to the conveyance system. Table 3-1 also shows the design flow rates for the RLS based on the Member Agency flow rates. The gravity pipeline will be used for both diurnal storage and peak wet weather storage. With gravity pipeline storage, the daily flow pumped from the RLS into the treatment processes will range from 12 to 18 mgd (or even smaller, tighter range depending on storage and gravity pipeline operation requirements) and the PWWF rate from the RLS will be reduced from 102.9 to 75 mgd.

Table 3-1. RLS design flow rates

Pump Station	Existing		Future (2040)		
	Min Flow (mgd)[1]	ADWF (mgd)[2]	ADWF (mgd)[3]	PDWF (mgd)[4]	PWWF (mgd)[5,6]
MPPS	0.2	3.7	4.6	10.0	22
RCPS	0.9	4.5	N/A	N/A	38
RCPS w/ MPPS PWWF	N/A	N/A	8.0	14.5[1]	60
San Carlos	0.6	1.3	2.9	5.8	26.6
Belmont	0.3	1.4	1.8	3.6	16.3
Total	**2.0[1]**	**10.9**	**17.3**	**33.9[2]**	**102.9[3]**
RLS Design Flow	12 to 18 mgd with diurnal storage, wet well cleaning at 11 mgd and tunnel flushing at 20 mgd				75

1. *Minimum flow rates from the Member Agencies occurred on different days in October and do NOT equal the minimum flow rate at the WWTP. Flow rate to the WWTP from the RLS could be 0 mgd when the RLS is not operating.*
2. *Minimum Flow and Average Dry Weather Flow (ADWF) are for October 2015 and are based on flow data provided by SVCW's Supervisory Control and Data Acquisition (SCADA) output from each pump station.*
3. *ADWF 2040 flow rates are from Table 5-9 of Technical Memorandum (TM) 1 for the Final Plant Capacity Study (Brown and Caldwell, May 2013).*
4. *peak dry weather flow (PDWF) 2040 are hourly flow rates and are from the Member Agency Master Plans and CSMP.*
5. *Peak Wet Weather Flow (PWWF) is the worst case timing where the storm event peak flow reaches the entry point into the conveyance system at the same time. The Master Plans and CSMP show approximately a one-hour difference in the time of concentration within each Member Agency.*
6. *Redwood Shores PWWF = 5 mgd but is not included in the table because the RLS will not be pumping it. Redwood Shores flows will be connected downstream of the RLS at the Flow Distribution Box.*

The RLS pumps must also be able to meet two additional pumping conditions:

1. **Wet well cleaning cycle.** The wet well will need to be periodically drawn down to the bottom of the wet well at a flow rate of approximately 11 mgd for three to five minutes to remove grit, debris and scum to be handled in the WWTP.
2. **Gravity pipeline flushing.** The operational strategy of daily diurnal storage in the gravity pipeline will require frequent flushing of the gravity pipeline to prevent the buildup of grit, scum and debris. Based on the “Grit Migration Predictions When Using a Tunnel for Storing Wastewater” Technical Memorandum (TM) by Bob Donaldson (B. Donaldson, 2015; Appendix A), SVCW Project Manager, and “Headworks Facility Project – Grit Facility Design Criteria Update” TM by CDM Smith (CDM Smith, 2017; Appendix A); flushing will require that the velocity in the gravity pipeline be increased to at least 4 feet per second (ft/sec) throughout the gravity pipeline length and that the gravity pipeline be drained to remove the grit, scum, and debris. To achieve 4 ft/sec, a flow rate of 20 mgd for at least 25 minutes will need to be achieved. Pipeline flushing values and wet well cleaning cycles will need to be further developed during the preconstruction process of project delivery.

3.2 Project Planning Period

The planning period for the RLS is 50 years, which is typical for a municipal facility. For further information on the life cycle analysis completed for the RLS Project, see Section 6.

3.3 Summary of Field Investigations

The following section summarizes field investigations and surveys completed to support the RLS design.

3.3.1 Hazardous materials survey

A Phase I Environmental Site Assessment (ESA) was completed by Cornerstone Earth Group in May 2016 as part of the Draft EIR. Hazardous conditions and materials are important to identify because it can affect the health of humans, plant and wildlife ecology present on or near the site. A 15,000-gallon underground storage tank (UST) used for fuel oil on the WWTP site was found during the ESA (Cornerstone Earth Group, May 2016). This tank is located south of the Solids Handling Building and is not in the FoP area. Because of this distance, releases from the UST do not appear to affect the soil conditions of the planned RLS site. Other than the UST, no other hazardous conditions were found.

3.3.2 Geotechnical investigation

Geotechnical investigations have been completed both for the gravity pipeline and the Headworks Facility. A Geotechnical Data Report (GDR) was completed in April 2016 by Geotechnical Consultants, Inc. (Geotechnical Consultants, Inc., 2016; Appendix B) for the gravity pipeline project. Four cone penetration tests (CPTs) were completed in the vicinity of the RLS. Three of the four CPTs were converted into groundwater observation wells for continued groundwater level monitoring. Moisture content, dry density, Atterberg limits, fines content, angle of internal friction, cohesion, unconfined compressive strength, and undrained shear strength tests were performed on all soil samples retrieved from the test borings to evaluate their physical characteristics and engineering properties.

A Draft TM with preliminary foundation design parameters for the Headworks Facility was completed by DCM Consultants, Inc. in 2017 (DCM Consultants, Inc., 2017; Appendix B). The geotechnical investigation included 22 CPTs throughout the FoP area. Composition, consistency, average moisture content, average dry unit weight, average total unit weight, average buoyant (effective) unit weight, over consolidation ratio, compression index, Ko, Poisson’s ratio, undrained shear strength, Su/p’ ratio, increase in Su with depth, and Young’s modulus tests were performed on all soil samples retrieved from the CPTs. Preliminary foundation recommendations provided in the DCM Consulting Inc., TM are discussed further in Section 5 as part of the considerations for final design.

3.3.3 Corrosivity investigation

A soil corrosivity evaluation was completed by V&A Consultant Engineers for the WWTP area (V&A Consultant Engineers, Inc., 2015; Appendix C). Soil samples were obtained and tested for soil resistivity, pH, and concentrations of water soluble chloride, sulfate, and bicarbonate ions. Results and recommendations from the corrosivity investigation are further discussed in Section 5.

3.3.4 Noise and vibration survey and regulations

A noise and vibration assessment was completed in November 2016 by Illingworth & Rodkin, Inc. as part of the Draft EIR. The following section summarizes the results of their survey.

The Redwood City Noise Ordinance is contained in the Municipal Code Chapter 42 “NOISE REGULATION” and establishes allowable hours of construction and noise limitations. The following are deemed to be excessive and unreasonable noises:

- Noise levels generated by construction activities, including demolition, alteration, repair or remodeling of or to existing structures and construction of new structures on property within the City, at more than 110 decibels (dB) measured at any point within a residential district of the City and outside of the plane of said property.
- Noise levels generated by an individual item of machinery, equipment or device used during construction activities, including demolition, alteration, repair or remodeling of or to existing structures and construction of new structures on property within the City, at more than 110 dB measured within a residential district of the City at a distance of twenty-five feet (25 ft) from said machinery, equipment or device. If said machinery, equipment or device is housed within a structure on the property, then the measurement shall be made at a distance as near to twenty-five feet (25 ft) from said machinery, equipment or device as possible.

In a residential district or within 500 ft of a residential district in the City, noise restrictions are implemented between the hours of eight o'clock (8:00) p.m. and seven o'clock (7:00) a.m. the following day, Monday through Friday of any week or at any time on Saturdays, Sundays or holidays. Restrictions are placed if the noise level generated by any such activity exceeds the local ambient noise measured at any point within the residential district and outside of the plane the construction site.

The Redwood City noise ordinance does not include noise limits that regulate noise from mechanical equipment. However, based on the ambient noise surveys conducted in 2012, 2013, 2014, and 2016, the calculated operational noise from the RLS will be at or below ambient noise levels. A 12-foot-tall sound wall and/or trees will be installed on portions of the WWTP property to further reduce ambient noise.

The maximum worst case noise event for construction at the RLS is anticipated to be during the installation of piles. No night time work is anticipated for RLS construction, but some weekend work may be needed to complete installation of key components.

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Section 4

Project Specific Analyses

This section discusses the alternatives analysis for the RLS, which included evaluation of the type of pump station, wet well configuration, number of wet wells and the number of shafts. The selection criteria are based on O&M consideration and construction cost. In addition, this section presents a siting evaluation for locating the RLS at the WWTP site and the hydraulic analysis completed as part of the pump selection.

4.1 Alternatives Analysis

A receiving shaft will be constructed at the FoP to receive the gravity pipeline's TBM. The RLS design will need to account for the repurposing of the receiving shaft for use as part of the RLS configuration. Six different RLS configurations were evaluated that considered type of pump station, wet well configuration, number of wet wells, shaft configuration and the number of shafts. The configurations considered both submersible and wet well/dry well type pump stations. The following configurations were analyzed, which are shown in Figure 4-1 through Figure 4-5:

1. Submersible Pump Station Configurations
   a. One circular shaft with dual wet wells and submersible pumps on the perimeter (Figure 4-1)
   b. Two circular shafts with submersible pumps on the perimeter of each wet well (Figure 4-2)
   c. Two circular shafts with a trench style wet well in each shaft (combination of Figure 4-2 and Figure 4-3)
   d. One circular shaft with dual trench wet wells (Figure 4-3)
2. Wet Well/Dry Well Pump Station Configurations
   a. One circular shaft with dual wet wells and the pumps on the perimeter (Figure 4-4)
   b. One circular shaft with dual trench style wells (Figure 4-5)

A dual trench-style wet well within one circular shaft (Configuration 1.d listed above, Figure 4-3) was selected. SVCW and BC visited similar sized pump stations of submersible and wet well/dry well types. SVCW preferred the submersible pump stations over the wet well/dry well types.

In addition, trench-style wet wells are recommended instead of the pumps located at the perimeter. Trench-style wet wells minimize dead zones where re-ragging of solids is likely to occur, and also help minimize grease and solids build up on the walls and floor of the wet well. Wet well geometry and water levels should conform to Hydraulic Institute (HI) and American National Standards Institute (ANSI) Standards for Rotodynamic Pumps for Pump Intake Design (HI/ANSI 9.8).

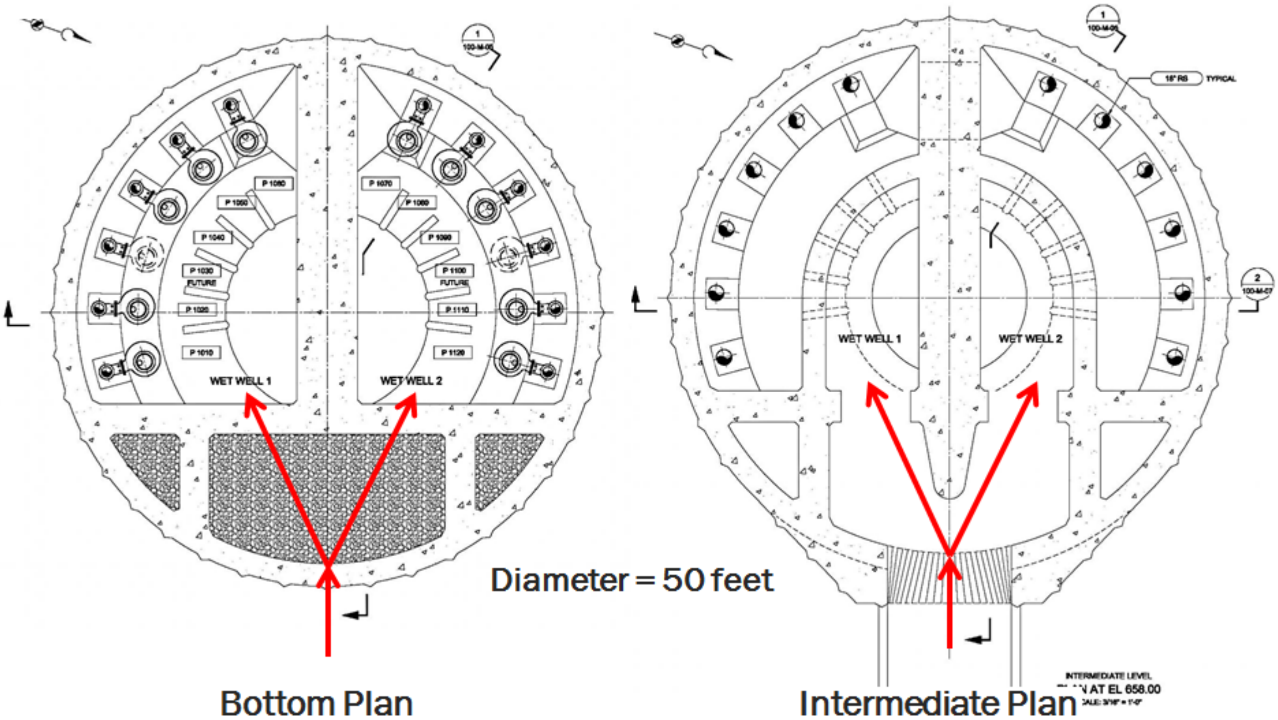


Figure 4-1. Submersible pump station - one circular shaft with dual wet wells and submersible pumps on the perimeter

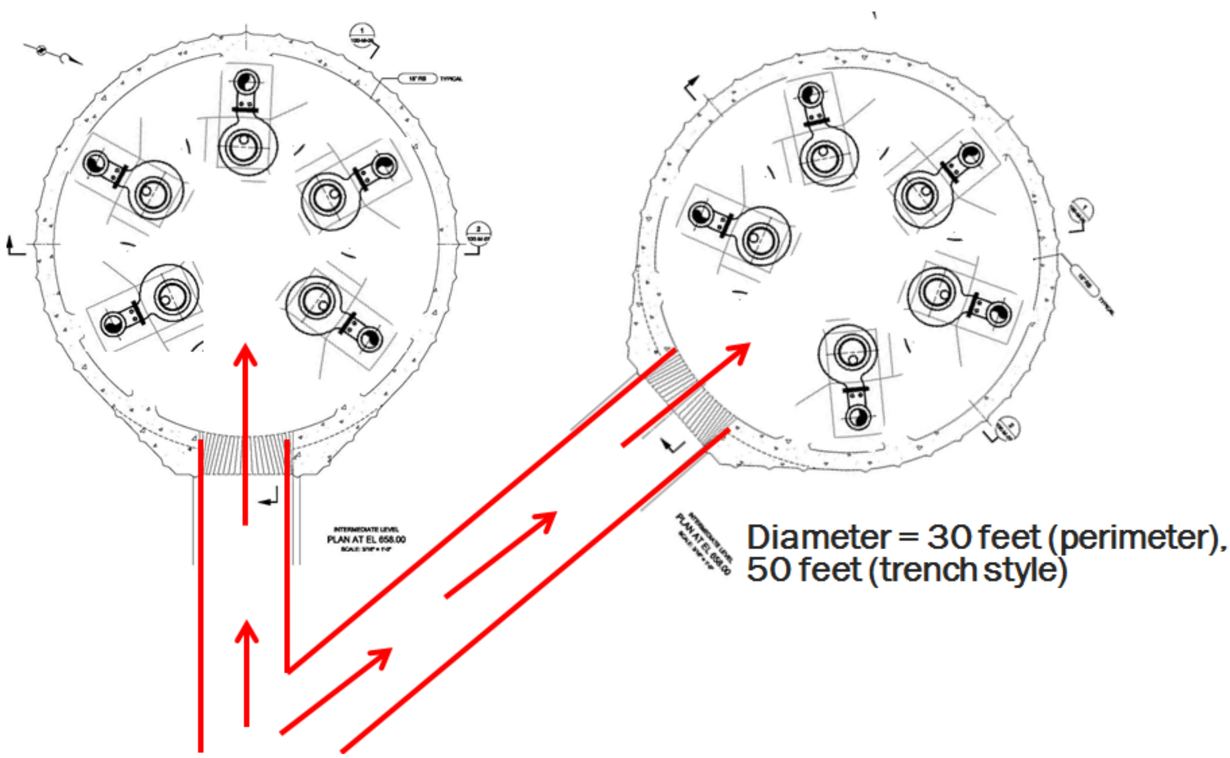


Figure 4-2. Submersible pump station - two circular shafts with submersible pumps on the perimeter of each wet well

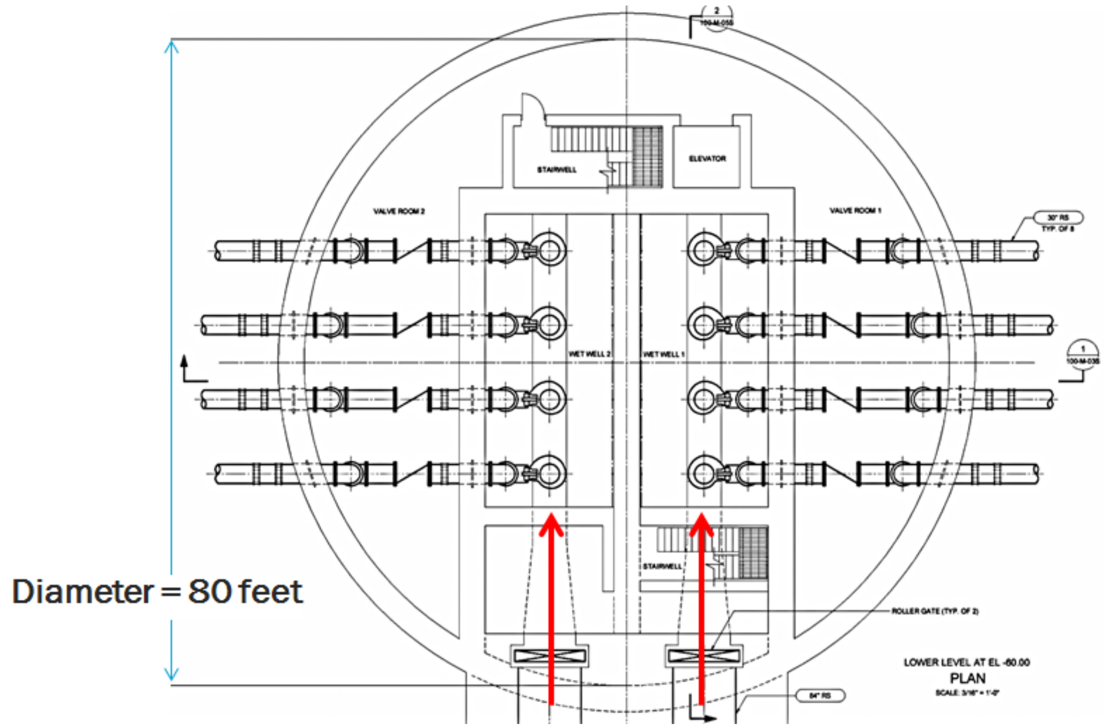


Figure 4-3. Submersible pump station - one circular shaft with dual trench wet wells

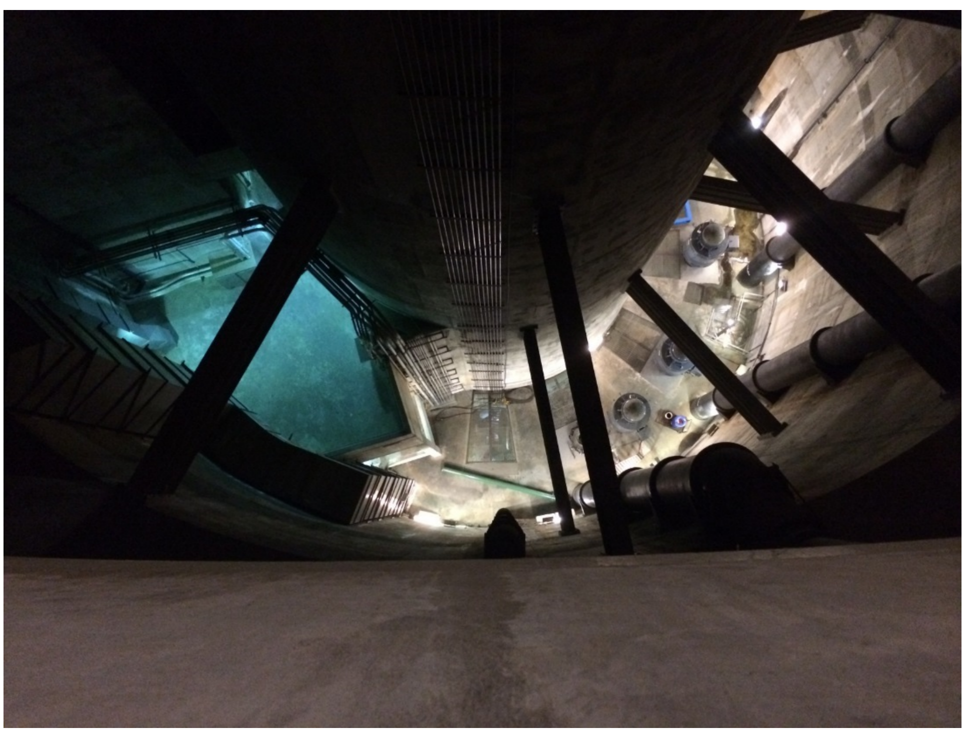


Figure 4-4. Wet well/dry well pump station - one circular shaft with wet wells and pumps on perimeter

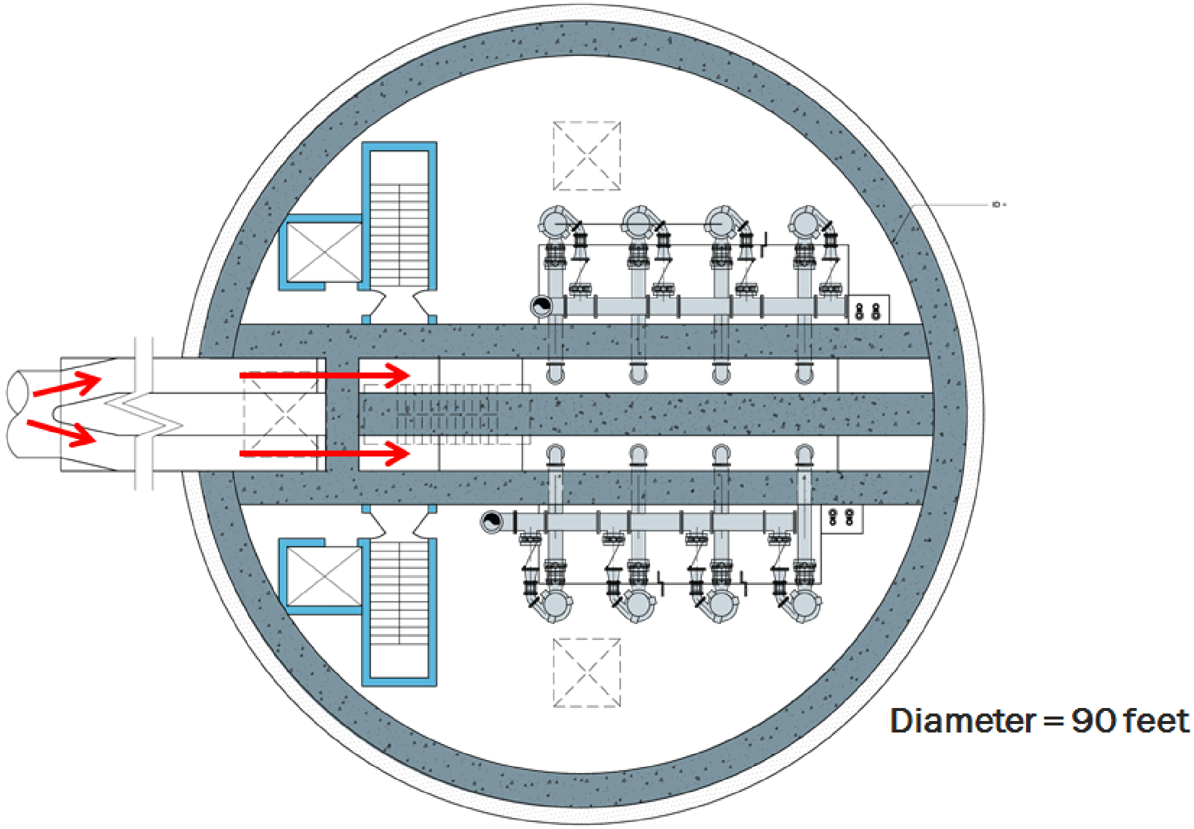


Figure 4-5. Wet well/dry well pump station - one circular shaft with dual trench wet wells

4.2 Siting Evaluation

The location of the RLS was selected based the alignment of the gravity pipeline and available space at the WWTP.

4.3 Hydraulic Analysis

By equalizing diurnal peak flows within the gravity pipeline, the range of daily flows (minimum hourly flow of 2.0 mgd to peak hourly dry weather flow rate of 33.9 mgd) can be controlled to 12 to 18 mgd or even a smaller, tighter range. This smaller range allows a single pump capacity (same size pumps) rather than multiple size pumps to meet the entire range of flows. At the PWWF rate of 75 mgd with gravity pipeline storage, five 15 mgd pumps with a sixth installed standby unit can be provided to meet the entire range of flow to 75 mgd as presented in Table 3-1.

4.3.1 Pump selection

Pump selection should be based on a range of operating conditions that the pump will frequently experience and not on a single, worst case point. The operating conditions for pump selection to meet the most frequent operating conditions and the peak flow requirements are defined as Points A, B, C, D and the cleaning and the gravity pipeline flushing cycle. A description of the operating points is provided below and shown in Figure 4-6.

Operating condition point A is defined as the pump's rated condition. This condition is guaranteed by the pump manufacturer in accordance with the test standards of the ANSI/HI. Condition A is based upon conditions where all duty pumps are in operation at full speed to achieve the installation full design capacity at the worst case total head condition.

Operating condition point B is defined as the run-out condition at full speed established by the intersection of the system and pump curves. Condition B must reside within the selected pump's Preferred Operating Range (POR) so the pump operates under conditions that minimize vibration and cavitation damage.

Operating condition point C is defined as an additional operating point and is used to describe sustained minimum speed operation for the high system curve.

Operating condition point D is defined as an additional operating point and is used to describe sustained minimum speed operation for the low system curve.

The Wet well cleaning and gravity pipeline flushing cycle is defined as the pump drawdown mode to remove debris and scum from the wet well surface and walls and the gravity pipeline. These flow rates are 11 and 20 mgd, respectively. Two pumps will need to be operating to perform the gravity pipeline flushing cycle.

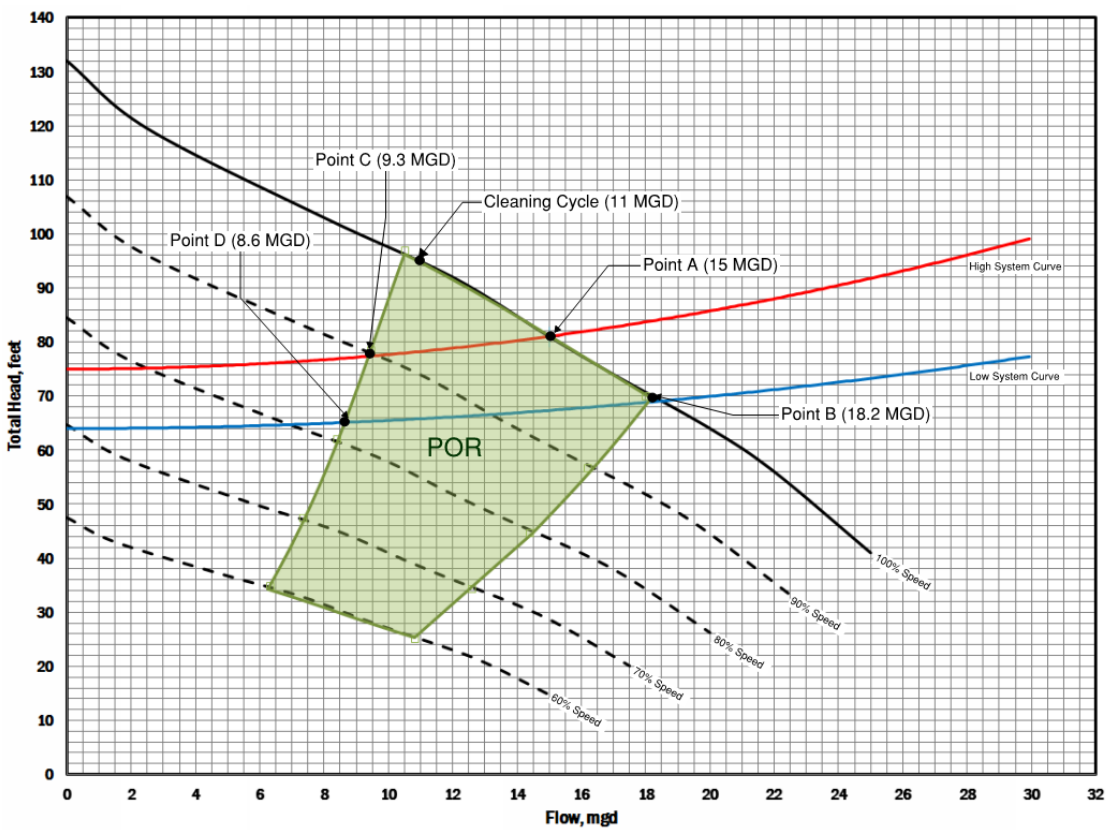


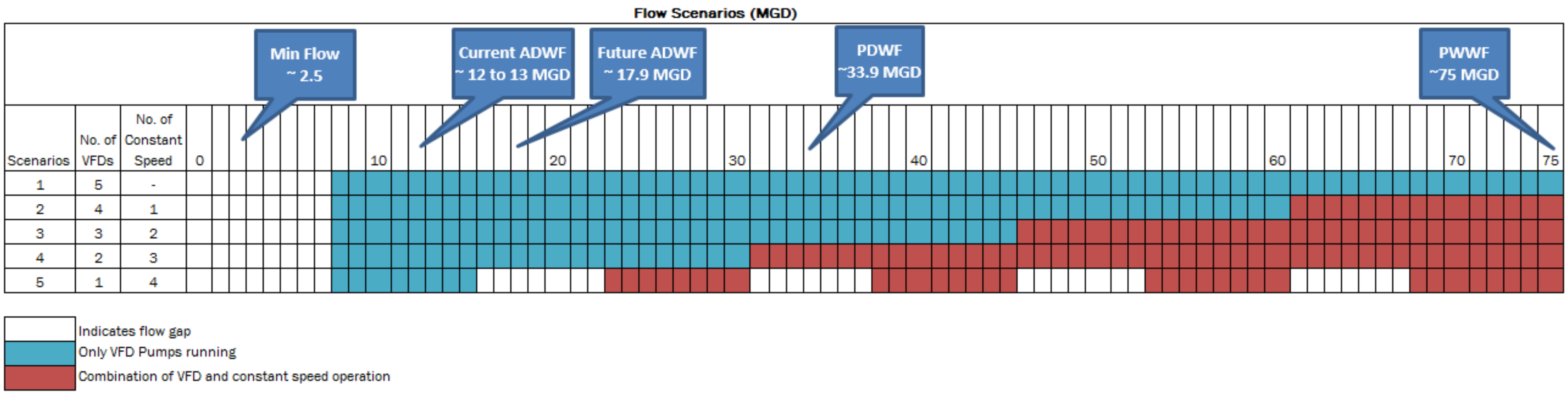
Figure 4-6. Operating condition points A, B, C, D and cleaning cycle for the 15 mgd pump

The system and pump curves in Figure 4-6 represent one 15 mgd pump. Only one pump is shown on the graph because each pump operates independently of the other pumps and has its own discharge pipe to the Headworks. To obtain the total RLS pumping capacity, the pumping rate is multiplied by the number of pumps operating. A summary of operating conditions for the selected 15 mgd pump are shown in Table 4-1. Pumping conditions will be refined as the design progresses and information on the gravity pipeline invert elevations and Headworks discharge conditions are finalized.

Table 4-1. Summary of operating conditions for pumps at main RLS shaft

Condition Point	Flow per Pump (mgd)	Total Head (ft)
A	15	81
B	18.2	69
C	9.3	78
D	8.6	65
Wet Well Cleaning Cycle	11	95
Tunnel Cleaning Cycle (requires two pumps)	20	78

With the selected pump, a pumping rate gap analysis was completed to evaluate variable speed operation versus constant speed operation. Variable speed operation would be achieved by using pumps controlled by VFDs. The analysis evaluated different combinations of the number of variable speed and constant speed pumps compared to the flow range to determine gaps in flow. The pumping rate gap analysis is presented in Figure 4-7 depicting five scenarios. A blue color represents a variable speed pump in operation, a red color represents a constant speed pump in operation and white represents a gap in the flow rate. The minimum pumping rate for the selected pump based on the pump and system curves shown in Figure 4-6 is between 8.6 and 9.3 mgd (Points C and D).



[1] *All scenarios contain six 15 mgd pumps, which includes one as a standby pump.*

[2] *The wet well will need to operate in fill-draw mode when flows are less than approximately 8 mgd.*

Figure 4-7. Pumping rate gap analysis

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The following is a description of the scenarios presented in Figure 4-7.

4.3.1.1 Scenario 1

All pumps have a VFD. One pump is a standby. This scenario does not have any pumping gaps between 8 to 75 mgd. Scenario 1 is the most expensive pumping combination compared to Scenarios 2 through 5 because VFDs have a higher capital cost than constant speed pumps. However, Scenario 1 provides the most flexibility because all pumps can operate in a variable speed mode. This also makes the control strategy the least complicated because pumps can operate at the same speed and not with a combination of variable and constant speed pumps.

4.3.1.2 Scenario 2

Scenario 2 has a combination of four pumps with VFDs and one constant speed pump with one constant speed pump as an installed standby unit. This scenario also does not have any pumping gaps between 8 and 75 mgd. However, a combination of VFD and constant speed pumps are required for flow conditions between 61 to 75 mgd if all VFD operated pumps are in service.

This scenario will be less costly compared to Scenario 1 because two less VFDs are required when the standby unit is included, but this scenario has less flexibility at higher flow rates when one VFD pump is not in service. This scenario will have a slightly more complicated control strategy than Scenario 1 with the combination of VFD and constant speed pumps operating together.

4.3.1.3 Scenario 3

Scenario 3 is similar to Scenario 2 in that four pumps have VFDs and two pumps are constant speed but this scenario assumes that one of the variable speed pumps is not in operation instead of one of the constant speed pumps. This scenario also has no pumping gaps; however, as indicated by Figure 4-7, a combination of VFD and constant speed pumps are required for flow rates between 45 and 75 mgd.

This scenario has a lower capital cost compared to Scenario 1 because of the reduced number of VFDs but has a more complicated control strategy than Scenarios 1 and 2. The control strategy is more complicated because of a combination of the VFD and constant speed pump operation. The control strategy becomes more complicated at 45 mgd when a combination of VFD and constant speed pumps are needed to achieve flow rates above 45 mgd.

4.3.1.4 Scenario 4

Scenario 4 has a combination of two pumps with VFDs and three constant speed pumps. One constant speed pump is a standby. This scenario has no pumping gaps between 8 and 75 mgd but a combination of VFD and constant speed pumps are required for flow rates between 31 and 75 mgd.

This scenario has a lower capital cost compared to Scenario 1 through 3 because of the reduced number of VFDs but has a more complicated control strategy than Scenarios 1 through 3 because of the greater amount of time operating with both variable and constant speed pumps.

4.3.1.5 Scenario 5

Scenario 5 is similar to Scenario 4 in that two pumps have VFDs and four pumps are constant speed but this scenario assumes that one of the variable speed pumps is a standby. With the limited number of variable speed pumps, there are four gaps in the range of flow as indicated by the white space in Figure 4-7. Like Scenario 4, this scenario has a lower cost compared to Scenarios 1 through 3.

4.3.1.6 Recommendation

Scenario 1 (all VFDs) or Scenario 2/3 (combination of four VFD pumps and two constant speed pumps) are recommended. These scenarios cover the flow range to 75 mgd without any pumping gaps, have less complicated pumping control strategies compared to Scenario 4/5 and provide greater flexibility. Scenario 2/3 with two less VFDs has the advantage of less cost but still provides the flexibility to pump up to 45 mgd, which is a high percentage of the pump operation, with variable speed pumps. For Scenarios 2/3, flow rates above 45 mgd will require a more complex control strategy with the combination of constant speed and variable speed pumps. The recommended configurations will need to be evaluated further during detailed design as the operation of the gravity pipeline and RLS are further refined.

Section 5

Selected Project Description

This section provides an overview of the RLS Project and describes the pump station design elements of the recommended RLS Project alternative. Criteria and guidelines for updating these elements during detailed, final design are summarized below. Detailed design criteria are further discussed in TM 9.1 – Design Criteria, Guidelines, and Standards (Administrative Draft), hereinafter referred to as TM 9.1, included as Appendix D.

5.1 Project Overview

The RLS will lift wastewater at the downstream end of the gravity tunnel and convey it to the Headworks for preliminary treatment. The RLS will consist of a flow splitter section and two trench-style wet wells that would each contain three submersible pumps. Each pump would have its own discharge piping and flow meter discharging into the Flow Distribution Box, which leads to the new Headworks.

Table 5-1 summarizes the major equipment included in the proposed RLS. The equipment list and sizes are subject to change as the design is refined.

Table 5-1. RLS major equipment

Description	Facility Needs/Quantity
Wet Wells	
Submersible Pumps (350 HP)	6
Dewatering Pumps (5 HP)	2
Pipe Gallery	
Magnetic Flow Meters (24-inch diameter)	6
Odor Control	
Supply Fans (Size: TBD)	2
Exhaust Fans (5 HP)	2

TBD = to be determined.

5.2 Site Layout

Figure 5-1 presents a site layout with the site access road, and the locations of proposed improvements at the FoP area, including the location of the RLS. Orientation of RLS and alignment of RLS to the straight run of influent gravity pipeline was carefully configured to optimize hydraulic performance of the RLS. The proposed RLS will consist of the following major components:

- Connection to the gravity pipeline, including use of the TBM retrieval shaft as the Flow Splitter Shaft.
- Two trench-style wet wells with submersible pumps
- Pipe gallery for pump discharge piping, odor control ducts, flow meters and flush water piping.

- Flushing lines located at the sluice gates and stop logs and at each pump intake
- Flow Distribution Box at the pump discharge to feed into the Headworks
- Odor control systems located in the Headworks Facility
- Electrical facilities located in the Headworks Facility

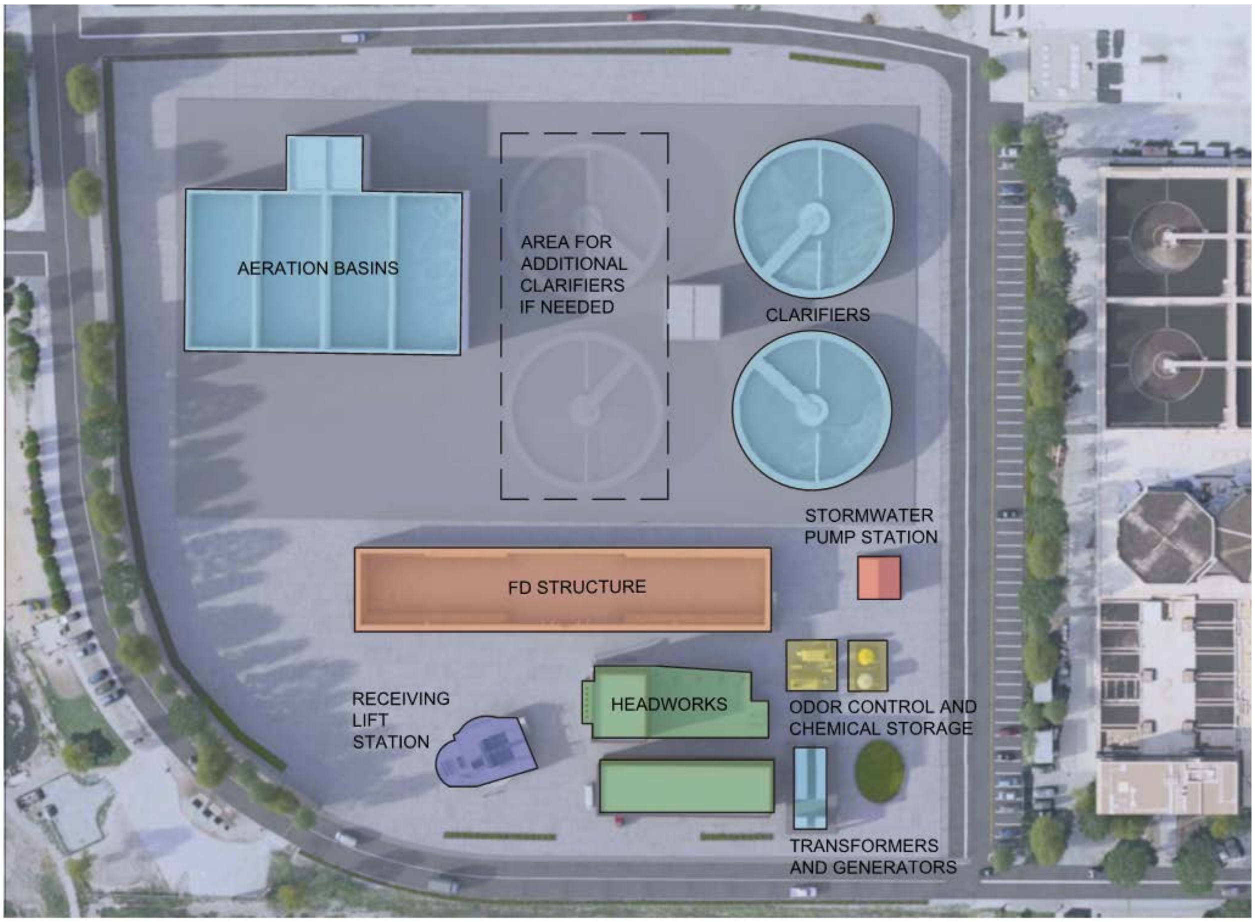


Figure 5-1: Front-of-plant site layout

(Source: Draft EIR, SVCW, 2016)

Note: The Flow Distribution Structure (FD Structure in figure above), Aeration Basins, and New Clarifiers may not be constructed as part of the proposed Conveyance System Project.

5.3 Pump Station Design Criteria

The following sections describe the design criteria for the major components of the RLS.

5.3.1 Connection to the gravity pipeline

The inlet to the RLS will be constructed within the receiving shaft of the gravity pipeline's TBM; a larger shaft housing the trench-style wet wells will be constructed adjacent to the receiving shaft. The two shafts and the major components are shown in Figure 5-2 and Figure 5-3.

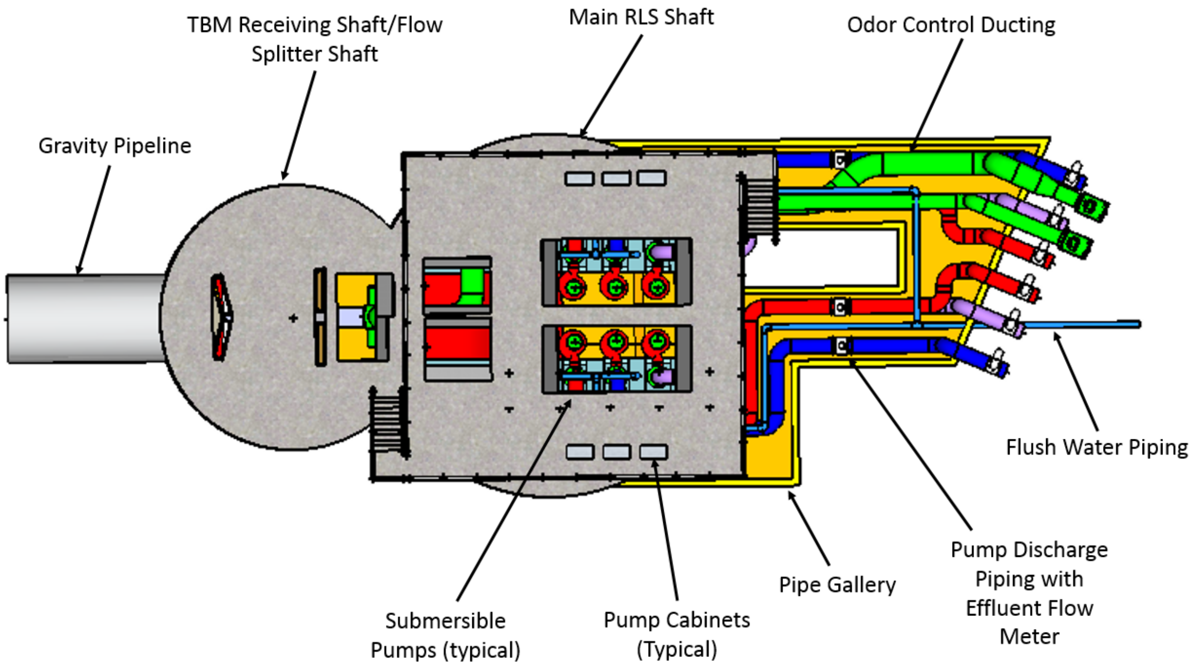


Figure 5-2. Overall RLS layout – plan view

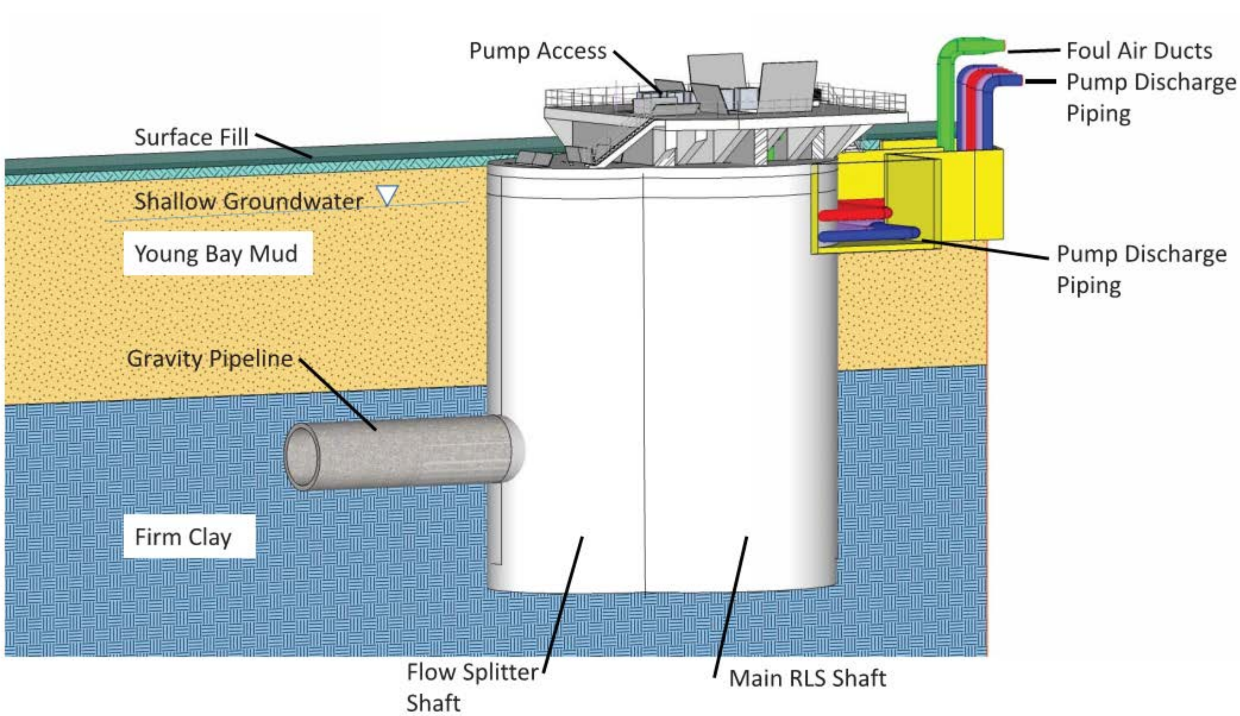


Figure 5-3. Overall RLS layout – side view

Figure 5-4 provides a detailed plan view of the connection of the gravity pipeline and the influent flow splitter section that will be located within the Flow Splitter Shaft.

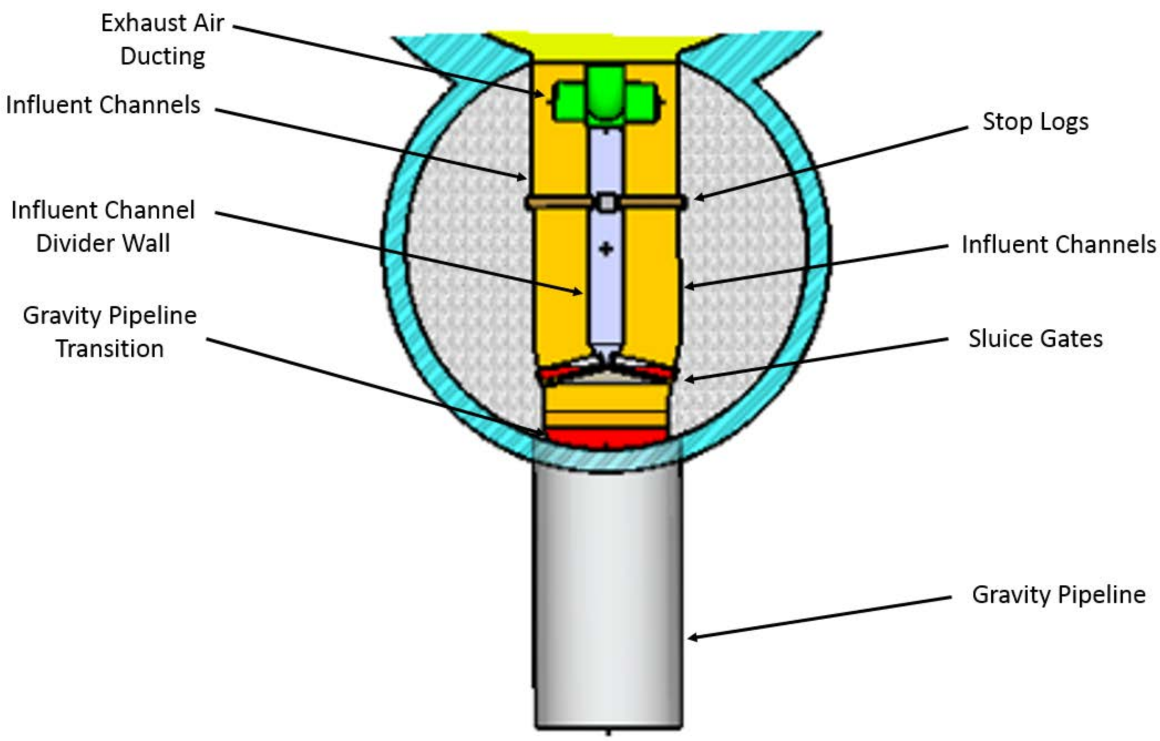


Figure 5-4. Flow Splitter Shaft – plan view

The gravity pipeline will enter through the TBM retrieval shaft wall and transition into a rectangular section before splitting into two influent channels that lead into each wet well. The influent channels are separated by a divider wall that will extend partially up the shaft. Sluice gates at the start of each influent channel will provide isolation of each wet well with a second mechanism of isolation achieved using stop logs. Exhaust air ducting will collect air from the gravity pipeline (TBM retrieval shaft) and Flow Splitter Shaft for conveyance and treatment by the Headworks Facility's odor control system.

5.3.2 Wet well design and pump selection

The main RLS shaft will consist of two rectangular trench-style wet wells that will each have submersible pumps, pump removal system, and discharge piping (see Figure 5-5 and Figure 5-6).

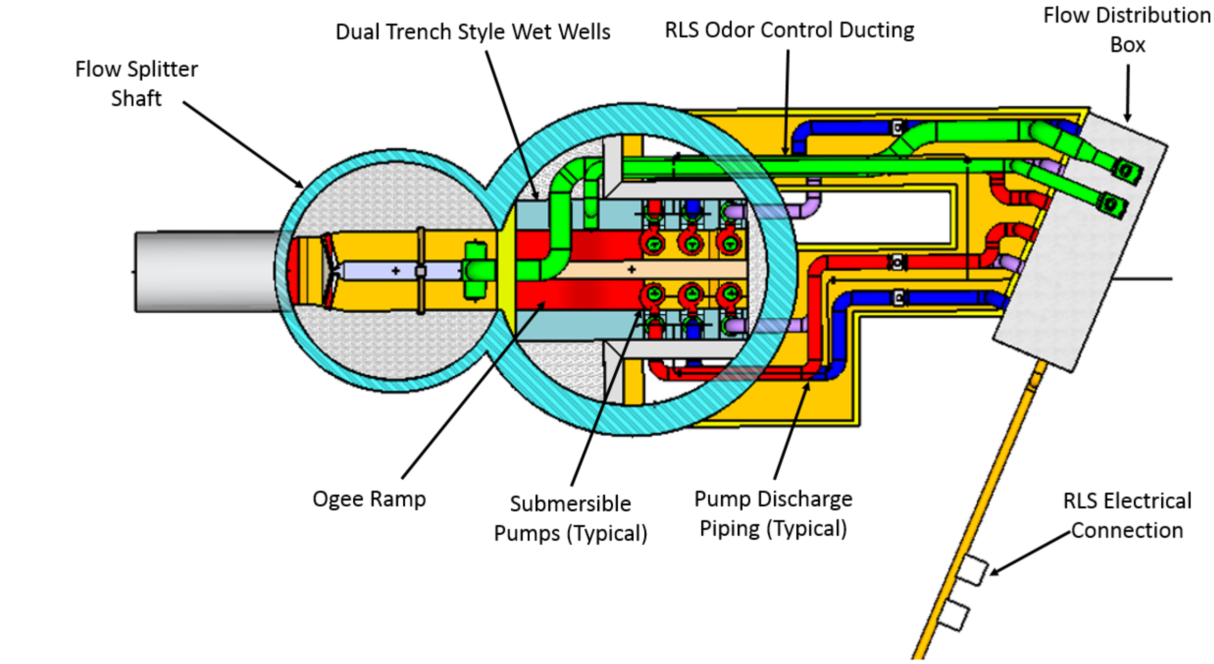


Figure 5-5. RLS wet well concept – plan view

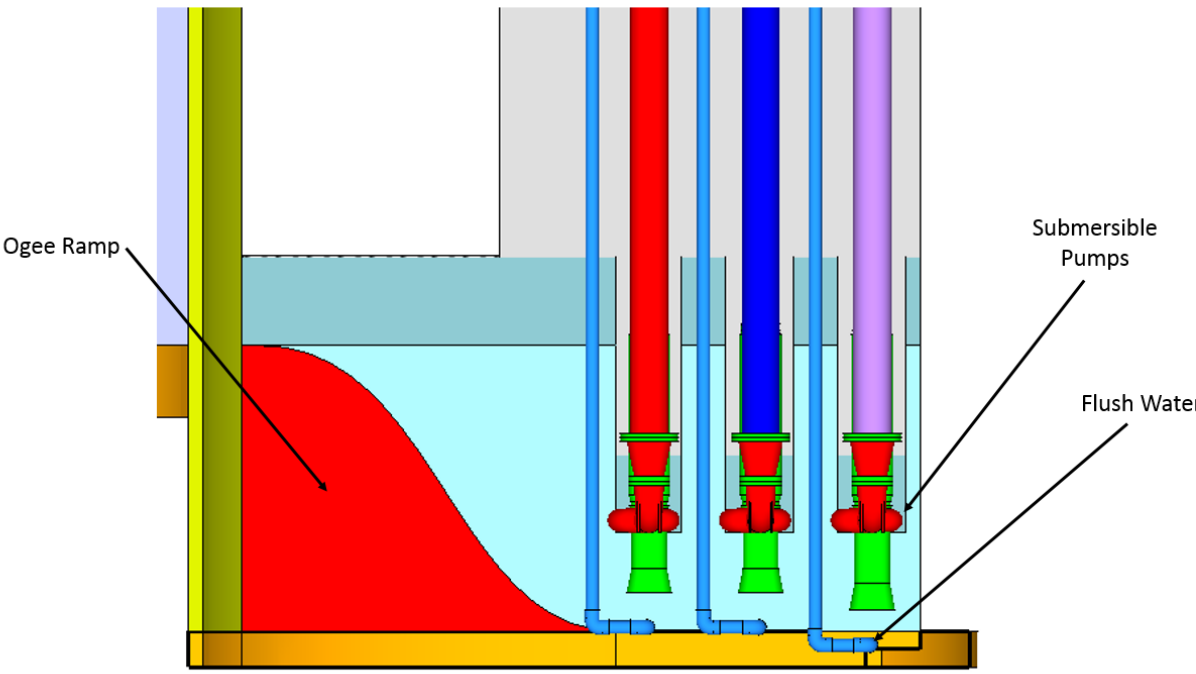


Figure 5-6. RLS wet well concept – section view

These wet well design and pump selection components are described below.

5.3.2.1 Approach channel design

The flow will be conveyed in the gravity pipeline to the wet wells by approach channels. The flow will be divided into two distinct approach channels, one for each wet well, in the Flow Splitter Shaft. Each channel will contain a slide gate to isolate a wet well from the other wet well. Guides for stop logs may also be provided in each channel to provide a second method of isolation.

The velocity in the approach channel, upstream from the wet well, will be no greater than 4.0 ft/s at PWWF. The approach channel upstream from the trench will be straight and free of fittings or devices that could disrupt the flow uniformity entering the trench for a distance equal to a minimum of five times the approach pipe diameter. Since the Flow Splitter Shaft does not completely meet ANSI/HI standards, BC recommends physically modeling the gravity pipeline Flow Splitter Shaft, and wet well to identify improvements to make the configuration ANSI/HI compliant.

5.3.2.2 Wet well design

The RLS will consist of two trench-style wet wells that will incorporate features to optimize the scouring velocities within the wet well during cleaning operations and to minimize pump problems resulting from flow currents. The wet well design will follow the HI/ANSI 9.8 standard with some modifications. Each wet well will contain three pumps for both dry and wet weather conditions.

TM 9.1 includes guidelines for the following wet well-related elements:

- **Pump inlet bell.** A suction nozzle, fitted with a flared bell inlet, will be installed on each pump. The suction nozzle will be sized for a suction velocity of 4 ft/sec (no less than 3 ft/sec and no more than 5 ft/sec). The nozzle length must exceed the difference between the inlet and outlet diameter of the nozzle. The pump inlet bell diameter will be sized to meet the criteria stated above.
- **Wet well cross section.** The wet well cross section dimensions are a function of the pump inlet bell diameter and the width of the incoming approach channel. The wet well cross section consists of a rectangular trench with a trapezoidal section above the trench that transitions to a rectangular section above that.
- **Design ramp for cleaning.** An ogee ramp (Figure 5-6) is required to gather speed down the ramp to cause a hydraulic jump during cleaning cycles. The hydraulic jump occurs at the base of the ramp that moves along the trench floor to the last pump. The purpose of inducing a hydraulic jump is to scour the trench floor and mobilize solids for suction by the last pump. The ogee ramp will consist of an upper curve and a lower curve connected by a 45-degree tangent.
- **Pump spacing.** Pump intakes will be spaced a minimum of 2.5 times the pump inlet diameter (D) from pump centerline to centerline. The first pump will be spaced a minimum of 0.5D from the end of the ogee ramp to the first pump centerline.
- **Inlet floor clearance.** The pump inlet floor clearance will be a minimum of 0.5D, unless otherwise specified. A minimum of three inches of clearance between the pump inlet and the flow splitter is required to allow solids to enter the inlet. Therefore, the pump inlet from the floor may be raised slightly to meet the three inches of clearance.
- **Flow splitters.** A flow splitter will be installed on the floor of the wet well at the centerline of the trench. Flow splitters help control vortices within the wet well and retain the hydraulic energy from the ramp to produce a swift flow of water along the floor during cleaning.
- **Fillets.** Fillets will be installed along the sides of the trench floor the entire length of the wet well trench to eliminate sidewall vortices. The fillets will extend from the top of the ogee ramp to

provide a good flow pattern down the ramp to the end wall. Fillets will have a 45-degree slope with a height of 0.38D.

- **Last pump.** The last pump will be used for cleaning and will be located in a recessed pocket lower than the main floor of the wet well. The pocket will help collect debris scoured during the cleaning process for conveyance into the last pump.
- **Anti-rotation baffle and floor cone at last pump.** An anti-rotation baffle will be placed between the last pump and the back wall to prevent circulation of liquid between the pump and the pump wall. A floor cone will also be placed under the last pump to aid flow movement.
- **Cleaning.** Cleaning will be conducted between flow rates of 1/3 to 2/3 of the capacity of the last pump. These flow rates can be achieved during PDWF, by temporarily closing the wet well influent gate to build up sufficient flow, or backing flow up in the gravity pipeline. At these flow rates, the wastewater will move down the ramp at supercritical velocity and form a hydraulic jump at the base of the ramp. The hydraulic jump re-suspends settled solids and conveys solids to the last pump. Additionally, during cleaning, the water level is drawn down and scum build up is incorporated into the flow and out of the wet well and removed by the last pump.
- **Flushing water.** Flushing water will be provided at the intake of each pump and at the sluice gate and stop log locations. The source of the flushing water will be grit dewatering water from the Headworks Facility. The purpose of the flushing water is to re-suspend dirt, grit, and debris that may accumulate around the pump intakes, gates and stop log guides.
- **Level control.** Flow control and sequenced pump starts and stops will be accomplished based upon the water surface level in the pump station lead wet well. VFDs will vary the speed on select pumps to maintain the normal depth level of the approach pipe. The number of VFDs required will need to be finalized in detailed design.

5.3.2.3 Pump selection

Pumps will be selected according to the requirements described in Section 4 and TM 9.1, included as Appendix D. Several pump combination alternatives were reviewed, though a final selection for the pumping configuration for the RLS has not yet been made. The operating conditions that the pumps will be required to meet are discussed in Section 4. Pumping conditions will be refined as the design progresses and information on the gravity pipeline invert elevations and Headworks discharge conditions are finalized.

5.3.2.4 Pipe gallery and flow distribution box

Each of the RLS pumps will have its own discharge piping that will discharge into the Flow Distribution Box (Figure 5-5 and Figure 5-7) to allow flexibility in operation and various options for conveyance during emergency situations. Each wet well will have three discharge pipes that exit the RLS. The discharge piping will be located within a pipe gallery structure below ground on each side of the RLS. The width and height of each pipe gallery will be approximately 12 feet wide by 16 feet deep and supported by a pile foundation.

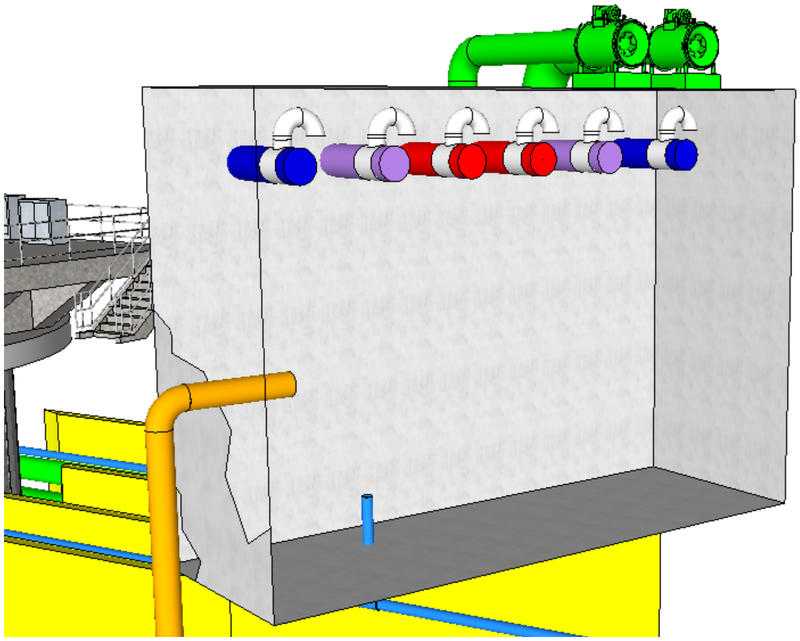


Figure 5-7. Flow distribution box

The Flow Distribution Box will collect flows from the RLS, Redwood Shores collection system and grit dewatering water that will be conveyed into the Headworks Facility. The configuration of the Flow Distribution Box will be determined during final design. An ogee ramp within the Flow Distribution Box is suggested to minimize dead zones and better transition flows into the Headworks Facility. Discharge piping will be set to an elevation six inches above the maximum water surface elevation (WSEL) of the Headworks Facility. Duckbill check valves (not pictured in Figure 5-7) are suggested at the exit of the discharge piping to prevent backflow from the Flow Distribution Box. At the time this report was written, the maximum WSEL of the Headworks Facility was 118.0 ft.

Air vent elbows on each pump discharge will be located at each pump's discharge pipe to allow the pipes to expel excess air that may be trapped within the pipes between pump use. Past experience shows that these air vents tend to expel some wastewater; therefore, the vents are located within the Flow Distribution Structure where it can be captured and treated.

5.3.3 Effluent flow metering

Effluent leaving the RLS will be measured by individual flow meters located on each of the discharge pipes from the RLS. The meters will be located in the pipe gallery. The flow meters will consist of magnetic meters with integral converter/indicating transmitter.

5.3.4 Gas detection system

A gas detection system will be located within the wet wells to detect explosive and/or hazardous conditions. The gas detection system consists of field mounted sensing elements and monitoring assemblies to detect the lower explosive limit (LEL) of combustible gases or vapors, low and high oxygen levels, and high hydrogen sulfide (H_2S) levels. The gas detection system alarms and alerts staff when the LEL, oxygen, or H_2S are outside of accepted ranges and may cause hazardous conditions. Alarms will be sent to SCADA. Audible and visual alarms will also be mounted outside of the building to alert staff of the hazardous conditions prior to entering the structures. However, these gas detection systems are not intended to replace personal protective equipment used as part of permitted confined space entry activities.

5.3.5 Odor control system

Odors expected in the air will be conveyed through the headspace of the gravity pipeline and combined with the RLS wet well air spaces. SVCW plans to continue injecting calcium nitrate or a similar odor control oxidant into the sewage upstream at each pump station to help control downstream odors. In the future, SVCW may explore other upstream alternatives for odor control, such as oxygen injection, that will have fewer delivery trucks (onsite oxygen production taken from air). Foul air (FA) reaching the RLS will be conveyed to the Odor Control Facilities located adjacent to the Headworks Facility. Odor control for the RLS will treat two distinct areas: air conveyed through the headspace of the tunnel and air within the wet wells. Air from the tunnel will be drawn from the front area of the RLS within the Flow Splitter Shaft using exhaust fans at a peak rate of approximately 3,900 cubic feet per minute (CFM) and conveyed to the Odor Control Facilities. The wet well odor handling system will require both supply and exhaust fans to ventilate the wet well air space within the larger RLS shaft. An air flow rate of approximately 7,400 CFM for four ventilation changes per hour will be supplied and ventilated from the space.

5.3.6 Standby generator

Standby power for the RLS is currently proposed to be supplied by existing standby generators at the WWTP. This may be revised based on the new SVCW electrical infrastructure plan during preliminary design.

5.3.7 Surge control system

Surge protection measures at the RLS will consist of air vents on the discharge side of the submersible pumps to allow air in the riser to vent and water to drain back into the wet well.

5.3.8 Composite sampling

Composite sampling for the RLS will be coordinated with the design of the Headworks Facility.

5.4 Energy/Electrical

The electrical service for the RLS will be designed in conjunction with the electrical service for the proposed Headworks Facility. A new electrical service will be required, and will be part of the design of the Headworks Facility. Approximately 1,532,100 kilowatt hours (kWh) is the projected annual energy consumption of the RLS. Electrical demands for the current selected pump sizes and configuration is 2,300 horsepower (HP) based on total connected HP. This is based on a six pump configuration. Each pump will have a 15 mgd capacity (385 HP). Final pump selection will be made during detailed design.

Pump cabinets, containing pump local control panels and electrical junction boxes, (Figure 5-2) will be located on the outer perimeter of the main RLS shaft. The RLS electrical facilities will require motor control centers, switchgear and VFDs, a remote terminal unit, and instrumentation systems. All electrical equipment will be located in the electrical room within the Headworks Facility with connection vaults/manholes located approximately 5 ft outside of the Headworks Facility (Figure 5-5).

For design of the RLS, where possible, energy efficient equipment will be incorporated, including:

- VFDs
- Light emitting diode (LED) light fixtures
- Premium efficient pump motors

Additional energy efficient measures for operations and construction will be explored further during subsequent design.

5.5 Additional Design Considerations

The following site considerations will be included in the final design and construction of RLS.

5.5.1 Civil

New facilities to be constructed for the RLS include pumps, piping, wet wells, and new building structures. The civil site improvements at the RLS will be coordinated with all other work planned for the overall FoP, and will include the following objectives:

1. Provide vehicle and pedestrian access to new and upgraded facilities and structures
2. Provide site grading to minimize earthwork and achieve positive drainage of storm water runoff away from the RLS facilities
3. Provide a secure site with two entrance/exit points
4. Pavement/ground improvements:
    a. Pavement should be installed around the RLS for site access. Ground improvements within the RLS area will be required to support heavy equipment during construction and operation of the RLS.
    b. The asphalt pavement section at the RLS should consist of a minimum of three inches of asphaltic concrete over twelve inches of Class 2 aggregate base rock. The pavement subgrade soil must be scarified to a depth of eight inches, moisture conditioned to near optimum moisture content and compacted to a minimum of 95 percent relative compaction per ASTM D1557. Use of lime treated base may be needed where soft soils are present in paved areas.
5. As part of the civil design, the following should also be provided:
    a. Utility coordination
    b. Survey control
    c. Site grading

5.5.2 Geotechnical

Geotechnical information and design criteria are currently being developed for the RLS Project. The structural design will incorporate the design considerations and geotechnical data presented in the following reports and TMs:

- "Draft Technical Memorandum, SVCW Headworks Facility at Front of Plant Preliminary Foundation Design Parameters," January 2017 (Appendix B)
- "New Administration and Plant Control Building Project." July 2009, prepared by DCM Consulting, Inc. (Appendix B)
- "Preliminary Characterization of Subsurface Conditions, SVCW Clean Water Tunnel – Alignment 4BE, Redwood City, California," December 2015, prepared by Geotechnical Consultants, Inc. (Appendix B)

- "Preliminary Pile Foundation Design Criteria, Peak Flow Diversion Structure," January 2016, prepared by DCM Consulting, Inc. (Appendix B)
- "Presentation of Site Investigation Results SVCW Front of Plant Improvements," January 2016, prepared by DCM Consulting, Inc. (Appendix B)
- "Soil Corrosivity Evaluation SVCW." December 2015, prepared by V&A Consulting Engineers. (Appendix C)

The following geotechnical information will be incorporated into the final design.

5.5.2.1 Existing conditions

The CPTs completed in the vicinity of the RLS encountered 45 to 55 feet of YBM, which consists of fat clay and elastic silt. YBM is characterized by extremely high water content, low dry density, low shear strength, and high compressibility. The YBM is underlain by much stiffer (and older) alluvium referred to as Old Bay Clay, characterized by lower water content, higher dry density, higher shear strength and lower compressibility.

5.5.2.2 Excavations

Both the RLS flow splitter/receiving shaft and the main RLS shaft will be approximately 93 feet below the ground surface, depending on the construction method. The RLS flow splitter/receiving shaft will also serve as the retrieval shaft for the TBM. Shaft excavation and development will be designed by the gravity pipeline design team.

Additional excavations required for the RLS include those required for the pipe gallery and connection to the Headworks Facility. These excavations will be shallow in comparison to the shaft excavation, and will require vertical shoring. All RLS Project excavations can be completed by appropriately sized conventional excavation equipment. For purposes of shoring design, groundwater should be assumed to be at the ground surface. All RLS Project excavations associated with the pipe gallery and connections to the Headworks Facility must be fully shored and supported with "watertight" shoring such as internally braced interlocking sheet piles. Any gaps in shoring, such as at pipeline penetrations, must be fully sealed to maintain excavation "water tightness." Jet grouting is the potential method for sealing shoring gaps. With a "watertight" shoring system, external dewatering should not be required. External dewatering is not advisable as it can cause subsidence of soft ground and settlement of nearby pipelines, utilities, and structures. Internal dewatering can be kept to a minimum by establishing adequate toe embedment of sheet piles to form a cutoff to groundwater inflows. The minimum toe embedment for sheet piles in the project soil and groundwater conditions is 15 feet below the base excavation.

5.5.2.3 Pipelines

All fluid piping required for the RLS is expected to be in the pipe gallery connecting the RLS to the Headworks Facility. The pipe gallery should be supported on a pile foundation as recommended by the geotechnical data in Section 5.5.2.

5.5.3 Corrosion mitigation

Interior corrosion control for the RLS will be provided in the Flow Splitter Shaft, Main RLS Shaft, Piping Gallery, and underground utilities. The gravity pipeline will also have corrosion protection but gravity pipeline corrosion protection is not part of the RLS and will be determined by the gravity pipeline design team.

Corrosion control will be provided with lining of concrete, materials selection such as Type 316 stainless steel, coating of equipment and piping, and ventilation of the Flow Splitter Shaft and Main

RLS Shaft. Corrosion for underground utilities will be developed as more site specific geotechnical information becomes available.

The Flow Splitter Shaft and Main RLS Shaft concrete will be plastic HDPE or polyvinyl chloride (PVC) lined including the walls from the top of the structures to the bottom of the wet well. The underside of the top slab will also have plastic lining and the hatches will be of corrosion resistant material such as type 316 stainless steel or aluminum.

The ventilation system will have powered supply and exhaust fans for the wet well and Piping Gallery. The Flow Splitter Shaft area will only have exhaust fans because it will also control the air movement exhausting from the gravity pipeline. The exhaust FA from the Flow Splitter Shaft and Main RLS Shaft will be treated by the odor control system provided as part of the Headworks Facility. Final corrosion control methods will be coordinated with the gravity pipeline and Headworks design teams as the RLS Project proceeds into design.

Per the latest soils corrosion study completed by V&A Consultant Engineers (V&A Consultant Engineers, 2015), the soils at the FoP are highly corrosive. Any civil site designs and modifications (e.g., addition of lime for stabilization) will need to consider its effect on RLS utilities and any potential for increases in soil corrosivity.

The following exterior corrosion protection measures are recommended for buried reinforced concrete piping and structures:

- Structures should be made of durable concrete such as described in American Concrete Institute (ACI) Standards 201.2R and 222R
- The water/cement ratio should not exceed 0.45
- The concrete cover applied over all steel reinforcement should be a minimum of two inches thick
- A bonded coating should be applied on top of the concrete cover to provide a barrier to corrosive soil
- Type V modified cement should be used
- Sand and water used in concrete mixtures should contain a maximum of 100 parts per million (ppm) of water-soluble chloride ions and water-soluble sulfate ions and have a pH in the range of 6.5 to 8.0. Water used in concrete mixtures should be potable water.

The following exterior corrosion protection measures are recommended for Buried PVC or HDPE pipe with metallic fittings:

- Wrap metallic fittings with petrolatum wax tape per American Water Works Association (AWWA) C217-04 and the manufacturer’s instructions. Using polyethylene encasement on the fittings is not as effective as using wax tape.
- Install galvanic anodes to provide cathodic protection to every metallic fitting or appurtenance

5.5.4 Safety issues and site security

O&M staff shall follow all safety protocols and procedures established by SVCW’s safety program. The designer and SVCW shall identify any safety issues at the new RLS that are not currently covered under the current safety protocol.

The following level of safety and security features will be incorporated into the RLS:

- Access hatches leading to the Pipe Gallery, for pump removal above the wet well, and above the Flow Splitter Shaft will be locked with padlocks to prevent entrance by unauthorized personnel.
- Electrical junction boxes for the pumps located on top of the wet wells will be locked to prevent entrance by unauthorized personnel.

- Lighting will be provided with a particular focus on camera monitored areas. Lights and cameras will be installed in locations with consideration for ease of maintenance but in a location inside the fence to avoid potential vandalism of the cameras and lights.
- An emergency call button will be located at the RLS and on local Programmable Logic Controllers (PLCs) and connected to SCADA.

Additionally, the plant perimeter fence will be extended to include the FoP area, which includes the RLS.

5.5.5 Property acquisition needs

No property acquisition is required for the new RLS. The new pump station will be constructed on the existing WWTP property.

5.5.6 Operational plan

With diurnal gravity pipeline storage, the range of daily flow rates (minimum hourly flow of 2.0 mgd to peak hourly dry weather flow rate of 33.9 mgd) can be controlled to 12 to 18 mgd or even a smaller, tighter range. This smaller range allows a single pump capacity (same sized pumps) rather than multiple size pumps to meet the entire range of flows.

There are four operational criteria that the RLS will be required to meet: the most frequent operating conditions, peak flow conditions, cleaning, and a tunnel flushing cycle, as described in Section 4.

5.5.7 Permits required for project implementation (federal, state, regional, local)

The following permits and approvals are anticipated to be required for construction of the improvements to the RLS. The following list is not inclusive of all permits that will be required:

- San Francisco Bay Conservation and Development Commission – Permit for work at WWTP
- Pacific Gas and Electric Company (PG&E) – Utility Relocation Agreement, Easement
- City of Redwood City – Street Excavation and Encroachment Permit, Permanent and Temporary Easements
- Bay Area Air Quality Management District – Authority to Construct

5.5.8 Structural and architectural

Load types as appropriate to the RLS Project are listed below. Loads will be based on the most stringent criteria of the building codes, and industry standards. In all cases, the minimum criterion will conform to the California Building Code (CBC). The following load types will be considered during design:

- Dead Loads
- Collateral Loads
- Live Loads and Associated Deflection Criteria
- Seismic Loads
- Wind Loads
- Rain Loads
- Impact Loads
- Vibratory Loads
- Handrail
- Heavy Equipment Loads

- Differential Settlement Loads
- Liquid Loads
- Earth Load

The architectural design features for the RLS will be minimal since most of the structure is below grade. The only portion of the RLS structure currently above grade is the RLS Shaft where the pump electrical cabinets are located. The upper elevation of the Flow Splitter Shaft shall be evaluated in subsequent design. To the extent practical, the architectural design will match the new Headworks facilities.

5.5.9 Lighting

Following construction, there will be no lighting on the staging areas which are located north of the 10-acre ornamental pond. Lighting will not be significantly different than the existing lighting at the WWTP. Lighting consistent with the RSB Specific Plan Objective 6.2.1 will be used for parking and driveways/drive aisles and security lighting. The lighting will consist of LED lighting and will vary between 0.5 to 2.0 foot-candles.

5.5.10 Instrumentation and controls/SCADA

All instrumentation and controls equipment will match SVCW's Automation Standards. The RLS will be remotely monitored and controlled from the SCADA Human Machine Interface (HMI) work station at the WWTP.

Redundancy will be provided for some critical instrumentation (i.e., dual wet well level control). Additional requirements for redundant instruments are included in SVCW's "Level Instrumentation Configuration for Pump Station Wet Wells" document.

The requirements for interfacing packaged equipment to the pump station control system including implementation of PLCs and the SCADA HMI monitoring and control requirements will need to be evaluated during final design.

Automation strategies will be further developed in subsequent design. The automation strategies describe the operation of the major processes at the RLS including pump control, flow metering, odor control and standby power supply. The automation strategies will be described in control narratives and are shown graphically on the process and instrumentation diagrams (P&IDs), which are included in Appendix E. The P&IDs will be further refined upon development of the automation strategies as the RLS and gravity pipeline design is progressed.

SVCW's automation standards are currently being revised; therefore, the final designs shall incorporate the new automation standards.

5.5.11 Interim operations, bypass requirements

Conveyance system improvements will be implemented over several years as discussed. Sequencing and interproject coordination are further discussed in Section 5.6

5.5.12 Stakeholders

Close coordination with the City of Redwood City will be required to mitigate impacts of planned developments, construction and zoning changes. Coordination will also be required for architectural, storm water and road improvements.

5.5.13 Environmental impacts and mitigations

Environmental impacts and mitigation measures were identified by the EIR (SVCW, 2016). A list of the major significant impacts related to the RLS and a summary of the proposed mitigation measures extracted from the Draft EIR are presented in Table 5-2. For the sake of completeness, the entire text has been copied for each relevant impact and mitigation measure, although some of the description may not be specifically relevant to the RLS Project.

Table 5-2. RLS environmental impacts and mitigations

Impact	Mitigation Measures
AIR-1: The proposed Project construction emissions would exceed the average daily threshold of 54 pounds per day for NO_x for calendar year 2018 which is a significant impact.	The construction contractor shall implement the following measures at the Project sites: • Ensure that all construction equipment (including generators) larger than 25 horsepower (HP) and used at the Project site for more than two work days meet, at a minimum, U.S. EPA Tier 2 engine emission standards; • Ensure that all stationary equipment larger than 25 HP (e.g., generators and hydraulic power packs) meet California Air Resources Board's (CARB's) most recent certification standard for off-road heavy duty diesel engines; • Portable diesel-powered equipment (including generators) larger than 25 HP and used at the project site for more than two work days meet, at a minimum, U.S. EPA Tier 3 engine emission standards for NOx; • Portable diesel-powered equipment used at the Redwood City Pump Station construction sites for more than two days shall include diesel particulate matter control devices in the form of CARB currently Verified Diesel Emission Control Strategies (VDECS); • All exposed surfaces shall be watered two times per day, or as necessary to control dust; • All haul trucks transporting soil, sand, or other loose material off-site shall be covered; • All visible mud or dirt tracked-out onto adjacent public roads shall be removed using wet power vacuum street sweepers at least once per day. The use of dry power sweeping shall be prohibited; • All vehicle speeds on unpaved roads shall be limited to 15 miles per hour; • All paving shall be completed as soon as possible after pipeline replacement work is finished; • Idling times shall be minimized either by shutting equipment off when not in use or reducing the maximum idling time to five (5) minutes (as required by the California airborne toxics control measure Title 13, Section 2485 of California Code of Regulations (CCR)). Clear signage shall be provided for construction workers at all access points; • All construction equipment shall be maintained and properly tuned in accordance with the manufacturer's specifications. All equipment shall be checked by a certified mechanic and determined to be running in proper condition prior to operation; and • Post a publicly visible sign with the telephone number and person to contact regarding dust complaints. This person shall respond and take corrective action within 48 hours. The BAAQMD's phone number shall also be visible to ensure compliance with applicable regulations.
Impact BIO-5: The proposed Project's construction activities at the WWTP Improvements Project footprint immediately adjacent to marsh vegetation could result in direct mortality and/or harassment of Federal and State Endangered Salt Marsh Harvest Mouse (SMHM) individuals and special-status Salt Marsh Wandering Shrew (SMWS) from individuals wandering into the construction area from adjacent suitable habitat, which would be considered a significant impact.	MM BIO-1.1 (Applicable to Impact BIO-05): Prior to ground disturbing activities adjacent to potential SMHM and SMWS habitat, exclusion barriers and/or fencing shall be installed to exclude individuals of these species from areas of active construction. The design of the exclusion barriers and fencing will be approved by a qualified biologist and shall be installed in the presence of a qualified biological monitor. The fence will be made of a material that does not allow SMHM or SMWS to pass through, and the bottom will be buried to a depth of a minimum of four (4) inches so that these species cannot crawl under the fence. All support for the exclusion fencing will be placed on the inside of the Project footprint. Additionally, it is not anticipated that removal of marsh or associated ruderal vegetation will be necessary for the proposed Project, but in the event removal of potential SMHM or SMWS habitat is necessary, it would be completed using only hand tools and in the presence of a biological monitor. MM BIO-1.2 (Applicable to Impact BIO-05): A qualified biological monitor will be present during wildlife exclusion fence installation and removal, and during all vegetation clearing and initial ground disturbance (if necessary) which take place in marsh habitats, and vegetation adjacent to marsh habitats. The monitor will have demonstrated experience in biological construction monitoring and knowledge of the biology of the special-status species that may be found in the Study Area, including

Table 5-2. RLS environmental impacts and mitigations	
Impact	**Mitigation Measures**
	SMHM and California Ridgeway Rail (CRR). The monitor(s) will have the authority to halt construction, if necessary, if noncompliance actions occur. The biological monitor(s) will be the contact person for any employee or contractor who might inadvertently kill or injure a special-status species or anyone who finds a dead, injured, or entrapped special-status species. Following fence installation, vegetation removal in potential habitat areas, and initial ground disturbance in potential habitat areas, the biologist will train an onsite monitor to continue to document compliance. The biologist will conduct weekly site checks to provide guidance for fence maintenance, provide environmental sensitivity training, and document compliance with permit conditions. MM BIO-1.3: The biological monitor shall provide an endangered species training program to all personnel involved in Project construction. At a minimum, the employee education program shall consist of a brief presentation by persons knowledgeable about the biology of sensitive species with potential to occur in the Project footprint, and about their legislative protection to explain concerns to contractors and their employees involved with implementation of the Project. The program shall include a description of this species and their habitat needs, any reports of occurrences in the area; an explanation of the status of these species and their protection under State and Federal legislation; and a list of measures being taken to reduce impacts to these species during construction. MM BIO-1.4: Food-related trash items such as wrappers, cans, bottles, and food scraps will be disposed of in solid, closed containers (trash cans) and removed at the end of each work day from the investigation site to eliminate an attraction to predators of listed species. MM BIO-1.5: If a Federal or State listed species is observed at any time during construction in the work area, work will not be initiated or will be stopped immediately until the animal leaves the vicinity of the work area of its own volition. If the animal in question does not leave the work area, work will not be reinitiated until the appropriate agency is contacted and has made a decision on how to proceed with work activities. The biological monitor will direct the contractor on how to proceed accordingly. The biological monitor or any other persons at the site will not pursue, capture, handle, or harass any species observed.
Impact BIO-6: The proposed Project's construction activities at the WWTP Improvements Project footprint may cause noise and visual disturbances that result in harassment of Federal and State Endangered California Ridgeway Rail (CRR) individuals causing nest abandonment, which would be considered a significant impact.	MM BIO-2.1: For Project activities occurring on Inner Bair Island, construction during the CRR breeding season (February 1 through August 31) will be avoided as much as feasible. If construction work is proposed during the CRR breeding season (February 1 through August 31), surveys will be conducted to determine the extent and location of nesting CRR. CRR surveys with USFWS-approved protocols will be conducted along Inner Bair Island in areas where construction or staging is to occur within 700 feet of tidal salt marsh habitat that is suitable for CRR nesting. Survey methods that are modified from the USFWS survey protocol may be permitted if approved by USFWS and CDFW. Results of protocol-level breeding surveys will be submitted to the USFWS and CDFW for approval. If no nesting CRR are found during the surveys, construction may proceed during the CRR breeding season. If nesting CRR are detected, work will be avoided within 700 feet of the active calling center until the end of the breeding season (August 31). MM BIO-2.2 (Applicable to Impact BIO-06): For Project activities occurring in the WWTP area or at the Menlo Park Pump Station, surveys for CRR as described in MM BIO-2.1 will be conducted during the nesting season just prior to initial ground disturbance. If nesting CRR are detected within 700 feet of construction at the WWTP or Menlo Park Pump Station during these preconstruction surveys, initial ground disturbance within 700 feet of the detected calling center will be delayed until the end of the breeding season (August 31). Alternatively, if CRR nesting is detected adjacent to the WWTP or Menlo Park Pump Station and avoiding construction within 700 feet of the calling center is not feasible, a visual and auditory barrier will be erected and maintained for the duration of construction along the southwestern boundary of the WWTP Project footprint, or northern boundary of the Menlo Park Pump Station. The size and material used for the barrier would be determined based on the location of any observed CRR nesting, and would be submitted to USFWS for approval. The barrier will augment the existing levees, to provide an additional visual and acoustic barrier to prevent the elevated local noise and activity levels of construction activities from disturbing any nesting CRR in the vicinity. Following initial ground disturbance, construction activities in these areas are anticipated to be constant with consistent types of construction equipment in use. The consistent disturbance in combination with the visual and acoustic barrier provided by the adjacent levees would provide a consistent baseline for conditions of noise and visual disturbance that would continue throughout construction.
Impact BIO-7: Project construction activities in the Project footprint for	MM BIO-4 (applicable to Impact BIO-10): Potential significant impacts to nesting special-status and other native nesting birds will be mitigated through avoiding disturbance to active nests. Initiation of

Table 5-2. RLS environmental impacts and mitigations	
Impact	**Mitigation Measures**
the WWTP Improvements have the potential to result in direct impacts or indirect disturbance to special-status nesting birds and other native nesting birds protected by the Migratory Bird Treaty Act (MBTA) and California Fish and Game Code (CFGC). Construction could directly destroy active nests or cause disturbance that results in nest abandonment.	construction activities during the avian nesting season (February 1 through August 31) will be avoided to the extent feasible. For areas where direct impacts to vegetation will occur, vegetation removal will be conducted outside of the nesting season to avoid potential delays in construction schedule due to nesting activity, as is feasible. Additionally, if water is present in the ornamental ponds prior to construction and it is necessary to drain one or both ponds, the ornamental ponds will be drained during the non-breeding season (i.e., they will be drained between September 1 and January 31). If construction initiation and/or ornamental pond draining during the nesting season cannot be avoided, pre-construction nesting bird surveys will be conducted within 14 days of initial ground disturbance or water/vegetation removal to avoid disturbance to active nests, eggs, and/or young of nesting birds. Surveys can be used to detect the nests of special-status as well as non-special-status birds. Surveys will encompass the entire construction area and the surrounding 500 feet. An exclusion zone where no construction would be allowed will be established around any active nests of any avian species found in the Study Area until a qualified biologist has determined that all young have fledged and are independent of the nest. Suggested exclusion zone distances differ depending on species, location, and placement of nest, and will be at the discretion of the biologist and, if necessary, USFWS and CDFW. These surveys would remain valid as long as construction activity is consistently occurring in a given area and will be completed again if there is a lapse in construction activities of more than 14 consecutive days during the breeding bird season.
Impact CUL-2: Construction activities associated with the proposed Project could disturb unknown buried archaeological resources.	MM CUL-2: In the event cultural resources are encountered during construction, work shall halt and the SVCW project manager shall be notified. • All construction activity within 50 feet (15 meters) of the find/feature/site will cease immediately. • If human bones are found, the appropriate County authority (Coroner) and the SVCW project manager shall be notified immediately. • In the event that Native American human remains or funerary objects are discovered, the provisions of the California Health and Safety Code shall be followed. Section 7050.5(b) of the California Health and Safety Code states: *In the event of discovery or recognition of any human remains in any location other than a dedicated cemetery, there shall be no further excavation or disturbance of the site or any nearby area reasonably suspected to overlie adjacent remains until the coroner of the county in which the human remains are discovered has determined, in accordance with Chapter 10 of Part 3 of Division 2 of Title 3 of the Government Code, that the remains are not subject to the provisions of Section 27492 of the Government Code or any other related provisions of law concerning investigation of the circumstances, manner and cause of death, and the recommendations concerning treatment and disposition of the human remains have been made to the person responsible for the excavation, or to his or her authorized representative, in the manner provided in Section 5097.98 of the Public Resources Code.*
Impact GEO-1: The soil at the Project site is highly corrosive to buried steel and concrete. Therefore, buried reinforced concrete structure would require corrosion protection to reduce the impact to less than significant.	MM GEO 1: The following measures or equivalent measures are recommended for corrosion control and are proposed as part of the Project for the steel and concrete portions of the Project that are buried or are in direct contact with the soil. • Buried reinforced concrete structures should be constructed of durable concrete such as described in ACI Standards 201.2R and 222R. • The water/cement ratio should not exceed 0.45. • The concrete cover applied over all steel reinforcement bars should generally be a minimum of two (2) inches thick. • All concrete used in the area would be a mix of 50% Type II and 50% Type V cement. • Sand and water used in concrete mixtures should contain a maximum of 100 ppm of water-soluble chloride ions and water-soluble sulfate ions and have a pH in the range of 6.5 to 8.0. Water used in concrete mixtures should be potable water.
Impact HAZ-1: Construction of the proposed Project could expose construction workers to risks from hazardous materials contamination or from the storage, use and/or disposal of hazardous materials.	MM HAZ-1.1: Prior to initiating earthwork activities, sampling and laboratory analyses should be conducted at planned earthwork locations where spill incidents appear most likely to have impacted soil and/or groundwater, including at the Belmont Pump Station site, the northerly portion of the planned gravity pipeline alignment, and the northeastern portion of the San Carlos Pump Station site. This shall be done in order to establish specific, appropriate site management protocols, including handling and disposal alternatives for contaminated materials and health and safety protocols.

Table 5-2. RLS environmental impacts and mitigations	
Impact	Mitigation Measures

	MM HAZ-1.2: This measure shall be implemented before and during construction of the gravity pipeline and pump stations, as well as any demolition.
	• A Site Management Plan (SMP) and Health Safety Plan (HSP) shall be prepared by the project contractor(s) and submitted to SVCW for review.
	• The SMP and HSP shall include the following:
	  • Site control procedures to control the flow of personnel, vehicles, and materials in and out of the construction site;
	  • Measures to minimize dust generation, storm water runoff, and tracking of soil off-site;
	  • If excavation de-watering is required, protocols to evaluate water quality and discharge/disposal options;
	  • Protocols for completing earthwork activities in areas where impacted soils, soil vapor, and/or groundwater are present or suspected;
	  • Worker training requirements, health and safety measures and soil handling procedures;
	  • Protocols to be implemented if buried structures, wells, debris, or unidentified areas of impacted soil are encountered during construction activities;
	  • Protocols to evaluate the quality of soil suspected of being contaminated so that appropriate mitigation, disposal, or reuse options can be determined;
	  • Procedures to evaluate and document the quality of any soil imported to the construction site;
	  • Methods to monitor trenches for the potential presence of volatile chemical vapors;
	  • Protocols to reduce the potential for construction equipment and vehicles to release contaminated soil onto public roadways or other off-site transfer; and
	  • Stockpiling protocols for “clean” and “impacted” soil.

Impact HYD-1: Construction of the proposed Project could increase contaminants in storm water runoff, which could adversely affect the water quality of the San Francisco Bay.	MM HYD-1.1: Prior to the commencement of any ground disturbing activities outside the fenced WWTP site, the project will comply with the State Water Resources Control Board’s NPDES General Construction Activities Permit, to the satisfaction of the SVCW construction manager, as follows: • SVCW will control the discharge of storm water pollutants including sediments associated with construction activities; • Permitting for storm water treatment could be obtained by one of two methods. The first option would be to obtain an Industrial Storm water General Permit by filing a Notice of Intent (NOI) with the SWRCB. The second option would be to reissue the existing individual permit that expires in December 2017 and file an application with revised storm drain discharge into wetlands or the bay. MM HYD-1.2: The project will include Best Management Practices (BMPs) to control the discharge of storm water pollutants including sediments associated with construction activities. Prior to installation, the contractor shall be required to prepare an Erosion Control Plan. The Erosion Control Plan may include BMPs as specified in the Manual of Standards Erosion & Sediment Control Measures for reducing impacts on the storm drainage system from installation activities. The following specific BMPs will be implemented to prevent storm water pollution and minimize potential sedimentation during construction: • Utilize on-site sediment control BMPs to retain sediment on the Project sites; • Utilize stabilized construction entrances and/or wash racks; • Implement damp street sweeping; • Provide temporary cover of disturbed surfaces to help control erosion during installation; • Provide permanent cover to stabilize the disturbed surfaces after installation has been completed; • Store, handle, and dispose of construction materials and wastes properly, so as to prevent their contact with storm water; • Control and prevent the discharge of all potential pollutants, including solid wastes, paints, concrete, petroleum products, chemicals, washwater or sediments, and non-storm water discharges to storm drains and watercourses; • Utilize sediment controls or filtration to remove sediment from dewatering effluent;

Table 5-2. RLS environmental impacts and mitigations	
Impact	Mitigation Measures
	• Avoid cleaning, fueling, or maintaining vehicles onsite, except in a designated area in which runoff is contained and treated. • Delineate clearing limits, easements, setbacks, sensitive or critical areas, buffer zones, trees, and drainage courses with field markers. • Protect adjacent properties and undisturbed areas from construction impacts using vegetative buffer strips, sediment barriers or filters, dikes, mulching, or other measures as appropriate. • Limit and time applications of pesticides and fertilizers to prevent polluted runoff.
Impact HYD-2: Water quality impacts from shallow groundwater encountered during construction could occur under the proposed Project.	MM HYD-2: A detailed, design-level geotechnical investigation shall be completed and shall address the need for dewatering during construction. Project construction shall follow the recommendations of the investigation.

Impact NOI-1: Construction activities in relation to the ambient noise conditions over extended periods could result in a potentially significant impact.	MM NOI -1: The following measures will be required for all construction sites to ensure the exterior noise levels at sensitive receptor locations stay within these thresholds when feasible:
	Daytime (7:00 a.m. to 10:00 p.m.)
	  • Residential districts: 60 dBA Leq (hr)
	  • Commercial districts: 70 dBA Leq (hr)
	  • Locations with ambient noise near thresholds: 5dBA Leq higher than ambient noise
	• Nighttime (10:00 p.m. to 7:00 a.m.)
	  • Residential districts: 45 dBA Leq (hr)
	  • Commercial districts: 52 dBA Leq
	  • Locations with ambient noise near thresholds: 5dBA Leq higher than ambient noise.
	• Noise due to extreme noise-generating construction activities, such as pile driving activities which are necessary for the proposed Project, shall be minimized to the extent feasible. Pile driving activities and other noisy construction activities shall be completed as quickly as possible to limit noise exposure. Where conditions allow, vibratory pile drivers shall be used to drive sheet piles. Pile holes shall be pre-drilled to minimize the number of blows required to seat the pile.
	• All equipment driven by internal combustion engines shall be equipped with mufflers, which are in good condition and appropriate for the equipment. Quieter internal combustion equipment or equipment powered by electrical motors shall be selected to reduce noise levels, where feasible.
	• The construction contractor shall utilize “quiet” models of air compressors, ventilation fans, and other stationary noise sources where technology reasonably exists.
	• Unnecessary idling of internal combustion engines shall be prohibited.
	• Construction staging areas shall, where practical, be established at locations that will create the greatest distance between the construction-related noise sources and receptors nearest the Project site during all Project construction.
	• Locate stationary noise sources as far from receptors as feasible. If they must be located near receptors, adequate muffling (with screens and enclosures where feasible and appropriate) will be used as necessary to stay within the above noise level thresholds. Any enclosure openings or venting will face away from receptors.
	• Locate material stockpiles, as well as maintenance/equipment staging and parking areas, as far as feasible from residential receptors.
	• Neighbors located adjacent to the construction site shall be notified of the construction schedule in writing and of significant changes to the schedule.
	• Designate a project liaison that will be responsible for responding to noise complaints during the construction phase. The name and phone number of the liaison will be conspicuously posted at construction areas and on all advanced notifications. This person will take steps to resolve complaints, including periodic noise monitoring, if necessary. Results of noise monitoring will be presented at regular Project meetings with the Project contractor, and the liaison will coordinate with the contractor to modify any construction activities that generated excessive noise levels to the extent feasible.

Table 5-2. RLS environmental impacts and mitigations	
Impact	**Mitigation Measures**

	• Require a reporting program that documents complaints received, actions taken to resolve problems, and effectiveness of these actions.
	• Hold a preconstruction meeting with the job inspectors and the general contractor/on-site project manager to confirm that noise mitigation and practices (including construction hours, construction schedule, and noise coordinator) are completed.
	• Implement a construction noise monitoring plan which includes a provision for noise monitoring at the nearby receptors to confirm that daytime and nighttime construction noise levels meet daytime and nighttime noise level thresholds at residential and commercial land uses. Construction monitoring shall occur weekly during the first month of general construction at a given site and on a monthly basis, thereafter, to show compliance with the construction noise level thresholds. Additional noise monitoring shall be completed on a more frequent basis if needed, in response to complaints. In the event of noise complaints, the contractor will provide information to SVCW within 48 hours of being notified of the complaint, regarding the noise levels measured and activities that correspond to the complaints, as well as the proposed changes at the site to reduce the noise levels to below the thresholds.
	• In the event the above noise thresholds are not being met, additional noise mitigation measures will be implemented to further reduce noise from construction activities. A site-specific noise control plan shall be developed to identify the specific construction noise control features that will be implemented at the construction site(s). These additional noise mitigation measures could include, but not be limited to, the following
	   • Erecting permanent or temporary noise barriers (at least 12 feet in height) and other noise control features at the perimeter of the construction site(s) between the construction activity and sensitive receptors and/or around major construction noise sources (i.e., noisy equipment) to provide shielding for nearby sensitive receptors. Permanent or temporary noise barriers could include, but would not be limited to, concrete, precast walls, plywood noise barriers, noise control blankets, cargo containers, or hay bales. The exact material, height, and configuration of these barriers shall be decided in consultation with the acoustical consultant, based on the specific equipment or activity that is causing the excessive noise.
	   • Scheduling specific high noise-generating construction activities for the middle of the day.
	• Additional noise monitoring shall be completed after the installation and completion of such measures, to confirm their effectiveness at achieving the above thresholds. If the noise thresholds are still not being met, an acoustical consultant shall make further recommendations to be implemented immediately to reduce noise levels at the construction site(s).

Impact NOI-2: Operational noise from regular operations at the WWTP and the specified pump stations as discussed above would lead to a potentially significant impact.	MM NOI-2: The following noise performance standards shall be applied to noise from regular operations at the WWTP and at the specified pump stations: • Noise resulting from regular (non-emergency) operations of WWTP equipment shall not exceed 50 dBA Leq at night (10 p.m. to 7 a.m.) at the nearest residential land use located 890 feet southwest of the WWTP Improvements buildings. If the mechanical equipment at the WWTP would cause levels to exceed 50 dBA Leq at night, controls could include, but are not limited to, design alternatives, fan silencers, enclosures, and screen walls. • Low-velocity ventilation systems (which are quieter than standard ventilation systems) and other ancillary noise controls shall be incorporated into the designs, as necessary, to meet the noise performance standards. The following noise performance standard shall be applied to noise from diesel engine-generator operations at WWTP and each of the pump stations: • The sound level from non-emergency operation of the diesel engine-generator at each facility shall not exceed 60 dBA when measured on any real property outside the property lines of the facilities (excluding US Highway 101 (U.S. 101), other roadways, and San Carlos Airport).
Impact UTIL-1: The relocation and modification of existing utilities could result in short-term service disruption impacts during construction.	MM UTIL-1: The project will incorporate the following measures into the Project construction documents: • Prior to and during construction of the gravity pipeline alignment and the proposed connections, all utility work shall be completed with approval and coordination with the respective utility providers to minimize any potential disruption in service. • All utility modifications and relocations shall comply with respective utility providers' notification process for any disruption of service, including USA North requirements.

5.6 Construction and Sequencing

The construction of the conveyance system will take place in stages and will need to account for the installation of equipment and design considerations discussed previously in Sections 5.1 through 5.3. A constructability review, proposed schedule and sequencing are discussed in the following sections.

5.6.1 Constructability review

The following section discusses the construction constraints, geotechnical requirements and coordination issues associated with RLS construction.

5.6.1.1 Constraints

The following constraints have been identified for the design and construction of RLS. Constraints include noise and vibration restrictions and sequencing restrictions.

- **Noise restrictions.** Construction noise shall be limited to normal working hours between the hours of 7 a.m. and 8 p.m. Monday through Friday and prohibited on weekends and holidays as summarized in Section 3.3.4.
- **Vibration restrictions.** Redwood City has no known quantitative standards for vibration; therefore, American Association of State Highway and Transportation Officials (AASHTO) and State of California Department of Transportation (Caltrans) guidelines should be followed. Sheet pile driving, concrete pile driving, and soil compaction are expected to be the major sources of on-going vibration during construction. Vibration from the excavation and other phases of construction should be below the typical criteria for building threshold damage for nearby buildings located offsite. Since the RLS is located within an area of Very High Susceptibility to liquefaction, operations from continuous vibratory equipment like a sheet pile driver should be limited to 0.1 peak ground acceleration (0.2 in/sec at 30 Hertz) near the existing RLS building if differential settlement cannot be tolerated. In addition to vibration effects on buildings, RLS construction will likely generate perceptible vibration that can be noticed by the WWTP.

5.6.1.2 Geotechnical requirements

The following geotechnical recommendations were made by the geotechnical engineer for the RLS.

- **Groundwater.** Per the geotechnical report, the groundwater level should be assumed to be at ground surface for design and construction purposes.
- **Shoring.** Excavations on RLS will be approximately 0.5 ft to 93 ft deep. The deeper excavations required for the RLS shaft will be designed by the engineer responsible for the gravity pipeline design. The remainder of the RLS excavations, including piping and the pipe gallery, will be much shallower than the shaft construction and will require vertical shoring (i.e., no side-sloped excavations) and supported with “watertight” shoring such as internally braced interlocking sheet piles. All gaps in shoring, such as pipeline penetrations, must be fully sealed to maintain a watertight system. External dewatering is not recommended by the geotechnical engineer due to the risk for subsidence of soft ground and settlement of nearby pipelines, utilities and structures. Instead, the geotechnical engineer recommends that the sheet pile toe be embedded a minimum of 15 feet below the excavation to form a cutoff to groundwater inflows. Internal dewatering may be used to keep the excavation dry.
- **Differential and structure settlement.** Soil conditions at or below the base elevation of the RLS consists of stiff (Old Bay Clay) clays that will adequately support uniformly loaded mat foundations. Pile foundations are not anticipated for RLS’s shafts; however, they will be required for the pipe gallery. RLS mat foundation settlement should be limited to less than one inch. For

structures shallower than the wet well excavation, Class 2 aggregate base and foundation rocks shall be installed per the geotechnical engineer's recommendations.

5.6.1.3 Coordination issues

The following coordination issues have been identified for the detailed design and construction of RLS.

- **Installation of new gravity pipeline.** The gravity pipeline and RLS will share the Flow Splitter Shaft. The Flow Splitter Shaft will be the receiving shaft for the TBM. The majority of the RLS construction is proposed to be completed prior to the TBM reaching the Flow Splitter Shaft.
- **Installation of Headworks.** The RLS will discharge to the Headworks. RLS discharge piping will be routed in a pipe gallery to the Headworks Distribution Box.
- **Odor control facilities.** The RLS will share odor control facilities with the Headworks.
- **Electrical and standby power facilities.** The RLS will share electrical and standby power facilities with the Headworks Facilities. The electrical and standby power facilities will be located in the Headworks Facility.
- **Site storm water pump station.** The FoP area will drain to a common site storm water pump station and discharge into the Headworks.
- **FoP design and construction.** The FoP project was originally going to be executed as a design-bid-build project with several design teams. However, in Fall 2016, SVCW determined that all FoP projects will likely be constructed under a single design-build contract which will ease coordination between the various FoP components identified above.

5.6.1.4 Shutdowns

The RLS is located on a new site. Major shutdown of the existing WWTP are not expected as part of the RLS Project, although shutdowns will be needed for other related FoP projects.

5.6.2 Construction staging, laydown areas and access

Construction of the RLS requires approximately 80,000 square feet of staging area. The staging areas for all FoP projects, including the RLS will be located north of the flow diversion structure, as shown in Figure 5-8.

Driveway entrances with security gates will be installed to enhance the safety of the public and prevent unauthorized access. Traffic will be limited to construction traffic only. Equipment activity for initial site staging would include a range of trucks and excavators necessary to: remove and transport waste from the site clearing and preparation operation, haul-in and spreading gravel, install construction trailers, provide sewer, water, and drainage facilities, and construct site fencing.

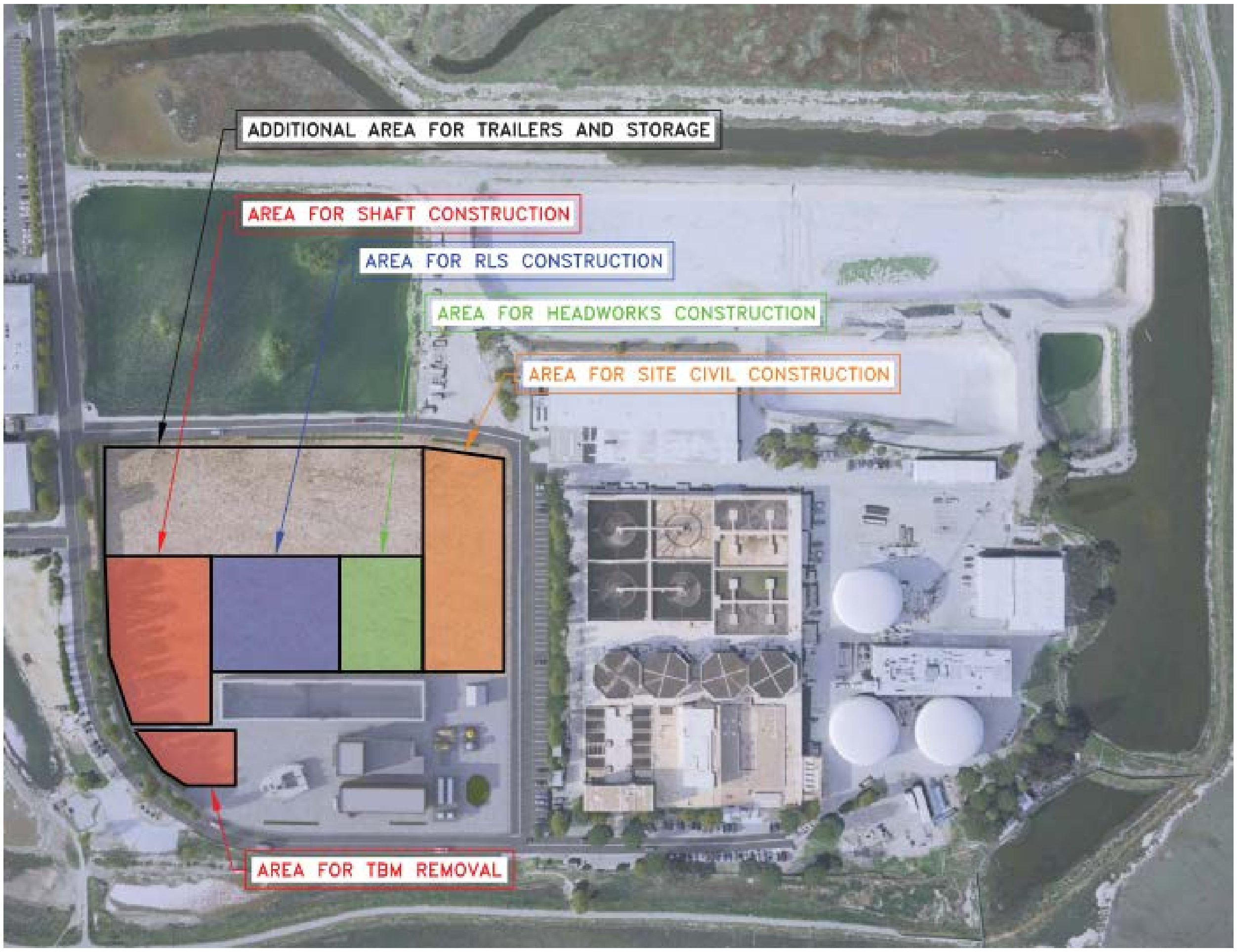


Figure 5-8. FoP improvements staging areas

5.6.3 Construction sequencing

The construction sequencing plan for the RLS is presented in Table 5-3, and consists of seven phases.

Table 5-3. RLS construction sequencing		
Phase	Activity	Duration (Months)
Shaft Structural Improvements	• Reinforced structural liner installation for anchoring of wet well facilities. • Interior improvements for converting shaft from temporary to permanent structures.	6
Construct interior wet well structural components	• Installation of influent channel and wet well separation walls. • Installation of ogee ramp and trench-style wet well. • Installation of plastic lining for corrosion protection.	4
Pump mounts and rail	• Installation of pump base, guide rails and anchoring systems. • Installation of sluice gate and stop log rails.	4
Construct top slab of wet well and pipe gallery	• Construction of top slap of wet well including access hatches and stairways. • Installation of pipe gallery pile foundation and construction of pipe gallery structure.	4
Mechanical installation	• Installation of pumps, discharge piping and FA ducting. • Installation of flow meters.	2
Electrical and controls	• Installation of pump cabinets, electrical conduit, instrumentation and controls.	6
Start up and commissioning	• Start-up and commissioning of RLS in conjunction with Headworks Facility.	6

The suggested construction sequencing plan is not intended to define the methods of construction, but to the assist SVCW and the contractor in identifying operational and practical constraints for the work. Sequencing workshops shall be held during detailed design to develop a more detailed sequencing approach during construction.

Section 6

Cost Estimate and Schedule

The RLS Life Cycle Cost (LCC) analysis model was used to estimate the LCC for the RLS Project's 50-year life. The model was completed in August 2016. The major considerations in developing the RLS LCC include capital cost, annual O&M running costs, replacement/rehabilitation costs and proposed Conveyance System Project schedule. The following sections describe the different components of the LCC.

6.1 Construction Costs

AACE International Class 3 construction costs for the RLS Project were calculated by BC. A summary of the construction costs by major project category is provided in Table 6-1. The detailed cost estimate is included in Appendix F. It should be noted that the cost estimate was prepared in May 2016 and the construction cost estimate is in 2016 dollars.

Table 6-1. RLS construction costs

Category/Phase	Total Net Cost
RLS Site Civil and Excavations	$1,143,063
RLS Pump Station Concrete	$1,528,565
RLS Pipe Gallery Concrete	$303,091
RLS Mechanical	$4,726,653
RLS Super Structure	$289,992
RLS HVAC and Odor Control	$242,090
Shaft Improvements and Corrosion Protection	$918,851
RLS Electrical Allowance	$1,044,126
Total	$10,196,431

Note: *Construction cost estimate is in 2016 dollars.*

The construction costs were converted into capital costs by applying soft costs, project contingencies, and market fluctuations to each individual cost component. The construction contingencies, soft costs, and market fluctuations are summarized in Table 6-2. Market fluctuations are applied to capture the range of costs that could potentially occur over the construction period for the entire conveyance system program upgrade.

Table 6-2. Capital cost factors	
Cost Factor	**Markup**
Construction Contingency[1]	25%
Soft Costs[1]	
Construction Management, Engineering Services during Construction, Testing, Inspection	18%
Contract Change Orders (CCO)	5%
Planning	5%
Design	10%
Project Management	5%
Soft Cost Subtotal	**43%**
Market Fluctuations[2]	
Low	-5%
High	15%

1. *Construction contingency developed by SVCW as presented in the comparison of construction cost estimates during the June 2, 2016 Department Head Meeting.*
2. *Market fluctuations developed by SVCW. Source: SVCW Conveyance System Construction Cost Analysis, Front of Plant, Revision Date: April 22, 2015, Revision 28b.*

Table 6-3 presents a summary of the RLS capital costs. The capital costs were originally developed in 2016 dollars, but were escalated to 2020, which is the midpoint year of construction.

Table 6-3. RLS capital cost	
	Total Net Cost
Total Construction Cost	$10.2 M
Contingency and Soft Cost Subtotal (25% and 43% of Construction Cost)	$2.5 M $4.4 M
2016 Capital Cost	$17.1 M
2020 Capital Cost	$20.0 M
Market Fluctuation Ranges[1]	$19.4 M – $21.8 M

1. *Market fluctuation range of -5 percent (low) to 15 percent (high) developed by SVCW. Source: SVCW Conveyance System Construction Cost Analysis, Front of Plant, Revision Date: April 22, 2015, Revision 28b.*

6.2 O&M Costs

The annual maintenance allowance is equal to one full time employee at $150,000/year per SVCW's direction during the original LCC analysis completed in May 2015. The maintenance allowance includes maintenance of odor control and crane maintenance. Odor control chemicals and pump rebuilding and inspection costs are not considered to be annual maintenance costs, and are accounted for separately in the LCC analysis. Odor control chemical costs are estimated to be $200,000/year due to the size of the facility. Pump inspection costs are estimated to be

$25,200/year, based on pulling all submersible pumps twice per year at a cost of$4,200/pump/year, as stated in Table 7.19 of the CSMP (Winzler & Kelly, 2011). Electrical costs are calculated using an electrical billing rate of $0.129/kWh, along with calculated equipment power usage at the site. The electrical rate is based on current SVCW electrical bills from PG&E. The total RLS annual equipment power usage is 2,168,900 kW (247.4 kWh). All O&M costs are in 2016 dollars.

6.3 Rehabilitation/Replacement Costs

The following rehabilitation and replacement assumptions were made for the RLS:

1. All pumps will be rebuilt every five years. Cost is assumed to be 50 percent of the total purchase cost for six pumps of $2,232,000. The assumption is to rebuild each pump every 5 years.
2. Pump replacement – once every 25 years. The cost to replace is assumed to be the total purchase cost for six pumps of $2,232,000. No rebuild costs are assumed within these years.
3. Electrical equipment will be replaced once every 25 years and instrumentation and control once every 15 years. Electrical equipment replacement cost is assumed to be $939,600 and the instrumentation and control equipment replacement cost is assumed to be $104,400.
4. Structural rehabilitation or replacement will occur once every 75 years for RLS since it will be a new station. Since this cost will occur outside of the period of analysis, it was not calculated for this LCC. The structural rehabilitation/replacement includes piping, valves, HVAC, sluice gates and odor control equipment.

6.4 Year of Analysis

The RLS Project construction is expected to begin in May 2019 and end in March 2021. Capital costs are applied in the LCC model at the midpoint year of construction. The Year 2020 is used as the midpoint year of construction. The end year of construction is used to establish the start of recurring O&M and rehabilitation/replacement costs. The Year of Analysis for the entire conveyance system program is the Year of Beneficial Use. The Year of Beneficial Use is the year major facilities of the conveyance system (i.e., gravity pipeline, RLS and Headworks) start up. Based on the current program-wide schedule (Version 20 dated February 1, 2017) developed by SVCW, the Year of Beneficial Use is the Year 2022.

6.5 Escalation and Discount Rates

To determine the present value of costs for the Year of Analysis, their values are escalated to future values and discounted back to the Year of Analysis. The discount and escalation rates used in the RLS LCC Analysis were developed by SVCW based on current and projected investment return rates as summarized in Table 6-4.

Table 6-4. Escalation and discount rates

Factor	Rate
Escalation	4%
Capital Project and Rehabilitation/Replacement Discount	7%
O&M Discount	3%

6.6 LCC Analysis Summary

The LCC analysis summarizes all cost components over a 50-Year period ending in the Year 2066. A 50-Year period was selected as it is the typical analysis period for municipal facilities. Table 6-5 displays the RLS LCC breakdown including O&M, rehabilitation/replacement, capital costs and LCC. The LCC analysis completed for the RLS is included in Appendix G.

Table 6-5. LCC summary by cost category

Cost Category	Cost
O&M	$6.4M
Rehabilitation/Replacement	$8.4M
Capital Cost[1]	$19.4M - $21.8M
Total LCC	$34.2M - $36.6M

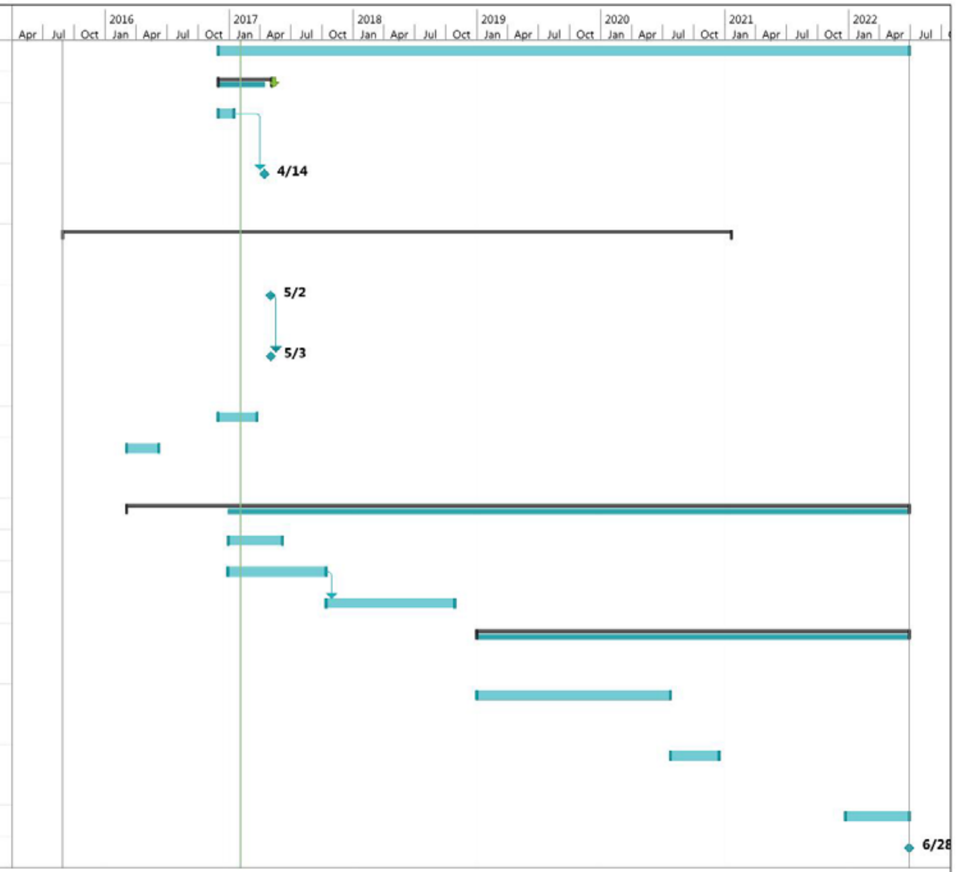
1. *Capital cost range is based on a market fluctuation factor as discussed in Section 6.1, and was developed for the midpoint year of construction (2020)*

The average total 50-year LCC for the RLS is $34.8 million with a range of $34.2 million to $36.6 million accounting for market fluctuations.

6.7 Schedule

The planning level project schedule during design and construction is shown in Figure 6-1. The schedule originates from the proposed Conveyance System Project program schedule (Version 20 dated February 1, 2017); therefore, gaps in specific RLS activity may occur. The estimated construction duration for the RLS Project is approximately three years.

Task Name	Duration	Start	Finish	Predecessors
RLS Project Schedule	**1456 days**	**Tue 11/29/16**	**Tue 6/28/22**	
Final EIR Preparation	**114 days**	**Tue 11/29/16**	**Fri 5/5/17**	
Public Review Period for Draft EIR	34 days	Tue 11/29/16	Fri 1/13/17	
Commission Certifies EIR and Approves Project	0 days	Fri 4/14/17	Fri 4/14/17	3
Conveyance System Project Permitting	**1408 days**	**Fri 8/28/15**	**Tue 1/19/21**	
Permitting Complete - FoP Tunnel Shaft and RLS	0 days	Tue 5/2/17	Tue 5/2/17	
Environmental, Acquisition, Permitting Complete	0 days	Wed 5/3/17	Wed 5/3/17	6
Project Planning Report	83 days	Mon 11/28/16	Wed 3/22/17	
RLS 60% Drawings for Permit Application	67 days	Fri 3/4/16	Mon 6/6/16	
FoP Progressive Design Build	**1648 days**	**Fri 3/4/16**	**Tue 6/28/22**	
RFQ Stage FoP Projects	113 days	Thu 12/29/16	Mon 6/5/17	
RFP Stage FoP Projects	208 days	Tue 12/27/16	Thu 10/12/17	
Stage 1B - RLS 60% Design	271 days	Fri 10/13/17	Fri 10/26/18	12
Stage 2B - RLS Final Design and Construction	**912 days**	**Mon 12/31/18**	**Tue 6/28/22**	
RLS Design and Construction Prior to TBM Removal	409 days	Mon 12/31/18	Thu 7/23/20	
RLS Construction after TBM Removal	102 days	Fri 7/24/20	Mon 12/14/20	
RLS Start Up	135 days	Wed 12/22/21	Tue 6/28/22	
RLS In Service	0 days	Tue 6/28/22	Tue 6/28/22	



Project: RLS
Date: Fri 2/3/17

Task; Split; Milestone; Summary; Project Summary; Inactive Task; Inactive Milestone; Inactive Summary; Manual Task; Duration-only; Manual Summary Rollup; Manual Summary; Start-only; Finish-only; External Tasks; External Milestone; Deadline; Progress; Manual Progress

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Figure 6-1. Construction schedule

(Version 20 dated February 1, 2017)

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Section 7

Outstanding Project Issues

The following section summarizes the RLS Project issues that require resolution as part of the final design process. These issues consider the impact to the RLS Project schedule and proposed Conveyance System Project costs (design and construction), potential additional field investigations, RLS Project components requiring alternatives analyses to determine a final resolution, interproject coordination needs and decisions to be made by SVCW staff/management to move the RLS Project forward.

7.1 Outstanding Issues to Carry into Subsequent Design

Several items will need further refinement and coordination with SVCW. These items are listed below.

- **Hydraulic model and pump selection.** Pump selection was based on selection of the proposed Conveyance System Project, based on information available in January 2017. As new information is developed, the hydraulic model will need to be updated and new system curves developed. The consultant updating the hydraulic model during final design will need to provide system curves for the detailed design team to use for pump selection.
- **RLS rated capacity.** The RLS capacity is based on SVCW wet weather storage decisions and efficient pumping design based on 60 or 80 mgd PWWF.
- **Corrosive air control**. Specific requirements may be needed for very corrosive ambient air used in building air exchanges. SVCW had considered commissioning a specific ambient air corrosion study.
- **Wet well dimensions.** Updated pump selections may require adjustments in the wet well dimensions.
- **Pump manufacturers.** Current pump selections were based on Flygt submersible pumps. Additional pump manufacturers should be contacted during final design.
- **Equipment removal and maintenance access.** Equipment removal and maintenance access to the pumps and equipment will need to be reviewed with SVCW O&M staff. The use of rented cranes, boom trucks, or combination of removal devices will need to be considered. The local municipalities' and neighbor businesses' interests should also be considered. In addition, discussions during conceptual design resulted in the possibility of hiring Flygt on a maintenance contract to perform inspection and rebuilds of the submersible pumps. This will need to be confirmed during final design.
- **Air exchange rates and gravity pipeline air volume.** Air exchange rates for the wet well need to be finalized during final design. The gravity pipeline air volume will also need to be estimated to size the odor control facilities at the Headworks.
- **Architectural.** The RLS will need to include architectural features to match the surrounding area. The final architectural features will need to be determined in final design. Redwood City's requirements and interests will need to be considered.
- **Alignment and grade of incoming gravity pipeline.** The alignment and grade of the incoming gravity pipeline will affect the depth and sizing of the RLS facilities, especially the wet well.

- **SVCW standards.** Updates to SVCW standards including automation standards and naming conventions will need to be incorporated into the detailed design. The detailed design teams will need to update the design documents to meet all of the new/updated design standards.
- **Environmental.** The Draft EIR released in November 2016 identified significant proposed Conveyance System Project impacts and proposed mitigation measures, which will need to be incorporated into the design of the RLS. Specific attention to air quality impacts, biological resources, and cultural resources will need to be considered, in addition to the other impacts discussed in the Draft EIR and summarized in this report.
- **State Revolving Fund (SRF).** SVCW plans to fund the proposed Conveyance System Project through the SRF program. SRF requirements will need to be incorporated into the bid documents. The design engineer should also expect to provide RLS Project information for the SRF application.
- **Environmental permits.** Environmental permits required for construction will need to be finalized during detailed design and will be identified during the environmental review process.
- **Non-environmental permits.** Non-environmental permits required for construction will need to be identified and finalized during detailed design.
- **Technical specifications.** Technical specifications for the RLS Project should be developed during final design.
- **Seismic design criteria.** Seismic design criteria will be determined based on criticality rating.

In addition to the items listed above, the following design refinements are recommended:

- **Size of pumps.** Use of all the same size pumps or multiple size pumps to pump the range of dry and wet weather flow.
- **Constant speed vs. variable speed pumps.** A combination of constant speed and variable speed pumps were explored in the conceptual analysis. The number of constant speed and variable speed pumps will be determined by the acceptable operating ranges under the various flow conditions.
- **Height of wet well separation wall.** The wall separating the two wet wells is currently configured to allow overflow from one wet well into another if pumps fail or an emergency situation occurs. The elevation of overflow will need to be refined during final design.
- **Configuration of tunnel shafts.** Two configurations were explored during conceptual design: a “Figure 8” configuration where the shafts intersect or twin shafts with a short connection between shafts. A determination of keeping the shafts together or separated will need to be made that heavily relies on constructability of the configurations and sequencing of the gravity pipeline and RLS construction.
- **Maintenance space needs.** Configuration of wet well platform and access to the pipe gallery will require refinement that considers maintenance space needs.
- **Final depth and inside diameter of the gravity pipeline.** The ultimate depth and inside diameter of the gravity pipeline will affect the overall pump selection.
- **Structural requirements for the shaft walls.** The shaft wall’s initial purpose is to provide a receiving shaft for the gravity pipeline’s TBM. The shaft walls will require improvement in order to convert the shafts into permanent structures. The design of the shafts will need to be incorporated into the overall RLS design.
- **Procurement (pre-purchase, pre-selection, or pre-qualifying) of submersible pumps.** Coordination of pump selection and procurement with the other pump stations in the conveyance system will be required during final design. Similar characteristics and requirements will ease procurement and operation/maintenance of the pumps.

Section 8

Limitations

This document was prepared solely for Silicon Valley Clean Water (SVCW) in accordance with professional standards at the time the services were performed and in accordance with the contract between SVCW and Brown and Caldwell dated December 16, 2016. This document is governed by the specific scope of work authorized by SVCW; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work.

Further, Brown and Caldwell makes no warranties, express or implied, with respect to this document, except for those, if any, contained in the agreement pursuant to which the document was prepared.

All data, drawings, documents, or information contained this report have been prepared exclusively for the person or entity to whom it was addressed and may not be relied upon by any other person or entity without the prior written consent of Brown and Caldwell unless otherwise provided by the Agreement pursuant to which these services were provided.

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Section 9

References

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Appendix A: Grit Analysis Technical Memoranda

- Grit Migration Predictions When Using a Tunnel for Storing Wastewater Technical Memorandum, December 2015, prepared by Bob Donaldson.
- Headworks Facility Project – Grit Facility Design Criteria Update", January 2017, prepared by CDM Smith.

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Grit Migration Predictions When Using a Tunnel for Storing Wastewater Technical Memorandum, December 2015, prepared by Bob Donaldson.

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Technical Memorandum

To: ***Kim Hackett* - Silicon Valley Clean Water**

From: ***Bob Donaldson* - Collaborative Strategies Consulting**

Subject: ***Grit Migration Predictions When Using a Tunnel for Storing Wastewater***

Date: 17 DEC 2015 – V3

Introduction

This Technical Memorandum is being issued at the request of Silicon Valley Clean Water (SVCW) in order to gain a better understanding of how storing wastewater flows in the tunnel will impact the migration of grit present in the liquid stream. While the data presented will give SVCW insight for making determinations concerning grit migration related to diurnal storage, the primary focus of this memorandum is to investigate grit migration issues when the tunnel is used for the more extreme purpose of wet weather grit storage. Furthermore, the wet weather scenarios investigated will be the worse case grit loading scenarios based on conditions experienced in the 1990's. The reason for this more extreme test is with the intent that by examining this data it becomes the best way to make sure that SVCW is building a system that is still reliable even under the most demanding conditions, even if those conditions are considered rare. Tunnel and RLS issues are contemplated.

Assumptions

Grit Characteristics

- This tech memo will focus on the grit characteristics that are encountered during wet weather events that could be classified as either "Fine Silt" or "Very Fine Silt."
- Fine or Very Fine (wet) Silt will have an assumed density of 125 lbs/ft^3.
- The daily grit characteristics produced by average dry weather flows will be considered either Course Sand or Very Course Sand.

Grit Production – Daily Dry Weather

- Daily Dry Weather Grit production is assumed to be 2 to 3 yards of course sand per day.

Grit Production During Significant Storm Events

- The assumed amount of Fine or Very Fine Silt produced during worse case storm events are based solely upon the recollection of the author.
- These assumptions are based on filling a half trailer, one trailer, two trailers or three trailers. As these trailers were changed out based on weight to avoid overloading, at weights above 21.5 tons, it will be assumed that each trailer produced approximately

20 tons of grit. One, two and three trailers of grit are used for the calculation tables, Tables 5 through 10.
- During smaller storm events half trailers were typical. During significant storm events (especially those that were the first very large storm events of the season) during the years starting in 1985 and ending in 2000, one to two trailers would be produced (or 20 to 40 tons) over a 24 to 36 hour period.
- In one particular event there were three trailers, or ~ 60 tons, produced over an 18 to 24 hour period.
- In another separate event, two of the four primary tanks suffered complete failure during a storm event because grit accumulation outpaced the system's ability to remove it.

Grit and Velocity

- For this report it is assumed that suspended grit will settle from the liquid stream at velocities of less than 2 feet per second (fps) and that the grit will not be re-suspended (once settled) until the liquid stream achieves a velocity of 4 (or more) feet per second.
- While 2 fps is an accepted "text book number" where course sand will drop out of the liquid stream, fine silts won't drop out until velocities are under 2 fps. Nonetheless 2 fps will be used in all cases so as to preserve the conservative nature of the predictions made in this report.

Significant Storm Events

- February storms of 1986, 1992 and 1993/January and March of 1995/March of 1996/New Years day of 1997/ January and February of 1998

Findings

The findings will be organized using the following general headings:

- **Dry Weather**
- **Grit Migration during Dry Weather (various related topics)**
- **Wet Weather**
- **Grit Migration**
- **Settling and Resuspension**
- **Table 1 – Interceptor Velocities**
- **Drop Point (Diagram 1)**
- **Table 2 – Length of Grit Loading Zones**
- **Accumulation During Filling (Diagram 2)**
- **Concentration During Draining (Diagram 3)**
- **Tunnel Fouling**
- **Predicting and Managing Concentrated Grit Loads**
- **Managing the System to Obtain Desired Results**
- **Standard Operating Procedure for Emptying the Tunnel after Storm Events**
- **Raw Data Tables 3 and 4**
- **Calculation Tables 5 through 10**
- **Conclusions**
- **Acknowledgments and Disclaimer**

Dry Weather

Grit Migration During Typical Dry Weather Flows

Table 1 shows typical flows experienced by the system during dry weather and wet weather conditions with both free-flow condition and full pipe conditions. **Table 1** also shows that typical dry weather system flows should be enough to move grit down stream from the San Carlos connection to the plant if total system flows are above 20 MGD for some time during the diurnal cycle.

If flows remain above 20 MGD during dry weather for one hour, all grit deposited that day will be removed. It's important to note that it's not necessary that the 20 MGD for one hour be achieved on a daily basis. For example, if 20 MGD were achieved every other day for 30 minutes, the girt would take four days to migrate to the RLS. There is no reason to believe that this process would be a problem, unless the down stream RLS and degritting system could not process four days of stored grit (or about 8 to 10 yards) in case there was a day where the system did hit 20 MGD for one hour with several days worth of grit stored in the tunnel.

This suggestion is not meant to promote one operational mode over another but is noted here to reveal that several days of stored grit migrating down the tunnel is not a problem from a tunnel perspective. The tunnel could contain many weeks worth of dry weather grit and not be adversely impacted in terms of performance. There is more than one way to operate this system to satisfy removal of dry weather grit deposits.

Grit Migration During Typical Dry Weather Flows Upstream of the San Carlos Connection

The **Table 1** scouring flows also apply to the section upstream from the San Carlos connection, indicating flows from Redwood City and West Bay may not be typically adequate to avoid accumulating grit in this section of the tunnel during dry weather conditions. That being said, if very short periodic maintenance flushing events (once a week or every couple weeks) could be implemented to get the grit just past the San Carlos connection (say 3500 ft. / 4 fps [20 MGD]) = 15 minutes, typical system flows down stream from the San Carlos connection should be adequate to remove dry weather grit when system wide flows are over 5 MGD for grit already suspended or over 20 MGD for brief moments to get the grit suspended then over 5 MGD to transport it.

Grit Migration When Using the Tunnel for Diurnal Storage

The data in **Table 1** strongly indicate that a daily draining of the tunnel with a momentary tunnel flow of 20 MGD, when empty, will provide the sufficient flushing to remove any grit deposited during a diurnal storage episode. Assuming Diurnal storage occupying ~ 6000 feet of tunnel length and resuspension at 4 fps = 20 MGD @ 25 minutes will remove all grit.

Table 1

Flow, MGD	Interceptor Velocity, fps			
	11 Foot Diameter		13 Foot Diameter	
	Condition: Free Flow	Condition: Full Pipe	Condition: Free Flow	Condition: Full Pipe
2	1.25		1.00	
5	2.31		1.95	
10	3.18		2.94	
15	3.71		3.50	
20	4.19		3.90	
25	4.65		4.26	
30	5.02	0.46	4.60	0.33
40	5.44	0.62	5.26	0.44
50	5.81	0.77	5.73	0.55
55	6.03	0.85	5.89	0.61
75	6.78	1.15	6.41	0.83
95	7.15	1.46	7.04	1.05
105		1.62		1.16
	B&C DEC 2015			

Wet Weather

Many of the dry weather flows and ***All*** free-flow conditions experienced during wet weather (say over 30 MGD) ***will always move suspended*** wet-weather-silt-grit from the tunnel. Under ***All*** wet weather flows (including 105 MGD) a full pipe condition ***will always store grit***.

Grit Migration When Using the Tunnel for Wet Weather Storage

The most important aspects concerning grit migration and tunnel storage of wet weather flows are:

A) The rate and process of grit accumulation when the tunnel is in a ***free-flowing*** condition and ***filling to create a full-pipe condition***, and

B) The rate and process of grit being re-suspended in the liquid stream as the ***stored*** volume of accumulated wastewater and grit is drained to the RLS, in a full-pipe condition ***draining to create a free-flow condition***.

The rate of grit deposition, over a particular period of time during the filling phase, will distribute grit along the entire length of the tunnel in those locations that experience a near full pipe and full pipe condition. When the tunnel is drained after a storm event, the collection and concentration of grit will play a key factor in determining how adjusting draining rates during the draining process can mitigate adverse impacts on the the down stream processes, namely the RLS and the degritting systems at the Headworks.

Settling and Resuspending

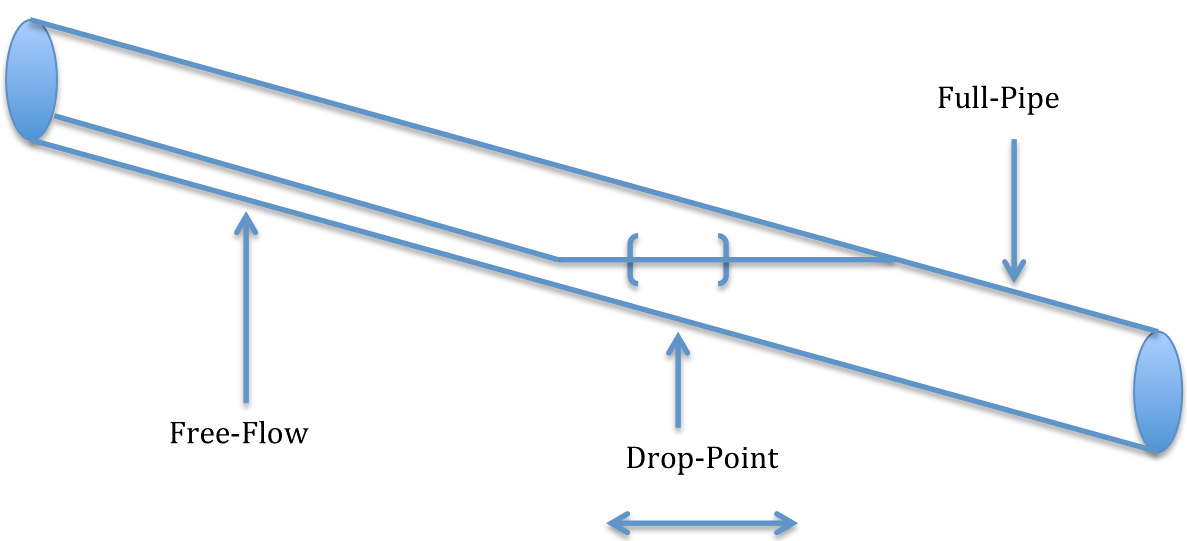
The data in **Table 1** clearly indicates that any free flowing flows in the tunnel from ~ 5 to > 95 MGD ***will result in velocities in excess of two feet per second. In other words, free flow data confirms that grit will <u>never</u> accumulate*** in the tunnel as long as the free-flow flow is above ~5 MGD. **Table 1** also shows that any free-flow conditions above 20 MGD will create resuspension velocities of over four feet per second.

Table 1 data also shows that in every scenario, where the tunnel section is completely full, whether that is an 11 or 13-foot tunnel, at no time does the velocity ever become more than 2 feet per second. ***This data indicates that whenever the tunnel is in a full-pipe condition it <u>always</u> stores grit***.

The current slope of the tunnel is assumed to be 0.0015 meaning that for every 1000 linear feet of tunnel the elevation profile will drop or rise by 1.5 feet. Therefore, at the point of complete inundation at the discharge end of an 11-foot tunnel (inside diameter), the pool created will occupy over 7000 linear feet of tunnel. This very large pool will remain this size for the first 10,500 feet of tunnel filling at which time it will start to be compressed as the pool hits the upstream end of the tunnel at Inner Bair Island causing it to shrink in size until the tunnel is (near) full. Knowing the length of this pool gives some perspective related to the very large portion of "partially filled" pipe that occupies an area of pipe with the free-flow condition on the upstream side of this pool and the full pipe condition on the down stream side of the pool. It is within the partially filled pipe location where the grit falls out of suspension and accumulates.

Knowing that ***free-flow conditions above 5 MGD always MOVES grit*** through the tunnel and that ***full-pipe conditions, regardless of flow, always STORES grit*** in the tunnel, gives us a clear indication that at some point in-between these two conditions, in this very long pool, the wastewater velocity will slow to the extent where the grit will start to settle out of the liquid stream. This report will label this important grit settling location with a unique identifier called the "***Drop-Point***." (**SEE Diagram 1**)

Diagram 1 The Drop-Point is the partially filled pipe location where the velocities drop below 2 fps allowing grit to drop out of the liquid stream. The Drop-Point location moves up or down stream depending on two factors.



The Drop-Point

The distance between the free-flow point and the drop-point defines the front end and the back end of the Grit Load Zone. The free-flow front end is where we know the grit is being resuspended and the Drop-point back end is where we know the grit is settling out because the velocity has dropped below 2 fps.

Its important to track the Drop-Point location, ***because it gives key insights that are necessary to understand in order to successfully predict the behavior of grit migration when using the tunnel for storage purposes***. The Drop-Point changes location based on two factors:

Factor One: as the level of the tunnel changes during a filling or draining mode, the point of slowed velocity (settling velocity) will move the Drop-Point either up or down stream with the changing level in the tunnel.

Factor Two: as the flow into the tunnel from the outlying gravity systems either decreases or increases, the Drop-Point will either move up-stream or down-stream, respectively. As free-flows increase the velocities will increase pushing the drop-point farther down stream allowing it to penetrate more deeply into the partially full tunnel. Conversely as the free-flow rate slows the Drop-Point velocities will move upstream into the shallower portion of the pool. (**SEE Table 2**)

If the flow does not change the Drop-Point will not change based on Factor Two flow changes but will continue to change its location (moving up or down the partially filled tunnel) based solely on the rising or falling level of the tunnel as mentioned in Factor One.

Table 2

"GRIT LOADING ZONE" (Length between free-flow entry point and drop-point)				
	11 Foot Diameter		13 Foot Diameter	
Flow, MGD	Length between free-flow entry point and drop-point (ft)	Depth of partially full pipe (in)	Length between free-flow entry point and drop-point (ft)	Depth of partially full pipe (in)
15	470	2.4	900	2.3
20	840	2.9	1260	2.5
25	1040	3.2	1400	2.7
30	1240	3.5	1790	3.3
40	1590	4.0	2310	4.1
50	2220	5.0	2630	4.6
55	2460	5.4	2760	4.8

B&C DEC 2015

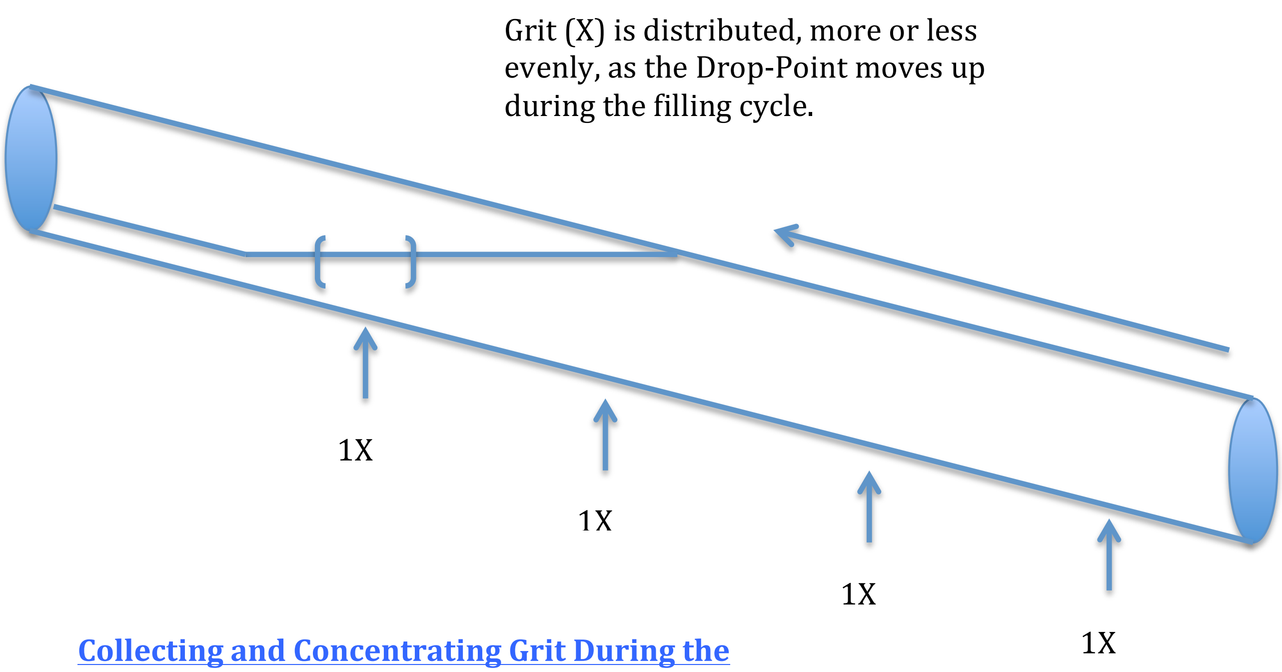
Accumulating Grit During the Filling Phase

As the tunnel is filling from a free-flow condition towards a full-pipe condition, grit will be deposited along the way at the Drop-point, thereby distributing the grit along the entire length of the tunnel invert as the filling process slows flows below 2 fps. The settled grit will not necessarily be evenly distributed along the length of the tunnel because of the hydraulic changes impacting the drop-point location typically encountered during the dynamic flow changes experienced during a storm event (because of the two factors just mentions).

However the distribution will be evenly portioned "enough" that this report will assume that *the grit entering the interceptor will nonetheless settle out, more or less, along the entire length of that portion of tunnel that achieves a near full-pipe condition* (**See Diagram 2**). The reason this assumption can be made is because having the original grit deposits being slightly uneven has little affect on what is to follow: *grit collection and concentration during the draining phase*.

At the moment when the tunnel stops rising at the end of a filling phase, but remains full (e.g. the flow into the tunnel from the contributing systems and the flow out of the tunnel via the RLS are the same and remain the same) the Drop-Point will remain at a stationary location, depositing the incoming grit at that same location until flow conditions change the location of the Drop-Point.

Diagram 2



Collecting and Concentrating Grit During the Draining Phase

As the tunnel switches over from a filling phase to a draining phase the Drop-Point will start to change location moving towards the RLS with the descending water level. As the Free-flow point also descends with the dropping level of the pool, the increased velocity always caused by the free-flow point (remember Table 1) will start to resuspend the grit that was deposited during the filling phase.

As the newly resuspended grit travels down stream past the Drop-Point (because not only is the level dropping but the flow in the tunnel continues flowing down stream) ***this recently resuspended grit will settle again but now on top of a layer of grit that is already present as it was deposited during the initial filling phase***.

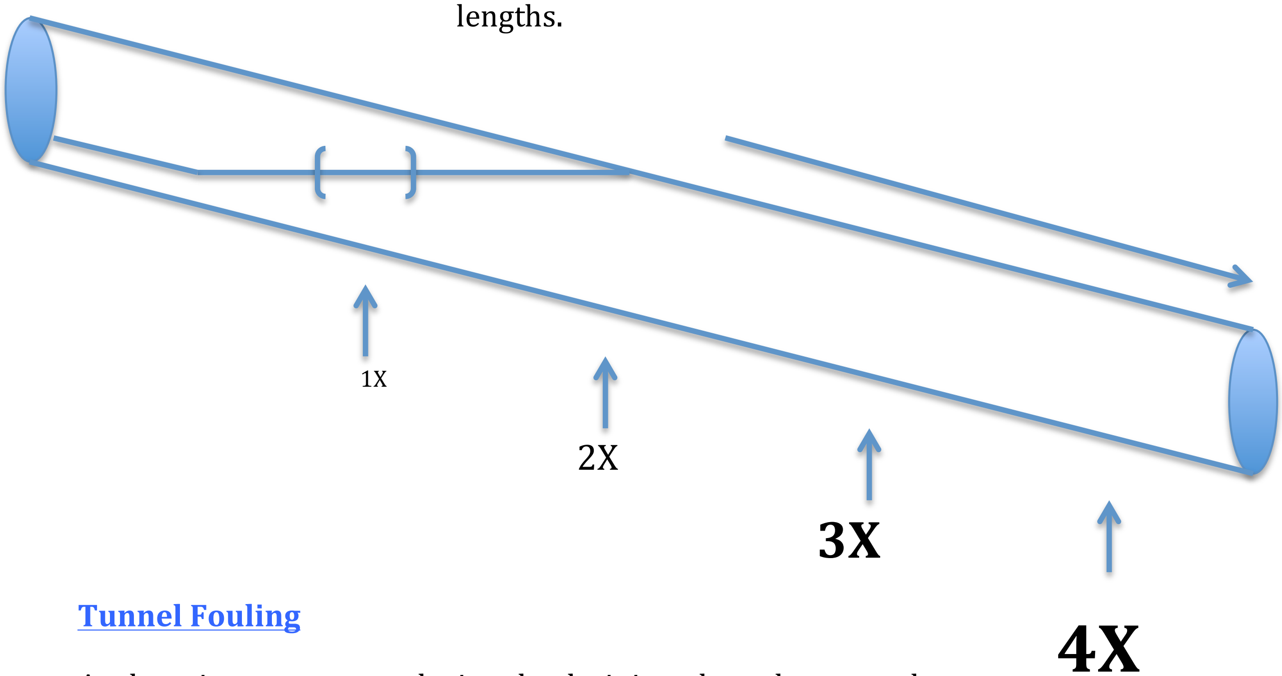
As the draining phase again continues to drop the level and Free-Flow point arrives down stream with the resuspension velocity necessary to resuspend grit, the Free-Flow point will eventually encounter the location of the two layers of grit. As the Free-Flow velocity arrives, the grit that had just previously been resuspended and had settled out, ***and*** now also the original grit layer, are both being resuspended and will both be sent down stream.

Both newly resuspended layers will again be sent down stream, again past the Drop-Point to now resettle on yet a third original layer of grit that was settled during the filling stage. As the draining phase continues the free-flow-resuspension-velocity will now pick up the three layers and deposit them on a forth layer ***and so on and so forth*** (**SEE Diagram 3**).

As this process continues collecting and concentrating the grit, the final draining process of the tunnel will be discharging larger amounts of grit to the RLS in a shorter period of time than would have happened otherwise, as compared to a situation had there been no wet weather storage in the tunnel. Predicting and managing the delivery of the concentrated grit load will be addressed later in this report.

Diagram 3

The descending Free-Flow point re-suspends and the descending Drop-Point then re-settles the ***same grit layers, over and over again,*** during a draining cycle. Grit (X) is now collected, and successively concentrates, as larger amounts of grit span ever-shorter tunnel lengths.



Tunnel Fouling

As the grit concentrates during the draining phase, between the Free-Flow point and the Drop-Point, a question arises that asks:

What are the chances that the grit could pile up in the tunnel to the extent that it would be completely block the tunnel?

The **Table 1** data, along with a closer examination of silt characteristics, seems to indicate that the occurrence of a blocked tunnel is extremely unlikely even under the worst silt-grit conditions because of the amount of grit that is expected and how water velocities change with narrowing orifices.

While a ***full*** tunnel will always store grit a *partially "fouled" full tunnel, will at some point, never store grit*. As the grit starts to concentrate (pile up in the tunnel) and a more narrow tunnel diameter results, the velocity will naturally increase when a successively *smaller bore is available for the same flow* (Bernoulli). And as the fouling creates ever smaller diameters for a given flow, the velocity will continue to increase until it either keeps the grit in suspension that is already in suspension (≥ 2 fps) no longer contributing to the fouling and/or the velocity will increase to the extent that it is scouring the more "narrowed bore" by removing grit via resuspending it at velocities of ≥ 4 fps.

Lastly, "wet fine silt" densities are upwards of 125 lbs/ft^3 (Multiple Sources). Assuming "wet" and assuming 60 tons as a worse case, the resulting volume is about 960 cubic feet of material. If distributed equally in the last 1000 feet of tunnel this would be about one cubic foot of slit per linear foot of tunnel length. Which means it's occupying (blocking) about 1% of the available surface area used for flow assuming an 11-foot diameter tunnel. This is not enough blockage to impact any flow under any condition.

Occupying 100 feet of tunnel the blockage would be 10% of available surface area used for flow, again not nearly enough tunnel blockage to have any affect in flow.

In other example, all 60 tons would need to (simultaneously) occupy only ten feet of linear tunnel space, in a highly concentrated fashion, in order to completely block the tunnel. It becomes very difficult to imagine how this would ever happen knowing the various flows involved and the worse case amounts of grit expected.

Predicting and Managing Delivery of the Concentrated Grit Loads

A few items before we dig into this section.

First, the following information are estimates based on the hydraulic model from Brown & Caldwell combined with assumptions as stated previously at the beginning of this report and again combined with the recollection of past events of silt-grit loading. These are only quasi-empirical guidelines.

Second, the grit zones are probably not as "tight" or as short as noted in the Grit Loading Zone table (**Table 2**). In other words, the grit is probably not as concentrated as what is assumed here. The reason for that is we are using a 2 fps grit drop out velocity assumption. For fine slits the drop out number is lower, downwards to 1 fps (organics are typically assumed to drop out at or less than 1 fps). As such the finer silt is still moving under 2 fps slightly expanding the grit zone and causing the grit zone to be slightly less concentrated that what is indicated. This is good news. And we want to stay with 2 fps so our estimates are conservative.

Three, there are two very important dynamics, occurring simultaneously, that are working with each other to either increase or decrease that actual tons of grit (tons per hour) delivered to the RLS and the degritting system.

A) What we want: Stretching out the grit zone so there is less grit per linear foot. In other words, longer grit zones with less concentration.

Remember the earlier description, using Diagram 3, where the free-flow and drop-point zones sequentially over lap, causing repeated patterns of resuspending and resettling grit over and over again, causing the grit to be ever more concentrated. What we know as a result of this phenomenon ***is the longer the distance this grit zone is the less these over lap cycles occur and lower the concentration exists in the grit loading zone.*** The higher the rate of Free-flow entering the partially full pipe the less recycling and concentrating of grit will occur. Higher flows work in our favor.

B) What we want: Slowing the rate of grit arrival so it is being introduced more slowly over time into the RLS.

The second important parameter is the speed at which this "grit load zone" arrives at the RLS. The faster this grit load zone arrives at the RLS the heavier the grit load will be on the downstream processes. Slowing the experience rate at the RLS by minimizing the delta between the exit flow at the RLS and the flows entering the tunnel from the gravity systems is ***highly effective at reducing grit loading rates on the RLS***. For example, if the flow into the system after a storm is at 40 MGD, its better the pump the RLS at 45 MGD, instead of 65 MGD just before the grit load zone enters the RLS. The delta 5 MGD (45-40=5)has the grit load zone entering at 208,000 gallons an hour whereas the delta 25 MGD (65-40=25) has the grit loads zone entering at 1,042,000 gallons an hour.

In an 11-foot tunnel, 208K gallons an hour is draining the tunnel and bringing in the grit load zone at 322 feet per hour, whereas the 1.042M gallons is draining the tunnel bringing in the grit zone at 1534 feet per hour!

How to Manage the System to Obtain the Desired Conditions

The primary objectives of managing the tunnel once it has been filled from a storm event are:

1- Stretching out the grit zone, so its less concentrated, because its desirable to lessen the grit load on the RLS and we now know this is best done by drawing down the tunnel during influent high flows.

2- Slowing the arrival and duration of the grit zone so the grit is "metered" into the system slowly to reduce the loading rate (tons/hour).

3- The tunnel is drawn down in a reasonable amount of time so as to prepare for another storm event.

As the following data will reveal objective #1 and objective #2 are competing objectives with objective #3.

If the delta between the influent flow to the tunnel and the effluent flow from the RLS is kept very low (objective #1 and #2), lets say 5 MGD, it will take an exceedingly long time to drain and will work against meeting objective #3. (assumed to be too long)

KEY POINT: The best way to resolve this conflict is to better understand the difference in importance between objectives #1 and #2. While both are important, ***the following data tables will reveal that SLOWING the flow into the RLS is the most effective method by which to lower grit loading on the RLS (objective #2) even if the grit zone has suffered from some concentration (objective #1) because we needed higher flows to initially drain the tunnel in order that it be drained in a reasonably short period of time (objective #3).***

Managing the Draining Process is the key to 1) gaining the benefits of using the tunnel for storage 2) draining the tunnel as soon as practical for the next storm event and 3) not overloading the RLS with grit.

Standard Operating Procedure for Emptying the Tunnel after the Storm Event

(This assumes the flow into the plant will be held at 55 MGD as the tunnel is draining. This assumption can change and this SOP will still be effective at meeting the objective if in fact 55 MGD can be replaced with 60 or 65 MGD or higher flows into the plant)

This SOP was developed using the calculation tables 5 and 6 below.

STEP 1 - As the storm event starts to abate and the flows going into the tunnel from the contributing systems start to drop, maintain flow into the plant at 55 MGD (or higher). (NOTE: *This will start the draining process*.)

STEP 2 – As the flow continues to drop from the contributing systems and the plant flow is held at 55 MGD ***the draining process will accelerate***. Maintain 55 MGD. (NOTE: *This step causes a necessary acceleration of the draining process to shorten the draining time even though it will also cause some additional concentration of the grit load zone - we will take care of that at step 3).*

STEP 3 – When the tunnel reaches a point where the last 1500 feet of tunnel (or 2000 feet if you want to be more conservative) remains partially full and continues to drain, ***switch the RLS pumping output to within 5 MGD above the combined flows into the system***. This is called the **RLS Delta 5 pumping mode**. (NOTE: *This will is SLOW the entry of the grit-loading zone and will lengthen the duration of which the RLS experiences the grit-loading zone thereby significantly lowering the loading rate in tons/hour*.)

STEP 4 – Remain in the "**RLS Delta 5 Pumping Mode**" until the contents of the tunnel are completely emptied. (NOTE: *This pumping mode can be programed into a PLC algorithm, the remaining 1500 or 2000 feet of partially filled tunnel can have its own measurement but will also be clearly indicated at the exit point of the tunnel and/or entry point of the RLS wet well*.)

--- End of SOP ---

The above SOP was developed (as noted using the calculation tables 5 and 6 below) to demonstrate that slowing the grit load zone into the RLS, at the very end of the draining process, will meet objectives #2 and #3 which will suffice in avoiding grit overload of the downstream processes, even at the partial expense of objective #1.

A few more notes that are revealed by the data before we dig into the tables:

- While grit loading zone concentration matters, ***slowing the flow*** in response to the concentrated grit zones is ***highly effective at reducing grit-loading rates to the RLS***.

- ***Using a 13 foot diameter*** instead of an 11 foot tunnel doesn't change the total volume of grit but it ***helps significantly to reduce grit loading rates*** of tons per hour by ***two-thirds*** *but will also slow drain times.*

- Remember the intent of this report was to ***prepare SVCW for worse case scenarios***, perhaps 90% of the storms experienced will not give SVCW the type of worse case silt-grit numbers listed in this report.

- The time necessary to empty the tunnel assumes the tunnel is full and that full condition will not happen during most of the storms if 55 MGD is maintained to the plant with the currently predicted flows from the member agencies. In addition, time to empty the tunnel listed in the calculation tables is dependent on the receiving flows dropping as recorded and in some cases they may drop faster-sooner or less-later or any combination.

Raw Data Tables

Tables 3 and 4 are the raw data tables that were used for the calculation tables 5 through 10 that follow.

(Note that the color-coding of the raw data **Table 3** (Influent Flow / Size of Grit Zone) and **Table 4** (Delta / Arriving Rate of Grit) correspond with the colored data fields in the calculation tables 5 thru 10.

Table 3 – Length of Grit Zone (Table 2 Again)

Grit Zone Length				
	11 Foot Diameter		13 Foot Diameter	
Flow, MGD	Length between free-flow point and drop-point (ft)	Depth of partially full pipe (in)	Length between free-flow point and drop-point (ft)	Depth of partially full pipe (in)
15	470	2.4	900	2.3
20	840	2.9	1260	2.5
25	1040	3.2	1400	2.7
30	1240	3.5	1790	3.3
40	1590	4.0	2310	4.1
50	2220	5.0	2630	4.6
55	2460	5.4	2760	4.8

B&C DEC 2015

Table 4 – Rate of Grit Zone Arrival

	RLS is Pumping At 55 MGD				
	13 Foot Tunnel		11 Foot Tunnel		
Delta (to 55)	Flow into the Tunnel (MGD)	Speed at which pond is draining (Feet / Hour)	Flow into the Tunnel (MGD)	Speed at which pond is draining (Feet / Hour)	Delta (to 55)
40	15	1775	15	2351	40
35	20	1574	20	2105	35
30	25	1361	25	1810	30
25	30	1131	30	1534	25
20	35	914	35	1248	20
15	40	688	40	953	15
10	45	475	45	637	10
5	50	227	50	322	5
B&C DEC 2015	>OR: 220 average foot rise/drop per 5 MGD		> OR: 300 average foot rise/drop per 5 MGD		

Calculation Tables

Tables 5 through 10 are calculation tables that illustrate the relationship between the delta of in and out flows, the length of the grit zone and the rate of arrival of the grit zone arrives at the RLS and the degritting system.

Table 5 - 11 foot at 55 MGD (preferred based on drain time)

11 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 55 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	25	20	1040	1810	0.6	35	0.6
		40	1040	1810	0.6	70	0.6
		60	1040	1810	0.6	104	0.6
25	30	20	1240	1534	0.8	25	0.8
		40	1240	1534	0.8	49	0.8
		60	1240	1534	0.8	74	0.8
15	40	20	1590	953	1.7	12	1.7
		40	1590	953	1.7	24	1.7
		60	1590	953	1.7	36	1.7
5	50	20	2220	322	7.9	3	7.9
		40	2220	322	7.9	5	7.9
		60	2220	322	7.9	8	7.9

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet ~ 15 hour pump down - Full Tunnel - Assumes in flow at 25 MGD							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 25	20	1040	322	3.2	6	3.2
		40	1040	322	3.2	12	3.2
		60	1040	322	3.2	19	3.2

11-foot tunnel - While the grit zone is only 1040 feet long (2220 feet would be better), by introducing the grit load zone over a 3-hour period at the end, the total drain times remain reasonable while not over loading the RLS with grit. 6 tons represents about 3.5 yards of silt material and 19 tons is a little over 11 yards of material per hour a 3-hour period. In order to get a longer and less concentrated grit-loading zone of 2220 feet the drain time would be increased significantly (over 57 hours !!).

Table 6 - 13 foot @ 55 MGD (preferred based on Grit Load)

13 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 55 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	25	20	1400	1361	1.0	19	1.0
		40	1400	1361	1.0	39	1.0
		60	1400	1361	1.0	58	1.0
25	30	20	1790	1131	1.6	13	1.6
		40	1790	1131	1.6	25	1.6
		60	1790	1131	1.6	38	1.6
15	40	20	2310	688	3.4	6	3.4
		40	2310	688	3.4	12	3.4
		60	2310	688	3.4	18	3.4
5	50	20	2630	227	11.6	2	11.6
		40	2630	227	11.6	3	11.6
		60	2630	227	11.6	5	11.6

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet ~ 21 hour pump down - Full Tunnel – Assumes influent flow at 25							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 25	20	1400	227	6.2	3	6.2
		40	1400	227	6.2	6	6.2
		60	1400	227	6.2	10	6.2

13-foot tunnel - While this grit zone is only 1400 feet long (2630 feet would be better), by introducing the grit load zone over a 3-hour period at the end, the total drain time is about 6 hours longer that the 11-foot tunnel but grit loading is lower with the same delta 5 pumping mode. 3 tons represents about 1.8 yards of silt material and 10 tons is a little over 6 yards of material per hour a 6-hour period. In order to get a longer and less concentrated grit-loading zone of 2630 feet the drain time would be increased significantly (over 82 hours !!).

Table 7 - 11 Foot @ 45 MGD (not preferred)

11 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 45 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	15	20	470	1810	0.3	77	0.3
		40	470	1810	0.3	154	0.3
		60	470	1810	0.3	231	0.3
25	20	20	840	1534	0.5	37	0.5
		40	840	1534	0.5	73	0.5
		60	840	1534	0.5	110	0.5
15	30	20	1240	953	1.3	15	1.3
		40	1240	953	1.3	31	1.3
		60	1240	953	1.3	46	1.3
5	40	20	1590	322	4.9	4	4.9
		40	1590	322	4.9	8	4.9
		60	1590	322	4.9	12	4.9
Pump Down at Delta 30 Switch to Delta 5 last 1500 feet - 17 hour pump down – Assumes 15 MGD influent – not likely							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 30	20	470	322	1.5	14	1.5
		40	470	322	1.5	27	1.5
		60	470	322	1.5	41	1.5

Table 8 – 13 Foot @ 45 MGD (not preferred)

13 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 45 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
30	15	20	900	1361	0.7	30.2	0.7
		40	900	1361	0.7	60.5	0.7
		60	900	1361	0.7	90.7	0.7
25	20	20	1260	1131	1.1	18.0	1.1
		40	1260	1131	1.1	35.9	1.1
		60	1260	1131	1.1	53.9	1.1
15	30	20	1790	688	2.6	7.7	2.6
		40	1790	688	2.6	15.4	2.6
		60	1790	688	2.6	23.1	2.6
5	40	20	2310	227	7.9	3	7.9
		40	2310	227	7.9	5	7.9
		60	2310	227	7.9	8	7.9

Pump Down at Delta 30 Switch to Delta 5 last 1500 feet ~24 hour pump down - Full Tunnel – assumes 15 MGD – not likely							
Pump Down @ Delta 30 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 15	20	900	227	4.0	5	4.0
		40	900	227	4.0	10	4.0
		60	900	227	4.0	15	4.0

Table 9 – 11 Foot @ 35 MGD (not preferred)

11 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 35 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
20	15	20	470	1248	0.4	53	0.4
		40	470	1248	0.4	106	0.4
		60	470	1248	0.4	159	0.4
15	20	20	840	953	0.9	23	0.9
		40	840	953	0.9	45	0.9
		60	840	953	0.9	68	0.9
10	25	20	1040	637	1.6	12	1.6
		40	1040	637	1.6	25	1.6
		60	1040	637	1.6	37	1.6
5	30	20	1240	322	3.9	5	3.9
		40	1240	322	3.9	10	3.9
		60	1240	322	3.9	16	3.9

Pump Down at Delta 30 Switch to Delta 5 last 2000 feet ~ 20 hour pump down - Full Tunnel Assumes 15 MGD influent – not likely							
Pump Down @ Delta 20 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 15	20	470	322	1.5	14	1.5
		40	470	322	1.5	27	1.5
		60	470	322	1.5	41	1.5

Table 10 – 13 foot @ 35 MGD (not preferred)

13 Foot Tunnel / 20 - 40 - 60 Tons - Grit Delivery Rates / RLS Pumping @ 35 MGD							
Delta (MGD)	Flow Into Tunnel (MGD)	Grit (Tons)	Distance Between Free-Flow Point and Drop-Point (Feet) See flow	Rate at Which Free-Flow Location is Arriving at RLS (Feet/Hour) See Delta	Total Duration Between Drop-Point Arrival and Free-Flow Arrival at RLS (Hours)	Approximate Delivery Rate of Grit (Tons / Hour)	Hours Experiencing Grit Loading
20	15	20	900	914	1.0	20	1.0
		40	900	914	1.0	41	1.0
		60	900	914	1.0	61	1.0
15	20	20	1260	688	1.8	11	1.8
		40	1260	688	1.8	22	1.8
		60	1260	688	1.8	33	1.8
10	25	20	1400	475	2.9	7	2.9
		40	1400	475	2.9	14	2.9
		60	1400	475	2.9	20	2.9
5	30	20	1790	227	7.9	3	7.9
		40	1790	227	7.9	5	7.9
		60	1790	227	7.9	8	7.9

Pump Down at Delta 20 Switch to Delta 5 last 1500 feet ~28 hour pump down - Full Tunnel – Assumes 15 MGD influent – not likely							
Pump Down @ Delta 20 Switch to Delta 5 last 1500 feet	Initial tunnel in flow - 15	20	900	227	4.0	5	4.0
		40	900	227	4.0	10	4.0
		60	900	227	4.0	15	4.0

Conclusions

- Free-flow conditions above 5 MGD will ***always*** move grit and full-pipe conditions will ***never*** move grit, regardless of the currently accepted system flows applied to a full tunnel up to and including 105 MGD.

- The data in **Table 1** strongly indicate that a daily draining of the tunnel with a momentary tunnel flow of 20 MGD, when empty, will provide the sufficient flushing to remove any grit deposited during a diurnal storage episode. Assuming Diurnal storage occupying ~ 6000 feet of tunnel length and resuspension at 4 fps = 20 MGD @ 25 minutes will remove all grit.

- The **Table 1** scouring flows also apply to the section upstream from the San Carlos connection, indicating flows from Redwood City and West Bay may not be typically adequate to avoid accumulating grit in this section of the tunnel during dry weather conditions. That being said, if very short periodic maintenance flushing events (once a week or every couple weeks) can be implemented to get the grit just past the San Carlos connection (say 3500 ft. / 4 fps [20 MGD]) = 15 minutes, typical system flows down stream from the San Carlos connection should be adequate to remove dry weather grit on a daily basis.

- Daily dry weather diurnal storage shows that full-pipe cycles will settle and store grit and that free-flow cycles can re-suspend grit during a single diurnal cycle. Free-flows below ~5 MGD and full-pipe conditions will allow grit will settle from the liquid stream and will be re-suspended when experiencing free-flow flows of 20 MGD.

- As the tunnel is filling from a free-flow condition to a full-pipe condition, the grit entering the interceptor will settle out more or less along the entire length of that portion of the tunnel that achieves a full-pipe condition.

- The data seems to indicate that tunnel will not have significant fouling issues related to grit accumulation as the Free-Flow velocities generated by flows ***over*** 20 MGD are more than adequate to scour the tunnel. Calculations assuming 60 tons of wet fine silt indicates having enough grit concentrated in a single location to completely block the tunnel, as extremely unlikely.

- The rate of grit deposition, over a particular period of time during the filling phase, will distribute grit along the entire length of the tunnel that has been nearly filled. The rate of grit collection during the draining phase, will concentrate the total amount of stored grit and will deliver it at the RLS in a more concentrated fashion than had the grit arrived based on a distributed migration rate provided (by a typical or) the same storm event not using the tunnel for storage.

- Whenever draining the tunnel at maximum velocity (say 50 MGD into the tunnel and pumping 55 MGD from the RLS to the plant) this high flow - low delta combination will minimize grit loading (tons grit/hour) on the downstream processes by expanding the grit zone (lowering its concentration and slowing the grit zone introduction to the RLS. This method of draining will also cause the drain time to be extremely long.

- Conversely, draining the tunnel at lower velocities (say 20 MGD into the tunnel while pumping 40 MGD from the RLS) will maximize grit-loading spikes to downstream processes by concentrating the grit zone and introducing the grit zone at a faster rate even though this will drain the tunnel in a more reasonable time frame.

- The best method by which to manage the tunnel after a storm, in order to meet the top three objectives (stretching the grit zone, slowing the rate of grit loading, draining the tunnel as quickly as possible) is to follow the SOP provided in this report. ***Drain the tunnel rapidly at the beginning and slow the flow just before the grit load zone arrives***.

- The 13-foot diameter tunnel allows for lower grit loading rates on the RLS, and a slower drain rate than the 11-foot tunnel. The 11-foot tunnel allows for reasonable grit loading and the fastest drain times.

- Grit introduction to the RLS can be adjusted up or down by simply using a different delta setting. If it is desired that less grit be introduced over time, simply use a lower delta set point towards the end of the draining phase.

- Based on the data contained in this report the primary question that needs answering is:

How will the down stream processes be prepared to handle the impact of these grit loads being presented by this data?

(Those being the RLS pumping station, first, and the Headworks degritting process that follows, second.)

Acknowledgement and Disclaimer

This report would have been impossible to complete without the dedicated help of Kevin Kai at Brown and Caldwell who, working on the project and taking my calls on weekends, undauntedly fulfilled my numerous obscure requests for hydraulic information, in an always ever-pleasant fashion.

Robert Donaldson is a Grade V Operator certified in the State of California and a former Operations Manager and Project Manager at a Sub-Regional Wastewater Treatment Facility. Robert Donaldson is not an engineer nor does Collaborative Strategies Consulting provide engineering services. As such no design decisions should be made based on the information provided in this report unless a certified professional engineer validates it.

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Headworks Facility Project – Grit Facility Design Criteria Update", January 2017, prepared by CDM Smith.

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Memorandum

To: *Bill Bryan, SVCW*

From: *Jan Davel, CDM Smith*

Prepared By: *Bill Schilling, CDM Smith*

Date: *January 20, 2017*

Subject: *Headworks Facility Project – Grit Facility Design Criteria Update*

1.0 Introduction

This memo presents design criteria recommended for use in developing the design of the Headworks Facility grit separators and grit handling equipment (Grit Facility), which will be installed as part of the Silicon Valley Clean Water (SVCW) Capital Improvement Program (CIP). Conceptual design criteria were previously developed and documented in the DRAFT Grit Removal and Grit Handling Evaluation Technical Memorandum (TM) prepared under Task 3.4 of the Headworks Facility Project. This TM presents updated design criteria based on recent grit sampling results, information received from former operations staff regarding historical extreme grit loads, and information on the operation of the Gravity Pipeline that will be installed as part of the SVCW CIP.

2.0 Project Background and Purpose

SVCW is implementing a CIP to improve the reliability of their conveyance system and wastewater treatment plant (WWTP). The CIP includes rehabilitation and repurposing of several collection system pump stations and installation of the following facilities:

- Gravity Pipeline to replace the existing 54-inch force main that conveys wastewater to the treatment plant
- Receiving Lift Station (RLS) located on the treatment plant site at the end of the new Gravity Pipeline
- Headworks Facility to remove screenings and grit from influent wastewater
- Influent Connector Pipe to convey flow from the Headworks Facility to the primary clarifiers
- Odor control facilities to treat foul air venting from the Gravity Pipeline, RLS, and Headworks Facility, referred to as the Front of Plant (FoP) Odor Control Facilities

- Odor control facility to treat foul air venting from one of the Gravity Pipeline drop shafts, referred to as the San Carlos Odor Control (SCOC) Facility.

An Environmental Impact Report (EIR) is currently being prepared for the CIP. The Headworks Facility Project is being performed to support the development of the EIR by developing the conceptual layouts and conceptual level cost estimates for the Headworks Facility, the FoP Odor Control Facility, and the SCOC Facility.

3.0 Approach for Updating Grit Facility Design Criteria

As discussed in Section 1.0, conceptual design criteria for the Grit Facility were previously developed and documented in the DRAFT Grit Removal and Grit Handling Evaluation TM prepared under Task 3.4 of the Headworks Facility Project. Since that TM was prepared, the following work has been completed:

- Three grit samples (two dry weather samples and one wet weather sample) were collected from the Influent Mix Box and analyzed by Black Dog Analytical, LLC for grit content.
- A Grit Sampling TM dated July 22, 2016 was prepared, summarizing the results of the analysis performed by Blackdog Analytical, LLC and results from grit sampling previously performed by SVCW.
- A Grit Migration Predictions When Using a Tunnel for Storing Wastewater TM (Grit Migration TM) was prepared for SVCW by Bob Donaldson. This TM, provided in Appendix A, summarizes the following:
    - Operations of the Gravity Pipeline during both dry weather diurnal equalization and wet weather storage
    - The conveyance of grit particles to the Headworks Facility during dry weather diurnal equalization operations and wet weather storage events
    - Information received from former operations staff regarding historical extreme grit loads to the WWTP

The information listed above was used to update the design criteria for the Grit Facility. The updated design criteria and the manner in which the information listed above was used is described in the sections below, which are organized as follows:

- Section 4. 0 summarizes the Black Dog Analytical, LLC grit sampling data.
- Section 5.0 summarizes the information included in the Grit Migration TM regarding Gravity Pipeline operations and grit conveyance.
- Section 6.0 includes updated design criteria for the Grit Facility based on the information presented in Sections 4.0 and 5.0.

- Section 7.0 discusses the anecdotal information received regarding historical grit loads.
- Section 8.0 includes final recommendations regarding design criteria for the Grit Facility.

4.0 Grit Sampling Data

Samples from the SVCW WWTP were collected and analyzed for grit content during several sampling events described in detail in the Grit Sampling TM, dated July 22, 2016. As discussed in that TM, the data from the samples collected from the Influent Mix Box during the period from February 3, 2016 – March 11, 2016 by Black Dog Analytical, LLC are recommended for use in developing design criteria for the Headworks Facility. The data from those samples are summarized in Table 1 and Figures 1 and 2, below. Revised design criteria for the Headworks Facility based on these sampling data are discussed in Section 6.0.

It should be noted that the data resulting from the grit sampling performed by SVCW during the period from March, 2014 to October, 2015 were generally in agreement with the data resulting from the grit sampling performed by Black Dog Analytical, LLC. Both sets of data indicated that there is a large fraction of fine grit, in terms of physical particle size, entering the WWTP during dry weather conditions. However, settling velocities were determined for the samples analyzed by Blackdog Analytical, whereas settling velocities were not determined for the samples analyzed by SVCW. Therefore, the Blackdog Analytical data is the primary data used in this TM.

Table 1. Concentrations of Grit in Influent Wastewater

Sampling Date	Grit Concentration (lbs/MG)
February 3, 2016 (Dry Weather Sample)	4.6
March 5, 2016 (Dry Weather Sample)	11.2
March 11, 2016 (Wet Weather Sample)	38.0

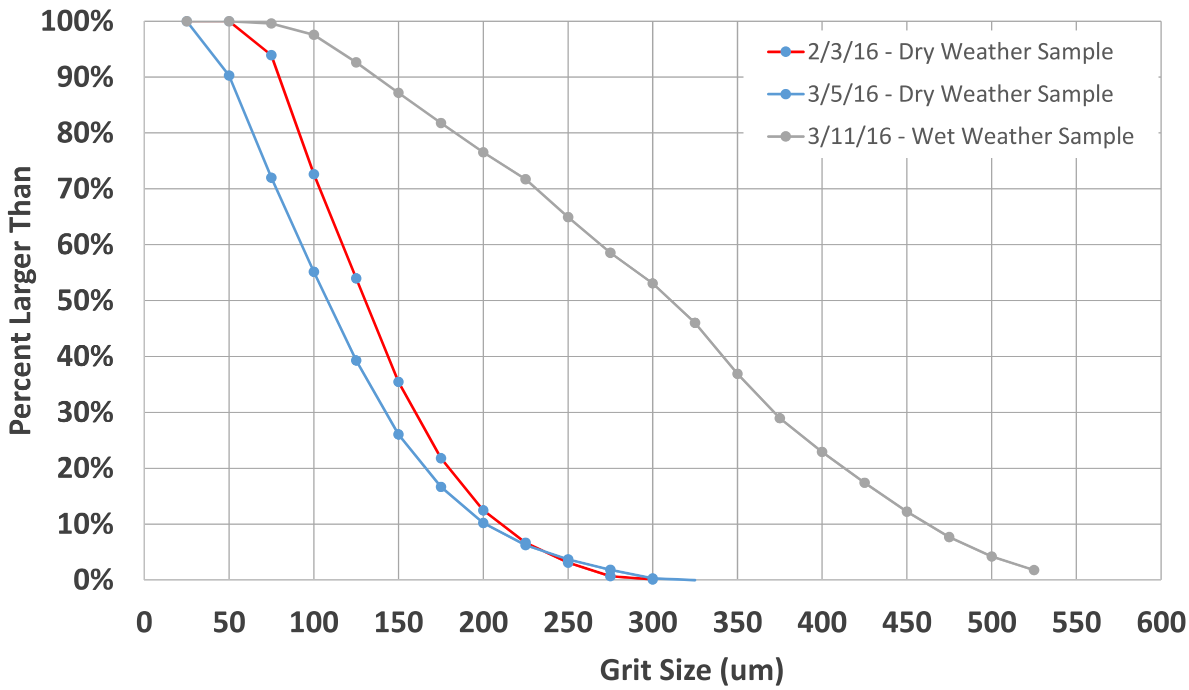

Figure 1
Sand Equivalent Size (SES) Distribution of Grit Particles in Influent Samples

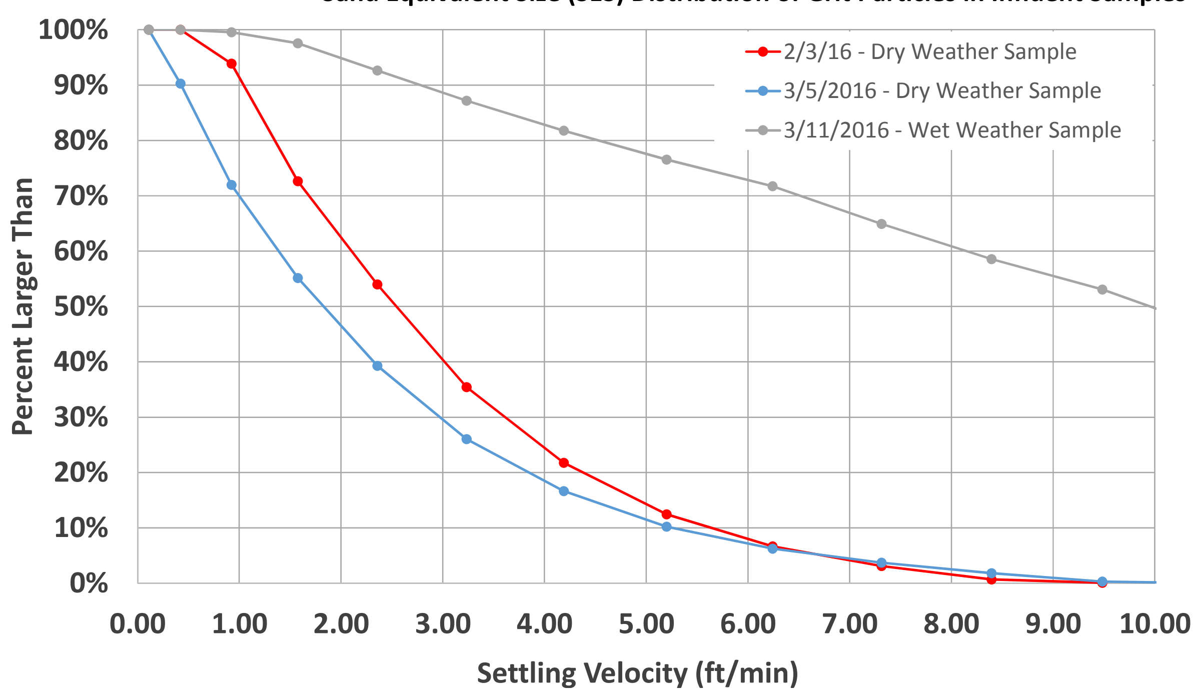

Figure 2
Settling Velocity Distribution of Grit Particles in Influent Samples

5.0 Gravity Pipeline Operations

SVCW may use the Gravity Pipeline for 1) equalizing dry weather diurnal flows to maintain the plant influent flow at 16 million gallons per day (mgd), and/or 2) storing flows during peak wet weather events to keep the influent flow into the plant below 80 mgd. Operation of the Gravity Pipeline during dry weather equalization and wet weather storage events will have an impact on the conveyance of grit down the pipeline to the Headworks Facility. This issue was analyzed in the Grit Migration TM. The findings of the Grit Migrations TM are discussed below. Additional considerations regarding how the findings of the Grit Migrations TMS should be used in developing design criteria for the Grit Facility are also presented below.

5.1 Grit Migration TM Findings

The Grit Migration TMs reported the following findings:

- Grit will settle in the Gravity Pipeline when flow velocities in the pipeline are less than 2 feet per second (ft/s). Grit that has settled in the Gravity Pipeline during low flow velocity conditions will not be re-suspended until the flow velocity in the pipeline increases above 4 ft/s.

- When the Gravity Pipeline is being used for dry weather diurnal equalization, the lower portion of the pipeline will be flowing full. Under these conditions, the flow velocities in lower portion of pipeline will be below 2 ft/s, causing grit to settle in that portion of the pipeline.

- To flush out grit which has settled in the pipeline during dry weather diurnal equalization, the pipeline should be periodically drained and allowed to flow freely (i.e. not flowing full) during times when the flow into the pipeline is high enough to produce a flow velocity of 4 ft/s. The recommended operation is to allow the pipeline to flow freely for 30 minutes a day during periods of peak dry weather flows, anticipated to be 20 mgd.

- If the pipeline is flushed once a day, as described above, the grit that has accumulated in the Gravity Pipeline during the 24 hours between flushings will be conveyed into the Headworks Facility during the 30 min flushing period.

- During a wet weather event, the RLS pumps will match the rate at which flows enter the Gravity Pipeline, up to the maximum capacity of the pumps (i.e., 80 mgd). When the flow entering the pipeline is less than 80 mgd, the pipeline will be free-flowing (i.e. it will not be flowing full). Under these conditions, the flow velocity in the pipeline will be > 2 ft/s and all grit entering the pipeline will be conveyed to the Headworks Facility in real-time, (i.e., no grit is expected to accumulate in the Gravity Pipeline under these conditions).

- When the flow entering the Gravity Pipeline rises above the maximum capacity of the RLS pumps (80 mgd), the rate at which flow is entering the pipeline will exceed the rate at which flow is being extracted from the pipeline, and the lower portion of the Gravity Pipeline will begin to fill up. Under these conditions, the flow velocities in the lower portion of the pipeline will drop below 2 ft/s, causing grit to settle in the pipeline. These conditions are anticipated to occur for a period up to 24 hours.

- After a wet weather event, the Gravity Pipeline will need to be drained to free up the storage volume in the pipeline for the next wet weather event.

- The recommended draining procedure is to drain the pipeline rapidly at the beginning of the draining procedure and then slowly near the end of the draining procedure. This will allow the tunnel to be drained in a relatively short period of time (< 24 hours), but will limit the peak grit load to the Headworks Facility to a manageable level.

- The specific recommended draining procedure is to drain the pipeline at a rate of 55 mgd during the beginning of the procedure. Once the pipeline is drained to the point where only 1,500 feet of the pipeline is flowing full, the draining rate should be reduced to 5 mgd above the rate at which raw sewage is entering the pipeline.

- If the draining procedure outlined above is followed, all the grit that accumulated in the tunnel during the wet weather storage event will be washed to the Headworks Facility during a 3-hour period at the end of the draining process. During this period, the influent rate to the Headworks Facility will be approximately 20 mgd.

5.2 Additional Considerations

The Grit Migration TM made some assumptions regarding design flows, pipeline operations, and grit characteristics, to simplify the fairly complex issues being evaluated in the TM. The authors of the Grit Migration TM, SVCW, and CDM Smith recognize that the operation of the Gravity Pipeline and the behavior of grit in the pipeline may differ from what is presented in the Grit Migration TM. Therefore, the following considerations should be made in using the findings of the Grit Migration TM to develop design criteria for the Grit Facility:

- Not all grit will settle in the Gravity Pipeline once the flow velocity in the pipeline falls below 2 ft/s. Therefore, even at low flow velocities, some grit will continue to be conveyed to the Headworks Facility.

- Not all grit that has settled in the Gravity Pipeline will be re-suspended once the flow velocity in the pipeline reaches 4 ft/s. Some grit will be re-suspended at a lower velocity and some will be re-suspended at a higher velocity.

- The manner in which the tunnel is periodically flushed during dry weather diurnal equalization operations could differ from the recommendations made in the Grit Migration TM, as follows:

  - The duration of time that the pipeline is allowed to flow freely could be changed. With a very short free flow period, it would take several flushings for grit that has accumulated in the upstream end of the pipeline to reach the Headworks Facility. This would increase the load of grit entering the Headworks Facility during each flushing. As the free flow period is increased, the load of grit to the Headwork Facility will be reduced until the point where the free flow period is long enough to flush all the grit that has accumulated in pipeline to the Headworks Facility.

  - The frequency at which the pipeline is flushed could be changed. If the pipeline is flushed less than once a day, the peak grit load to the Headworks Facility would be increased. If the pipeline is flushed more than once a day, the peak grit load to the Headworks Facility would be decreased.

- The rate at which the Gravity Pipeline is drained after a wet weather storage event storage event could differ from the recommendations made in the Grit Migration TM. Draining the pipeline at a lower rate, during any phase of the draining, will decrease the grit load to the Headworks Facility, but will increase the amount of time it takes to drain the pipeline. Draining the pipeline at a higher rate, during any phase of the draining, will increase the grit load to the Headworks Facility, but will decrease the amount of time it takes to drain the pipeline.

5.3 Recommended Assumptions

Based on the information discussed in Sections 5.1 and 5.2, it is recommended that the following assumptions be made regarding the operation of the Gravity Pipeline and the conveyance of grit to the Headworks Facility:

- 50% - 100% of the grit in the raw sewage entering the Gravity Pipeline could settle when flow velocities in the pipeline fall below 2 ft/s.

- During dry weather diurnal equalization operations, the Gravity Pipeline could be flushed every 1 – 2 days for a period of 15 – 60 min.

- Grit could accumulate in the Gravity Pipeline for a period of 12 – 36 hours during a wet weather storage event.

- During draining of the Gravity Pipeline after a wet weather storage event, the grit which has accumulated in the pipeline could be conveyed to the Headworks Facility over a 1.5 – 6 hour period.

6.0 Grit System Sizing Based on Grit Sampling & Gravity Pipeline Operation

6.1 Influent Flows

Revised influent design flows for the Headworks Facility are presented in Table 2. The revised design flows were developed as follows:

- As discussed in Section 5.0, the Gravity Pipeline could be used for dry weather diurnal equalization, which would result in a nearly constant flow of 16 mgd being delivered to the plant during dry weather operations.
- During dry weather conditions, the Gravity Pipeline may be periodically drained and allowed to flow freely. During these periods, the flow into the Headworks Facility would not be equalized and could be as high as the peak hour dry weather flow entering the pipeline, anticipated to be 20 mgd.
- The Gravity Pipeline could be used to equalize wet weather flows, resulting in a peak wet weather flow of 80 mgd.
- When wet weather flows are not equalized in the Gravity Pipeline, the peak wet weather flow into the Headworks Facility will be equal to the peak wet weather flow into the pipeline, which is approximately 108 mgd.

Table 2. Influent Flows

Criteria	Value	Units
Minimum Dry Weather Flow (MDWF)	mgd	16
Average Dry Weather Flow (ADWF)	mgd	16
Peak Hour Dry Weather Flow (PHDWF)	mgd	20
Equalized Peak Wet Weather Flow (PWWF)	mgd	80
Un-equalized Peak Wet Weather Flow (PWWF)	mgd	108

6.2 Grit Loads

Revised grit loads for the Headworks Facility are presented in Table 3. The revised grit loads were developed as follows:

- The data from the grit sampling discussed in Section 4.0 indicated a grit concentration of 11 lb/MG during dry weather conditions and a grit concentration of 38 lb/MG during wet weather conditions. These concentrations are much lower than typical concentrations reported in MOP-8 (i.e., 170 – 790 lb/MG). Also, grit concentrations can vary significantly from day to day. Therefore, it is recommended that a safety factor of two be applied to the grit concentrations reported in Section 4.0, resulting in the grit concentration design criteria shown in Table 3.

- The average day grit load entering the Gravity Pipeline shown in Table 3, was developed based on the dry weather grit concentration (22 lbs/MG) and the average daily flow (16 mgd). The max wet weather day grit load entering the Gravity Pipeline was based on the wet weather grit concentration (76 lbs/MG) and the peak wet weather flow (80 mgd).

- The peak hour grit load entering the Headworks Facility during dry weather was developed based on the following:

  - 0.1 – 0.35 tons of grit could accumulate in the Gravity Pipeline between dry weather flushings. This is based on a minimum of 50% of the grit in the raw sewage accumulating over a 1-day period and a maximum of 100% of the grit in the raw sewage accumulating over a 2-day period.

  - The grit that accumulates in the Gravity Pipeline during dry weather could be flushed to the Headworks Facility during a 15-minute to 60-minute period flushing period.

  - The dry weather flushing operations, described in the two previous bullets, would result in a Headworks Facility influent grit load of 0.1 – 1.4 ton/hr.

- The peak hour grit load entering the Headworks Facility during wet weather was developed based on the following:

  - 0.8 – 4.5 tons of grit could accumulate in the Gravity Pipeline during wet weather storage events. This is based on a minimum of 50% of the grit in the raw sewage accumulating over a 12-hour period and a maximum of 100% of the grit in the raw sewage accumulating over a 36-hour period.

  - The grit that accumulates in the Gravity Pipeline during wet weather storage events could be conveyed to the Headworks Facility in a 1.5 – 6-hour period during the draining of the pipeline.

  - The wet weather operations, described in the previous two bullets, would result in a Headworks Facility influent grit load of 0.1 – 3.0 ton/hr.

Table 3. Raw Grit Loads – Entering Gravity Pipeline

Criteria	Value	Units
Raw Grit Concentration, Average		
Dry Weather	lb/MG	22
Wet Weather	lb/MG	76
Raw Grit Loads – Entering Gravity Pipeline		
Average Dry Weather Day	ton/d	0.2
Max Wet Weather Day	ton/d	3
Raw Grit Loads – Entering Headworks		

Table 3. Raw Grit Loads – Entering Gravity Pipeline

Criteria	Value	Units
Peak Hour, Dry Weather Draining Event	ton/hr	0.1 – 1.4
Peak Hour, Wet Weather Draining Event	ton/hr	0.1 – 3.0

6.3 Grit Separator Basin Design Criteria

As discussed in the Grit Removal and Grit Handling Evaluation TM, the Headworks Facility grit separator basins are being designed based on Headcell units with twelve 12-foot diameter trays. The number of Headcell units required is dependent on the flow being processed and the desired overflow rate, or target settling velocity. Increasing the number of Headcells will reduce the amount of flow being processed by each unit, which will decrease the overflow rate in that unit and allow grit particles with lower settling velocities to be captured.

Tables 4 – 6 below show the performance of the Grit Facility at various flows, using various numbers of Headcell units. The information shown in Tables 4 – 6 was developed as follows:

- The total tray surface area shown in each row was calculated based on the number of Headcells listed for that row assuming each Headcell has twelve 12-foot diameter trays.
- The overflow rate shown in each row was calculated based on the total surface area and influent flow rate listed for that row.
- The minimum settling velocity shown in each row was calculated based on the overflow rate listed for that row. Grit particles with settling velocities higher than the maximum settling velocity would be captured in the grit basin. Grit particle with settling velocities lower than the maximum settling velocity would escape the grit basin.
- The SES cutpoint in each row was calculated based on the minimum setting velocity listed for that row assuming a spherical grit particle with a specific gravity of 2.65.
- The grit capture shown in each row was determined by using the settling velocity and SES distribution data presented in Section 4.0 to determine how much of the influent grit has settling velocities/SES lower than the minimum settling velocity/SES listed for that row.

Table 4. Performance of Grit Separator Basins during Peak Hour Dry Weather Flows (20 mgd)

Headcells	Tray Surface Area	Performance at PDWF (20 mgd)			
		Overflow Rate	Settling Velocity	SES Cutpoint	Grit Capture
1	1,360 ft2	10 gpm/ft2	1.4 ft/min	95 um[1]	55%
2	2,710 ft2	5 gpm/ft2	0.7 ft/min	65 um[1]	80%

[1]Grit handling systems are typically designed for an SES cutpoint of 100um. Therefore, grit particles with an SES < 100um, although captured in the grit separator, will typically flow through the grit handling systems to downstream processes.

Table 5. Performance of Grit Separator Basins during Equalized Peak Wet Weather Flows (80 mgd)

Headcells	Tray Surface Area	Performance at PWWF (80 mgd)			
		Overflow Rate	Settling Velocity	SES Cutpoint	Grit Capture
1	1,360 ft2	41 gpm/ft2	5.5 ft/min	205 um	75%
2	2,710 ft2	21 gpm/ft2	2.7 ft/min	135 um	90%
3	4,070 ft2	14 gpm/ft2	1.8 ft/min	110 um	96%
4	5,430 ft2	10 gpm/ft2	1.4 ft/min	95 um[1]	98%
5	6,790 ft2	8 gpm/ft2	1.1 ft/min	80 um[1]	> 99%

[1]Grit handling systems are typically designed for an SES cutpoint of 100um. Therefore, grit particles with an SES < 100um, although captured in the grit separator, will typically flow through the grit handling systems to downstream processes.

Table 6. Performance of Grit Separator Basins during Un-Equalized Peak Wet Weather Flows (108 mgd)

Headcells	Tray Surface Area	Performance at PWWF (108 mgd)			
		Overflow Rate	Settling Velocity	SES Cutpoint	Grit Capture
1	1,360 ft2	55 gpm/ft2	7.4 ft/min	250 um	65%
2	2,710 ft2	28 gpm/ft2	3.7 ft/min	160 um	85%
3	4,070 ft2	18 gpm/ft2	2.5 ft/min	130 um	92%
4	5,430 ft2	14 gpm/ft2	1.8 ft/min	110 um	96%
5	6,790 ft2	11 gpm/ft2	1.5 ft/min	95 um[1]	98%

[1]Grit handling systems are typically designed for an SES cutpoint of 100um. Therefore, grit particles with an SES < 100um, although captured in the grit separator, will typically flow through the grit handling systems to downstream processes.

The following observations can be made from the data presented in Tables 4 – 6:

- Under dry weather conditions, 1 Headcell unit would capture grit with a settling velocity as low as 1.4 ft/min (95um SES), which constitutes 55% of the influent grit.

- Under dry weather conditions, 2 Headcell units would capture grit with a settling velocity as low as 0.7 ft/min (65 um SES), which constitutes 80% of the influent grit. This is a significant improvement over the performance of a single Headcell unit in terms of percent grit captured. However, grit processing equipment is typically designed only to retain grit particles with settling velocities above ~1.5 ft/min (SES > 100 um). Therefore, the additional grit captured by a second Headcell unit would not be fully captured by the grit processing system, and some of the grit would get introduced back into the wastewater. Therefore, a second Headcell unit under dry weather conditions would not significantly improve overall grit capture, without modification to the grit processing system (e.g., additional grit classifiers).

- Under equalized wet weather flows, 1 Headcell would capture grit with a setting velocity as low as 5.5 ft/min (205 um SES), which constitutes 75% of the influent grit.

- Under equalized wet weather flows, 3 Headcells would capture grit with a setting velocity as low as 1.8 ft/min (110 um SES), which constitutes 96% of the influent grit. This is a significant increase in performance versus the performance of one or two Headcell units. Therefore, it is recommended that 3 Headcells be installed for treating wet weather flows.
- Under equalized wet weather flow, the grit capture rate does not increase significantly by increasing the number of Headcells beyond three. Therefore, installing more than three Headcells is not recommended. However, it is recommended that space be provided for a fourth Headcell and additional grit processing facilities if at some point in the future it is determined to be necessary. These additional facilities may be needed if actual grit loads and capture efficiencies do not match the design values.
- Under un-equalized wet weather flows, four Headcells are needed to achieve the same performance as three Headcells under equalized wet weather flows. However, the Grit Facility will likely rarely have to process un-equalized. Therefore, it is not recommended that additional Headcells be installed to process un-equalized wet weather flows.

Based on this analysis, it is recommended that the grit separators be designed based on the design criteria in Table 7.

Table 7. Updated Grit Facility Design Criteria

Criteria	Value	Units
Type	-	Headcell
Number of Units	-	3
Tray Diameter	ft	12
Number of Trays	-	12
Target settling velocity @ PWWF	ft/min	1.8
SES cutpoint at PWWF	µm	110
Grit Capture @ PWWF	%	>95
Target settling velocity @ ADWF	ft/min	1.4
SES cutpoint at ADWF	µm	95
Grit Capture @ ADWF	%	55

Although this TM recommends installation of three Headcells, as discussed above, consideration should be given to installation of only two Headcells during the next phase of design of the Grit Facility. As shown in Table 5, two Headcells would capture up to 90% of the influent grit during wet weather conditions, which is a significant portion of the influent grit, and may be an acceptable level of performance for SVCW. Installation of only two Headcells would eliminate some of the capital costs associated with the Grit Facility. However, there would be impacts to the system hydraulics and the grit handling facilities, which may add capital cost to the facility. These impacts should be evaluated further during the next phase of design.

6.4 Grit Handling

There are no proposed revisions to the grit handling design criteria as a result of the information presented above. The recommended grit handling design criteria are shown in Table 8. An image of the recommended grit washing equipment is shown in Figure 3. The Headcell grit separators require a continuous underflow pumping of 400 gpm. Therefore, the grit washers will need to be designed to receive a continuous flow of 400 gpm, as shown in Table 8.

Table 8. Grit Washer Design Criteria

Design Criteria	Units	Value
Grit Washer Type	-	Cone Washer
Number, per Grit Separator Basin	-	1 per Basin
Number, total	-	3 total
Flow Capacity	gpm	400
Flow Capacity	lbs/hr	2,500
Removal Efficiency		95% of >100µm SES
Effluent Water Content, Max	%	3%
Effluent Volatile Solids Content, Max	%	10%

Figure 3
Recommended Grit Washing Equipment

6.5 Grit Bins

There are no proposed revisions to the grit bin design criteria as a result of the information presented above. The recommended grit bin design criteria are shown in Table 9. As shown in Table 9, a 10 cubic yard dumpster provides 40 days of dry weather capacity. A smaller bin may be adequate, but a 10 cubic yard dumpster is still recommended. The additional capacity may be required if actual grit loads and capture efficiencies do not match the design values. It should be noted that the bins shown in Table 9 are separate from the screenings bins that will be provided as part of the Screening Facility.

Table 9. Grit Bin Design Criteria

Design Criteria	Units	Value
Number	-	1 Duty, 1 Standby
Bin Volume Capacity	yd^3	10
Bin Weight Capacity	tons	8
Average Dry Weather Daily Load	ton/d	0.2
Max Wet Weather Daily Load	ton/d	3
Time to Fill Bin (Dry Weather)	day	40
Time to Fill Bin (Wet Weather)	day	2.7

7.0 Historical Extreme Event Grit Loads

Former operations staff indicated that there were occasions when up to 20 tons of grit were received at the plant over the course of a single wet weather event. It was also indicated that there was at least one day when up to 60 tons of grit was received at the plant over the course of a single wet weather event. Designing the system based on these grit loads would have the following implications:

- Assuming the Gravity Pipeline were drained after an extreme event, as described in Section 5.0, the peak hour grit load during the draining process could be as high as 40 ton/hr. This is based on 60 tons of grit accumulating in the pipeline during the extreme event and the accumulated grit being conveyed to the Grit Facility in as little as 1.5 hours.

- If the Grit Facility were projected to receive grit loads as high as mentioned in the previous bullet (40 tons/hr), SVCW staff would likely mitigate this impact by operating the Gravity Pipeline in a manner to reduce the peak hour grit load to the Grit Facility. If the pipeline is drained after an extreme event so that accumulated grit is conveyed to the Headworks Facility in a minimum of 6 hours, the maximum peak hour grit load would be reduced to 10 tons/hr.

- The design presented in Section 6.0 includes three grit washers, each with a maximum grit processing capacity of 1.25 ton/hr, resulting in a total grit processing capacity of 3.75 ton/hr. The design could be modified to include grit washers with a capacity of 3 tons/hr, to increase the total grit processing capacity to 9 ton/hr. However, these types of grit washers are limited to an inlet of 250 gpm and need to be equipped with a hydrocyclone, as shown schematically in Figure 5, to be able accept the full underflow from the grit separators (400 gpm). This arrangement would require that the height of the building over the grit washers be higher because the hydrocyclones are located on top of the grit washers. The larger-capacity grit washer, the hydrocyclone, and the taller building will increase the capital cost of the Grit Facility. Hydrocyclones are high-wear pieces of equipment and also require a high inlet pressure, increasing the energy required to pump grit out of the grit basins. Therefore, this option would also increase the O&M costs associated with the Headworks Facility.

- In order to increase the grit processing capacity of the Headworks facility so that it could process up to 10 tons of grit/hr, the design would have to be revised to include 4 grit washers, each with a capacity of 3 tons/hr, and each grit washer would have to be equipped with a hydrocyclone. This arrangement would add significant capital and O&M costs to the Headworks Facility.

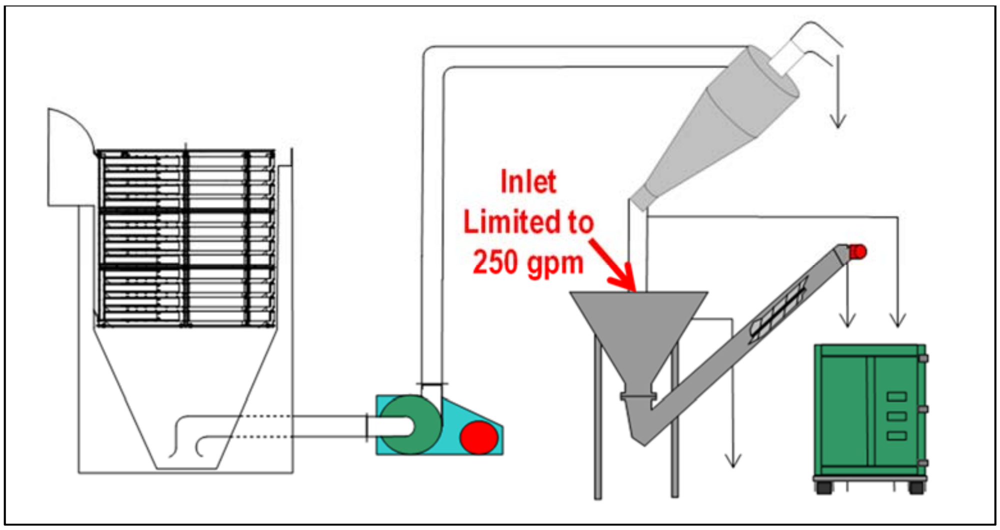

Figure 5
Arrangement of Grit Processing Equipment Required for High Grit Loads

It is not recommended that the Headworks Facility be designed to include the modifications described above (i.e. higher capacity grit washers with hydrocyclones or additional grit washers). This recommendation is supported by the following:

- The analysis performed above assumes that the full 60 tons of grit that enters the pipeline during an extreme wet weather event will accumulate in the pipeline. However, grit will not begin accumulating in the pipeline until the flow in the pipeline exceeds the capacity of the RLS pumps, and the pipeline begins filling up. Much of the grit that enters the pipeline during an extreme wet weather event will have passed through the pipeline by this point. This means that much less than 60 tons of grit will accumulate in the pipeline during a storm event and that the analysis above is very conservative.

- During the beginning of an extreme event when flows in the Gravity Pipeline are less than the capacity of the RLS pumps (80 mgd), the grit entering the pipeline will be sent directly to the Headworks Facility, i.e., will not be stored in the pipeline. The rate at which grit will be sent to the Headworks Facility during these periods will be approximately 2.5 ton/hr, assuming the extreme grit loads described above (60 tons/day) are delivered to the plant in a 24-hour period. The grit handling equipment recommended in Section 6 has a total capacity of 3.75 tons/hr, which is ample for the scenario when flows are delivered to the Headworks Facility directly, i.e., without storage in the pipeline.

- As mentioned above, when the Gravity Pipeline is being drained after an extreme event, there is the potential of draining the pipeline in a manner that would overload the recommended grit handling equipment. This could be avoided by modifying the draining procedure to increase the time over which accumulated grit is delivered the Headworks Facility.

- If extreme grit loads to the Headworks Facility during were as high as 10 ton/hr, the grit separator basins and the grit removal pumps are expected to have adequate capacity to process these extreme loads. However, the capacity of the grit washers would be exceeded, resulting in the discharge of grit through the grit washer overflow pipes. During these periods, the overflow from the grit washers could be directed to downstream processes or an off-line storage basin. The grit that is deposited in these locations could be processed after the extreme grit loading event has subsided.

The extreme grit loads discussed above are significantly higher than the grit loads determined based on the grit sampling. This could be the result of the grit sampling being performed during a wet weather event which resulted in an influent flow much lower than the influent flow observed during the extreme events described above. Therefore, it is recommended that additional wet weather sampling be performed during the detailed design of the Headworks Facility to confirm the peak hour grit loads.

8.0 Recommended Approach & Design Criteria

The design criteria recommended for the Preliminary Design of the Headworks Grit Facility is presented in Table 10. These design criteria were developed based on the information presented above.

Table 10. Updated Grit Facility Design Criteria

Criteria	Value	Units
Influent Flows		
Minimum Dry Weather Flow (MDWF)	mgd	16
Average Dry Weather Flow (ADWF)	mgd	16
Peak Hour Dry Weather Flow (PHDWF)	mgd	20
Equalized Peak Wet Weather Flow (PWWF)	mgd	80
Un-Equalized Peak Wet Weather Flow (PWWF)	mgd	108
Grit Loads		
Raw Grit Concentration, Average		
Dry Weather	lb/MG	22
Wet Weather	lb/MG	76
Raw Grit Loads – Entering Gravity Tunnel		
Average Dry Weather Day	ton/d	0.2
Max Wet Weather Day	ton/d	3
Raw Grit Loads – Entering Headworks		
Peak Hour, Dry Weather Draining Event	ton/hr	0.1 – 1.4
Peak Hour, Wet Weather Draining Event	ton/hr	0.1 – 3.0
Grit Separator		
Type	-	Headcell
Number of Units	-	3
Tray Diameter	ft	12
Number of Trays	-	12
Target settling velocity @ PWWF	ft/min	1.8
SES cutpoint at PWWF	µm	110
Grit Capture @ PWWF	%	>95
Target settling velocity @ ADWF	ft/min	1.4
SES cutpoint at ADWF	µm	95
Grit Capture @ ADWF	%	55
Grit Washer		
Grit Washer Type	-	Cyclone Washer
Number	-	1 Washer per Basin
Flow Capacity	gpm	400
Flow Capacity	lbs/hr	2,500
Removal Efficiency (Provided by Manufacturer)		95% of >100µm
Grit Bins		
Number	-	1 Duty, 1 Standby
Bin Volume Capacity	yd^3	10
Bin Weight Capacity	tons	8
Time to Fill Bin (Weight)	day	40

Appendix B: Geotechnical Investigations

- Draft Technical Memorandum, SVCW Headworks Facility at Front of Plant Preliminary Foundation Design Parameters, January 2017
- New Administration and Plant Control Building Project, July 2009, prepared by DCM Consulting, Inc.
- "Preliminary Characterization of Subsurface Conditions, SVCW Clean Water Tunnel – Alignment 4BE, Redwood City, California," December 2015, prepared by Geotechnical Consultants, Inc.
- "Preliminary Pile Foundation Design Criteria, Peak Flow Diversion Structure," January 2016, prepared by DCM Consulting, Inc.
- "Presentation of Site Investigation Results SVCW Front of Plant Improvements," January 2016, prepared by DCM Consulting, Inc.

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Draft Technical Memorandum, SVCW Headworks Facility at Front of Plant Preliminary Foundation Design Parameters, January 2017

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DCM Consulting, Inc.

Draft Technical Memorandum

P.O. Box 225, Lafayette, CA 94549, Telephone: 925.322.9590 www.dcmconsults.com

To:	Bill Schilling CDM Smith	Date:	January 17, 2017
From:	Dave Mathy DCM Consulting, Inc.	File:	No. 222
Subject:	Silicon Valley Clean Water (SVCW) Headworks Facility at Front of Plant Preliminary Foundation Design Parameters SVCW Waste Water Treatment Plant Redwood City, California		

1.0 INTRODUCTION

The purpose of this technical memorandum is to provide preliminary geotechnical engineering recommendations for structure foundations in support of CDM Smith's conceptual design of new headworks facility structures at the SVCW waste water treatment plant in Redwood City, California. The SVCW waste water treatment plant is located at the northeastern end of the Redwood Shores Peninsula on the western margin of San Francisco Bay. The treatment plant site is on reclaimed tidal marshland with the first construction of dikes for land reclamation on the Redwood Shores Peninsula in the early 1900s. In the 1950s, significant levees and fills were placed on the Redwood Shores Peninsula for land development. The most recent fills at the project site were placed during development of the SVCW waste water treatment plant in the late 1970s to early 1980s. The soils underlying the waste water treatment plant consist of very thick deposits of Young Bay Mud (YBM) underlain by Old Bay Clay (OBC). Bedrock is hundreds of feet deep at the waste water treatment plant site (approximately 600 feet deep as referenced in U.S.G.S. Open File Report 90-496, 1990). The YBM is characterized by extremely low unit weight, extremely high moisture content, low shear strength and high compressibility. The YBM is considered to be normally consolidated and is still consolidating (settling) at the treatment plant under the weight of areal fills placed in the late 1970s (i.e. underconsolidated with respect to the late 1970s fill placement). As a result of the thick deposit of soft and weak YBM, the waste water treatment plant structures are supported by deep driven pile foundations deriving capacity by skin friction within the underlying OBC.

The new headworks facility site is located at the front of the treatment plant in an area presently designated as an ornamental pond (Front of Plant area). The current ground surface elevation within the Front of Plant area varies from Elevation 99 to Elevation 100. The Front of Plant area was not filled upon with engineered areal fill during original plant construction in 1978/1979, however, this area was reportedly used as a construction staging area and as a result thin (non-engineered) fills of highly variable composition and consistency with near surface buried construction debris can be encountered. When the ornamental pond is drained, occasional construction debris can be seen on the ground surface. Since completion of the original treatment plant in 1978/1979, the Front of Plant area has been flooded with a few feet of standing water and used as on ornamental pond. As a result, the Young Bay Mud within the Front of Plant has been nearly continuously submerged below surface waters. The headworks facility, which will be located immediately, east of a future Receiving Lift Station (RLS) also within the Front of Plant area, will include the following:

- headworks building, footprint area approximately 7,900 square feet;
- electrical and loadout building, footprint area approximately 5,200 square feet; and
- odor control equipment buildings, footprint areas of approximately 1,500 and 1,200 square feet.

The Front of Plant area, including the RLS and Headworks Facility, will be raised in elevation with about 4 feet of areal fill to a finished grade elevation of approximately Elevation 103 to 104. The at-grade portions of the Headworks Facility will be at Elevation 103 to 104, however the grit chamber portion of the headworks building will extend down to Elevation 94 (approximately 9 to 10 feet below finished grade).

The preliminary pile foundation design criteria presented herein is based on:

- CPT probes completed within the Front of Plant area to map the bottom of YBM;
- recent deep geotechnical borings completed for the RLS project by GTC Consultants;
- physical laboratory testing of soil samples taken from recent test borings for the RLS project;
- construction precedent of pile driving in 2015 for the plant's Influent Screening Facility;
- construction precedent of pile driving in 2010 for the plant's Administration Building Stairwell and Elevator Shaft;
- foundation design precedent for the City of Redwood City's Recycled Water Treatment Facility in 2004; and
- foundation design precedent for the original waste water treatment plant in 1977-1979.

2.0 FINDINGS

2.1. Cone Penetration Tests and Geotechnical Borings

In order to establish the thickness of YBM across the Front of Plant area, a total of 22 Cone Penetration Test (CPT) probes were completed in 2015. Appendix A includes a map of the Front of Plant area with 24 CPT locations (CPT Nos. 21 and 22 were not completed) along with depth to the bottom of Young Bay Mud (YBM) at each CPT location and bottom of YBM elevation contours. CPT's completed within the Front of Plant area were pushed with a small track mounted all terrain rig with limited depth capability. As a result the CPT's completed in the Front of Plant area extend completely through the YBM and met refusal in the top of the OBC with 10' to 25' of penetration into the OBC. The purpose of the Front of Plant CPT's was simply to map the bottom of the YBM/top of the OBC contact (see Appendix A).

In addition to the Front of Plant CPT probes, GTC Consultants completed 6 deep geotechnical borings (well into the OBC) for the RLS project immediately west of the Headworks Facility site in 2015. Appendix B includes the GTC boring location map and boring logs. At the time of GTC Consultants' drilling of test boring B-101, DCM Consultants obtained undisturbed soil samples for laboratory testing specific to the Headwork Facility Project. Undisturbed Shelby tube soil samples were retrieved from GTC Consultants at the time of drilling and delivered to Cooper Testing Laboratories on the same day. Appendix C contains laboratory test results completed specifically for the Headworks Facility Project. CPT-1 is approximately 50 feet north of GTC Consultants' B-101. CPT-1 indicates that the bottom of the YBM is approximately 45 feet deep (approximately El. 55). Geotechnical boring B-101 by GTC Consultants logs zero blow count (i.e. N=0) very soft YBM from ground surface to 40 feet deep. At 45 feet deep (El. 54.5) B-101 logs a blow count of N=24 which is a stiff clay and represents the bottom of YBM/top of the OBC. The remaining borings by GTC Consultants similarly log the bottom of YBM at El. 54 to 57. Therefore, there is good correlation in logging the bottom of YBM between the Front of Plant CPTs and geotechnical borings completed by GTC Consultants for the RLS. The geotechnical borings completed by GTC Consultants for the RLS describe the soils below the YBM as Upper Layered Sediments and Old Bay Deposits. For purposes of this Technical Memorandum all soils below the YBM are described as Old Bay Clay (OBC).

2.2. Engineering Properties of Soils

YOUNG BAY MUD (YBM)

- Thickness: 45 to 55 feet under the Headworks Building and Electrical and Loadout Building and 55 to 75 feet under the Odor Control Equipment Buildings (see Appendix A)
- Composition: Fat Clay (CH) and Elastic Silt (MH)
- Consistency: Very soft, Standard Penetration Test Blow Count, N = 0 to 2
- Moisture Content: 73% to 105% (note that moisture contents > 100% indicate that there is more water than soil solids in a given unit volume of YBM)
- Average Dry Unit Weight: 50 pcf
- Average Total Unit Weight: 92 pcf
- Average Buoyant (effective) Unit Weight: 30 pcf
- Overconsolidation Ratio: 1
- Compression Index, Cc: 1.2 to 1.3
- Ko: 0.65
- Poisson's Ratio: 0.50

- Undrained Shear Strength (Su): 80 psf to 330 psf
- Su/p′: 0.20 to 0.30
- Increase in Su with depth: 9 psf/ft
- Young's Modulus: approx. 30,000 psf

OLD BAY CLAY (OBC)

- Thickness: > 80′
- Composition: Lean Clay (CL) to Fat Clay (CH) with significant non-cohesive Poorly Graded Sand (SP-SM) interlayered with minor Poorly Graded Gravel (GP), non-cohesive sands and gravels occur from about El. 35 to El. 5, ranging from 25′ to 30′ thick
- Consistency: Stiff to very stiff clays (N = 8 to 25) and medium dense to dense sands and gravels (N = 15 to 50)
- Average Moisture Content: 45% in clays, 21% in sands
- Average Dry Unit Weight: 72 pcf in clays, 105 pcf in sands
- Average Total Unit Weight: 104 pcf in clays, 127 pcf in sands
- Average Buoyant (effective) Unit Weight: 42 pcf in clays, 65 pcf in sands
- Overconsolidation Ratio: approx. 4
- Compression Index, Cc: 0.25
- Ko: approx. 1.0
- Poisson's Ratio: 0.50
- Undrained Shear Strength: Average 1,400 psf in clays
- Su/p′ Ratio: 0.30 to 0.60
- Increase in Su with depth: approx. 30 psf/ft
- Young's Modulus: approx. 500,000 psf

2.3. Construction Precedent

All of the original waste water treatment structures at SVCW are supported by driven, pre-cast, pre-stressed concrete piles. The concrete piles were driven through the YBM and into the underlying OBC.

Pile capacity is generated by the depth of embedment in the OBC. For the original plant construction (circa 1978/1979), typical design pile capacity was 50 tons per pile for 12-inch-square piles with pile lengths of 100 to 105 feet.

Remodeling for the new Administration Building in 2010 included the addition of a stairwell and elevator shaft to the building entry. The stairwell and elevator shaft addition is supported by a total of 11, 14-inch-square pre cast, pre-stressed concrete piles that are 106 to 116 feet long. Net pile design capacity was approximately 80 tons per pile. (Net pile capacity is gross capacity minus negative skin friction in the YBM.) During construction, obstructions were encountered in the upper fill soils that required coring and removal (through a concrete slab) to allow for pipe installation. An APE D30-22 diesel hammer with a maximum rated energy of approximately 69,000 ft.-lbs. was used to drive all piles. The pile driving contractor was Stroer and Graff, Inc. of Antioch, California. The final pile driving blow count for the last foot of driving ranged from 9 to 29 blows per foot with an average of 15 blows per foot at fuel stop setting, FS=4.

Construction of the new Influent Screening Facility in 2015 included driving a total of 16, 14-inch-square, pre-cast, pre-stressed concrete piles that are 109 feet long. Net pile design pile capacity was approximately 100 tons per pile. During construction obstructions were encountered in the upper fill and existing sedimentation tank structure backfill that required excavation for removal. Obstructions consisted of boulder sized chunks of concrete debris. A Delmag D-30 diesel hammer with a maximum rated energy of approximately 69,000 ft.-lbs. was used to drive all piles. The pile driving contractor was Stroer and Graff, Inc. of Antioch, California. The final pile driving blow count for the last foot of driving ranged from 8 to 18 blows per foot with an average of 12 blows per foot at fuel stop setting FS=3. Pile driving for the Influent Screening Structure also included PDA and CAPWAP instrumentation by Abe Construction Services, Inc. of Livermore, California. The Abe Construction Services report for the Influent Screening Facility pile driving is included for reference as Appendix D. From the PDA results, the average gross pile capacity is 100 tons. Net pile capacity after deducting for negative skin friction in 75 feet of YBM is 100 – 16 = 84 tons. Restriking on one sample pile, three days after installation indicated a 30-ton setup gain (approximately +30% gain) occurred after driving. Pile capacity gains such as this are expected for friction piles in OBC.

3.0 PRELIMINARY FOUNDATION RECOMMENDATIONS

3.1. Front of Plant Areal Settlement

Present ground surface elevations in the Front of Plant area are approximately El. 99 to El. 100. Planned finished grade in the Front of Plant area is approximately El. 103 to 104. Therefore, approximately 4 feet of areal fill will be placed over the entire Front of Plant area including the Headworks Facility area. Adding 4 feet of areal fill over the YBM will cause long-term consolidation settlement. Long-term consolidation settlements will be uneven reflecting the variable thickness of the YBM under the Headworks Facilities. As shown in Appendix A the thickness of YBM under the Headworks Facilities area varies from about 45’ to 75’. Assuming the new fill will have a total unit weight of 135 pcf, the total areal surcharge load on the YBM will be on the order of 540 psf. This is a significant load on the underlying YBM and will lead to long-term consolidation settlements of approximately 2’ to 2.8’ as a function of

YBM depths of 45’ to 75’, respectively. In the first 25 years consolidation settlements should be in the range of 1’ to 1.4’. At the end of 50 years, consolidation settlements should be in the range of 1.3’ to 1.7’. Long-term consolidation settlement will have the following impacts on Front of Plant structures and site improvements:

- Reduction in finished ground surface elevations;
- Changes in surface drainage slopes and drainage structure elevations;
- Negative skin friction on pile foundations in YBM (as the YBM consolidates and settles, soil adhesion on the pile surface pulls the pile downward). [This also applies to the deep RLS structure.]
- Differential settlement between pile supported structures (or deep structures such as the RLS) and non-pile-supported pipelines, pavements and drainage facilities; and
- Differential settlement between the Front of Plant area and existing plant area where the majority of consolidation settlement has already occurred in the existing plant area.

As a result of filling the Front of Plant Area to approximately El. 104, all pile foundations must be designed to include negative skin friction from the consolidating YBM.

3.2. Pile Foundations

Pile foundations for the new Headworks Facility structures should consist of 14-inch square, pre-cast, pre-stressed concrete piles that reach a minimum of 80 feet below present ground surface (i.e. below El. 100) and derive support by skin friction in the OBC. Starting at depths of 45’ to 75’ below present ground surface (i.e. below El. 100), the allowable “positive” pile skin friction in the OBC may be taken as 750 psf. The allowable “positive” pile skin friction can be increased by one-third for short-term, transient wind and seismic loads. As previously described in Section 3.1, the YBM from present ground surface to 45’ to 75’ below present ground surface will be consolidating under new areal fill loading and will therefore produce a “negative” skin friction on the piles. The “negative” skin friction in the Young Bay Mud should be taken as -100 psf. For an allowable 50 ton capacity on an individual 14-inch square pile, the total required pile length below El. 100 is a function of the YBM thickness and negative skin friction deduction from gross pile capacity in the OBC. For a YBM thickness of 45’, a 14-inch square pile with a pile surface area of 4.67sf/ft, and a desired 50 ton capacity, the pile length below El. 100 is calculated as follows:

- 100,000 lbs = (4.67 sf/ft * 750 psf * L) – (45’ * 4.67sf/ft *100 psf)

  L = 35’ of required embedment in OBC

  Total pile length below El. 100 = 45’ + 35’ = 80’

Similar calculation for a YBM thickness of 55’ results in a pile length below El. 100 of 91’. For a YBM thickness of 65’, total pile length below El. 100 is 102’ and for a YBM thickness of 75’, total pile length below El. 100 is 115'. For practical purposes, including transportation, and for installation safety, pile lengths in excess of 109' (109' long piles were used for the Influent Screening structure) should be avoided. Therefore, where the YBM thickness is on the order of 75', preliminary design pile capacities of less than 50 tons per pile should be considered.

For piles in tension, the YBM should be ignored and the allowable uplift capacity should come solely from the OBC at 750 psf pile skin friction.

Total settlement of any individual pile should be less than one-half inch. Differential settlement between any two piles should be less than one-quarter inch. Center to center pile spacing should be at least 3 times pile width.

The lateral capacity of the 14-inch-square piles was evaluated by L-Pile (a lateral load vs. lateral pile deflection program) for the Administration Building Stairwell and Elevator Shaft project in 2010 and is included for reference as Appendix E. While site specific conditions will be different, the Administration Building Stairwell and Elevator Shaft conditions are reasonably close to the Front of Plant. The P-Y curves in Appendix E were run for a lateral load of 5 kips, 10 kips and 15 kips. As demonstrated by Kie-Con in 2015 (for the Influent Screening Facility project), a lateral load of 15 kips is too much for a Kie-Con designed 14-inch square pile (see Appendix F, for reference). Therefore, an allowable lateral load of 10 kips per pile should be used for preliminary design. At 10 kips applied lateral load the top of pile deflection for "fixed head" conditions is under 0.50". Lateral loading on the Headworks Facilities structures may be resisted by the sum of individual pile allowable lateral load capacity with modifications for areas of close pile spacing and group effects. Friction across the base of the structures should not be included in lateral load resistance as the Young Bay Mud will be consolidating creating a slight gap between the bottom of the pile supported structure and underlying subgrade.

Pile driving at the new Headworks Facility structures must be carefully planned. The Young Bay Mud will be within 3 to 4 feet of the finished ground surface (as measured from finished grade, El. 104). In the past, heavy construction equipment within the SVCW waste water treatment plant has punched through pavement and thin fills becoming stuck in the soft Young Bay Mud. Crane mats should be used to transport and support heavy equipment such as the pile driving crane and outriggers. In addition, there are fragile, shallow pipelines and utilities (e.g. plant electrical service in Radio Road) in and around the existing waste water treatment plant that must be protected from construction equipment live loading. Limitations on construction equipment travel paths at the waste water treatment plant, including Radio Road, and positioning of heavy construction equipment such as the pile driving crane must be coordinated with SVCW engineering staff.

The pile driving hammer should be consistent with the pile design, construction precedent and the subsurface conditions described herein and should have a minimum energy rating on the order of 50,000 foot pounds. Piles may be driven from the finished ground surface at El. 104 to deeper elevations (e.g. El. 94 for the grit chamber) by the use of a follower to reach top of pile elevation.

As previously discussed, the Front of Plant area was reportedly used for construction staging during the original waste water treatment plant construction. Construction debris is likely present in the top several feet of the Front of Plant area. In order to get through the new areal Front of Plant fill and likely remnant construction debris from 1978/1979, pre-drilling should be required to a minimum depth of about 15’ to 20’. The pre-drilled auger-hole diameter should be a maximum of 70% of the pile width. The purpose of pre-drilling is to ensure removal of fill and construction debris prior to pile driving to protect the piles and minimize vibrations on nearby structures/pipelines during pile driving.

4.0 LIMITATIONS

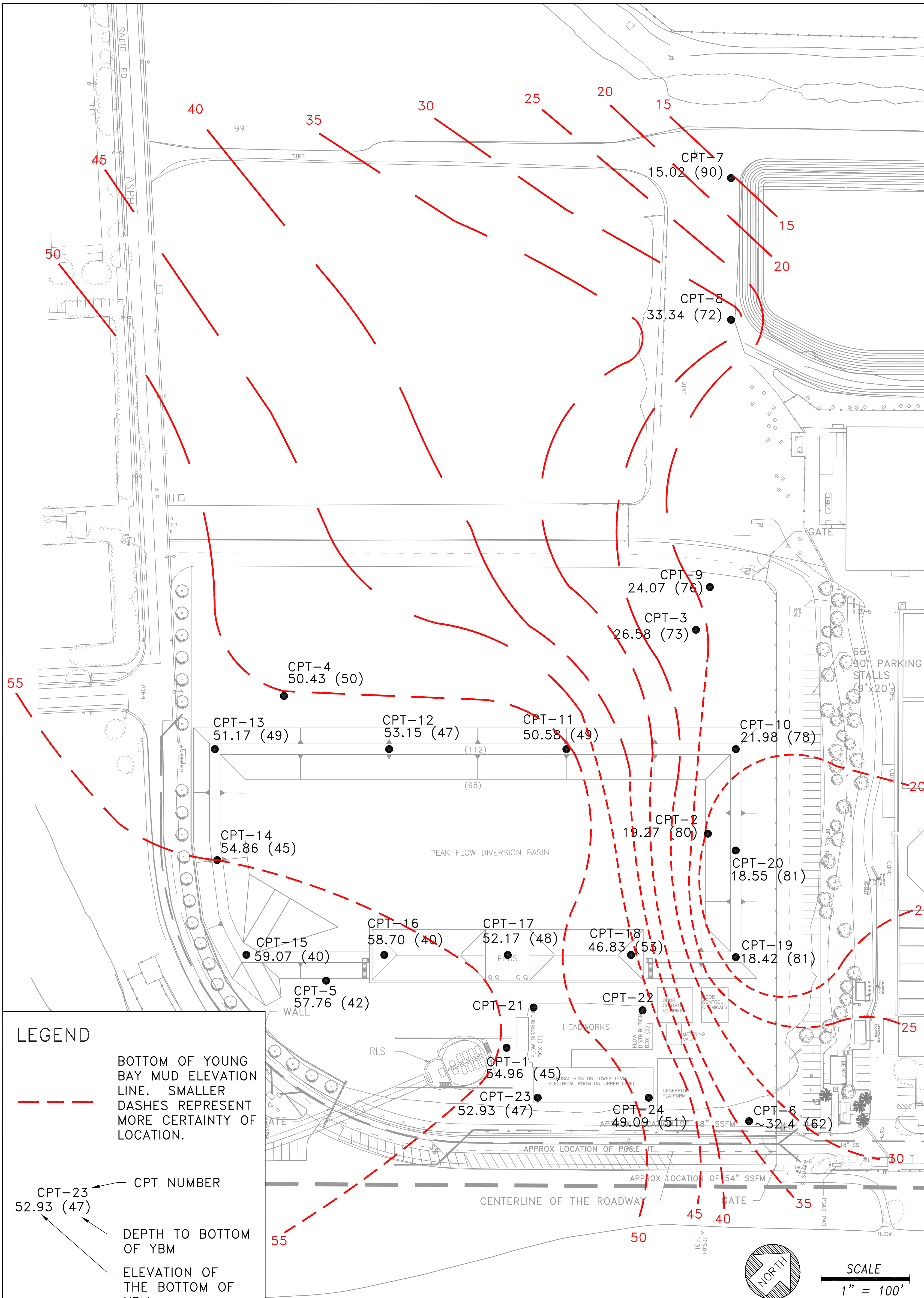
This Technical Memorandum has been prepared for the exclusive use of CDM Smith and SVCW in support of CDM Smith’s conceptual design of the Headworks Facility project as described herein. This Technical Memorandum may not be used for any other purpose or for any other project. The preliminary geotechnical design parameters for pile foundations as described herein are to be followed up with a design level geotechnical investigation, analysis and report with specific recommendations for final pile lengths as a function of variable underlying YBM thickness including an indicator pile program, final lateral pile load capacity with site specific P-Y curves, seismic design parameters, mitigation measures for differential settlement between the pile supported structures and non-pile supported site improvements including pipelines, etc. Within the limitations of scope, schedule and budget, DCM Consulting, Inc.’s services have been provided in accordance with generally accepted practices in the field of geotechnical engineering in the San Francisco Bay Area at the time the services were completed. The conclusions and opinions presented in this Technical Memorandum are based on the author’s professional knowledge, judgment and experience. No warranty or other conditions express or implied should be understood.

David C. Mathy
C.E. 28082
G.E. 569

Attachments

Appendix A – Front of Plant CPTs and YBM Contours
Appendix B – Geotechnical Borings for the RLS
Appendix C – Laboratory Testing Completed for the Headworks Facility
Appendix D – Abe Construction Services PDA Report for the Influent Screening Facility
Appendix E – P-Y Curves Completed for the Administration Building Stairwell and Elevator
Appendix F – Limitation on 14-inch-square Pre-cast, Pre-stressed Pile Lateral Capacity from Kie-Con

APPENDIX A



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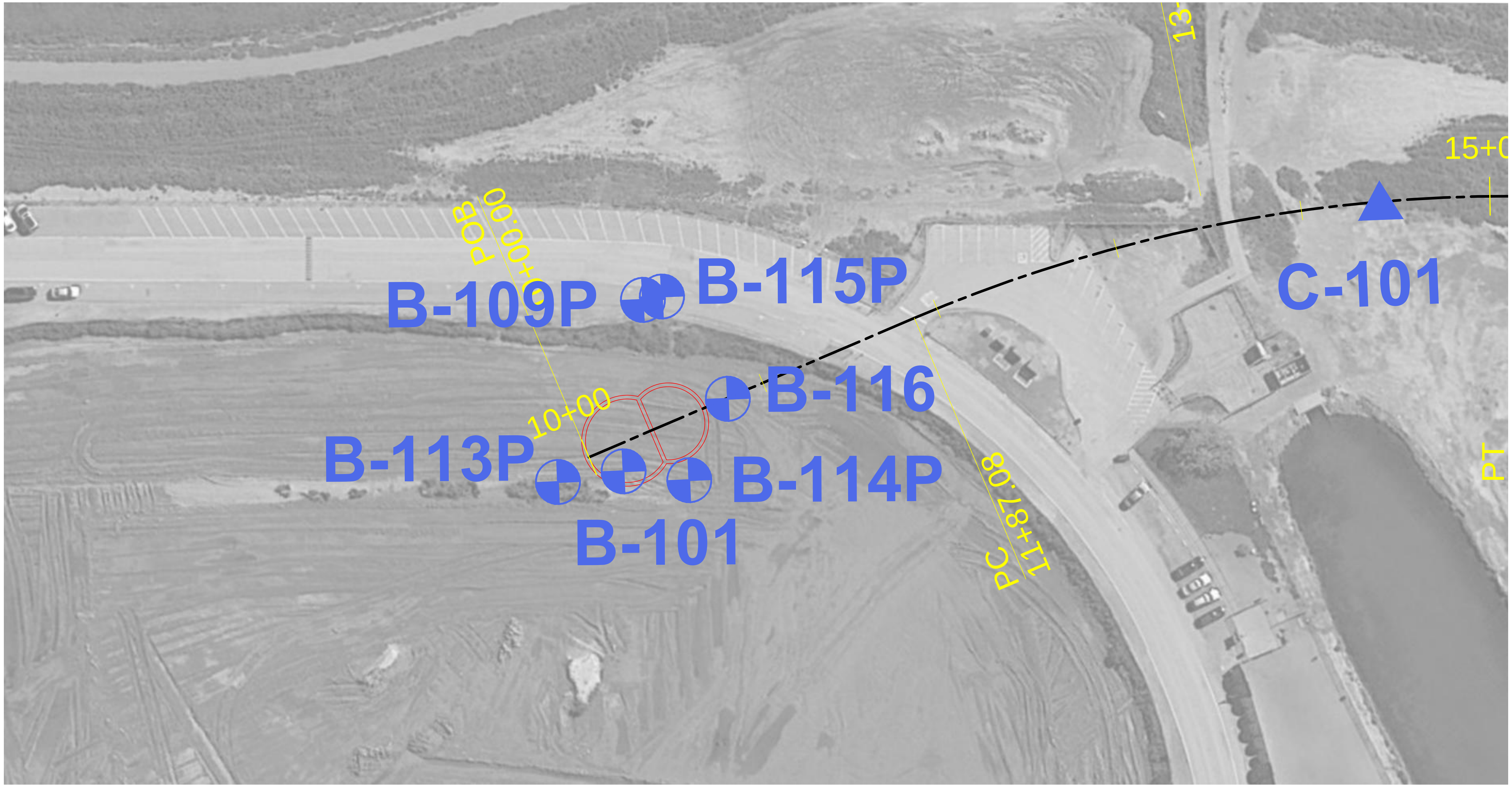
DRAFT - WORK IN PROGRESS
BOTTOM OF YBM CONTOURS
FRONT OF PLANT IMPROVEMENT
SILICON VALLEY CLEAN WATER

VERSION AS OF 12/04/2015

APPENDIX B



PLAN
SCALE: 1" = 30'

LEGEND

B-101 Phase 1 Geotechnical Borings

C-103 Phase 1 Cone Penetrometer Tests

Centerline of Proposed Tunnel Alignment

Tunnel Shafts

GEOTECHNICAL CONSULTANTS, INC. 500 Sansome Street, Suite 402 San Francisco, CA 94111	PHASE 1 GEOTECHNICAL EXPLORATION LOCATION MAP	PLATE
	SILICON VALLEY CLEAN WATER TUNNEL, ALTERNATIVE 4BE REDWOOD CITY CALIFORNIA	1
	DECEMBER 2015	SF14014A

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"ARTIFICIAL FILL (af)" CLAYEY SILT with GRAVEL (ML), dark olive brown, wet, soft, with mixed gravel, some fine to medium grained sand, with scattered cobbles. (POND SEDIMENTS)						
							"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), very dark greenish gray, moist, very soft, no odor, no organics.						
94.5	5		0										
89.5	10							46	98				C
			WOR										
								47	94	90	36	181 (UCS)	
84.5	15		0										OC
79.5	20		WOR										
							Abundant shells.						
74.5	25							48	92				C
			WOR										
							Minor shell fragments.	51	82	71	35	386 (TXUU)	
69.5	30		0	0.13			Soft.						
64.5	35		0	0.14									OC
59.5	40							51	85				C
			WOR 75 psi					56	73	65	28	330 (UCS)	
54.5	45		24				Greenish gray, stiff, minor silt.						
							"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), light olive brown, moist, stiff, minor silt, medium plasticity.						
49.5	50		21		1.15			97	28	43	21	1283 (UCS)	CORR

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			28				"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: stiff to very stiff.						
39.5	60		200psi 250psi 385psi							30	19		GS (-#200=87%)
							SANDY SILT to SILTY SAND (ML/SM), olive brown, wet, stiff silt to dense sand, minor clay fines.						
			30										
34.5	65		22				POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, medium dense, fine grained sand.						
							CLAYEY SAND (SC), brown, wet.						
29.5	70		48				LEAN CLAY (CL), olive brown, wet, hard, minor fine grained sand.	104	21				CORR, GS (-#200=94%)
							POORLY GRADED SAND with SILT (SP-SM), dark olive gray, wet, dense, medium to coarse grained sand, with trace very fine gravel.						
24.5	75		30										GS (-#200=10%)
19.5	80		30				POORLY GRACED SAND with SILT and GRAVEL (SP-SM), dark olive gray, wet, dense, mixed fine to coarse gravel, subrounded to angular, spherical to elongated, medium to coarse sand.						GS (-#200=12%)
14.5	85		50				POORLY GRADED SAND (SP), coarse grained. POORLY GRADED GRAVEL (GP), fine subrounded to rounded, up to 1/2 inch. POORLY GRADED SAND with SILT (SP-SM), dark olive gray, wet, dense, mixed fine to coarse gravel, subrounded to angular, medium to coarse sand.						
9.5	90		46					117	17				GS (-#200=11%)
4.5	95		33				"OLD BAY DEPOSITS (Qobd)" FAT CLAY (CH), greenish gray, moist, very stiff.						
-0.5	100		25				SILTY CLAY (CH), greenish gray, moist, stiff, moderate to high plasticity.	73	50	79	28	1595 (UCS)	
-5.5	105												

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			29		2.2 1.8		"OLD BAY DEPOSITS (Qobd)" cont. SILTY CLAY (CH) cont. At 110 feet: stiff to very stiff.	64	61	94	29	1376 (UCS)	
-15.5	115												
-20.5	120		7		1.05		Medium stiff to stiff, with scattered shell fragments.	65	60			1000 (UCS)	

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater measured at approximately 1.3 feet on 9/24/15.
3) Boring backfilled with cement grout on 9/24/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 86.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-109P
DRILLING DATE: September 24-25, 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								3.5 inches asphalt; 6 inches of aggregate base.						
								"ARTIFICIAL FILL (af)" POORLY GRADED SAND (SP), grayish brown, damp, fine grained.						
97.7	5		1					Very loose, wet.						
			2					"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), very dark greenish gray, moist, no organics, no odor.						
92.7	10													
			0 psi		0.09	0.07		Very soft.	48 45	92 100	102	41	161 (TxUU)	C
87.7	15													
82.7	20		0 psi 50 psi			0.22		Soft.	52 54	83 78	88	35	412 (TxUU)	C
77.7	25													
72.7	30		WOR			0.19		Very soft.						
67.7	35													
62.7	40		WOR			0.17			53	77	75	32		
57.7	45													
								SILTY CLAY (CH), greenish gray, moist, stiff, moderate to high plasticity.						
52.7	50		18			1.75 1.3		"UPPER LAYERED SEDIMENTS (Quls)" SILTY CLAY (CL), light olive brown, moist, stiff, low plasticity.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 86.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-109P
DRILLING DATE: September 24-25, 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"UPPER LAYERED SEDIMENTS (Quls)" cont. SILTY CLAY (CL) cont.						
								SANDY CLAY (CL), olive brown, moist, stiff.						
42.7	60		36					POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, medium dense, fine grained sand.	105	22				CORR
37.7	65		17					SILT with CLAY and SAND (ML), olive green, moist, stiff, non-plastic silt. SILTY SAND (SM), olive brown, moist, dense, fine grained sand.						
32.7	70		38											GS (-#200=17%)
27.7	75		22					Olive gray, wet, medium dense, fine grained.						GS (-#200=22%)
22.7	80		27					Increased amount of medium grained sand.						GS (-#200=12%)
17.7	85		45					Olive gray, wet, dense, medium to coarse grained, trace to minor fine rounded gravel. SANDY GRAVEL (GP), olive brown, wet, dense, fine gravel, subrounded to subangular, matrix of medium to coarse grained sand with clayey silt fines.						

NOTES:
1) Bottom of boring at 86.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-109P on 9/25/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"ARTIFICIAL FILL (af)" CLAY (CL), dark gray, damp, soft.						
94.9	5		0		0.16	0.25		"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, very soft.						
89.9	10		50 psi		0.09	0.15			46	100	101	41	155 (TxUU)	
84.9	15		0		0.15	0.3		Soft.						
79.9	20													
74.9	25		0		0.19	0.4								
69.9	30		50 psi		0.45			Medium stiff, trace shells.	51 50	85 88	88	36	344 (TxUU)	C
64.9	35													
59.9	40													
54.9	45		16			1.8		"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), grayish brown, moist, stiff, minor orange mottling.						
49.9	50		18			1.2		Dark olive brown with grayish brown mottling, trace concretions up to 1/2 inch.	92	31	60	25	1606 (UCS)	CORR

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			21			2.6		"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont. At 55 feet: Very stiff, increasing orange mottling.						
39.9	60		7			1.2		SILTY CLAY (CL), grayish brown with minor orange mottling, moist, stiff.						
34.9	65		28			1.0		Grades to Clayey Sand.	106	22				GS (-#200=39%)
								POORLY GRADED SAND (SP), dark brown to dark gray, wet, medium dense, fine to medium grained.						
29.9	70		16											
24.9	75		24					WELL GRADED SAND with CLAY (SW-SC), gray to brown, wet, medium dense, gravel up to 1/4 inch diameter, fine to coarse sand.						GS (-#200=10%)
19.9	80		26					Decreasing gravel, dense.						
14.9	85		26					"OLD BAY DEPOSITS (Qobd)" LEAN CLAYEY GRAVEL with SAND to GRAVELLY FAT CLAY (GC/CH), dark olive brown, moist, stiff to very stiff.						
9.9	90		36					Dark gray.			45	23		
4.9	95													
-0.1	100		15			2.0		Very dark gray with trace orange mottling, moist, stiff.	69	54			1244 (UCS)	
-5.1	105													

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			12			1.2		"OLD BAY DEPOSITS (Qobd)" LEAN CLAYEY GRAVEL with SAND to GRAVELLY FAT CLAY (GC/CH) cont.	63	61	79	32	984 (UCS)	
-15.1	115													
-20.1	120		16			1.75		Dark greenish gray, trace shells.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-113P on 10/15/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"ARTIFICIAL FILL (af)" LEAN CLAY (CL), dark gray, moist, soft, minor orange mottling, trace plant debris. (POND SEDIMENTS)						
94.6	5		0		0.15			"YOUNG BAY MUD (Qybm)" FAT CLAY to ELASTIC SILT (CH/MH), dark gray, wet, soft.						
89.6	10		50psi		0.15				44 46	105 96	83	39	285 (TxUU)	C
84.6	15		0			0.5								
79.6	20		0			0.4		Abundant shells.						
74.6	25		0			0.4								
69.6	30		0		0.24	0.6		Abundant shell fragments.	48	92	83	35		CORR
64.6	35		0			0.5								
59.6	40		4		0.52	1.25		Moist, stiff.						
								"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), grayish brown to dark olive brown, moist, very stiff, trace black and orange mottling.						
54.6	45		23			2.0			100	26	55	24	1999 (UCS)	
49.6	50		15			1.9		Gray to orange mottling, stiff.						

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		25		2.7	"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: Brownish gray with dark gray and orange mottling, very stiff.						
39.6	60	32			CLAYEY SAND (SC), medium brown, wet, medium dense, fine grained sand, minor silt.						
34.6	65	26									GS (-#200=29%)
29.6	70	15									GS (-#200=24%)
24.6	75	34 26			Fine to medium grained sand.	101	17				DS, CORR GS (-#200=13%)
19.6	80	23			WELL GRADED SAND and CLAY (SW-SC), brown to gray, wet, medium dense, gravel clasts 3/4 inches in diameter, fine to coarse grained sand.						GS (-#200=9%)
14.6	85	33			Dense, increasing fine gravel.						GS (-#200=9%)
9.6	90	16			"OLD BAY DEPOSITS (Qobd)" FAT CLAY (CH), dark greenish brown, moist, very stiff, trace gravel.						
4.6	95	29		2.4		100	26	67	23	2130 (UCS)	
-0.4	100	16		2.4	No gravel.						
-5.4	105	18		3.5	Dark greenish gray.						

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			13			1.5		"OLD BAY DEPOSITS (Qobd)" cont. LEAN CLAY (CL) cont. At 110 feet: Stiff.	63	61			827 (UCS)	
-15.4	115													
-20.4	120		11			1.5		Dark gray.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-114P on 10/21/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 98 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: K. Khatri, J. Thurber
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-115P
DRILLING DATE: November 2-3, 2015
ELEVATION: 102.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								2 inches Asphalt Concrete.						
								"ARTIFICIAL FILL (af)" CLAYEY SAND (SC), brown, moist.						
97.5	5							GRAVELLY CLAY (CL), dark gray, damp, very stiff, angular 1/4 -1 inch diameter gravel clasts, filter fabric fragment.						
								Medium brown, moist, 3 inch diameter hard gravel clasts.						
								LEAN CLAY with GRAVEL (CL), gray brown, moist to wet, stiff.						
92.5	10							"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, soft.						
87.5	15													
82.5	20													
77.5	25													
72.5	30													
67.5	35													
								Trace shell fragments.						
62.5	40													
								Shell fragments.						
57.5	45							"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), dark olive brown to grayish brown, wet, trace shell fragments.						
52.5	50													

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 98 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: K. Khatri, J. Thurber
CHECKED BY: D. Agnew

DRILL HOLE NO.: B-115P
DRILLING DATE: November 2-3, 2015
ELEVATION: 102.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		40	2.5	"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont. At 55 feet: dark brown with gray mottling, moist, hard.	88 90	34 32	69	29	2221 (UCS)	
42.5	60	29	1.4	SILTY SAND (SM), dark brown, moist, medium dense, fine grained sand.						CORR
37.5	65	8		SILTY CLAY (CL), brown, wet, soft.						
				SILTY SAND (SM), dark brown, wet, loose, very fine grained sand.						
32.5	70	41		Very dark brown, dense, trace medium grained sand.						
27.5	75	27		POORLY GRADED SAND with SILT (SP-SM) to SILTY SAND (SM), dark brown to dark gray, wet, medium dense, fine to medium grained sand.						GS (-#200=8%)
22.5	80	30		Dark gray, dense, trace coarse grained sand, trace gravel up to 1 inch in diameter.						CORR
17.5	85	27		Increasing grain size, coarse grained sand to fine gravel.						GS (-#200=14%)
12.5	90	29		LEAN CLAY (CL), dark greenish gray, wet, very stiff.						
7.5	95	47	2.7	Dark grayish brown, moist, hard.						

NOTES:
1) Bottom of boring at 98 feet.
2) Groundwater not observed due to drilling method.
3) Boring reamed to 10 inches in diameter and completed as 5-inch diameter well (Piezometer B-115P) on 11/3/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY: J. Seibold

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
					"ARTIFICIAL FILL (af)" SILTY CLAY/CLAYEY SILT (CL/ML), dark gray, moist. (POND SEDIMENTS)						
94.5	5		0.24	0.275	"YOUNG BAY MUD (Qybm)" ELASTIC SILT to FAT CLAY (MH/CH), dark olive gray to very dark gray, moist to wet, very soft.						
					Wet.						
89.5	10	0			Minor organics.	47	96	102	44		CORR
84.5	15	0	0.20 0.40		Minor shells.	49	88			297 (TxUU)	
79.5	20	0	0.19		Decreasing elasticity.						
					FAT CLAY (CH), dark gray, wet, very soft. Abundant shells.						
74.5	25	0	0.26		Minor organics.		95				OC
69.5	30	50psi				51 54	86 78	89	37	385 (TxUU)	C
64.5	35	0	0.26		Abundant shells.						
59.5	40	0 12	0.26 0.27								
					"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), mottled olive gray, dark gray, and light olive gray, moist, stiff to very stiff, trace fine grained sand, trace concretions and carbonate cement.						
54.5	45	20 10		1.8 2.7	Yellowish brown.	104	23	46	20	1125 (UCS)	
49.5	50	18 12		1.9 2.1	Minor orange mottling.						CORR

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY: J. Seibold

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			31				"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont.	94	30			2225 (UCS)	
			14				At 56 feet: Very stiff, trace black mottling.						
39.5	60		32		2.4								
			33				SILTY SAND (SM), medium brown, wet, dense, fine grained sand.						
34.5	65		18				SANDY SILT/SILTY SAND (ML/SM), brown, wet, medium dense, fine grained sand.	103	25				FC (-#200=64%)
			41				Very dense.						
29.5	70		35				POORLY GRADED SAND with SILT (SP-SM), dark brown to dark gray, wet, medium dense, fine to coarse grained sand.	100	23				CORR, DS, GS (-#200=10%)
			21				Increasing grain size. Trace gravel clasts to 1/2 inch in diameter.						
24.5	75		19				SILTY SAND (SM), brown to gray, wet, medium dense, fine to coarse grained sand, fine gravel, trace gravel clasts up to 1 1/3 inch diameter.						GS (-#200=12%)
19.5	80		30				WELL GRADED SAND with SILT (SW-SM), brown to gray, wet, dense, trace gravel up to 1 inch diameter.						GS (-#200=10%)
							Trace to minor clay. Mixture of sand, gravel, and clay.						
14.5	85		30				FAT CLAY (CH), dark brownish gray, moist, hard.						
9.5	90		30		3.75		Brownish gray and grayish olive brown mottling, very stiff.	95	30	63	29	2412 (UCS)	
4.5	95		38		2.75		Dark gray with brownish gray mottling, hard.						
-0.5	100		18		2.5		Dark bluish gray, very stiff.	71	52			1280 (UCS)	
-5.5	105												

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY: J. Seibold

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			18		3.5		"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont.	65	59	89	36	1263 (UCS)	
-15.5	115												
-20.5	120		18		2.2		Very dark gray.						

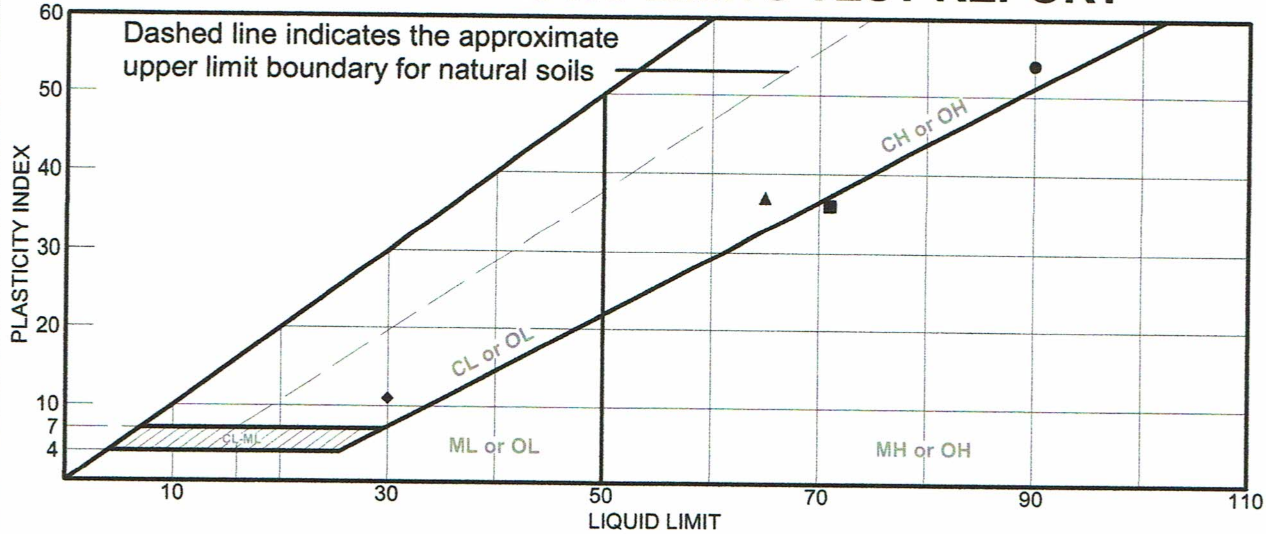
NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring backfilled with cement grout on 10/28/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

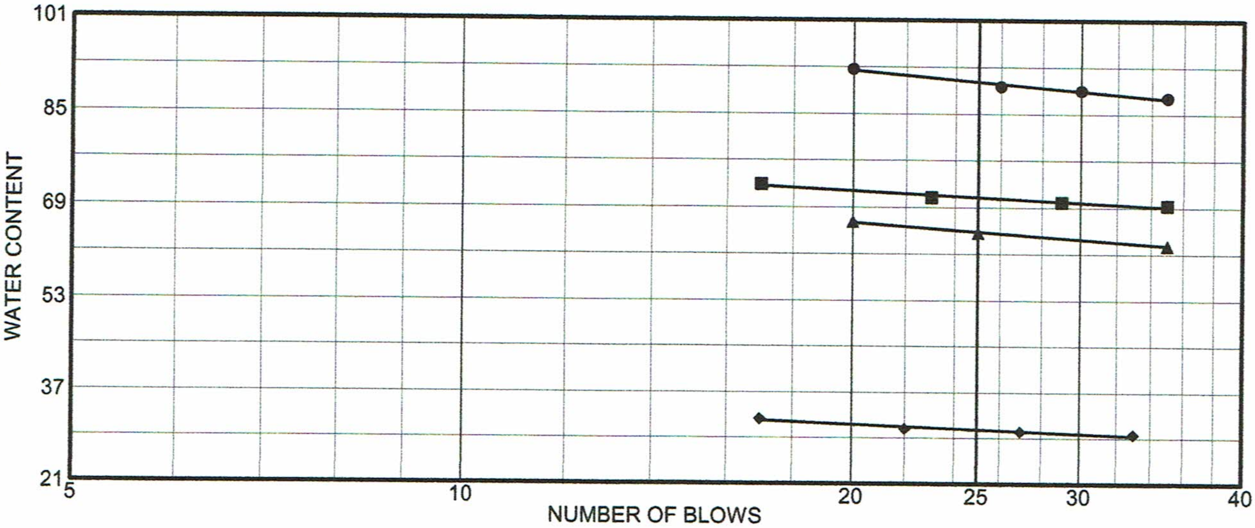
LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 2/3/16

LEGEND TO LOGS ON PLATE A-2

APPENDIX C

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Fat CLAY (Bay Mud)	90	36	54			
■	Greenish Gray Elastic SILT (Bay Mud)	71	35	36			
▲	Greenish Gray Fat CLAY (Bay Mud)	65	28	37			
◆	Olive Brown Lean CLAY	30	19	11	99.9	86.6	CL

Project No. 836-002 **Client:** DCM Consulting, Inc.

Project: SVCW Headworks

● **Source:** B-101 **Elev./Depth:** 10-13'

■ **Source:** B-101 **Elev./Depth:** 25-28'

▲ **Source:** B-101 **Elev./Depth:** 40-43'

◆ **Source:** B-101 **Elev./Depth:** 60-63'

Remarks:

●

■

▲

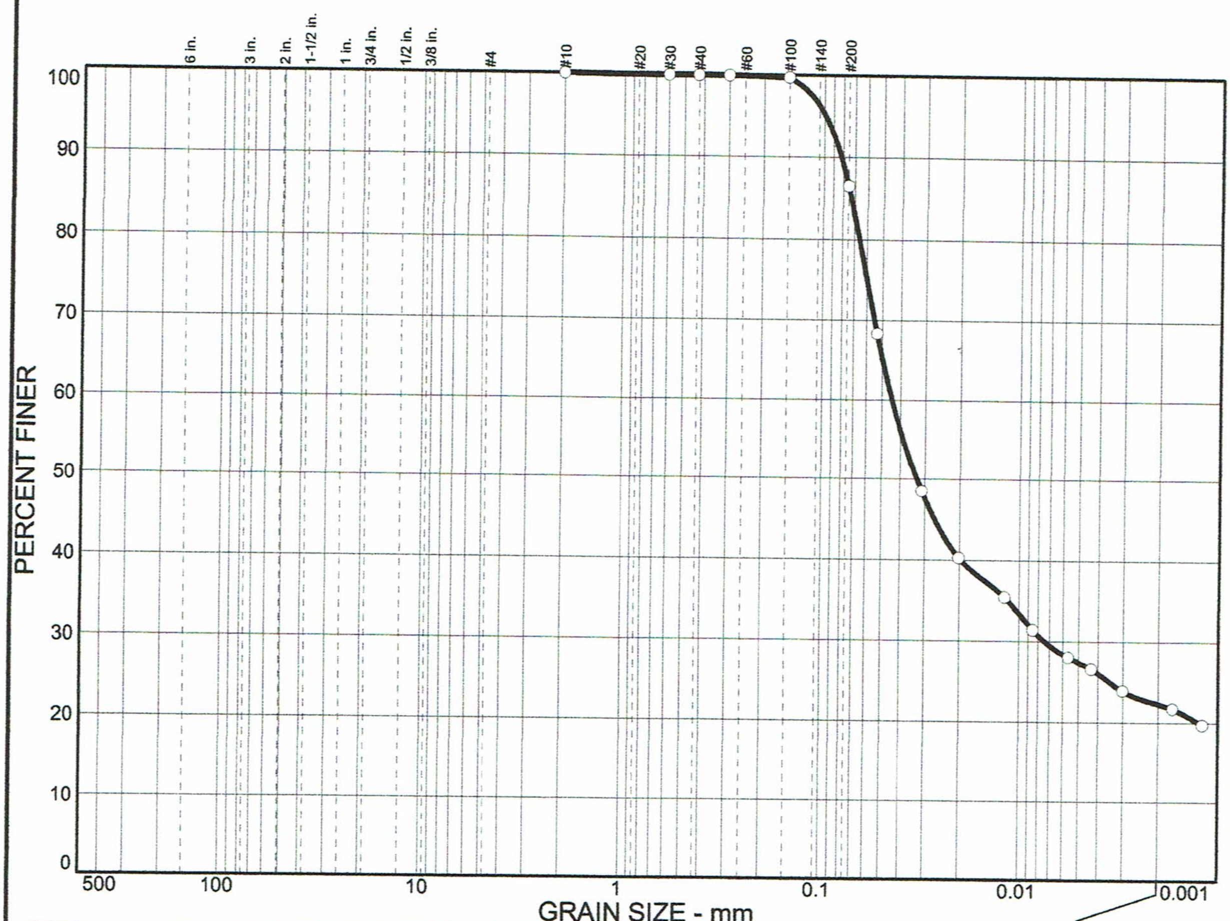
◆

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	13.4	64.3	22.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.9		
#40	99.9		
#50	99.9		
#100	99.7		
#200	86.6		
#270	68.3		
0.0311 mm.	48.5		
0.0202 mm.	40.3		
0.0119 mm.	35.4		
0.0085 mm.	31.4		
0.0056 mm.	28.0		
0.0043 mm.	26.6		
0.0030 mm.	23.9		
0.0017 mm.	21.7		
0.0012 mm.	19.7		

* (no specification provided)

Soil Description

Olive Brown Lean CLAY

Atterberg Limits

PL= 19 LL= 30 PI= 11

Coefficients

D_{85}= 0.0724 D_{60}= 0.0442 D_{50}= 0.0329
D_{30}= 0.0074 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO=

Remarks

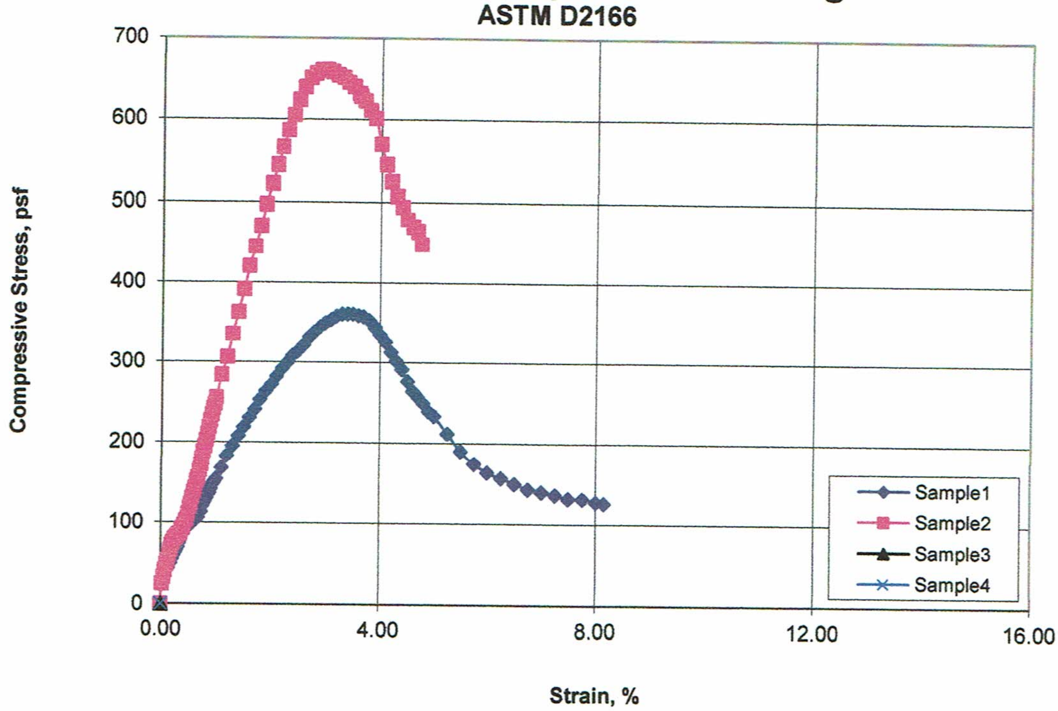
Sample No.:
Location:
Source of Sample: B-101
Date: 10/16/15
Elev./Depth: 60-63'

COOPER TESTING LABORATORY

Client: DCM Consulting, Inc.
Project: SVCW Headworks
Project No: 836-002 **Figure**

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	361	661			
Unconfined Compressive Strength, psi	2.5	4.6			
Undrained Shear Strength, psf	181	330			
Failure Strain, %	3.4	3.0			
Strain Rate, % per minute	1.0	1.0			
Strain Rate, inches/minute	0.06	0.06			
Moisture Content, %	94.1	72.7			
Dry Density, pcf	46.5	56.1			
Saturation, %	96.8	97.8			
Void Ratio	2.625	2.006			
Specimen Diameter, inches	2.875	2.875			
Specimen Height, inches	6.10	6.08			
Height to Diameter Ratio	2.1	2.1			
Assumed Specific Gravity	2.70	2.70			

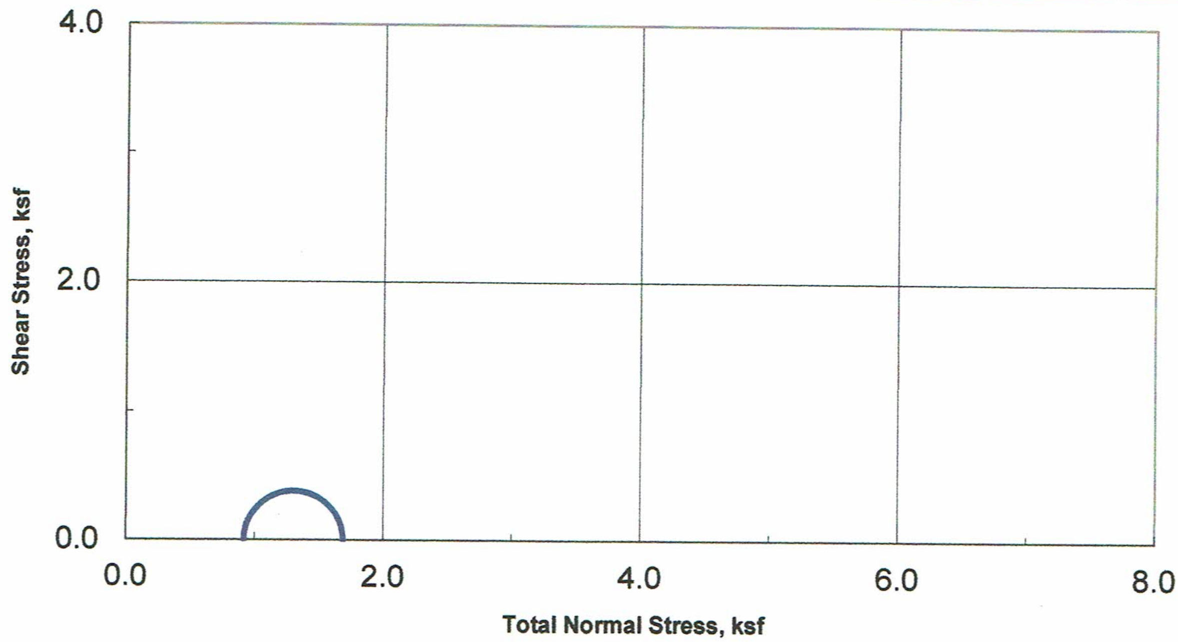
	Sample Location			
	Boring	Sample	Depth, ft.	Soil Description
1	B-101		10-13(Tip-4.5")	Greenish Gray Fat CLAY (Bay Mud)
2	B-101		40-43(Tip-5")	Greenish Gray Fat CLAY (Bay Mud)
3				
4				

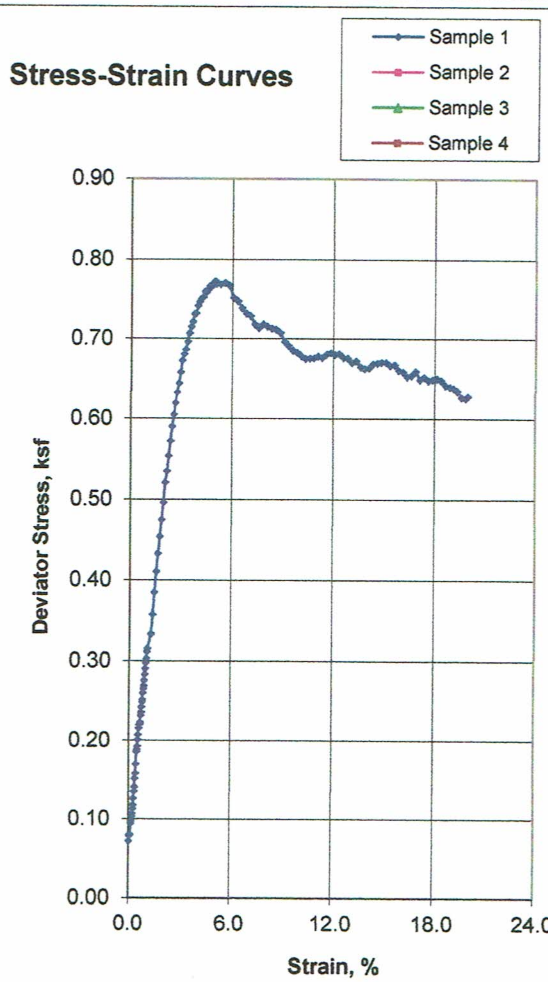
Job No.:	836-002	Type of Sample	Undisturbed
Client:	DCM Consulting, Inc.		
Project:	SVCW Headworks	Remarks:	
Date:	10/13/2015 By: MD/RU		

COOPER TESTING LABORATORY

Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data

	1	2	3	4
Moisture %	82.2			
Dry Den,pcf	51.2			
Void Ratio	2.291			
Saturation %	96.9			
Height in	6.09			
Diameter in	2.88			
Cell psi	6.4			
Strain %	4.95			
Deviator, ksf	0.772			
Rate %/min	1.04			
in/min	0.064			

Job No.:	836-002			
Client:	DCM Consulting, Inc.			
Project:	SVCW Headworks			
Boring:	B-101			
Sample:				
Depth ft:	25-28(Tip-6.5")			

Visual Soil Description

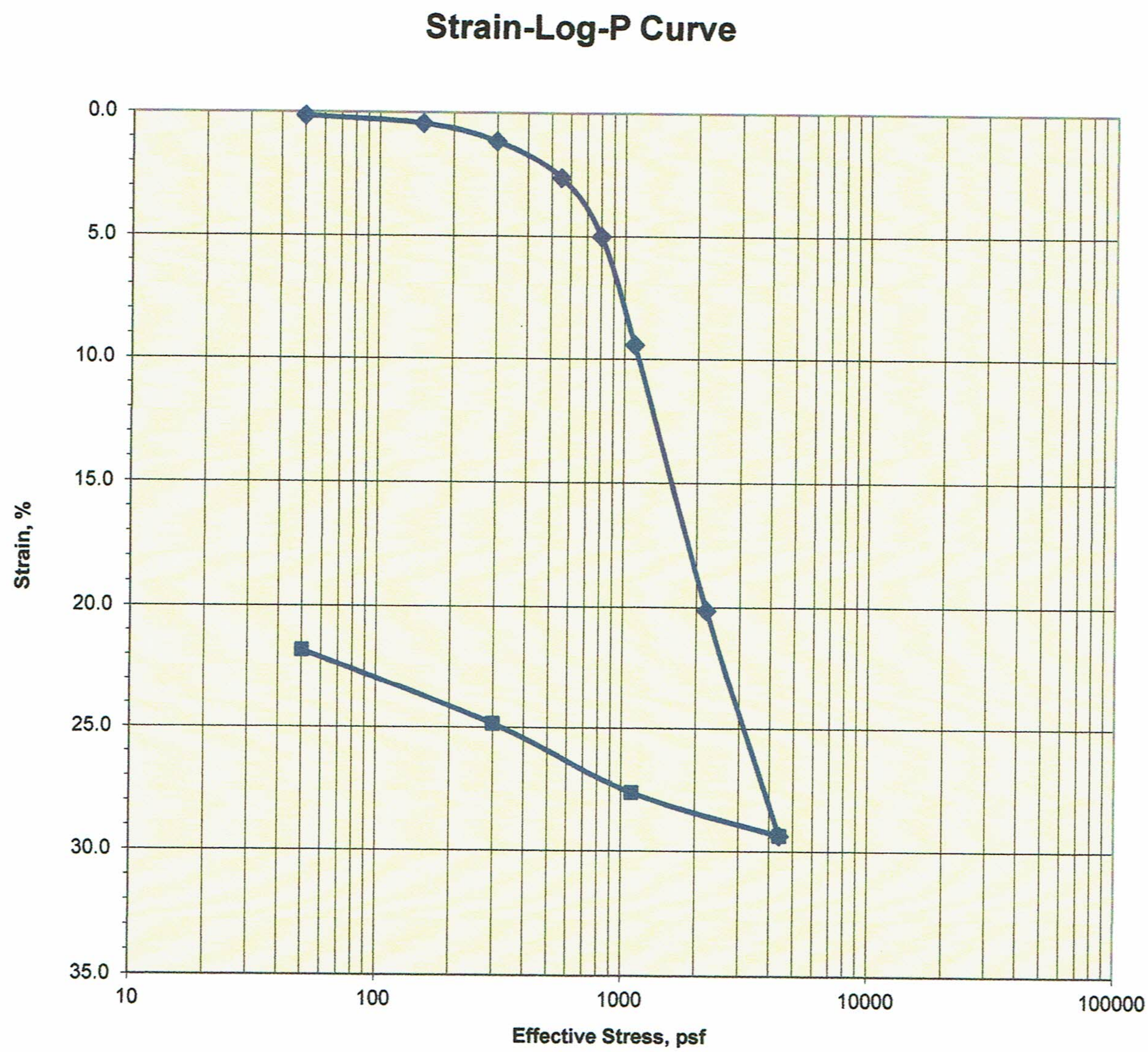
Sample #	
1	Greenish Gray Elastic SILT (Bay Mud)
2	
3	
4	

Remarks:

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	10-13(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Fat CLAY (Bay Mud)			**Date:**	10/16/2015

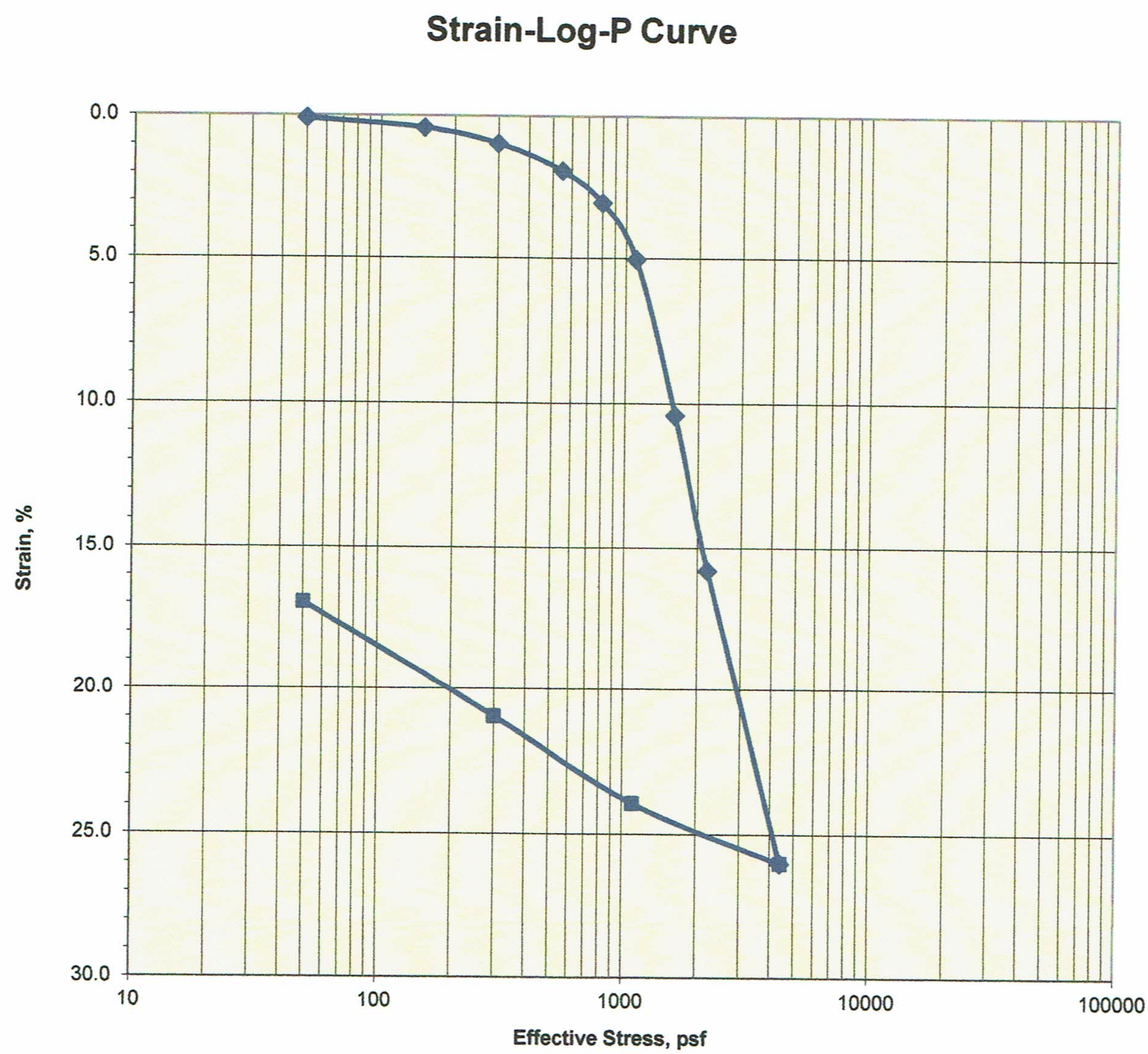


Assumed Gs 2.7	Initial	Final
Moisture %:	97.6	68.5
Dry Density, pcf:	45.8	59.1
Void Ratio:	2.680	1.850
% Saturation:	98.4	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	836-002	Boring:	B-101	Run By:	MD
Client:	DCM Consulting, Inc.	Sample:		Reduced:	PJ
Project:	SVCW Headworks	Depth, ft.:	25-28(Tip-6")	Checked:	PJ/DC
Soil Type:	Greenish Gray Elastic SILT (Bay Mud)			Date:	10/20/2015



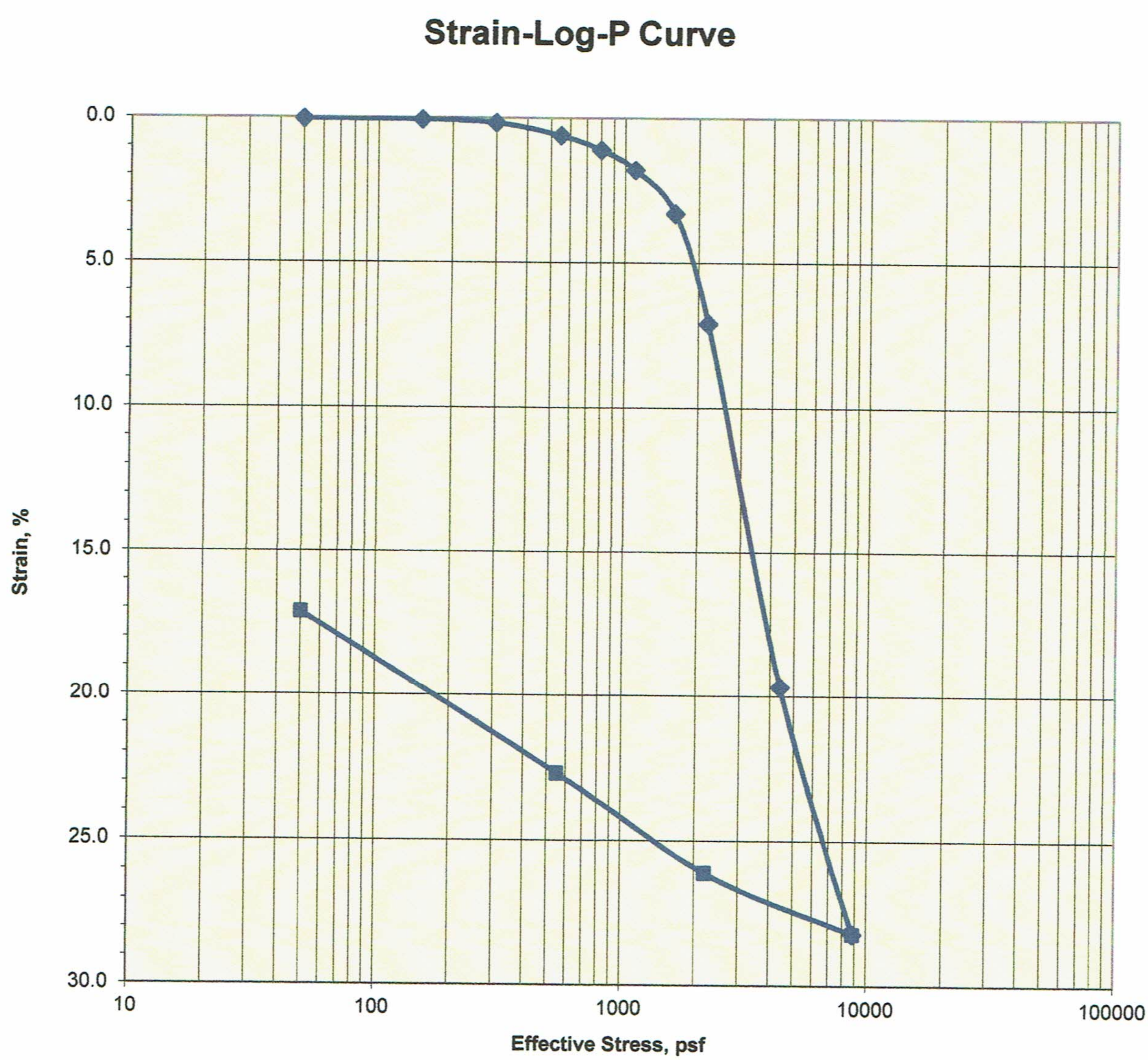
Assumed Gs 2.65	Initial	Final
Moisture %:	92.2	69.8
Dry Density, pcf:	47.8	58.0
Void Ratio:	2.462	1.851
% Saturation:	99.3	100.0

Remarks:

Consolidation Test
ASTM D2435

COOPER TESTING LABORATORY

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	40-43(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Fat CLAY (Bay Mud)			**Date:**	10/20/2015

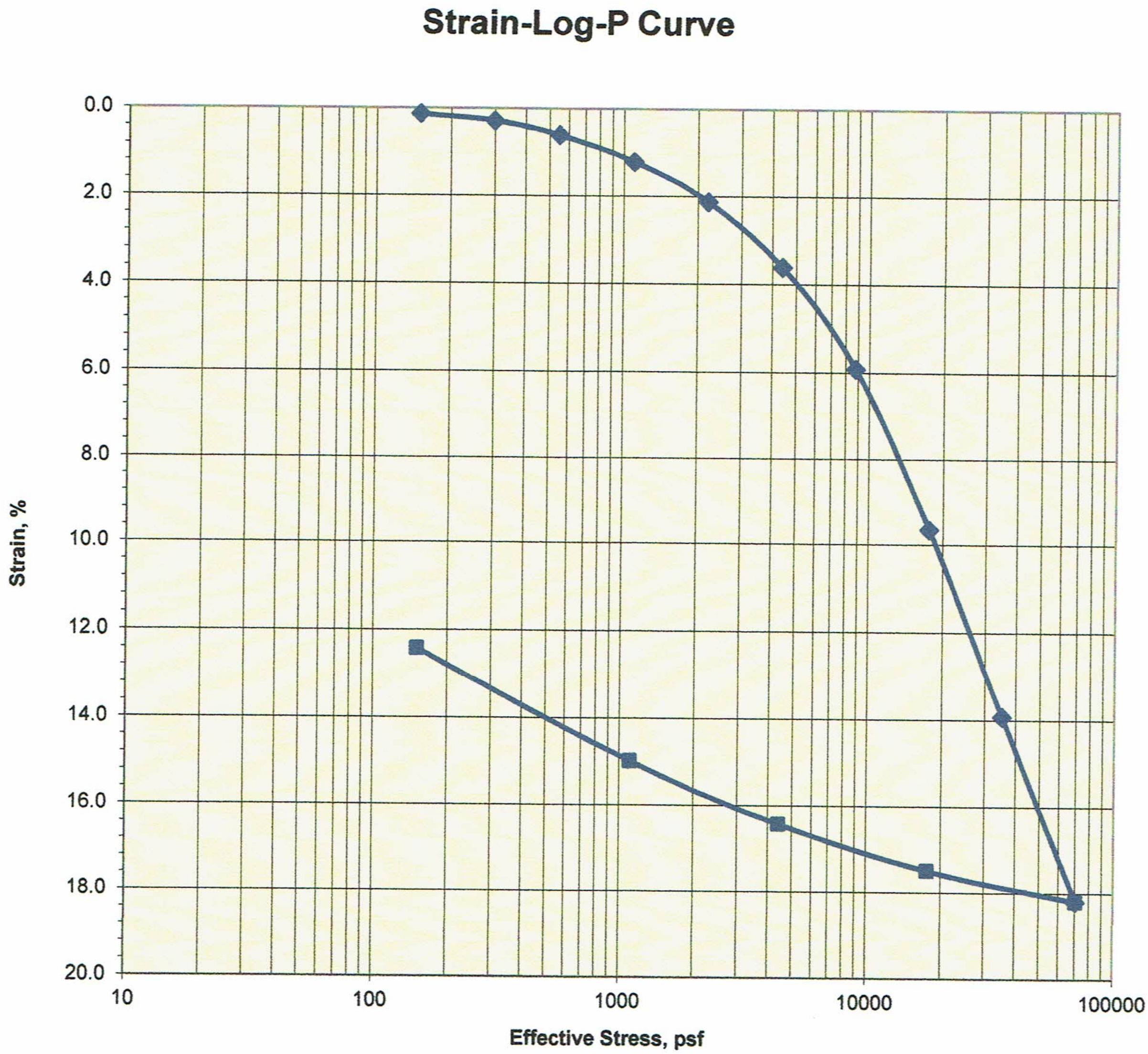


Assumed Gs 2.7	Initial	Final
Moisture %:	85.2	63.8
Dry Density, pcf:	50.9	61.9
Void Ratio:	2.314	1.724
% Saturation:	99.4	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	60-63(Tip-8")	**Checked:**	PJ/DC
Soil Type:	Olive Brown Lean CLAY			**Date:**	10/23/2015



Assumed Gs 2.75	Initial	Final
Moisture %:	25.0	20.2
Dry Density, pcf:	96.8	110.3
Void Ratio:	0.773	0.556
% Saturation:	89.1	100.0

Remarks:

APPENDIX D

Abe Construction Services, Inc.

5111 Doolan Rd, Livermore, CA 94551
PHONE: 925-944-6363 FAX: 925-476-1588
EMAIL: SA@ACSpile.com

Dynamic Pile Test Report

Company:	Stroer & Graff		June 4, 2015
Attn:	Dan McWilliams	**From:**	Steve Abe
Re:	Silicon Valley Clean Water Plant Redwood City, CA		Job No. 15037

This report presents dynamic pile monitoring results for the project referenced above obtained during initial driving for sixteen piles on June 1 and June 2, and during one restrike for Pile 14 on June 4, 2015. The primary test objectives were to evaluate soil resistance at the time of testing, pile driving stresses, and hammer performance. The dynamic testing was performed using a Model PAX Pile Driving Analyzer (PDA) according to the ASTM D4945 test standard. Subsequent CAPWAP analysis was performed for selected restrike test data to further evaluate pile capacity and soil resistance distributions.

Pile Details

The piles consist of 109 ft long 14" square PCPS concrete piles with an ultimate concrete strength of 6000 PSI and effective concrete prestress of 999 PSI with maximum allowable compression and tension driving stress limits of 4.10 KSI and 1.23 KSI.

Hammer / Driving System Details

The piles were driven with an APE D30-32 diesel hammer which has a maximum rated energy of 74.42 kip-ft.

Subsurface Soil Conditions

The general soil profile was not provided at the time of testing, however the piles driven in 30ft oversized predrilled holes.

DYNAMIC TEST RESULTS

The following PDA calculated Case Method results are printed versus blow number and pile penetration depth in Appendix A as well as CAPWAP analysis results which are included in Appendix B.

- RMX- the Case Method ultimate static capacity estimate using a Case Damping factor of 0.7
- EMX- maximum energy transferred to the pile.
- CSX- the maximum axial compression stress at the sensor location, computed using the average of two strain transducer measurements.
- TSX- the maximum axial tension stress at the sensor location, computed using the average of two strain transducer measurements.

The PDA results and CAPWAP Analysis results are summarized in the following table for selected pile penetration depths.

					PDA Results				
Pile No.	Type	Date	Depth BG	Blow Count	RMX (kips)	CSX (KSI)	TSX (KSI)	STK (ft)	EMX (kip-ft)
Pile 1	EOD	6/1	105.8	10	160	3.25	1.57	6.9	22.4
Pile 2	EOD	6/2	106.0	11	221	3.76	1.40	7.5	26.9
Pile 3	EOD	6/2	106.0	11	220	3.31	1.34	7.3	23.9
Pile 4	EOD	6/2	105.5	12	232	3.34	1.52	7.3	23.8
Pile 5	EOD	6/1	105.0	19	174	3.17	1.44	6.9	21.7
Pile 6	EOD	6/2	105.5	10	160	3.27	1.43	7.1	22.3
Pile 7	EOD	6/2	106.1	8	204	3.35	1.55	7.3	23.0
Pile 8	EOD	6/2	105.5	12	218	3.28	1.38	7.2	22.7
Pile 9	EOD	6/1	106.4	7	99	2.93	1.40	6.6	19.9
Pile 10	EOD	6/1	106.0	9	205	3.23	1.44	7.4	23.1
Pile 11	EOD	6/1	105.5	12	266	3.52	1.44	7.4	25.4
Pile 12	EOD	6/2	105.3	13	224	3.19	1.34	7.3	22.1
Pile 13	EOD	6/1	105.5	8	137	3.33	1.46	7.1	23.9
Pile 14	EOD	6/1	103.0	15	240	3.31	1.19	7.3	23.6
Pile 14R	BOR	6/4	104.0	40	304	4.37	0.83	7.9	26.4
Pile 15	EOD	6/1	106.5	16	258	3.27	1.23	7.2	23.0
Pile 16	EOD	6/1	106.1	9	212	3.08	1.24	7.1	22.2

The restrike CAPWAP capacity for Pile 14 was approximately 302 kips consisting of 187 kips shaft resistance and 115 kips toe resistance. Comparison of the EOD and BOR RMX capacity estimates for Pile 14 indicate that about 60 kips set-up gain occurred after driving. The RMX capacity estimates at EOD for the other piles ranged from 160 kips to 266 kips. The measured tensile driving stresses did exceed the allowable driving stress limits during initial driving, however no pile damage was observed in the PDA records for any piles.

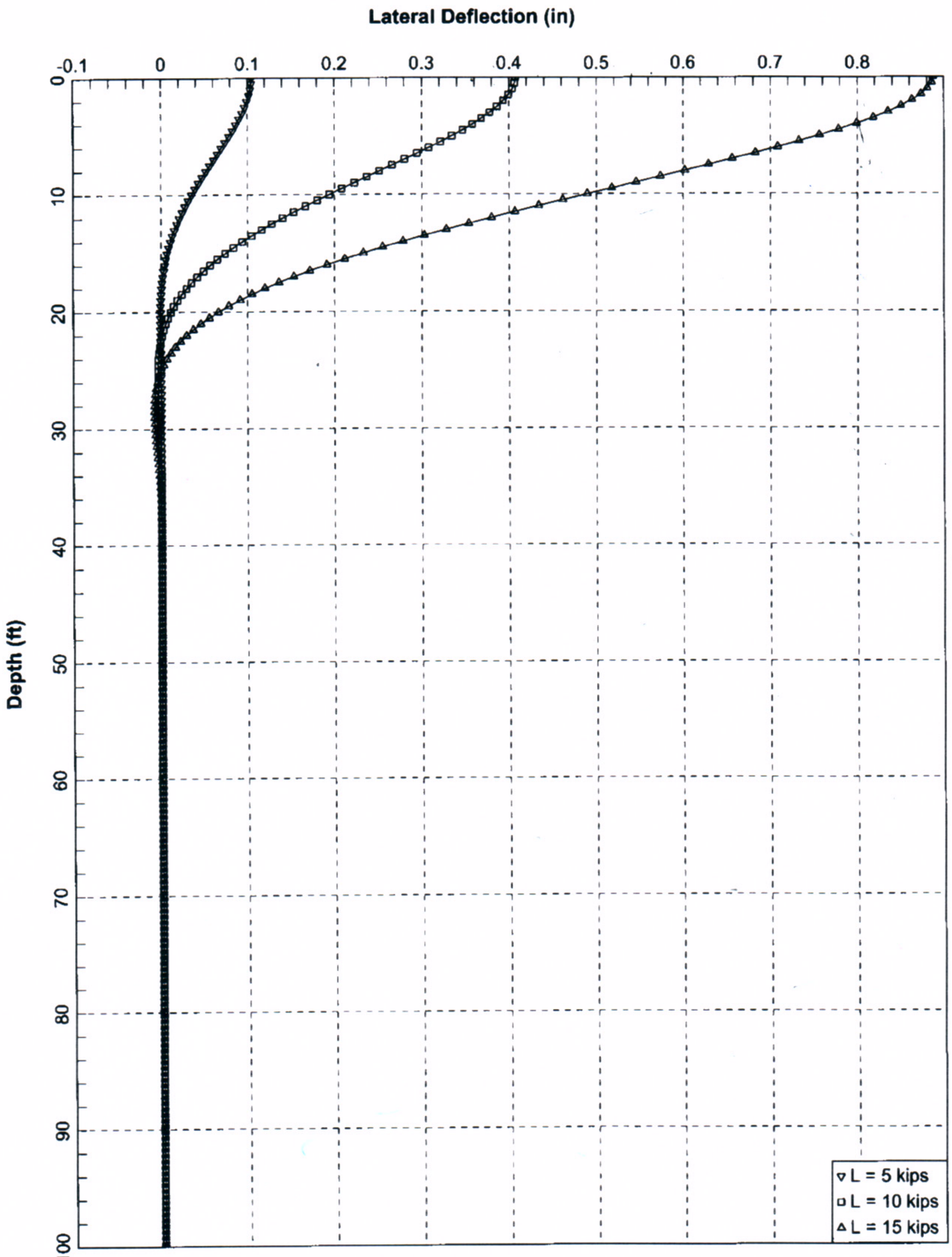
Please review the attached "LIMITATIONS AND CONSIDERATIONS REGARDING DYNAMIC TEST RESULTS". I appreciate the opportunity to assist you with this project. Please contact me if you have any questions regarding these results, or if we may be of further service.

Sincerely,

ACS, Inc.
Steve Abe, P.E.

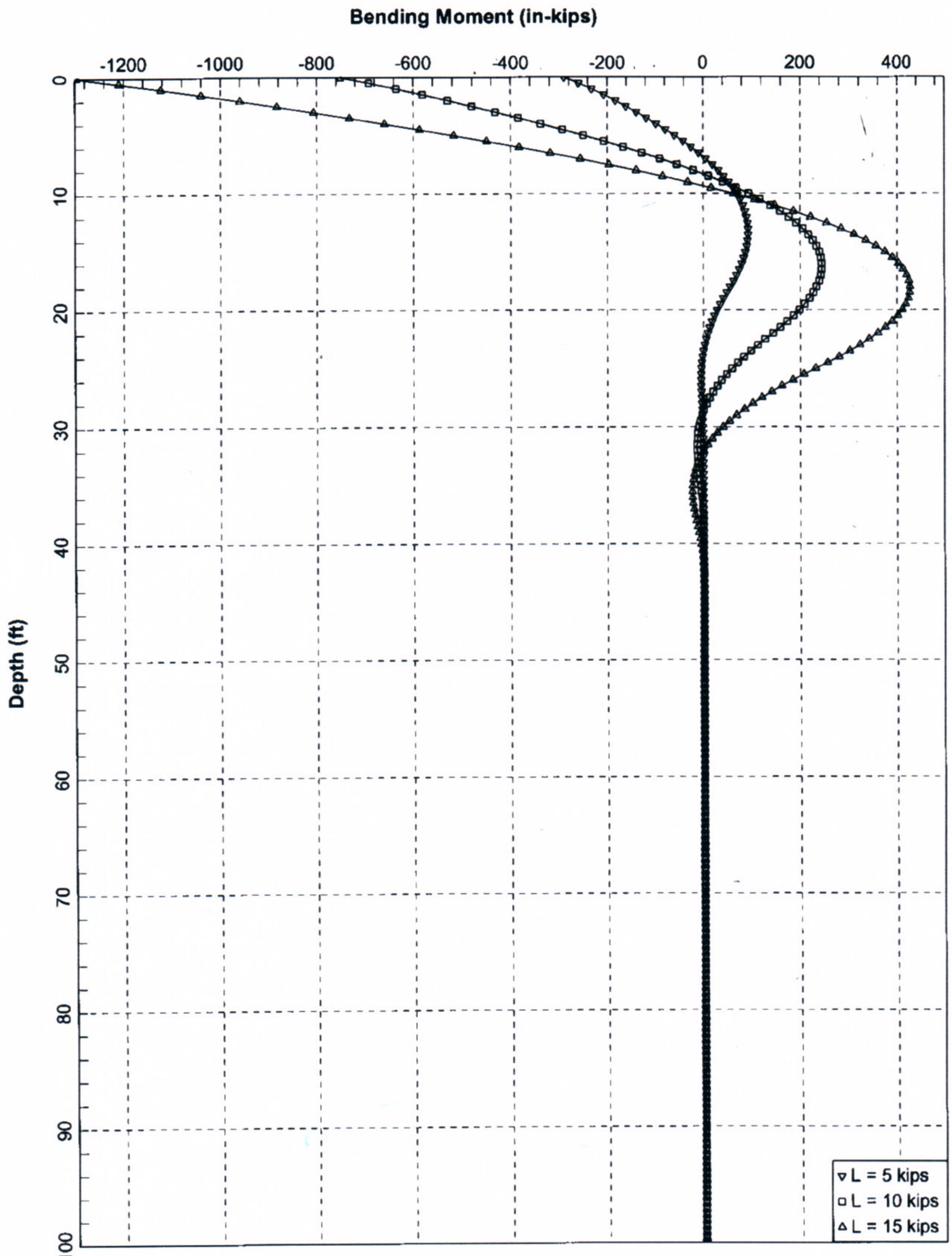
REGISTERED PROFESSIONAL ENGINEER
STEVEN K. ABE
No. C 055277
Exp 12/31/15
CIVIL
STATE OF CALIFORNIA

APPENDIX E



Lateral Deflection - 14-inch PCCP - Fixed Head Condition

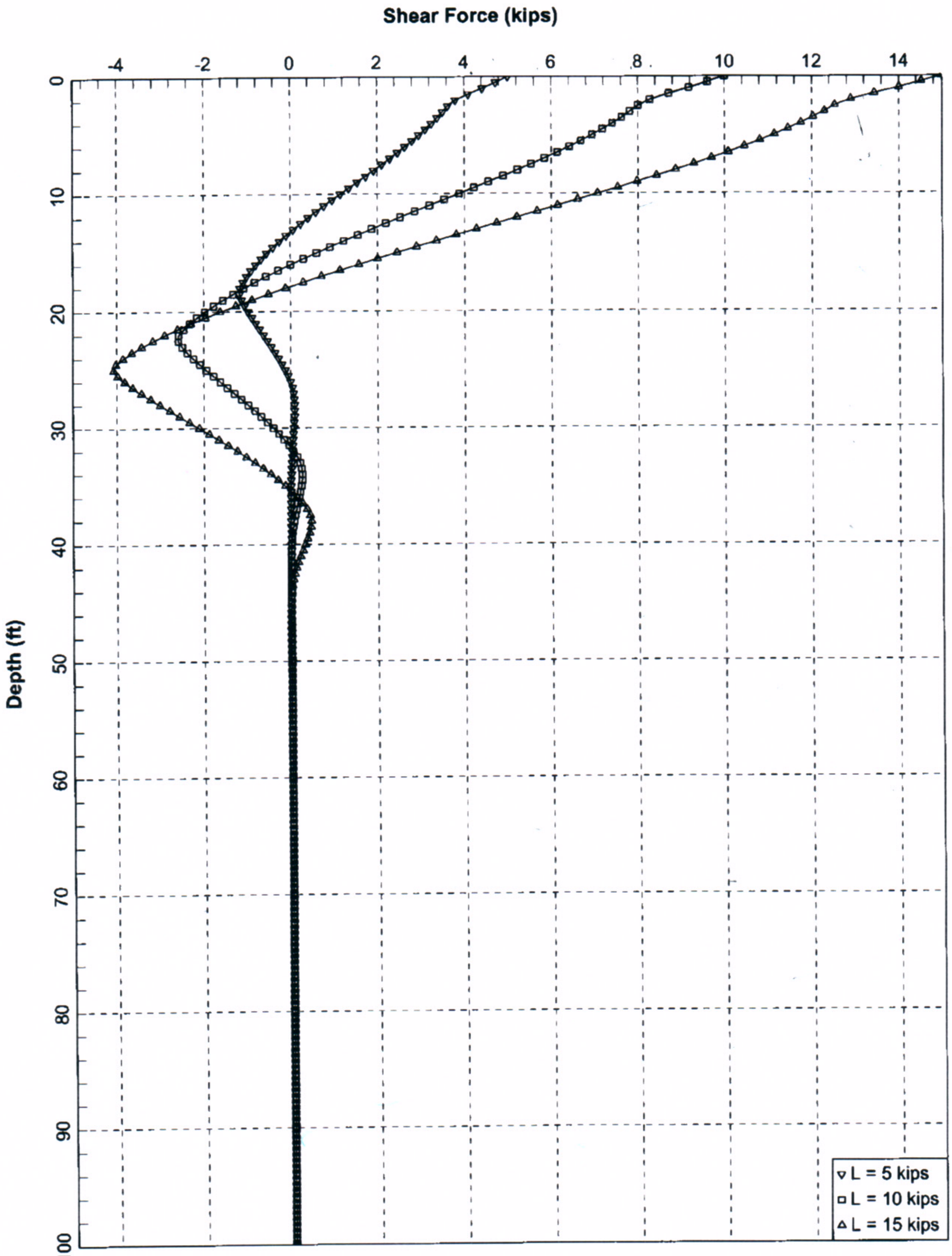
SBSA Administration and Control Building Project
New Stairway/Elevator Structure



Bending Moment - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project

New Stairway/Elevator Structure



Shear Force - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project
New Stairway/Elevator Structure

APPENDIX F

KIE-CON Inc.

3551 WILBUR AVENUE, ANTIOCH, CA 94509

REQUEST FOR INFORMATION

RFI #: RFI-409-2015-1

To:	**Project Manager**	Copy to:			
Company					
Email:		From:	Danny Wong	Total Pg:	2
Fax #:		Tel:	925.754.9494 x 7107	Fax:	925.754.0624
Phone #:		Email:	dwong@kiecon.com	Date:	2/20/2015
Project:	**Influent Screen Phase 1, San Mateo, CA**			**KC ref**	**409-2015**
Reference	**REQUEST FOR INIFORMATION; PRESTRESSED PILES**				

LADIES / GENTLEMEN:

We are in the process of preparing the shop drawing. And we need the EOR to look into the lateral load on the pile.

The contract drawing calls for 15 kips working load, yielding 1100 k-in fixed moment. Using the standard 1.4 factor, the factored moment becomes 128.3 k-ft. This is way beyond a 14" square pile capacity. Please request for the EOR to reduce the lateral load and soil engineer regenerate the new appropriate Lpile moment profile. If reduction not possible, then the EOR need to add more piles.

Attached is the interaction diagram of a 14" sq pile with 6 #9 rebars extended into the pile cap. The project factored loads are also shown. 6 #9 is probably the maximum number of rebars we like to put in without congestion.

☐ **Please Review** ☑ **Please Review & Reply** ☐ ______________

Reply:

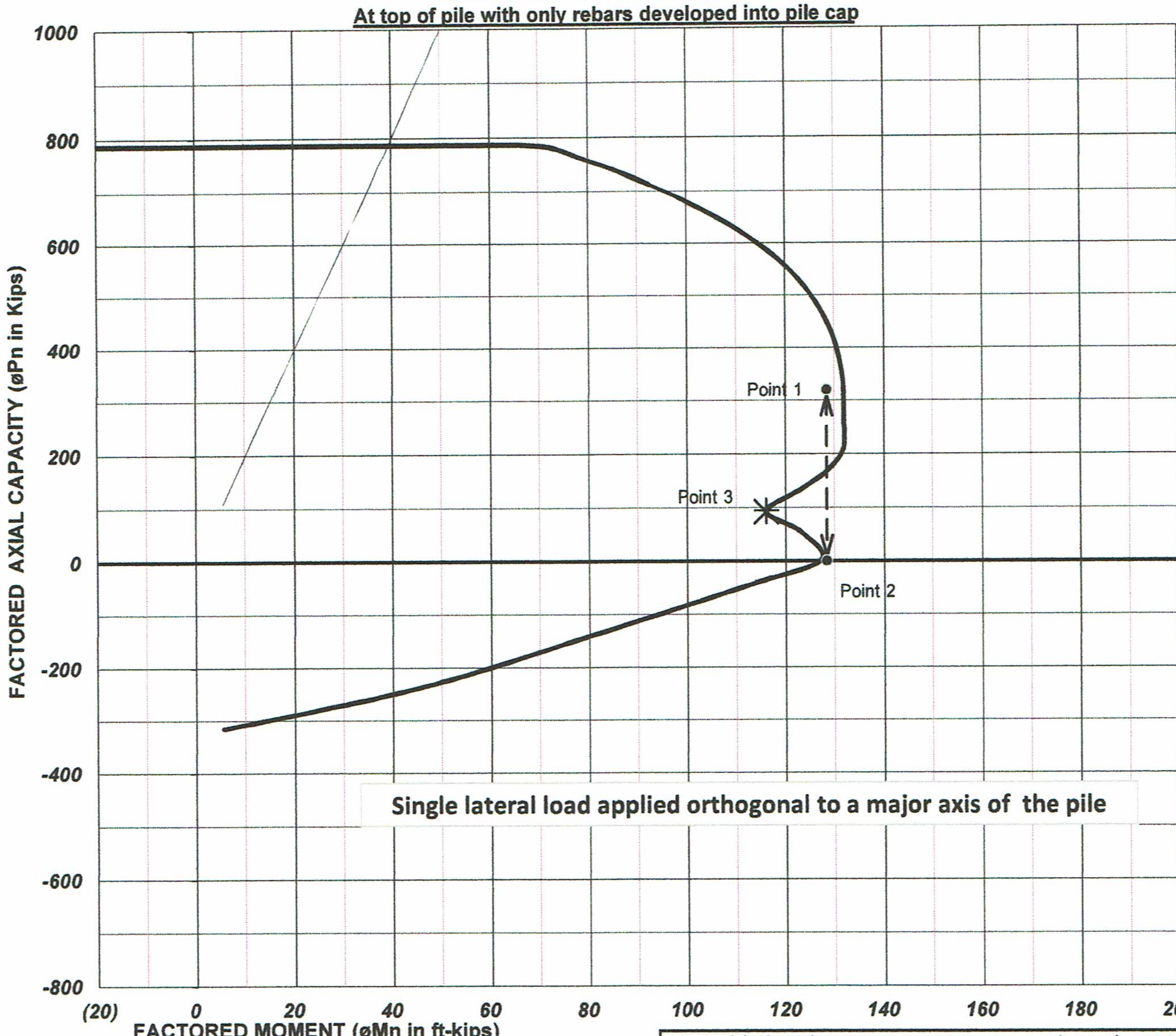
Name / Signature: ______________________________ **Date:** ____________________

P1-1

PILE INTERACTION DIAGRAM

Influent Screen - Non-Tension Piles

At top of pile with only rebars developed into pile cap



Allowable Loads

D = 133 kips	L = 67 kips	Lateral = 15.0 kips
		E / 1.4 = 67 kips
Drag = 0 kips	T = 0 kips	Moment = 92 k-ft

This is at the top of pile with rebars extended into pile cap.
14" Square Pile   f'c = 6,000 psi   Min. Cover = 2.0 "
No Strand Developed Into Pilecap
Effective Prestress (fpc) = 0 psi
6-#9 Rebar (GR60) Inside Spiral Wire
No Rebar (GR60) In Outside Corners

Factored Loads

1.2[D +DD] + 1.0E + fi*L =	320 kips	<---Point 1
1.4 x allowable moment =	128 k-ft	**NG: exceed Capacity**
Ten max = 1.4Ten =	0 kips	<---Point 2
1.4 x allowable moment =	128 k-ft	**NG: exceed Capacity**
Controlling MomentCapacity :	116 k-ft	<--Point 3; Curve Controlling

PILE DESIGNER
dwong@kiecon.com (Danny Wong)

CONTRACTOR:
TBD

NO	BY	DATE	REVISION
△			
△			

KIE-CON Inc.

3551 WILBUR AVENUE
ANTIOCH, CALIFORNIA
925/754-9494   FX 925/754-0624

JOB: **Influent Screen**

LOCATION: **San Mateo, CA**

BY: **WBW**   DATE: **07/01/14**   EST **E14-140**   SHT:

C:\Kie-Con\estimate\2014\14-140 San Mateo Influent - piling\Design 14-140 Pile Design R14-2014 .xlsx

New Administration and Plant Control Building Project, July 2009, prepared by DCM Consulting, Inc.

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DCM | GeoEngineers

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TECHNICAL MEMORANDUM

TO: South Bayside System Authority
c/o Ms. Teresa Herrera
1400 Radio Road
Redwood City, CA 94065

DATE: July 6, 2009

FROM: Robert Kahl

FILE: 18190-004-00

SUBJECT: New Administration and Plant Control Building Project
South Bayside System Authority
Wastewater Treatment Plant
Redwood City, California

This technical memorandum presents the findings, conclusions, and recommendations of our geotechnical engineering evaluation of the New Administration and Plant Control Building project located at and in front of the existing administration and plant control building at South Bayside System Authority's (SBSA) Wastewater Treatment Plant (WWTP) in Redwood City, California.

The scope of work for this memorandum was defined in a letter to SBSA dated May 26, 2009.

1.0 PROJECT DESCRIPTION

The purpose of this geotechnical memorandum is to report the findings, conclusions, and recommendations of our geotechnical engineering evaluation for the new Administration and Plant Control Building project at the SBSA's WWTP in Redwood, California.

Information on the current project was provided to us by Mr. Dan Kallenback of HKIT Architects (HKIT), Mr. Donald Ervin of Kennedy/Jenks Consultants (KJC), and Mr. Michael O'Donnell with BKF Engineers (BKF) by email and phone. It is our understanding that the new administration and plant control building will replace the current administration and plant control building which is supported by the existing pile-supported primary sedimentation tanks. New foundations and a geotechnical investigation are not required for the new building; however, geotechnical engineering recommendations are needed for the following improvements (identified on the attached Plate 1):

- a new stairway/elevator structure at the site of the existing stairway to the administration and plant control building, which is to be demolished;
- new entrance way to the stairway/elevator structure from the parking lot which includes structural concrete slabs and slabs-on-grade and a new 5-foot high signage wall;
- modifications and expansion of the existing parking lot and driveway; and
- new fills of 1 to 3 feet to maintain positive drainage around new improvements.

2.0 EXISTING SITE CONDITIONS AND HISTORIC DEVELOPMENT

The project area is located within SBSA's WWTP site overlying and along the south side of the existing primary sedimentation tanks (on which the existing administration and control building is supported). The WWTP site area was created by placing levees and fill over reclaimed marshland starting in about the 1950s. The most recent fill was placed during development of the SBSA WWTP in the late 1970s and early 1980s.

The primary sedimentation tanks and existing administration and control building (including the existing stairway structure) were constructed in the early 1980s. The June 2006 Revised Record Drawings 362 and 364 of 425 (Jenks and Harrison, 1977) contain the pile layouts and foundation details for the primary sedimentation tanks and existing stairway structure. The existing stairway is shown to be founded on 5 piles with a cutoff (top) elevation of 97.75 feet (the site baseline elevation is 100 feet). The pile lengths reported on Drawing 364 of 425 are 100 to 105 feet.

The new stairway/elevator structure will be constructed at the site of the existing stairway structure. The new stairway/elevator structure has a footprint area of 22 by 24 feet, which is larger than the existing stairway structure. The new entrance way will be located in the area of the existing entrance on the south side of the building. The parking lot expansion includes six new parking places at the southeast corner of the parking lot which currently contains landscaping (e.g., trees).

3.0 GEOTECHNICAL INVESTIGATION

Our geotechnical investigation for the project included shallow borings and review of boring logs from a previous geotechnical investigation (i.e., reference borings) made in the area of the project site.

3.1 Shallow Test Borings

Eight (8) shallow borings (SB-1 through SB-8) were drilled to investigate the condition and thickness of fill in the project area (see Plate 1 for mapped boring locations). The borings were drilled through the fill and into the underlying native Bay Mud soils. Soil and groundwater conditions encountered during drilling were logged by our field geologist. Representative samples of the fill and Bay Mud from the borings were collected, sealed in plastic bags, and returned to our laboratory for further visual examination. The findings (e.g., fill thickness) from the shallow borings are presented in Table 1 in Section 4.0.

After sampling and logging, the borings were backfilled with cement grout and capped with asphalt patch (when in paved areas).

3.2 Reference Test Borings

Previous geotechnical engineering investigations were made in the general area of the project site at the SBSA WWTP by Cooper, Clark & Associates (CC&A, 1978, 1978A, and 1980). The logs of ten borings by CC&A and their Method of Soil Classification are presented in Appendix A. The locations of the reference borings are shown on Plate 1.

4.0 FINDINGS

4.1 Geologic Setting

Geologic mapping by the U.S. Geological Survey (Brabb, Graymer and Jones, 1998) indicates that Young Bay Mud (YBM) deposits underlie the fill at the project site. The YBM is described as water-saturated estuarine mud, predominantly gray, green and blue clay and silty clay underlying marshlands and tidal mud flats of the San Francisco Bay (Brabb, Graymer and Jones, 1998). These soil descriptions are consistent with the native soils encountered in our shallow borings and in the reference borings made by CC&A (1978, 1978A and 1980).

4.2 Subsurface Soil and Groundwater Conditions

Subsurface soil and groundwater conditions encountered at our shallow boring locations are summarized in Table 1:

Table 1 - Summary of Subsurface Soil and Groundwater Conditions at Shallow Borings

Shallow Boring #	Boring Depth	Asphalt Thickness	Fill			Young Bay Mud	Groundwater Depth[5]
			Thickness	USCS[3]	N_{SPT}[4]	N_{SPT}[4] (Depth)	
SB-1	5 ft	4 in	1.5 ft[1]	SC	NT[2]	15* (2½ ft) 11 (4 ft)	1.5 ft
SB-2	6.5 ft	-	4 ft	CL	6*	4 (4 ft) 3* (5½)	1 ft
SB-3	5 ft	4 in	1.5 ft	GW (AB)	NT	14* (2½ ft) 5 (4 ft)	NE
SB-4	5 ft	4 in	1.5 ft	SC	NT	15* (2½ ft) 2 (4 ft)	NE
SB-5	5 ft	4 in	1 ft	SC	NT	20* (2½ ft) 5 (4 ft)	NE
SB-6	5 ft	-	3.5 ft	CL, CH, & CL	18*	4 (4 ft)	NE
SB-7	5 ft [6]	-	3 ft	CL	21*	4 (4 ft)	3.5 ft
SB-8	5 ft	-	4 ft	CL, CH	13*	6 (4 ft)	NE

[1] Thickness includes aggregate base rock.
[2] NT = Not taken.
[3] USCS – Unified Soil Classification System (see Method of Soil Classification in Appendix A).
[4] Standard Penetration Test Blow Count (*Modified California Sample blow count reduced by factor of 0.7).
[5] Borings were not open long enough to determine equilibrium groundwater level. NE = Not Encountered during duration of drilling.
[6] First attempt of drilling encountered possible obstruction at 3½ feet. Boring moved 7 feet to the northeast and redrilled.

The pre-WWTP development borings (1975 CC&A reference borings, see Appendix A) we reviewed show about 2 feet of YBM crust over the project area. Post-WWTP development borings show between 1 to 4 feet of fill has been placed over the YBM crust, which is consistent with the subsurface findings at our shallow borings.

Below the fill and YBM crust, soft, highly compressible YBM extends to a depth of approximately 75 feet in the project area. Below the YBM, firm to stiff clay interlayered with dense sand extends to the maximum depth explored by CC&A of 200 feet.

Groundwater was measured in three of the eight shallow borings at depths between 1 and 3.5 feet at the end of drilling prior to backfilling. Groundwater levels were not recorded on the reference boring logs. The geotechnical investigations for the Recycled Water Storage and Disinfection Facilities by Fugro West (2004) reported groundwater at about 3 feet below ground surface (Elevation 97) which is at the top of the YBM. Groundwater should be expected throughout the site at depths as shallow as 1 to 3 feet below present ground surface.

4.3 Seismic Hazards

4.3.1 Ground Rupture

The nearest "active" fault to the new administration and plant control building is the San Andreas fault which is located 10.5 kilometers (6.5 miles) to the southwest. The risk of ground rupture at the project site due to faulting is low.

4.3.2 Ground Shaking

The project will be subject to ground shaking during future displacement on the San Andreas fault and on other seismogenic sources (e.g., Hayward fault, San Gregorio fault) in Northern California.

The estimated peak firm bedrock acceleration at the planned new administration and plant control building during maximum magnitude (characteristic) earthquakes, having a 10% probability of exceedance in 50 years (i.e., a seismic recurrence interval of one event in 475 years), is on the order of 0.50g. The actual ground surface acceleration that will occur at the project site during an earthquake will be a function of earthquake magnitude, epicenter distance, mode and direction of seismic wave propagation (directivity), soil amplification or attenuation, and near source factors.

4.3.3 Liquefaction

Liquefaction is a phenomenon in which soil deposits undergo a loss of internal strength as a result of increased pore water pressure generated by shear stresses within the soil mass upon cyclic loading. This behavior is commonly induced by strong ground shaking during earthquakes. Soils which have liquefied historically have typically been saturated silts and sands of low to medium density that are relatively free of clay.

The subsurface soils at the project site have been mapped by Knudsen and others (2000) as being highly susceptible to liquefaction. However, based on the site-specific reference borings (see Appendix A), the project site is underlain by soft clays (YBM), firm to stiff clays, clayey sand, and dense sands which are not susceptible to liquefaction. Therefore, the potential for liquefaction at the project site is low.

5.0 EVALUATION OF BAY MUD CONSOLIDATION SETTLEMENT

Based on the findings of our shallow borings and our review of boring logs from previous geotechnical investigations made between 1975 and 1980 in the vicinity of the planned stairway/elevator structure and existing parking lot/driveway, the project area is covered with 1 to 4 feet of fill that is underlain by approximately 75 feet of soft YBM.

In addition to the new structures outside the footprint of the existing administration and plant control building, new fills of 1 to 3 feet thick will be placed to maintain positive drainage. When loads (e.g., fill, foundation loads) are added to sites underlain by YBM, they induce consolidation of the YBM layer and settlement of the ground surface. Consolidation settlement can take years to complete due to the thickness and very low permeability of the YBM. The following paragraphs present the findings of our evaluation of 1) the ongoing consolidation settlement from the existing fill loads, and 2) the additional settlements associated with raising the existing grade (i.e., new fill loads).

5.1 Ongoing Settlement from Existing Fill Loads

The following table (Table 2) presents estimated ultimate settlement, settlement completed to date, and the anticipated settlement in the next 25 years from existing fill loads (i.e., fills placed in the late 1970s) based on fill thicknesses ranging from 1 to 4 feet.

Table 2 - Preliminary YBM Settlement Estimates from Existing Fill Load[1]

Fill Thickness	Estimated Ultimate Settlement	Estimated Settlement Completed to Date[2]	Estimated Settlement in the Next 25 Years (i.e., between 2009 and 2034)
1 foot	8.5 inches	3 inches	1 inch
2 feet	15 inches	5.5 inches	1.5 inches
3 feet	24 inches	9 inches	2 inches
4 feet	30 inches	11.5 inches	2.5 inches

[1] Settlement estimates have been rounded off to the nearest 0.5 inch.
[2] Between about 1980 and 2009 (i.e., 29 year period).

5.2 Additional Settlement from Raising Grades (i.e., new fill loads)

If the current grades in the project area are raised, additional YBM settlement (i.e., in addition to the ongoing Bay Mud settlement estimated in Table 2 above) will occur. The additional ground settlement is dependent on the magnitude of the new loading (i.e., grade change) and the area (i.e., plan dimensions) of the new loading.

The following table (Table 3) presents conservative additional Bay Mud settlement estimates associated with new fill loads (i.e.. raising the grade from the current grade).

Table 3 - Preliminary Settlement Estimates Associated with Raising Grade[1]

Height of Grade Change	Estimated Ultimate Settlement[2]	Estimated Settlement in the Next 25 Years (i.e., between 2009 and 2034[3]
1 foot	4 inches	1.5 inches
2 feet	7.5 inches	2.5 inches
3 feet	12 inches	4 inches

[1] Settlement estimates have been rounded off to the nearest 0.5 inch.
[2] Based on the entire parking lot area in front of the administration and plant control building being regraded.
[3] Between about 2009 and 2034 (i.e., 25-year period).

Table 3 will be revisited after receipt and review of grading plans.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of our geotechnical investigation as described herein, the following represents the primary geotechnical challenges for design, construction and long-term performance of the new project structures and improvements.

- Support of construction equipment on thin fills over YBM;
- Differential settlement between the existing pile-supported sedimentation tanks and the new stairway/elevator structure;

- Differential settlement between the new pile-supported stairway/elevator structure and entrance way;
- Foundation capacity, both vertical and lateral;
- Seismic shaking; and
- YBM consolidation and ground surface settlement.

The following recommendations address the above geotechnical challenges.

6.1 Site Preparation and Grading

Building contractors should be informed that the underlying subgrade soils at the project site are soft and heavy equipment could potentially sink into the YBM. Low ground pressure equipment and/or crane mats should be used at the project site.

All existing structures and improvements (e.g., existing stairway structure, concrete slabs-on-grade, curbs) within the footprint of the new stairway/elevator structure, concrete entrance way, concrete entrance sign structure, and asphaltic concrete pavements should demolished and removed from the project site.

If the existing stairway structure piles are found to be suitable for support of the new stairway/elevator structure (see Section 6.2), care needs to be taken during the demolition of the existing stairway structure to not damage the existing piles.

Resultant holes created by removal of the existing structures and improvements should be cleared of loose material and backfilled with Caltrans Class 2 Aggregate Base (Class 2 AB). The Class 2 AB should be compacted to a minimum relative compaction of 90 percent of maximum dry density, at a moisture content of at or near optimum moisture content based on ASTM D1557.

The stairway/elevator structure, concrete slab-on-grade entrance way, and concrete entrance sign structure sites should be overexcavated to a minimum depth of 12 inches below the base of the structure. The overexcavated areas should extend a minimum of 3 feet beyond the improvement footprint area.

The soils at the base of the overexcavation should be scarified to a minimum depth of 6 inches and compacted to a minimum relative compaction of 90 percent of maximum dry density, at a moisture content of at least 2 percent above optimum moisture content based on ASTM D1557. Soils which are too wet to meet the above compaction requirements should be dried prior to compaction and soils which are too dry to meet the compaction requirement should be wetted prior to compaction.

A woven geotextile stabilization fabric (Mirafi 600x or equal) should be placed on the overexcavation base. At seams, the geotextile fabric should be overlapped a minimum of 3 feet.

After placement of the geotextile fabric, the overexcavations should be backfilled with Caltrans Class 2 AB compacted to 90 percent of maximum dry density, at a moisture content at or near optimum moisture content based on ASTM D1557.

6.2 New Stairway/Elevator Structure Foundation

6.2.1 Reuse of Existing Pile Foundations

Note 4 on Drawing 364 of 425 (Jenks and Harrison, 1977) indicates the pile lengths for the primary sedimentation tanks were 100 and 105 feet long. However, the as-built pile lengths under the existing stairway structure were not specifically identified on the drawing.

The pile driving records for the existing piles below the new stairway/elevator structure footprint should be reviewed to determine pile type used and the as-built pile length. If the pile type (e.g., pile cross-section and steel reinforcing, etc.) is acceptable to the structural engineer for reuse at the new stairway/elevator structure, we will upon request review the pile driving records, pile lengths and pile cross-sections and provide recommendations for vertical and lateral capacity of the existing pile foundations.

6.2.2 New Pile Foundations

Pile foundations have been used to support the major structures at the WWTP plant site. Geotechnical reports in the 1970s at the site recommended 12-inch square, pre-cast concrete piles (CC&A, 1978). More recently, structures have been supported on 14- to 18-inch square precast, prestressed, concrete (PPC) piles driven into medium stiff to stiff clays with allowable skin friction values of 625 to 750 psf (Fugro West, 2004).

The most suitable foundation system for the new stairway/elevator structure is 14-inch square, PPC piles. The following are geotechnical parameters for pile design.

- <u>Vertical Pile Capacity</u>: The PPC piles should be driven through the YBM and founded within the underlying alluvium consisting of medium dense clayey sand to dense sand and medium stiff to hard clay. An allowable compression and uplift skin friction value of 750 psf can be used for the alluvium which was encountered at a depth of about 75 feet in the reference borings. The allowable skin friction can be increased by one-third for short-term wind and seismic loading. Center to center pile spacing (including existing piles) should be at least three (3) times the pile width.

- <u>Down-Drag Forces</u>: The ongoing settlement of the YBM will impose down-drag loads on the pile foundations. A down-drag load of 100 psf within the fill and YBM should be used for the preliminary design of axial pile capacity.

- <u>Lateral Load Resistance</u>: YBM settlement occurring over time will result in a gap between the bottom of the pile-supported stairway/elevator structure and ground surface. As such, sliding resistance at the base of the stairway/elevator structure will be zero. Lateral load resistance will be provided by the pile foundations. We performed a laterally-loaded pile analysis using the computer program LPILE. The LPILE program calculates the deflection, bending moment, and shear within a single pile from given loading conditions and pile sections. Plots of single pile head deflection and maximum bending moment versus lateral load and plots of pile deflection and bending moment along the length of 14-inch square concrete piles under the at-grade stairway/elevator structure are provided in Appendix B.

- Lateral Load Capacity Group Effect Reduction: The lateral load capacity (for a corresponding allowable deflection) of piles will vary depending on the allowable lateral deflection, pile spacing, number of piles, pile configuration, and free- or fixed-head pile conditions which are not available to us at this time. To account for group effects, we recommend that lateral pile capacity for the individual pile groups be reduced by the reduction factors given in Table 4.

Table 4 - Lateral Load Reduction Factors for Pile Groups

Pile Spacing[1]	Reduction Factor Applied to Single Capacity[2]	
	Leading Row Piles	Trailing Row Piles
7d	1.00	1.00
6d	1.00	0.90
5d	0.90	0.75
4d	0.75	0.60
3d	0.60	0.45
2d	0.40	0.25

[1] d = pile width.

[2] Reduction factors can be linearly interpolated between pile spacing shown.

- Total and Differential Settlement: For the pile-supported stairway/elevator structure, designed as recommended herein, the total settlement should be less than one-half inch and the differential settlements between piles should be approximately one-half the total settlement (i.e., one-quarter inch differential settlement).

- Differential Settlement Between Pile Supported Stairway/Elevator Structure and Adjacent Concrete Walkway: The new stairway/elevator structure will be founded on piles. As such, differential settlement will occur between the new stairway/elevator structure and the adjacent concrete slab-on-grade walkway due to the ongoing YBM settlement. The parking lot entrance slab will be designed to accommodate the differential settlement. See Table 2 in Section 4.0 for estimated settlements in the next 25 years.

6.2.3 Miscellaneous Pile Construction Considerations

Soft YBM soils are located within a few feet of the existing grade. Crane mats should be used to support the pile driving crane.

The pile driving hammer should be compatible with the pile and subsurface conditions reported herein. The pile hammer should have the ability to drive the pile through and into the subsurface fill and native soils at the site without damaging the pile. The hammer should have a minimum energy rating of 50,000 foot pounds. A follower can be used to drive the head of the pile to the final pile head cutoff elevation.

To mitigate damage to piles due to potential debris within the existing on-site fill and to mitigate potential vibration-induced damages to nearby structures, foundations, and pipelines, we recommend pre-drilling through the existing fill and 15 feet into the Young Bay Mud prior to driving piles. The diameter of the pre-drill auger and its bit should be no greater than 14 inches for a 14-inch square pile.

The condition of existing adjacent structures and improvements (i.e., pipelines) should be carefully documented before, during, and after pile driving. In addition, vibration monitoring should be provided during pile driving to objectively document construction vibration levels.

6.3 Entrance Sign Foundation

The 5-foot high concrete sign along the entrance way can be supported on a shallow spread footing. The spread footing foundations should be a minimum of 3 feet wide and the footing bottom should have a minimum embedment depth of 18 inches.

6.3.1 Allowable Bearing Capacity

The foundation bottom will be located on 12 inches of compacted Class 2 AB (as recommended in Section 6.1 above) and existing fill/YBM crust just above the top of the YBM. For these conditions and the minimum dimensions above, we recommend using an allowable bearing capacity of 500 psf. The soil bearing pressure can be increased by one-third for transient loading such as wind and seismic forces.

6.3.2 Lateral Load Resistance

An allowable coefficient of sliding friction of 0.35 times dead load may be used for footings founded on a minimum of 12 inches of Class 2 AB for resistance of lateral loads.

6.4 Concrete Slab-on-Grade Entrance Way

The slab-on-grade concrete entrance way will be founded on a minimum of 6 inches of compacted Class 2 AB as recommended in Section 6.1. The concrete slab-on-grade should be a minimum of 6 inches thick. The minimum concrete slab-on-grade reinforcement should consist of No. 4 deformed reinforcing bars placed at 18 inches on-center in each direction.

6.5 Asphaltic Concrete Pavement

Pavement recommendations for asphalt concrete paving are provided in Table 5 for Traffic Indices ranging from 4.0 to 5.5 in 0.5 increments (typical for automobile traffic and parking). For the subgrade at the site, we have conservatively assumed a design R-Value of 5. Pavement recommendations for higher traffic indices (for truck traffic) can be provided upon request. Based on this design R-Value and the Caltrans Flexible Pavement Design Method, alternative pavement sections are presented below.

Table 5 - Preliminary Asphaltic Pavement Section

Assume R-Value = 5		
Traffic Index	Asphalt Concrete (ft.)	Aggregate Base (ft.)
4.0	0.20	0.65
4.5	0.20	0.80
5.0	0.20	0.95
5.5	0.25	1.00

Pavements should be sloped and drainage gradients maintained to carry all surface water off the site. Ponding should not be allowed anywhere on-site. Design of the pavement slopes adjacent to pile-supported buildings should take into account the anticipated differential settlement of pavements adjacent to the building perimeter.

New pavement construction should also meet the following criteria:

- The upper 12 inches of soil subgrade should be compacted to a minimum of 90% relative compaction based on ASTM D1557 at a moisture content at or near optimum moisture.
- All aggregate base (i.e., Caltrans Class 2 Aggregate Base) should be compacted in lifts no greater than 8 inches in loose thickness and compacted to 90% relative compaction based on ASTM D1557.
- Pavements should be sloped and drainage gradients maintained to carry all surface water to storm drain inlets or other existing site drainage facilities.
- The asphalt concrete materials should conform to the specifications stated in Section 39 of the State of California Standard Specifications, latest edition or equal.

6.6 Seismic Design

Site Class E should be used for design and construction detailing in accordance with the foundation and seismic provisions of the 2006 International Building Code (IBC)/2007 California Building Code (CBC). Note that a site-specific response analysis was developed by Fugro (2004) for the recently constructed Recycled Water Storage and Disinfection Facility.

7.0 ADDITIONAL SERVICES AND LIMITATIONS

7.1 Additional Services

In order to provide continuity to this project, DCM/GeoEngineers should be given the opportunity to provide the following additional services through the completion of construction.

- Review of 90 percent design drawings and specifications for conformance with geotechnical conditions and recommendations contained herein; and

- Review of contractor’s pile driving submittal and periodic construction observations during foundation construction for conformance of subsurface conditions as encountered during construction with the subsurface conditions described herein upon which our recommendations are based.

These recommended reviews and observations are to evaluate design interpretations and observe actual project construction with respect to the geotechnical findings and recommendations provided in this memorandum.

7.2 Limitations

We have prepared this report for the exclusive use of the South Bayside System Authority, and their authorized agents for the New Administration and Plant Control Building project at the SBSA WWTP site in Redwood City, California.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this technical memorandum was prepared. The conclusions, recommendations, and opinions presented in this technical memorandum are based on our professional knowledge, judgment and experience. No warranty or other conditions, expressed or implied, should be understood. The potential of soil or groundwater contamination or corrosion at the project site and studies of, and design recommendations related to contamination and corrosion, if any, at the project site, and the mitigation thereof, is not part of our scope of services for this project.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments should be considered a copy of the original document. The original document is stored by DCM/GeoEngineers, Inc. and will serve as the official document of record.

Please refer to Appendix C titled "Report Limitations and Guidelines for Use" for additional information pertaining to use of this technical memorandum.

8.0 CLOSURE

We trust this technical memorandum meets the present needs of the South Bayside System Authority and Kennedy/Jenks Consultants. Thank you for the opportunity to be of service to South Bayside System Authority on this project. Please contact us if you have any questions concerning the recommendations contained herein or need additional information.

Attachments: References
Plate 1 - Site and Boring Map
Appendix A - CC&As Method of Soil Classification and Logs of Borings 2, 3, 4, 5, 9, A-1, A-7, A-11, B-1, and B-2 (7 pages)
Appendix B - LPILE Results (6 pages)
Appendix C - Report Limitations and Guidelines for Use

cc: Mr. Donald Ervin, Kennedy/Jenks Consultants
Mr. Dan Kallenback, HKIT Architects
Mr. Michael O'Donnell, BKF Engineers

REFERENCES

Brabb, Graymer, and Jones, 1998, USGS Open File Report 98-137.

Cao, T., and others, 2003, The Revised 2002 California Probabilistic Seismic Hazard Maps: California Geological Survey, an update to DMG Open-File Report 96-08.

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Knudson, K.L. and others, 2000, Preliminary Maps of Quaternary Deposits and Liquefaction Susceptibility, Nine County San Francisco Bay Region, California, U.S. Geological Survey Open-file Report 00-444, Sheet 2 (of 2).

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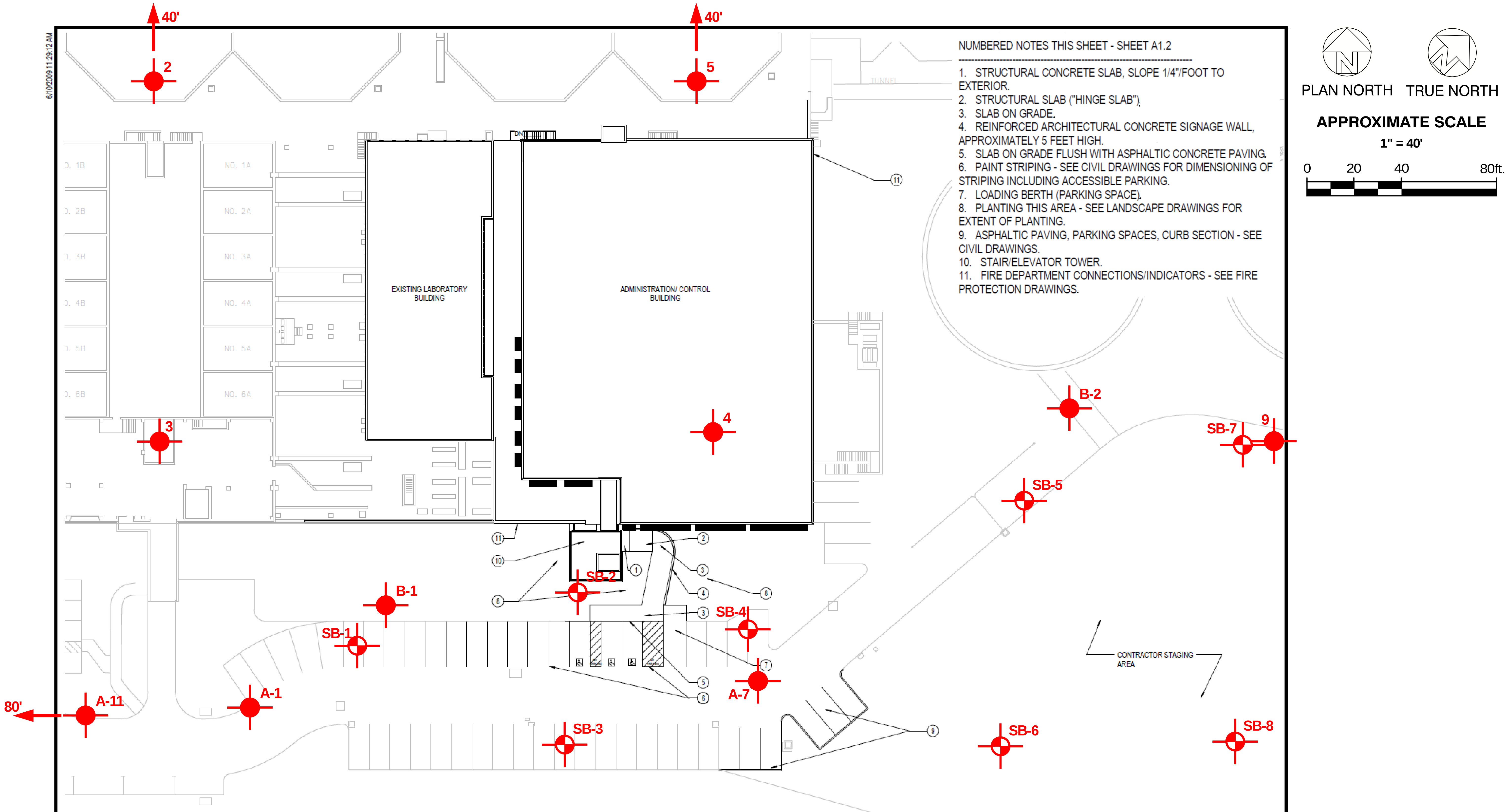


Base Map from: HKit Architects (2009)

LEGEND:

SB-1 - Approx. location and reference number for shallow project borings (Shallow boring findings are summarized on Table 1 in text of memorandum).

A-1 - Approx. location and reference number for reference borings (see Appendix A).

50' - Approx. distance and heading to actual location of borings not visible on Site Map.

DCM GEOENGINEERS

FILE NO. 18190-004-00 | JUNE 2009

SBSA
New Administration/Control Building Project
SBSA WWTP
Redwood City, California

SITE AND BORING MAP

PLATE NO.
1
(COLOR PLATE)

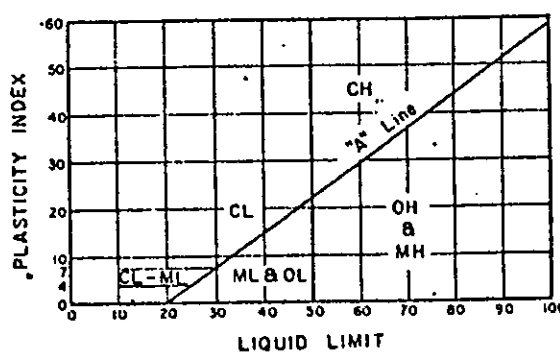
APPENDIX A

MAJOR DIVISIONS		SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than 1/2 of soil > no. 200 sieve size)	GRAVELS (More than 1/2 of coarse fraction > no. 4 sieve size)	GW	Well graded gravels or gravel-sand mixtures, little or no fines
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (More than 1/2 of coarse fraction < no. 4 sieve size)	SW	Well graded sands or gravelly sands, little or no fines
		SP	Poorly graded sands or gravelly sands, little or no fines
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS (More than 1/2 of soil < no. 200 sieve size)	SILTS & CLAYS LL < 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
	SILTS & CLAYS LL > 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils

CLASSIFICATION CHART
(Unified Soil Classification System)

CLASSIFICATION	RANGE OF GRAIN SIZES	
	U.S. Standard Sieve Size	Grain Size in Millimeters
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	305 to 76.2
GRAVEL	3" to No. 4	76.2 to 4.76
coarse	3" to 3/4"	76.2 to 19.1
fine	3/4" to No. 4	19.1 to 4.76
SAND	No. 4 to No. 200	4.76 to 0.074
coarse	No. 4 to No. 10	4.76 to 2.00
medium	No. 10 to No. 40	2.00 to 0.420
fine	No. 40 to No. 200	0.420 to 0.074
SILT & CLAY	Below No. 200	Below 0.074

GRAIN SIZE CHART



PLASTICITY CHART

METHOD OF SOIL CLASSIFICATION

3151773

[redacted]

PLATE A-2

Revisions:
By______ Date______
By______ Date______
Location Redwood City

By BSK Date 10/27/75
Checked By [handwritten initials] Date 10/27/75
Job Number 1726-A Name South Bayside System Authority

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		BLOWS/FOOT
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	
			DS	300	Natural	400	52.4	63	3
			DS	300	Natural	260	74.7	51	
			DS	500	Natural	290	83.0	49	
			DS	600	Natural	270	84.2	49	
			DS	800	Natural	290	72.7	53	
							73.7	54	
			DS	1200	Natural	500	64.9	57	
			DS	1600	Natural	600	71.8	55	
							66.5	56	
			DS	1900	Natural	600	41.1	74	4
	44.0	22.0	DS	2200	Natural	650	31.9	86	6

BORING 2

ELEVATION 99.3 FEET

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75

Grayish-brown organic silty clay (OH) (bay mud crust)

Gray organic silty clay (OH) (soft bay mud)

Water Level 9/29/75

Boring continued on Plate A-IE

BORING LOG

(4-74)

3151779 [redacted]

PLATE A-1D

BORING 2 (Continued)

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA				
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/ FOOT	DEPTH FEET	
										75	
										80	
											Gray silty coarse sand (SM)
			DS	2600	Natural	1250	32.1	90	20	85	Greenish-gray silty clay (CL) (firm)
											Brown silty clay (CL) (stiff)
	37.0	12.0	DS	2900	Natural	1400	25.8	100	35	90	
										95	
							36.7	82	25		(Piece of gravel)
										100	
											(Grading gray)
			DS	3000	Natural	2600	42.5	76	27	105	
										110	
											Gray silty clay (CH) (firm) (Old bay mud)
			DS	3000	Natural	1050	54.1	66	14		
										115	
										120	
							51.4	68	7		
										125	
										130	Greenish-gray silty clay (CL) (stiff) (Grading brown)
			DS	3000	Natural	1650	23.9	100	45		
										135	
											(Grading sandy)
										140	
			DS	3000	Natural	2800	23.2	104	70		
										145	
											Gray silty clay (CH) (stiff) (Old bay mud)
			DS	3000	Natural	2000	45.6	72	20	150	

BORING LOG

By BSK Date 10/27/75
Checked By [signature] Date 10/?/75
Job Number 1726-A Name South Bayside System Authority Location Redwood City
Revisions: By ______ Date ______
By ______ Date ______

-74)

3151780 [redacted]

PLATE A-1E

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	300	Natural	260	97.6	43
			DS	600	Natural	350	83.9	48
							76.7	53
			DS	1300	Natural	570	79.9	52
			DS	1600	Natural	560	71.8	56
			DS	2100	Natural	900	32.1	87

BORING 3

ELEVATION 99.2 FEET

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70

Grayish-brown organic silty clay (OH) (bay mud crust)

Gray organic silty clay (OH) (soft bay mud)

Boring continued on Plate A-1G

BORING LOG

Revisions:
By____ Date____
By____ Date____

By BSK Date 10/27/75
Checked By R.K. Date 10/30/75
Job Number 1726-A Name South Bayside System Authority Location Redwood City

3151780

[redacted]

(1-74)

BORING 3 (Continued)

% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT
CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
			DS	500	Natural	250	20.5	100	
			DS	2700	Natural	1450			
			DS	3000	Natural	1650	33.1	88	31
	72.2	46.0	DS	3000	Natural	2700	27.5	97	40
			DS	3000	Natural	1250	43.5	75	12
			DS	3000	Natural	1150	42.6	76	15
			DS	500	Natural	400	22.8	102	34
			DS	3000	Natural	1650			

DEPTH IN FEET: 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125, 130, 135, 140

75 – Gray clayey sand (SC) (loose)
(Some organic)

80 – (Gas coming out from this depth)

90 – Grayish-brown silty clay (CH) (stiff)

110 – Gray silty clay (CH) (with some broken shells (firm)
(Old bay mud)

135 – Grayish-brown silt (ML) (firm)

Boring continued on Plate A-1H

BORING LOG

By BSK Date 10/27/75
Checked By BH Date 10/29/75
Job Number 1726-A Name South Bayside System Authority Location Redwood City
Revisions:
By____ Date____
By____ Date____

3151782

[redacted]

PLATE A-1G

BORING 3 (Continued)

Classification Data: % Fines (-No. 200)	Liquid Limit	Plasticity Index	Strength Data: Type of Strength Test	Test Surcharge Pressure, lbs/sq ft	Test Moisture Content, %	Shear Strength, lbs/sq ft	Moisture-Density Data: Natural Moisture Content, %	Dry Density, lbs/cu ft	Blows/Foot	Depth in Feet	Description
										140	
										145	Gray silty clay (CL) (stiff)
			DS	3000	Natural	2900	32.4	91	26		
										150	Gray silty clay (CH) (stiff) (Old bay mud)
	79.5	52.4	DS	3000	Natural	2800	46.7	74	18	155	
										160	
										165	
			DS	3000	Natural	2300	22.3	104	30		
										170	
										175	Gray clayey sand (SC) (medium dense) (Few broken shells)
			DS DS	1000 3000	Natural Natural	800 1800	22.5	102	30	180	
										185	Gray silty clay (CL) (stiff)
	39.7	22.4	DS	3000	Natural	2050	22.6	104		190	
										195	Grayish-brown silty clay (CH) (stiff)
			DS	3000	Natural	2700	26.1	98	35	200	
										205	

Revisions:
By______ Date______
By______ Date______

By BSK Date 10/27/75
Checked By [signature] Date 10/27/75
Job Number 1726-A Name South Bayside System Authority Location Redwood City

BORING LOG

3151783

[redacted]

PLATE A-1H

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	300	Natural	340	90.9	48
			DS	600	Natural	300	102.8	43
							75.6	53
			DS	1200	Natural	520	83.0	49
			DS	1700	Natural	530	69.8	56

BORING 4

ELEVATION 99.2 FEET

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

Grayish-brown organic silty clay (OH) (bay mud crust)

Gray organic silty clay (OH) (soft bay mud)

Boring continued on Plate A-1J

By BSK Date 10/27/75
Checked By RM Date 10/27/75
Job Number 1726-A Name South Bayside System Authority Location Redwood City

Revisions:
By____ Date____
By____ Date____

BORING LOG

3151784

[redacted]

BORING 4 (Continued)

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA				
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT	DEPTH IN FEET	
										55	
			DS	2100	Natural	730	42.0	77		65–70	
										75	Gray clayey sand (SC) with bay mud (medium dense)
			DS	2700	Natural	750	23.6	102	12	80	
										85	Gray coarse sand (SP) (dense) (Piece of wood) (Some gravel)
			DS	3000	Natural	3900	7.4	117	47	90	
										95	Grayish-brown silty clay (CH) (stiff)
										100	Gray silty clay (CH) (firm) (Old bay mud)
			DS	3000	Natural	1100	40.0	78	40	105	
										110	

Revisions:
By____ Date____
By____ Date____
Redwood City Location

By BSK Date 10/27/75
Checked By [signature] 10/30/75
Job Number 1726-A Name South Bayside System Authority

BORING LOG

3151785

[redacted]

PLATE A-1J

BORING 5

ELEVATION 99.3 FEET

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA			
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/FOOT	DEPTH IN FEET
							30.3	67	9	0
			DS	400	Natural	230	97.9	45		10
			DS	900	Natural	410	71.1	55		25
			DS	1300	Natural	640	73.7	54		40

Depth scale (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

Grayish-brown organic silty clay (OH) (firm) (bay mud crust)

Gray organic silty clay (OH) (soft bay mud)

Boring continued on Plate A-1L

BORING LOG

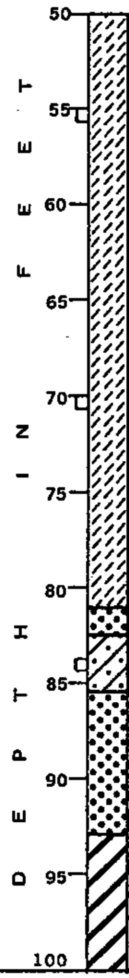
By BSK Date 10/30/75
Checked By [illegible] Date [illegible]
Job Number 1726-A Name South Bayside System Authority Location Redwood City
Revisions:
By ____ Date ____
By ____ Date ____

3151786

[redacted]

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	1800	Natural	800	61.8	61
			DS	2700	Natural	800	26.7	88
			DS	3000	Natural	750	39.8	80

BORING 5 (Continued)



Gray sand (SP) (dense)

Gray clayey sand (SC) with some wood (medium dense)

Gray coarse sand (SP) (dense)

Grayish-brown silty clay (CH) (stiff)

By BSK Date 10/30/75
Checked By
Job Number 1726-A Name South Bayside System Authority Location Redwood City
Revisions:
By Date
By Date

BORING LOG

3151787

[redacted]

PLATE A-IL

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	400	Natural	250	100.2	44
							90.9	46
							72.2	54
			DS	1300	Natural	600	59.4	61
							70.5	56
			DS	1900	Natural	720	64.9	59
							28.6	91

BORING 9

ELEVATION 98.4 FEET

DEPTH IN FEET

0 Grayish-brown organic silty clay (OH) (bay mud crust)

Gray organic silty clay (OH) (soft bay mud)

5

10

15

20

25

30

35

40

45

50

55

60

65 (Grading sandy)

70

Boring continued on Plate A-1T

BORING LOG

Revisions:
By_____ Date_____
By_____ Date_____

By BSK Date 10/30/75
Checked By [illegible] Date [illegible]
Job Number 1726-A Name South Bayside System Authority Location Redwood City

3151794

[redacted]

BORING 9 (Continued)

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA		
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT	BLOWS/ FOOT
			DS	2400	Natural	1600	23.9	100	
			DS	2800	Natural	2500	22.0	103	40
							12.9	114	60
			DS	3000	Natural	2500	46.0	73	23
			DS	3000	Natural	1800	54.0	66	13
			DS	3000	Natural	2800	14.7	118	30
							33.3	84	50

DEPTH IN FEET

Depth (ft)	Description
70	
75	Brown silty sand (SM) (medium dense)
80	Brown coarse sand (SP) (dense)
85	(Some gravel)
90	
95	(Grading coarser)
100	Grayish-brown silty clay (CH) (stiff)
105	
110	Gray organic silty clay (CH) (firm) (Old bay mud)
115	
120	
125	Greenish-gray silty clay (CH) (stiff)
130	Gray sandy silt (ML) (dense)
135	
140	

Boring continued on Plate A-1U

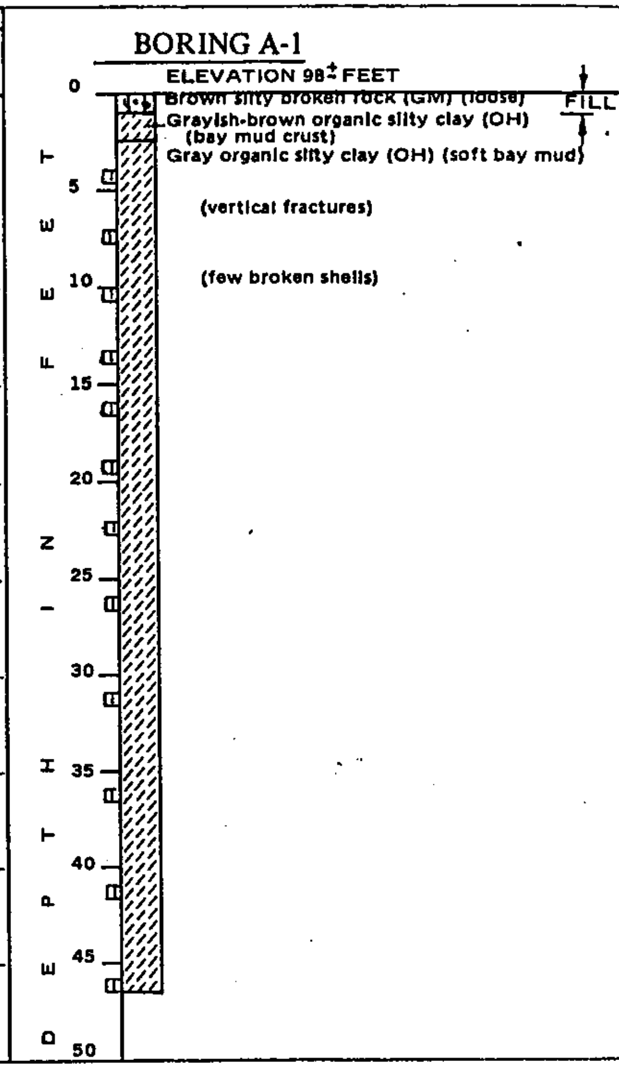
By BSK Date 10/30/75
Checked By [illegible] Date [illegible]
Job Number 1726-A Name South Bayside System Authority Location Redwood City

Revisions:
By ______ Date ______
By ______ Date ______

BORING LOG

3151795

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	300	Natural	300	82.1	51
			DS	400	Natural	250	96.2	46
			DS	500	Natural	250	103.0	44
			DS	600	Natural	340	90.5	47
							114.5	42
			DS	800	Natural	350	87.1	49
							90.6	46
			DS	900	Natural	320	100.2	45
			DS	1100	Natural	435	87.5	50
			DS	1200	Natural	455	83.4	53
							95.9	48
			DS	1500	Natural	615	71.6	56



FIELD NOTES

1. The borings were drilled on September 28 through 30 and October 2 through 6, 1978 with truck-mounted, 5-inch-diameter, rotary-wash equipment.
2. The following symbol, ◫ , denotes an undisturbed sample taken in 2½-inch-diameter, 16 gage, Shelby tube, pushed into the soil.
3. Boring elevations were estimated by interpolation between contours of photography dated 9/28/78.

LABORATORY NOTES AND ABBREVIATIONS

The tabulated shear strengths are maximum values.

DS = Strain controlled direct shear test at natural moisture content.

BORING LOG

By BSK/te Date 10/18/78
Checked By [illegible] [illegible]
Job Number 1726-A5 Name South Bayside Authority
Location Redwood City, California
Revisions:
By ______ Date ______
By ______ Date ______

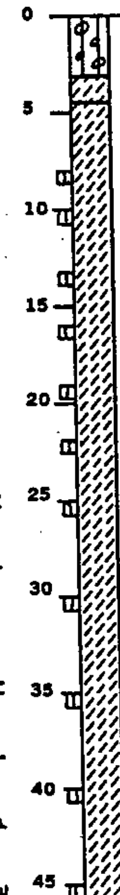
3152258 [redacted]

BORING A-7

ELEVATION 99.7± FEET

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	300	Natural	290	94.7	47
			DS	400	Natural	215	102.4	43
			DS	400	Natural	250	101.4	44
			DS	600	Natural	280	94.9	46
			DS	600	Natural	320	100.5	45
			DS	700	Natural	280	97.2	46
			DS	800	Natural	365	81.3	50
			DS	900	Natural	405	75.6	52
			DS	1000	Natural	435	79.9	53
			DS	1300	Natural	560	67.1	62
			DS	1300	Natural	645	70.5	58

DEPTH IN FEET



Brown silty broken rock (GM) (medium dense) FILL

Brown organic silty clay (OH) with rock fragments

Gray organic silty clay (OH) (soft bay mud)

(vertical fractures)

(few broken shells)

(grading less fractured)

Revisions:

By______ Date______

By______ Date______

By BSK Date 10/18/78

Checked By______ Name South Bayside Systems Authority Location Redwood City, California

Job Number 1726-A5

BORING LOG

COOPER · CLARK & ASSOCIATES

CLASSIFICATION DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
% FINES (-NO. 200)	LIQUID LIMIT	PLASTICITY INDEX	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	DRY DENSITY, LBS/CU FT
			DS	300	Natural	780	53.9	66
			DS	300	Natural	115	101.3	45
			DS	400	Natural	240	110.1	43
			DS	400	Natural	250	101.2	44
							96.1	46
			DS	600	Natural	270	95.1	48
			DS	700	Natural	310	90.6	48
							88.8	48
			DS	1000	Natural	410	82.9	51
			DS	1300	Natural	470	82.9	50

BORING A-11

ELEVATION 99.0± FEET

DEPTH IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

- 0: Brown silty broken rock (GM) (medium dense) — FILL
- Grayish-brown organic silty clay (OH) (bay mud crust)
- Gray organic silty clay (OH) (very soft bay mud)
- (vertical fractures)
- (grading to soft)
- (grading slightly fractured)
- (few broken shells)
- (not fractured)

BORING LOG

Revisions:

By______ Date______

By______ Date______

By BSK Date 10/18/78

Checked By BK 10/18/78

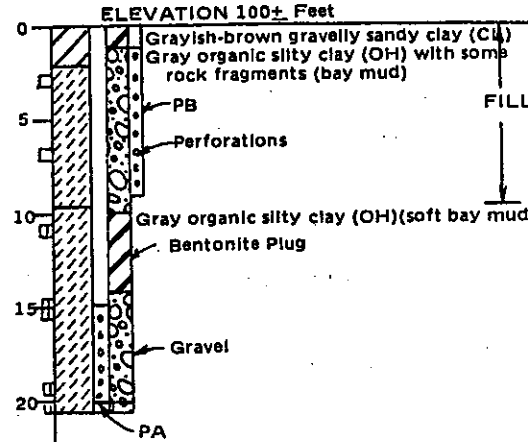
Job Number 1726-A5 Name South Bayside Systems Authority Location Redwood City

315225

GROUNDWATER LEVEL DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
DATE	ELEVATION PA	ELEVATION PB	TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	FIELD DRY DENSITY LBS/CU FT
8/2/80	97.8	Dry	DS	300	Natural	1450	31.2	114/87
8/26	97.5	Dry	DS	400	Natural	600	43.6	112/78
8/10	97.5	Dry						
9/22	97.6	Dry					86.3	93/50
9/29	97.6	Dry					93.5	91/47
10/13	97.5	Dry					99.0	90/45
							74.5	89/51
							77.9	94/53

BORING B-1

ELEVATION 100± Feet



FIELD NOTES:

1. The borings were drilled on August 8 and 11, 1980 with truck-mounted, power-driven, 5-inch-diameter, helical auger equipment.
2. The following symbol, □, denotes an undisturbed sample taken in a 2½-inch-diameter, split-tube barrel driven into the soil by 245-pound slip jars falling 18± inches inside the boring.
3. The following symbol, ◫, denotes an undisturbed sample taken in a 2½-inch-diameter, 16-gauge, Shelby tube pushed into the soil.
4. Boring elevations were estimated by interpolation between the plot plan spot elevations.

LABORATORY NOTES AND ABBREVIATIONS:

The tabulated shear strengths are yield point values.

DS = Strain controlled direct shear test at natural moisture content.

Revisions: By___ Date___ By___ Date___ Location Redwood City

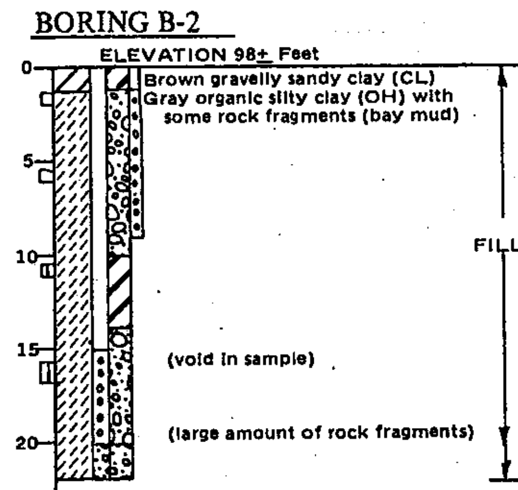
By BSK Date___ Checked By RK 11/5/80 Job Number 1726-A6 Name SBSA

BORING LOG

3151831

[redacted]

GROUNDWATER LEVEL DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
DATE	ELEVATION		TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	FIELD DRY DENSITY LBS/CU FT
	PA	PB						
8/20/80	84.4	Dry	DS	300	Natural	1100	42.3	107/75
8/26	85.2	Dry						
9/10	85.0	Dry	DS	400	Natural	280	58.9	102/64
9/22	85.2	Dry						
9/29	85.6	Dry	DS	500	Natural	350	49.6	108/72
10/13	85.3	Dry						
							45.6	105/72
							44.9	97/67



GROUNDWATER LEVEL DATA			STRENGTH DATA				MOISTURE-DENSITY DATA	
DATE	ELEVATION		TYPE OF STRENGTH TEST	TEST SURCHARGE PRESSURE, LBS/SQ FT	TEST MOISTURE CONTENT, %	SHEAR STRENGTH, LBS/SQ FT	NATURAL MOISTURE CONTENT, %	FIELD DRY DENSITY LBS/CU FT
	PA	PB						
8/21/80	84.6	Dry					42.9	110/77
8/26	84.2	Dry						
9/10	[illegible]3.4	Dry	DS	[illegible]400	[illegible]	250	51[illegible]0	110/[illegible]8
9/22	[illegible]3.7	Dr[illegible]						
9/29	[illegible]4.6	Dry						
10/13	83.9	Dry	DS	500	Natural	500	49.7	106/71
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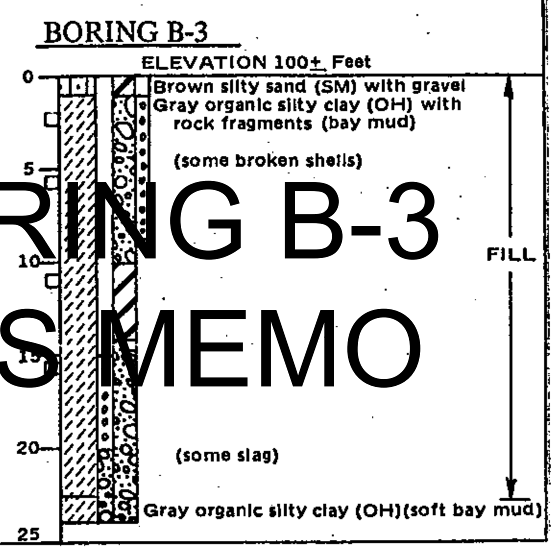
REFERENCE BORING B-3
NO PART OF THIS MEMO



BORING LOGS

Revisions:
By ______ Date ______
By ______ Date ______
Location Redwood City

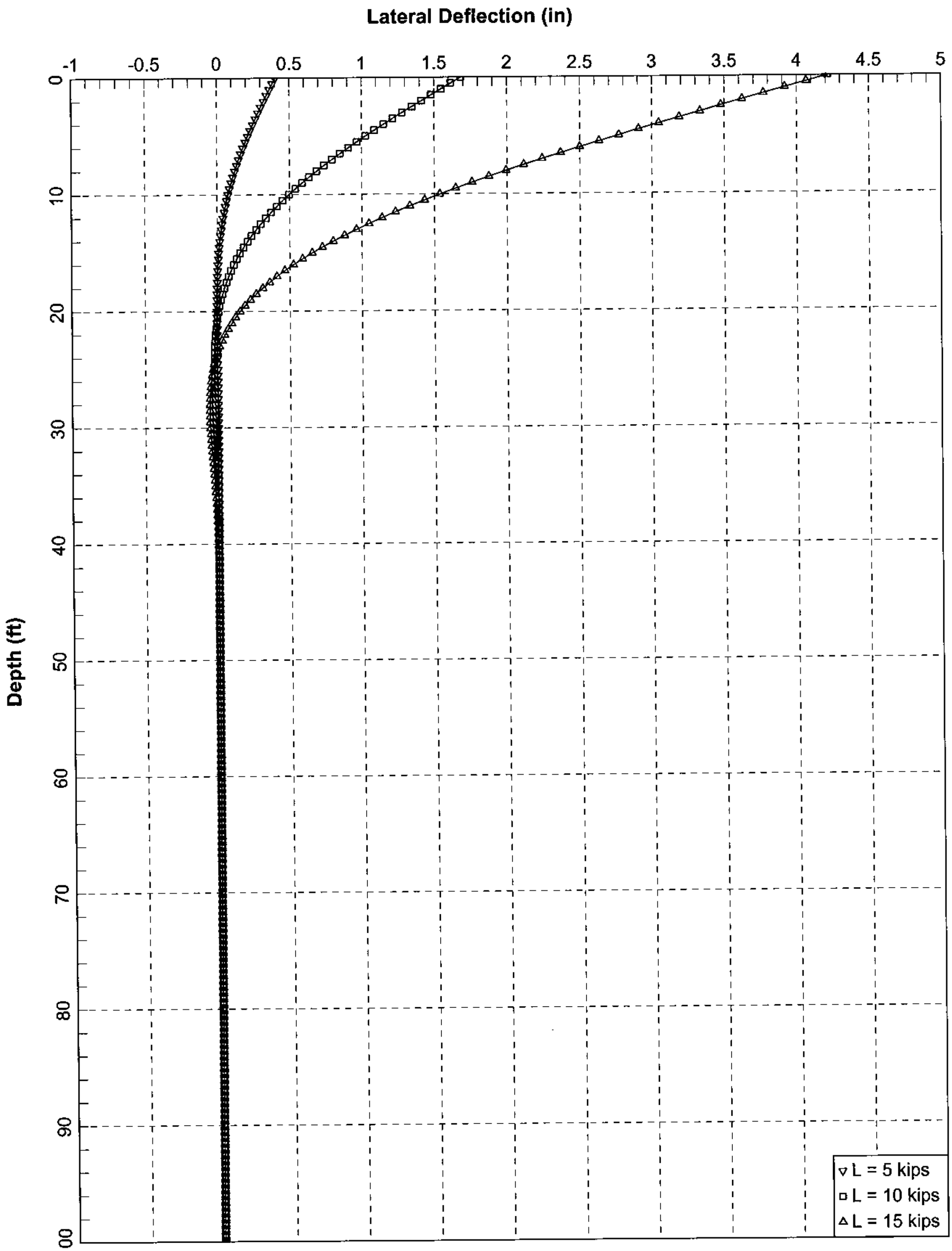
By BSK Date ______
Checked By BK Date 11/5/80
Job Number 1726-A6 Name SBSA

3151832

[redacted]

APPENDIX B

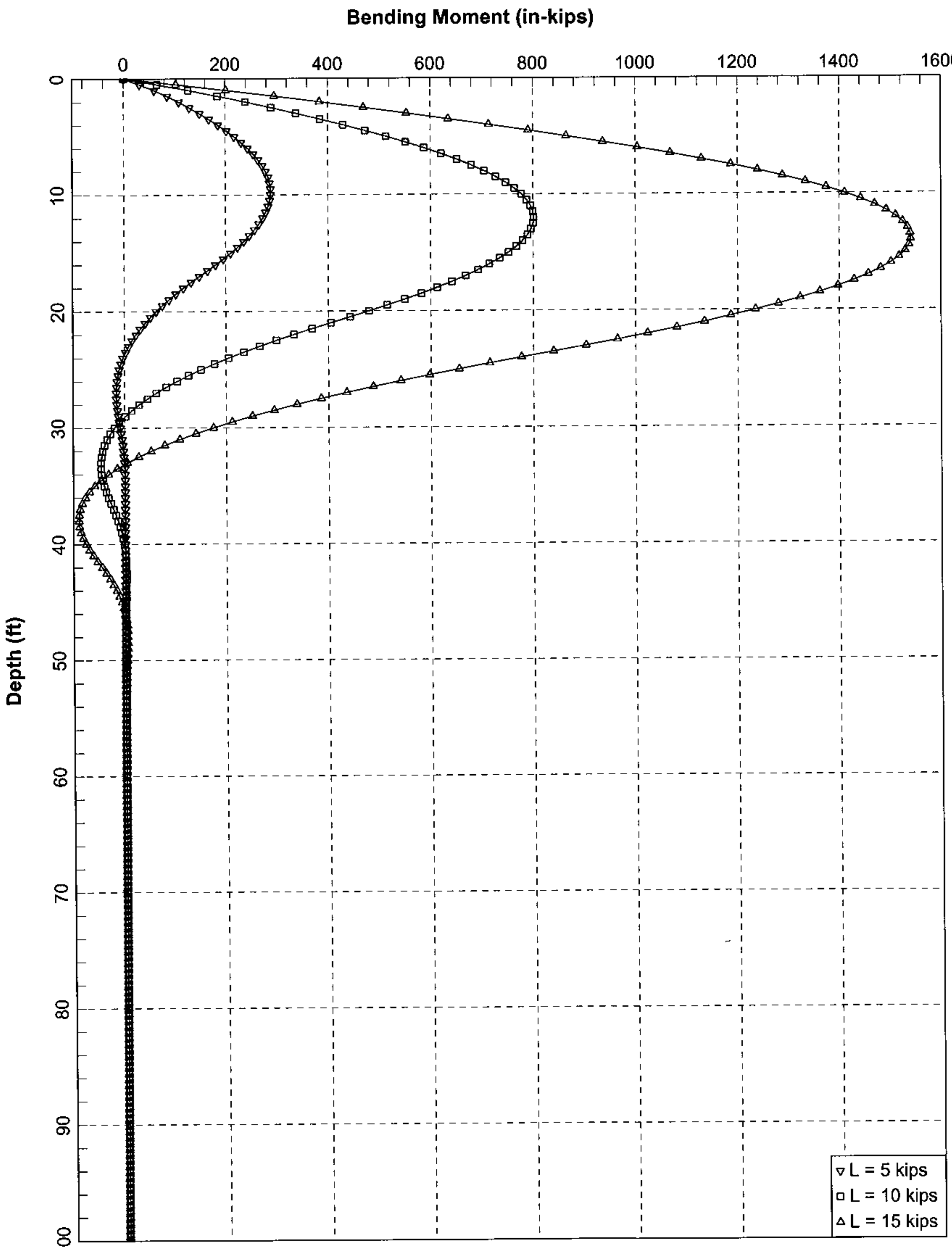
DCM | GeoEngineers



Lateral Deflection 14-inch PCCP - Pinned (Freehead) Condtion

SBSA Administration and Control Building Project

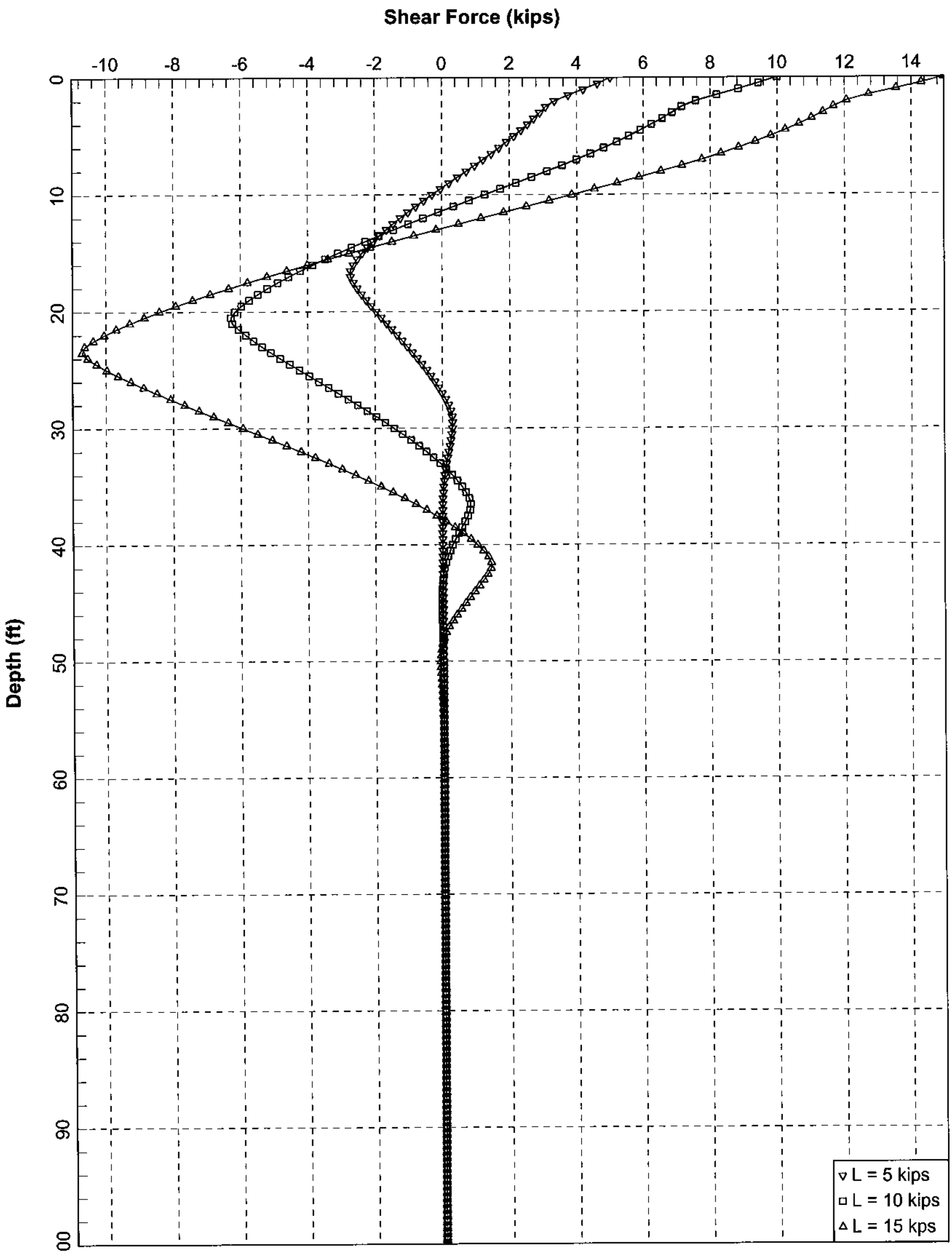
New Stairway/Elevator Structure



Bending Moment - 14-inch PCCP - Pinned (Freehead) Conditions

SBSA Administration and Control Building Project

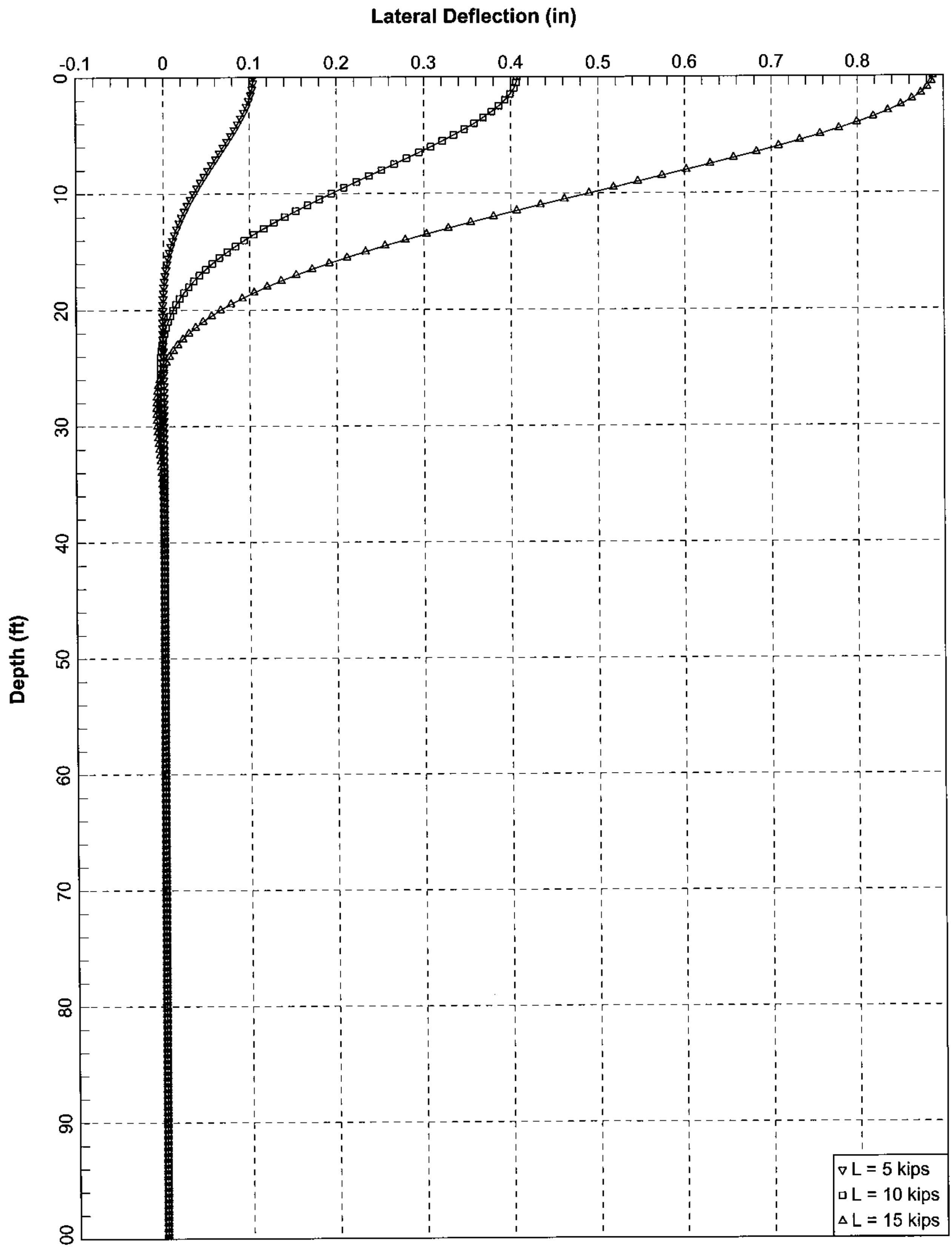
New Stairway/Elevator Structure



Shear Force - 14-inch PCCP - Pinned (Freehead) Conditions

SBSA Administration and Control Building Project

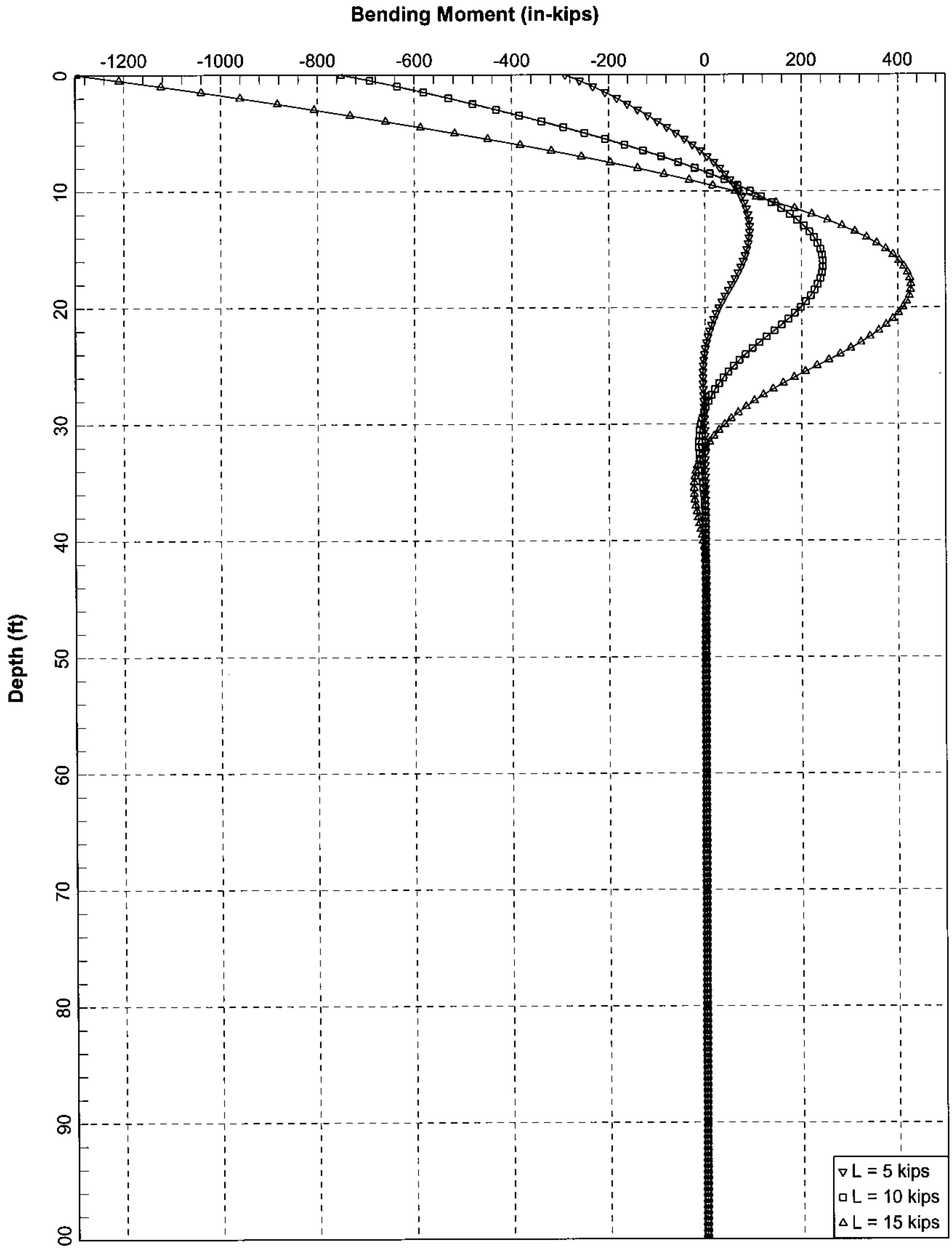
New Stairway/Elevator Structure



Lateral Deflection - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project

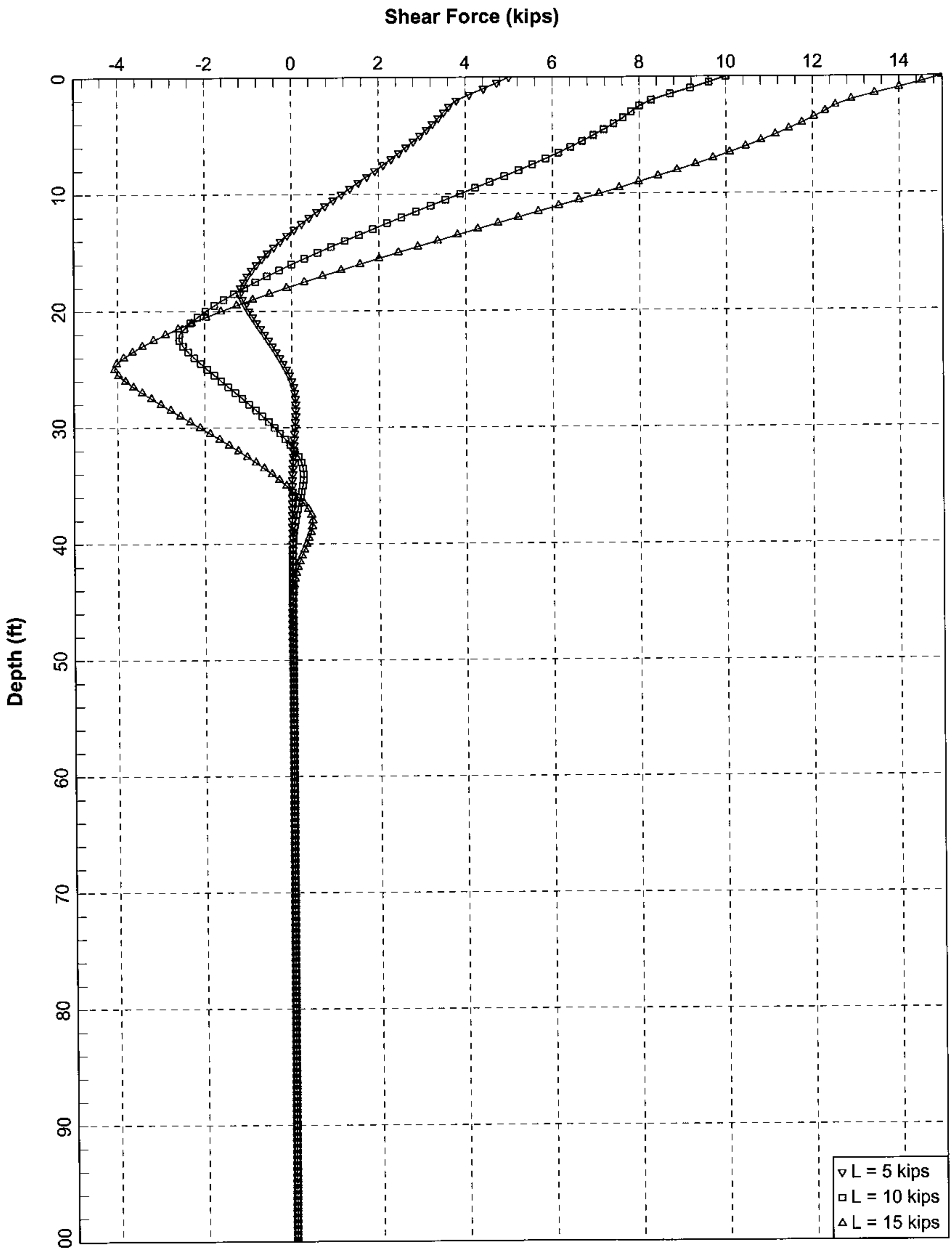
New Stairway/Elevator Structure



Bending Moment - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project

New Stairway/Elevator Structure



Shear Force - 14-inch PCCP - Fixed Head Condition

SBSA Administration and Control Building Project
New Stairway/Elevator Structure

APPENDIX C

APPENDIX C

REPORT LIMITATIONS AND GUIDELINES FOR USE

REPORT USE AND RELIANCE

This technical memorandum has been prepared for South Bayside System Authority, their authorized agents and regulatory agencies. GeoEngineers structures our services to meet the specific needs of our clients. No party other than South Bayside System Authority, their authorized agents and regulatory agencies may rely on the product of our services unless we agree to such reliance in advance and in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance Task No. 2008-01, Phase 2 – Subsurface Geotechnical Design Investigation, our Master Agreement for Professional Consulting Services with the South Bayside Authority System dated September 2, 2008, our May 26, 2008 Scope of Work, Budget and Schedule, and generally accepted geotechnical practices in this area at the time this report was prepared. Use of this report is not recommended for any purpose or project except the one originally contemplated.

This report should not be applied for any purpose or project except the one originally contemplated. If important changes are made to the project or property after the date of this technical memorandum, we recommend that GeoEngineers be given the opportunity to review our interpretations and recommendations, and then we can provide written modifications or confirmation, as appropriate.

INFORMATION PROVIDED BY OTHERS

GeoEngineers has relied upon certain data or information provided or compiled by others in the performance of our services. Although we used sources that are believed to be trustworthy, GeoEngineers cannot warrant or guarantee the accuracy or completeness of information provided or compiled by others.

CONDITIONS CAN CHANGE

This report is based on conditions that existed at the time the study was performed. The findings and conclusions of this technical memorandum report may be affected by the passage of time, by events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the described events may have occurred, please contact GeoEngineers before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

PROFESSIONAL JUDGMENT

It is important to recognize that the geoscience practices (geotechnical engineering, geology and environmental science) are less exact than other engineering and natural science disciplines. By necessity, GeoEngineers uses its professional judgment in arriving at our conclusions and recommendations. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce the risk of misunderstandings regarding the inexact nature of our professional services. Please confer with GeoEngineers if you need to know how these "Report Limitations and Guidelines for Use" apply to your project or site.

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"Preliminary Characterization of Subsurface Conditions, SVCW Clean Water Tunnel – Alignment 4BE, Redwood City, California," December 2015, prepared by Geotechnical Consultants, Inc.

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Transmittal

Kennedy/Jenks Consultants
2350 Mission College Blvd., Suite 525
Santa Clara, California 94303
(650) 852-2800 FAX: (650) 856-8527

TO: Bruce Burnworth
Silicon Valley Clean Water
1400 Radio Road
Redwood City, CA 94065

FROM: Theresa Hlavinka
DATE: 21 December 2015
K/J #: 1568063*01
SUBJECT: 63-inch Force Main Reliability Improvements Project – CIP #6008: Transmittal of Final Phase 1 Geotech TM

VIA: ☒ E-Mail ☐ Overnight ☐ Courier ☐ Fax pgs. (inc. cover)

PLEASE FIND ENCLOSED:

Copies	Date	No.	Description
1	12/21/15	N/A	Final Phase 1 Geotechnical Technical Memorandum (Adobe format)

THESE ARE SUBMITTED AS CHECKED BELOW:

☒ As requested
☐ For information and coordination
☐ Return material when review complete
☐ Return after loan to us
☐ For approval by: Return to:
☐ For review and comment by: Return to:
☐ Other: ____________________

REMARKS: Bruce:

Please find attached the Final Phase 1 Geotechnical Technical Memorandum for your records.

Please contact me if you have any questions.

Thank you.

Signed: Theresa Hlavinka
Theresa Hlavinka

Copies to: Mark Nelson, Kennedy/Jenks
Mark Minkowski, Kennedy/Jenks
File

GEOTECHNICAL CONSULTANTS, INC.
Geotechnical Engineering • Geology • Hydrogeology

Technical Memorandum

Kennedy/Jenks Consultants, Inc.
2350 Mission College Blvd, Suite 525
Santa Clara, CA, 95054

December 9, 2015
Project No. SF14014A

Attention: Mark Minkowski, P.E.

Subject: Preliminary Characterization of Subsurface Conditions
SVCW Clean Water Tunnel – Alignment 4BE
Redwood City, California

This Technical Memorandum (TM) provides a preliminary characterization of geological and geotechnical subsurface conditions along the proposed Silicon Valley Clean Water (SVCW) Conveyance Tunnel Alternative 4BE alignment for the 63-inch Force Main Reliability Improvement Project in Redwood City and City of San Carlos, California. The characterization of geology, earth materials, and groundwater conditions described in this TM are based on: (1) review of available geologic maps and reports, (2) review of available geotechnical information from past investigation in the vicinity of the Alternative 4BE alignment, and (3) geotechnical information from the recently completed Phase 1I exploration for the Alternative 4BE alignment. The project alignment is presented on ***Figure 1 – Site Location Map.***

One of the objectives of the Phase 1 exploration for the proposed Alternative 4BE alignment, which consisted of 16 borings and 22 Cone Penetration Tests (CPTs) with one of the CPT's (C-122) being aborted due to near-surface obstruction (likely construction debris or rip-rap), was to provide sufficient subsurface material characterization and definition for the project team to prepare a preliminary geologic profile and a description of subsurface materials to support the project environmental impact report. This information is summarized in the following sections of this TM. Boring logs and CPT soundings are appended to this TM. Boring and CPT locations are presented on ***Plates 1.1 through 1.4 – Boring Location Map***.

FIGURE 1 – SITE LOCATION MAP

GEOLOGY

The SVCW Tunnel alignment is located on the western margin of San Francisco Bay that occupies a deep structural depression formed by subsidence of the San Francisco Bay structural block, which is bound by the San Andreas Fault on the west and the Calaveras/Hayward faults on the east. The structural trough comprises basement rock of the Franciscan Complex, which is overlain by marine, alluvial, and estuarine sedimentary deposits.

The local subsurface geology and stratigraphy along the Alternative 4BE alignment is presented on ***Plate 2 – Geologic Profile***. As shown in the profile, Old Bay Deposits (Q_{obd}) occur at the deepest levels of the project exploration and are comprised of marine and estuarine deposits. Deposition along the bay margin reflects ancient sea level changes such that both marine and non-marine deposits overlie each other. These transgressive and regressive sequences occur in the Upper Layered Sediments (Q_{uls}), which in turn are overlain by Young Bay Mud (Q_{ybm}) representing the most recent shallow marine depositional conditions. Artificial fill underlies the ground surface, which was placed to accommodate the commercial and residential development present along the alignment.

The local geologic stratigraphy along the proposed SVCW Tunnel Alternative 4BE alignment is summarized on ***Table 1***, which provides a schematic stratigraphic column of the different soil and rock types along the tunnel alignment. The soil deposits that underlie the Alternative 4BE alignment that potentially impact the planning and design of the tunnel can be divided into four general stratigraphic units. These geologic units are identified in ***Table 1*** and on the Phase 1 investigation boring logs as: Artificial Fill (af), Young Bay Mud (Q_{ybm}), Upper Layered Sediments (Q_{uls}), and Old Bay Deposits (Q_{obd}).

TABLE 1 – ALTERNATIVE 4BE ALIGNMENT SUBSURFACE STRATIGRAPHY

Geologic Era	Regional Classification(s)	Unit Name and Symbol	Approximate range of depth to top of deposit, (feet bgs)	Approximate range of deposit thickness, (feet)
Historic (0 to 200 years old)	Recent Fill	Artificial Fill (af)	0 (ground surface)	2 to 16
Holocene to late Pleistocene (0 to ~0.4 million years old)	Alluvial, Colluvial, and Marine Deposits	Young Bay Mud (Q_{ybm})	2 to 16	2 to 45
		Upper Layered Sediments (Q_{uls})	16 to 50	15 to 50
		Old Bay Deposits (Q_{obd})	55 to 100	(1)

(1) Depth to bottom of Old Bay Deposits were not observed in the Phase 1 subsurface investigation.

At greater depths (not expected to impact the project planning, design, and tunnel construction), Old Bay Deposits are underlain by Lower Layered Sediments (Q_{lls}) and Franciscan Complex Bedrock (KJ_f). These units were not encountered within the depths of the Phase 1 subsurface exploration and are not further characterized in this summary.

EARTH MATERIALS

A description of the earth materials associated with the geologic units in ***Table 1***, as observed in the Phase 1 subsurface exploration, as well as review of previous borings by others in the immediate project vicinity, is provided in the following sections.

Artificial Fill (af). Deposits of artificial fill, which blanket the Alternative 4BE alignment, were encountered in the Phase 1 geotechnical exploration from the ground surface to depths ranging from 2 to 16 feet. The fill predominantly consists of a heterogeneous mix of silt and clay with varying fractions of sand and gravel (USCS classification symbol CL and ML), and poorly graded to well-graded sands and gravels in a matrix of silt and clay (USCS symbols GW, GC, SC, and SP). The gravelly fill (GW, GC) typically contains loose to medium dense mixed gravel that is fine to coarse grained (¼ to 1½ inches), sub-rounded to sub-angular, and may include scattered cobbles greater than 3 inches. The sandy fill (SC, SP, SM) typically contains very loose to medium dense fine to medium grained sand, with minor amounts of coarse grained sand. The fill is typically damp near the ground surface becoming moist to wet with depth.

Young Bay Mud (Q_{ybm}). Artificial fill along the tunnel alignment is underlain by Young Bay Mud, which extends from the bottom of fill to depths ranging from about 10 to 50 feet below ground surface, with a deposit thickness ranging from 2 to 45 feet. The Young Bay Mud typically consists of very soft to soft, highly compressible, dark greenish gray fat clay (USCS symbol "CH"). The Young Bay Mud includes zones with trace to abundant shell fragments, zones of trace to minor organic material, and very occasional thin layers of peat (less than a few feet thick). Occasionally, the Young Bay Mud possesses a mild to moderate hydrogen sulfide (H_2S) odor.

Laboratory testing from the Phase 1 exploration indicates that the Young Bay Mud is near normally consolidated, highly plastic, and highly compressible. Laboratory-measured dry density of the Young Bay Mud ranges from about 45 to 60 pcf (pounds per cubic foot), with measured water contents ranging from about 70 to 95 percent. Measured liquid limit (LL) ranges from 65 to 90, with a plasticity index (PI) ranging from 36 to 54. Field measurements of Young Bay Mud strength using pocket penetrometer and torvane instruments, indicated undrained shear strengths ranging from as low as 70 psf near the mudline to 1,050 psf near the bottom of the thicker deposits.

Upper Layered Sediments (Q_{uls}). A sequence of inter-fingered beds of alluvial and marine sediments underlies the Young Bay Mud. Throughout the tunnel project, this layer will be referred to as "Upper Layered Sediments" (Q_{uls}). Based on Phase 1 boring observations, this unit consists of alternating layers of silty sands (SM), clayey sands (SC), sandy to clayey silts (ML), lean to fat clays (CL, CH), and clean poorly graded sands (SP). The alluvial deposits within the unit are typically olive, yellowish, and grayish brown, while the marine sediments are typically gray to dark greenish gray. The thickness and sequencing of these alternating layers are highly variable, but the overall thickness of the deposit ranges from about 15 to 50 feet, extending to depths ranging from 50 to 95 feet below ground surface.

The granular materials within this unit are typically fine grained sands that are dense to very dense. Laboratory-measured dry density of sandy soils within the unit ranged from 105 to 125 pcf, with water content ranging from 14 to 22 percent.

The fine grained soils within this unit (USCS symbol CL, CH, and ML) are typically stiff to very stiff. Field strength measurements of Upper Layered Sediments made using pocket penetrometer and torvane instruments indicated undrained shear strengths typically ranging from 1,000 to over 4,500 pounds per square foot (psf), with occasional soft to medium stiff layers with strengths ranging from 500 to 1,000 psf. Laboratory-measured undrained shear strength of select samples from the Phase 1 exploration ranged from 2,150 to 3,350 psf. Laboratory-measured dry density of fine grained soils within the unit ranged from 80 to 110 pcf, with water content ranging from 21 to 42 percent.

Old Bay Deposits (Q_{obd}). Underlying the Upper Layered Sediments is a relatively uniform layer marine sediments comprised of fat clay (CH) and lean to silty clay (CL), referred to as Old Bay Deposits. The Old Bay Deposits encountered in the Phase 1 exploration typically consist of bluish and greenish gray to dark greenish gray lean (CL) to fat (CH) clay. The clays are typically moist and medium stiff to very stiff with occasional scattered shell fragments. Field measurements of shear strength using a pocket penetrometer indicate undrained shear strengths ranging from 1,000 to 4,000 pounds per square foot (psf). Available laboratory data from past geotechnical investigations in the project vicinity indicate a dry unit weight of 80 to 90 pcf for the Older Bay Deposits, with a water content ranging from about 30 to 40 percent. Laboratory tests on the Older Bay Deposits, particularly at the shaft locations, will be carried out during the Phase 2 exploration.

A summary of typical engineering characteristics of the earth materials is presented in ***Table 2 – Summary of Earth Materials*** for comparison purposes.

TABLE 2 – SUMMARY OF EARTH MATERIALS

Material Unit Name	Typical Consistency/Relative Density	Typical Range of Compressive Strength	Plasticity and Compressibility
Artificial Fill	Loose to medium dense, quite heterogeneous	---	Low plasticity to non-plastic
Young Bay Mud	Very soft to soft	Typically about 500 psf or less	Highly plastic, highly compressible
Upper Layered Sediments	Mostly stiff to very stiff clays. Granular interbeds are dense to very dense	Typically over 2,000 psf to over 3,000 psf	Low plasticity, typically low compressibility
Older Bay Deposits	Medium stiff to very stiff clays	About 1,000 psf to 4,000 psf.	Moderate to high plasticity, moderate compressibility

GROUNDWATER

In the vicinity of the tunnel alignment, groundwater is generally characterized as shallow tide-influenced groundwater within artificial fill that overlies estuarine deposits. Groundwater levels are generally less than ten feet below the ground surface and experience varying degrees of fluctuation coinciding with the tidal stage of the adjacent Steinberger Slough, Phelps Slough, and Pulgas Creek. Considering the local shallow groundwater regime is tidally influenced and hydraulically connected to the nearby sloughs, seasonal influences are not anticipated to exceed the tidal effects. Quarterly groundwater level monitoring will be performed in all project piezometers to identify any seasonal fluctuations.

The sediments associated with the Young Bay Mud, the Upper Layered Sediments, and the Old Bay Deposits are predominantly clayey, hence relatively impervious. As a result, the groundwater regime along the alignment is characterized mainly by (1) unconfined phreatic groundwater within the granular near-surface artificial fill that lies on top of the clayey Young Bay Mud unit, and (2) confined water bearing strata beneath clayey Young Bay Mud within deeper granular soil layers associated with the Upper Layered Sediments.

Granular water-bearing deposits were encountered in borings drilled at three of the four proposed shafts. At the Inner Bair Island shaft, the upper water-bearing strata (observed in boring B-112Ps) consists of 3 to 5 foot thick layers of poorly graded sand with gravel (SP) and clayey sand with gravel (SC) interbedded with clay and silty clay (CL) at depths of 22 to 32 feet below ground level. Static water level measured about 7.5 feet below ground surface indicates that the unit is consistent with the water level in Pulgas Creek, and that an hydraulic connection occurs locally, despite the presence of the overlying clay layers. The lower water-bearing unit at Inner Bair Island (observed in boring B-112Pd) is a thin layer (3 feet) of clayey sand with gravel (SC) at depth 46 to 49 feet, within a thick layer of very stiff clay (CL). Static water level measured approximately 7.5 feet below ground level indicates the aquifer is also hydraulically connected to Pulgas Creek despite the thick overlying clay layers.

Three borings (B-107, B-111Ps, and B-111Pd) drilled at the San Carlos shaft encountered a very thin upper water-bearing unit of sandy silt (ML) at depth 16 feet, and a 4 foot thick lower unit at depth 64 to 68 feet comprising silty sand (SM) and very thin poorly graded sand (SP) lenses interbedded with clayey sand (SM) and clay with sand (CL). Both the upper and lower water-bearing units at San Carlos thin out laterally and have relatively low permeability (indicated by the piezometers bailed and/or pumped dry during development). Static water levels (6.6 feet below ground level) indicate the upper unit may be unconfined and hydraulically connected to the overlying saturated Young Bay Mud. Static water level in the lower aquifer at the San Carlos shaft is approximately 5.2 feet below ground level and indicate this unit is confined by the thick overlying medium stiff to stiff clay layer.

No groundwater or water-bearing layers were observed in two borings (B-106 and B-110) drilled at the Middle Out Shaft during the Phase 1 exploration, which encountered only fine-grained silts and clays to the full depth of the exploratory points. These clays were typically moist to wet, and likely reflect saturated conditions consistent with a nearby open water channel (Phelps Slough) and Steinberger Slough.

A thick sequence of sandy silt (ML), silty sand (SM), poorly graded sand with silt (SP-SM), poorly graded sand (SP), well graded sand with clay (SW-SC), and sandy gravel (GW, GP) extends from 62 to 96 feet below ground surface at the Receiving Lift Station (RLS) shaft (as observed in boring B-101). Similar layers, although thinner and finer grained, were also encountered at the three piezometer borings (B-109P, B-113P, and B-114P) located south, east, and west of the RLS shaft (see Plate 1). Static water levels in the piezometers are approximately 1½ feet above ground level at the RLS shaft site reflecting more than 60 feet of artesian pressure conditions within this confined aquifer. Water level monitoring indicate the groundwater levels are also influenced by tidal fluctuations; 0.8 to 1.1 feet of rise and fall was measured from November 14 through November 16, 2015.

SEISMIC SETTING

Active faults in California have been divided into activity categories by the California Geological Survey (CGS) based on their predicted activity and ability to generate strong earthquakes; "Type

A" faults which generally have higher and better defined slip rates and well defined recurrence intervals, and "Type B" faults with well-defined slip rates but poorly constrained recurrence intervals. "Type A" faults are commonly considered more active (generally with higher slip rates) and/or capable of generating larger earthquakes than "Type B" faults. Both "Type A" and "Type B" faults that are mapped in the vicinity of the project site are summarized in ***Table 3 – Significant Active Faults***.

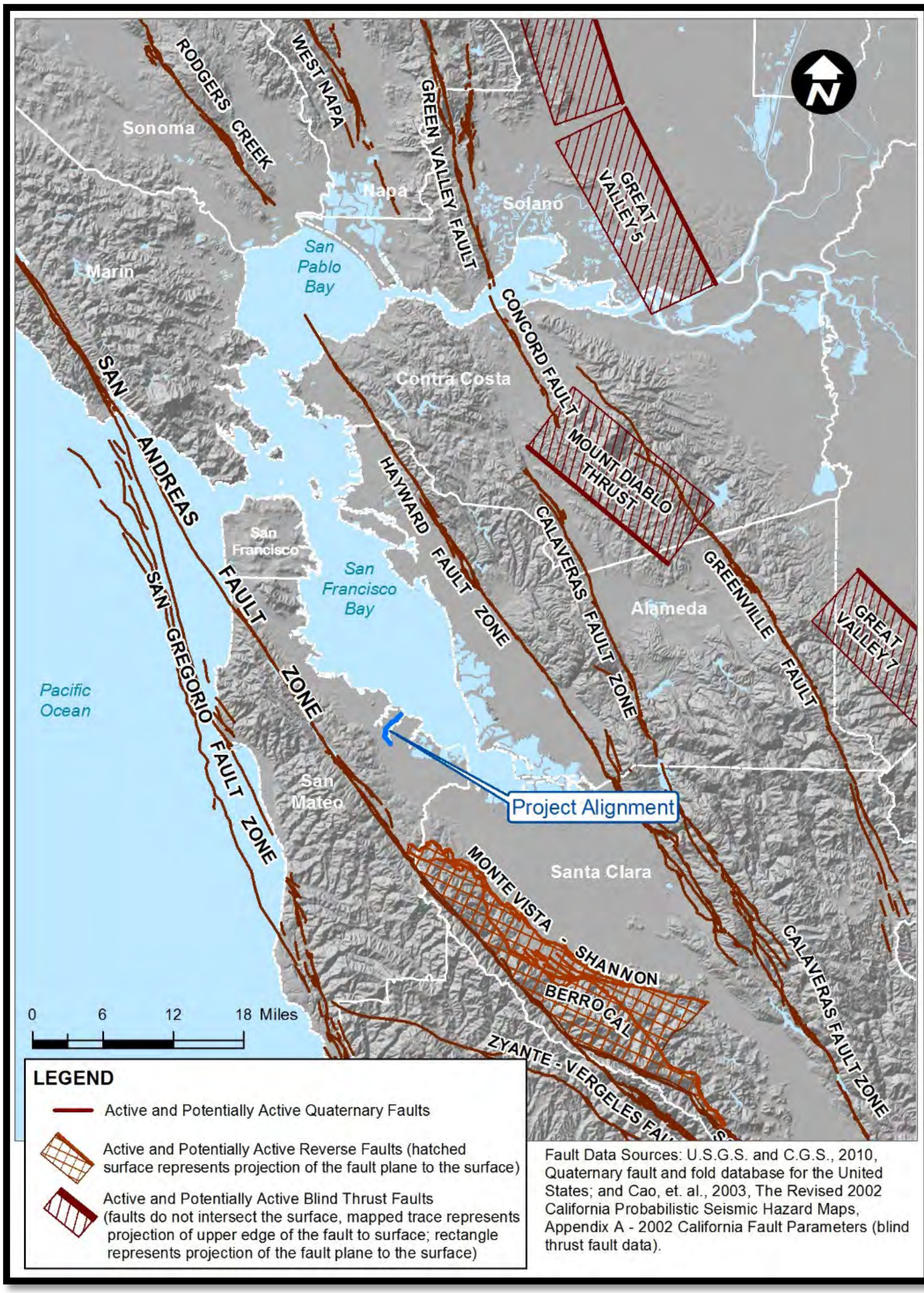
The nearest fault to the project sites is the Peninsula segment of the N. San Andreas Fault Zone, passing about 4.2 miles (6.8 kilometers) to the west of the alignment at its closest point and 6.5 miles (10.5 kilometers) west of the alignment at its most distant point (the northeast end). The distance to significant active faults, the CGS assigned fault type ("A" or "B"), estimated maximum magnitude earthquake, and 30-year probability of a M≥6.7 earthquake on the faults are summarized in ***Table 3***. Location of Bay Area faults within approximately 50 miles of the project alignment are presented on ***Figure 2 – Regional Fault Map***.

TABLE 3 – SIGNIFICANT ACTIVE FAULTS

Fault Name and Fault Segment Rupture Combinations	Distance to Fault, Closest Point Along Alignment[1] (miles)	Estimated Earthquake Magnitude[2]	30-Year Probability of M>6.7 Earthquake[3] (%)
Type A Faults			
N. San Andreas (Varying rupture combinations of segments of the N. San Andreas Peninsula segment alone and with varying combinations of the Offshore, North Coast, and Santa Cruz Mountain segments)	4.2	7.2-7.9	21
N. San Andreas (Varying combinations of rupture of the N. San Andreas North Coast segment alone and with of the Offshore segment)	25.3	7.5-7.8	
N. San Andreas (Rupture of the N. San Andreas Santa Cruz segment alone)	26.3	7.1	
Hayward-Rodgers Creek (Varying rupture combinations of the Hayward South segment alone and with the Rodgers Creek and South segments)	11.8	5.8-7.3	31
Hayward-Rodgers Creek (Varying rupture combinations of the Hayward South segment alone and with the Rodgers Creek segment)	19.6	6.6-7.2	
Hayward-Rodgers Creek (Rupture of the Rodgers Creek segment alone)	39.2	7.1	
Calaveras (Varying rupture combinations of the Calaveras Northern segment alone and with the Central and Southern segments)	19.1	6.8-6.9	7
Calaveras (Varying rupture combinations of the Calaveras Central segment alone and with Southern segment)	24.1	6.2-6.4	
Type B Faults			
Monte Vista- Shannon	8.8	6.5	-
San Gregorio Connected[4]	12.2	7.5	-
Mount Diablo Thrust	24.2	6.6	-
Green Valley Connected	27.9	6.7	-
Greenville Connected	30.8	7.0	-

Notes:
1. Fault-to-site distances based on the 2008 National Seismic Hazard Maps - Fault Parameters website at http://geohazards.usgs.gov/cfusion/hazfaults_search/hf_search_main.cfm; and the U.S.G.S. and C.G.S., 2010, Quaternary fault and fold database for the United States at http://earthquake.usgs.gov/hazards/qfaults/download.php.
2. Maximum Moment Magnitude based on The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2) by the USGS (2008), and/or as suggested by the SFPUC's General Seismic Requirements – Appendix A (SFPUC, 2009). Range of magnitudes represents varying rupture scenarios of one or more segments along a fault.
3. 30-year probability of M>6.7 earthquake based on 2007 Working Group on California Earthquake Probabilities (WGCEP, 2008).
4. San Gregorio fault is analyzed as a Type A fault by the 2007 Working Group on California Earthquake Probabilities.

FIGURE 2 – REGIONAL FAULT MAP



CORROSION

The Young Bay Mud and similar marine deposits are generally corrosive towards ferrous materials. We are in the process of testing representative soil samples along the tunnel alignment and along the depth of the shafts for soil corrosivity measures such as resistivity, chlorides, sulfates, and pH to assess the corrosion potential against steel and concrete.

PHASE 2 GEOTECHNICAL EXPLORATION

A Phase 2 geotechnical exploration program is currently being implemented to supplement the findings from the Phase 1 investigation and to provide design-level geotechnical recommendations for the project. The Phase 2 exploration, which would include additional borings and CPT's along the tunnel alignment as well as surveys of the ground surface at the borings and CPT locations, would help in refining and updating the Geologic Profile shown in ***Plate 2***.

REGISTERED PROFESSIONAL ENGINEER
G. NEELAKANTAN
No. 2391
Exp. 9/30/2017
GEOTECHNICAL
STATE OF CALIFORNIA

Submitted by:
GEOTECHNICAL CONSULTANTS, INC.

G. 'Neel' Neelakantan, Ph.D., P.E., G.E.
Geotechnical Engineer 2391

Attachments

JS/JT/Neel

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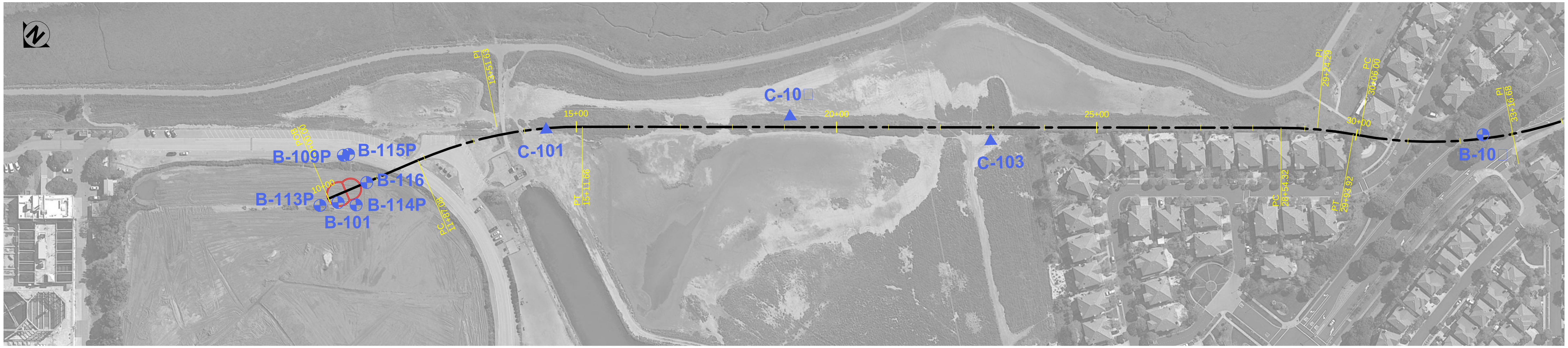
Working Group on California Earthquake Probabilities (WGCEP), 2008, The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2): USGS Open-File Report 2007-1437 and CGS Special Report 203.

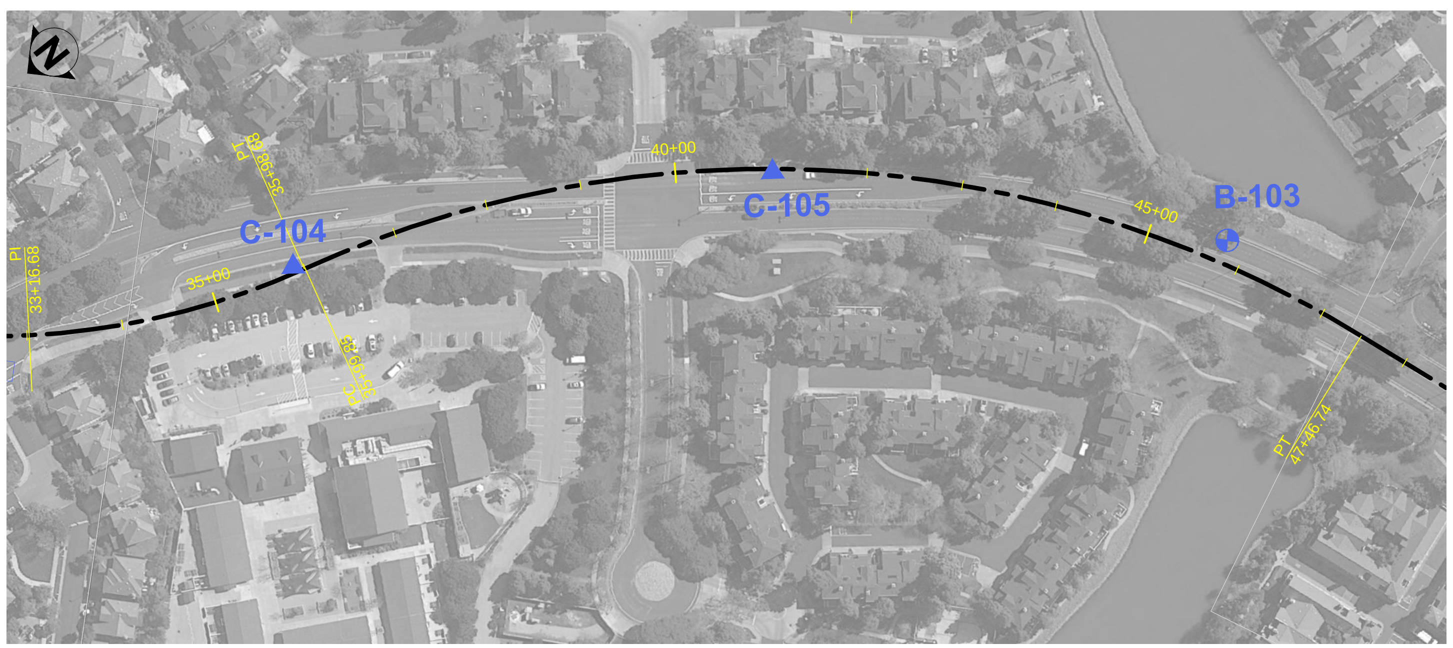
ATTACHMENTS

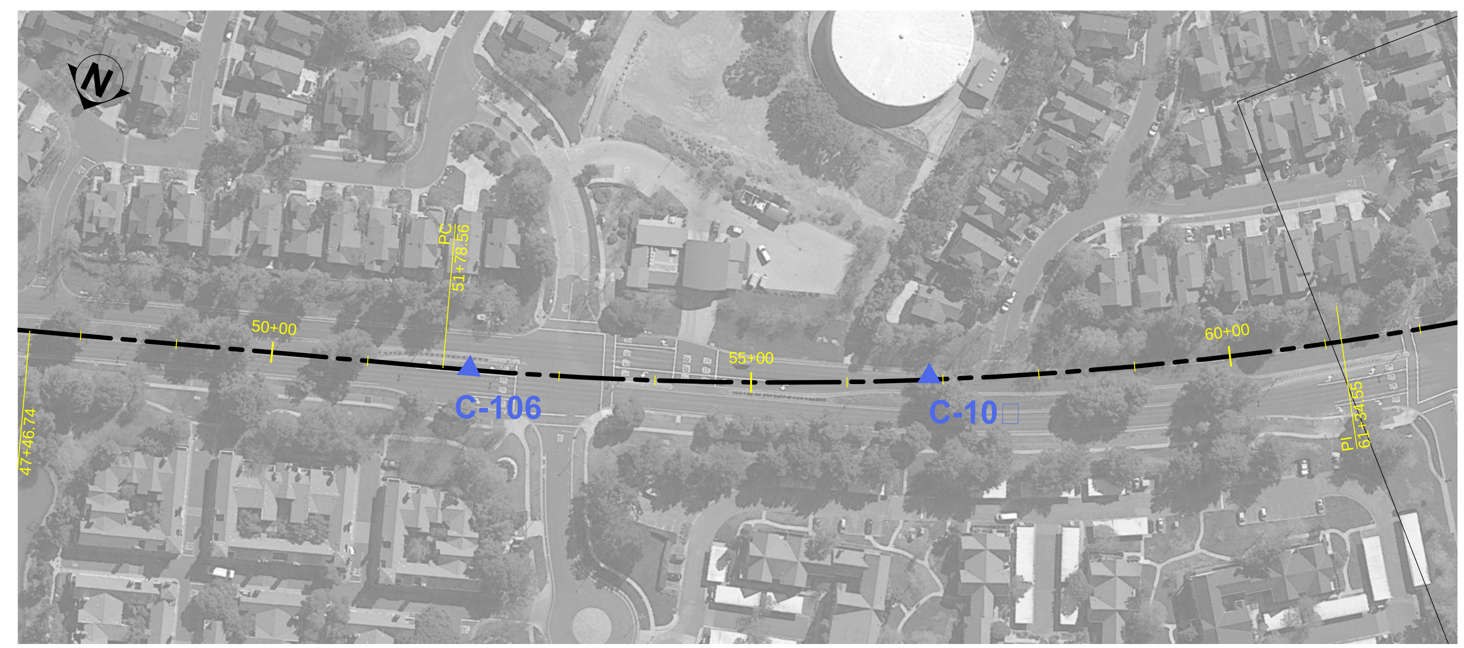
1. **Plates 1.1 through 1.4 – Boring and CPT location map**
2. **Plate 2 – Geologic Profile**
3. **Plates A-1.1 through A-1.16 – Log of Test Borings B-101 through B-116**
4. **Plate A-2 Legend to Logs**
5. **Cone Penetrometer Soundings C-101 through C-122**
6. **Laboratory Test Results**

PLATES 1.1 THROUGH 1.4

BORING AND CPT LOCATION MAP







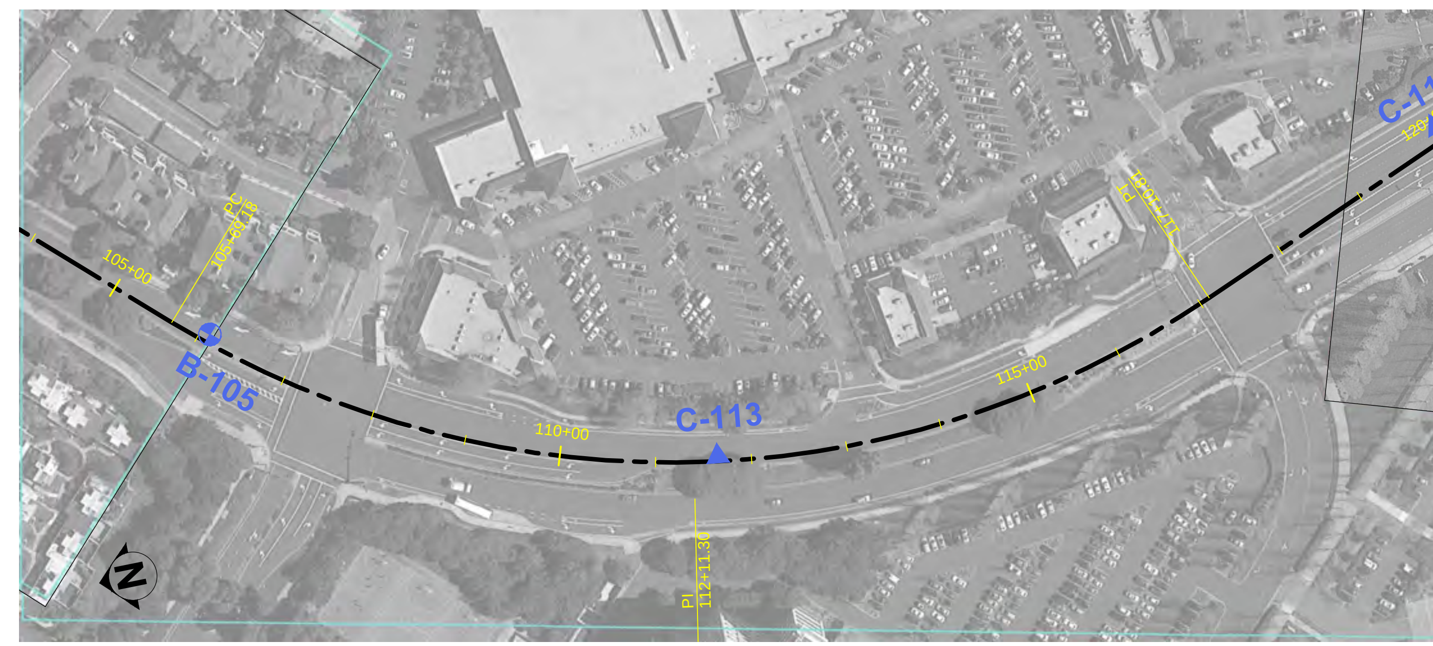
PLAN
SCALE: 1" = 100'

LEGEND

B-101	Phase 1 Geotechnical Borings
C-103	Phase 1 Cone Penetrometer Tests
	Centerline of Proposed Tunnel Alignment
	Tunnel Shafts

GEOTECHNICAL CONSULTANTS, INC.
500 Sansome Street, Suite 402
San Francisco, CA 94111

PHASE 1 GEOTECHNICAL EXPLORATION LOCATION MAP	PLATE
SILICON VALLEY CLEAN WATER TUNNEL, ALTERNATIVE 4BE REDWOOD CITY CALIFORNIA	1 1
DECEMBER 2015	SF14014A



PLAN
SCALE: 1" = 100'

LEGEND

B-101 — Phase 1 Geotechnical Borings

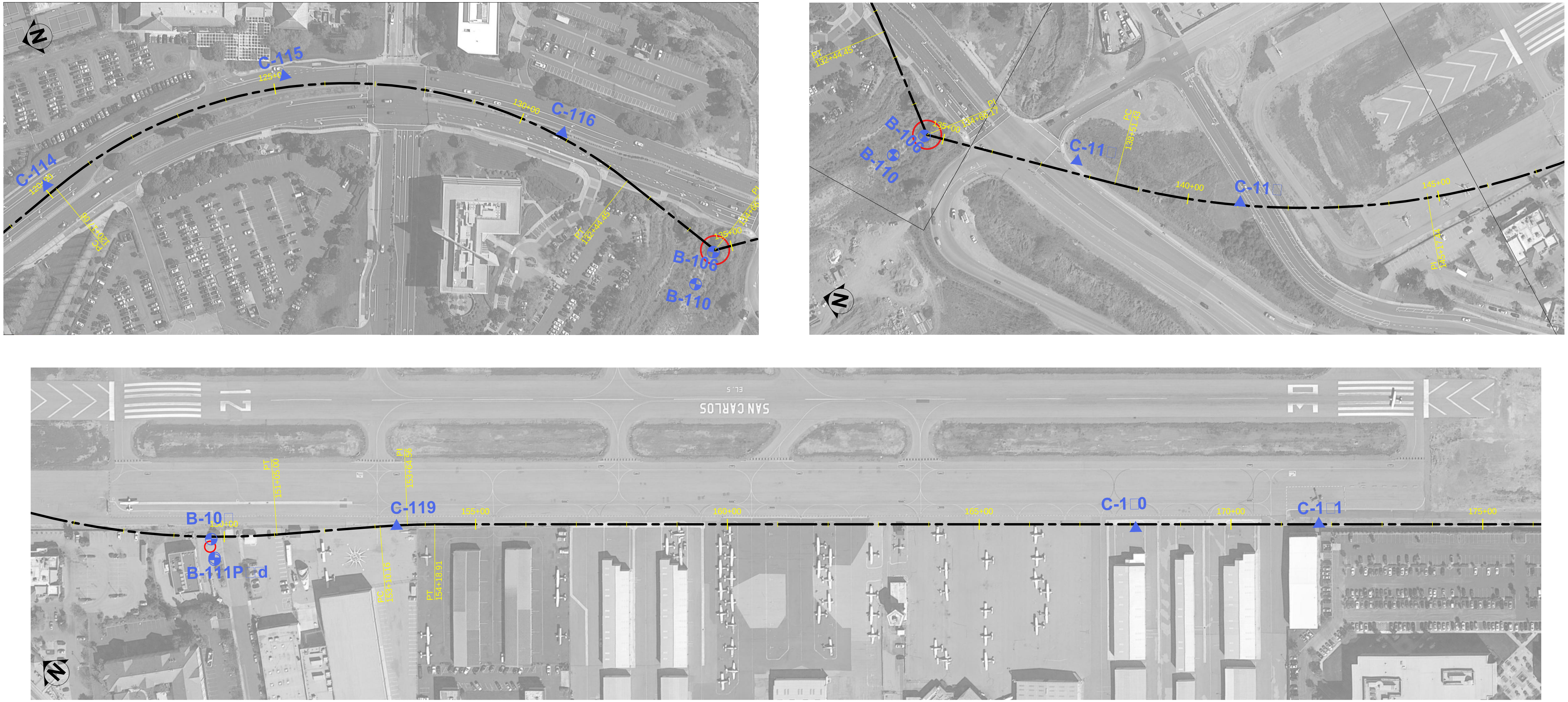
C-103 — Phase 1 Cone Penetrometer Tests

Centerline of Proposed Tunnel Alignment

Tunnel Shafts

GEOTECHNICAL CONSULTANTS, INC.
500 Sansome Street, Suite 402
San Francisco, CA 94111

PHASE 1 GEOTECHNICAL EXPLORATION LOCATION MAP	PLATE
SILICON VALLEY CLEAN WATER TUNNEL, ALTERNATIVE 4BE REDWOOD CITY CALIFORNIA	1
DECEMBER 2015	SF14014A



PLAN
SCALE: 1" = 100'

LEGEND

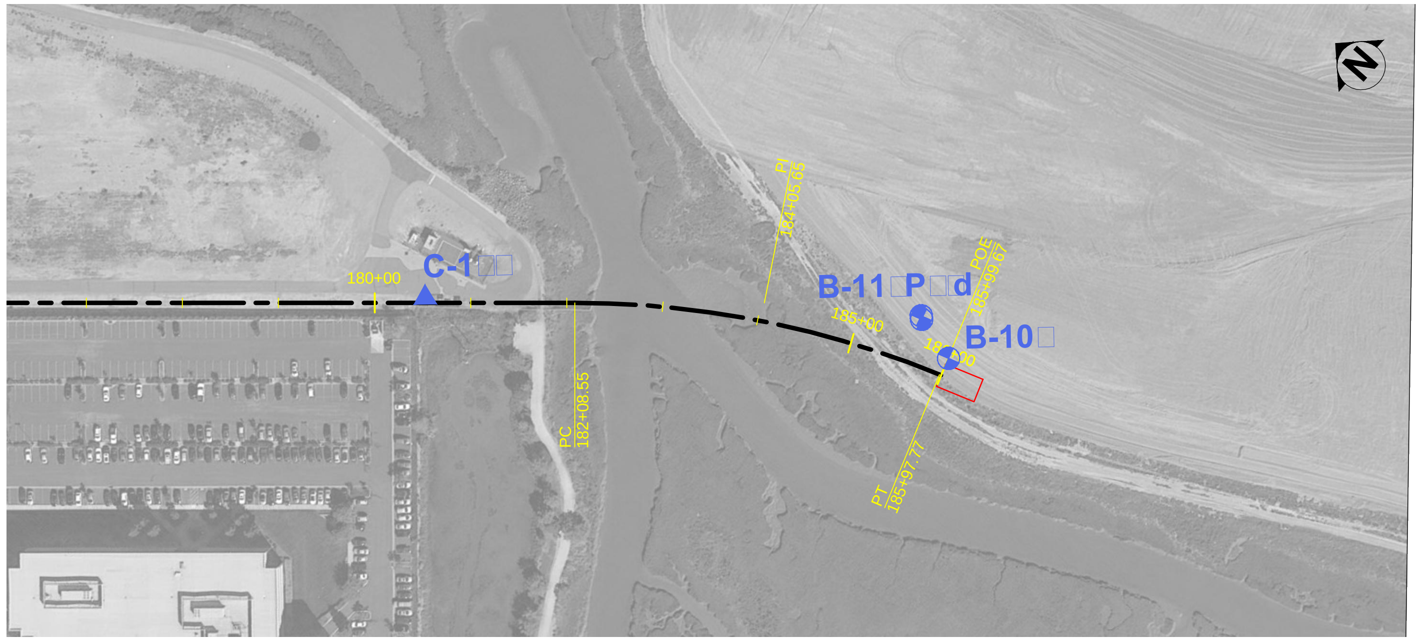
B-101 Phase 1 Geotechnical Borings

C-103 Phase 1 Cone Penetrometer Tests

Centerline of Proposed Tunnel Alignment

Tunnel Shafts

GEOTECHNICAL CONSULTANTS, INC. 500 Sansome Street, Suite 402 San Francisco, CA 94111	PHASE 1 GEOTECHNICAL EXPLORATION LOCATION MAP	PLATE
	SILICON VALLEY CLEAN WATER TUNNEL, ALTERNATIVE 4BE REDWOOD CITY CALIFORNIA	1□3
	DECEMBER 2015	SF14014A



PLAN
SCALE: 1" = 100'

LEGEND

B-101	Phase 1 Geotechnical Borings
C-103	Phase 1 Cone Penetrometer Tests
	Centerline of Proposed Tunnel Alignment
	Tunnel Shafts

GEOTECHNICAL CONSULTANTS, INC.
500 Sansome Street, Suite 402
San Francisco, CA 94111

PHASE 1 GEOTECHNICAL EXPLORATION LOCATION MAP	PLATE
SILICON VALLEY CLEAN WATER TUNNEL, ALTERNATIVE 4BE REDWOOD CITY CALIFORNIA	1 4
DECEMBER 2015	SF14014A

PLATE 2

GEOLOGIC PROFILE

Draft for Discussion

Explanation

- af — ARTIFICIAL FILL: Clay (CL, CH) and Sand (SP, SM)
- Qybm — YOUNG BAY MUD: Very soft to soft Fat Clay (CH).
- Quls — UPPER LAYERED SEDIMENTS: Firm to stiff Clay (CL, CH)
- Quls — UPPER LAYERED SEDIMENTS: Medium dense to dense Sand (SP/SM), Gravelly Sand (SP), and Sandy Gravel (GP).
- Qobd — OLD BAY DEPOSITS: Stiff to hard Clays (CL, CH) with layers of firm clay (CL, CH).
- Qobd — OLD BAY DEPOSITS: Medium dense to dense Sands (SM, SC, SP).
- Kf — FRANCISCAN COMPLEX: Bedrock.
- C-1 — CPT SOUNDINGS by GTC JULY 2014
- C-121 — BORINGS and CPT SOUNDINGS by GTC JULY-OCTOBER 2015 (Elevation of top or borings and CPTs per Overbo survey conducted November 2015)

GEOTECHNICAL CONSULTANTS, INC. 500 Sansome Street, Suite 402 San Francisco, CA 94111	GEOLOGIC PROFILE	PLATE
	CONVEYANCE TUNNEL - ALTERNATIVE 4BE SILICON VALLEY CLEAN WATER	2
	DECEMBER 2015	SF14014A

PLATES A-1.1 THROUGH A-1.16

LOG OF TEST BORINGS B-101 THROUGH B-116

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"ARTIFICIAL FILL (af)" CLAYEY SILT with GRAVEL (ML), dark olive brown, wet, soft, with mixed gravel, some fine to medium grained sand, with scattered cobbles. (POND SEDIMENTS)						
94.5	5		0				"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), very dark greenish gray, moist, very soft, no odor, no organics.						
89.5	10		WOR					47	94	90	36	181 (UCS)	
84.5	15		0										
79.5	20		WOR				Abundant shells.						
74.5	25		WOR				Minor shell fragments.	51	82	71	35	386 (TXUU)	
69.5	30		0	0.13			Soft.						
64.5	35		0	0.14									
59.5	40		WOR 75 psi					56	73	65	28	330 (UCS)	
54.5	45		24				Greenish gray, stiff, minor silt.						
49.5	50		21		1.15		"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), light olive brown, moist, stiff, minor silt, medium plasticity.						

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		28			"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: stiff to very stiff.						
39.5	60	200psi 250psi 385psi						30	19		GS (-#200=87%)
		30			SANDY SILT to SILTY SAND (ML/SM), olive brown, wet, stiff silt to dense sand, minor clay fines.						
34.5	65	22			POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, medium dense, fine grained sand.						
29.5	70	48			CLAYEY SAND (SC), brown, wet. POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, dense, fine grained sand.						
24.5	75	30			POORLY GRADED SAND (SP), dark olive gray, wet, dense, medium to coarse grained sand, with trace very fine gravel.						
19.5	80	30			SANDY GRAVEL (GW), dark olive gray, wet, dense, mixed fine to coarse gravel, subrounded to angular, spherical to elongate, medium to coarse sand, minor silt.						
14.5	85	50			POORLY GRADED SAND (SP), coarse grained. POORLY GRADED GRAVEL (GP), fine subrounded to rounded, up to 1/2 inch. SANDY GRAVEL (GW), dark olive gray, wet, dense, mixed fine to coarse gravel, subrounded to angular, medium to coarse sand, minor silt.						
9.5	90	46									
4.5	95	33			"OLD BAY DEPOSITS (Qobd)" FAT CLAY (CH), greenish gray, moist, very stiff.						
-0.5	100	25			SILTY CLAY (CL/CH), greenish gray, moist, stiff, moderate to high plasticity.						
-5.5	105										

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-121.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-101
DRILLING DATE: September 23-24, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		■	29		2.2 1.8		"OLD BAY DEPOSITS (Qobd)" cont. SILTY CLAY (CL/CH) cont. At 110 feet: stiff to very stiff.						
-15.5	115												
-20.5	120	■	7		1.05		Medium stiff to stiff, with scattered shell fragments.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater measured at approximately 1.3 feet on 9/24/15.
3) Boring backfilled with cement grout on 9/24/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy & Seastorm Dr., Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-91.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-102
DRILLING DATE: July 27, 2015
ELEVATION: 102.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
					13-inches Asphalt Concrete.						
					"ARTIFICIAL FILL (af)" SANDY CLAY (CL) grayish brown, dry, loose, minor gravel clasts to 1 3/4 inches in diameter. Damp, increasing clay and gravel.						
97.1	5	15		1.0	SANDY CLAY with GRAVEL (CL), dark greenish gray, damp, stiff, abundant fine gravel clasts to 1/4 inch in diameter, minor black mottling, fine to coarse grained sand.						
		0	0.25		"YOUNG BAY DEPOSITS (Qybd)" FAT CLAY (CH), dark gray, wet, soft.	50.0	87.9	89	37		
92.1	10										
87.1	15										
82.1	20	0	0.25		Minor shells.	52.4	83.4				
77.1	25										
72.1	30	0	0.25		Dark greenish gray.	52.6	82.2	75	34		
67.1	35	0	0.30		Trace shells.						
62.1	40	0	0.30								
		28	1.13	2.0	"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), dark gray, wet, very stiff, trace black mottling, trace very fine grained sand and silt.	105.1	22.5	50	16	2126 (UCS)	
57.1	45										
52.1	50	27		2.5	Dark yellowish brown, with minor fine grained sand, trace black mottling.	92.0	31.3			2157 (UCS)	GS (-#200=96.9%)

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy & Seastorm Dr., Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-91.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-102
DRILLING DATE: July 27, 2015
ELEVATION: 102.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			16		1.0		"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: Yellowish brown, wet, stiff, trace fine grained sand, trace orange mottling.	88.3	34.9			1260 (UCS)	
42.1	60		51		2.0		CLAYEY SAND (SC), grayish brown, wet, dense, medium grained sand.	105.7	20.9				GS (-#200=28.3%)
37.1	65												
32.1	70		53		2.3		"OLD BAY DEPOSITS (Qobd)" SILTY CLAY (CL), grayish brown, wet, very stiff, trace orange mottling, trace fine grained sand.						
27.1	75												
22.1	80												
17.1	85												
12.1	90		50		2.75		LEAN CLAY (CL), grayish brown, wet, very stiff, trace orange mottling, trace fine grained sand and silt.						

NOTES:
1) Bottom of boring at 91.5 feet.
2) Groundwater not measured due to drilling method.
3) Boring backfilled with cement grout on 7/27/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-86.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-103
DRILLING DATE: July 28, 2015
ELEVATION: 101.8 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							5-inches Asphalt.						
							"ARTIFICIAL FILL (af)" CLAYEY SAND (SC), brown to gray, damp, loose, fine to medium grained sand, minor gravel to 1 inch diameter.						
96.8	5						LEAN CLAY (CL) with SAND, dark gray to black, wet, stiff, minor sand, minor gravel to 1/4 inch in diameter.						
							"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, soft.						
91.8	10		0	0.22									
86.8	15												
81.8	20		0	0.25				54.7	77.4	70	32		
76.8	25												
71.8	30		0	0.22			Minor shells.	54.0	79.0	77	35		
66.8	35												
			19		1.1		"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), very dark gray, wet, very stiff, trace black mottling.						
61.8	40		20				Trace brown mottling.						
56.8	45		20				Brownish gray to yellowish brown, stiff.						
			10		1.0			106.5	22.7	39	18	1817 (UCS)	
51.8	50		15				Trace fine grained sand.						
			11		0.6			102.5	24.5	37	16	845 (UCS)	

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-86.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-103
DRILLING DATE: July 28, 2015
ELEVATION: 101.8 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			10		0.5		"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont.						
			5				At 55 feet: Increasing silt and fine grained sand.						
							SANDY CLAY (CL), dark gray to medium brown, wet, medium stiff, fine grained sand, trace orange mottling.						
41.8	60		14				Very dark gray.						
							With fine to medium grained sand.	109.8	20.9			541 (UCS)	
			12				Stiff, decreasing sand content, approximately 2 inch thick gravel layer with clasts up to 1/2 inch.						
			24				CLAYEY GRAVEL with SAND (GC), dark gray to brown with brown clay/sand matrix, wet, dense, gravel clasts to 3/4 inches in diameter, fine to coarse grained sand.						GS (-#200=48.4%)
36.8	65		51										
								107.6	22.3				GS (-#200=42.9%)
			47										
31.8	70		36		3.5		"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), brownish gray, wet, very stiff, trace fine grained sand.						
26.8	75		35		1.5		Stiff.						
21.8	80												
							SILTY CLAY (CL), brownish gray with yellowish brown mottling, wet, hard, trace fine to medium grained sand.						
16.8	85		58										

NOTES:
1) Bottom of boring at 86.5 feet.
2) Groundwater observed at 4 feet in hand auger boring on 7/28/15.
3) Boring backfilled with cement grout on 7/28/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Marlin Dr., Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-81.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-104
DRILLING DATE: July 30, 2015
ELEVATION: 103.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							10 inches Asphalt. "ARTIFICIAL FILL (af)" CLAYEY SAND (SC), medium brown and gray, dry, loose, fine to medium grained sand, trace gravel clasts to 1/2 inch in diameter, slight petroleum odor. Cobble at 3 feet.						
98.1	5	B	10	0.80	0.5		SANDY CLAY (CL), dark gray, moist, very stiff. LEAN CLAY (CL), dark gray to black, wet, stiff, trace black mottling. "YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark greenish gray, wet, very soft.						
93.1	10		0	0.20			Very dark gray.						
88.1	15												
83.1	20												
78.1	25		0	0.26				51.9	82.2	68	32		
73.1	30												
68.1	35		6 23	0.64	1.75		"UPPER LAYERED SEDIMENTS (Quls)" FAT CLAY (CH), dark gray to light gray, wet, stiff, trace fine grained sand.	80.6	41.6	56	21	224 (UCS)	
63.1	40		23		1.5		Yellowish brown to grayish brown.						
58.1	45		30		2.5		Minor orange and dark brown mottling.	98.9	26.9	62	24	1993 (UCS)	
53.1	50		27		2.25		Medium brown to grayish brown.						

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Marlin Dr., Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-81.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-104
DRILLING DATE: July 30, 2015
ELEVATION: 103.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			38		2.2		"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont. At 55 feet: Grayish brown, very stiff.	99.2	26.8			2247 (UCS)	
43.1	60		42		2.8		"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), dark gray, wet, very stiff.						
38.1	65		37		2.75		Medium brownish gray.						
33.1	70												
28.1	75												
23.1	80		38		2.6		Minor orange mottling.						

NOTES:
1) Bottom of boring at 81.5 feet.
2) Groundwater observed at 7 feet on 7/30/15.
3) Boring backfilled with cement grout on 7/30/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Shoreline Dr., Redwood City
DRILLING METHOD: 0-4.5 ft, 6- inch diameter Auger; 4.5-76.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-105
DRILLING DATE: July 31, 2015
ELEVATION: 102.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
					9-inches Asphalt Concrete.						
					"ARTIFICIAL FILL (af)" SANDY GRAVEL (GW), light brownish gray, dry, mixed gravel to 1-inch diameter in sand with silt matrix.						
97.6	5				POORLY GRADED SAND (SP), yellowish brown, moist, fine grained sand. At 4.5 feet: Wet. At 6 feet: Gray, loose, trace shell fragments.						
		13									
92.6	10	WOH	0.22	0.4	"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, moist, soft, moderate H_2O odor.						
87.6	15	0	0.21	0.4	Layer of Elastic Silt (MH).	47.4	93.0	87	39		
82.6	20	0	0.15	0.28	At 20-20.5 feet: Organics, strong H_2O odor.	54.0	76.0	72	32		
77.6	25	18 17			FAT CLAY with SILT AND SAND (CH), gray, moist, medium stiff, moderate very fine grained sand.						
72.6	30	39 34			"UPPER LAYERED SEDIMENTS (Quls)" CLAYEY SAND with GRAVEL (SC). olive brown, moist, dense, fine mixed gravel from 1/4 to 3/4 inch in diameter, angular to subangular gravel clasts, clayey sand matrix.	125.3	13.6				GS (-#200=27.8%)
67.6	35	43 49			WELL GRADED SAND witH GRAVEL AND CLAY (SW), brownish gray, moist to wet, dense, fine to coarse grained sand, fine gravel with clayey blebs, scattered minor shell fragments.						
62.6	40	23 11		1.35	CLAYEY GRAVEL (GC), brown, moist, dense, subangular to angular gravel clasts up to 3/4 inch diameter, clay matrix.	97.1	28.5			1221 (UCS)	
					LEAN CLAY (CL), brown, moist, stiff, medium plasticity. Grading to gray, increased plasticity.						
57.6	45	27		2.85	FAT CLAY (CH), gray and greenish gray, moist, stiff to very stiff, trace organic matter.	98.9	26.7	57	19	1707 (UCS)	
52.6	50	18		2.1	SILTY CLAY (CL), light olive brown, moist, stiff to very stiff, low plasticity.						

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Shoreline Dr., Redwood City
DRILLING METHOD: 0-4.5 ft, 6- inch diameter Auger; 4.5-76.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-105
DRILLING DATE: July 31, 2015
ELEVATION: 102.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		■	17		1.2		"UPPER LAYERED SEDIMENTS (Quls)" SILTY CLAY (CL) cont. At 55 feet: Trace to minor sand, medium stiff to stiff.	103.2	24.0	36	18	864 (UCS)	
42.6	60												
							"OLD BAY CLAY (Qobc)" FAT CLAY (CH), greenish gray, moist, minor silt.						
37.6	65	■	34		2.7		Very stiff.						
32.6	70												
27.6	75	■	33		2.7								

NOTES:
1) Bottom of boring at 76.5 feet.
2) Groundwater encountered at 4.5 feet bgs.
3) Boring backfilled with cement grout on 7/31/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Shoreway Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-84.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-106
DRILLING DATE: September 23, 2015
ELEVATION: 98.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"ARTIFICIAL FILL (af)" SANDY CLAY (CL), orange brown to grayish brown, damp, loose, fine sand, trace gravel clasts up to 1/4 inch, minor organic plant debris, dark brown rust nodules up to 1/2 inch diameter. Increasing clay, trace plant debris.						
93.9	5		2	0.37	0.6		"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, moist, soft, slight H_2S odor.						
			100 psi				Dark brown to dark gray with rusty brown mottling, with trace fine grained sand.						
88.9	10												
			4				LEAN CLAY (CL), gray with brown mottling, wet, soft, trace of sand.						
83.9	15						Dark brown.						
							"UPPER LAYERED SEDIMENTS (Quls)" SANDY CLAY to CLAYEY SAND (CL/SC), dark olive brown trace rust mottling, moist, very stiff.						
			20										
78.9	20												
							LEAN CLAY (CL), olive brown to grayish brown with black mottling, moist, very stiff.						
			17		2.1								
73.9	25												
							SILTY CLAY (CL), dark gray, moist, medium stiff, trace fine sand.						
			7		0.5								
68.9	30												
							LEAN CLAY (CL), dark bluish gray with trace black and rust mottling, moist to wet, stiff.						
			13		1.4								
63.9	35												
							Dark grayish brown.						
			17		1.6								
58.9	40												
							Dark gray.						
			25		1.75								
53.9	45												
							Trace orange mottling.						
			27										
48.9	50												
							SANDY CLAY (CL), dark gray, moist, very stiff, minor silt, fine grained sand.						
			21										

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Shoreway Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-84.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-106
DRILLING DATE: September 23, 2015
ELEVATION: 98.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"UPPER LAYERED SEDIMENTS (Quls)" cont. SANDY CLAY (CL) cont.						
							"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), dark gray, moist, very stiff, trace silt and fine grained sand.						
			50		3.6								
38.9	60												
							Gravel and sand layer.						
			12				Stiff, trace gravel clasts up to 1/2 inch diameter.						
33.9	65												
							Increasing sand content.						
			24		2.9		Dark grayish brown with yellowish brown mottling.						
28.9	70												
			20		2.0								
23.9	75												
			30		2.8		SANDY CLAY (CL), brownish gray to medium brown with trace dark brown mottling, wet, very stiff, fine grained sand.						
18.9	80												
			50		3.0		Dark yellowish brown to medium brown, trace black mottling.						

NOTES:
1) Bottom of boring at 84.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring backfilled with cement grout on 9/23/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 150 Monte Vista Dr. (East end), Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-10 ft., Flight Auger; 10-71.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-107
DRILLING DATE: September 4. 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							2.5 inches Asphalt Concrete.						
							6 inches Aggregate Base.						
							"ARTIFICIAL FILL (af)" SILTY CLAY with GRAVEL and SAND (CL), dark grayish brown, damp to moist, fine grained sand, fine to medium mixed gravel, some debris (geotextile, etc.) Grading to FAT CLAY (CH), dark gray.						
97.7	5		75psi										
			125psi	0.32	0.6		"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, moist, medium stiff, with moderate H_2S odor.						
92.7	10		100psi 200psi				With peat, strong H_2S odor.						
					1.05								
87.7	15		10										
			17		2.7		"UPPER LAYERED SEDIMENTS (Quls)" SANDY SILT (ML), olive brown, moist, medium stiff, fine grained sand. SILTY CLAY with SAND (CL), dark grayish brown, moist, very stiff, medium to high plasticity, grades to yellowish to pale yellowish brown, trace fine gravel (quartz and sandstone clasts).						
82.7	20		19		2.2								
							Grading to very pale brown and yellowish brown.						
77.7	25		20		1.4		LEAN CLAY (CL), very pale brown to yellowish brown, moist, stiff, moderate to high plasticity.			72	21	2150 (TXUU)	
72.7	30		15		1.9		Very pale brown with yellowish brown mottling.						
67.7	35		38		3.5 3.3		Light olive brown, very stiff.			42	18	3350 (TXUU)	
			39		3.5								
62.7	40		28				2 inch lens/layer of Clayey Sand. Greenish gray with yellow brown mottling.						
							FAT CLAY (CH), bluish gray with olive brown mottling, moist, hard, moderately to highly plastic.						
			43		4.4			102.4	24.2	58	28		
57.7	45		28		1.55		1 foot thick stiff layer with trace organic matter.						
			35		2.55		Greenish gray with olive brown mottling, very stiff.	97.0	27.7	55	23	2750 (TXUU)	
52.7	50		27										

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 150 Monte Vista Dr. (East end), Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-10 ft., Flight Auger; 10-71.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-107
DRILLING DATE: September 4. 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			36		2.75		"UPPER LAYERED SEDIMENTS (Quls)" cont. FAT CLAY (CH) cont.						
42.7	60		24				SANDY CLAY (CL), olive, moist to wet, stiff, fine to medium grained sand, trace coarse sand and very fine subangular to subrounded gravel.	111.6	19.2				GS (-#200=70%)
							Increasing sand.						
37.7	65		49				SILTY SAND(SP-SM), olive brown, wet, dense, fine to medium grained sand, clayey silt fines.						
			20				Alternating layers of POORLY GRADED SAND (SP), SILTY CLAYEY SAND (SM), and LEAN CLAY with SAND (CL), olive brown with 2 inch thick black silty sand lens, fine to medium grained sand in silt/clay matrix/layers.						GS (-#200=39%)
32.7	70		3	1.4			Grading to light gray, increased clay.						
							"OLD BAY DEPOSITS (Qobd)" FAT CLAY (CH), bluish gray with yellowish orange mottling, moist, stiff.						

NOTES:
1) Bottom of boring at 71.5 feet.
2) Groundwater not noted in upper 10 feet, groundwater not observed in remaining portion of boring due to drilling method.
3) Boring backfilled with cement grout on 9/4/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Inner Bair Island, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-74.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-108
DRILLING DATE: September 28, 2015
ELEVATION: 108.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"ARTIFICIAL FILL (af)" SANDY CLAY with GRAVEL (SC), medium brown to medium gray, moist, soft, gravel up to 3/4 inch diameter, fine grained sand.						
103.6	5		25				CLAYEY GRAVEL with SAND (GC), dark brown, moist, medium dense, gravel up to 2 inch diameter, fine to coarse grained sand.						
			6										
98.6	10						LEAN CLAY (CL), dark gray, moist, medium stiff, abundant orange and black wood debris.						
			0	0.35			"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, medium stiff, slight H_2S odor, trace gravel to 1/2 inch diameter, trace very fine grained sand.						
93.6	15												
			30	1.35	3.25		"UPPER LAYERED SEDIMENTS (Quls)" SILTY CLAY (CL), dark olive brown to grayish brown, moist, very stiff, abundant orange and black mottling, trace small (1/4 inch) gravel clasts.						
88.6	20												
			13				SILTY SAND to CLAYEY SAND (SM/SC), grayish brown to dark yellowish brown, wet, loose, fine to medium sand.						
83.6	25												
			10				6 inch thick gravel layer.						
							LEAN CLAY (CL), dark olive brown with trace black and rust mottling, moist, stiff.						
78.6	30												
			26				CLAYEY GRAVEL with SAND (GC), gray and brown, wet, medium dense, gravel up to 3/4 inch diameter.						
73.6	35												
							LEAN CLAY (CL), dark gray with rust mottling, wet, stiff.						
			24		1.25		SILTY SAND (SM), dark gray, wet, medium dense, fine to medium grained sand.						
68.6	40												
			74				POORLY GRADED SAND with GRAVEL (SP), dark brown to dark gray, wet, very dense, minor gravel up to 1/2 inch diameter, fine to coarse grained sand.						
63.6	45												
			9				LEAN CLAY (CL), dark grayish brown with trace rust mottling, moist, stiff.						
58.6	50												
			34		2.9		Very dark gray, hard.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Inner Bair Island, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5-74.5 ft., 4-inch diameter Rotary Wash; Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-108
DRILLING DATE: September 28, 2015
ELEVATION: 108.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont.						
			20	1.23	2.1		Increasing dark yellowish brown mottling, very stiff.						
48.6	60												
			40		3.7		"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), dark greenish gray, moist, very stiff, trace fine grained sand.						
43.6	65												
			32		3.6		SANDY CLAY (CL), dark olive gray, moist to wet, very stiff, fine grained sand, trace gravel up to 1/4 inch diameter.						
38.6	70												
			35		3.5		SILTY CLAY (CL), dark greenish gray with trace rust mottling, moist, very stiff.						

NOTES:
1) Bottom of boring at 74.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring backfilled with cement grout on 9/28/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 86.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-109P
DRILLING DATE: September 24-25, 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								3.5 inches asphalt; 6 inches of aggregate base.						
								"ARTIFICIAL FILL (af)" POORLY GRADED SAND (SP), grayish brown, damp, fine grained.						
97.7	5		1					Very loose, wet.						
			2					"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), very dark greenish gray, moist, no organics, no odor.						
92.7	10													
			0 psi					Very soft.						
					0.09	0.07								
87.7	15													
82.7	20		0 psi											
			50 psi			0.22		Soft.						
77.7	25													
72.7	30		WOR			0.19		Very soft.						
67.7	35													
62.7	40		WOR			0.17								
57.7	45													
								SILTY CLAY (CH), greenish gray, moist, stiff, moderate to high plasticity.						
52.7	50		18			1.75								
						1.3		"UPPER LAYERED SEDIMENTS (Quls)" SILTY CLAY (CL), light olive brown, moist, stiff, low plasticity.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 86.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: J. Seibold
CHECKED BY:

DRILL HOLE NO.: B-109P
DRILLING DATE: September 24-25, 2015
ELEVATION: 102.7 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"UPPER LAYERED SEDIMENTS (Quls)" cont. SILTY CLAY (CL) cont.						
								SANDY CLAY (CL), olive brown, moist, stiff.						
42.7	60		36					POORLY GRADED SAND with SILT (SP-SM), olive brown, wet, medium dense, fine grained sand.						
37.7	65		17					SILT with CLAY and SAND (ML), olive green, moist, stiff, non-plastic silt.						
								POORLY GRADED SAND with SILT (SP-SM), olive brown, moist, fine grained sand.						
32.7	70		38											
27.7	75		22					POORLY GRADED SAND (SP), olive gray, wet, medium dense, fine grained, minor medium grained sand.						
22.7	80		27					Increased amount of medium grained sand.						
17.7	85		45					Olive gray, wet, dense, medium to coarse grained, trace to minor fine rounded gravel.						
								SANDY GRAVEL (GP), olive brown, wet, dense, fine gravel, subrounded to subangular, matrix of medium to coarse grained sand with clayey silt fines.						

NOTES:
1) Bottom of boring at 86.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-109P on 9/25/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Shoreway Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 69.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-110
DRILLING DATE: September 24, 2015
ELEVATION: 104.0 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"ARTIFICIAL FILL (af)" CLAYEY GRAVEL with SAND (GC), dark brown, damp, loose, gravel up to 1 inch diameter, fine grained sand, trace roots.						
							SANDY CLAY with GRAVEL (CL), dark brown with minor black and orange mottling, moist, stiff, fine to coarse grained sand, minor gravel up to 1/2 inch diameter, trace brick and glass debris.						
99.0	5		17		2.1								
			WOH	0.32			"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, medium stiff.						
94.0	10												
			WOH	0.31			Slight H_2S odor, abundant wood fragments.						
89.0	15												
			7		1.25		"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), medium to dark gray, moist, stiff, trace silt and very fine grained sand.						
84.0	20												
			27		2.25		Increasing sand. Dark olive brown with trace black mottling, very stiff, trace gravel up to 1/4 inch diameter, trace fine grained sand.						
79.0	25												
74.0	30												
			10		0.6		SANDY CLAY (CL), dark yellowish brown with trace black mottling, moist, medium stiff, very fine grained sand.						
69.0	35												
64.0	40												
			21		1.5		LEAN CLAY (CL), dark gray, moist, stiff.						
59.0	45												
54.0	50												
			27		2.6		Very stiff, with trace dark brown mottling.						

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Redwood Shores Pkwy and Shoreway Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 69.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-110
DRILLING DATE: September 24, 2015
ELEVATION: 104.0 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
							"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont.						
							"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), very dark gray with dark yellowish brown mottling, moist, very stiff.						
		■	26		2.0								
44.0	60												
		■	36		4.0		Hard, trace gravel up to 1/4 inch diameter.						
39.0	65												
		■	23		2.0		Dark olive brown, moist, very stiff.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 150 Monte Vista Dr. (East end), Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 19 ft, Flight Auger

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-111Ps
DRILLING DATE: September 11, 2015
ELEVATION: 103.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								3 inches Asphalt Concrete						
								"ARTIFICIAL FILL (af)" SILTY CLAY with GRAVEL and SAND (CL), dark brown to dark gray, damp to moist, loose, fine grained sand, gravel up to 1/2 inch diameter, minor debris (geotextile, brick fragments)						
98.1	5							"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, moist, soft.						
								Black mottling, H_2S odor.						
93.1	10							Increasing moisture.						
								Abundant wood debris.						
								Increasing stiffness.						
								Dark bluish gray.						
88.1	15													
								"UPPER LAYERED SEDIMENTS (Quls)" SANDY SILT (ML), dark olive brown, wet, soft, fine grained sand.						
								LEAN CLAY with SAND (CL), medium brown, wet, medium stiff, trace coarse sand.						

NOTES:
1) Bottom of boring at 19 feet.
2) Groundwater observed at 13 feet on 9/11/15.
3) Boring completed as Piezometer B-111Ps.

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 150 Monte Vista Dr. (East end), Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 19 ft, Flight Auger; 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-111Pd
DRILLING DATE: September 11, 2015
ELEVATION: 103.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								Asphalt, 3 inches.						
								"ARTIFICIAL FILL (af)" SILTY CLAY with GRAVEL (CL), dark brown, moist, minor fine grained sand, gravel up to 2 inch diameter.						
98.1	5							"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray to black, moist to wet, soft to medium stiff.						
			0		0.28	0.45								
93.1	10													
88.1	15													
			9					"UPPER LAYERED SEDIMENTS (Quls)" SANDY CLAY to CLAYEY SAND (CL/SC), grayish brown, wet, stiff clay, loose sand, fine grained sand.						
			8					LEAN CLAY (CL), dark brownish gray with trace black mottling, wet, medium stiff, trace fine to medium grained sand.						
83.1	20													
78.1	25													
73.1	30		21		0.92	1.6		Medium brown to grayish brown with minor black mottling, stiff.						
68.1	35		44			4.7		Hard, mottled dark brown and gray, trace concretions.						
63.1	40													
58.1	45		30			1.8		Very stiff, dark gray mottled with dark orange brown.						
53.1	50													

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 150 Monte Vista Dr. (East end), Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 19 ft, Flight Auger; 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-111Pd
DRILLING DATE: September 11, 2015
ELEVATION: 103.1 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			28			1.0		"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: Stiff, grayish brown with orange brown mottling, trace silt and fine grained sand, trace small concretion.						
43.1	60		18			1.5		SILTY CLAY (CL), grayish brown with trace rust brown mottling, wet, stiff, trace fine grained sand.						
38.1	65		21					"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), bluish gray to dark gray, moist, stiff.						
			13					Dark grayish brown with orange brown mottling.						

NOTES:
1) Bottom of boring at 69.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-111Pd on 9/11/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

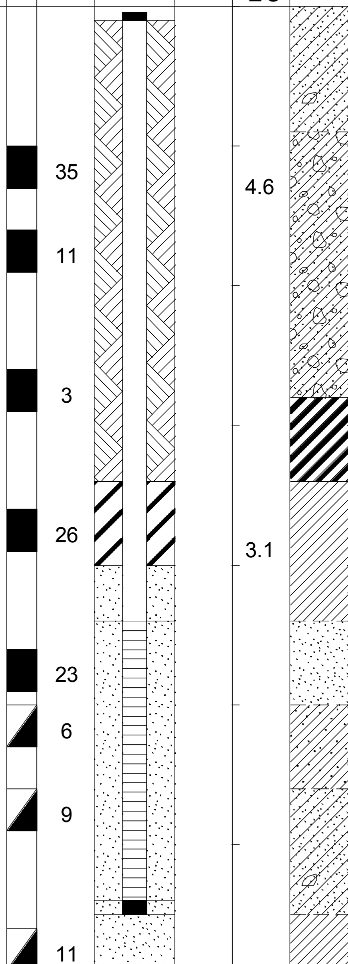
JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Inner Bair Island
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 34.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-112Ps
DRILLING DATE: September 29, 2015
ELEVATION: 110.4 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION
				"ARTIFICIAL FILL (af)" CLAYEY SAND with GRAVEL (SC), medium brown, damp, fine to coarse grained sand, minor gravel up to 1/4 inch diameter, trace brick debris.
105.4	5	35	4.6	CLAY with SAND and GRAVEL (CL), medium brown to dark brown with trace yellow and black mottling, moist, hard, minor gravel up to 1/2 inch diameter,
		11		Gravel up to 3 inch diameter.
100.4	10			
		3		Gravel layer.
95.4	15			"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, soft.
		26	3.1	"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), dark greenish gray with abundant orange and black mottling, moist, very stiff, trace fine grained sand and silt.
90.4	20			
		23		POORLY GRADED SAND with GRAVEL (SP), brown and gray, wet, medium dense, fine to coarse grained sand gravel up to 1/2 inch diameter.
85.4	25	6		SILTY CLAY (CL) to SILTY SAND (SM), grayish brown to medium brown, wet, medium stiff, fine grained sand.
		9		CLAYEY SAND with GRAVEL (SC), medium brown, wet, medium dense, fine grained sand, gravel up to 1/2 inch.
80.4	30			
		11		LEAN CLAY (CL), olive brown, moist, stiff.

Other columns: SAMPLE, WELL COMPLETION, TORVANE SHEAR STRENGTH (TSF), GRAPHIC LOG, DRY DENSITY (PCF), MOISTURE CONTENT (%), ATTERBERG LIMITS — LIQUID LIMIT (%), PLASTIC LIMIT (%), UNDRAINED SHEAR STRENGTH (PSF), ADDITIONAL TESTS



NOTES:
1) Bottom of boring at 34.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-112Ps on 9/29/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: Inner Bair Island
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 49.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-112Pd
DRILLING DATE: September 29-30, 2015
ELEVATION: 110.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
				"ARTIFICIAL FILL (af)" SANDY CLAY with GRAVEL (SC), light to medium brown, dry to damp, fine to coarse grained sand, gravel up to 1/4 inch diameter.						
105.5	5									
				CLAYEY GRAVEL (GC), gray to brown, wet, very loose, gravel up to 1/2 inch diameter.						
		4								
100.5	10									
95.5	15									
				"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), dark gray with rust mottling, moist, very stiff, trace fine grained sand.						
		19	3.25							
90.5	20									
85.5	25									
				CLAYEY SAND to SILTY CLAY (SC/CL) medium brown with trace black mottling, wet, medium dense, trace concretions, fine grained sand.						
		20	1.8							
80.5	30									
				LEAN CLAY (CL), olive brown with trace black mottling, moist, very stiff.						
		21	2.6							
75.5	35									
		23	1.75	Stiff, dark grayish brown with trace orange mottling, moist.						
70.5	40									
		24		Increasing orange mottling, trace sand.						
65.5	45									
				CLAYEY SAND with GRAVEL (SC), dark gray to dark brown, wet, medium dense, fine to coarse grained sand, trace gravel up to 1/2 inch diameter.						
		20		LEAN CLAY (CL), dark gray, moist, very stiff.						

NOTES:
1) Bottom of boring at 49.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-112Pd on 9/30/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"ARTIFICIAL FILL (af)" CLAY (CL), dark gray, damp, soft.						
94.9	5		0		0.16	0.25		"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, very soft.						
89.9	10		50 psi		0.09	0.15								
84.9	15		0		0.15	0.3		Soft.						
79.9	20													
74.9	25		0		0.19	0.4								
69.9	30		50 psi		0.45			Medium stiff, trace shells.						
64.9	35													
59.9	40													
54.9	45		16			1.8		"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), grayish brown, moist, stiff, minor orange mottling.						
49.9	50		18			1.2		Dark olive brown with grayish brown mottling, trace concretions up to 1/2 inch.						

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION
		21	2.6	"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: Very stiff, increasing orange mottling.
				SILTY CLAY (CL), grayish brown with minor orange mottling, moist, stiff.
39.9	60	7	1.2	
34.9	65	28	1.0	POORLY GRADED SAND (SP), dark brown to dark gray, wet, medium dense, fine to medium grained.
29.9	70	16		
				POORLY GRADED SAND with GRAVEL (SP), gray to brown, wet, medium dense, gravel up to 1/4 inch diameter, fine to coarse sand.
24.9	75	24		
19.9	80	26		Decreasing gravel, dense.
14.9	85	26		
				"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), dark olive brown, moist, stiff to very stiff.
9.9	90	36		Dark gray.
4.9	95			
-0.1	100	15	2.0	Very dark gray with trace orange mottling, moist, stiff.
-5.1	105			

Other columns: SAMPLE, WELL COMPLETION, TORVANE SHEAR STRENGTH (TSF), GRAPHIC LOG, DRY DENSITY (PCF), MOISTURE CONTENT (%), ATTERBERG LIMITS: LIQUID LIMIT (%), PLASTIC LIMIT (%), UNDRAINED SHEAR STRENGTH (PSF), ADDITIONAL TESTS

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 85 ft, 6-inch diameter Rotary Wash, 85 to 121.5 feet 4-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-113P
DRILLING DATE: October 14-15, 2015
ELEVATION: 99.9 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			12			1.2		"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL) cont.						
-15.1	115													
-20.1	120		16			1.75		Dark greenish gray, trace shells.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-113P on 10/15/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								"ARTIFICIAL FILL (af)" LEAN CLAY (CL), dark gray, moist, soft, minor orange mottling, trace plant debris. (POND SEDIMENTS)						
94.6	5		0		0.15			"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, soft.						
89.6	10		50psi		0.15									
84.6	15		0			0.5								
79.6	20		0			0.4		Abundant shells.						
74.6	25		0			0.4								
69.6	30		0		0.24	0.6		Abundant shell fragments.						
64.6	35		0			0.5								
59.6	40		4		0.52	1.25		Moist, stiff.						
								"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), grayish brown to dark olive brown, moist, very stiff, trace black and orange mottling.						
54.6	45		23			2.0								
49.6	50		15			1.9		Gray to orange mottling, stiff.						

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			25			2.7		"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: Brownish gray with dark gray and orange mottling, very stiff.						
39.6	60		32					CLAYEY SAND (SC), medium brown, wet, medium dense, fine grained sand, minor silt.						
34.6	65		26											GS (-#200=29%)
29.6	70		15											GS (-#200=24%)
24.6	75		34 26					Fine to medium grained sand.						GS (-#200=13%)
19.6	80		23					WELL GRADED SAND and CLAY (SW-SC), brown to gray, wet, medium dense, gravel clasts 3/4 inches in diameter, fine to coarse grained sand.						GS (-#200=9%)
14.6	85		33					Dense, increasing fine gravel.						GS (-#200=9%)
9.6	90		16					"OLD BAY DEPOSITS (Qobd)" LEAN CLAY (CL), dark greenish brown, moist, very stiff, trace gravel.						
4.6	95		29			2.4								
-0.4	100		16			2.4		No gravel.						
-5.4	105		18			3.5		Dark greenish gray.						

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 121.5 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-114P
DRILLING DATE: October 20-21, 2015
ELEVATION: 99.6 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			13			1.5		"OLD BAY DEPOSITS (Qobd)" cont. LEAN CLAY (CL) cont. At 110 feet: Stiff.						
-15.4	115													
-20.4	120		11			1.5		Dark gray.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring completed as Piezometer B-114P on 10/21/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LOG_DRILL_HOLE_WITH_ELEVATION&PIEZO SF14014 SVCW TUNNEL PIEZOS.GPJ BORE_WELL.GDT 12/16/15

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 98 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: K. Khatri, J. Thurber
CHECKED BY:

DRILL HOLE NO.: B-115P
DRILLING DATE: November 2-3, 2015
ELEVATION: 102.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
								2 inches Asphalt Concrete.						
								"ARTIFICIAL FILL (af)" CLAYEY SAND (SC), brown, moist.						
								GRAVELLY CLAY (CL), dark gray, damp, very stiff, angular 1/4 -1 inch diameter gravel clasts, filter fabric fragment.						
97.5	5							Medium brown, moist, 3 inch diameter hard gravel clasts.						
								LEAN CLAY with GRAVEL (CL), gray brown, moist to wet, stiff.						
								"YOUNG BAY MUD (Qybm)" FAT CLAY (CH), dark gray, wet, soft.						
92.5	10													
87.5	15													
82.5	20													
77.5	25													
72.5	30													
67.5	35													
								Trace shell fragments.						
62.5	40													
								Shell fragments.						
57.5	45							"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), dark olive brown to grayish brown, wet, trace shell fragments.						
52.5	50													

LOG OF DRILL HOLE

JOB NO.: SF14014A
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1400 Radio Road, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to 98 ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: K. Khatri, J. Thurber
CHECKED BY:

DRILL HOLE NO.: B-115P
DRILLING DATE: November 2-3, 2015
ELEVATION: 102.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	WELL COMPLETION	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			40			2.5		"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont. At 55 feet: dark brown with gray mottling, moist, hard.						
42.5	60		29			1.4		SILTY SAND (SM), dark brown, moist, medium dense, fine grained sand.						
37.5	65		8					SILTY CLAY (CL), brown, wet, soft. SILTY SAND (SM), dark brown, wet, loose, very fine grained sand.						
32.5	70		41					Very dark brown, dense, trace medium grained sand.						
27.5	75		27					POORLY GRADED SAND (SP), dark brown to dark gray, wet, medium dense, fine to medium grained sand.						
22.5	80		30					Dark gray, dense, trace coarse grained sand, trace gravel up to 1 inch in diameter.						
17.5	85		27					Increasing grain size, coarse grained sand to fine gravel.						
12.5	90		29					LEAN CLAY (CL), dark greenish gray, wet, very stiff.						
7.5	95		47			2.7		Dark grayish brown, moist, hard.						

NOTES:
1) Bottom of boring at 98 feet.
2) Groundwater not observed due to drilling method.
3) Boring reamed to 10 inches in diameter and completed as 5-inch diameter well (Piezometer B-115P) on 11/3/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

LEGEND TO LOGS ON PLATE A-2

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION
					"ARTIFICIAL FILL (af)" SILTY CLAY/CLAYEY SILT (CL/ML), dark gray, moist. (POND SEDIMENTS)
94.5	5		0.24	0.275	"YOUNG BAY MUD (Qybm)" ELASTIC SILT with CLAY (MH), dark olive gray to very dark gray, moist to wet, very soft.
					Wet. Minor organics.
89.5	10	0			
84.5	15	0	0.20 0.40		Minor shells.
79.5	20	0	0.19		Decreasing elasticity.
					FAT CLAY (CH), dark gray, wet, very soft. Abundant shells.
74.5	25	0	0.26		Minor organics.
69.5	30	50psi			
64.5	35	0	0.26		Abundant shells.
59.5	40	0 12	0.26 0.27		
					"UPPER LAYERED SEDIMENTS (Quls)" LEAN CLAY (CL), mottled olive gray, dark gray, and light olive gray, moist, stiff to very stiff, trace fine grained sand.
54.5	45	20 10		1.8 2.7	Yellowish brown.
49.5	50	18 12		1.9 2.1	Minor orange mottling.

LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
		31			"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont.						
		14			At 56 feet: Very stiff, trace black mottling.						
39.5	60	32		2.4							
		33			SILTY SAND (SM), medium brown, wet, dense, fine grained sand.						
34.5	65	18			CLAYEY SAND/SILTY SAND (SC/SM), brown, wet, medium dense, fine grained sand.						
		41			Very dense.						
29.5	70	35			POORLY GRADED SAND (SP), dark brown to dark gray, wet, medium dense, fine to coarse grained sand.						
		21			Increasing grain size. Trace gravel clasts to 1/2 inch in diameter.						
24.5	75	19			SAND and GRAVEL (SP/GP), brown to gray, wet, medium dense, fine to coarse grained sand, fine gravel, trace gravel clasts up to 1 1/3 inch diameter.						
19.5	80	30			Dense, increasing grain size, trace gravel clasts up to 1 inch in diameter.						
14.5	85	30			Trace to minor clay. Mixture of sand, gravel, and clay.						
					LEAN CLAY (CL), dark brownish gray, moist, hard.						
9.5	90	30		3.75	Brownish gray and grayish olive brown mottling, very stiff.						
4.5	95	38		2.75	Dark gray with brownish gray mottling, hard.						
-0.5	100	18		2.5	Dark bluish gray, very stiff.						
-5.5	105										

LOG OF DRILL HOLE

JOB NO.: SF14014
PROJECT: SVCW Tunnel, Alternative 4BE, Phase 1
LOCATION: 1440 Radio Road at Tunnel/RLS Shaft interface, Redwood City
DRILLING METHOD: 0-5 ft, Hand Auger; 5 to xxxx ft, 6-inch diameter Rotary Wash, Automatic Hammer

LOGGED BY: D. Agnew, M. Simpson
CHECKED BY:

DRILL HOLE NO.: B-116
DRILLING DATE: October 27-28, 2015
ELEVATION: 99.5 feet
DATUM: NGVD29 + 100 ft.

ELEVATION (FEET)	DEPTH (FEET)	SAMPLE	BLOW COUNT	TORVANE SHEAR STRENGTH (TSF)	POCKET PENETROMETER COMP. STRENGTH (TSF)	GRAPHIC LOG	GEOTECHNICAL DESCRIPTION AND CLASSIFICATION	DRY DENSITY (PCF)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTIC LIMIT (%)	UNDRAINED SHEAR STRENGTH (PSF)	ADDITIONAL TESTS
			18		3.5		"UPPER LAYERED SEDIMENTS (Quls)" cont. LEAN CLAY (CL) cont.						
-15.5	115												
-20.5	120		18		2.2		Very dark gray.						

NOTES:
1) Bottom of boring at 121.5 feet.
2) Groundwater not observed due to drilling method.
3) Boring backfilled with cement grout on 10/28/15.
4) Hammer efficiency of automatic hammer assumed to be 75 percent (C_E=1.25).

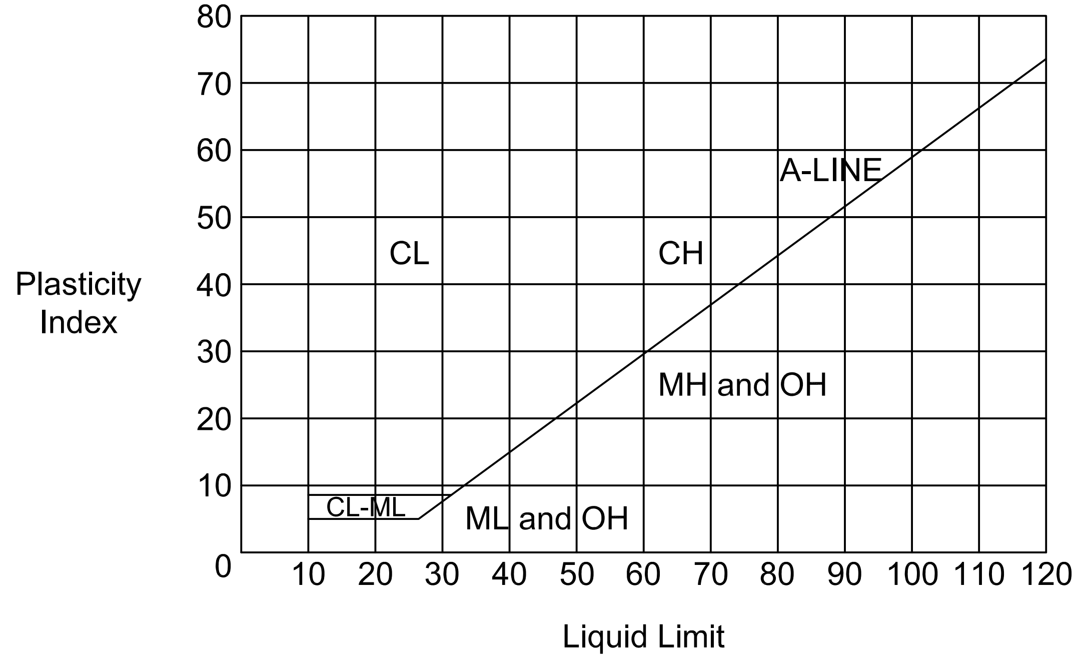
LOG_DRILL_HOLE_WITH_ELEVATION SF14014 SCVW TUNNEL.GPJ GTC.GDT 12/17/15

LEGEND TO LOGS ON PLATE A-2

PLATE A-2

LEGEND TO LOGS

PLASTICITY CHART - Used for Classification of Fine Grained Soils



BLOW COUNT - The number of blows required to drive the sampler the last 12 inches of an 18-inch drive. When the sampler is not advanced the last 12 inches, i.e. 100 blows in 9 inches, the notation is 100/9". WOH (Weight of Hammer) denotes only the weight of the drive hammer was required to drive the sampler or zero blows.

ADDITIONAL TESTS -

C: Consolidation
CL: Chloride
CORR: Corrosion
CP: Compaction
DS: Direct Shear
EL: Elasticity Index
EX: Expansion
FC: Fines Content (#200 Sieve Wash)
GS: Grain Size Distribution
OC: Organic Matter Content
pH: Hydrogen Ion Concentration
PM: Permeability
R: R-Value
RS: Resistivity
S: Swell
SE: Sand Equivalent
SP: Specific Gravity
SU: Sulfate
TD: Triaxial Compression, Drained
TDy: Triaxial Compression, Dynamic
TCU: Triaxial Compression, Consolidated Undrained
TxUU: Triaxial Compression, Unconsolidated Undrained
UCS: Unconfined Compressive Strength Test
VS: Field Vane Shear Test

SAMPLE TYPES:

MODIFIED CALIFORNIA SAMPLE
DISTURBED SLEEVE
UNSUCCESSFUL SLEEVE
SHELBY TUBE
STANDARD PENETRATION
STANDARD PENETRATION NO RECOVERY
ROCK or SOIL CORE
B BULK SAMPLE
2-INCH MODIFIED CALIFORNIA SAMPLE
UNSUCCESSFUL 2-INCH SLEEVE
FIELD VANE SHEAR TEST

WATER LEVEL:

STABILIZED or PARTIALLY STABILIZED GROUNDWATER LEVEL
UNSTABILIZED GROUNDWATER LEVEL
SEEPAGE LEVEL

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISION			GROUP SYMBOL	DESCRIPTION	GRAPHIC LOG
COARSE GRAINED SOILS Over 50% By Weight Coarser Than No.200 Sieve Size	GRAVELLY SOILS OVER 50% OF COARSE FRACTION LARGER THAN NO.4 SIEVE SIZE	CLEAN GRAVELLY SOILS LITTLE OR NO FINES	GW	well graded gravels or gravel-sand mixtures	
			GP	poorly graded gravels or gravel-sand mixtures	
		GRAVELLY SOILS WITH FINES OVER 12% FINES	GM	silty gravels or gravel-sand-silt mixtures	
			GC	clayey gravels or gravel-sand-clay mixtures	
	SANDY SOILS OVER 50% OF COARSE FRACTION SMALLER THAN NO.4 SIEVE SIZE	CLEAN SANDY SOILS LITTLE OR NO FINES	SW	well graded sands or gravelly sands	
			SP	poorly graded sands or gravelly sands	
		SANDY SOILS WITH FINES OVER 12% FINES	SM	silty sands or sand-silt mixtures	
			SC	clayey sands or sand-clay mixtures	
FINE GRAINED SOILS Over 50% By Weight Finer Than No.200 Sieve Size	SILTY AND CLAYEY SOILS LIQUID LIMIT LESS THAN 50		ML	inorganic silts, very fine sands, silty fine sands, clayey silts with slight plasticity	
			CL	inorganic clays, gravelly, sandy, silty, or lean clays, of low to medium plasticity	
			OL	organic clays or organic silts of low plasticity	
	SILTY AND CLAYEY SOILS LIQUID LIMIT GREATER THAN 50		MH	inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
			CH	inorganic clays of high plasticity, fat clays	
			OH	organic clays or organic silts of medium to high plasticity	
HIGHLY ORGANIC SOILS			Pt	peat or other highly organic soil, organic content greater than 60%	
				trash fill-landfill refuse (not a part of unified soil classification system)	

GEOTECHNICAL CONSULTANTS, INC.
500 Sansome Street, Suite 402
San Francisco, CA 94111

LEGEND TO LOGS

PLATE A - 2

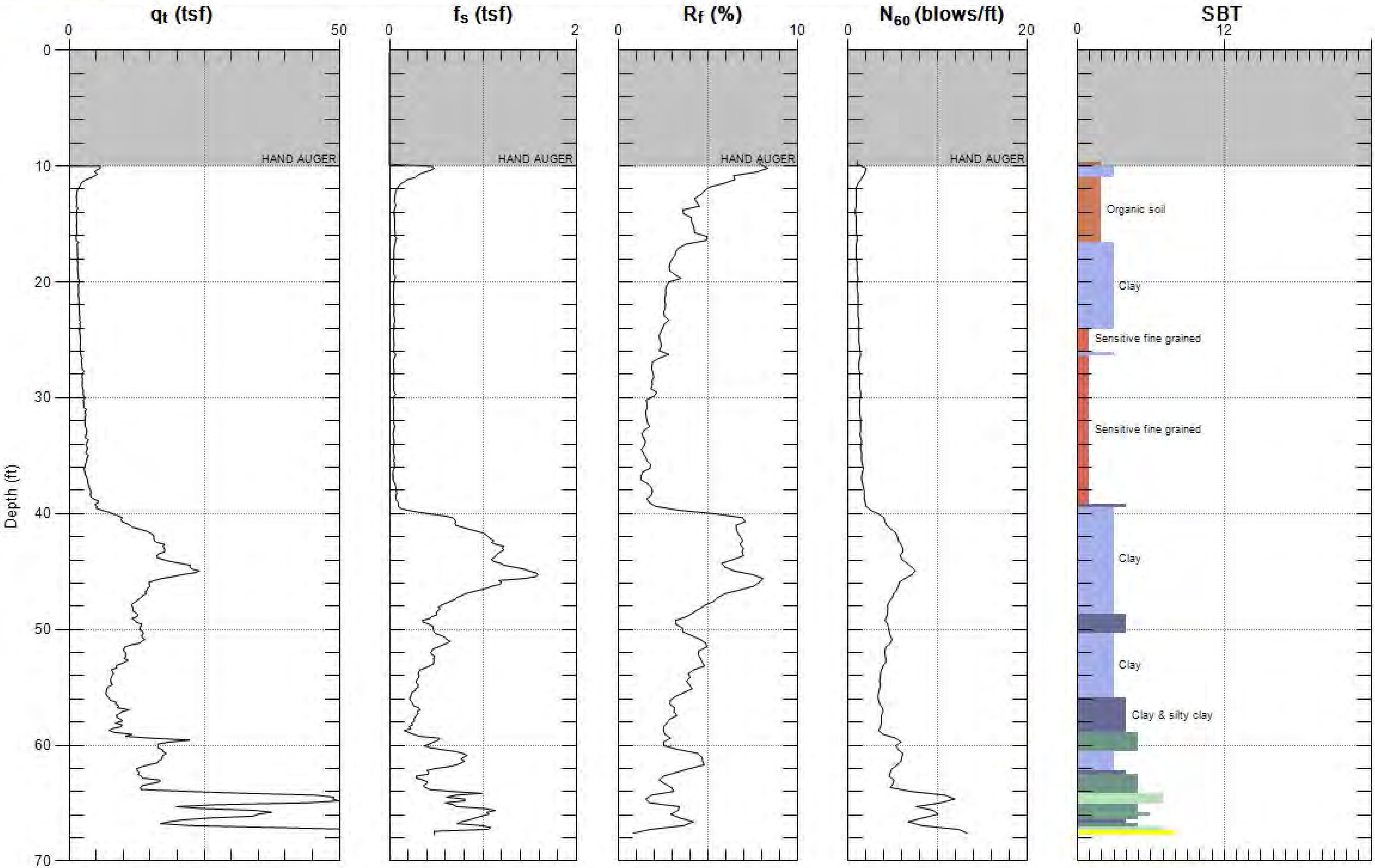
CONE PENETROMETER SOUNDINGS

C-101 THROUGH C-122

Elevation: 100.1 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-101
Engineer: D.AGNEW
Date: 8/5/2015 09:53



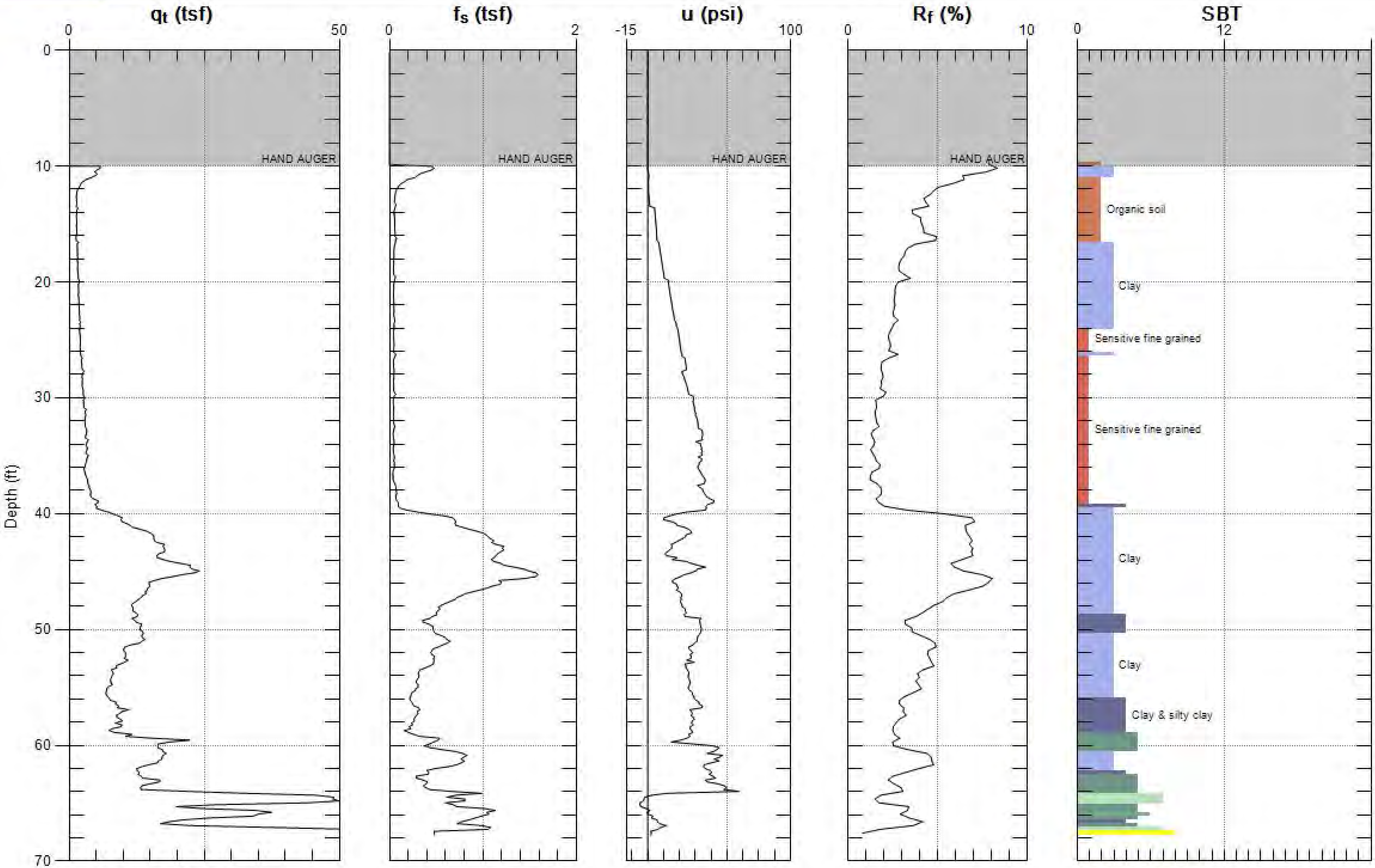
Max. Depth: 67.749 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.1 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE | **Engineer: D.AGNEW**
Sounding: C-101 | **Date: 8/5/2015 09:53**



Max. Depth: 67.749 (ft)
Avg. Interval: 0.328 (ft)

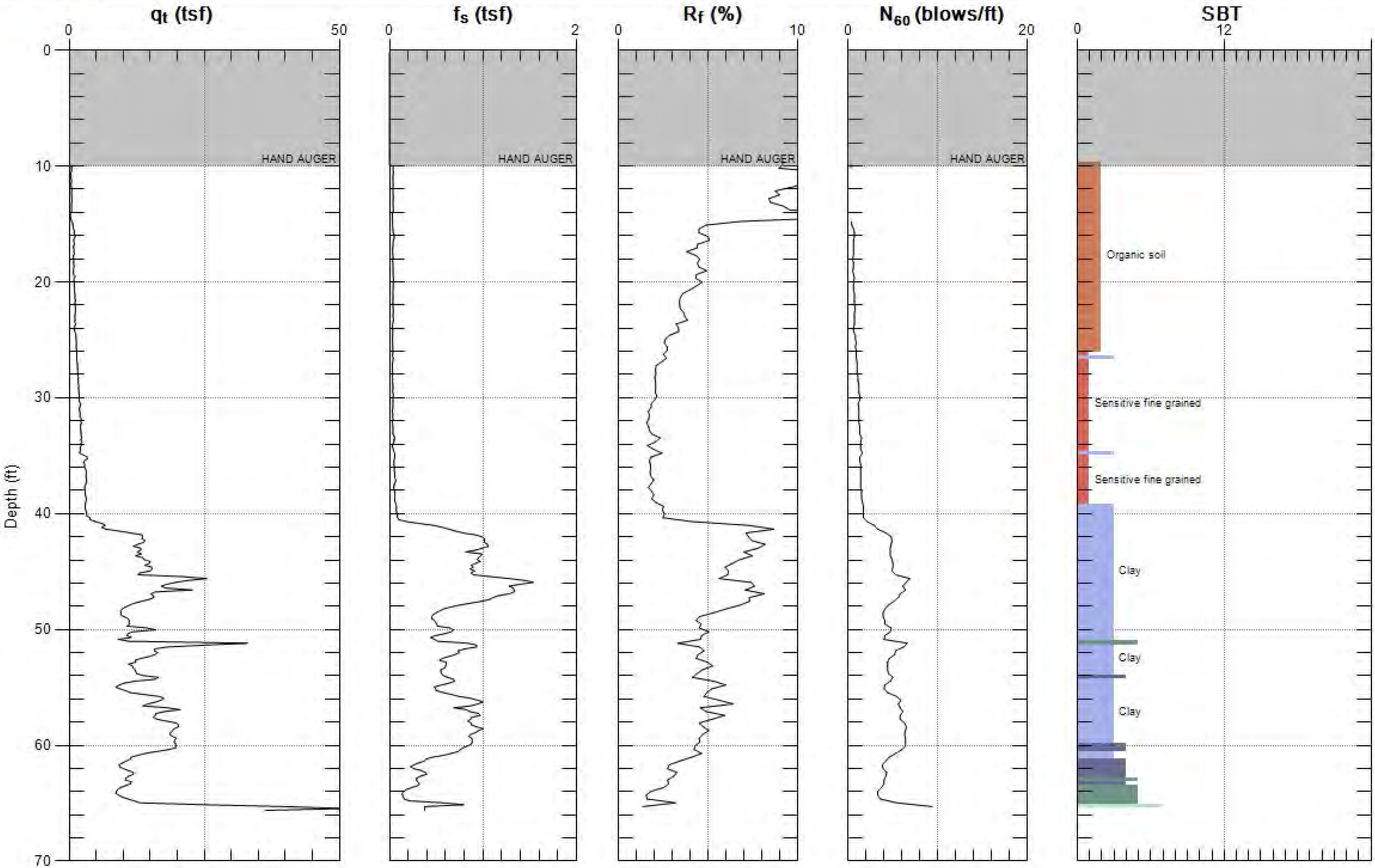
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 99.2 ft
Datum: NGVD29 +100 ft

GREGG

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-102 **Date: 8/5/2015 11:36**



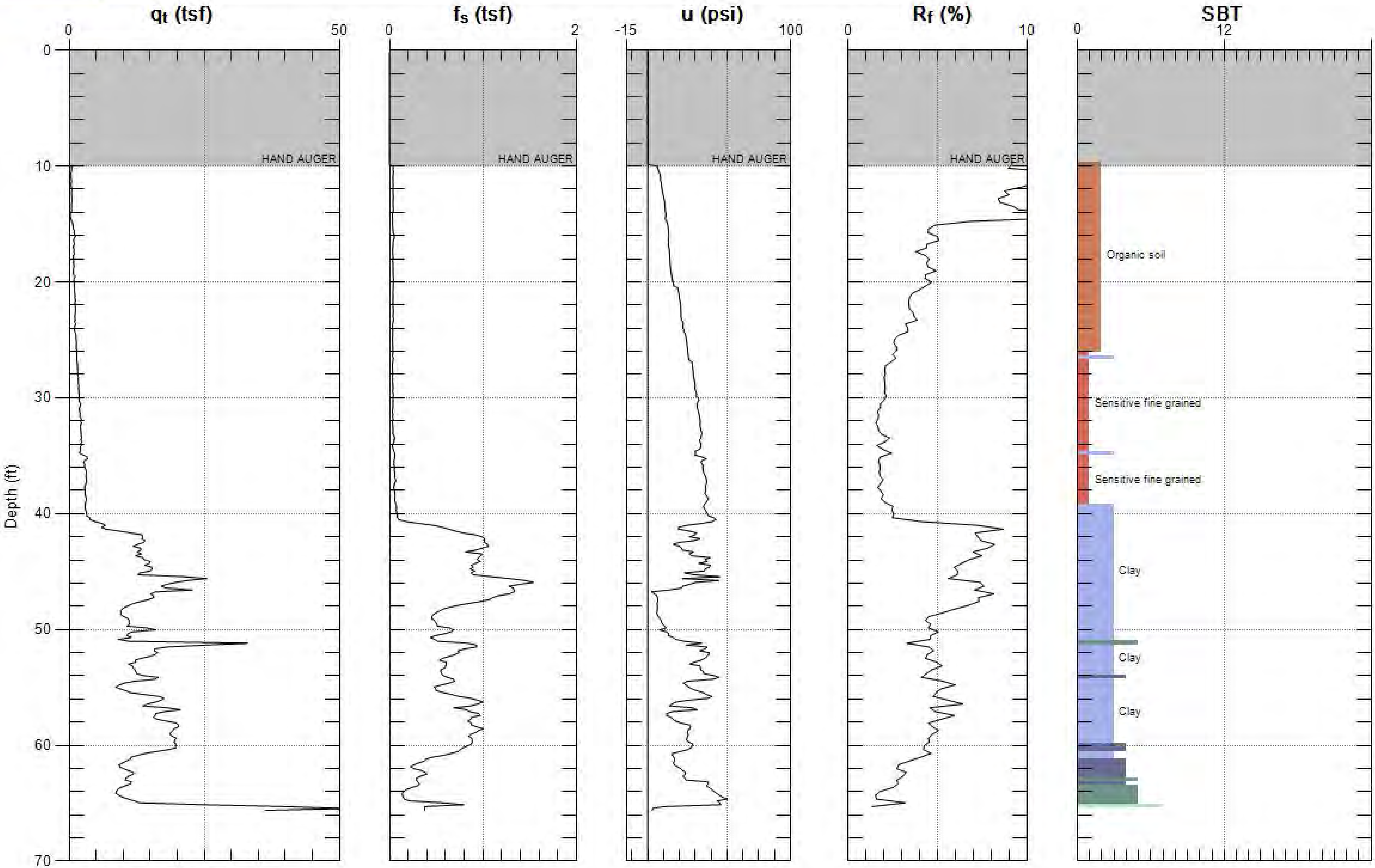
Max. Depth: 65.617 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 99.2 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-102 **Date: 8/5/2015 11:36**



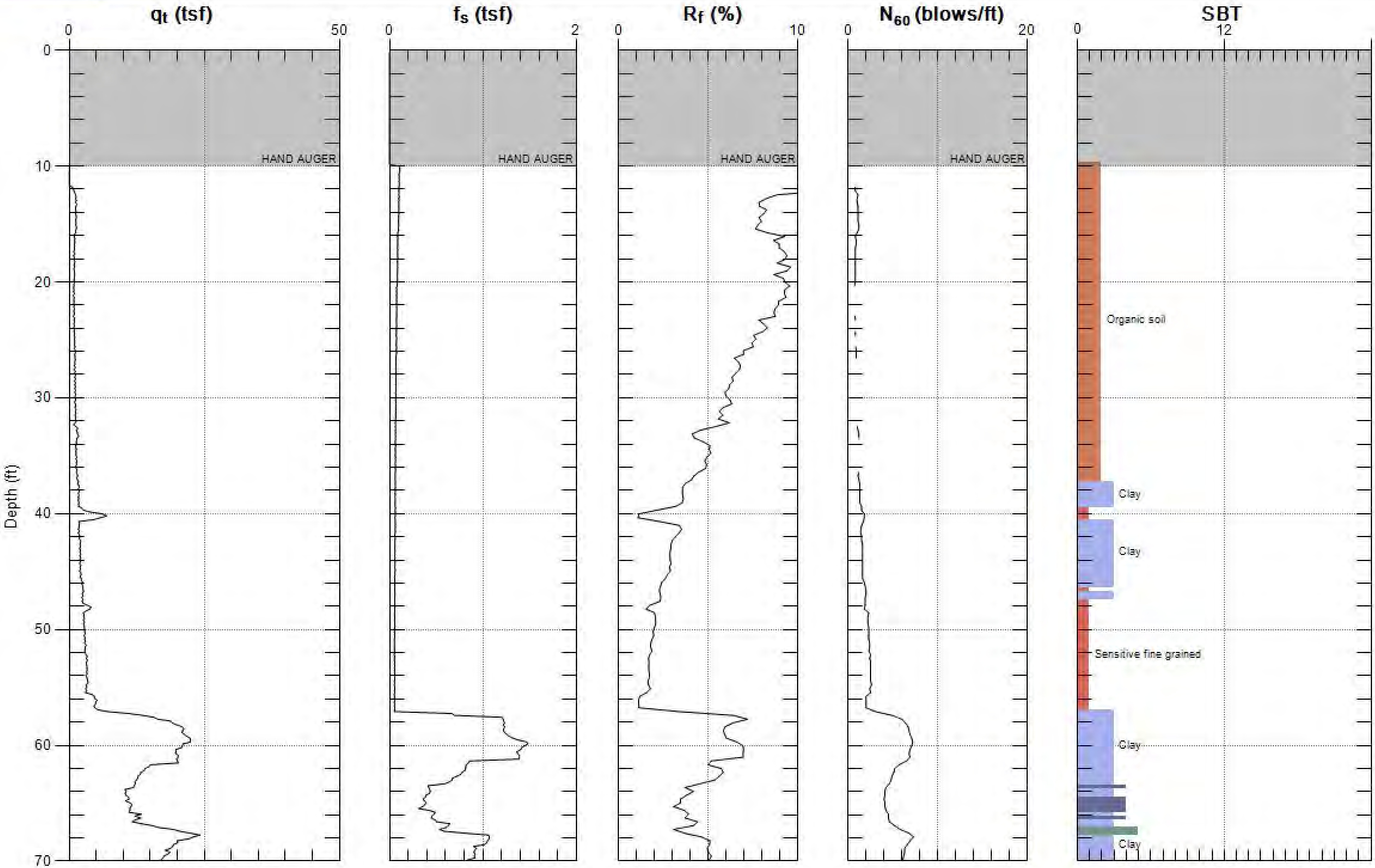
Max. Depth: 65.617 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 99.0 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-103
Engineer: D.AGNEW
Date: 8/5/2015 01:30



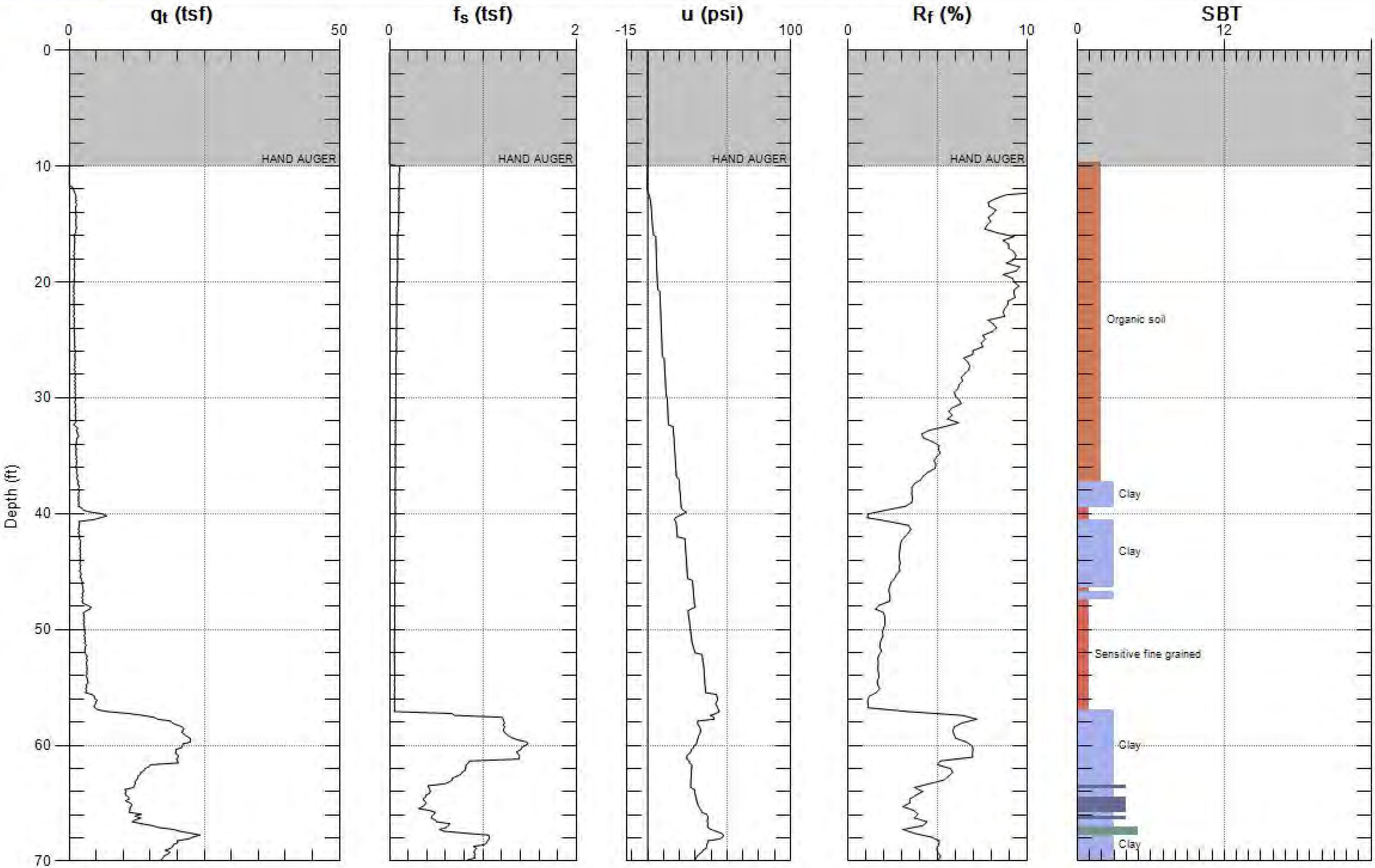
Max. Depth: 70.210 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 99.0 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-103 **Date: 8/5/2015 01:30**



Max. Depth: 70.210 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 101.4 ft
Datum: NGVD29 +100 ft

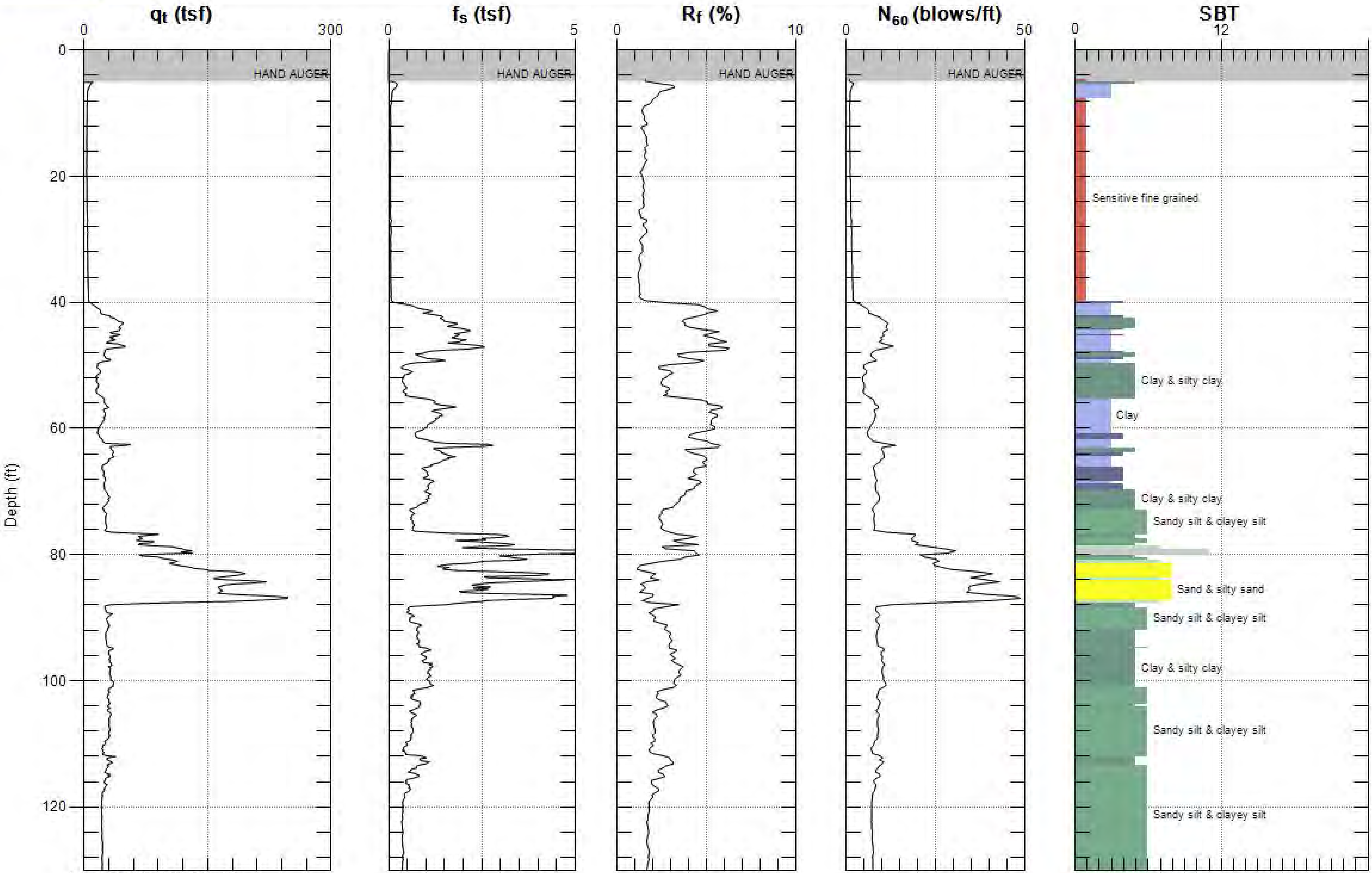
GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE

Sounding: C-104

Engineer: D.AGNEW

Date: 8/10/2015 08:53



Max. Depth: 130.085 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

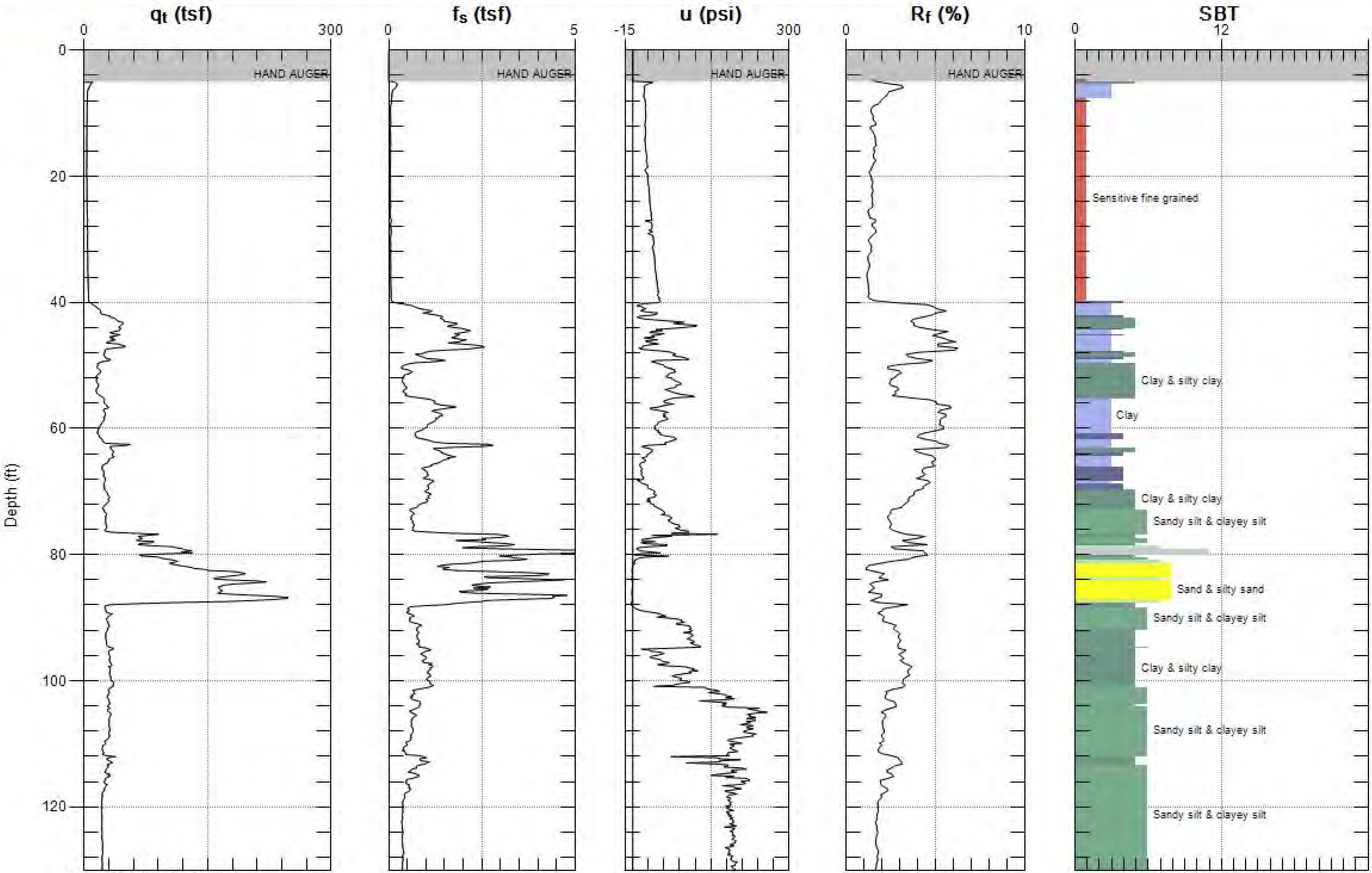
Elevation: 101.4 ft
Datum: NGVD29 +100 ft

GREGG

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-104

Engineer: D.AGNEW
Date: 8/10/2015 08:53



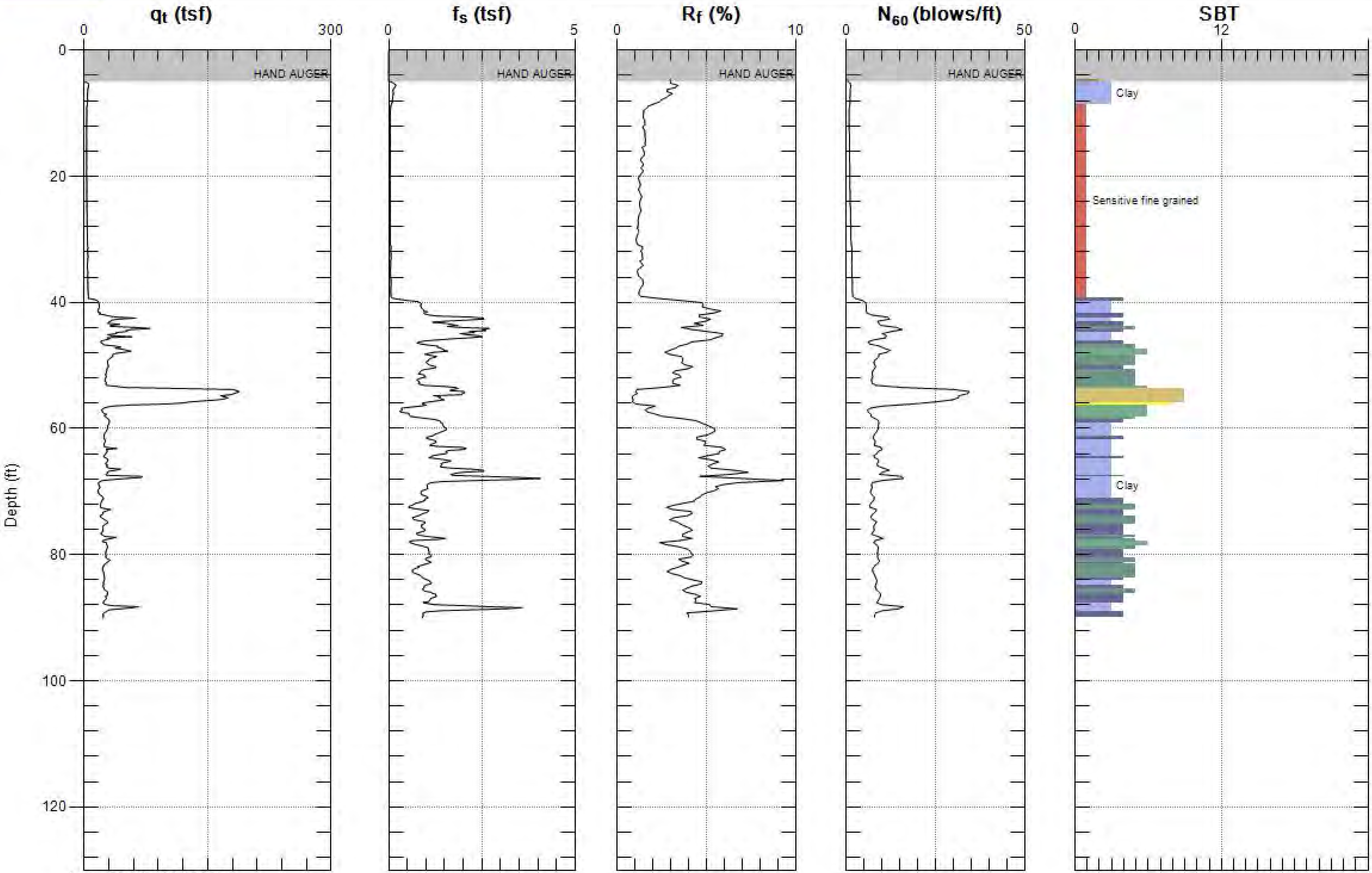
Max. Depth: 130.085 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.1 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-105 **Date: 8/10/2015 11:47**



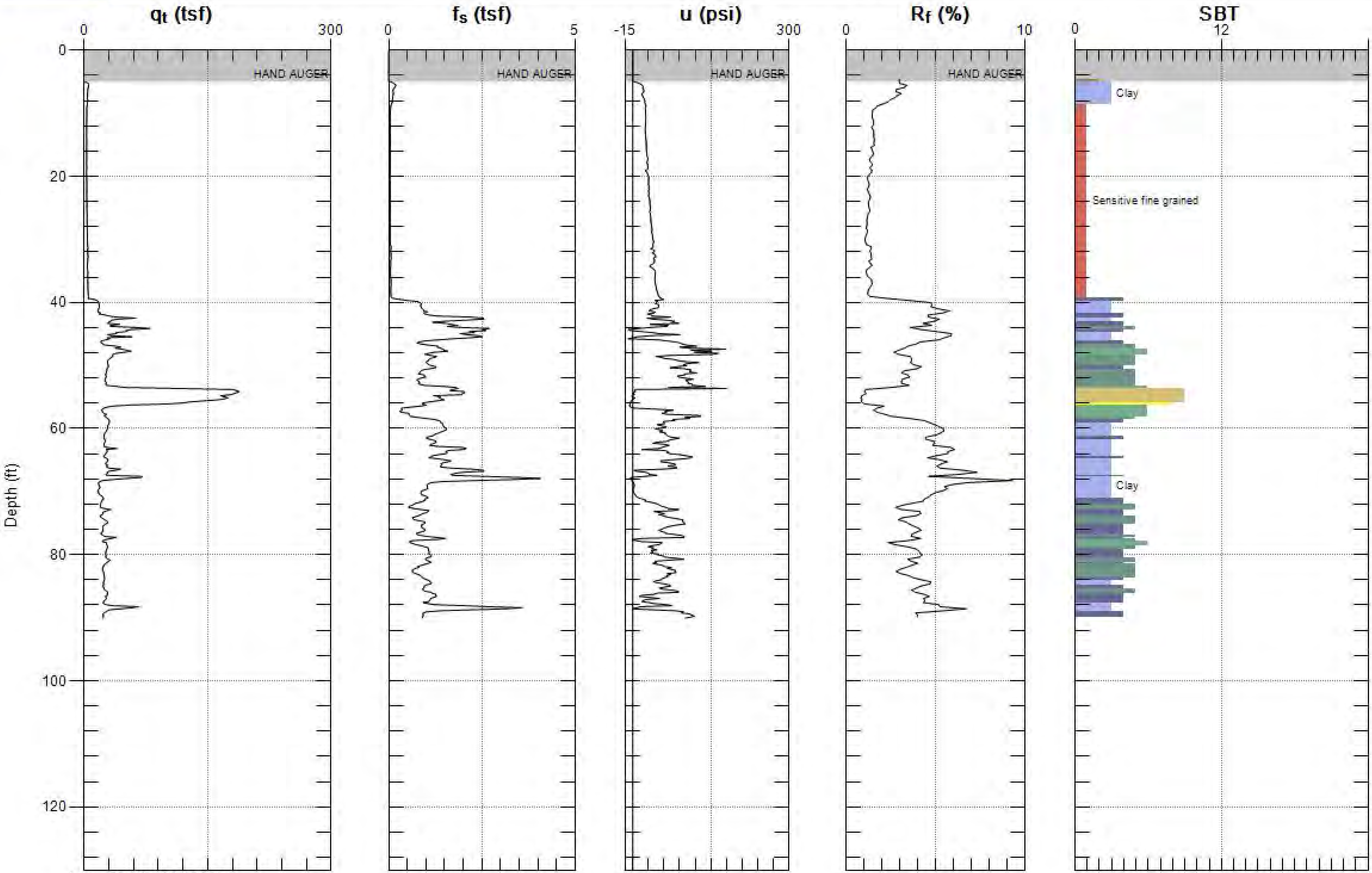
Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.1 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-105
Engineer: D.AGNEW
Date: 8/10/2015 11:47



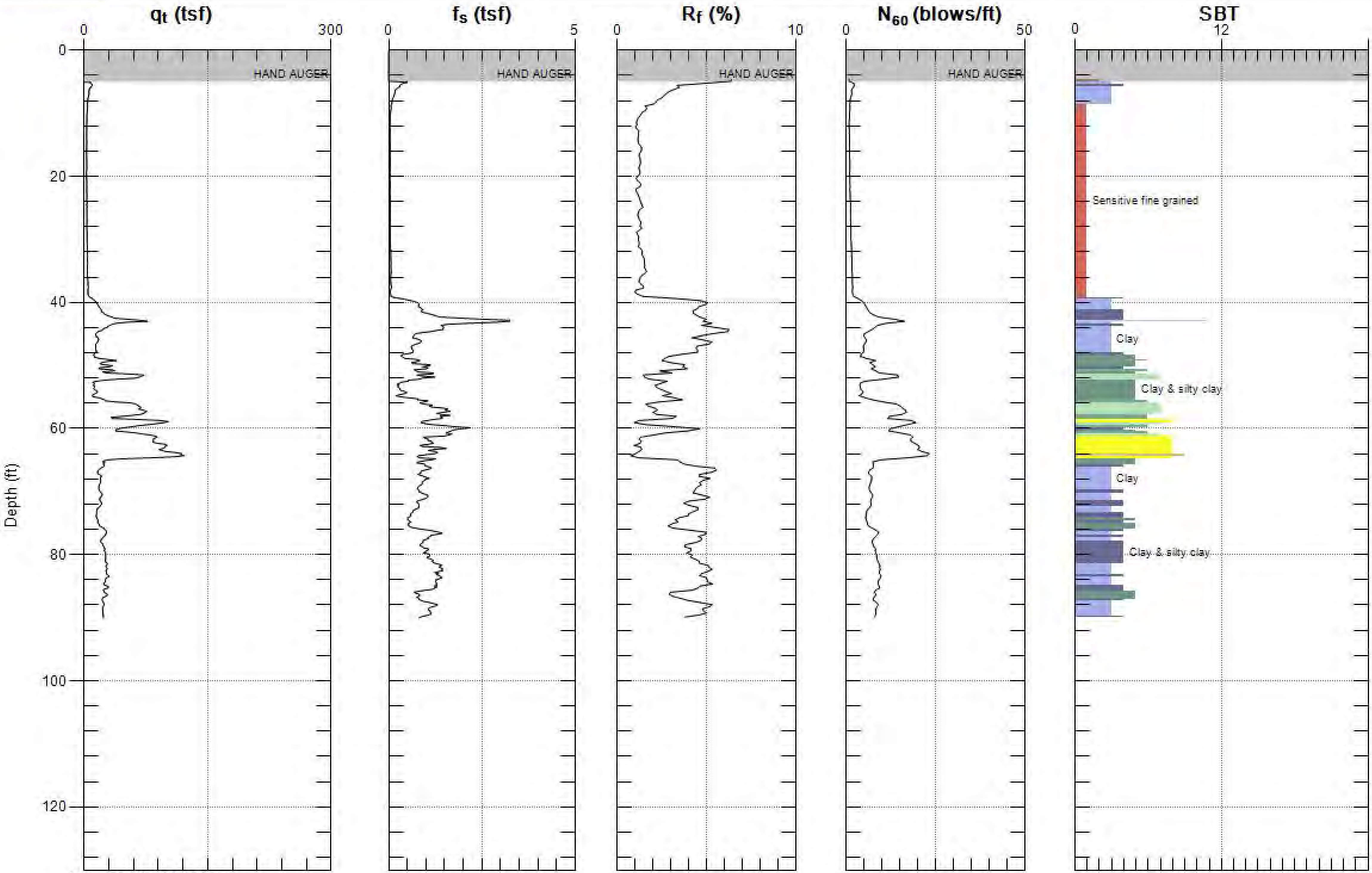
Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.2 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-106
Engineer: D.AGNEW
Date: 8/10/2015 02:32



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

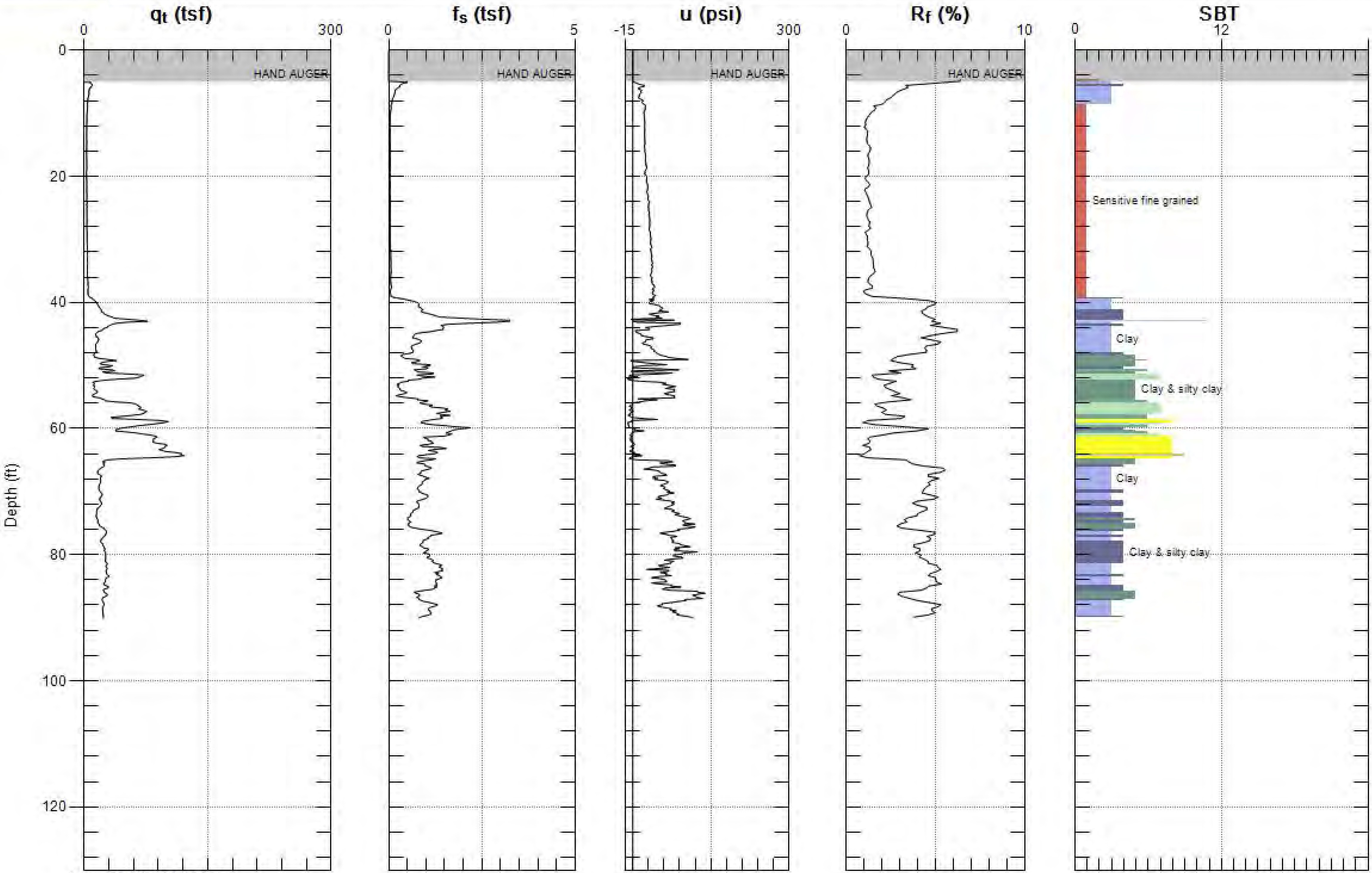
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.2 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-106 **Date: 8/10/2015 02:32**



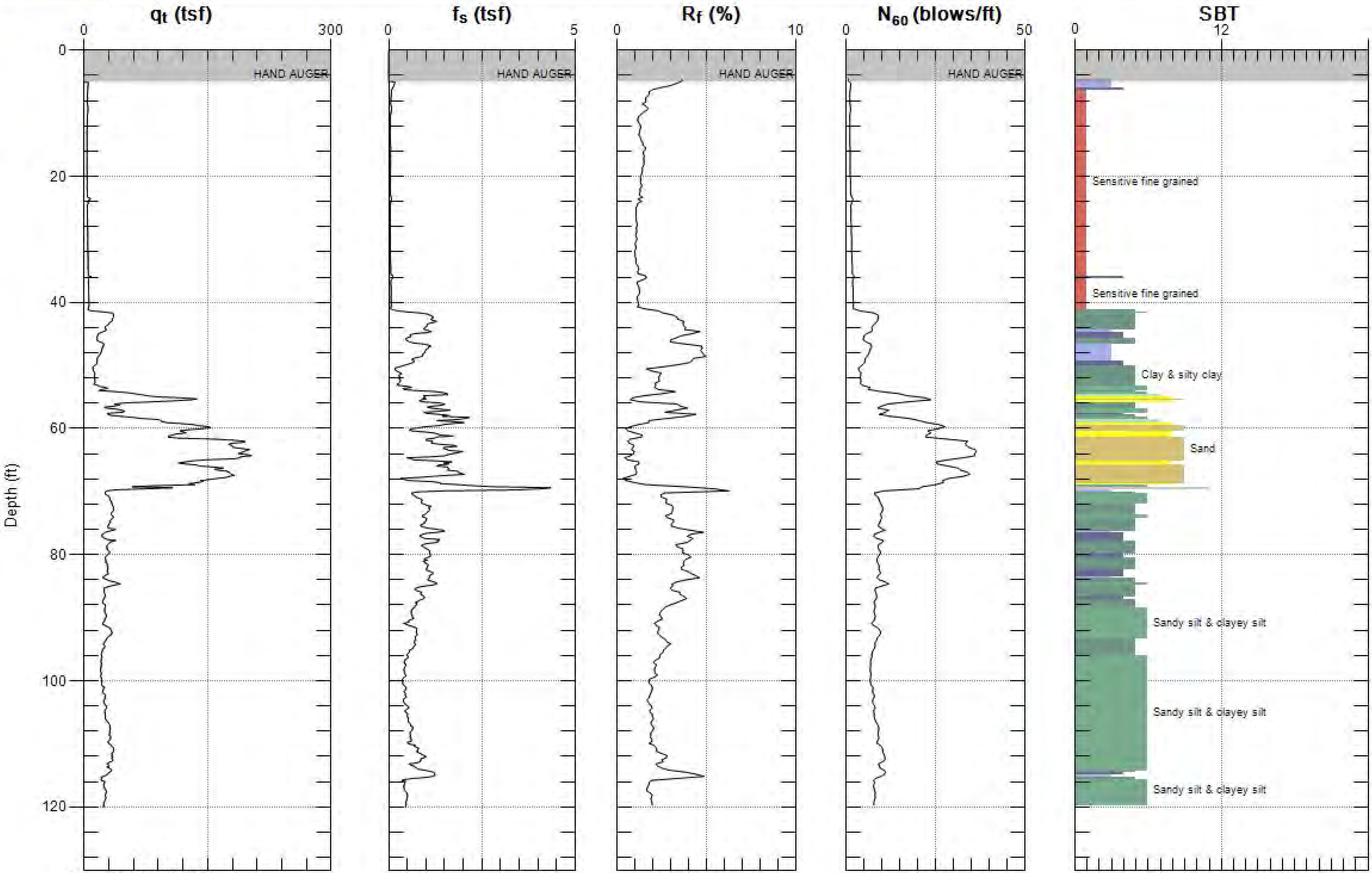
Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.1 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-107 **Date: 8/11/2015 09:16**



Max. Depth: 120.079 (ft)
Avg. Interval: 0.328 (ft)

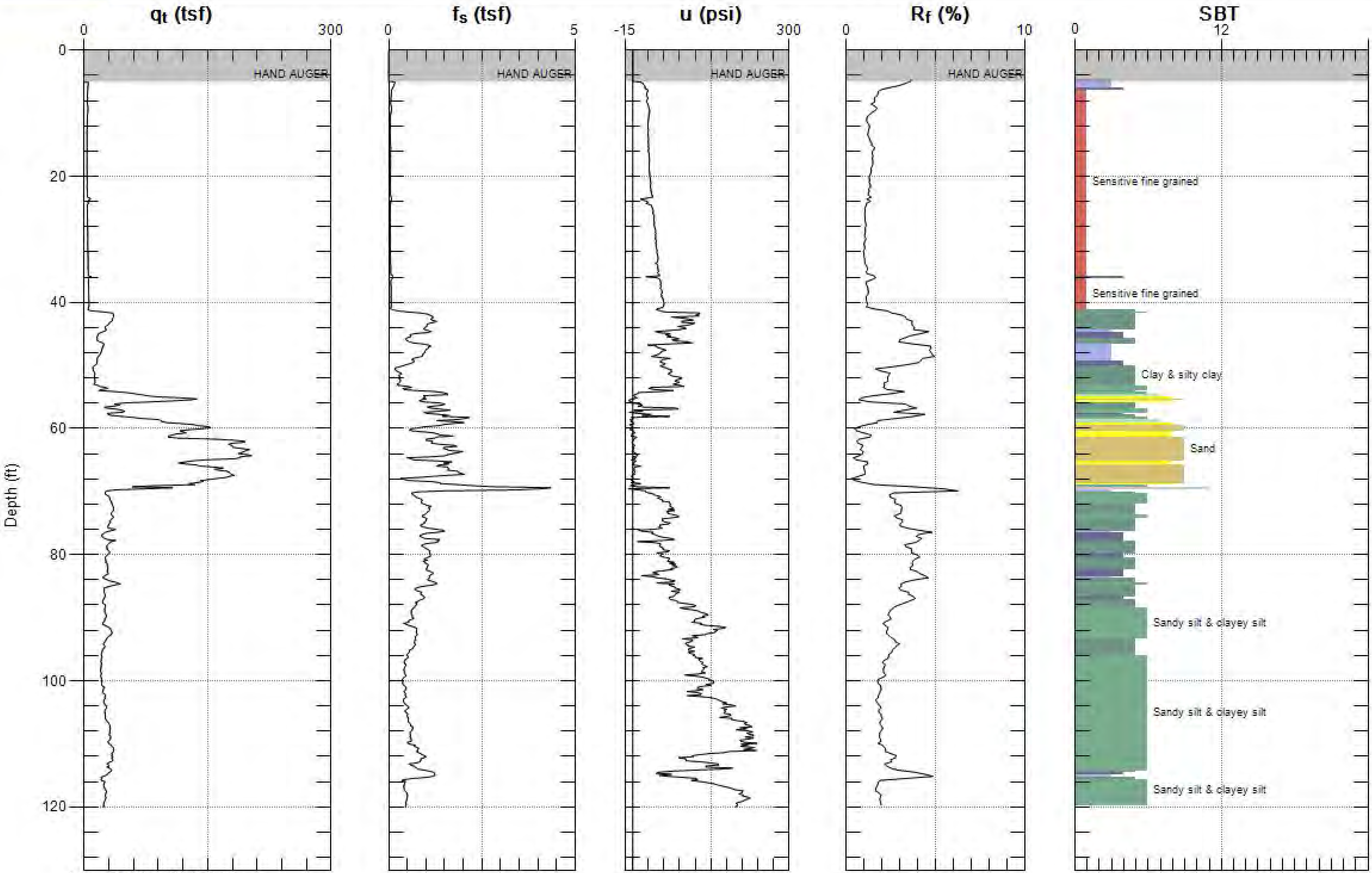
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.1 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE
Sounding: C-107

Engineer: D.AGNEW
Date: 8/11/2015 09:16



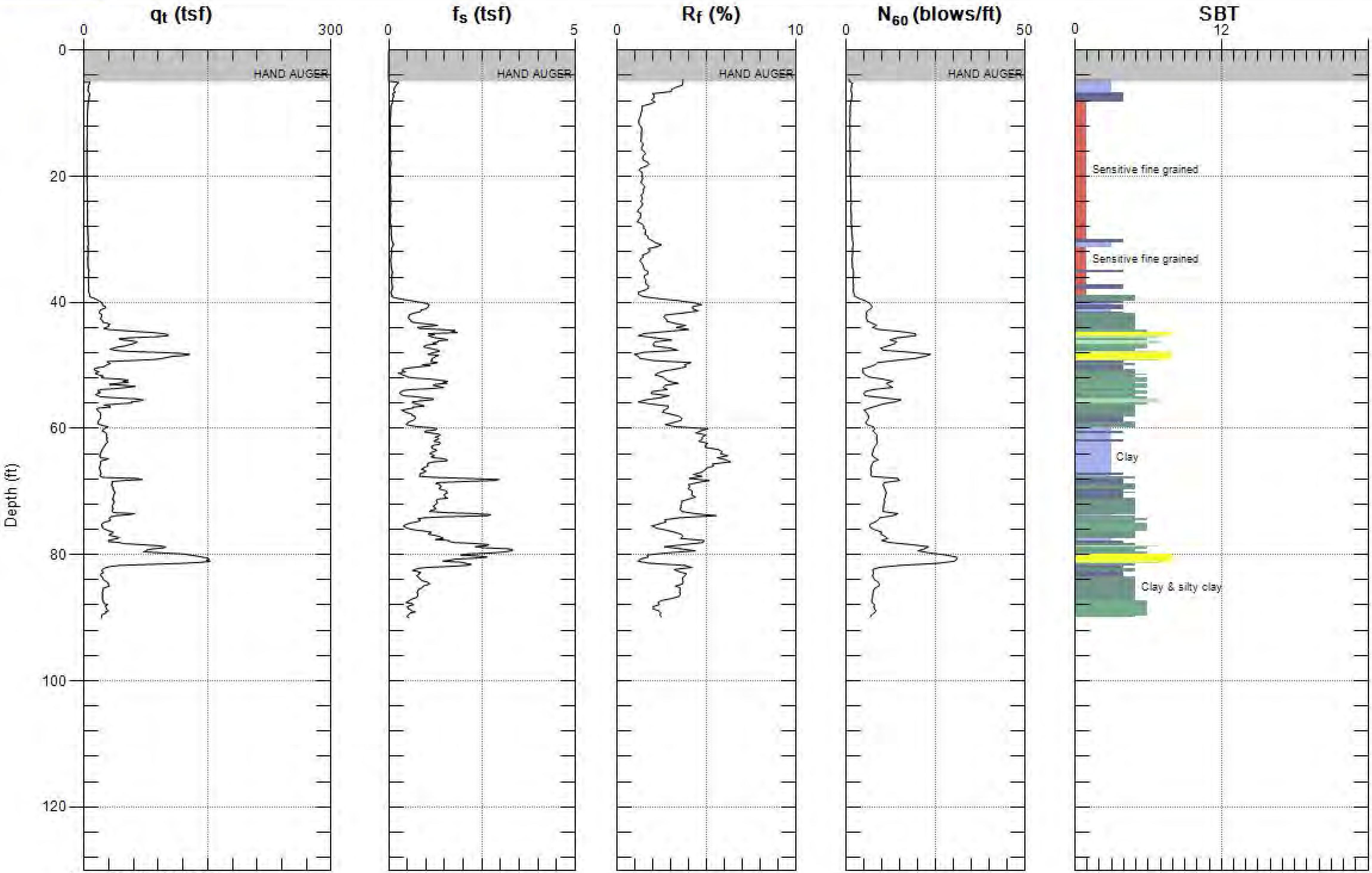
Max. Depth: 120.079 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.2 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-108
Engineer: D.AGNEW
Date: 8/11/2015 12:16



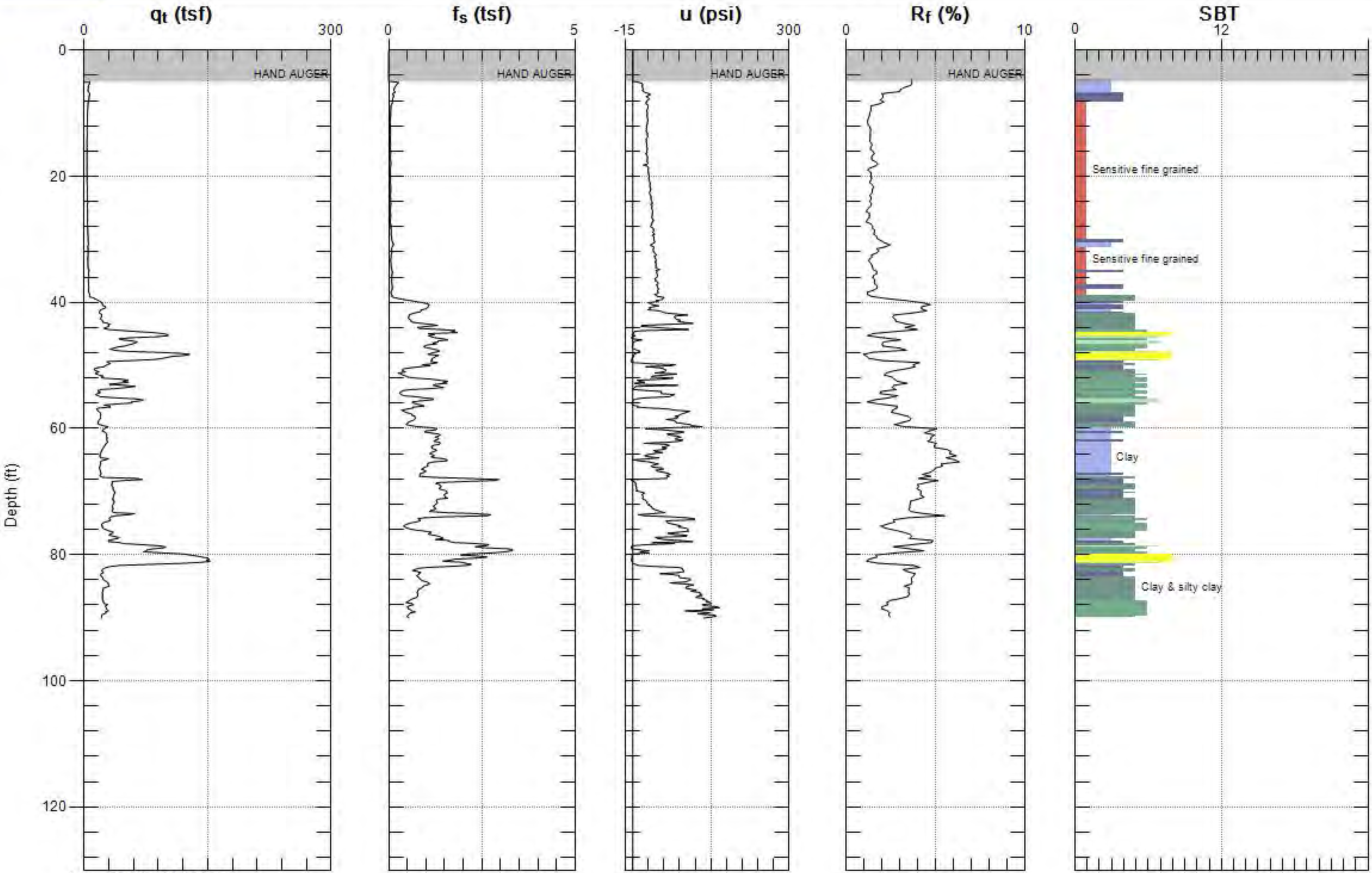
Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.2 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-108 **Date: 8/11/2015 12:16**



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.0 ft
Datum: NGVD29 +100 ft

GREGG

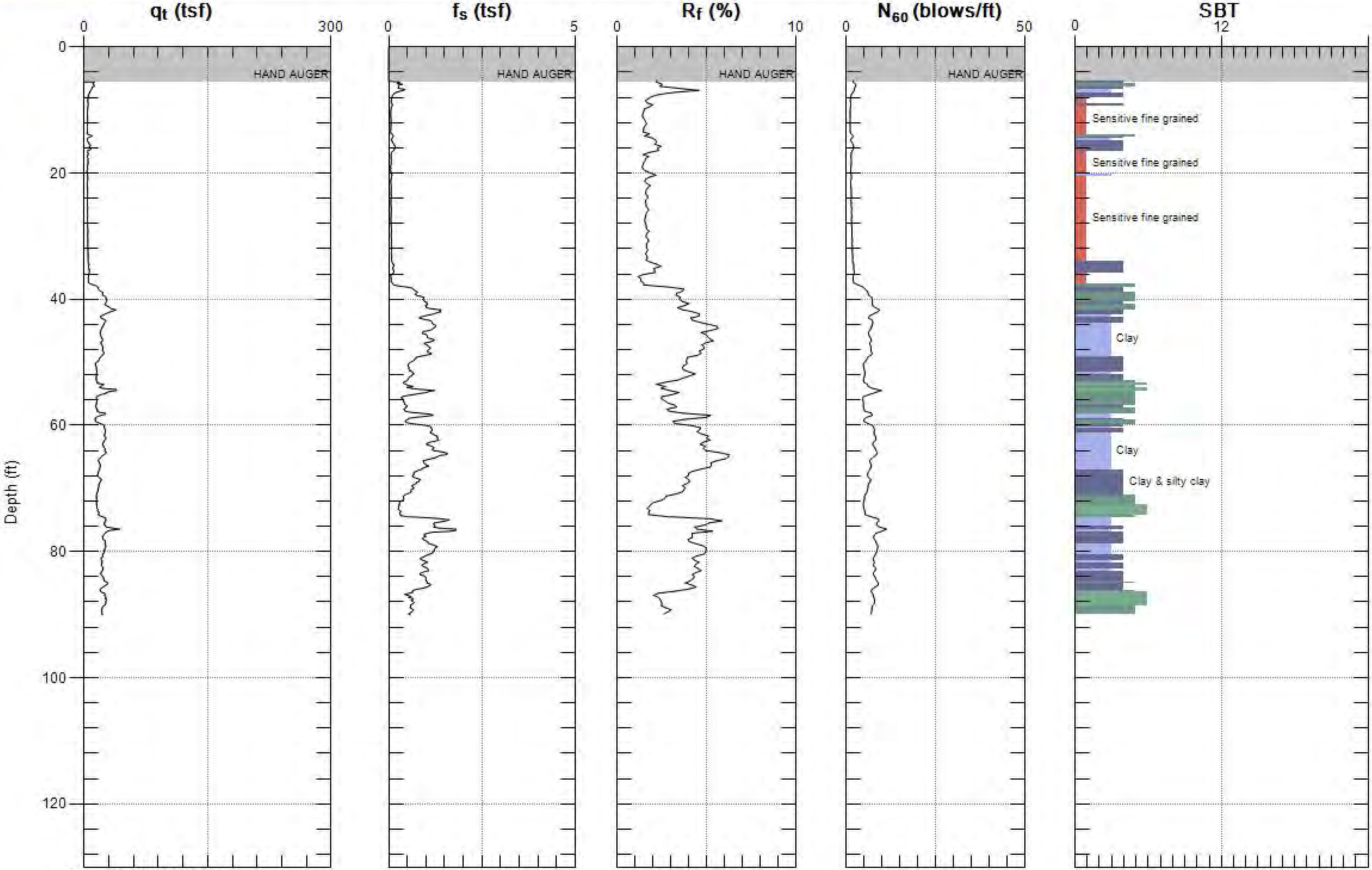
GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE

Sounding: C-109

Engineer: D.AGNEW

Date: 8/11/2015 02:59



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

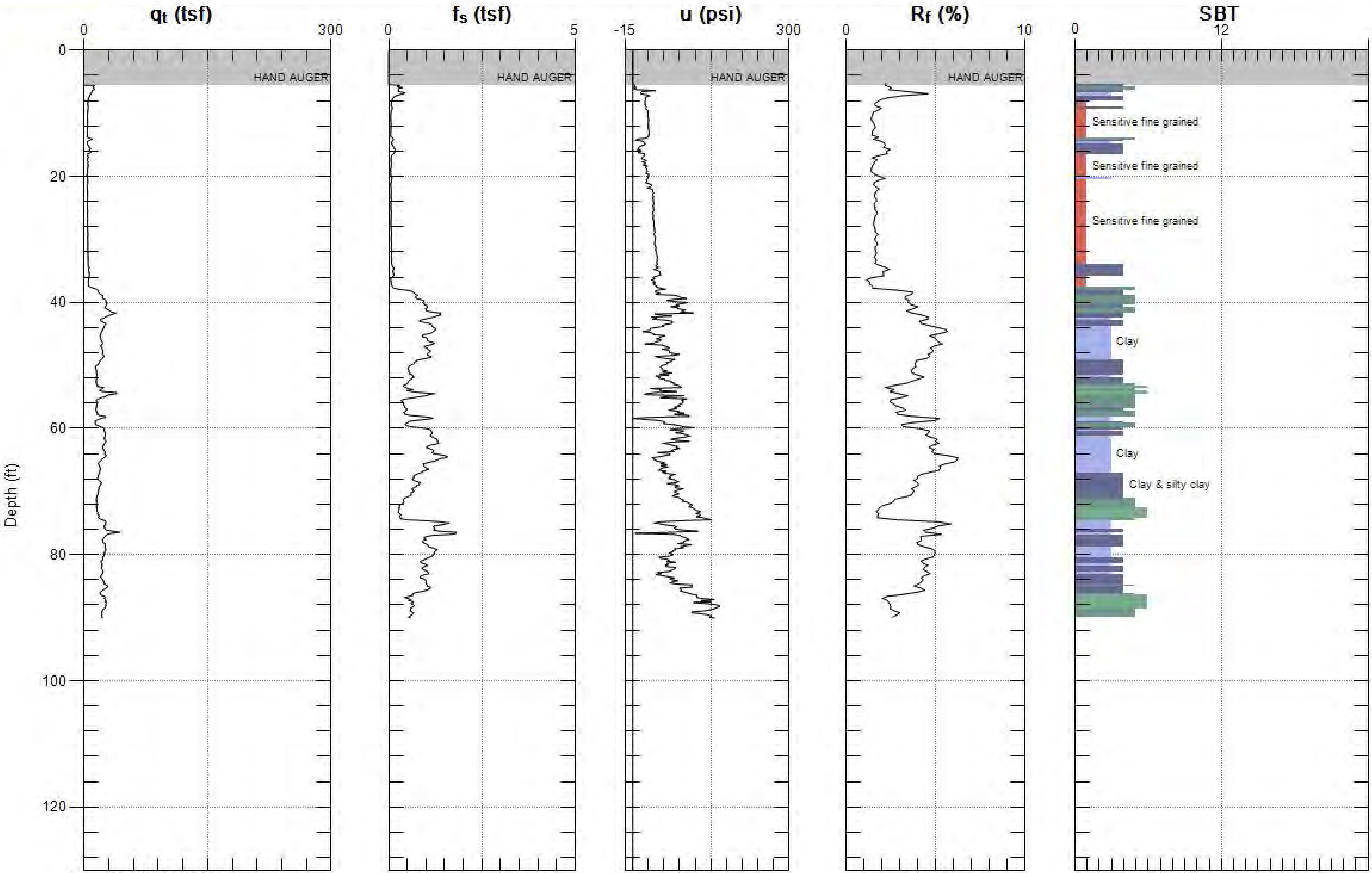
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.0 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-109

Engineer: D.AGNEW
Date: 8/11/2015 02:59



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

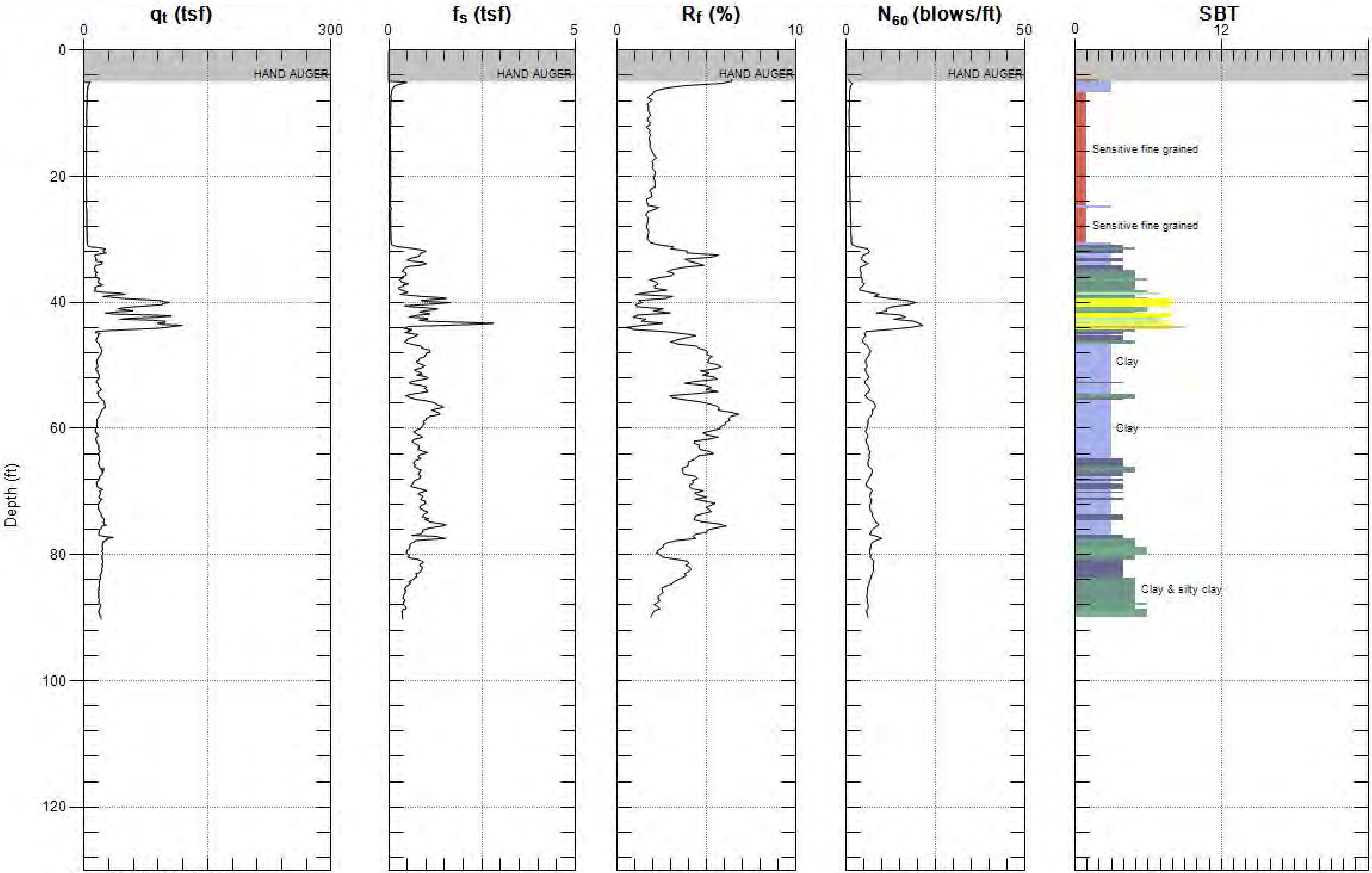
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.4 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-110

Engineer: D.AGNEW
Date: 8/7/2015 02:15



Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

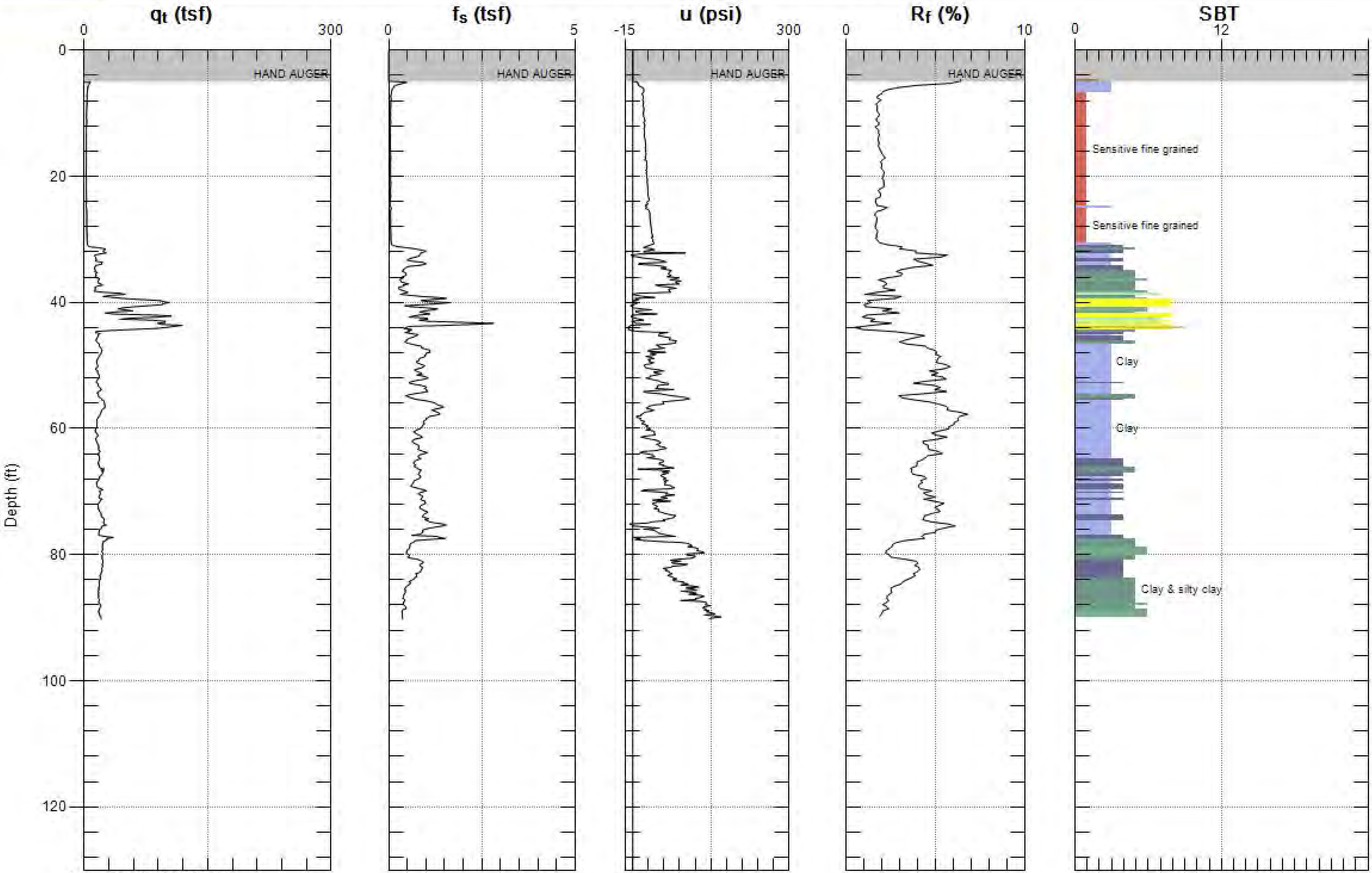
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.4 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-110 **Date: 8/7/2015 02:15**



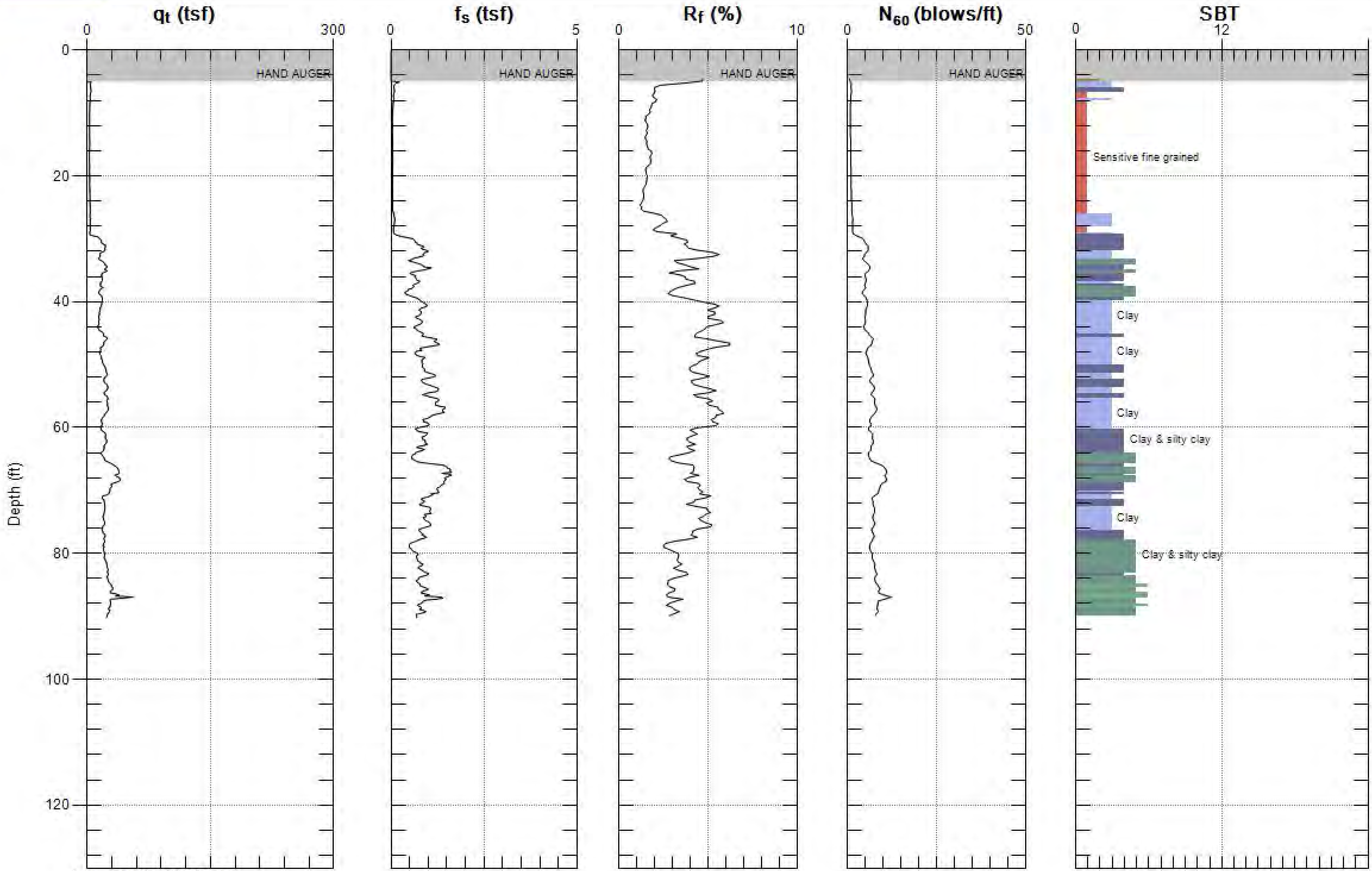
Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.1 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Engineer: D.AGNEW
Sounding: C-111
Date: 8/7/2015 11:12



Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

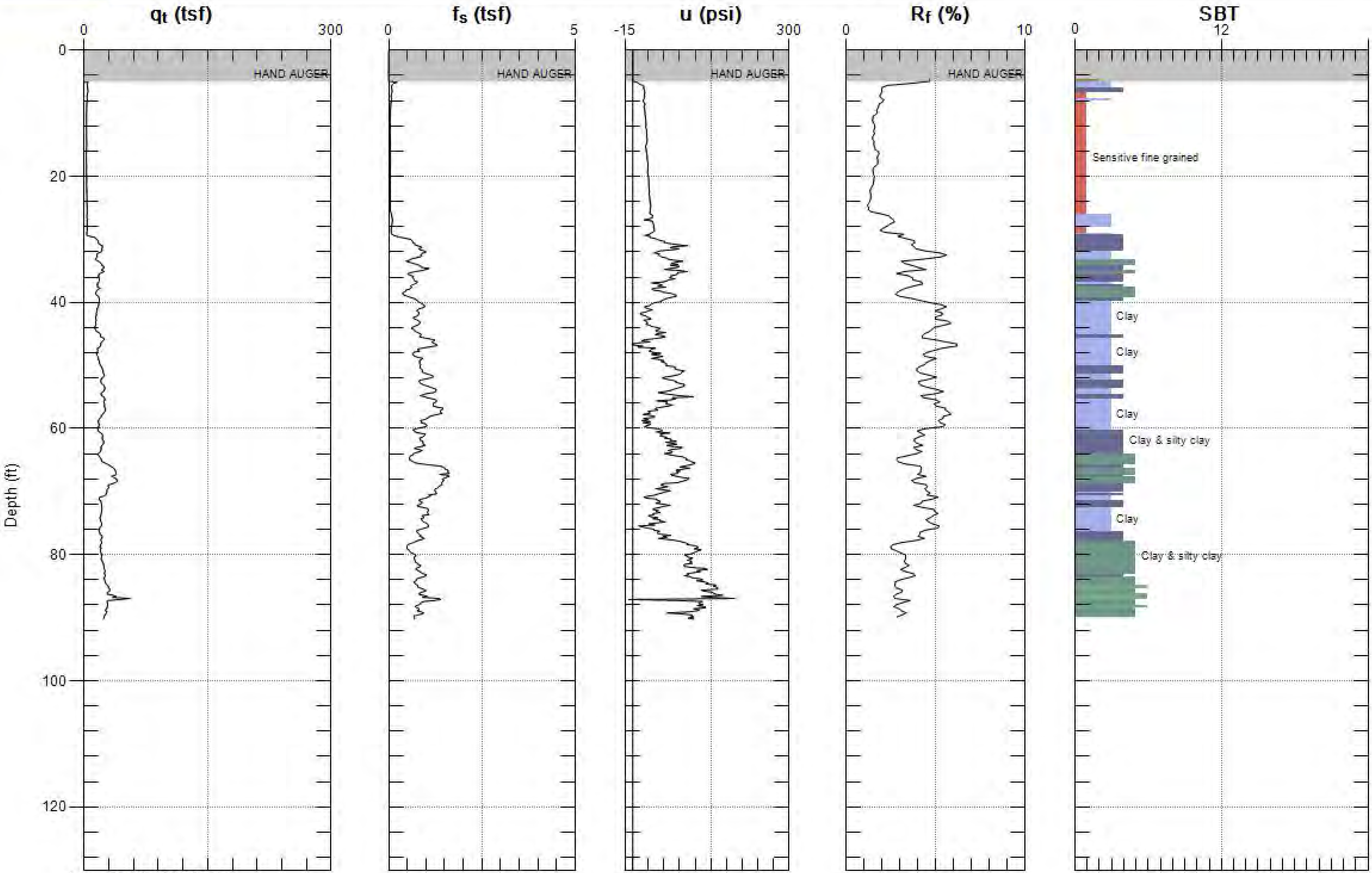
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.1 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-111 **Date: 8/7/2015 11:12**



Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

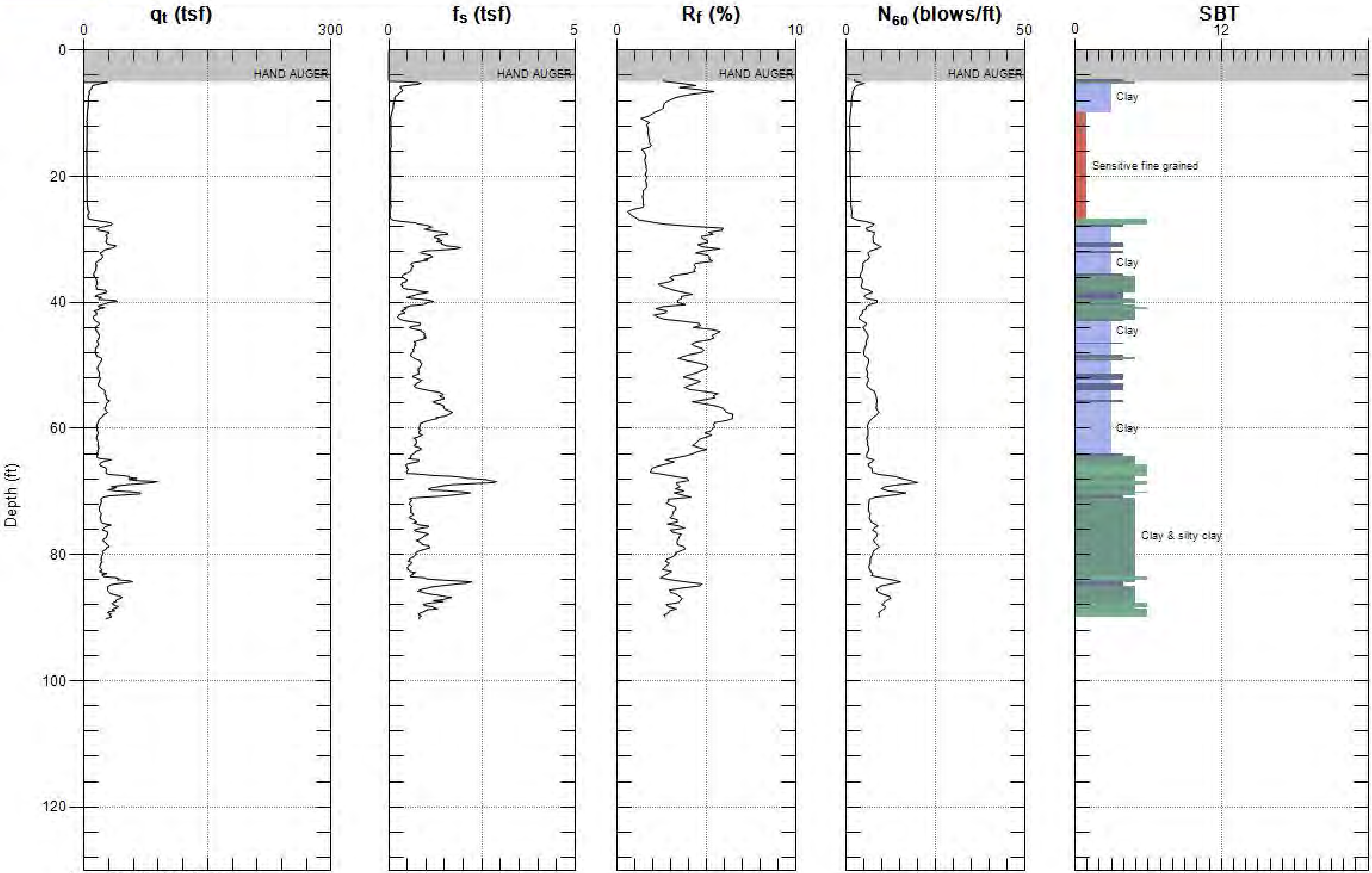
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.6 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-112 **Date: 8/7/2015 08:54**



Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

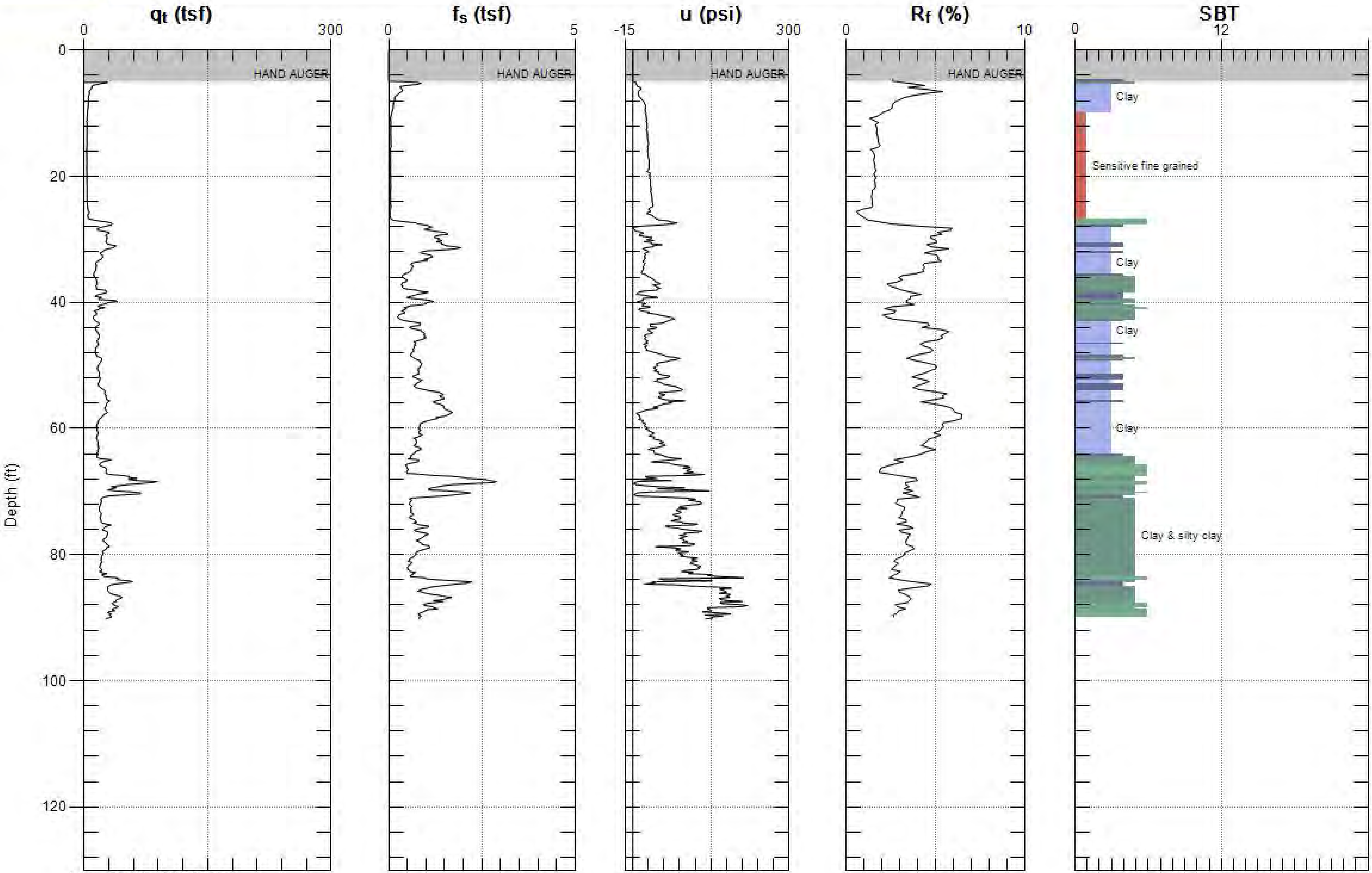
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.6 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-112

Engineer: D.AGNEW
Date: 8/7/2015 08:54



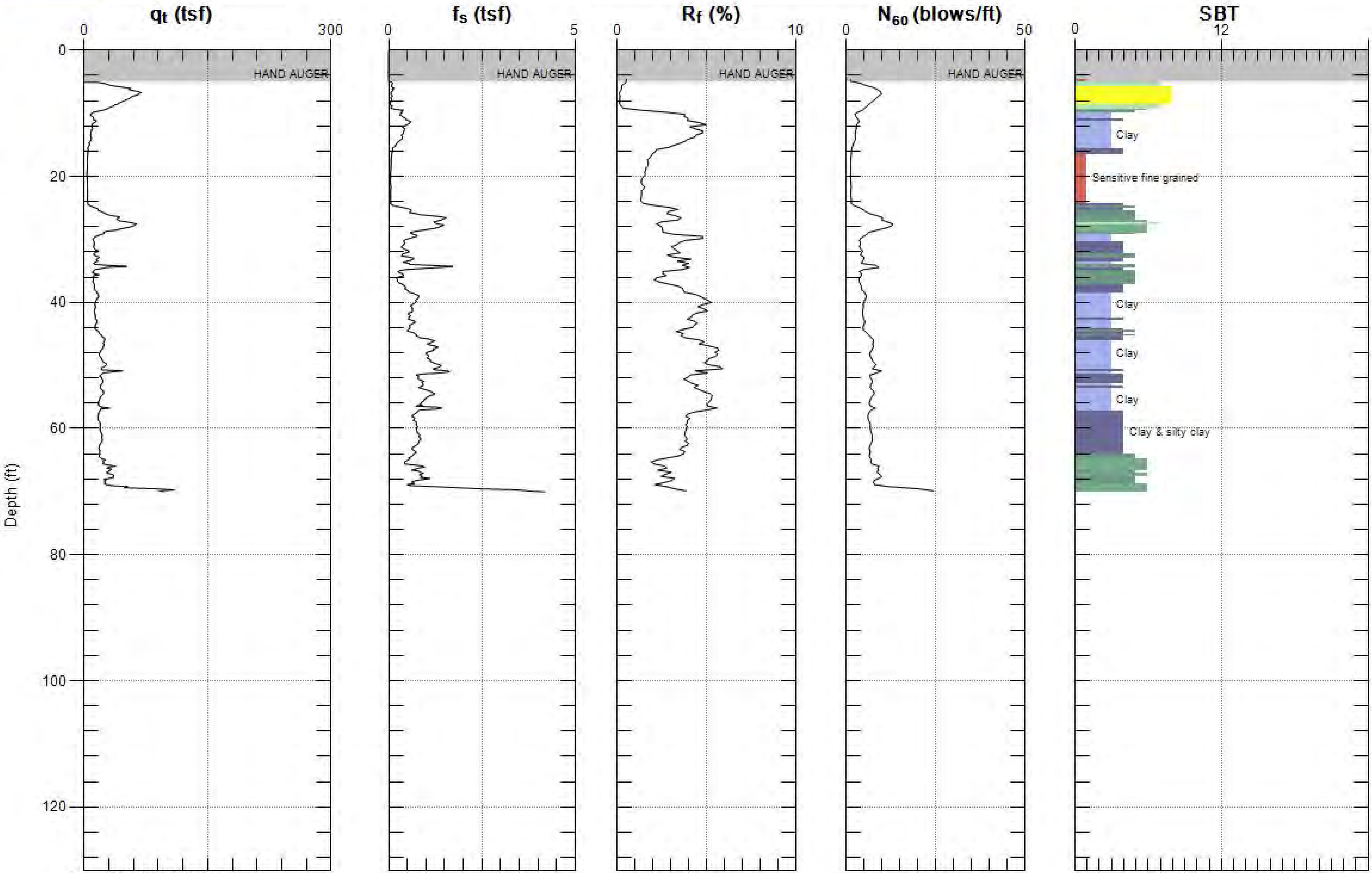
Max. Depth: 90.223 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.5 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-113 **Date: 8/6/2015 01:19**



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

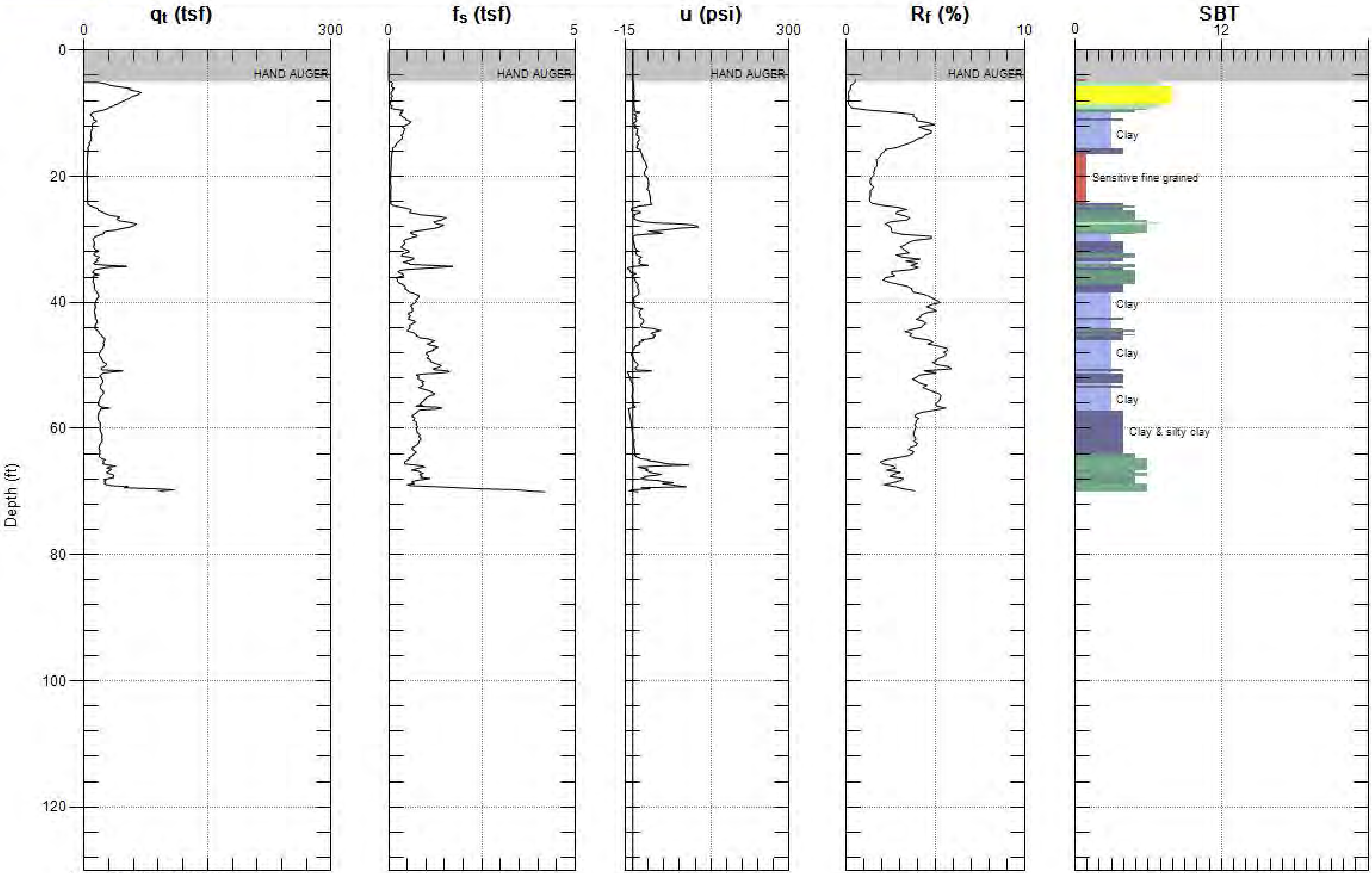
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.5 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE | **Engineer: D.AGNEW**

Sounding: C-113 | **Date: 8/6/2015 01:19**



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

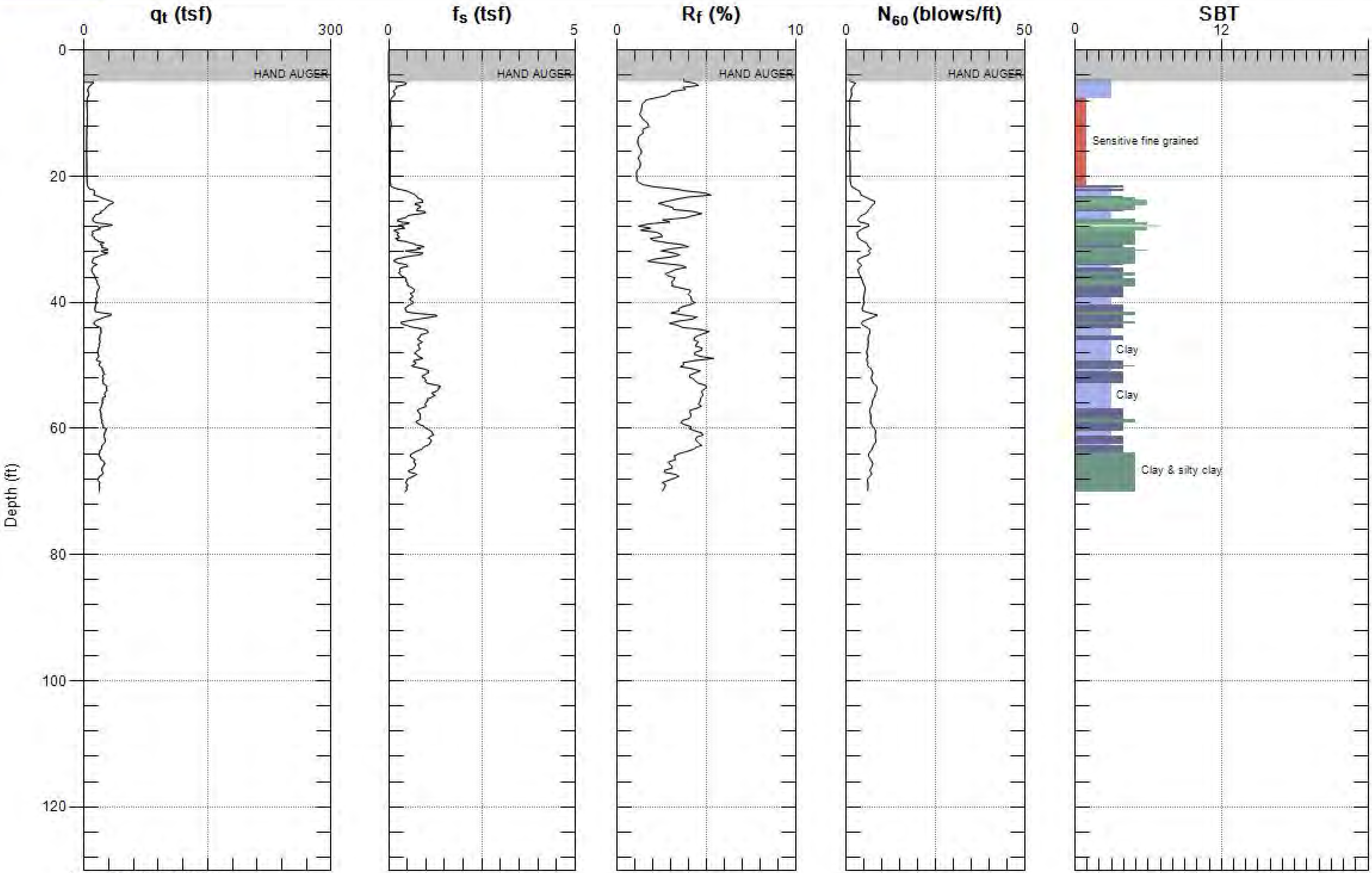
Elevation: 102.7 ft
Datum: NGVD29 +100 ft

GREGG

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-114

Engineer: D.AGNEW
Date: 8/6/2015 11:13



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

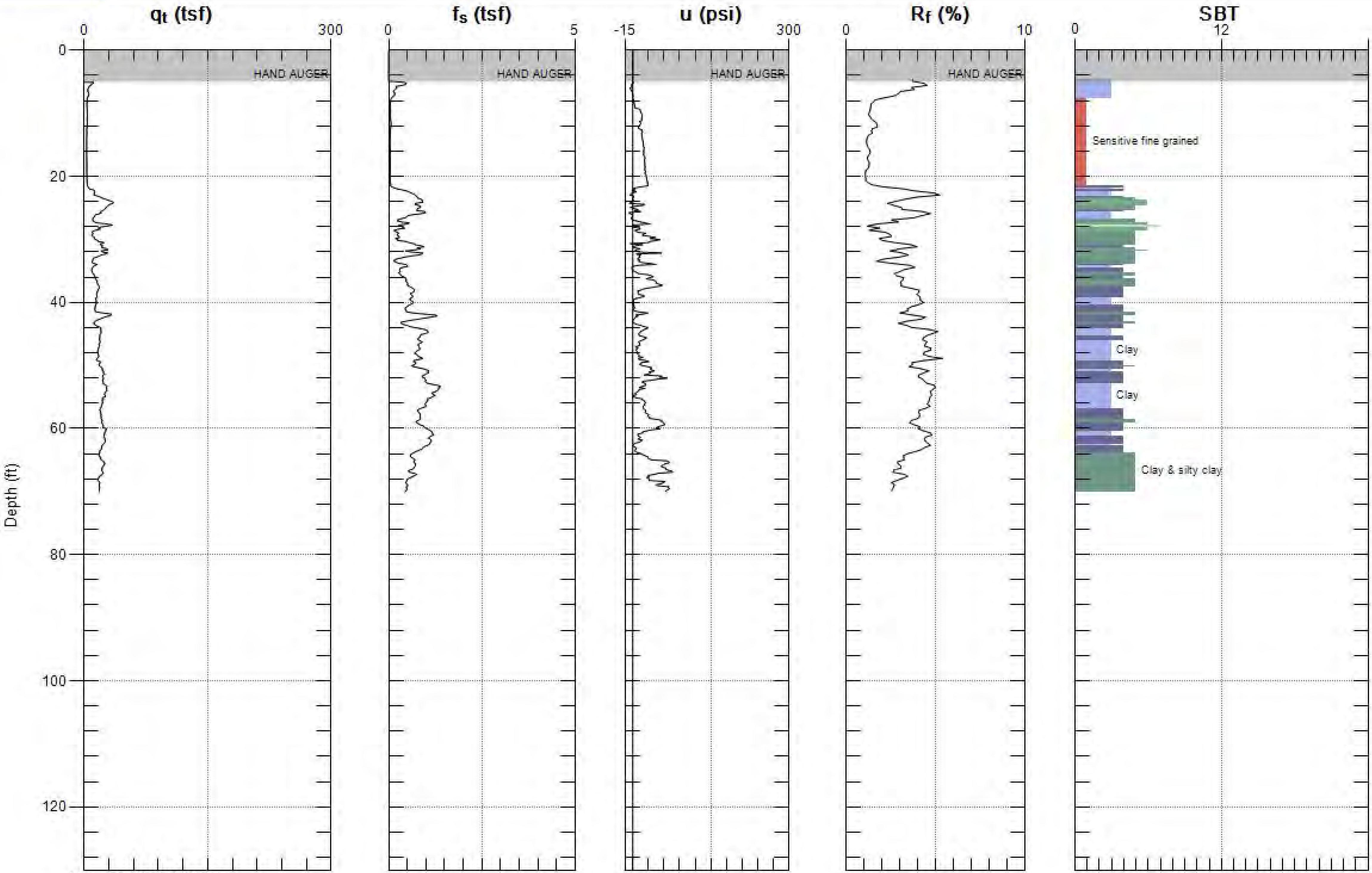
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.7 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-114 **Date: 8/6/2015 11:13**



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

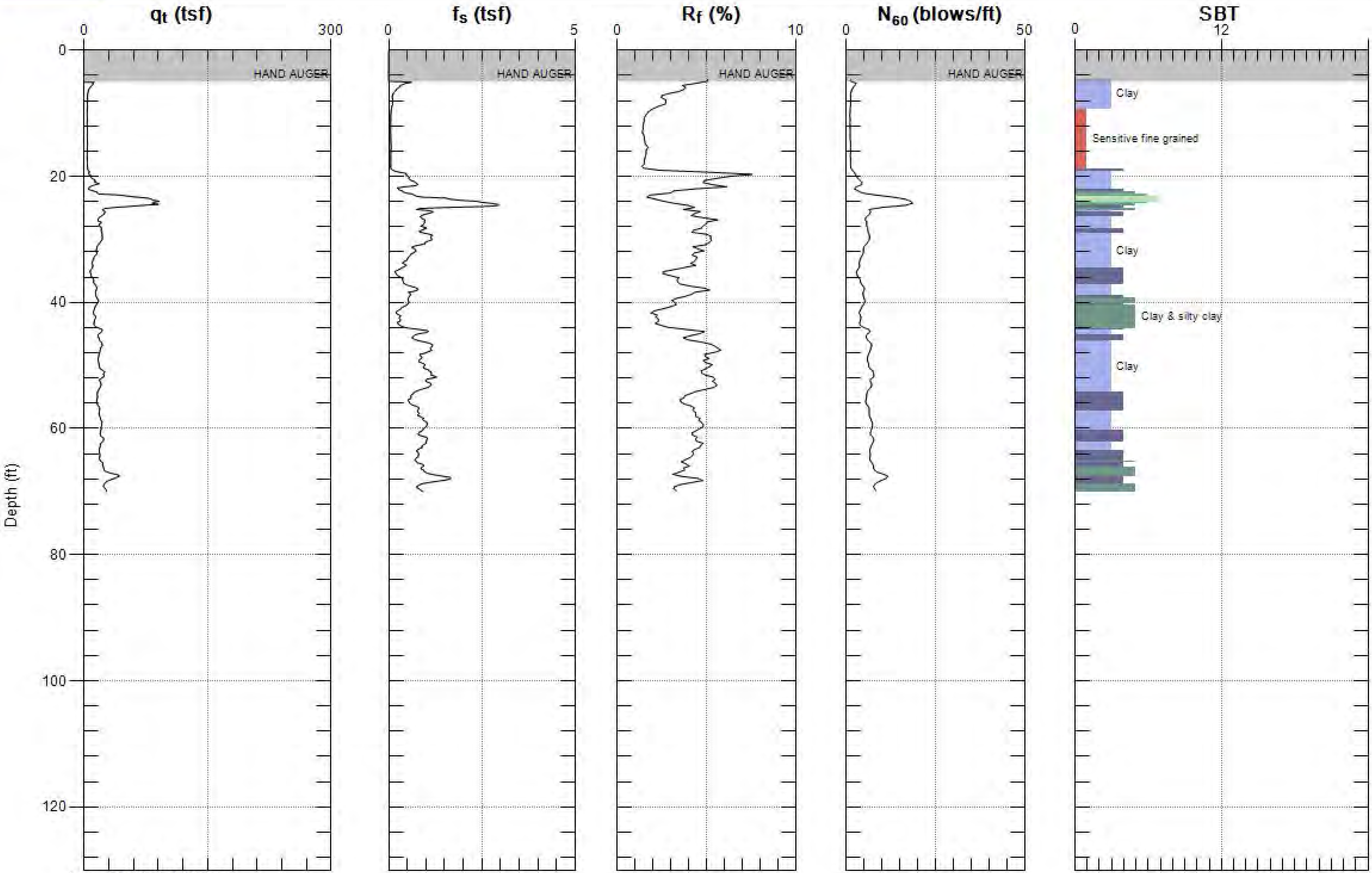
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.4 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-115

Engineer: D.AGNEW
Date: 8/6/2015 09:24



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.4 ft
Datum: NGVD29 +100 ft

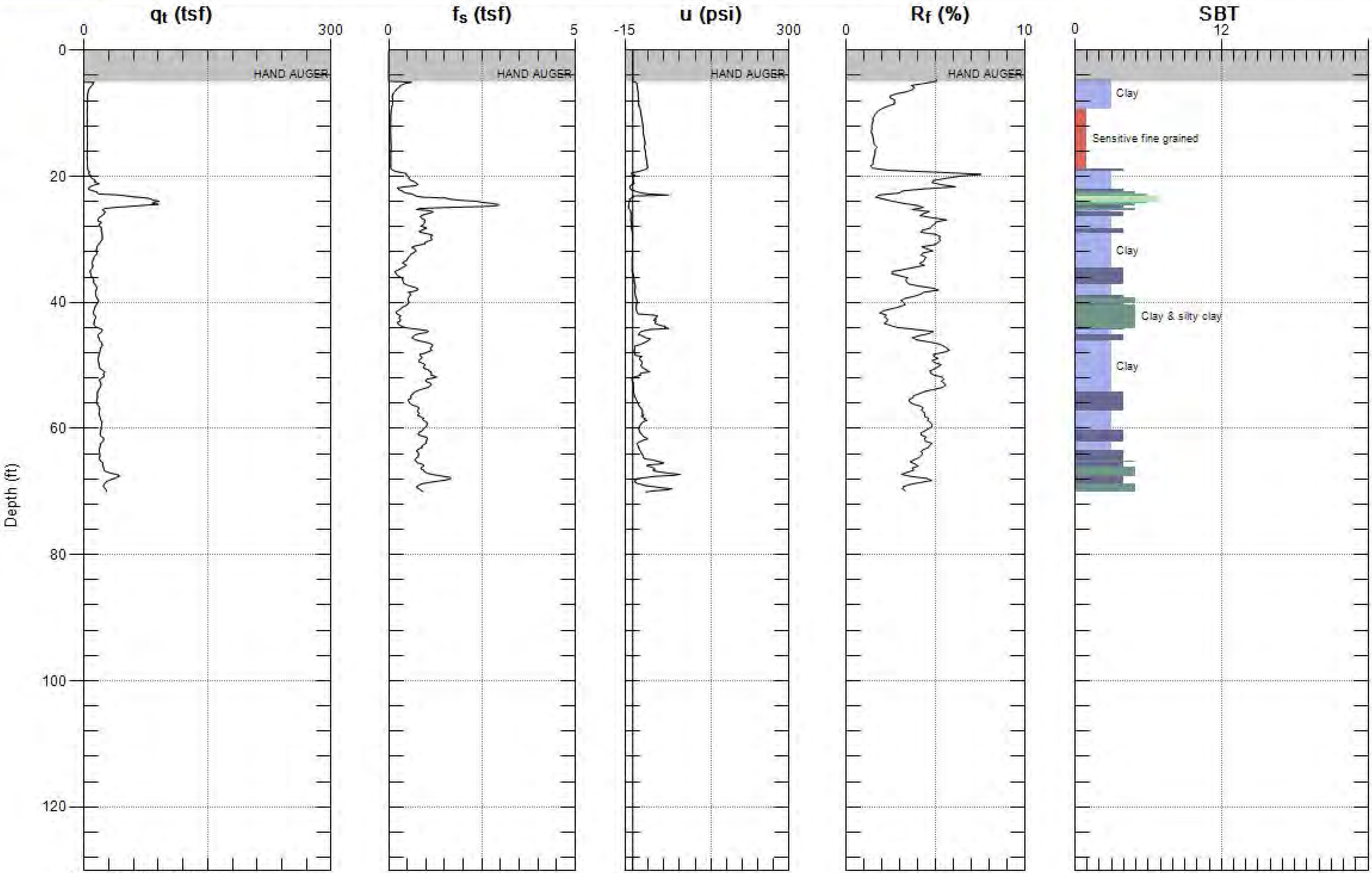
GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE

Sounding: C-115

Engineer: D.AGNEW

Date: 8/6/2015 09:24



Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

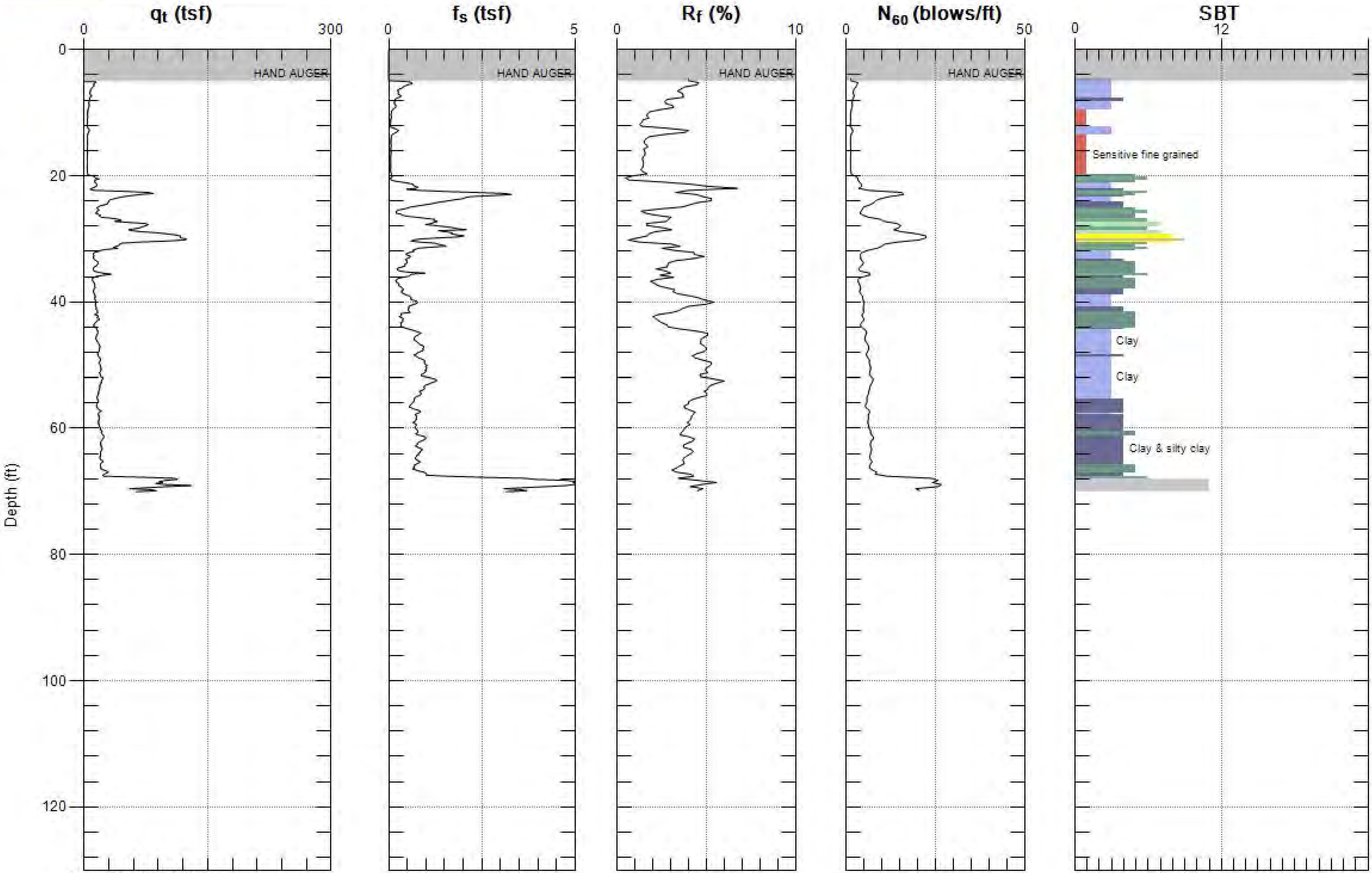
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 104.4 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-116

Engineer: D.AGNEW
Date: 8/6/2015 03:07



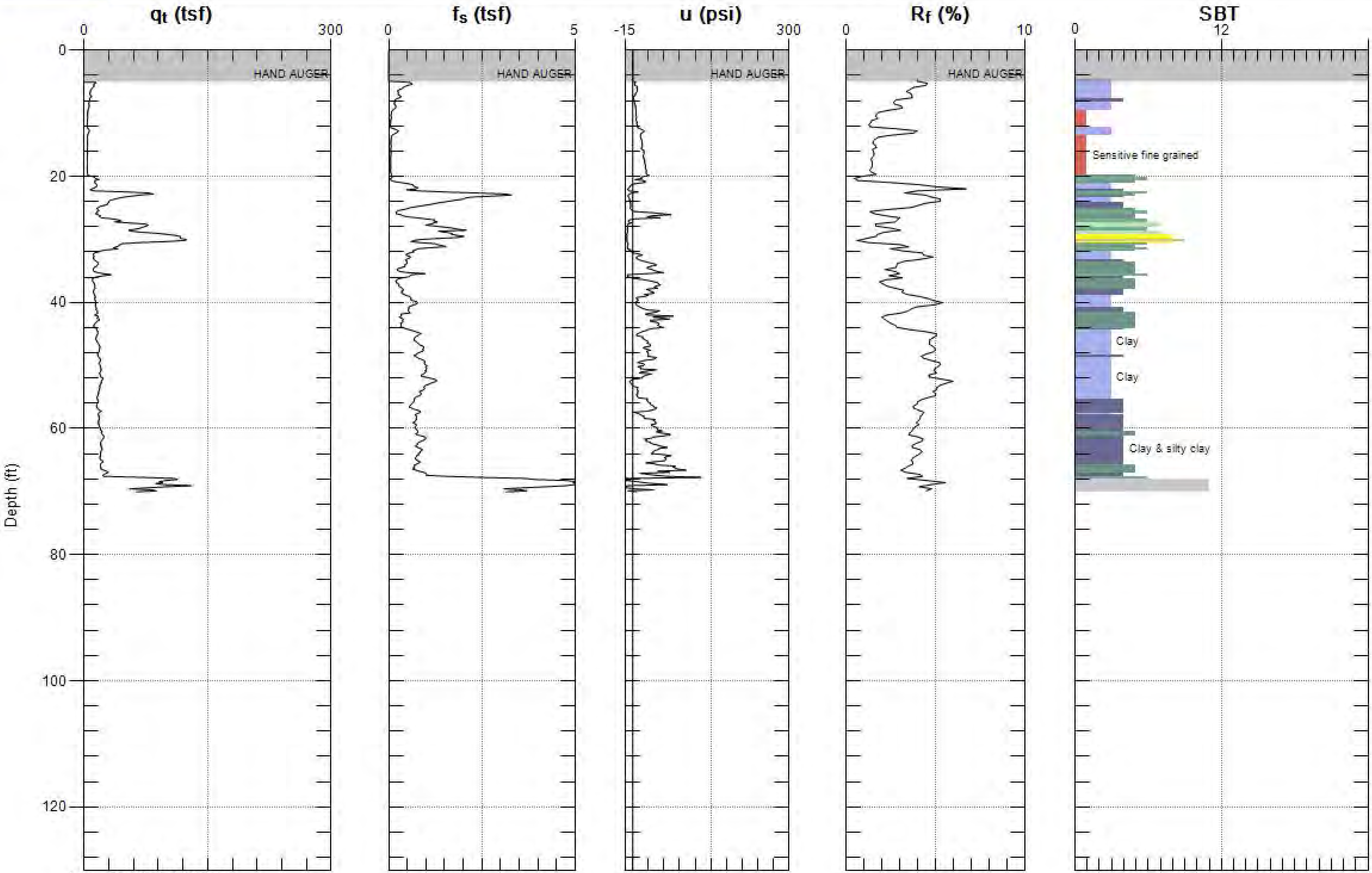
Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 104.4 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-116 **Date: 8/6/2015 03:07**



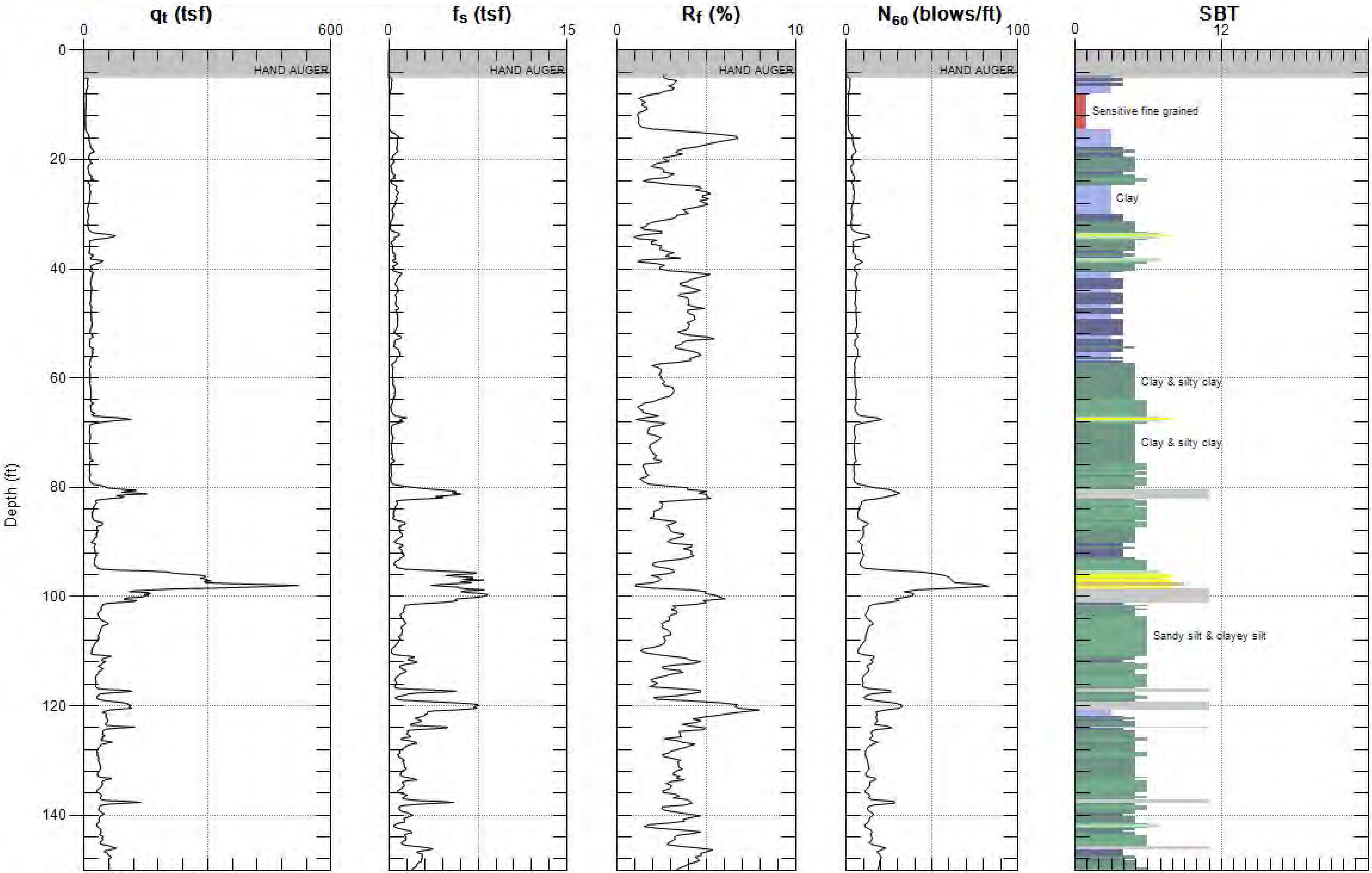
Max. Depth: 70.046 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.4 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-117 **Date: 9/2/2015 10:48**



Max. Depth: 150.262 (ft)
Avg. Interval: 0.328 (ft)

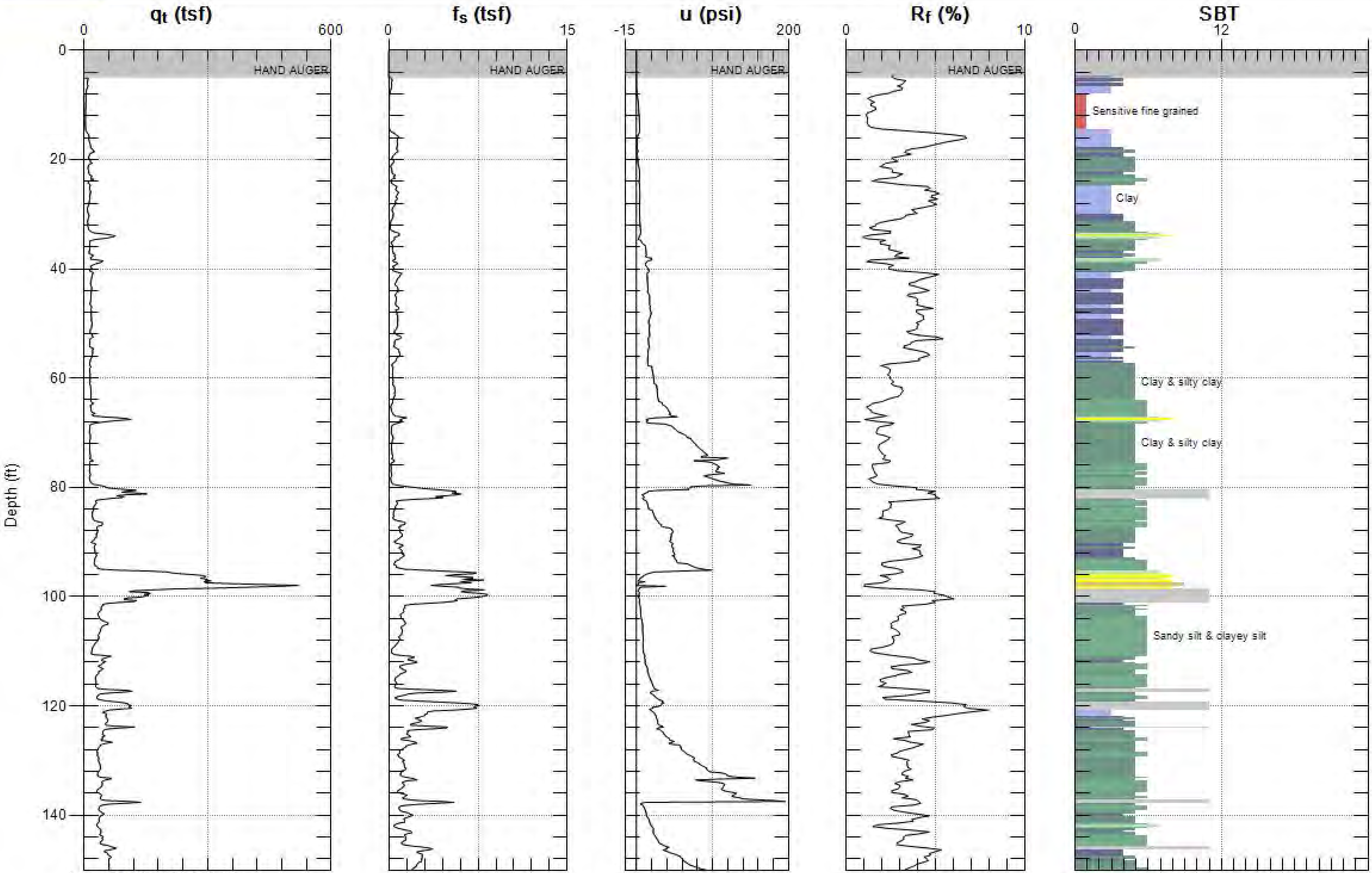
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 102.4 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE | **Engineer: D.AGNEW**

Sounding: C-117 | **Date: 9/2/2015 10:48**



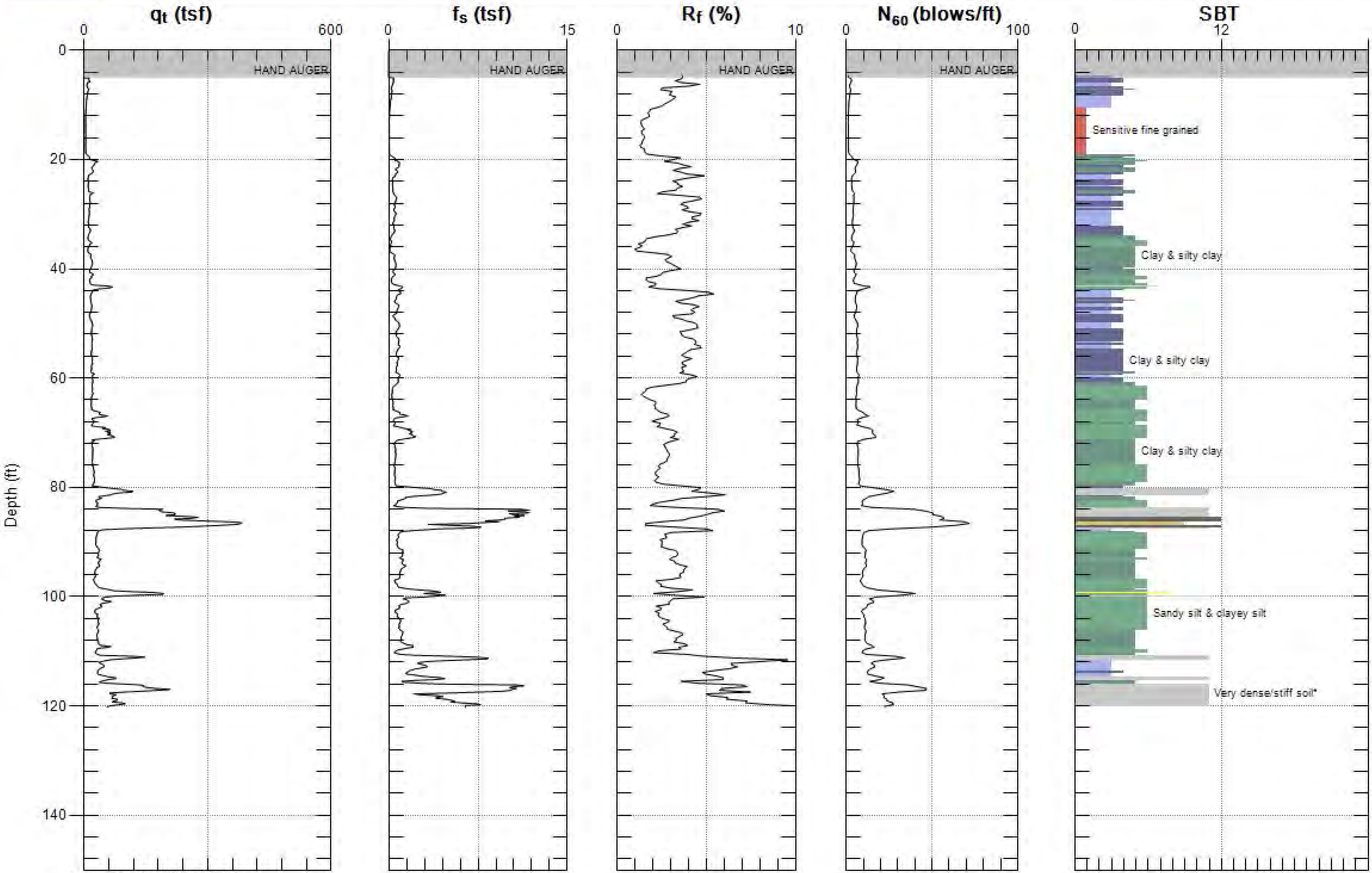
Max. Depth: 150.262 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.5 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**
Sounding: C-118 **Date: 9/2/2015 08:13**



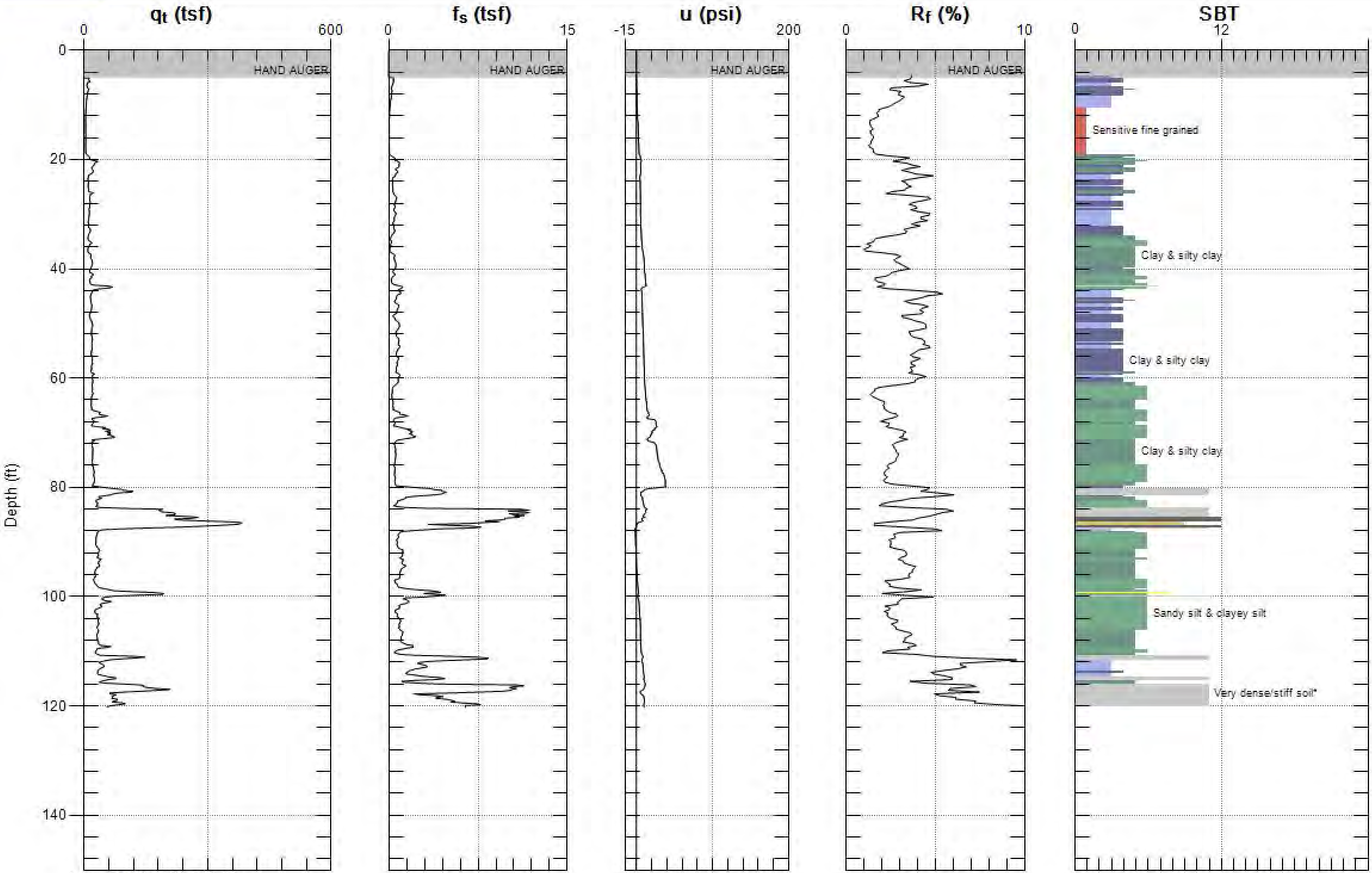
Max. Depth: 120.243 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 103.5 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-118
Engineer: D.AGNEW
Date: 9/2/2015 08:13



Max. Depth: 120.243 (ft)
Avg. Interval: 0.328 (ft)

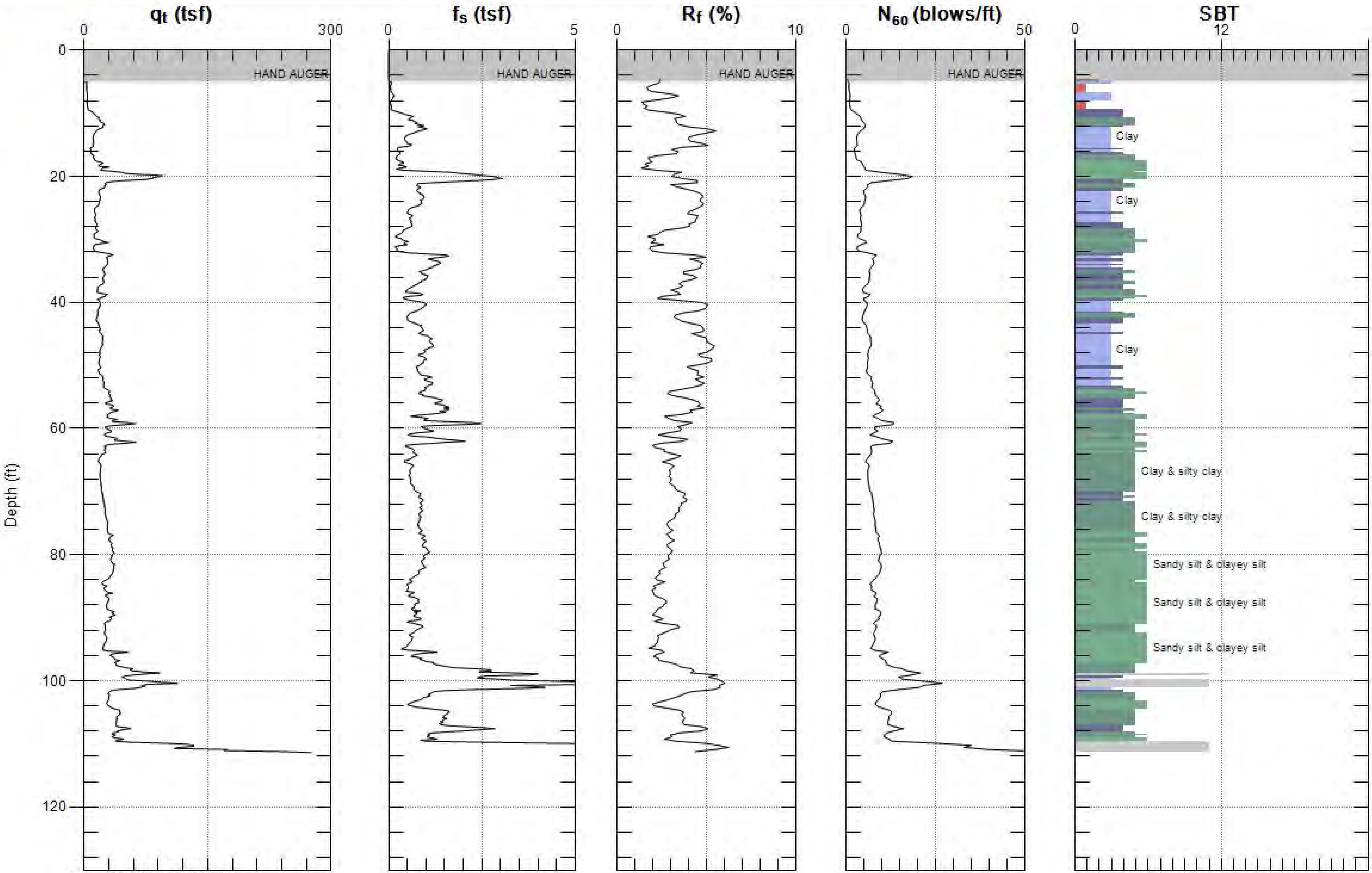
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.7 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-119

Engineer: D.AGNEW
Date: 8/12/2015 08:19



Max. Depth: 111.385 (ft)
Avg. Interval: 0.328 (ft)

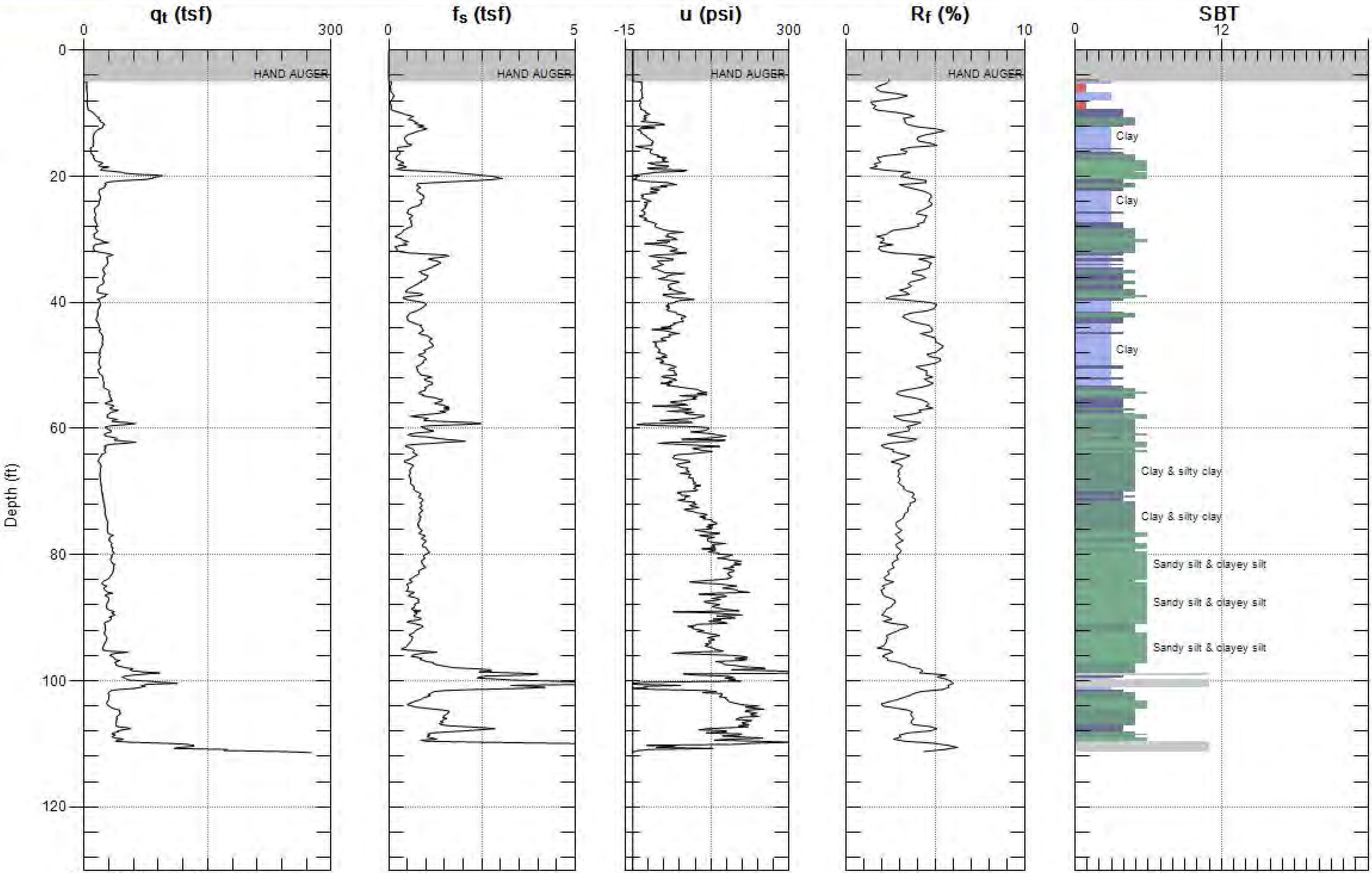
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.7 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-119 **Date: 8/12/2015 08:19**



Max. Depth: 111.385 (ft)
Avg. Interval: 0.328 (ft)

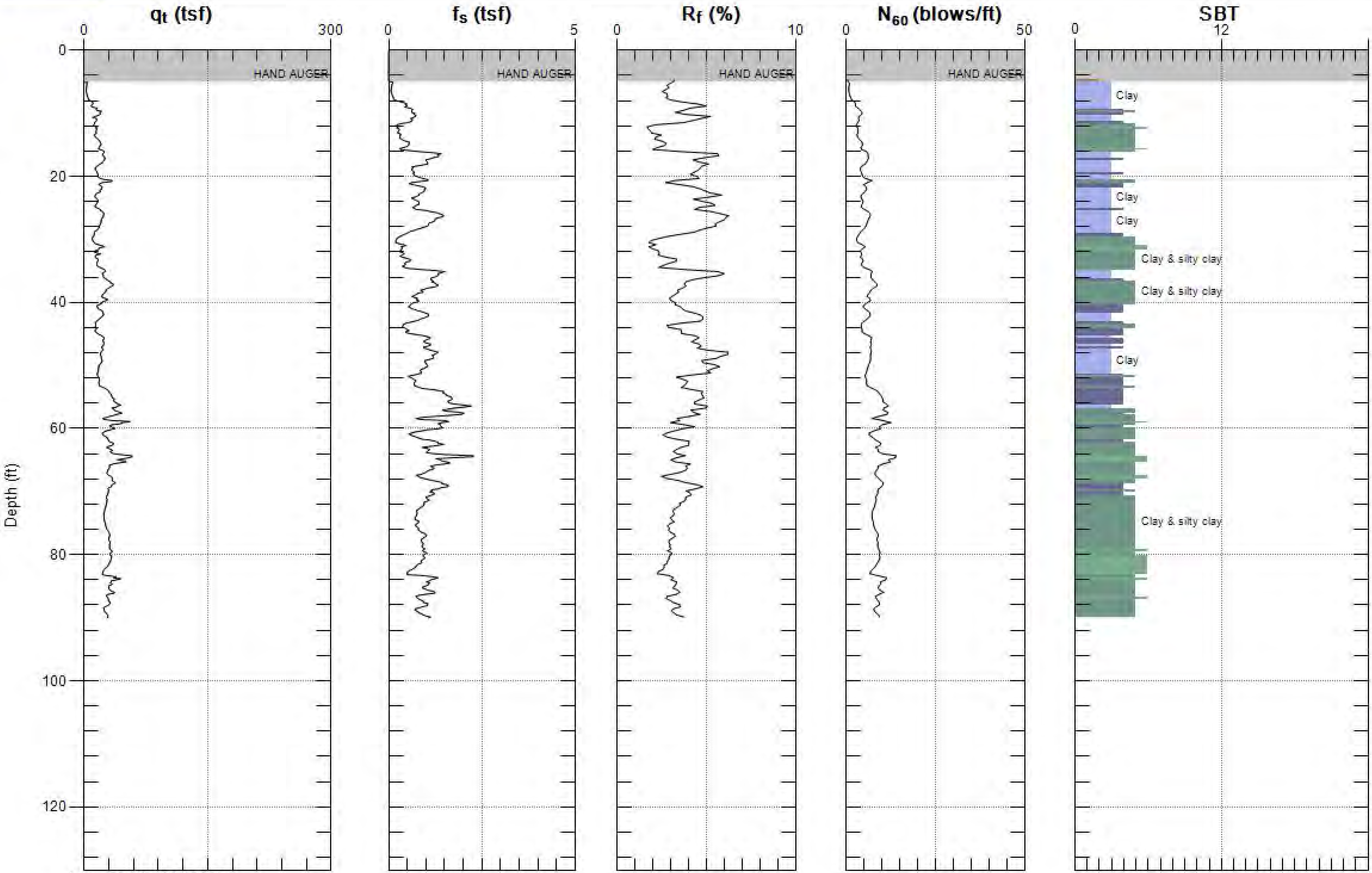
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 101.7 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-120

Engineer: D.AGNEW
Date: 8/12/2015 01:42



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 101.7 ft
Datum: NGVD29 +100 ft

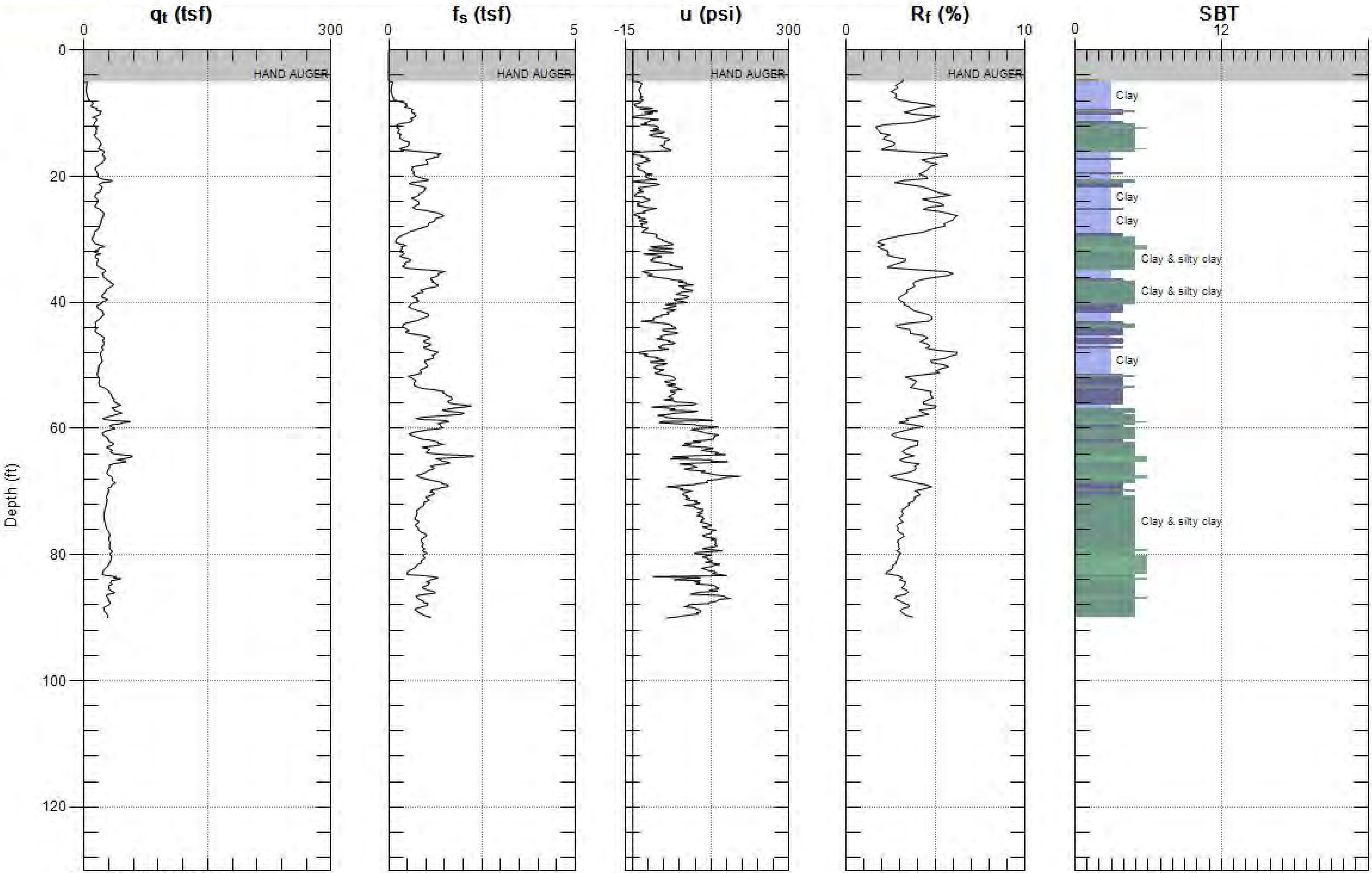
GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE

Sounding: C-120

Engineer: D.AGNEW

Date: 8/12/2015 01:42



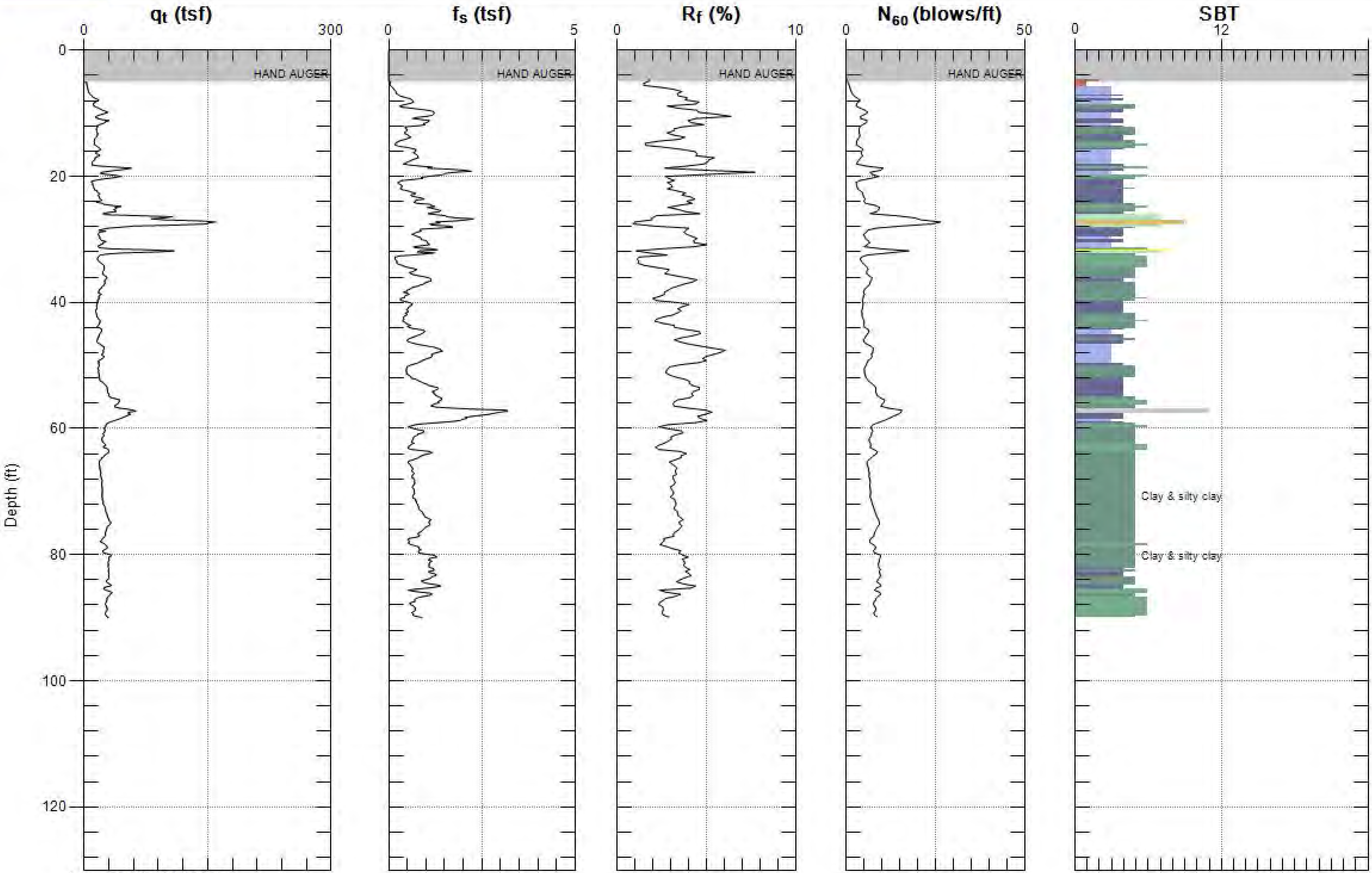
Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.6 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE | **Engineer: D.AGNEW**
Sounding: C-121 | **Date: 8/12/2015 12:21**



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

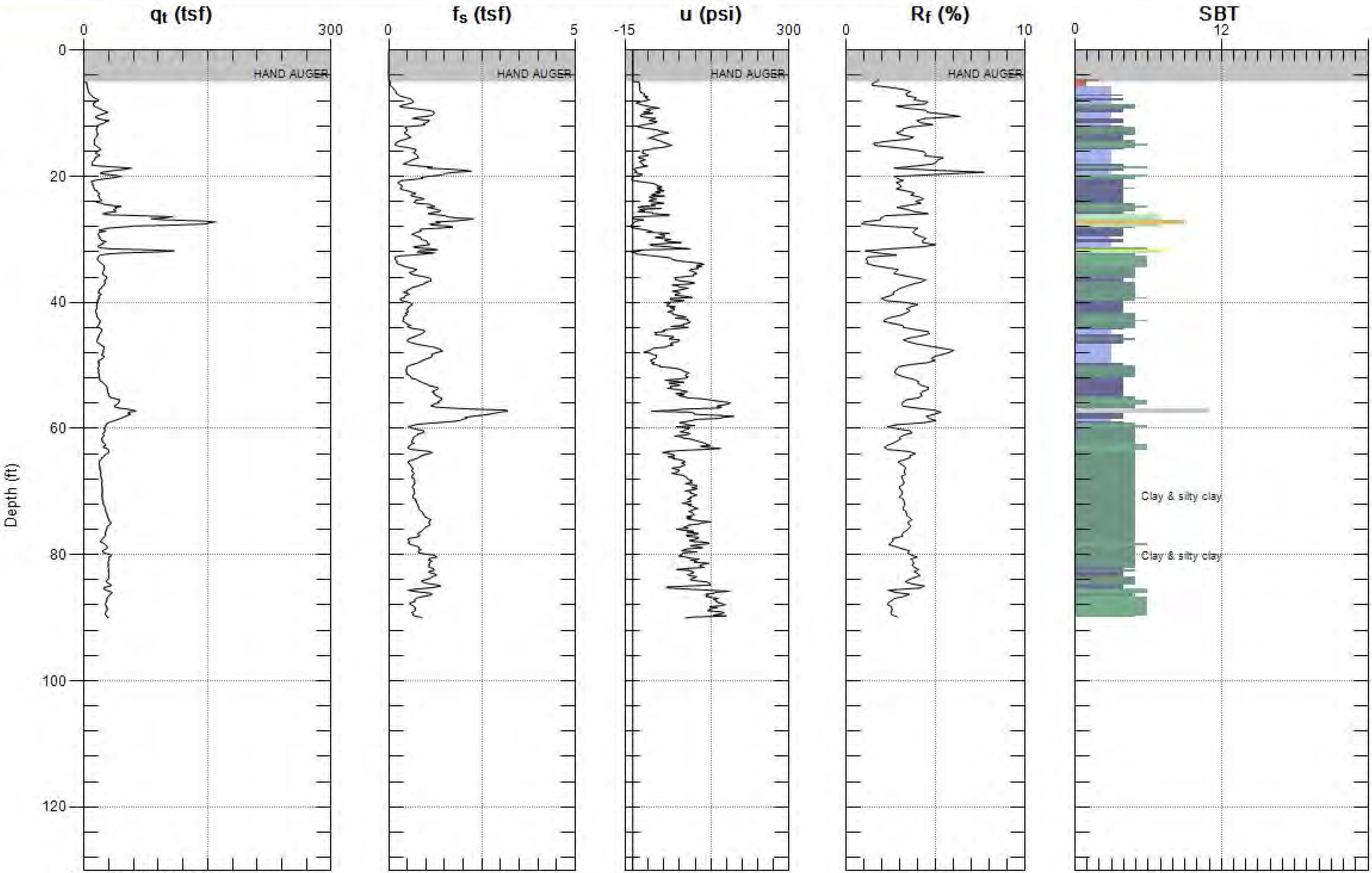
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.6 ft
Datum: NGVD29 +100 ft

GREGG **GEOTECHNICAL CONSULTANTS**

Site: SVCW CONVEYANCE **Engineer: D.AGNEW**

Sounding: C-121 **Date: 8/12/2015 12:21**



Max. Depth: 90.059 (ft)
Avg. Interval: 0.328 (ft)

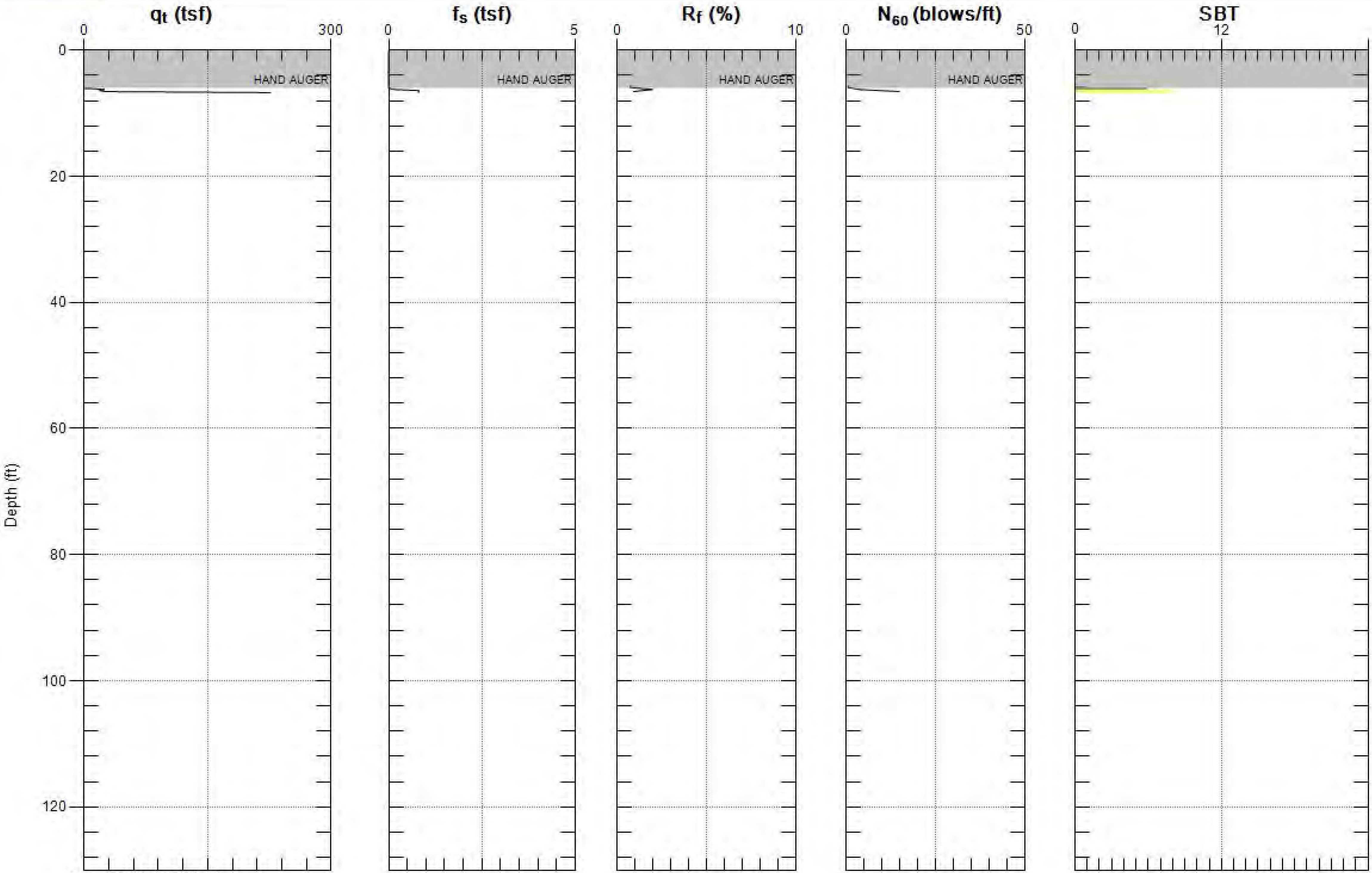
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.7 ft
Datum: NGVD29 +100 ft

GREGG GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-122

Engineer: D.AGNEW
Date: 8/12/2015 11:01



Max. Depth: 6.726 (ft)
Avg. Interval: 0.328 (ft)

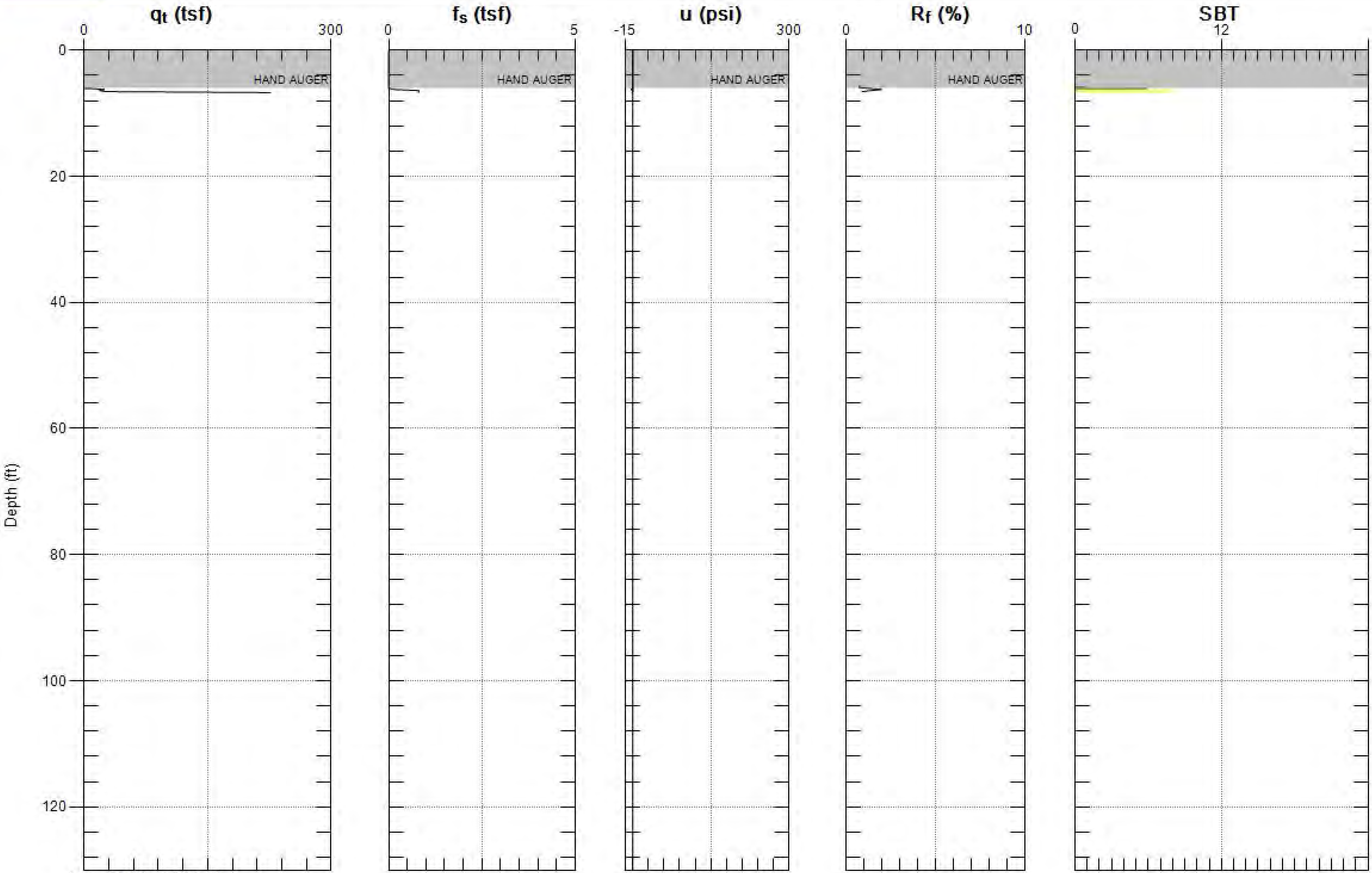
SBT: Soil Behavior Type (Robertson 1990)

Elevation: 100.7 ft
Datum: NGVD29 +100 ft

GEOTECHNICAL CONSULTANTS

Site: SVCW CONVEYANCE
Sounding: C-122

Engineer: D.AGNEW
Date: 8/12/2015 11:01



Max. Depth: 6.726 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

LABORATORY TEST RESULTS

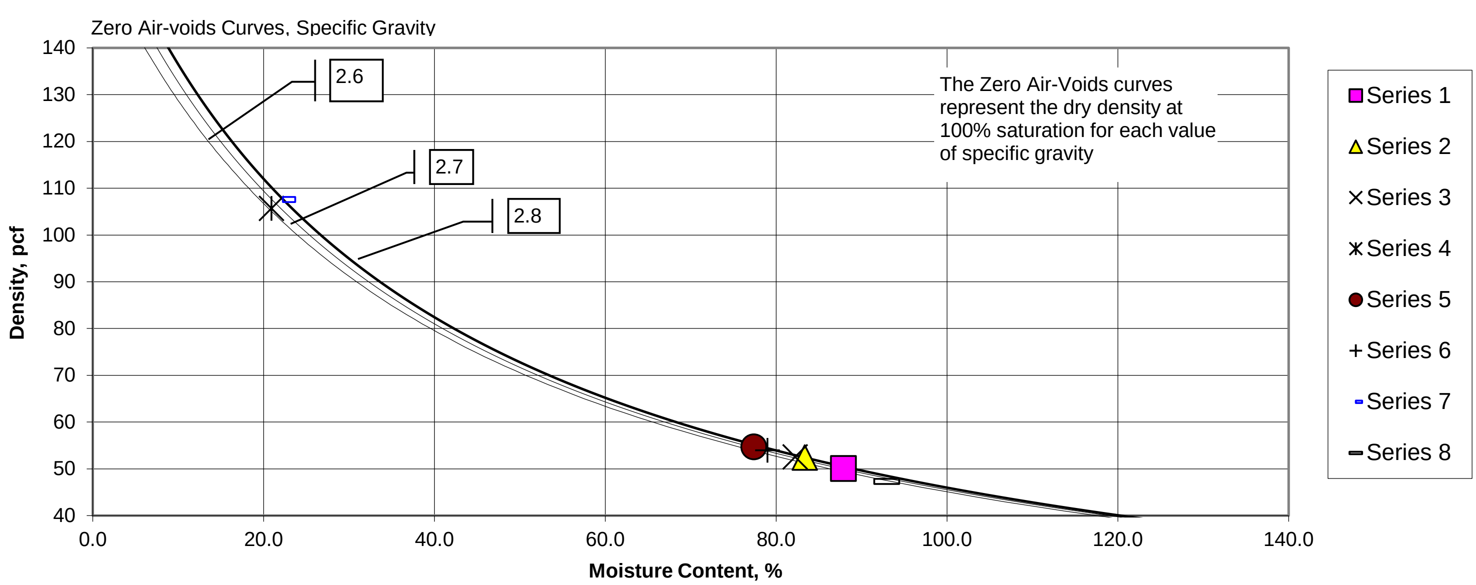
Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: 208-036a **Project No.** SF14014A **By:** RU
Client: GTC **Date:** 08/31/15
Project Name: SVCW Tunnel **Remarks:**

Boring:	B-102	B-102	B-102	B-102	B-103	B103	B-103	B-105
Sample:								
Depth, ft:	9-9.5	21-21.5	31-31.5	61-61.5	21-21.5	31-31.5	66-66.5	16-16.5
Visual Description:	Dark Bluish Gray Fat CLAY	Dark Bluish Gray CLAY	Dark Bluish Gray Fat CLAY	Olive Brown Clayey SAND	Dark Gray Fat CLAY w/ Sand pockets	Dark Gray Fat CLAY w/ shells	Dark Greenish Gray Clayey GRAVEL w/ Sand	Dark Gray Elastic SILT
Actual G_s								
Assumed G_s	2.80	2.80	2.80	2.70	2.80	2.80	2.80	2.70
Moisture, %	87.9	83.4	82.2	20.9	77.4	79.0	22.3	93.0
Wet Unit wt, pcf	94.0	96.2	95.8	127.8	97.0	96.6	131.6	91.4
Dry Unit wt, pcf	50.0	52.4	52.6	105.7	54.7	54.0	107.6	47.4
Dry Bulk Dens.pb, (g/cc)	0.80	0.84	0.84	1.69	0.88	0.86	1.72	0.76
Saturation, %	98.6	99.9	98.9	94.7	98.6	98.7	99.6	98.0
Total Porosity, %	71.4	70.0	70.0	37.4	68.7	69.2	38.5	71.9
Volumetric Water Cont,Θw,%	70.4	70.0	69.2	35.4	67.8	68.2	38.3	70.5
Volumetric Air Cont., Θa,%	1.0	0.1	0.8	2.0	1.0	0.9	0.2	1.5
Void Ratio	2.50	2.34	2.33	0.60	2.20	2.24	0.63	2.56
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density

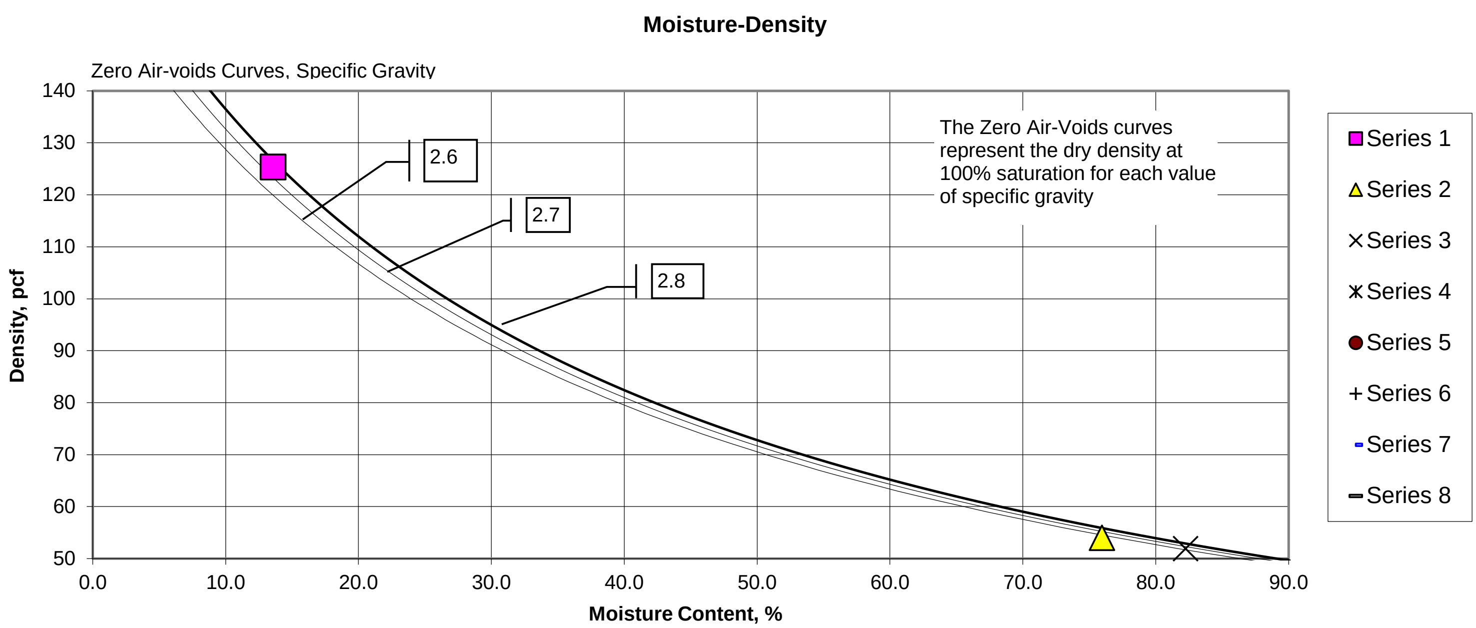


Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: 208-036b | **Project No.** SF14004A | **By:** RU
Client: GTC | **Date:** 08/31/15
Project Name: SVCW Tunnel | **Remarks:**

Boring:	B-105	B-105	B-104					
Sample:								
Depth, ft:	31-31.5	21-21.5	26-26.5					
Visual Description:	Greenish Gray Clayey SAND w/ Gravel	Dark Gray CLAY	Dark Gray Fat CLAY					
Actual G_s								
Assumed G_s	2.80	2.70	2.70					
Moisture, %	13.6	76.0	82.2					
Wet Unit wt, pcf	142.4	95.0	94.7					
Dry Unit wt, pcf	125.3	54.0	51.9					
Dry Bulk Dens.ρb, (g/cc)	2.01	0.87	0.83					
Saturation, %	96.1	96.6	98.8					
Total Porosity, %	28.3	68.0	69.2					
Volumetric Water Cont,Θw,%	27.2	65.7	68.4					
Volumetric Air Cont., Θa,%	1.1	2.3	0.8					
Void Ratio	0.40	2.12	2.25					
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.



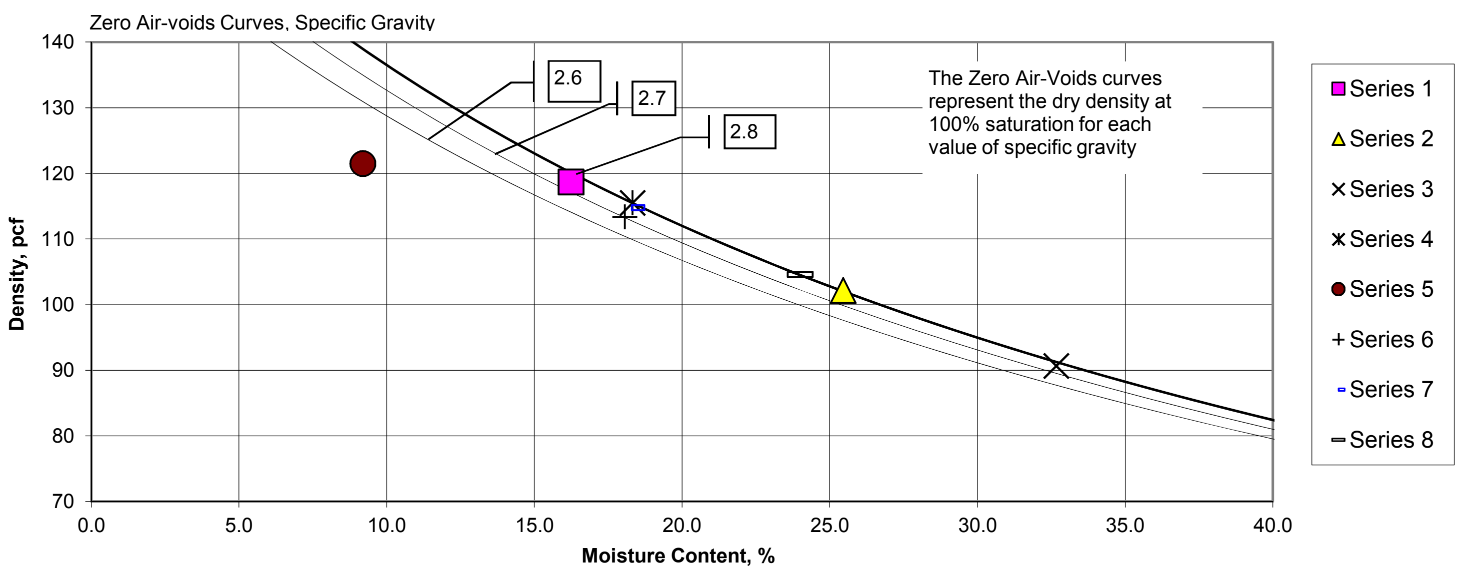
Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No:	208-045a	**Project No.**	SF14014A	**By:**	RU
Client:	GTC	**Date:**	12/01/15		
Project Name:	SVCW	**Remarks:**			

Boring:	B-106	B-106	B-106	B-106	B-108	B-108	B-108	B-108
Sample:								
Depth, ft:	19-19.5	29-29.5	38.5-39	78.5-79	5.5-6	14-14.5	24-24.5	34-34.5
Visual Description:	Olive Gray Sandy Lean CLAY	Dark Gray Lean CLAY w/ Sand	Olive Gray Sandy Fat CLAY	Olive Gray Sandy Lean CLAY	Yellowish Brown Clayey SAND w/ Gravel	Very Dark Gray Sandy Silty CLAY	Olive Clayey SAND	Yellowish Brown CLAY w/ Sand
Actual G_s								
Assumed G_s	2.80	2.80	2.80	2.80	2.70	2.70	2.80	2.80
Moisture, %	16.2	25.5	32.7	18.3	9.2	18.1	18.3	24.0
Wet Unit wt, pcf	137.9	128.1	120.3	136.7	132.7	133.8	135.7	129.7
Dry Unit wt, pcf	118.6	102.1	90.7	115.5	121.5	113.3	114.7	104.6
Dry Bulk Dens.pb, (g/cc)	1.90	1.64	1.45	1.85	1.95	1.82	1.84	1.67
Saturation, %	95.9	100.0	98.4	99.7	64.0	99.9	97.7	99.9
Total Porosity, %	32.2	41.6	48.2	34.0	28.0	32.8	34.4	40.2
Volumetric Water Cont,Өw,%	30.9	41.6	47.4	33.9	17.9	32.8	33.6	40.2
Volumetric Air Cont., Өa,%	1.3	0.0	0.8	0.1	10.1	0.0	0.8	0.1
Void Ratio	0.47	0.71	0.93	0.51	0.39	0.49	0.52	0.67
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density



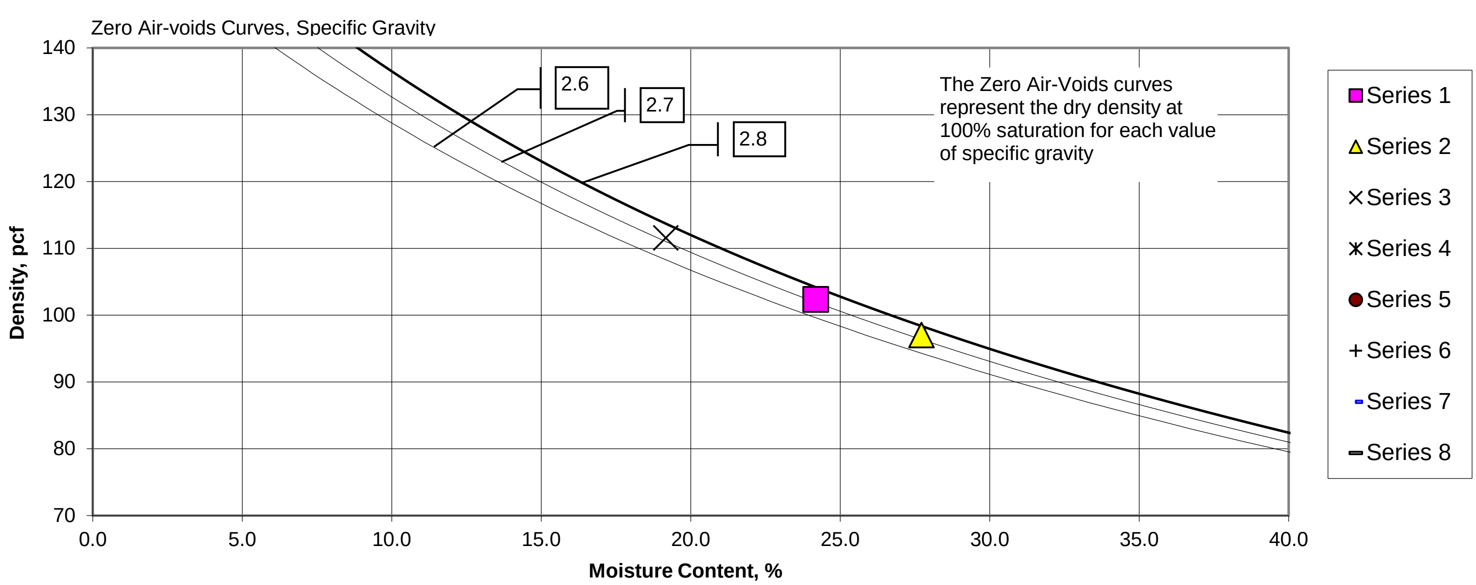
Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No: 208-040 **Project No.** SF14014A **By:** RU
Client: GTC **Date:** 09/24/15
Project Name: SVCW Tunnel **Remarks:**

Boring:	B-107	B-107	B-107					
Sample:								
Depth, ft:	43-43.5	48-48.5	61-61.5					
Visual Description:	Dark Greenish Gray Fat CLAY, trace Sand	Dark Greenish Gray Fat CLAY	Olive Brown Sandy CLAY					
Actual G_s								
Assumed G_s	2.75	2.75	2.75					
Moisture, %	24.2	27.7	19.2					
Wet Unit wt, pcf	127.1	123.9	133.0					
Dry Unit wt, pcf	102.4	97.0	111.6					
Dry Bulk Dens.pb, (g/cc)	1.64	1.55	1.79					
Saturation, %	98.0	98.9	97.6					
Total Porosity, %	40.4	43.5	35.1					
Volumetric Water Cont,Өw,%	39.6	43.0	34.2					
Volumetric Air Cont., Өa,%	0.8	0.5	0.8					
Void Ratio	0.68	0.77	0.54					
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density



Moisture-Density Lab Worksheet

CTL Job No.:	208-045b	**Date:**	12/1/15
Client:	GTC	**By:**	RU
Project Name:	SVCW		
Project No.:	SF14014A		

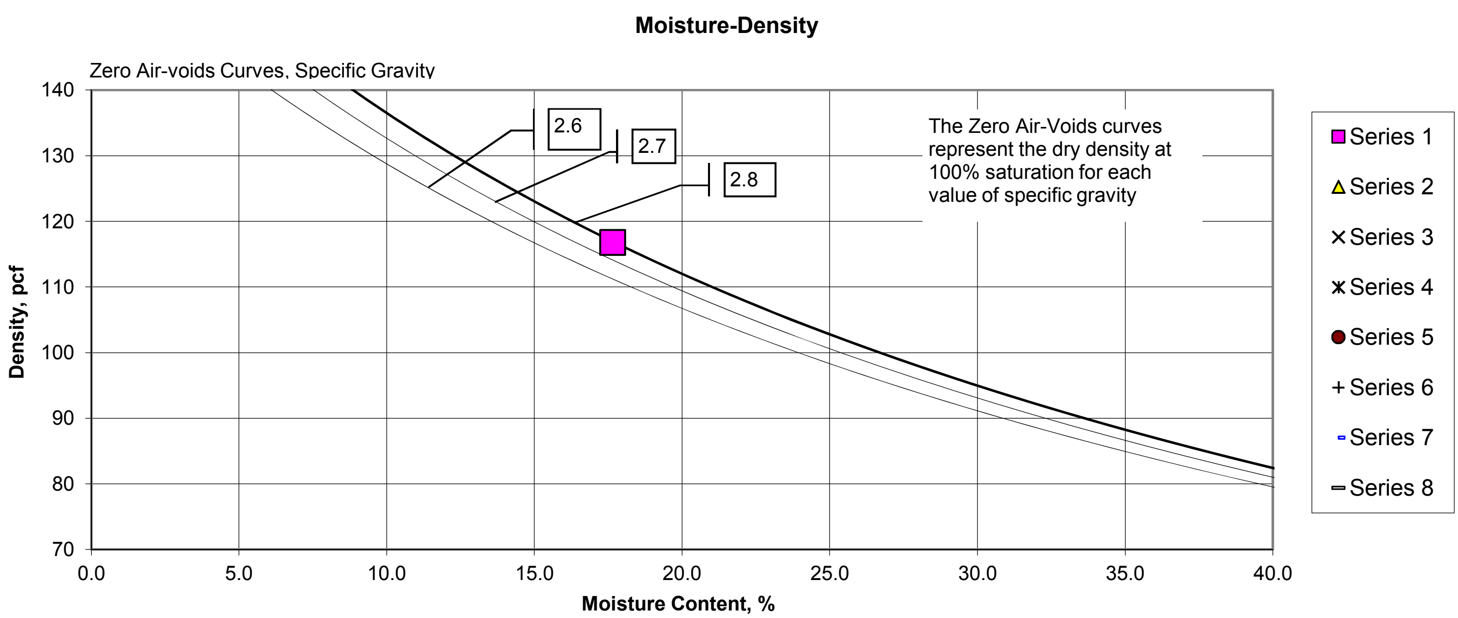
Boring:	B-108	B-108	B-108	B-110	B-110	B-110	B-110	B-112 P-5
Sample:								
Depth, ft.:	44-44.5	58.5-59	69-69.5	5.5-6	9-9.5	24-24.5	33.5-34	24-24.5
Density Data								
Height, in.:	2.0	2.0	2.0	1.90	2.02	2.0	1.99	2.0
Diameter, in.:	2.39	2.4	2.38	2.39	2.4	2.39	2.4	2.39
Determined Sp. Grav.:								
Assumed Sp. Grav.:	2.7	2.8	2.7	2.7	2.8	2.7	2.8	2.7
Total Wt of Soil& Tare, g:	402.39	374.56	398.23	363.2	312.95	395	395.84	424.74
Tare, g:	85.92	85.92	89.17	89.17	89.17	89.17	89.17	89.17
Total Wet Wt of Soil, g:	316.47	288.64	309.06	274.03	223.78	305.83	306.67	335.57
Moisture Content Data								
Tare No.:								
Wet Wt. Of Soil & Tare, g:	668.5	127.84	533.4	613.03	140.85	612.9	650.1	697.1
Dry Wt of Soil & Tare, g:	610.5	101.79	476.5	549.5	82.31	536.5	561.2	641.5
Tare, g:	173.16	20.19	174.6	174.47	20.54	174.78	173.59	172.25
Visual Classification:	Olive Brown Well-Graded SAND w/ Clay & Gravel	Olive Gray Sandy Lean CLAY	Olive Gray Sandy CLAY	Dark Olive Brown Clayey SAND w/ Gravel	Dark Gray Elastic SILT	Olive Brown Lean CLAY w/ Sand & CaCO3	Olive Sandy CLAY	Olive Poorly Graded SAND w/ Clay & Gravel

Moisture-Density-Porosity Report
Cooper Testing Labs, Inc. (ASTM D7263b)

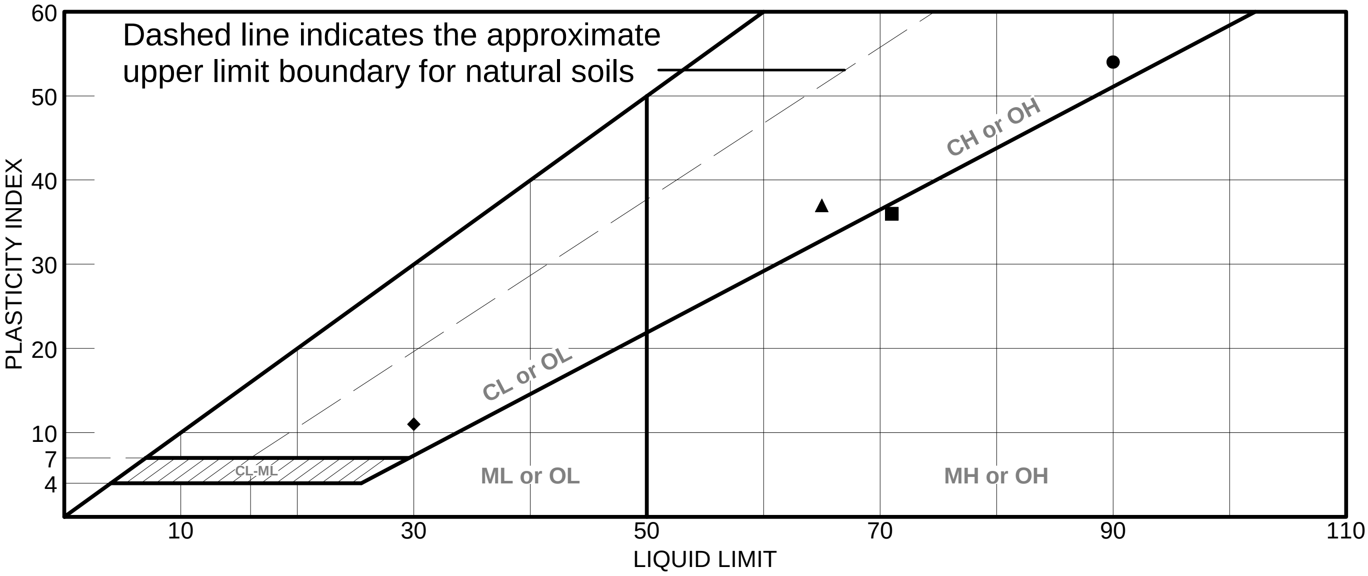
CTL Job No:	208-045c	**Project No.**	SF14014A	**By:**	RU
Client:	GTC	**Date:**	12/01/15		
Project Name:	SVCW	**Remarks:**			

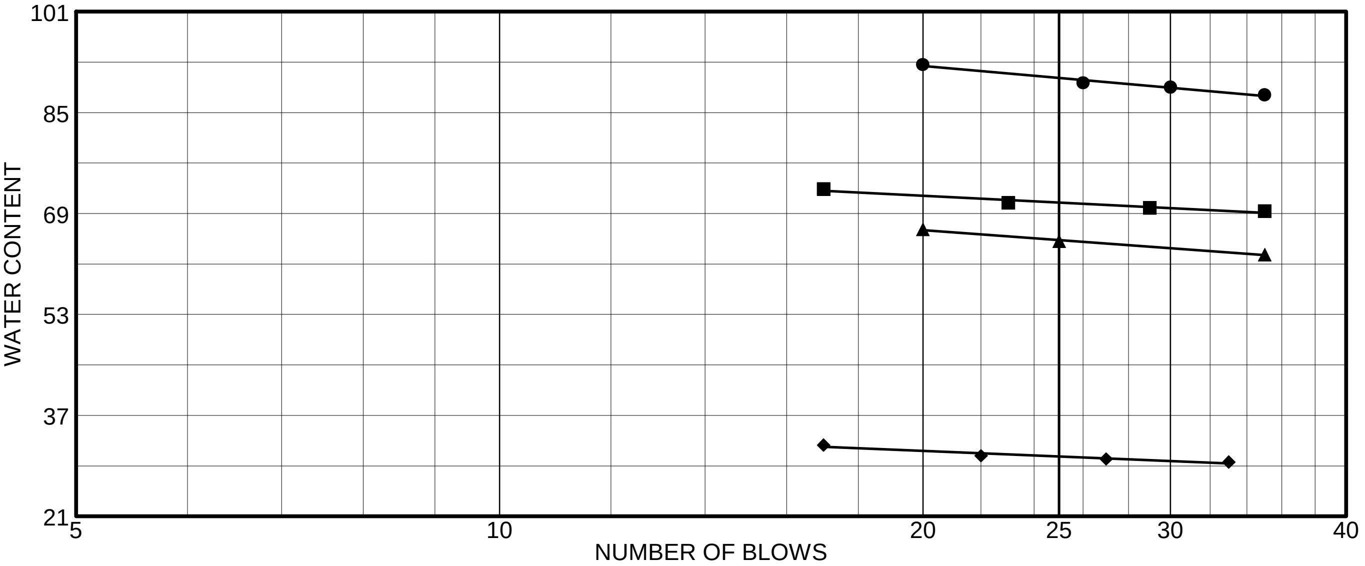
Boring:	B-112 P-D							
Sample:								
Depth, ft:	29-29.5							
Visual Description:	Olive Sandy CLAY							
Actual G_s								
Assumed G_s	2.80							
Moisture, %	17.7							
Wet Unit wt, pcf	137.4							
Dry Unit wt, pcf	116.8							
Dry Bulk Dens.pb, (g/cc)	1.87							
Saturation, %	99.3							
Total Porosity, %	33.2							
Volumetric Water Cont,Θw,%	33.0							
Volumetric Air Cont., Θa,%	0.2							
Void Ratio	0.50							
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.



LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Fat CLAY (Bay Mud)	90	36	54			
■	Greenish Gray Elastic SILT (Bay Mud)	71	35	36			
▲	Greenish Gray Fat CLAY (Bay Mud)	65	28	37			
◆	Olive Brown Lean CLAY	30	19	11	99.9	86.6	CL

Project No. 836-002 **Client:** DCM Consulting, Inc.

Project: SVCW Headworks

● **Source:** B-101 **Elev./Depth:** 10-13'

■ **Source:** B-101 **Elev./Depth:** 25-28'

▲ **Source:** B-101 **Elev./Depth:** 40-43'

◆ **Source:** B-101 **Elev./Depth:** 60-63'

Remarks:

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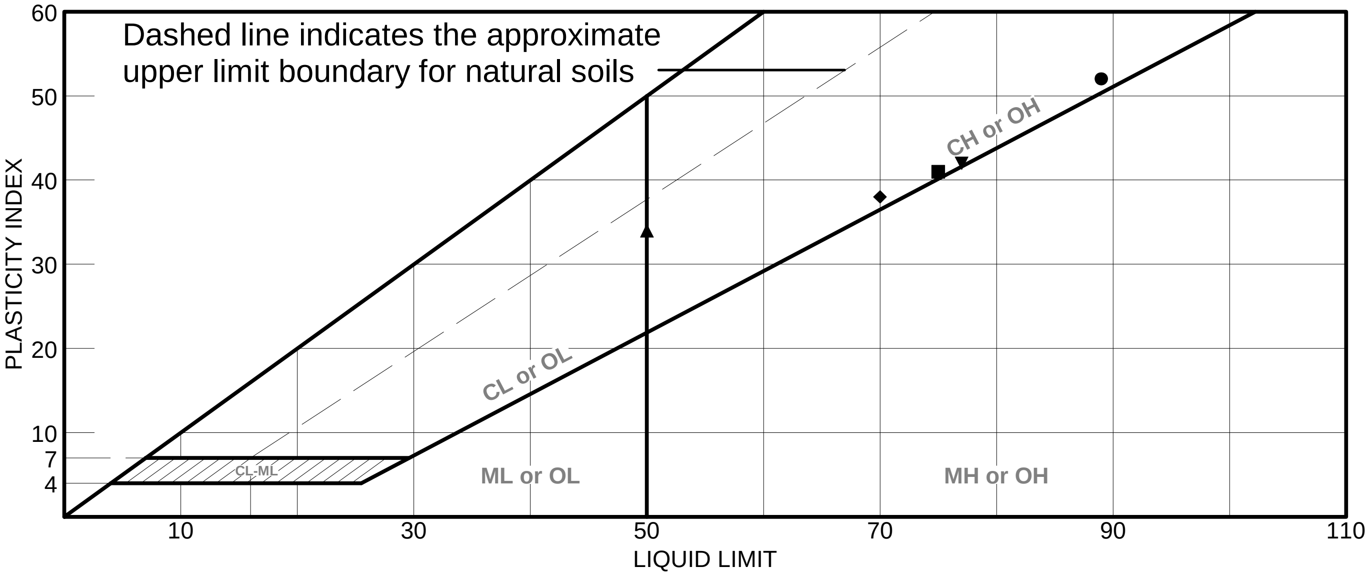
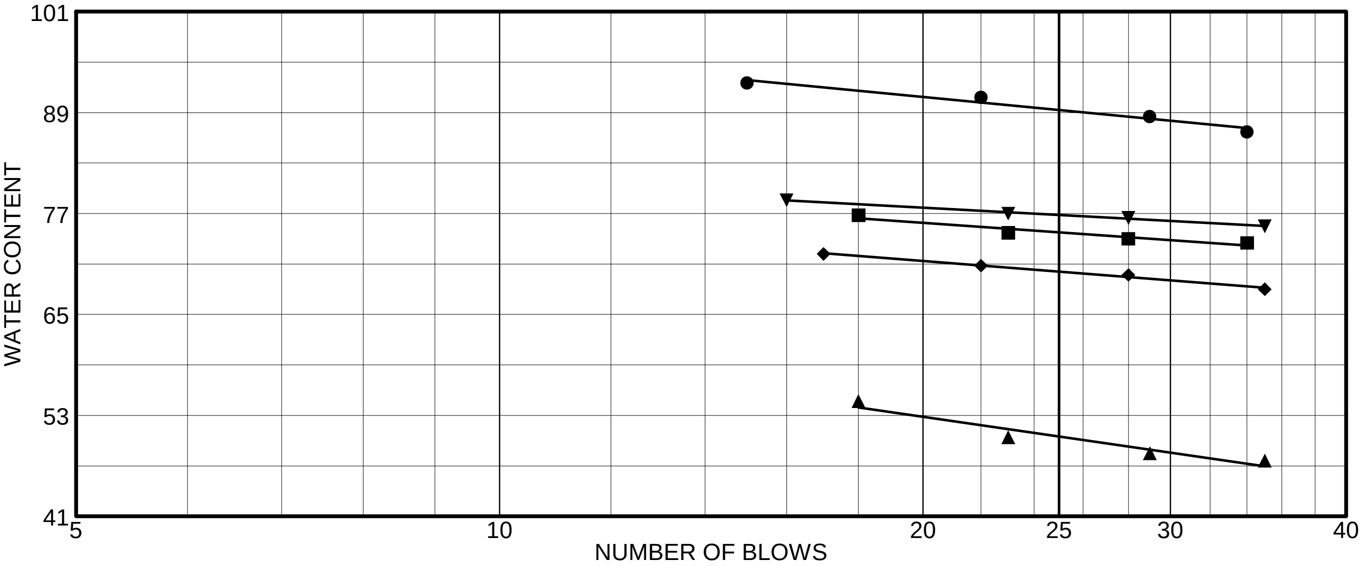
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Bluish Gray Fat CLAY	89	37	52			
■	Dark Bluish Gray Fat CLAY	75	34	41			
▲	Bluish Gray Lean CLAY	50	16	34			
◆	Dark Gray Fat CLAY w/ Sand pockets	70	32	38			
▼	Dark Gray Fat CLAY w/ shells	77	35	42			

Project No. 208-036 **Client:** GTC

Project: SVCW Tunnel - SF14014A

● **Source:** B-102 **Elev./Depth:** 9-9.5'

■ **Source:** B-102 **Elev./Depth:** 31-31.5'

▲ **Source:** B-102 **Elev./Depth:** 43-43.5'

◆ **Source:** B-103 **Elev./Depth:** 21-21.5'

▼ **Source:** B-103 **Elev./Depth:** 31-31.5'

Remarks:

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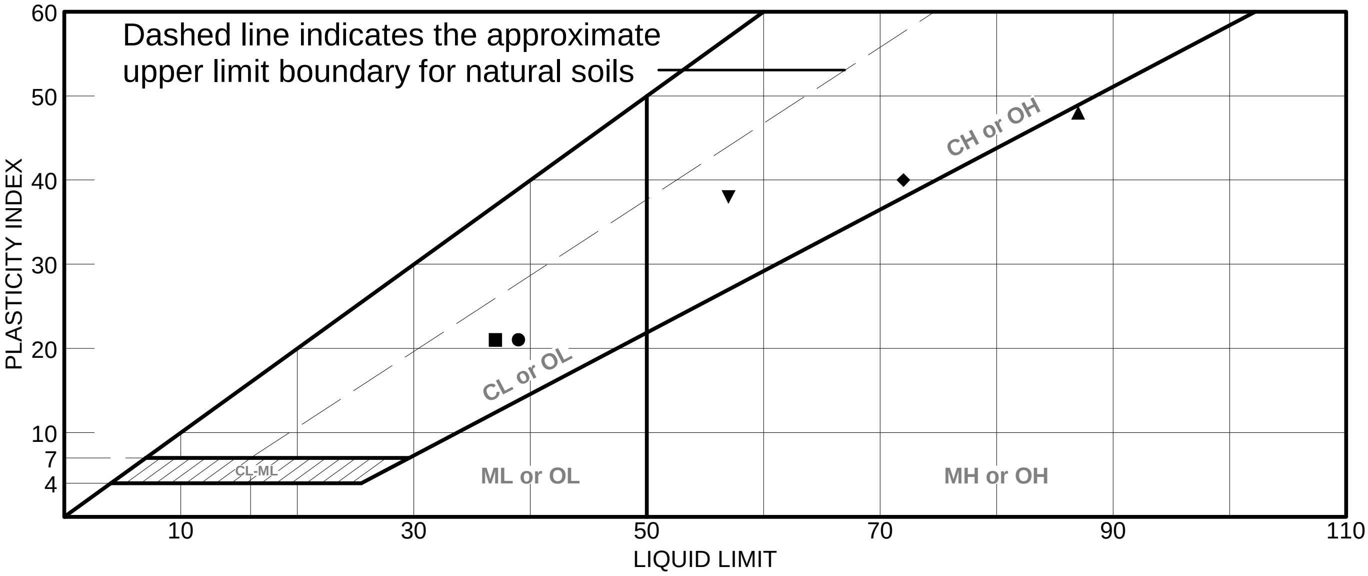
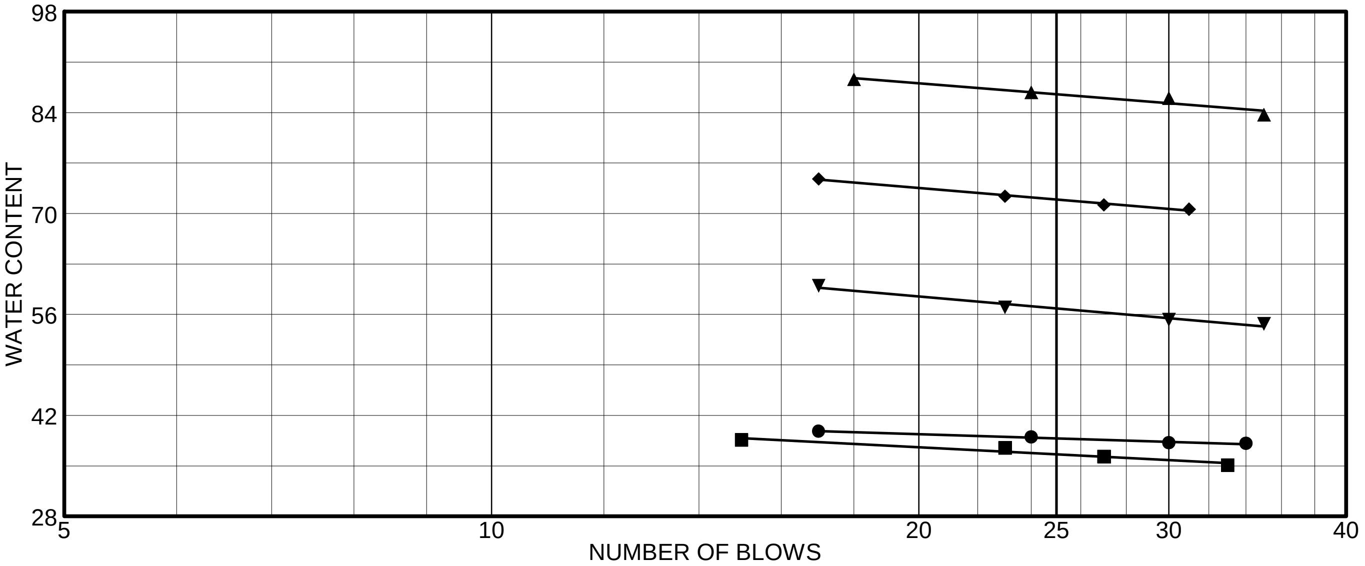
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish Brown Lean CLAY w/ Sand	39	18	21			
■	Olive Sandy Lean CLAY	37	16	21			
▲	Dark Gray Elastic SILT	87	39	48			
◆	Dark Gray Fat CLAY	72	32	40			
▼	Greenish Gray Fat CLAY	57	19	38			

Project No. 208-036 **Client:** GTC

Project: SVCW Tunnel - SF14014A

● **Source:** B-103 **Elev./Depth:** 46-46.5'
■ **Source:** B-103 **Elev./Depth:** 51-51.5'
▲ **Source:** B-105 **Elev./Depth:** 16-16.5'
◆ **Source:** B-105 **Elev./Depth:** 21-21.5'
▼ **Source:** B-105 **Elev./Depth:** 46-46.5'

Remarks:
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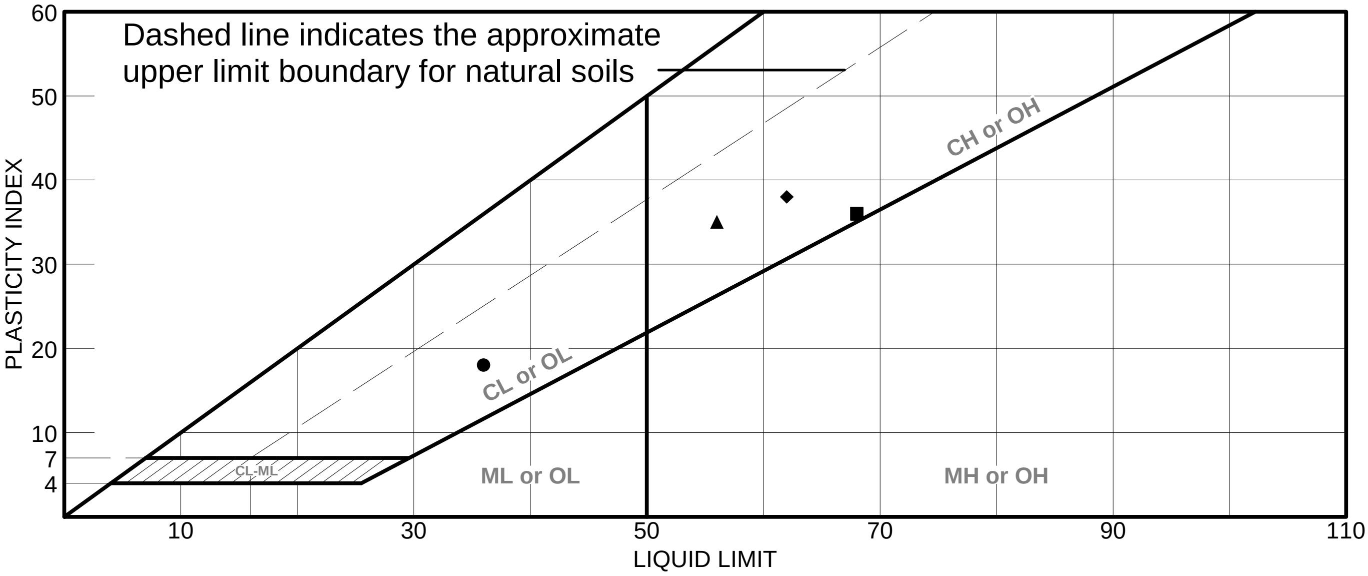
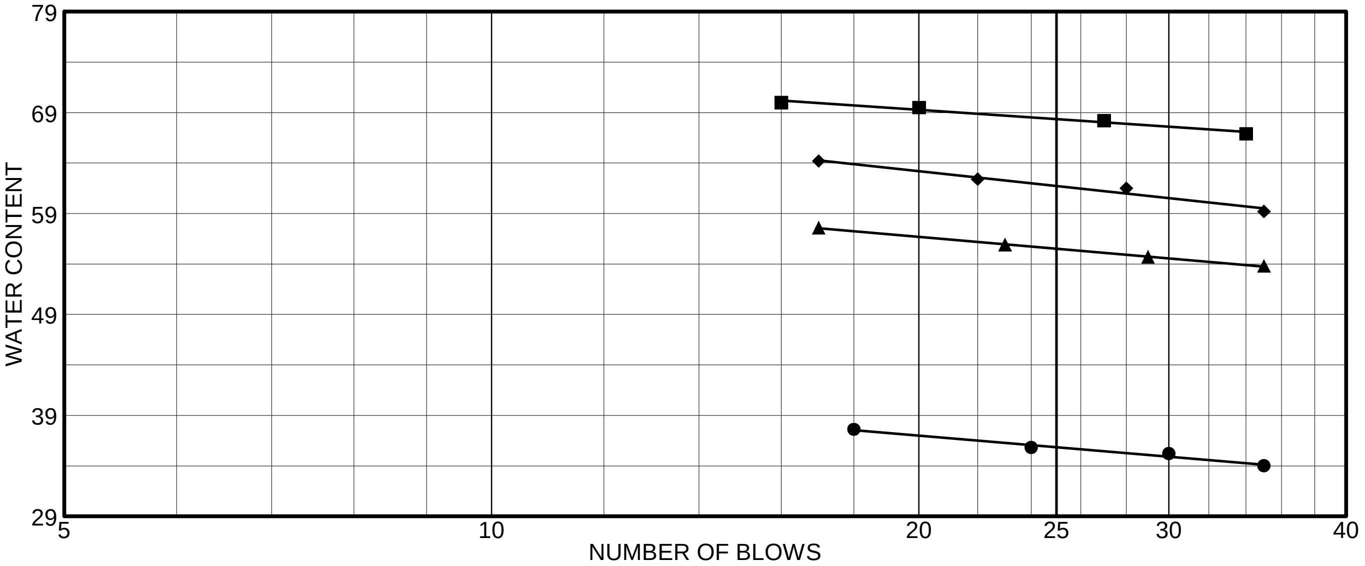
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Lean CLAY w/ Sand	36	18	18			
■	Dark Gray Fat CLAY	68	32	36			
▲	Light Greenish Gray Fat CLAY, trace Sand	56	21	35			
◆	Olive Fat CLAY, trace Sand	62	24	38			

Project No. 208-036 **Client:** GTC

Project: SVCW Tunnel - SF14014A

● **Source:** B-105 **Elev./Depth:** 56-56.5'

■ **Source:** B-104 **Elev./Depth:** 26-26.5'

▲ **Source:** B-104 **Elev./Depth:** 36-36.5'

◆ **Source:** B-104 **Elev./Depth:** 46-46.5'

Remarks:

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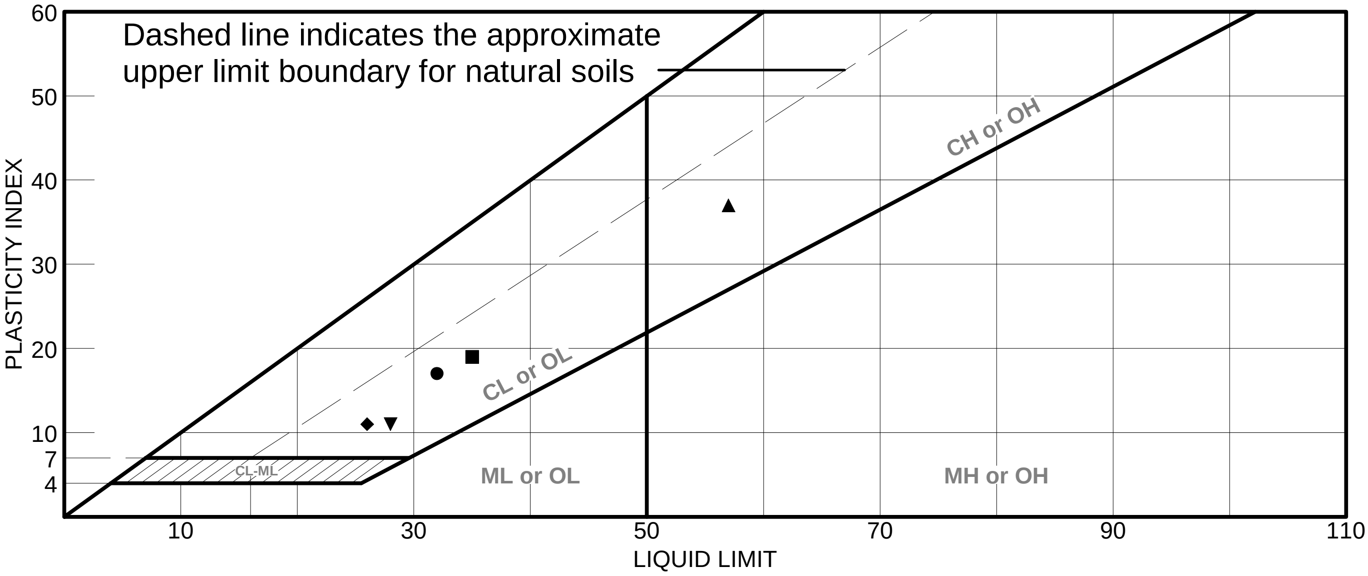
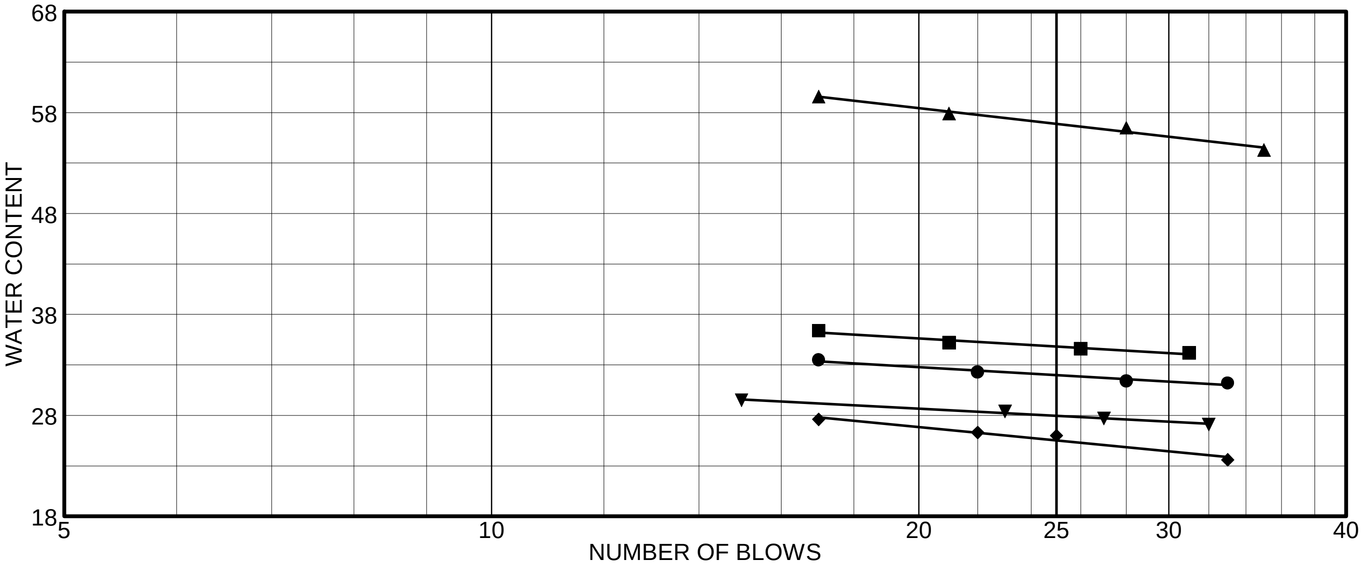
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Olive Gray Sandy Lean CLAY	32	15	17	95.3	56.1	CL
■	Dark Gray Lean CLAY w/ Sand	35	16	19	99.5	76.1	CL
▲	Olive Gray Sandy Fat CLAY	57	20	37	96.1	94.7	CH
◆	Olive Sandy Lean CLAY	26	15	11			
▼	Olive Gray Sandy Lean CLAY	28	17	11	92.5	56.7	CL

Project No. 208-045 **Client:** GTC

Project: SVCW - SF14014A

● **Source:** B-106 **Elev./Depth:** 19-19.5'

■ **Source:** B-106 **Elev./Depth:** 29-29.5'

▲ **Source:** B-106 **Elev./Depth:** 38.5-39'

◆ **Source:** B-106 **Elev./Depth:** 54-54.5'

▼ **Source:** B-106 **Elev./Depth:** 78.5-79'

Remarks:
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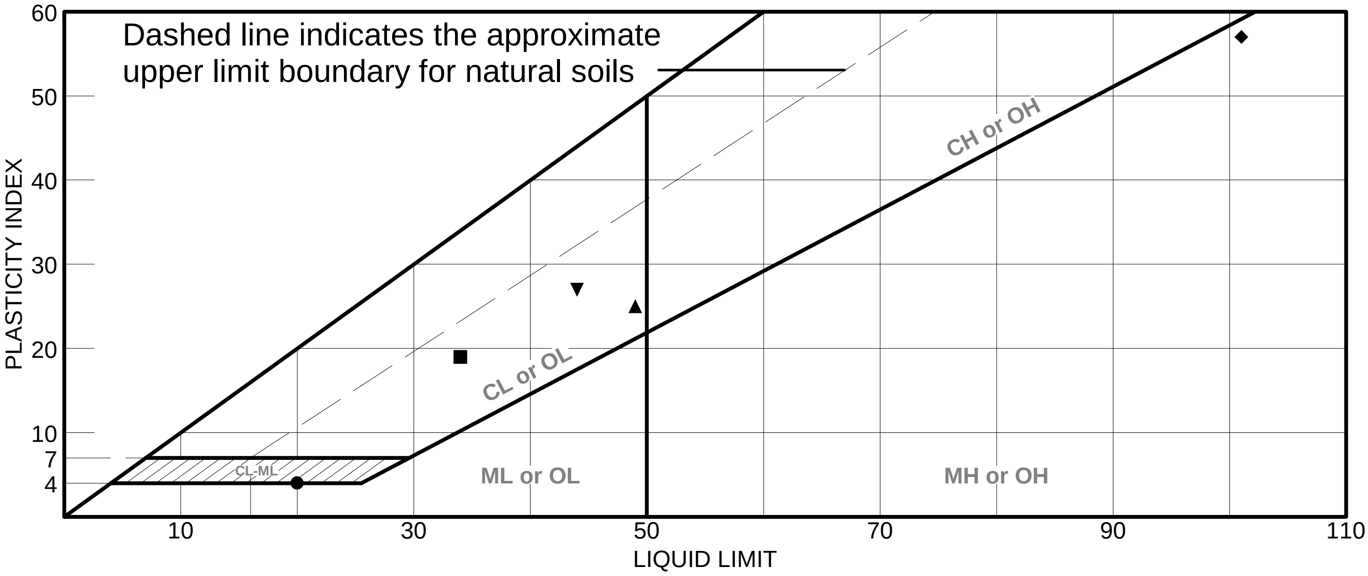
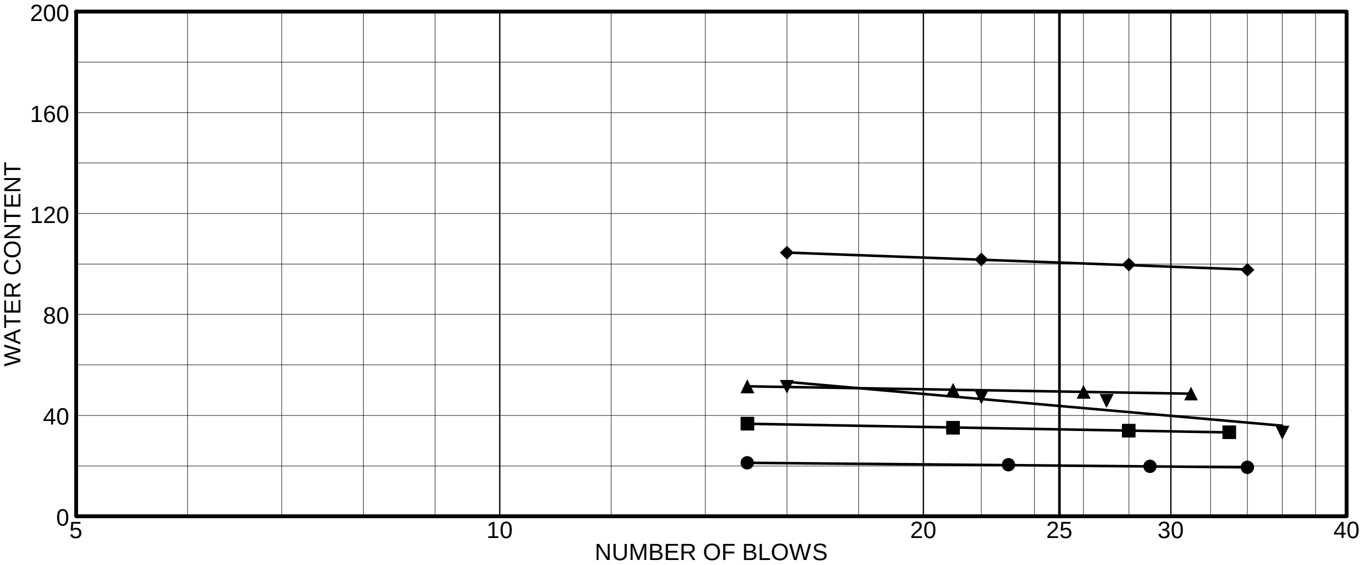
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Very Dark Gray Sandy Silty CLAY	20	16	4			
■	Olive Brown Lean CLAY	34	15	19			
▲	Olive Gray Sandy Lean CLAY	49	24	25			
◆	Dark Gray Elastic SILT	101	44	57			
▼	Olive Brown Lean CLAY w/ Sand & CaCO3	44	17	27	96.9	81.8	CL

Project No. 208-045 **Client:** GTC

Project: SVCW - SF14014A

● **Source:** B-108 **Elev./Depth:** 14-14.5'

■ **Source:** B-108 **Elev./Depth:** 19-19.5'

▲ **Source:** B-108 **Elev./Depth:** 58.5-59'

◆ **Source:** B-110 **Elev./Depth:** 9-9.5'

▼ **Source:** B-110 **Elev./Depth:** 24-24.5'

Remarks:

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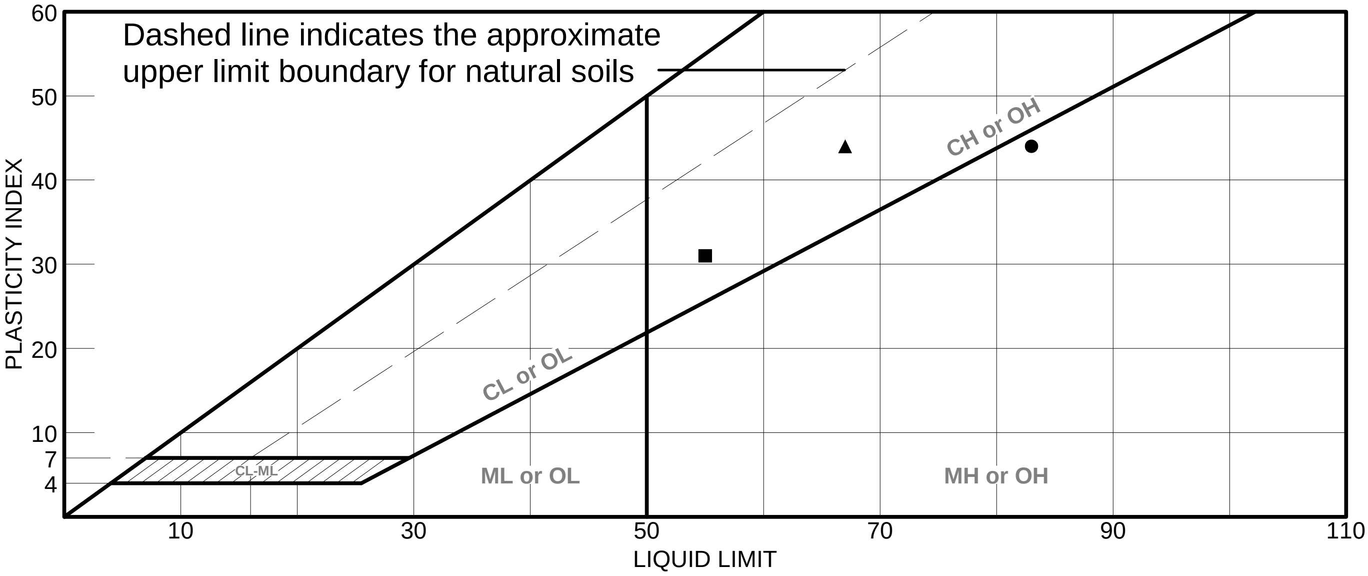
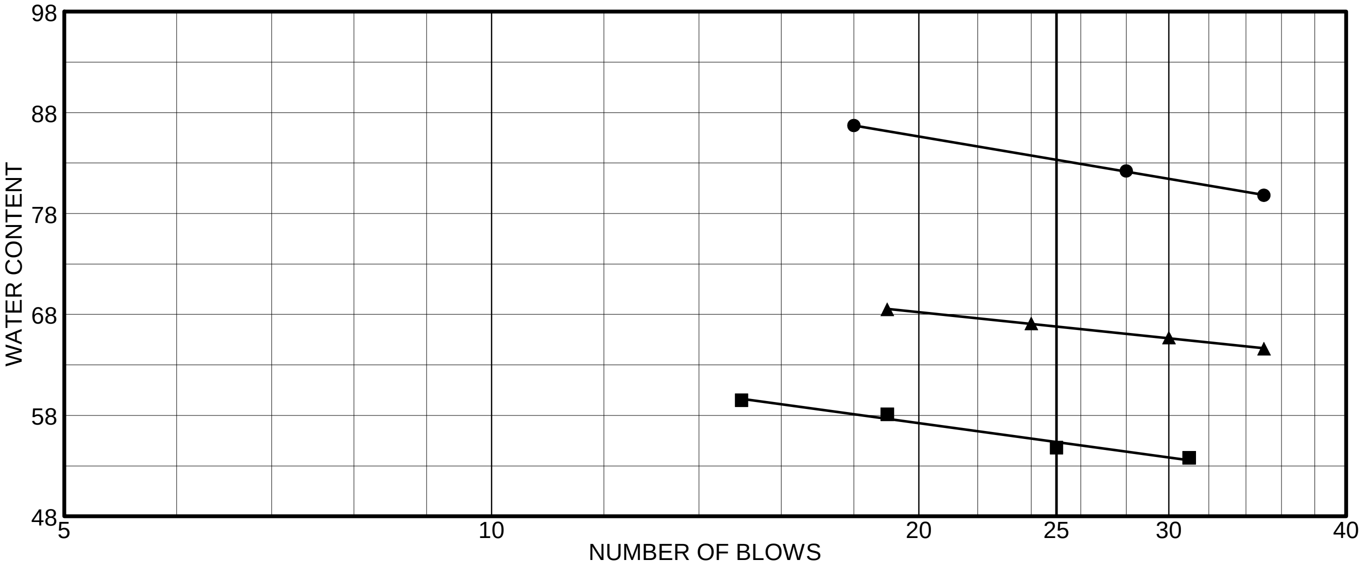
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray Elastic SILT (Bay Mud)	83	39	44			
■	Greenish Gray grading to Olive Brown Fat CLAY	55	24	31			
▲	Olive Fat CLAY	67	23	44			

Project No. 208-045 **Client:** GTC

Project: SVCW - SF14014A

● **Source:** B-114P **Elev./Depth:** 10-12.5'

■ **Source:** B-114P **Elev./Depth:** 46-46.5'

▲ **Source:** B-114P **Elev./Depth:** 96-96.5'

Remarks:

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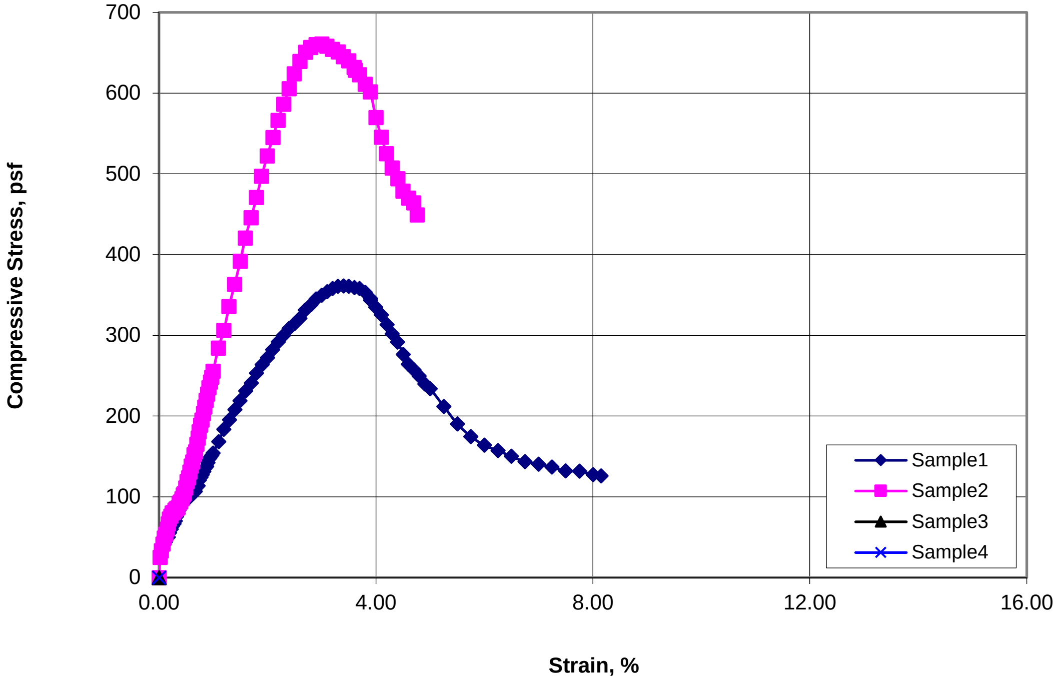
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	361	661			
Unconfined Compressive Strength, psi	2.5	4.6			
Undrained Shear Strength, psf	181	330			
Failure Strain, %	3.4	3.0			
Strain Rate, % per minute	1.0	1.0			
Strain Rate, inches/minute	0.06	0.06			
Moisture Content, %	94.1	72.7			
Dry Density, pcf	46.5	56.1			
Saturation, %	96.8	97.8			
Void Ratio	2.625	2.006			
Specimen Diameter, inches	2.875	2.875			
Specimen Height, inches	6.10	6.08			
Height to Diameter Ratio	2.1	2.1			
Assumed Specific Gravity	2.70	2.70			

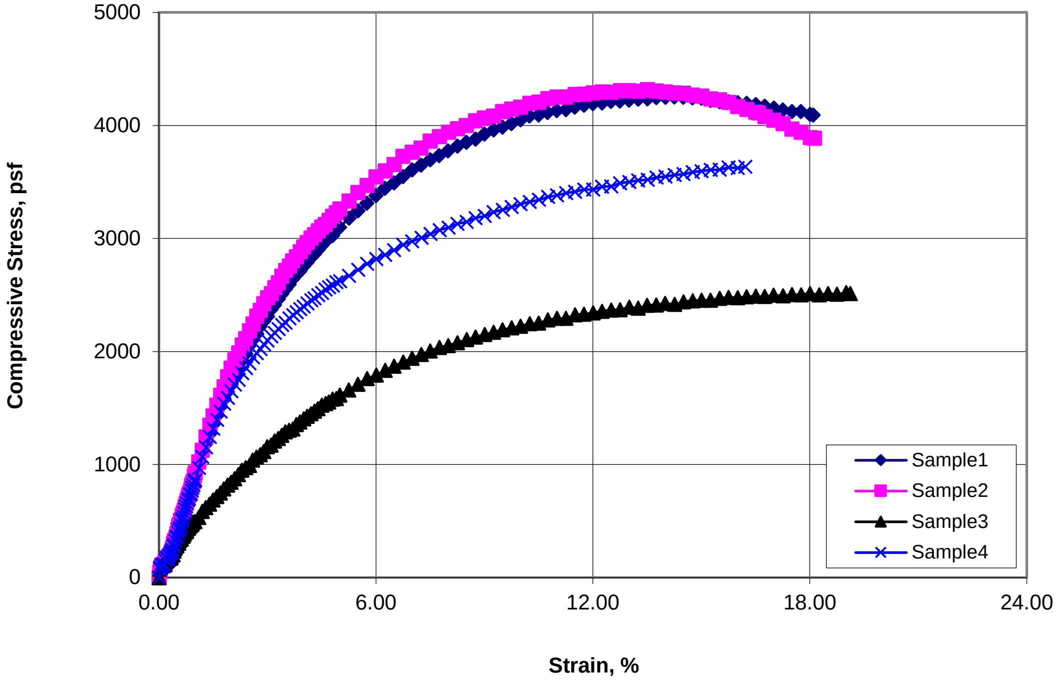
Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-101		10-13(Tip-4.5")	Greenish Gray Fat CLAY (Bay Mud)
2	B-101		40-43(Tip-5")	Greenish Gray Fat CLAY (Bay Mud)
3				
4				

Job No.:	836-002	Type of Sample	Undisturbed
Client:	DCM Consulting, Inc.		
Project:	SVCW Headworks	Remarks:	
Date:	10/13/2015 By: MD/RU		

COOPER TESTING LABORATORY

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	4251	4315	2521	3635	
Unconfined Compressive Strength, psi	29.5	30.0	17.5	25.2	
Undrained Shear Strength, psf	2126	2157	1260	1817	
Failure Strain, %	14.3	13.5	19.0	16.2	
Strain Rate, % per minute	1.0	1.0	1.0	1.0	
Strain Rate, inches/minute	0.05	0.05	0.05	0.05	
Moisture Content, %	22.5	31.3	34.9	22.7	
Dry Density, pcf	105.1	92.0	88.3	106.5	
Saturation, %	97.8	99.5	99.7	99.2	
Void Ratio	0.634	0.866	0.980	0.641	
Specimen Diameter, inches	2.385	2.390	2.382	2.389	
Specimen Height, inches	5.04	5.00	4.97	4.97	
Height to Diameter Ratio	2.1	2.1	2.1	2.1	
Assumed Specific Gravity	2.75	2.75	2.80	2.80	

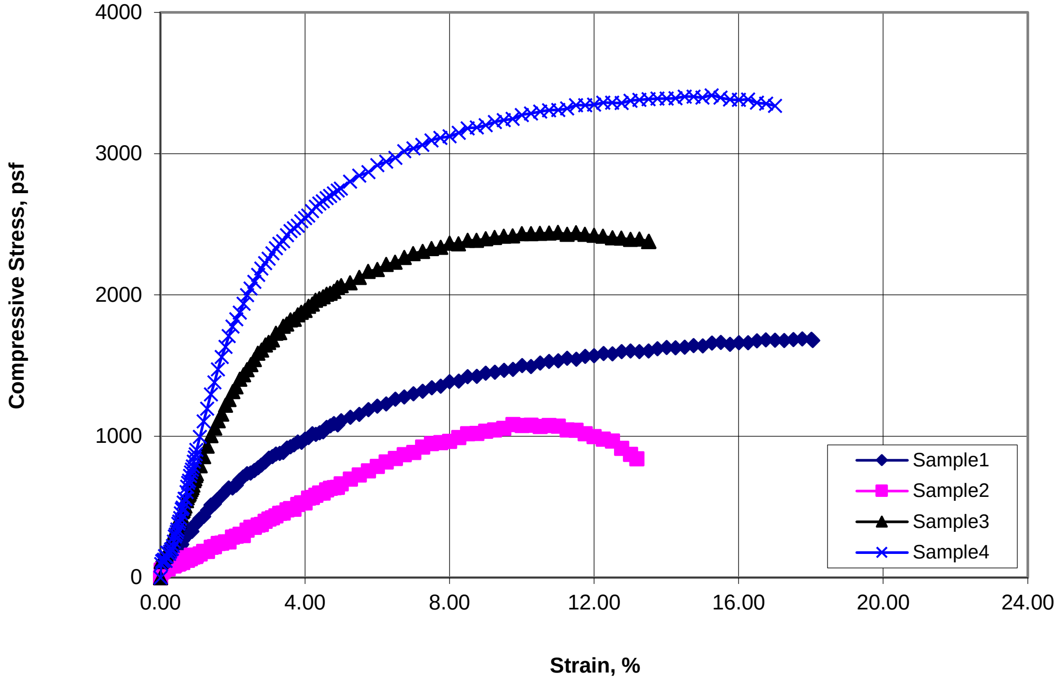
Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-102		43-43.5	Bluish Gray CLAY Lean
2	B-102		51-51.5	Olive Brown CLAY
3	B-102		56-56.5	Yellowish Brown CLAY
4	B-103		46-46.5	Yellowish Brown Lean CLAY w/ Sand

Job No.:	208-036a	Type of Sample	Undisturbed
Client:	GTC		
Project:	SVCW Tunnel - SF14014A	Remarks:	
Date:	8/31/2015 By: MD/RU		

COOPER TESTING LABORATORY

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	1689	1082	2442	3414	
Unconfined Compressive Strength, psi	11.7	7.5	17.0	23.7	
Undrained Shear Strength, psf	845	541	1221	1707	
Failure Strain, %	17.8	9.8	11.0	15.3	
Strain Rate, % per minute	1.0	1.0	1.0	1.0	
Strain Rate, inches/minute	0.05	0.05	0.05	0.05	
Moisture Content, %	24.5	20.9	28.5	26.7	
Dry Density, pcf	102.5	109.8	97.1	98.9	
Saturation, %	97.3	98.8	99.9	97.4	
Void Ratio	0.705	0.593	0.800	0.767	
Specimen Diameter, inches	2.391	2.372	2.382	2.390	
Specimen Height, inches	4.98	4.96	5.01	5.01	
Height to Diameter Ratio	2.1	2.1	2.1	2.1	
Assumed Specific Gravity	2.80	2.80	2.80	2.80	

Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-103		51-51.5	Olive Sandy Lean CLAY
2	B-103		61-61.5	Dark Bluish Gray Sandy CLAY
3	B-105		41-41.5	Olive CLAY, trace Sand
4	B-105		46-46.5	Greenish Gray Fat CLAY

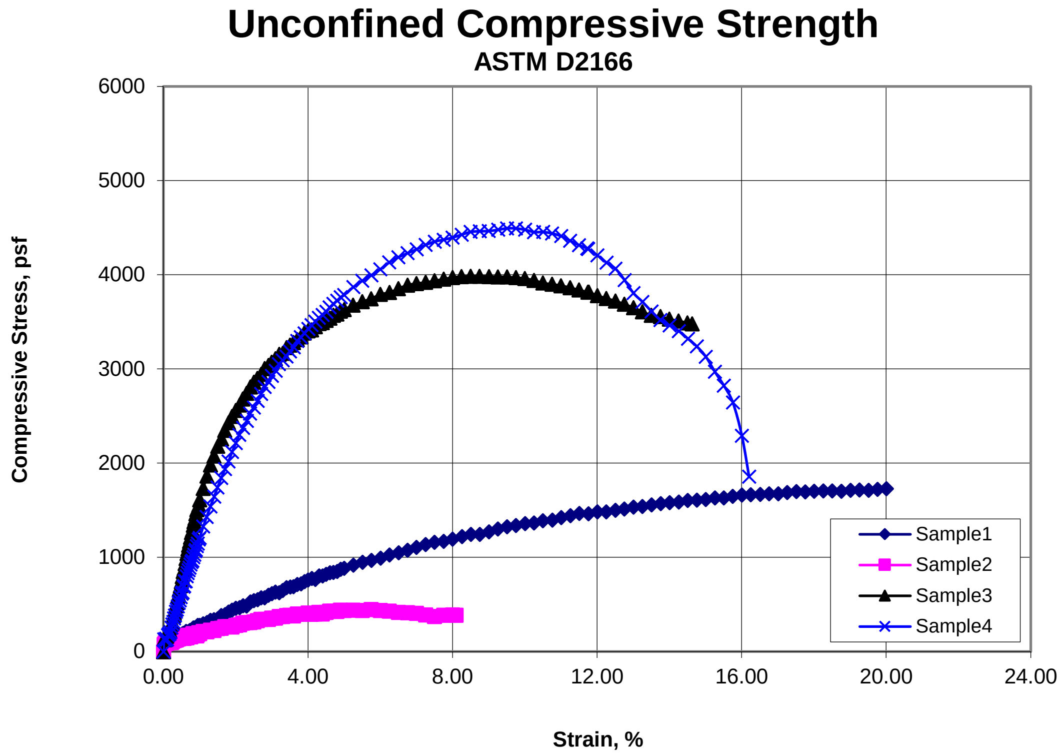
Job No.:	208-036b	Type of Sample	Undisturbed
Client:	GTC		
Project:	SVCW Tunnel - SF14014A		
Date:	8/31/2015 By: MD/RU		

Remarks:

COOPER TESTING LABORATORY

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	1729	447	3986	4494	
Unconfined Compressive Strength, psi	12.0	3.1	27.7	31.2	
Undrained Shear Strength, psf	864	224	1993	2247	
Failure Strain, %	20.0	5.7	8.7	9.5	
Strain Rate, % per minute	1.0	1.0	1.0	1.0	
Strain Rate, inches/minute	0.05	0.05	0.05	0.05	
Moisture Content, %	24.6	41.6	26.9	26.8	
Dry Density, pcf	103.2	80.6	98.9	99.2	
Saturation, %	99.3	99.8	98.2	98.3	
Void Ratio	0.694	1.167	0.767	0.762	
Specimen Diameter, inches	2.400	2.385	2.405	2.389	
Specimen Height, inches	4.91	4.98	4.98	5.00	
Height to Diameter Ratio	2.0	2.1	2.1	2.1	
Assumed Specific Gravity	2.80	2.80	2.80	2.80	

Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-105		56-56.5	Greenish Gray Lean CLAY w/ Sand
2	B-104		36-36.5	Light Greenish Gray Fat CLAY, trace Sand
3	B-104		46-46.5	Olive Fat CLAY, trace Sand
4	B-104		56-56.5	Dark Greenish Gray CLAY

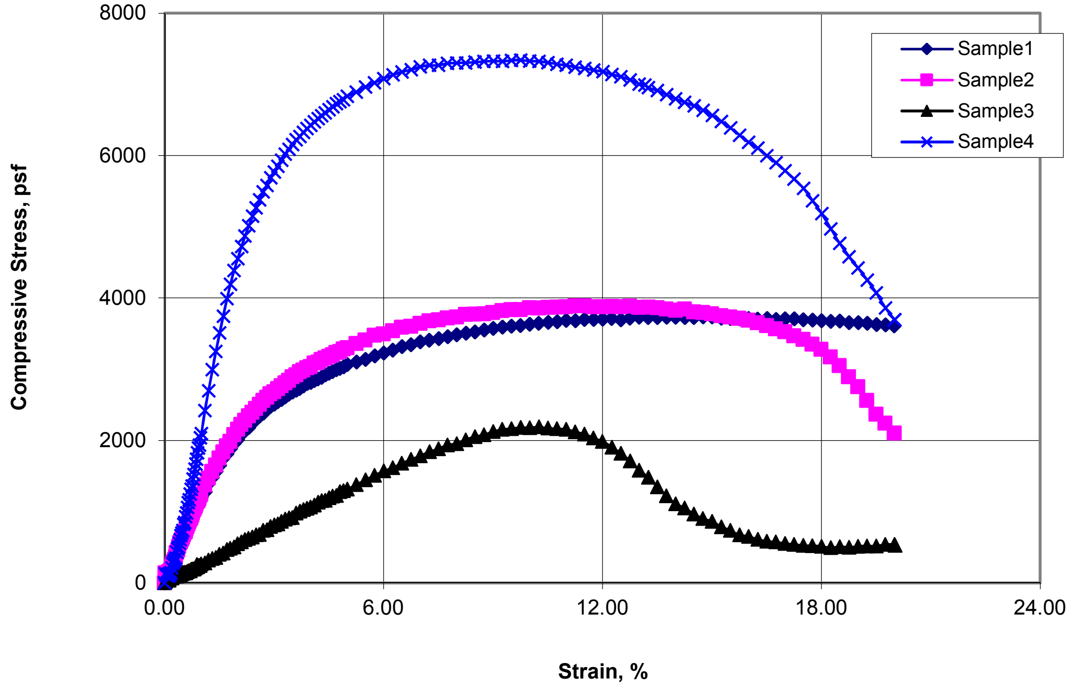
Job No.:	208-036c	Type of Sample	Undisturbed
Client:	GTC		
Project:	SVCW Tunnel - SF14014A		
Date:	8/31/2015 By: MD/RU		

Remarks:

COOPER TESTING LABORATORY

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	3736	3887	2189	7341	
Unconfined Compressive Strength, psi	25.9	27.0	15.2	51.0	
Undrained Shear Strength, psf	1868	1943	1094	3670	
Failure Strain, %	15.0	11.5	10.3	9.8	
Strain Rate, % per minute	1.0	1.0	1.0	1.0	
Strain Rate, inches/minute	0.05	0.05	0.05	0.05	
Moisture Content, %	24.6	32.1	20.2	21.9	
Dry Density, pcf	102.4	91.7	110.1	106.1	
Saturation, %	97.5	99.3	96.2	94.8	
Void Ratio	0.707	0.906	0.588	0.648	
Specimen Diameter, inches	2.379	2.385	2.390	2.402	
Specimen Height, inches	5.05	5.00	4.99	5.04	
Height to Diameter Ratio	2.1	2.1	2.1	2.1	
Assumed Specific Gravity	2.80	2.80	2.80	2.80	

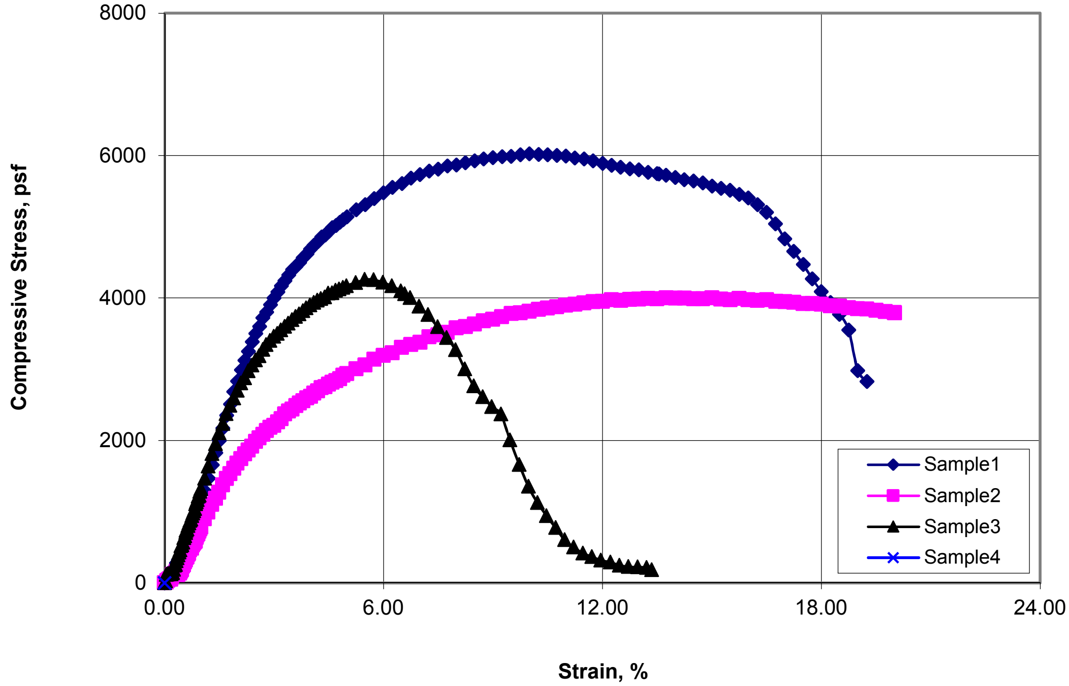
Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-106		34-34.5	Very Dark Bluish Gray CLAY w/ Sand
2	B-106		44-44.5	Very Dark Bluish Gray CLAY w/ Sand
3	B-106		54-54.5	Olive Sandy Lean CLAY
4	B-106		59-59.5	Very Dark Bluish Gray CLAY w/ Sand

Job No.:	208-045a	Type of Sample	Undisturbed
Client:	GTC		
Project:	SF14014A	Remarks:	
Date:	11/25/2015 By: MD/RU		

COOPER TESTING LABORATORY

Unconfined Compressive Strength

ASTM D2166



Sample No.:	1	2	3	4	
Unconfined Compressive Strength, psf	6025	3999	4259		
Unconfined Compressive Strength, psi	41.8	27.8	29.6		
Undrained Shear Strength, psf	3012	1999	2130		
Failure Strain, %	10.0	15.0	5.5		
Strain Rate, % per minute	1.0	1.0	1.0		
Strain Rate, inches/minute	0.05	0.05	0.05		
Moisture Content, %	18.7	26.1	26.4		
Dry Density, pcf	112.8	100.1	100.2		
Saturation, %	95.1	97.9	99.4		
Void Ratio	0.550	0.747	0.744		
Specimen Diameter, inches	2.389	2.386	2.405		
Specimen Height, inches	5.05	5.01	5.05		
Height to Diameter Ratio	2.1	2.1	2.1		
Assumed Specific Gravity	2.80	2.80	2.80		

Sample Location				
	Boring	Sample	Depth, ft.	Soil Description
1	B-108		19-19.5	Olive Brown Lean CLAY
2	B-114P		46-46.5	Greenish Gray grading Olive Brown Fat CLAY
3	B-114P		96-96.5	Olive Fat CLAY
4				

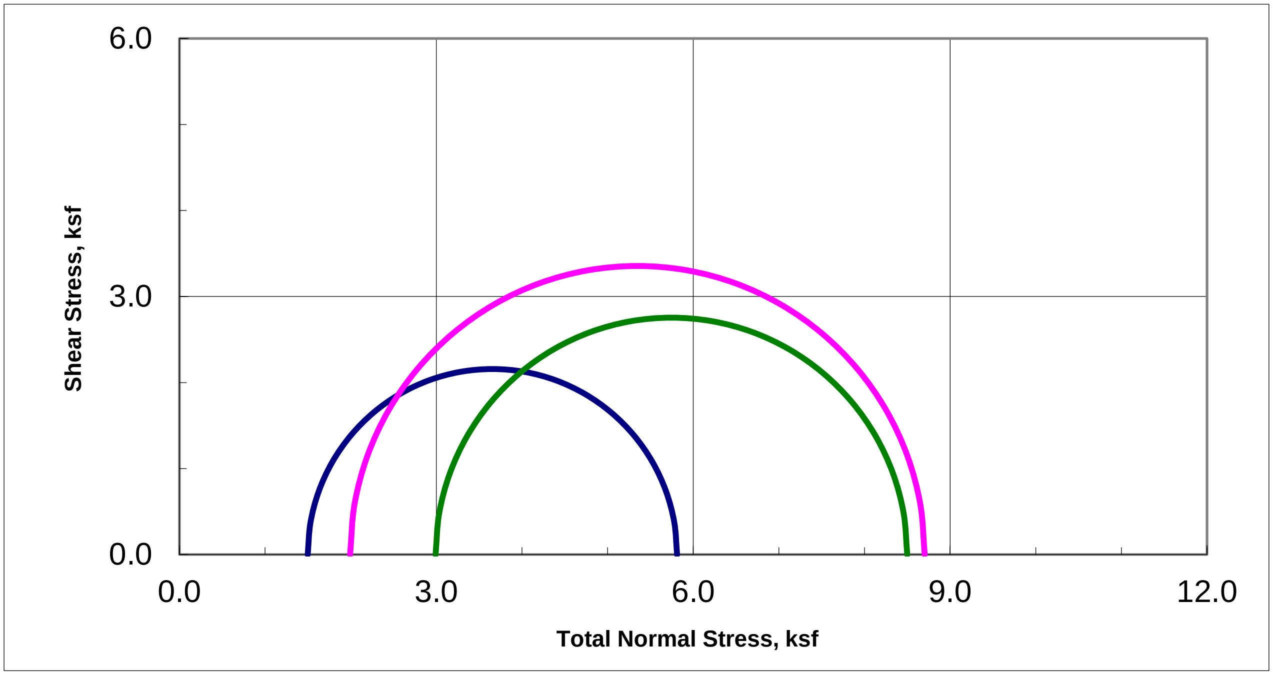
Job No.:	208-045b	Type of Sample	Undisturbed
Client:	GTC		
Project:	SF14014A		
Date:	11/25/2015 By: MD/RU		

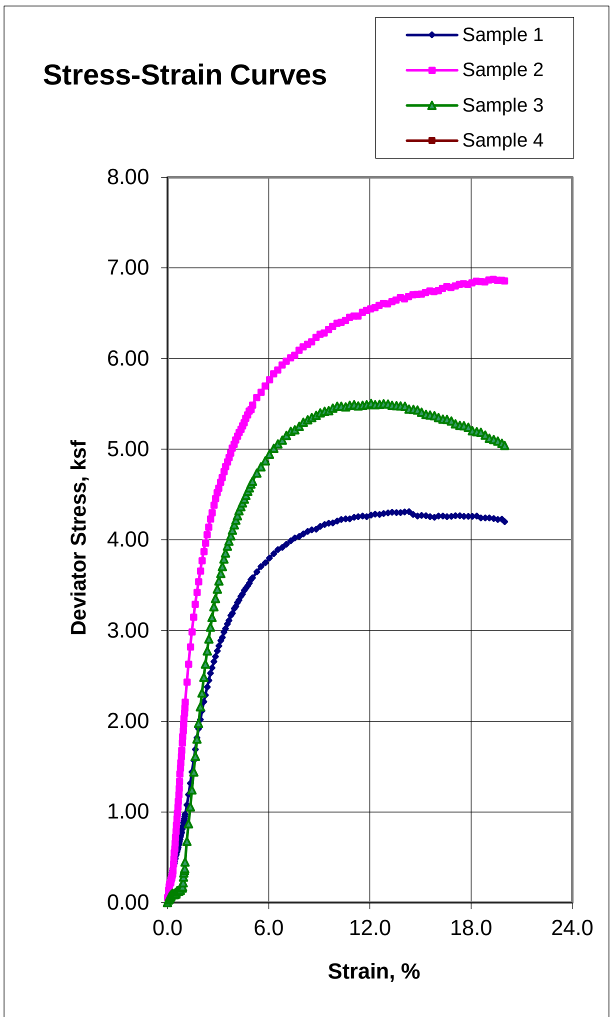
Remarks: Sample 3- slickensided @ failure (shear).

COOPER TESTING LABORATORY

Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data				
	1	2	3	4
Moisture %	28.7	20.1	26.5	
Dry Den,pcf	94.4	109.1	98.9	
Void Ratio	0.785	0.544	0.737	
Saturation %	98.6	99.9	99.0	
Height in	5.00	5.05	5.02	
Diameter in	2.40	2.39	2.39	
Cell psi	10.4	13.8	20.8	
Strain %	14.32	15.00	12.06	
Deviator, ksf	4.314	6.710	5.508	
Rate %/min	1.00	1.00	1.00	
in/min	0.050	0.050	0.050	
Job No.:	**208-040**			
Client:	**GTC**			
Project:	**SVCW Tunnel - SF14014A**			
Boring:	B-107	B-107	B-107	
Sample:				
Depth ft:	26-26.5	36-36.5	48.5-49	

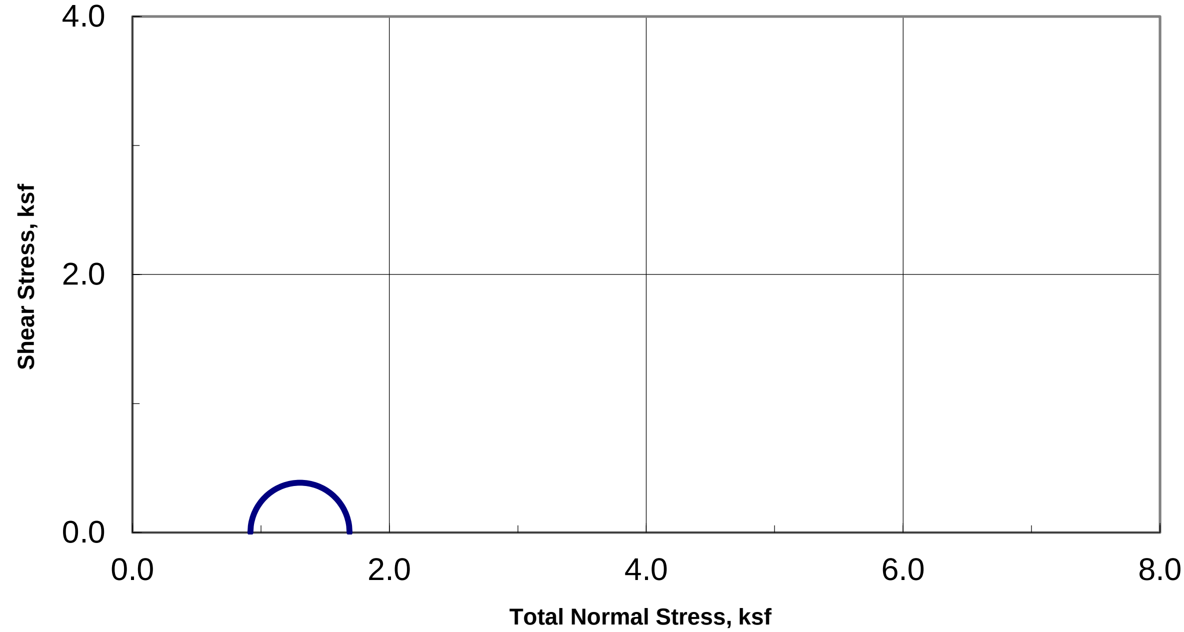
Visual Soil Description	
Sample #	
1	Light Olive Brown Fat CLAY
2	Olive Brown Lean CLAY w/ Sand
3	Dark Greenish Gray CLAY
4	

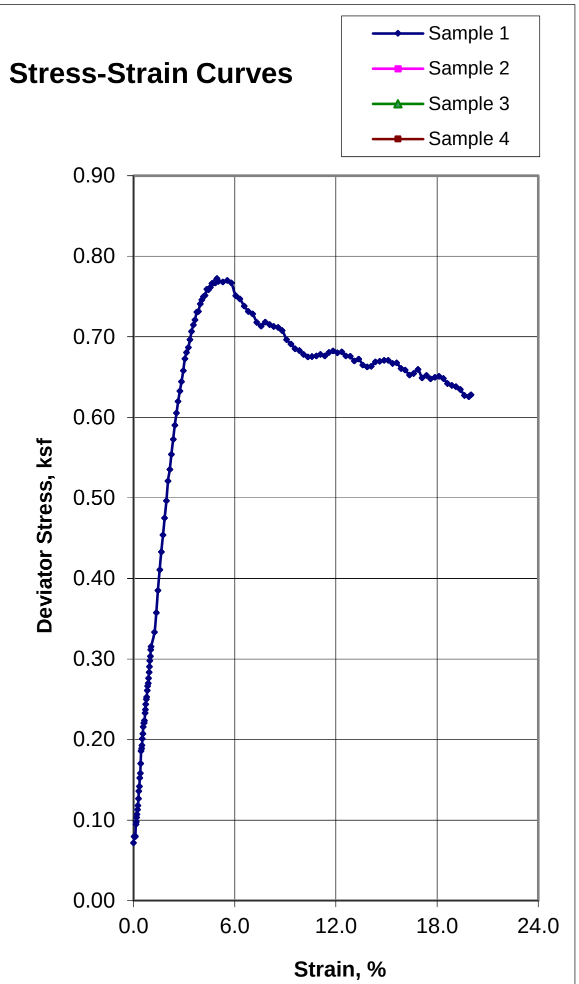
Remarks:

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

Cooper Testing Labs, Inc.
937 Commercial Street
Palo Alto, CA 94303

Unconsolidated-Undrained Triaxial Test
ASTM D2850





Sample Data				
	1	2	3	4
Moisture %	82.2			
Dry Den,pcf	51.2			
Void Ratio	2.291			
Saturation %	96.9			
Height in	6.09			
Diameter in	2.88			
Cell psi	6.4			
Strain %	4.95			
Deviator, ksf	0.772			
Rate %/min	1.04			
in/min	0.064			
Job No.:	**836-002**			
Client:	**DCM Consulting, Inc.**			
Project:	**SVCW Headworks**			
Boring:	B-101			
Sample:				
Depth ft:	25-28(Tip-6.5")			

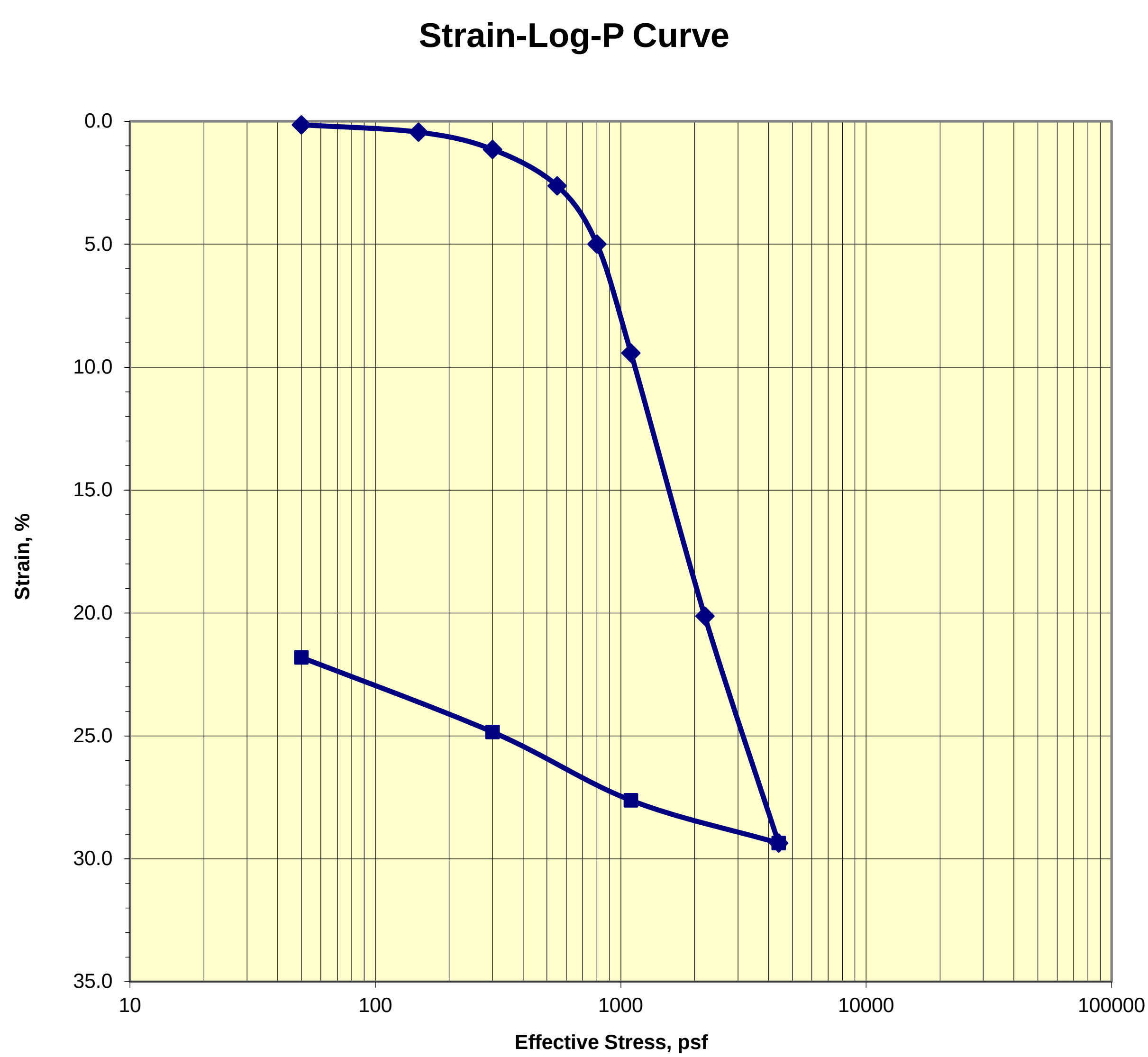
Visual Soil Description	
Sample #	
1	Greenish Gray Elastic SILT (Bay Mud)
2	
3	
4	

Remarks:

Note: Strengths are picked at the peak deviator stress or 15% strain which ever occurs first per ASTM D2850.

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	10-13(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Fat CLAY (Bay Mud)			**Date:**	10/16/2015

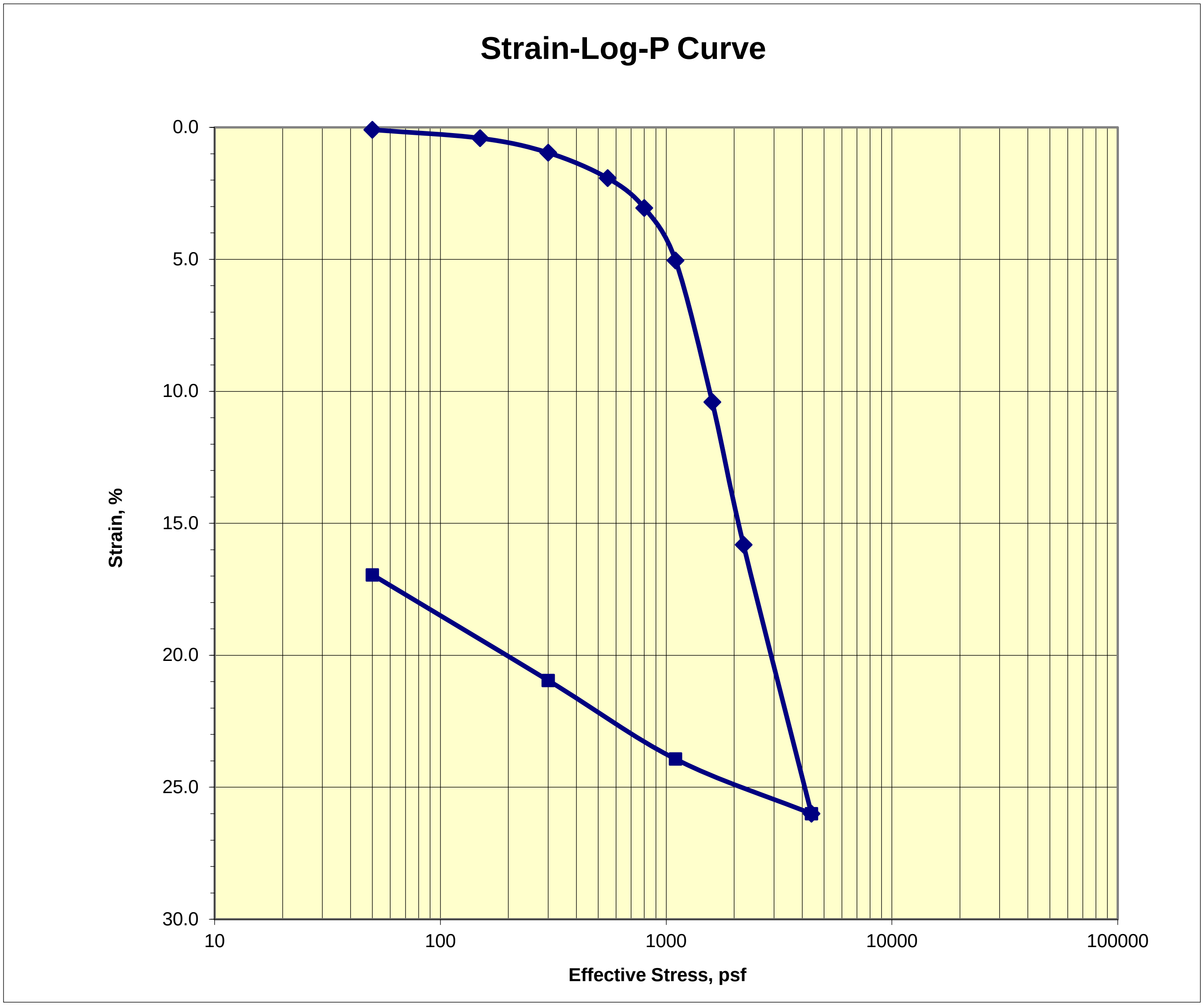


Assumed Gs 2.7	Initial	Final
Moisture %:	97.6	68.5
Dry Density, pcf:	45.8	59.1
Void Ratio:	2.680	1.850
% Saturation:	98.4	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	25-28(Tip-6")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Elastic SILT (Bay Mud)			**Date:**	10/20/2015



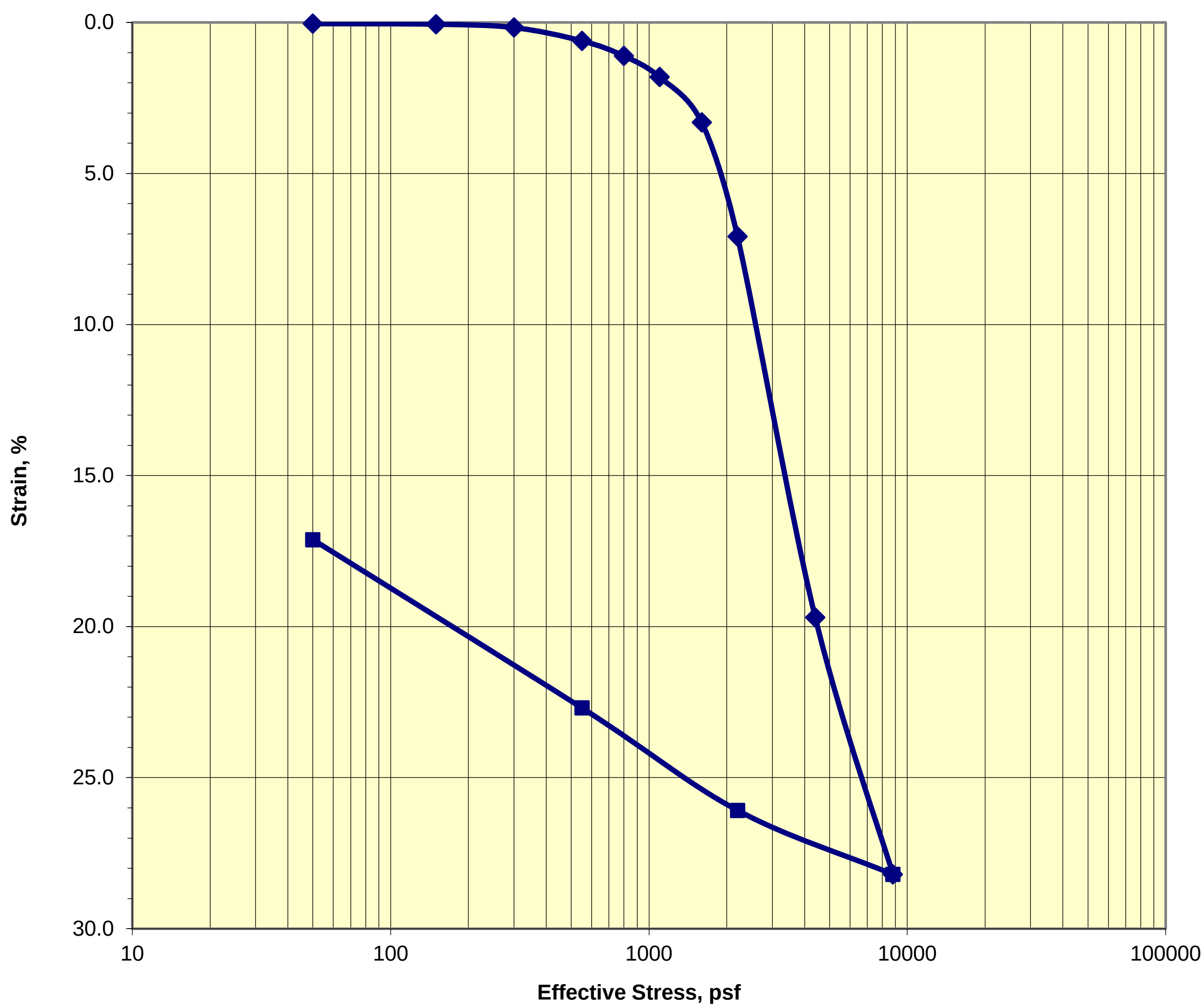
Assumed Gs 2.65	Initial	Final
Moisture %:	92.2	69.8
Dry Density, pcf:	47.8	58.0
Void Ratio:	2.462	1.851
% Saturation:	99.3	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	836-002	**Boring:**	B-101	**Run By:**	MD
Client:	DCM Consulting, Inc.	**Sample:**		**Reduced:**	PJ
Project:	SVCW Headworks	**Depth, ft.:**	40-43(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Fat CLAY (Bay Mud)			**Date:**	10/20/2015

Strain-Log-P Curve

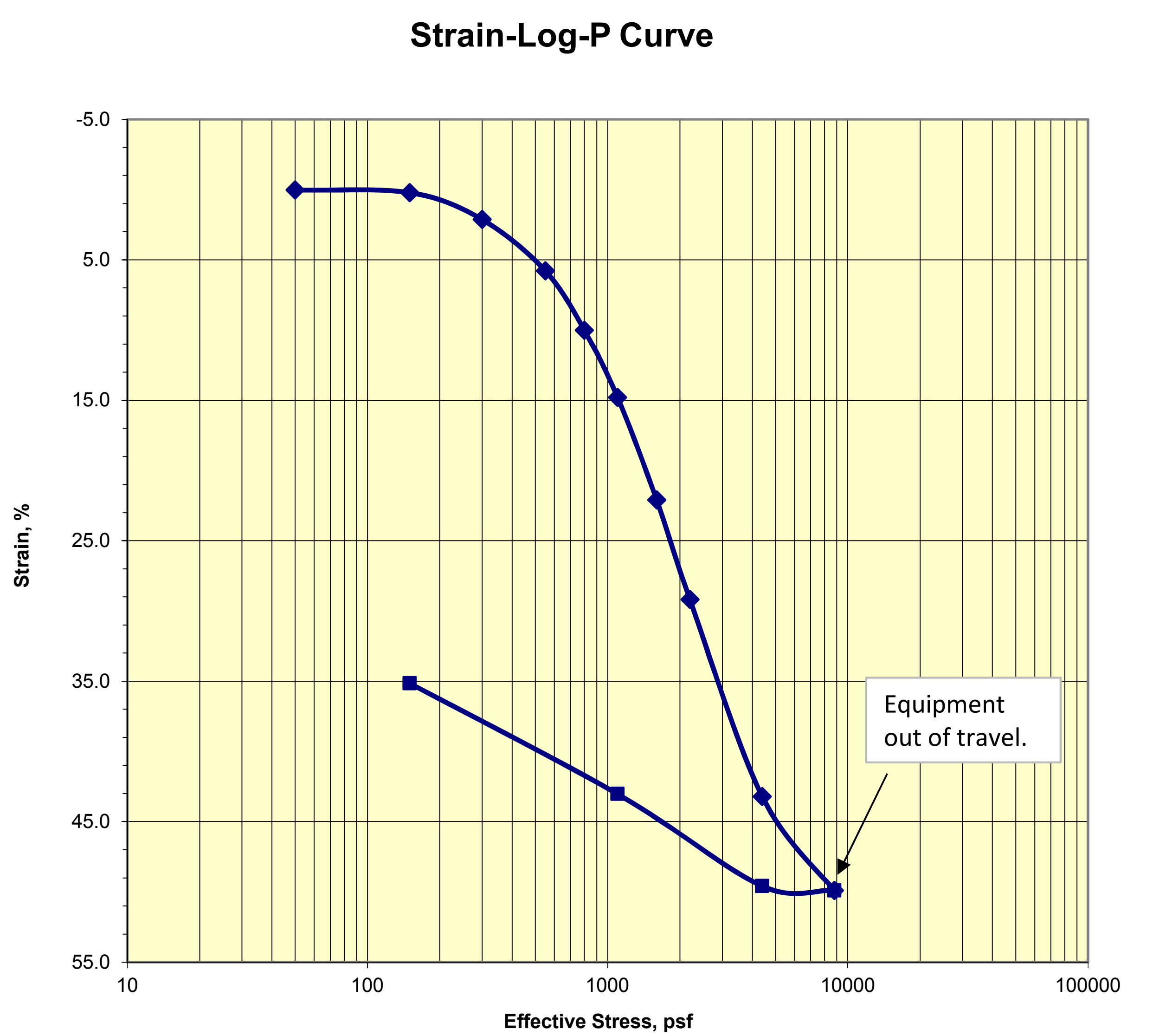


Assumed Gs 2.7	Initial	Final
Moisture %:	85.2	63.8
Dry Density, pcf:	50.9	61.9
Void Ratio:	2.314	1.724
% Saturation:	99.4	100.0

Remarks:

Consolidation Test
ASTM D2435

Job No.:	208-045	**Boring:**	B-106	**Run By:**	MD
Client:	GTC	**Sample:**		**Reduced:**	PJ
Project:	SF14014A	**Depth, ft.:**	6.5-9(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Organic CLAY (Bay Mud)			**Date:**	12/7/2015

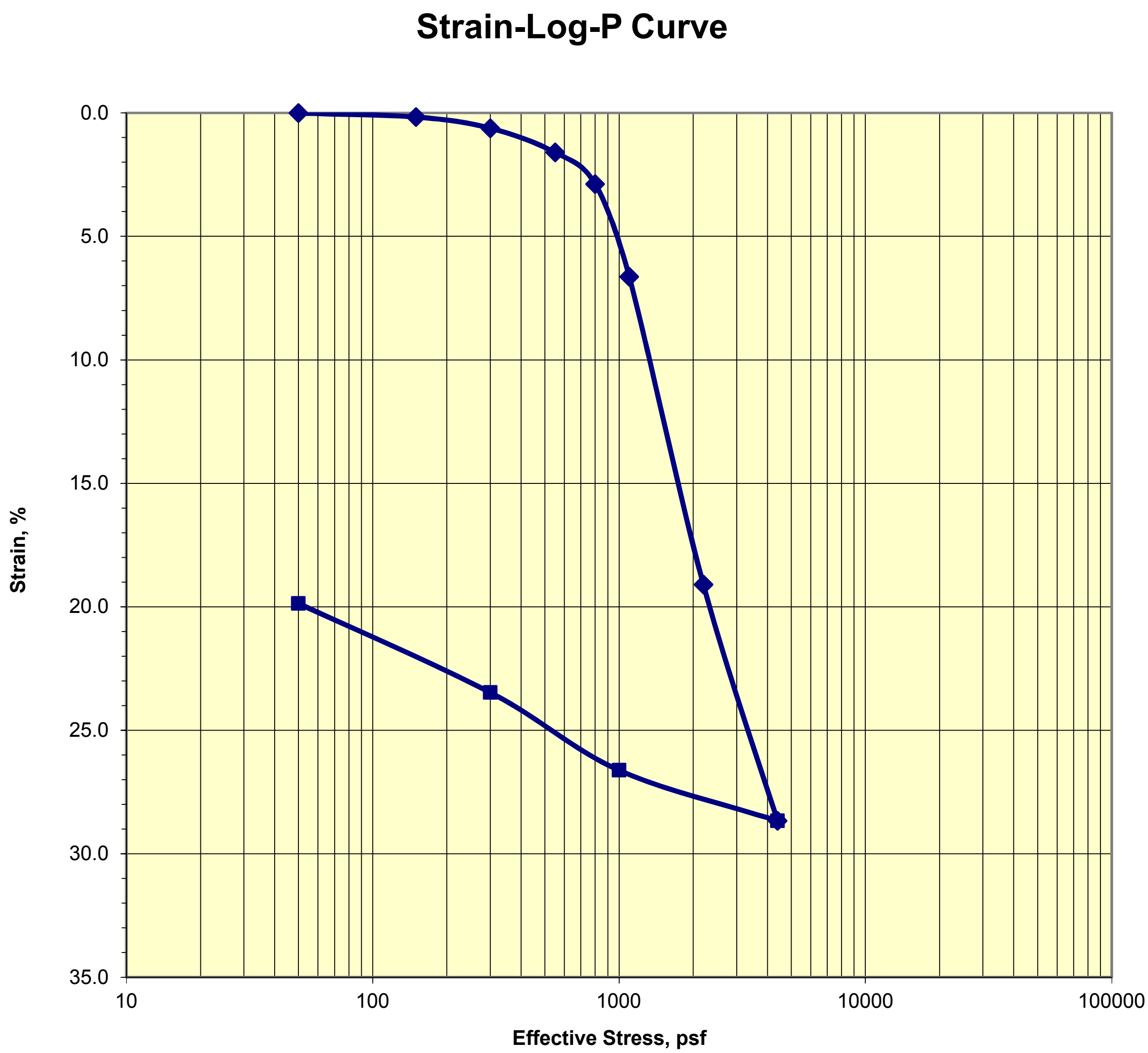


Assumed Gs 2.6	Initial	Final
Moisture %:	281.0	171.3
Dry Density, pcf:	18.5	29.8
Void Ratio:	7.759	4.455
% Saturation:	94.2	100.0

Remarks: The equipment ran out of travel on the 8800psf load.

Consolidation Test
ASTM D2435

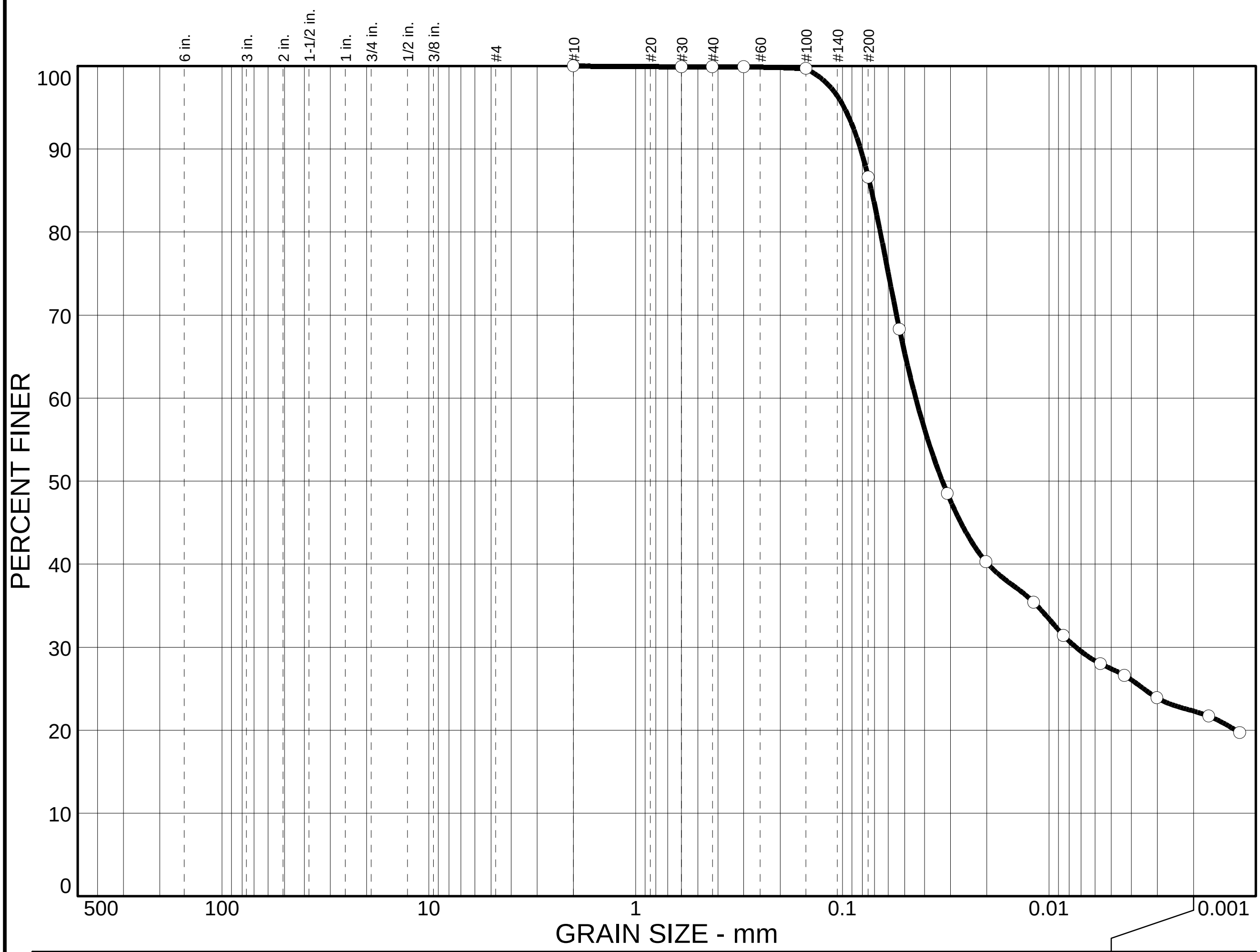
Job No.:	208-045	**Boring:**	B-114P	**Run By:**	MD
Client:	GTC	**Sample:**		**Reduced:**	PJ
Project:	SF14014A	**Depth, ft.:**	10-12.5(Tip-4")	**Checked:**	PJ/DC
Soil Type:	Greenish Gray Elastic SILT (Bay Mud)			**Date:**	12/7/2015



Assumed Gs 2.65	Initial	Final
Moisture %:	104.6	75.7
Dry Density, pcf:	43.6	55.0
Void Ratio:	2.797	2.005
% Saturation:	99.1	100.0

Remarks:

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	13.4	64.3	22.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.9		
#40	99.9		
#50	99.9		
#100	99.7		
#200	86.6		
#270	68.3		
0.0311 mm.	48.5		
0.0202 mm.	40.3		
0.0119 mm.	35.4		
0.0085 mm.	31.4		
0.0056 mm.	28.0		
0.0043 mm.	26.6		
0.0030 mm.	23.9		
0.0017 mm.	21.7		
0.0012 mm.	19.7		

* (no specification provided)

Soil Description

Olive Brown Lean CLAY

Atterberg Limits

PL= 19 LL= 30 PI= 11

Coefficients

D_{85}= 0.0724 D_{60}= 0.0442 D_{50}= 0.0329
D_{30}= 0.0074 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO=

Remarks

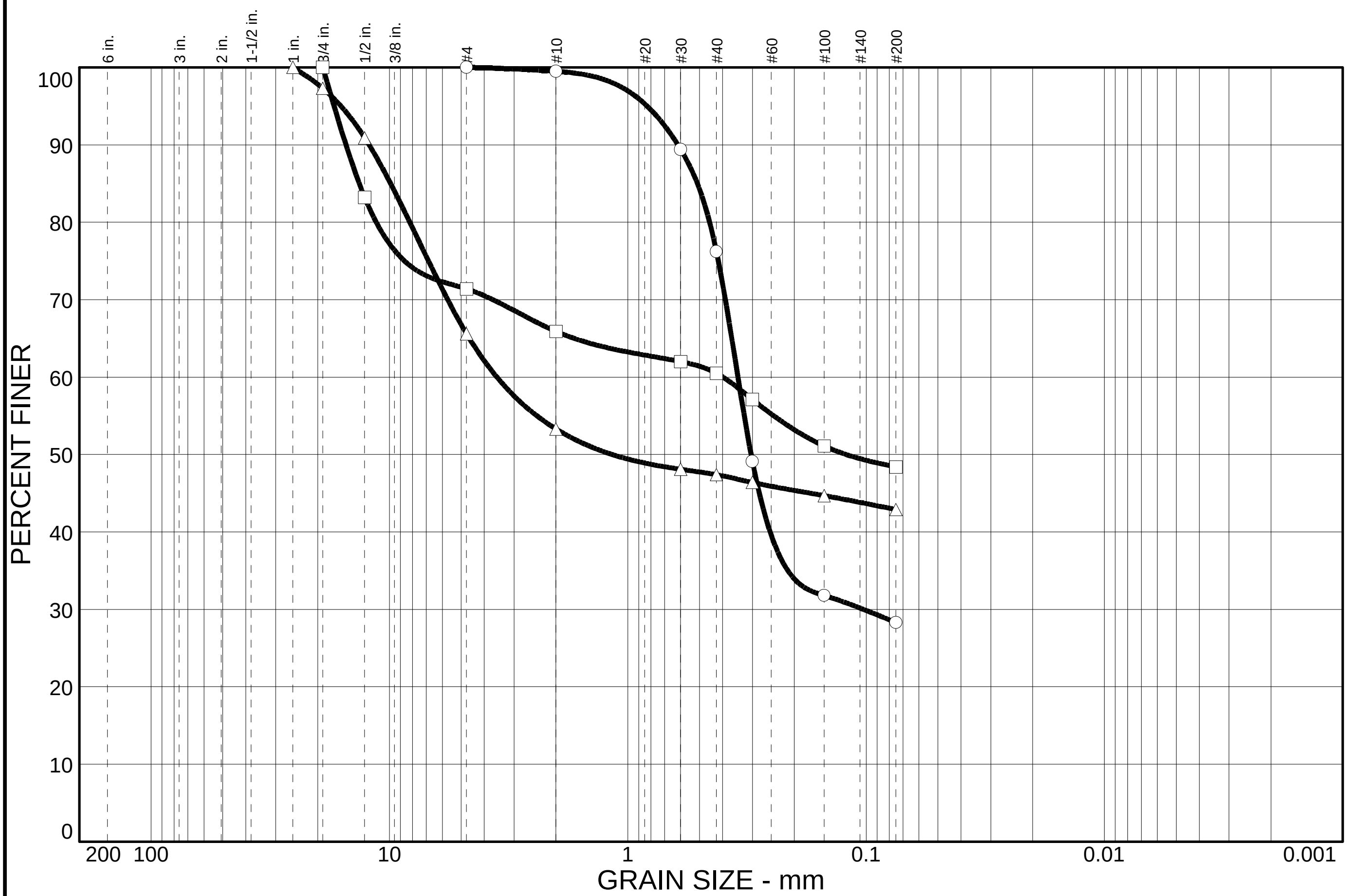
Sample No.: **Source of Sample:** B-101 **Date:** 10/16/15
Location: **Elev./Depth:** 60-63'

COOPER TESTING LABORATORY

Client: DCM Consulting, Inc.
Project: SVCW Headworks

Project No: 836-002 **Figure**

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			71.7	28.3					
□		28.6	23.0	48.4					
△		34.4	22.7	42.9					

SIEVE inches size	PERCENT FINER ○	□	△
1"			100.0
3/4"		100.0	97.3
1/2"		83.2	90.9
GRAIN SIZE			
D_{60}	0.345	0.399	3.54
D_{30}	0.103		
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	100.0	71.4	65.6
#10	99.5	65.9	53.3
#30	89.4	62.0	48.1
#40	76.2	60.5	47.4
#50	49.1	57.1	46.4
#100	31.8	51.1	44.7
#200	28.3	48.4	42.9

SOIL DESCRIPTION

○ Olive Brown Clayey SAND

□ Dark Greenish Gray Clayey GRAVEL w/ Sand

△ Dark Greenish Gray Clayey GRAVEL w/ Sand

REMARKS:

○

□

△

○ Source: B-102 Elev./Depth: 61-61.5'

□ Source: B-103 Elev./Depth: 63.5-64'

△ Source: B-103 Elev./Depth: 66-66.5'

COOPER TESTING LABORATORY

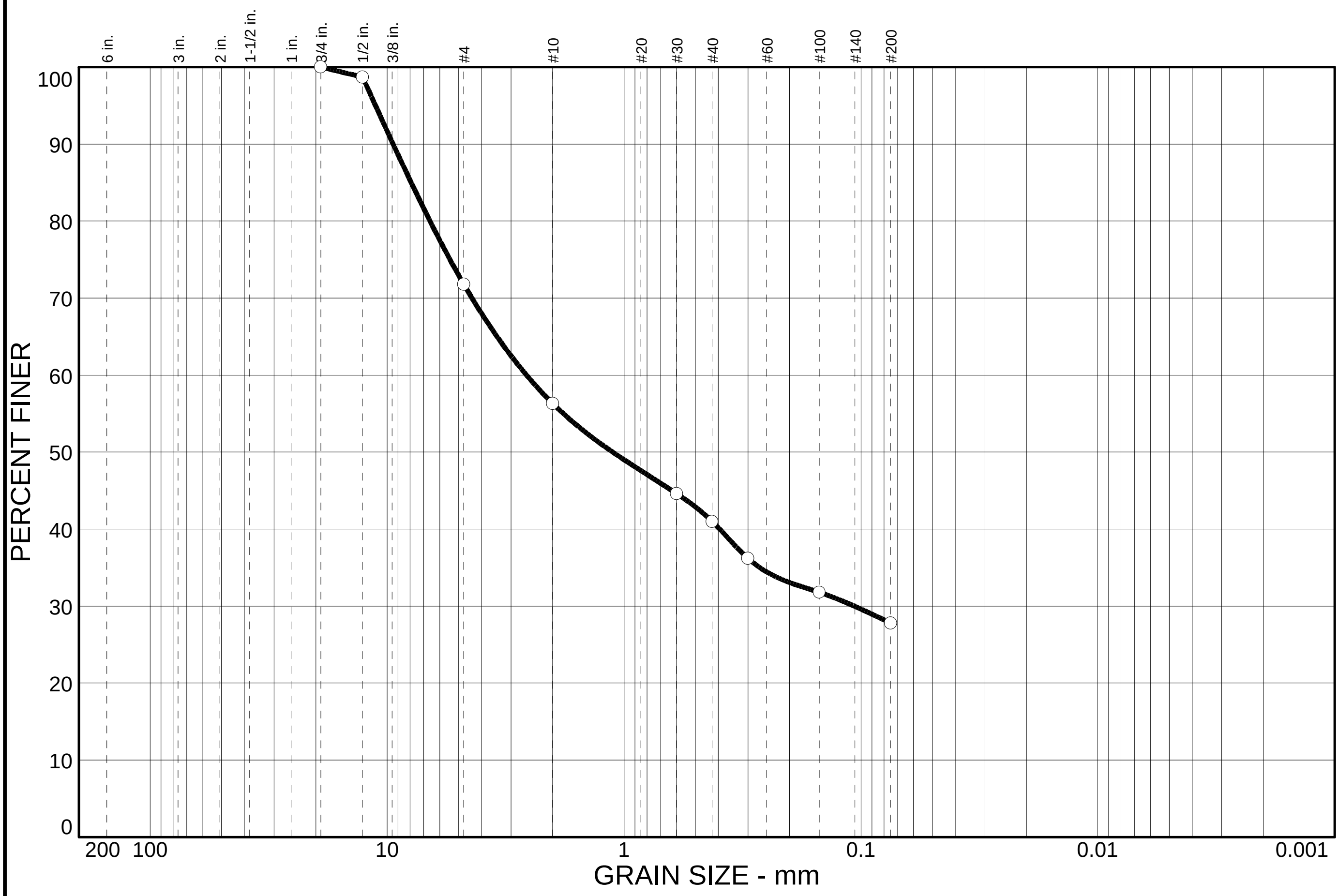
Client: GTC

Project: SVCW Tunnel - SF14014A

Project No.: 208-036

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		28.2	44.0	27.8					

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
1/2"	98.7		
	GRAIN SIZE		
D_{60}	2.58		
D_{30}	0.107		
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○		
#4	71.8		
#10	56.3		
#30	44.6		
#40	41.0		
#50	36.2		
#100	31.8		
#200	27.8		

SOIL DESCRIPTION

○ Greenish Gray Clayey SAND w/ Gravel

REMARKS:

○

○ Source: B-105

Elev./Depth: 31-31.5'

COOPER TESTING LABORATORY

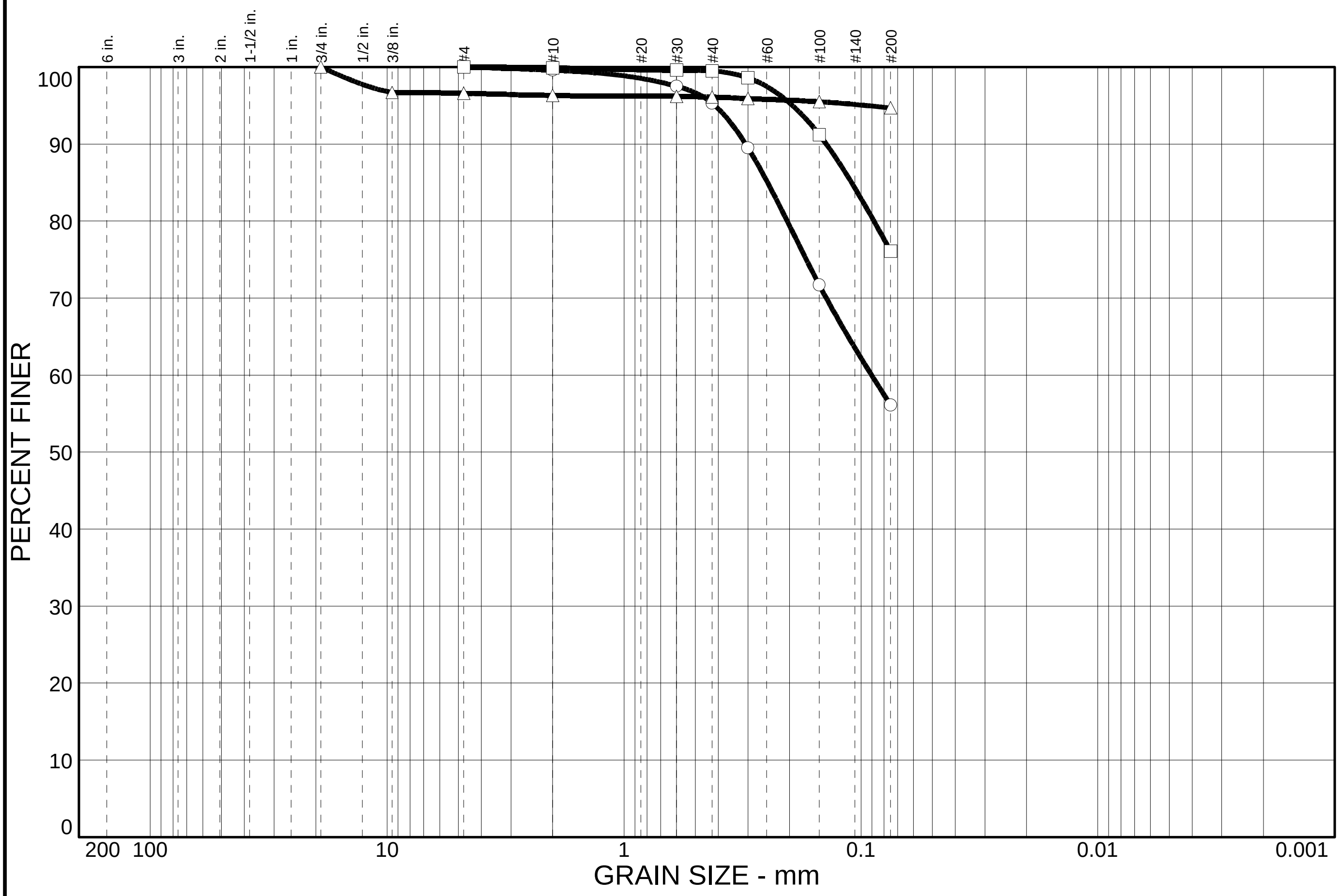
Client: GTC

Project: SVCW Tunnel - SF14014A

Project No.: 208-036

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			43.9	56.1		CL		15	32
□			23.9	76.1		CL		16	35
△		3.4	1.9	94.7		CH		20	57

SIEVE inches size	PERCENT FINER ○	□	△
3/4"			100.0
3/8"			96.7

GRAIN SIZE	○	□	△
D_{60}	0.0902		
D_{30}			
D_{10}			

COEFFICIENTS	○	□	△
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	100.0	100.0	96.6
#10	99.6	99.9	96.3
#30	97.5	99.6	96.2
#40	95.3	99.5	96.1
#50	89.5	98.6	95.9
#100	71.7	91.2	95.5
#200	56.1	76.1	94.7

SOIL DESCRIPTION

○ Olive Gray Sandy Lean CLAY

□ Dark Gray Lean CLAY w/ Sand

△ Olive Gray Sandy Fat CLAY

REMARKS:

○

□

△

○ Source: B-106 Elev./Depth: 19-19.5'

□ Source: B-106 Elev./Depth: 29-29.5'

△ Source: B-106 Elev./Depth: 38.5-39'

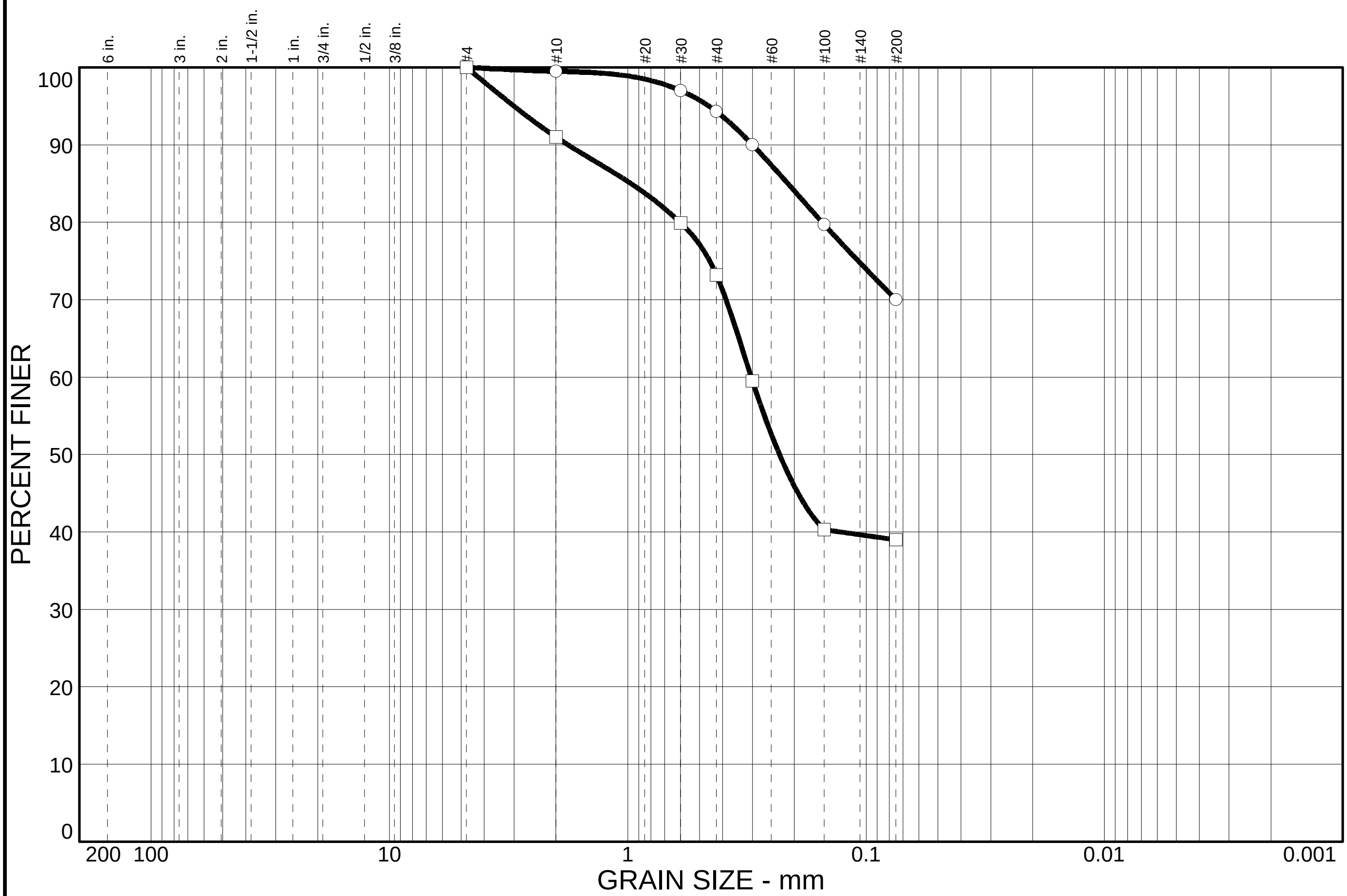
COOPER TESTING LABORATORY

Client: GTC

Project: SVCW - SF14014A

Project No.: 208-045 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			30.0	70.0					
□			61.0	39.0					

SIEVE inches size	PERCENT FINER ○	□	

	GRAIN SIZE		
D_{60}		0.304	
D_{30}			
D_{10}			

	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	
#4	100.0	100.0	
#10	99.5	91.0	
#30	97.0	79.9	
#40	94.3	73.2	
#50	90.0	59.5	
#100	79.7	40.3	
#200	70.0	39.0	

SOIL DESCRIPTION

○ Olive Brown Sandy CLAY

□ Olive Brown Clayey SAND

REMARKS:

○

□

○ Source: B-107 Elev./Depth: 61-61.5'

□ Source: B-107 Elev./Depth: 66.5-67'

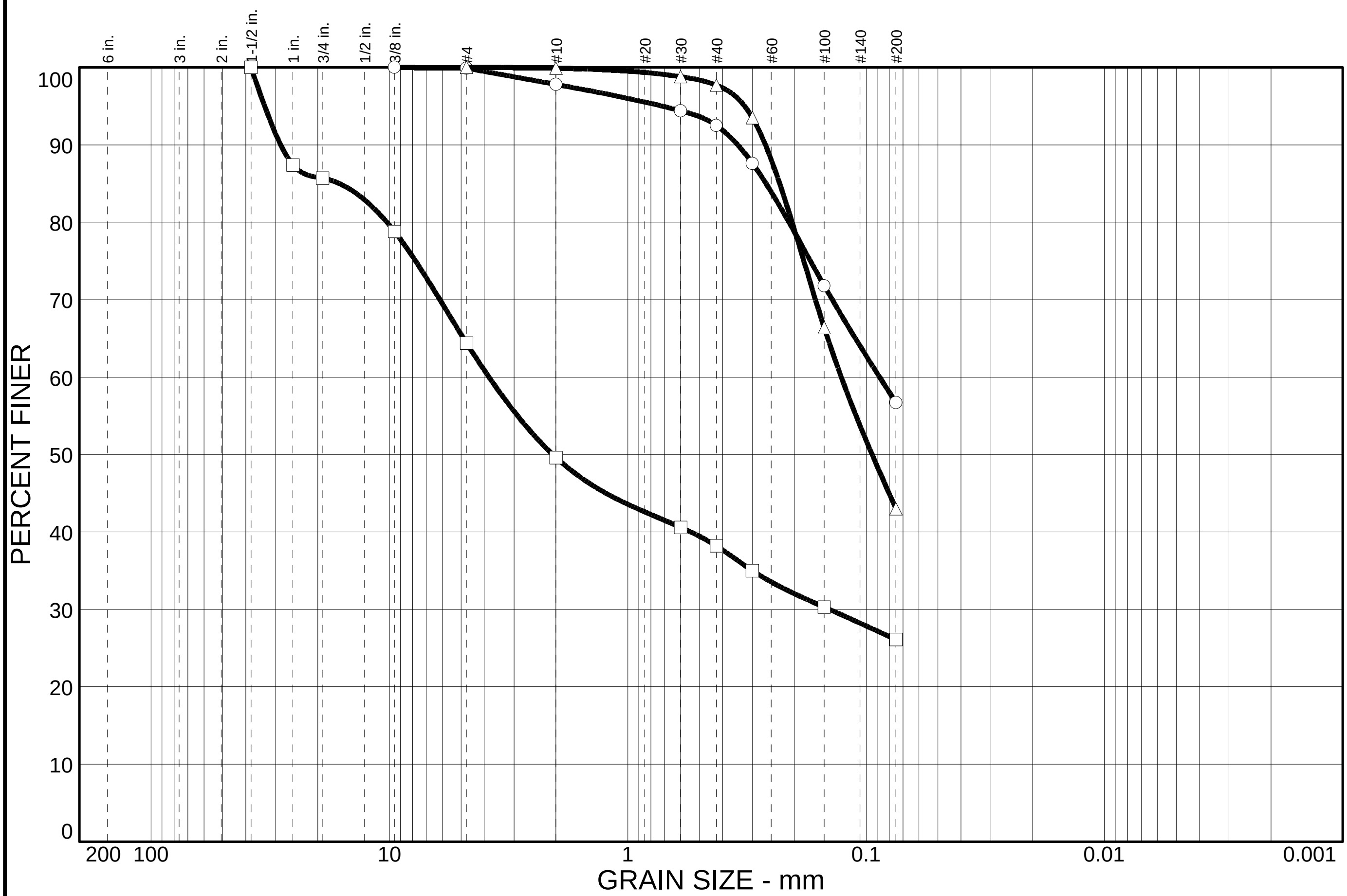
COOPER TESTING LABORATORY

Client: GTC

Project: SVCW Tunnel - SF14014A

Project No.: 208-040 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		0.1	43.2	56.7		CL		17	28
□		35.6	38.3	26.1					
△			57.0	43.0					

SIEVE inches size	PERCENT FINER ○	□	△
1.5"		100.0	
1"		87.4	
3/4"		85.7	
3/8"	100.0	78.8	
GRAIN SIZE			
D_{60}	0.0878	3.83	0.127
D_{30}		0.143	
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	99.9	64.4	100.0
#10	97.8	49.6	99.9
#30	94.4	40.6	98.8
#40	92.5	38.2	97.7
#50	87.6	35.0	93.5
#100	71.8	30.3	66.4
#200	56.7	26.1	43.0

SOIL DESCRIPTION

○ Olive Gray Sandy Lean CLAY

□ Yellowish Brown Clayey SAND w/ Gravel

△ Olive Clayey SAND

REMARKS:

○

□ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

△

○ Source: B-106 Elev./Depth: 78.5-79'

□ Source: B-108 Elev./Depth: 5.5-6'

△ Source: B-108 Elev./Depth: 24-24.5'

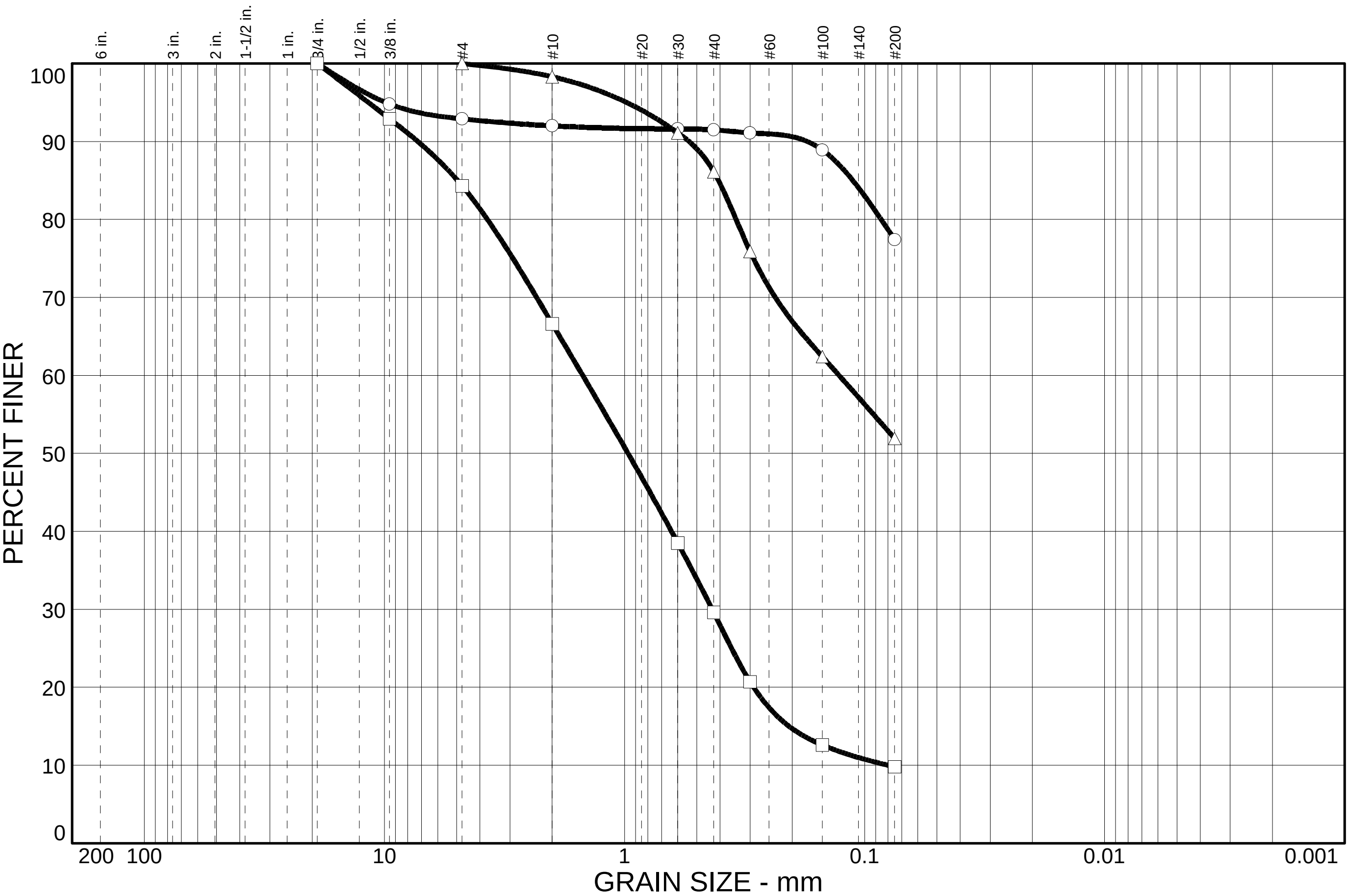
COOPER TESTING LABORATORY

Client: GTC

Project: SVCW - SF14014A

Project No.: 208-045 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		7.1	15.5	77.4					
□		15.7	74.5	9.8					
△			48.1	51.9					

SIEVE inches size	PERCENT FINER ○	□	△
3/4"	100.0	100.0	
3/8"	94.8	92.9	
	GRAIN SIZE		
D_{60}		1.49	0.128
D_{30}		0.431	
D_{10}		0.0797	
	COEFFICIENTS		
C_c		1.56	
C_u		18.74	

SIEVE number size	PERCENT FINER ○	□	△
#4	92.9	84.3	100.0
#10	92.0	66.6	98.3
#30	91.6	38.5	91.1
#40	91.5	29.6	86.1
#50	91.1	20.7	75.9
#100	88.9	12.6	62.4
#200	77.4	9.8	51.9

SOIL DESCRIPTION

○ Yellowish Brown CLAY w/ Sand

□ Olive Brown Well-Graded SAND w/ Clay & Gravel

△ Olive Gray Sandy CLAY

REMARKS:

○ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

□ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

△

○ Source: B-108 Elev./Depth: 34-34.5'

□ Source: B-108 Elev./Depth: 44-44.5'

△ Source: B-108 Elev./Depth: 69-69.5'

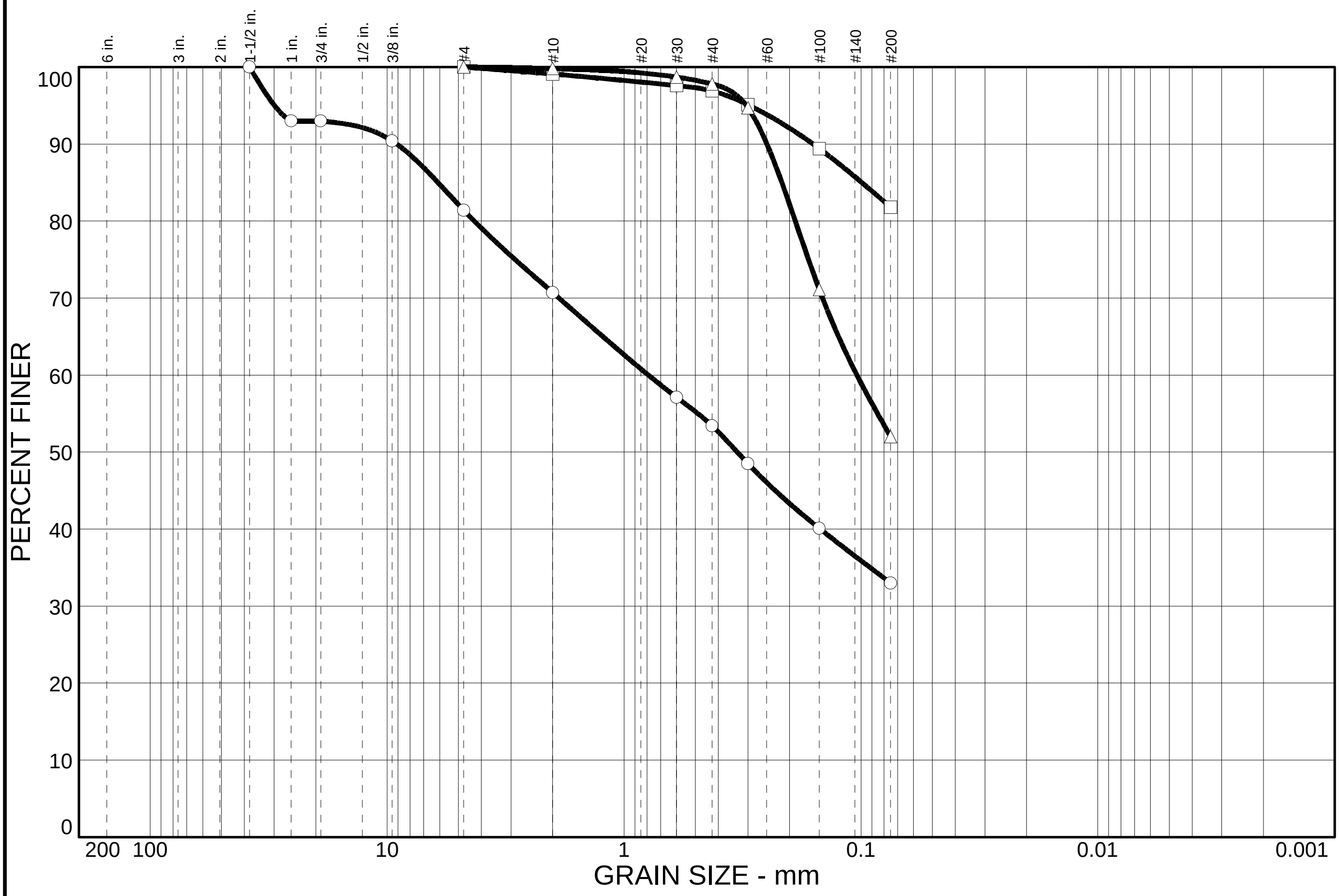
COOPER TESTING LABORATORY

Client: GTC

Project: SVCW - SF14014A

Project No.: 208-045 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		18.6	48.4	33.0					
□			18.2	81.8		CL		17	44
△			48.0	52.0					

SIEVE inches size	PERCENT FINER ○	□	△
1.5"	100.0		
1"	93.0		
3/4"	93.0		
3/8"	90.4		
	GRAIN SIZE		
D_{60}	0.790		0.104
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	81.4	100.0	100.0
#10	70.7	99.1	99.8
#30	57.1	97.6	98.7
#40	53.4	96.9	97.8
#50	48.5	95.1	94.7
#100	40.1	89.4	71.1
#200	33.0	81.8	52.0

SOIL DESCRIPTION

○ Dark Olive Brown Clayey SAND w/ Gravel

□ Olive Brown Lean CLAY w/ Sand & CaCO3

△ Olive Sandy CLAY

REMARKS:

○ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

□

△

○ Source: B-110 Elev./Depth: 5.5-6'

□ Source: B-110 Elev./Depth: 24-24.5'

△ Source: B-110 Elev./Depth: 33.5-34'

COOPER TESTING LABORATORY

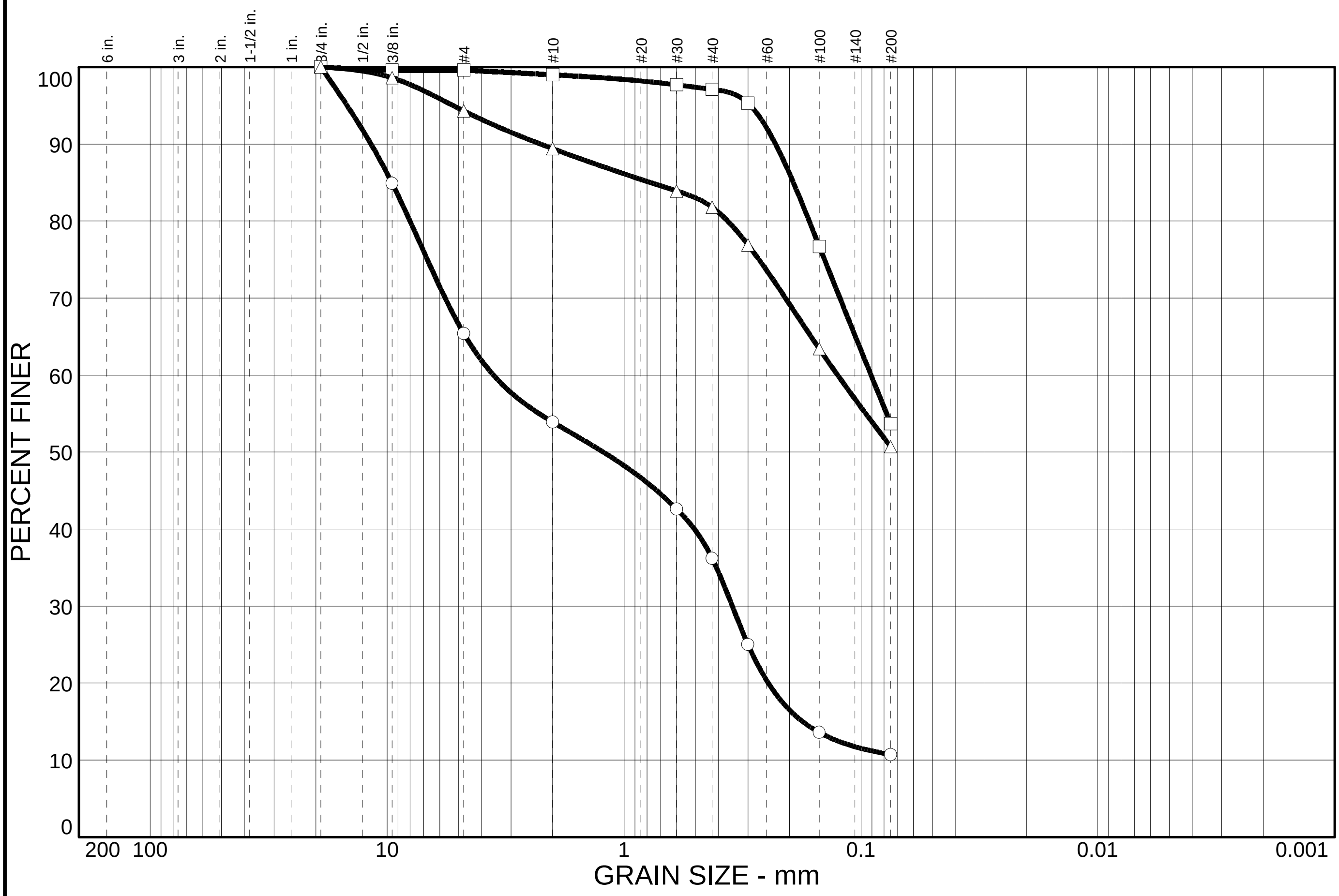
Client: GTC

Project: SVCW - SF14014A

Project No.: 208-045

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		34.6	54.7	10.7					
□		0.4	45.9	53.7					
△		5.7	43.6	50.7					

SIEVE inches size	PERCENT FINER ○	□	△
3/4"	100.0	100.0	100.0
3/8"	84.9	99.6	98.6
	GRAIN SIZE		
D_{60}	3.56	0.0908	0.126
D_{30}	0.349		
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	65.4	99.6	94.3
#10	53.9	99.0	89.4
#30	42.6	97.7	83.9
#40	36.2	97.1	81.8
#50	25.0	95.3	76.9
#100	13.6	76.7	63.4
#200	10.7	53.7	50.7

SOIL DESCRIPTION

○ Olive Poorly Graded SAND w/ Clay & Gravel

□ Olive Sandy CLAY

△ Olive Sandy CLAY

REMARKS:

○

□

△

○ Source: B-112 P-5 Elev./Depth: 24-24.5'

□ Source: B-112 P-5 Elev./Depth: 25-26.5'

△ Source: B-112 P-5 Elev./Depth: 28-29.5'

COOPER TESTING LABORATORY

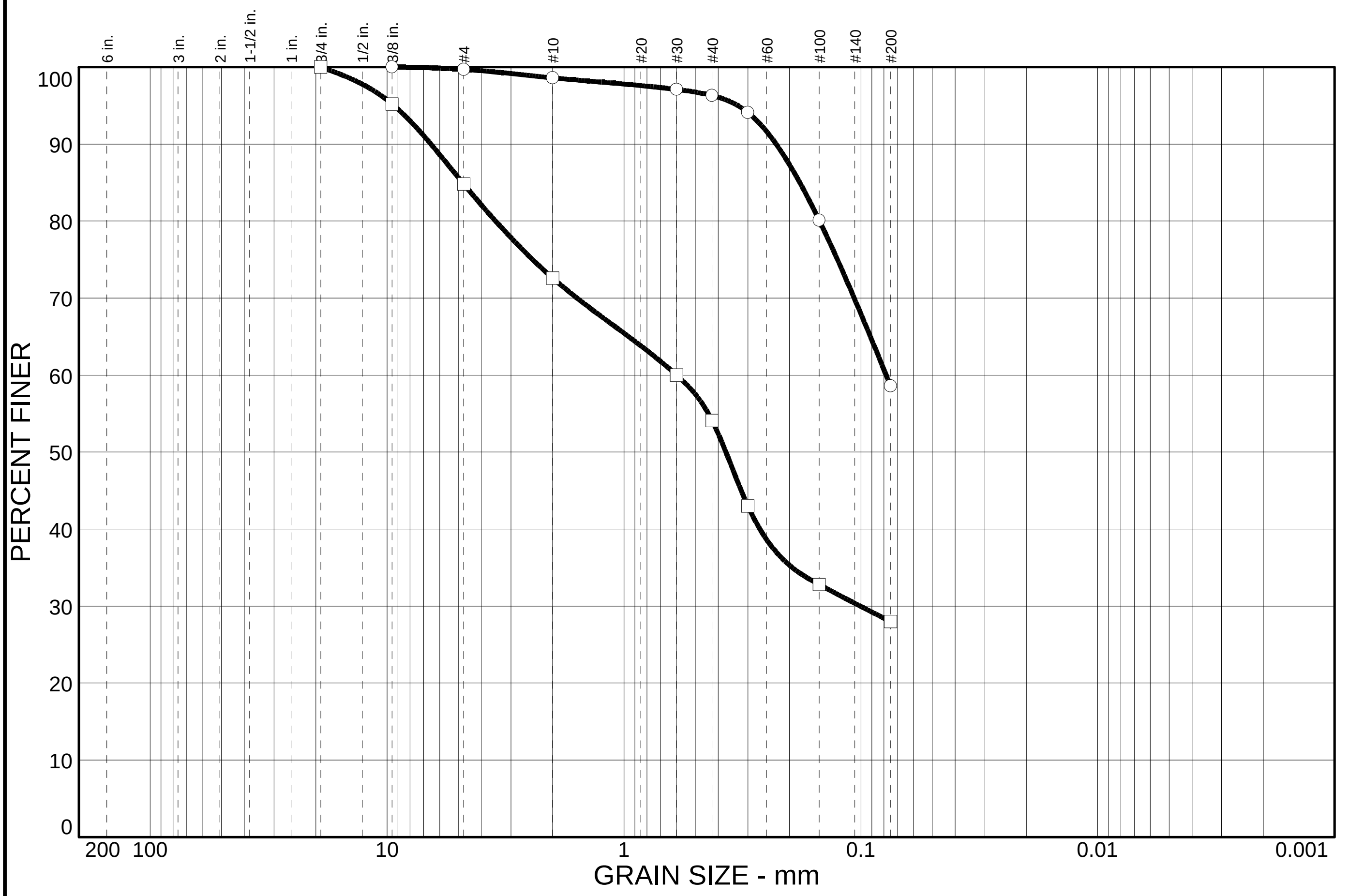
Client: GTC

Project: SVCW - SF14014A

Project No.: 208-045

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		0.3	41.1	58.6					
□		15.2	56.8	28.0					

SIEVE inches size	PERCENT FINER ○	□	
3/4"		100.0	
3/8"	100.0	95.2	
	GRAIN SIZE		
D_{60}	0.0783	0.600	
D_{30}		0.101	
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	
#4	99.7	84.8	
#10	98.6	72.6	
#30	97.1	60.0	
#40	96.3	54.1	
#50	94.1	43.0	
#100	80.1	32.8	
#200	58.6	28.0	

SOIL DESCRIPTION

○ Olive Sandy CLAY

□ Olive Brown Clayey SAND w/ Gravel

REMARKS:

○

□

○ Source: B-112 P-D Elev./Depth: 29-29.5'

□ Source: B-112 P-D Elev./Depth: 48-49.5'

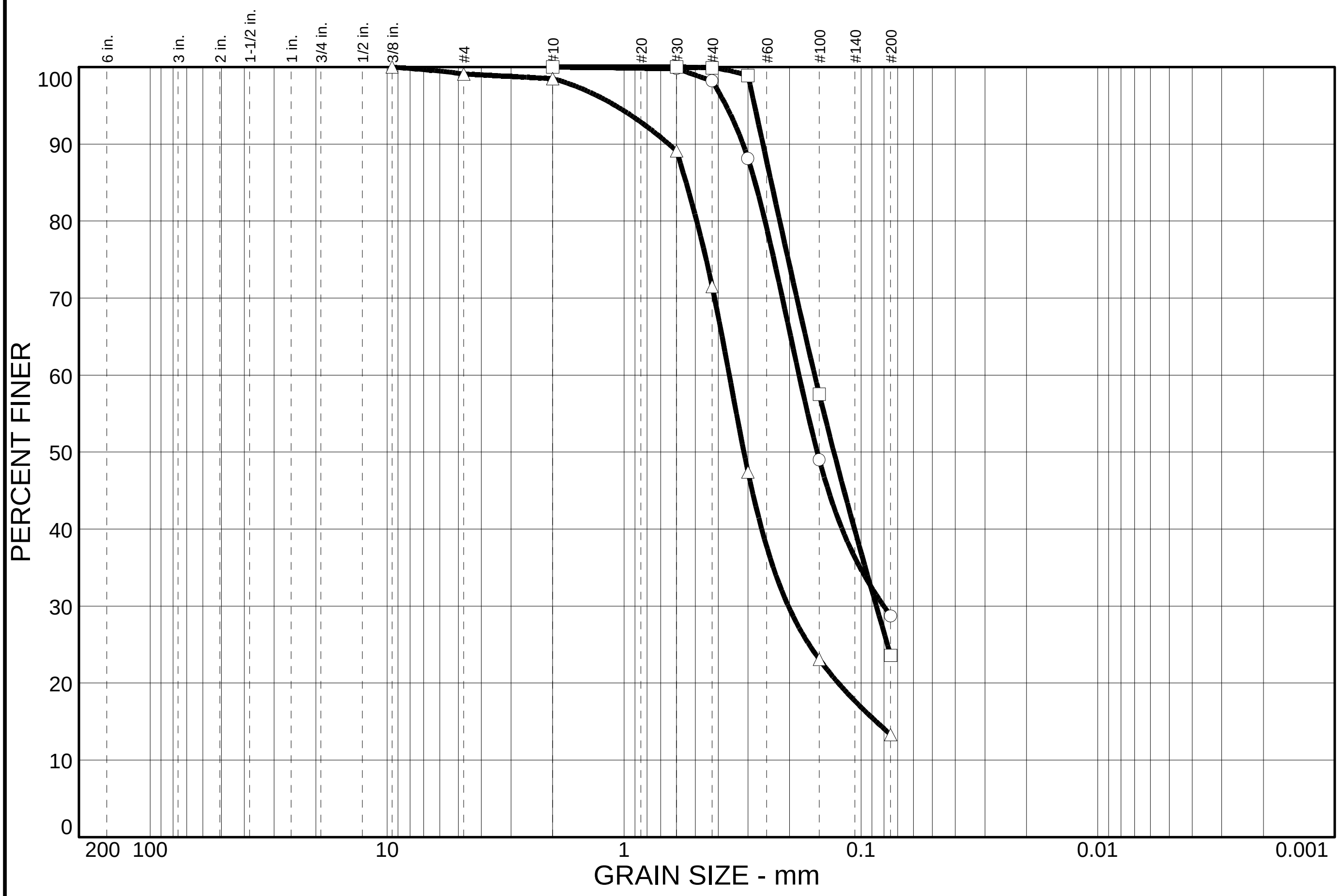
COOPER TESTING LABORATORY

Client: GTC

Project: SVCW - SF14014A

Project No.: 208-045 Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○			71.3	28.7					
□			76.4	23.6					
△		0.9	85.8	13.3					

SIEVE inches size	PERCENT FINER ○	□	△
3/8"			100.0

	GRAIN SIZE ○	□	△
D_{60}	0.183	0.157	0.360
D_{30}	0.0802	0.0862	0.203
D_{10}			

	COEFFICIENTS ○	□	△
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4			99.1
#10	100.0	100.0	98.5
#30	99.8	100.0	89.1
#40	98.2	99.9	71.5
#50	88.1	98.9	47.4
#100	49.0	57.5	23.1
#200	28.7	23.6	13.3

SOIL DESCRIPTION

○ Olive Brown Clayey SAND

□ Olive Brown Clayey SAND

△ Olive Brown Clayey SAND

REMARKS:

○

□

△

○ Source: B-114P Elev./Depth: 65-66.5'

□ Source: B-114P Elev./Depth: 70-71.5'

△ Source: B-114P Elev./Depth: 76.5-78'

COOPER TESTING LABORATORY

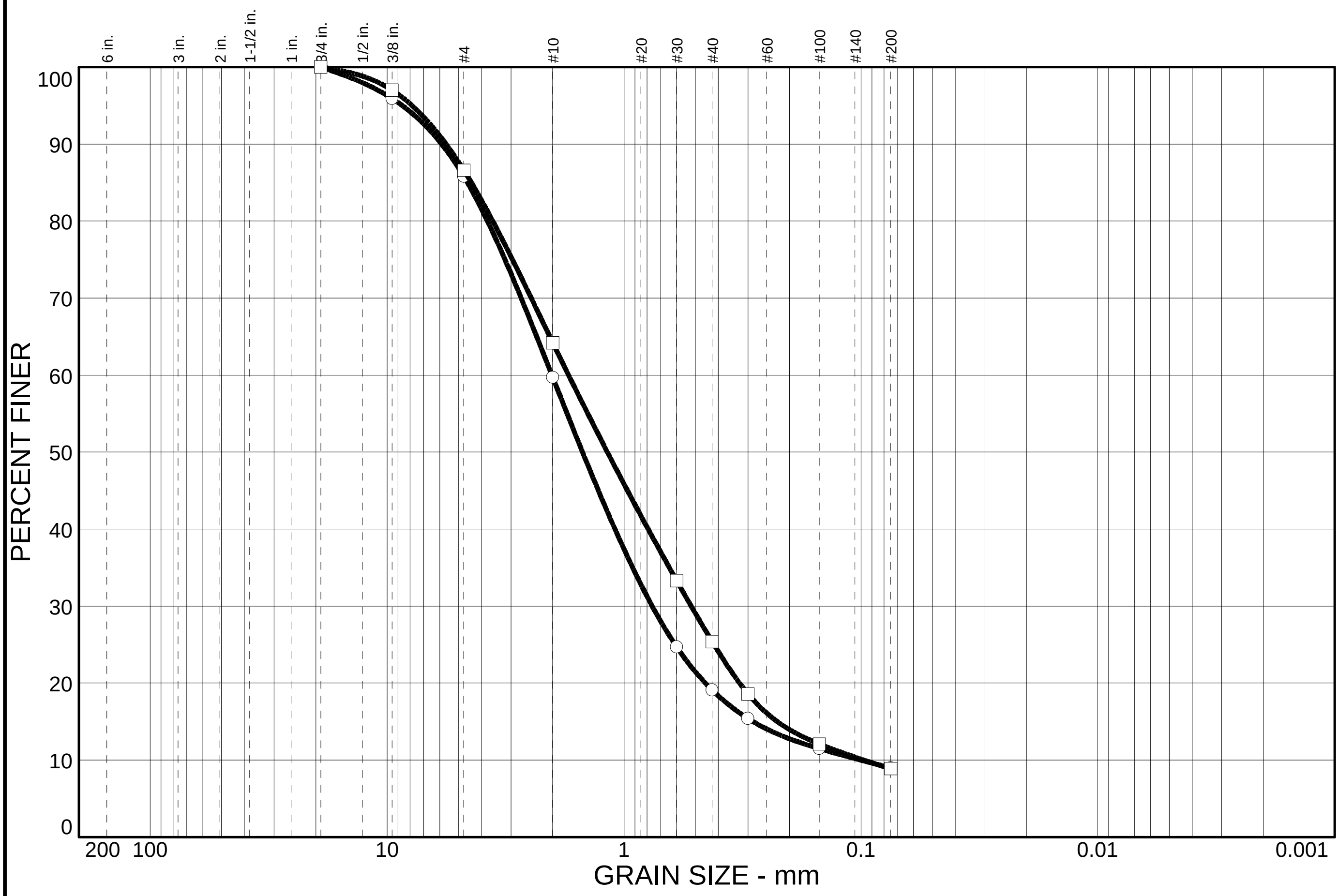
Client: GTC

Project: SVCW - SF14014

Project No.: 208-044

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		14.2	76.8	9.0					
□		13.4	77.7	8.9					

SIEVE inches size	PERCENT FINER ○	□	
3/4"	100.0	100.0	
3/8"	95.9	97.0	
	GRAIN SIZE		
D_{60}	2.02	1.72	
D_{30}	0.761	0.521	
D_{10}	0.100	0.0971	
	COEFFICIENTS		
C_c	2.87	1.63	
C_u	20.15	17.66	

SIEVE number size	PERCENT FINER ○	□	
#4	85.8	86.6	
#10	59.7	64.2	
#30	24.7	33.3	
#40	19.1	25.4	
#50	15.4	18.6	
#100	11.5	12.1	
#200	9.0	8.9	

SOIL DESCRIPTION

○ Olive Brown Well-Graded SAND w/ Clay

□ Olive Brown Well-Graded SAND w/ Clay

REMARKS:

○

□

○ Source: B-114P Elev./Depth: 80-81.5'

□ Source: B-114P Elev./Depth: 85-86.5'

COOPER TESTING LABORATORY

Client: GTC

Project: SVCW - SF14014

Project No.: 208-044

Figure

#200 Sieve Wash Analysis
ASTM D 1140

Job No.:	208-036	**Project No.:**	SF14014A	**Run By:**	MD
Client:	GTC	**Date:**	8/25/2015	**Checked By:**	DC
Project:	SVCW Tunnel				

Boring:	B-102								
Sample:									
Depth, ft.:	51-51.5								
Soil Type:	Olive Brown CLAY								
Wt of Dish & Dry Soil, gm	464.4								
Weight of Dish, gm	278.1								
Weight of Dry Soil, gm	186.3								
Wt. Ret. on #4 Sieve, gm	1.4								
Wt. Ret. on #200 Sieve, gm	5.8								
% Gravel	**0.8**								
% Sand	**2.3**								
% Silt & Clay	**96.9**								

Remarks: As an added benefit to our clients, the gravel fraction may be included in this report. Whether or not it is included is dependent upon both the technician's time available and if there is a significant enough amount of gravel. The gravel is always included in the percent retained on the #200 sieve but may not be weighed separately to determine the percentage, especially if there is only a trace amount, (5% or less).

"Preliminary Pile Foundation Design Criteria, Peak Flow Diversion Structure," January 2016, prepared by DCM Consulting, Inc

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DCM Consulting, Inc.

Technical Memorandum

P.O. Box 225, Lafayette, CA 94549, Telephone: 925.322.9590 www.dcmconsults.com

To:	Rich Laureta Freyer & Laureta	Date:	January 11, 2016
From:	Dave Mathy DCM Consulting, Inc.	File:	No. 178
Subject:	Preliminary Pile Foundation Design Criteria Peak Flow Diversion Structure Silicon Valley Clean Water Redwood City, California		

1.0 INTRODUCTION

This technical memorandum presents preliminary pile foundation design criteria for Silicon Valley Clean Water's (SVCW) peak flow diversion structure at the SVCW waste water treatment plant in Redwood City, California. The peak flow diversion structure (PFDS) will be located at the front of the treatment plant in an area presently designated as an ornamental pond. The PFDS will be a reinforced concrete tank with footprint dimensions of 330 feet long by 78 feet wide, a total height of 28 feet and a waste water storage capacity of 3 million gallons. The floor of the PFDS will be approximately 13 feet below existing site grades. The existing ground surface at the front of plant area is approximately plant Elevation 99, which puts the top of floor of the PFDS at approximately plant Elevation 86. The preliminary pile foundation design criteria presented herein is based on:

- recent CPT probes completed within the front of plant area;
- physical laboratory testing of soil samples taken from recent test borings for the Receiving Lift Station, also in the front of plant area;
- construction precedent of pile driving in 2015 for the plant's Influent Screening Facility;
- construction precedent of pile driving in 2010 for the plant's Administration Building stairwell and elevator shaft;
- design precedent for the City of Redwood City's Recycled Water Treatment Facility in 2004; and
- design precedent for the original waste water treatment plant in 1977-1979.

2.0 SOIL PROFILE

The soil profile at the PFDS consists of Young Bay Mud (YBM) underlain by Old Bay Clay (OBC). Bedrock is hundreds of feet deep at the plant site and is not a factor in pile foundation design. Groundwater elevation should be taken at the front of plant existing ground surface. The YBM is characterized by extremely low dry unit weight, extremely high moisture content, low shear strength and high compressibility. The YBM is normally consolidated and subject to large settlements upon any increase in vertical loading. Standard Penetration Test blow counts, N-values in the YBM are N = 0 to 3. The underlying OBC is characterized by typical soil dry unit weights and moisture contents and moderate shear strengths. Standard Penetration Test blow count N-values in the OBC are typically in the range of N = 10 to 20. The OBC includes layers of sand with gravel that are several feet thick to as much as 20 to 30 feet thick. Figure 1 is a map of the thickness of YBM and bottom of YBM elevation contours at the front of plant area. The PFDS is at CPTs 16, 17 and 18.

The front of plant site area around the PFDS will be raised with as much as four feet of areal fill. As such, the YBM will experience long-term consolidation settlement in range of one to two feet. This long-term consolidation settlement will produce downdrag (negative skin friction) on pile foundations.

3.0 PILE FOUNDATIONS

3.1. Typical Pile

Recent pile foundations at the plant site consist of 14-inch-square, pre-cast, pre-stressed concrete piles. Piles as long as 109 feet have been driven successfully using a Delmag D-30 hammer with a rated energy range of approximately 35,000 to 70,000 ft-lbs. The same pile type and pile hammer energy rating is recommended for the PFDS.

3.2. Pile Capacity

3.2.1. Vertical Loading

Allowable pile capacity under vertical loading at the plant site has historically been 50 tons per pile. In order to develop an allowable net capacity of 50 tons per pile for the PFDS the piles need to be driven a minimum of 45 feet into the OBC. Design positive skin friction in the OBC may be taken as 750 psf (consistent with precedent construction). Design negative skin friction in the YBM is taken as 300 psf. Figure 2 is an illustration of the PFDS and allowable net pile capacity accounting for the negative skin friction induced by consolidation settlement of the YBM with four feet of areal fill placed around the structure. The total pile length required is 84 feet with the top of pile at Elevation 84. The 50 tons per pile allowable capacity is for vertical loading in compression. For piles in tension the YBM should be ignored and the allowable uplift capacity should come from the OBC only at 80% of the OBC skin friction or about 60 tons per pile for a pile with 45 feet of OBC embedment. If needed, additional single pile capacity can be gained by increasing the depth of embedment into the OBC in accordance with the calculations on Figure 2. For example, a 100 foot long pile will have an allowable vertical capacity in compression of approximately 80 tons. Allowable pile capacities in compression and tension may be increased by one-third for transient loading (i.e. wind and seismic loads).

3.2.2. Lateral Loading

From recent construction precedent (i.e., L-pile analysis at the recycled water treatment plant, administration building stairwell and influent screening structure) the allowable single pile lateral load capacity should be taken at 10 kips per pile. Pile deflection at 10 kips lateral load against the soft YBM should be less than 0.5 inches.

Lateral loading on the PFDS may be resisted by the sum of individual pile allowable capacities and at-rest earth pressure on the buried portion of the sides of the structure. At-rest earth pressure (I.e. no wall deflection required) on the side of the structure in YBM may be taken as 60 pcf equivalent fluid pressure (i.e., triangular distribution).

4.0 LIMITATIONS

This Technical Memorandum has been prepared for the exclusive use of Freyer & Laureta and SVCW for preliminary design of the PFDS pile foundations as described herein. Final pile foundation design may require additional analysis once pile spacing and pile lengths are determined (e.g. L-pile analysis for allowable lateral loading vs. pile deflection can be refined with final pile lengths and dimensions). This Technical Memorandum may not be used for any other purpose or for any other project. Within the limitations of scope, schedule and budget, DCM Consulting, Inc.'s services have been provided in accordance with generally accepted practices in the field of geotechnical engineering in the San Francisco Bay Area at the time services were completed. The conclusions and recommendations presented in this Technical Memorandum are based on the author's professional knowledge, judgment and experience. No warranty or other conditions express or implied should be understood.

David C. Mathy
C.E. 28082
G.E. 569

Attachments:

- Figure 1 – Bottom of YBM Contours
- Figure 2 – Allowable Pile Capacity

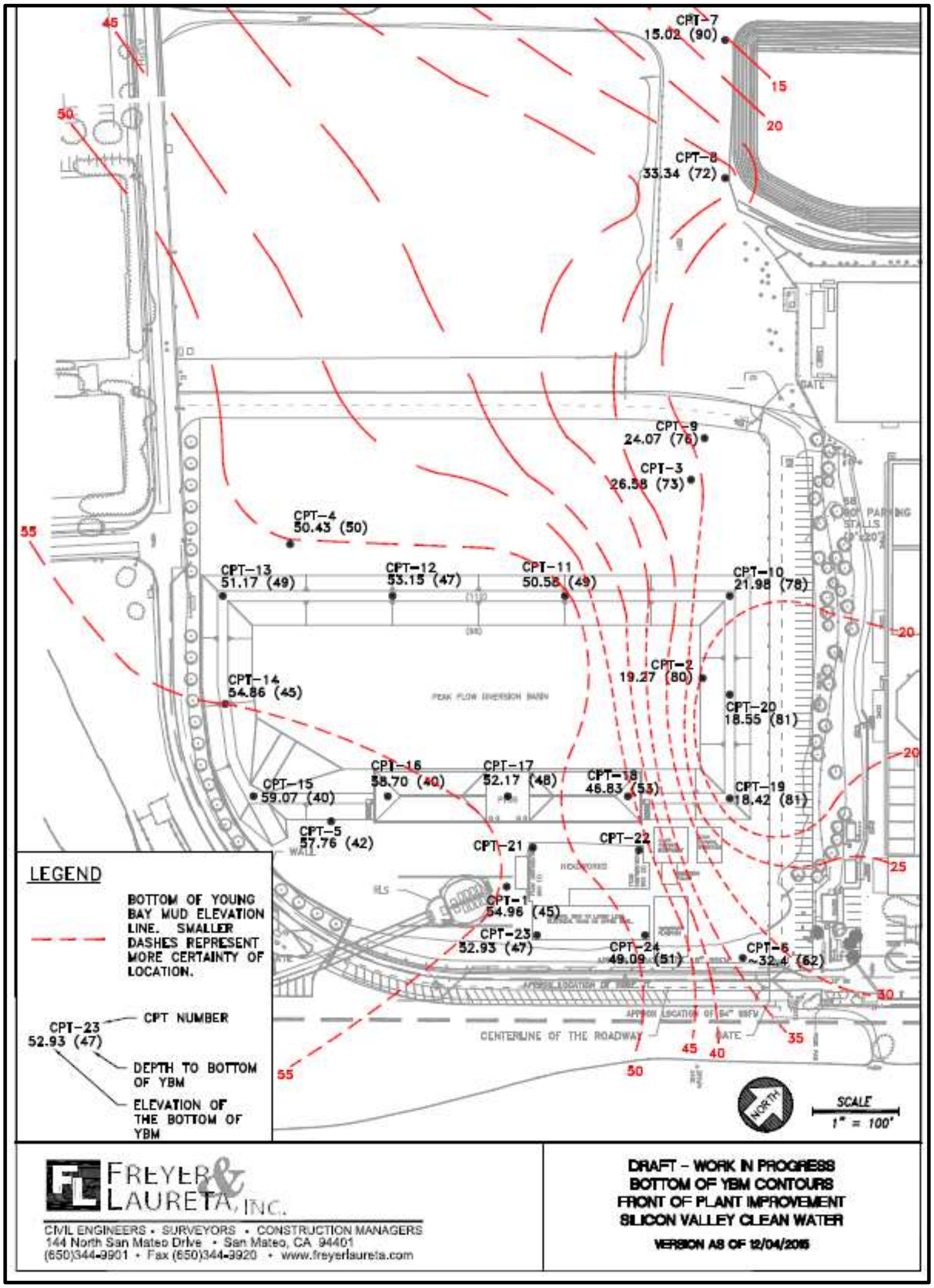
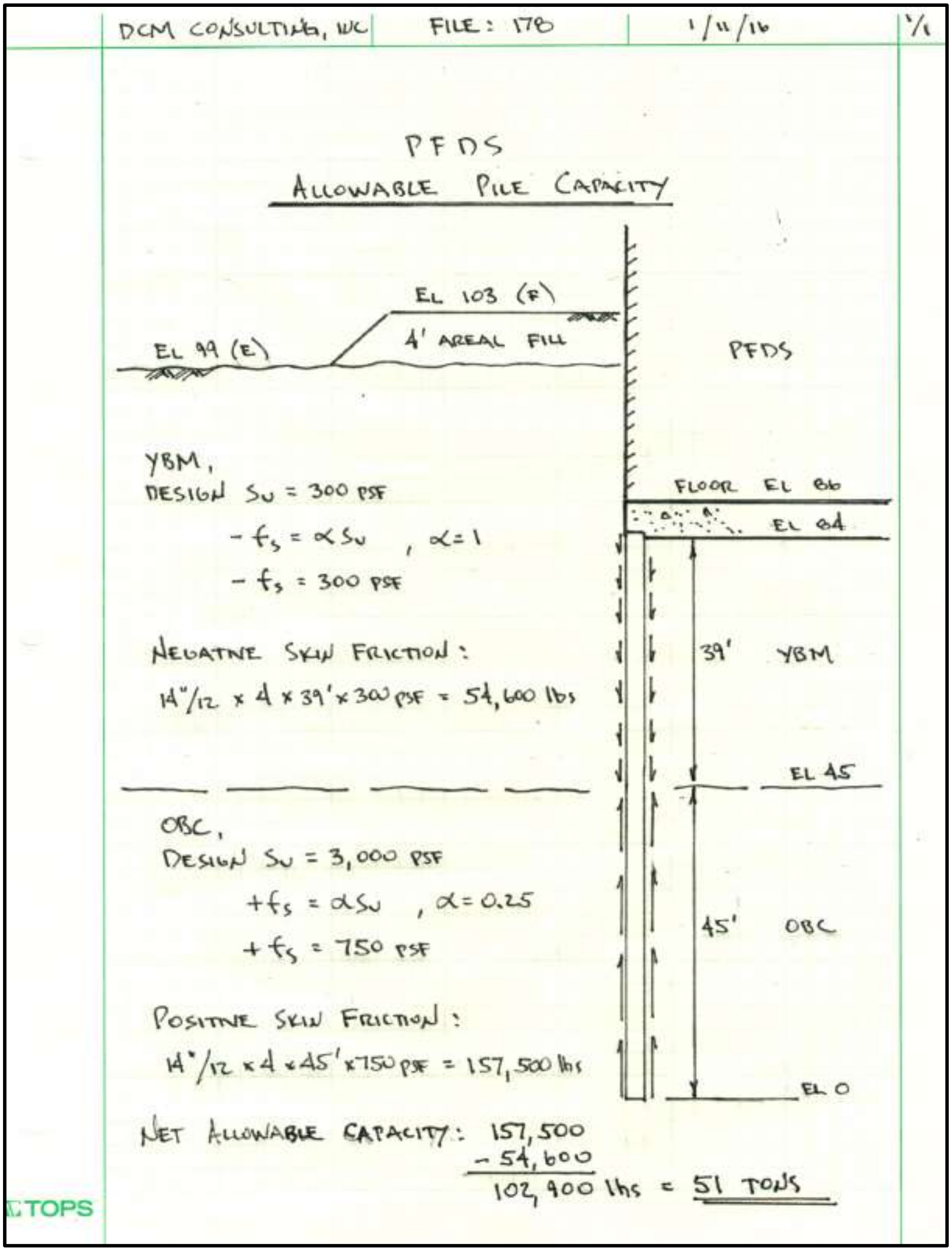


Figure 1 – Bottom of YBM Contours



DCM CONSULTING, INC | FILE: 178 | 1/11/16 | 1/1

PFDS

ALLOWABLE PILE CAPACITY

EL 103 (F)

4' AREAL FILL

EL 99 (E)

PFDS

YBM,

DESIGN S_u = 300 PSF

$-f_s = \alpha S_u \quad , \alpha = 1$

$-f_s$ = 300 PSF

FLOOR EL 86

EL 84

NEGATIVE SKIN FRICTION:

14"/12 × 4 × 39' × 300 PSF = 54,600 lbs

39' YBM

EL 45

OBC,

DESIGN S_u = 3,000 PSF

$+f_s = \alpha S_u \quad , \alpha = 0.25$

$+f_s$ = 750 PSF

45' OBC

POSITIVE SKIN FRICTION:

14"/12 × 4 × 45' × 750 PSF = 157,500 lbs

EL 0

NET ALLOWABLE CAPACITY: 157,500
− 54,600
102,900 lbs = 51 TONS

TOPS

Figure 2 – Allowable Pile Capacity

"Presentation of Site Investigation Results SVCW Front of Plant Improvements," January 2016, prepared by DCM Consulting, Inc.

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PRESENTATION OF SITE INVESTIGATION RESULTS

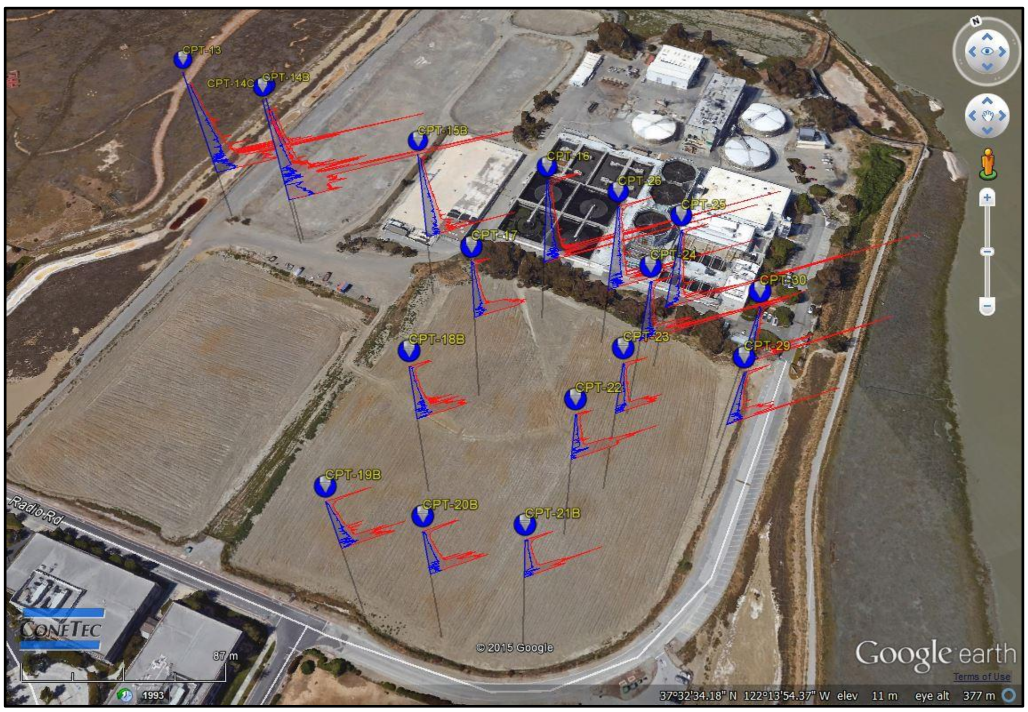
SVCW Front of Plant Improvements

Prepared for:

DCM Consulting, Inc.

CPT Inc. Job No: 15-56018

Project Start Date: 03-Nov-2015
Project End Date: 06-Nov-2015
Report Date: 10-Nov-2015



Prepared by:

California Push Technologies Inc.
820 Aladdin Avenue
San Leandro, CA 94577

Tel: (510) 357-3677

Email: cpt@cptinc.com
www.cptinc.com

Introduction

The enclosed report presents the results of the site investigation program conducted by CPT Inc. for DCM Consulting, Inc. at the Silicon Valley Clean Water plant. The program consisted of 17 cone penetration tests (CPT).

Project Information

Project	
Client	DCM Consulting, Inc.
Project	SVCW Front of Plant Improvements
CPT Inc. project number	15-56018

A map from Google earth including the CPT test locations is presented below.

Rig Description	Deployment System	Test Type
CPT track rig (GPT1)	20 ton rig cylinder	CPT
CPT truck rig (C15)	30 ton rig cylinder	CPT

Coordinates		
Test Type	Collection Method	EPSG Reference
CPT	Consumer Grade GPS	32610

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional plots	Advanced plots with Su (Nkt)
Additional comments	

Cone Penetrometers Used for this Project						
Cone Description	Cone Number	Cross Sectional Area (cm^2)	Sleeve Area (cm^2)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
413:T375F10U200	AD413	15	225	375	10	200
443:T1500F15U500	AD443	15	225	1500	15	500
The CPT summary indicates which cone was used for each sounding.						

Interpretation Tables	
Additional information	The Soil Behaviour Type (SBT) classification chart (Robertson et al., 1986 presented by Lunne, Robertson and Powell, 1997) was used to classify the soil for this project.

Limitations

This report has been prepared for the exclusive use of DCM Consulting, Inc. (Client) for the project titled "SVCW Front of Plant Improvements". The report's contents may not be relied upon by any other party without the express written permission of CPT Inc. CPT Inc. has provided site investigation services, prepared the factual data reporting, and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to CPT Inc. by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

The cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd. of Richmond, British Columbia, Canada.

CPT Inc.'s piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

The penetrometers are manufactured with various tip, friction and pore pressure capacities in both 10 cm^2 and 15 cm^2 tip base area configurations in order to maximize signal resolution for various soil conditions. The specific piezocone used for each test is described in the CPT summary table presented in the first appendix. The 15 cm^2 penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm^2 piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u_2" position (ASTM Type 2). The filter is 6 mm thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. Our calibration criteria also meet or exceed those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

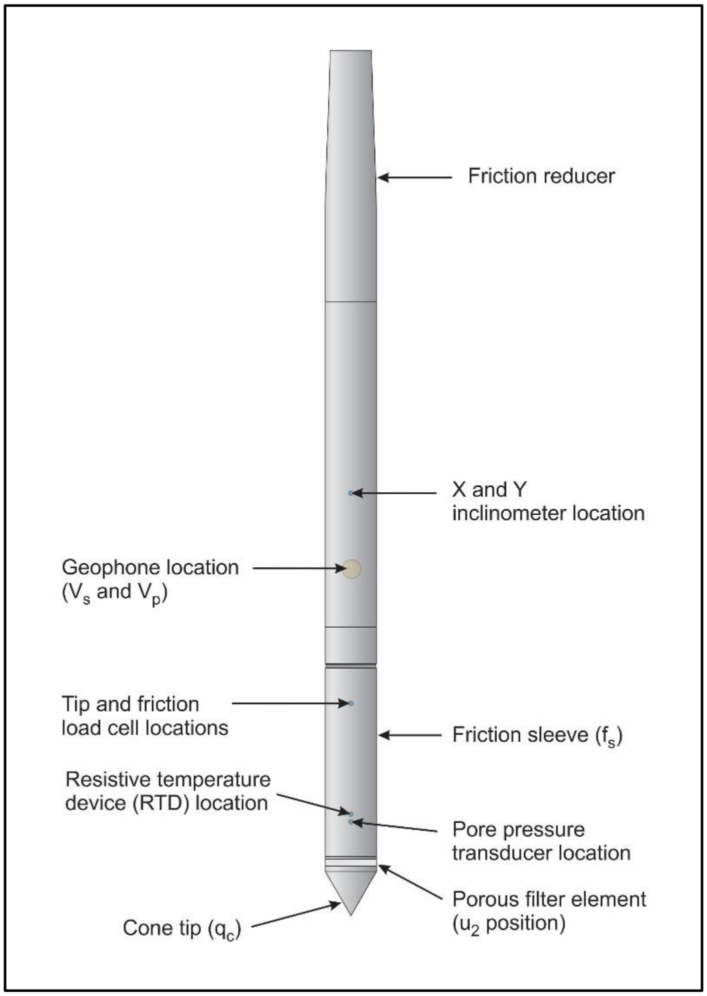


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording intervals are either 2.5 cm or 5.0 cm depending on project requirements; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to CPT Inc.'s CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerin or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to CPT Inc.'s cone penetration testing procedures:

- Each filter is saturated in silicone oil or glycerin under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of the piezocone data and associated calculated parameters for this report are based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson (1990) and Robertson (2009). It should be noted that it is not always possible to accurately identify a soil type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behavior type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al, 1986:

$$q_t = q_c + (1\text{-}a) \bullet u_2$$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for CPT Inc. probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all CPT Inc. piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (Rf) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of files with calculated geotechnical parameters were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the methods used is also included in the data release folder.

For additional information on CPTu interpretations and calculated geotechnical parameters, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

The cone penetration test is halted at specific depths to carry out pore pressure dissipation (PPD) tests, shown in Figure PPD-1. For each dissipation test the cone and rods are decoupled from the rig and the data acquisition system measures and records the variation of the pore pressure (u) with time (t).

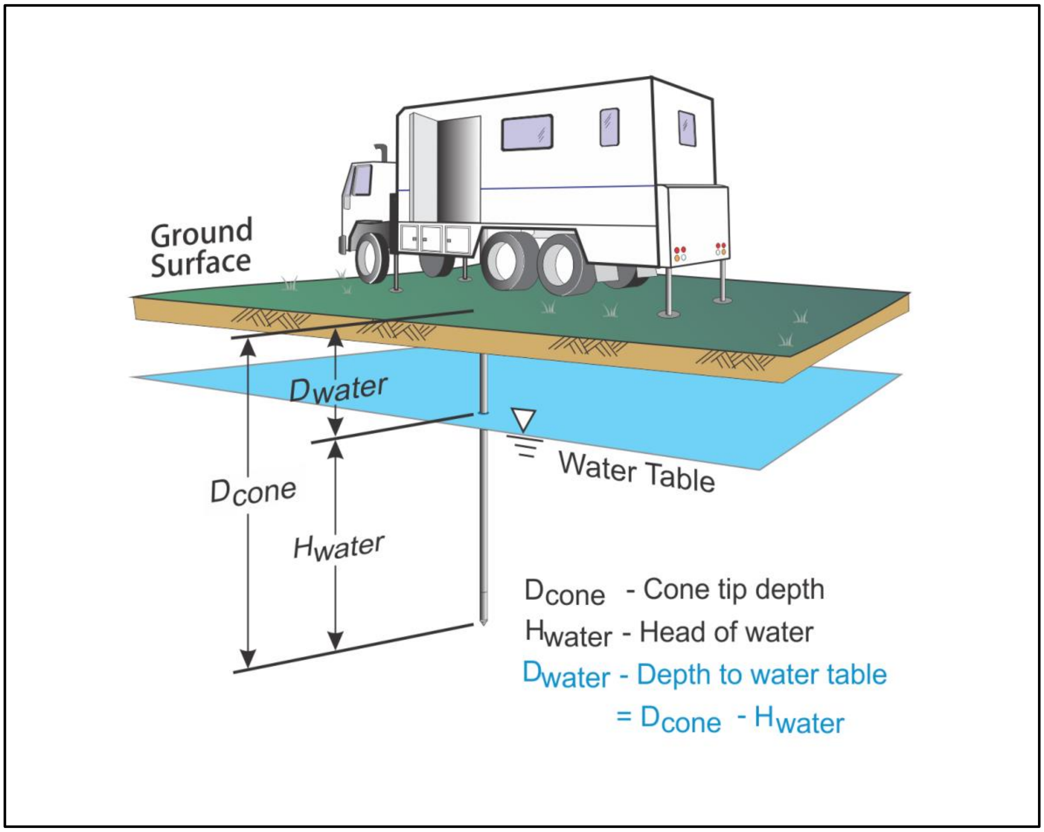


Figure PPD-1. Pore pressure dissipation test setup

Pore pressure dissipation data can be interpreted to provide estimates of ground water conditions, permeability, consolidation characteristics and soil behavior.

The typical shapes of dissipation curves shown in Figure PPD-2 are very useful in assessing soil type, drainage, in situ pore pressure and soil properties. A flat curve that stabilizes quickly is typical of a freely draining sand. Undrained soils such as clays will typically show positive excess pore pressure and have long dissipation times. Dilative soils will often exhibit dynamic pore pressures below equilibrium that then rise over time. Overconsolidated fine-grained soils will often exhibit an initial dilatory response where there is an initial rise in pore pressure before reaching a peak and dissipating.

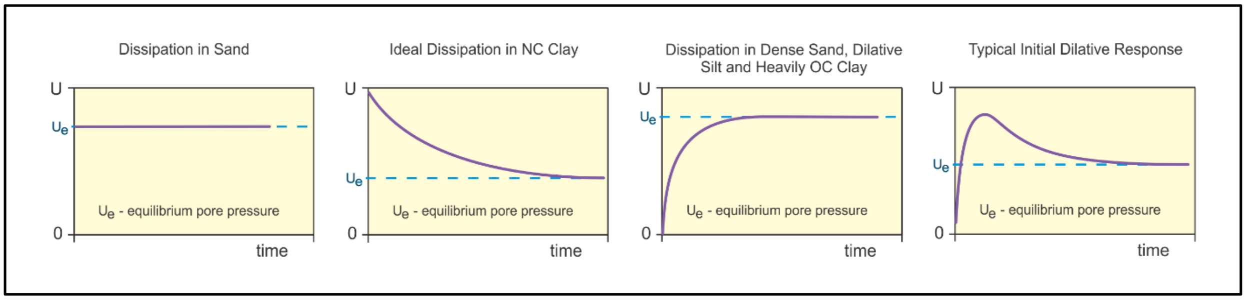


Figure PPD-2. Pore pressure dissipation curve examples

In order to interpret the equilibrium pore pressure (u_{eq}) and the apparent phreatic surface, the pore pressure should be monitored until such time as there is no variation in pore pressure with time as shown for each curve of Figure PPD-2.

In fine grained deposits the point at which 100% of the excess pore pressure has dissipated is known as t_{100}. In some cases this can take an excessive amount of time and it may be impractical to take the dissipation to t_{100}. A theoretical analysis of pore pressure dissipations by Teh and Houlsby (1991) showed that a single curve relating degree of dissipation versus theoretical time factor (T*) may be used to calculate the coefficient of consolidation (c_h) at various degrees of dissipation resulting in the expression for c_h shown below.

$$c_h = \frac{T^* \cdot a^2 \cdot \sqrt{I_r}}{t}$$

Where:

T^* is the dimensionless time factor (Table Time Factor)
a is the radius of the cone
I_r is the rigidity index
t is the time at the degree of consolidation

Table Time Factor. T* versus degree of dissipation (Teh and Houlsby, 1991)

Degree of Dissipation (%)	20	30	40	50	60	70	80
T* (u_2)	0.038	0.078	0.142	0.245	0.439	0.804	1.60

The coefficient of consolidation is typically analyzed using the time (t_{50}) corresponding to a degree of dissipation of 50% (u_{50}). In order to determine t_{50}, dissipation tests must be taken to a pressure less than u_{50}. The u_{50} value is half way between the initial maximum pore pressure and the equilibrium pore pressure value, known as u_{100}. To estimate u_{50}, both the initial maximum pore pressure and u_{100} must be known or estimated. Other degrees of dissipations may be considered, particularly for extremely long dissipations.

At any specific degree of dissipation the equilibrium pore pressure (u at t_{100}) must be estimated at the depth of interest. The equilibrium value may be determined from one or more sources such as measuring the value directly (u_{100}), estimating it from other dissipations in the same profile, estimating the phreatic surface and assuming hydrostatic conditions, from nearby soundings, from client provided information, from site observations and/or past experience, or from other site instrumentation.

For calculations of c_h (Teh and Houlsby, 1991), t_{50} values are estimated from the corresponding pore pressure dissipation curve and a rigidity index (I_r) is assumed. For curves having an initial dilatory response in which an initial rise in pore pressure occurs before reaching a peak, the relative time from the peak value is used in determining t_{50}. In cases where the time to peak is excessive, t_{50} values are not calculated.

Due to possible inherent uncertainties in estimating I_r, the equilibrium pore pressure and the effect of an initial dilatory response on calculating t_{50}, other methods should be applied to confirm the results for c_h.

Additional published methods for estimating the coefficient of consolidation from a piezocone test are described in Burns and Mayne (1998, 2002), Jones and Van Zyl (1981), Robertson et al. (1992) and Sully et al. (1999).

A summary of the pore pressure dissipation tests and dissipation plots are presented in the relevant appendix.

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Robertson, P.K., 1990, "Soil Classification Using the Cone Penetration Test", Canadian Geotechnical Journal, Volume 27: 151-158.

Robertson, P.K., 2009, "Interpretation of cone penetration tests – a unified approach", Canadian Geotechnical Journal, Volume 46: 1337-1355.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, "Use of Piezometer Cone Data", Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

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Teh, C.I., and Houlsby, G.T., 1991, "An analytical study of the cone penetration test in clay", Geotechnique, 41(1): 17-34.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots
- Advanced Cone Penetration Test Plots with Ic, Su(Nkt) and N1(60)
- Pore Pressure Dissipation Summary and Pore Pressure Dissipation Plots

Cone Penetration Test Summary and
Standard Cone Penetration Test Plots

CALIFORNIA PUSH
TECHNOLOGIES
INCORPORATED

Job No:	15-56018
Client:	DCM Consulting, Inc.
Project:	SVCW Front of Plant Improvements
Start Date:	03-Nov-2015
End Date:	06-Nov-2015

CONE PENETRATION TEST SUMMARY

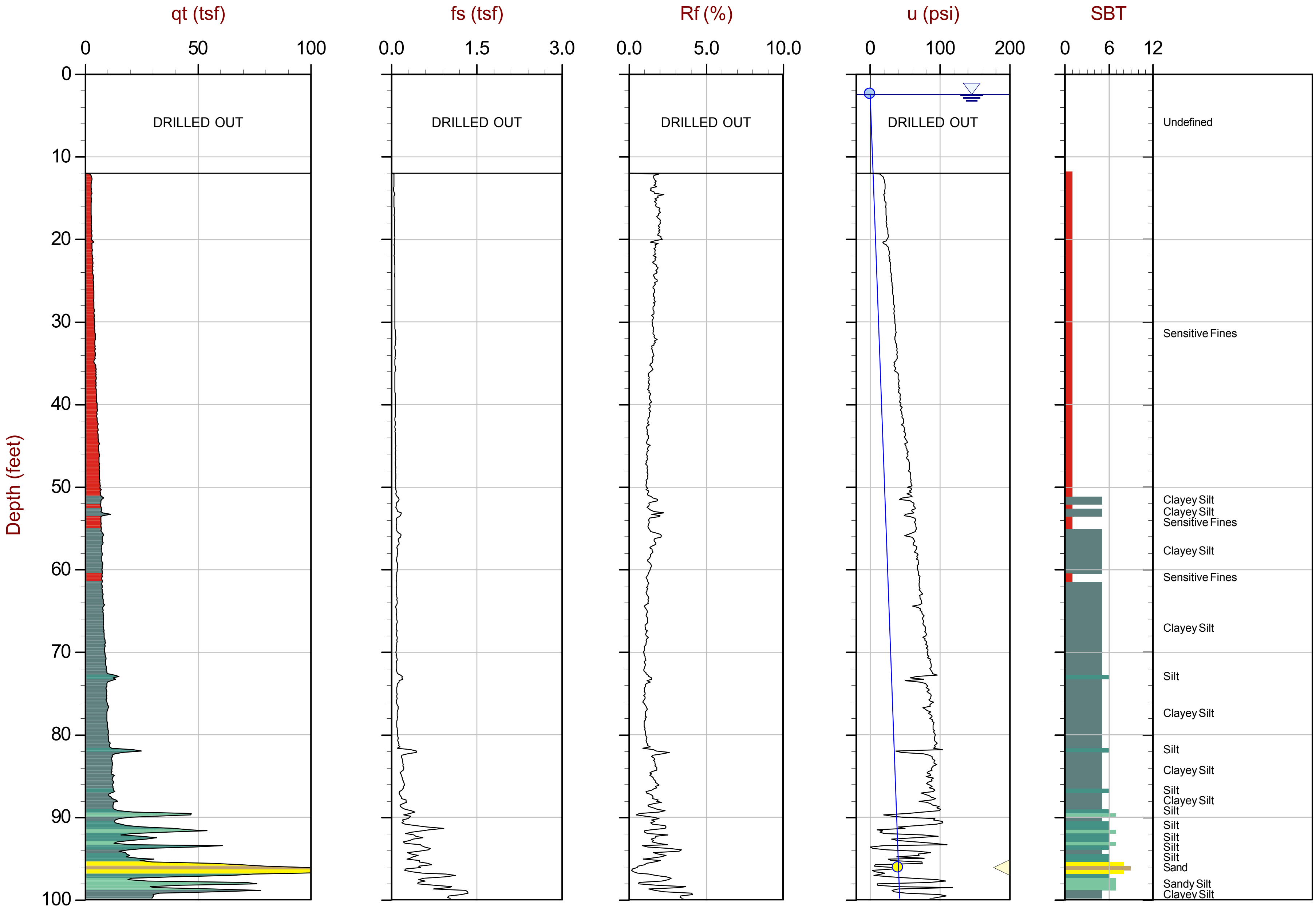
Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface[1] (ft)	Final Depth (ft)	Northing[2] (m)	Easting (m)	Refer to Notation Number
CPT-13	15-56018_CP13	03-Nov-2015	443:T1500F15U500	2.4	110.24	4155649	567923	
CPT-14B	15-56018_CP14B	03-Nov-2015	443:T1500F15U500	2.2	110.07	4155611	567958	3
CPT-14C	15-56018_CP14C	05-Nov-2015	413:T375F10U200	2.2	83.33	4155614	567960	
CPT-15B	15-56018_CP15B	06-Nov-2015	413:T375F10U200	0.0	89.98	4155547	568021	
CPT-16	15-56018_CP16	06-Nov-2015	413:T375F10U200	0.0	90.39	4155509	568073	
CPT-17	15-56018_CP17	06-Nov-2015	413:T375F10U200	0.0	60.61	4155471	568023	
CPT-18B	15-56018_CP18B	04-Nov-2015	413:T375F10U200	0.0	60.70	4155425	567982	
CPT-19B	15-56018_CP19B	04-Nov-2015	413:T375F10U200	0.0	60.45	4155377	567938	
CPT-20B	15-56018_CP20B	04-Nov-2015	413:T375F10U200	0.0	57.33	4155355	567967	
CPT-21B	15-56018_CP21B	04-Nov-2015	413:T375F10U200	0.0	50.61	4155340	567999	
CPT-22	15-56018_CP22	05-Nov-2015	413:T375F10U200	0.0	53.56	4155382	568035	
CPT-23	15-56018_CP23	05-Nov-2015	413:T375F10U200	0.0	57.58	4155398	568062	
CPT-24	15-56018_CP24	05-Nov-2015	413:T375F10U200	0.0	66.35	4155434	568091	
CPT-25	15-56018_CP25	05-Nov-2015	413:T375F10U200	0.0	86.37	4155457	568117	
CPT-26	15-56018_CP26	06-Nov-2015	413:T375F10U200	0.0	92.77	4155481	568097	
CPT-29	15-56018_CP29	05-Nov-2015	413:T375F10U200	0.0	60.37	4155377	568104	
CPT-30	15-56018_CP30	05-Nov-2015	413:T375F10U200	0.0	64.63	4155405	568127	

1. The phreatic surface was estimated using the results of pore pressure dissipation tests and field observations. Hydrostatic profiles were used for the interpretation tables.
2. Coordinates were collected with a consumer grade GPS device with datum WGS84/UTM Zone 10 North. Elevations were not collected.
3. The sounding data exhibits electrical noise. At the clients request, the data is still being presented as it delineates a sand layer.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 15:19
Site: SVCW Front of Plant Improvements
Sounding: CPT-13
Cone: 443:T1500F15U500



Max Depth: 33.600 m / 110.23 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP13.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155649m E: 567923m
Sheet No: 1 of 2

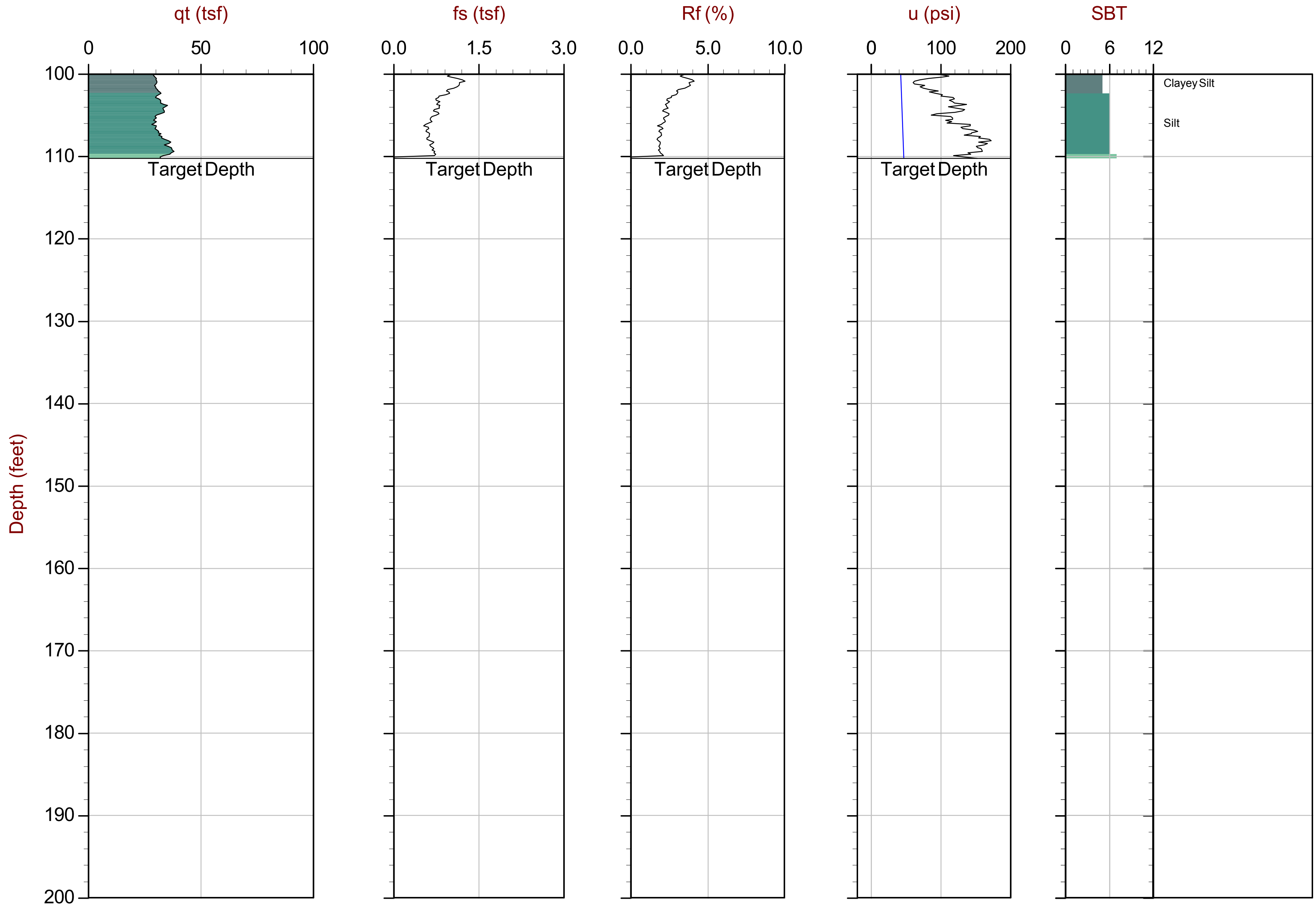
Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 15:19
Site: SVCW Front of Plant Improvements
Sounding: CPT-13
Cone: 443:T1500F15U500



Max Depth: 33.600 m / 110.23 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP13.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155649m E: 567923m
Sheet No: 2 of 2

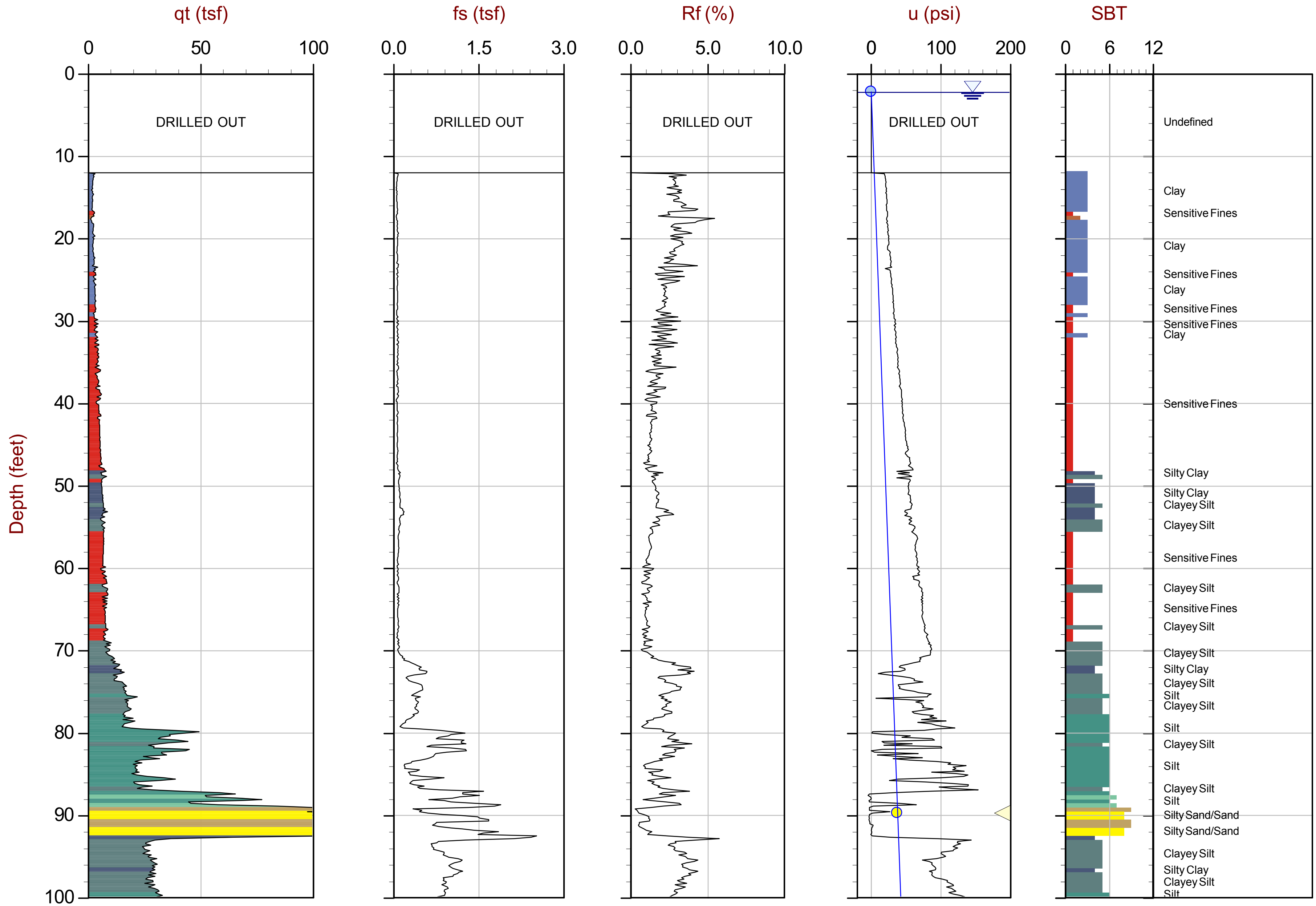
Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 16:39
Site: SVCW Front of Plant Improvements
Sounding: CPT-14B
Cone: 443:T1500F15U500



Max Depth: 33.550 m / 110.07 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP14B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155611m E: 567958m
Sheet No: 1 of 2

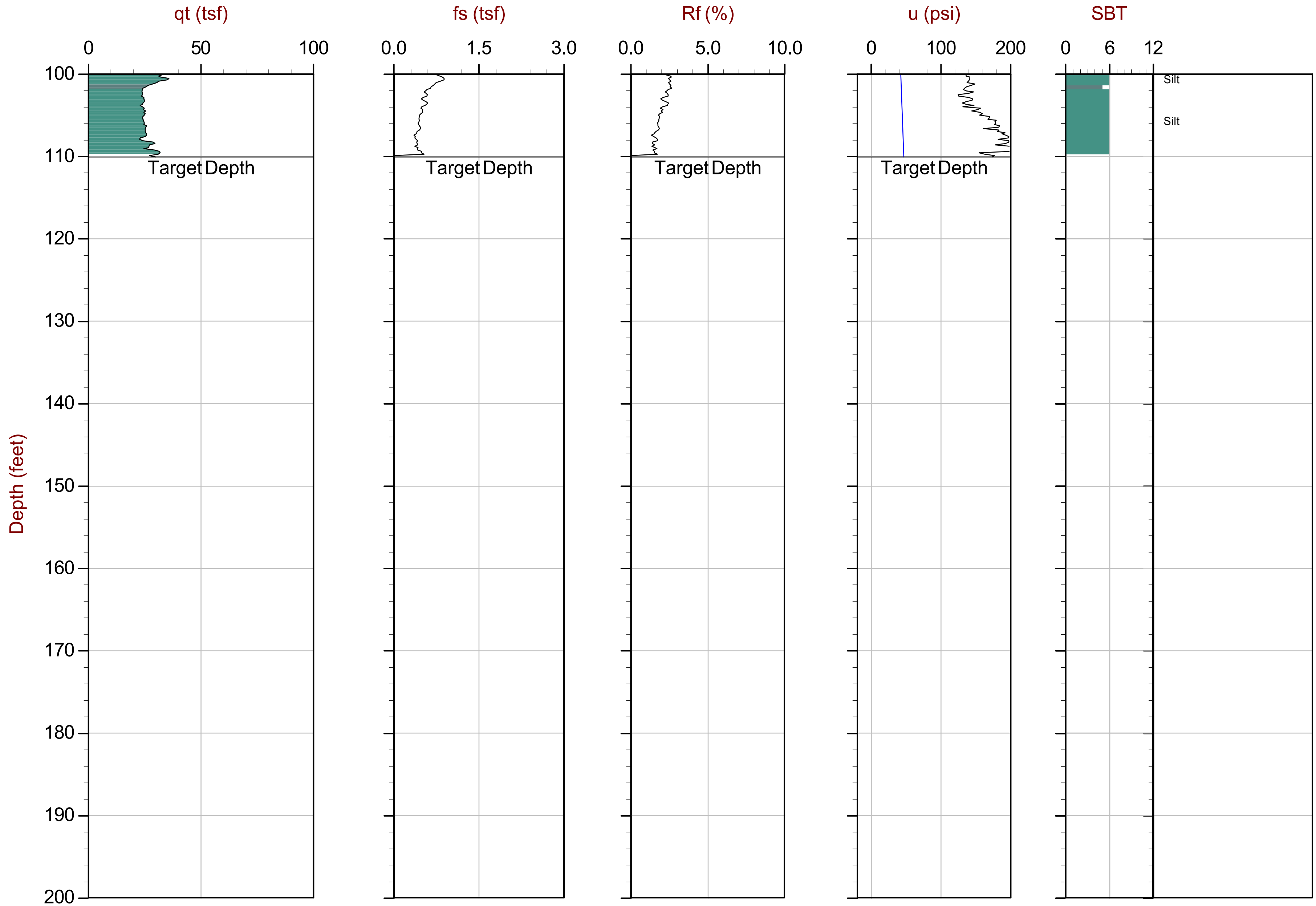
Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 16:39
Site: SVCW Front of Plant Improvements
Sounding: CPT-14B
Cone: 443:T1500F15U500



Max Depth: 33.550 m / 110.07 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP14B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155611m E: 567958m
Sheet No: 2 of 2

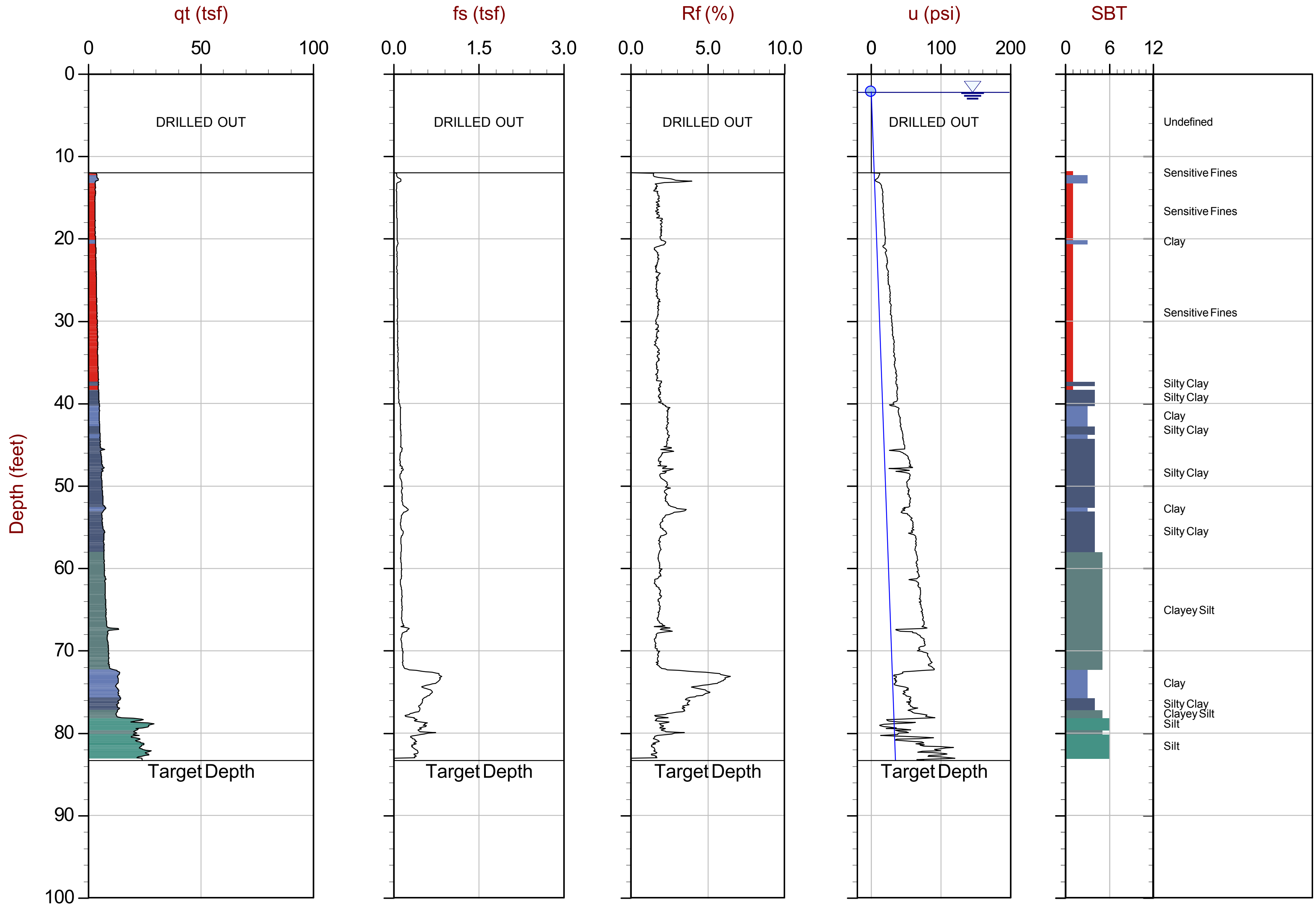
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 08:36
Site: SVCW Front of Plant Improvements
Sounding: CPT-14C
Cone: 413:T375F10U200



Max Depth: 25.400 m / 83.33 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP14C.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155614m E: 567960m
Sheet No: 1 of 1

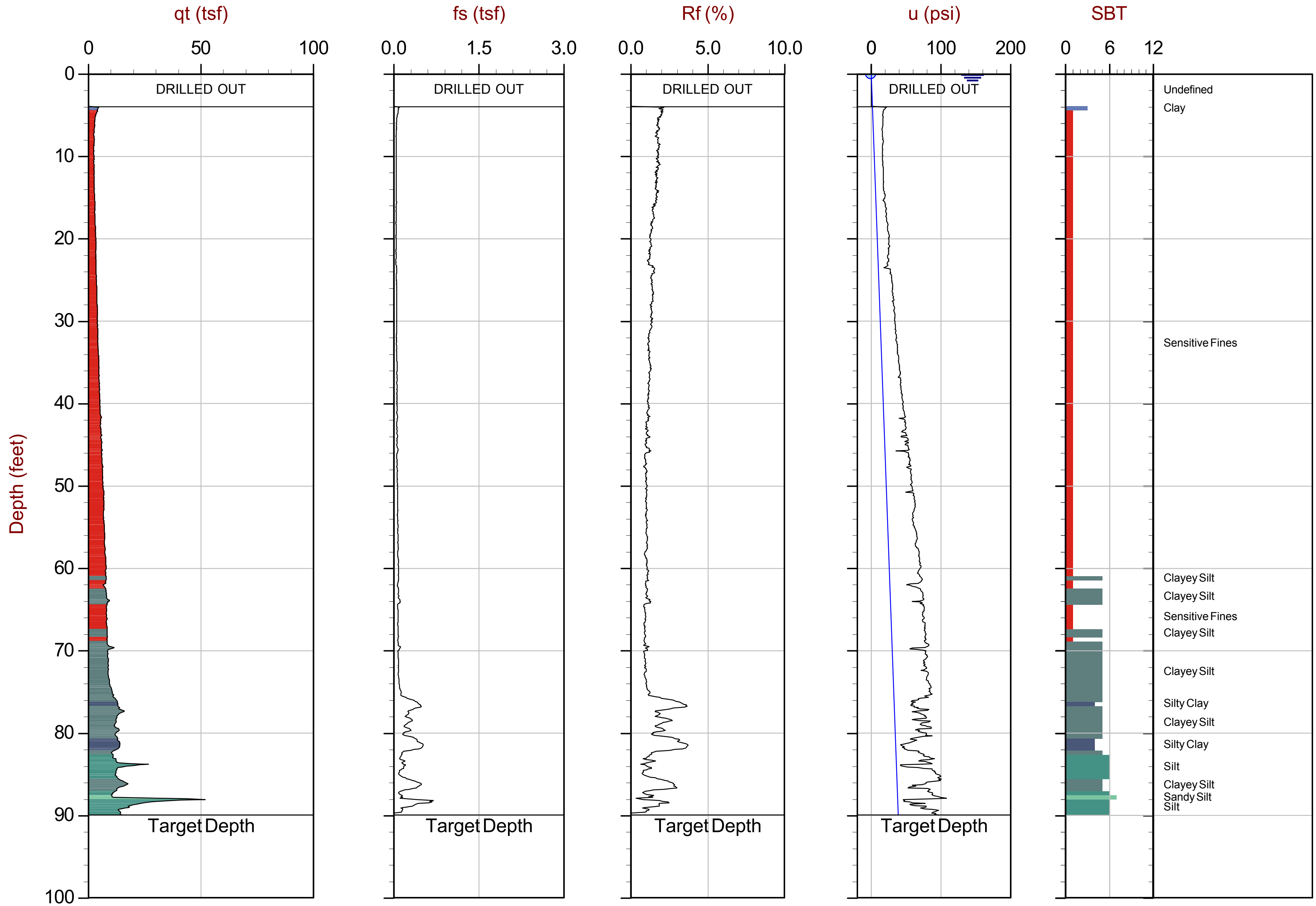
Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 15:03
Site: SVCW Front of Plant Improvements
Sounding: CPT-15B
Cone: 413:T375F10U200



Max Depth: 27.425 m / 89.98 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP15B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155547m E: 568021m
Sheet No: 1 of 1

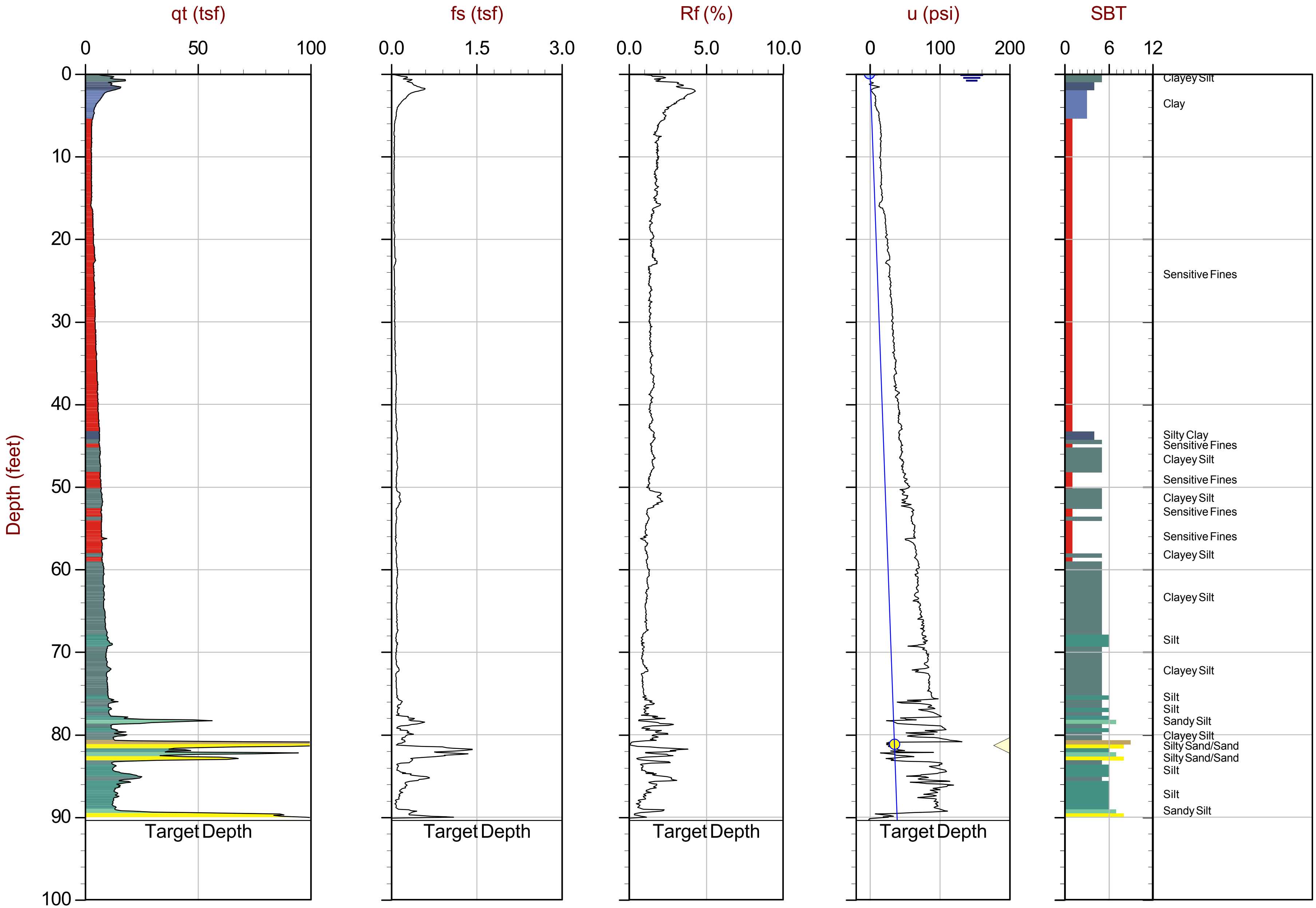
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 10:31
Site: SVCW Front of Plant Improvements
Sounding: CPT-16
Cone: 413:T375F10U200



Max Depth: 27.550 m / 90.39 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP16.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155509m E: 568073m
Sheet No: 1 of 1

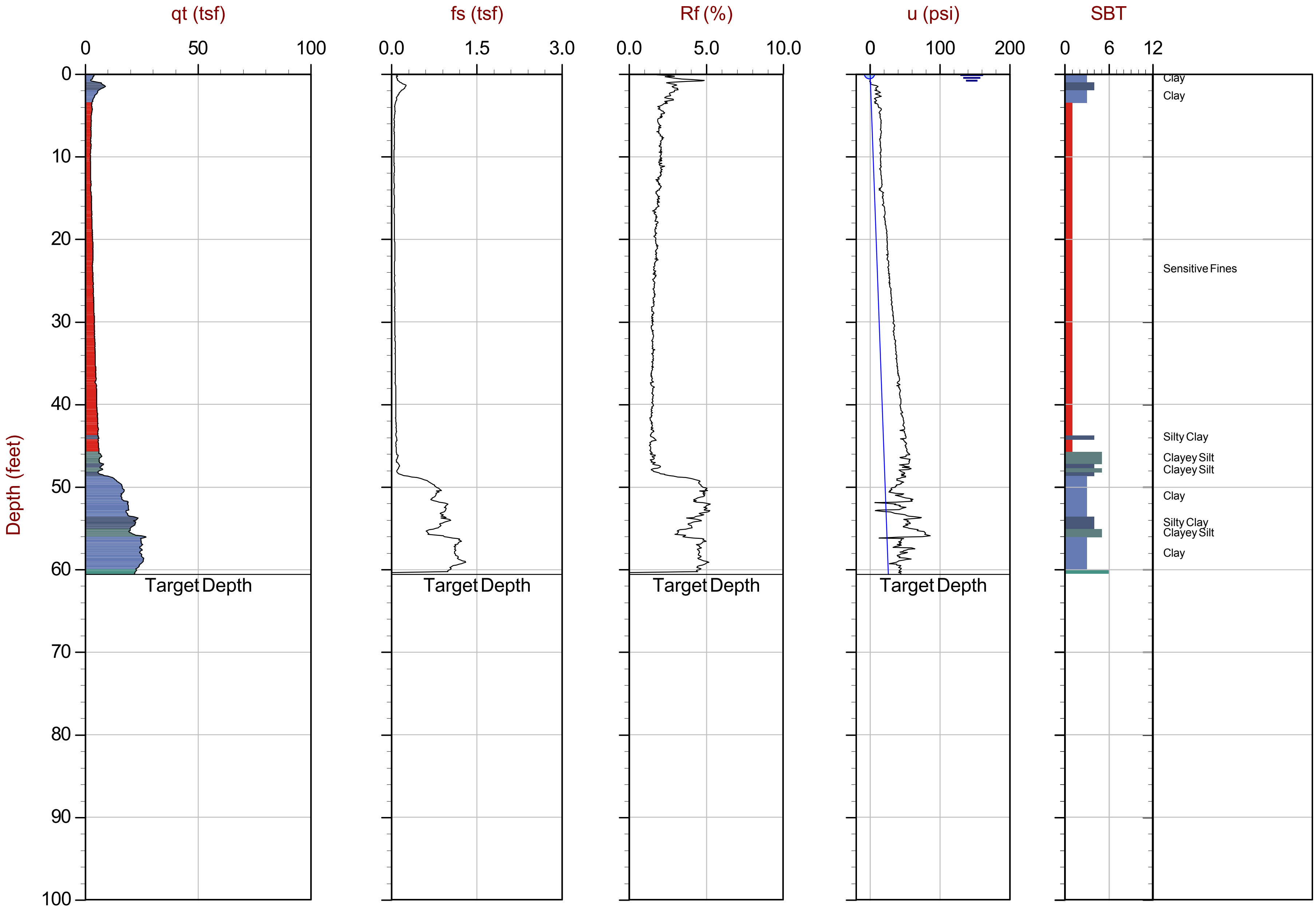
Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 12:00
Site: SVCW Front of Plant Improvements
Sounding: CPT-17
Cone: 413:T375F10U200



Max Depth: 18.475 m / 60.61 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP17.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155471m E: 568023m
Sheet No: 1 of 1

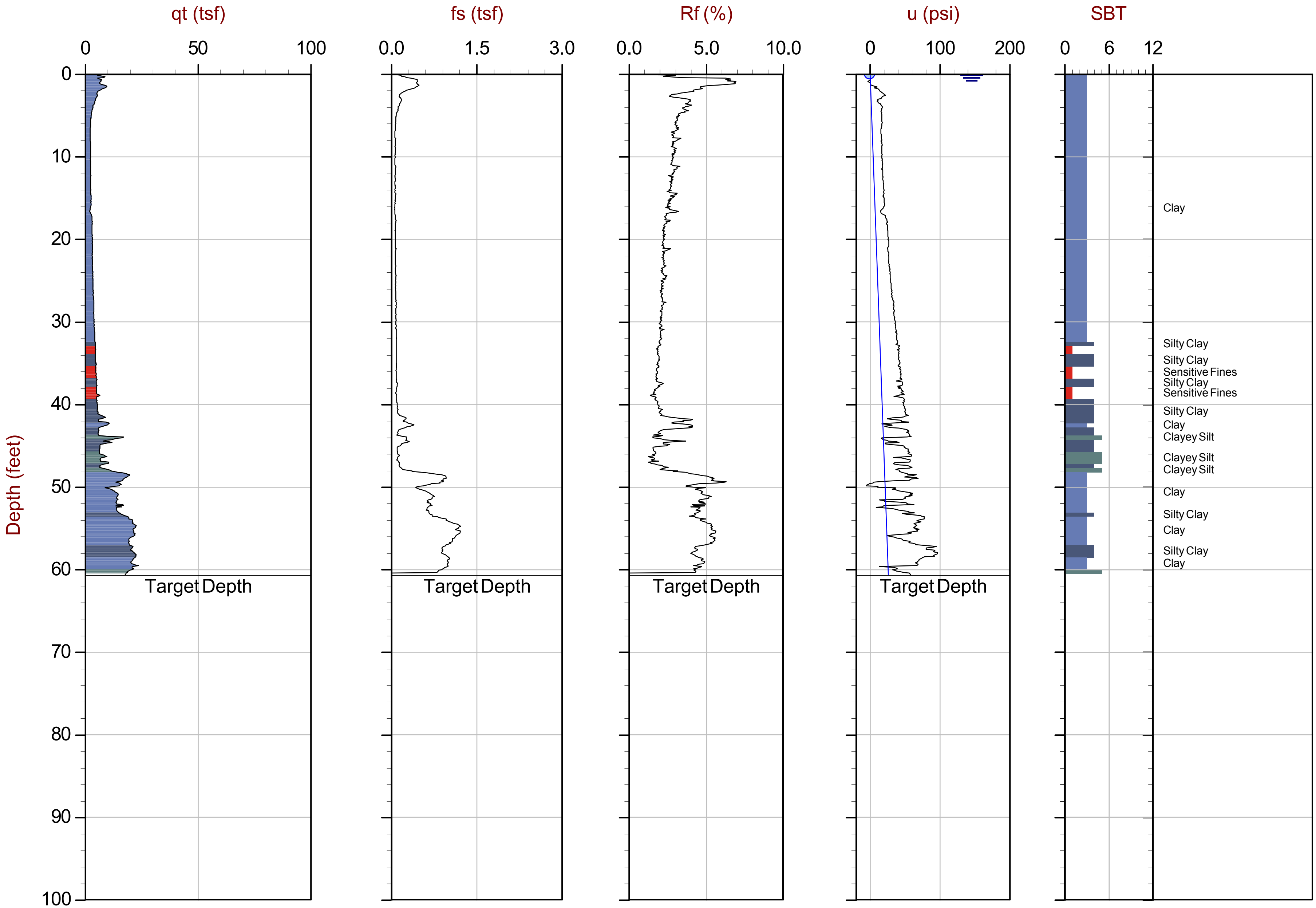
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 13:06
Site: SVCW Front of Plant Improvements
Sounding: CPT-18B
Cone: 413:T375F10U200



Max Depth: 18.500 m / 60.69 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP18B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155425m E: 567982m
Sheet No: 1 of 1

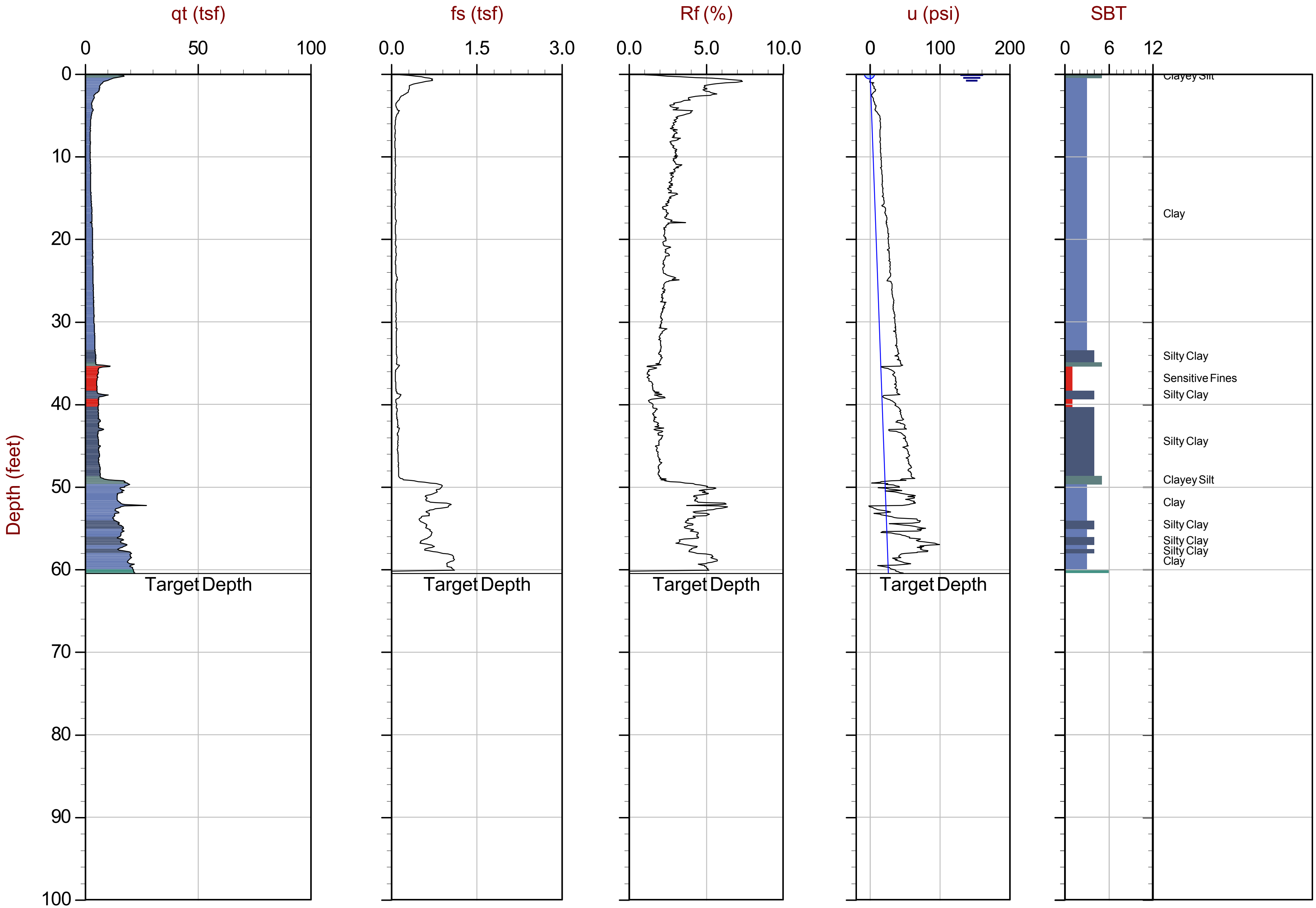
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 11:56
Site: SVCW Front of Plant Improvements
Sounding: CPT-19B
Cone: 413:T375F10U200



Max Depth: 18.425 m / 60.45 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP19B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155377m E: 567938m
Sheet No: 1 of 1

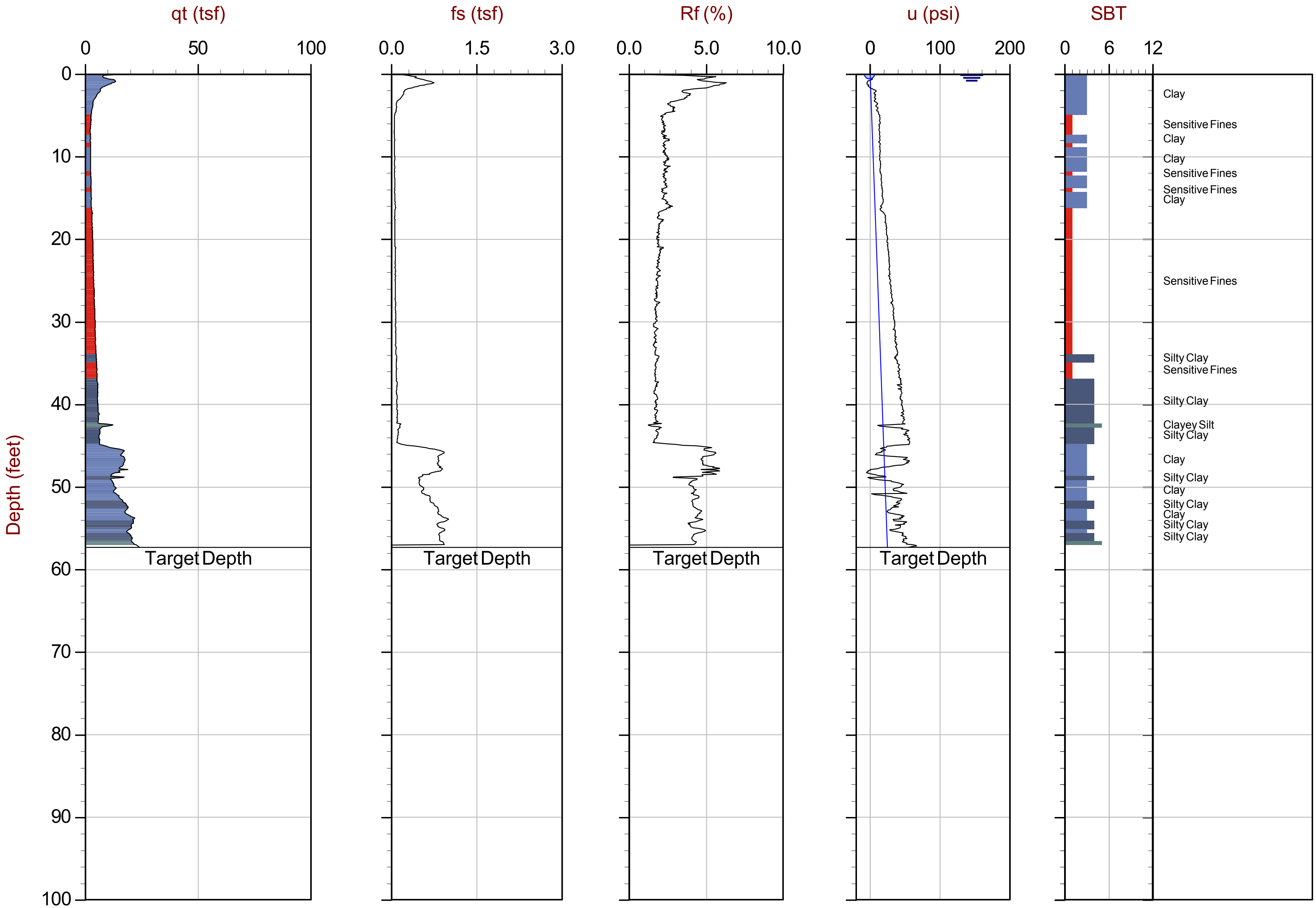
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 14:10
Site: SVCW Front of Plant Improvements

Sounding: CPT-20B
Cone: 413:T375F10U200



Max Depth: 17.475 m / 57.33 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP20B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155355m E: 567967m
Sheet No: 1 of 1

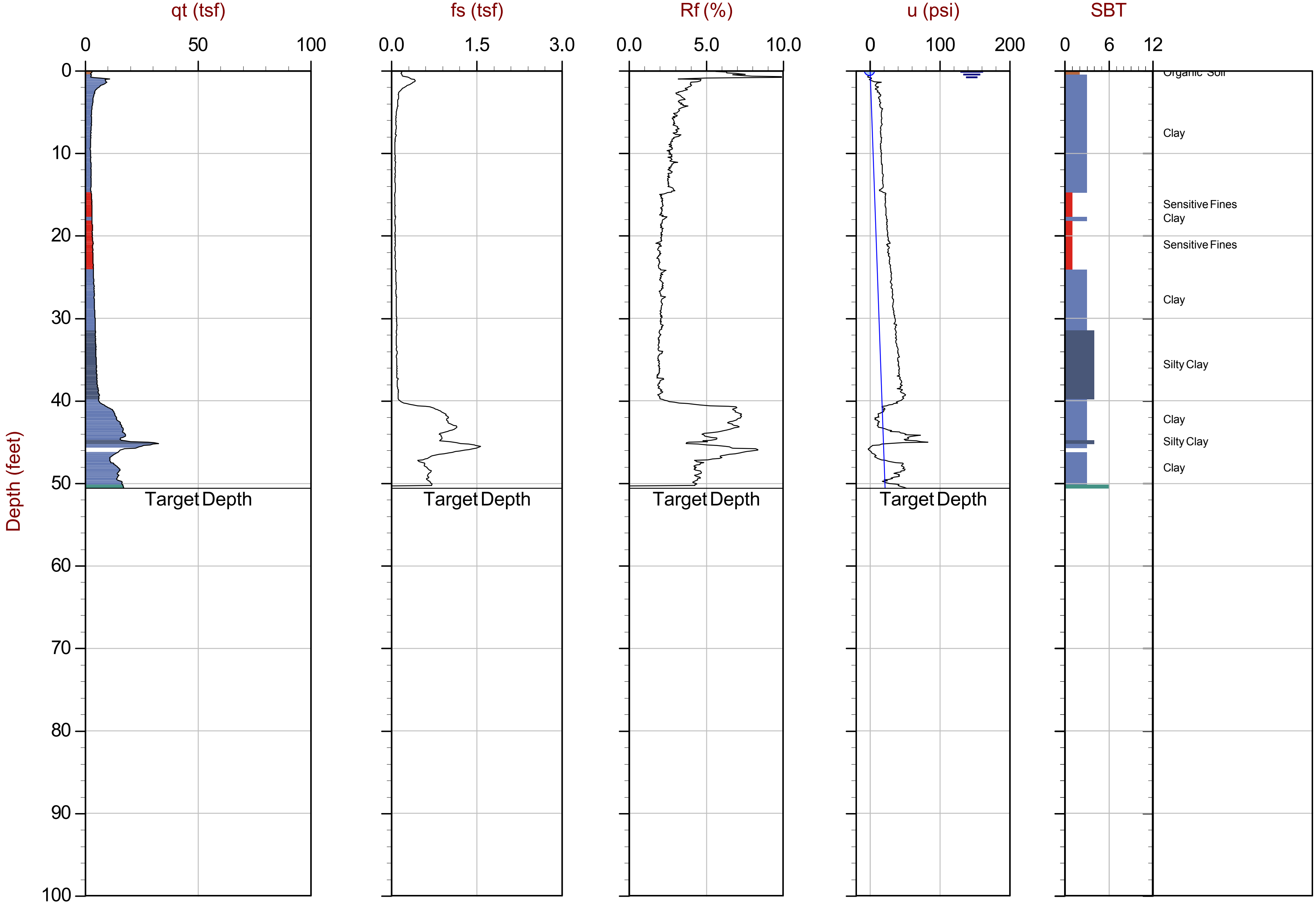
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 14:58
Site: SVCW Front of Plant Improvements
Sounding: CPT-21B
Cone: 413:T375F10U200



Max Depth: 15.425 m / 50.61 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP21B.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155340m E: 567999m
Sheet No: 1 of 1

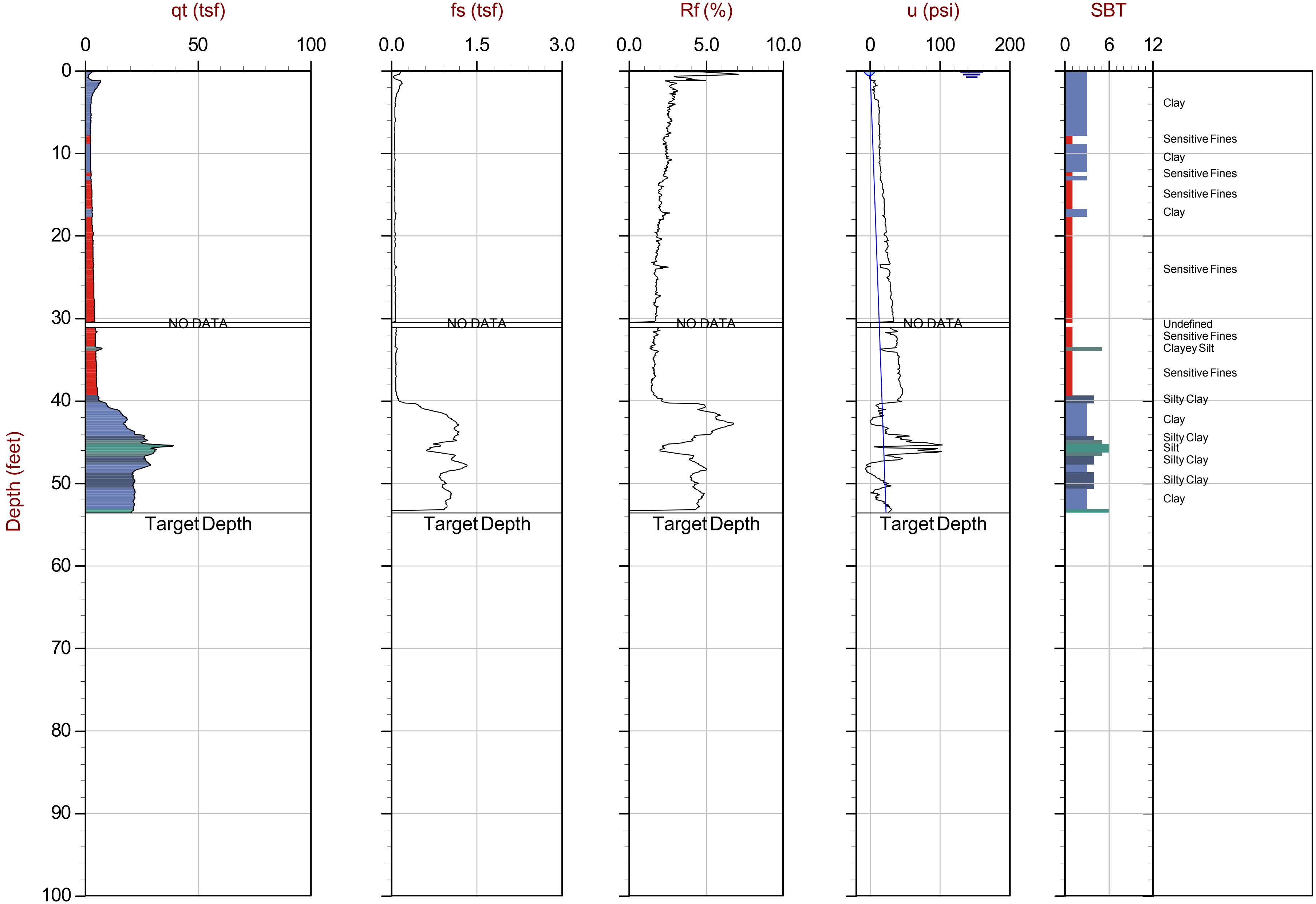
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 10:18
Site: SVCW Front of Plant Improvements
Sounding: CPT-22
Cone: 413:T375F10U200



Max Depth: 16.325 m / 53.56 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP22.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155382m E: 568035m
Sheet No: 1 of 1

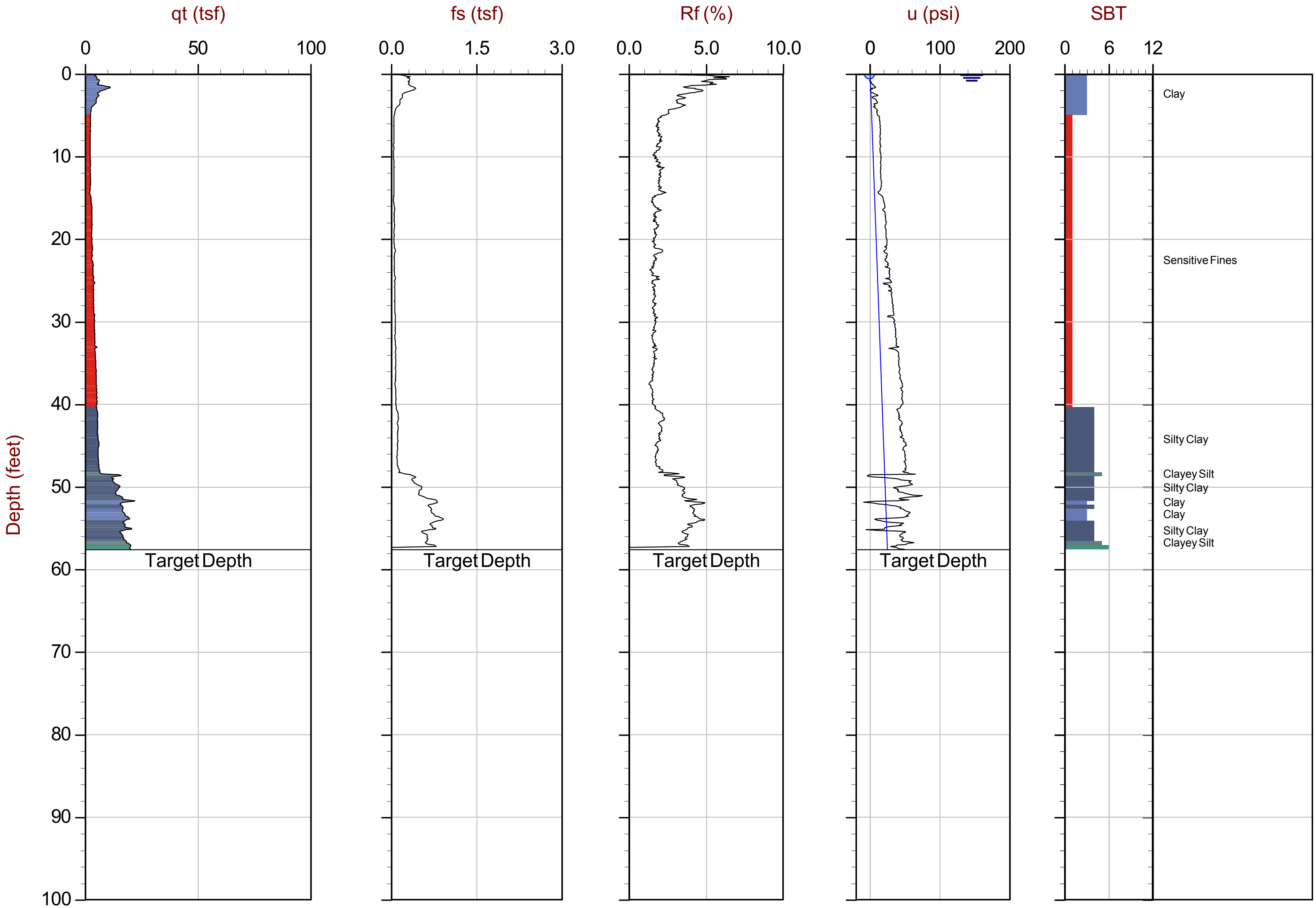
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 11:31
Site: SVCW Front of Plant Improvements
Sounding: CPT-23
Cone: 413:T375F10U200



Max Depth: 17.550 m / 57.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP23.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155398m E: 568062m
Sheet No: 1 of 1

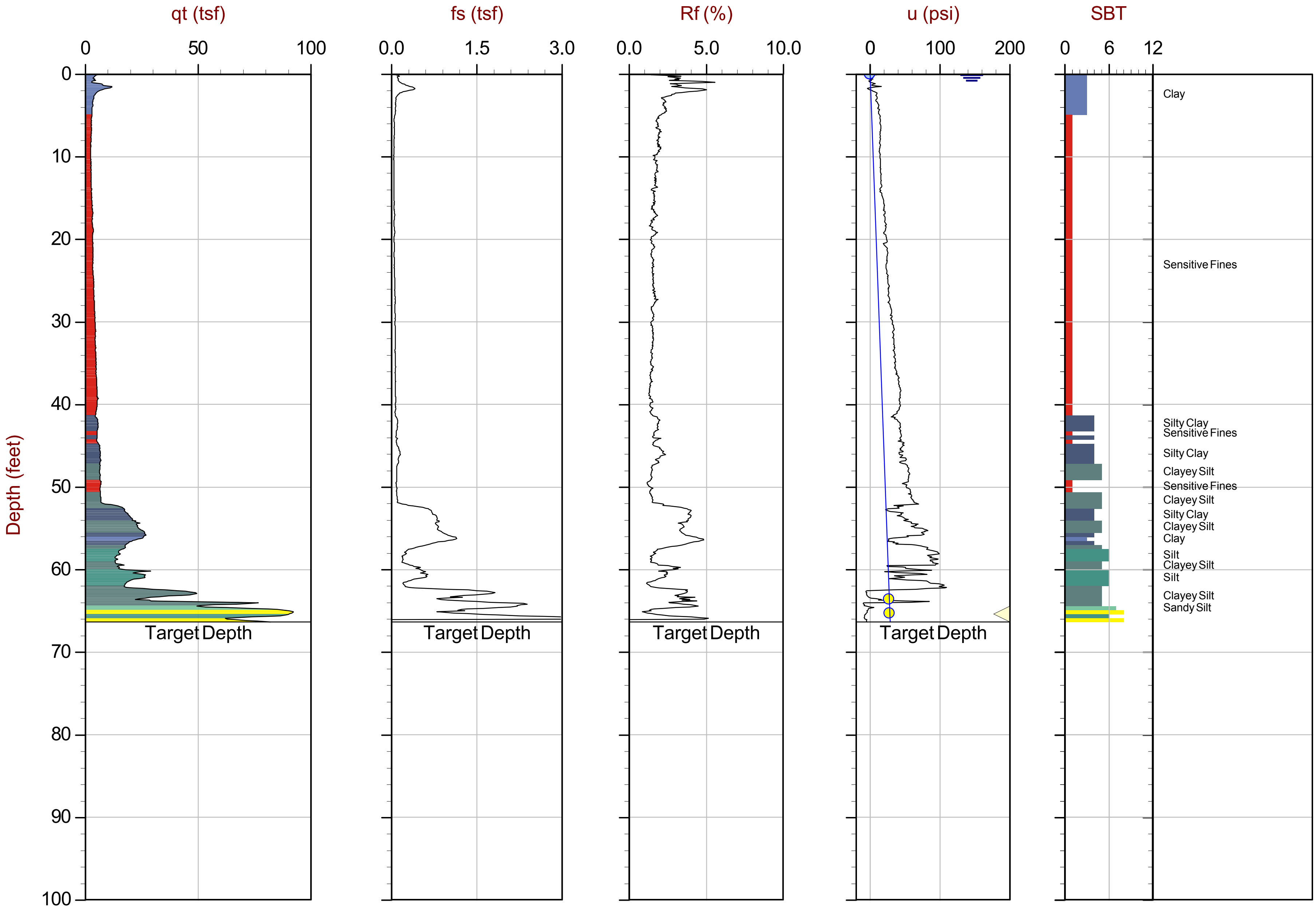
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 12:23
Site: SVCW Front of Plant Improvements
Sounding: CPT-24
Cone: 413:T375F10U200



Max Depth: 20.225 m / 66.35 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP24.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155434m E: 568091m
Sheet No: 1 of 1

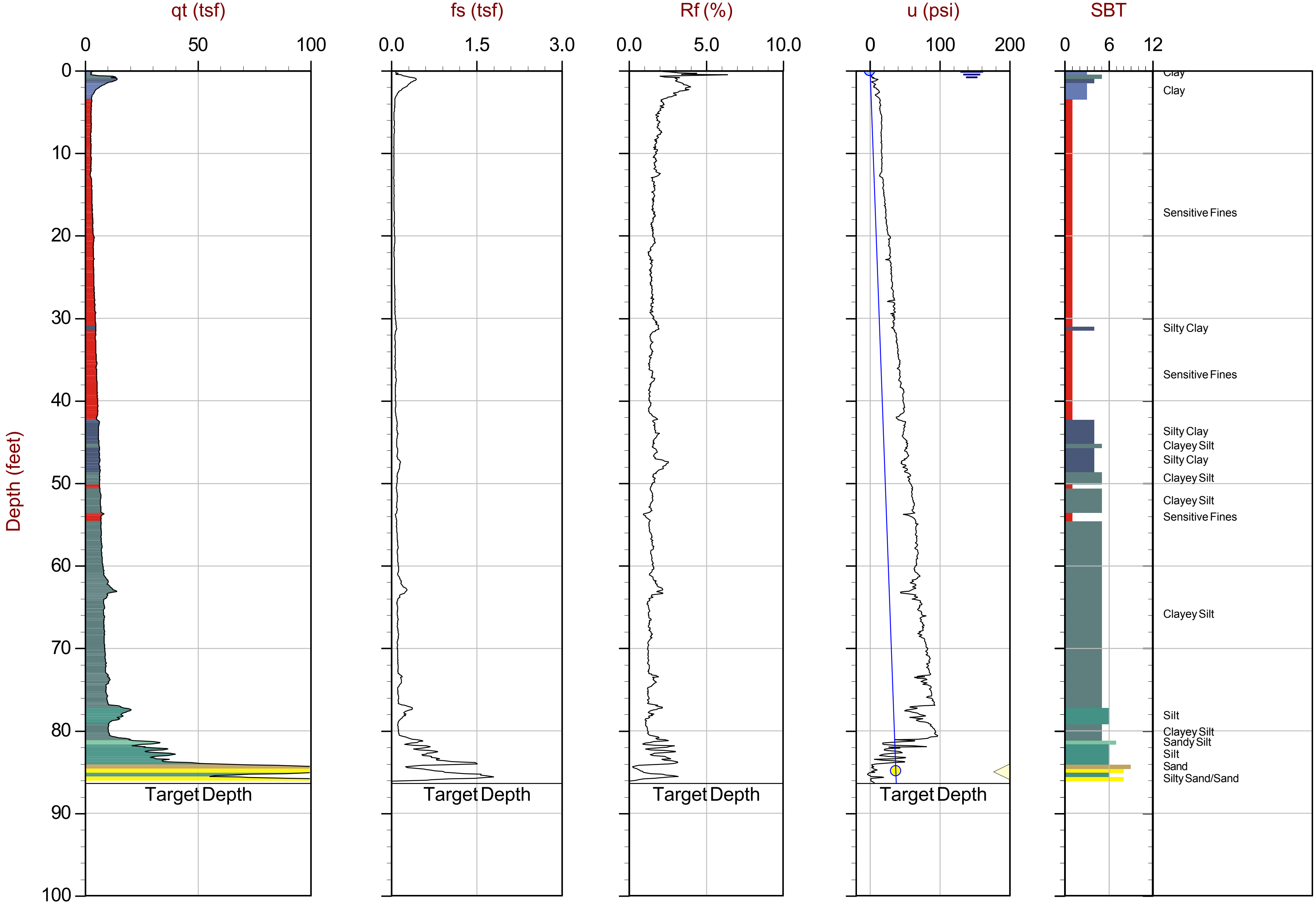
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 13:26
Site: SVCW Front of Plant Improvements
Sounding: CPT-25
Cone: 413:T375F10U200



Max Depth: 26.325 m / 86.37 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP25.COR
Unit Wt: SBT Zones

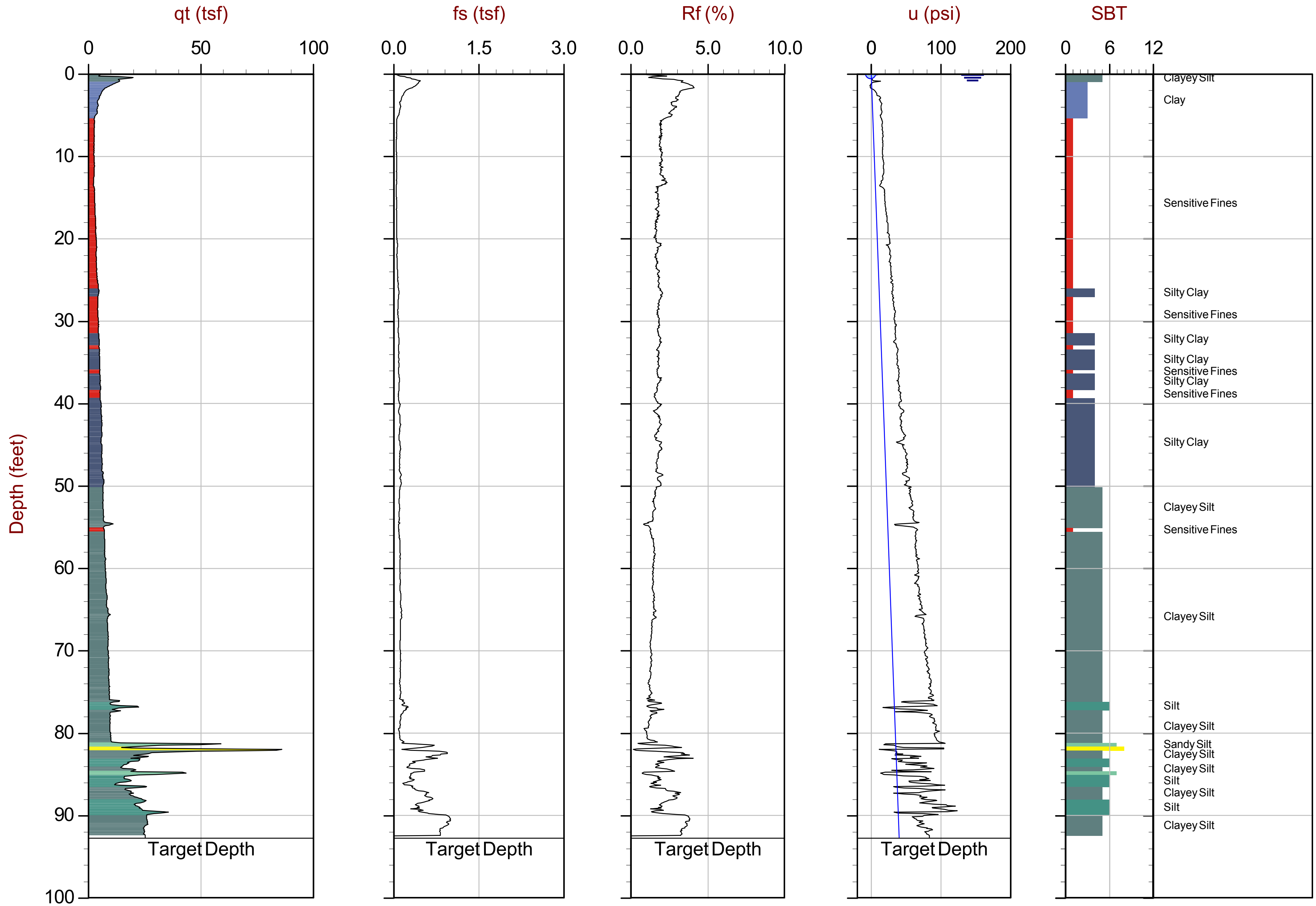
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155457m E: 568117m
Sheet No: 1 of 1

Equilibrium Pore Pressure (Ueq) | Assumed Ueq | Dissipation, Ueq achieved | Dissipation, Ueq not achieved | Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 09:12
Site: SVCW Front of Plant Improvements
Sounding: CPT-26
Cone: 413:T375F10U200



Max Depth: 28.275 m / 92.76 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP26.COR
Unit Wt: SBT Zones

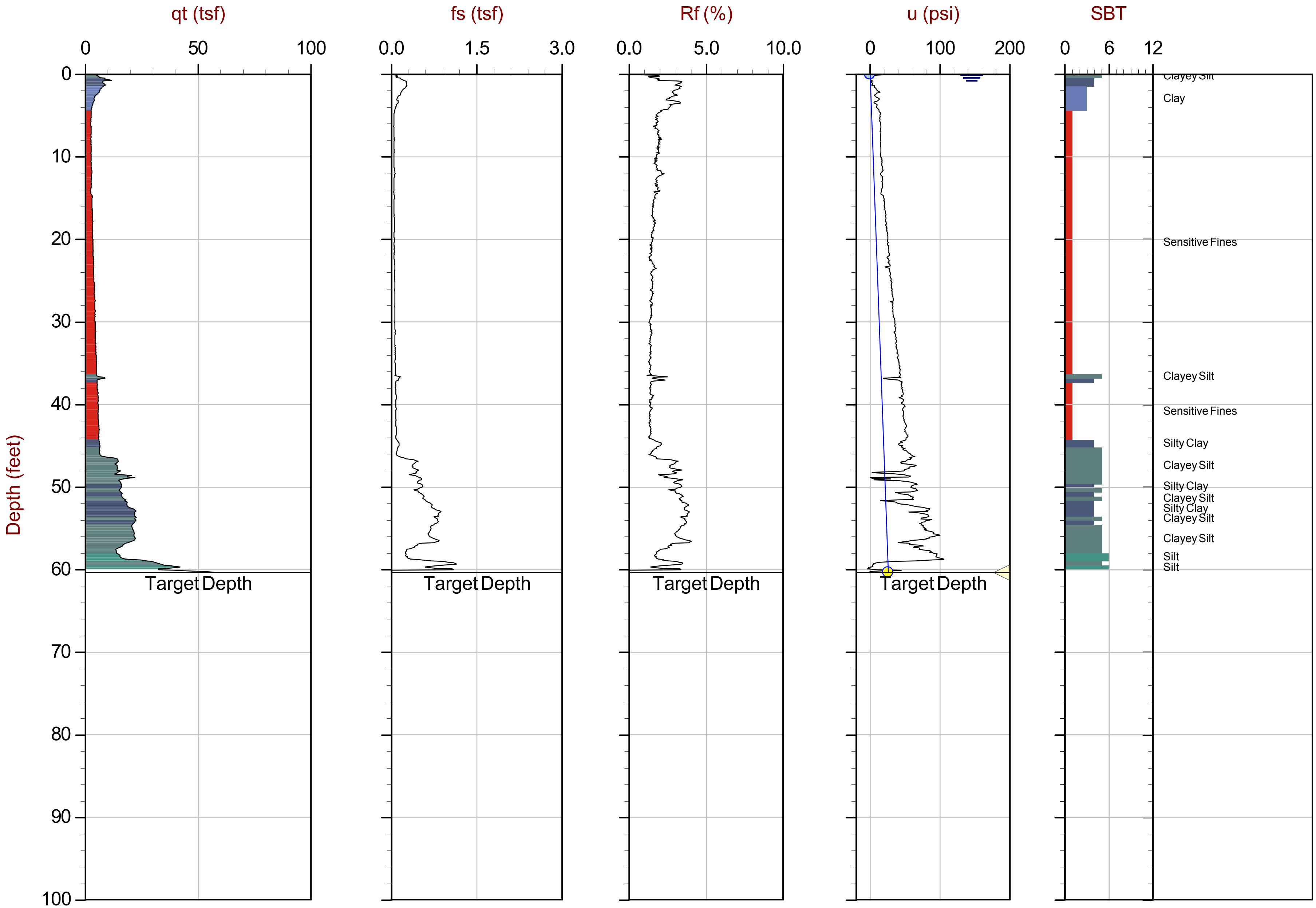
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155481m E: 568097m
Sheet No: 1 of 1

Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 15:40
Site: SVCW Front of Plant Improvements
Sounding: CPT-29
Cone: 413:T375F10U200



Max Depth: 18.400 m / 60.37 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP29.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155377m E: 568104m
Sheet No: 1 of 1

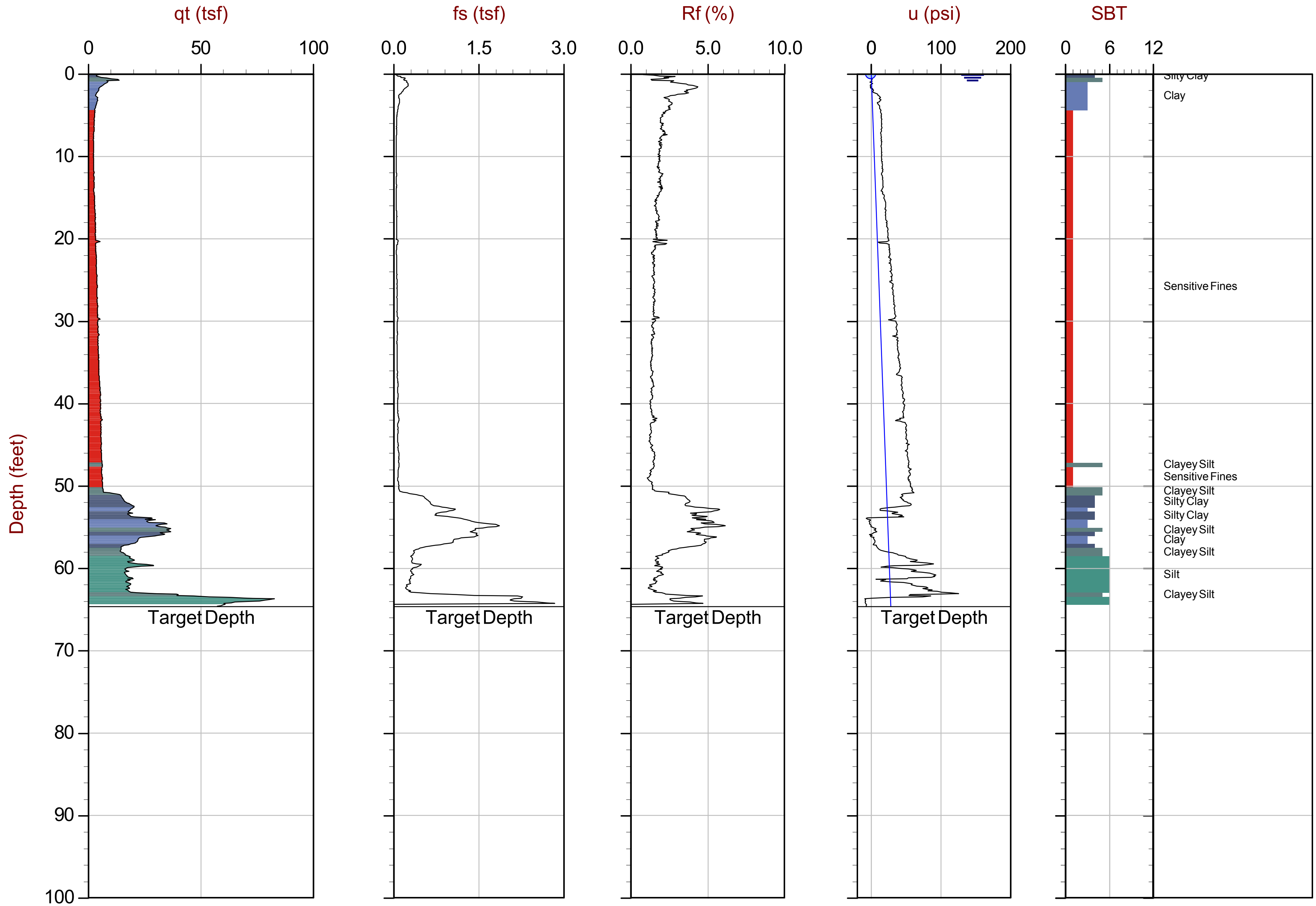
Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 14:42
Site: SVCW Front of Plant Improvements
Sounding: CPT-30
Cone: 413:T375F10U200



Max Depth: 19.700 m / 64.63 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP30.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155405m E: 568127m
Sheet No: 1 of 1

Equilibrium Pore Pressure (Ueq) Assumed Ueq Dissipation, Ueq achieved Dissipation, Ueq not achieved Hydrostatic Line

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

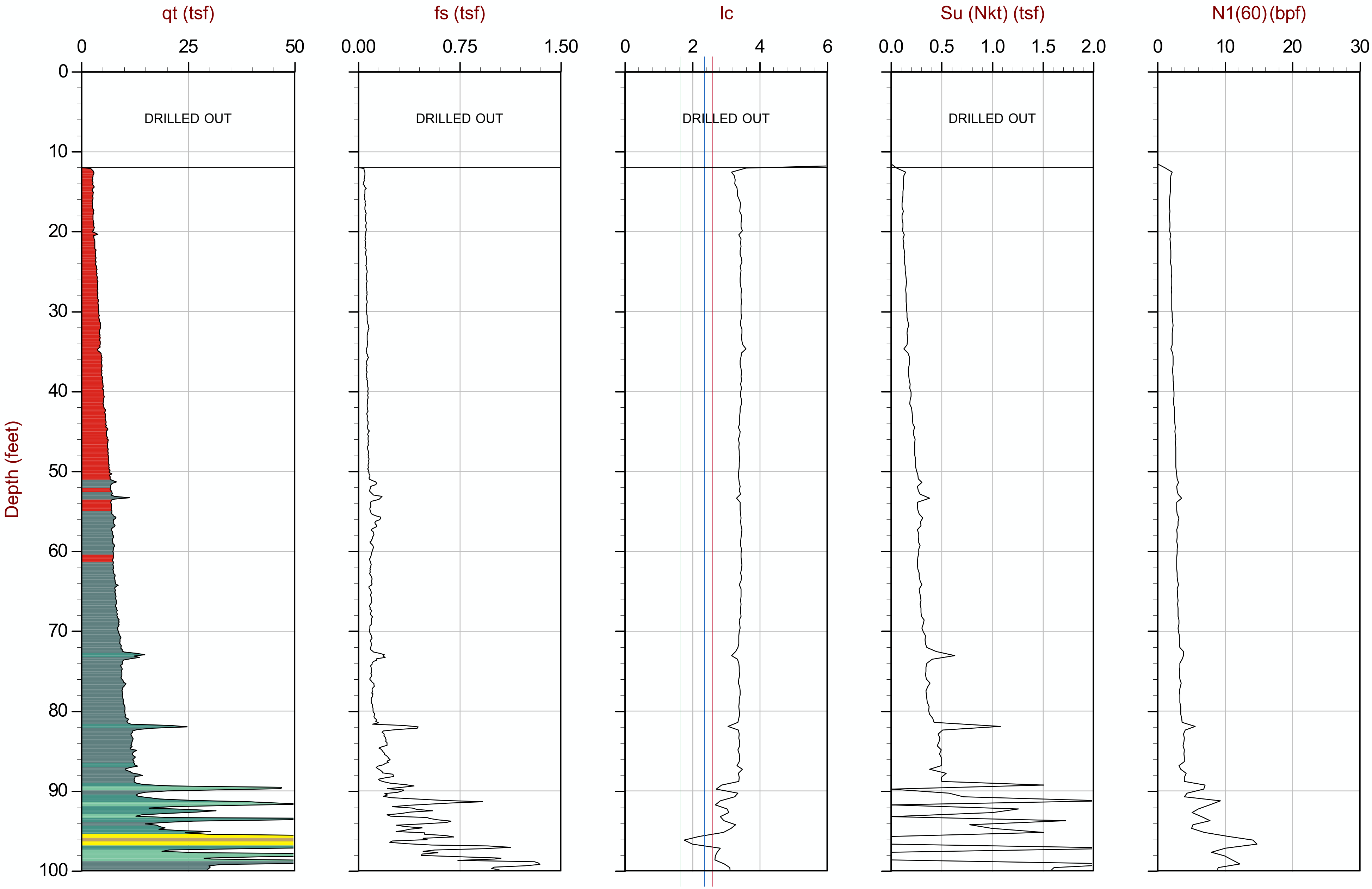
Advanced Cone Penetration Test Plots with Ic, Su(Nkt) and N1(60)

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 15:19
Site: SVCW Front of Plant Improvements

Sounding: CPT-13
Cone: 443:T1500F15U500



Max Depth: 33.600 m / 110.23 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP13.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

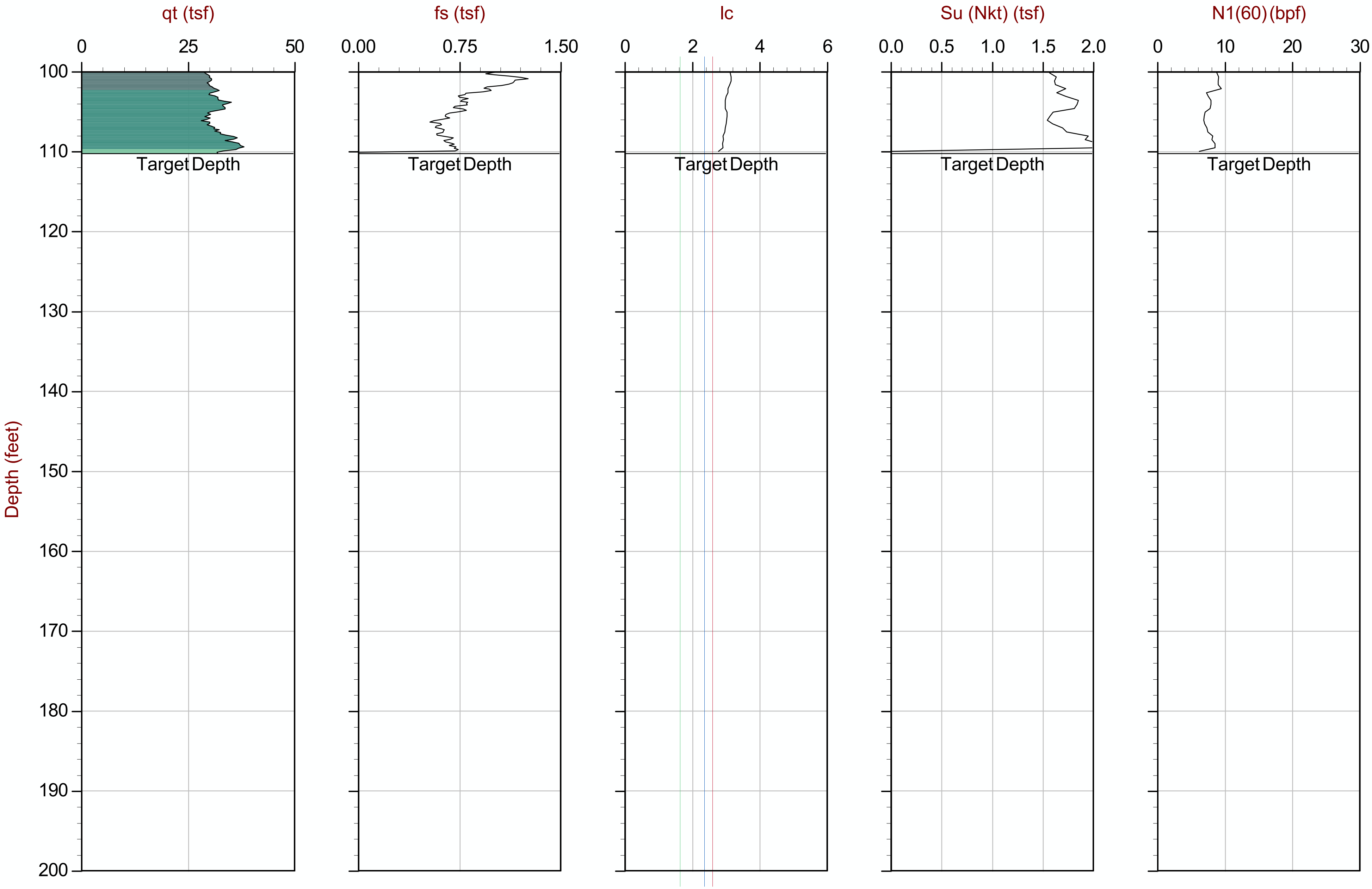
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155649m E: 567923m
Sheet No: 1 of 2

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 15:19
Site: SVCW Front of Plant Improvements
Sounding: CPT-13
Cone: 443:T1500F15U500



Max Depth: 33.600 m / 110.23 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP13.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

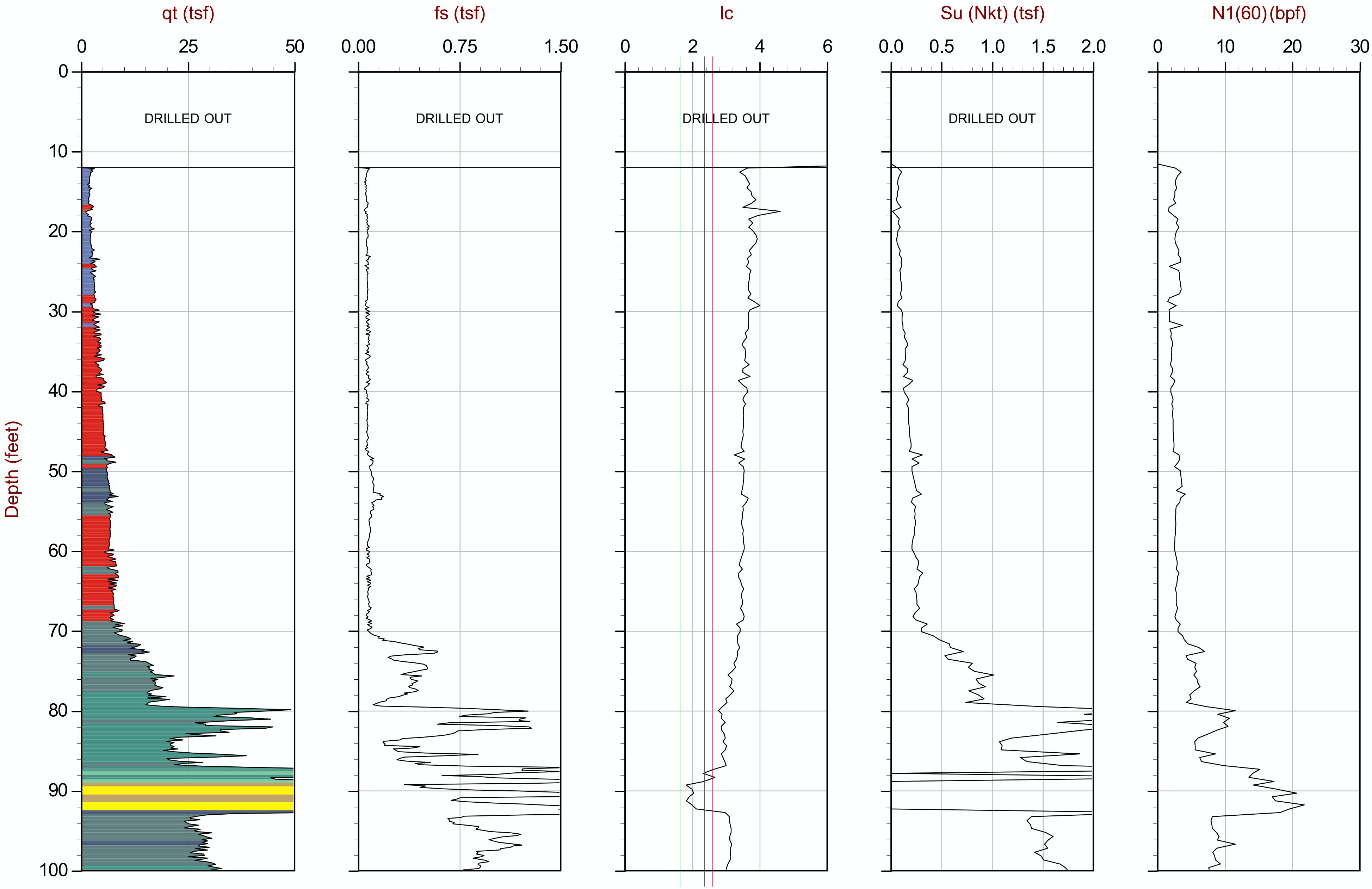
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155649m E: 567923m
Sheet No: 2 of 2

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 16:39
Site: SVCW Front of Plant Improvements
Sounding: CPT-14B
Cone: 443:T1500F15U500



Max Depth: 33.550 m / 110.07 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP14B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

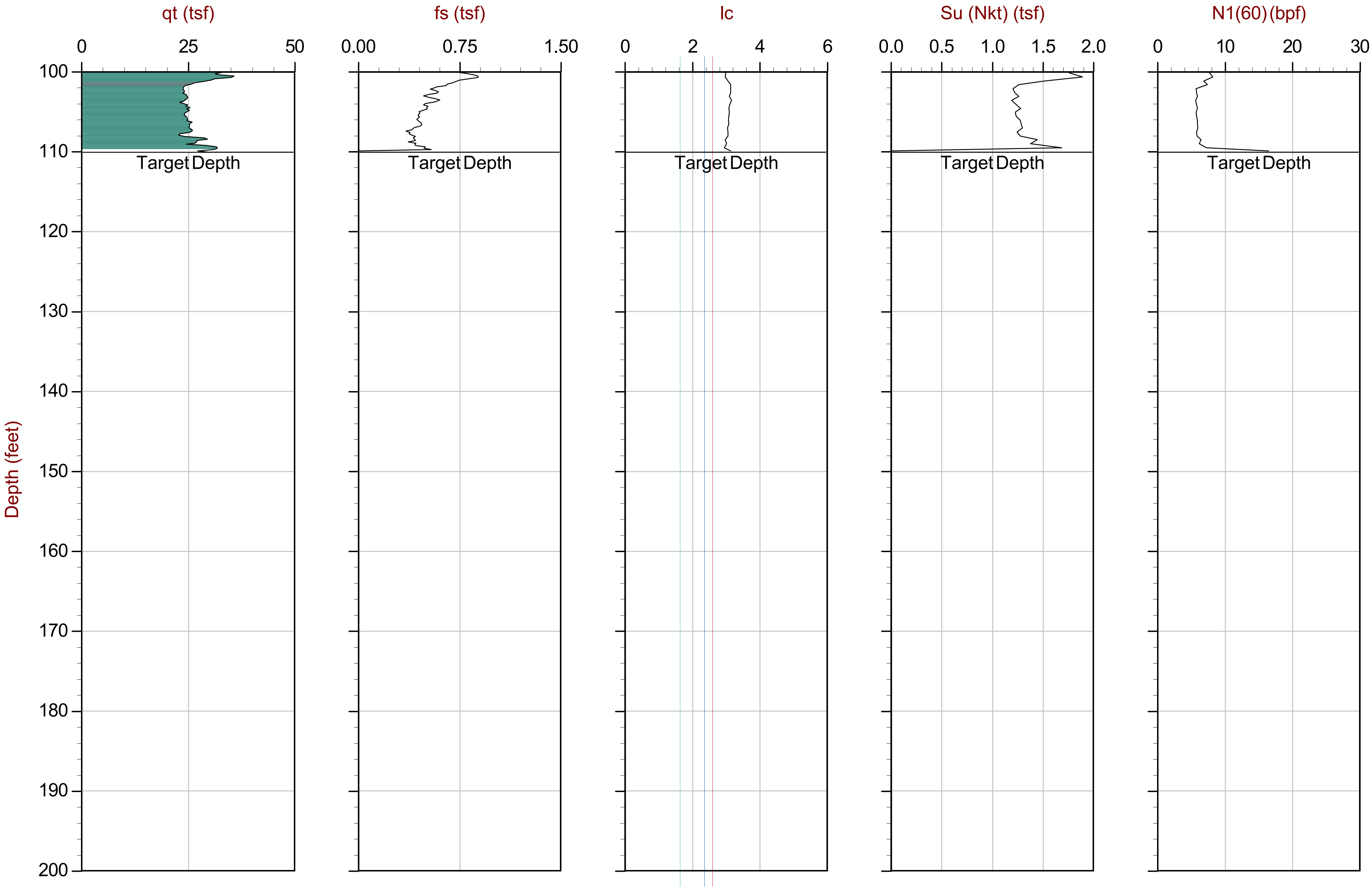
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155611m E: 567958m
Sheet No: 1 of 2

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:03:15 16:39
Site: SVCW Front of Plant Improvements
Sounding: CPT-14B
Cone: 443:T1500F15U500



Max Depth: 33.550 m / 110.07 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 15-56018_CP14B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

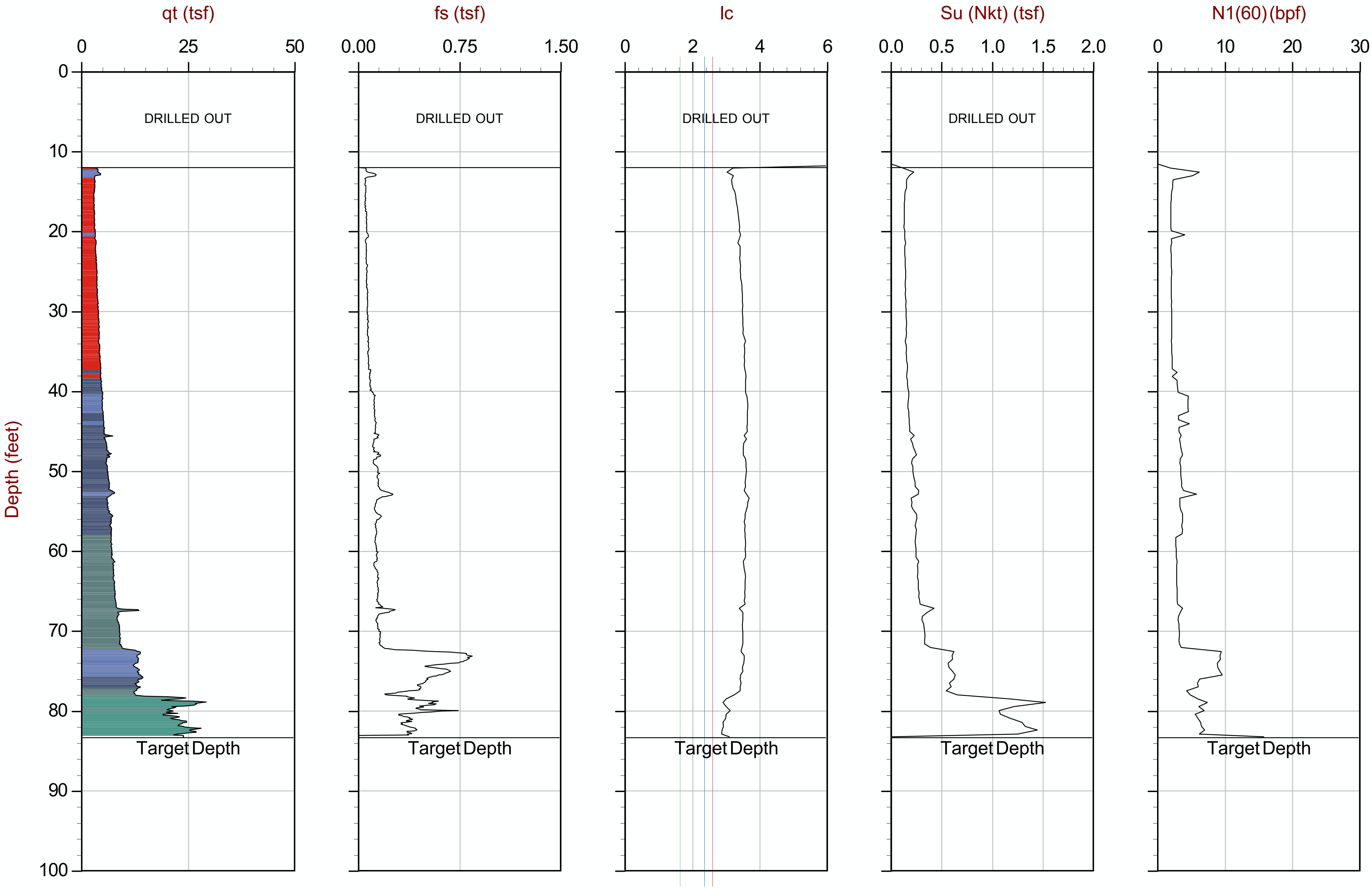
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155611m E: 567958m
Sheet No: 2 of 2

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 08:36
Site: SVCW Front of Plant Improvements
Sounding: CPT-14C
Cone: 413:T375F10U200



Max Depth: 25.400 m / 83.33 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP14C.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

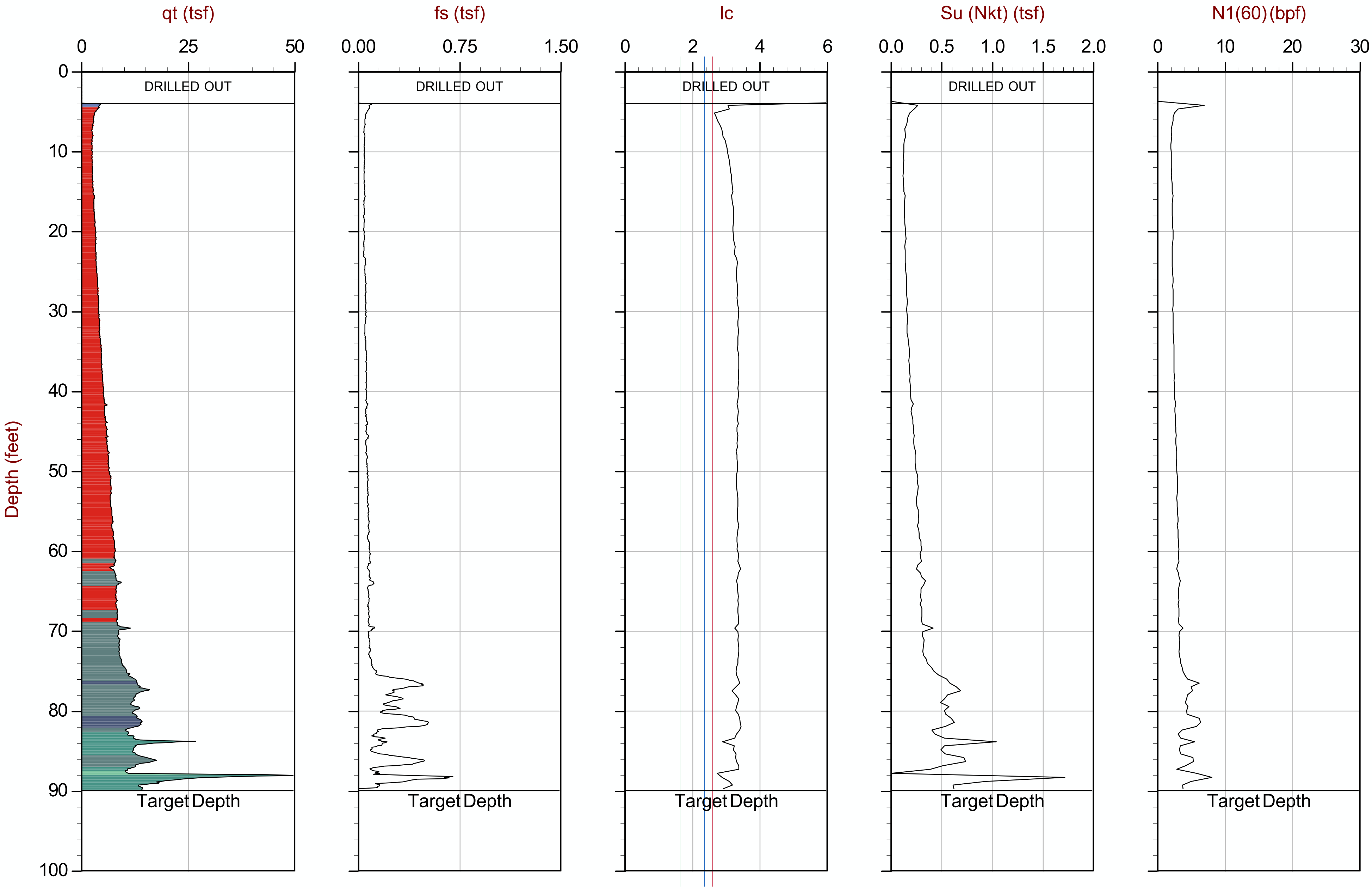
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155614m E: 567960m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 15:03
Site: SVCW Front of Plant Improvements
Sounding: CPT-15B
Cone: 413:T375F10U200



Max Depth: 27.425 m / 89.98 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP15B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155547m E: 568021m
Sheet No: 1 of 1

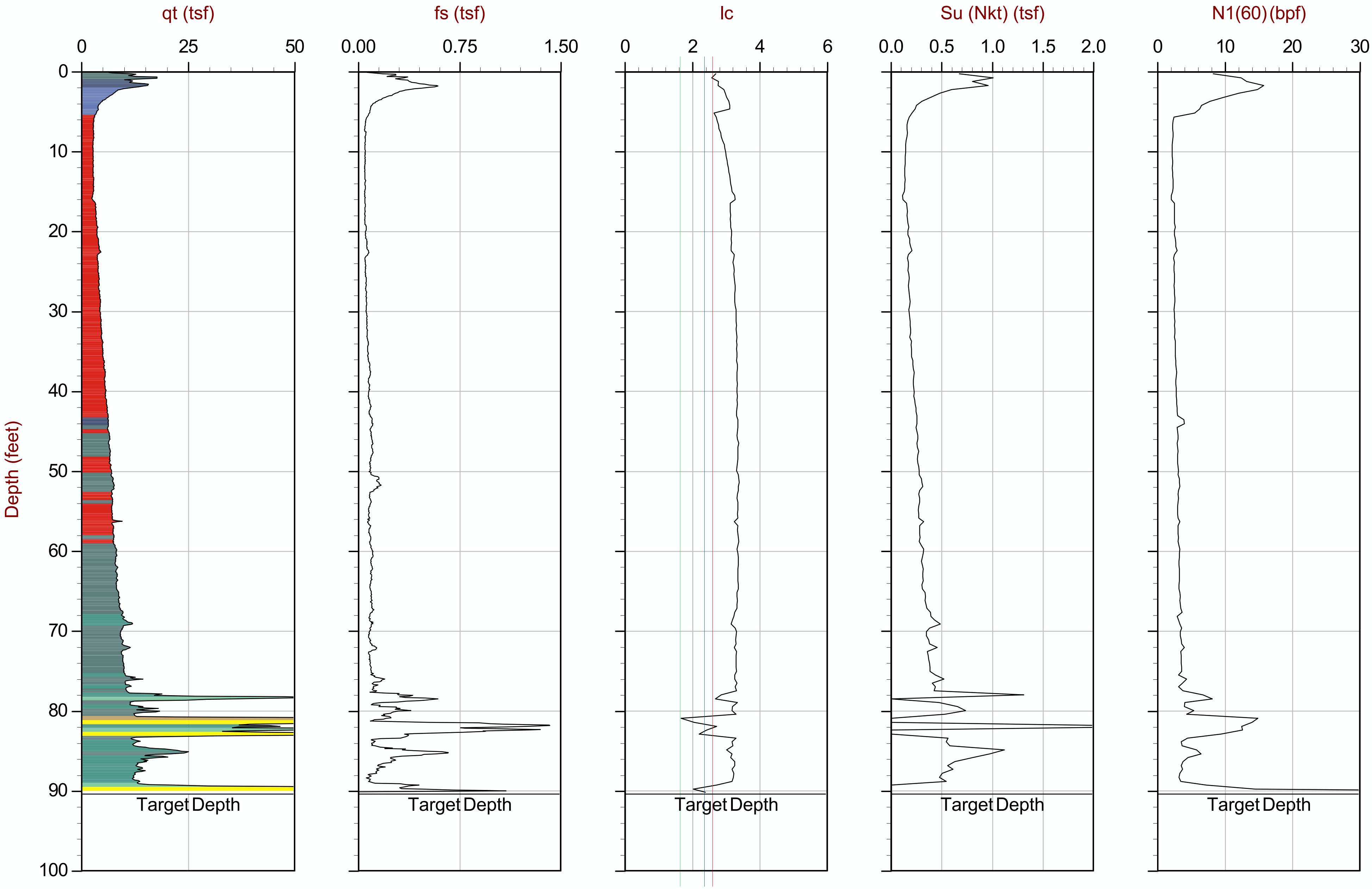
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 10:31
Site: SVCW Front of Plant Improvements

Sounding: CPT-16
Cone: 413:T375F10U200



Max Depth: 27.550 m / 90.39 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP16.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

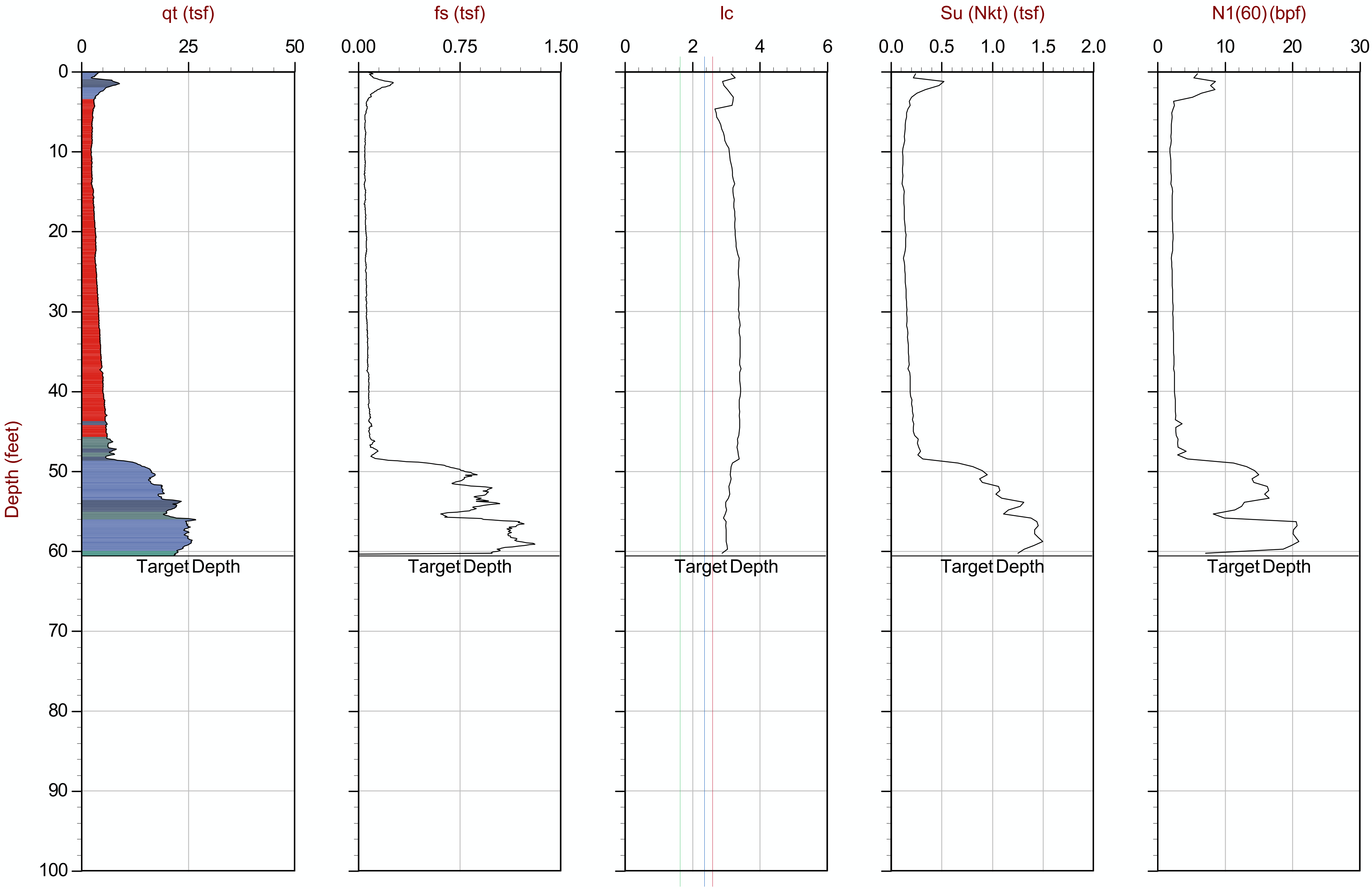
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155509m E: 568073m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 12:00
Site: SVCW Front of Plant Improvements
Sounding: CPT-17
Cone: 413:T375F10U200



Max Depth: 18.475 m / 60.61 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP17.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155471m E: 568023m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

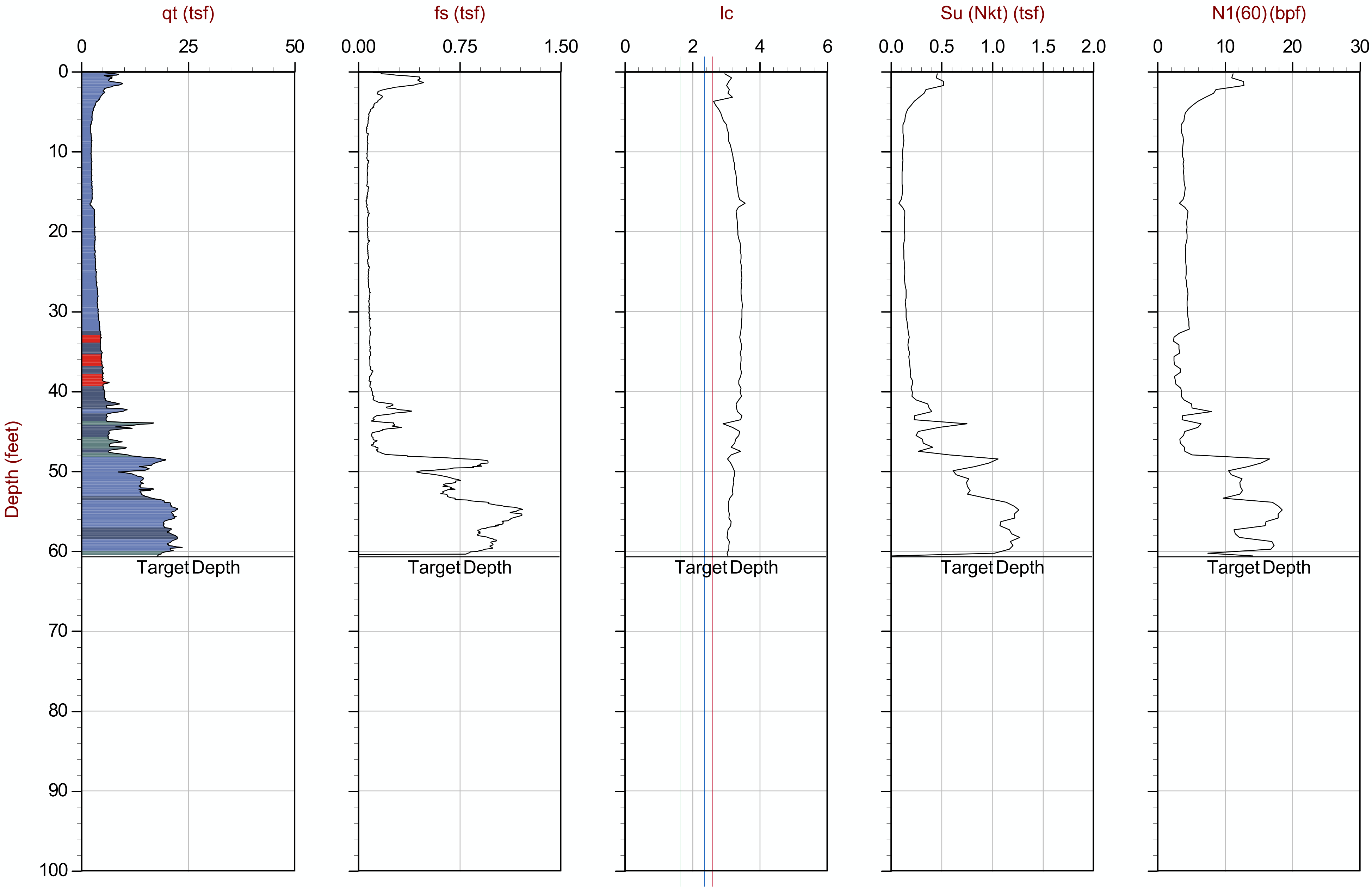
Job No: 15-56018

Date: 11:04:15 13:06

Site: SVCW Front of Plant Improvements

Sounding: CPT-18B

Cone: 413:T375F10U200



Max Depth: 18.500 m / 60.69 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP18B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

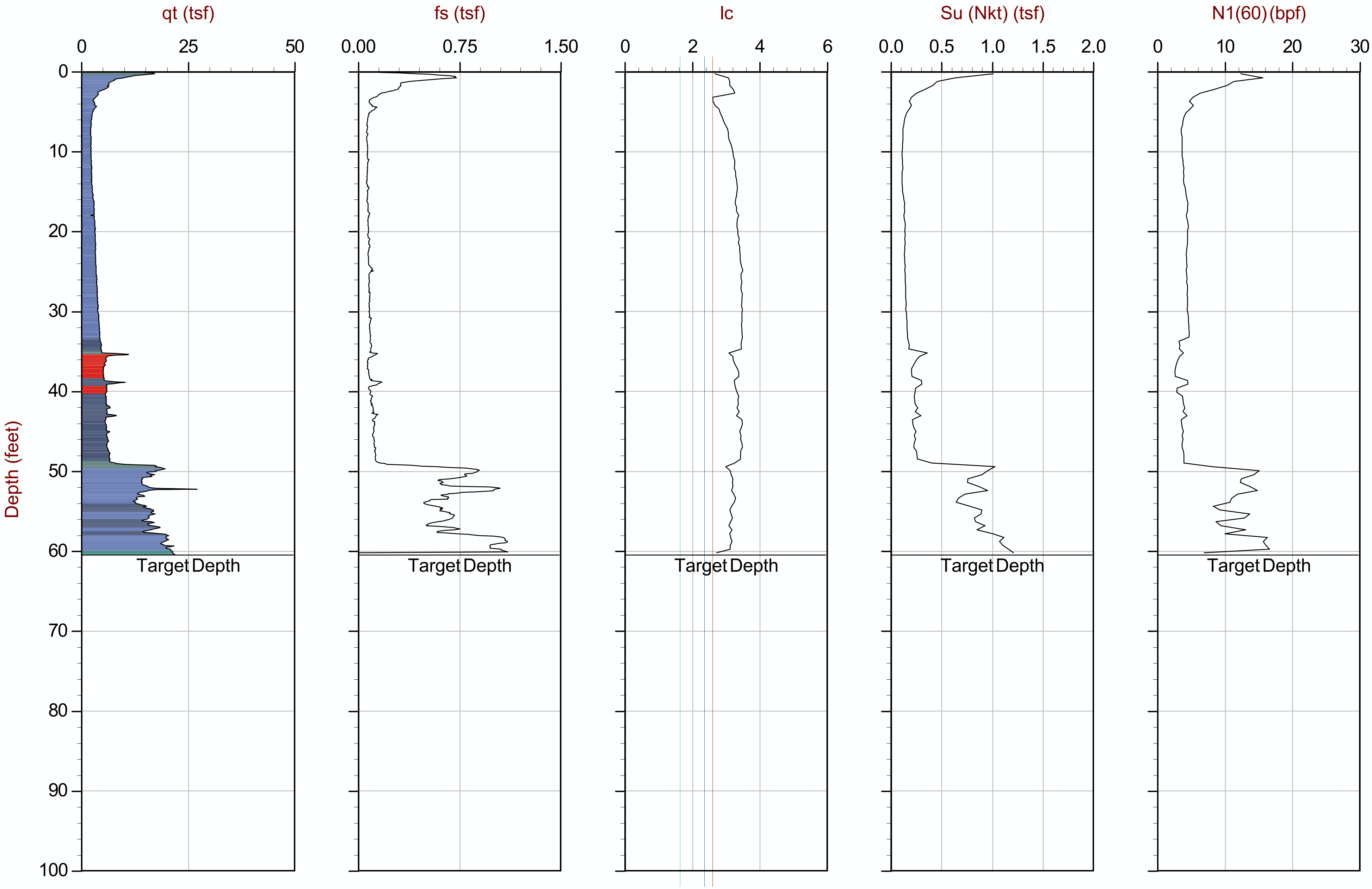
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155425m E: 567982m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 11:56
Site: SVCW Front of Plant Improvements
Sounding: CPT-19B
Cone: 413:T375F10U200



Max Depth: 18.425 m / 60.45 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP19B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

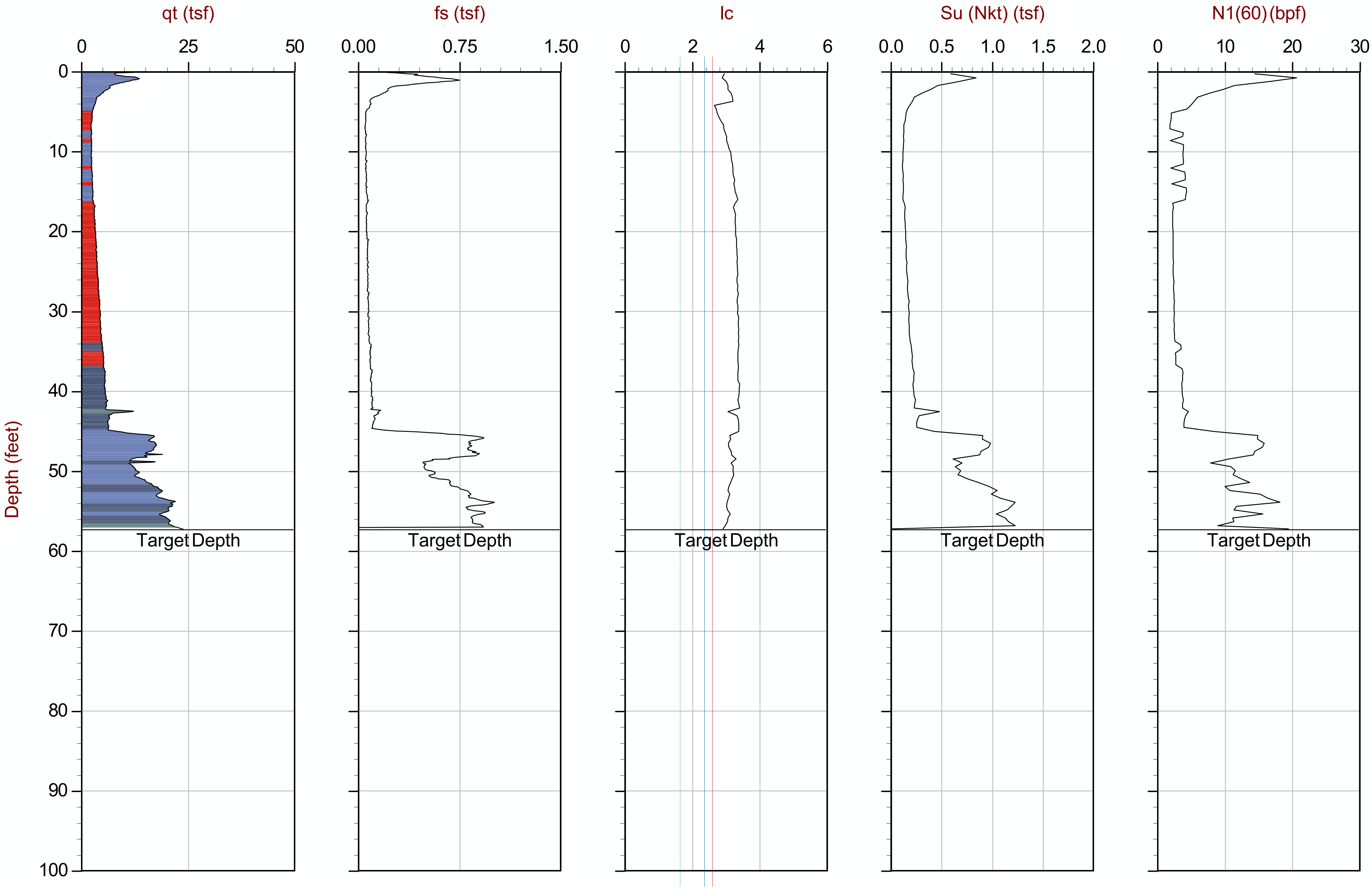
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155377m E: 567938m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 14:10
Site: SVCW Front of Plant Improvements
Sounding: CPT-20B
Cone: 413:T375F10U200



Max Depth: 17.475 m / 57.33 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP20B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

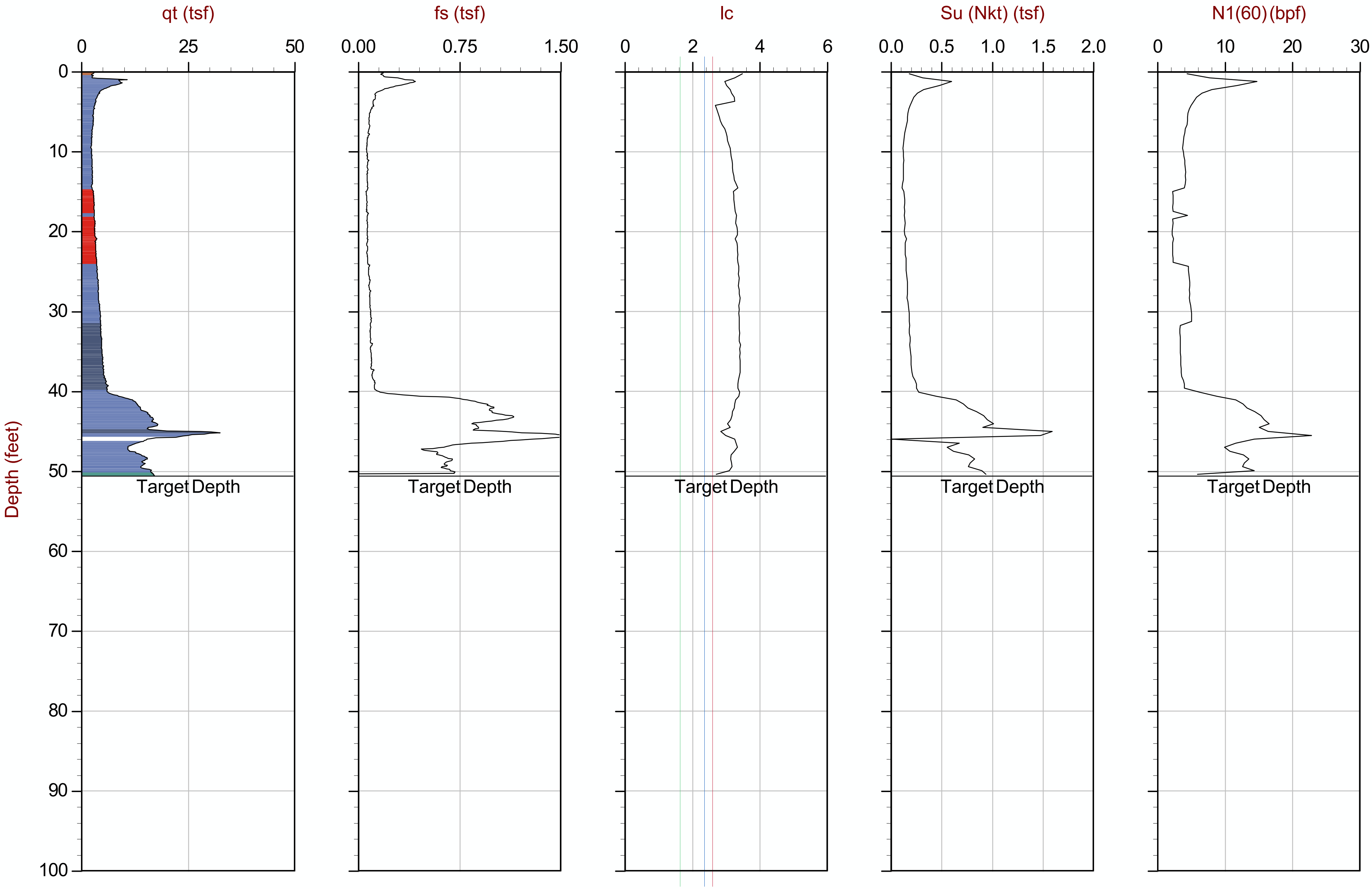
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155355m E: 567967m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:04:15 14:58
Site: SVCW Front of Plant Improvements
Sounding: CPT-21B
Cone: 413:T375F10U200



Max Depth: 15.425 m / 50.61 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP21B.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

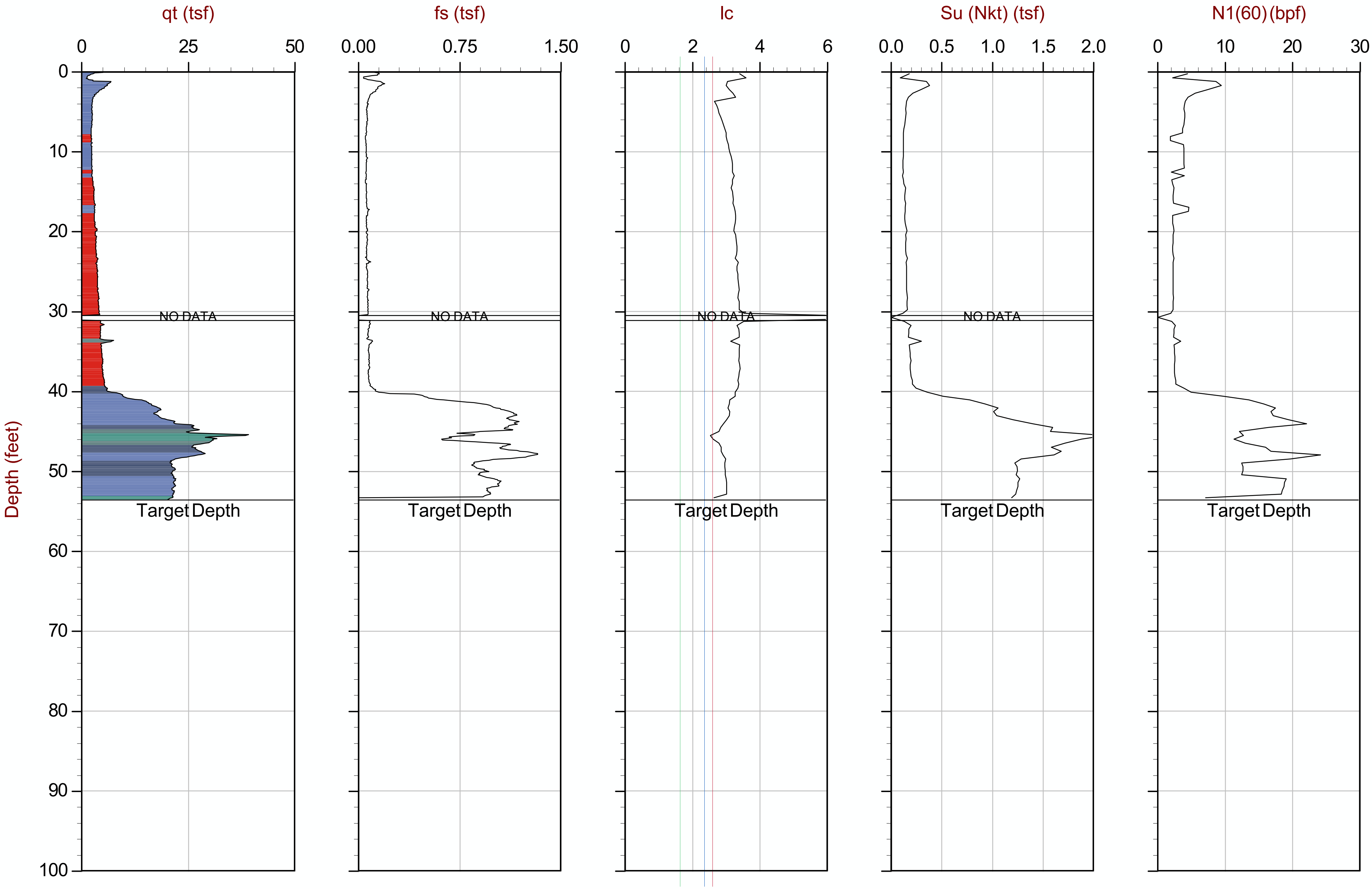
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155340m E: 567999m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 10:18
Site: SVCW Front of Plant Improvements
Sounding: CPT-22
Cone: 413:T375F10U200



Max Depth: 16.325 m / 53.56 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

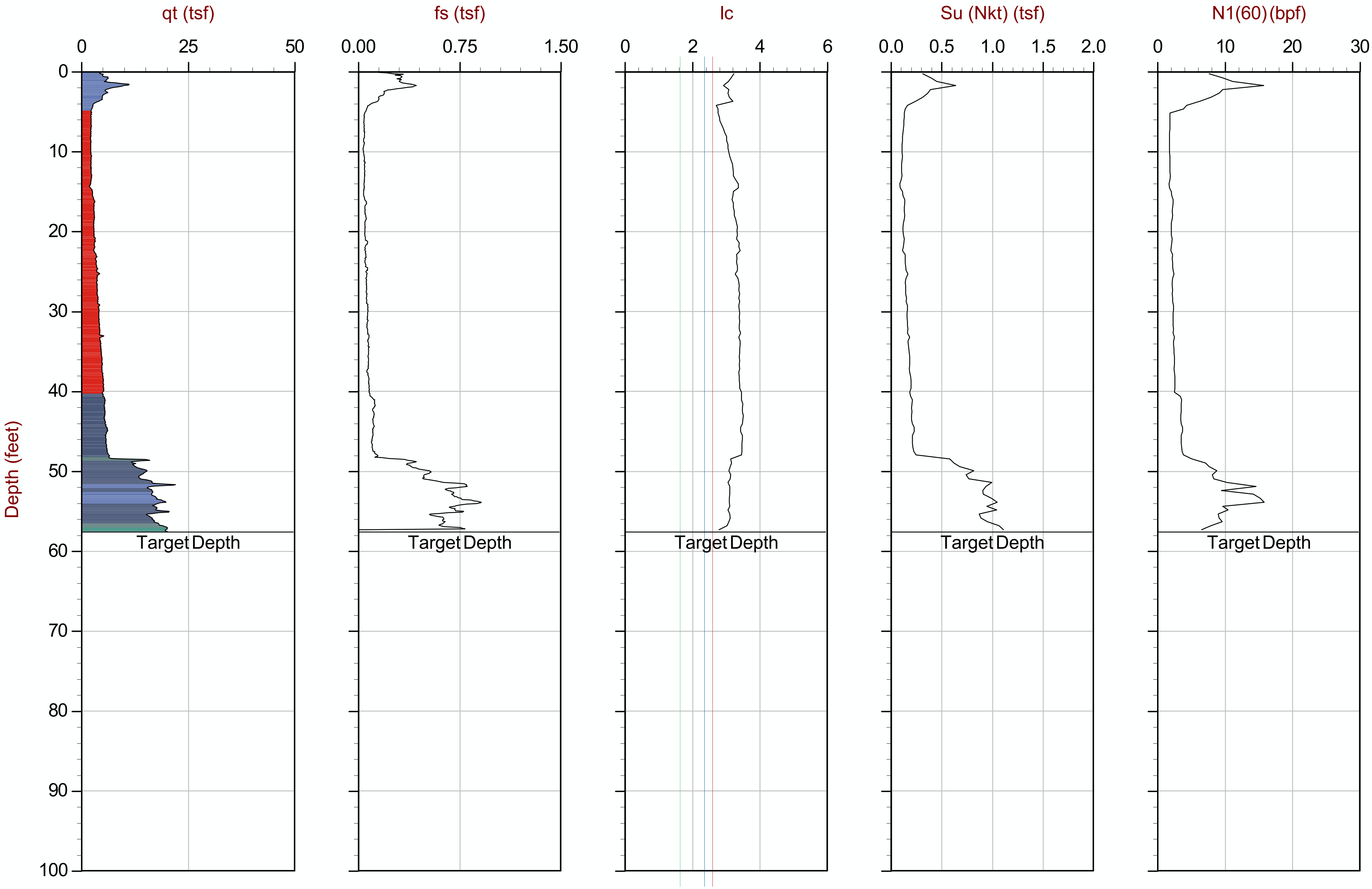
File: 15-56018_CP22.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155382m E: 568035m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 11:31
Site: SVCW Front of Plant Improvements
Sounding: CPT-23
Cone: 413:T375F10U200



Max Depth: 17.550 m / 57.58 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP23.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

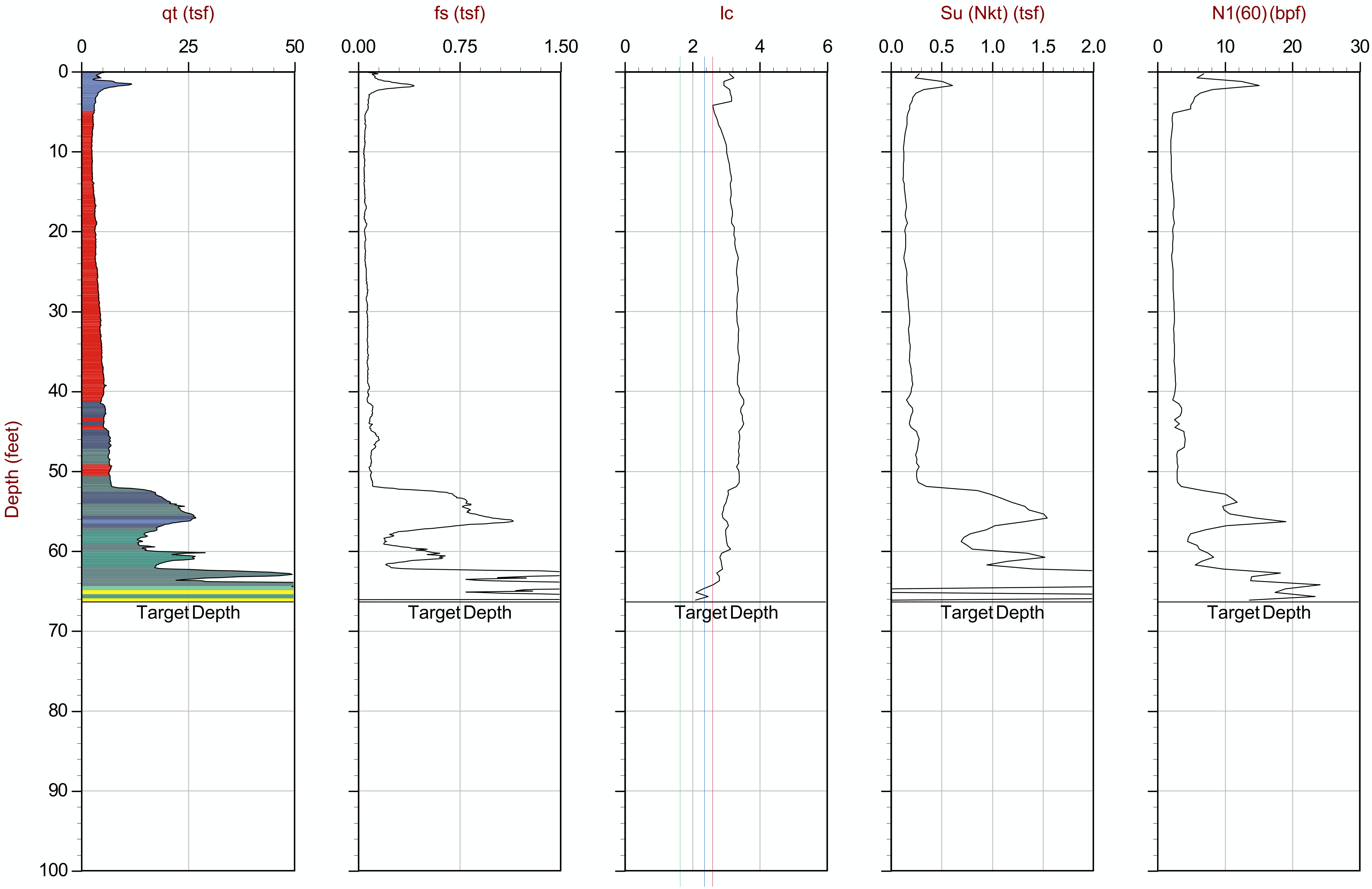
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155398m E: 568062m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 12:23
Site: SVCW Front of Plant Improvements
Sounding: CPT-24
Cone: 413:T375F10U200



Max Depth: 20.225 m / 66.35 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP24.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

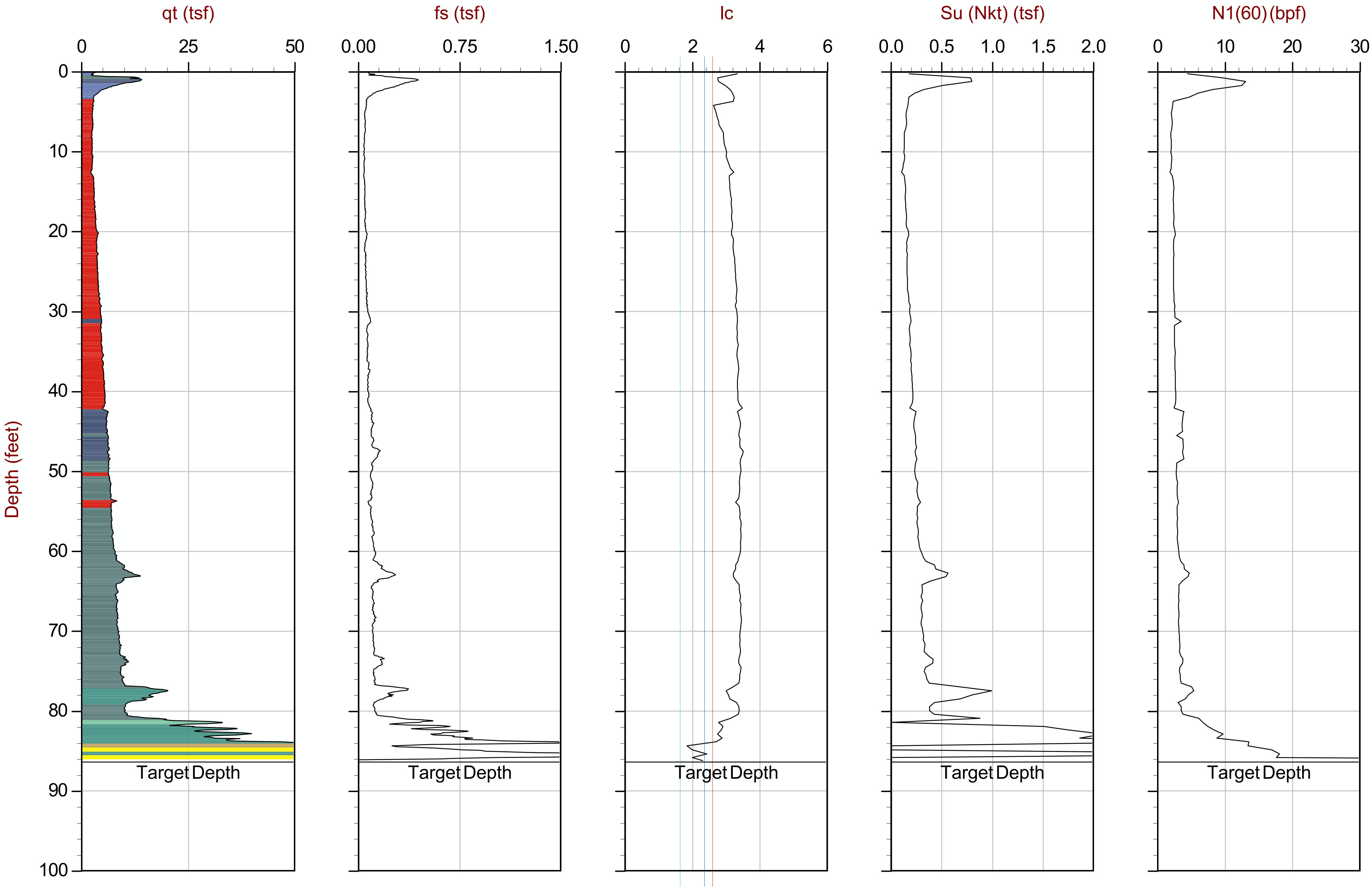
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155434m E: 568091m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 13:26
Site: SVCW Front of Plant Improvements
Sounding: CPT-25
Cone: 413:T375F10U200



Max Depth: 26.325 m / 86.37 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP25.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

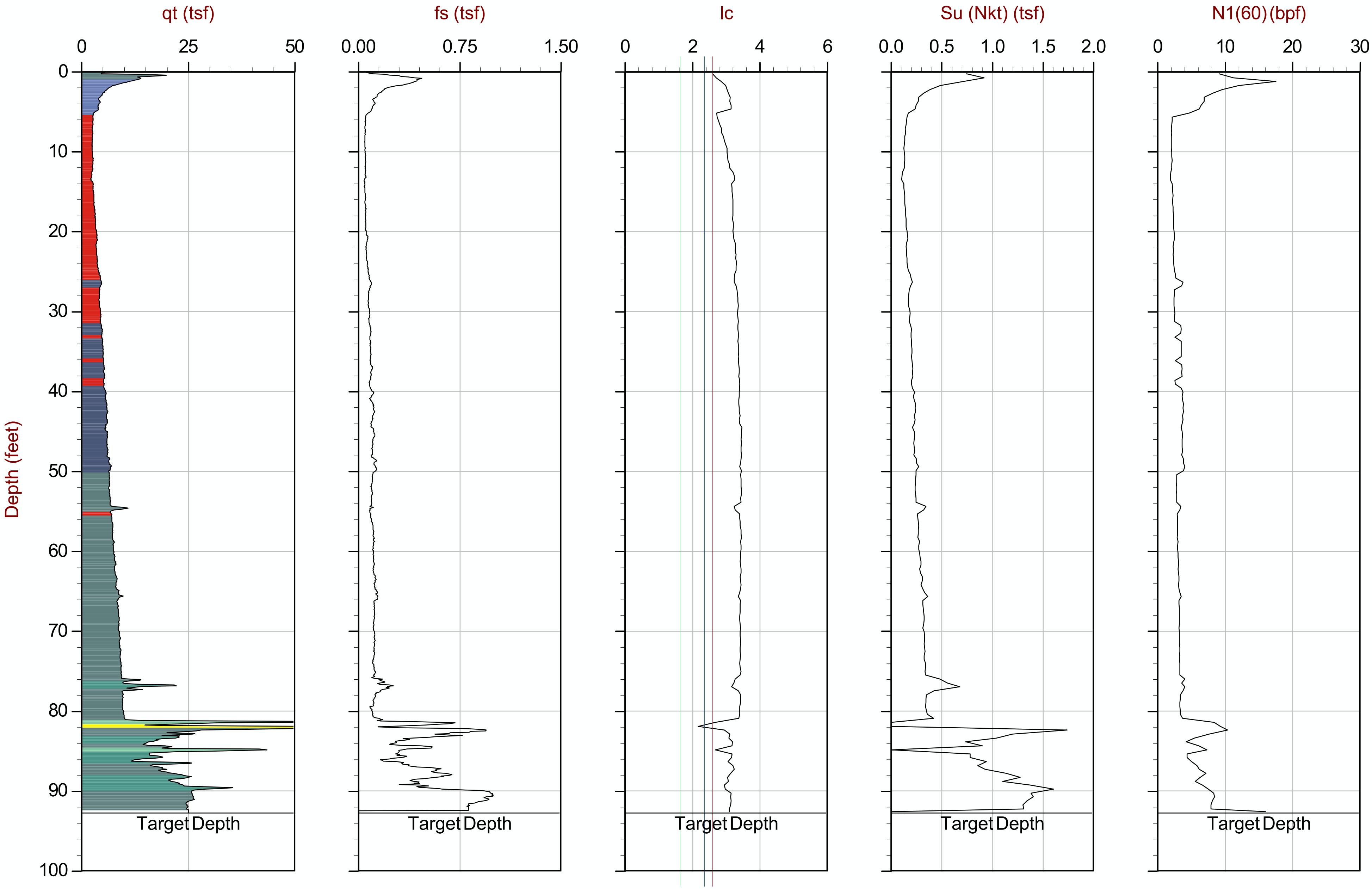
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155457m E: 568117m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:06:15 09:12
Site: SVCW Front of Plant Improvements
Sounding: CPT-26
Cone: 413:T375F10U200



Max Depth: 28.275 m / 92.76 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP26.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155481m E: 568097m
Sheet No: 1 of 1

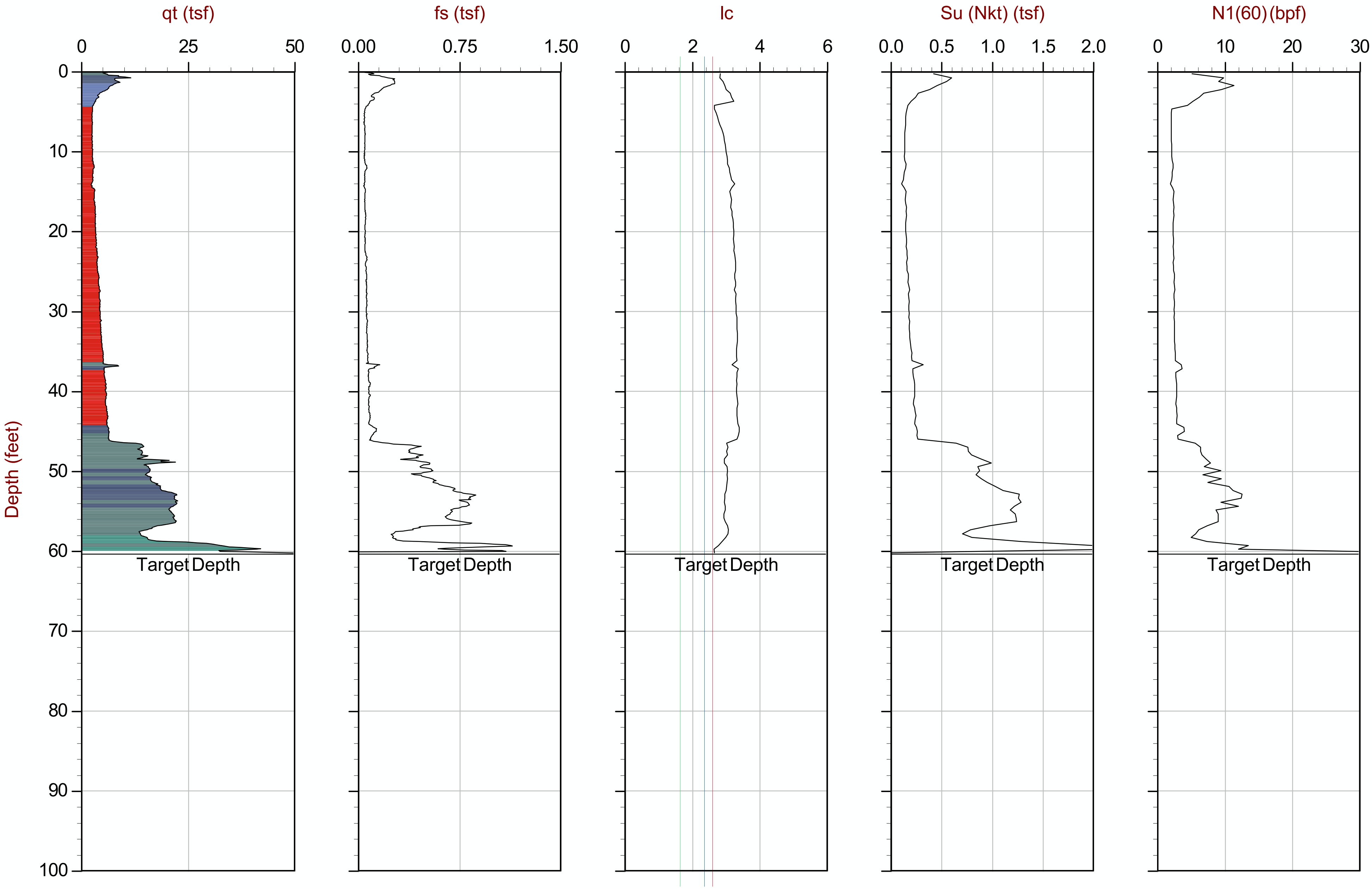
The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 15:40
Site: SVCW Front of Plant Improvements

Sounding: CPT-29
Cone: 413:T375F10U200



Max Depth: 18.400 m / 60.37 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP29.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

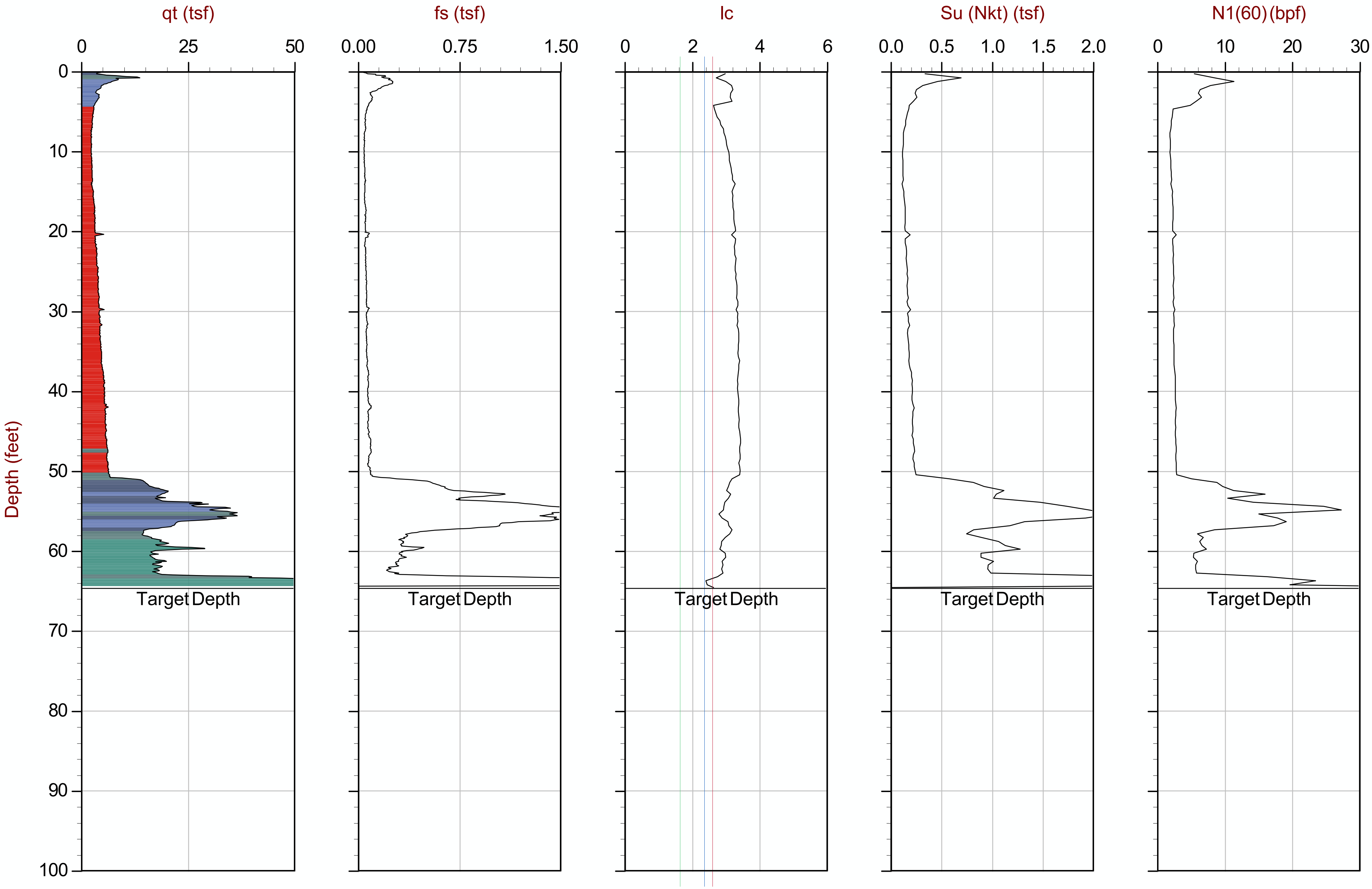
SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155377m E: 568104m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11:05:15 14:42
Site: SVCW Front of Plant Improvements
Sounding: CPT-30
Cone: 413:T375F10U200



Max Depth: 19.700 m / 64.63 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: 0.150 m

File: 15-56018_CP30.COR
Unit Wt: SBT Zones
Su Nkt: 15.0

SBT: Robertson and Campanella, 1986
Coords: WGS84 10S N: 4155405m E: 568127m
Sheet No: 1 of 1

The reported coordinates were acquired from consumer grade GPS equipment and are only approximate locations. The coordinates should not be used for design purposes.

Pore Pressure Dissipation Summary and
Pore Pressure Dissipation Plots

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

Job No: 15-56018
Client: DCM Consulting, Inc.
Project: SVCW Front of Plant Improvements
Start Date: 03-Nov-2015
End Date: 06-Nov-2015

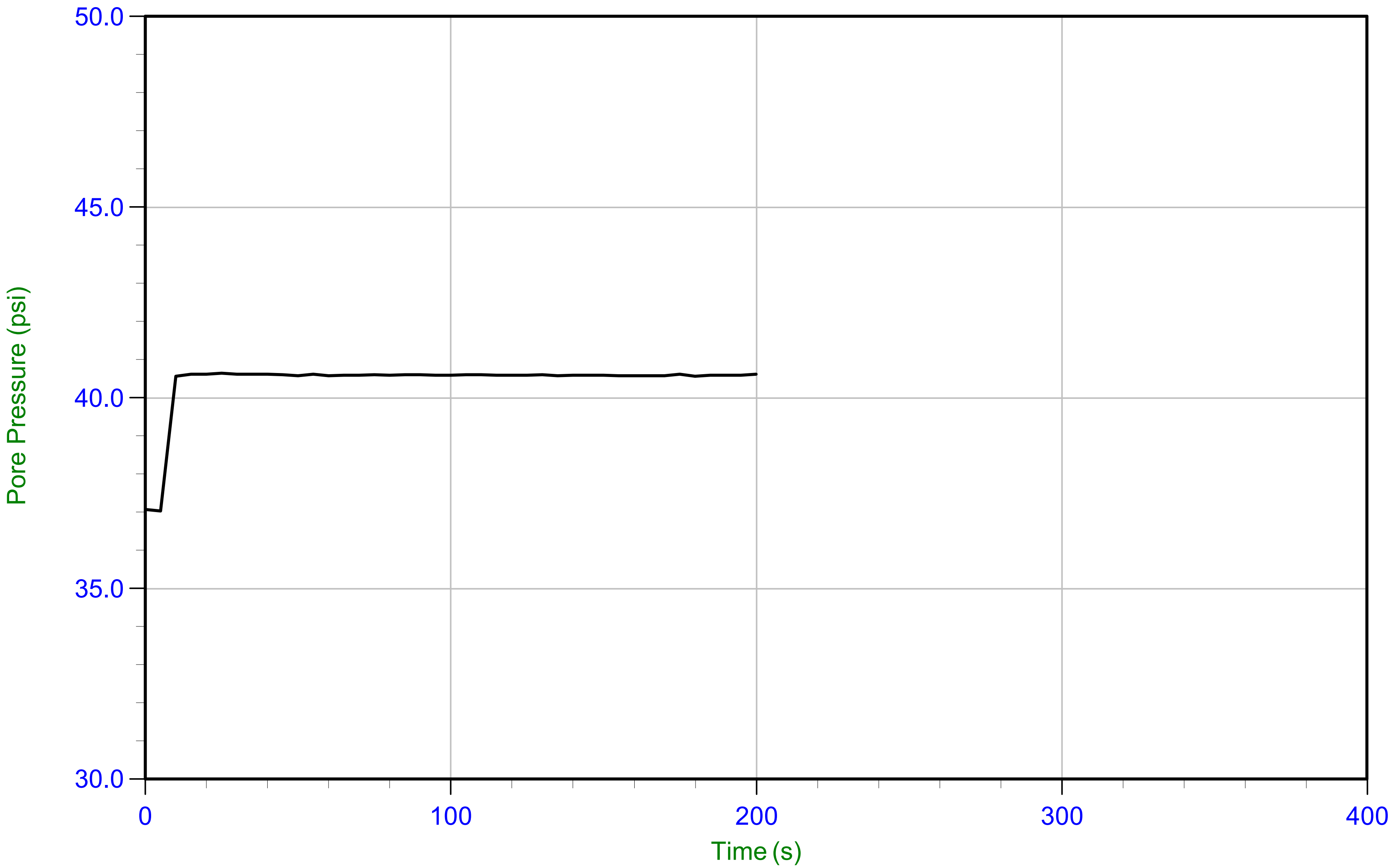
CPTu PORE PRESSURE DISSIPATION SUMMARY

Sounding ID	File Name	Cone Area (cm^2)	Duration (s)	Test Depth (ft)	Estimated Equilibrium Pore Pressure U_{eq} (psi)	Calculated Phreatic Surface (ft)
CPT-13	15-56018_CP13	15	200	96.1	40.6	2.4
CPT-14B	15-56018_CP14B	15	150	89.7	37.9	2.2
CPT-16	15-56018_CP16	15	460	81.3	36.1	-1.9
CPT-24	15-56018_CP24	15	220	65.4	28.6	-0.6
CPT-25	15-56018_CP25	15	140	85.0	37.5	-1.5
CPT-29	15-56018_CP29	15	300	60.4	26.5	-0.9

DCM Consulting, Inc.

Job No: 15-56018
Date: 11/03/2015 15:19
Site: SVCW Front of Plant Improvements

Sounding: CPT-13
Cone: 443:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 15-56018_CP13.PPF
Depth: 29.300 m / 96.127 ft
Duration: 200.0 s

U Min: 37.0 psi
U Max: 40.6 psi

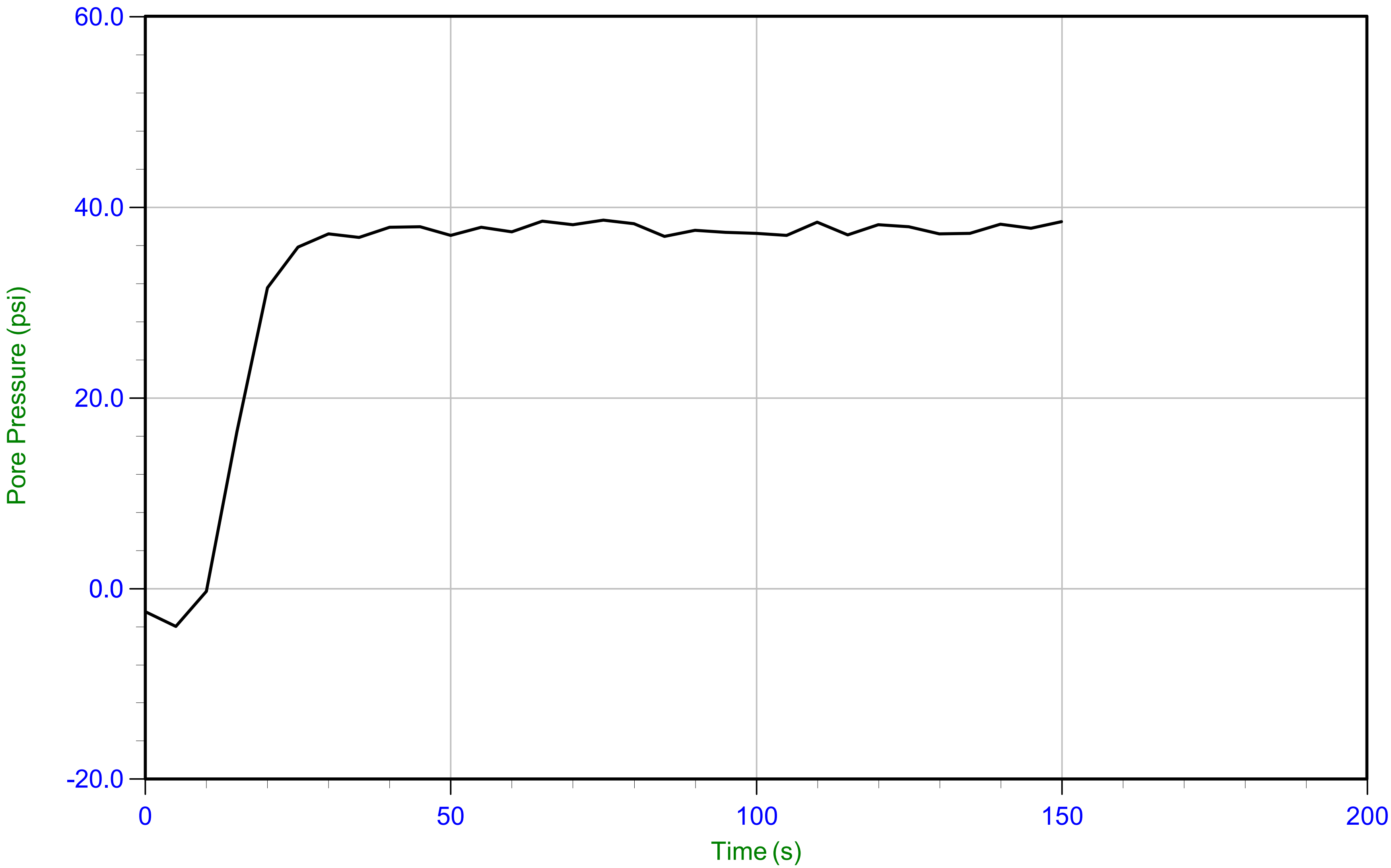
WT: 0.744 m / 2.441 ft
Ueq: 40.6 psi

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11/03/2015 16:39
Site: SVCW Front of Plant Improvements

Sounding: CPT-14B
Cone: 443:T1500F15U500
Cone Area: 15 sq cm



Trace Summary:

Filename: 15-56018_CP14B.PPF
Depth: 27.350 m / 89.730 ft
Duration: 150.0 s

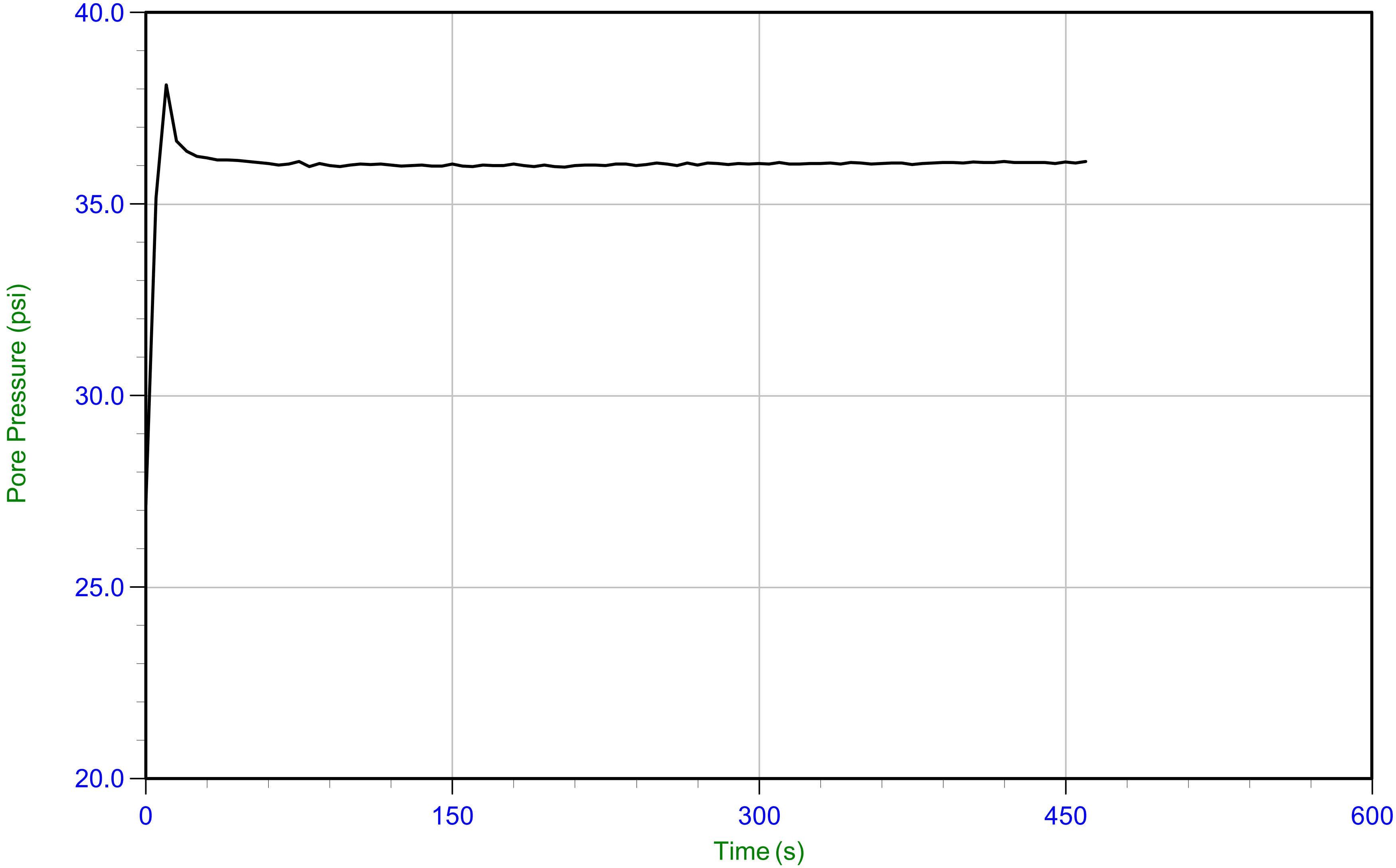
U Min: -4.0 psi
U Max: 38.7 psi

WT: 0.679 m / 2.228 ft
Ueq: 37.9 psi

DCM Consulting, Inc.

Job No: 15-56018
Date: 11/06/2015 10:31
Site: SVCW Front of Plant Improvements

Sounding: CPT-16
Cone: 413:T375F10U200
Cone Area: 15 sq cm



Trace Summary:

Filename: 15-56018_CP16.PPF
Depth: 24.775 m / 81.282 ft
Duration: 460.0 s

U Min: 27.1 psi
U Max: 38.1 psi

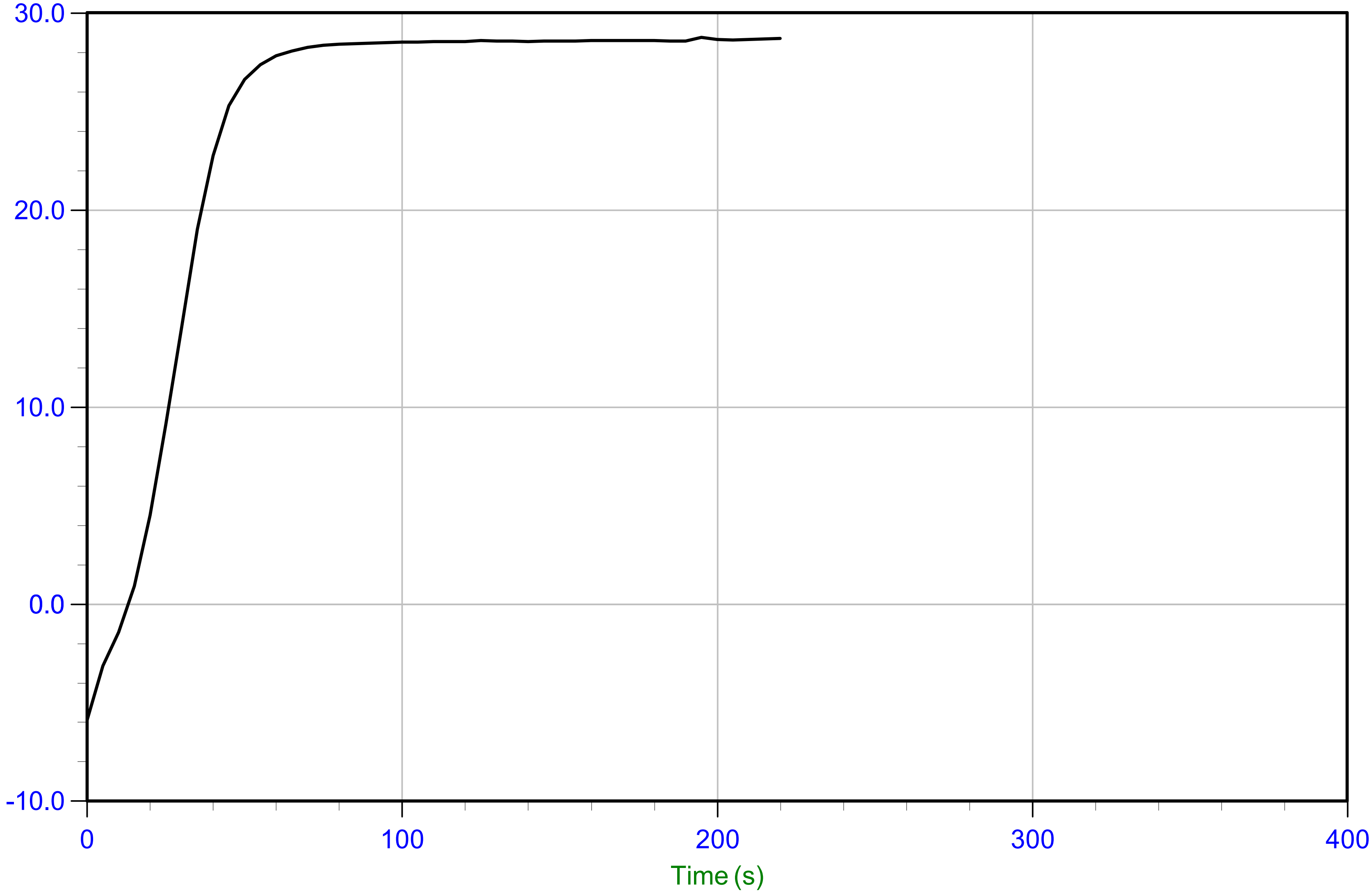
WT: -0.579 m / -1.900 ft
Ueq: 36.1 psi

CALIFORNIA PUSH TECHNOLOGIES INCORPORATED

DCM Consulting, Inc.

Job No: 15-56018
Date: 11/05/2015 12:23
Site: SVCW Front of Plant Improvements

Sounding: CPT-24
Cone: 413:T375F10U200
Cone Area: 15 sq cm



Trace Summary:

Filename: 15-56018_CP24.PPF
Depth: 19.925 m / 65.370 ft
Duration: 220.0 s

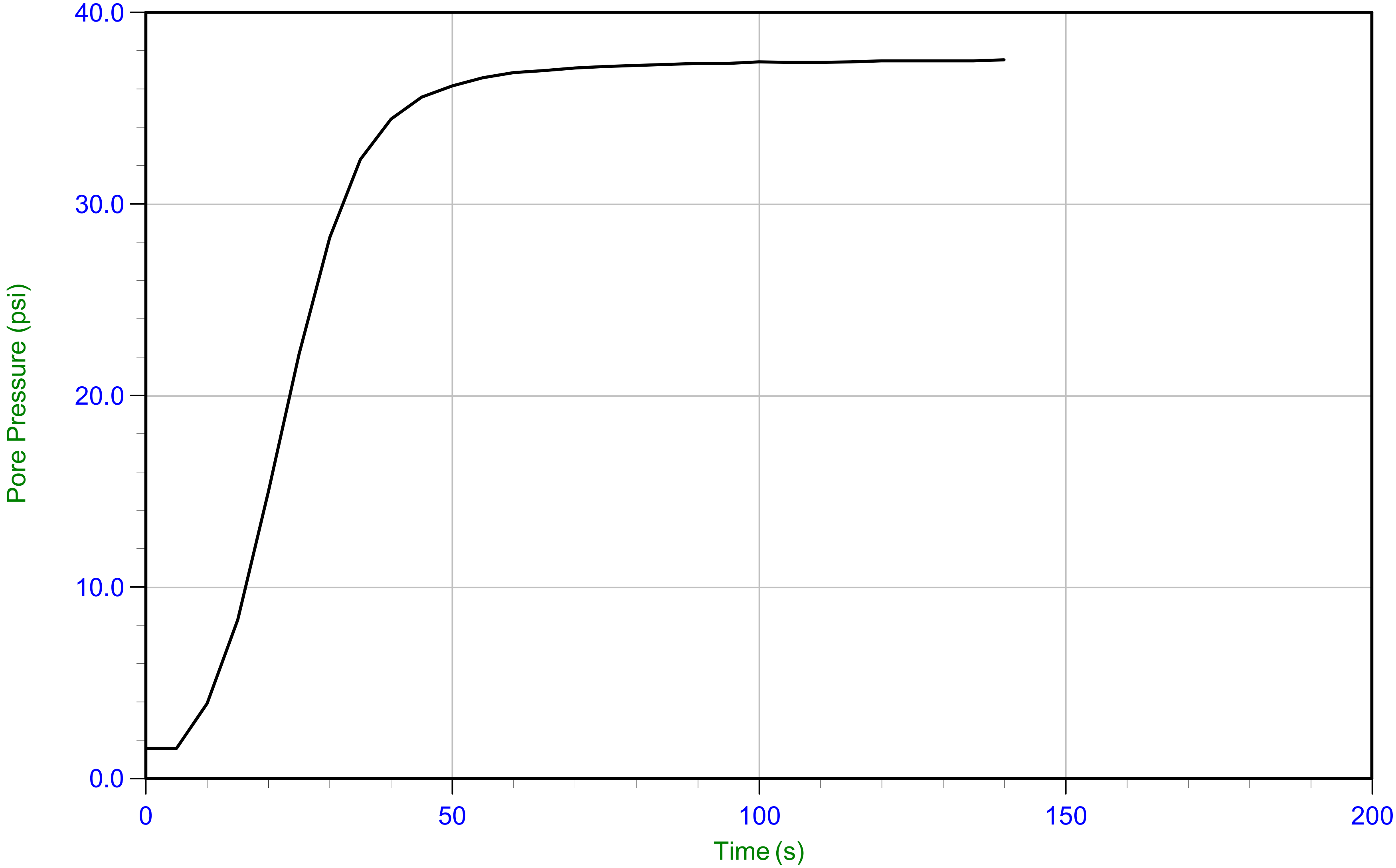
U Min: -5.9 psi
U Max: 28.7 psi

WT: -0.194 m / -0.636 ft
Ueq: 28.6 psi

DCM Consulting, Inc.

Job No: 15-56018
Date: 11/05/2015 13:26
Site: SVCW Front of Plant Improvements

Sounding: CPT-25
Cone: 413:T375F10U200
Cone Area: 15 sq cm



Trace Summary:

Filename: 15-56018_CP25.PPF
Depth: 25.900 m / 84.973 ft
Duration: 140.0 s

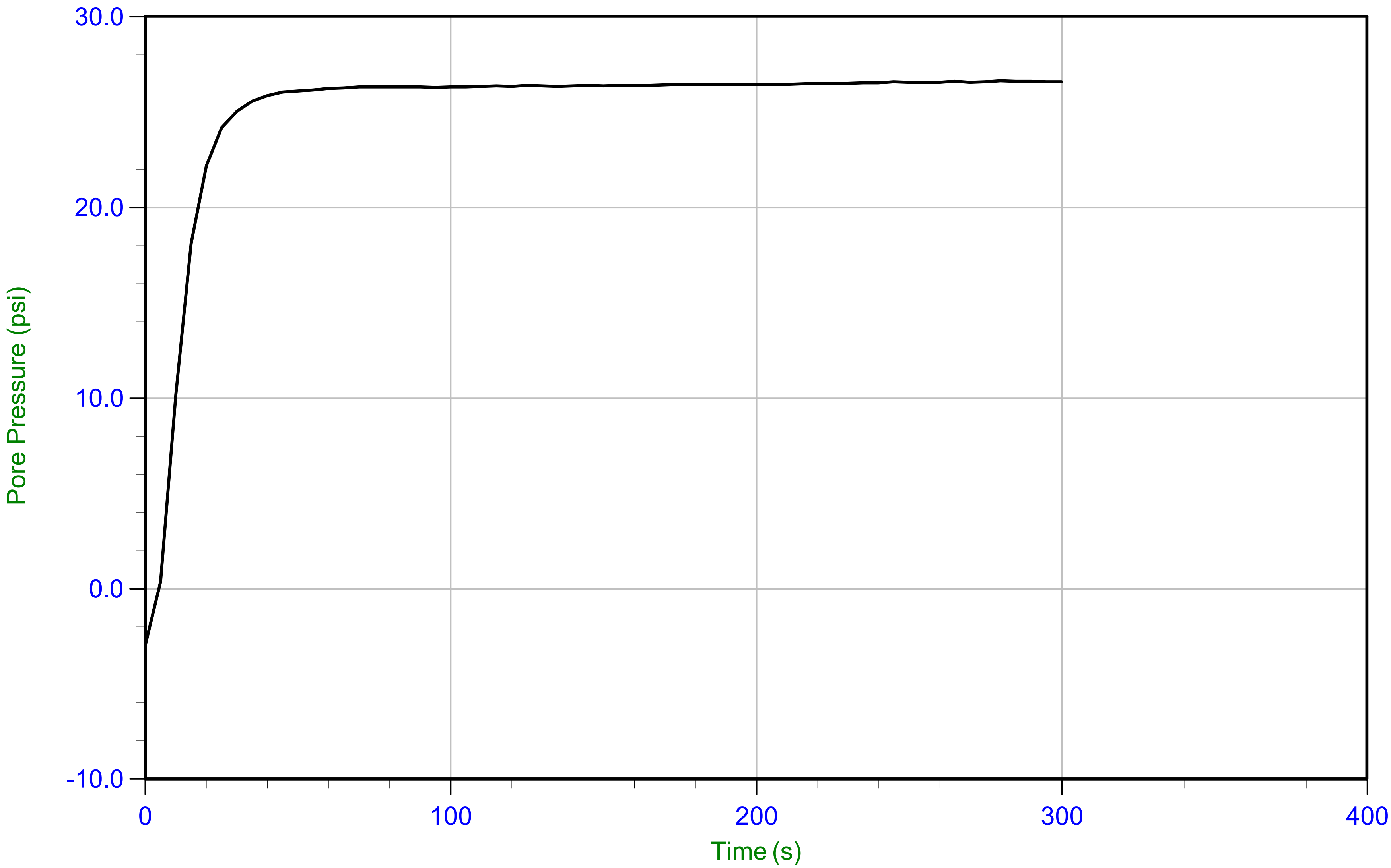
U Min: 1.6 psi
U Max: 37.5 psi

WT: -0.459 m / -1.506 ft
Ueq: 37.5 psi

DCM Consulting, Inc.

Job No: 15-56018
Date: 11/05/2015 15:40
Site: SVCW Front of Plant Improvements

Sounding: CPT-29
Cone: 413:T375F10U200
Cone Area: 15 sq cm



Trace Summary:

Filename: 15-56018_CP29.PPF
Depth: 18.400 m / 60.367 ft
Duration: 300.0 s

U Min: -3.0 psi
U Max: 26.6 psi

WT: -0.258 m / -0.846 ft
Ueq: 26.5 psi

Appendix C: Soil Corrosivity Evaluation, Silicon Valley Clean Water (SVCW)

V&A Consulting Engineers, Inc., December 2015

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TECHNICAL MEMORANDUM

FREYER & LAURETA, INC.
SOIL CORROSIVITY EVALUATION
SILICON VALLEY CLEAN WATER (SVCW)

Prepared for: Richard Laureta, P.E., Freyer and Laureta, Inc.

Prepared by: Matt Snow, E.I.T., V&A Consulting Engineers
Dan Day, V&A Consulting Engineers

Reviewed by: Chelsea Teall, P.E., V&A Consulting Engineers
Glenn Willson, P.E., V&A Consulting Engineers

Date: December 2015

V&A Project No.: 15-0300

1.0 INTRODUCTION

V&A Consulting Engineers (V&A) was retained by Freyer and Laureta, Inc., to perform a soil corrosivity evaluation for the Silicon Valley Clean Water (SVCW) wastewater treatment plant located at 1400 Radio Rd, Redwood City, California. A map of the project location is presented in Figure 1-1. The soil characterized was in a drained and dried ornamental pond previously filled with recycled water.

V&A evaluated the corrosivity of the soil in proximity of buried metallic or concrete piping between grade and down to 15 feet below grade. The discharge piping for the RLS (receiving lift station) and PFDS will both be approximately 10 to 15 feet below grade. The RLS will have an invert elevation of about 80 feet below grade and the PFDS will be approximately 30 feet below grade; both the RLS and PFDS are outside the scope of this soil corrosivity evaluation.

V&A achieved the following objectives during this evaluation.

1. Reviewed existing corrosion and geotechnical data.
2. Performed an in situ soil resistivity evaluation.
3. Analyzed the results of laboratory testing on soil samples that included measuring resistivity and chemical constituents.
4. Provided corrosion control recommendations for discharge piping associated with the RLS and PFDS.

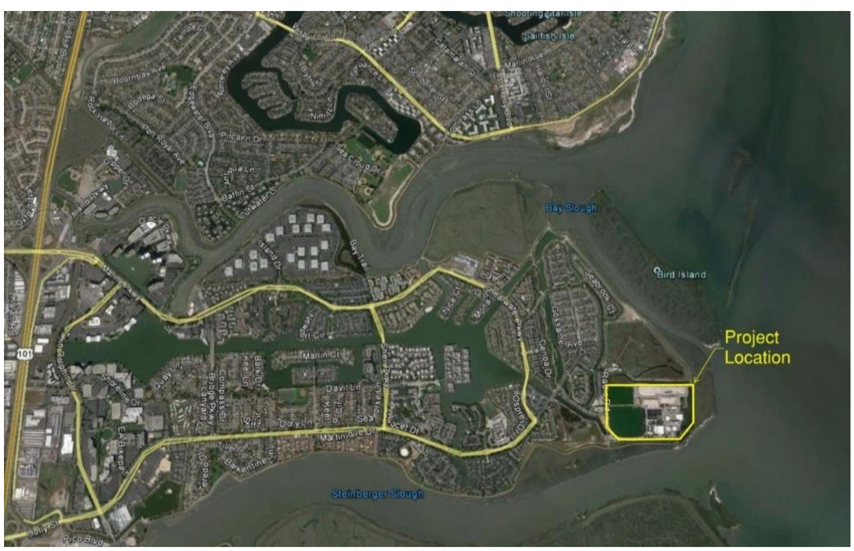

Figure 1-1. Project Location Map

2.0 TEST METHODS

In attempting to predict corrosion problems associated with a particular type of structure prior to installation, it is necessary to investigate the soil conditions the structure will encounter. Since corrosion is an electrochemical process that is accompanied by current flow, the electrochemical characteristics of a soil are of primary importance when evaluating corrosivity. Test methods utilized during this investigation reflect the current practices for evaluating soil corrosivity.

2.1 In Situ Soil Resistivity Evaluation

2.1.1 Wenner 4-Electrode Method General Information

The Wenner 4-Electrode Method determines how easily an electric current flows through an electrolyte, which directly relates to the degree of corrosivity of the electrolyte. Each test location is set up by driving four metallic pins into the ground in a straight line at equidistant spacing. Each pin is driven into the ground to a depth that allows for adequate contact between the soil and the pin. An insulated harness containing multiple wires is laid out along the pins, and clips are used to create a metallic connection between each pin and the corresponding wire inside the harness. Each of the wires is referred to as one of the following: C1, P1, P2, or C2. Pins C1 and C2 are used to provide electric current to the soil and are positioned as the outer two pins of the array while pins P1 and P2 are used to measure potential and are positioned as the inner two pins of the array. Figure 2-1 is presented to visually represent this concept. The wires are connected to a soil resistance meter, and the resistance of the soil mass below the pins is determined as follows.

The soil resistance meter discharges alternating current into the electrolyte between pins C1 and C2 in a hemispherical manner. Due to the resistance of the soil, the current creates a voltage gradient that is proportional to the average resistance of the soil mass to a depth equal to the spacing between each pin. While the alternating current is flowing through the electrolyte, the soil resistance meter measures the voltage drop, or potential, between pins P1 and P2. The average resistance of the soil mass is calculated by the meter by rearranging Ohm's Law (V=IR) to solve for resistance. Once the resistance value from the display of the meter is recorded, the spacing between each pin is adjusted and the measurement is repeated. The harness allows a series of four pins to be connected for resistance measurements to different soil depths. The four pins associated with each soil depth can be activated for a measurement by using a selector switch box wired to the appropriate test pins.

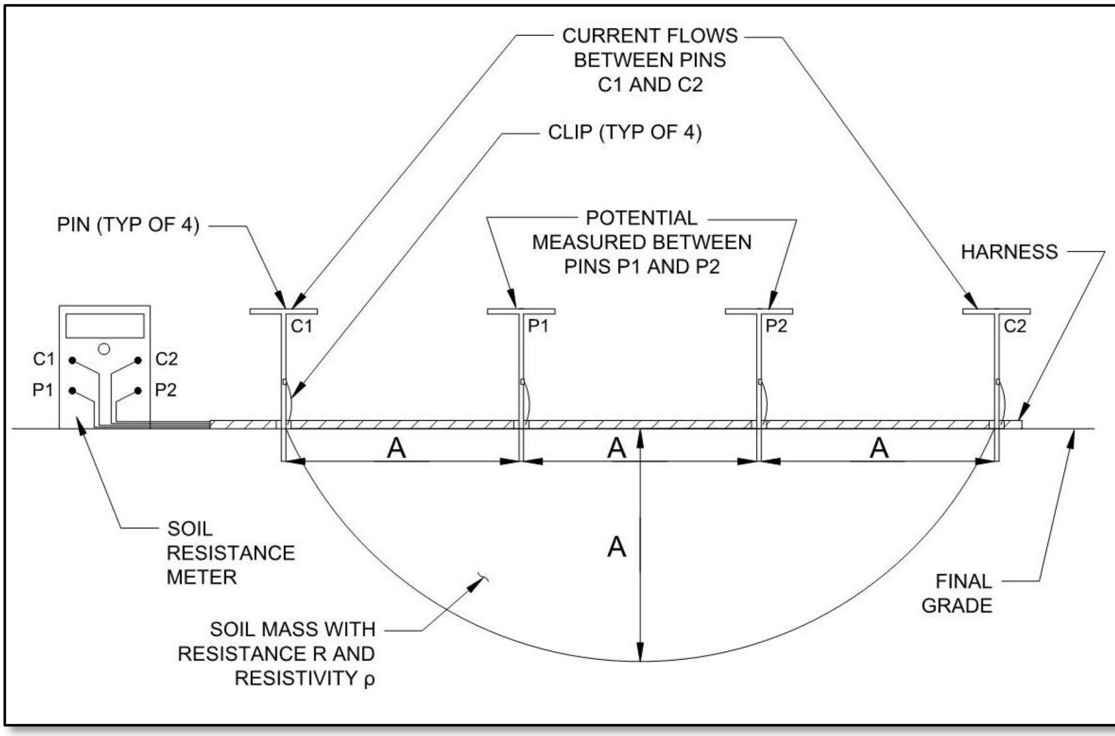

Figure 2-1. Wenner 4-Electrode Method Schematic

At each location, soil resistance measurements were recorded at pin spacings of 2.5, 5, 7.5, 10, and 15 feet. The meter measures soil resistances, and the soil resistance values recorded from the meter display were used to calculate soil resistivity to depth and resistivity by layer.

2.1.2 Resistivity to Depth

Average resistivity (ρ) of the soil mass below the pins to a depth equal to the spacing between each pin is calculated with the following equation:

$$\rho = 2 \cdot \pi \cdot A \cdot R$$

Where:	ρ	=	Average soil resistivity to a depth of *A* (ohm-cm)
	A	=	Distance between electrodes (cm)
	R	=	Soil resistance to a depth of *A*, soil resistance meter reading (ohm)
	π	=	3.14 (approximately)

The product of this equation provides a resistivity value that represents the average resistivity of the soil below the pins to a depth equal to the pin spacing. The resistivity values were then compared to generally accepted ranges of resistivity and their corresponding level of corrosiveness. The in situ resistance measurements and calculated resistivity values are presented in Section 3.1.1.

2.1.3 Resistivity by Layer (Barnes Layer Soil Resistivity)

The recorded soil resistance values were also used to calculate the resistivity of multiple layers of soil, as opposed to the average resistivity of the soil from grade to a desired depth. For example, after the resistance of the soil mass to a depth of five feet is measured and the resistance of the soil mass to a depth of ten feet is measured, the average resistivity of the soil layer between five feet and ten feet below grade may be calculated. This method of calculating the resistivity of a layer of soil is referred to as the Barnes Layer Soil Resistivity Calculation; Figure 2-2 is presented to visually represent this concept.

When determining the resistivity and corresponding corrosivity of the electrolyte, the Barnes Layer Soil Resistivity calculations are used in lieu of the average resistivity to depth calculations. This is due to the Barnes Layer Resistivity Calculation's ability to isolate the layer of soil that the proposed structure will be in contact with while neglecting the soil in layers that will not be in contact with the structure. The soil in the layers that are not in contact with the structure will have little to no effect on the corrosion rate of the water pipeline. By isolating the layer of soil that will be in contact with the proposed structure, a more accurate representation of the proposed structure's environment may be obtained.

The average soil layer resistivity ($\rho_{A\text{-}B}$) is calculated with the following equation.

$$\rho_{A\text{-}B} = 2 \cdot \pi \cdot (B - A) \cdot R_{A\text{-}B}$$

Where:	$\rho_{A\text{-}B}$	=	Average resistivity of soil layer between depth *A* to depth *B* (ohm-cm)
	A	=	Depth below grade to top of soil layer (cm)
	B	=	Depth below grade to bottom of soil layer (cm)
	$R_{A\text{-}B}$	=	Resistance of soil layer between depth *A* and depth *B* (ohm)
	π	=	3.14 (approximately)

The individual soil layer resistances ($R_{A\text{-}B}$) were calculated using the following equation.

$$R_{A\text{-}B} = (R_A \cdot R_B)/(R_A - R_B)$$

Where:	$R_{A\text{-}B}$	=	Resistance of soil layer between depth *A* and depth *B* (ohm)
	R_A	=	Soil resistance to a depth of *A*, soil resistance meter reading (ohm)
	R_B	=	Soil resistance to a depth of *B*, soil resistance meter reading (ohm)

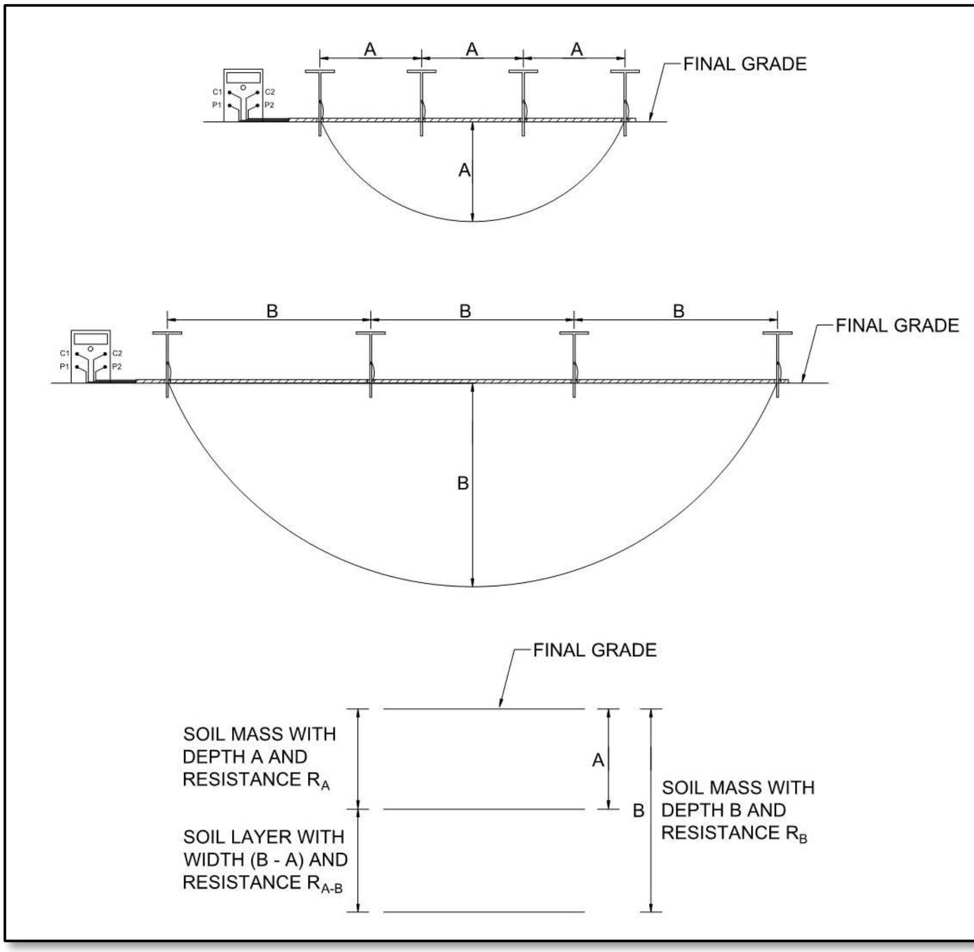

Figure 2-2. Barnes Method for Determining the Resistance of a Soil Layer

The results of the Barnes Layer Soil Resistivity Calculations are presented in Section 3.1.1.

2.2 Laboratory Soil Resistivity Test Methods

Soil samples were obtained from the site and tested in the laboratory. The as-received and saturated (minimum) soil resistivity was determined using a soil box (see Figure 2-3). The resistivity testing was performed in accordance with ASTM G57. A discussion of the test procedure is provided below.

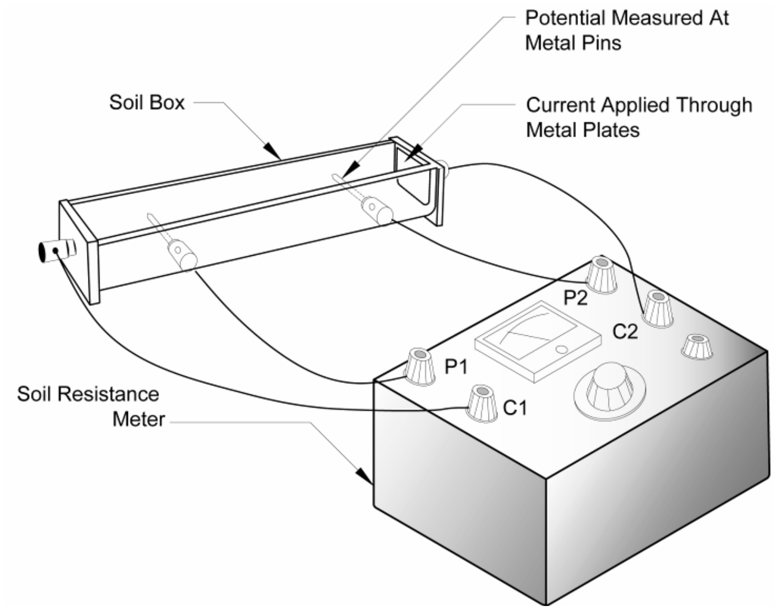

Figure 2-3. Soil Resistivity Measurement Using the Soil Box Method

The test apparatus consists of a small plastic box with metal end plates for passing current through the soil sample packed tightly into the box. Current flows through the sample, causing a voltage drop across the sample, which is measured between the two pins. The current is supplied by a Soil Resistance Meter, which also measures the voltage drop between Pins P1 and P2. The meter calculates the soil resistance using Ohm's Law, stated as "resistance equals the voltage divided by the current," or R = V/I. The geometry of the soil box is designed so that the measured soil resistance is also the sample resistivity in ohm-cm.

Soil samples were placed in the soil box, and the soil resistivity was measured in the "as-received" state. Distilled water was added to the soil sample, and the resistivity was measured after each addition. As the soil sample becomes more saturated with water, the soil resistivity decreases until the minimum soil resistivity is reached. The saturated (minimum) resistivity represents the most corrosive conditions in the soil to iron and steel structures, which occurs when all the soluble salts are taken into solution. The dissolved salts provide less resistance to electric current flow in the soil, which facilitates corrosion activity on buried metal.

2.3 Soil Chemical Analysis Test Methods

Soil samples obtained from the site were tested for pH and concentrations of water soluble chloride, sulfate, and bicarbonate ions. The samples were sent to Curtis & Tompkins, Ltd. Analytical Laboratories in Berkeley, California for analysis. The following standard analytical methods were utilized for determining these chemical constituents:

- pH by EPA 9045D
- Inorganic anions (chloride and sulfate) by EPA 300.0
- Bicarbonate Alkalinity (as $CaCO_3$) by SM 2320B

3.0 TEST RESULTS

Data obtained during this investigation has been summarized in tabular form for analysis and presentation. Resistivity values as measured and calculated from the field and laboratory have been compared to generally accepted ranges of soil resistivity and the corresponding degree of corrosivity. The results of the chemical analysis are also presented in this section as well as a discussion of the results as they pertain to the corrosivity of soil.

A composite sample composed of smaller samples from four boring locations (7-02.0, 9-01.0, 11-15.0, and 12-15.0) was obtained by Iris Environmental for resistivity testing and chemical analysis. The samples were blended in equal amounts to provide an average of all four samples. Soil sample locations and depths were not provided to V&A. In addition, V&A conducted in situ resistivity testing at four (4) locations, which are identified in Figure 3-1.

3.1 Soil Resistivity Test Results

Understanding how easily current will travel through a medium surrounding a metallic object is important in evaluating the corrosive environment. Resistivity is an inverse measure of the ability of a soil to conduct an electric current, with higher resistivity resulting in less current flow. Corrosion rate depends on current flow between a metal and the adjacent medium. Normally, the corrosion activity on metals in soil increases as soil resistivity decreases. The following table correlates resistivity values with degree of corrosivity. The interpretation of this correlation varies somewhat among corrosion engineers. However, Table 3-1 is a generally accepted guide.

Table 3-1. Effect of Soil Resistivity on the Corrosivity of Soil [1]

Soil Resistivity (ohm-cm)	Degree of Corrosivity
< 500	Very High
500 – 1,000	High
1,000 – 2,000	Moderate
2,000 – 10,000	Mild
> 10,000	Negligible

1 Peabody, A. and Parker, M., “Corrosion Basics, an Introduction”, Ed. by Brasunas, A., NACE International, p. 191 (1984)

3.1.1 In Situ Resistivity

The first test method utilized by V&A to evaluate the resistivity of the soil within the project location is the Wenner 4-Electrode Method per ASTM G57. This in situ soil resistivity test was conducted at four locations chosen by Freyer and Laureta, Inc., on October 30th, 2015. A site map of the resistivity test locations is presented below as Figure 3-1.

Figure 3-1. In Situ Resistivity Locations

The following Table 3-2 features the resistance to depth values that were recorded from the display of the soil resistance meter, the calculated resistance of each layer of soil, the calculated average resistivity of the soil to depth, the calculated resistivity of each layer of soil, and the corresponding degree of corrosivity of the soil based on the resistivity values. As shown in Figure 3-1, the resistivity of all soil layers measured in all locations was between 25 and 214 ohm-cm, which is considered *very highly corrosive* to steel.

Table 3-2. In Situ Resistivity Results

Site Number	Depth (feet)	Resistance to Depth, Meter Reading (ohm)	Layer (feet)	Resistance of Soil Layer (ohm)	Resistivity of Soil Layer (ohm-cm)	Degree of Corrosivity for Layer
C-301	2.5	0.21	0 - 2.5	0.21	101	Very High
	5	0.12	2.5 - 5	0.28	134	Very High
	7.5	0.07	5 - 7.5	0.17	80	Very High
	10	0.03	7.5 - 10	0.05	25	Very High
	15	0.02	10 - 15	0.06	57	Very High
C-302	2.5	0.29	0 - 2.5	0.29	139	Very High
	5	0.15	2.5 - 5	0.31	149	Very High
	7.5	0.08	5 - 7.5	0.17	82	Very High
	10	0.05	7.5 - 10	0.13	64	Very High
	15	0.02	10 - 15	0.03	32	Very High
C-303	2.5	0.19	0 - 2.5	0.19	91	Very High
	5	0.13	2.5 - 5	0.41	197	Very High
	7.5	0.07	5 - 7.5	0.15	73	Very High
	10	0.04	7.5 - 10	0.09	45	Very High
	15	0.03	10 - 15	0.12	115	Very High
C-304	2.5	0.33	0 - 2.5	0.33	158	Very High
	5	0.19	2.5 - 5	0.45	214	Very High
	7.5	0.11	5 - 7.5	0.26	125	Very High
	10	0.07	7.5 - 10	0.19	92	Very High
	15	0.04	10 - 15	0.09	89	Very High

3.1.2 Laboratory Resistivity

Laboratory resistivity measurements were performed by Cooper Testing Labs, Inc. and reported by Curtis & Tompkins, Ltd. The as-received and saturated (minimum) resistivity was determined for the composite sample using a soil box as described in Section 2.2. Table 3-3 lists the as-received and saturated soil resistivity for the composite sample. The soil is most corrosive at its saturated resistivity. In real world conditions, the soil may become saturated when it rains or when the ornamental pond is filled. The as-received and saturated soil resistivity were 61 and 58 ohm-cm, respectively, which are both considered *very highly corrosive* to iron and steel pipe.

Table 3-3. Summary of Laboratory Soil Resistivity Data*

Iris Environmental Sample ID	Resistivity (ohm-cm)	
	As-Received	Saturated
11-15.0/12-15.0/9-01.0/7-02.0	61	58

* Analyzed by Cooper Testing Labs, Palo Alto, California.

3.2 Soil Chemical Analysis Test Results

Soil chemical analysis was performed by Curtis & Tompkins, Ltd. In Berkeley, California using the methods described in Section 2.3. A wide variety of water-soluble salts are typically found in soils. Two soils having the same resistivity may have significantly different corrosion characteristics, depending on the specific ions available. The major constituents which accelerate corrosion are chlorides, sulfates, bicarbonates, and the acidity (pH) of the soil. Table 3-4 presents the laboratory analytical results for these constituents.

Table 3-4. Summary of Soil Chemical Analysis Data*

Soil Boring Sample*	pH	Chloride (mg/kg)	Sulfate (mg/kg)	Bicarbonate (mg/kg)
11-15.0/12-15.0/9-01.0/7-02.0	7.6	13,000	2,900	320

* Analyzed by Curtis & Tompkins, Ltd., Berkeley, California.

3.2.1 Acidity

Acidity, as indicated by the pH value, is an important factor influencing the corrosivity of soil. Lower pH (more acidic) soil will be more corrosive to buried metal and concrete structures. When the pH increases above 7.0 (the neutral value) the soil becomes more alkaline. In alkaline environments, iron and steel form a protective surface oxide layer. This is referred to as passivation. V&A developed Table 3-5, which correlates the effect of pH on the corrosion rate (corrosivity) for buried iron and steel pipe. The pH of the tested soil sample is 7.6. This is considered *negligibly corrosive* to buried iron, steel, and reinforced concrete.

Table 3-5. Effects of pH on Soil Corrosivity[2, 3]

pH	Soil Corrosivity
< 5.5	High
5.5 - 6.5	Moderate
6.5 - 7.5	Mild
> 7.5	Negligible

3.2.2 Chloride Ions

Chloride ions tend to break down protective surface oxide films and render metal surfaces susceptible to corrosion. Table 3-6 shows the effect of chloride ions on the corrosivity of soil to buried iron and steel pipe. The water-soluble chloride concentration in the composite soil sample was 13,000 mg/kg, which is considered *very highly corrosive* to buried iron and steel pipe.

Table 3-6. Effects of Chloride Ions on Soil Corrosivity

Chloride Concentration (ppm)	Soil Corrosivity
> 5,000	Very High
1,500 - 5,000	High
500 - 1,500	Moderate
100 - 500	Mild
< 100	Negligible

3.2.3 Sulfate Ions

Sulfate ions will reduce soil resistivity, which facilitates metal corrosion; however, sulfates in soil do not directly attack iron or steel. Sulfate ions will attack the Portland cement matrix in concrete, causing it to expand and crack. This exposes steel reinforcement, which can then corrode. Table 3-7 correlates the effect of sulfates on soil corrosivity. The water-soluble sulfate concentration in the composite soil sample was 2,900 mg/kg. This is considered *very highly corrosive* to buried reinforced concrete structures and buried iron and steel pipe by lowering the soil resistivity.

2 Romanoff, M., "Underground Corrosion", NACE International, p. 8 (1989)

3 Uhlig H., "Corrosion and Corrosion Control", 2nd Edition, John Wiley & Sons Inc., pp.98-106 (1971); V&A's experience

Table 3-7. Effects of Sulfate Ions on Soil Corrosivity[4]

Sulfate Concentration (ppm)	Soil Corrosivity
> 2,000	Very High
1,000 - 2,000	Moderate
< 1,000	Negligible

3.2.4 Bicarbonate Ions

Bicarbonate ions reduce soil resistivity, which facilitates metal corrosion; however, bicarbonates in soil do not directly attack iron or steel. The bicarbonate ion concentration in the soil sample is 320 mg/kg. This concentration would contribute to lowering the soil resistivity, therefore promoting corrosion of buried iron and steel pipe.

4 V&A's interpretation of Table 8.22.2, Bridge Design Specifications, California Department of Transportation (2000)

4.0 CONCLUSIONS

- The in situ soil resistivity determined by V&A indicates the soil to a depth of 15 feet is *very highly corrosive* to buried iron and steel pipe. Likewise, the as-received and saturated resistivities measured in the laboratory indicate the soil is *very highly corrosive* to buried iron and steel pipe.
- The soil pH at the project site is *negligibly corrosive* to buried concrete and metallic structures.
- The high chloride concentration of the composite soil sample indicates the soil at the project site is *very highly corrosive* to buried iron and steel pipe.
- The sulfate concentration of the composite soil sample indicates the soil at the project site is *very highly corrosive* to buried reinforced concrete structures. The high sulfate concentration contributes to the exceedingly low soil resistivity indicative of very highly corrosive conditions to buried iron and steel pipe.
- It should be noted that no locations or sampling depths were provided to V&A for the soil samples that made up the composite soil sample used for laboratory analysis.
- Based on the collective data obtained during the soil corrosion investigation, the soil at the project site should be considered *very highly corrosive*. Buried reinforced concrete structures and iron and steel pipe will require corrosion protection.

5.0 RECOMMENDATIONS

V&A proposes the following recommendations for corrosion control.

5.1 Iron and Steel Pipe

1. Install a cathodic protection system.
2. Ensure electrical continuity of the pipeline.
3. Electrically isolate the pipeline from other metallic structures, such as other metallic pipes, reinforced concrete, or where a change in piping or coating material occurs.
4. Install corrosion test stations at each insulating joint, casing, and foreign pipeline crossing. Install monitoring test stations whenever required to limit spacing between test stations to no more than 800 feet.
5. Apply a bonded coating to the pipe.
6. If mortar coatings are used in addition to the bonded coating, follow the recommendations provided in Section 5.2.
7. Coat or wrap joints, valves, and any other steel appurtenances in metallic contact with the pipe to inhibit galvanic corrosion between dissimilar materials. The recommended coating or wrap will vary depending on the pipe material selected.
    a. For mortar coated pipe, apply a coat of cementitious mortar to maintain an environment similar to that of the pipe. Mortar coating can be performed by grouting the joints with a diaper, backfilling with a controlled low strength material (pH>10), or applying a cementitious mortar to the surfaces.
    b. For many other types of pipe, the appropriate method is wrapping with petrolatum wax tape. Wrap metallic valves and fittings with petrolatum wax tape per AWWA C217-04 and the manufacturer's instructions. Wax tape can be applied to conform tightly to irregular surfaces, such as nuts and bolts, or to irregular surface contours. The wax tape is impregnated with corrosion inhibitors to provide additional protection.

5.2 Buried Reinforced Concrete Piping and Structures

1. Buried reinforced concrete structures should be constructed of durable concrete such as described in ACI Standards 201.2R and 222R.
2. The water/cement ratio should not exceed 0.45.
3. The concrete cover applied over all steel reinforcement should be a minimum of 2 inches thick.
4. A bonded coating should be applied on top of the concrete cover to provide a barrier to the corrosive soil.
5. Type V modified cement should be used.
6. Sand and water used in concrete mixtures should contain a maximum of 100 ppm of water-soluble chloride ions and water-soluble sulfate ions and have a pH in the range of 6.5 to 8.0. Water used in concrete mixtures should be potable water.

5.3 Buried PVC or HDPE Pipe with Metallic Fittings

1. Buried PVC, HDPE, or other non-metallic pipe does not require corrosion protection; however, any metallic fitting or appurtenances associated with that piping does require corrosion protection.
2. Wrap metallic fittings with petrolatum wax tape per AWWA C217-04 and the manufacturer's instructions. Wax tape can be applied to conform tightly to irregular surfaces, such as nuts and bolts, or to irregular surface contours. The waxes impregnate the tape and contain corrosion inhibitors to provide additional protection. Using polyethylene encasement on the fittings is not as effective as using wax tape.
3. Install galvanic anodes to provide cathodic protection to every metallic fitting or appurtenance. Install test stations to monitor the cathodic protection system performance over the design life.

Appendix D: TM 9.1 – Design Criteria, Guidelines and Standards

Brown and Caldwell, October 2016

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Technical Memorandum

DRAFT

Prepared for: Silicon Valley Clean Water

Project Title: RLS Conceptual Design

Project No.: 148380

Technical Memorandum 9.1

Subject: Design Criteria, Guidelines, and Standards (Administrative Draft)

Date: October 17, 2016

To: Bill Bryan, Project Manager, Silicon Valley Clean Water

From: Charles Joyce, P.E., Project Manager, Brown and Caldwell

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Limitations:

This is a draft memorandum and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It will not be relied upon; consult the final report.

This document was prepared solely for Silicon Valley Clean Water in accordance with professional standards at the time the services were performed and in accordance with the contract between Silicon Valley Clean Water and Brown and Caldwell dated February 28, 2012. This document is governed by the specific scope of work authorized by Silicon Valley Clean Water; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Silicon Valley Clean Water and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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List of Abbreviations

A/B	Allen-Bradley
AASHTO	American Association of State Highway and Transportation Officials
ABMA	American Bearing Manufacturers Association
ac/hr	acres per hour
ACI	American Concrete Institute
ADWF	Average Dry Weather Flow
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI/HI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASD	Adjustable Speed Drive
ASHRAE	Air Conditioning Engineers
ASME B&PV	American Society of Mechanical Engineers, Boiler and Pressure Vessel
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BC	Brown and Caldwell
BEP	Best Efficiency Point
BPS	Belmont Pump Station
CBC	California Building Standards Code
CEC	California Electrical Code or
	California Energy Code
cfm	cubic feet per minute
CMAA	Crane Manufacturers Association of America
CMC	California Mechanical Code
CSMP	Conveyance System Master Plan
D	Diameter
dBA	A-weighted decibel(s)
FOP	Front of Plant
ft	feet
FVNR	Full Voltage Non-Reversing
HDPE	High Density Polyethylene
HP	horsepower
HVAC	Heating, ventilating, and air conditioning
I/O	input/output
IEEE	Institute of Electrical and Electronics Engineers Association
ISA	International Society of America
LRFD	load resistance factor design
MCC	Motor Control Center
mgd	million gallons per day
MPPS	Menlo Park Pump Station
NCS	National CAD Standards
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NPSH3	Net Positive Suction Head Required - Three Percent Reduction
NPSHA	Net Positive Suction Head Available
O&M	Operation and Maintenance
OSHA	U.S. Department of Labor Occupational Safety and Health Act
P&IDs	process and instrumentation diagrams
PACL	Pump Application Capacity Limits
PLCs	Programmable Logic Controllers
ppmv	part(s) per million by volume
PSF	per square foot
PVC	Polyvinyl coated
PWWF	Peak Wet Weather Flow
RAC	Rigid Aluminum Conduit
RCPS	Redwood City Pump Station
RLS	Receiving Lift Station
S	Second
SCADA	supervisory control and data acquisition
SMACNA	Sheet Metal and Air Conditioner Contractor’s National Association
SVCW	Silicon Valley Clean Water (formerly SBSA Silicon Valley Clean Water)
TBD	to be determined
TDH	total dynamic head
TM	technical memorandum
UL	Underwriters Laboratories Inc.
VFD	variable frequency drive
WWTP	Wastewater Treatment Plant

Section 1: Introduction

Technical Memorandum (TM) 9.1 describes the criteria, guidelines, and standards used for the Silicon Valley Clean Water (SVCW) Receiving Lift Station (RLS) at the Wastewater Treatment Plant (WWTP) in Redwood City. This TM is meant to be a working document such that as the design progresses, changes can be made based on stakeholder reviews and consensus.

It should be noted that a final decision on the number of pumps, size of pumps and how many pumps contain variable frequency drives (VFD) has not been made. This TM and the design elements within the TM assumes that the RLS will contain a total of six 15 million gallons per day (mgd) pumps with four variable speed pumps and two constant speed pumps split equally in dual wet wells.

1.1 Background

SVCW is undertaking the replacement of its existing conveyance system pump stations and force mains. Fifteen alternatives were evaluated with Alternative 4BE selected to proceed into pre-design. A description of the alternatives evaluated is provided in the August 30, 2016 TM prepared by Whitley Burchett Associates titled Alternative Analysis used to select the Recommended SVCW Conveyance System Replacement Project. Alternative 4BE consists of a new deep Tunnel interceptor with a new RLS, modifications to the Menlo Park Pump Station (MPPS), replacement of the Redwood City Pump Station (RCPS), renovation to the Belmont Pump Station (BPS), repurposing on the San Carlos Pump Station and their respective connections (including pipeline rehabilitations, ancillary facilities and equipment) from its four Member Agencies' sanitary sewer collection systems. During this same time period, SVCW also decided to relocate the flow equalization facility from the existing site in Menlo Park to the WWTP site and to use the Tunnel for both dry weather and wet weather flow equalization. The RLS will need to reliably convey all wastewater flow rates up to 75 mgd and be configured to allow wastewater and grit to effectively pass through the wet well and pumps. In addition to the RLS, a new headworks and possibly additional flow equalization storage, will be located near the RLS within the area known as the Front of the Plant.

1.2 Purpose

The purpose of this document is to provide conceptual level guidance for the RLS design based on known information and to identify additional information needed to move forward with preliminary design. This set of design criteria, guidelines and standards is only for the RLS. Design criteria for other aspects of Alternative 4BE will be completed in separate documents.

1.3 Federal, State and Local Regulations and Standards

The latest versions of regulations, standards, and codes referred to during development of and/or referenced in this TM will need to be confirmed during final design. The final design will be updated to the latest versions of regulations, standards and codes such that the RLS is compliant with current requirements at the start of final design.

1.4 Document Contents

This document includes criteria and guidelines for the following categories:

- Pumps and Wet Well
- Odor Control
- Civil Design Criteria/Assumptions (Freyer and Lauretta will provide design criteria in a separate document for the civil/site work as part of the overall Front of the Plant projects)
- Security Criteria
- Corrosion Control
- Architectural Design
- Structural Design and Geotechnical Considerations
- Process and Instrumentation Diagram Requirements
- Mechanical Design
- Heating, ventilating, and air conditioning (HVAC) Design
- Electrical and Power
- Instrumentation and Control
- National Fire Protection Association (NFPA) Requirements
- Noise Attenuation Requirements
- Sole Source Specification and Purchase of Standardized Equipment List

1.5 Additional Technical Information

In addition to this document, several other documents provide information related to the RLS design. The documents include the following:

- RLS Workshop Presentations
  - January 7, 2015
  - January 21, 2015
  - June 23, 2015
  - October 21, 2015
  - December 2, 2015
  - January 12, 2016
  - January 27, 2016
  - February 9, 2016
  - March 8, 2016
- Process and Instrumentation Workshop presentation, March 22, 2016
- Multiple RLS and Tunnel Coordination Meetings
- Grit Migration Predictions When Using a Tunnel for Storing Wastewater by Bob Donaldson, December 17, 2015
- Grease Accumulation from Tunnel Storage Operation by Bob Donaldson, March 10, 2016
- Multiple hydraulic model runs completed by Brown and Caldwell (BC)

- SBSA Security Guidance Document, Draft October 2011
- SBSA Corrosion Control and Odor Master Plan, June 29, 2010
- Geotechnical Data Report by Jacobs Associates, October 22, 2013
- Geotechnical Report by DCM Consulting Inc., Draft November 25, 2013
- SVCW Hard Assets Standard Naming Convention (latest document available)
- SVCW Automation Standards (latest document available)
- Control Narratives (includes process and instrumentation diagrams [P&IDs])
- SVCW CAD Standards

During the RLS Workshops with SVCW Engineering and Operation and Maintenance (O&M) staff, several decisions were made related to the RLS design criteria. The following decisions were agreed upon based on the information available at the time of the workshops:

1. The RLS will be considered an essential facility from a structural and seismic perspective.
2. The RLS will use submersible pumps. Chopper pumps will be used for pump discharge diameters less than 12 inches.
3. The RLS total pumping capacity will be 75 mgd. The Tunnel will be used for peak wet weather storage to limit the RLS pumping capacity to 75 mgd.
4. The Tunnel will be used for daily diurnal storage to equalize the average daily flow rate to the Headworks between 12 to 18 mgd.
5. The submersible pumps will have VFDs on four of the six pumps but further evaluation of providing VFDs on all pumps will be completed during pre-design. This document assumes that four pumps will have VFDs and two will be constant speed.
6. The RLS pump redundancy will include installed capacity of 75 mgd with the largest pump out of service and a spare pump on the shelf or spare pumps if multiple sized pumps are used.
7. In addition to pump equipment redundancy, the wet well design and pump selection will also allow the wet well to rise upwards of 15 feet (ft) from the top of the tunnel to gain more pumping capacity (pumping rate of 20 to 25 mgd per pump), which would mean that three to four pumps in operation instead of five pumps could meet 75 mgd for a short term period without significantly damaging the pumps.
8. Pump removal will be by a contracted crane service or the pump supplier. An on-site dedicated gantry crane will not be provided.
9. The RLS will contain dual self-cleaning trench style wet wells.
10. An isolation slide gate will be provided for each wet well.
11. Screenings and grit will be removed after the RLS.
12. High pressure flushing assemblies will be provided at the inlet channels and at the inlet of each pump.
13. The Tunnel design team will identify the Tunnel invert at the RLS entrance.
14. The headworks design team will identify the hydraulic grade line for the RLS discharge.
15. Each pump will have its own discharge pipe into the headworks that is currently expected to discharge above the high water surface. Check valves and isolation valves will not be provided on the pump discharges.
16. The top of Flow Splitter Shaft will be at grade and Main RLS Shaft will be above the flood elevation at 110 ft. The hatches on the Flow Splitter Shaft will be water tight.

The following items have not been finalized as part of this draft design criteria submittal and will be determined as design progresses:

1. Size of pumps – use of all the same size pumps or multiple size pumps to pump the range of dry weather and wet weather flow.
2. Number of VFDs to be installed (see item 4 above).
3. Wet well wall separation height.
4. Configuration of Tunnel shafts, either a “Figure 8” or twin shafts with connection between shafts.
5. Configuration of wet well platform (Elevation 110) including maintenance space need and requirements of if a platform for the electrical cabinets is sufficient.
6. Need for another isolation gate/stop log guides to provide dual isolation.
7. Final depth and inside diameter of Tunnel (to be completed by others and coordinated with the RLS design team).
8. Structural requirements for the shaft walls and RLS concrete (to be coordinated with the Tunnel design team).
9. Access requirements to the Piping Gallery.
10. Procurement (pre-purchase, pre-selection, or pre-qualifying) of submersible pumps and coordination of pump selection and procurement with the other pump stations in the Conveyance System.

Section 2: Pumps and Wet Well

This section provides design criteria for the RLS pump selection and wet well design. Additional detailed criteria are located in Attachment B. All pumps will be designed in accordance with applicable portions of ANSI/HI 1.1 – 1.4, 2.1 – 2.4 and 9.6.2 – 9.6.6. The pumps will be designed to pump raw wastewater and operate within the pump’s preferred operating region for the most frequent range of flows and within the allowable operating region for the worst case peak wet weather flow (PWWF). Pumps will be selected as detailed in this section.

2.1 Design Flows

The existing and future design flows, which are based on the latest Member Agency master plans and the Conveyance System Master Plan (CSMP), are summarized in Table 2-1. The PWWF rates for each Member Agency are based on a single ten year 24-hour storm event occurring over the entire service area with a coincident time of concentration for each Member Agency Pump Station and connection to the Conveyance System. Table 2-1 also shows the design flow rates for the RLS based on the Member Agency flow rates. The Tunnel will be used for both diurnal storage and peak wet weather storage. With Tunnel storage, the daily flow will range from 12 to 18 mgd (or even smaller, tighter range depending on storage and Tunnel operation requirements) and the PWWF rate from the RLS will be reduced from 102.9 to 75 mgd.

Table 2-1. Design Flow Rates					
	Existing		Future (2040)		
Pump Station	Min Flow (mgd)[1]	ADWF (mgd) (Oct 2015)	ADWF (mgd)	Peak Dry Weather Flow (mgd)	PWWF (mgd)
MPPS	0.2	3.7	4.6	10.0	22
RCPS	0.9	4.5	8.0	14.5 (1)	38
San Carlos	0.6	1.3	2.9	5.8	26.6
BPS	0.3	1.4	1.8	3.6	16.3
Total	**2.0**[1]	**10.9**	**17.3**	**33.9**[2]	**102.9**[3]
RLS Design Flow	12 to 18 mgd with Diurnal Storage, wet well cleaning at 11 mgd and Tunnel flushing at 20 mgd				75

Notes

- *Minimum Flow and Average Dry Weather Flow (ADWF) are for October 2015 and are based on flow data provided by SVCW's supervisory control and data acquisition (SCADA) output from each pump station.*
- *ADWF 2040 flow rates are from Table 5-9 of TM 1 for the Final Plant Capacity Study*
- *Peak Dry Weather Flow 2040 are hourly flow rates and are from the Member Agency Master Plans and CSMP*
- *Redwood Shores PWWF = 5 mgd but is not included in the table because the RLS will not be pumping it.*
- *(1) Minimum flow rates occurred on different days in October and do NOT equal the minimum flow rate at the WWTP.*
- *(2) Includes Redwood Shores flows.*
- *(3) PWWF is the worst case timing where the storm event peak flow reaches the entry point into the Conveyance System at the same time. The Master Plans and CSMP show approximately a one-hour difference in the time of concentration within each Member Agency.*

The pumps must also be able to meet two additional pumping conditions: 1) wet well cleaning cycle and 2) Tunnel flushing. The wet well will need to be periodically drawn down to the bottom of the wet well at a flow rate of approximately 11 mgd to remove grit, debris and scum to be handled in the WWTP. The operational strategy of daily diurnal storage in the Tunnel will require frequent flushing of the Tunnel to prevent the buildup of grit, scum and debris. Based on the *"Grit Migration Predictions When Using a Tunnel for Storing Wastewater"* and *"Grease Accumulation from Tunnel Storage Operation"* TMs by Bob Donaldson, flushing will require that the velocity in the Tunnel be increased to at least four ft per second throughout the Tunnel length and that the Tunnel be drained to remove the grit, scum, and debris. To achieve four ft per second, a flow rate of 20 mgd for at least 25 minutes will need to be achieved.

2.2 Pump Selection and Operation

With diurnal Tunnel storage, the range of daily flow rate (minimum hourly flow of 2.0 mgd to peak hourly dry weather flow rate of 33.9 mgd) can be controlled to 12 to 18 mgd or even a smaller, tighter range. This smaller range allows a single pump capacity (same size pumps) rather than multiple size pumps to meet the entire range of flows. At the PWWF rate of 75 mgd with Tunnel storage, five 15 mgd pumps with a sixth installed standby unit can be provided to meet the entire range of flow to 75 mgd presented in Table 2-1.

2.2.1 Pump Selection

Pump selection should be based on a range of operating conditions that the pump will frequently experience and not on a single, worse case point. The operating conditions for pump selection to meet the most frequent operating conditions and the peak flow requirements are defined as Points A, B, C, D and the cleaning and the Tunnel flushing cycle. A description of the operating points is provided below and shown in Figure 2-1.

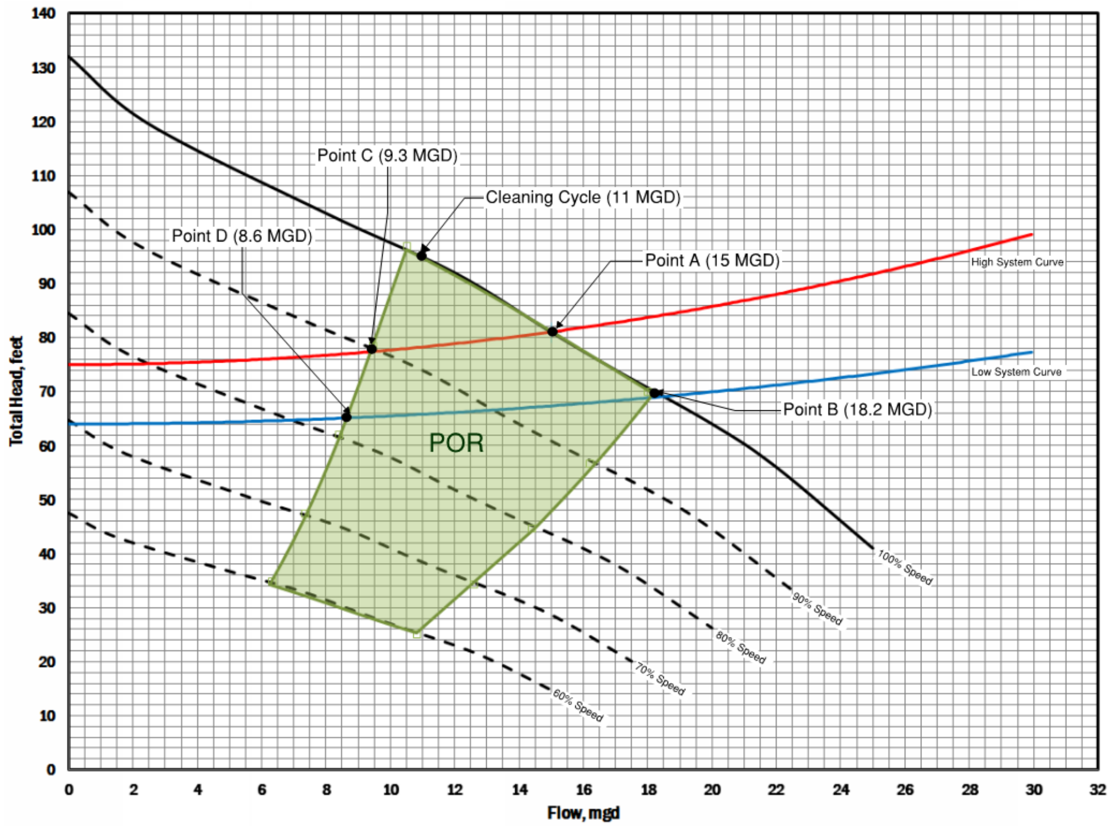


Figure 2-1. Operating Condition Points A, B, C, D and Cleaning Cycle for the 15 mgd pump

Operating Condition Point A is defined as the pump's rated condition. This condition is guaranteed by the pump manufacturer in accordance with the test standards of the American National Standards Institute/Hydraulic Institute (ANSI/HI). Condition A is based upon conditions where all duty pumps are in operation at full speed to achieve the installation full design capacity at the worst case total head condition.

Operating Condition Point B is defined as the run-out condition at full speed established by the intersection of the system and pump curve. Condition B must reside within the selected pump's Pump Application Capacity Limits (PACL) so the pump operates under conditions that minimize vibration and cavitation damage.

Operating Condition Point C is defined as an additional operating point and is used to describe sustained minimum speed operation for the high system curve.

Operating Condition Point D is defined as an additional operating point and is used to describe sustained minimum speed operation for the low system curve.

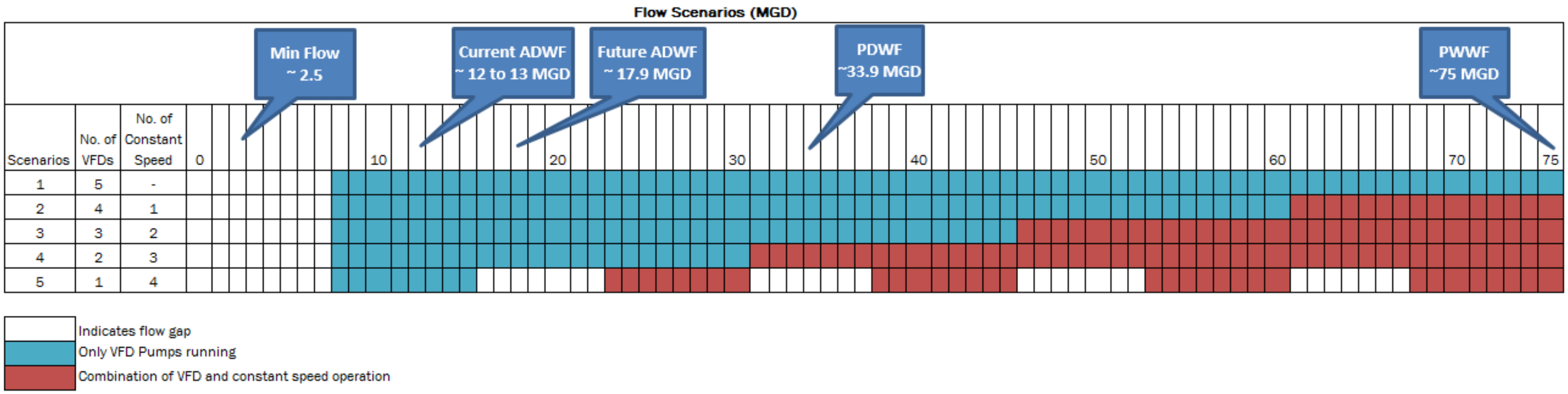
The Wet Well Cleaning and Tunnel Flushing Cycle is defined as the pump drawdown mode to remove debris and scum from the wet well surface and walls and the Tunnel. These flow rates are 11 and 20 mgd, respectively. Two pumps will need to be operating to perform the Tunnel flushing cycle.

The system and pump curve in Figure 2-1 represents one 15 mgd pump. Only one pump is shown on the graph because each pump operates independent of the other pumps and has its own discharge pipe to the headworks. To obtain the total RLS pumping capacity, the pumping rate is multiplied by the number of pumps operating. A summary of operating conditions for the selected 15 mgd pump are shown in Table 2-2. Pumping conditions will be refined as the design progresses and information on the Tunnel invert elevations and Headworks discharge conditions are finalized.

Table 2-2. Summary of Operating Conditions for Pumps at Main RLS Shaft

Condition Point	Flow per Pump (mgd)	Total Head ft)
A	15	81
B	18.2	69
C	9.3	78
D	8.6	65
Wet Well Cleaning Cycle	11	95
Tunnel Cleaning Cycle (requires two pumps)	20	78

With the selected pump, a pumping rate gap analysis was completed to evaluate variable speed operation vs. constant speed operation. The analysis evaluated different combinations of the number of variable speed and constant speed pumps compared to the flow range to determine gaps in flow. The pumping rate gap analysis is presented in Figure 2-2 depicting five scenarios. A blue color represents a variable speed pump in operation, a red color represents a constant speed pump in operation and white represents a gap in the flow rate. The minimum pumping rate for the selected pump based on the pump and system curve shown in Figure 2-1 is between 8.6 and 9.3 mgd (Points C and D).



[1] *All scenarios contain six 15 mgd pumps, which includes one as a standby pump.*

[2] *The wet well will need to operate in fill-draw mode when flows are less than approximately 8 mgd.*

Figure 2-2. Pumping Rate Gap Analysis

The following is a description of the scenarios presented in Figure 2-2.

Scenario 1

All pumps have a VFD. One pump is a standby. This scenario does not have any pumping gaps between 8 to 75 mgd. Scenario 1 is the most expensive pumping combination compared to Scenarios 2 through 5 because VFDs have a higher capital cost than constant speed pumps. However, Scenario 1 provides the most flexibility because all pumps can operate in a variable speed mode. This also makes the control strategy the least complicated because pumps can operate at the same speed and not with a combination of variable and constant speed pumps.

Scenario 2

Scenario 2 has a combination of four pumps with VFDs and one constant speed pump with one constant speed pump as an installed standby unit. This scenario also does not have any pumping gaps between 8 and 75 mgd. However, a combination of VFD and constant speed pumps are required for flow conditions between 61 to 75 mgd if all VFD operated pumps are in service.

This scenario will be less costly compared to Scenario 1 because two less VFDs are required when the standby unit is included but this scenario has less flexibility at higher flow rates when one VFD pump is not in service. This scenario will have a slightly more complicated control strategy than Scenario 1 with the combination of VFD and constant speed pumps operating together.

Scenario 3

Scenario 3 is similar to Scenario 2 in that four pumps have VFDs and two pumps are constant speed but this scenario assumes that one of the variable speed pumps is not in operation instead of one of the constant speed pumps. This scenario also has no pumping gaps; however, as indicated by the Figure 2-2, a combination of VFD and constant speed pumps are required for flow rates between 45 and 75 mgd.

This scenario has a lower capital cost compared to Scenario 1 because of the reduced number of VFDs but has a more complicated control strategy than Scenarios 1 and 2. The control strategy is more complicate because of a combination of the VFD and constant speed pump operation. The control strategy becomes more complicated at 45 mgd when a variation of VFD and constant speed pumps are needed to achieve flow rates above 45 mgd.

Scenario 4

Scenario 4 has a combination of two pumps with VFDs and three constant speed pumps. One constant speed pump is a standby. This scenario has no pumping gaps between 8 and 75 mgd but a combination of VFD and constant speed pumps are required for flow rates between 31 and 75 mgd.

This scenario has a lower capital cost compared to Scenario 1 through 3 because of the reduced number of VFDs but has a more complicated control strategy than Scenarios 1 through 3 because of the greater amount of time operating with variable and constant speed pumps.

Scenario 5

Scenario 5 is similar to Scenario 4 in that two pumps have VFDs and four pumps are constant speed but this scenario assumes that one of the variable speed pumps in not in operation instead of one of the constant speed pumps. With the limited number of variable speed pumps, there are four gaps in the range of flow as indicated by the white space in Figure 2-2.

Like Scenario 4, this scenario has a lower cost compared to Scenarios 1 through 3.

Recommendation

Scenarios 1 (all VFDs) or Scenario 2/3 (combination of four VFD pumps and two constant speed pumps) is recommended. These scenarios cover the flow range to 75 mgd without any pumping gaps, have less complicated pumping control strategies compared to Scenario 4/5 and provide greater flexibility. Scenario 2/3 with two less VFDs has the advantage of less cost but still provides the flexibility to pump up to 45 mgd, which is a high percentage of the pump operation, with variable speed pumps. For Scenarios 2/3, flow rates above 45 mgd will require a more complex control strategy with the combination of constant speed and variable speed pumps.

2.2.2 Pump Operational Requirements

In addition to pumps needing to meet a range of operational criteria as discussed in Section 2.2.1, the pumps have two additional pump operating requirements included in the pump performance specifications that they must meet. These are the PACL and net positive suction head (NPSH) requirements.

2.2.2.1 PACL

PACL is important, especially in raw wastewater pumping applications, because a pump operating within its PACL will require less maintenance, be more reliable, and tend to clog with rags and debris less than a pump operating outside of its PACL. Pump selection for a given application will be predicated on locating the specified most frequent operating condition(s) in the PACL. These points will always include Condition Points A and B and additionally will include any other Condition Points indicated as continuous duty conditions, or any additionally specified for inclusion in the PACL. Condition Point A will be the pump's rated condition and will be guaranteed to meet both specified head and flow within the limit established in ANSI/HI 14.6, acceptance grade 1U.

A given pump's PACL will be determined as a percentage of Best Efficiency Flow (BEPQ) at the given speed, the pump's suction specific speed as determined in accordance with ANSI/HI 1.3, paragraph 1.3.2.2 and the relationships presented in the Table 2-3 below.

Table 2-3. Limiting Flow, Percent Best Efficiency Point Flow (BEPQ)[1]

Suction Specific Speed, Less than but not Greater than:	Solids Bearing Liquids Pumps, Minimum Limit (%)	Solids Bearing Liquids Pumps, Maximum Limit (%)
7000	70	125
8000	75	122
9000	80	120
10000	83	117
11000	85	112
12000	88	110
13000	91	110

(1) Straight line interpolation may be used for intermediate values of suction specific speed

Exceptions to the above will be considered only when certified test data demonstrating conclusively a wider region of stable pump performance can be provided. The test data will need to include suction pressure pulse information as well as actual service information for the same impeller design and trim, operating at the same speed, capacities and head for the same size pump as required for the specified application.

Pumps will function without loss of head due to cavitation or excessive vibration over the entire specified range of flow and head conditions defined by the region bounded by Condition Points A, B and C. Operating Condition Points B and C will reside within the region defined by the PACL limits shown in Table 2-3 based upon the pump's suction specific speed. Operating Condition A may reside in the area outside the PACL limits but must be within the pump manufacturer's defined allowable operating region.

2.2.2.2 NPSH Requirements

The NPSH required is defined as the pressure needed at the pump impeller to operate without experiencing damaging cavitation and a dramatic reduction in pumping production. The NPSH required is provided by the pump manufacturer and is determined when there is a three percent reduction in total dynamic head (THD) for a given flow rate. This is referred to as NPSH3. In other words, during NPSH testing, when a three percent reduction in TDH is measured, the Net Positive Suction Head Available (NPSHA) at that point is established as the pump's Net Positive Suction Head Required - Three Percent Reduction (NPSH3).

The NPSH margin, which is the NPSHA divided by the NPSH3, is based on the suction specific speed of the pump. Pumps with higher suction specific speeds require a greater NPSH margin. The following items provide guidelines for NPSH margin requirements.

- NPSH Margin > 1.1 for centrifugal pumps with suction specific speeds less than 8,500 at any operating condition within 85 and 115 percent for BEP. The minimum acceptable NPSH margin ratio at any other location on the pump's head/capacity curve will be 1.2.
- Pumps with suction specific speeds greater than the above limitations will have NPSH margins of 1.5 and 2 applicable to the capacity envelope limitations defined previously. Under no circumstances will the absolute value of the margin above NPSH3 be less than 3.5 ft.
- Pumps with suction specific speeds greater than the above limitations and pumps with impeller materials that do not meet the requirement for duplex cast stainless steel, and all pumps with suction specific speeds greater than 10,000 will have NPSH margins not less than 2.5 at operating conditions within ±15 percent of best efficiency capacity and not less than 3.5 for all operating conditions falling outside the ±15 percent of best efficiency capacity envelope. Under no circumstances will the absolute value of the margin for pumps qualifying with the foregoing restrictions, be less than 3.5 ft greater than NPSH3.

2.3 Wet Well Approach Channel Design

The flow will be conveyed in the Tunnel by gravity to the wet wells. The flow will be divided into two distinct approach channels, one for each wet well in the Flow Splitter Shaft. Each channel will contain a slide gate to isolate a wet well from the other wet well. Guides for stop logs may also be provided in each channel to provide a second method of isolation.

The velocity in the approach channel, upstream from the wet well, will be no greater than 4.0 ft/s at PWWF.

The approach channel upstream from the trench will be straight and free of fittings or devices that could disrupt the flow uniformity entering the trench for a distance equal to a minimum of five times the approach pipe diameter. Since the Flow Splitter Shaft does not completely meet ANSI/HI standards, BC recommends physically modeling the Tunnel exit, Flow Splitter Shaft, and wet well to identify improvements to make the configuration ANSI/HI compliant.

2.4 Wet Well Design

This section establishes criteria for the design of trench-style wet wells. The design of trench-style wet wells incorporates features to re-suspend settled grit and sand and incorporate scum, grease and debris into the wastewater to then be pumped out of the wet well during the cleaning operation. The trench style configuration also provides flow conditions into the pump inlet and pump impeller that promote efficient pumping and reduced O&M requirements. The wet well design will primarily follow the ANSI/HI for Rotodynamic Pumps for Pump Intake Design (ANSI/HI 9.8) with modifications to accommodate the tunnel shaft requirements and the deep setting of the wet well. The pump station will have two wet wells that each contains three pumps for both dry and wet weather conditions. In total, there are five duty pumps and one standby pump for wet well 1 and 2.

The wet well configuration and dimensions are largely based on the pump inlet bell diameters. The wet well dimensions are located in Attachment A. The following describe the requirements for the configuration of the wet well.

2.4.1 Pump Inlet Bell

A suction nozzle, fitted with a flared bell inlet, will be installed on each pump. The suction nozzle will be sized for a suction velocity to 4.0 ft per second (no less than 3 ft per second and no more than 5 ft per second) at Condition Point B as defined in Table 2.2 of Section 2.2. The nozzle length must exceed the difference between the inlet and outlet diameter of the nozzle. The pump inlet bell diameter will be sized to meet the criteria stated above.

2.4.2 Wet Well Cross Section

The wet well cross section dimensions are a function of the pump bell inlet diameter and the incoming approach pipe diameter. The wet well cross section consists of a rectangular trench with a trapezoidal section above the trench that transition to a rectangular section above that. Dimensions of the wet well cross section are discussed below.

2.4.2.1 Trench Width

The wet well trench width will be a minimum of 2D where D is the pump inlet bell. The trench width will have to accommodate the selected pump volute diameter plus a minimum of four inches of clearance on each side of the volute. Depending on the pump manufacturer, the pump volute diameter may be larger than the designed pump inlet bell diameter.

The trench width will be consistent throughout the length of the wet well.

2.4.2.2 Minimum Submergence

The recommended minimum submergence for reducing free surface vortices as recommended by ANSI/HI 9.8-2012 is as follows:

$S = D + 0.574\frac{Q}{D^{1.5}}$, where

D = pump bell inlet diameter (inches)

Q = Design flow gallons per minute

S= Submergence, the distance between the minimum liquid level and the inlet (not minimum level to floor; inches)

The minimum submergence shall be calculated at the maximum pump capacity. The minimum submergence shall be compared to NPSH margins requirements as discussed in Section 2.2.2.2 and in Attachment B. The trench depth will be adjusted accordingly to meet both the minimum submergence and NPSH margin requirements.

2.4.2.3 Above the Trench

The area above the trench will be a trapezoidal area with the outer side sloped outward, away from the trench at a minimum of 45 degrees. The interior divider wall between the two wet wells will be vertical. The wet well will be plastic (Polyvinyl coated [PVC] or High Density Polyethylene [HDPE]) lined for corrosion protection and to prevent solids, scum and grease from sticking to the walls. The plastic lining will extend to half the depth of the fillet at the wall/floor (partially anchored into the fillet).

The wet well will be designed to match the approach pipe liquid level with the maximum velocity in the trapezoidal area above the trench at a maximum velocity of 1.0 ft/s. However, normal operation of the tunnel and wet well will be to store wastewater in the Tunnel, which will result in the water surface elevation above the trapezoidal area.

2.4.2.4 Water Guide

A water guide is required at the top of the trench and extended to the middle of the ogee ramp. In section view, a water guide fills the sloped sections of the wet well at the top of the trench extending the trench vertically to the length of the first half of the ramp. The water guide keeps the water confined within the width of the trench to guide it down the ramp and prevent it from creeping up the sloped sides of the wet well upon exiting the approach pipe. The water guide will extend to the height of the approach channel. The top of the water guides will be sloped two percent towards the trench to drain any water that may accumulate on the water guide.

2.4.3 Design Ramp for Cleaning

An ogee ramp is required to gather speed down the ramp to create a hydraulic jump during cleaning cycles. The hydraulic jump occurs at the base of the ramp and then moves along the trench floor to the last pump during the final drawdown and cleaning portion of the cleaning cycle. The purpose of inducing a hydraulic jump is to scour the trench floor and mobilize solids for suction by the last pump. The ogee ramp will consist of an upper curve and a lower curve connected by a maximum 45-degree tangent.

2.4.3.1 Upper Ramp Radius

The radius of curvature for the upper portion of the ramp, R_{upper}, will be at least 2.3 times the pressure head of the approach pipe upstream of the sluice gate during cleaning or 2D, whichever is greater. The radius using the pressure head of the approach pipe will be calculated as follows:

$R_{upper} = FS \cdot 2.33v^2/2g$, where

R_{upper} = Upper ramp radius (ft)

FS = 2; Factor of Safety

v = Cleaning Velocity (ft/s); Calculated using the velocity of the approach pipe at half of the last pump's capacity when the flow freely discharging from the approach pipe is at critical velocity

g= 32.2 ft/s^2; acceleration of gravity

2.4.3.2 Lower Ramp Radius

The radius of the curvature at the bottom of the ogee, R_{lower}, will be large enough for a smooth transition to horizontal flow. The lower ramp will be 0.5 to 1.0 times R_{upper}.

2.4.3.3 Dimensions of the Ramp

The ramp angle will be 45 degrees and connect the upper ramp radius to the lower ramp radius. The following equations will be used to determine the horizontal and vertical projections of the ramp:

Horizontal Projection of Upper Curve, H_{upper}:

$H_{upper} = R_{upper} \cdot \sin(\theta_{ramp\_angle})$;

Vertical Projection of Upper Curve, V_{upper}:

$V_{upper} = R_{upper} - R_{upper} \cdot \cos(\theta_{ramp\_angle})$;

Horizontal Projection of Lower Curve, H_{lower}:

$H_{lower} = R_{lower} \cdot \sin(\theta_{ramp\_angle})$;

Vertical Projection of Lower Curve, V_{lower}:

$V_{lower} = R_{lower} - R_{lower} \cdot \cos(\theta_{ramp\_angle})$;

Vertical and Horizontal Projection of Tangent Between Curves, $H_{tangent}$ and $V_{tangent}$;

$H_{tangent} = V_{tangent} = S + 0.5D_{wetweather} - V_{upper} - V_{lower}$; and

Total Horizontal Projection of Ramp, H_{total_ramp}:

$H_{total\_ramp} = H_{tangent} + H_{lower} + H_{upper}$; where

R_{upper} = Upper ramp radius (ft)

R_{lower} = Lower ramp radius (ft)

S = Required Submergence (see Section 2.5.2.2)

θ_{ramp_angle}= angle of tangent connecting upper and lower radius of the ramp (degrees)

2.4.4 Pump Spacing

Pump intakes will be spaced a minimum of 2.5D from pump centerline to centerline. The first pump will be spaced a minimum of 0.5D from the end of the ogee ramp. See Section 2.4.7 for spacing of the last pump from the end wall.

2.4.5 Inlet Floor Clearance

The pump inlet clearance from the floor will be a minimum of 0.5D, unless otherwise specified. A minimum of three inches of clearance between the pump inlet and the flow splitter is required to allow solids to enter the inlet. Therefore, the pump inlet from the floor may be raised slightly to meet the three inches of clearance.

2.4.6 Flow Splitters and Fillets

Fillets will be installed along both sides of the trench floor for the entire length of the wet well trench to eliminate sidewall vortices. The fillets will extend from the top of the ogee ramp to provide a good flow pattern down the ramp to the end wall. Fillets will have a 45-degree slope with a height of 0.38 of the pump inlet diameter (D).

Fillets will be made of shotcrete (Gunite) sprayed, screed, and troweled smooth. The fillets will be anchored into the corners of the trench.

Flow splitters help control flow vortices within the wet well and retain the hydraulic energy from the ramp to produce a swift flow of water along the floor during cleaning. A flow splitter will be installed on the floor of the wet well at the centerline of the trench. The flow splitter will start at the top of the ramp and end just short of the recessed portion of the wet well for the last pump. The flow splitter will consist of a triangular section with a height of 0.38D and side slopes of 45 degrees. At the top of the ramp, the flow splitter will have a nose that tapers to zero to minimize hydraulic disturbances. The flow splitter nose will extend 1.67D down the ramp and connect to the full triangular flow splitter. Flow splitters will consist of a stainless steel plate exterior filled with grout and attached with stainless steel adhesive anchors or stainless steel headed studs to the wet well floor.

A vertical stainless steel plate will be installed beneath the second pump from the wet well inlet to minimize floor vortices from entering the second pump. The stainless steel plate will start at the wet well floor and extend beyond the apex of the flow splitter with the plane of the plate perpendicular to the length of the flow splitter. The stainless steel plate will be 1.5D long and centered below the second pump. The height of the stainless steel plate will be 0.38D.

2.4.7 Last Pump

The end wall clearance to the last pump centerline will be spaced at 0.75D unless the selected pump's volute dimensions prevent the specified clearance. If the pump's volute diameter is too large to allow the 0.75D clearance, then the last pump will be placed as close to the end wall as physically possible with a minimum of 3 inches of clearance between the pump volute and the end wall.

Elevation of last pump will be calculated by the following method:

1. Calculate the sequent depth of the hydraulic jump during wet well cleaning near the end of the wet well. The design flow for a cleaning cycle will be approximately 11 mgd.
2. Set the bottom of the pump inlet bell at 0.5D below the sequent depth.
3. Set the floor 0.25D below the pump inlet bell. This will create a recessed floor beneath the last pump where solids may accumulate during the cleaning cycle.

The floor between the last two pumps will be sloped 30 degrees to reach the floor elevation beneath the last pump. The recessed floor for the last pump will be large enough to accommodate the pump bell inlet outside diameter and provide at least 4-inches of clearance.

2.4.8 Anti-rotation Baffle and Floor Cone at Last Pump

An anti-rotation baffle will be placed between the last pump and the back wall to prevent circulation of liquid between the pump and the pump wall. The anti-rotation baffle will consist of a stainless steel plate that protrudes towards the pump as far as possible. The anti-rotation baffle will extend from the floor of the trench at the end wall to the crown of the approach pipe in the wet well unless the volute of the pump prevents this configuration. The anti-rotation baffle will be placed such that it does not interfere with the installation and removal of the pump. If the volute dimensions of the pump prevent the baffle from extending from the floor of the wet well to the crown of the approach pipe, then the baffle will extend from the floor to just below the pump volute with 3 inches of clearance. The pump volute dimensions will be coordinated with the pump manufacturer. Stainless steel adhesive anchors will be used to fasten the baffle to the wall.

A floor cone will be placed under the last pump. Two vanes, a fore and aft vane, will be attached to the cone. The floor cone height will be three inches below the inlet bell of the last pump with 45-degree side slopes. The vanes will be centered beneath the pump inlet bell parallel with the longitudinal section of the wet well and extend the length of the inlet bell outside diameter. Both the vanes and the cone will be made of stainless steel and welded to a stainless steel plate that is then attached to the wet well floor with stainless steel headed studs.

2.4.9 Pump Bell Flushing Line

A separate piping system using plant water, grit and/or screening dewatering water from the headworks will be used to re-suspend settled solids in the wet well and channels in the Flow Splitter Shaft.

Back flushing of the pumps will occur each time the pumps are stopped. Flow will back through the pump to help remove debris within the pumps and provide some flushing of the solids deposition at the bottom of the wet well.

2.5 Pump Removal

The pump supplier will provide the pump installation and retrieval systems. Each submersible pump will be equipped with a lifting bail attached to cable support yoke, as show in Figure 2-3 and Figure 2-4.

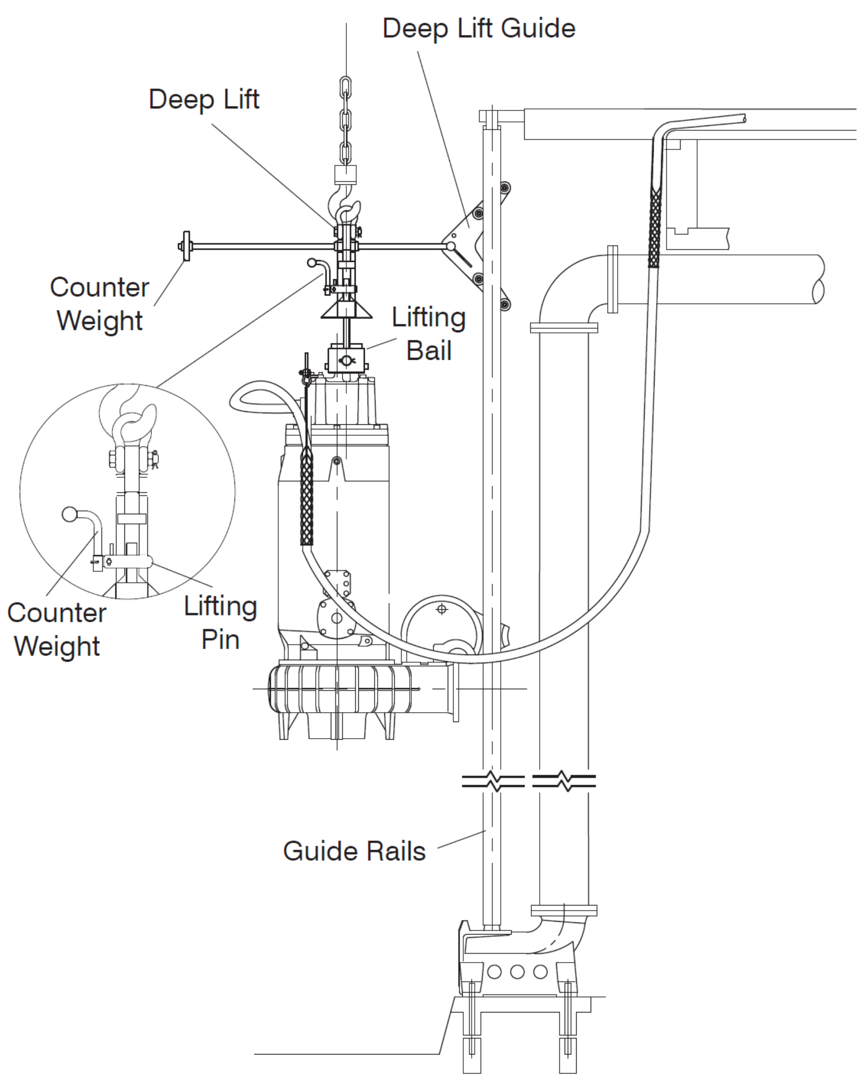


Figure 2-3. Conceptual deep lift system for pump retrieval

Figure 2-4. Conceptual deep lift guide

The lifting bail will be designed to work with a lifting device. The lifting device will be automatically guided down the pump guide bars as the hoist lowers the device down towards the installed pump, as shown in Figure 2-5 and Figure 2-6. A camera can also be installed on the lifting device to assist with pump installation and removal.

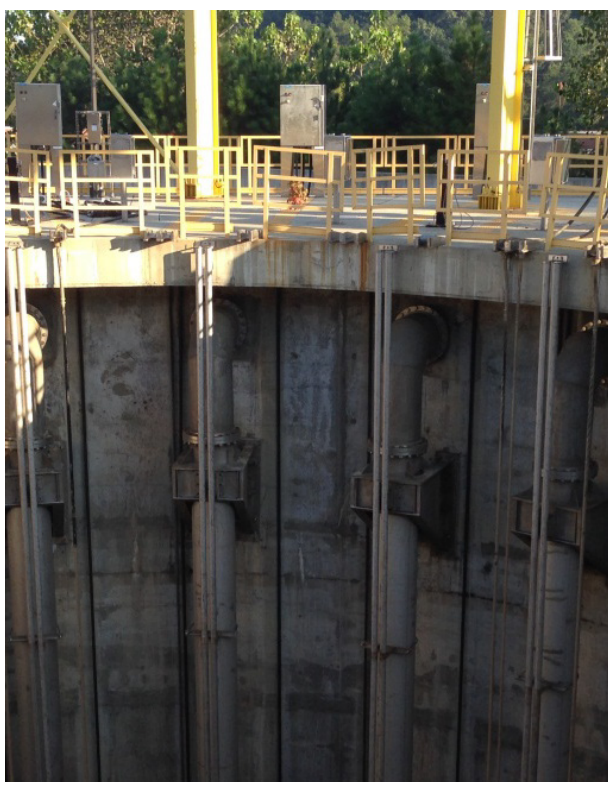


Figure 2-5(A). Pump guide bars

Figure 2-6(B). Pump guide bars

When meeting the top of the pump, it will automatically and securely engage the pump lifting bail when coupled to the pump. When a pump is installed, a separate hook release device (Figure 2-7) will be temporarily added to the deep-lift. This device will insure that once a pump is seated on the discharge connection (as shown in Figure 2-8), the deep-lift can be automatically released and brought back up the guide rails.

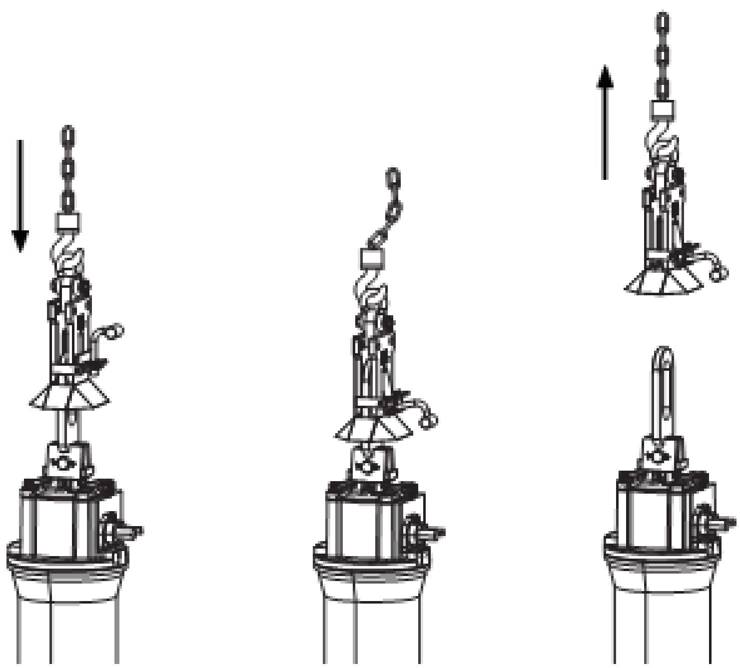


Figure 2-7. Conceptual pump discharge elbow and pipe

Figure 2-8. Conceptual pump discharge connection

2.6 Wet Well Operation

The wet well operation is described in the following sections.

2.6.1 Typical Operating Mode

The Main RLS Shaft is comprised of two wet wells with each containing two variable speed and one constant speed pump as shown in Figure 2-9. The configuration of the two variables speed pumps with one constant speed pump is the current configuration but other variable speed pump combination will be reviewed in pre-design. Within each wet well, the three pumps are comprised of identically sized pumps. The Tunnel will provide storage for both daily diurnal and PWWFs. Flow control and sequencing of pump starts and stops will be accomplished by the water surface level in the wet well and Tunnel. VFDs will vary the speed/pumping rate from each of the pumps to maintain an operating flow set point as long as the water surface level in wet well and Tunnel are within a defined range.

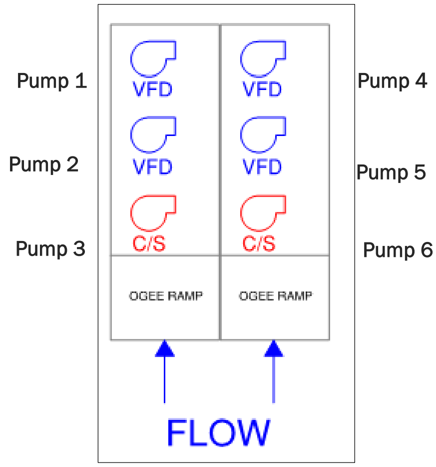


Figure 2-9. Sketch of the conceptual arrangement of the variable and constant speed pumps

The lead and lag wet wells will be determined based on the user selected based on dry and wet weather pump sequence configuration in both wet wells. The user selects which pumps in each wet well will be in the lead, lag2 and lag3 (or standby) for the different flow conditions.

2.6.2 Cleaning Mode

Cleaning of the wet wells will be completed by placing the pump in "SCADA Manual" where wastewater is accumulated in the wet well and Tunnel pipe, and flushed using the pumps furthest from the inlet (Pump 1 in Wet Well 1 and Pump 3 in Wet Well 2) to re-suspend solids that have accumulated in the wet well, as well as clearing the wet well of accumulated scum and debris. The typical cleaning cycle duration ranges from 3 to 5 minutes for only the wet well. Figure 2-10 through Figure 2-13 shows the typical sequence of the cleaning mode for the wet well. A Tunnel flushing can also be completed as part of the wet well cleaning. A Tunnel flushing will take approximately 25 minutes.

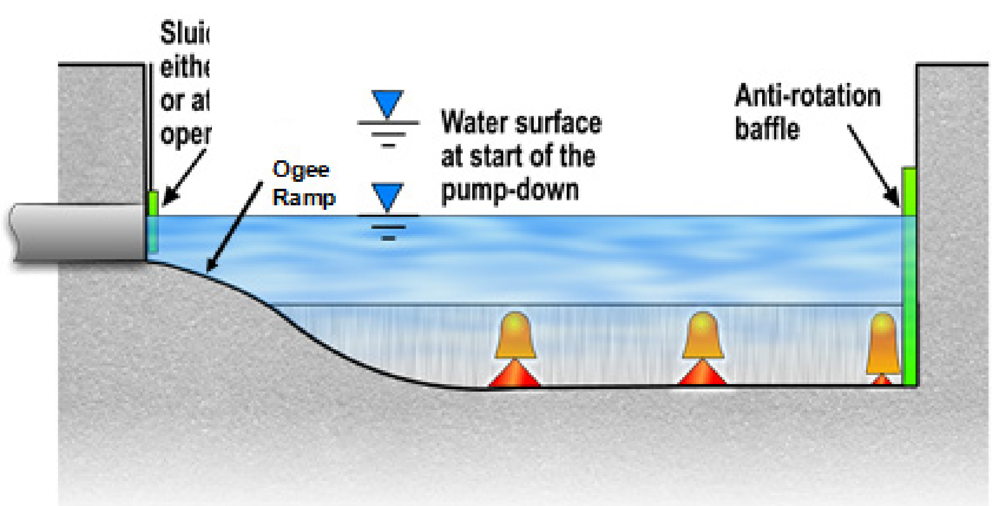


Figure 2-10. Cleaning Cycle (Step 1)

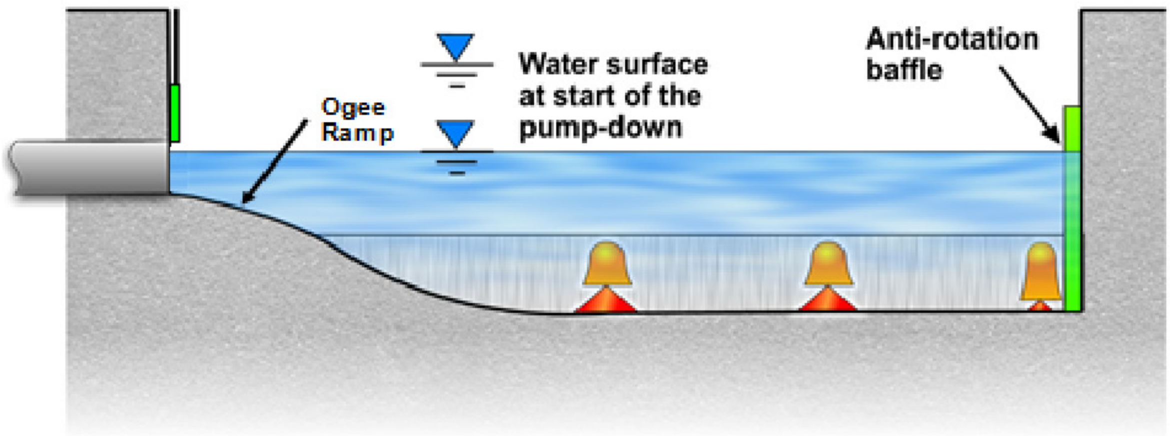


Figure 2-11. Cleaning Cycle (Step 2)

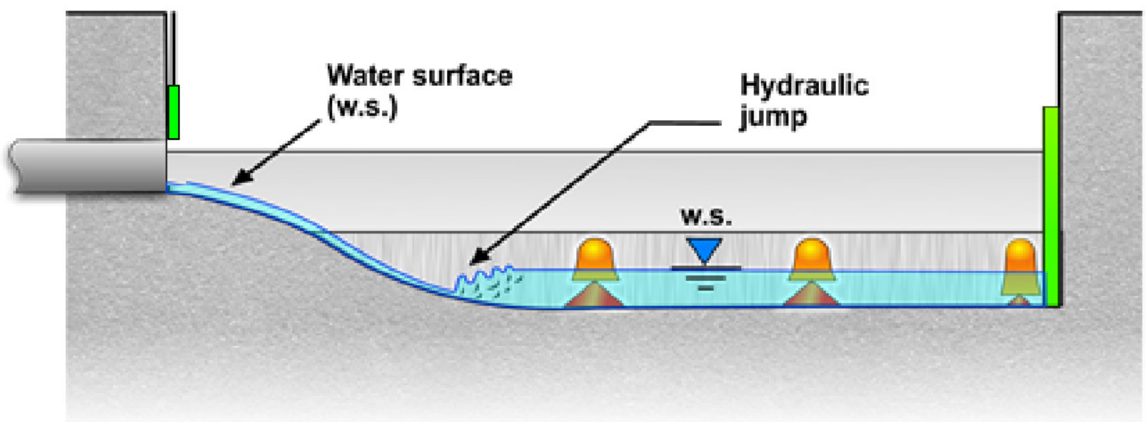


Figure 2-12. Cleaning Cycle (Step 3)

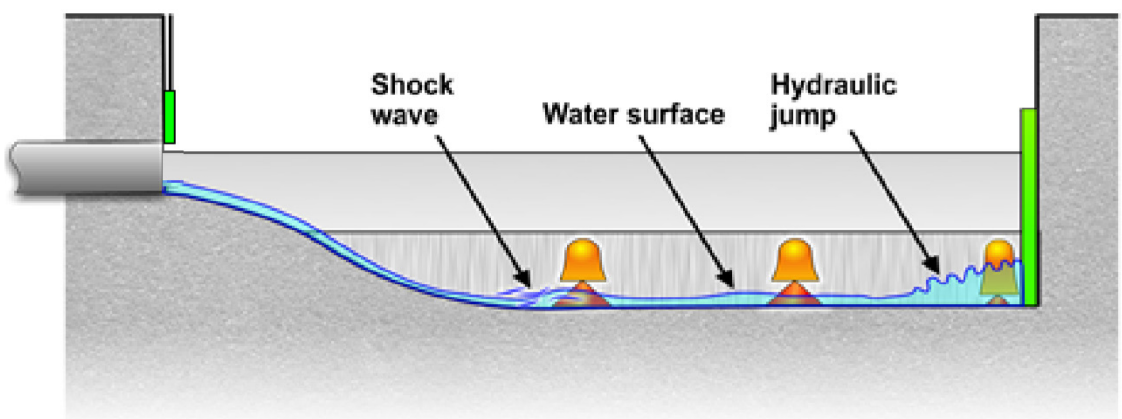


Figure 2-13. Cleaning Cycle (Step 4)

2.7 Submersible Pump Monitoring

The following monitoring will be provided for each submersible pump:

- Winding temperature – temperature switch (bimetal) in winding
- Coolant temperature, if coolant is used
- Bearing temperature at the pump and drive end
- Leakage inside motor
- Mechanical seal leakage
- Leakage in impeller area – float switch
- Vibration sensor

2.8 Additional RLS Maintenance and Safety Considerations

The following maintenance and safety items will also be part of the RLS design:

- Hatches will have fall-protection netting or integral safety grates
- Tie downs will be provided and used anytime hatches are open
- Railing will be provided around the Main RLS Shaft and Flow Splitter Shaft structures for fall protection
- Pump removal will be through a contracted crane service
- Remote cameras will be provided on the pump removal equipment and to assist with wet well cleaning
- A cradle located at grade will be provided for pump maintenance
- Hatches large enough to insert a basket to remove debris that the pumps cannot convey will be provided
- Combustible gas detectors will be provided in the wet well
- Instrument installation that does not require entry into the wet well for maintenance will be provided
- Flushing water from the plant water system and Headworks and pipes for each pump and at each Flow Splitter Shaft entrance channel will be provide
- Passive emergency overflow from one wet well to the other (low dividing wall) will be provided in the Flow Splitter and Main RLS Shafts
- Facilities for onsite, routine maintenance, major rebuilds and repairs will be performed by a manufacturers' authorized outside service company

These items will be developed further during design and workshops with O&M staff.

Section 3: Odor Control and Ventilation

The RLS will have an on-site odor control system treating odors from the Tunnel, Flow Splitter Shaft and Main RLS Shaft. The odor control treatment system will be designed by the Headworks facility design team. The Pipe Gallery will be ventilated but not connected to the odor control system.

The preliminary odor control design criteria for the RLS are shown in Table 3-1. The RLS design criteria will include the supply fans for the wet wells, the associated ducting for supply and exhaust air for the wet well and Flow Splitter Shaft, and the ventilation system for the Pipe Gallery. Supply and exhaust fans will be provided for each wet well and for the pipe gallery. Exhaust fans will only be provided for the Flow Splitter Shaft and the air conveyed from the Tunnel. The location of the supply and exhaust fans has not been determined.

Ducting for the exhaust fans for odor treatment will be routed to just outside of the Headworks Building where the Headworks design firm will be responsible for continuation of the ducting to the odor control system. The headworks facility design team will be also responsible for developing the size and design of the ducting and odor control system.

Table 3-1. RLS General Odor Control Design Criteria

Parameter	Units	Value	Notes
Air Stream Design Criteria			
Total Air Flow Rate			Based on wet well volume and air changes per hour; will be updated and finalized upon final configuration of RLS
Flow Splitter Shaft	cfm	2,230	Tunnel ventilation rate needs to be added to the air flow rate. Flow Splitter Shaft will only have exhaust fans.
Main RLS Shaft	cfm	7,720	
Air Change Rate	ACH[b]	4/6	To provide ventilation for corrosion protection in shafts/declassify Pipe Gallery (6 ACH)
Total Air Stream H_2S Concentration	ppmv	TBD	Typical range may be from 0 to 100 ppmv for shafts, depending on upstream conditions. Values to be determined by Headworks and Tunnel odor control design teams.
Fan Design Criteria			
Number of Supply Fans (duty/stand-By)	-	see notes	One per wet well (minimum) Two for the Pipe Gallery (minimum); number and locations TBD in final design No supply fans will be provided for the Flow Splitter Shaft
Supply Fan Horsepower (hp)	hp	5	To be updated and finalized upon final configuration of RLS
Number of Exhaust Fans (duty/stand-By)	-	see notes	Constant speed exhaust fans; one per wet well Two for the Pipe Gallery (minimum); number and locations TBD in final design Minimum of one for the Flow Splitter Shaft
Exhaust Fan hp	hp	5	To be updated and finalized upon final configuration of RLS

Note:
cfm = cubic feet per minute
ppmv = parts per million by volume
TBD = to be determined

Final air exchange rates and facility volumes will be coordinated with the Tunnel and Headworks facility design teams during design. Provisions for increasing the ventilation capacity for manned entry into the wet wells could be considered during design. These provisions may include a future connection for portable blower hookup or connection ports for larger ducting and equipment.

Section 4: Headworks Flow Distribution Box

The RLS pumps will discharge into a flow distribution box that will be designed by the Headworks facility design team. At this time, the pump discharge is assumed to be a free discharge with a minimum air gap of 2 ft above the high water surface elevation of the Flow Distribution Box to provide backflow prevention. The pipes will be cast into the Flow Distribution Box wall. The Flow

Distribution Box needs to be configured to minimize dead zones and prevent debris deposition. The Headworks Flow Distribution Box design will be further developed and coordinated with the Headworks design team as design progresses. Additional options such as Tideflex style check valves at the point of discharge, side discharge with an ogee ramp, center distribution discharge with Headworks recycle flows and Redwood Shores flow providing flushing and end distribution box discharge with Headworks recycle flows and Redwood Shores flow providing flushing will be explored.

Section 5: Civil Design Criteria

The Civil Design Criteria is being provided by Freyer and Lauretta under a separate task order as part of the overall Front of Plant (FOP) civil site design.

The top of the wet well will be at elevation 110.00 (NGVD 29 datum +100 ft). The electrical cabinets/junctions boxes for each submersible pump will be located at this elevation.

The top of the Pipe Gallery and the Flow Splitter Shaft will be approximately 0.5 ft above the finished grade with positive drainage away from the structures. The Flow Splitter Shaft, Pipe Gallery and the equipment and instrumentation in these structures will be designed for flooding. The Flow Splitter Shaft and Pipe Gallery access points will be equipped with water-tight hatches.

The Pipe Gallery will include a sump pumps for dewatering the Pipe Gallery of nuisance and or flood water. The Flow Splitter Shaft and Main RLS Shaft will also have sump pumps to remove water between the shaft concrete and the structural concrete for the flow splitter channels and wet well. These sump pumps will convey drainage to the FOP storm water system.

Section 6: Security Criteria

The Security Criteria is based on the SVCW Security Guidance Document, February 2012. This design criteria document will be updated when the standards are updated.

6.1 Purpose

The purpose of this section is to establish the levels of security for the RLS to be used in design. The security program will support the increased automation of the operations at the treatment plant and will be compatible with the Automation System Integration. Overall site security (e.g., fences, gates, etc.) will be designed by others as part of the overall FOP civil site design.

6.2 Security Requirements

The following level of safety and security features will be incorporated into the RLS:

- Access hatches leading to the Pipe Gallery, for pump removal above the wet well, and above the Flow Splitter Shaft will be locked with padlocks to prevent entrance by unauthorized personnel.
- Electrical junction boxes for the pumps located on top of the wet wells will be locked to prevent entrance by unauthorized personnel.
- Lighting will be provided with a particular focus on camera monitored areas. Lights and cameras will be installed in locations with consideration for ease of maintenance but in a location inside the fence to avoid potential vandalism of the cameras and lights.

- An emergency call button will be located at the RLS site and on local Programmable Logic Controllers (PLCs) and connected to SCADA.

6.3 SCADA

The SVCW SCADA system is comprised of SCADA Servers, SCADA Workstations, PLC to control individual processes, and network/communications infrastructure. The system has distributed logic such that the individual PLCs can operate independently of the SCADA server. The RLS PLC Workstation will be located within the SVCW WWTP. Recommended physical security of the SCADA equipment will include:

- Instrumentation – critical instruments for process control will be located within locked cabinets or buildings with perimeter protection preventing easy access of vandals.
- PLC/SCADA Network Panels - panels will be located in locked, access-controlled buildings. PLCs and SCADA Network equipment will be within locked cabinets. Door switches will be included to provide operator notification through SCADA that the PLC or SCADA network panel door has been opened.
- SCADA Workstations will be located in locked, access-controlled buildings. Control for all workstations located outside of the plant server room or plant control room will require authentication in the form of individually identifiable accounts with access being logged. Building door switches will be included to provide operator notification through SCADA on access into building.
- Security cameras connected to the SCADA network will be fixed focus and evaluated on a case by case basis. If security systems require separation from the SCADA network, these systems will need to be reviewed and approved by SVCW. Pan-Tilt-Zoom features, if used, cannot be controlled by the SCADA network.
- SCADA Servers, Workstations, Network Equipment, and PLCs will be installed above flood areas. Seismic bracing will be provided for all SCADA equipment including all workstations. Power will be protected from surges with adequate backup and redundancy to maintain power through typical failures.
- Network cabling will be encased in conduits. All access points to the cabling will be locked or sealed to prevent easy access. Redundant communications with using redundant physical paths for in-plant networks will be provided. Encryption capabilities will be considered during the design.
- Physical equipment failure protection will be provided in the form of highly available architectures (unit redundancy) and automatic failover. Consideration will also be given to highly available logical data flow paths. These paths can be adversely affected through logical or physical means. Actively monitored access, logical and physical will be provided. This includes SCADA servers and workstations as well as User Account control servers that may or may not reside inside of physically secure plant perimeters.
- Air spaces around SCADA and electrical equipment will have atmospheric/air quality conditioning and treatment.

Section 7: Corrosion Control

Corrosion control for the RLS will be provided in the Flow Splitter Shaft, Main RLS Shaft, Piping Gallery, and underground utilities. The Tunnel will also have corrosion protection but Tunnel corrosion protection is not part of the RLS and will be determined by the Tunnel design team.

Corrosion control will be provided with lining of concrete, materials selection such as Type 316 stainless steel, coating of equipment and piping, and ventilation of the Flow Splitter Shaft and Main RLS Shaft. Corrosion for underground utilities will be developed as more site specific geotechnical information becomes available. Per the latest soils corrosion study, the soils at the FOP are highly corrosive. The soil may also be lime treated for stabilization, which will need to be considered if this occurs.

The Flow Splitter Shaft and Main RLS Shaft concrete will be plastic (HDPE or PVC) lined including the walls from the top of the structures to the bottom of the wet well. The underside of the top slab will also have plastic lining and the hatches will be of corrosion resistant material such as type 316 stainless steel or aluminum.

The ventilation system will have powered supply and exhausts fans for the wet well and Piping Gallery. The Flow Splitter Shaft area will only have exhaust fans because it will also control the air movement exhausting from the Tunnel. The exhaust foul air from the Flow Splitter Shaft and Main RLS Shaft will be treated by the odor control system provided as part of the Headworks facility. Ventilation design rates are discussed in Section 3 of this TM. Final corrosion control methods will be coordinated with the Tunnel and Headworks design teams as the projects proceed into design.

Section 8: Architectural Design

The architectural design features for the RLS will be minimal since most of the structure is below grade. The only portion of the RLS structure above grade is the portion of the Flow Splitter Shaft where the pump electrical cabinets are located. To the extent practical, the architectural design could match the new headworks facilities.

Section 9: Structural Design and Geotechnical Considerations

This section describes the structural design guidelines that will be used for design of the RLS, both building and non-building structures, including applicable codes and standards, design load criteria, and materials of construction. The RLS will be considered an essential facility from a structural and seismic perspective.

The Tunnel design team will construct the receiving shafts for the Tunnel and the RLS. It is anticipated that, as part of the RLS design, structural shaft improvements (e.g., reinforced structural liner for anchoring of wet well facilities) will be required to convert the shaft into a permanent structure. Additional improvements will include construction of the Flow Splitter Shaft, Main RLS Shaft, superstructure above grade for the RLS, and the Pipe Gallery. The Pipe Gallery will be supported on piles. Pile support will also be provided for other large utilities and duct banks that are not located in the Pipe Gallery.

9.1 Codes and Standards

The project will be designed to comply with applicable portions of the codes and standards listed in Table 9-1 below. The edition of codes will be the latest edition adopted by the State of California at the start of the project final design. The edition of the referenced standards will be the latest published edition at the start of the project final design.

Table 9-1. Codes and Standards for Structural Design

Reference	Title
ACI 301	Specifications for Structural Concrete
ACI 318/318R	Building Code Requirements for Structural Concrete and Commentary
ACI 350/350R	Code Requirements for Environmental Engineering Concrete Structures and Commentary
ACI 350.1/350.1R	Specification for Tightness Testing of Environmental Engineering Concrete Containment Structures and Commentary
ACI 350.3/350.3R	Seismic Design of Liquid-Containing Concrete Structures and Commentary
ACI 350.4R	Design Considerations for Environmental Structures
ACI 530/American Society of Civil Engineers (ASCE)5/TMS 402	Building Code Requirements for Masonry Structures
American Institute of Steel Construction (AISC) 341	Seismic Provisions for Structural Steel Buildings
AISC 360	Specification for Structural Steel Buildings
AISC	Specification for Structural Joints using American Society for Testing and Materials (ASTM) A325 or
ASCE 7	Minimum Design Loads for Buildings and Other Structures
Aluminum Design Manual	Aluminum Association
American Association of State Highway and Transportation Officials (AASHTO)	AASHTO - Standard Specifications for Highway Bridges
CMAA	Crane Manufacturers Association of America - Specifications No. 70 and 74 for Cranes
AWS D1.1	American Welding Society - Structural Welding Code-Steel
AWS D1.2.	American Welding Society – Structural Welding Code - Aluminum
AWS D 1.4	American Welding Society-Structural Welding Code- Reinforcing Steel
AWS D 1.6	American Welding Society-Structural Welding Code-Stainless Steel
California Building Standards Code (CBC)	California Building Code, with local amendments
U.S. Department of Labor Occupational Safety and Health Act (OSHA)	Code of Federal Regulations, 24 CFR Part 1910, Occupational Safety and Health Administration Standards, with local amendments
International Code Council	Evaluation Service Reports as applicable for manufactured structural components
All applicable state and local codes	Various

9.2 Design Loads

Load types as appropriate to the project are listed below. Loads will be based on the most stringent criteria of the building codes, standards listed above, as well as industry standards. In all cases, the minimum criterion will conform to the California Building Code. The following load types will be considered in design:

- Dead Loads
- Collateral Loads
- Live Loads and Associated Deflection Criteria
- Seismic Loads

- Wind Loads
- Rain Loads
- Impact Loads
- Vibratory Loads
- Handrail
- Heavy Equipment Loads
- Differential Settlement Loads
- Liquid Loads
- Earth Load

For detailed load criteria, see Attachment C. The Tunnel design team and the RLS design team will establish consistent design loads that will be used within the completed shafts.

9.3 Buoyancy Loads

Buoyancy will be investigated. Design factors will follow ACI 350.4R Section 3.1 guidelines recommending a 1.1 factor of safety for groundwater at the 100-year design flood elevation, not considering soil, and 1.25 considering soil and groundwater elevations below the 100-year design flood elevation.

The 100-year design flood level for this location is elevation 110 (NGVD 29 + 100 ft).

9.4 Load Combinations

Load combinations will be as prescribed by the CBC and ASCE 7 and as amended by ACI 318 and ACI 350. Environmental structures shall employ the durability factor and load combinations in accordance with ACI 350, Chapter 9 Strength and Serviceability Requirements.

In General, load combinations for load resistance factor design (LRFD) and Adjustable Speed Drive (ASD) will be applied to materials and systems as summarized in Table 9-2.

Table 9-2. Load Combinations

Material	LRFD/ASD
Aluminum	ASD
Anchorage to Concrete	LRFD
Reinforced concrete (precast and cast-in-place)	LRFD
Reinforced concrete (crack control)	Strength design with durability factor
Soils	ASD
Steel	ASD or LRFD

Load combinations are intended to capture anticipated load conditions that structures will be subjected to during their service life. Such load conditions include the service or operating conditions, temporary conditions, earthquake and other extraordinary loads. The following provides a description of how load combinations are proposed to be used under different load conditions.

- **Operational:** Includes all long-term dead loads, fluid loads, live loads, thermal-straining loads, and earth-pressure loads in various combinations. Because groundwater levels fluctuate, buoyant uplift loads will not be considered in reducing downward loads. Backfill will be assumed at finished grade with surcharge in areas of adjacent traffic (minimum two-foot surcharge with no liquid in the tank).

- **Hydrostatic testing**: Dead loads, fluid loads, and live load, but no backfill or earth pressure loads where structures are below grade. Hydrostatic testing will occur prior to backfilling (design operating liquid surface elevation with no backfill),
- **Seismic:** Operational loads and seismic loads in various combinations. However, earth pressure and fluid loads will not be considered in reducing seismic loads to walls and earth pressure loads will not be considered in reducing seismic downward loads on deep foundations. A factory of safety of 1.5 will be provided against seismic overturning and sliding.
- **Buoyant Uplift**: Water bearing structures founded below the groundwater table may be subject to net uplift pressures. High groundwater in combination with a completely empty basin will be considered.
- **Overflow:** This is considered to be an extraordinary load case and the special load combination of ASCE 7-10, equation 2.5-1 will apply. Overflow levels are defined as those levels at which the structure can no longer retain water. This condition will include 1 foot of surcharge.
- **Flood:** Flood loads will be combined with various service load conditions with a load factor of 1.0
- **Construction**: Structures will not be designed to accommodate various loading conditions in the partially complete state. Unless special provisions are made, the contractor will be required to brace structures and portions thereof where loads exceed specified design loads, and/or where structural members or structures are to be loaded and not yet complete or have not attained their specified design strength.

9.5 Materials of Construction

The major materials of construction include concrete, structural steel, aluminum and fiberglass reinforced plastic. The material design criteria are discussed further in Attachment C.

9.6 Geotechnical Information

Geotechnical information and design criteria are currently being developed for this project. The structural design will incorporate the design considerations and geotechnical data presented in the following reports and TMs:

- “Draft Predesign Geotechnical Interpretive Report, South Bayside System Authority Pump Station Predesign,” November 2013, prepared by DCM Consulting, Inc.
- “Draft Geotechnical Data Report,” SVCW Tunnel Project, April 2016, prepared by Geotechnical Consultants, Inc.
- “Preliminary Pipe Foundation Design Criteria,” January 2016, prepared by DCM Consulting, Inc.
- “Soil Corrosivity Evaluation SVCW,” December 2016, prepared by V&A Consulting Engineers.
- “New Administration and Plant Control Building Project,” July 2009, prepared by DCM Consulting, Inc.

The design will consider additional geotechnical information and design criteria as additional analysis and recommendations are developed.

Section 10: Process and Instrumentation Diagram Requirements

P&IDs provide a schematic representation of process piping, equipment, instrumentation and connections to the area, PLCs and the main SCADA System. P&IDs will follow the International Society of Automation (ISA) standards and the latest SVCW Automation Standards. Lines and symbols used on the P&IDS will follow the symbols on the Instrumentation Symbol Sheet in the SVCW CAD Standards Design Production Standard 5.0 (SVCW's CAD Standards).

10.1 Equipment Naming

A unique tag number will be assigned to any item at the RLS that requires automation or monitored for a particular parameter (e.g., level). SVCW standard equipment and valve identification naming convention will be used for assigning names to equipment, valves, and instrumentation on this project.

Each piece of equipment will be named based on the following four components:

1. Process Area – i.e., wet well, headworks, etc.
2. Process Function – primary purpose of the piece of equipment
3. Equipment Designator – type of equipment
4. A five-digit sequential number - The first two digits represent the SVCW location code (55 for RLS). The third digit in the sequential number is assigned based on the major areas it is related to at the WWTP. The fourth and fifth digits are sequential numbers assigned based on order in the process line. Lower numbers are in the beginning of the process line and higher numbers are further along the process line.

The resulting equipment and instrument numbers will include the four components separated by an underscore as follows:

- "Process_Area_Process_Function_Equipment_Designator_Sequential_Number."

The equipment names for the RLS will be generated using the latest equipment name builder Excel spreadsheet developed by SVCW. The latest version of the SVCW equipment name builder is the version dated May 8, 2014 (Attachment D). During design, the most current version at the start of design of the equipment name builder will be obtained from SVCW.

10.2 P&ID Format

The P&IDs will be developed in AutoCAD Smart P&ID and divided into three distinct panels with a dividing line between each section:

1. **Field.** This section of the P&IDs includes equipment, piping and instrumentation and is located at the base of the sheet. Major equipment is identified with an equipment number and common name at the bottom of the diagram. Local control panels are also located within the field section.
2. **Motor Control Center (MCC).** MCCs for motor-operated equipment will be located in the MCC section. MCCs typically include motor circuit breakers, VFDs, programmable controllers, and metering. This section is located between the Field and PLC sections. If there are no MCCs present, the MCC section may be eliminated.
3. **PLC.** SCADA tag naming, descriptions, and equipment input/output (I/O) are located in the PLC section. This section is located at the top of each sheet. SCADA tag naming and description conventions will be per the latest SVCW Equipment & Tag Naming Documents. Standard

equipment I/O conventions will be per latest SVCW Equipment & Tag Naming Documents. In the PLC section, the Control Panel will be named and numbered in the top left corner of the P&ID drawing.

Process flow on each diagram will be from left to right. Sheet references to areas that flow into the process area will be located on the left edge of the field section. Page references to which the process area continues on to are located on the right side of the field section.

Additional project-specific considerations that apply to the P&IDs include instrument identifiers, panel indicators, and SCADA I/O Tag Names. Instrument Identifier Bubble and Panel Indicator Bubble conventions and SCADA I/O Tag Names standards will be labeled and displayed. Identifiers, panel indicators and SCADA I/O Tag Name conventions will follow the latest SVCW Equipment & Tag Naming documents at the time of design.

Section 11: Mechanical Design

This section outlines the parameters that will form the basis of the RLS mechanical design. Additional mechanical design details are located in Attachment E.

11.1 Codes and Standards

Mechanical equipment and piping systems will be designed and built to the following codes and standards:

1. California Building Standards Code (CBC), latest Code edition adopted by the State of California at the time of design.
2. Underwriters Laboratories Inc. (UL) standards.
3. OSHA.
4. NFPA codes and standards.
5. Metal Framing Manufacturers Association standards.
6. American Iron and Steel Institute (AISI) standards.
7. American Institute of Steel Construction (AISC) standards.
8. American Bearing Manufacturers Association (ABMA) standards.
9. ASTM standards.
10. American Society of Mechanical Engineers, Boiler and Pressure Vessel (ASME B&PV) Code.
11. ANSI/HI standards.
12. Manufacturers Standardization Society of the Valve and Fittings Industry standards.
13. Expansion Joint Manufacturers Association standards.
14. American Water Works Association standards.
15. ANSI/HI standards.

11.2 Pump, Mechanical Equipment and Valves

Detailed pump, mechanical equipment and valve criteria are discussed in Appendix E. Primary equipment that will be included in the RLS design include supply fans, pumps, motors, sluice gates and stop gates. Ball valves will be used as isolation devices on drains; however, no isolation and/or backflow prevention valves will be needed on the pumps since the pumps will discharge to a free discharge.

11.3 Piping Services Index and Specifications

Each pipe service will be given a symbol that will be used on the drawings. Color coding and fluid category will be provided for quick reference of a pipe service. The piping services anticipated to be used at the RLS are displayed in Table 11-1.

Table 11-1. Piping Services

Symbol	Service	Fluid Category	Pipe Marker Background Color
BW	Backwash Water	Water	Green
D	Drain	Drain/Vent	Green
FA	Foul Air	Foul Air	Yellow
FM	Force Main	Wastewater	Green
PD	Pumped Drainage	Wastewater	Green
RS	Raw Sewage (Gravity)	Wastewater	Green
SD	Sanitary Drain	Drain/Vent	Green
STD	Storm Drain	Drain/Vent	Green
V	Vent	Drain/Vent	Yellow

Section 12: HVAC Design

HVAC systems will be designed to provide ventilation for air quality, personnel safety, and equipment and corrosion protection. All of the spaces will be designed as process or unconditioned spaces. Materials and coatings will be selected for corrosion resistance in marine environments. Powered equipment will be selected for quiet operation, but noise attenuation measures will not be incorporated.

The SCADA and electrical equipment including VFDs will be located in the Headworks Building and be served with a dedicated HVAC system for equipment cooling, including mechanical filtration, chemical filtration, and positive pressure to maintain a clean, noncorrosive atmosphere. The electrical room and associated HVAC system will be designed by the Headworks design team with input from the RLS design team.

12.1 Codes and Standards

Ventilating and air conditioning (HVAC) design will comply with the CBC, the California Mechanical Code (CMC), the California Energy Code (CEC), the American Society of Heating Refrigerating and Air Conditioning Engineers, and the NFPA.

HVAC construction will be performed in accordance with the most current version of the following codes and standards:

- ANSI/HI standards.
- NFPA: Standard for Fire Protection in Wastewater Treatment and Collection Facilities (NFPA 820).
- California Building Code (California Code of Regulations, Title 24, Part 2).
- CMC (California Code of Regulations, Title 24, Part 4).

- California Energy Code (California Code of Regulations, Title 24, Part 6).
- Sheet Metal and Air Conditioner Contractor's National Association (SMACNA) standards.

12.2 Design Conditions

The RLS and Pipe Gallery will be ventilated. The wet well space will be ventilated as discussed in Section 3. Physical separation will be provided between the wet well and associated Pipe Gallery.

12.3 HVAC Equipment and Materials

The following equipment and materials will be used for the RLS HVAC system. The scope of the RLS project will include supply air for the wet well and Pipe Gallery and ducting for exhaust air routed to just outside of the Headworks building. The odor control system for the RLS will be designed by the Headworks design team.

Roof Fans. Roof fans will be direct drive if possible to minimize maintenance. Roof fans will be specified with manufacturer-supplied mounting curbs. Fans equipped with ducting will be centrifugal type. Supply fans will be specified with disposable particulate filters.

Ducting. All ductwork and duct accessories will be specified as aluminum for corrosion resistance. Ductwork will be fabricated according to SMACNA. Access doors will be provided adjacent to all pieces of duct-mounted equipment or instrumentation. Ductwork insulation is not anticipated to be required.

Louvers. Intake and exhaust louvers will be provided with bird screens or insect screens. Louvers will be sized for a face velocity of 500 to 750 ft per minute, less than 0.10-inch water column pressure drop and no water penetration. Louvers will be of aluminum construction with an anticorrosion coating.

Grilles, Registers, and Diffusers. Grilles, registers, and diffusers shall be of aluminum construction and shall be sized in accordance with the manufacturer's recommendations for noise level, air velocity, pressure drop, and throw.

12.4 HVAC Controls

Ventilation systems will run continuously. Ventilation systems used to downgrade the electrical classification of a space will be provided with ventilation failure alarms. Supply air for the Pipe Gallery will run only when there is a need to occupy the space.

Section 13: Electrical and Power

The RLS electrical equipment will be powered from electrical infrastructure (switchgear, MCCs, panelboards, etc.) within the new Headworks that is being designed by others. BC will coordinate with the other engineering firm(s) responsible for the Headworks facility electrical design by providing information on the RLS electrical loads and equipment footprint requirements.

VFDs located inside the Headworks facility will supply power and provide speed control to four of the six wet well pump motors. The VFDs will be powered from switchgear located inside the Headworks facility electrical room. The RLS sluice gates, yard lighting, and other electrical equipment will be powered from electrical panels or MCCs within the Headworks facility.

Detailed electrical and power requirements are discussed further in Attachment F. Lighting and site design requirements are also included in Attachment F. The following sections discuss the general RLS electrical and power design concepts.

13.1 Codes and Standards

Electrical design and construction will comply with the National Electrical Code (NEC), the California Electrical Code, the Occupational Safety and Health Act, and the requirements of local codes in effect at the start of design. All electrical construction will be performed in the accordance with the most current version of the following codes and standards:

- ANSI/HI standards.
- Insulated Cable Engineers Association standards.
- Institute of Electrical and Electronics Engineers Association (IEEE) standards.
- International Society of Automation (ISA) standards.
- California Electrical Code (CEC), 2016.
- NFPA, NEC (NFPA 70), 2015.
- NFPA, Standard for Electrical Safety in the Workplace (NFPA 70E).
- NFPA, Standard for Fire Protection in Wastewater Treatment and Collection Facilities (NFPA 820).
- National Electrical Manufacturers Association (NEMA) standards.
- OSHA standards.
- InterNational Electrical Testing Association.
- UL.
- Insulated Power Cable Engineers Association

If this document overlaps or conflicts with governing codes, standards or manufacturer's directions and instructions, the more restrictive interpretation or requirements will be followed. In instances where two or more codes are at variance, the most restrictive requirements will apply. Codes and standards referenced will be considered minimum acceptable work.

All work will also be performed in accordance with SVCW, Federal, State, County and local standards and Utility codes.

13.2 Power Distribution and Utility Coordination

RLS load capacity, short circuit, distribution, utilization voltage, power quality, and voltage drop calculations will be completed during design. The RLS design team will need to work closely with the Headworks facility team to coordinate electrical design. The electrical equipment will be located within the Headworks facility. Cables and conduits will be routed from the RLS to a manhole just outside of the Headworks facility. The Headworks facility team will be responsible for all conduit and cable inside the Headworks facility.

Standby power, under the current pump configuration, will be supplied as part of the Headworks facility. Dedicated generators will be shared amongst the WWTP facilities and the RLS.

13.3 Electrical Equipment

Electrical equipment to be included in the RLS design include VFDs, full voltage non-reversing (FVNR) motor start units, electrical enclosures and boxes, lockout stop pushbutton control stations, and wiring devices. The VFDs and FVNRs will be located in the Headworks facility electrical room. Pump termination cabinets will be located on the RLS superstructure at an elevation of 110.

Section 14: Instrumentation and Control

This section outlines the parameters which will form the basis of the RLS instrumentation and controls design.

14.1 Codes and Standards

The project will be designed to comply with applicable portions of the codes and standards listed in Table 14-1 below. The edition of codes will be the latest edition adopted by the State of California at the start of the project final design. The edition of the referenced standards will be the latest published edition at the start of the project final design:

Table 14-1. Codes and Standards for Instrumentation and Controls Design

Reference	Title
IEEE 100	Standard Dictionary of Electrical and Electronics Terms
ISA S5.4	Instrument Loop Diagrams
ISA S20	Specification Forms for Process Measurement and Control Instrumentation, Primary Elements, and Control Valves
ISA S51.1	Process Instrumentation Terminology
ISA TR20.00.01	Specification Forms for Process Measurement and Control Instruments Part 1: General Considerations
NEMA ICS 1	General Standards for Industrial Control and Systems

14.2 Control Design Guidelines

Unless otherwise noted, the instrumentation and controls design will comply with the SVCW Automation Standards latest edition at the start of the project final design.

Where SVCW standards do not apply, the design will follow the International Society of Automation (ISA) standards.

14.3 PLC Design Requirements

PLCs used in the RLS design will be manufactured by Allen-Bradley (A/B). ControlLogix will be used for all major applications. For smaller systems and for vendor packaged systems, A/B CompactLogix or MicroLogix may be used.

All PLCs will have Ethernet communications capability.

All major systems deemed critical will be required to have redundant hot-standby ControlLogix PLC processors.

Operator interfaces will be A/B PanelView Plus touchscreen. The operator interfaces will be Model A/B PVP1000 or larger. Operator interface screens will communicate Ethernet IP and be powered from 120VAC or 24VDC.

PLC communications will be Ethernet IP. Communications from the PLCs to the main plant SCADA system may be done by other forms (cable, DSL, telephone, cellular, or other services) as approved by SVCW for the project.

14.4 Equipment

All instrumentation and controls equipment will be provided in accordance with the SVCW Automation Standards latest edition at the start of the project final design. Instrumentation will not be sole-sourced unless specifically directed by SVCW. For communications equipment, Ethernet/IP (industrial protocol) shall be used. Unless otherwise approved, all automation components communicating within a common control system environment will be natively Rockwell Ethernet/IP utilizing A/B Stratix switches. For Layer 2 standards, Stratix 8000 will be used. Stratix 8300 will be used for Layer 2 standards, and unmanaged switches will be Stratix 2000 series.

Section 15: NFPA Requirements

NFPA classifications for the different areas of the RLS are presented in Table 15-1. In some cases, two classifications are presented for an area. The final classifications will be determined during final design.

Table 15-1. Hazardous Area Classifications for Project Areas

Location	NFPA 820 Reference	Extent of Classified Area	Ventilation	NEC-Area Electrical Classification (All Group D where classified)	Affects
Flow Splitter Shaft	Table 4.2.2, Row 16, Line a	Enclosed space	No ventilation, or less than 12 acres per hour (ac/hr)	Class I, Division 1	Isolation gates, instrumentation
	Table 4.2.2, Row 29, Line b	Enclosed space	12 ac/hr	Class I, Division 2	Isolation gates, instrumentation
Below Grade Wet Well	Table 4.2.2, Row 16, Line a	Entire space or room	No ventilation, or less than 12 ac/hr	Class I, Division 1	Wet well instrumentation Submersible pumps Ducting
	Table 4.2.2, Row 16, Line b	Entire space or room	12 ac/hr	Class I, Division 2	Wet well instrumentation Submersible pumps Ducting
Above Grade Area Over Wet Wells	Table 4.2.2, Row 18	N/A	Not required	Unclassified	Electrical equipment
Below Grade Pipe Gallery and Metering Vault	Table 4.2.2, Row 36, Line a	Enclosed space	Not normally ventilated	Class I, Division 2	Pipe instrumentation Flow meter
	Table 4.2.2, Row 36, Line b	Enclosed space	6 ac/hr	Unclassified	Pipe instrumentation Flow meter
Headworks Discharge	Table 5.2.2, Row 2, Line a	Enclosed – entire space	No ventilation, or less than 12 ac/hr	Class I, Division 2	
	Table 5.2.2, Row 2, Line b	Enclosed – entire space	12 ac/hr	Class I, Division 2	
	Table 5.2.2, Row 2, Line c	Within 3m (10 ft) envelope around equipment and open channel	Not enclosed, open to atmosphere	Unclassified	

Section 16: Noise Attenuation Requirements

The following noise and vibration restrictions have been identified for the RLS construction and operation:

- **Noise Restrictions.** Construction noise shall be limited to normal working hours between the hours of 7 A.M. and 8 P.M. Monday through Friday and prohibited on weekends and holidays. Per the Redwood City Noise Ordinance, Municipal Code Chapter 24 "Noise Regulation," no individual piece of machinery, equipment, or devices shall produce a sound in excess of 110 A-weighted decibels (dBA) measured 25 ft from such machinery, equipment, or device. Also, work noise level at any point outside of the construction site property plane will not exceed 110 dBA. Weekend and holiday work may be needed to complete installation of key components of the RLS and will be coordinated with Redwood City.

- **Vibration Restrictions.** Redwood City has no known quantitative standards for vibration; therefore, AASHTO and State of California Department of Transportation guidelines will be followed. Sheet pile driving and soil compaction will be the major sources of on-going vibration during construction. Vibration from the excavation and other phases of construction will be below the typical criteria for building threshold damage for nearby buildings located offsite. Since the RLS, is located within an area of Very High Susceptibility to liquefaction, operations from continuous vibratory equipment like a sheet pile driver will be limited to 0.1 g (0.2 inches per second at 30 hertz) near the existing WWTP facilities if differential settlement cannot be tolerated. In addition to vibration effects on buildings and nearby structures, RLS construction will likely generate perceptible vibration that can be noticed by residents and/or businesses nearby. Advanced outreach and communication with building occupants and residents is recommended.

Coordination with Overall FOP Program and final mitigation pressures as outlined in the adopted environmental impact report regarding noise attenuation and vibration requirements will be needed. Redwood City Noise Guidelines for Land Use Planning as detailed in the 2010 Redwood City General Plan and Chapter 24 of the Redwood City Municipal Code will be followed for design of permanent facilities. Since the land use category in the vicinity of the RLS is mixed, confirmation of the land use category and associated community noise equivalent level will need to be confirmed with SVCW and Redwood City.

Section 17: Sole Source Specification and Purchase of Standardized Equipment List

A list of equipment that is eligible to sole source is provided in Attachment G. The list is valid for a five-year period from July 2014 through July 2019. The list will be confirmed with SVCW in final design in the event the sole source list is updated before July 2019. In addition, manufacturers and/or equipment such as large submersible pumps that are not listed on the sole source list will be discussed with SVCW and may be candidates for addition.

Attachment A: Preliminary Wet Well Dimensions

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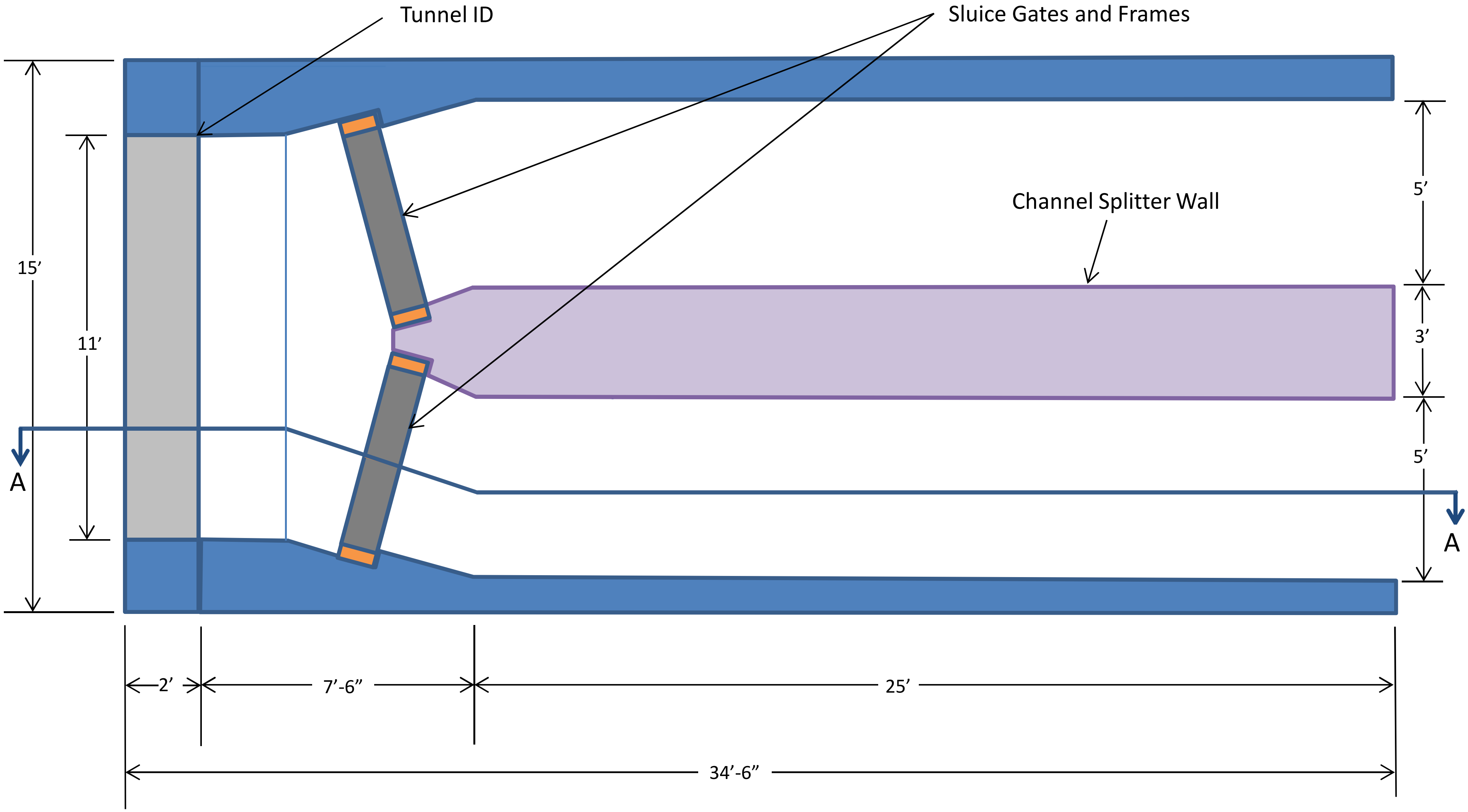
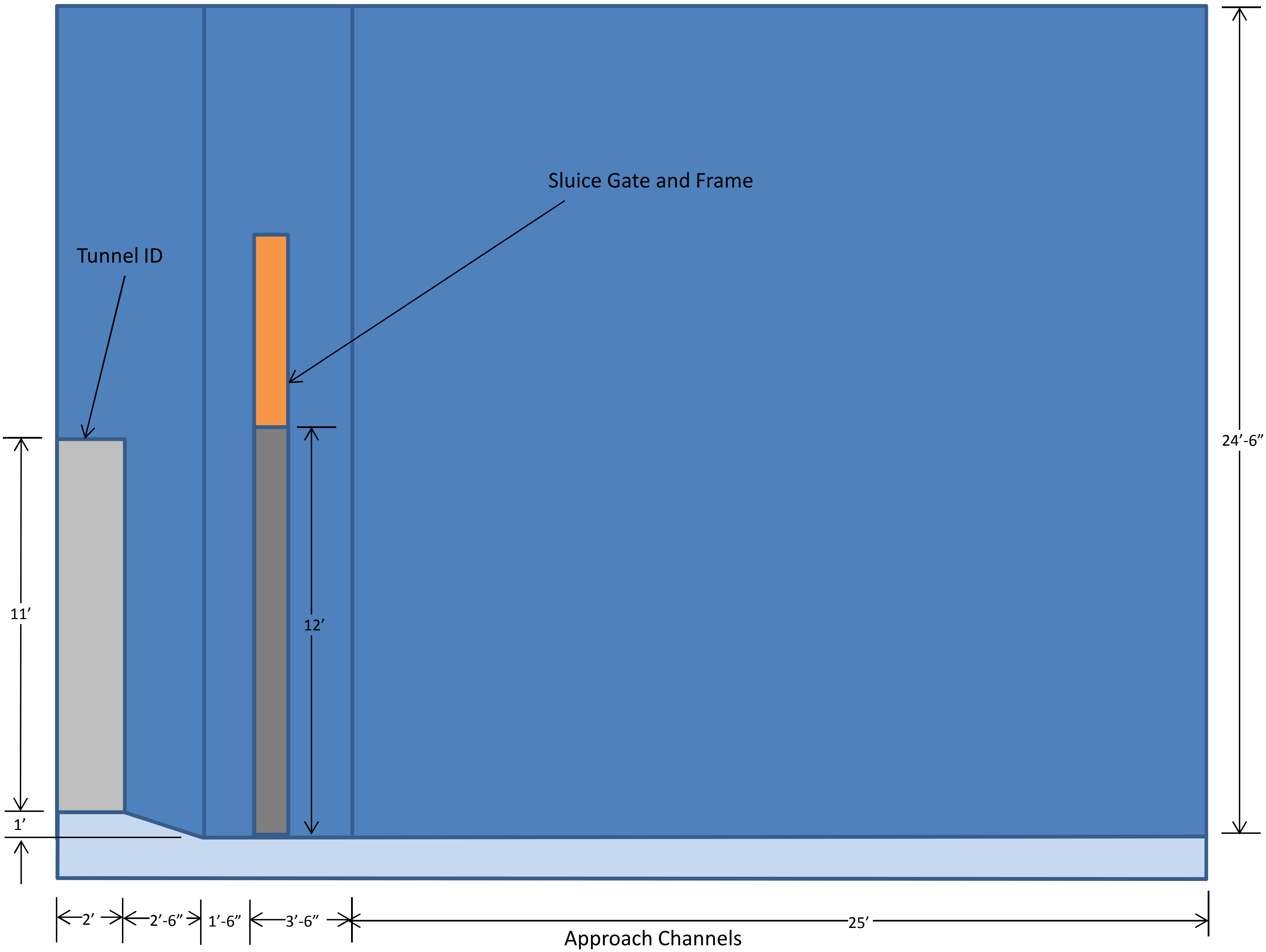
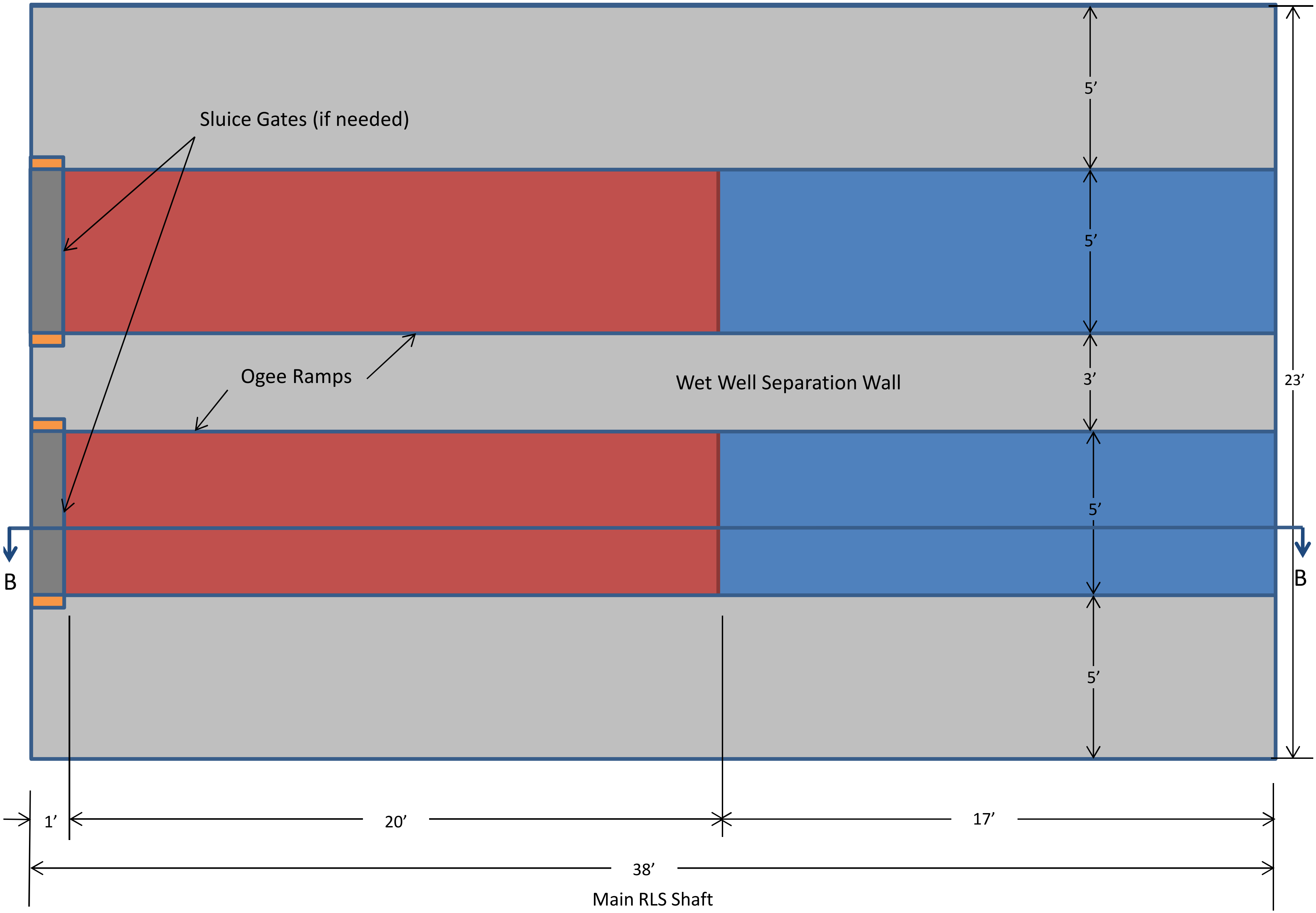


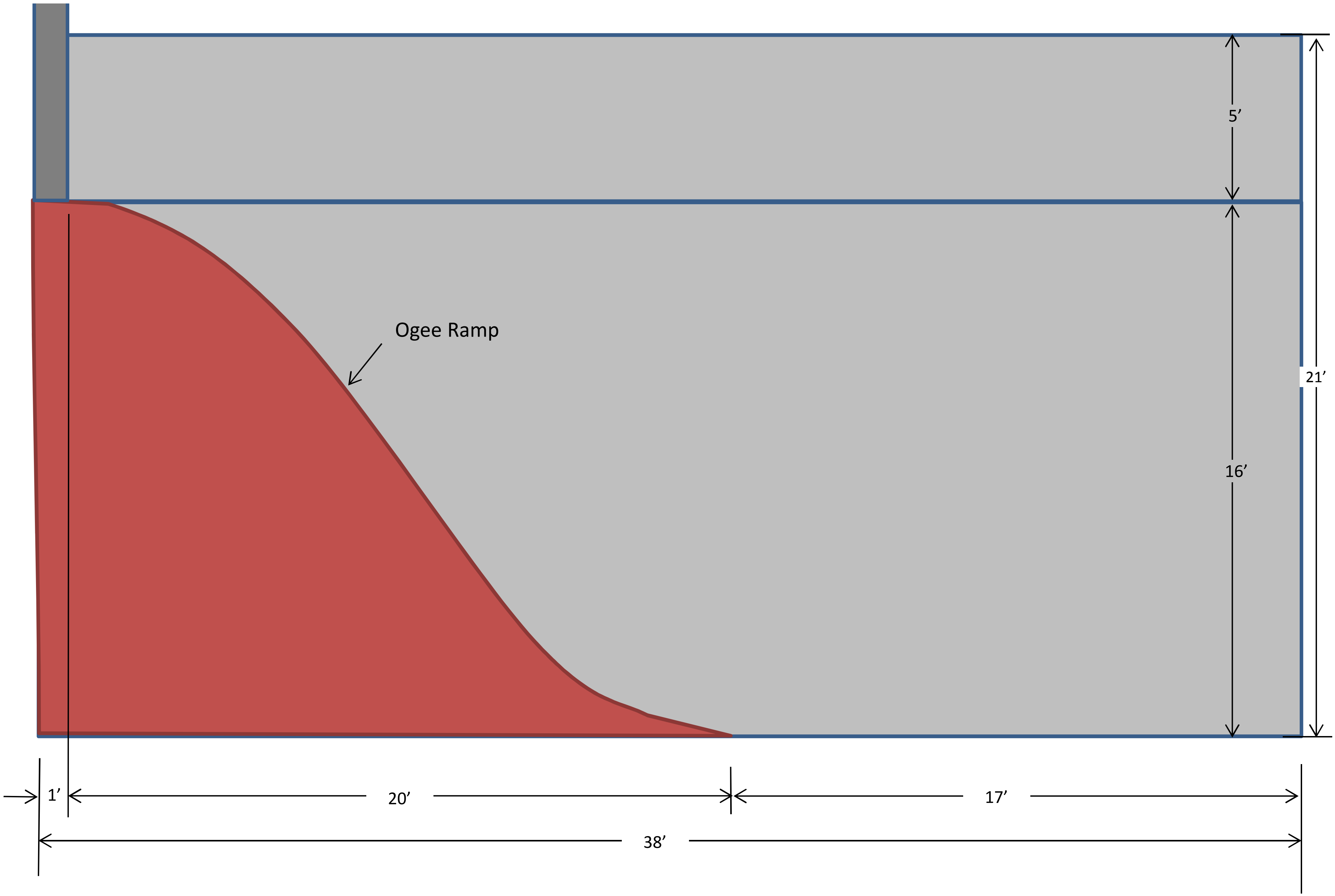
Flow Splitter Shaft
Approach Channels
Plan
Scale: ¼" = 1"-0"



Approach Channels
Section A-A
Scale: ¼" = 1'-0"



Main RLS Shaft
Wet Well Interior Plan
Scale: ¼” = 1’-0”



Main RLS Shaft
Wet Well Interior
Section B-B
Scale: ¼” = 1’-0”

Attachment B: Additional Pump Criteria

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Attachment B: Additional Pump Criteria

This section outlines the parameters that will form the basis of the detailed pump design and selection. This document is meant to be a working document such that during design, changes can be made based on design team review and consensus.

B.1 Pump Equipment

Pump equipment needs to conform to the requirements and objectives of paragraph 6.1, ANSI/API 610. Components associated with the rotating elements in the drive train, including equipment supports and supports for rotating elements, will be selected and designed to function without damage or disassembly at reverse rotational speeds up to 150 percent of maximum operational speed during flow reversals through the pump. The complete pumping unit will operate without overload on any component at any point along the pump's entire full-speed operating curve.

B.2 Pump Selection

Selected pumps will be proven designs that will have been in service under similar conditions of service with no objectionable performance characteristics for a period of not less than five years. A list of similar pump installations to the selected pumps will be provided to SVCW for performance verification. Listed pump will be of the same size volute or bowl, discharge case and nozzle size, impeller design (including number of vanes) and will be operating under similar conditions of pumped fluid, head, capacity, speed, rotation, and Net Positive Suction Head Available (NPSHA).

If these above conditions cannot be met, other pumps can be selected under the following conditions:

- The proposed design has been in successful operation under similar conditions of volute or bowl, discharge case and nozzle size, impeller design (including number of vanes), pumped fluid, head, capacity, rotation and NPSHA, but at a higher speed for a period of not less than three years.
- The proposed design has been in operation in designs where both larger and smaller nozzle size pumps have been in service for a period of not less than five years, and impeller design (including number of vanes), pumped fluid, head, capacity, speed and NPSHA are similar to that for the proposed installation. Under no circumstances will an existing pump design operating at a higher speed than those currently in service in similar applications be considered.

Pumps that qualify under either exception (a. or b.) will be demonstrated, by operation of a test pump in a fully equipped hydraulic test facility, to have acceptable operating characteristics under the conditions identified for the proposed installation of the proposed pump in the size and at the speed proposed, with the proposed impeller design. The test pump will be set up and a witnessed demonstration will be performed prior to designing, fabrication and testing any of the equipment proposed for the specific installation. Testing will be included in project bid if required.

B.2.1 General Performance Criteria

Pumps will be designed to operate without loss of head due to cavitation or vibration over the entire specified range of flow and head conditions and will be specifically selected for NPSH margin requirements detailed in Section B.6.

B.2.2 General Design Criteria

All pumps will be designed in accordance with applicable portions of ANSI/HI 1.1 – 1.4, 2.1 – 2.4 and ANSI/HI 9.6.2 – 9.6.6. The pumps will be specifically designed to pump raw wastewater and will operate without clogging or fouling caused by material in the pumped fluid at any operating condition within the range of service per the pump's non-clog size rating.

Pump head capacity curves will slope in one continuous curve within the identified operating conditions. No points of reverse slope inflection capable of causing unstable operation will be permitted within the specified zone of continuous duty operation. Pumps with head/capacity curves with a reverse inflection are specifically prohibited if these characteristics will cause unstable operation within the specified range of operating conditions.

Pumps will have bells selected to provide an intake velocity of not less than 3.5 feet/second nor more than 4.0 feet/second when operating at the maximum specified flow or the flow resulting from the lowest specified operating head at maximum speed, whichever is the greatest ("peak flow").

Pumps specified to operate at variable speed will function without loss of head due to cavitation or excessive vibration over the entire specified range of flow and head conditions defined by the region bounded by Condition Points A, B and C and any other continuous duty operating condition. Acceptance criteria will include the following:

- Operating Condition Points B and C will reside within the region defined by the PACL limits set forth in this section for the proposed pump selection, based upon the pump's suction specific speed.
- No more than 10 percent of the region noted above will reside outside the PACL limits set forth in this section for the proposed pump selection, based upon the pump's suction specific speed. Operating Condition A may reside in the area outside the PACL but within the manufacturer's defined allowable operating region.

Pumps will be specifically selected for NPSH margin requirements detailed in Section B.7. Pump selections which do not provide the specified margin will be rejected.

B.2.3 PACL

Pump selection for a given application will be predicated on locating the specified most frequent operating condition(s) in the PACL. These points will always include Condition Points B and C and additionally will include any other Condition Points indicated as continuous duty conditions, or any additionally specified for inclusion in the PACL. Condition Point A will be the pump's rated condition and will be guaranteed to meet both specified head and flow within the limit established in ANSI/HI 14.6, acceptance grade 1U.

A given pump's PACL will be determined as a percentage of Best Efficiency Flow (BEPQ) at the given speed, the pump's suction specific speed as determined in accordance with ANSI/HI 1.3, paragraph 1.3.2.2 and the relationships presented in the Table B-1 below.

Table B-1. Limiting Flow, per cent Best Efficiency Point Flow (BEPQ)[1]		
Suction Specific Speed, less than but not greater than:	Solids Bearing Liquids Pumps, minimum limit	Solids Bearing Liquids Pumps, maximum limit
7000	70	125
8000	75	122
9000	80	120
10000	83	117
11000	85	112
12000	88	110
13000	91	110

[1]*Straight line interpolation may be used for intermediate values of suction specific speed*

Exceptions to the foregoing will be considered only when certified test data demonstrating conclusively a wider region of stable pump performance can be provided. The test data will include suction pressure pulse information as well as actual service information for the same impeller design and trim, operating at the same speed, capacities and head for the same size pump as required for the specified application.

B.3 Critical Speeds and Natural Frequencies

Critical speed and natural frequency data submittal requirements depend upon the pump type.

B.4 Impeller Clearances, Vane Passing Frequency and Impeller Keyways

The radial clearance between the tip of the impeller vane and diffuser or volute vanes will be not less than 3 percent and 6 percent, respectively, of impeller diameter. The ratio of liquid channel widths (diffuser or volute/impeller) will be not less than 1.4 nor more than 1.5 for volute-type pumps. The pump will be designed so that internal geometry will not cause uneven flow distribution at impeller vane inlets.

B.5 Torsional and Combined Shaft Stresses

Shaft stresses will be calculated using the following equation and the stress concentration factors in Table B-2 below.

Where:

S = stress, psi

S_{cf} = stress concentration factor, dimensionless

D = minimum shaft diameter at point of concentration, inches

$\Delta\Theta$ = twist in shaft between adjacent masses, radians

L = effective length between masses, inches

G = shear modulus of shaft material, PSF

The S_{cf}, to be applied at all the roots of all keyways and changes in shaft diameter will be as follows:

Table B-2. Stress Concentration Factors

S_{cf}	Ratio of fillet radius to shaft diameter
4.3	0.0025
3.7	0.01
3.05	0.02
2.75	0.03
2.6	0.04
2.55	0.05 and greater

Values of S_{cf} between data points in the table above will be based upon a straight line interpolation.

B.5.1 Shaft Deflection

Pump shafts on volute type pumps will be designed to provide sufficient stiffness to operate without distortion or damaging vibration throughout the range of service specified. Shaft deflection at the face (impeller side) of the shaft seal will be limited to no more than 1.5 mils at any operating condition within the zone described by the specified continuous duty operating conditions. Calculation of radial thrust loads will be performed in accordance with the methodology set forth in ANSI/HI 1.3, paragraph 1.3.5.1. Shaft deflection calculations will be performed in accordance with ANSI/HI 1.3.5.4. Shaft deflection criteria and limits will be as required by API 610 (ISO 13709).

B.5.2 Bearings

Anti-friction bearings for pumps will be selected for a minimum L–10 life of 50,000 hours in accordance with ABMA 9 or 11. Bearings will be heavy-duty, oil lubricated or permanently greased lubricated anti-friction type double shielded and factory sealed. Bearings for other elements in the rotating system such as motors will be selected using the same criteria as specified for the pump. Bearing selection will be based upon the worst combination of continuous duty operating conditions specified and will include both steady state and transient loads.

B.6 Net Positive Suction Head Margin Limitations

Net Positive Suction Head Required - 3 Percent Reduction (NPSH3) characteristics for the candidate pump will be based upon documented test data not more than five years old, performed on a pump not more than two nominal pump diameters larger or smaller than the proposed pump with an impeller of the same geometry as that proposed for the pump to be used for the subject application, and operating at the same speed as the pump for the proposed application.

The Net Positive Suction Head Available (NPSHA) information for anticipated operating conditions for each application will be generally referenced to a specific elevation, stated in terms of project datum. The pump manufacturer will adjust the NPSHA information to the elevation of the pump impeller eye for the specific pump model and size proposed for the application. NPSH3, as used in the following paragraphs, will mean the NPSH3 at the impeller eye, determined in accordance with ANSI/HI 11.6 or 14.6, as applicable for the proposed pump.

Pumps classified as centrifugal pumps under ANSI/HI 1.1 – 1.2 with suction specific speeds less than 8500 with cast duplex stainless steel impellers, a minimum NPSHA/NPSH3 margin ratio of 1.1 will apply to pumps at any operating condition within 85 percent and 115 percent of best efficiency capacity. The minimum acceptable NPSH margin ratio at any other location on the pump's head/capacity curve will be 1.2.

Pumps with suction specific speeds greater than the above limitations will have NPSH margins of 1.5 and 2 applicable to the capacity envelope limitations defined previously. Under no circumstances will the absolute value of the margin above NPSH3 be less than 3.5 feet.

Pumps with suction specific speeds greater than the above limitations and pumps with impeller materials that do not meet the requirement for duplex cast stainless steel set forth in this section, and all pumps with suction specific speeds greater than 10,000 will have NPSH margins not less than 2.5 at operating conditions within ±15 percent of best efficiency capacity and not less than 3.5 for all operating conditions falling outside the ±15 percent of best efficiency capacity envelope. Under no circumstances will the absolute value of the margin for pumps qualifying with the foregoing restrictions, be less than 3.5 feet greater than NPSH3.

B.7 Casing

The volute casing will be a one-piece casting with a tangential or center discharge nozzle. The cutwater will be specifically designed for use in fluids with stringy solids and rags. The volute casting will be specifically designed to bear the loads associated with removal and placement of the pump when submerged or exposed and to withstand the loads imposed. The discharge nozzle will be reinforced for the loads imposed by the specified conditions of service. The nozzle flange face will be designed to mate with the discharge fitting. The volute casing will be drilled and tapped or otherwise fitted with an inlet nozzle.

B.8 Shaft

The pump shaft will be turned, ground and polished, of proportions suitable for use in the specified application. The shaft will be of sufficient section to limit deflection at the shaft seal to not more than 1.5 mils when the pump is operating at any continuous-duty point. Additionally, under no circumstances will the distance from the lower bearing and the hub of the impeller exceed two times the diameter of the shaft.

B.9 Bearings

Bearings will be heavy-duty, oil lubricated or permanently greased lubricated anti-friction type double shielded and factory sealed. Bearings will be designed for an L-10 rating life of at least 50,000 hours at Operating Conditions A, B, or C.

B.10 Impeller

The impeller will be dynamically balanced after trimming to the diameter required by the specified operating conditions, and have a non-clog design capable of passing solids, fibrous materials, heavy sludge, and other matter found in wastewater applications through to the discharge nozzle. Impellers for pumps with discharges 8 inches in diameter and greater will be not less than two-vane design. Fit between the impeller and the shaft will be a sliding fit with a taper-lock bushing pressed by a screw, which is threaded into the end of the shaft, or a slip fit onto the shaft and drive key and fastened to the shaft by an impeller nut having cover for protection from pumped fluid. A wearing ring system designed for abrasion resistance will provide efficient sealing between the volute and impeller.

B.11 Mechanical Seals

The pump will be provided with a tandem double mechanical seal running in an oil reservoir, composed of two separate lapped face seals. The lower seal unit, between the pump and oil chamber, will consist of one stationary and one positively driven, rotating tungsten-carbide or ring, with each pair of rings held in contact by a separate spring. The upper seal unit, between the oil sump and the motor housing, will consist of one stationary tungsten-carbide or silicon-carbide ring and one positively driven silicon-carbide or rotating carbon ring. Ceramic seals will not be acceptable. The seals will require neither maintenance nor adjustment and will be easily replaceable. Conventional double mechanical seals with a single or a double spring between the rotating faces, or that require constant differential pressure to effect sealing and are subject to opening and penetration by pumping forces, will not be acceptable. The pump will be capable of continuous submergence without loss of watertight integrity to a depth of 65 feet.

Each pump will be provided with a seal lubricant chamber for the shaft sealing system. The seal lubricant chamber will be designed to assure that an air pocket is provided in the seal lubricant chamber, to absorb the expansion of the seal lubricant due to temperature variations. The drain and inspection plug with positive anti-leak seal will be easily accessible from the outside.

B.12 Motors

The pump motor will be a squirrel-cage induction, shell type design, housed in an air-filled or an oil-filled, watertight chamber, NEMA B type Inverter Duty with a service factor of 1.15 based upon nameplate rating. The stator winding and stator leads will be insulated with moisture resistant Class H insulation, which will be rated at a temperature of 155 degrees C. The motor will be designed for continuous duty, capable of sustaining a minimum of 12 starts per hour. The temperature rise of the motor will not be in excess of that specified in NEMA MG-1 for class B insulating materials when operating continuously under load. Motors will be Factory Mutual or UL listed in accordance with UL 674 and 1207 for Class I, Group D hazardous atmospheres. The junction chamber, containing the terminal board, will be hermetically sealed from the motor. Connection between the cable conductors and stator leads will be made with threaded compressed type binding post permanently affixed to a terminal board. The submersible electrical cable will be of sufficient length to reach the junction box indicated.

The cooling system may be of the oil filled or air filled motor housing type. Thermal sensors will be provided to monitor stator temperatures. The stator will be equipped with three thermal sensors, embedded in the end coils of the stator winding (one sensor in each stator phase). These will be used in conjunction with external motor overload protection and wired to the control panel. The design will be suitable for continuous motor operation at listed motor rating in 95-degree F water.

The cooling system may rely on radiation of excess heat energy to the fluid in the wet well or, alternatively, the pumped fluid via a closed circuit circulating system utilizing either oil or glycol, or a combination of these. It is specifically required that the cooling system must be compatible with the contemplated control schedule, which may require that the motor case to be exposed continuously or intermittently. Cooling systems will not employ the pumped fluid to directly cool the motor through wastewater passageways incorporated into the motor shell. It is preferred that the motor be cooled by the wastewater via fins incorporated into the motor shell. If an internal liquid circulation system is employed for cooling purposes, the liquid will be glycol or heat transfer oil, which will in turn circulate a heat exchanger incorporated into the cavity behind the pump impeller.

If the motor is an oil-filled type, it will be positively cooled by circulating non-toxic oil through the windings to passages within the pump designed as a heat exchanger to transfer heat to the pumped fluid. Vanes cast into the rear impeller shroud will be provided to circulate pumped flow past a heat exchanger in the shaft seal area to provide the required cooling. Cooling water passages in the motor's shell designed to convey the pumped fluid for cooling purposes are specifically prohibited. The system will be designed to prevent clogging by virtue of dimensions and configuration and will be specifically configured to maintain motor temperatures within conservative limits when the pump is operating at variable speed under the operating conditions specified.

Motor bearings will be protected with bearing isolators. Spacer shafts will be placed between pumps and motors to allow for the quick and easy removal of backheads and rotors of end suction pumps.

B.13 Moisture Detectors

Air-filled motors 10 horsepower and larger and all oil-filled motors will be provided with an electronic moisture detection system. A primary moisture detector will be provided between the tandem mechanical seals. A secondary leakage sensor will be located in the motor housing and will be specifically designed to detect the presence of water in the motor housing. In addition, motors 15 horsepower and larger will be fitted with moisture detectors in the cable junction box. All moisture detectors will be wired to the junction box for connection to the specified monitoring system.

B.14 Variable Speed Drive

Some pumps will be furnished with a variable speed drive. The variable speed drive will be fully compatible with the characteristics and requirements of the pump motor and vice-versa and will be furnished by the pump manufacturer.

B.15 Cables

The pump cable(s) provided by the pump manufacturer will include seven conductors: three conductors for power, two conductors for control, and two ground conductors. The cable design will be suitable for installation in a municipal wastewater pumping station. The cable length will not exceed the product manufacturer's recommended length. A cable rack will be provided and installed in the wet well to neatly store the cable slack when the pumps are in service. The cabling will be direct connections without the use of any junction boxes.

The cable entry water seal design will preclude specific torque requirements to insure a watertight and submersible seal. The cable entry will be comprised of individual cylindrical elastomer clamps having a close tolerance fit against the cable conductor insulation and the entry inside diameter and compressed by the entry body containing a strain relief function, separate from the function of sealing the cable. The cable entry junction chamber and motor will be separated by a stator lead sealing gland, potting chamber or terminal board, which will isolate the motor interior from foreign material gaining access through the pump top. If a potting chamber is used, the potting procedure will employ an epoxy-potting compound combined with a procedure that insures penetration of the compound into the individual cable conductor strands to prevent development of wicking pathways for entrance of water into the motor.

The pump will be designed such that power/ control cable can be removed from the pump motor without breaking the cable seal. The power/ control cable will be sealed to a removable motor chamber cap that will be universally mateable to the same manufacturer's pump series. The pump will be able to be removed from the wet well and disconnected from the cable by removing the motor chamber cap. A spare removable chamber cap with sufficient length of cable will be provided.

B.16 Junction Boxes

NEMA 7X (stainless steel) junction boxes will be provided for both motor power and system monitors. Sensor leads will be provided for termination of the thermal sensor and moisture detectors for connection to the monitoring system indicated. The sensor junction box will be separate from that shown for motor power.

B.17 Inlet Nozzle

The wet well design has been developed on the basis of a limiting velocity at the pump inlet of 4 feet per second and a confined inlet designed for cleaning by operating the pump until it breaks suction. Inlet nozzles are required for all pumps with entrance velocities exceeding this limitation. If a nozzle is required, the pump casing will be drilled and tapped to receive an inlet nozzle and bell fitting to extend the pump inlet connection into the confines of the wet well or sump to achieve the floor separation required by the Hydraulic Institute Intake Standard (ANSI/HI 9.8). The inlet nozzle may be of commercially available forged steel fittings or cast iron and will have a smooth, flared transition from a bell fitting at the entrance to the nozzle and a smooth, direct entry to the connection at the impeller inlet. The final configuration of the inlet bell and nozzle will be selected to efficiently convey the pumped fluid into the impeller eye.

B.18 Pump Discharge Connection Seal

The connection between the pump discharge connections will be fitted with a replaceable dynamic sealing feature to affect a complete closure between the pump discharge flange and the mating connection on the anchor fitting. The dynamic seal will function to effect a water tight connection as further defined in this paragraph. Leakage through the seal will not exceed 1.5 percent of the flow specified for Condition Point A when operating at pump shutoff head and not more than 1 percent of total pump flow at Condition Point B.

The dynamic seal will affect a seal meeting the requirements of this paragraph using the head developed by the pump when in operation to expand the sealing device, which may be of metallic or elastomeric construction, against the inner contours of the discharge fitting. The design of the seal will incorporate features to protect the integrity of the seal during the pump removal/setting process. The seal will be attached to the pump side of the pump/anchor connection and will be easily replaceable.

B.19 Pump Anchorage, Guide System and Access Cover

The pump will be provided with a guide system to allow easy removal of the pump without entering the wet well. The guide rail system will be dual rail type. The discharge connection will be bolted to the structure as indicated and will serve as a lower attachment for the guide rails. The discharge connection will be elbow discharge type.

The pump and guide rail system will be designed to automatically connect the pump to the discharge piping when lowered into place on the discharge connection. The design will be non-sparking and will conform to UL requirements for installation in a location classified in accordance with NFPA 70, Article 500 for Class 1, Group D, Division 1 locations. The pump will be easily removable for inspection or service, requiring no bolts, nuts, or other fastenings to be removed for this purpose, and no need for personnel to enter the pump wet well or sump. Sealing of the pumping unit to the discharge connection will be accomplished by a simple linear downward motion of the pump with the entire weight of the pumping unit guided to and pressing tightly against the discharge connections. No portion of the pump will bear directly on the floor of the sump and no rotary motion of the pump will be required for sealing. Guide bars provided for directing the pump into position or for removing the pump for maintenance will steer the pump into proper contact with the discharge elbow. Once the pump has been positioned on its support fitting at the discharge fitting, the guide bar system will not be required for pump support.

Unless otherwise specified, pumps installed in structures located out of doors will be provided with a hinged access cover with frame cast into the top slab. Cover will be aluminum with a skidproof design, furnished with a flush locking mechanism and will be designed to support a uniform live load of 125 pounds per square foot with a safety factor of three. The doors will be provided with stainless steel hinges and lifting handle will open to 90 degrees and lock automatically in that position. The frame will include upper attachments for the guide rails and attachments for the lifting chain and power cable. Access frames and covers will be sized as specified. Hardware and miscellaneous attachments will all be constructed out of ASTM A276, Type 316 stainless steel. Dielectric isolation will be provided between dissimilar metals.

B.20 Spare Parts

At a minimum, the following spare parts will be provided for each pump:

- 2 sets--all gaskets
- 2 sets--all bearings
- 1 set--mechanical seals
- 2 sets—discharge connection sealing devices

Additional spare parts will be provided as recommended by the pump manufacturer. Spare parts will be tagged by project equipment number and identified by part number, equipment manufacturer, and subassembly component (if appropriate).

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Attachment C: Structural Criteria

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Attachment C: Structural Design

This section outlines the structural design guidelines that will be used for design of the RLS, both building and non-building structures, including applicable codes and standards, design load criteria and materials of construction.

C.1 General Service Loads

C.1.1 Dead Loads

Dead loads will consist of the weight of all structure construction materials including walls, floors, roofs, stairways, finishes, cladding, and other similar structural and architectural items. Fixed service equipment, including cranes, will be added to the total dead load. Equipment pads will be considered superimposed dead loads.

C.1.2 Collateral Dead Loads

A superimposed dead load of 20 pounds per square foot (PSF) will be included in the design of floors and roof structures to account for HVAC ductwork, piping, electrical wiring and lighting. Partition loading allowance will be computed on the basis of materials used.

C.1.3 Live Loads and Deflection Criteria

Minimum design live loads and deflection criteria are summarized in Table C-1. Actual equipment weights will be used where the minimum PFS loading is exceeded.

Table C-1. Design Live Loads and Deflection Criteria

Location	Criteria
Live Loads	
Roof Live Load (non-reducible)	20 PSF + Equipment Load or 50 PSF, whichever governs
Roof Mechanical Electrical Allowance	5 PSF
Process Areas	200 PSF overall (design individual slabs and beams that support equipment for 300psf)
Mechanical Rooms	200 PSF
Mechanical Rooms where equipment may be moved)	300 PSF, 4000 pounds concentrated load
Electrical/Control Rooms	300 PSF, 2000 pounds concentrated load
Storage Areas	250 PSF
Corridors, exits, stairways	100 PSF
Catwalks, platforms for access only	100 PSF
Slab-on-grade (vehicle area)	250 PSF
Deck-at-grade (vehicle area)	AASHTO HS-20 loading or applicable crane/vehicle loading
Forklift	Manufacturer’s maximum axle load plus 25% for impact
Heavy Storage	250 PSF
Grating, checkered plate, and hatches	125 PSF or same as adjacent area, whichever is greater

Table C-1. Design Live Loads and Deflection Criteria	
Location	**Criteria**
Allowable Deflections (deflection to span ratio)	
Vertical Deflections	
Under Running Monorail Hoist Girder	L/600
Monorail Supporting Structure	L/450
Bridge Crane Girders	L/1000
Steel Floor Plates and grating (live load)	L/360
Roofs	L/240
Mechanical Rooms where equipment may be moved	L/360
Electrical/Laboratory/Controls Rooms	L/360
Steel Roof Deck	L/240
Lateral Deflections	
Hoist Girders and Runways	L/450

C.1.3 Seismic Loads

The seismic design of the RLS will be performed in accordance with the CBC, ASCE 7 Chapter 15, and ACI 350.3. Seismic Design Criteria for the RLS will be based on the parameters listed in Table C-2.

Table C-2. Seismic Load Criteria	
Parameter	**Design Criteria**
Risk Category	III
Site Class	E
Mapped Spectral Acceleration Values (site specific)	Lat 37° 32' 36.36" Long 122° 13' 47.55"
Short Period	1.5g
1 second Period	0.648g
Site Coefficients	
Short Period Coefficient	0.9
Long Period Coefficient	2.4
Maximum Considered Earthquake Spectral Response Acceleration Parameters	
Short Period	1.350g
1 Second Period	1.555g
Design Spectral Response Acceleration Parameters	
Short Period	0.90g
1 second Period	1.037g
Seismic Design Category	E
Importance Factor	1.25

C.1.4 Wind Loads

Design Wind Loads will be computed in accordance with CBC Chapter 16 and ASCE 7, based upon the parameters listed below:

Three-second peak gust wind speed:	115 mph
Exposure category:	C
Risk Category:	III
Topographic Factor (K_{zt}):	1.0

C.1.5 Rain Loads

Rain Loads will be computed in accordance with the CBC.

C.1.6 Impact Loads

For live loads that induce impact, the assumed live loads will be increased as indicated below.

American Association of State Highway and Transportation Officials (AASHTO) Standard Specification for Highway Bridges will be used for impact forces caused by moving vehicular wheel loads.

Light machinery supports (shaft or motor driven): 20 percent minimum or manufacturer's recommendation.

Reciprocating machinery or power driven unit supports: 50 percent minimum or manufacturer's recommendation.

Bridge cranes (remotely operated, powered):

- Vertical: 25 percent.
- Lateral (perpendicular to runway beam): 20 percent of the sum of the rated capacity of the crane and the weight of the hoist and trolley.
- Longitudinal: 10 percent of the maximum wheel load of the crane.
- Monorail cranes (powered 25 percent).

C.1.7 Vibratory Loads

Consideration will be given to equipment vibration and its effect on the supporting structure. The basic approach to controlling vibration by equipment will be as follows:

1. Locate vibrating equipment at grade where possible
2. Isolate from surrounding slab where possible
3. Provide foundation blocks/structural support systems with a mass of three times the weight of the equipment, or 10 times the mass of the rotating equipment
4. Include mechanical methods to mitigate vibration where possible (vibration isolation pads and dampening systems)

Critical dynamic response of framing supporting vibrating machinery will be at least fifty percent out of phase with the disturbing force.

C.1.8 Handrails

Handrails will have a uniform load of 50 pounds per linear foot applied in any direction or a concentrated load of 200 pounds applied at any point and in any direction along the top of the rail, whichever produces the greater stress. The uniform and concentrated loads will not be applied simultaneously.

C.1.9 Heavy Equipment Loads

In areas subject to heavy equipment traffic, the structures will be capable of supporting existing and planned vehicle loads including impact such as forklifts, maintenance vehicles, mobile cranes, etc. Consideration will be given for moving, stationary, and operational loads (such as crane setup to lift equipment loads), including expected Contractor's equipment to be used during construction.

All equipment gallery floors, ground level floors with large access doors will be designed for forklift loads or any anticipated maintenance vehicle loads.

The design engineer will coordinate with the SVCW Operation and Maintenance group to obtain information regarding typical vehicle and forklift used at the facilities.

C.1.10 Differential Settlement Loads

For backfilled foundations, the structure will be checked for a minimum ¼-inch differential settlement over 20 feet, or as recommended by the geotechnical engineer.

C.1.11 Liquid Loads

Liquid-holding basins will be designed for maximum liquid levels and loading conditions as identified in the Load Combinations section below. Maximum loads from any combination of full or empty tank cells will be applied.

C.1.12 Earth Loads

Below-grade structures and liquid holding basins will be designed for worst-case load of combinations of full height of backfill plus a minimum 2-foot soil surcharge with tanks empty in areas with traffic adjacent to the basin. Additional surcharge loads will be applied to account for unique conditions due to adjacent structure proximity and traffic or equipment loading.

C.2 Materials

The following section provides a list of guidelines to be used with the RLS construction materials. Primary construction materials include cast-in-place concrete, structural steel, aluminum and fiber reinforced plastic.

C.2.1 Cast-in-place Concrete

The RLS will be comprised of cast-in-place reinforced concrete. Table C-3 summarizes design criteria for cast in place concrete and reinforcing steel.

Table C-3. Cast in Place Concrete Criteria	
Parameter	**Design Criteria**
Minimum Compressive Strength (f'c) for structural applications	4,500 PSI
Minimum compressive strength (f'c) for concrete fill	2,500 PSI
Required Cement Type	Type II
Reinforcing Steel (typical)	ASTM A615 Grade 60
Reinforcing Steel (to be welded)	ASTM A706 Grade 60
Concrete Admixtures requirements	Air Entrainment (4 percent to 7 percent) High range water reducer (Superplacticizer) is required in all basin walls and slabs Fly Ash: 15 to 25 percent cement replacement by weight
Maximum Water to Cement+Fly Ash ratios	0.40 (hydraulic structures) 0.42 (concrete pavement)
Concrete Joint Spacing	
Construction Joint Spacing -basin slab	60-foot maximum spacing
Construction joint spacing – basin walls	60-foot maximum spacing Additional construction joints approximately 10 to 20 feet from wall corners

Details of reinforcing:

- Minimum concrete cover:
  - Unformed concrete against earth: 3 inch
  - Typical unless noted otherwise: 2 inch

Laps and hooks will conform to project standard details. Minimum temperature and shrinkage reinforcing will be in conformance with the provisions of ACI 318 or ACI 350 as appropriate.

C.2.2 Structural Steel

Table C-4 summarizes the design criteria for steel.

Table C-4. Structural Steel Criteria	
Parameter	**Material Requirements**
Rolled W-shapes	ASTM A992 (galvanized)
Plates and other rolled shapes	ASTM A36 (galvanized)
Steel Tube	ASTM A500, Grade B (35ksi)
Structural Bolts	ASTM A325-N ASTM325-F for slip critical connections
Anchor bolts	ASTM A193 Type 315 SST
Metals in contact with liquid	ASTM A193, Type 316 SST
Welding Electrodes	E70XX

C.2.3 Aluminum

Table C-5 summarizes the design criteria for aluminum.

Table C-5. Aluminum Criteria	
Parameter	**Material Requirements**
Aluminum shapes and plates	Alloy 6061-T6 conforming to the ASTM sections in the aluminum Association Design manual.
Handrails	Rails, Posts, and formed elbows: Extruded Alloy 6105-T5, 6061-T6, or equivalent Toe Boards: Molded or extruded Alloy 6063-T6 or 6061-T6.
Bolts	Do not use aluminum bolts. Bolts for aluminum connections will be type 316 stainless steel.

C.2.4 Fiberglass Reinforced Plastic

Table C-6 summarizes the design criteria for fiberglass reinforced plastic.

Table C-6. Fiberglass Reinforced Plastic Criteria	
Parameter	**Material Requirements**
Vinyl ester with fiberglass reinforcing	Type V
Fire retardant	ASTM E84 25 or less
Resin Type	Selected by manufacturer to meet requirements of chemical resistance specified.
Color	To be selected by owner.

Attachment D: SVCW Equipment Name Builder

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SBSA Standard Equipment and Valve Identification Naming Convention

Standard naming convention for all hard assets: , equipment - electrical equipment, instruments

Tagging/Labeling Convention Examples:

Process Area - Process Function - Equipment Designator - Sequential Number

Example of Primary Sludge Pump #1

Process Area - Primary Sludge = PSL
Process Function -Transfer = TRS
Equipment Designator - Pump = PMP
Sequential number - Always 5 digits -varies = 14101

Digit 1 and 2	Primary Sedimentation --14
Digit 3	Unit number --1
Digit 4 and 5	Sequencing number --one-- 01

Primary Sludge Pump number one = **PSL_TRS_PMP_14101**

Example of Gravity Thickener Unit #4 Blanket Level Sensor

Process Area - Cogeneration = GT
Process Function -Detector = DET
Equipment Designator - Blanket Depth Sensor = BLT
Sequential number - Always 5 digits -varies = 22401

Digit 1 and 2	Sludge Thickening --22
Digit 3	Unit - Area number --4
Digit 4 and 5	Sequencing number -- one--01

Gravity Thickener Unit 1 Blanket Level Detector = **GT_DET_BLT_22401**

Example of Main Transformer T-1

Process Area - Power = PWR
Process Function -Supply = SUP
Equipment Designator - Transformer = TFR
Sequential number - Always 5 digits -varies = 27601

Digit 1 and 2	Building and Utilities --27
Digit 3	Unit number --0
Digit 4 and 5	Sequencing number --one-- 01

Main Transformer T-1 number one = **PWR_SUP_TFR_27001**

Example of MCC Electrical Panel P4

Process Area - Power = PWR
Process Function -Control = CNT
Equipment Designator - Panel = PNL
Sequential number - Always 5 digits -varies = 27604

Digit 1 and 2	Building and Utilities --27
Digit 3	Unit - Area number --0
Digit 4 and 5	Sequencing number -- one--04

Cogeneration Unit 1 Control Panel = **PWR_CNT_PNL_27004**

Example of Cogeneration Unit #2 Control Panel

Process Area - Cogeneration = CGN
Process Function -Control = CNT
Equipment Designator - Panel = PNL
Sequential number - Always 5 digits -varies = 14101

Digit 1 and 2	Cogeneration --23
Digit 3	Unit number --2
Digit 4 and 5	Sequencing number -- one--01

Cogeneration Unit 1 Control Panel = **CGN_CNT_PNL_23201**

Example of Cogeneration Standby Generator Unit #2

Process Area - Cogeneration = CGN
Process Function -Supply = SUP
Equipment Designator - Standby Generator = EGN
Sequential number - Always 5 digits -varies = 27602

Digit 1 and 2	Building and Utilities --27
Digit 3	Unit number --2
Digit 4 and 5	Sequencing number -- one--02

Cogeneration Generator Unit 2 = **CGN_SUP_EGN_27202**

Process Area Designations Approved List	
Abbreviation	**Process Area**
AS	Activated Sludge
1W	No. 1 Water System (Potable Water)
2W	No. 2 Water System (Downstream fr/BFP)
3W	No. 3 Water System
4W	Recycled Water
AB	Aeration Basins
ASC	Air Scour
AUX	Auxiliary Systems
BLG	Bilge
BLR	Boiler
BST	Booster Station
BPS	Belmont Pump Station
BW	Backwash
CGN	Cogeneration
CON	Conveyance System
DIG	Digester
DIS	Disinfection Area (Hypochlorite)
DMF	Dual Media Filters
DMX	Digester Mixing
DRC	Digester Recirculation
DW	Dewatering
EFF	Effluent
EGN	Emergency Generators
EPT	Enhanced Primary Treatment
FE	Final Effluent
FEF	Flow Equalization Facility
FEP	Final Effluent Pumping
FFR	Fixed Film Reactor
GEN	General
GRS	Grease Receiving Station
GRT	Degritting
GT	Gravity Sludge Thickeners
GTS	Gas Treatment System
HDW	Headworks
HPA	High Pressure Air
HVA	Heating Ventilation Air Conditioning
HWS	Hot Water System
ILS	Influent Lift Station
INF	Influent
MPS	Menlo Park Pump Station
PD	Plant Drain
PE	Primary Effluent
PS	Primary Sedimentation
PSC	Primary Scum
PSL	Primary Sludge
PWR	Electrical Power
Q	Flow
RAS	Return Activated Sludge
RPS	Redwood City Pump Station
RW	Recycled Water
SBS	Dechlorination (Sodium Bisulfite)
SD	Storm Drain System
SDB	Sludge Drying Beds
SE	Secondary Effluent
SEC	Secondary Clarifiers
SEP	Septage
SLD	Sludge Disposal
SLG	Sludge
SPS	San Carlos Pump Station
SRG	Surge
SS	Sanitary Sewer
SW	Site Waste System
THS	Thickened Sludge
WAS	Waste Activated Sludge
WGB	Waste Gas Burner
WW	Wet Well

Process Area Designations Pending Changes	
Abbreviation	**Process Area**
AS	Activated Sludge
1W	No. 1 Water System (Potable Water)
2W	No. 2 Water System (Downstream fr/BFP)
3W	No. 3 Water System
4W	Recycled Water
AB	Aeration Basins
ASC	Air Scour
AUX	Auxiliary Systems
BLG	Bilge
BLR	Boiler
BST	Booster Station
BPS	Belmont Pump Station
BW	Backwash
CGN	Cogeneration
CON	Conveyance System
DIG	Digester
DIS	Disinfection Area (Hypochlorite)
DMF	Dual Media Filters
DMX	Digester Mixing
DRC	Digester Recirculation
DW	Dewatering
EFF	Effluent
EGN	Emergency Generators
EPT	Enhanced Primary Treatment
FE	Final Effluent
FEF	Flow Equalization Facility
FEP	Final Effluent Pumping
FFR	Fixed Film Reactor
GEN	General
GRS	Grease Receiving Station
GRT	Degritting
GT	Gravity Sludge Thickeners
GTS	Gas Treatment System
HDW	Headworks
HPA	High Pressure Air
HVA	Heating Ventilation Air Conditioning
HWS	Hot Water System
ILS	Influent Lift Station
INF	Influent
MPS	Menlo Park Pump Station
PD	Plant Drain
PE	Primary Effluent
PS	Primary Sedimentation
PSC	Primary Scum
PSL	Primary Sludge
PWR	Electrical Power
Q	Flow
RAS	Return Activated Sludge
RPS	Redwood City Pump Station
RW	Recycled Water
SBS	Dechlorination (Sodium Bisulfite)
SD	Storm Drain System
SDB	Sludge Drying Beds
SE	Secondary Effluent
SEC	Secondary Clarifiers
SEP	Septage
SLD	Sludge Disposal
SLG	Sludge
SPS	San Carlos Pump Station
SRG	Surge
SS	Sanitary Sewer
SW	Site Waste System
THS	Thickened Sludge
WAS	Waste Activated Sludge
WGB	Waste Gas Burner
WW	Wet Well

Process Function Designations Approved Listing	
Abbreviation	**Process Function**
ANA	Analyzer
COL	Collector
CNT	Control
DET	Detector
DRN	Drain
DIS	Discharge
EXH	Exhaust
FIL	Fill
FSH	Flush Water
GS	General Service
INJ	Injection
INL	Inlet
INT	Instrument
ISL	Isolation
MET	Metering
MIX	Mixing
MOD	Modulating
MON	Monitor
NET	Network
OUT	Outlet
PLY	Polymer
PWR	Power / Electricity
RET	Return
REC	Recirculation
SCR	Screen
SDW	Sludge Dewatering
SKM	Skimmer
SPR	Spray
SUP	Supply
SW	Seal Water
SUC	Suction
SUM	Sump
TRA	Transmitter
TRS	Transfer

Process Function Designations Pending Changes	
Abbreviation	**Process Function**
ANA	Analyzer
COL	Collector
CNT	Control
DET	Detector
DRN	Drain
DIS	Discharge
EXH	Exhaust
FIL	Fill
FSH	Flush Water
GS	General Service
INJ	Injection
INL	Inlet
INT	Instrument
ISL	Isolation
MET	Metering
MIX	Mixing
MOD	Modulating
MON	Monitor
NET	Network
OUT	Outlet
PLY	Polymer
PWR	Power / Electricity
RET	Return
REC	Recirculation
SCR	Screen
SDW	Sludge Dewatering
SKM	Skimmer
SPR	Spray
SUP	Supply
SW	Seal Water
SUC	Suction
SUM	Sump
TRA	Transmitter
TRS	Transfer

Equipment Designations
Approved List

Abbreviation	Equipment
AC	Air Conditioning Unit
ACD	Analyzer Conductivity
AD	Auto Dialer
AHU	Air Handling Unit
AI	Analog Input
ALM	Alarm
AO	Analog Output
ATS	Automatic Transfer Switch
AUD	Audible Alarm
BAT	Battery
BDV	Blow Down Valve
BFS	Burner Flame Sensor (Cadmium Eye)
BI	Analyzer Blanket Indicating
BLR	Boiler
BLT	Blanket Depth Sensor
BLW	Blower
BUB	Bubbler
C2	Analyzer Carbon Dioxide
CEN	Centrifuge
CH	Chiller
CHG	Battery Charger
CL	Analyzer Chlorine
CLK	Clock
CNV	Conveyor
CO	Analyzer Carbon Monoxide
COL	Collector
CP	Control Panel
CR	Control Relay
DI	Discrete Input
DIS	Distributor Arm
D/O	Discrete Output
DO	Analyzer Dissolved Oxygen
DOP	Doppler
DU	Drive Unit
EIT	Voltage (E) Indicating Transmitter
FAN	Fan
FE	Flow Sensing Element
FIT	Flow Indicating Transmitter
FLC	Flocculator
FLT	Float Switch
FQI	Flow Totalizer w/Indicator
FQT	Flow Totalizing Transmitter
FS	Flow Switch
FT	Flow Transmitter
GDR	Grinder
GEN	Generator
GLS	Gate Limit Switch (Open/Closed)
HEX	Heat Exchanger
HS	Hand Switch
IE	Current Element (Amp Meter)
IIT	Current Indicating Transmitter (Amp Meter)
IT	Current Transmitter (Amp Meter)
JE	Power Sensing Element
JIT	Power Indicating Transmitter
JT	Power Transmitter
LE	Level Sensing Element
LGT	Alarm Light
LI	Level Indicator (non transmitting)
LIT	Level Indicating Transmitter
LS	Level Switch
LT	Level Transmitter
MBS	Mechanical Bar Screen
MCC	Motor Controller Center
MME	Miscellaneous Mechanical
MTR	Motor
MXR	Mixer
NT	Analyzer Turbidity
PCV	Pressure Control Valve
PDT	Pressure Differential Indicating Transmitter
PE	Pressure Sensing Element
pH	Analyzer pH
PI	Pressure Indicator (non transmitting)
PIT	Pressure Indicating Transmitter
PLC	Programmable Logic Controller
PMP	Pump
PNL	Panel
PRX	Proximity Sensor
PSW	Pressure Switch
PT	Pressure Transducer
PWR	Power Supply
RDR	Radar LIT
RFP	Rotary Fan Press
RTU	Remote Terminal Unit
SE	Speed Element
SG	Slide Gate
SI	Analyzer Sulfite Ion
SIT	Speed Indicating Transmitter
SS	Analyzer Suspended Solids
ST	Speed Transmitter
SV	Solenoid Valve (added)
SWB	Switchboard
SWR	Switchgear
T	Transmitter
TE	Temperature Sensing Element
TFR	Transformer
TG	Analyzer Gas
TI	Temperature Indicator (non transmitting)
TIT	Temperature Indicating Transmitter
TNK	Tank
TRQ	Torque Switch, Transmitter, or specific relay
TS	Temperature Switch
%TS	Analyzer Total Solids
TT	Temperature Transmitter
TTG	Analyzer Triple Gas
TTL	Totalizer
TTM	Transit Time
TVS	Transient Voltage Suppressor
UPS	Un-interruptible Power Supply
USD	Ultra Sound
VBE	Vibration Element
VBT	Vibration Indicting Transmitter
VFD	Variable Frequency Drive
VLV	Valve
VNT	Venturi
VPS	Valve Position Sensor (% open)
VBT	Vibration Transmitter
VLT	Voltage Transmitter
WC	Washer Compactor Unit
WE	Torque Element
WGB	Waste Gas Burner
WSK	Whisker Switch
XFR	Transfer Switch
ZSC	Position Closed Switch/Indicator
ZSO	Position Open Switch/Indicator

Equipment Designations
Pending Changes

Abbreviation	Equipment
AC	Air Conditioning Unit
ACD	Analyzer Conductivity
AD	Auto Dialer
AHU	Air Handling Unit
AI	Analog Input
ALM	Alarm
AO	Analog Output
ATS	Automatic Transfer Switch
AUD	Audible Alarm
BAT	Battery
BDV	Blow Down Valve
BFS	Burner Flame Sensor (Cadmium Eye)
BI	Analyzer Blanket Indicating
BLR	Boiler
BLT	Blanket Depth Sensor
BLW	Blower
BUB	Bubbler
C2	Analyzer Carbon Dioxide
CEN	Centrifuge
CH	Chiller
CHG	Battery Charger
CL	Analyzer Chlorine
CLK	Clock
CNV	Conveyor
CO	Analyzer Carbon Monoxide
COL	Collector
CP	Control Panel
CR	Control Relay
DI	Discrete Input
DIS	Distributor Arm
D/O	Discrete Output
DO	Analyzer Dissolved Oxygen
DOP	Doppler
DU	Drive Unit
EIT	Voltage (E) Indicating Transmitter
FAN	Fan
FE	Flow Sensing Element
FIT	Flow Indicating Transmitter
FLC	Flocculator
FLT	Float Switch
FQI	Flow Totalizer w/Indicator
FQT	Flow Totalizing Transmitter
FS	Flow Switch
FT	Flow Transmitter
GDR	Grinder
GEN	Generator
GLS	Gate Limit Switch (Open/Closed)
HEX	Heat Exchanger
HS	Hand Switch
IE	Current Element (Amp Meter)
IIT	Current Indicating Transmitter (Amp Meter)
IT	Current Transmitter (Amp Meter)
JE	Power Sensing Element
JIT	Power Indicating Transmitter
JT	Power Transmitter
LE	Level Sensing Element
LGT	Alarm Light
LI	Level Indicator (non transmitting)
LIT	Level Indicating Transmitter
LS	Level Switch
LT	Level Transmitter
MBS	Mechanical Bar Screen
MCC	Motor Controller Center
MME	Miscellaneous Mechanical
MTR	Motor
MXR	Mixer
NT	Analyzer Turbidity
PCV	Pressure Control Valve
PDT	Pressure Differential Indicating Transmitter
PE	Pressure Sensing Element
pH	Analyzer pH
PI	Pressure Indicator (non transmitting)
PIT	Pressure Indicating Transmitter
PLC	Programmable Logic Controller
PMP	Pump
PNL	Panel
PRX	Proximity Sensor
PSW	Pressure Switch
PT	Pressure Transducer
PWR	Power Supply
RDR	Radar LIT
RFP	Rotary Fan Press
RTU	Remote Terminal Unit
SE	Speed Element
SG	Slide Gate
SI	Analyzer Sulfite Ion
SIT	Speed Indicating Transmitter
SS	Analyzer Suspended Solids
ST	Speed Transmitter
SV	Solenoid Valve (added)
SWB	Switchboard
SWR	Switchgear
T	Transmitter
TE	Temperature Sensing Element
TFR	Transformer
TG	Analyzer Gas
TI	Temperature Indicator (non transmitting)
TIT	Temperature Indicating Transmitter
TNK	Tank
TRQ	Torque Switch, Transmitter, or specific relay
TS	Temperature Switch
%TS	Analyzer Total Solids
TT	Temperature Transmitter
TTG	Analyzer Triple Gas
TTL	Totalizer
TTM	Transit Time
TVS	Transient Voltage Suppressor
UPS	Un-interruptible Power Supply
USD	Ultra Sound
VBE	Vibration Element
VBT	Vibration Indicting Transmitter
VFD	Variable Frequency Drive
VLV	Valve
VNT	Venturi
VPS	Valve Position Sensor (% open)
VBT	Vibration Transmitter
VLT	Voltage Transmitter
WC	Washer Compactor Unit
WE	Torque Element
WGB	Waste Gas Burner
WSK	Whisker Switch
XFR	Transfer Switch
ZSC	Position Closed Switch/Indicator
ZSO	Position Open Switch/Indicator

Process Location Code (Characters 1 and 2) Approved Codes		Process Location Code (3) Approved Codes		Sequential Code (4,5) Approved Codes
Abbreviation	Location Code	Code Value	Location Code	Code Value
01	West Bay S.D.	0	Common Area	00
02	Redwood City	1	Unit Process #	01
03	Fair Oaks S.D.	2	Unit Process #	02
04	San Carlos	3	Unit Process #	03
05	Harbors S.M.D.	4	Unit Process #	04
06	Booster Pump Station	5	Unit Process #	05
07	Belmont	6	Unit Process #	06
08	Redwood Shores	7	Unit Process #	07
09	33" FM	8	Unit Process #	08
10	48" FM	9	Unit Process #	09
11	54" FM			10
12	Outfall			11
13	Lift Pumping			12
14	Primary Sedimentation			13
15	F.F.R.			14
16	Aeration			15
17	Secondary Clarifiers			16
18	Filtration			17
19	Disinfection			18
20	Dechlorination			19
21	Effluent Pumping			20
22	Sludge Thickening			21
23	Sludge Digestion			22
24	Sludge Dewatering			23
25	Recycled Water			24
26	Sludge Disposal			25
27	Buildings & Utilities			
28	Roads and Grounds			
29	Vehicles			
30	Process Analysis			
31	Regulatory Affairs			
32	General			
33	Supervision			
34	Training			
35	Odor Control			
36	Pollution Prevention			
37	San Carlos/Booster			
38	Flow Equalization Facility			
39	Information Management			
40	CIP Staff Support			
41	Safety			
42	Screening			
43	Grit Removal (future)			
44				
45				
46				
47				
48				
49				
50				
51	Remote Pump Station #1			
52	Remote Pump Station #2			
53	Remote Pump Station #3			

Process Location Code (Characters 1 and 2) Pending Changes	
Code Value	Location Code
01	West Bay S.D.
02	Redwood City
03	Fair Oaks S.D.
04	San Carlos
05	Harbors S.M.D.
06	Booster Pump Station
07	Belmont
08	Redwood Shores
09	33" FM
10	48" FM
11	54" FM
12	Outfall
13	Lift Pumping
14	Primary Sedimentation
15	F.F.R.
16	Aeration
17	Secondary Clarifiers
18	Filtration
19	Disinfection
20	Dechlorination
21	Effluent Pumping
22	Sludge Thickening
23	Sludge Digestion
24	Sludge Dewatering
25	Recycled Water
26	Sludge Disposal
27	Buildings & Utilities
28	Roads and Grounds
29	Vehicles
30	Process Analysis
31	Regulatory Affairs
32	General
33	Supervision
Pending Changes	
Code Value	Location Code
34	Training
35	Odor Control
36	Pollution Prevention
37	San Carlos/Booster
38	Flow Equalization Facility
39	Information Management
40	CIP Staff Support
41	Safety
42	Screening
43	Grit Removal (future)
44	
45	
46	
47	
48	
49	
50	
51	Remote Pump Station #1
52	Remote Pump Station #2
53	Remote Pump Station #3

Instrumentation / PLC IO Suffixes Approved List	
Acronym	Description of Acronym/Use
AAH	Analyzer Alarm High
AAHH	Analyzer Alarm Very High
AAL	Analyzer Alarm Low
AALL	Analyzer Alarm Very Low
AUTO	Switch Position=AUTO
BATTLO	Battery Low
CAL	Calibration Mode Value
CH4	Methane
CL2	Chlorine
CLS	Close Command as Output
CLSD	Valve or Gate Closed
CT	Current Transducer
DG	Digester Gas
DP	Differential Pressure
EIT	Voltage (=E) Indicating Transmitter
FAH	Flow Alarm High
FAHH	Flow Alarm Very High
FAIL	Fail Alarm - Any Cause
FAL	Flow Alarm Low
FALL	Flow Alarm Very Low
FLTD	Faulted
FSHH	Flow Switch Very High
FSLL	Flow Switch Very Low
HR	Heat Recovery
HX#	Heat Exchanger/Placeholder
HX1	Heat Exchanger #1
HX2	Heat Exchanger #2
HX3	Heat Exchanger #3
HX4	Heat Exchanger #4
HX5	Heat Exchanger #5
HX6	Heat Exchanger #6
HX7	Heat Exchanger #7
HX8	Heat Exchanger #8
HX9	Heat Exchanger #9
IN	Inch or Inches
KW	KiloWatt
LAH	Level Alarm High
LAHH	Level Alarm Very High
LAL	Level Alarm Low
LALL	Level Alarm Very Low
LOAD	Electrical Load
LOC	Switch Position=LOCAL
LOS	Lock Out Stop Switch Device
LPF	Line Power Failed
LSH	Level Switch High
LSHH	Level Switch Very High
LSL	Level Switch Low
LSLL	Level Switch Very Low
MFLM	Main Flame
MGD	Millions of Gallons Per Day
MST	Moisture Alarm or Switch
NG	Natural Gas
OFF	Switch is in Off Position
OL	Overload
ONBATT	On Battery Power
OPN	Open Command as Output
OPND	Valve or Gate Opened
PAH	Pressure Alarm High
PAHH	Pressure Alarm Very High
PAL	Pressure Alarm Low
PALL	Pressure Alarm Very Low
PF	Power Failed
PFLM	Pilot Flame
POS_CMD	Position Command as Ouput
POS_IND	Position Indication as Input
PRI	Primary Device in two device system
PSH	Pressure Switch High
PSHH	Pressure Switch Very High
PSI	Pounds Per Square Inch
PSL	Pressure Switch Low
PSLL	Pressure Switch Very Low
PSA	Power Supply A (redundant systems)
PSB	Power Supply B (redundant systems)
RBATT	Replace Battery
RDR	Radar Level Component
REM	Switch Position=REMOTE
RFAIL	Run Failed or Fail to Start
RST	Output command to Reset
RUN	Run Confirmation for Equipment
SEC	Secondary in two device system
SIM	Simulation Value to Represent Signal
SPD_CMD	Speed Commanded
SPD_IND	Speed Feedback
STOP	Stop Command to Equipment (if applicable)
STRT	Start Command to Equipment
SWF	Seal Water Failure
TSF	Transfer Switch Failure
TSH	Temperature Switch High
TSL	Temperature Switch Low
US	Ultrasonic Detection
VAC	Volts - AC
VDC	Volts - DC
VSH	Vibration Switch High
XMT	Transmitter

Instrumentation / PLC IO Suffixes Pending Changes	
Acronym	Description of Acronym/Use
AAH	Analyzer Alarm High
AAHH	Analyzer Alarm Very High
AAL	Analyzer Alarm Low
AALL	Analyzer Alarm Very Low
AUTO	Switch Position=AUTO
BATTLO	Battery Low
CAL	Calibration Mode Value
CH4	Methane
CL2	Chlorine
CLS	Close Command as Output
CLSD	Valve or Gate Closed
CT	Current Transducer
DG	Digester Gas
DP	Differential Pressure
EIT	Voltage (=E) Indicating Transmitter
FAH	Flow Alarm High
FAHH	Flow Alarm Very High
FAIL	Fail Alarm - Any Cause
FAL	Flow Alarm Low
FALL	Flow Alarm Very Low
FLTD	Faulted
FSHH	Flow Switch Very High
FSLL	Flow Switch Very Low
HR	Heat Recovery
HX#	Heat Exchanger/Placeholder
HX1	Heat Exchanger #1
HX2	Heat Exchanger #2
HX3	Heat Exchanger #3
HX4	Heat Exchanger #4
HX5	Heat Exchanger #5
HX6	Heat Exchanger #6
HX7	Heat Exchanger #7
HX8	Heat Exchanger #8
HX9	Heat Exchanger #9
IN	Inch or Inches
KW	KiloWatt
LAH	Level Alarm High
LAHH	Level Alarm Very High
LAL	Level Alarm Low
LALL	Level Alarm Very Low
LOAD	Electrical Load
LOC	Switch Position=LOCAL
LOS	Lock Out Stop Switch Device
LPF	Line Power Failed
LSH	Level Switch High
LSHH	Level Switch Very High
LSL	Level Switch Low
LSLL	Level Switch Very Low
MFLM	Main Flame
MGD	Millions of Gallons Per Day
MST	Moisture Alarm or Switch
NG	Natural Gas
OFF	Switch is in Off Position
OL	Overload
ONBATT	On Battery Power
OPN	Open Command as Output
OPND	Valve or Gate Opened
PAH	Pressure Alarm High
PAHH	Pressure Alarm Very High
PAL	Pressure Alarm Low
PALL	Pressure Alarm Very Low
PF	Power Failed
PFLM	Pilot Flame
POS_CMD	Position Command as Ouput
POS_IND	Position Indication as Input
PRI	Primary Device in two device system
PSH	Pressure Switch High
PSHH	Pressure Switch Very High
PSI	Pounds Per Square Inch
PSL	Pressure Switch Low
PSLL	Pressure Switch Very Low
PSA	Power Supply A (redundant systems)
PSB	Power Supply B (redundant systems)
RBATT	Replace Battery
RDR	Radar Level Component
REM	Switch Position=REMOTE
RFAIL	Run Failed or Fail to Start
RST	Output command to Reset
RUN	Run Confirmation for Equipment
SEC	Secondary in two device system
SIM	Simulation Value to Represent Signal
SPD_CMD	Speed Commanded
SPD_IND	Speed Feedback
STOP	Stop Command to Equipment (if applicable)
STRT	Start Command to Equipment
SWF	Seal Water Failure
TSF	Transfer Switch Failure
TSH	Temperature Switch High
TSL	Temperature Switch Low
US	Ultrasonic Detection
VAC	Volts - AC
VDC	Volts - DC
VSH	Vibration Switch High
XMT	Transmitter

PLC Discrete IO Group Order of Presentation Table

Discrete PLC Presentation Order	Remote Input Groups				
1	REM	REM	REM	REM	
2	LOC	LOC	OFF	OFF	
3	OPND	OPND	LOC	LOC	
4	CLSD	CLSD	OPND	OPND	
5		FLTD	CLSD	CLSD	
6				FLTD	
	Auto Input Groups				
1	AUTO	AUTO	AUTO	AUTO	AUTO
2	OFF	OFF	OFF	OFF	OFF
3	HAND	HAND	HAND	HAND	HAND
4		RUN	RUN	RUN	RUN
5			LOS	LOS	LOS
6			OL	OL	OL
7				SWF	SWF
8				TSH	TSH
9					PSH
Additional Inputs here if not listed.					Other
10 or greater				**Always Last>**	FLTD
	Discrete Output Groups				
1	OPN	OPN	STRT	STRT	
2	CLS	STOP	RST	STOP	
3	Other	CLS	Other	RST	
4		Other		Other	

Attachment E: Mechanical Criteria

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Attachment E: Mechanical Design

This section outlines the parameters that will form the basis for the mechanical design. Mechanical components consist of sluice gates, stop logs, piping and valves, and supply fans.

E.1 General

Each item of driven equipment and each motor weighing more than 50 pounds will be fitted with a minimum of one lifting eye.

E.2 Miscellaneous Items

Caution signs will be provided for equipment with guarded moving parts that operate automatically or by remote control.

Pressure taps will be provided on the suction and discharge side of pumps and blowers.

Equipment nameplates will have the equipment name and number engraved or stamped on stainless steel material. All equipment, including valves, will be provided with nameplates.

A fall prevention system adjacent to the wet wells will be installed for maintenance technicians to anchor their safety lines during maintenance activities. The fall prevention system will prevent technicians from falling into open hatches, especially during installation or removal of pumps. Safety netting or grating will also be provided with access hatches.

E.3 Equipment Mounting

All supports, anchorage, and mounting of all equipment will be in accordance with the manufacturer's recommendations, the CBC, and industry standard requirements.

Equipment baseplate for floor mounted equipment will be fabricated steel or cast iron, hot-dipped galvanized after fabrication.

Anchor bolts will be designed for lateral forces for both pullout and shear in accordance with CBC and ASCE 7; the component importance factor (I_P) for all equipment will be 1.50. Minimum diameter of anchor bolts will be ½-inch. Material for equipment anchor bolts will be Type 316 stainless steel.

Pumps will be installed in accordance with ANSI/HI 1.4 and ANSI/HI 2.4. Grouting of equipment bases will take place prior to connecting any field piping or electrical and instrumentation systems.

Connecting piping with flexible connections and/or expansion joints will be anchored such that the intended uses of these joints are maintained in the piping system without imposing strain on the equipment connections.

E.4 Electric Motors

All pump motors will be required to be supplied by the pump equipment supplier. The electric motors will be specified with bearings rated for an L-10 life of 100,000 hours. Electric motors specified for use with variable frequency drives will be totally enclosed, air-over, blower-cooled with 1.00 service factor, voltage as appropriate, Class F insulation, inverter duty rated and specified with resistance temperature detectors.

E.5 Vibration Isolation

Curb mounted equipment, principally rooftop ventilating equipment, will be mounted on vibration isolation bases that fit over the curb and under the isolated equipment. Seismic restraints will meet the requirements of the CBC and ASCE 7; the component importance factor (I_P) for all vibration isolated equipment will be 1.50.

E.6 Noise

The maximum permissible noise levels for a complete piece of mechanical equipment located within or outside a structure will be coordinated with the City of Redwood City and SVCW during final design. A complete piece of mechanical equipment is defined as the driver and driven equipment, plus any intermediate couplings, gears, and auxiliaries.

Noise reduction measures such as sound reduction enclosures, acoustical equipment mountings, acoustical wall or ceiling panels, and acoustical insulation on equipment will be provided where necessary following installed equipment field noise testing.

E.7 Gates

Isolation gates for the RLS will either be sluice gates or stop gates depending on the need for flow control and/or isolation redundancy. The type and location of the gates will be determined during final design.

E.7.1 Sluice Gates

Sluice gates will be heavy-duty, flat-back frame type meeting the requirements of AWWA C501. Materials of construction will be as follows in Table E-1.

Table E-1. Sluice Gate Materials

Component	Material
Gate, guide, and frame	ASTM A126, Class B, cast iron
Seating faces	ASTM B103 or B 139, bronze
Wall thimbles	ASTM A126, Class B, cast iron
Stems	ASTM A276, stainless steel, Type 316
Wedges, thrust nut, stem couplings, fasteners and adjusting hardware	ASTM A276, stainless steel, Type 316, or ASTM F593 and F94, stainless steel, group 1 or group 2
Yoke	ASTM A126, Class B, cast iron
Flush bottom seal	Neoprene
Flush bottom retainer bar	ASTM A276, stainless steel, Type 316

E.7.2 Stop Gates

Stop gates will be self-contained, embedded type meeting the requirements of AWWA C561. Materials of construction will be as shown in Table E-2.

Table E-2. Sluice Gate Materials	
Component	**Material**
Frame Guides and Invert	Stainless Steel, Type 316, ASTM A240
Slide, Stiffeners and Lifting Handle	Stainless Steel, Type 316, ASTM A240
Anchor Studs, Fasteners and Nuts	Stainless Steel, Type 316, ASTM A276
Invert Seal	Neoprene ASTM D2000 or Buna-N
Seat/Seal and Facing	Ultra High Molecular Weight Polyethylene ASTM D4020

E.8 Piping, Valves, and Accessories

The following describes the general requirements for piping, fittings, valves, and accessories. Piping, fittings, and valves will be as designated in the piping specification sheets (PIPESPEC) to be developed during detailed design.

E.8.1 Flanges and Pipe Threads

Flanges on equipment and appurtenances will conform in dimensions and drilling to ANSI B16.1, Class 125. Pipe threads will conform in dimension and limits of size to ANSI B1.1, coarse thread series, Class 2 fit.

Threaded flanges will have a standard taper pipe thread conforming to ANSI B1.20.1. Flanges will be flat-faced whenever practical.

Flange assembly bolts will be heavy pattern, hexagonal head, carbon steel machine bolts with heavy pattern, hot-pressed, hexagonal nuts conforming to ANSI B18.2.1 and B18.2.2. Threads will be Uniform Screw Threads, Standard Coarse Thread Series, Class 2A and 2B, ANSI B1.1.

E.8.2 Ball Valves

Ball valves 2-inches and smaller will be threaded, full bore, will have bronze or brass bodies, balls and stems, and Teflon seats at both ends. Valves will be rated at 300 psi and will be so constructed as to make positive shutoff with flow in either direction.

Ball valves larger than 2-inches will be flanged, full bore, will have carbon steel or ductile iron bodies, balls and stems, and Teflon seats at both ends. Valves will be rated at 275 psi and will be so constructed as to make positive shutoff with flow in either direction.

Ball valves will be used for isolating service on water service applications.

E.8.3 Pipe Supports

Pipe hanger and support selection and application will conform to the requirements of MSS SP-69, FEDSPEC WW-H-171e and governing state and local codes. In case of conflict, governing state or local codes will be followed. Pipe hanger and support materials, design and manufacture will conform to the requirements of MSS SP-58. Pipe hanger and support fabrication and installation will conform to the requirements of MSS P-89. Metal framing system components and application will conform to MFMA-2 and MFMA-101.

Pipe hangers and supports, structural attachments, fittings and accessories will be Type 316 stainless steel. Nuts, bolts and washers will be Type 316 stainless steel.

For pipes less than 12-inches in diameter, the supports will be designed by the Contractor.

E.8.4 Seismic Restraints

The seismic restraint system will be designed by the professional engineer retained by the construction contractor for design of the pipe support systems. Seismic restraint details will be designed in conjunction with preparation of pipe hanger support system drawings. All drawings and calculations for the seismic restraint system will bear the professional engineer's registration seal and signature.

Pipe restraint materials, design, manufacture, testing, installation and application will conform to the requirements of MSS SP-58, MSS-SP-69, MSS-SP-89, MFMA-2, and MFMA-101. Restraints, including braces, and pipe and structural attachments, will be Type 316 stainless steel. Nuts, bolts and washers will be Type 316 stainless steel. For corrosive areas, all pipe support, anchor and brace components (not just fittings and accessories) will be made of fiberglass.

E.8.5 Expansion Control

The expansion control system will be designed by the professional engineer retained by the construction contractor for design of the pipe support systems. Expansion control details will be designed in conjunction with preparation of pipe hanger support system and seismic restraint systems drawings. All drawings and calculations for the expansion control system will bear the professional engineer's registration seal and signature.

Anchors and guides will be manufactured of 316 stainless steel, including braces, pipe and structural attachments, and will be hot-dip galvanized after fabrication. Supports cast integrally with cast iron fittings will be specifically prohibited for use in any application where shear forces may be imposed on the support. Nuts, bolts and washers will be Type 316 stainless steel.

E.8.6 Miscellaneous

Exposed piping, interior and exterior, and piping in ceiling spaces, pipe trenches, pipe chases, and pipe galleries will be identified with plastic legend markers and directional arrows located at each side of the walls, floorings, and ceilings, at one side of each piece of equipment, at piping intersections, and at approximately 50 foot centers.

Connection of ferrous to nonferrous metal piping will be with an insulating section of rubber or plastic pipe having a minimum length of 12 pipe diameters or with a dielectric union.

Buried ferrous piping will be corrosion protected by coating with liquid epoxy conforming to ANSI/AWWA C210, polyethylene tape coating conforming to ANSI/AWWA C214, fusion epoxy, or other cathodic protection determined by the soils report.

Buried ductile iron piping will be corrosion protected by coating with asphaltic coating conforming to ANSI/AWWA C151/A21.11 and wrapped with polyethylene film conforming to ANSI/AWWA C1051A21.5.

Attachment F: Electrical and Power Requirements

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Attachment F: Electrical and Power Criteria

This section describes the electrical design criteria and construction standards for the design of the RLS. Included in the design criteria are the electrical distribution system, MCCs, VFDs, starters, conduit and wiring.

F.1 Standard Definitions and Abbreviations

The following standard definitions and abbreviations are used throughout this section.

1. Authority Having Jurisdiction (AHJ) – An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.
2. Corrosive Location – An area normally subject to corrosive gasses or liquids. Material types for enclosures, conduit and conduit supports will be compatible with corrosive gasses or liquids and not subject to premature failure.
3. Damp Location - Locations protected from weather and not subject to saturation with water or other liquids but subject to moderate degrees of moisture. Examples of such locations include partially protected locations under canopies, marquees, roofed open porches, and like locations, and interior locations subject to moderate degrees of moisture, such as some basements, some barns and some cold-storage warehouses.
4. Dry Location – A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.
5. GRS-PVC (conduit) – Galvanized Rigid Steel with Polyvinyl Chloride coating.
6. RAC-PVC (conduit) – Rigid Aluminum Conduit with Polyvinyl Chloride coating.
7. Hazardous (Classified) Location – A location that is classified based on the properties of the flammable vapors, or gases, combustible dusts, or fibers that might be present and the likelihood that a flammable or combustible concentration or quantity is present. The following NFPA 820 hazardous location classifications are as follows:
   a. Class I, Division 1 Location: A location (1) in which ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors can exist under normal operating conditions; or (2) in which ignitable concentrations of such flammable gases, flammable liquid-produced vapors, or combustible liquids above their flash points may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown of faulty operation of equipment or processes might also cause simultaneous failure of electrical equipment to become a source of ignition. Classification of locations are subject to NFPA 820.
   b. Class I, Division 2 Location: A location (1) in which volatile flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors are handled, processed, or used, but in which the liquids, vapors or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; (2) in which ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors are normally prevented by positive mechanical ventilation and which might become hazardous through failure or abnormal operation of the ventilation equipment; or (3) that is adjacent to a Class I, Division 1 location and to which ignitable

concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors above their flash point might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided. Classification of locations is subject to NFPA 820.

8. I/O – Input and Output – Used to describe any program, operation or device that transfers data to or from a computer and to or from a peripheral device. Every transfer is an output from one device and an input into another.
9. Intrinsic Safety – A type of protection in which a portion of the electrical system contains only intrinsically safe equipment (apparatus, circuits, and wiring) that is incapable of causing ignition in the surrounding atmosphere. No single device or wiring is intrinsically safe by itself (except for battery-operated self-contained apparatus such as portable pagers, transceivers, gas detectors, etc., which are specifically designed as intrinsically safe self-contained devices) but is intrinsically safe only when employed in a properly designed intrinsically safe system.
   a. Intrinsic Safety Barrier: A component containing a network designed to limit the energy (voltage and current) available to the protected circuit in the hazardous (classified) location under specified fault conditions.
   b. Intrinsically Safe Circuit: A circuit in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable of releasing sufficient electrical or thermal energy to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentration.
   c. Intrinsically Safe Equipment (apparatus, circuits, and wiring): Equipment and wiring that, under normal or abnormal conditions, are incapable of releasing sufficient electrical or thermal energy to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentration.
10. Labeled Equipment – Equipment or materials, to which has been attached a label, symbol, or other identifying mark of an organization concerned with product evaluation, that may maintain periodic inspection of the production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.
11. LED – Light Emitting Diode
12. Listed – Equipment, materials or services included in a list published by an organization acceptable to the AHJ that is concerned with evaluation of products, that conducts periodic inspection of the production of the listed equipment or materials, and whose listing states either that the equipment, material or service meets appropriate designated standards, or has been tested and found suitable for a specified purpose.
13. MCC – Motor control center – A means to provide a convenient method for grouping motor control, as well as associated distribution equipment.
14. PLC – Programmable Logic Controller – A digital computer used for automation of electromechanical processes.
15. PPE – Personal Protective Equipment – Refers to protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury.
16. Qualified Person – One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.

17. SCADA – Supervisory Control and Data Acquisition – Type of industrial control system, computer controlled system that monitor and control industrial processes that exist in the physical world.
18. Short Circuit Rating – The value of symmetrical fault current at a nominal voltage that an apparatus or system can withstand without sustaining damage within a defined acceptance criteria.
19. THD – Total Harmonic Distortion.
20. UPS – Uninterruptable Power Supply.
21. VFD – Variable Frequency Drive.
22. Wet Location – Installations underground or in concrete slabs in direct contact with the earth; in locations subject to saturation with water or other liquids such as vehicle washing areas or areas requiring wash down by operations staff; or in unprotected locations exposed to weather.

F.2 Power Distribution and Utility Coordination

The following power distribution and utility coordination will be conducted with the Headworks design team and outside utilities.

F.2.1 RLS Load Capacity

A detailed load analysis and load calculation will be provided to the engineering firm responsible for the Headworks facility electrical infrastructure design in order to determine the impact of the RLS loads on the new Headworks power distribution system. The load analysis will be based on the NEC requirements and operational requirements of the RLS.

F.2.2 Short Circuit Calculations

Power system short circuit analysis for all new electrical equipment will be coordinated with the engineering firm responsible for the Headworks facility electrical infrastructure design.

F.2.3 Distribution

The circuit breakers supplying each RLS load will be provided by others. The sizing of the breakers will be coordinated with engineering firm responsible for the Headworks facility design.

F.2.4 Utilization Voltage

Utilization voltage will be as follows:

- 480V, three phase (3Ø), 60Hz for all motors 1 HP to 500 HP.
- 120/240V for controls, receptacles and lighting circuits.
- 24VDC for low voltage control and signals.

F.2.5 Power Quality

Voltage regulation will include maintenance of voltage regulation to ±3 percent under normal conditions. Harmonic interference will be mitigated with sensitive equipment as necessary. Individual current harmonics will be limited to no greater than the values listed in Table 2 of IEEE 519 – 2014 for the ratio of short circuit to load current that is applicable to each point of common coupling. Total voltage harmonic distortion will be limited to not greater than 5 percent at this point.

F.2.6 Voltage Drop

Voltage drop calculations confirming available voltage at equipment during motor start and run conditions will be completed. Calculations will be completed for conductor runs over 250 feet.

Calculations will incorporate limiting the starting voltage drop to less than 10 percent and running voltage drop to less than 3 percent for branch circuitry, and not exceeding 5 percent for feeder and branch circuit combined.

F.3 Standby Power

Standby power under the current pump configuration will be supplied by others as part of the Headworks facility power.

F.4 Electrical Equipment

The following electrical equipment will be incorporated into the RLS design.

F.4.1 Variable Frequency Drives (VFDs)

Most of the pumps will include VFDs. The VFDs will be of the latest technology and used to control and maintain a process variable (level, flow, pressure, speed, etc.) by varying the motor speed. The VFDs will constantly monitor the load current with an electronic thermal overload relay and shutdown the drive on motor overload. The electronic overload relay will be adjustable and compensate for the reduced cooling of the motor at reduced speeds.

For each programmed warning and fault protection function, the drive will display a message in complete English words or Standard English abbreviations. The three (3) most recent fault messages along with time, current, speed, voltage, frequency and digital input status will be stored in the drives fault history. The last ten (10) fault names will be stored in the drive memory.

Transient and surge voltage power line input and output protection will be provided for each VFD through use of metal oxide varistors (MOVs), phase-to-ground filter capacitors, or other approved equal methods. Eighteen pulse VFDs will be provided for all motors 100 HP and greater and will be the free-standing type.

The VFDs will be located indoors, in climate controlled rooms located in the Headworks facility electrical room. The room or enclosures will include environmental controls to maintain an internal temperature less than 40 Degrees Celsius.

VFDs will be configured to reset automatically after a power failure (no manual reset required) to continue automatic operation by the RLS control system. External control circuits and devices will be 120 VAC unless derived from the VFD 24 VDC supply. External devices such as pilot lights, meters, relay, and other miscellaneous equipment will be 120 VAC.

VFDs will be provided with a door-mounted, alpha-numeric human interface module (HIM) digital display with keypad to view and adjust the setpoints, parameters, diagnostic, and status indicators. Ethernet communications for non-essential data will also be provided.

VFDs will be provided with the following protection:

- Inrush current limit
- Ground fault
- Over-temperature heat sink thermal switch to protect against excessive ambient temperature or loss of cooling
- DC bus protection
- Under voltage
- Over frequency

- Input or output phase loss
- Speed compensated electronic motor overload current

Requirements of the latest addition of IEEE 519 at the Point of Common Coupling (PCC) will be considered while assessing the impact of harmonics from new VFDs on the overall power system at the PCC. Each VFD will come equipped with harmonic mitigating equipment such as, but not limited to, input line reactors or active harmonic filters. The design will consider either of these options to mitigate harmonics and will be coordinated with the Headworks facility electrical infrastructure system.

A maximum allowable audible noise from the VFD system will be 85 A-weighted decibels (dBA) at a distance of one (1) meter (3.3 feet) at any speed or load condition. VFDs with output dv/dt filters will be provided when the motor load exceeds the manufacture's recommended distance to mitigate waveform distortion at the motor. VFDs will be Eaton SVX9000 series (100HP and less) and Eaton CPX9000 series (greater than 100 HP), Allen-Bradley/Rockwell PowerFlex 755 series, or equal.

F.4.2 Full Voltage Non-Reversing (FVNR) Motor Starter Units

Full voltage non-reversing starters units will be provided for all motors not using a VFD and be rated for a minimum of 65,000 RMS symmetrical amperes or as deemed necessary after coordinating with the engineering firm designing the Headworks facility motor control centers (MCCs).

Contactors will be full voltage, 3 pole, 600 volt AC, NEMA Size-1 minimum. Contacts will be double break, silver-cadmium oxide and weld resistant. Contacts will be isolated to prevent arcing. Coils and magnets will be capable of being removed or replaced without special tools.

Control power for starter units will be derived from individual 120 VAC control power transformers with secondary fuses that include blown fuse indicators. All starter units will be rated and designated in accordance with NEMA standards. Contactors designated as IEC ratings or with dual IEC/NEMA ratings will not be allowed.

FVNR motor starters will include a molded case motor circuit protector (MCP) to provide an instantaneous trip for short circuit protection. The trip setting will be adjustable to at least 130 percent of the NEC motor full load current (FLC). FVNR motor starters will also include a solid state motor overload relay with Class 10A, 10, 20, or 30 selectable tripping characteristics. The overload trip setting will be adjustable from 85 percent to 140 percent of motor nameplate full load ampere (FLA) rating.

F.4.3 Electrical Enclosures and Boxes

Enclosures will be per SVCW standards and NEMA rated for installed locations with fast access door latches. Enclosure construction will be 14 gauge minimum with continuously welded seams. Outer door will have provisions for locking enclosure with standard padlock. Enclosure ratings are listed in Table F-1.

Table F-1. Enclosure ratings

Item	NEMA Rating	Material	Closure Type	Notes
Local Control Panels	NEMA 4X	FRP	Latch-bale type closures with hinges per vendor design.	Generally in close proximity to equipment and processes and so exposure to water, gases, sludge, etc. require the NEMA 4X rating
PLC & RIO Panels	NEMA 4X	FRP	Latch-bale type closures with hinges per vendor design.	Generally in close proximity to equipment and processes and so exposure to water, gases, sludge, etc. require the NEMA 4X rating
Junction Boxes	Per design engineer with possible review by SVCW as warranted	Per design engineer with possible review by SVCW as warranted	Per design engineer with possible review by SVCW as warranted	
Pull Boxes	Per design engineer with possible review by SVCW as warranted	Per design engineer with possible review by SVCW as warranted	Per design engineer with possible review by SVCW as warranted	
VFD enclosures	NEMA 12	Painted Steel	Full piano hinge and three point lockable door latch.	Protection from gasses, dust, water drip & dust.
LOS Boxes	NEMA 4X	316 SS	Lift off/screw on covers.	At the Equipment. Wall mounted or pedestal mounted.

Notes:

1.NEMA 4X panels/boxes become 3R when penetrated, but 4X is the starting basis for the panels and boxes specified to be purchased/provided by the contractor.

2. If local hazards drive a higher level of protection such as NEMA 7, the higher level of protection will be used in lieu of the designation above.

3. Panels located outside expose to sun will be 316 stainless steel. FRP will not be installed where subject to direct sun exposure.

A full-height, white-back pan, thermoplastic data pocket mounted on the inside door and 10 tap (min) copper ground bus will be provided. Enclosures with accessories including a breaker to disconnect incoming power, pad lockable disconnect for breakers used in circuits above 120 volts, dead front door, heater, fan, removable metal filters, louvers and thermostats will be provided. Enclosure will be provided with engraved phenolic nameplate.

Terminal boxes installed at the wet well area will be sized per NEC fill and conductor radius requirements. The terminal box type and installation will meet the requirements of NEC Article 500 and 501 if located in a hazardous area. The terminal box will provide hard mounted lugs for motor conductors larger than 10 AWG as well as din rail mounted terminal blocks for the motor temperature and moisture (leak) sensors conductors. A physical barrier between 480V and 120V circuits inside of the termination box will be provided. Din rail mounted terminal blocks will be coordinated with the pump control conductors and rated at 600 volt minimum. Power terminal blocks will be coordinated with the pump cables and rated at 600 volt. The design of the enclosure and conduit penetrations will allow for pump cable entry without requiring conduit or cable seals on these cables. The enclosure will be rated as corrosion resistant and weatherproof, NEMA 4X 316 Stainless Steel. Terminal box will be installed a minimum of 18" above finished grade. Copper ground bar with lugs sized for ground conductor, cable supports and cable connectors will be provided.

F.4.4 Lockout Stop Pushbutton Control Stations (LOS)

Control stations will consist of a NEMA 4X, 316 stainless steel enclosure, a 2-position pushbutton with maintained push and pull operation, and a padlock attachment. The lockout stop pushbutton control station will be as manufactured by Eaton Cat #10250TN33 enclosure, #10250T5B62 pushbutton with a 10250Ta64 padlock attachment or equal. Auxiliary contacts on the pushbuttons for LOS status to SCADA will be used.

F.4.5 Wiring Devices

Three phase receptacles will be suitable for 480 volt, 3-phase, 3-wire service with ampere ratings as specified. Receptacles and plugs will be designed so that the grounding pole is permanently connected to the housing. The grounding pole will make contact before the line poles are engaged when the plug is connected to the receptacle housing. The plug sleeve will also make contact with the receptacle housing before the line and load poles make contact. Receptacles will be provided complete with cast back box, angle adapter, gaskets, and a gasketed screw-type, weathertight cap with chain fastener. Each receptacle will be provided with one plug.

Receptacles for use in hazardous areas will be rated in accordance with NEC for the area in which they are to be located and will be factory sealed. Receptacles will be designed so the plug must be inserted and turned before load is energized. Receptacles will be provided with mounting box, sealing chamber, and compatible plug.

F.5 Cable Requirements

F.5.1 Low Voltage Conductors

Conductors will be copper with 600 volt minimum rated insulation and Class C stranded. The insulation or jacket will be marked with the manufacturer's name or trademark, conductor size, insulation type and UL label. Power and control conductors will have insulation type XHHW-2, rated 90 degrees Celsius in dry and wet locations, and oil resistant.

Lighting and receptacle conductors will have insulation type THHN/THWN, 19 strand, rated 90 degrees Celsius in dry locations and 75 degrees Celsius in wet locations, and oil resistant. Seven strand conductors are not acceptable.

Power circuit conductors will be minimum 12 AWG. Signal circuit conductors will be minimum 14 AWG. The number of conductors routed in conduits will be per NEC conduit fill requirements. Splices will be made with water-tight kits manufactured by 3M or Raychem. Motor terminations will be made with motor disconnect/boot kits. Power conductors from VFDs to motors will be minimum 600 volt, VFD rated.

F.5.2 Equipment Internal Wiring

Internal wiring conductors will be copper with 600 volt rated insulation – Type MTW, NFPA standard 79. The conductors for individual circuits 100 volt and above will be 16 AWG.3. Conductors for individual circuits below 100 volt will be 18 AWG.

F.5.3 Instrument Wiring

Instrument wiring will conform to UL 2250, UL 1581, and NFPA 70 Type ITC. Field instrument cables will be rated 600 volt, with twisted pair 16 AWG conductors, 100 percent individual and overall foil shield coverage, and drain wire.

F.5.4 Data Cable

Data cables will be Category 6 cables. Data network cable (indoor) will be multi-conductor, four (4) pair unshielded twisted pair with 24 AWG solid conductors. The cable will be rated per IEEE for the service intended. Data network cable (outdoor) will be multi-conductor, four (4) pair shielded twisted pair with 24 AWG solid conductors. The cable will be rated per IEEE for the service intended.

F.6 Conduit

Conduit types will be designed per area designations and use according to the following criteria:

- Data conduits: Rigid Aluminum Conduit, PVC coated (RAC-PVC), the entire length of the run
- Dry areas: Rigid Aluminum Conduit (RAC)
- Wet areas: Rigid Aluminum Conduit, PVC coated (RAC-PVC)
- Corrosive areas: Rigid Aluminum Conduit, PVC coated (RAC-PVC) or PVC Schedule 80 (PVC-80)
- Class I hazardous area: Rigid Aluminum Conduit (RAC) and Rigid Aluminum Conduit, PVC coated (RAC-PVC) when required in other designated areas.
- Stud framed walls in insulated and temperature controlled buildings: Electrical Metallic Tubing (EMT)
- Concrete block or brick walls: PVC Schedule 40 (PVC-40)
- Direct buried conduits and duct banks: PVC Schedule 80 (PVC-80)
- Beneath floor slab-on grade: PVC Schedule 40 (PVC-40)
- Transition from underground to above ground: Rigid Aluminum Conduit, PVC coated (RAC-PVC)

Twenty percent spare conduits for power, control, signal, and communication types (1-inch diameter minimum) will be provided in duct banks between MCCs, switchboards, electrical rooms, PLC cabinets, major process area pull boxes, handholes and manholes.

F.6.1 Conduit Requirements

Rigid aluminum conduit, couplings, bends and nipples will be in accordance with NECA 102. Flexible conduit will only be installed in exposed or accessible locations and will be less than 36-inches (1/2-inch minimum trade size). Flex connectors will be PVC coated when connected to RAC-PVC conduits or when located in a NEMA 4X area. Conduit between vibrating equipment and outlet boxes or conduits will be liquid tight flexible electrical conduit.

F.6.2 Conduit Installation

Conduit transition (from below to above grade, through walls, through concrete, etc.) will be RAC-PVC. The transition will be made below grade at the final sweep RAC-PVC elbow or 1-foot minimum before the transition for exposed conduit. RAC-PVC conduit will extend 1-foot minimum beyond the transition. The conduit transition will conform to NEC requirements in classified areas.

The entire electrical raceway system will be bonded to form a continuous conductive path from service point to all electrical equipment. Metallic conduits terminating at concentric knock-outs or reducing washers will be bonded using insulated grounding bushings. Grounding bushings will be connected to the grounding system using conductors sized in compliance with NEC. Conduit connected to enclosures that are outdoors, exposed to weather, or in areas subject to excessive moisture will be fitted with water tight sealing hubs. Surface mounted raceways for lighting, HVAC and receptacles are permitted.

Rigid conduit will be supported at 10-foott intervals and PVC conduits at 5-foot intervals except where NEC requires additional support at lesser intervals. All conduits will be supported within 3-foot of boxes or changes in direction. Vertical conduit risers will use riser supports with clamps. For multiple conduit runs, conduits will be grouped together and supported from the ceiling by means of trapeze hangers. Conduits installed outdoors or in corrosive areas above grade will be braced in place with stainless steel Unistrut stanchions and PVC coated clamps with back plates. Single hole conduit supports will not be permitted.

Spare conduits for future use will have a pull cord and be capped with a cap or coupling and plug. Each spare conduit will be checked with a mandrel. A waterproof label will be provided on each end of pull cords in spare conduits to indicate the location of the other end.

All conduit and wire associated with removal or demolition of any equipment will be recycled or disposed. Conduits will not penetrate any water bearing walls or slabs subject to flooding. Raceways passing through the boundary between a classified and unclassified area will include seals if required per NEC Article 501.

F.6.3 Underground Boxes

All underground boxes located in paved areas or other areas will vehicle traffic will be H-20 loading rated and have traffic rated metal covers. Boxes over 2 x 3 feet will be double leaf assemblies with end hinged, torsion spring opening assist-type covers.

Concrete perimeter skirts will be poured around underground boxes in paved areas. The skirt will extend a minimum of six-inches horizontally and twelve-inches vertically around the box. Extension sections for boxes will be specified to reach the depth of underground conduits with a maximum depth of 48-inches. Eighteen-inches (minimum) of ¾-inch crushed rock will be provided under the lowest section of pull box, extending 8-inches outside pull box perimeter.

The 4/0 AWG bare copper ground will continue through pull box when used with conduit duct bank. A screw-type copper ground bus will be provided in each box to terminate duct bank ground cables. The pull box cover frame, cover and other exposed metal parts will be grounded to the grounding system. A 10-foot long, ¾-inch diameter ground rod will be provided inside all manholes. All covers will be engraved or bead welded (minimum thickness ¼-inch) “ELECTRICAL” or “CONTROL” as applicable with specific pull box numbers.

The number of directional changes of the conduit will be limited to total no more than the equivalent of 270 degrees in any run between pull points. Pull boxes will be installed for ease of pulling and as necessary to meet code requirements. Conduit runs between two vaults, pull or junction boxes will be limited to a maximum of 300 feet, or less 50 feet for every 90 degrees of conduit change in direction. A maximum of three equivalent 90 degree elbows are allowed in any continuous conduit run.

F.7 Electrical Identification

The following electrical identification system will be used for the various electrical components.

F.7.1 Equipment

All equipment numbering will be as shown on the P&IDs. Each major piece of electrical equipment will have a manufacturer’s nameplate showing the name, model designation, part and model number, serial number and pertinent ratings such as voltage, amperage, number of phases, range, calibration, etc.

All equipment will have rigid laminated black phenolic plastic nameplates with beveled edges and white lettering. Engraved aluminum nameplates secured with stainless steel screws for outdoor equipment will be provided. No letters will be smaller than 3/16-inch.

F.7.2 Conductors

All wires, field and interior to equipment, will be identified with wire labels on both ends of each wire.

Wire labels will be machine printed on with white heat shrinkable tubing. The labels will be shrunk to a loose fit on the wires. Wire labels for lighting and receptacle circuits will consist of the panel board and circuit number and a unique node number.

Wire color codes will be as shown below:

A. CONTROL CONDUCTORS:

Single-conductor control conductors will have the following colors for the indicated voltage listed in Table F-2:

Table F-2. Single-conductor Control Conductors Color Coding

Control Conductor	120V
Power (AC)	Black
Control (AC)	Red
Neutral	White
Ground	Green
Foreign Voltage (DC)	Blue/White
Foreign Voltage (AC) Non-powered contact interface	Yellow
Power (DC)	Blue
Control (DC)	Violet

B. POWER CONDUCTORS:

Power conductors will have the following colors for the indicated voltage listed in Table F-3:

Table F-3. Power Conductor Color Coding

Power Conductor	480V	240/120V
Phase A	Brown	Black
Phase B	Orange	Red
Phase C	Yellow	Blue
Ground	Green	Green
Neutral	Gray	White

The cables may be black with colored 3/4-inch vinyl plastic tape applied at each cable termination. The tape will be wrapped with 25 percent overlay to provide 3-inches minimum coverage.

F.7.3 Conduits

Power and control conduits will be identified on the drawings. Conduit will have conduit tags at both ends of each conduit run and where conduit enters and leaves an open transition point such as junction boxes, terminal boxes, pull boxes, vaults, and manholes, etc. All conduits will have unique conduit names, including spare conduits. Conduit prefixes will be as follows:

C – Control wires

D – Data / Communications

H – Medium voltage (voltage > 1000 V)

P – Power wires (480 V– 120 V)

S – Signal wires (low voltage analog)

X – Spare

Tag material will be aluminum with machine stamped lettering. The size of the tag will be ½-inch high. No letters are allowed smaller than ¼-inch. The tag will be attached to the conduit with 316 stainless steel wire of the type normally used for this purpose. Stainless steel wire will be crimp connected. Twisting tagging wire ends together is not acceptable.

F.8 Lighting Requirements

Area lighting for each site will be from LED pole mounted lamps with 120 volt weatherproof GFI receptacles in each pole. Lighting products will minimize up-light and illuminate only the subject area. All indoor areas will be provided with switchable circuits with a minimum number of non-switched lighting fixtures for personal safety. Motion activated primary lighting may be provided in infrequently visited areas to the extent that is suitable for the environmental and safety conditions of the area. Illumination levels will be established in compliance with California Title 24 energy levels, with illumination level goals as follows:

AREA	MAINTAINED FOOT CANDLES (FC)
a. Mechanical equipment rooms	30 FC
b. Outdoor areas	Compatible with existing systems. (Generally 1-2 FC)

Lighting circuits will be 120 volts or 277 volts as economically determined for each area, except the outdoor lighting system will be 120 volt or 240 volt. All new lighting fixtures will be suitable for use with LED lamps. Per SVCW standard on lights, BAYLED78W (no equal) for all indoor lights will be provided. Lighting panel boards will be provided by others.

Convenience (120 volt) receptacles will be provided in all new areas of the RLS. Receptacles will be powered from different circuits than the lighting fixtures. Where convenient, these circuits may occupy the same raceways. Receptacles located outdoors will include ground fault interrupters and weather proof wet-in-use covers. Receptacles will use pressure lugs to accommodate 19 strands THHN or other suitable conductors.

F.9 Site Design

Electrical systems will be heavy-duty industrial type with a design emphasis placed on safety, reliability, maintainability and economics. It is the intent to secure the highest quality in all materials and equipment in order to facilitate operation and maintenance of the RLS. All equipment and materials will be new and the products of reputable suppliers with adequate experience in the manufacture of these particular items will be used. All electrical equipment will be UL listed.

All equipment will be designed for the service intended and will be of rugged construction, of ample strength for all stresses which may occur during fabrication, transportation, erection and continuous or intermittent operation. All equipment will be adequately braced and anchored and will be installed in a neat and workmanlike manner. Appearance and safety, as well as utility, will be given consideration in the design of details. All components and devices installed will be standard items of industrial grade and will be of sturdy and durable construction suitable for long, trouble-free service. Light duty, fragile, or competitive grade devices will not be acceptable for use.

Electrical and instrument installations will be made at the SVCW WWTP that is continuously receiving and processing wastewater. The contractor will schedule all required work with SVCW, including all shutdown periods. Each shutdown will be scheduled to minimize disruption of WWTP operations. Shutdowns may have to be scheduled outside of normal working hours when flow is at a minimum. The work will not disrupt any existing operations without prior approval by SVCW.

F.9.1 Safety

Power system short circuit, coordination, and arc flash analysis for all new electrical equipment will be coordinated with the engineering firm responsible for the Headworks facility electrical infrastructure design. Design will meet the requirements of the NEC and NFPA 70E. Classified areas will be identified and designed to meet the requirements of NFPA 820.

F.9.2 Reliability

The design will consider the reliability of the power distribution system and how the RLS electrical equipment connections are configured. Reliability is defined as a measurement of the ability of a component or system to perform its designated function without failure. When designing the electrical system, the following elements will be incorporated:

- Standby Generator – Confirm that a standby generator provides capacity (sufficient to power the pump stations vital components) in case of failure of normal plant power.
- Redundancy - The redundancy of vital components within a system ensures reliability of the power supply to the vital component loads by providing alternate paths for the electrical power supply.
- Sizing - Correct sizing of vital components of the electrical distribution system prevent premature component failure and maintain reliability of the system.
- Coordination - Electrical protective devices need to be sized and set to provide fast isolation of electrical faults and minimum interference with the remaining healthy system. Poor coordination between protective devices reduces the reliability of the system.
- Protection - Judicious placement of equipment or physical protection of vital components of the electrical system prevent possible physical damage.

F.9.3 Underground Conduits and Duct Banks

All equipment and instrumentation located below grade fed by conduits from above grade will have conduit drain boxes. Conduit interiors will be plugged with a sealant to keep water from traveling down conduits into equipment or instrumentation. Drain boxes will not be located over or on top of electrical panels.

Underground conduits outside of structures, excluding utility conduits, will have a minimum cover of 24-inches. Signal conduits will be separated from power and control conduits by a minimum of 12-inches.

Detectable warning tape will be buried approximately 12-inches above all underground duct banks and other conduits runs over 10-feet in length. Detectable warning tape will be aligned parallel to and within 3-inches of the centerline of the conduit or duct bank. Red tape for “Electric” service and orange tape for “Communication” service will be used. Labels will be provided for all pull boxes and at end of parallel runs and tees.

A minimum of 20 percent spare conduits will be provided in main duct banks with a minimum size of 1-inch. All duct banks that are installed under roadway or motor vehicle pathways, will be concrete reinforced to protect the conduits. Duct banks will include a 4/0 AWG bare copper ground wire that is connected to the plant ground grid at least at one point.

F.9.4 Grounding System

The RLS grounding system will consist of a buried perimeter ground grid, 4/0 AWG bare copper wire, with ground test wells The RLS ground grid will be connected to the new Headworks facility ground grid or the existing plant ground grid using 4/0 AWG bare copper wire.

The ground grid will have copper-clad ground rods driven to a depth of 10-feet. Building steel, pumping equipment, all electrical equipment and enclosures, and exposed metal that might become a current carrying conductor will be connected to the ground grid to limit touch potential. An equipment grounding conductor sized per applicable codes will be run in all raceways carrying power conductors. Ground connections that are buried or embedded will be made by the exothermic welding method.

F.9.5 Equipment Layout

The following will be required for equipment layout:

- Minimum clear working space around all electrical equipment as required by the NEC.
- Climate controlled rooms for efficient cooling and heating for the new equipment and to maintain ambient temperature rating of equipment.
- Housekeeping pads for all pad mounted equipment. Housekeeping pads will be 3-1/2-inches above surrounding finished floor or grade unless otherwise shown and will be 4-inches larger in width on all sides of equipment. Concrete will be precisely leveled so that equipment set in place will not require shimming.

The use of concealed conduits will be maximized where possible. However, conduits embedded in concrete slabs will not exceed the limit at which the concrete slab integrity becomes compromised. The electrical engineer will coordinate with structural design regarding location of concrete embedded conduits.

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Attachment G: Sole Source Equipment, Product and Service List

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EQUIPMENT IN USE AT WASTEWATER TREATMENT PLANT CONSIDERATION AND APPROVAL TO SOLE SOURCE EQUIPMENT

ISSUE
Approval to sole source specific equipment in use at the SVCW Wastewater Treatment Plant.

BACKGROUND
SVCW's purchasing guidelines are delineated by the charter of the City of Redwood City which, in turn, is guided by the California Public Contracts Code (PCC). One of the statutes in the PCC (Section 3400) restricts public agencies from drafting specifications for bids (1) in a manner that limits the bidding, directly or indirectly, to any one specific concern, or (2) calling for a designated material, product, thing, or service by specific brand or trade name unless the specification is followed by the words "or equal," so bidders may furnish any equal material, product, thing, or service. However, this subdivision is not applicable under certain circumstances, including: (1) in order for a field test or experiment to be made to determine the product's suitability for future use (2) in order to match other products in use on a particular public improvement either completed or in the course of completion (3) in order to obtain a necessary item that is only available from one source or (4) in order to respond to an emergency declared by a local agency or by the state.

Staff last presented lists of equipment that has been standardized or proven to be effective for the delineated uses to the Commission in August 2013. The Commission approved the lists of equipment allowing staff to proceed with sole source purchase, when the need arises, to replace the listed equipment. From August 2013 to now, one additional piece of equipment has been identified as needing to be standardized to match existing equipment.

DISCUSSION
Under PCC Section 3400, SVCW is allowed to utilize specific equipment without specifying "or equal" manufacturers and equipment (sole source). To facilitate equipment specifying and purchasing, staff is requesting that one additional item be added to the previously approved list of equipment. The addition to the existing list is indicated by italicized text and shaded cells in the following table.

Equipment to Match Existing for Standardization:

Equipment	Manufacturer	Location Used	Reason for Sole Source
Electric Valve Actuator[1]	*Rotork*	*Process Piping*	*Match Existing Equipment for Standardization and Proven Effective and Reliable*

Report By: AMB for TH

Gas Flow Monitoring	FCI	Biogas and Natural Gas Systems	Match Existing Equipment for Standardization and Proven Effective and Reliable
Thermal Dispersion Flow Monitoring	FCI	Hot Water and Lube Oil Systems	Match Existing Equipment for Standardization and Proven Effective and Reliable
Sludge Heat Exchanger	Alpha-Laval	Sludge Heating System	Match Existing Equipment for Standardization and Proven Effective and Reliable
Radar Level Transmission	Magnetrol	Process Tanks	Match Existing Equipment for Standardization and Proven Effective and Reliable
Pressure Switch	Ashcroft	Process Piping	Match Existing Equipment for Standardization and Proven Effective and Reliable
Power Distribution Panel[2]	Eaton Cutler-Hammer	Electrical Power Distribution	Match Existing Equipment for Standardization
Paints and Coatings	Sherwin-Williams	Walls, Tanks, Digester Domes, Piping	Standardize, Proven Effective and Reliable; also Tested as Effective and Recommended
Chlorine Analyzers	DULCO	Disinfection, Recycled Water, Dechlorination	Match Existing and only one found to work consistently
Hypochlorite and bi-sulfite peristaltic dosing pumps	Watson Marlow	Hypo and bisulfate storage tanks	Standardized and proven effective
Hydrogen Sulfide Meter	Arizona Instrument	Digester Gas and various staff and instrument buildings	Match Existing Equipment (2) which have operated for 18 years
Flow-through Bioassay System	Aqua Science	Final Effluent monitoring in Laboratory	Sole provider for Cal EPA Region 2 Dischargers
Steam Sterilizer	Getinge	Disinfect Lab materials and media	Standardize, Proven Effective and Reliable

Switches, Routers and other Network Appliances	Cisco	Data Center	Match Existing Equipment and Proven Effective & Reliable
Servers and Storage Devices	Dell	Data Center	Match Existing Equipment and Proven Effective & Reliable
Uninterruptable Power Supply (UPS)	Eaton/Powerware	Data Center	Match Existing Equipment and Proven Effective & Reliable
Positive Displacement Pumps	Moyno	Thickeners, Digesters, Dewatering, Grease Receiving Station	Match Existing Equipment for Standardization
Centrifugal Pumps	FloServe (Worthington)	Final Effluent, DMFs, RAS, Pump Stations	Match Existing Equipment for Standardization
Centrifugal Pumps	WEMCO	Primary Sludge	Match Existing Equipment for Standardization
Gas Management	Varec	Digester Gas	Match Existing Equipment for Standardization
Grinders	Franklin Miller	Pump Stations	Tests on various manufacturers proved this one effective
Valves	Pratt	Various and numerous locations	Match Existing Equipment for Standardization
Plug Valves	Dezurik	Various and numerous locations	Match Existing Equipment for Standardization
Sample Pumps	Paco	Various and numerous locations	Match Existing Equipment for Standardization
Submersible Pumps	WILO	Bilge system	Match Existing (4 pumps)
Submersible Pumps	FloServe (Worthington)	Stormdrain System	Match Existing (3 pumps)
Electrical Parts	Allen Bradley	Electrical Equipment and Motor Drives	Match Existing Equipment For Standardization
Pump Station Flow Meters	Thermo Scientific (Doppler)	Pump Stations	Standardized and proven effective

Flow Monitoring	Flowtect (pressure switch)	Eyewash/Emergency Showers	Standardized and proven effective
Pressure Monitoring	Rosemount	No. 3 Water Uses	Standardized and proven effective
Turbidity	Hach	DMF Effluent	Matching existing (7)

Equipment Selected based on Testing and Efficacy[3]:

Equipment	Manufacturer	Location Used	Reason for Sole Source
Ultrasonic Level Monitoring	Siemens (aka Milltronics)	Various locations	Tests on various manufacturers proved this one effective
In-Plant Flow Meters	Krohne (Magnetic) Rosemount (Magnetic) Thermo Scientific (Doppler)	Various locations with high solids content material	Tests on various manufacturers proved these effective
Pressure Level Transducers	Rosemount Druck (hydrostatic)	Various locations	Tests on various manufacturers proved these effective
pH Monitoring	Horiba	Various locations	Tests on various manufacturers proved this one effective
TSS Monitoring[2]	Cerlic ITX (in-line)	RAS, WAS, Thickener Overflow, Effluent	Tested and recommended
MLSS Monitoring[2]	Cerlic ITX (immersion style)	Aeration basins	Tested and recommended
Dissolved Oxygen[2]	Cerlic O2X	Aeration basins	Tested and recommended
Sludge Blanket Level[2]	Entech EchoSmart	Secondary Clarifiers	Tested and recommended

[1]Reference Memorandum from Bill Bryan, SVCW re: SVCW Electric Valve Actuator – Sole Source Manufacturer Justification, June 25, 2014.
[2]Reference Memorandum from Beecher Engineering Inc. re: SBSA Switchgear PDP-2 – Sole Source Manufacturer Justification, August 27, 2012.
[3]Reference Instrumentation Screening and Evaluation Technical Memorandum for Activated Sludge Process Automation Design (CIP 8017), December 20, 2010, by Kennedy/Jenks

RECOMMENDATION

(i) Move approval TO SUSPEND COMPETITIVE BIDDING REQUIREMENTS ON THE BASIS OF PUBLIC CONTRACTS CODE (PCC) SECTION 3400 WHICH AUTHORIZES THE SILICON VALLEY CLEAN WATER TO PURCHASE SPECIFIC EQUIPMENT WITHOUT SPECIFYING “OR EQUAL” MANUFACTURERS AND EQUIPMENT (SOLE SOURCE)

(ii) Move adoption of RESOLUTION ALLOWING FOR THE SOLE SOURCE SPECIFICATION AND PURCHASE OF STANDARDIZED EQUIPMENT AND MATERIALS AS LISTED, TO MATCH EXISTING, PROVEN EFFECTIVE OR TESTED EFFECTIVE EQUIPMENT FOR A PERIOD OF FIVE YEARS FROM JULY 2014 THROUGH JUNE 2019

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Appendix E: RLS P&IDs

Brown and Caldwell, March 2016

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EQUIPMENT

VFD — VARIABLE FREQUENCY DRIVE

RVSS — REDUCED VARIABLE SPEED START

M — MOTOR

PUMP, CENTRIFUGAL

PUMP, SUBMERSIBLE

BLOWER OR CENTRIFUGAL FAN

SLIDE GATE (NORMALLY CLOSED)

SLIDE GATE (NORMALLY OPEN)

SLUICE GATE (NORMALLY CLOSED)

SLUICE GATE (NORMALLY OPEN)

NO — BUTTERFLY GATE (NORMALLY OPEN)

NC — BUTTERFLY GATE (NORMALLY CLOSE)

SAMPLE TAP

AIR VENT

D — DRAIN

DV — DRAIN VALVE

ELASTOMER AND FABRIC EXPANSION JOINT

KNIFE GATE

PIPELINE DEVICES

GLOBE VALVE (NORMALLY OPEN)

GLOBE VALVE (NORMALLY CLOSED)

REDUCER / INCREASER

BALL VALVE (NORMALLY OPEN)

BALL VALVE (NORMALLY CLOSED)

PLUG VALVE (NORMALLY OPEN)

PLUG VALVE (NORMALLY CLOSED)

DIAPHRAGM VALVE (NORMALLY OPEN)

DIAPHRAGM VALVE (NORMALLY CLOSED)

NO — BUTTERFLY VALVE (NORMALLY OPEN)

NC — BUTTERFLY VALVE (NORMALLY CLOSED)

SWING CHECK VALVE

BALL CHECK VALVE

BALANCING COCK

PNEUMATIC VALVE

GATE VALVE (NORMALLY OPEN)

GATE VALVE (NORMALLY CLOSED)

S — SOLENOID VALVE

EQUIPMENT CONNECTION FITTING

FLEXIBLE TUBING

CAP OR PLUG

BLIND FLANGE

SAMPLING AND FLUSHING CONNECTIONS

FLOAT VALVE

DAMPER

AIR INTAKE FILTER SCREEN

PROCESS AND SIGNAL CROSS REFERENCE SYSTEM

LINE CROSS REFERENCE
SYMBOL LOCATION IDENTIFICATION LETTERS

FROM — TO

TO/FROM SYMBOL EXAMPLES

(I-601-052) ######### (TO) — (I-602-052) ######### (FROM)

DEFINES A LINE CONTINUING FROM DRAWING "(I-601-052)", TO DRAWING "(I-602-052)".

(I-601-052) ######### (FROM) — (I-602-052) ######### (TO)

DEFINES A LINE CONTINUING FROM DRAWING "(I-601-052)", TO DRAWING "(I-602-052)".

PROCESS LINES

NEW PRIMARY PROCESS FLOW

NEW SECONDARY PROCESS FLOW

FUTURE

EXISTING PROCESS FLOW, EQUIPMENT, OR SIGNAL PATH (SCREENED)

NEW/EXISTING CONNECTIONS

TEMPORARY PIPING

NOTES:

1. THIS DRAWING IS GENERAL IN NATURE. SOME SYMBOLS SHOWN HEREON MAY NOT BE USED ON THE CONTRACT DRAWINGS.
2. SEE DRAWING G003 FOR ABBREVIATIONS.
3. SEE DRAWING G001 FOR EQUIPMENT NUMBER PREFIXES, PIPING SYSTEM AND DESIGNATIONS SYSTEMS.
4. SYMBOLS ARE ARRANGED ON SPECIFIC DRAWINGS AND IN CATEGORIES FOR CONVENIENCE ONLY; SYMBOLS MAY BE USED ON ANY OF THE CONTRACT DRAWINGS.

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APPROVED: BROWN AND CALDWELL DATE:

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SCALE: STAFF
DESIGNED: ACL
DRAWN:
CHECKED:
APPROVED:

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C33166
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ZONE	REV.	DESCRIPTION	BY	DATE	APP.

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SVCW Silicon Valley Clean Water

PROCESS

PROCESS SYMBOLS

FILENAME
BC PROJECT NUMBER 142399
DRAWING NUMBER I-001-055
SHEET NUMBER
OF

Path: C:\Users\alilly\Desktop\SVCW PID TEMPLATE\SVCW\PID.DWG Filename: I-001-055.dwg Plot Date: March 21, 2016 - 11:11 AM CADD User: Adam Lilly

FUNCTIONAL IDENTIFICATION

MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A ANALYSIS		ALARM		
B BURNER, COMBUSTION				
C CONDUCTIVITY			CONTROL	CLOSE
D DENSITY, SPECIFIC GRAVITY	DIFFERENTIAL			
E VOLTAGE		PRIMARY ELEMENT		
F FLOW RATE	RATIO			
G FIRE, SMOKE		GLASS		
H HAND				HIGH
I CURRENT (ELEC)		INDICATE		
J POWER	SCAN			
K TIME, TIME SCHEDULE	TIME RATE OF CHANGE		CONTROL STATION	
L LEVEL		LIGHT		LOW
M MOISTURE, HUMIDITY	MOMENTARY			MIDDLE, INTERMEDIATE
N EQUIPMENT STATUS				
O DISSOLVED OXYGEN		ORIFICE		OPEN
P PRESSURE, VACUUM		POINT (TEST) CONNECTION		
Q QUANTITY	INTEGRATE, TOTALIZE			
R RADIATION		RECORD		
S SPEED, FREQUENCY	SAFETY		SWITCH	
T TEMPERATURE			TRANSMIT	
U MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V VIBRATION, MECHANICAL ANALYSIS			VALVE, DAMPER, LOUVER	
W WEIGHT, FORCE, TORQUE		WELL		
X UNCLASSIFIED	X AXIS			
Y EVENT, STATE, OR PRESENCE	Y AXIS		RELAY, COMPUTE, CONVERT	
Z POSITION, DIMENSION	Z AXIS		DRIVER, ACTUATOR, FINAL CONTROL ELEMENT	

INSTRUMENT FUNCTION DESIGNATIONS

Σ	SUMMING
Δ	DIFFERENCE
± + −	BIAS
AVG OR Σ/n	AVERAGE
×	MULTIPLYING
÷	DIVIDING
√	SQUARE ROOT EXTRACTION
X^n OR $X^{1/n}$	EXPONENTIAL
f(x)	CHARACTERIZE
f(t)	TIME FUNCTION
1:1	BOOST AND ISOLATE
∀	VELOCITY LIMITER
>	HIGH SELECTING
⋗	HIGH LIMITING
<	LOW SELECTING
⋖	LOW LIMITING
REV	REVERSE ACTION
GAF	GAP ACTION FLOATING
S&H	SAMPLE AND HOLD
SRG	SPLIT-RANGING
OR	OR LOGIC
E/P , I/P (TYPICAL)	FOR INPUT/OUTPUT CONVERTERS USING FOLLOWING SIGNALS: E - VOLTS H - HYDRAULIC I - CURRENT O - ELECTROMAGNETIC OR SONIC P - PNEUMATIC R - RESISTANCE A - ANALOG B - BINARY D - DIGITAL F - FREQUENCY
% OR P	PROPORTIONAL CONTROL ACTION
−% OR −P	REVERSE PROPORTIONAL CONTROL ACTION
∫ OR I	INTEGRAL CONTROL ACTION
d/dt OR D	DERIVATIVE CONTROL ACTION
1−0	ON-OFF CONTROL ACTION
Δ1 −0	DIFFERENTIAL GAP CONTROL ACTION
1:3, 1:2 (TYPICAL)	GAIN
3:1, 2:1 (TYPICAL)	ATTENUATE

PRIMARY ELEMENT SYMBOLS

PITOT TUBE

FI

VARIABLE AREA FLOW INDICATOR (ROTAMETER)

DIAPHRAGM SEAL

IN-LINE PRESSURE SENSOR

M

MAGNETIC FLOWMETER

SONIC FLOWMETER (DOPPLER OR TRANSIT TIME)

T

THERMAL FLOW ELEMENT

FLOAT LEVEL ELEMENT

ULTRASONIC LEVEL ELEMENT

BUBBLER LEVEL TUBE

FUNCTIONAL IDENTIFICATION

P D IT 35 01 A

SUFFIX - USED ONLY WHEN TWO OR MORE INSTRUMENTS WOULD OTHERWISE HAVE THE SAME TAG NUMBER

LOOP NUMBER (SEE NOTE)

PROCESS AREA

SUCCEEDING LETTERS; READOUT OR PASSIVE FUNCTION AND/OR OUTPUT FUNCTION WITH MODIFIER WHEN REQUIRED

MODIFIER LETTER, WHEN REQUIRED

MEASURED OR INITIATING VARIABLE LETTER

FUNCTIONAL IDENTIFICATION SEE TABLE THIS DRAWING

EXAMPLE:

PDIT 01A

NUMBER (PROCESS AREA NUMBER EXCLUDED)

NOTE:

TWO DIGITS FOR UNIQUE INSTRUMENT OR THREE DIGITS FOR MECHANICAL EQUIPMENT RELATED INSTRUMENT.

INSTRUMENT AND FUNCTIONAL SYMBOLS

FIELD MOUNTED INSTRUMENT

FACE MOUNTED INSTRUMENT ON MAIN PANEL, OPERATOR ACCESSIBLE

INSTRUMENT MOUNTED ON/IN MAIN PANEL, OPERATOR INACCESSIBLE

FACE MOUNTED INSTRUMENT ON FIELD PANEL, OPERATOR ACCESSIBLE

INSTRUMENT MOUNTED ON/IN FIELD PANEL, OPERATOR INACCESSIBLE

MULTIFUNCTION INSTRUMENT WITH SHARED HARDWARE (USED FOR "VIDEO DISPLAY SYSTEMS")

COMPUTER FUNCTION

E34C

CONTROL DIAGRAM NUMBER (PREFIXED BY "01")

INTERLOCKING OR SEQUENTIAL CONTROL FUNCTION

PROGRAMMABLE LOGIC CONTROL FUNCTION

STATUS INDICATION LAMP

I/O SYMBOLS

ANALOG OUTPUT

ANALOG INPUT

OR

DISCRETE OUTPUT

DISCRETE INPUT

TYPICAL INSTRUMENT IDENTIFICATION

OUTPUT

LP2

√ 1:1

FIT 01A

INPUT

PANEL LOCATION *

FUNCTIONAL IDENTIFICATION

OPERATING FUNCTION *

BASIC INSTRUMENT

SUFFIX *

NUMBER (PROCESS AREA NUMBER EXCLUDED)

* OPTIONAL

ABBREVIATIONS

ANALYTICAL FUNCTIONS

CL2	RESIDUAL CHLORINE
DO	DISSOLVED OXYGEN
ORP	OXYGEN REDUCTION POTENTIAL
pH	pH
SS	SUSPENDED SOLIDS
O2	OXYGEN
H2S	HYDROGEN SULFIDE
SD	SOLIDS DENSITY

SWITCHING FUNCTIONS

B/W	BACKWASH
C	CLOSE
E	EMULSION
EC	EMERGENCY CLOSE
ES	EMERGENCY STOP
ESD	EMERGENCY SHUTDOWN
FR	FORWARD-REVERSE
FS	FAST-SLOW
HA	HAND-AUTO
HOA	HAND-OFF-AUTO
JOR	JOG-OFF-REMOTE
LL	LEAD-LAG
LR	LOCAL REMOTE
M	MANNICH
MA	MANUAL-AUTO
MO	MANUAL OVERRIDE
O	OPEN
OC	OPEN-CLOSE
OCA	OPEN-CLOSE-AUTO
OL	OVERLOAD
OO	ON-OFF
OOC	OPEN-OFF-CLOSE
OSC	OPEN-STOP-CLOSE
PV	PROCESS VARIABLE
RDY	READY
REM	REMOTE
RST	RESET
SP	SETPOINT
SRT	SOLIDS RESIDENCE TIME
SS	START-STOP
UON	UNLESS OTHERWISE NOTED

INSTRUMENT SIGNAL SYMBOLS

INSTRUMENT SUPPLY, PROCESS TAPS

PNEUMATIC SIGNAL

ELECTRIC SIGNAL (MISCELLANEOUS)

CAPILLARY TUBE OR FILLED SYSTEM

ELECTROMAGNETIC OR SONIC SIGNAL (GUIDED)

ELECTROMAGNETIC OR SONIC SIGNAL (UNGUIDED)

SOFTWARE OR DATA LINK

MECHANICAL LINK

HYDRAULIC

ES — ELECTRIC POWER SUPPLY 120 VAC 60 HZ UON

SA — SERVICE AIR SUPPLY

IA — INSTRUMENT QUALITY AIR SUPPLY

2W — WATER SUPPLY 1W, 2W, 3W, ETC

MISCELLANEOUS LINE TYPES

VENDOR PACKAGE BOUNDARY

J J J — ELECTRICAL POWER

MISCELLANEOUS SYMBOLS

P — PURGE OR FLUSHING DEVICE

R — RESET FOR LATCH-TYPE OPERATOR

C — SEAL WATER CONTROL UNIT

NOTES:

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2. SEE DRAWING G003 FOR ABBREVIATIONS.
3. SEE DRAWING G004 FOR EQUIPMENT NUMBER PREFIXES, PIPING SYSTEM SYMBOLS AND DESIGNATION SYSTEM.
4. SEE DRAWINGS P001, P002, E001, AND E002 FOR ADDITIONAL SYMBOLS
5. SYMBOLS ARE ARRANGED ON SPECIFIC DRAWINGS AND IN CATEGORIES FOR CONVENIENCE ONLY; SYMBOLS MAY BE USED ON ANY OF THE CONTRACT DRAWINGS.
6. GAGES SHOWN WITHOUT TAG NUMBERS ON PID SHALL BE PROVIDED AS SPECIFIED IN SECTION 15095.

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PROCESS

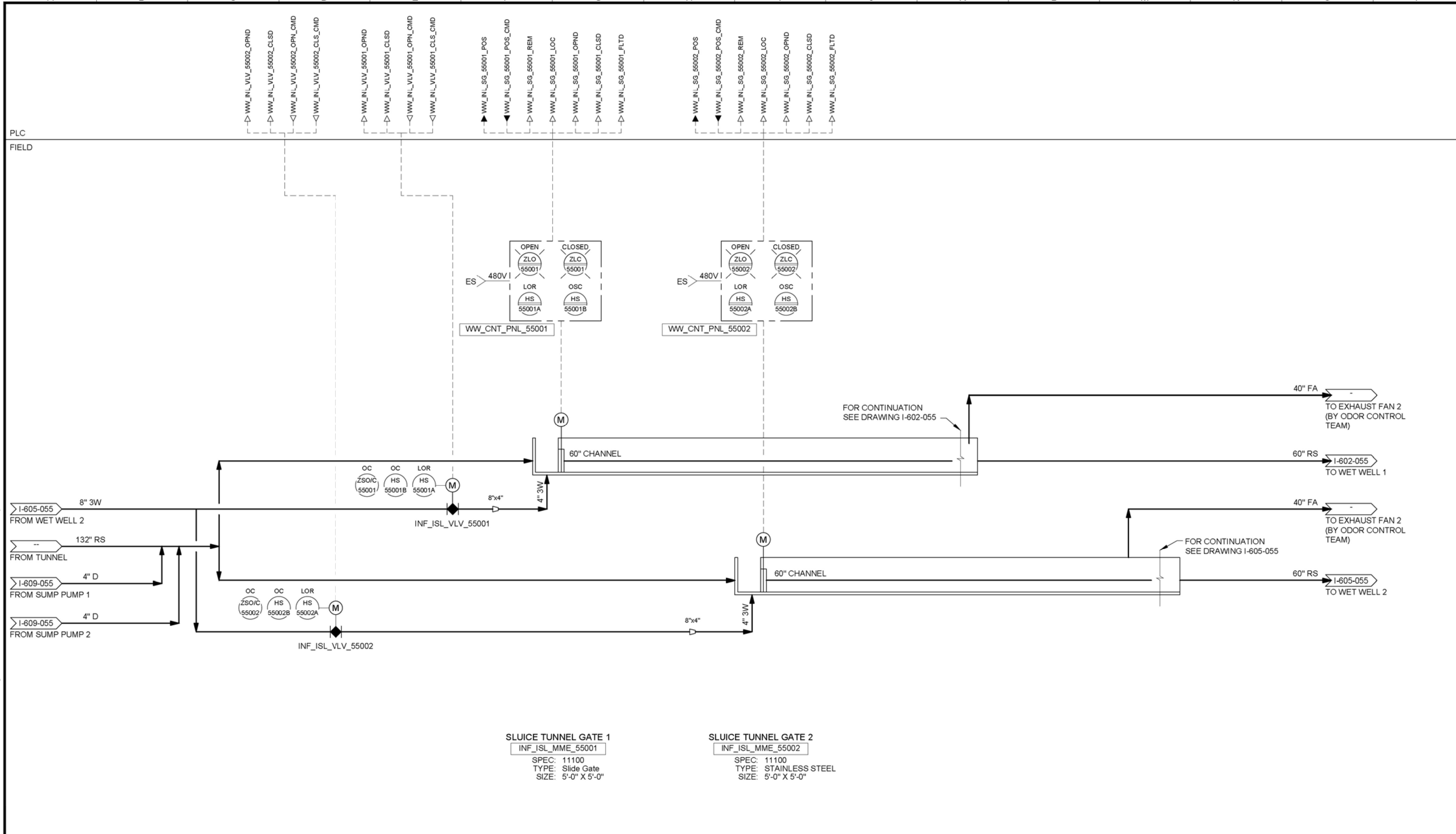
INSTRUMENTATION SYMBOLS AND IDENTIFICATION SYSTEMS

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-002-055

SHEET NUMBER OF



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PROCESS

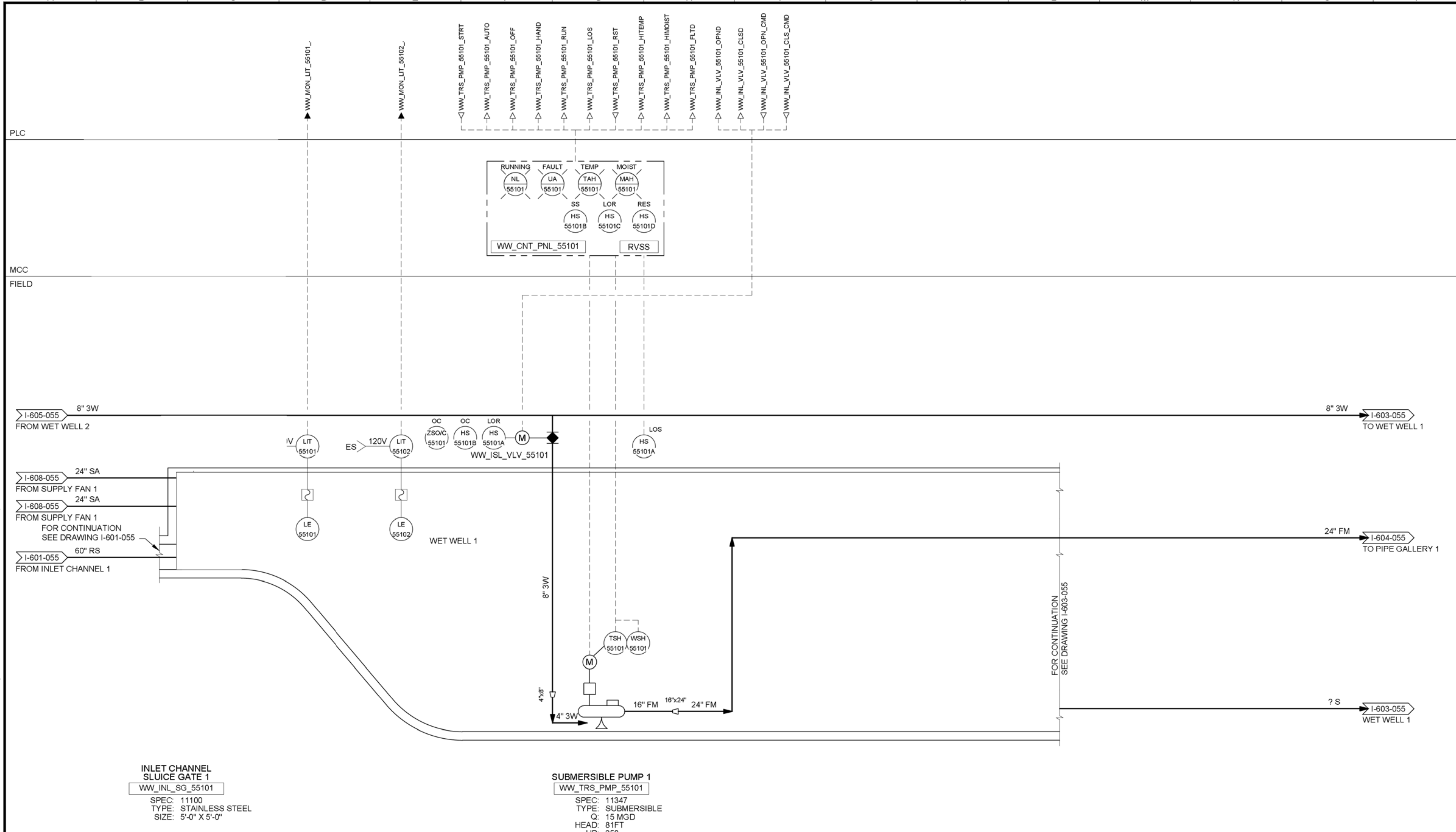
INLET CHANNELS 1 AND 2
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-601-055

SHEET NUMBER OF



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APPROVED: ______ BROWN AND CALDWELL DATE: ______

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SVCW Silicon Valley Clean Water

PROCESS

WET WELL 1
PUMP 1 AND PUMP 2
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-602-055

SHEET NUMBER OF

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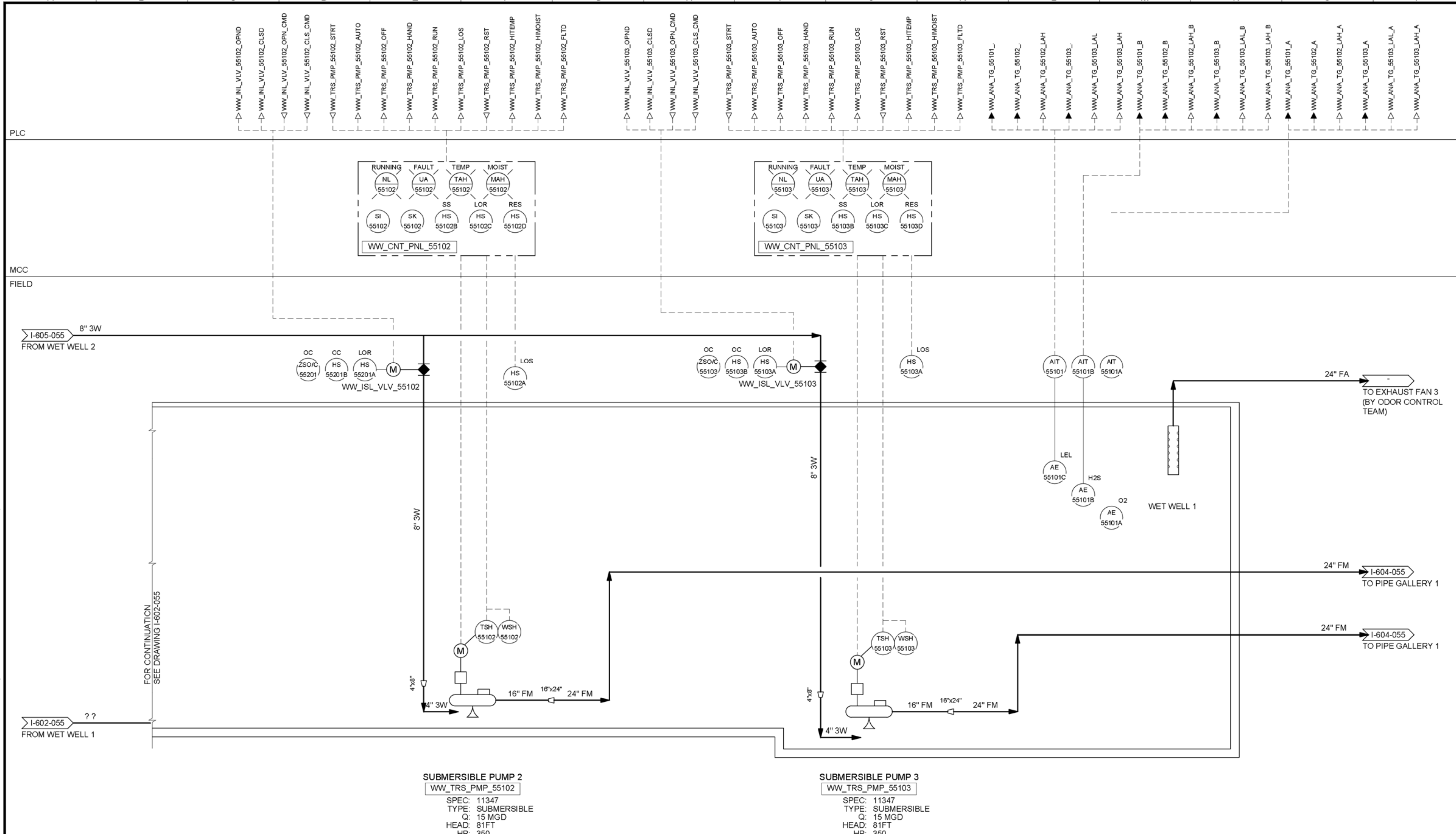

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APPROVED: ____ BROWN AND CALDWELL DATE: ____

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)

SCALE:

DESIGNED: ACL

DRAWN:

CHECKED:

APPROVED:

EXTERNAL REFERENCE FILES

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SVCW Silicon Valley Clean Water

PROCESS

WET WELL 1
PUMP 3 AND PUMP 4
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-603-055

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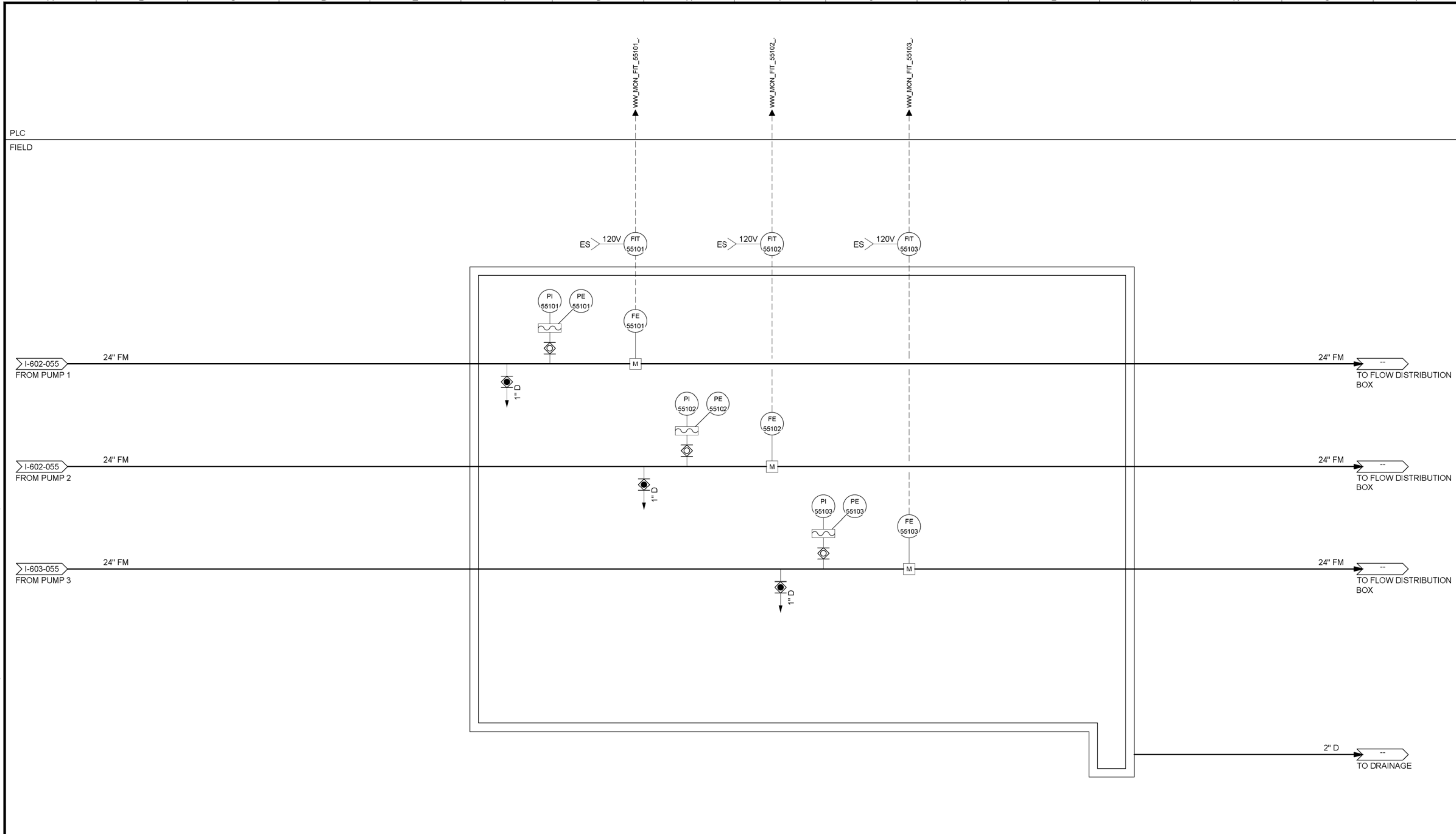

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REVISIONS					
ZONE	REV.	DESCRIPTION	BY	DATE	APP.

RECEIVING LIFT STATION PRE-DESIGN

SVCW Silicon Valley Clean Water

PROCESS

WET WELL 1
GALLERY 1
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-604-055

SHEET NUMBER OF

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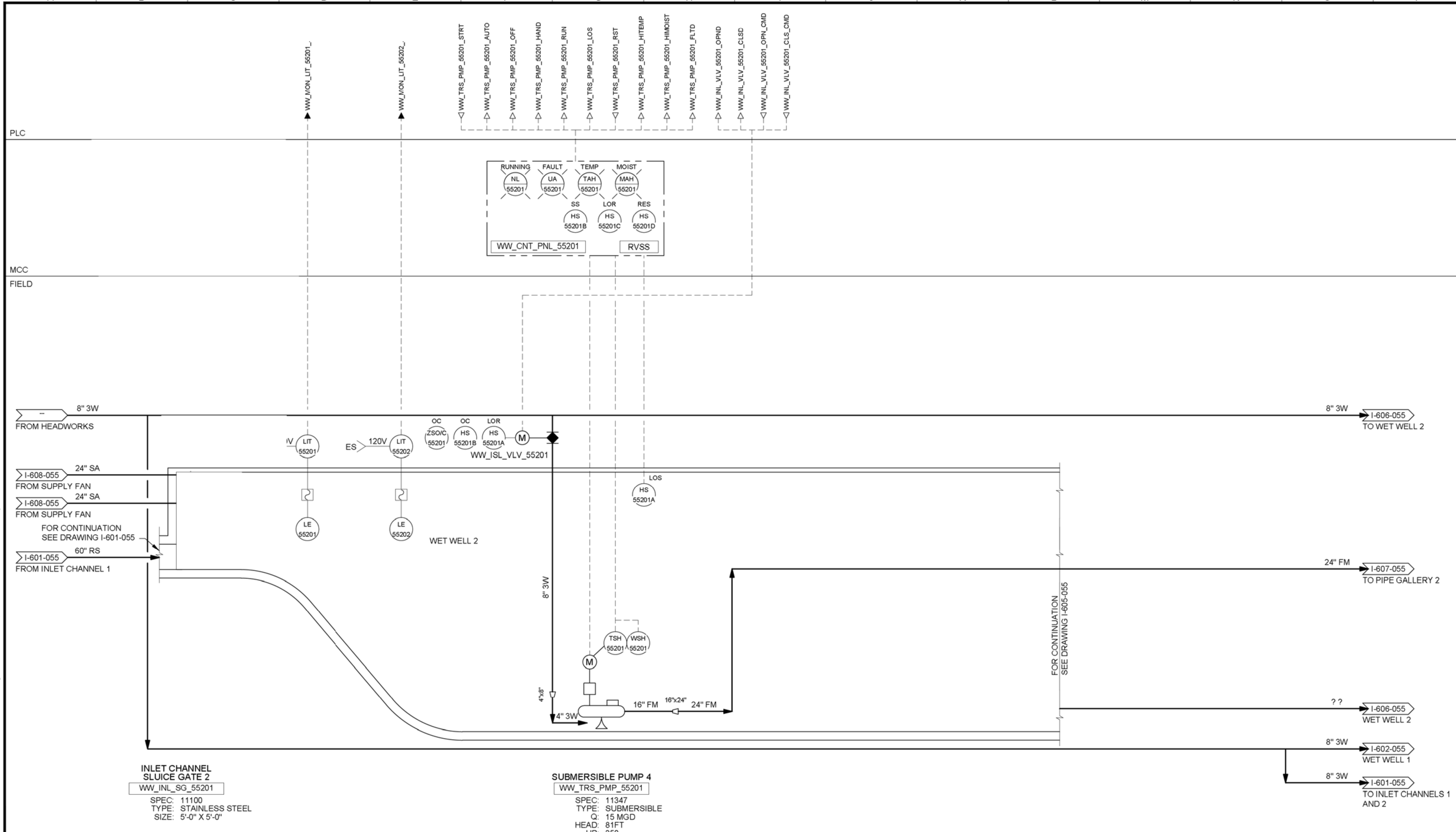

Brown AND Caldwell
WALNUT CREEK, CALIFORNIA

SUBMITTED: ________ PROJECT MANAGER DATE: ________
APPROVED: ________ BROWN AND CALDWELL DATE: ________

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)
SCALE: STAFF
DESIGNED: ACL
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CHECKED:
APPROVED:

EXTERNAL REFERENCE FILES
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PRELIMINARY

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CHARLES W. JOYCE
ENGINEER-IN-RESPONSIBLE CHARGE
C33166
CALIFORNIA REGISTRATION NUMBER

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.

RECEIVING LIFT STATION PRE-DESIGN

SVCW Silicon Valley Clean Water

PROCESS

WET WELL 2
PUMP 5 AND PUMP 6
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME
BC PROJECT NUMBER 142399
DRAWING NUMBER I-605-055
SHEET NUMBER
OF

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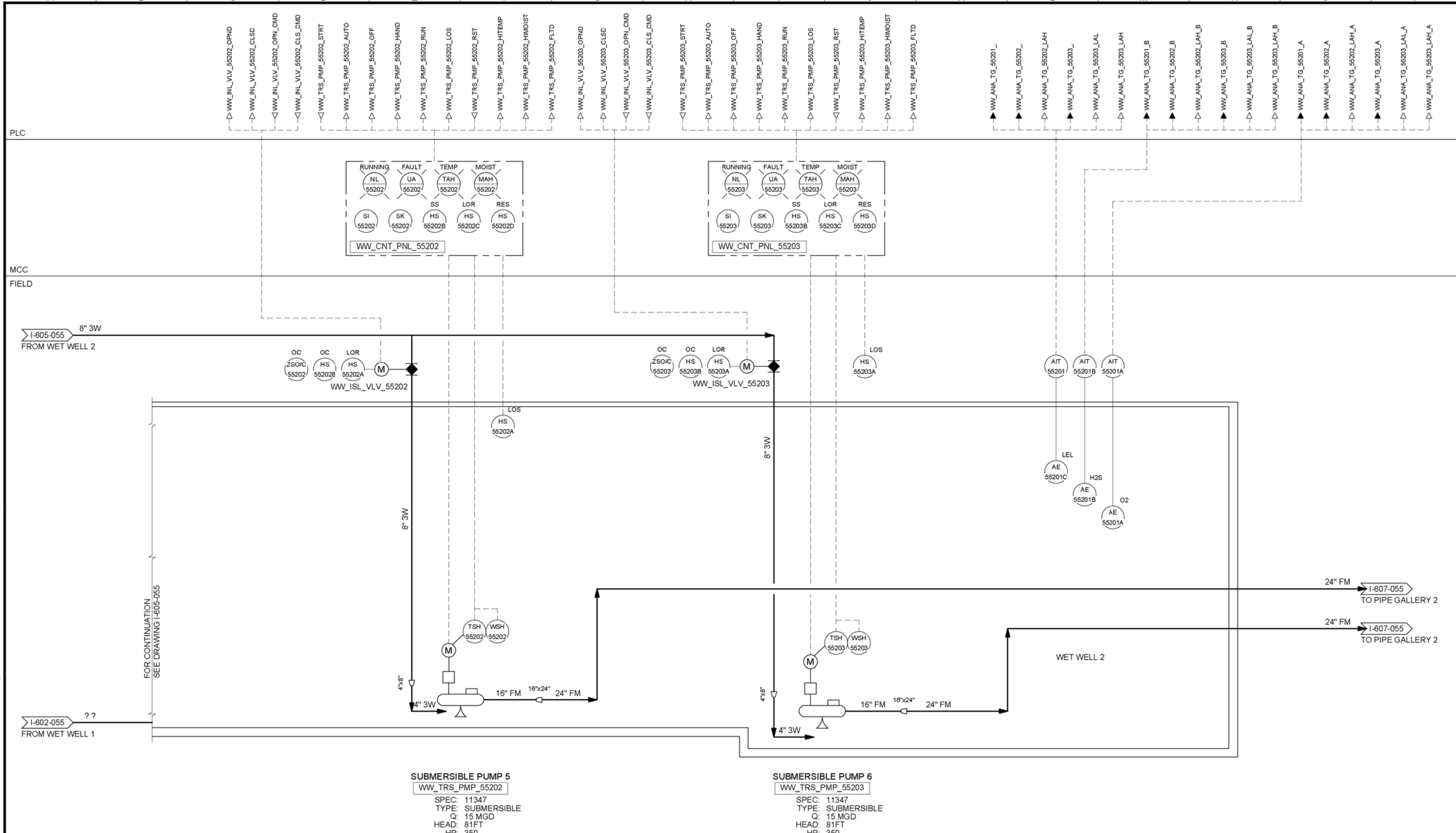

Brown AND Caldwell

WALNUT CREEK, CALIFORNIA

SUBMITTED: ______ PROJECT MANAGER DATE: ______

APPROVED: ______ BROWN AND CALDWELL DATE: ______

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RECEIVING LIFT STATION PRE-DESIGN

SVCW Silicon Valley Clean Water

PROCESS

WET WELL 2
PUMP 7 AND PUMP 8
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-606-055

SHEET NUMBER OF

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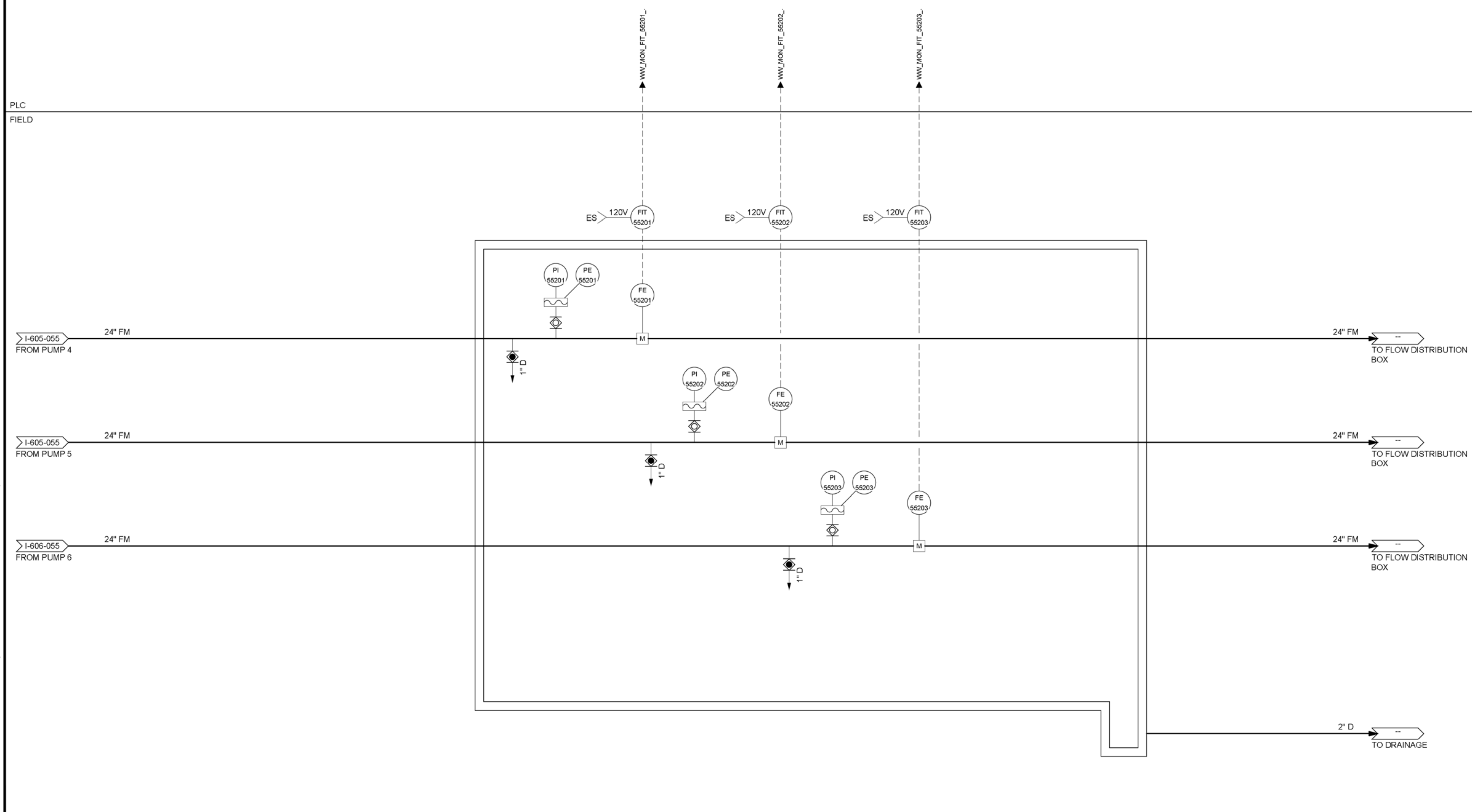

Brown AND Caldwell WALNUT CREEK, CALIFORNIA	LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)	EXTERNAL REFERENCE FILES	PRELIMINARY	RECEIVING LIFT STATION PRE-DESIGN
SUBMITTED: PROJECT MANAGER DATE:	SCALE: STAFF	142399-TB-redwood city.dwg	THIS DRAWING IS NOT VALID FOR CONSTRUCTION PURPOSES UNLESS IT BEARS THE SEAL AND SIGNATURE OF A DULY REGISTERED PROFESSIONAL	SVCW Silicon Valley Clean Water
APPROVED: BROWN AND CALDWELL DATE:	DESIGNED: ACL		CHARLES W. JOYCE ENGINEER-IN-RESPONSIBLE CHARGE	
	DRAWN:		C33166 CALIFORNIA REGISTRATION NUMBER	
	CHECKED:			
	APPROVED:			

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.

PROCESS

WET WELL 2
PIPE GALLERY 2
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-607-055

SHEET NUMBER
OF

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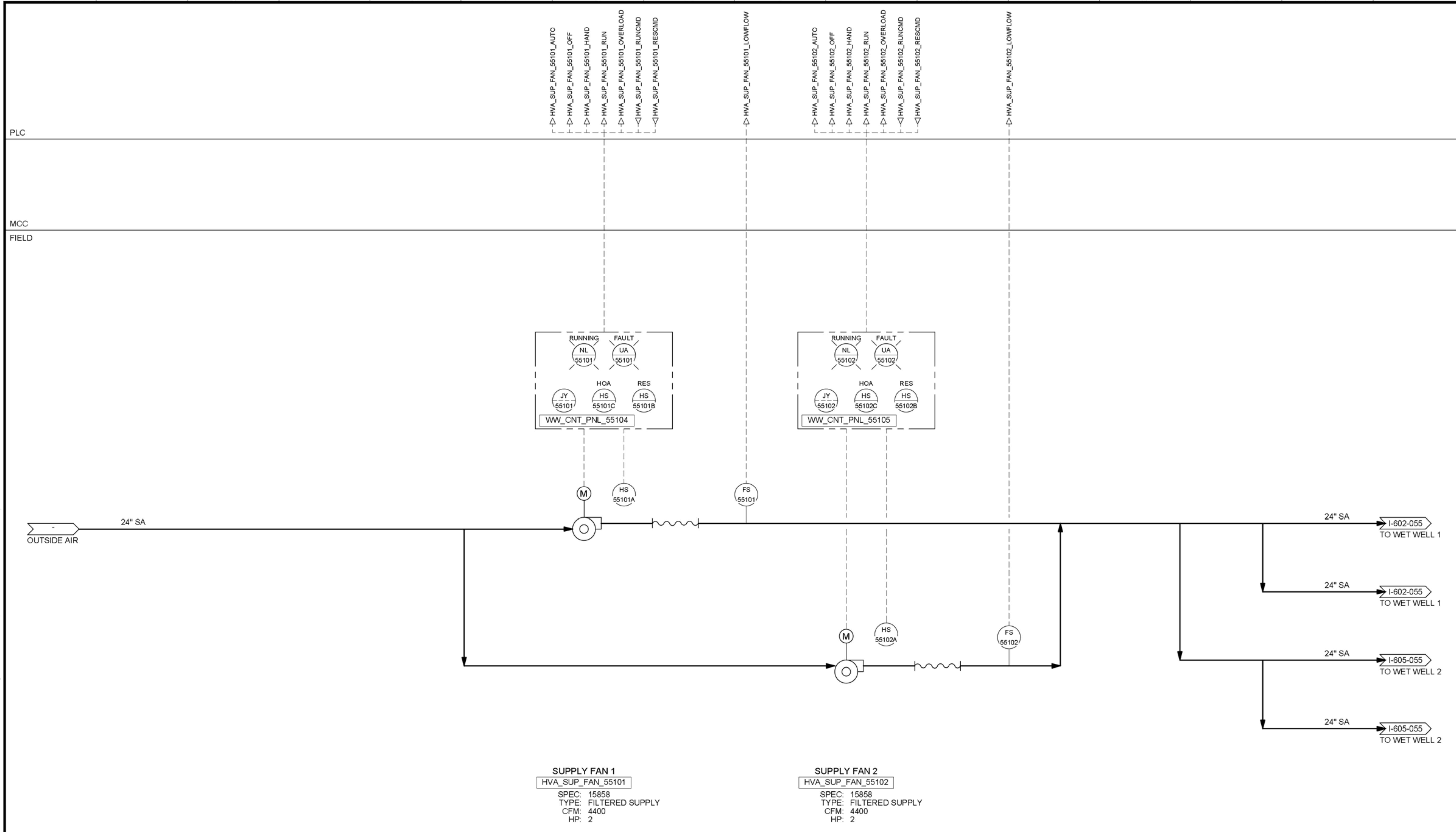

Brown AND Caldwell

WALNUT CREEK, CALIFORNIA

SUBMITTED: ______ DATE: ______
PROJECT MANAGER

APPROVED: ______ DATE: ______
BROWN AND CALDWELL

LINE IS 2 INCHES AT FULL SIZE
(IF NOT 2" - SCALE ACCORDINGLY)

SCALE: STAFF

DESIGNED: ACL

DRAWN:

CHECKED:

APPROVED:

EXTERNAL REFERENCE FILES

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CHARLES W. JOYCE
ENGINEER-IN-RESPONSIBLE CHARGE
C33166
CALIFORNIA REGISTRATION NUMBER

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.

RECEIVING LIFT STATION PRE-DESIGN

SVCW
Silicon Valley Clean Water

PROCESS

SUPPLY FANS 1 AND 2
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER 142399

DRAWING NUMBER I-608-055

SHEET NUMBER
OF

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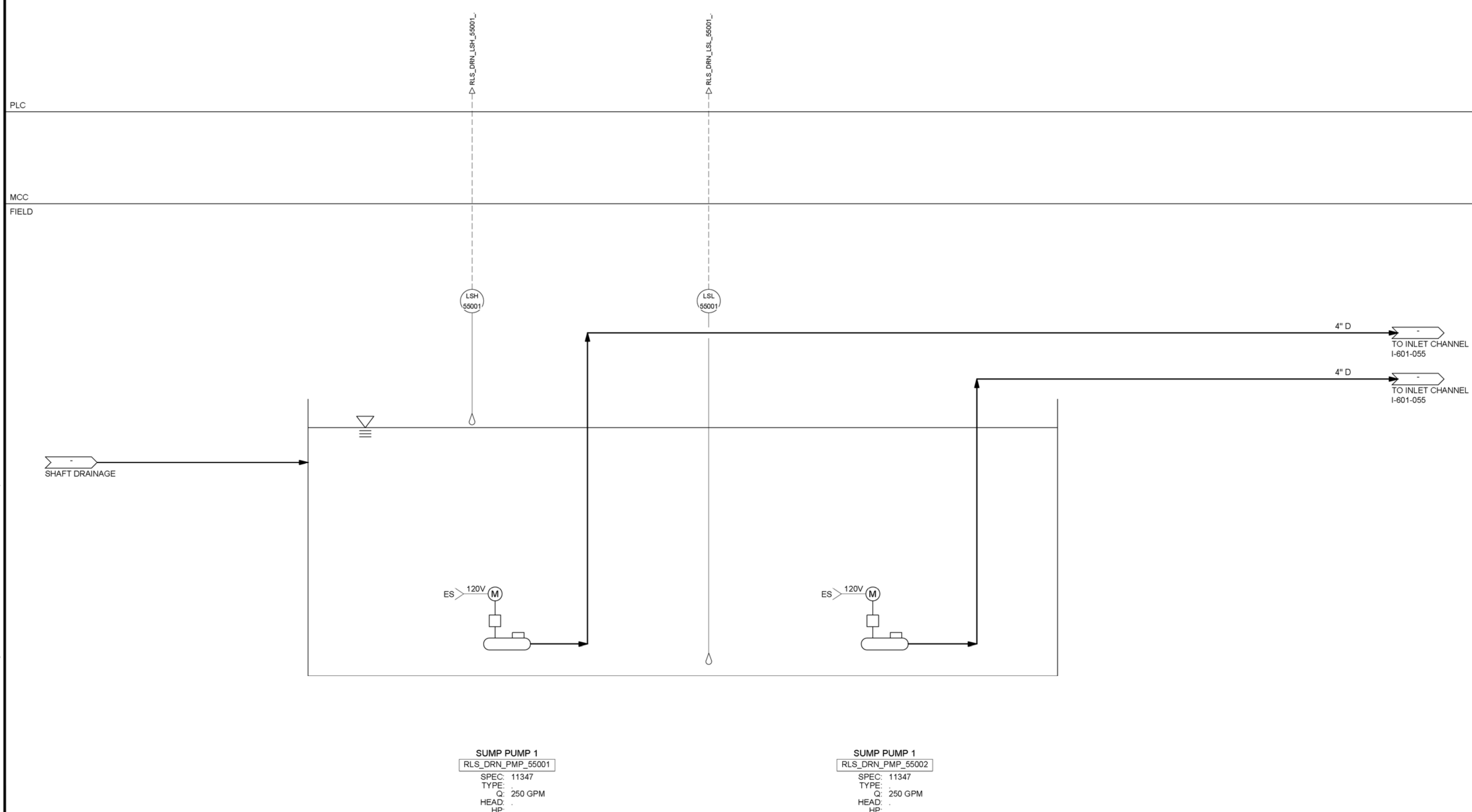

Brown AND Caldwell

WALNUT CREEK, CALIFORNIA

SUBMITTED: ______ PROJECT MANAGER DATE: ______

APPROVED: ______ BROWN AND CALDWELL DATE: ______

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2" - SCALE ACCORDINGLY)

SCALE: STAFF

DESIGNED: ACL

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CHECKED:

APPROVED:

EXTERNAL REFERENCE FILES

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CHARLES W. JOYCE
ENGINEER-IN-RESPONSIBLE CHARGE
C33166
CALIFORNIA REGISTRATION NUMBER

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.

RECEIVING LIFT STATION PRE-DESIGN

SVCW
Silicon Valley Clean Water

PROCESS

INLET CHANNEL SUMP PUMP 1
AND SUMP PUMP 2
PROCESS AND INSTRUMENTATION DIAGRAM

FILENAME

BC PROJECT NUMBER
142399

DRAWING NUMBER
I-609-055

SHEET NUMBER
OF

Path: C:\Users\alily\Desktop\SVCW PID TEMPLATE\SVCW PID.DWG Filename: I-609-055.dwg Plot Date: March 21, 2016 - 11:11 AM CADD User: Adam Lilly

Appendix F: RLS Detailed Cost Estimate

Brown and Caldwell, May 2016

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SILICON VALLEY CLEAN WATER
RLS PUMP STATION
CONCEPTUAL LEVEL CLASS 3 ESTIMATE

Engineer	BROWN AND CALDWELL
Estimator	Ian Kruljac
BC Project Manager	CHARLIE JOYCE
BC Office	WALNUT CREEK
Estimate Issue No.	3
QA/QC Reviewer	DESIGN TEAM
QA/QC Review Date	4/1/2016

Project Number: 142399
Estimate Issue: 3
Due Date: 5/5/2016
Estimator: Ian Kruljac

RLS PUMP STATION

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
01 RLS SITE CIVIL AND EXCAVATIONS									
31250	Pipe Gallery Sheet Pile Shoring	2,145.0 SQFT	22.24	16.32		9.61		48.17 /SQFT	103,320
31315	Excavation and Backfill - Pipe Gallery	1,111.0 CYD	11.60	10.31		12.30		34.22 /CYD	38,015
31455	Pipe Gallery Piles - 16" Square Precast, 40 at 100 vlf each	00.0 vlf	82.88	148.85	1.90	16.80		250.43 /vlf	1,001,729
	01 RLS SITE CIVIL AND EXCAVATIONS	1.0 LSUM	392,125.93	641,861.92	7,601.23	101,473.76		1,143,062.84 /LSUM	1,143,063
02 RLS PUMPSTATION CONCRETE									
03330	Slabs Wet Well Base Slab - 36" thick	171.0 CYD	73.28	186.87		6.20		266.36 /CYD	45,547
03330	Inlet Channel Base Slab - 36" thick	51.0 CYD	78.19	193.65		6.23		278.08 /CYD	14,182
03345	Concrete Walls - Wet Well	1,204.0 CYD	363.35	223.04		9.83		596.22 /CYD	717,850
03345	Concrete Walls - Inlet Channel	441.0 CYD	366.24	223.81		9.85		599.90 /CYD	264,554
03345	Concrete Walls - Wet Well - Mid wall	145.0 CYD	788.61	301.77		10.59		1,100.97 /CYD	159,641
03345	Concrete Walls - Channel inlet - Mid wall	73.0 CYD	787.71	301.43		10.58		1,099.72 /CYD	80,279
03345	Concrete Fillets - Wet Well	171.0 CYD	213.34	192.18		9.61		415.13 /CYD	70,988
03345	Concrete - OG Ramps - Wet Well	50.0 CYD	77.51	185.91		9.65		273.06 /CYD	13,653
03345	Concrete Fillets - Inlet Channel	169.0 CYD	349.23	222.61		9.85		581.69 /CYD	98,305
03350	Elevated Slab - Channel Inlet	22.0 CYD	388.25	319.85		13.27		721.36 /CYD	15,870
03350	Elevated Slab - Tunnel Shaft	69.0 CYD	368.12	310.11		13.03		691.26 /CYD	47,697
	02 RLS PUMPSTATION CONCRETE	2,566.0 CYD	358.79	227.22		9.68		595.70 /CYD	1,528,565
03 RLS PIPE GALLERY CONCRETE									
03330	Pipe Gallery Base Slab - 24" Thick	122.0 CYD	67.74	186.11		6.29		260.14 /CYD	31,738
03345	Concrete Walls - Pipe Gallery 18" Thick	250.0 CYD	602.09	254.58		10.10		866.77 /CYD	216,693
03350	Elevated Slabs - Pipe Gallery 18" Thick	90.0 CYD	337.11	255.96		14.26		607.33 /CYD	54,660
	03 RLS PIPE GALLERY CONCRETE	462.0 CYD	409.37	236.77		9.90		656.04 /CYD	303,091
04 RLS MECHANICAL									
11999	Pumps Station - Pumps and Instr..	6.0 Each	17,688.37	350,797.86		3,480.42		371,966.65 /Each	2,231,800
14999	Track Mounted 15 Ton Monorail	1.0 Each	43,123.26	416,876.71		7,345.85		467,345.82 /Each	467,346
22999	Tie Ins Work Allownace	1.0 LS			69,608.37			69,608.37 /LS	69,608
27999	24" Flowmeters	6.0 Each	1,320.48	16,669.69				17,990.17 /Each	107,941
40120	24" Ductile Iron Piping	775.0 LFT	228.07	268.51				496.58 /LFT	384,849
40510	CPVC Piping	990.0 LFT	66.85	107.29				174.14 /LFT	172,402
46999	Channel Intel and Outlet Gates	4.0 Each	58,722.75	264,454.29				323,177.04 /Each	1,292,708
	04 RLS MECHANICAL	1.0 LSUM	635,001.10	3,993,815.50	69,608.37	28,228.36		4,726,653.33 /LSUM	4,726,653
05 RLS SUPER STRUCTURE									
03335	Super Structure Columns	97.0 CYD	698.21	441.42		20.24		1,159.86 /CYD	112,506
03350	Elevated Slab - Super Structure	128.0 CYD	387.15	324.79		13.37		725.31 /CYD	92,840
05517	Metal Stairs	20.0 RSR	126.98	649.80		6.90		783.68 /RSR	15,674
05999	Hand Railing	210.0 LFT	35.60	67.56		1.29		104.45 /LFT	21,934
05999	Access Hatches	8.0 EACH	420.69	5,459.09				5,879.78 /EACH	47,038
	05 RLS SUPER STRUCTURE	225.0 CYD	580.72	689.98		18.15		1,288.85 /CYD	289,992

RLS PUMP STATION

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
06 RLS HVAC AND ODOR CONTROL									
23999 Foul Air Fans and Damper		2.0 Each	1,717.73	9,573.24				11,290.97 /Each	22,582
23999 FRP Foul Air Ducting		305.0 LFT	481.33	238.37				719.70 /LFT	219,508
	06 RLS HVAC AND ODOR CONTROL	1.0 LSUM	150,239.79	91,850.29				242,090.08 /LSUM	242,090
07 SHAFT IMPROVEMENTS AND CORRISION PROTECTION									
03345 Strcutural Concrete Liner - 74'T x 178' L x12"W		13,172.0 SQFT	22.29	11.79		0.42		34.50 /SQFT	454,445
13999 T-Lock Liner Corrosion Protection		22,239.0 SQFT			20.88			20.88 /SQFT	464,406
	07 SHAFT IMPROVEMENTS AND CORRISION PROTECTION	35,411.0 SQFT	8.29	4.39	13.12	0.16		25.95 /SQFT	918,851
08 RLS ELECTRICAL ALLOWANCE									
26999 El&C Allowance		1.0 LSUM			1,044,125.54			1,044,125.54 /LSUM	1,044,126
	08 RLS ELECTRICAL ALLOWANCE	1.0 LSUM			1,044,125.54			1,044,125.54 /LSUM	1,044,126
	01 SVCW RLS PUMP STATION	1.0 LSUM	2,711,465.51	5,730,478.93	1,585,741.31	168,744.79		10,196,430.54 /LSUM	10,196,431

Estimate Totals

Description	Rate	Hours	Amount	Totals
Labor		21,783 hrs	2,711,466	
Material			5,730,479	
Subcontract			1,585,741	
Equipment		1,453 hrs	168,745	
Gross Markups			**10,196,431**	**10,196,431**
Total				**10,196,431**

SILICON VALLEY CLEAN WATER
RLS PUMP STATION
CONCEPTUAL LEVEL CLASS 3 ESTIMATE

Engineer	BROWN AND CALDWELL
Estimator	Ian Kruljac
BC Project Manager	CHARLIE JOYCE
BC Office	WALNUT CREEK
Estimate Issue No.	3
QA/QC Reviewer	DESIGN TEAM
QA/QC Review Date	4/1/2016

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
01 RLS SITE CIVIL AND EXCAVATIONS									
31250 Pipe Gallery Sheet Pile Shoring									
31-41-16.10	Sheet piling, steel, 38 psf, 25' excavation, per S.F., drive, extract and salvage, excludes wales	2,145.0 sf	15.42	10.15	-	6.90	-	32.47 /sf	69,655
31-41-16.10	Sheet piling, wales, connections and struts, 2/3 salvage	2.9 ton	-	480.00	-	-	-	480.00 /ton	1,392
	Pipe Gallery Sheet Pile Shoring	**2,145.0 SQFT**	**15.42**	**10.80**		**6.90**		**33.12 /SQFT**	**71,047**
31315 Excavation and Backfill - Pipe Gallery									
31-23-16.42	Excavating, bulk bank measure, 1-1/2 C.Y. capacity = 160 C.Y./hour, shovel, excluding truck loading	1,111.0 bcy	0.95	-	-	0.99	-	1.94 /bcy	2,152
31-23-23.18	Hauling, excavated or borrow material, loose cubic yards, 5 mile round trip, 1 load/hour, 16.5 C.Y. dump trailer, highway haulers, excludes loading	1,111.0 lcy	5.03	-	-	6.86	-	11.89 /lcy	13,208
31-05-16.10	Aggregate for earthwork, bank run gravel, spread with 200 H.P. dozer, includes load at pit and haul, 2 miles round trip, excludes compaction	211.0 lcy	3.35	22.00	-	4.71	-	30.05 /lcy	6,341
31-23-23.23	Compaction, 3 passes, 6" to 11", 8" lifts, rammer tamper	211.0 ecy	2.57	-	-	0.26	-	2.83 /ecy	597
31-23-23.17	Fill, gravel fill, compacted, under floor slabs, 12" deep	2,000.0 sf	0.52	1.47	-	0.03	-	2.02 /sf	4,040
	Excavation and Backfill - Pipe Gallery	**1,111.0 CYD**	**8.04**	**6.82**		**8.84**		**23.71 /CYD**	**26,337**
31455 Pipe Gallery Piles - 16" Square Precast, 40 at 100 vlf each									
31-62-13.13	Piling special costs, pre-augering up to 30' D, avg soil, 14" diam	4,000.0 vlf	22.64	-	-	8.37	-	31.00 /vlf	124,016
31-62-13.23	Prestressed concrete piles, square, 40' long, 16" square, priced using 200 piles, excludes pile caps or mobilization	4,000.0 vlf	31.98	98.50	-	3.16	-	133.64 /vlf	534,571
31-62-13.13	Piling special costs, cutoffs, precast concrete piles	4.0 ea	494.03	-	-	-	-	494.03 /ea	1,976
31-62-13.23	Prestressed concrete piles,mobilization,25,000 pile job,priced using 200 piles,60'long,unless specified otherwise,excludes pile caps mobilization,add	4,000.0 vlf	2.11	-	-	0.21	-	2.32 /vlf	9,259
31-06-60.14	Pilings, load and haul excess auger spoils, to 2 miles	158.2 cy	6.41	-	-	8.31	-	14.72 /cy	2,329
31-62-13.13	Test piles for refusal depth and pull, average cost per pile	4.0 ea	-	-	1,365.00	-	-	1,365.00 /ea	5,460
	Pipe Gallery Piles - 16" Square Precast, 40 at 100 vlf each	**4,000.0 vlf**	**57.47**	**98.50**	**1.37**	**12.07**		**169.40 /vlf**	**677,611**

RLS PUMP STATION

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
	01 RLS SITE CIVIL AND EXCAVATIONS	**1.0 LSUM**	**271,900.45**	**424,745.75**	**5,460.00**	**72,889.02**		**774,995.22 /LSUM**	**774,995**
02 RLS PUMPSTATION CONCRETE									
03330 Slabs Wet Well Base Slab - 36" thick									
03-15-13.50	Waterstop, PVC, ribbed type, split, 3/8" thick x 6" wide	122.0 lf	5.61	4.38	-	-	-	9.99 /lf	1,219
03-15-13.50	Waterstop, fittings, rubber, flat, dumbbell or center bulb, field union, 3/8" thick x 9" wide	10.0 ea	14.60	47.50	-	-	-	62.10 /ea	621
03-21-10.60	Reinforcing steel, in place, slab on grade, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	1.3 ton	1,070.05	1,000.00	-	-	-	2,070.05 /ton	2,720
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - slabs	1.3 ton	44.16	-	-	7.51	-	51.67 /ton	68
03-21-10.60	Reinforcing in place, crane cost for handling, add to above, slabs	1.3 ton	48.01	-	-	8.17	-	56.17 /ton	74
03-31-05.35	Concrete, ready mix, regular weight, slabs/mats, 4000 psi	171.8 cy	-	107.00	-	-	-	107.00 /cy	18,387
03-31-05.70	Structural concrete, placing, slab on grade, pumped, over 6" thick, includes vibrating, excludes material	171.8 cy	22.78	-	-	4.31	-	27.10 /cy	4,656
03-35-29.30	Concrete finishing, floors, monolithic, screed, float and hand trowel finish	1,501.5 sf	1.23	-	-	-	-	1.23 /sf	1,842
03-39-13.50	Curing, sprayed membrane curing compound	15.0 csf	10.53	11.05	-	-	-	21.58 /csf	324
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 1 coat	1,501.5 sf	0.28	0.18	-	-	-	0.46 /sf	686
	Slabs Wet Well Base Slab - 36" thick	**171.0 CYD**	**50.81**	**123.66**		**4.46**		**178.93 /CYD**	**30,597**
03330 Inlet Channel Base Slab - 36" thick									
03-15-13.50	Waterstop, PVC, ribbed type, split, 3/8" thick x 6" wide	60.0 lf	5.61	4.38	-	-	-	9.99 /lf	600
03-15-13.50	Waterstop, fittings, rubber, flat, dumbbell or center bulb, field union, 3/8" thick x 9" wide	5.0 ea	14.60	47.50	-	-	-	62.10 /ea	310
03-21-10.60	Reinforcing steel, in place, slab on grade, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	0.4 ton	1,070.05	1,000.00	-	-	-	2,070.05 /ton	816
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - slabs	0.4 ton	44.16	-	-	7.50	-	51.68 /ton	20
03-21-10.60	Reinforcing in place, crane cost for handling, add to above, slabs	0.4 ton	48.00	-	-	8.17	-	56.17 /ton	22
03-31-05.35	Concrete, ready mix, regular weight, slabs/mats, 4000 psi	51.5 cy	-	107.00	-	-	-	107.00 /cy	5,511
03-31-05.70	Structural concrete, placing, slab on grade, pumped, over 6" thick, includes vibrating, excludes material	51.5 cy	22.78	-	-	4.31	-	27.10 /cy	1,395
03-35-29.30	Concrete finishing, floors, monolithic, screed, float and hand trowel finish	450.0 sf	1.23	-	-	-	-	1.23 /sf	552

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03330 Inlet Channel Base Slab - 36" thick									
03-39-13.50	Curing, sprayed membrane curing compound	4.5 csf	10.53	11.05	-	-	-	21.58 /csf	97
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 1 coat	450.0 sf	0.28	0.18	-	-	-	0.46 /sf	206
	Inlet Channel Base Slab - 36" thick	**51.0 CYD**	**54.22**	**128.15**		**4.48**		**186.84 /CYD**	**9,529**
03345 Concrete Walls - Wet Well									
03-11-13.85	Cip concret forms,walls,steel framed plywd,over 16'20'h,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	21,082.0 sfca	10.41	0.74	-	-	-	11.15 /sfca	235,143
03-11-13.85	C.I.P. concrete forms, wall, box out for opening, to 16" thick, over 10 S.F. (use perimeter), includes erecting, bracing, stripping and cleaning	20.0 lf	14.88	2.31	-	-	-	17.19 /lf	344
03-15-05.12	Chamfer strip, polyvinyl chloride, 3/4" wide with leg	40.0 lf	1.39	0.68	-	-	-	2.07 /lf	83
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	56.2 gal	-	20.50	-	-	-	20.50 /gal	1,152
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	31.6 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	57,566
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	31.6 ton	44.17	-	-	7.51	-	51.68 /ton	1,634
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	31.6 ton	48.01	-	-	8.17	-	56.17 /ton	1,776
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	1,204.1 cy	-	107.00	-	-	-	107.00 /cy	128,835
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	1,204.1 cy	35.12	-	-	6.65	-	41.77 /cy	50,298
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	10,521.0 sf	1.17	0.04	-	-	-	1.21 /sf	12,718
	Concrete Walls - Wet Well	**1,204.0 CYD**	**251.94**	**147.60**		**7.06**		**406.60 /CYD**	**489,550**
03345 Concrete Walls - Inlet Channel									
03-11-13.85	Cip concret forms,walls,steel framed plywd,over 16'20'h,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	7,776.0 sfca	10.41	0.74	-	-	-	11.15 /sfca	86,731
03-11-13.85	C.I.P. concrete forms, wall, box out for opening, to 16" thick, over 10 S.F. (use perimeter), includes erecting, bracing, stripping and cleaning	20.0 lf	14.88	2.31	-	-	-	17.19 /lf	344

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03345 Concrete Walls - Inlet Channel									
03-15-05.12	Chamfer strip, polyvinyl chloride, 3/4" wide with leg	40.0 lf	1.39	0.68	-	-	-	2.07 /lf	83
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	20.7 gal	-	20.50	-	-	-	20.50 /gal	425
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	11.7 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	21,233
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	11.7 ton	44.17	-	-	7.51	-	51.68 /ton	603
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	11.7 ton	48.01	-	-	8.17	-	56.17 /ton	655
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	441.5 cy	-	107.00	-	-	-	107.00 /cy	47,243
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	441.5 cy	35.12	-	-	6.65	-	41.77 /cy	18,444
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	3,858.0 sf	1.17	0.04	-	-	-	1.21 /sf	4,664
	Concrete Walls - Inlet Channel	**441.0 CYD**	**253.95**	**148.11**		**7.07**		**409.13 /CYD**	**180,425**
03345 Concrete Walls - Wet Well - Mid wall									
03-11-13.85	Cip concret forms,walls,steel framed plywd,over 16'20'h,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	5,727.0 sfca	10.41	0.74	-	-	-	11.15 /sfca	63,877
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	15.3 gal	-	20.50	-	-	-	20.50 /gal	313
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	8.6 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	15,639
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	8.6 ton	44.17	-	-	7.51	-	51.68 /ton	444
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	8.6 ton	48.01	-	-	8.17	-	56.17 /ton	483
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	145.7 cy	-	107.00	-	-	-	107.00 /cy	15,585
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	145.7 cy	35.12	-	-	6.65	-	41.77 /cy	6,084
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	5,727.0 sf	1.17	0.04	-	-	-	1.21 /sf	6,923
	Concrete Walls - Wet Well - Mid wall	**145.0 CYD**	**546.82**	**199.69**		**7.61**		**754.12 /CYD**	**109,348**
03345 Concrete Walls - Channel inlet - Mid wall									

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03345 Concrete Walls - Channel inlet - Mid wall									
03-11-13.85	Cip concret forms,walls,steel framed plywd,over 16'20'h,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	2,880.0 sfca	10.41	0.74	-	-	-	11.15 /sfca	32,123
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	7.7 gal	-	20.50	-	-	-	20.50 /gal	157
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	4.3 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	7,864
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	4.3 ton	44.17	-	-	7.51	-	51.68 /ton	223
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	4.3 ton	48.01	-	-	8.17	-	56.17 /ton	243
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	73.2 cy	-	107.00	-	-	-	107.00 /cy	7,837
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	73.2 cy	35.12	-	-	6.65	-	41.77 /cy	3,060
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	2,880.0 sf	1.17	0.04	-	-	-	1.21 /sf	3,482
	Concrete Walls - Channel inlet - Mid wall	**73.0 CYD**	**546.20**	**199.47**		**7.60**		**753.27 /CYD**	**54,988**
03345 Concrete Fillets - Wet Well									
03-11-13.85	C.I.P. concrete forms, wall, job built, plywood, over 16' high, 4 use, includes erecting, bracing, stripping and cleaning	1,200.0 sfca	12.62	0.88	-	-	-	13.50 /sfca	16,203
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	7.4 gal	-	20.50	-	-	-	20.50 /gal	151
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	2.8 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	5,039
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	2.8 ton	44.17	-	-	7.51	-	51.68 /ton	143
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	2.8 ton	48.01	-	-	8.17	-	56.17 /ton	155
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	165.6 cy	-	107.00	-	-	-	107.00 /cy	17,716
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	171.0 cy	35.12	-	-	6.65	-	41.77 /cy	7,143
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	1,384.0 sf	1.17	0.04	-	-	-	1.21 /sf	1,673

Phase	Estimate Breakdown	Quantity		Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit		Total Net Amount
	Concrete Fillets - Wet Well	**171.0**	**CYD**	**147.93**	**127.17**		**6.90**		**282.01**	**/CYD**	**48,223**
03345 Concrete - OG Ramps - Wet Well											
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	2.1	gal	-	20.50	-	-	-	20.50	/gal	43
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	0.8	ton	820.37	1,000.00	-	-	-	1,820.37	/ton	1,365
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	0.9	ton	44.17	-	-	7.52	-	51.69	/ton	46
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	0.9	ton	48.01	-	-	8.17	-	56.18	/ton	50
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	50.0	cy	-	107.00	-	-	-	107.00	/cy	5,350
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	50.0	cy	35.12	-	-	6.65	-	41.77	/cy	2,089
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	200.0	sf	1.17	0.04	-	-	-	1.21	/sf	242
	Concrete - OG Ramps - Wet Well	**50.0**	**CYD**	**53.75**	**123.02**		**6.93**		**183.70**	**/CYD**	**9,185**
03345 Concrete Fillets - Inlet Channel											
03-11-13.85	C.I.P. concrete forms, wall, job built, plywood, over 16' high, 4 use, includes erecting, bracing, stripping and cleaning	2,240.0	sfca	12.62	0.88	-	-	-	13.50	/sfca	30,245
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	11.9	gal	-	20.50	-	-	-	20.50	/gal	245
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	4.5	ton	820.37	1,000.00	-	-	-	1,820.37	/ton	8,155
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	4.5	ton	44.17	-	-	7.51	-	51.68	/ton	232
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	4.5	ton	48.01	-	-	8.17	-	56.17	/ton	252
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	169.2	cy	-	107.00	-	-	-	107.00	/cy	18,109
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	169.2	cy	35.12	-	-	6.65	-	41.77	/cy	7,070
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	2,240.0	sf	1.17	0.04	-	-	-	1.21	/sf	2,708
	Concrete Fillets - Inlet Channel	**169.0**	**CYD**	**242.16**	**147.31**		**7.08**		**396.54**	**/CYD**	**67,015**
03350 Elevated Slab - Channel Inlet											

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03350 Elevated Slab - Channel Inlet									
03-11-13.35	C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	384.0 sf	7.44	1.26	-	-	-	8.70 /sf	3,340
03-11-13.35	C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	64.0 lf	5.38	0.21	-	-	-	5.59 /lf	358
03-11-13.35	Cip concrete forms,elevated slab,box-out for shallow slab openings,over 10 sf (use perimeter),includes shoring,erecting,bracing,stripping and cleaning	24.0 lf	6.94	1.61	-	-	-	8.55 /lf	205
03-15-05.70	Shores, reshoring at elevated decks, allow	288.0 sf	1.04	0.58	-	-	-	1.62 /sf	467
03-21-10.60	Reinforcing steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	1.3 ton	848.67	1,000.00	-	-	-	1,848.67 /ton	2,437
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - decks	0.0 ton	44.50	-	-	7.00	-	52.00 /ton	1
03-21-10.60	Reinforcing steel, crane cost for handling, maximum, add	0.0 ton	126.00	-	-	22.00	-	148.00 /ton	2
03-31-05.35	Concrete, ready mix, regular weight, elevated decks, 4000 psi	22.0 cy	-	107.00	-	-	-	107.00 /cy	2,351
03-31-05.70	Structural concrete, placing, elevated slab, with crane and bucket, over 10" thick, includes vibrating, excludes material	22.0 cy	37.09	-	-	9.53	-	46.61 /cy	1,024
03-35-29.30	Concrete finishing, floors, monolithic, screed finish	384.0 sf	0.32	-	-	-	-	0.32 /sf	124
03-39-13.50	Curing, sprayed membrane curing compound, elevated decks	3.8 csf	10.53	11.05	-	-	-	21.58 /csf	83
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 2 coats	384.0 sf	0.40	0.63	-	-	-	1.03 /sf	397
	Elevated Slab - Channel Inlet	**22.0 CYD**	**269.21**	**211.66**		**9.53**		**490.39 /CYD**	**10,789**
03350 Elevated Slab - Tunnel Shaft									
03-11-13.35	C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	1,183.0 sf	7.44	1.26	-	-	-	8.70 /sf	10,290
03-11-13.35	C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	178.0 lf	5.38	0.21	-	-	-	5.59 /lf	995
03-11-13.35	Cip concrete forms,elevated slab,box-out for shallow slab openings,over 10 sf (use perimeter),includes shoring,erecting,bracing,stripping and cleaning	24.0 lf	6.94	1.61	-	-	-	8.55 /lf	205

Phase	Estimate Breakdown	Quantity		Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit		Total Net Amount
03350 Elevated Slab - Tunnel Shaft											
03-15-05.70	Shores, reshoring at elevated decks, allow	709.8	sf	1.04	0.58	-	-	-	1.62	/sf	1,152
03-21-10.60	Reinforcing steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	4.1	ton	848.66	1,000.00	-	-	-	1,848.66	/ton	7,509
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - decks	0.0	ton	44.00	-	-	7.60	-	51.80	/ton	2
03-21-10.60	Reinforcing steel, crane cost for handling, maximum, add	0.0	ton	126.20	-	-	21.50	-	147.60	/ton	5
03-31-05.35	Concrete, ready mix, regular weight, elevated decks, 4000 psi	67.7	cy	-	107.00	-	-	-	107.00	/cy	7,243
03-31-05.70	Structural concrete, placing, elevated slab, with crane and bucket, over 10" thick, includes vibrating, excludes material	67.7	cy	37.09	-	-	9.53	-	46.61	/cy	3,155
03-35-29.30	Concrete finishing, floors, monolithic, screed finish	1,183.0	sf	0.32	-	-	-	-	0.32	/sf	383
03-39-13.50	Curing, sprayed membrane curing compound, elevated decks	11.8	csf	10.53	11.05	-	-	-	21.58	/csf	255
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 2 coats	1,183.0	sf	0.40	0.63	-	-	-	1.03	/sf	1,224
	Elevated Slab - Tunnel Shaft	**69.0**	**CYD**	**255.25**	**205.21**		**9.36**		**469.83**	**/CYD**	**32,418**
	02 RLS PUMPSTATION CONCRETE	**2,566.0**	**CYD**	**248.79**	**150.36**		**6.96**		**406.11**	**/CYD**	**1,042,067**

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03 RLS PIPE GALLERY CONCRETE									
03330 Pipe Gallery Base Slab - 24" Thick									
03-21-10.60	Reinforcing steel, in place, slab on grade, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	1.5 ton	1,070.06	1,000.00	-	-	-	2,070.06 /ton	3,018
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - slabs	1.5 ton	44.16	-	-	7.51	-	51.67 /ton	75
03-21-10.60	Reinforcing in place, crane cost for handling, add to above, slabs	1.5 ton	48.00	-	-	8.17	-	56.17 /ton	82
03-31-05.35	Concrete, ready mix, regular weight, slabs/mats, 4000 psi	122.4 cy	-	107.00	-	-	-	107.00 /cy	13,097
03-31-05.70	Structural concrete, placing, slab on grade, pumped, over 6" thick, includes vibrating, excludes material	122.4 cy	22.78	-	-	4.31	-	27.10 /cy	3,317
03-35-29.30	Concrete finishing, floors, monolithic, screed and bull float(darby) finish	1,620.0 sf	0.39	-	-	-	-	0.39 /sf	629
03-39-13.50	Curing, sprayed membrane curing compound	16.2 csf	10.53	11.05	-	-	-	21.58 /csf	350
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 1 coat	1,620.0 sf	0.28	0.18	-	-	-	0.46 /sf	740
	Pipe Gallery Base Slab - 24" Thick	**122.0 CYD**	**46.97**	**123.16**		**4.52**		**174.65 /CYD**	**21,307**
03345 Concrete Walls - Pipe Gallery 18" Thick									
03-11-13.85	Cip concret forms,walls,steel framed plywd,over 8'16'hg,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	9,000.0 sfca	9.26	0.74	-	-	-	10.00 /sfca	89,972
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	24.0 gal	-	20.50	-	-	-	20.50 /gal	492
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	7.5 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	13,653
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	7.5 ton	44.17	-	-	7.51	-	51.68 /ton	388
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	7.5 ton	48.01	-	-	8.17	-	56.17 /ton	421
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	255.0 cy	-	107.00	-	-	-	107.00 /cy	27,285
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	255.0 cy	35.12	-	-	6.65	-	41.77 /cy	10,652
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	4,500.0 sf	1.17	0.04	-	-	-	1.21 /sf	5,440
	Concrete Walls - Pipe Gallery 18" Thick	**250.0 CYD**	**417.49**	**168.47**		**7.25**		**593.21 /CYD**	**148,303**

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03350 Elevated Slabs - Pipe Gallery 18" Thick									
03-11-13.35	C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	1,620.0 sf	7.44	1.26	-	-	-	8.70 /sf	14,091
03-11-13.35	C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	334.0 lf	5.38	0.21	-	-	-	5.59 /lf	1,867
03-15-05.75	Accessories, can and sleeve elev deck penetrations, avg. 24" diameter	6.0 ea	12.16	110.00	-	-	-	122.16 /ea	733
03-21-10.60	Reinforcing steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	0.1 ton	848.70	1,000.00	-	-	-	1,848.70 /ton	153
03-23-05.50	Prestressing steel, ungrouted single strand, 100' elevated slab, 35 kip, post-tensioned in field	1,296.0 lb	1.68	0.63	-	0.02	-	2.33 /lb	3,020
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - decks	0.7 ton	44.16	-	-	7.50	-	51.67 /ton	36
03-21-10.60	Reinforcing steel, crane cost for handling, maximum, add	0.7 ton	126.20	-	-	21.47	-	147.67 /ton	102
03-31-05.35	Concrete, ready mix, regular weight, elevated decks, 5000 psi	91.8 cy	-	113.00	-	-	-	113.00 /cy	10,373
03-31-05.70	Structural concrete, placing, elevated slab, with crane and bucket, over 10" thick, includes vibrating, excludes material	91.8 cy	37.09	-	-	9.53	-	46.61 /cy	4,279
03-35-29.30	Concrete finishing, floors, monolithic, screed finish	1,620.0 sf	0.32	-	-	-	-	0.32 /sf	524
03-39-13.50	Curing, sprayed membrane curing compound, elevated decks	16.2 csf	10.53	11.05	-	-	-	21.58 /csf	350
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 2 coats	1,620.0 sf	0.40	0.63	-	-	-	1.03 /sf	1,676
	Elevated Slabs - Pipe Gallery 18" Thick	**90.0 CYD**	**233.76**	**169.38**		**10.25**		**413.38 /CYD**	**37,204**
	03 RLS PIPE GALLERY CONCRETE	**462.0 CYD**	**283.86**	**156.68**		**7.11**		**447.65 /CYD**	**206,814**

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
04 RLS MECHANICAL									
11999 Pumps Station - Pumps and Instr..									
46-06-22.00	Submersible pump - 15 MGD Pumps	6.0 ea	6,867.18	200,000.00	-	2,500.00		209,367.18 /ea	1,256,203
46-06-22.00	Submersible pump Local Control Panel and VFD	4.0 ea	2,746.87	25,000.00	-		0.00	27,746.87 /ea	110,987
27-20-57.00	LIT - Level Indicating Ultrasonic or Std - Install, Calibrate, Test, Loop Check	4.0 ea	1,464.29	2,500.00	-	-	-	3,964.29 /ea	15,857
27-20-07.00	Ultrasonic Level Transmitters	4.0 ea	464.85	2,798.00	-	-	-	3,262.85 /ea	13,051
27-20-10.00	AI - Comb. Gas Analyzers	2.0 ea	464.85	3,715.00	-	-	-	4,179.85 /ea	8,360
27-20-53.00	AI - Analyzer Indicator - Install, Calibrate, Test, Loop Check	2.0 ea	883.22		-	-	-	883.22 /ea	1,766
46-06-22.00	Submersible pump - FLYGT 250 Gpm	2.0 ea	5,493.75	32,100.00	-			37,593.75 /ea	75,187
	Pumps Station - Pumps and Instr..	**6.0 Each**	**12,265.13**	**232,137.00**		**2,500.00**		**246,902.13 /Each**	**1,481,413**
14999 Track Mounted 15 Ton Monorail									
41-22-13.13	Overhead bridge crane, under hung hoist, electric operating, 2 girder, 15 ton, 60' span	1.0 ea	25,000.04	269,000.00	-	5,000.00	-	299,000.04 /ea	299,000
41-22-13.10	Crane Rails, running track only, 104 lb per yard, excl. equipment	10,400.0 lb	0.47	0.66	-	0.03	-	1.16 /lb	12,042
	Track Mounted 15 Ton Monorail	**1.0 Each**	**29,901.71**	**275,864.00**		**5,276.56**		**311,042.27 /Each**	**311,042**
22999 Tie Ins Work Allownace									
22-05-00.10	Allowance - Piping, Process - Tie Ins work	1.0 ls	-	-	50,000.00	-	-	50,000.00 /ls	50,000
	Tie Ins Work Allownace	**1.0 LS**			**50,000.00**			**50,000.00 /LS**	**50,000**
27999 24" Flowmeters									
27-20-03.00	24" Magnetic flowmeters, 150# AWWA flanges	6.0 ea	915.62	11,031.00	-	-	-	11,946.62 /ea	71,680
	24" Flowmeters	**6.0 Each**	**915.62**	**11,031.00**				**11,946.62 /Each**	**71,680**
40120 24" Ductile Iron Piping									
40-05-19.20	Pipe Plain End-Ductile Iron--C-151 24 Inch (600mm)	643.0 lf	-	110.00	-	-	-	110.00 /lf	70,730
40-05-19.20	Fitting Flanged & Bolted-Ductile Iron-Ell90-Non-Specific 24 Inch (600mm)	33.0 ea	-	1,500.00	-	-	-	1,500.00 /ea	49,500
40-05-19.10	Fitting Flanged & Bolted-Cast Iron-Flange Thr-Non-Specific 24 Inch (600mm)	12.0 ea	-	1,084.20	-	-	-	1,084.20 /ea	13,010
40-05-05.00	Pipe Erection-Handle Fittings-Metal-Std 24 Inch (600mm)	33.0 ea	238.32	-	-	-	-	238.32 /ea	7,865
40-05-19.10	Shop Fabrication-Cast Iron-Shop Cut & Thread & Attach Flange-Class C 24 Inch (600mm)	12.0 ea	-	103.16	-	-	-	103.16 /ea	1,238
40-05-19.20	Pipe Erection-Straight Run-Ductile Iron-Non-Specific 24 Inch (600mm)	775.0 lf	132.15	-	-	-	-	132.15 /lf	102,412

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
40120 24" Ductile Iron Piping									
40-05-05.00	Make Up Bolted Joint incl B-7 Nuts, Bolts, 1/16 Inch Rubber Gasket-Cls 150 (PN20) 24 Inch (600mm)	6.0 ea	109.57	537.94	-	-	-	647.51 /ea	3,885
40-05-05.00	Field Testing-Hydrotest-Non-Specific 24 Inch (600mm)	775.0 lf	15.00	-	-	-	-	15.00 /lf	11,625
	24" Ductile Iron Piping	**775.0 LFT**	**158.14**	**177.69**				**335.83 /LFT**	**260,266**
40510 CPVC Piping									
40-05-31.23	Pipe Plain End-CPVC--Sch 40 4 Inch (100mm)	105.2 lf	-	30.11	-	-	-	30.11 /lf	3,168
40-05-31.23	Pipe Plain End-CPVC--Sch 40 8 Inch (200mm)	727.5 lf	-	52.16	-	-	-	52.16 /lf	37,948
40-05-31.23	Pipe Plain End-CPVC--Sch 80 4 Inch (100mm)	96.3 lf	-	41.82	-	-	-	41.82 /lf	4,027
40-05-31.23	Fitting Socket Weld-CPVC-Ell90-Non-Specific 4 Inch (100mm)	8.0 ea	-	167.33	-	-	-	167.33 /ea	1,339
40-05-31.23	Fitting Socket Weld-CPVC-Ell90-Non-Specific 8 Inch (200mm)	40.0 ea	-	175.00	-	-	-	175.00 /ea	7,000
40-05-31.23	Fitting Socket Weld-CPVC-Ell90-Sch 80 4 Inch (100mm)	6.0 ea	-	97.20	-	-	-	97.20 /ea	583
40-05-31.23	Fitting Socket Weld-CPVC-Tee-Non-Specific 4 Inch (100mm)	1.0 ea	-	160.00	-	-	-	160.00 /ea	160
40-05-31.23	Fitting Socket Weld-CPVC-Tee-Non-Specific 8 Inch (200mm)	10.0 ea	-	196.52	-	-	-	196.52 /ea	1,965
40-05-31.23	Fitting Socket Weld-CPVC-Tee-Sch 80 4 Inch (100mm)	1.0 ea	-	122.06	-	-	-	122.06 /ea	122
40-05-31.23	Fitting Flanged & Bolted-CPVC-Flange SW-Cls 150 (PN20) 4 Inch (100mm)	12.0 ea	-	169.89	-	-	-	169.89 /ea	2,039
40-05-05.00	Pipe Erection-Handle Fittings-Plastic-Sch 40 4 Inch (100mm)	17.0 ea	24.65	-	-	-	-	24.65 /ea	419
40-05-05.00	Pipe Erection-Handle Fittings-Plastic-Sch 40 8 Inch (200mm)	78.0 ea	48.10	-	-	-	-	48.10 /ea	3,752
40-05-65.23	Valve Socket Weld-CPVC-Check-Cls 150 (PN20) 4 Inch (100mm)	4.0 ea	-	600.00	-	-	-	600.00 /ea	2,400
40-05-05.00	Pipe Erection-Handle Fittings-Plastic-Sch 80 4 Inch (100mm)	11.0 ea	24.55	-	-	-	-	24.55 /ea	270
40-05-63.00	Valve Socket Weld-CPVC-Ball-Cls 150 (PN20) 4 Inch (100mm)	4.0 ea	-	900.00	-	-	-	900.00 /ea	3,600
40-05-51.00	Pipe Erection-Handle Valves-Metal-Non-Specific 1/2 Inch (13mm)	22.0 ea	28.60	-	-	-	-	28.60 /ea	629

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
40510 CPVC Piping									
40-05-31.23	Pipe Erection-Straight Run-CPVC-Sch 40 4 Inch (100mm)	110.0 lf	7.89	-	-	-	-	7.89 /lf	868
40-05-31.23	Pipe Erection-Straight Run-CPVC-Sch 40 8 Inch (200mm)	780.0 lf	10.52	-	-	-	-	10.52 /lf	8,205
40-05-05.00	Pipe Erection-Make Up Cemented Plastic Socket Joint-Non-Specific 4 Inch (100mm)	62.0 ea	76.70	-	-	-	-	76.70 /ea	4,755
40-05-05.00	Pipe Erection-Make Up Cemented Plastic Socket Joint-Non-Specific 8 Inch (200mm)	166.0 ea	76.70	-	-	-	-	76.70 /ea	12,732
40-05-31.23	Pipe Erection-Straight Run-CPVC-Sch 80 4 Inch (100mm)	100.0 lf	10.52	-	-	-	-	10.52 /lf	1,052
40-05-05.00	Make Up Bolted Joint incl B-7 Nuts, Bolts, 1/16 Inch Rubber Gasket-Non-Specific 1/2 Inch (13mm)	36.0 ea	10.96	6.34	-	-	-	17.30 /ea	623
40-05-07.00	Pipe Support 4 Inch (100mm)	6.0 ea	109.57	15.00	-	-	-	124.57 /ea	747
40-05-07.00	Pipe Support 8 Inch (200mm)	10.0 ea	109.57	25.00	-	-	-	134.57 /ea	1,346
40-05-07.00	Hanger Rod 4 Inch (100mm)	6.0 ea	32.87	25.00	-	-	-	57.87 /ea	347
40-05-07.00	Hanger Rod 8 Inch (200mm)	20.0 ea	43.83	150.00	-	-	-	193.83 /ea	3,877
40-05-07.00	Hilti-Chemical Anchor - Pipe Support Size 4 Inch (100mm)	36.0 ea	21.92	20.00	-	-	-	41.92 /ea	1,509
40-05-07.00	Hilti-Chemical Anchor - Pipe Support Size 8 Inch (200mm)	60.0 ea	32.87	25.00	-	-	-	57.87 /ea	3,472
40-05-05.00	Field Testing-Hydrotest-Non-Specific 4 Inch (100mm)	210.0 lf	3.07	-	-	-	-	3.07 /lf	644
40-05-05.00	Field Testing-Hydrotest-Non-Specific 8 Inch (200mm)	780.0 lf	8.44	-	-	-	-	8.44 /lf	6,581
	CPVC Piping	**990.0 LFT**	**46.35**	**71.00**				**117.35 /LFT**	**116,180**
46999 Channel Intel and Outlet Gates									
46-06-10.00	Hydraulic structures, sluice gate, HD, self cont actuator, 72" x 120"	4.0 ea	40,718.40	175,000.00	-	-	-	215,718.40 /ea	862,874
	Channel Intel and Outlet Gates	**4.0 Each**	**40,718.40**	**175,000.00**				**215,718.40 /Each**	**862,874**
	04 RLS MECHANICAL	**1.0 LSUM**	**440,310.26**	**2,642,867.72**	**50,000.00**	**20,276.56**		**3,153,454.54 /LSUM**	**3,153,455**

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
05 RLS SUPER STRUCTURE									
03335 Super Structure Columns									
03-11-13.25	Cip concrete forms,col,square,steel framed plywd,30"x30",based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	3,360.0 sfca	6.11	1.00	-	-	-	7.11 /sfca	23,901
03-15-05.12	Chamfer strip, wood, 1" wide	1,120.0 lf	1.42	0.33	-	-	-	1.75 /lf	1,956
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	9.0 gal	-	20.50	-	-	-	20.50 /gal	184
03-21-10.60	Reinforcing steel, in place, columns, #8 to #18, A615, grade 60, incl labor for accessories, excl material for accessories	14.0 ton	1,070.05	1,000.00	-	-	-	2,070.05 /ton	28,981
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	14.0 ton	44.17	-	-	7.51	-	51.68 /ton	724
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	14.0 ton	48.01	-	-	8.17	-	56.17 /ton	786
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	96.1 cy	-	107.00	-	-	-	107.00 /cy	10,286
03-31-05.70	Structural concrete, placing, column, square or round, with crane and bucket, 36" thick, includes vibrating, excludes material	96.1 cy	48.21	-	-	12.39	-	60.60 /cy	5,825
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	3,360.0 sf	1.17	0.04	-	-	-	1.21 /sf	4,062
	Super Structure Columns	**97.0 CYD**	**484.14**	**292.10**		**14.54**		**790.78 /CYD**	**76,705**
03350 Elevated Slab - Super Structure									
03-11-13.35	C.I.P. concrete forms, elevated slab, flat plate, plywood, to 15' high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	2,252.0 sf	7.44	1.26	-	-	-	8.70 /sf	19,588
03-11-13.35	C.I.P. concrete forms, elevated slab, edge forms, to 6" high, 4 use, includes shoring, erecting, bracing, stripping and cleaning	209.0 lf	5.38	0.21	-	-	-	5.59 /lf	1,168
03-11-13.35	Cip concrete forms,elevated slab,box-out for shallow slab openings,over 10 sf (use perimeter),includes shoring,erecting,bracing,stripping and cleaning	165.0 lf	6.94	1.61	-	-	-	8.55 /lf	1,411
03-15-05.70	Shores, reshoring at elevated decks, allow	2,026.8 sf	1.04	0.58	-	-	-	1.62 /sf	3,289
03-21-10.60	Reinforcing steel, in place, elevated slabs, #4 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	7.7 ton	848.66	1,000.00	-	-	-	1,848.66 /ton	14,294
03-21-10.60	Reinforcing in place, unloading & sorting, add to above - decks	0.1 ton	44.20	-	-	7.50	-	51.70 /ton	3

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
03350 Elevated Slab - Super Structure									
03-21-10.60	Reinforcing steel, crane cost for handling, maximum, add	0.1 ton	126.30	-	-	21.40	-	147.70 /ton	9
03-31-05.35	Concrete, ready mix, regular weight, elevated decks, 4000 psi	128.9 cy	-	107.00	-	-	-	107.00 /cy	13,788
03-31-05.70	Structural concrete, placing, elevated slab, with crane and bucket, over 10" thick, includes vibrating, excludes material	128.9 cy	37.09	-	-	9.53	-	46.61 /cy	6,007
03-35-29.30	Concrete finishing, floors, monolithic, screed finish	2,252.0 sf	0.32	-	-	-	-	0.32 /sf	728
03-39-13.50	Curing, sprayed membrane curing compound, elevated decks	22.5 csf	10.53	11.05	-	-	-	21.58 /csf	486
03-35-29.30	Concrete finishing, floor, dustproofing, solvent-based, 2 coats	2,252.0 sf	0.40	0.63	-	-	-	1.03 /sf	2,329
	Elevated Slab - Super Structure	**128.0 CYD**	**268.45**	**214.93**		**9.61**		**492.98 /CYD**	**63,102**
05517 Metal Stairs									
05-51-19.50	Stair, shop fabricated, steel, 4'-0" W, incl pipe railing, stringers, grating treads w/ safety nosing, per riser	20.0 risr	88.05	430.00	-	4.96	-	523.00 /risr	10,460
	Metal Stairs	**20.0 RSR**	**88.05**	**430.00**		**4.96**		**523.00 /RSR**	**10,460**
05999 Hand Railing									
05-05-23.20	anchor 1/2" dia x 7" L, in concrete, brick or stone, excl layout & drilling	84.0 ea	5.84	1.70	-	-	-	7.54 /ea	633
03-82-16.10	Concrete impact drilling, for anchors, 4" d, 1/2" dia, in concrete or brick walls and floors, includes bit cost, layout and set up time, excl anchor	84.0 ea	14.60	0.06	-	-	-	14.66 /ea	1,231
05-52-13.50	Railing, pipe, aluminum, clear anodized, 2 rails, 3'-6" high, posts @ 5' O.C., 1-1/4" dia, shop fabricated With Toe plate	210.0 lf	16.51	44.00	-	0.93	-	61.44 /lf	12,902
	Hand Railing	**210.0 LFT**	**24.68**	**44.70**		**0.93**		**70.32 /LFT**	**14,766**
05999 Access Hatches									
08-31-13.35	Doors, specialty, access, floor, industrial, aluminum, 150 psf L.L., double leaf, 10' x 10'	2.0 opng	291.71	4,500.00	-	-	-	4,791.71 /opng	9,583
08-31-13.35	Doors, specialty, access, floor, industrial, aluminum, 150 psf L.L., double leaf, 10' x 12'	2.0 opng	291.71	5,000.00	-	-	-	5,291.71 /opng	10,583
08-31-13.35	Doors, specialty, access, floor, industrial, aluminum, 150 psf L.L., double leaf, 6' x 10'	2.0 opng	291.71	1,950.00	-	-	-	2,241.71 /opng	4,483
08-31-13.35	Doors, specialty, access, floor, industrial, aluminum, 150 psf L.L., double leaf, 8' x 10'	1.0 opng	291.71	3,500.00	-	-	-	3,791.71 /opng	3,792
08-31-13.35	Doors, specialty, access, floor, industrial, aluminum, 150 psf L.L., double leaf, 5' x 12'	1.0 opng	291.71	2,500.00	-	-	-	2,791.71 /opng	2,792

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
	Access Hatches	**8.0 EACH**	**291.71**	**3,612.50**				**3,904.21 /EACH**	**31,234**
	05 RLS SUPER STRUCTURE	**225.0 CYD**	**402.67**	**456.59**		**13.04**		**872.30 /CYD**	**196,267**
06 RLS HVAC AND ODOR CONTROL									
23999 Foul Air Fans and Damper									
23-34-00.00	Fans, axial flow, compact, lo sound, 2.5" S.P., 6,400 CFM, 5 HP	2.0 ea	771.37	4,375.00	-		-	5,146.37 /ea	10,293
22-20-00.45	24" FRP Dampers, volume control	2.0 ea	114.46	760.00	-	-	-	874.46 /ea	1,749
22-20-00.45	42" FRP Dampers, volume control	2.0 ea	305.25	1,200.00	-	-	-	1,505.25 /ea	3,010
	Foul Air Fans and Damper	**2.0 Each**	**1,191.07**	**6,335.00**				**7,526.07 /Each**	**15,052**
23999 FRP Foul Air Ducting									
22-20-00.45	Duct, FRP, 24" dia.	160.0 lnft	171.68	59.00	-	-	-	230.68 /lnft	36,909
22-20-00.45	Fitting, FRP, Tee , 24" dia.	4.0 ea	457.81	471.00	-	-	-	928.81 /ea	3,715
22-20-00.45	Fitting, FRP, 90 Elbow, 24" dia.	5.0 ea	755.39	295.00	-	-	-	1,050.39 /ea	5,252
22-20-00.45	Duct, FRP, 40" dia.	145.0 lnft	251.80	106.00	-	-	-	357.80 /lnft	51,881
22-20-00.45	Fitting, FRP, Tee , 40" dia.	2.0 ea	915.63	1,883.00	-	-	-	2,798.63 /ea	5,597
22-20-00.45	Fitting, FRP, 90 Elbow, 40" dia.	8.0 ea	686.72	1,177.00	-	-	-	1,863.72 /ea	14,910
22-20-00.45	Fitting, FRP, Weld, 40" dia.	22.0 ea	727.01	118.00	-	-	-	845.01 /ea	18,590
22-20-00.45	Fitting, FRP, Weld, 24" dia.	20.0 ea	364.27	59.00	-	-	-	423.27 /ea	8,465
22-20-00.45	Fitting, FRP, Flange, 24" dia.	1.0 ea	228.91	189.00	-	-	-	417.91 /ea	418
22-20-00.45	Fitting, FRP, Flange, 40" dia.	1.0 ea	457.81	442.00	-	-	-	899.81 /ea	900
22-20-00.45	Fitting, FRP, Reducer 40" dia.	1.0 ea	915.62	2,353.00	-	-	-	3,268.62 /ea	3,269
	FRP Foul Air Ducting	**305.0 LFT**	**333.75**	**157.74**				**491.49 /LFT**	**149,905**
	06 RLS HVAC AND ODOR CONTROL	**1.0 LSUM**	**104,176.41**	**60,781.00**				**164,957.41 /LSUM**	**164,957**

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
07 SHAFT IMPROVEMENTS AND CORRISION PROTECTION									
03345 Strcutural Concrete Liner - 74'T x 178' L x12"W									
03-11-13.85	Cip concrete forms,walls,steel framed plywd,over 16'20'h,based 50 us purchsd forms,4 us bracing lumber,includes erecting,bracing,stripping and cleaning	13,172.0 sfca	10.41	0.74	-	-	-	11.15 /sfca	146,917
03-15-05.95	Form oil, up to 800 S.F. per gallon, coverage, includes material only	70.3 gal	-	20.50	-	-	-	20.50 /gal	1,440
03-21-10.60	Reinforcing steel, in place, walls, #3 to #7, A615, grade 60, incl labor for accessories, excl material for accessories	36.2 ton	820.37	1,000.00	-	-	-	1,820.37 /ton	65,939
03-21-10.60	Reinforcing in place, unloading & sorting, add - walls, cols, beams	36.2 ton	44.17	-	-	7.51	-	51.68 /ton	1,872
03-21-10.60	Reinforcing, crane cost for handling, add to above, walls, cols, beams	36.2 ton	48.01	-	-	8.17	-	56.17 /ton	2,035
03-31-05.35	Concrete, ready mix, regular weight, walls/cols/beams, 4000 psi	512.2 cy	-	107.00	-	-	-	107.00 /cy	54,810
03-31-05.70	Structural concrete, placing, walls, pumped, 15" thick, includes vibrating, excludes material	512.2 cy	35.12	-	-	6.65	-	41.77 /cy	21,398
03-35-29.60	Concrete finishing, walls, burlap rub with grout, includes breaking ties and patching voids	13,172.0 sf	1.17	0.04	-	-	-	1.21 /sf	15,923
	Strcutural Concrete Liner - 74'T x 178' L x12"W	**13,172.0 SQFT**	**15.46**	**7.80**		**0.30**		**23.56 /SQFT**	**310,334**
13999 T-Lock Liner Corrosion Protection									
03-05-13.81	Membrane lining, T-lock liner - Small shaft	6,646.0 sqft	-	-	15.00	-	-	15.00 /sqft	99,690
03-05-13.81	Membrane lining, T-lock liner Large Shaft	15,593.0 sqft	-	-	15.00	-	-	15.00 /sqft	233,895
	T-Lock Liner Corrosion Protection	**22,239.0 SQFT**			**15.00**			**15.00 /SQFT**	**333,585**
	07 SHAFT IMPROVEMENTS AND CORRISION PROTECTION	**35,411.0 SQFT**	**5.75**	**2.90**	**9.42**	**0.11**		**18.18 /SQFT**	**643,919**

Phase	Estimate Breakdown	Quantity	Labor Cost/Unit	Material Cost/Unit	Sub Cost/Unit	Equip Cost/Unit	Other Cost/Unit	Total Cost/Unit	Total Net Amount
08 RLS ELECTRICAL ALLOWANCE									
26999 EI&C Allowance									
26-00-00.02	Electrical and Instrumentation Subcontract - Allowance	1.0 ls			750,000.00	-	-	750,000.00 /ls	750,000
	EI&C Allowance	**1.0 LSUM**			**750,000.00**			**750,000.00 /LSUM**	**750,000**
	08 RLS ELECTRICAL ALLOWANCE	**1.0 LSUM**			**750,000.00**			**750,000.00 /LSUM**	**750,000**
	01 SVCW RLS PUMP STATION	**1.0 LSUM**	**1,880,132.31**	**3,792,087.45**	**1,139,045.00**	**121,210.16**		**6,932,474.92 /LSUM**	**6,932,475**

Estimate Totals

Description	Rate	Hours	Amount	Totals
Labor		21,783 hrs	1,880,132	
Material			3,792,087	
Subcontract			1,139,045	
Equipment		1,453 hrs	121,210	
			6,932,474	**6,932,474**
Labor Mark-up	15.000 %		282,020	
Material Mark-up	10.000 %		379,209	
Subcontractor Mark-up	10.000 %		113,905	
Construction Equipment Mark-up	10.000 %		12,121	
			787,255	**7,719,729**
Material Shipping & Handling	2.000 %		75,842	
Material Sales Tax	9.000 %		375,417	
Net Markups			**451,259**	**8,170,988**
Contractor General Conditions	12.000 %		980,518	
Mobe/Demob	5.000 %		408,549	
			1,389,067	**9,560,055**
Start-Up, Training, O&M	2.000 %		191,201	
			191,201	**9,751,256**
Contractor Bonds & Insurance	2.000 %		195,025	
			195,025	**9,946,281**
Bldg Risk, Liability Auto Ins	1.000 %		99,463	
			99,463	**10,045,744**
CGL Insurance	1.500 %		150,686	
Gross Markups			**150,686**	**10,196,430**
Total				**10,196,430**

Appendix G: RLS LCC Analysis

Brown and Caldwell, August 2016

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August 31, 2016

Brown AND Caldwell

Mr. Bill Bryan
Silicon Valley Clean Water (SVCW)
1400 Radio Road
Redwood City, CA 94065

Project No. 146228

Subject: Receiving Lift Station Life Cycle Analysis

Dear Mr. Bryan:

This letter summarizes the assumptions and sources of information for the cost components incorporated into the Receiving Lift Station (RLS) Life Cycle Cost (LCC) analysis model. The major considerations in developing the RLS LCC include capital cost, annual operation and maintenance (O&M) running costs, replacement/rehabilitation costs and overall project schedule.

Construction Costs. The RLS will be located at the terminus of the Gravity Pipeline at the SVCW Wastewater Treatment Plant. The RLS will be used to pump raw sewage from the Gravity Pipeline to the Headworks. The RLS will consist of an inlet area, isolation gates and channels followed by two trench-style wet wells that will each house three submersible pumps for a total of six pumps.

Construction costs were calculated by Brown and Caldwell. The construction costs were converted into capital costs by applying soft costs, project contingencies, and market fluctuations to each individual cost component.

The construction contingencies, soft costs, and market fluctuations are summarized in Table 1. Market fluctuations are applied to capture the range of costs that could potentially occur over the construction period for the entire conveyance system program upgrade.

Table 1. Capital Cost Factors	
Cost Factor	**Markup**
Construction Contingency[1]	**25%**
Soft Costs[2]	
Construction Management, Engineering Services During Construction, Testing, Inspection	18%
Contract Change Orders (CCO)	5%
Planning	5%
Design	10%
Project Management	5%
Soft Cost Subtotal	**43%**
Market Fluctuations[3]	
Low	-5%
High	15%

Notes:

[1,2]Construction contingency and soft costs developed by SVCW as presented in the comparison of construction cost estimates during the June 2, 2016 Department Head Meeting.

[3]Market fluctuations developed by SVCW. Source: SVCW Conveyance System Construction Cost Analysis, Front of Plant, Revision Date: April 22, 2015, Revision 28b.

O&M Costs. Annual maintenance allowance is equal to one full time employee at $150,000/year per SVCW's direction during the original LCC analysis completed in May 2015 (includes odor control and crane maintenance). Odor control costs are included in this analysis and include costs for chemical and water to operate the system on an annual basis at an estimated cost of $200,000/year due to the size of the facility. Pump inspection (pull all submersible pumps) – once every six months; $25,200/year based on $4,200/pump/year in Table 7.19 of the Conveyance System Master Plan (2011, prepared by Winzler & Kelly). Electrical costs are calculated using an electrical billing rate of $0.129/kWh, along with calculated equipment power usage at the site. The electrical rate is based on current SVCW electrical bills from PG&E. The total RLS annual equipment power usage is 2,168,892 kW (247.4 kWh).

Rehabilitation/ Replacement Costs. The following rehabilitation and replacement assumptions were made for the RLS:

1. All pumps will be rebuilt every five years. Cost is assumed to be 50 percent of the total purchase cost for six pumps of $2,232,000. The assumption is to rebuild each pump every 5 years.
2. Pump replacement – once every 25 years. The cost to replace is assumed to be the total purchase cost for six pumps of $2,232,000. No rebuild costs are assumed within these years.

3. Electrical equipment will be replaced once every 25 years and instrumentation and control once every 15 years. Electrical equipment replacement cost is assumed to be $939,600 and the instrumentation and control equipment replacement cost is assumed to be $104,400.
4. Structural rehabilitation or replacement will occur once every 75 years for RLS since it will be a new station. Since this cost will occur outside of the period of analysis, it was not calculated for this LCC. The structural rehabilitation/replacement includes piping, valves, HVAC, sluice gates and odor control equipment.

Schedule. The RLS project construction is expected to begin in May 2019 and end in March 2021. Capital costs are applied in the LCC model at the midpoint year of construction. The Year 2020 is used as the midpoint year of construction. The end year of construction is used to establish the start of recurring O&M and rehabilitation/replacement costs. The Year of Analysis for the entire conveyance system program is the Year of Beneficial Use. The Year of Beneficial Use is the year major facilities of the conveyance system (i.e., Tunnel, Receiving Lift Station and Headworks) start up. Based on the current program-wide schedule (Version 13 dated June 23, 2016) developed by SVCW, the Year of Beneficial Use is the Year 2022.

Escalation and Discount Rates. To determine the present value of costs for the Year of Analysis, their values were escalated to future values and discounted back to the Year of Analysis. The discount and escalation rates used in the RLS LCC Analysis were developed by SVCW based on current and projected investment return rates as summarized in Table 3.

Table 3. Escalation and Discount Rates

Factor	Rate
Escalation	4%
Capital Project and Rehabilitation/Replacement Discount	7%
O&M Discount	3%

The LCC analysis summarizes all cost components over a 50-Year period ending in the Year 2066. The calculation for determining the RLS LCC is located in Attachment A. The total 50-year LCC for the RLS is $34.8 million with a range of $34.3 million to $36.6 million accounting for market fluctuations.

Very truly yours,

Brown and Caldwell

Charlie Joyce, Project Manager
Walnut Creek, CA

cc: Kim Hackett, SVCW
Roanne Ross, Whitley Burchett & Associates

Attachments (1)

- Attachment A: Receiving Lift Station LCC Calculation

Attachment A: SVCW Life Cycle Cost (LCC) Receiving Lift Station Calculation

A. Purpose: This sheet provides the Receiving Lift Station LCC calculation for a 50-year analysis period. The equations used below are further explained in TM 11-3: Life Cycle Cost Analysis Guidelines.

B. Step 1: Conversion from Construction Cost to Capital Cost: The following equation is used to convert the construction cost developed by each team into a capital cost. Contingency, soft cost and market fluctuation cost factors are displayed below.

Capital Cost = Construction Cost x [1 + Project Contingency + Σ(Soft Costs) + Market Fluctuations]

1. Project Contingency (all projects except Gravity Pipeline), Cont:

$Cont := 25\%$

2. Soft Costs, SC:

- Construction Management and Engineering Services: $SC_{CM} := 18\%$
- Conract Change Orders: $SC_{CCO} := 5\%$
- Planning: $SC_{Plan} := 5\%$
- Design: $SC_{Design} := 10\%$
- Project Management $SC_{PM} := 5\%$

3. Market Fluctuation, MF:
Curently set by SVCW

$MF_{low} := -5\%$

$MF_{base} := 0\%$

$MF_{high} := 15\%$

4. Capital Cost, CC: For the RLS, the construction cost is $10,196,430 (2016 dollars) and occurs in the midyear of construction.

Display Unit of Dollars: $dollars := 1$

$Cost_{Construction} := 10196430dollars$ *Note: From Receiving Lift Station Conceptual Level Class 3 Estimate, May 2016, prepared by BC.*

$$Cost_{Capital\_low} := Cost_{Construction} \cdot \left(1 + Cont + SC_{CM} + SC_{CCO} + SC_{Plan} + SC_{Design} + SC_{PM} + MF_{low}\right) = 16.62 \times 10^{6} \cdot dollars$$

$$Cost_{Capital\_base} := Cost_{Construction} \cdot \left(1 + Cont + SC_{CM} + SC_{CCO} + SC_{Plan} + SC_{Design} + SC_{PM} + MF_{base}\right) = 17.13 \times 10^{6} \cdot dollars$$

$$Cost_{Capital\_high} := Cost_{Construction} \cdot \left(1 + Cont + SC_{CM} + SC_{CCO} + SC_{Plan} + SC_{Design} + SC_{PM} + MF_{high}\right) = 18.66 \times 10^{6} \cdot dollars$$

$Y_{capital}$ = Midpoint Year of Construction $Y_{capital} := 2020$

C. Step 2: Calculate Operation and Maintenance (O&M) Costs: The following O&M assumptions are made for the RLS:

1. Annual general maintenance allowance at 1.0 FTE at $150K/year/employee per SVCW's direction during the original LCC analysis completed in May 2015. General maintenance includes odor control and crane maintenance.

2. Pump inspection (pull all submersible pumps) occurs once every six months; $25,200/year based on $4,200/pump/year.

3.Annual odor control costs are based on comparable pump station projects, (includes costs for chemical, water, and electrical). Estimated cost is $200,000/year.

1. General Maintenance Allowance

- Annual general maintenance allowance, $Cost_{Annual\_OM}$
- Occurs every year from end of construction through end of analysis.

- Year End of Construction, $Y_{EndConst}$:

$$Y_{EndConst} := 2021$$

- Year End of Analysis, $Y_{Analysis}$:

$$Y_{Analysis} := 2066$$

- Annual cost as follows:

$$Cost_{Annual\_OM} := 150000 \cdot dollars$$

2. Pump Inspection

- Annual pump inspection cost of 6 pumps, $Cost._{Annual\_Pump}$:
- Occurs every year from end of construction through end of analysis.

$$Cost_{Annual\_Pump} := 25200 \cdot dollars$$

3. Odor Control

- Annual Odor Control Cost, $Cost_{Annual\_Odor}$:
- Occurs every year from end of construction through end of analysis.

$$Cost_{Annual\_Odor} := 200000 \cdot dollars$$

3. Electrical

- Estimated pump station power required (based on equipment load) kWh, Power
- Electrical rate for the RLS ($/KWh), Rate
- Estimated annual cost, $Cost_{Annual\_Elec}$
- Electrical costs occur annually from end of construction to end of LCC analysis (2021 to 2066):

$kWh := 1$ $\quad$ $year := 1$

$hours := 1$ $\quad$ $days := 1$

$$Power := 247.6kWh$$

$$Rate := 0.129 \cdot \frac{dollars}{kWh}$$

$$Cost_{Annual\_Elec} := Power \cdot Rate \cdot 24\frac{hours}{days} \cdot 365\frac{days}{year} = 279.798 \times 10^{3} \cdot dollars$$

<u>D. Step 3: Calculate Rehabilitation and Replacement Costs:</u> The following R&R assumptions are made for the RLS:

1. The pumps are assumed to be rebuilt once every 5 years; cost is assumed to be 50% of purchase cost from the May 2016 cost estimate.

2. All pumps will be replaced once every 25 years; cost is assumed to be the purchase cost from the May 2016 cost estimate. Cost will be purchase cost from May 2016 cost estimate with no rebuild occuring in that year.

3. Electrical equipment replacement occurs once every 25 years and Instrumentation and Control equipment will be replaced once every 15 years, cost is assumed to be the construction cost from the May 2016 cost estimate.

4. Structural Rehabilitation or Replacement occurs once every 75 years; therefore, will not be included in this LCC analysis.

1. Pump Rebuild

- Pump cost from May 2016 cost estimate, $Cost_{Pump}$
- Assume 50% of purchase cost, $Cost_{Pump\ Rebuild}$

$$Cost_{Pump} := 2232000 dollars$$

$$Cost_{Pump\_Rebuild} := 0.5 \cdot Cost_{Pump} = 1.12 \times 10^{6} \cdot dollars$$

Pump rebuild occurs every 5 years under a 50-year cycle, except for years when pumps are replaced (2046); therefore, pump rebuild occurs in the following years:

$$Y_{Pump\_Rebuild\_1} := Y_{EndConst} + 5 = 2026$$

$$Y_{Pump\_Rebuild\_2} := Y_{EndConst} + 10 = 2031$$

$$Y_{Pump\_Rebuild\_3} := Y_{EndConst} + 15 = 2036$$

$$Y_{Pump\_Rebuild\_4} := Y_{EndConst} + 20 = 2041$$

$$Y_{Pump\_Rebuild\_5} := Y_{EndConst} + 30 = 2051$$

$$Y_{Pump\_Rebuild\_6} := Y_{EndConst} + 35 = 2056$$

$$Y_{Pump\_Rebuild\_7} := Y_{EndConst} + 40 = 2061$$

$$Y_{Pump\_Rebuild\_8} := Y_{EndConst} + 45 = 2066$$

3. Pump Replacement

- Pump purchase cost from May 2016 cost estimate, $Cost_{Pump}$
- Pump replacement cost (assumed to purchase cost), $Cost_{Pump\_Repl}$

$$Cost_{Pump\_Repl} := Cost_{Pump} = 2.23 \times 10^{6} \cdot dollars$$

Pump replacement occurs every 25 years under a 50-year cycle; therefore, pump replacement occurs in the following years:

$$Y_{Pump\_Repl\_1} := Y_{EndConst} + 25 = 2.05 \times 10^{3}$$

5. Electrical and I&C Equipment Replacement

- Electrical cost (assumed to be 90% of lump electrical/I&C allowance from May 2016 construction cost), $Cost_{Electrical\_RR}$
- I&C replacement cost (assumed to be 10% of lump electrical/I&C allowance from May 2016 construction cost), $Cost_{IC\_RR}$

$$Cost_{Electrical\_Allowance} := 1044000dollars$$

$$Cost_{Electrical\_RR} := 0.9 \cdot Cost_{Electrical\_Allowance} = 939.6 \times 10^{3} \cdot dollars$$

$$Cost_{IC\_RR} := 0.1 \cdot Cost_{Electrical\_Allowance} = 104.4 \times 10^{3} \cdot dollars$$

Electrical Equipment Replacement occurs every 25 years under a 50-year cycle; therefore, electrical equipment replacement occurs in the following year:

$$Y_{Electrical\_RR\_1} := Y_{EndConst} + 25 = 2.05 \times 10^{3}$$

I&C equipment replacement occurs every 15 years under a 50-year cycle; therefore, I&C replacement occurs in the following year:

$$Y_{IC\_RR\_1} := Y_{EndConst} + 15 = 2.04 \times 10^{3}$$

$$Y_{IC\_RR\_2} := Y_{EndConst} + 30 = 2.05 \times 10^{3}$$

$$Y_{IC\_RR\_3} := Y_{EndConst} + 45 = 2.07 \times 10^{3}$$

E. Step 4a: Future Value of All Costs calculation:

- Current Year, $Y_{current}$: $Y_{current} := 2016$
- Escalation, i: $i := 4\%$
- Calculate future values, FV using TM 11-3, EQ 4-1:

FV = PV x $(1+i)^{Yn-Ycurrent}$,

where Y_n is the year the cost occurs and PV = present value.

For annual costs: FV= PV $\frac{\left[(1+i)^n - 1\right]}{i}$, where n is number of years the cost occurs and is assumed to occur from end of construction to end of analysis.

$$FV_{capital\_low} := Cost_{Capital\_low} \cdot (1+i)^{Y_{capital} - Y_{current}} = 19.44 \times 10^6 \cdot dollars$$

$$FV_{capital\_base} := Cost_{Capital\_base} \cdot (1+i)^{Y_{capital} - Y_{current}} = 20.04 \times 10^6 \cdot dollars$$

$$FV_{capital\_high} := Cost_{Capital\_high} \cdot (1+i)^{Y_{capital} - Y_{current}} = 21.83 \times 10^6 \cdot dollars$$

$$FV_{Pump\_Rebuild\_1} := round\left[Cost_{Pump\_Rebuild} \cdot (1+i)^{Y_{Pump\_Rebuild\_1} - Y_{current}}, -4\right] = 1.65 \times 10^6 \cdot dollars$$

$$FV_{Pump\_Rebuild\_2} := round\left[Cost_{Pump\_Rebuild} \cdot (1+i)^{Y_{Pump\_Rebuild\_2} - Y_{current}}, -4\right] = 2.01 \times 10^6 \cdot dollars$$

$$FV_{Pump\_Rebuild\_3} := round\left[Cost_{Pump\_Rebuild} \cdot (1+i)^{Y_{Pump\_Rebuild\_3} - Y_{current}}, -4\right] = 2.45 \times 10^6 \cdot dollars$$

$$FV_{Pump\_Rebuild\_4} := \mathrm{round}\left[Cost_{Pump\_Rebuild}\cdot(1+i)^{Y_{Pump\_Rebuild\_4}-Y_{current}}, -4\right] = 2.98\times10^{6}\cdot dollars$$

$$FV_{Pump\_Rebuild\_5} := \mathrm{round}\left[Cost_{Pump\_Rebuild}\cdot(1+i)^{Y_{Pump\_Rebuild\_5}-Y_{current}}, -4\right] = 4.4\times10^{6}\cdot dollars$$

$$FV_{Pump\_Rebuild\_6} := \mathrm{round}\left[Cost_{Pump\_Rebuild}\cdot(1+i)^{Y_{Pump\_Rebuild\_6}-Y_{current}}, -4\right] = 5.36\times10^{6}\cdot dollars$$

$$FV_{Pump\_Rebuild\_7} := \mathrm{round}\left[Cost_{Pump\_Rebuild}\cdot(1+i)^{Y_{Pump\_Rebuild\_7}-Y_{current}}, -4\right] = 6.52\times10^{6}\cdot dollars$$

$$FV_{Pump\_Rebuild\_8} := \mathrm{round}\left[Cost_{Pump\_Rebuild}\cdot(1+i)^{Y_{Pump\_Rebuild\_8}-Y_{current}}, -4\right] = 7.93\times10^{6}\cdot dollars$$

$$FV_{Pump\_Repl\_1} := \mathrm{round}\left[Cost_{Pump\_Repl}\cdot(1+i)^{Y_{Pump\_Repl\_1}-Y_{current}}, -4\right] = 7.24\times10^{6}\cdot dollars$$

$$FV_{Electrical\_RR\_1} := \mathrm{round}\left[Cost_{Electrical\_RR}\cdot(1+i)^{Y_{Electrical\_RR\_1}-Y_{current}}, -4\right] = 3.05\times10^{6}\cdot dollars$$

$$FV_{IC\_RR\_1} := \mathrm{round}\left[Cost_{IC\_RR}\cdot(1+i)^{Y_{IC\_RR\_1}-Y_{current}}, -4\right] = 230\times10^{3}\cdot dollars$$

$$FV_{IC\_RR\_2} := \mathrm{round}\left[Cost_{IC\_RR}\cdot(1+i)^{Y_{IC\_RR\_2}-Y_{current}}, -4\right] = 410\times10^{3}\cdot dollars$$

$$FV_{IC\_RR\_3} := \mathrm{round}\left[Cost_{IC\_RR}\cdot(1+i)^{Y_{IC\_RR\_3}-Y_{current}}, -4\right] = 740\times10^{3}\cdot dollars$$

4b Future Value of Annual Costs:

Future value of annual costs before and after year of Beneficial Use are calculated differently below:

- Annual costs begin in 2021, which is the year construction ends, $Y_{EndConst}$
- Annual costs occuring in 2021 and 2022 will not be discounted like all other annual costs occuring after 2022 in Step 5; therefore, separate future values are calculated below.
- Year of Beneficial Use, Y_{BFU}:

$$Y_{BFU} := 2022$$

Calculate future values for Year 2021 O&M costs:

$$FV_{General\_OM\_1} := \mathrm{round}\left[Cost_{Annual\_OM} \cdot (1+i)^{Y_{EndConst}-Y_{current}}, -4\right] = 180 \times 10^3 \cdot \mathrm{dollars}$$

$$FV_{Pump\_OM\_1} := \mathrm{round}\left[Cost_{Annual\_Pump} \cdot (1+i)^{Y_{EndConst}-Y_{current}}, -4\right] = 30 \times 10^3 \cdot \mathrm{dollars}$$

$$FV_{ODOR\_OM\_1} := \mathrm{round}\left[Cost_{Annual\_Odor} \cdot (1+i)^{Y_{EndConst}-Y_{current}}, -4\right] = 240 \times 10^3 \cdot \mathrm{dollars}$$

$$FV_{Electrical\_1} := \mathrm{round}\left[Cost_{Annual\_Elec} \cdot (1+i)^{Y_{EndConst}-Y_{current}}, -4\right] = 340 \times 10^3 \cdot \mathrm{dollars}$$

Calculate future values for Year 2022 O&M costs:

$$FV_{General\_OM\_2} := \mathrm{round}\left[Cost_{Annual\_OM} \cdot (1+i)^{Y_{BFU}-Y_{current}}, -4\right] = 190 \times 10^3 \cdot \mathrm{dollars}$$

$$FV_{Pump\_OM\_2} := \mathrm{round}\left[Cost_{Annual\_Pump} \cdot (1+i)^{Y_{BFU}-Y_{current}}, -4\right] = 30 \times 10^3 \cdot \mathrm{dollars}$$

$$FV_{ODOR\_OM\_2} := round\left[Cost_{Annual\_Odor}\cdot(1+i)^{Y_{BFU}-Y_{current}}, -4\right] = 250\times10^{3}\cdot dollars$$

$$FV_{Electrical\_2} := round\left[Cost_{Annual\_Elec}\cdot(1+i)^{Y_{BFU}-Y_{current}}, -4\right] = 350\times10^{3}\cdot dollars$$

Calculate future values for O&M costs after 2022 assuming they are projected to end of analysis year (2066):

$$FV_{General\_OM} := round\left[FV_{General\_OM\_2}\cdot\frac{\left[(1+i)^{Y_{Analysis}-Y_{BFU}}-1\right]}{i}, -4\right] = 21.93\times10^{6}\cdot dollars$$

$$FV_{Pump\_OM} := round\left[FV_{Pump\_OM\_2}\cdot\frac{\left[(1+i)^{Y_{Analysis}-Y_{BFU}}-1\right]}{i}, -4\right] = 3.46\times10^{6}\cdot dollars$$

$$FV_{ODOR\_OM} := round\left[FV_{ODOR\_OM\_2}\cdot\frac{\left[(1+i)^{Y_{Analysis}-Y_{BFU}}-1\right]}{i}, -4\right] = 28.85\times10^{6}\cdot dollars$$

$$FV_{Electrical} := round\left[FV_{Electrical\_2}\cdot\frac{\left[(1+i)^{Y_{Analysis}-Y_{BFU}}-1\right]}{i}, -4\right] = 40.39\times10^{6}\cdot dollars$$

F. Step 5: Present Value at Year of Beneficial Use Calculation:

- Discount Rate for O&M, r_{OM}: $r_{OM} := 3\%$
- Discount Rate for Capital and Rehab/Replace, $r_{capital}$: $r_{capital} := 7\%$
- Calculate Present Values for all Years above Year of Beneficial Use using TM 11-3, EQ 4-2:

  Z = FV x (1+r)^-(Y_n-Y_{BFU}),
  where Z is the cost at the Year of Beneficial Use and FV is
  the future value calcuated in Step 4 and n is the year of occurence.

- For all costs occuring before Year of Beneficial Use, assume these costs are sunk costs in the year it occurs. Therefore, the future value as calculated in Step 4 will be used.

$$Z_{capital\_low} := \text{if}\left[Y_{capital} \le Y_{BFU}, FV_{capital\_low}, FV_{capital\_low} \cdot (1 + r_{capital})^{-(Y_{capital}-Y_{BFU})}\right] = 19.44 \times 10^6 \cdot \text{dollars}$$

$$Z_{capital\_base} := \text{if}\left[Y_{capital} \le Y_{BFU}, FV_{capital\_base}, FV_{capital\_base} \cdot (1 + r_{capital})^{-(Y_{capital}-Y_{BFU})}\right] = 20.04 \times 10^6 \cdot \text{dollars}$$

$$Z_{capital\_high} := \text{if}\left[Y_{capital} \le Y_{BFU}, FV_{capital\_high}, FV_{capital\_high} \cdot (1 + r_{capital})^{-(Y_{capital}-Y_{BFU})}\right] = 21.83 \times 10^6 \cdot \text{dollars}$$

$$Z_{Pump\_Rebuild\_1} := \text{round}\left[\text{if}\left[Y_{Pump\_Rebuild\_1} \le Y_{BFU}, FV_{Pump\_Rebuild\_1}, FV_{Pump\_Rebuild\_1} \cdot (1 + r_{capital})^{-(Y_{Pump\_Rebuild\_1}-Y_{BFU})}\right], -4\right] = 1.26 \times 10^6 \cdot \text{dollars}$$

$$Z_{Pump\_Rebuild\_2} := \text{round}\left[\text{if}\left[Y_{Pump\_Rebuild\_2} \le Y_{BFU}, FV_{Pump\_Rebuild\_2}, FV_{Pump\_Rebuild\_2} \cdot (1 + r_{capital})^{-(Y_{Pump\_Rebuild\_2}-Y_{BFU})}\right], -4\right] = 1.09 \times 10^6 \cdot \text{dollars}$$

$$Z_{Pump\_Rebuild\_3} := \text{round}\left[\text{if}\left[Y_{Pump\_Rebuild\_3} \le Y_{BFU}, FV_{Pump\_Rebuild\_3}, FV_{Pump\_Rebuild\_3} \cdot (1 + r_{capital})^{-(Y_{Pump\_Rebuild\_3}-Y_{BFU})}\right], -4\right] = 950 \times 10^3 \cdot \text{dollars}$$

$$Z_{Pump\_Rebuild\_4} := \mathrm{round}\left[\mathrm{if}\left[Y_{Pump\_Rebuild\_4} \le Y_{BFU}, FV_{Pump\_Rebuild\_4}, FV_{Pump\_Rebuild\_4}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Pump\_Rebuild\_4} - Y_{BFU}\right)}\right], -4\right] = 820\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{Pump\_Rebuild\_5} := \mathrm{round}\left[\mathrm{if}\left[Y_{Pump\_Rebuild\_5} \le Y_{BFU}, FV_{Pump\_Rebuild\_5}, FV_{Pump\_Rebuild\_5}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Pump\_Rebuild\_5} - Y_{BFU}\right)}\right], -4\right] = 620\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{Pump\_Rebuild\_6} := \mathrm{round}\left[\mathrm{if}\left[Y_{Pump\_Rebuild\_6} \le Y_{BFU}, FV_{Pump\_Rebuild\_6}, FV_{Pump\_Rebuild\_6}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Pump\_Rebuild\_6} - Y_{BFU}\right)}\right], -4\right] = 540\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{Pump\_Rebuild\_7} := \mathrm{round}\left[\mathrm{if}\left[Y_{Pump\_Rebuild\_7} \le Y_{BFU}, FV_{Pump\_Rebuild\_7}, FV_{Pump\_Rebuild\_7}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Pump\_Rebuild\_7} - Y_{BFU}\right)}\right], -4\right] = 470\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{Pump\_Rebuild\_8} := \mathrm{round}\left[\mathrm{if}\left[Y_{Pump\_Rebuild\_8} \le Y_{BFU}, FV_{Pump\_Rebuild\_8}, FV_{Pump\_Rebuild\_8}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Pump\_Rebuild\_8} - Y_{BFU}\right)}\right], -4\right] = 400\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{Pump\_Repl\_1} := \mathrm{round}\left[\mathrm{if}\left[Y_{Pump\_Repl\_1} \le Y_{BFU}, FV_{Pump\_Repl\_1}, FV_{Pump\_Repl\_1}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Pump\_Repl\_1} - Y_{BFU}\right)}\right], -4\right] = 1.43\times 10^{6}\cdot \mathrm{dollars}$$

$$Z_{Electrical\_RR\_1} := \mathrm{round}\left[\mathrm{if}\left[Y_{Electrical\_RR\_1} \le Y_{BFU}, FV_{Electrical\_RR\_1}, FV_{Electrical\_RR\_1}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{Electrical\_RR\_1} - Y_{BFU}\right)}\right], -4\right] = 600\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{IC\_RR\_1} := \mathrm{round}\left[\mathrm{if}\left[Y_{IC\_RR\_1} \le Y_{BFU}, FV_{IC\_RR\_1}, FV_{IC\_RR\_1}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{IC\_RR\_1} - Y_{BFU}\right)}\right], -4\right] = 90\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{IC\_RR\_2} := \mathrm{round}\left[\mathrm{if}\left[Y_{IC\_RR\_2} \le Y_{BFU}, FV_{IC\_RR\_2}, FV_{IC\_RR\_2}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{IC\_RR\_2} - Y_{BFU}\right)}\right], -4\right] = 60\times 10^{3}\cdot \mathrm{dollars}$$

$$Z_{IC\_RR\_3} := \mathrm{round}\left[\mathrm{if}\left[Y_{IC\_RR\_3} \le Y_{BFU}, FV_{IC\_RR\_3}, FV_{IC\_RR\_3}\cdot\left(1 + r_{capital}\right)^{-\left(Y_{IC\_RR\_3} - Y_{BFU}\right)}\right], -4\right] = 40\times 10^{3}\cdot \mathrm{dollars}$$

Present Value of Annual Costs:

$$Z_{General\_OM} := \mathrm{round}\left[\left(FV_{General\_OM\_1} + FV_{General\_OM\_2}\right) + FV_{General\_OM}\left(1 + r_{capital}\right)^{-\left(Y_{Analysis} - Y_{BFU}\right)}, -4\right] = 1.49\times 10^{6}\cdot \mathrm{dollars}$$

$$Z_{Pump\_OM} := \text{round}\left[\left(FV_{Pump\_OM\_1} + FV_{Pump\_OM\_2}\right) + FV_{Pump\_OM}\left(1 + r_{capital}\right)^{-\left(Y_{Analysis} - Y_{BFU}\right)}, -4\right] = 240 \times 10^{3} \cdot \text{dollars}$$

$$Z_{ODOR\_OM} := \text{round}\left[\left(FV_{ODOR\_OM\_1} + FV_{ODOR\_OM\_2}\right) + FV_{ODOR\_OM}\left(1 + r_{capital}\right)^{-\left(Y_{Analysis} - Y_{BFU}\right)}, -4\right] = 1.96 \times 10^{6} \cdot \text{dollars}$$

$$Z_{Electrical} := \text{round}\left[\left(FV_{Electrical\_1} + FV_{Electrical\_2}\right) + FV_{Electrical}\left(1 + r_{capital}\right)^{-\left(Y_{Analysis} - Y_{BFU}\right)}, -4\right] = 2.75 \times 10^{6} \cdot \text{dollars}$$

G. Step 6: Total Cost for the Year of Beneficial Use calculated by Summing the Adjusted Values in Step 5:

$$Z_{total\_low} := Z_{capital\_low} + Z_{General\_OM} + Z_{Pump\_OM} + Z_{ODOR\_OM} + Z_{Electrical} + Z_{Pump\_Rebuild\_1} \cdots + Z_{Pump\_Rebuild\_2} + Z_{Pump\_Rebuild\_3} + Z_{Pump\_Rebuild\_4} + Z_{Pump\_Rebuild\_5} + Z_{Pump\_Rebuild\_6} \cdots + Z_{Pump\_Rebuild\_7} + Z_{Pump\_Rebuild\_8} + Z_{Pump\_Repl\_1} + Z_{Electrical\_RR\_1} + Z_{IC\_RR\_1} + Z_{IC\_RR\_2} + Z_{IC\_RR\_3} = 34.3 \times 10^{6} \cdot \text{dollars}$$

$$Z_{total\_base} := Z_{capital\_base} + Z_{General\_OM} + Z_{Pump\_OM} + Z_{ODOR\_OM} + Z_{Electrical} + Z_{Pump\_Rebuild\_1} \cdots + Z_{Pump\_Rebuild\_2} + Z_{Pump\_Rebuild\_3} + Z_{Pump\_Rebuild\_4} + Z_{Pump\_Rebuild\_5} + Z_{Pump\_Rebuild\_6} \cdots + Z_{Pump\_Rebuild\_7} + Z_{Pump\_Rebuild\_8} + Z_{Pump\_Repl\_1} + Z_{Electrical\_RR\_1} + Z_{IC\_RR\_1} + Z_{IC\_RR\_2} + Z_{IC\_RR\_3} = 34.8 \times 10^{6} \cdot \text{dollars}$$

$$Z_{total\_high} := Z_{capital\_high} + Z_{General\_OM} + Z_{Pump\_OM} + Z_{ODOR\_OM} + Z_{Electrical} + Z_{Pump\_Rebuild\_1} \cdots + Z_{Pump\_Rebuild\_2} + Z_{Pump\_Rebuild\_3} + Z_{Pump\_Rebuild\_4} + Z_{Pump\_Rebuild\_5} + Z_{Pump\_Rebuild\_6} \cdots + Z_{Pump\_Rebuild\_7} + Z_{Pump\_Rebuild\_8} + Z_{Pump\_Repl\_1} + Z_{Electrical\_RR\_1} + Z_{IC\_RR\_1} + Z_{IC\_RR\_2} + Z_{IC\_RR\_3} = 36.6 \times 10^{6} \cdot \text{dollars}$$

The total 50-Year LCC for the Year of Beneficial Use is $34.8 million for the Receiving Lift Station with a range of $34.3 million to $36.6 million accounting for market fluctuations.

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