NFEnergía LLC
SAN JUAN MICRO-FUEL HANDLING FACILITY
RESOURCE REPORT 13—ENGINEERING AND DESIGN MATERIAL

I.1 EARTHQUAKES

Document Number	Document Title	Appendix Security
--	Probabilistic Seismic Hazard Analysis and Site-Specific Response Spectrum	Public

I.2 TSUNAMI AND SEICHE

Document Number	Document Title	Appendix Security
--	San Juan Tsunami Evacuation Map	Public

I.3 HURRICANES AND OTHER METEOROLOGICAL EVENTS

Document Number	Document Title	Appendix Security
HSEQ-P220	Hurricane and Severe Weather Procedure	CEII

I.4 TORNADOS

See Appendix 13.I.3 for meteorological event procedures. Wind speed design and criteria are discussed in Moffatt and Nichol Basis of Design included in Appendix 13.B.1.

I.5 FLOODS

Flood Data for the MFH Facility is provided in Moffatt and Nichol Basis of Design included in Appendix 13.B.1.

I.6 RAIN, ICE, AND SNOW

Rain Data for the MFH Facility is provided in Moffatt and Nichol Basis of Design included in Appendix 13.B.1. Ice and snow data was not explicitly included in the design of the MFH Facility.

J.1 TOPOGRAPHIC MAP

Document Number	Document Title	Appendix Security
--	Topographic Contour Map	Public

J.2 BATHYMETRIC CHART

A Bathymetric Chart for the MFH Facility is provided in Moffatt and Nichol Basis of Design included in Appendix 13.B.1.

J.3 CLIMATIC DATA

Climatic Data for the MFH Facility is provided in Moffatt and Nichol Basis of Design included in Appendix 13.B.1.

J.4 GEOTECHNICAL INVESTIGATION

Document Number	Document Title	Appendix Security
--	Report on the Geotechnical Exploration Performed At The Site Of The Proposed NFE Microfuel Handling Facility Puerto Nuevo Wharf, San Juan, Pr	Public
B-101	Boring Location Plan	CEII
B-601	Boring Logs (1 of 8)	CEII
B-602	Boring Logs (2 of 8)	CEII
B-603	Boring Logs (3 of 8)	CEII
B-604	Boring Logs (4 of 8)	CEII
B-605	Boring Logs (5 of 8)	CEII
B-606	Boring Logs (6 of 8)	CEII
B-607	Boring Logs (7 of 8)	CEII
B-608	Boring Logs (8 of 8)	CEII

J.5 FOUNDATION RECOMMENDATIONS

Recommendations from the Seismic Hazard Analysis (13.I.1) have been implemented in the Moffatt & Nichol foundation design. The Geotechnical Report in Appendix 13.J.4 includes design recommendations as well.

J.6 STRUCTURAL DESIGN BASIS AND CRITERIA

See Moffet and Nichol Design Basis in Appendix 13.B.1 and Civil Specification in Appendix 13.F.1.

J.7 STRUCTURAL DRAWINGS AND CALCULATIONS

Document Number	Document Title	Appendix Security
	Structural Report - Suction Drum	CEII
--	Structural Report - Impoundment and Trench	CEII
--	Structural Notes (1 of 2)	CEII
S-001	Structural Notes (2 of 2)	CEII
S-002	Structural Framing Key Plan	CEII
SF-101	Framing Plan (1 of 3)	CEII
SF-111	Framing Plan (2 of 3)	CEII
SF-112	Framing Plan (3 of 3)	CEII
SF-113	Hose Tower Framing Details (1 of 9)	CEII
SF-501	Hose Tower Framing Details (2 of 9)	CEII
SF-502	Hose Tower Framing Details (3 of 9)	CEII
SF-503	Hose Tower Framing Details (4 of 9)	CEII
SF-504	Hose Tower Framing Details (5 of 9)	CEII
SF-505	Hose Tower Framing Details (6 of 9)	CEII
SF-506	Hose Tower Framing Details (7 of 9)	CEII
SF-507	Hose Tower Framing Details (8 of 9)	CEII
SF-508	Hose Tower Framing Details (9 of 9)	CEII
SF-509	Truck Loading Bridge Framing	CEII
SF-510	Truck Loading Bridge Structures	CEII
SF-511	Equipment Connection Details	CEII
SF-512	Reel Connection Details	CEII
SF-513	Framing Details	CEII
SF-514	Pipe Rack 1 - Framing Plan (1 of 3)	CEII
SF-520	Pipe Rack 1 - Framing Plan (2 of 3)	CEII
SF-521	Pipe Rack 1 - Framing Plan (3 of 3)	CEII
SF-522	Pipe Rack 2 - Framing Plan (1 of 3)	CEII
SF-523	Pipe Rack 2 - Framing Plan (2 of 3)	CEII
SF-524	Pipe Rack 2 - Framing Plan (3 of 3)	CEII
SF-525	Pipe Rack 3 - Framing Plan (1 of 3)	CEII
SF-526	Pipe Rack 3 - Framing Plan (2 of 3)	CEII
SF-527	Pipe Rack 3 - Framing Plan (3 of 3)	CEII
SF-528	Pipe Rack 4 - Framing Plan (1 of 3)	CEII
SF-529	Pipe Rack 4 - Framing Plan (2 of 3)	CEII
SF-530	Pipe Rack 4 - Framing Plan (3 of 3)	CEII
SF-531	Pipe Rack 1 - Framing Elevation (1 of 2)	CEII
SF-532	Pipe Rack 1 - Framing Elevation (2 of 2)	CEII
SF-533	Pipe Rack 2 - Framing Elevation	CEII
SF-534	Pipe Rack 3 - Framing Elevation	CEII
SF-535	Pipe Rack 4 - Framing Elevation	CEII
SF-536	Pipe Rack - Sections (1 of 4)	CEII
SF-537	Pipe Rack - Sections (2 of 4)	CEII
SF-538	Pipe Rack - Sections (3 of 4)	CEII
SF-539	Pipe Rack - Sections 41 of 4)	CEII
SF-540	Cable Tray Support	CEII
SF-541	Side Shield Details	CEII

Document Number	Document Title	Appendix Security
SF-542	Suction & K.O. Drum Platform Framing Plans	CEII
SF-543	BOG Compressor Platform Framing Plan	CEII
SF-544	Platform Framing Sections (1 of 4)	CEII
SF-545	Platform Framing Sections (2 of 4)	CEII
SF-546	Platform Framing Sections (3 of 4)	CEII
SF-547	Platform Framing Sections (4 of 4)	CEII
SF-548	Pipe Support Details (1 of 6)	CEII
SF-550	Pipe Support Details (2 of 6)	CEII
SF-551	Pipe Support Details (3 of 6)	CEII
SF-552	Pipe Support Details (4 of 6)	CEII
SF-553	Pipe Support Details (5 of 6)	CEII
SF-554	Pipe Support Details (6 of 6)	CEII
SF-555	F&G Device Support Details	CEII
SF-557	Base Plate Details (1 of 4)	CEII
SF-560	Base Plate Details (2 of 4)	CEII
SF-561	Base Plate Details (3 of 4)	CEII
SF-562	Base Plate Details (4 of 4)	CEII
SF-563	BOG Platform Sections (1 of 3)	CEII
SF-564	BOG Platform Sections (2 of 3)	CEII
SF-565	BOG Platform Sections (3 of 3)	CEII
SF-566	Typical Steel Details (1 of 2)	CEII
SF-591	Typical Steel Details (2 of 2)	CEII

J.8 FOUNDATION DRAWINGS

Document Number	Document Title	Appendix Security
S-001	Structural Notes (1 of 2)	CEII
S-001	Structural Notes (2 of 2)	CEII
SB-101	Foundation Key Plan	CEII
SB-110	Foundation Plan (1 of 4)	CEII
SB-111	Foundation Plan (2 of 4)	CEII
SB-112	Foundation Plan (3 of 4)	CEII
SB-113	Foundation Plan (4 of 4)	CEII
SB-401	Enlarged Pile Plan (1 of 5)	CEII
SB-402	Enlarged Pile Plan (2 of 5)	CEII
SB-403	Enlarged Pile Plan (3 of 5)	CEII
SB-404	Enlarged Pile Plan (4 of 5)	CEII
SB-405	Enlarged Pile Plan (5 of 5)	CEII
SB-410	Enlarged Pipe and F&G Device Support Layout Plan (1 of 8)	CEII
SB-411	Enlarged Pipe and F&G Device Support Layout Plan (2 of 8)	CEII
SB-412	Enlarged Pipe and F&G Device Support Layout Plan (3 of 8)	CEII
SB-413	Enlarged Pipe and F&G Device Support Layout Plan (4 of 8)	CEII
SB-414	Enlarged Pipe and F&G Device Support Layout Plan (5 of 8)	CEII

Document Number	**Document Title**	**Appendix Security**
SB-415	Enlarged Pipe and F&G Device Support Layout Plan (6 of 8)	CEII
SB-416	Enlarged Pipe and F&G Device Support Layout Plan (7 of 8)	CEII
SB-417	Enlarged Pipe and F&G Device Support Layout Plan (8 of 8)	CEII
SB-418	Enlarged Plan - Boil Off Gas Compressor	CEII
SB-430	Canopy Foundation Plan	CEII
SB-501	Gate Arm Foundation	CEII
SB-502	Foundation Details	CEII
SB-521	Truck Loading Suction Drum Foundation	CEII
SB-522	Truck Loading Pump Skid Foundation	CEII
SB-523	LNG Pump Skid Foundation	CEII
SB-524	Air & N2 Equipment Foundation	CEII
SB-525	Gas Combustion Unit Foundation	CEII
SB-526	Stand By Generator Foundation	CEII
SB-527	Electrical Transformer Foundation	CEII
SB-528	Drain Drum and GCU Knock Out Drum Foundation	CEII
SB-529	Glycol Water Loop Pump Skid Foundation	CEII
SB-530	Metering Skid Foundation	CEII
SB-531	Boil Off Gas (BOG) Compressor Foundation	CEII
SB-532	Gas Fired Vaporizer Foundation	CEII
SB-533	Make-up Water Tank Foundation	CEII
SB-534	Shell and Tube Foundation	CEII
SB-535	Regasification Suction Drum Foundation	CEII
SB-536	Gas Fire Vaporizer Foundation Sections	CEII
SB-537	Make-up Water Pump Foundation	CEII
SB-538	LIN Ambient Air Vaporizer Foundation	CEII
SB-539	LNG Ambient Air Vaporizer Foundation	CEII
SB-540	Support Details (1 of 2)	CEII
SB-541	Support Details (2 of 2)	CEII
SB-547	Canopy Foundation Details	CEII
SB-548	Vapor Barrier Details	CEII
SB-560	Truck Loading Skid & Truck Scale Foundation (1 of 5)	CEII
SB-561	Truck Loading Skid & Truck Scale Foundation (2 of 5)	CEII
SB-562	Truck Loading Skid & Truck Scale Foundation (3 of 5)	CEII
SB-563	Truck Loading Skid & Truck Scale Foundation (4 of 5)	CEII
SB-564	Truck Loading Skid & Truck Scale Foundation (5 of 5)	CEII
SB-566	Miscellaneous Equipment Connection Details	CEII
SB-571	Pipe Rack Type I & Type III Foundations	CEII
SB-572	Pipe Rack Pedestals Type I, II, III	CEII
SB-573	Pipe Rack Pedestals Type IV & V	CEII
SB-574	Pipe Rack Types II and Type VIII Foundations	CEII
SB-575	Containment Area Mat Foundation Details	CEII

Document Number	Document Title	Appendix Security
SB-576	Truck Loading Pipe Birdge Type I Foundation	CEII
SB-578	Truck Loading Pipe Birdge Type II Foundation	CEII

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RESOURCE REPORT 13—ENGINEERING AND DESIGN MATERIAL

S.4 PASSIVE PROTECTION DRAWINGS

Document Number	Document Title	Appendix Security
--	Brochure - FOAMGLAS PFS System Gen 2	Public

Appendix I.1

TERRATEC, Inc.
Consultants in Foundations and Earth Structures.
Geology, Geophysics, and Environmental Engineering

NFE-V-08 DEVELOPMENT
SAN JUAN, PUERTO RICO.

PROBABILISTIC SEISMIC HAZARD ANALYSIS
AND
SITE-SPECIFIC RESPONSE SPECTRUM

Submitted to:

Jaca & Sierra

Submitted by:

TerraTec, Inc.

J. G. Paniagua, PhD. President
Jose M. Lockhart, MS. PE. Earthquake Engineering Consultant

J. Guillermo Paniagua, PhD., P.E.	**José M. Lockhart, MS, SE, PE**
President	**Associate**
PR Lic. # 25360	

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TABLE OF CONTENT

TITLE PAGE NO.

1 INTRODUCTION 1

2 REGIONAL GEOLOGY AND SEISMOTECTONICS 4

3 SEISMIC SOURCE MODEL FOR THE CARIBBEAN REGION 8

4 SEISMIC SOURCES OF PR 21

5 PROBABILISTIC SEISMIC HAZARD ANALYSIS 24

6 SITE RESPONSE ANALYSES 27

7 SITE CATEGORIZATION 32

8 SITE-SPECIFIC RESPOSE SPECTRUM 33

10 REFERENCES 42

LIST OF FIGURES

FIG. NO. PAGE NO.

1. PUERTO RICO ISLAND MAP 2

2. PROJECT LOCATION 3

3. SAN JUAN QUADRANGLE 7

4. MAIN SEISMIC HAZARDS 21

5. SEISMIC SOURCES 22

6. UNIFORM HAZARD SPECTRUM (UHS) 26

7. BORING LOG SWV-1, 7a/7b/7c 27/29

8. SHEAR WAVE VELOCITY 31

9. SEISMIC HAZARD DEAGGREGATION, 9a/9b/9c 35/36

10. UHS SPECTRUM 37

11. RISK-TARGETED UHS 37

12. SITE-SPECIFIC SSE RESPONSE SPECTRA 39

13. SITE-SPECIFIC OBE RESPONSE SPECTRA 41

14. REFERENCES 42

LIST OF TABLE

TABLE NO.

1. SEISMIC SHEAR WAVE VELOCITIES 17

2. SEISMIC SOURCES 34

3. CONDITIONAL MEAN RESPONSE SPECTRA 39

4. SITE SEISMIC CATEGORIZATION 40

5. PEER GROUND MOTIONS 41

6. SITE-SPECIFIC RESPONSE SPECTRUM 44

7. SITE-SPECIFICDESIGN RESPONSE SPECTRUM 46

APPENDICES

APPENDIX 1. PROBABILISTIC SEISMIC HAZARD ANALYSIS

APPENDIX 2. RESPONSE SPECTRUM MATCHING

APPENDIX 3. GEOTECHNICAL & GEOPHYSICAL SURVEYS

APPENDIX 4. SEISMIC SOURCES MODELS

APPENDIX 5. SITE RESPONSE APPENDIX

1 INTRODUCTION

The US Commonwealth Puerto Rico (Fig. 1) is a country with one of the highest population density in the world with approximately 4,000,000 people and a land area of only 8,959 square km. Puerto Rico Island is surrounded by very active offshore seismic sources. In the past the seismic hazard analyses for PR included only offshore seismogenic structures such as Puerto Rico Trench northern PR, Los Muertos Trough southern PR, and Anegada Passage and La Mona Passage to the east and west of the island, respectively. Recent paleoseismology and paleoliquefaction studies (Prentice et al., 2000; Tuttle et al., 2007; Piety et al., 2018) show the existence of active inland Holocene seismogenic structures capable of triggering damaging earthquake in PR. These earthquake hazards associated with a high population concentration define a high seismic risk scenario for Puerto Rico.

The 1985 Mexico earthquake with epicenter located off the Pacific coast of Michoacan at a distance of 350 km from Mexico City, has been considered one of the most devastating earthquake in the history of the Americas. One of the lessons learned from this earthquake is that site-specific soil conditions may play an important role in the magnification of earthquake intensity at places located at great distances from the seismic source.

The ongoing understanding of the Caribbean region tectonic has brought the development of new tectonic models and predictive ground motion relations, which improve the accuracy and reduce the uncertainties in the Probabilistic Seismic Hazard Assessment of Puerto Rico.

The PSHA for the NFE-V-08 DEVELOPMENT project site, in San Juan, PR, incorporates the recent advances in the modeling of Puerto Rico seismic sources and Site-specific Ground Motion Response prediction, and includes all seismic sources within 200 km from the project site.

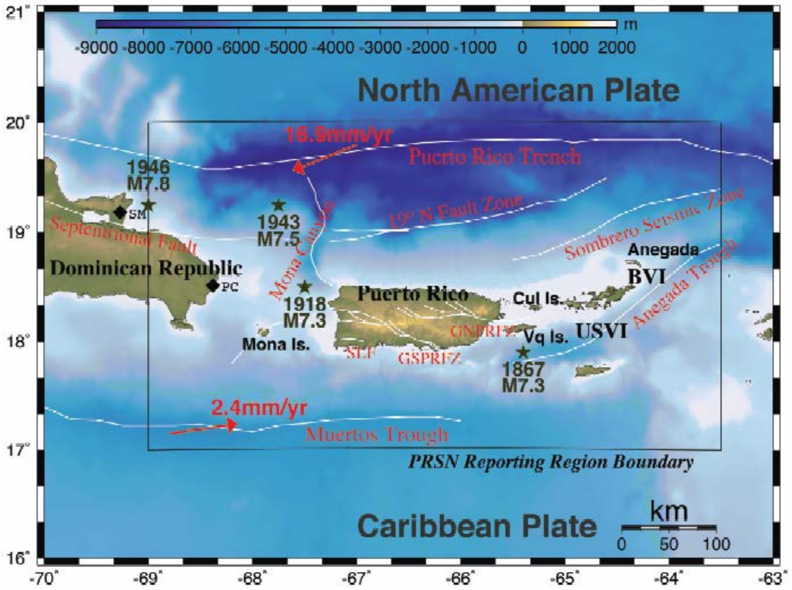


Fig. 1. Puerto Rico Island

Puerto Rico geology presents young sediments comprising layers of alluvial sand. Previous liquefaction potential analysis using the standard cyclic stress procedure for alluvial terraces similar to the soil deposits found in the city of San Juan have shown that these soils would liquefy when subjected to ground motion shaking of the intensities expected at the site. As per ASCE 7-16, the presence of soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, defines the site as Class F. The ASCE 7-16 enforces the development of site-specific response spectra for site class F in accordance to Section 11.4.7, and Chapter 21 (ASCE 7-16). Essential facilities such as power plants form part of a community's infrastructure that must remain operational or can be restored quickly after an earthquake for a community to respond effectively. Thus, site-specific seismic hazard studies are strongly recommended for planning, design and construction of all essential facilities in earthquake prone countries. In the particular case of the NFE-V-08 DEVELOPMENT project, the RFP provided by the developer calls for a probabilistic seismic hazard analysis for the project site, including site-specific response spectra for 0.5 %, 2.0 %, 5.0%, 10.0 % and 20.0 % damping.

This report provide site-specific response spectra for 0.5 %, 2.0 %, 5.0%, 10.0 % and 20.0 % damping, and recommends ground motion parameters to properly carry out the dynamic structural analyses and seismic design of the NFE-V-08 DEVELOPMENT project, in compliance with ASCE 7-16, and PR Building Code. Site geological hazards are not part of the scope of work of this report.

The NFE-V-08 DEVELOPMENT project comprises a complex of energy generation facilities at berths A, B and C, in Puerto Nuevo Wharf, San Juan, Puerto Rico. The project is located at the geographical coordinates 18°25'44.67"N and 66° 6'15.99"W, in San Juan, Puerto Rico. The map below shows the location of the project site (Fig. 2).

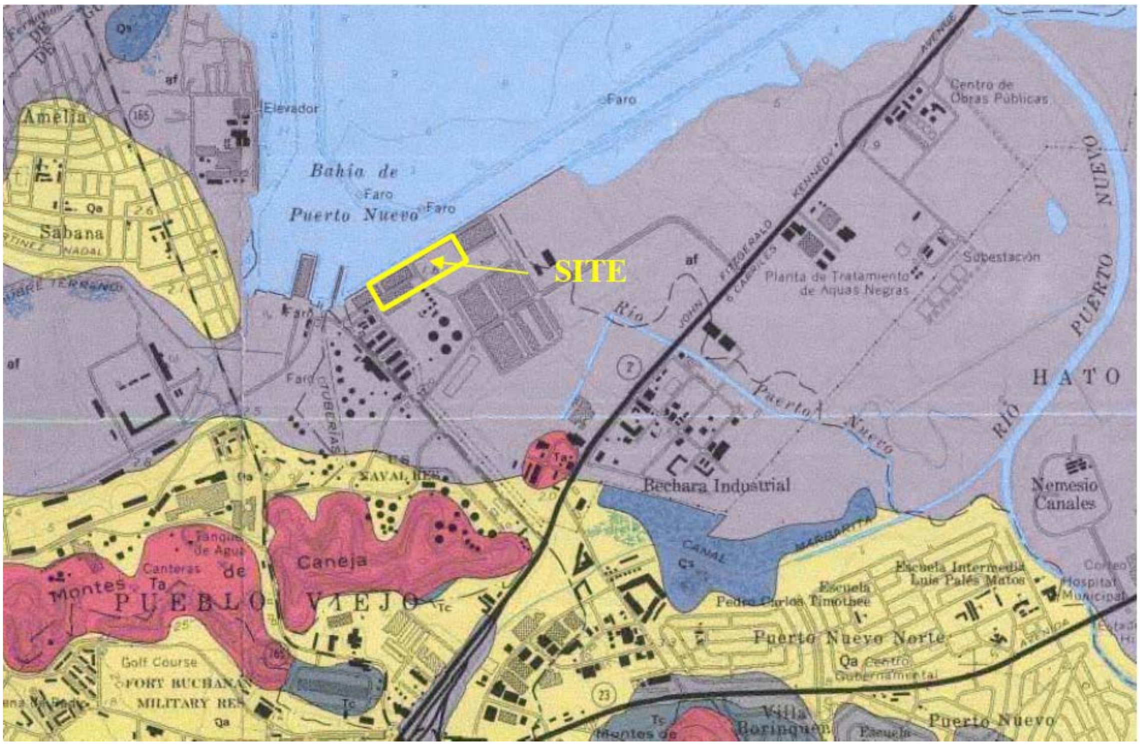


Fig. 2. The NFE-V-08 DEVELOPMENT Project Site

2 REGIONAL GEOLOGY AND SEISMOTECTONICS

2.1 REGIONAL TECTONIC SETTING

Puerto Rico Island is located on the boundary between the Caribbean Sea and the Atlantic Ocean as the connecting link between the Greater and Lesser Antilles islands. The Greater and Lesser Antilles islands delimit the boundary between the North American and Caribbean tectonic plates. The North American plate moves west-southwestward relative to the Caribbean plate at a rate of approximately 19.4 mm/yr (Jansma el al., 2000). West of Puerto Rico these two plates move along typical transform structures. On northeastern Puerto Rico the North American plate subducts westward beneath the Caribbean plate, forming the volcanic island arc of Lesser Antilles. Tectonic plate interaction occurs in a 250-kilometer-wide, and an east-west-trending zone of complex transpressional deformation, delimited by the Puerto Rico trench in the north and the Muertos trough in the south (Frankel et al., 2003). The Mona Passage in the west, and Anegada Trough in the east, in transtensional deformation regimes, act as transfer mechanisms between Puerto Rico trench and Los Muertos through. Puerto Rico Island lies on a shallow submarine bank within this complex deformational zone.

Slow subduction of the North America plate beneath the leading edge of the Caribbean plate dominates the tectonic environment of northeastern Caribbean. To the north and east lies the west-southwesterly moving North American plate, locally represented by the floor of the Atlantic Ocean and the Bahamas platform. To the south and west lie the various basins of the Caribbean Sea, within the rigid Caribbean plate. The Puerto Rico-Virgin Islands platform is part of an arc massif along the northeast fringe of the Caribbean plate. It straddles and is cut by major tectonic and seismically active features that form the boundary zone between the major plates (LaForge and McCann, 2005).

The Puerto Rico trench and the Los Muertos trough bound the Puerto Rico microplate to the north and south, respectively. Motion along these features reflects oblique convergent slip between the major plates and the Puerto Rico microplate. To the east, the micro plate ends in a wide zone of NE-SW direct transtension in western Puerto Rico, Mona Passage, and the eastern Dominican Republic (Van Gestel et al., 1998). To the west, its margin lies at the extensional Anegada trough (Litgow et al., 1987). Deformation in the Mona Passage and Anegada trough occurs along the edges of microplates within the plate boundary zone (Byrne et al., 1985), and serves to transfer slip from the Los Muertos trough to the Puerto Rico trench. Two active faults presumable related to the

Mona Passage deformation have been identify on land in western Puerto Rico (Mann and Prentice, 2001; Prentice et al., 2003).

Because the North America plate motion is nearly parallel to the Puerto Rico trench (Calais et al., 2002), a number of transtensional features have developed in the accretionary wedge above the downgoing North America plate. The most important of these features are the Septentrional fault and the Bowing fault zone. In Central Hispaniola, the Septentrional fault exhibits a slip rate of 8±5 mm/year (Calais, 2006) and accounts for a significant proportion of the relative plate motion. To the east, however, this rate decreases by an unknown amount because of the presence of similar features that serve the same function. The Bowin fault zone lies on the east side of the Mona Canyon, adjacent to the east end of the Septentrional fault. In addition to these seismogenic features, ground-shaking hazards are also represented by upper crustal randomly subduction earthquakes not associated with known structures (LaForge and McCann, 2005).

Historical and instrumental records account for the seismicity of Puerto Rico. Major earthquakes have occurred in Puerto Rico several times during the past 500 years. These earthquakes struck and damaged Puerto Rico in 1520, 1615, 1751, 1776, 1787 (magnitude ~8.0, Puerto Rico Trench); 1867 (~7.3, Anegada Passage), 1918 (~7.5, Mona Passage); 1943 (~7.7, plate interface, Puerto Rico Trench); and 1946 (~8.0, plate interface, northeastern Hispaniola).

The seismicity of Puerto Rico is basically related to the subduction of the North American plate interface with the Caribbean plate south of the Puerto Rico Trench, and to the interactions of several probable microplates within the complex boundary zone. Using geodesy and seismicity data it can be assumed the existence of a Puerto Rico microplate that is relatively rigid and seismically quiescent internally (USGS 2003). The majority of seismogenic sources in Puerto Rico are concentrated offshore. The Great Northern and Great Southern Puerto Rico faults, major left-lateral strike-slip systems, were considered inactive until recently (Prentice, 2002; Tuttle, 2007).

Megathrust faulting along the plate interface; intraslab faulting within the subducting North American plate; and strike-slip faulting along several structures, including the Septentrional fault, which is the main plate boundary structure in central Hispaniola; and the North and South Puerto Rico Slope fault zones and related structures, are associated to deformation along North American and Caribbean plates. Other seismic sources are area sources related to microplate interactions, such as the Mona Passage, on the west of

Puerto Rico, and the Anegada passage on the east. In addition to the tectonic features on the limits, other onshore seismic sources include Great Puerto Rico North fault, Great Puerto Rico South fault, and related structures, and the Lajas fault in southeastern Puerto Rico.

It has been reported the existence of at least two faults in San Juan area inferred to have been active in the late Tertiary (2.58 million years ago) (Kaye, C.A., 1959). The United States Nuclear Regulatory Commission (USNRC), NUREG/CR-7320, “Seismic Design Standards and Calculational Methods in the United States and Japan”, defines an active fault as a fault with observed movement or seismic activity in the last 130,000 yr. Thus, based on the preceding definition of active fault, it can be concluded that there is no active fault in the San Juan quadrangle, which is the location of NFE-V-08 DEVELOPMENT project site.

2.2 LOCAL GEOLOGIC SETTING

In Puerto Rico Island, surficial deposits of sediment that have eroded off the Cordillera Central and the mogotes cover the area lying between the mountains and the coastline. Coastal plains are better developed on the northern side of the island due to greater rates of erosion caused by higher rainfall. The coast itself is characterized by beaches and mangrove swamps.

Tertiary limestone, together with aerially extensive Quaternary sediments deposited by fluvial, marine, and eolian processes, underlain the northern coastal plain of Puerto Rico. Residual clayey soils and weathered saprolite cover most of bedrock units. Quaternary sediments include sands, clayey sands, sand and gravel, soft organic clay, silty clay, peat, and calcareous mud that accumulated in streams, beaches, lagoons, estuaries, and swamps. Eolian sands also are deposited along the coastline and increase the sand component of the swamps and estuarine deposits near the beach. Much of the built-up areas of San Juan along lagoon or coastal margin were formed by artificial filling that locally included sluicing of hydraulic fill.

Based on the geological mapping of Pease and Monroe (1977), aerial photograph interpretation and field reconnaissance, the Quaternary geologic history of the San Juan metropolitan area involves extensive erosion of materials from the highlands and deposition of alluvium and alluvial fan complexes along the stream systems and slopes. These deposits intermingle with coastal lagoon deposits and beach-eolian sands on the coastal plain. A combination of sea-level change and regional tectonic uplift caused

Holocene river channels to incise deeply into broad Pleistocene flood plains. Holocene deposits generally appear confined to the incised channel systems, beach, estuary, and lagoon environments.

In addition to regional tectonic uplift, Quaternary sea-level fluctuation have changed stream base levels and have influenced the development of stream systems and deposition of sediments along the northern coastal plain. Coastal stream were incised and graded to lower base levels during low stands of sea level. Paleovalleys that formed during sea-level low stands were drawn and filled as sea level rose to its present elevation through the Holocene. Former beach sands were blown into dunes and sand sheets against hillsides and within topographic depressions. The bay and estuary deposits of Bahia San Juan and Laguna San Jose, and alluvial deposits shed from coastal mountains, now blanket most of the low-lying landscape. Swamps and mangroves that formed at lower stands of sea level were drowned and are now marked by buried, preserved peat layers within the bay and estuary deposits.

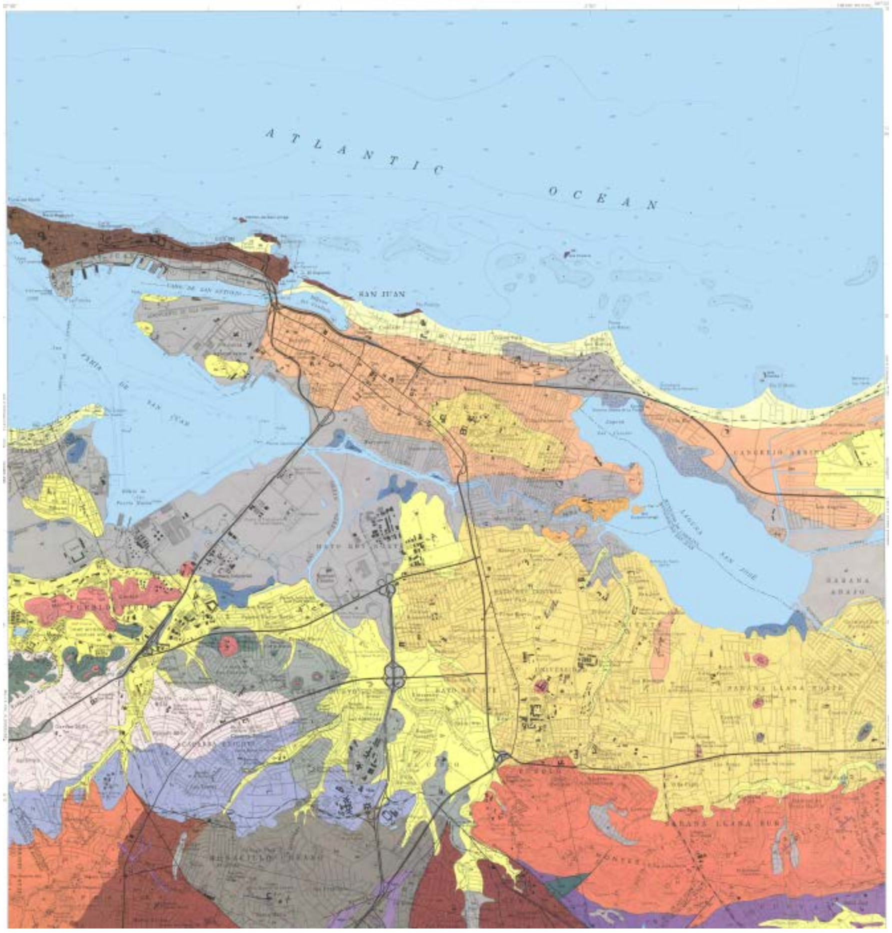


Fig. 3. San Juan Quadrangle (MH Pease Jr and WH Monroe, 1977)

3 SEISMIC SOURCES. SEISMIC SOURCE MODEL FOR THE CARIBBEAN REGION

The Caribbean region tectonic regime is an ongoing complex dynamic process within different seismotectonic and geologic environments, including all sort of plate boundaries such as transform, convergent, oblique-convergent, and divergent boundaries in oceanic and continental crust. The Caribbean plate is moving east-northeastward relative to North America and South America plates at a rate of about 20 mm/yr. Crust and oceanic material of the Caribbean plate underlain most of the Caribbean region. At Northeastern Caribbean major seismic sources are located at the plate boundary zones where the Caribbean plate motion is being accommodated. Here the Bahama carbonate banks subducts beneath Hispaniola and Puerto Rico with an oblique-convergent motion. This oblique-convergent motion is partitioned between the North Hispaniola Deformation Belt thrust fault and the Septentrional and Enriquillo-Plantain-Garden left-lateral strike-slip faults onshore the Dominican Republic and Haiti. North-dipping subduction of the Caribbean plate is undergoing beneath southern Hispaniola and Puerto Rico where the convergent motion is being accommodated by Los Muertos Deformation Belt.

The seismic source model incorporated in EZ-FRISK computer code (William Lettis & Associates, 2015) and used for the Probabilistic Seismic Hazard Analysis of the NFE-V-08 DEVELOPMENT Project site, in San Juan, Puerto Rico, includes documentation for areal source zones for shallow crustal provinces and fault sources that represent the specific tectonic features within a radius of 200 km from the location of the project site (Fig.4). Three types of fault sources are included: shallow crustal faults, subduction interface zones, and subduction intraplate zones. Line sources represent crustal faults with characteristic earthquake distributions. Gently dipping line sources provide for subduction interface zones with truncated exponential distributions. Intraplate subduction fault zones are represented by dipping lines sources with exponential distributions.

The "Summary of Methodology for Source Model Development. Caribbean Seismic Risk Assessment" (William Lettis & Associates, 2006), is included here in extenso as follows (Appendices cited in the following WLA Seismic Source Model description are not included in this report):

Subduction Sources

Subduction zone related earthquakes are modeled as three types of seismic sources: (1) characteristic “great” earthquakes (i.e. M>8) caused by thrust motion on the dipping interface between the oceanic plate and the over-riding continental crust (modeled as planar dipping fault sources and referred to as the plate interface zone); (2) earthquakes originating along the shallow part of the subduction fault (i.e. 10 to 40 km), and (3) deep earthquakes within the subducted oceanic slab (referred to as intraplate” or “slab” events). The first two types of sources are combined, and earthquake recurrence within these sources is characterized by a truncated exponential distribution. Earthquakes of lesser magnitude than the characteristic “great” earthquakes include shallow events within the descending oceanic slab and smaller plate interface events (so-called “patch” events).

The intraplate, or slab, sources include deep (about 40 to 200 km depth) earthquakes that occur within the subducted slab down dip of the plate interface. Earthquake recurrence within this source is assumed to have an exponential distribution.

Regional seismological and geodetic studies indicate that the subduction zones in the western, eastern, and northwestern margin of the Caribbean Plate have complex geometries that locally change along their length. The geometries of the subduction zones used in the source model are based on analyses of our composite seismicity catalog (see Appendix G for description), and seismological and geodetic analyses presented in scientific literature (Appendix A). There are 18 separate subduction zone segments on the interface portion (Appendix C). The subduction zone segments were defined based on occurrence of large magnitude historical earthquakes, difference in the geometry (strike and dip) of the subducted plate, difference in age of the subducting plates, and presence of physical asperities such as seamounts chains and oceanic fracture zones.

Plate interface sources

Slip rates along the plate interface zones were estimated taking into consideration the overall plate motion rate, plate-normal component motion, and amount of seismic coupling or the seismic efficiency along the plate interface. Plate motions were derived from published vectors determined by local GPS geodetic networks, global plate motion models (e.g., NUVEL 1-A) or GPS- based global plate motion models obtained through the UNAVCO web-based plate motion calculator (e.g., REVEL2000; Sella et al., 2002). The plate-normal component of the relative horizontal plate-motion vector was used to estimate the slip rate on the plate interface. This reflects the general assumption that only the plate-normal component accumulates strain to be released in great earthquakes, while the plate margin-parallel component of motion is partitioned onto shallow crustal sources. The slip rate on the plate interface also was corrected to account for the observation that only a fraction of the measured relative plate motion goes into producing the elastic strain energy that is released by earthquakes. The proportion of strain accumulated on the plate interface relative to the total possible strain is described by the seismic coupling coefficient (Pacheco et al., 1993). We estimated seismic coupling coefficients based on published values derived from historical seismicity or elastic models constraint by geodetic data. The seismic coupling coefficient is a major source of uncertainty in our final slip rate values.

The maximum earthquake magnitude distribution for the plate interface events is based on two or three potential fault rupture scenarios (characteristic earthquakes) for each subduction zone segment. The final selection of the magnitude values in the distribution is based on the available data and judgment that the distribution reflects a realistic and reasonable range of values given the historical seismological record and physical characteristic of the subduction zone segment. Factors considered in the analysis of maximum magnitude include: (a) the minimum size of the rupture area based on the maximum historical rupture area for each segment; (b) uncertainties in the rupture length and width; (c) presence of physical features on the subducting plate (i.e. fracture zones) that could act as rupture termination points; and (d) the possibility of rupture larger than historical maximums could occur. For instances where the length of the subduction zone segment exceeds the predicted rupture length from the characteristic earthquake, we consider that characteristic earthquake to "float" or occur anywhere along the interface zone.

The recurrence intervals were estimated for each maximum magnitude estimate on each plate interface segment. The recurrence was calculated by dividing seismic moment (M_o) of each characteristic earthquake by moment rate, where moment was calculated directly from the relationship between M_o and M_w, and moment rate is calculated as the product of the effective slip rate, shear modulus, and specific area of each characteristic earthquake. These estimated recurrence intervals were compared to the historical earthquake catalog to help guide estimates of M_{max} and seismic coupling.

The recurrence interval estimates for the "patch" earthquakes were based on the magnitude-frequency distribution of historical events occurred within the volume of crust along the plate interface. The volume is defined as the length of the segment, the horizontal width from the trench to the interface/intraplate zone boundary, and the depth interval from zero to the interplate/intraplate zone boundary (typically about 40 km). All events within this volume are conservatively assumed to occur on the plate interface. This approach is necessary because the event location uncertainties are too large to distinguish between true plate interface events, shallow upper-plate events, or events within the shallow portion of the subducting slab.

Intraplate (or slab) sources

Earthquake recurrence on intraplate sources is modeled as an exponential magnitude distribution. The maximum earthquake magnitude estimates for the intraplate events are based both on recorded seismicity, examples from similar tectonic settings, and the physics behind the earthquake generating mechanisms in these environments. The historical magnitude-frequency distribution for the intraplate source zone is determined for those events occurring within the volume of crust defined by the map projection of the intraplate zone and extending from the base of the shallow crust (e.g., 40 km) to the maximum depth of recorded earthquakes inferred to be associated with the subducted slab (typically about 200 km). These events are conservatively assumed to occur along the plane representing the top of the subducted slab.

Shallow Crustal Source Zones

The seismic source model for the shallow crust (i.e. < 20 km) includes 43 areal source zones and 93 line sources (Appendices D and E). The areal source zones represent parts of the region with similar tectonic and seismologic characteristics. Definition of the areal source zones was based on examination of spatial patterns of topography, fault locations and kinematics, and historical seismicity. Input parameters for areal sources include: (1) source location; (2) depth of earthquake occurrence; (3) style of faulting; and (4) maximum earthquake magnitude (M_{max}) distribution and weights. The subsurface rupture length vs magnitude relation (all earthquake types) developed by Wells and Coppersmith (1994) was recommended for all zones, and estimated rupture lengths and aspect ratios were calculated for all M_{max} values.

The recurrence model for the areal source zones is based on the historical magnitude frequency distribution for events occurring within the volume of crust defined by the areal source zone boundary and extending from the surface to the base of the shallow crust (~40 km). These events are conservatively assumed to occur on structures within an areal source volume that is commonly much shallower (e.g., 0 to 12 km) than the area of sampled seismicity.

Upper plate line sources, or fault sources, included in the model are from the published literature (Appendix A). The faults included in the model are only those that meet the criteria of having a reported slip rate of 0.2 mm/yr or higher. Slip rates attributed to these line sources are based on the published rate or a rate estimated based on regional geodetic networks or analogy with similar faults of known slip rate.

Input parameters for upper plate line sources include: (1) source location; (2) dip, dip direction, and maximum depth; (3) style of faulting; and (4) maximum earthquake magnitude distribution and weights. The subsurface rupture length vs magnitude relation (all earthquake types) developed by Wells and Coppersmith (1994) was recommended for all zones. Maximum magnitudes and weights for the line sources were based on historical seismicity, fault length versus magnitude relationships, and judgment. Estimated rupture lengths and aspect ratios were calculated for all M_{max} values. For instances where the line source exceeds the predicted rupture length, we consider that characteristic earthquake to "float" or occur anywhere along the line source.

Earthquake Catalog and Aftershock Removal

The earthquake catalog was compiled by WLA's subcontractor, geoForecaster. A description of the catalog sources and conversion to moment magnitude (Mw) is presented in their report in Appendix G. Aftershock removal was performed by WLA's subcontractor, Lahontan Geosciences. Aftershocks were removed using the computer code CLUSTER2000 (Reasonberg, 1985) separately on three subcatalogs consisting of subduction zone plate interface sources, intraplate (slab) sources, and upper plate (areal) sources. Upper plate seismicity was defined as events less than or equal to 40 km depth that are located outside plate interface source zones. CLUSTER2000 uses magnitude-dependent time and distance parameters that determine whether an event should be included in an aftershock "cluster." The time and distance parameters were adjusted iteratively until visual inspection of large earthquakes and comparisons of pre- and postdeclustering indicated that sufficient aftershocks were removed. The declustered earthquake catalogs were further divided into subduction zone and areal sources and submitted electronically to Risk Engineering, Inc.

REMOVAL OF DUPLICATE EVENTS

We use an automated system to remove duplicate events in our catalog compilation. The program looks for similarities in time, location, and magnitude to score successive events as duplicates. Removal of duplicates is then done through a prioritization of the reporting agencies. International or global data collection agencies that provide their own locations often use a global velocity model to determine locations. While this may be satisfactory on a global scale, it may lead to serious location errors on a local scale. In this case we also look at local network distribution and integrity in keeping some events and not others. Once the automated system is run, we also do a quick manual check to insure that duplicates are removed.

AFTERSHOCKS

Generally, we do not remove aftershocks from catalog searches. There are two reasons for this. First, computer codes that remove aftershocks based on the Omori law of aftershock decay or declustering algorithms often leave a “hole” in the catalog. A space time plot of aftershocks removed from earthquake catalogs will clearly show boxed periods of no activity. In essence, these automated codes remove every single event including background seismicity after the main shocks are identified. [It should be noted that many seismologists consider background seismicity as a superposition of long, drawn-out aftershock sequences]. Second, aftershocks can be just as damaging as some of the background seismicity and are just as important to engineering structures in terms of vulnerability. In many cases it is the aftershocks which bring buildings to a total collapse after the initial damage from a main shock. To date, there is no consensus among seismologists or engineers as to whether aftershocks should be included in the seismic hazard studies. However, since many hazard studies consider earthquakes occurrence as a Poissonian process then dependent events (e.g. aftershocks) must be removed to maintain the independence and random nature of seismicity.

For this study, the removal of aftershocks was required and the approach of *Gardner and Knopoff (1974) [also Mueller et. al. (1995)]*, which has been used in several seismicity studies was considered. The following questions should be considered in any removal process.

1. How far away in space can an aftershock occur?
2. How far away in time can an aftershock occur?
3. What is a main shock?

There is no unique answer to these questions since there is essentially no difference between aftershocks and main shocks. Each one is a consequence of the same process and is a natural response to the loading of an area. The only difference lies in the size of the sampling window that one chooses to distinguish an aftershock from a mainshock. Theoretically, one may choose scales that approach global proportions and time frames on the order of decades to model aftershocks. At this level, almost every earthquake becomes part of an aftershock series.

New developments in modeling earthquake occurrence are now leaning toward a Unified Law for Earthquakes that describes the probability of inter-occurrence times between mainshock earthquakes for a cutoff magnitude and region size. This Law links together the key areas of earthquake research, the Gutenberg–Richter Law, the Omori Law of aftershock decay**,** and the fractal dimension of a fault.

While a Unified Law is a step in the right direction, there is still no adequate method that is all-inclusive in modeling all earthquake activity (to include swarms, temporal rate changes, and triggering) for seismic hazard studies. Since most methods assume a Poissonian model, artificial methods of removing clusters such as aftershocks are necessary to preserve independence between events. Hazard analysts should be aware that there is no consistency among these methods and that hazard analysis will always be subject to these biases and systematic errors.

For this project we initially considered the Gardner and Knopoff approach to remove aftershocks from a catalog. This technique has been used extensively in the past such as on a GSHAP project in the north Balkans as well as in New Zealand. However, another GSHAP report for the Northern Andes used Maeda's (1996) relationships. These relations establish spatial and temporal criteria to eliminate aftershocks from the original data as follows (but if minimum magnitudes are not chosen carefully, then negative numbers can result):

For distance: $L\ 10^{(0.5Mm-1.8)}$
For time: $t\ 10^{(0.17+0.85(Mm-4.0))/1.3} - 0.3$
For magnitude: $Ma < Mm - 1.0$ Ma < Mm - 1.0

where L represents the epicentral distance from the main shock, t is the time in days from occurrence of a main shock, Mm is the magnitude of a mainshock, and Ma is that of an aftershock. These relations were derived by Utsu (1970) and consider the exponential decay in the number and magnitude of aftershocks.

Many engineers use the declustering algorithm, CLUSTER2000, that is available on the USGS website based on the work of Reasenberg and others. While this algorithm is also imperfect, it has nevertheless been largely adopted by the hazard analysis community for declustering catalogs as a standard solution. This work was performed by a third party.

MAGNITUDES

Magnitudes are a useful way to indicate the size of earthquakes, yet there are many shortcomings to this measure as an absolute way to know the size of an event. For example, it is well known that discrepancies exist between seismological and geodetically determined magnitudes. In addition, there are differences in seismological magnitude types as well as in how they are computed. Seismologists have developed numerous magnitude scales to address different seismological constraints, instrumental concerns, and local site conditions. These magnitudes include:

Ml: Local magnitude. The formula for calculating local magnitudes is very specific to the region in which they are used. Ml in one region may not be equivalent to another.

Mb: Body wave magnitude. *mb* is valid up to *mb*=6.5, which means that even if another magnitude measure suggests a larger magnitude, the *mb* determination will saturate or not go higher than 6.5. It is therefore an unreliable measure for major earthquakes.

Ms: Surface wave magnitude. *Ms* is valid up to about *Ms*=7.2 where it saturates. *Ms* is generally not calculated for deep earthquakes or where there is an absence of surface waves.

MD: Duration (or coda) magnitude. This is sometime written as *Mc*. The calculation of this magnitude depends upon the duration of the seismic waves (coda) above noise or a pre-determined level.

Mw: Moment magnitude. *Mw* is based on the moment of the earthquake and relies on the fault dimensions (rupture area). It is calculated using the corner frequency from which seismic waves fall off in size.

The USGS describes these same magnitudes as:

Magnitude type	**Applicable magnitud**	**Distance range**	**Comments**
Duration (Md)	<4	0-400 km	Based on the duration of shaking as measured by the time decay of the amplitude of the seismogram. Often used to compute magnitude from seismograms with "clipped" waveforms due to limited dynamic recording range of analog
Local (ML)	2-6	0-400 km	The original magnitude relationship defined by Richter and Gutenberg for local earthquakes in 1935. It is based on the maximum amplitude of a seismogram recorded on a Wood-Anderson torsion seismograph.
Surface wave (Ms)	5-8	20-180 degrees	A magnitude for distant earthquakes based on the amplitude of Rayleigh surface waves measured at a period near 20 sec.
Moment (Mw)	>3.5	all	Based on the moment of the earthquake, which is equal to the rigidity of the earth times the average amount of slip on the fault times the amount of fault area that slipped.
Body (Mb)	4-7	16-100 degrees (only deep earthquakes)	Based on the amplitude of P body-waves. This scale is most appropriate for deep-focus earthquakes.

Given the variety of issues at hand, it is nearly impossible to arrive at a single measure that encompasses all the nuances of using different instruments as well as recordings from different locations that have different site characteristics and propagation geometries.

Nevertheless, we have established the following relationships between magnitudes from different reporting agencies for the area under consideration:

CARIBBEAN MAGNITUDE RELATIONS	r squared	# of points
Ms(ISC) = 1.3682Mb(ISC) - 2.2657	0.5667	1747

Mw(SAT) = 0.6793Ms(R-I) + 2.1545	0.9983	272
Mw(SAT) = 0.6636Ms(ISC) + 2.2274	0.9902	24
Mw(SAT) = 0.7964Ms(AKW) + 1.4579	0.9873	21
Mw(SAT) = 0.8827Ms(W&C) + 0.8427	0.9824	32

Mw(SAT) = 0.7902 Mb(CER) + 0.7944	0.8276	46
Mw (SAT) = 0.822 Mb(GS) + 0.6613	0.8657	111
Mw(SAT) = Mb(IGE) = Mb(SAA,NIC,TRN)	1	168
Mw(SAT) = 0.7397Mb(ISC) + 1.0038	0.7367	483
Mw(SAT) = 1.1068Mb(ZUN) - 0.7566	0.6634	50
Mw(SAT) = 0.1092Mb^3 - 1.2983Mb^2 + 5.8736Mb -	0.892	1134

Mw(SAT) = MD(all)	1	144
Mw(SAT) = ML(all)	1	317

Mw(HRV) = 0.938Mb(GS) + 0.6839	0.552	559
Mw(HRV) = 1.0098Mw(GS) - 0.0974	0.9713	83
Mw(HRV) = 0.6854Ms(GS) + 2.124	0.8815	423
Mw(GS) = 0.6659Ms(GS) + 2.2863	0.8854	128

MB(GS) = 0.7879MD(TRN) + 0.9233	0.6931	791

A Cautionary Note in Using Magnitude Relationships for Seismic Hazard Studies

Minor changes in magnitudes will ultimately affect b-values which may lead to systematic errors that propagate through the entire seismic hazard analyses. *Bender (1983)* indicated that “Probabilistic ground motions calculated for a range of b-values show that a small fractional change in the assumed b-value can have a substantially larger fractional effect on the ground motion calculated.”

One of the greatest sources of error in magnitude and location determinations is the type and version of velocity model that is employed. The more information one has about the three dimensional variations in density through which seismic waves must propagate, the better. However, almost all networks use an approximate 1-D model where the velocity of seismic waves varies with depth only. This approach leads many software programs to "fix" the depth at 5, 12, 33, 70, or 100 km to allow the programs to converge on a solution for the location. These inherent location errors invariably lead to errors in magnitude as well. Although generally less than 1 magnitude unit, the errors are significant.

A very real example can be made with ISC (International Seismological Centre) data which uses mostly European observatories and shows consistently smaller magnitudes by about 0.5-0.7 units for earthquakes in Mexico over those determined by local and regional networks. This is because the influence of the subduction zone slab is not taken into account by ISC. Likewise, locations for events in Mexico by North American networks are quite consistently 50-100 km north of those determined by the local Mexican network.

For those unaccustomed to working with these earthquake location programs and models, it may come as a surprise that there could be numerous 1-D models employed for any single area. A local network will use a model specific to that region to calculate *mb*, for example. Over time, this velocity model might change (usually for the better) yielding magnitude estimates that are more accurate. However, this does not guarantee that all prior earthquakes will have their magnitudes recalculated in a catalog. Finally, an international agency will generally use an approximate global velocity model to calculate *mb* which in some cases can lead to differences up to 1.0 magnitude units. In the end we could be faced with three different *mb* determinations in a local catalog, all of which will differ by varying amounts.

The moment magnitude, *Mw*, was created to help alleviate these problems by using the "corner frequency" which is the point at which the frequency content of the signal rapidly decays relative to the principal frequencies in the signal. The process of determining magnitude with this approach is that it is possible to determine moment magnitude at all scales. However, this is generally not done in practice for magnitudes less than M4.5. (see USGS website and Appendix figures). For regions with relatively few earthquakes, this leaves a relatively small magnitude range from which to determine recurrence relations.

Finally, any conversion of other magnitude types (*mb* or *Ms*) to *Mw* will carry all the inherent errors outlined previously leading to systematic errors in hazard analysis studies.

While it is recognized that some unit of common measure must be used in probabilistic seismic hazard studies (and one does the best they can with what is available), it should be understood that the ultimate outcomes will reflect all the errors and uncertainties carried in the data. In Latin America, the historical data is notorious for incompleteness and severe limitations in consistency.

COMPLETENESS

Changes in seismic networks and earthquake reporting thresholds are not uncommon. These changes may come as upgrades to the instrumentation (e.g. conversion of analog to digital equipment), increases in the number or distribution density of stations which may lead to lower magnitude detection thresholds, implementation of new velocity models in calculating magnitudes, personnel changes which affect the quality of the manual earthquake phase picks, or network shut downs leading to incomplete or inhomogeneous records.

The DNAG catalog is not complete for periods before 1900 and only complete from about M 5.5 up through 1960 for Central America. There are no good complete catalogs for this region prior to 1964.

The reasons for these completeness problems is that very little attention was given to non-destructive earthquakes in the Caribbean and Central America through the mid-20th century. Long periods of time can transpire in the many regions of the world without destructive earthquakes. It was only with the introduction of the WWSSN in 1964 that any attempt was made to catalog the moderate sized events in the Latin American region. Smaller events were gradually added in the 1970s and 1980s.

After the Defense Department began compiling earthquake catalogs in association with the Nuclear Test Ban Treaty in 1990 did smaller events (M4.5-5.0) become consistently reported. Some local catalogs exist for areas like Mexico and Chile but these are scattered in time and space. The Mexican catalog, for example, may have good coverage for a year and then none for two or three years during a time when funding was not available.

Finally, earthquake magnitudes were not given to events in Central and South America until after 1964. Only the largest shocks were given magnitudes and often long after the event occurred. This was the reason the DNAG and CERESIS catalogs were sought after in this study. An attempt was made by these projects (DNAG and CERESIS) to homogenize the magnitudes and to place magnitudes on the larger events which were previously only given intensities. Since all events without magnitudes were removed from the catalog, this eliminated most events prior to 1964 in both catalogs (cut at M 3.5). This cut is not very valid for events prior to 1964 since any event recorded in that time period was almost certainly greater than magnitude M 4.5. (Sic).

Some of the earthquake catalogs used in this study are: United States Geological Survey (USG), Decade of North America Geology (DNGA project), Harvard, Massachusetts (HRV), International of Seismological Center (ISC), Preliminary Determination of Epicenters from NEIS/CGS, and Puerto Rico Seismic Network (PRSN).

3.1 SEISMIC SOURCES OF PUERTO RICO

The main seismic hazards of Puerto Rico island are represented by all seismic sources comprised in the region delimited by Puerto Rico Trench in the north, the Muertos trough in the south, the Mona Passage in the west, and the Anegada Passage in the east, offshore PR, and GNPRFZ, GSPRFZ, and Lajas Fault onshore PR, as shown in the Fig. 4.

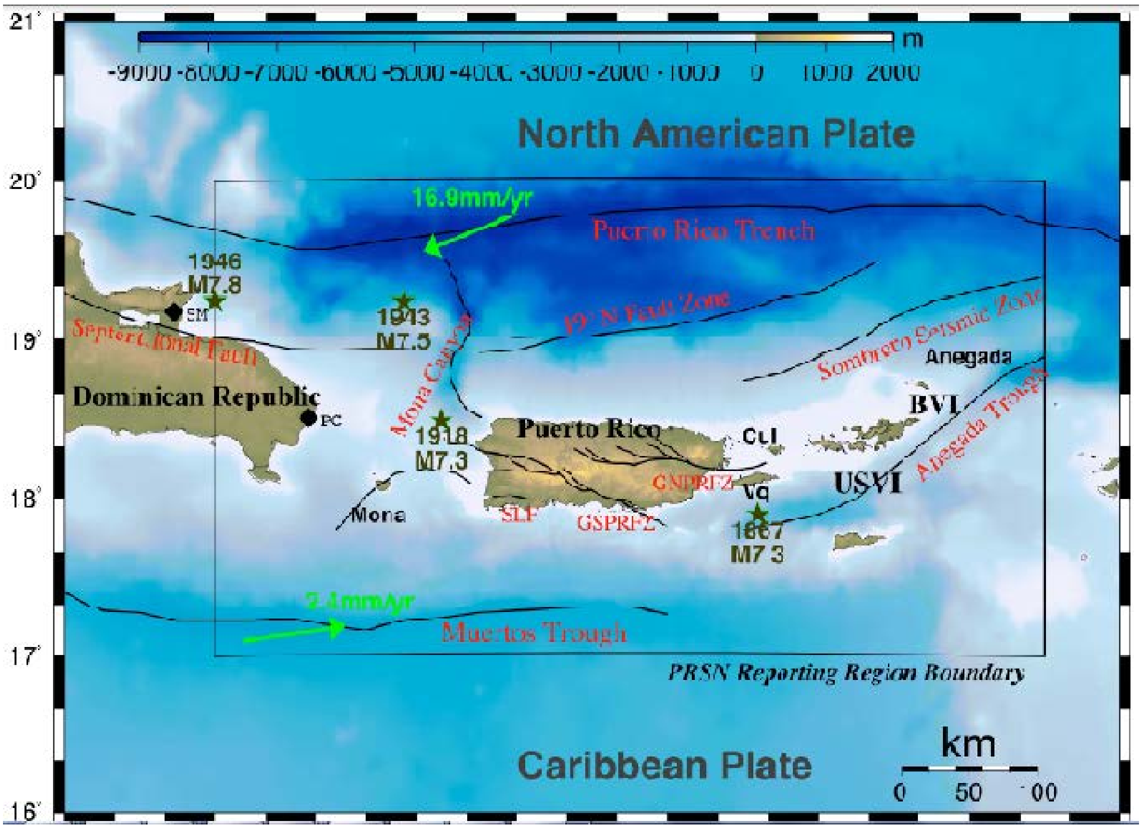


Fig. 4. Main Seismic Hazards

In this study, the probabilistic seismic hazard analysis for the NFE-V-08 DEVELOPMENT Project Site, the seismic hazards considered are those present within an area delimited by a circle with radius of 200 km from the project site, as shown in the Fig. 5.

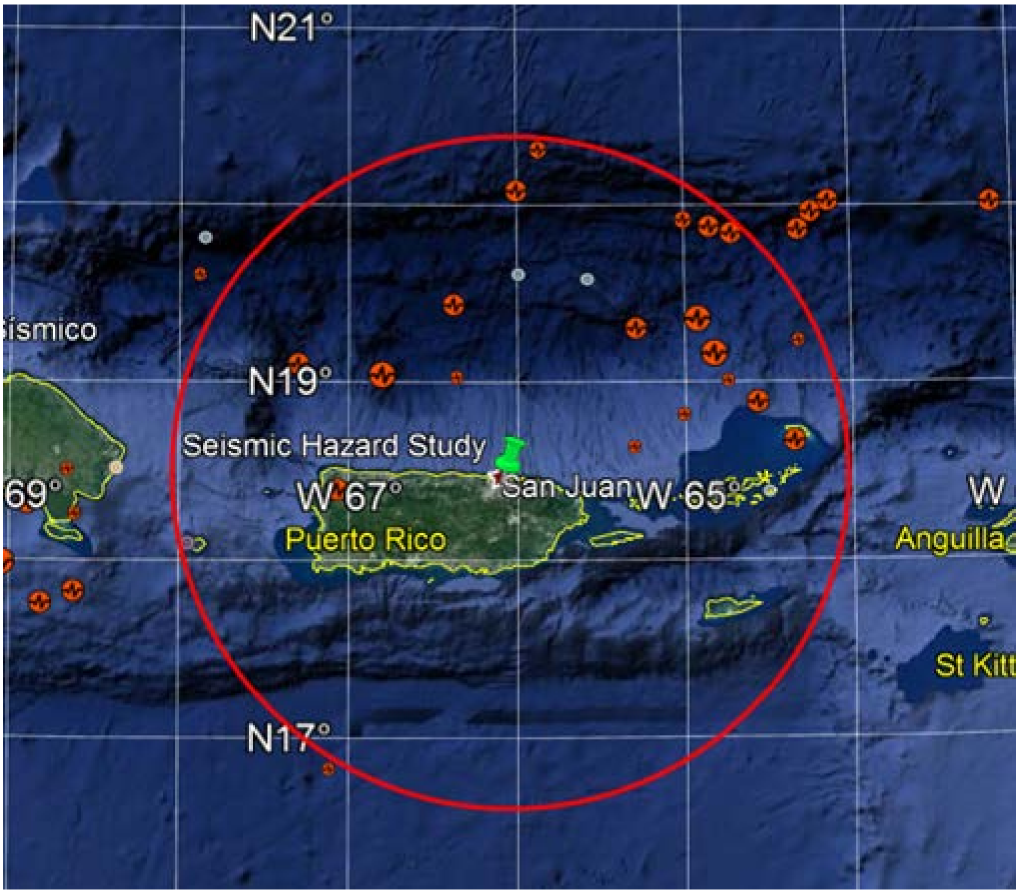
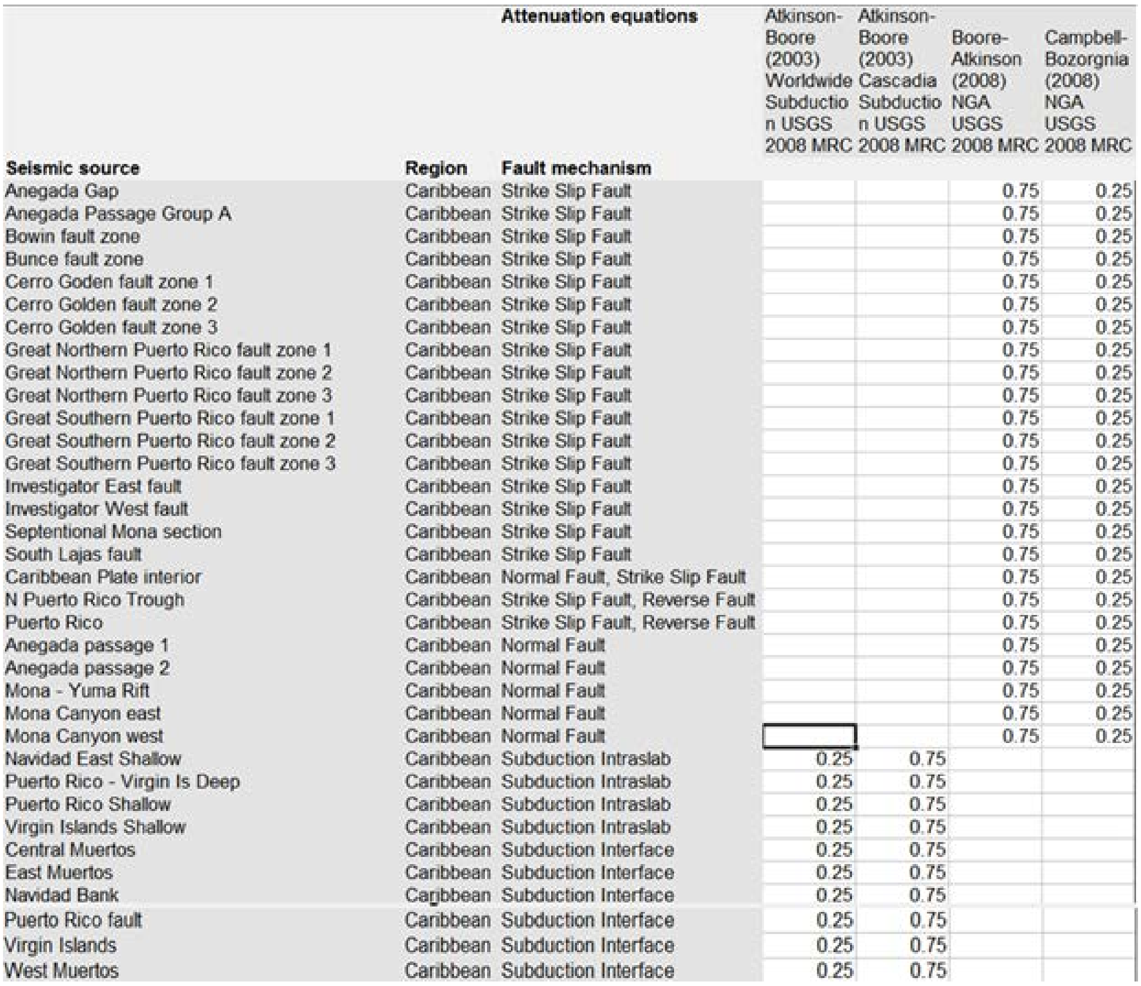


Fig. 5. Seismic Sources NFE-V-08 DEVELOPMENT Project Site

The seismic sources are listed as follows:



		Attenuation equations	Atkinson-Boore (2003) Worldwide Subduction USGS 2008 MRC	Atkinson-Boore (2003) Cascadia Subduction USGS 2008 MRC	Boore-Atkinson (2008) NGA USGS 2008 MRC	Campbell-Bozorgnia (2008) NGA USGS 2008 MRC
Seismic source	**Region**	**Fault mechanism**				
Anegada Gap	Caribbean	Strike Slip Fault			0.75	0.25
Anegada Passage Group A	Caribbean	Strike Slip Fault			0.75	0.25
Bowin fault zone	Caribbean	Strike Slip Fault			0.75	0.25
Bunce fault zone	Caribbean	Strike Slip Fault			0.75	0.25
Cerro Goden fault zone 1	Caribbean	Strike Slip Fault			0.75	0.25
Cerro Golden fault zone 2	Caribbean	Strike Slip Fault			0.75	0.25
Cerro Golden fault zone 3	Caribbean	Strike Slip Fault			0.75	0.25
Great Northern Puerto Rico fault zone 1	Caribbean	Strike Slip Fault			0.75	0.25
Great Northern Puerto Rico fault zone 2	Caribbean	Strike Slip Fault			0.75	0.25
Great Northern Puerto Rico fault zone 3	Caribbean	Strike Slip Fault			0.75	0.25
Great Southern Puerto Rico fault zone 1	Caribbean	Strike Slip Fault			0.75	0.25
Great Southern Puerto Rico fault zone 2	Caribbean	Strike Slip Fault			0.75	0.25
Great Southern Puerto Rico fault zone 3	Caribbean	Strike Slip Fault			0.75	0.25
Investigator East fault	Caribbean	Strike Slip Fault			0.75	0.25
Investigator West fault	Caribbean	Strike Slip Fault			0.75	0.25
Septentional Mona section	Caribbean	Strike Slip Fault			0.75	0.25
South Lajas fault	Caribbean	Strike Slip Fault			0.75	0.25
Caribbean Plate interior	Caribbean	Normal Fault, Strike Slip Fault			0.75	0.25
N Puerto Rico Trough	Caribbean	Strike Slip Fault, Reverse Fault			0.75	0.25
Puerto Rico	Caribbean	Strike Slip Fault, Reverse Fault			0.75	0.25
Anegada passage 1	Caribbean	Normal Fault			0.75	0.25
Anegada passage 2	Caribbean	Normal Fault			0.75	0.25
Mona - Yuma Rift	Caribbean	Normal Fault			0.75	0.25
Mona Canyon east	Caribbean	Normal Fault			0.75	0.25
Mona Canyon west	Caribbean	Normal Fault			0.75	0.25
Navidad East Shallow	Caribbean	Subduction Intraslab	0.25	0.75		
Puerto Rico - Virgin Is Deep	Caribbean	Subduction Intraslab	0.25	0.75		
Puerto Rico Shallow	Caribbean	Subduction Intraslab	0.25	0.75		
Virgin Islands Shallow	Caribbean	Subduction Intraslab	0.25	0.75		
Central Muertos	Caribbean	Subduction Interface	0.25	0.75		
East Muertos	Caribbean	Subduction Interface	0.25	0.75		
Navidad Bank	Caribbean	Subduction Interface	0.25	0.75		
Puerto Rico fault	Caribbean	Subduction Interface	0.25	0.75		
Virgin Islands	Caribbean	Subduction Interface	0.25	0.75		
West Muertos	Caribbean	Subduction Interface	0.25	0.75		

Table 1. NFE-V-08 DEVELOPMENT Project Site Seismic Sources

Where two or more seismic sources overlap, the magnitudes ranges are adjusted in order to avoid double counting of hazard contributions. All seismic sources that are located more than 200 km from the study site, are excluded from the seismic hazard analysis.

Two ground-motion-relations are applied to the subduction models:

Atkinson-Boore (USGS 2008 MRC) Worldwide Subduction, and (ii) Atkinson-Boore (USGS 2008 MRC) Cascadia Subduction. Two ground-motion- relations are applied for the strike-slip faults, normal faults, reverse faults: (i) Boore-Atkinson (USGS 2008 MRC), and (ii) Campbell-Bozorgnia (USGS 2008 MRC). To modify the ground-motion relations to represent the Maximum-Rotated Component, FEMA P-750, Table 21.2-1 is used (EZ-FRISK User's Manual, Implementation Notes). These ground motion attenuation relationships are, among others, typically used in seismic hazard studies for Puerto Rico (Johnson et al., 1992; Frankel et al. 2003; LaForge and McCann, 2005). Table 1 above shows how the attenuation relations are related to seismic sources and the weights assigned to each attenuation model when two or more ground motion relations are associated with the same seismic source.

4.0 PROBABILISTIC SEISMIC HAZARD ANALYSIS (PSHA)

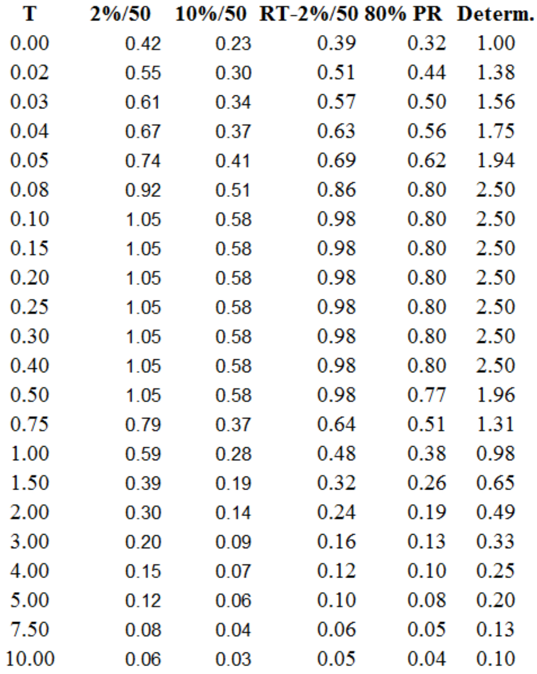
A seismic hazard analysis has been performed for the NFE-V-08 DEVELOPMENT Project site using appropriate computer code EZ_FRISK 7.65.004. (WLA-Risk Engineering, Inc., 2015). Statistical independence has been assumed. An earthquake from any source occurs without affecting the other sources. Although this requirement can be relaxed (Robin McGuire, 2004), there is no evidence of strong coupling among seismic sources in PR (Calais, 2006).

Appendix 1 shows the PSHA results. Soft bedrock ground accelerations and 5% damped Uniform Hazard Response Spectra (UHS) were computed for this site, corresponding to 2% probability of being exceeded in 50 years (2475 year return period) and 10% probability of being exceeded in 50 years (475 year return period), respectively. Also, a 5% damped Risk-Targeted Uniform Hazard Spectrum (UHS) was computed for this site, corresponding to 2% probability of being exceeded in 50 years (2475 year– average return period) as per ASCE 7-16, Chapter 21, Method 2, based on the Maximum-Rotated Horizontal Ground Motion Component.

EZ-FRISK's built-in Recurrence Models for the Caribbean Region includes both Exponential and Characteristic recurrences models for Puerto Rico seismic sources. In this study exponential and characteristic recurrence models are used. Truncated Exponential Recurrence Models are used for both subduction zone seismic sources and for lines and areal seismic sources. Uniform Hazard Response Spectra (UHS) are obtained from the hazard analysis. The uncertainties in the probabilistic seismic hazard analysis are taken into account by the application of three recurrence models: a)

Characteristic Model, b) Exponential Model, and c) Truncated Exponential Model. The weighted average of these models are applied to every seismogenic fault considered in this study. Other uncertainties are included based on the decision-tree method, as described in the reference document “Seismic Source Model for the Caribbean Region”.

Table 2 below shows the pseudo acceleration response spectra for rock type B, including adjusted effective PGA, UHS 2 %/50, 10%/50, Risk-Targeted RT-2%/50, 80% PR 2%/50, and the Deterministic response spectra, respectively. As per ASCE 7-16, Chapter 21, Site-Specific Ground Motion Procedures for Seismic Design, the site-specific response spectrum spectral accelerations should not be lower than 80% of the spectral acceleration of the current building codes. The site-specific response spectrum spectral accelerations do not have to be higher than the corresponding Deterministic Response Spectrum, as specified in ASCE 7-16, Section 21.2.2. The Uniform Hazard Spectra (UHS), 2%/50 and RT-2%/50, derived from the site-specific probabilistic seismic hazard analysis performed for the site of the NFE-V-08 DEVELOPMENT Project, predicts acceleration values for bedrock type B, which are in compliance with the requirements of ASCE 7-16, as shown in Table 2 and Fig.6 below.



T	2%/50	10%/50	RT-2%/50	80% PR	Determ.
0.00	0.42	0.23	0.39	0.32	1.00
0.02	0.55	0.30	0.51	0.44	1.38
0.03	0.61	0.34	0.57	0.50	1.56
0.04	0.67	0.37	0.63	0.56	1.75
0.05	0.74	0.41	0.69	0.62	1.94
0.08	0.92	0.51	0.86	0.80	2.50
0.10	1.05	0.58	0.98	0.80	2.50
0.15	1.05	0.58	0.98	0.80	2.50
0.20	1.05	0.58	0.98	0.80	2.50
0.25	1.05	0.58	0.98	0.80	2.50
0.30	1.05	0.58	0.98	0.80	2.50
0.40	1.05	0.58	0.98	0.80	2.50
0.50	1.05	0.58	0.98	0.77	1.96
0.75	0.79	0.37	0.64	0.51	1.31
1.00	0.59	0.28	0.48	0.38	0.98
1.50	0.39	0.19	0.32	0.26	0.65
2.00	0.30	0.14	0.24	0.19	0.49
3.00	0.20	0.09	0.16	0.13	0.33
4.00	0.15	0.07	0.12	0.10	0.25
5.00	0.12	0.06	0.10	0.08	0.20
7.50	0.08	0.04	0.06	0.05	0.13
10.00	0.06	0.03	0.05	0.04	0.10

Table 2. Uniform Hazard Spectra (UHS)

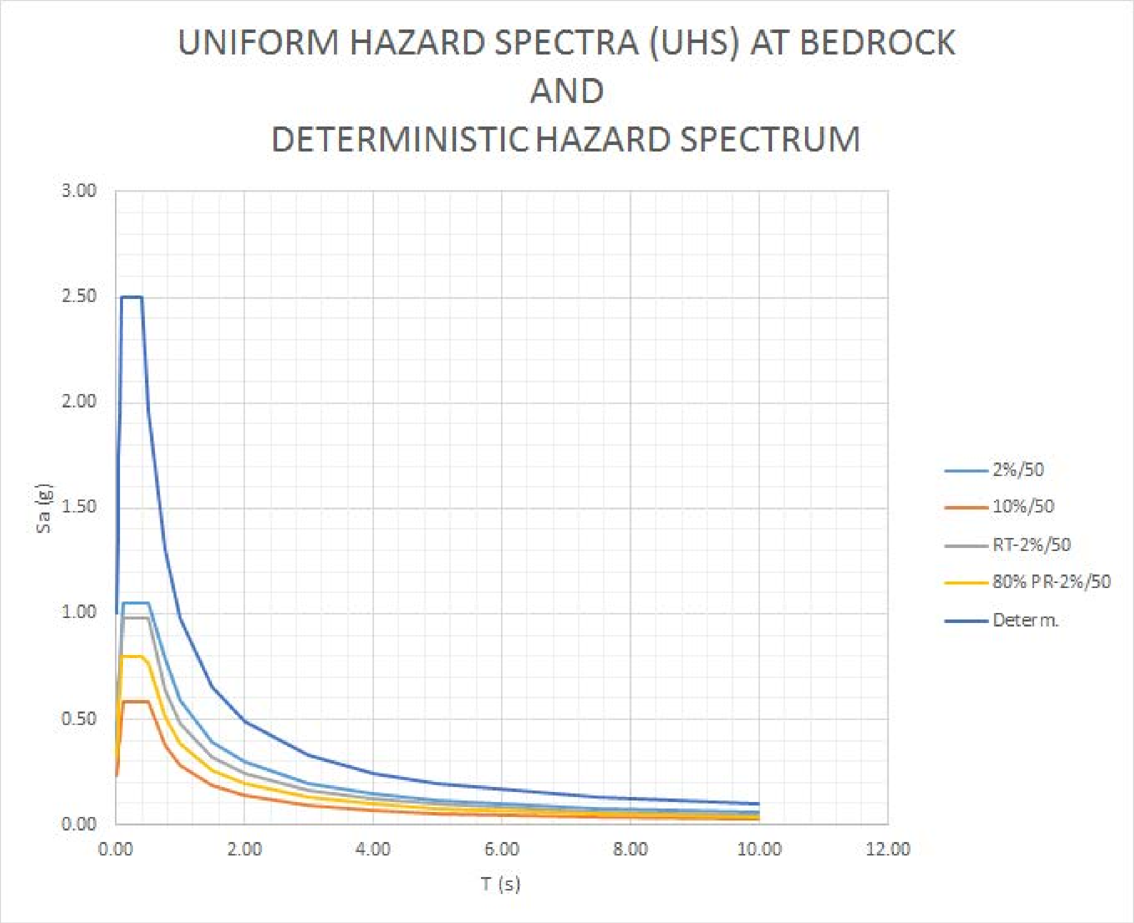
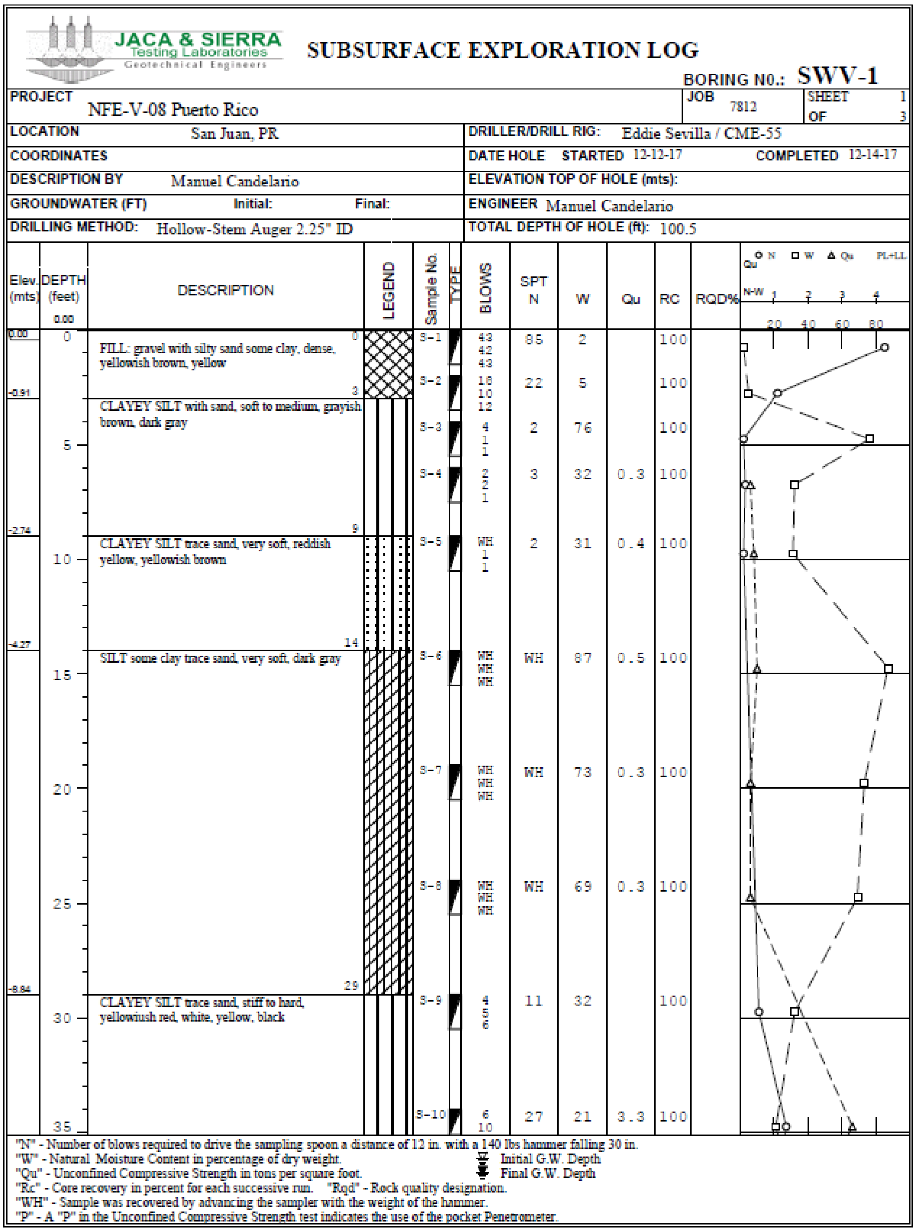


Fig.6. UHS Response Spectra at Bedrock

5.0 SITE RESPONSE ANALYSIS

To support this site-specific ground motion response study, Jaca & Sierra performed site-specific geotechnical investigations, including borings and geophysical surveys (see Appendix 3). One boring have been selected as representative of the site soil stratigraphy. Figs. 7a, 7b, and 7c below show the NFE-V-08 DEVELOPMENT Project Site Soil Profile for boring SWV-1, including the soil layers description.



JACA & SIERRA Testing Laboratories Geotechnical Engineers

SUBSURFACE EXPLORATION LOG

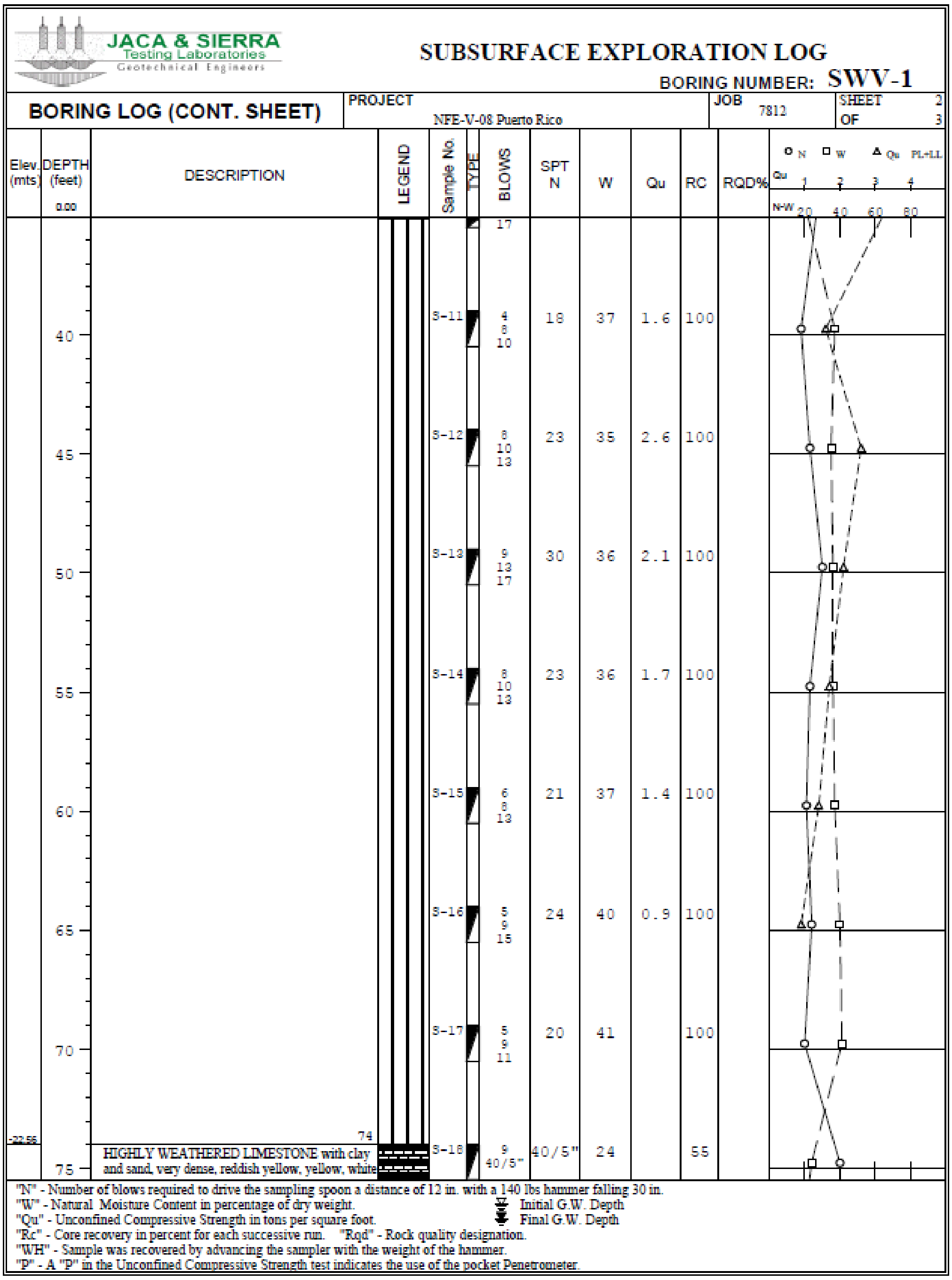
BORING N0.: **SWV-1**

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 1 OF 3
LOCATION San Juan, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES
DATE HOLE STARTED 12-12-17 COMPLETED 12-14-17
DESCRIPTION BY Manuel Candelario
ELEVATION TOP OF HOLE (mts):
GROUNDWATER (FT) Initial: Final:
ENGINEER Manuel Candelario
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH OF HOLE (ft): 100.5

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	Sample No.	BLOWS	SPT N	W	Qu	RC	RQD%
0.00	0	FILL: gravel with silty sand some clay, dense, yellowish brown, yellow	S-1	43 42 43	85	2		100	
			S-2	18 10 12	22	5		100	
-0.91	3	CLAYEY SILT with sand, soft to medium, grayish brown, dark gray	S-3	4 1 1	2	76		100	
			S-4	2 2 1	3	32	0.3	100	
-2.74	9	CLAYEY SILT trace sand, very soft, reddish yellow, yellowish brown	S-5	WH 1 1	2	31	0.4	100	
-4.27	14	SILT some clay trace sand, very soft, dark gray	S-6	WH WH WH	WH	87	0.5	100	
			S-7	WH WH WH	WH	73	0.3	100	
			S-8	WH WH WH	WH	69	0.3	100	
-8.84	29	CLAYEY SILT trace sand, stiff to hard, yellowiush red, white, yellow, black	S-9	4 5 6	11	32		100	
			S-10	6 10	27	21	3.3	100	

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.
Initial G.W. Depth
Final G.W. Depth

Fig. 7a



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SUBSURFACE EXPLORATION LOG

BORING NUMBER: SWV-1

BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

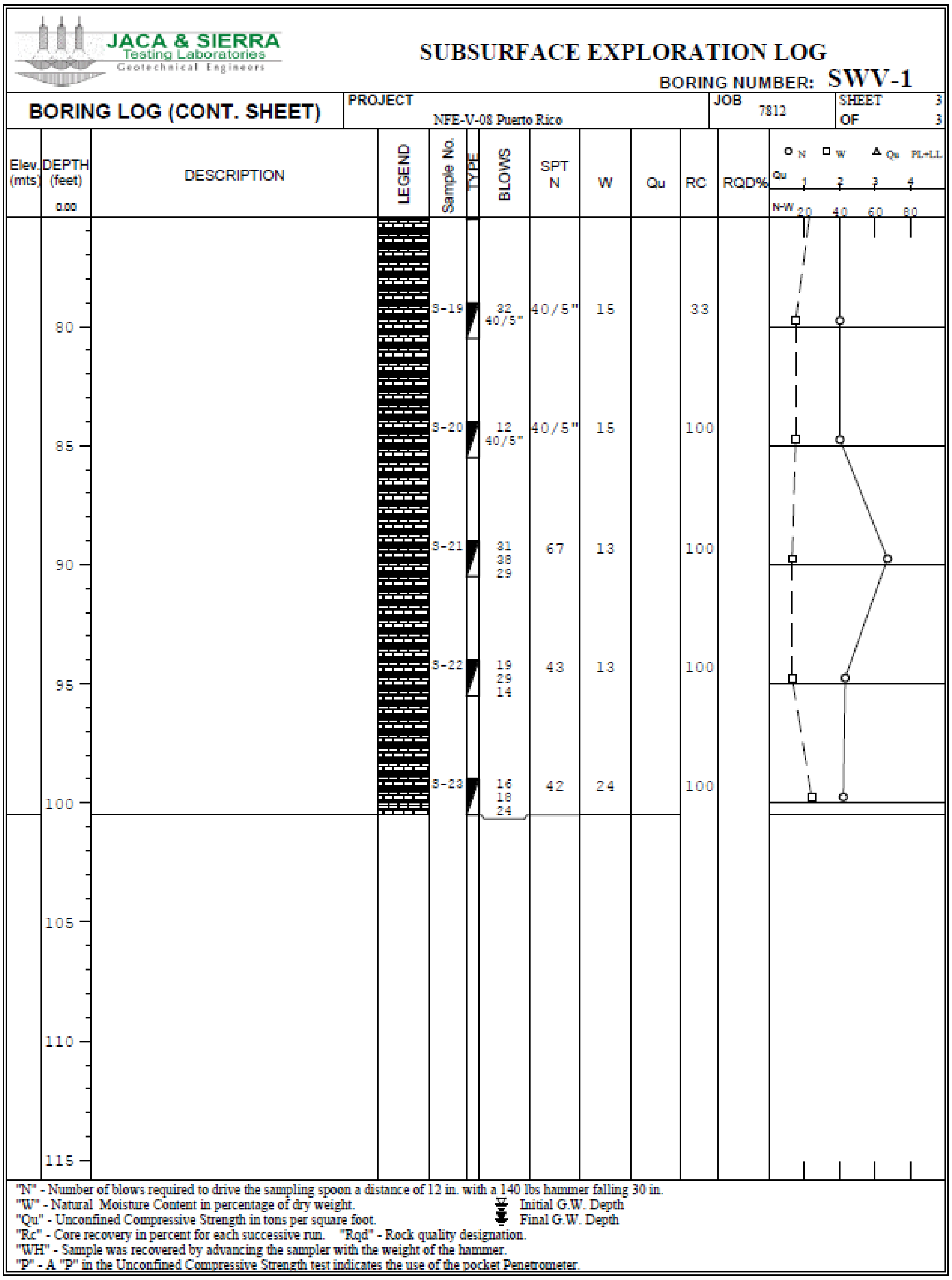
JOB 7812

SHEET 2 OF 3

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	Sample No.	BLOWS	SPT N	W	Qu	RC	RQD%
				17					
	40		S-11	4 8 10	18	37	1.6	100	
	45		S-12	8 10 13	23	35	2.6	100	
	50		S-13	9 13 17	30	36	2.1	100	
	55		S-14	8 10 13	23	36	1.7	100	
	60		S-15	6 8 13	21	37	1.4	100	
	65		S-16	5 9 15	24	40	0.9	100	
	70		S-17	5 9 11	20	41		100	
-22.56	74 75	HIGHLY WEATHERED LIMESTONE with clay and sand, very dense, reddish yellow, yellow, white	S-18	9 40/5"	40/5"	24		55	

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.
Initial G.W. Depth
Final G.W. Depth

Fig. 7b



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SUBSURFACE EXPLORATION LOG

BORING NUMBER: SWV-1

BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 3 OF 3

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
				S-19		32 40/5"	40/5"	15		33	
				S-20		12 40/5"	40/5"	15		100	
				S-21		31 38 29	67	13		100	
				S-22		19 29 14	43	13		100	
				S-23		16 18 24	42	24		100	

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.
Initial G.W. Depth
Final G.W. Depth

Fig. 7c

5.1 SEISMIC VELOCITY DATA

Jaca & Sierra provided also the Shear Wave Velocity Survey results for NFE-V-08 DEVELOPMENT Project site. One seismic downhole profile was carried out. The results are shown in Table 3, and Fig. 8.

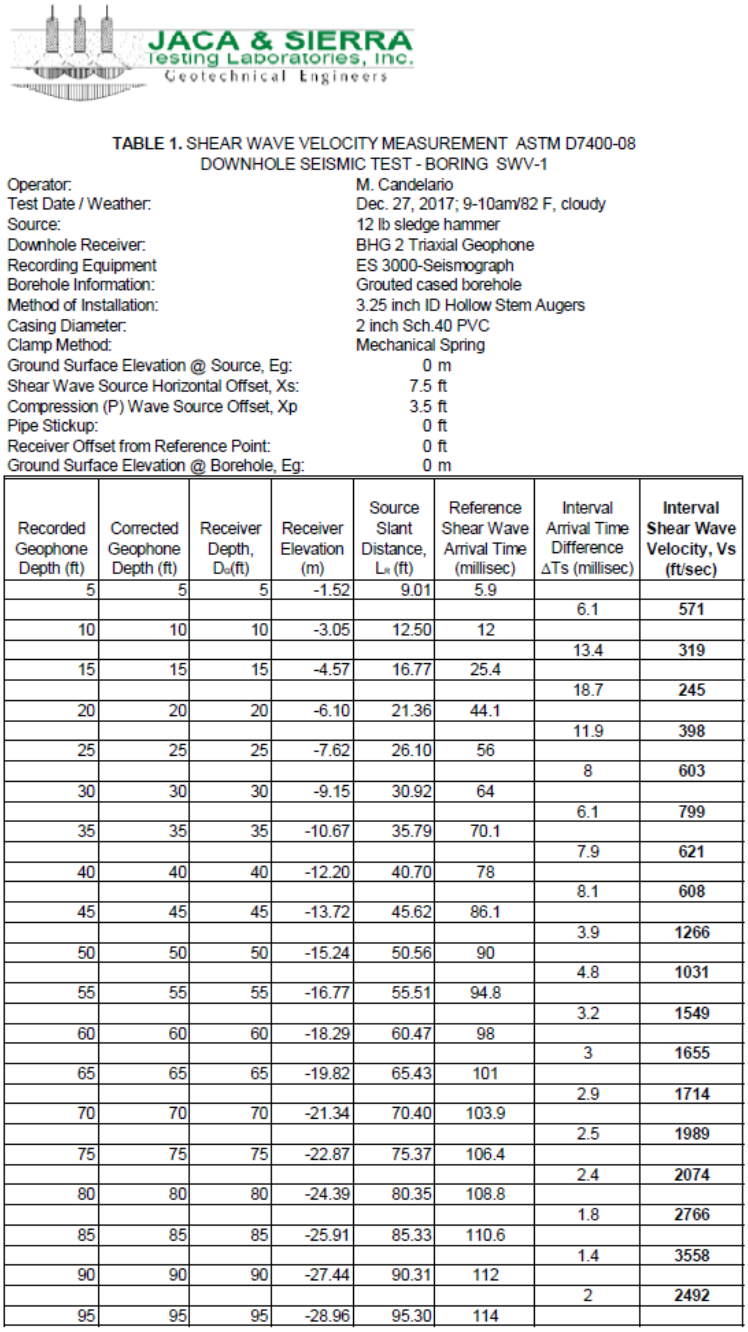

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TABLE 1. SHEAR WAVE VELOCITY MEASUREMENT ASTM D7400-08
DOWNHOLE SEISMIC TEST - BORING SWV-1

Operator: M. Candelario
Test Date / Weather: Dec. 27, 2017; 9-10am/82 F, cloudy
Source: 12 lb sledge hammer
Downhole Receiver: BHG 2 Triaxial Geophone
Recording Equipment ES 3000-Seismograph
Borehole Information: Grouted cased borehole
Method of Installation: 3.25 inch ID Hollow Stem Augers
Casing Diameter: 2 inch Sch.40 PVC
Clamp Method: Mechanical Spring
Ground Surface Elevation @ Source, Eg: 0 m
Shear Wave Source Horizontal Offset, Xs: 7.5 ft
Compression (P) Wave Source Offset, Xp 3.5 ft
Pipe Stickup: 0 ft
Receiver Offset from Reference Point: 0 ft
Ground Surface Elevation @ Borehole, Eg: 0 m

Recorded Geophone Depth (ft)	Corrected Geophone Depth (ft)	Receiver Depth, D_G(ft)	Receiver Elevation (m)	Source Slant Distance, L_R (ft)	Reference Shear Wave Arrival Time (millisec)	Interval Arrival Time Difference ΔTs (millisec)	**Interval Shear Wave Velocity, Vs (ft/sec)**
5	5	5	-1.52	9.01	5.9		
						6.1	**571**
10	10	10	-3.05	12.50	12		
						13.4	**319**
15	15	15	-4.57	16.77	25.4		
						18.7	**245**
20	20	20	-6.10	21.36	44.1		
						11.9	**398**
25	25	25	-7.62	26.10	56		
						8	**603**
30	30	30	-9.15	30.92	64		
						6.1	**799**
35	35	35	-10.67	35.79	70.1		
						7.9	**621**
40	40	40	-12.20	40.70	78		
						8.1	**608**
45	45	45	-13.72	45.62	86.1		
						3.9	**1266**
50	50	50	-15.24	50.56	90		
						4.8	**1031**
55	55	55	-16.77	55.51	94.8		
						3.2	**1549**
60	60	60	-18.29	60.47	98		
						3	**1655**
65	65	65	-19.82	65.43	101		
						2.9	**1714**
70	70	70	-21.34	70.40	103.9		
						2.5	**1989**
75	75	75	-22.87	75.37	106.4		
						2.4	**2074**
80	80	80	-24.39	80.35	108.8		
						1.8	**2766**
85	85	85	-25.91	85.33	110.6		
						1.4	**3558**
90	90	90	-27.44	90.31	112		
						2	**2492**
95	95	95	-28.96	95.30	114		

Table 3. Shear Wave Velocities

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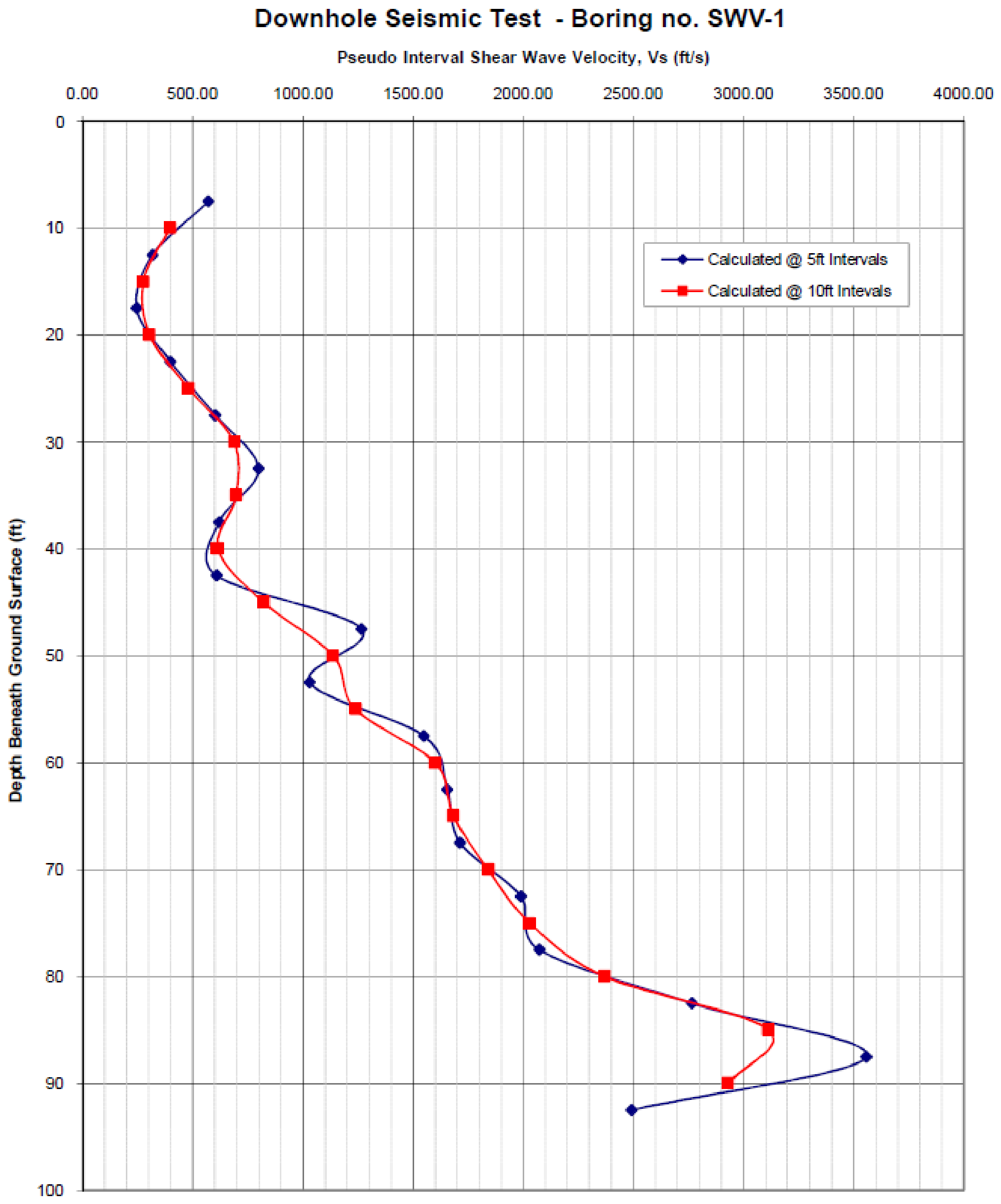
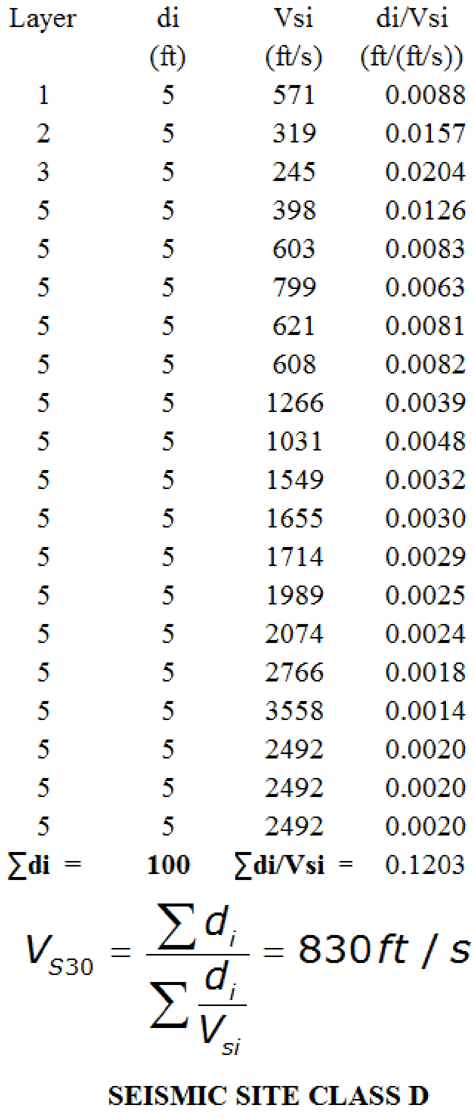


Fig. 8. Shear Wave Velocity Profile (ft/s)

5.2. SITE CATEGORIZATION. SEISMIC SITE CLASS

Based on the shear wave velocity, Vs30, analysis and the results shown in Table 5, the Site Class is D as per ASCE 7-16, Chapter 20. However, the geotechnical boring logs show the presence of a very soft soil stratum at a depth between 15 ft and 30 ft. As per ASCE 7-16, Table 20.3-1, the presence of this soil stratum classifies the site as E or F.



Layer	di (ft)	Vsi (ft/s)	di/Vsi (ft/(ft/s))
1	5	571	0.0088
2	5	319	0.0157
3	5	245	0.0204
5	5	398	0.0126
5	5	603	0.0083
5	5	799	0.0063
5	5	621	0.0081
5	5	608	0.0082
5	5	1266	0.0039
5	5	1031	0.0048
5	5	1549	0.0032
5	5	1655	0.0030
5	5	1714	0.0029
5	5	1989	0.0025
5	5	2074	0.0024
5	5	2766	0.0018
5	5	3558	0.0014
5	5	2492	0.0020
5	5	2492	0.0020
5	5	2492	0.0020
∑di =	**100**	**∑di/Vsi =**	0.1203

$$V_{S30} = \frac{\sum d_i}{\sum \frac{d_i}{V_{si}}} = 830 ft / s$$

SEISMIC SITE CLASS D

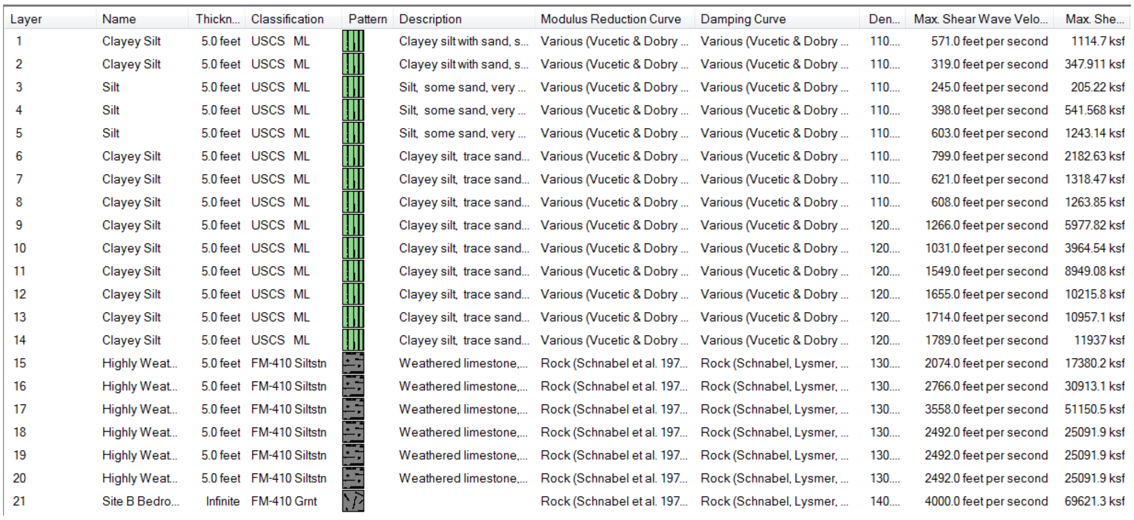
Table 4. Boring SWV-1. Seismic Site Class

6.0 SITE-SPECIFIC GROUND RESPONSE ANAYLSES

6.1 SHAKE ANALYSES

The SHAKE Code (Schnabel, 1972; Idriss and Sun, 1991) is a widely used program for computing the seismic response of horizontally stratified homogeneous isotropic viscoelastic medium subjected to vertically propagating waves (FEMA 450/NEHRP 2003). The program models the nonlinear behavior of soils in an equivalent linear fashion by iterating the strain-dependent shear modulus and damping ratio of each layer until values of these parameters are compatible with the computed shear strain. EZ-FRISK 7.65.004 uses SHAKE 91 for calculating the ground motion response at the surface given a bedrock ground motion and the layers of soil that overlain the bedrock at the site.

Five (5) SHAKE analyses have been run for the soil column SWV-1 based on the corresponding mechanical properties provided in the geotechnical and geophysical investigations reports, as shown in Tables 3 and 5. The Magnitude-Distance-Epsilon deaggregated seismic hazards (Figs. 9, 10, 11) show that 8.0 Mw earthquakes ground motions can be expected from subduction zone seismogenic structures at a distance of 80 km from the project site. Likewise, 6.5 Mw earthquakes can be expected from on land strike-slip faults at a distance of 20 km. A suite of five ground motions with earthquake magnitudes, epicenter distances, source mechanisms, and site geology similar to the deaggregated seismic hazards for NFE-V-08 DEVELOPMENT Project Site (See Appendix 4) have been selected for the purpose of this study, and are shown in Table 7, and included in Appendix 5. A total of five (5) acceleration time histories, corresponding to the Maximum-Rotated horizontal components have been scaled to obtain the Response Acceleration Compatible Ground Motion Time Histories using the well- known RSPM99 spectral matching algorithm, based on the Time-Domain-Approach method (Lilahanad and Tseng 1988, Abrahamson 1992), and modified to preserve non-stationarity at long periods by using different functional forms for the adjustment of the time-histories (Risk engineering, Inc., 2009) to match the Adjusted Risk-Targeted Uniform Hazard Spectrum (UHS) for 2% probability of being exceeded in 50 yr for bedrock, resulted from the seismic hazard analysis. This UHS has been obtained by adjusting the 2%/50 UHS Acceleration Response Spectrum, as shown in Table 7 and Fig. 12 below, following the Method 2 in ASCE 7-16, and combining the Total Hazard Curve resulted from the PSHA with the built-in Fragility Curve for San Juan PR included in the USGS tool Risk-Targeted Ground Motion Calculator (Luca et al., 2007). . These ground motions where entirely input in separate program runs to the base layer of the SHAKE column. This bedrock layer is designated as Site Class B per ASCE 7-16. Puerto Rico Vs30 soft rock layer has been encounter to be NEHERP Class C (USGS B) (Motazedian and Atkinson, 2005). The results of these SHAKE analyses are graphically shown in Appendix 5.



Layer	Name	Thickn...	Classification	Pattern	Description	Modulus Reduction Curve	Damping Curve	Den...	Max. Shear Wave Velo...	Max. She...
1	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt with sand, s...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	571.0 feet per second	1114.7 ksf
2	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt with sand, s...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	319.0 feet per second	347.911 ksf
3	Silt	5.0 feet	USCS ML	🟩	Silt, some sand, very ...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	245.0 feet per second	205.22 ksf
4	Silt	5.0 feet	USCS ML	🟩	Silt, some sand, very ...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	398.0 feet per second	541.568 ksf
5	Silt	5.0 feet	USCS ML	🟩	Silt, some sand, very ...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	603.0 feet per second	1243.14 ksf
6	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	799.0 feet per second	2182.63 ksf
7	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	621.0 feet per second	1318.47 ksf
8	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	110....	608.0 feet per second	1263.85 ksf
9	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	120....	1266.0 feet per second	5977.82 ksf
10	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	120....	1031.0 feet per second	3964.54 ksf
11	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	120....	1549.0 feet per second	8949.08 ksf
12	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	120....	1655.0 feet per second	10215.8 ksf
13	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	120....	1714.0 feet per second	10957.1 ksf
14	Clayey Silt	5.0 feet	USCS ML	🟩	Clayey silt, trace sand...	Various (Vucetic & Dobry ...	Various (Vucetic & Dobry ...	120....	1789.0 feet per second	11937 ksf
15	Highly Weat...	5.0 feet	FM-410 Siltstn	▨	Weathered limestone,...	Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	130....	2074.0 feet per second	17380.2 ksf
16	Highly Weat...	5.0 feet	FM-410 Siltstn	▨	Weathered limestone,...	Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	130....	2766.0 feet per second	30913.1 ksf
17	Highly Weat...	5.0 feet	FM-410 Siltstn	▨	Weathered limestone,...	Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	130....	3558.0 feet per second	51150.5 ksf
18	Highly Weat...	5.0 feet	FM-410 Siltstn	▨	Weathered limestone,...	Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	130....	2492.0 feet per second	25091.9 ksf
19	Highly Weat...	5.0 feet	FM-410 Siltstn	▨	Weathered limestone,...	Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	130....	2492.0 feet per second	25091.9 ksf
20	Highly Weat...	5.0 feet	FM-410 Siltstn	▨	Weathered limestone,...	Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	130....	2492.0 feet per second	25091.9 ksf
21	Site B Bedro...	Infinite	FM-410 Grnt	▨		Rock (Schnabel et al. 197...	Rock (Schnabel, Lysmer, ...	140....	4000.0 feet per second	69621.3 ksf

Table 5. SHAKE Column for Boring SWV-1

SELECTED EARTQUAKE GROUND MOTIONS (NGA PEER DATABASE)

EARTHQUAKE	MAGNITUDE (Mw)	SITE	COMPONENT
Loma Prieta	6.93	B	LOMAP_A01000.AT2
Hector Mine	7.13	B	HECTOR_PFT090.AT2
ChiChi Taiwan	7.62	B	CHICHI_CHY010-N.AT2
Cape Mendocino	7.51	B	CAPEMEND_LFS270.AT2
Sierra Mexico	7.20	B	COALINGHSC3090

Table 6. PEER Ground Motions

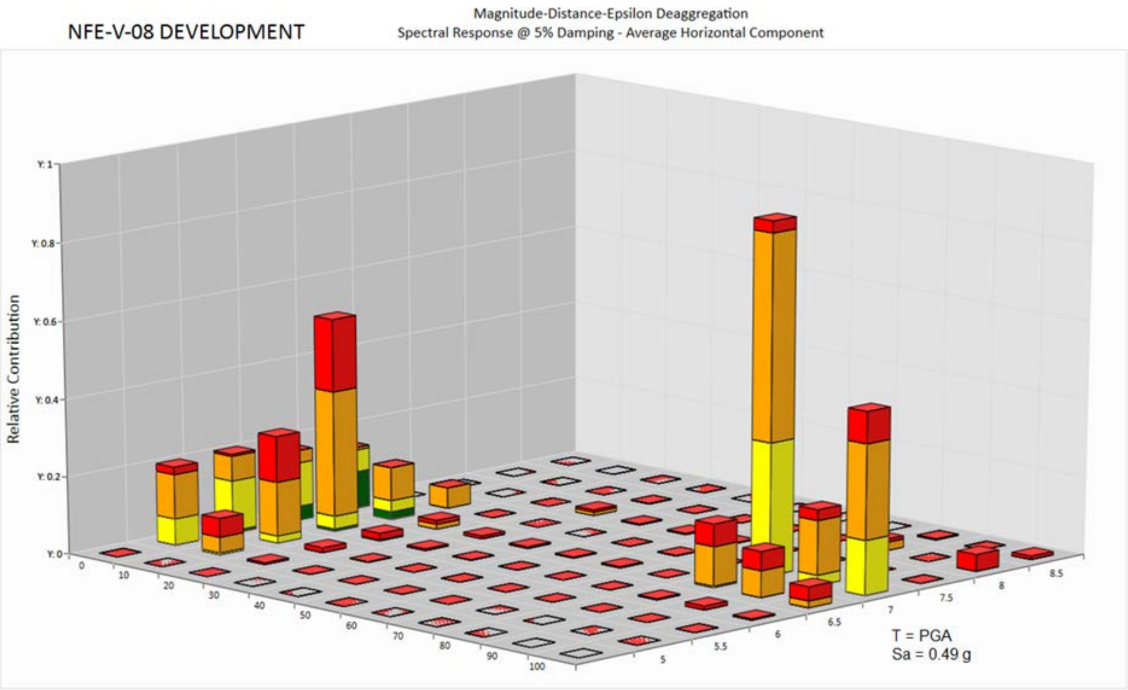


Fig. 9a. Deaggregated Seismic Hazards. T = 0.0 s and Sa = 0.49g

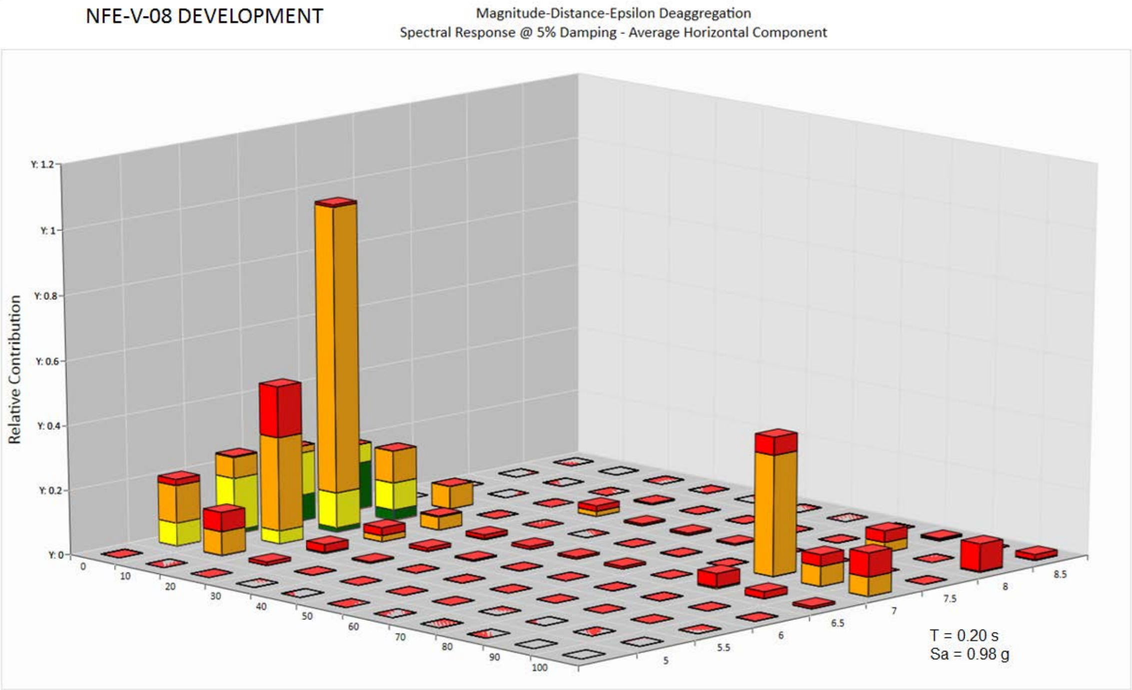


Fig. 9b. Deaggregated Seismic Hazards. T = 0.20 s and Sa = 0.98g

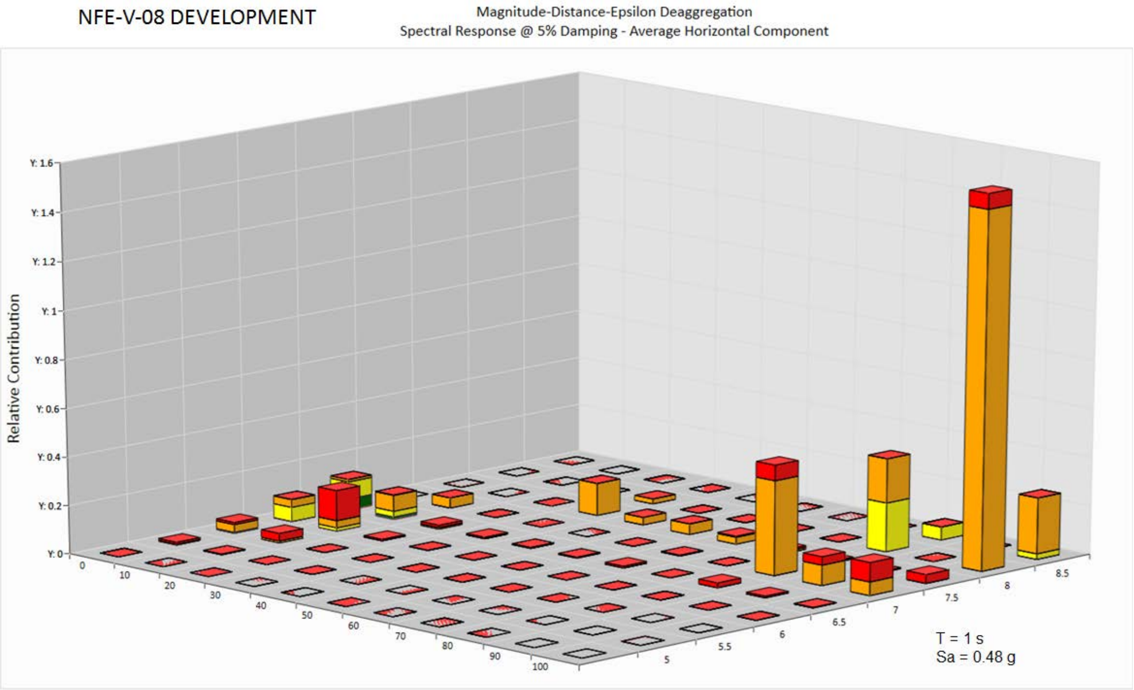


Fig. 9c. Deaggregated Seismic Hazards. T = 1.0 s and Sa = 0.48g

T	Sa	CR	RT-Sa
0.00	0.53	0.94	0.49
0.02	0.59	0.94	0.55
0.03	0.65	0.94	0.61
0.04	0.71	0.94	0.67
0.05	0.75	0.94	0.71
0.08	0.89	0.94	0.84
0.10	1.01	0.94	0.95
0.15	1.08	0.94	1.02
0.20	1.05	0.94	0.98
0.25	0.94	0.94	0.88
0.30	0.87	0.94	0.82
0.40	0.85	0.94	0.80
0.50	0.76	0.94	0.72
0.75	0.60	0.94	0.56
1.00	0.52	0.94	0.48
1.50	0.37	0.94	0.34
2.00	0.29	0.94	0.27
3.00	0.15	0.94	0.14
4.00	0.12	0.94	0.11
5.00	0.08	0.94	0.08
7.50	0.04	0.94	0.04
10.00	0.02	0.94	0.02

Table 7. Risk-Targeted UHS Response Spectrum

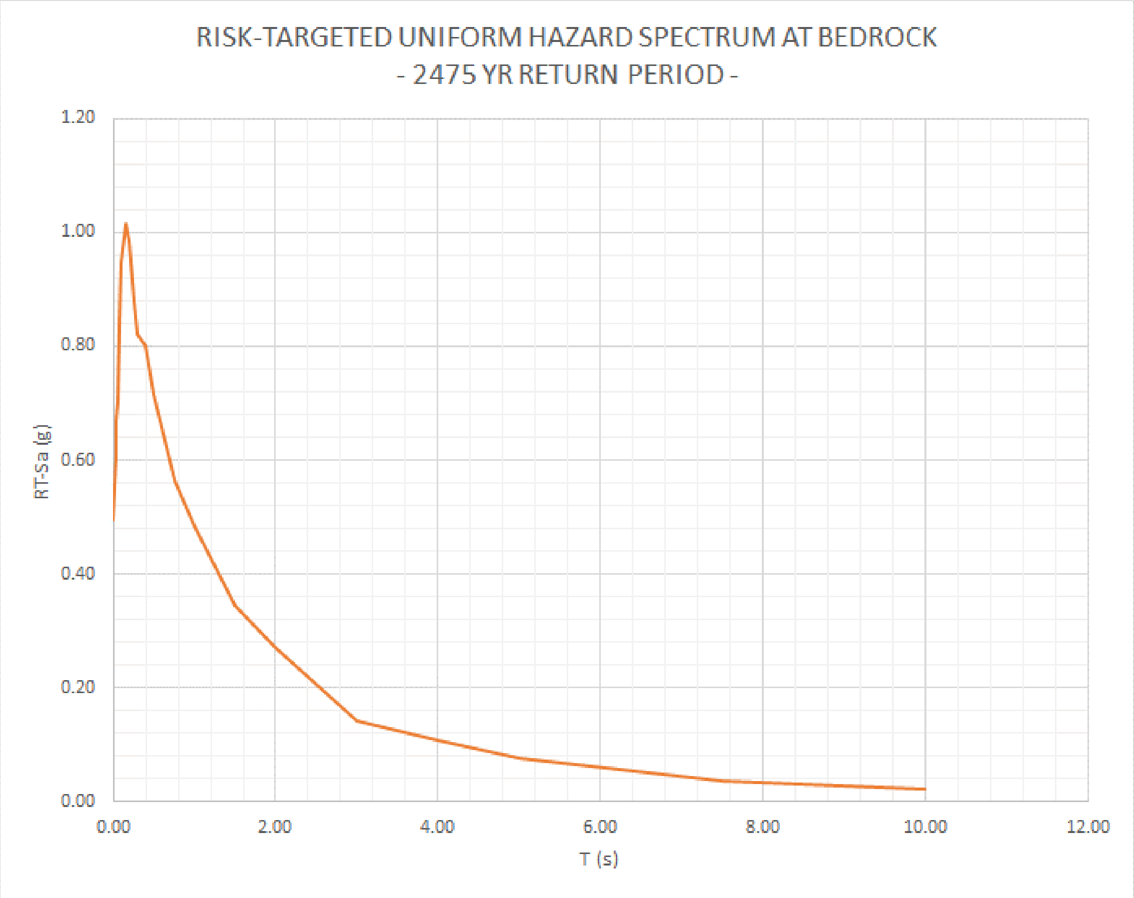


Fig. 10. Risk-Targeted UHS Response Spectrum

6.2 SITE-SPECIFIC DESIGN RESPONSE SPECTRUM. SSE AND OBE EARTHQUAKE GROUND MOTIONS SPECTRA.

Finally, and following the procedure stated in ASCE 7-16, Chapter 21, and using the five response spectra at surface resulted from the SHAKE analyses, the Acceleration Response Spectrum Parameters S_s and S_1 for 0.50%, 2.0%, 5.0%, 10.0%, and 20.0% damping, respectively, are obtained, corresponding to separate averages of spectral ordinates at T = 0.20s and T = 1s of the five site-specific ground motion response spectra. The Site-specific Ground Response Spectra for 0.50%, 2.0%, 5.0%, 10.0%, and 20.0% damping, 2% Probability of Exceedance in 50 yr, (2475 yr return period) and 10% of Probability of Exceedance in 50 yr (475 yr return period) for the NFE-V-08 DEVELOPMENT Project Site were developed as per ASCE 7-16 specifications as mentioned above, and are given in Tables 8 and 9 below, and are shown in Figs. 13 and 14, respectively. These response spectra represent the Safe Shutdown Earthquake (SSE) and the Operating Basis Earthquake (OBE), respectively, as requested by the project's RFP.

T	Damp. 0.50 % RT-Sa	T	Damp. 2.0 % RT-Sa	T	Damp. 5.0 % RT-Sa	T	Damp. 10.0 % RT-Sa	T	Damp. 20.0 % RT-Sa
0.00	0.81	0.00	0.50	0.00	0.38	0.00	0.30	0.00	0.26
0.02	0.93	0.02	0.56	0.02	0.44	0.02	0.35	0.02	0.29
0.03	0.99	0.03	0.59	0.03	0.47	0.03	0.37	0.03	0.31
0.04	1.06	0.04	0.62	0.04	0.50	0.04	0.40	0.04	0.33
0.05	1.12	0.05	0.66	0.05	0.53	0.05	0.42	0.05	0.35
0.08	1.27	0.08	0.73	0.08	0.60	0.08	0.48	0.08	0.40
0.10	1.42	0.10	0.81	0.10	0.67	0.10	0.53	0.10	0.45
0.15	1.73	0.15	0.96	0.15	0.82	0.15	0.65	0.15	0.54
0.20	2.03	0.20	1.11	0.20	0.96	0.20	0.76	0.20	0.64
0.25	2.03	0.25	1.26	0.25	0.96	0.25	0.76	0.25	0.64
0.30	2.03	0.30	1.26	0.30	0.96	0.30	0.76	0.30	0.64
0.40	2.03	0.40	1.26	0.40	0.96	0.40	0.76	0.40	0.64
0.50	2.03	0.50	1.26	0.50	0.96	0.50	0.76	0.50	0.64
0.75	2.03	0.75	1.26	0.75	0.96	0.75	0.76	0.75	0.64
0.85	2.03	0.85	1.26	0.85	0.96	0.85	0.76	0.85	0.64
1.00	2.03	1.00	1.26	1.00	0.96	1.00	0.76	1.00	0.54
1.20	1.59	1.20	1.26	1.20	0.83	1.20	0.63	1.20	0.45
1.50	1.27	1.50	0.97	1.50	0.67	1.50	0.51	1.50	0.36
2.00	0.96	2.00	0.73	2.00	0.50	2.00	0.38	2.00	0.27
3.00	0.64	3.00	0.49	3.00	0.33	3.00	0.25	3.00	0.18
4.00	0.48	4.00	0.37	4.00	0.25	4.00	0.19	4.00	0.14
5.00	0.38	5.00	0.29	5.00	0.20	5.00	0.15	5.00	0.11
7.50	0.25	7.50	0.19	7.50	0.13	7.50	0.10	7.50	0.07
10.00	0.19	10.00	0.15	10.00	0.10	10.00	0.08	10.00	0.05

Table 8. Safe Shutdown Earthquake (SSE) Response Spectra

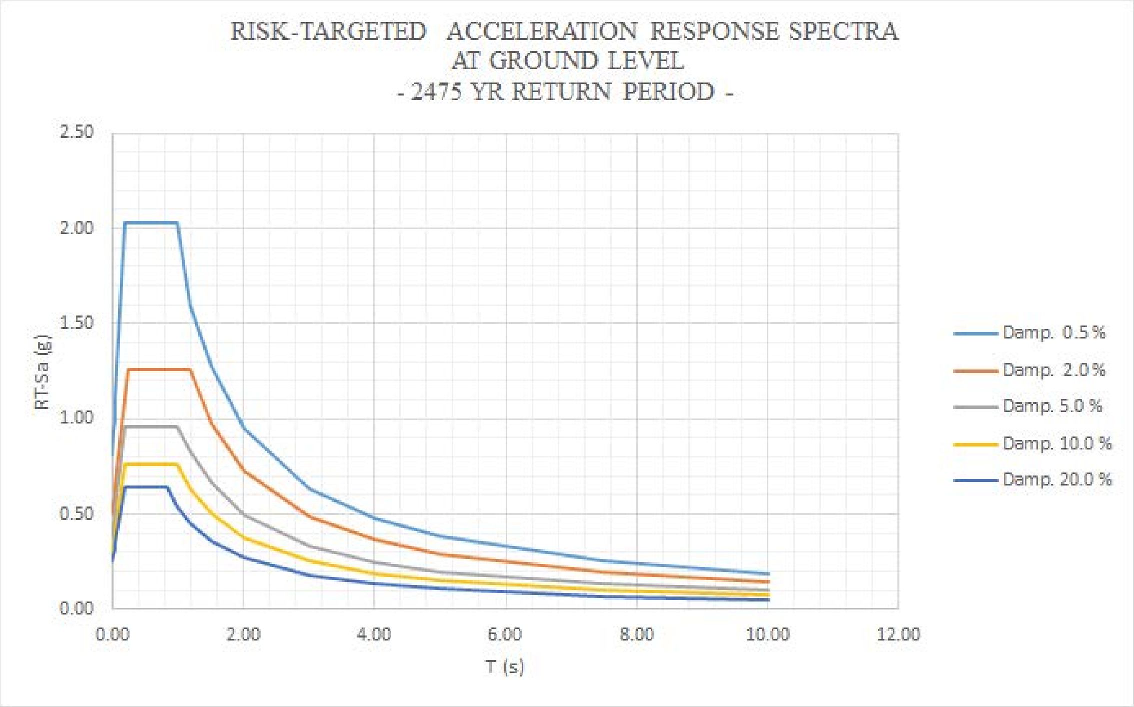


Fig. 11. Safe Shutdown Earthquake (SSE) Response Spectra

	Damp.		Damp.		Damp.		Damp.		Damp.
	0.50 %		2.0 %		5.0 %		10.0 %		20.0 %
T	RT-Sa	T	RT-Sa	T	RT-Sa	T	RT-Sa	T	RT-Sa
0.00	0.54	0.00	0.34	0.00	0.26	0.00	0.20	0.00	0.17
0.02	0.62	0.02	0.38	0.02	0.29	0.02	0.23	0.02	0.20
0.03	0.66	0.03	0.40	0.03	0.31	0.03	0.25	0.03	0.21
0.04	0.70	0.04	0.42	0.04	0.33	0.04	0.26	0.04	0.22
0.05	0.74	0.05	0.44	0.05	0.35	0.05	0.28	0.05	0.23
0.08	0.85	0.08	0.49	0.08	0.40	0.08	0.32	0.08	0.27
0.10	0.95	0.10	0.54	0.10	0.45	0.10	0.35	0.10	0.30
0.15	1.15	0.15	0.64	0.15	0.54	0.15	0.43	0.15	0.36
0.20	1.35	0.20	0.74	0.20	0.64	0.20	0.51	0.20	0.36
0.25	1.35	0.25	0.84	0.25	0.64	0.25	0.51	0.25	0.36
0.30	1.35	0.30	0.84	0.30	0.64	0.30	0.51	0.30	0.36
0.40	1.35	0.40	0.84	0.40	0.64	0.40	0.51	0.40	0.36
0.50	1.35	0.50	0.84	0.50	0.64	0.50	0.51	0.50	0.36
0.75	1.35	0.75	0.84	0.75	0.64	0.75	0.51	0.75	0.36
0.85	1.35	0.85	0.84	0.85	0.64	0.85	0.51	0.85	0.36
1.00	1.35	1.00	0.84	1.00	0.64	1.00	0.51	1.00	0.36
1.20	1.06	1.20	0.84	1.20	0.56	1.20	0.42	1.20	0.30
1.50	0.85	1.50	0.65	1.50	0.44	1.50	0.34	1.50	0.24
2.00	0.64	2.00	0.49	2.00	0.33	2.00	0.25	2.00	0.18
3.00	0.42	3.00	0.32	3.00	0.22	3.00	0.17	3.00	0.12
4.00	0.32	4.00	0.24	4.00	0.17	4.00	0.13	4.00	0.09
5.00	0.25	5.00	0.19	5.00	0.13	5.00	0.10	5.00	0.07
7.50	0.17	7.50	0.13	7.50	0.09	7.50	0.07	7.50	0.05
10.00	0.13	10.00	0.10	10.00	0.07	10.00	0.05	10.00	0.04

Table 9. Operating Basis Earthquake (OBE) Response Spectra

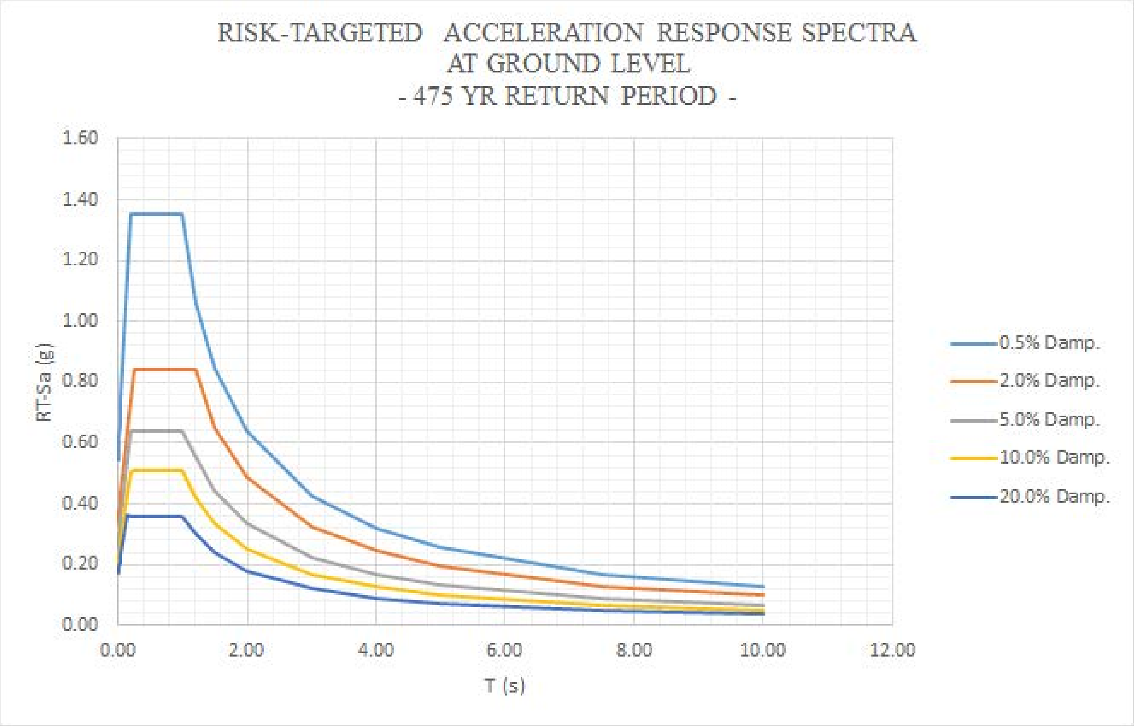


Fig. 12. Operating Basis Earthquake (OBE) Response Spectra

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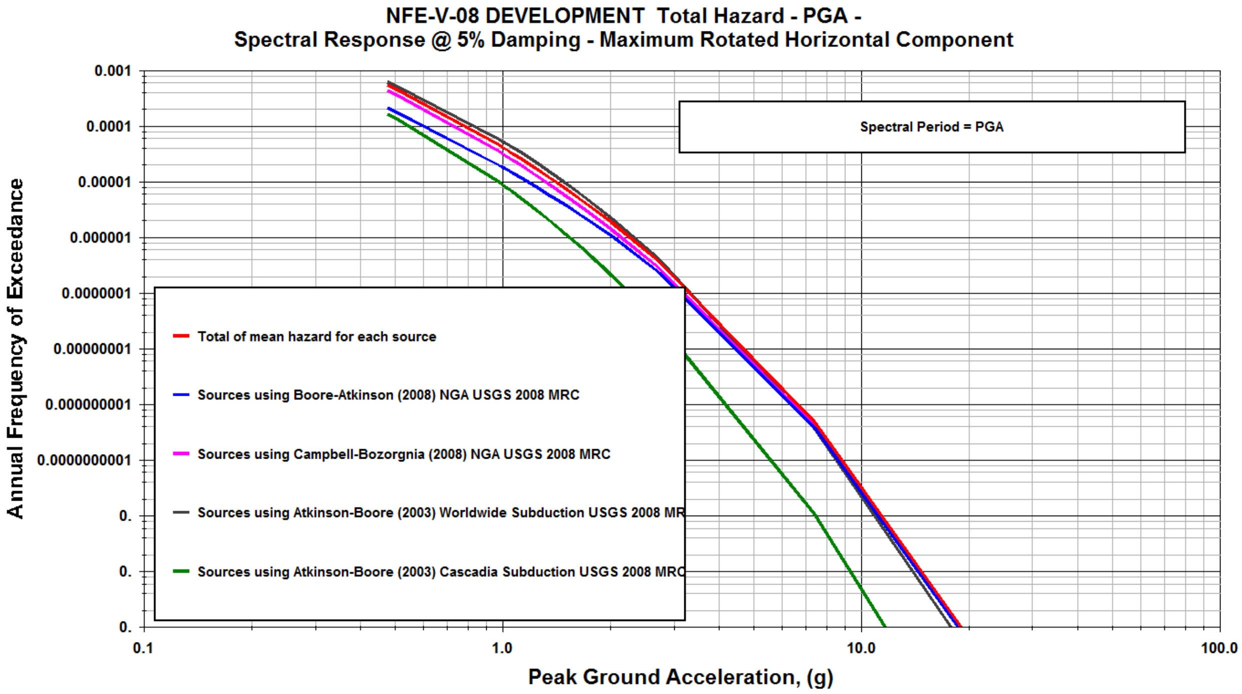
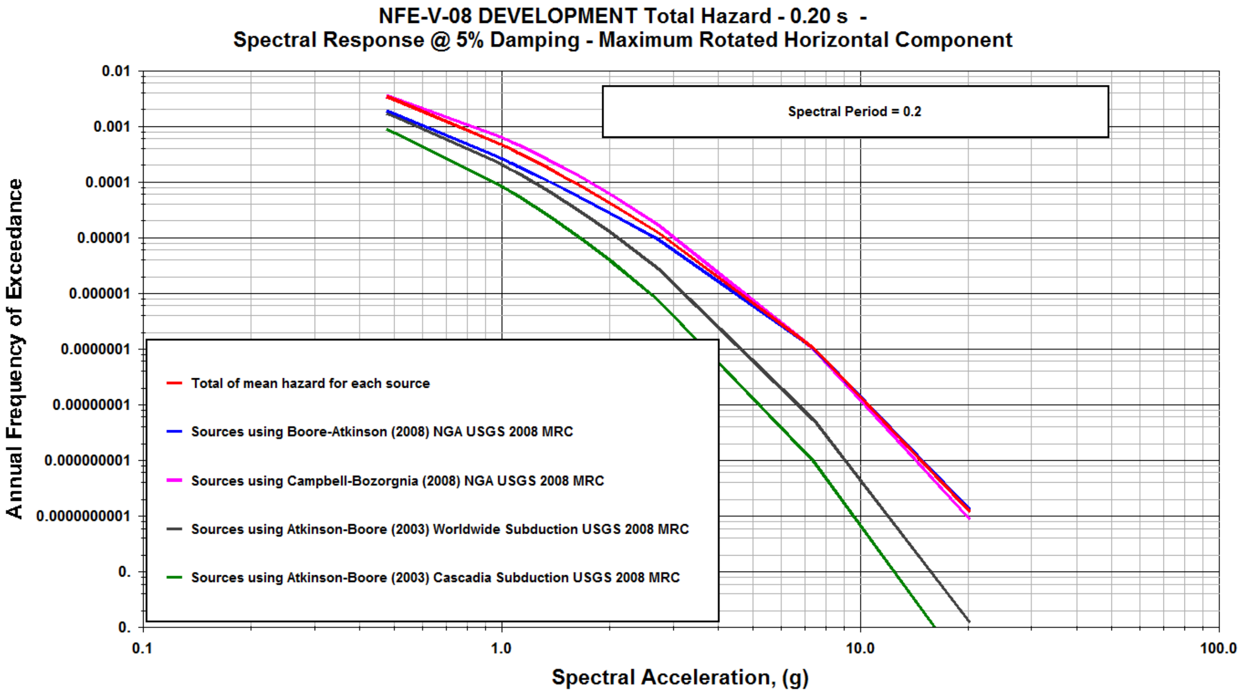
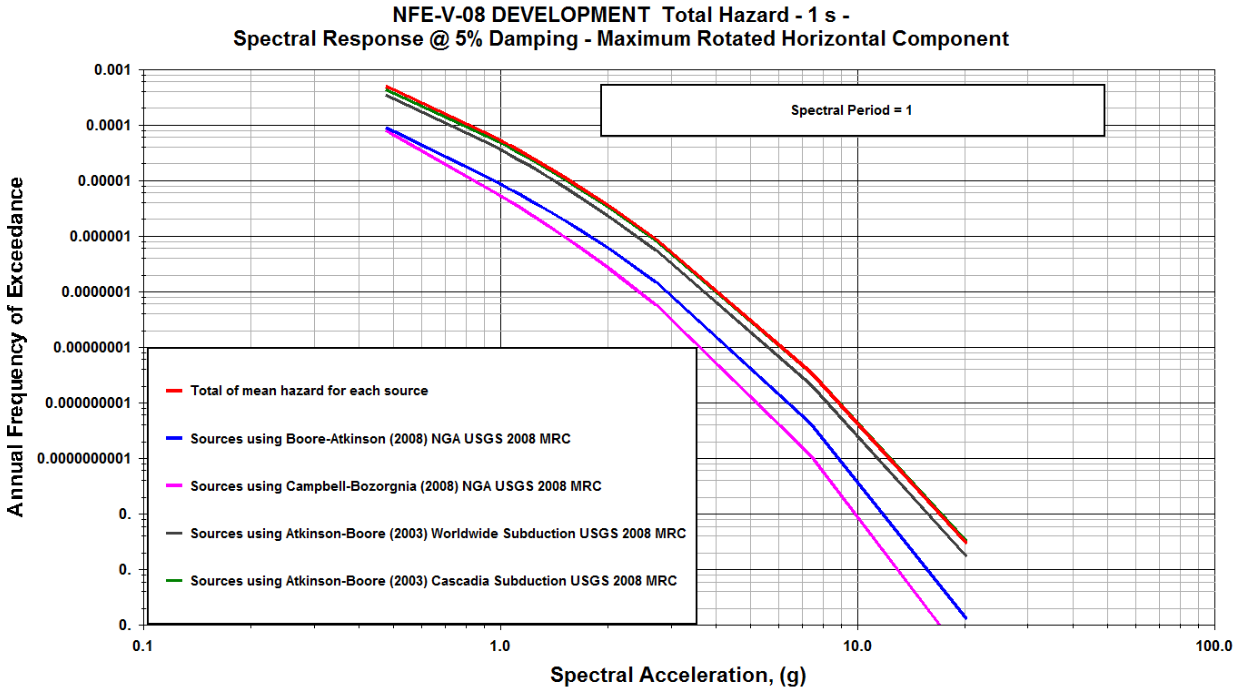
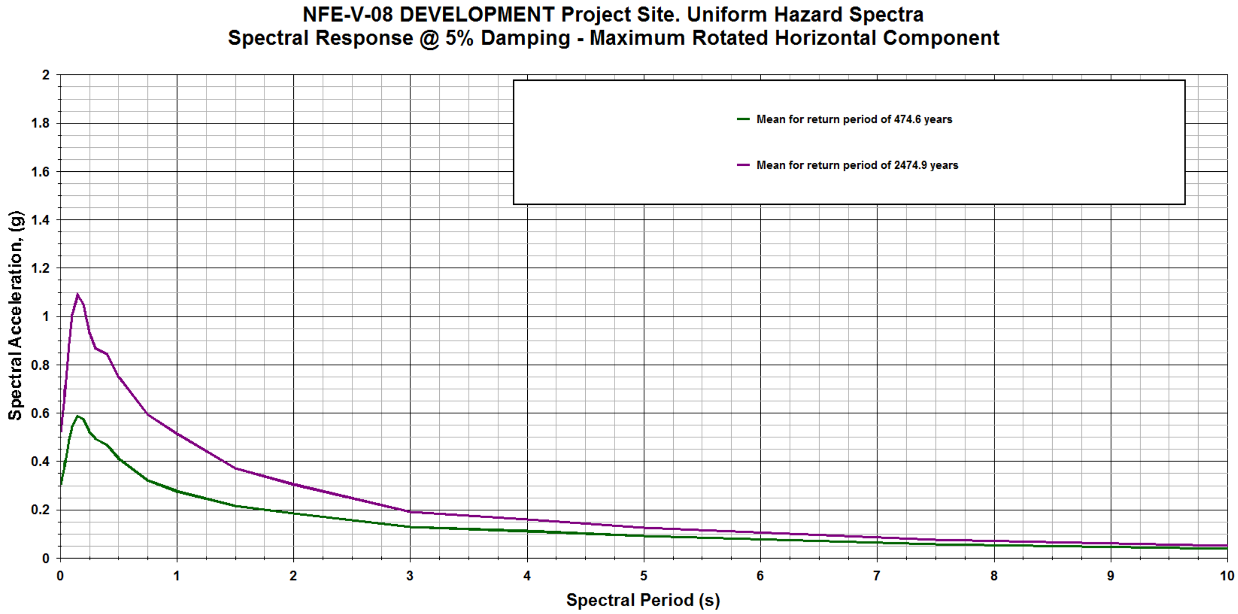
Appendix 1

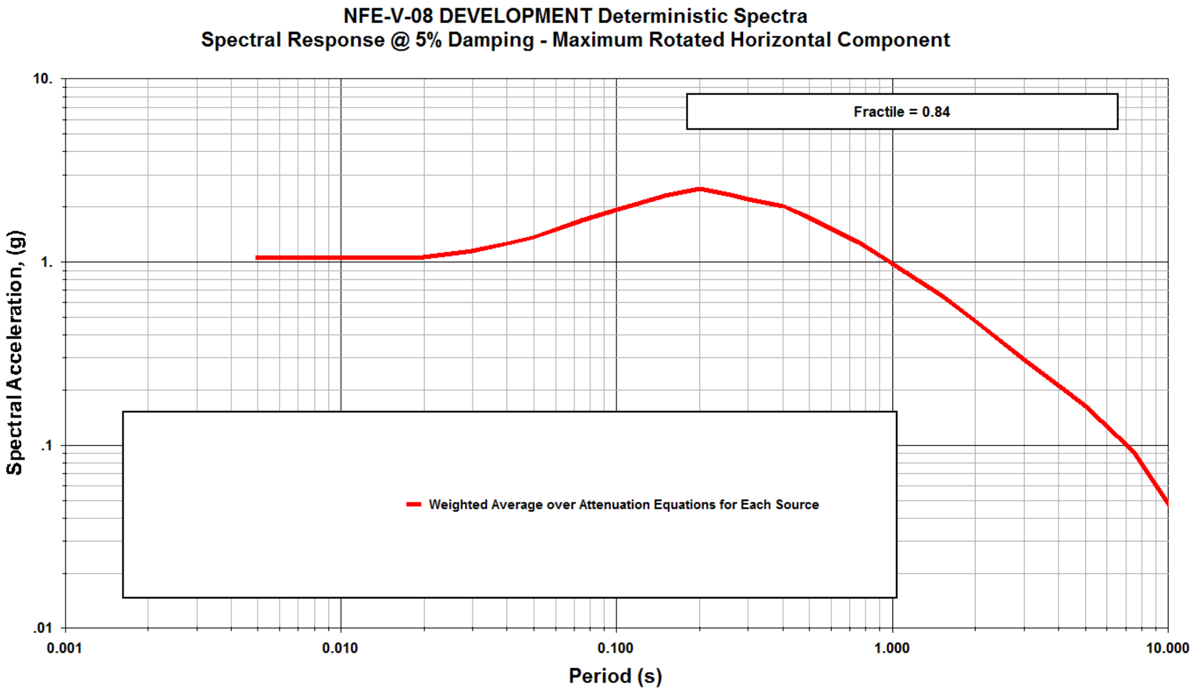
Probabilistic Seismic Hazard Analysis

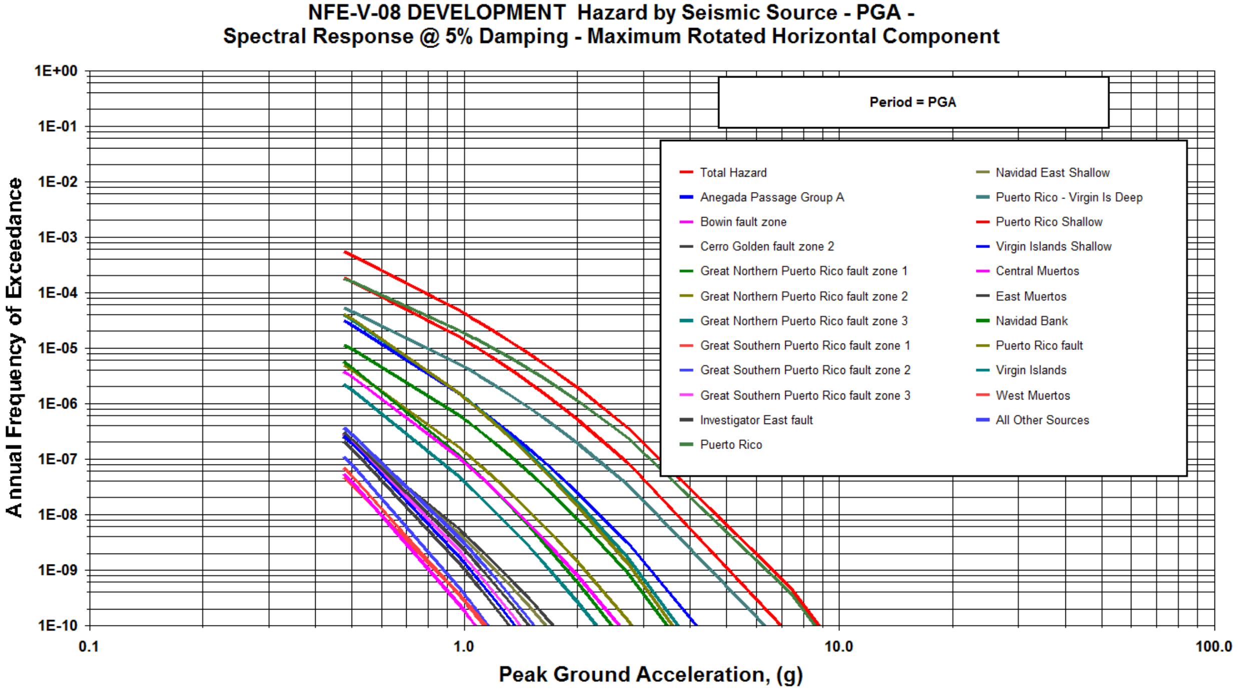

NFE-V-08 DEVELOPMENT Total Hazard - PGA -
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component
Spectral Period = PGA
Annual Frequency of Exceedance
0.001
0.0001
0.00001
0.000001
0.0000001
0.00000001
0.000000001
0.0000000001
0.
0.
0.
0.1
1.0
10.0
100.0
Peak Ground Acceleration, (g)
Total of mean hazard for each source
Sources using Boore-Atkinson (2008) NGA USGS 2008 MRC
Sources using Campbell-Bozorgnia (2008) NGA USGS 2008 MRC
Sources using Atkinson-Boore (2003) Worldwide Subduction USGS 2008 MR
Sources using Atkinson-Boore (2003) Cascadia Subduction USGS 2008 MRC


NFE-V-08 DEVELOPMENT Total Hazard - 0.20 s -
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component
Spectral Period = 0.2
Annual Frequency of Exceedance
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
0.00000001
0.000000001
0.0000000001
0.
0.
0.1
1.0
10.0
100.0
Spectral Acceleration, (g)
Total of mean hazard for each source
Sources using Boore-Atkinson (2008) NGA USGS 2008 MRC
Sources using Campbell-Bozorgnia (2008) NGA USGS 2008 MRC
Sources using Atkinson-Boore (2003) Worldwide Subduction USGS 2008 MRC
Sources using Atkinson-Boore (2003) Cascadia Subduction USGS 2008 MRC

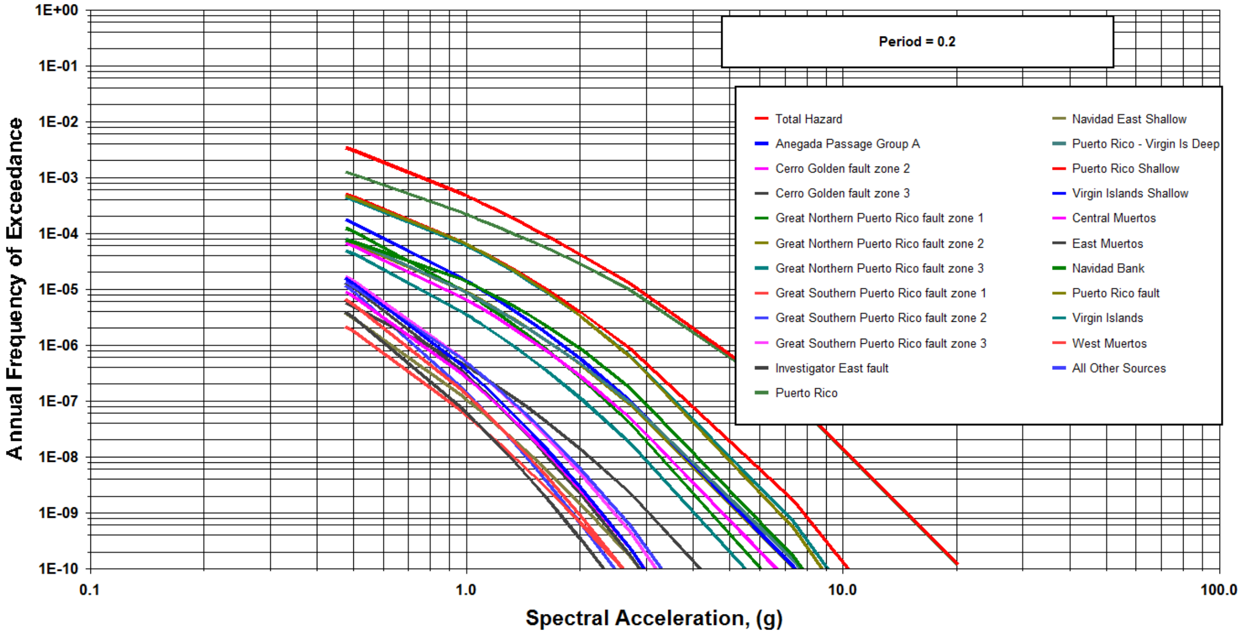

NFE-V-08 DEVELOPMENT Total Hazard - 1 s -
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component
Annual Frequency of Exceedance
0.001
0.0001
0.00001
0.000001
0.0000001
0.00000001
0.000000001
0.0000000001
0.
0.
0.
0.1
1.0
10.0
100.0
Spectral Acceleration, (g)
Spectral Period = 1
Total of mean hazard for each source
Sources using Boore-Atkinson (2008) NGA USGS 2008 MRC
Sources using Campbell-Bozorgnia (2008) NGA USGS 2008 MRC
Sources using Atkinson-Boore (2003) Worldwide Subduction USGS 2008 MRC
Sources using Atkinson-Boore (2003) Cascadia Subduction USGS 2008 MRC


NFE-V-08 DEVELOPMENT Project Site. Uniform Hazard Spectra
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component
Spectral Acceleration, (g)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9
10
Spectral Period (s)
Mean for return period of 474.6 years
Mean for return period of 2474.9 years

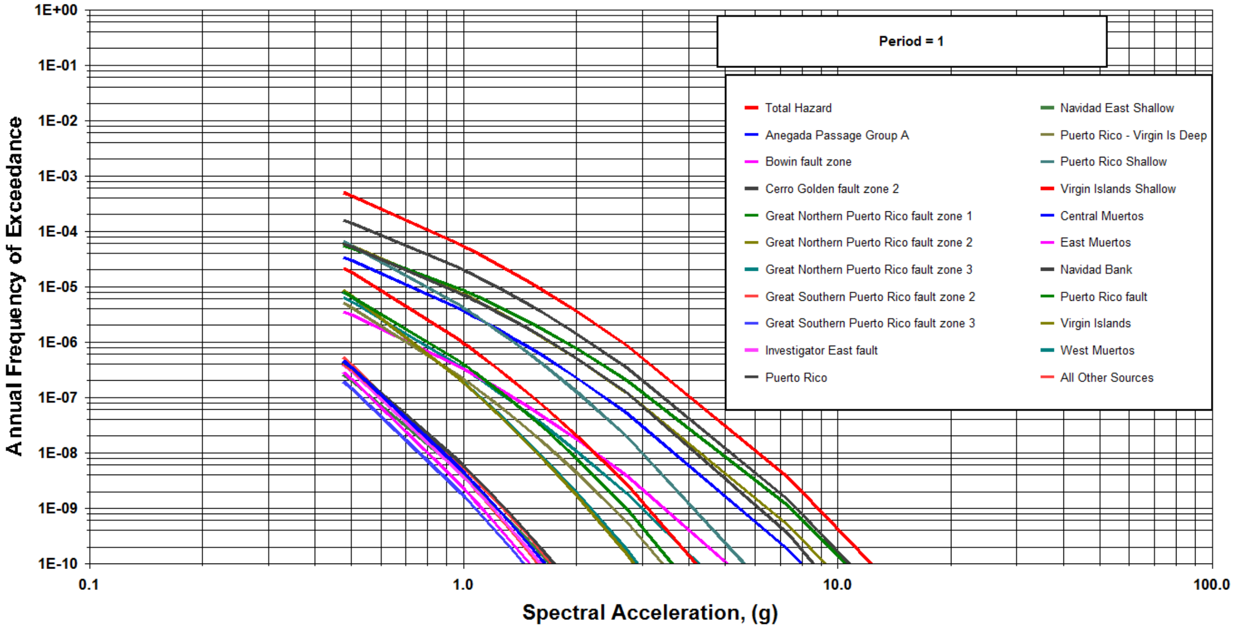

NFE-V-08 DEVELOPMENT Deterministic Spectra
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component
Fractile = 0.84
Weighted Average over Attenuation Equations for Each Source
Spectral Acceleration, (g)
10.
1.
.1
.01
0.001
0.010
0.100
1.000
10.000
Period (s)

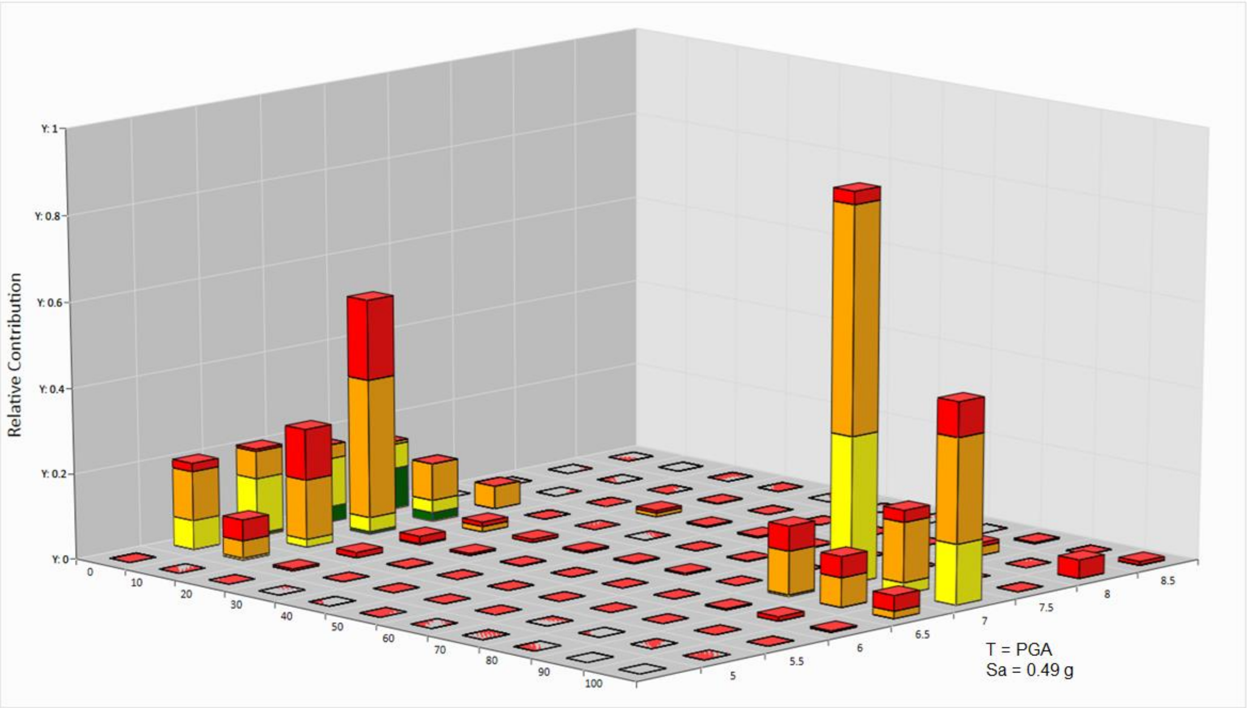

NFE-V-08 DEVELOPMENT Hazard by Seismic Source - PGA -
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component
Period = PGA
Total Hazard
Anegada Passage Group A
Bowin fault zone
Cerro Golden fault zone 2
Great Northern Puerto Rico fault zone 1
Great Northern Puerto Rico fault zone 2
Great Northern Puerto Rico fault zone 3
Great Southern Puerto Rico fault zone 1
Great Southern Puerto Rico fault zone 2
Great Southern Puerto Rico fault zone 3
Investigator East fault
Puerto Rico
Navidad East Shallow
Puerto Rico - Virgin Is Deep
Puerto Rico Shallow
Virgin Islands Shallow
Central Muertos
East Muertos
Navidad Bank
Puerto Rico fault
Virgin Islands
West Muertos
All Other Sources
Annual Frequency of Exceedance
1E+00
1E-01
1E-02
1E-03
1E-04
1E-05
1E-06
1E-07
1E-08
1E-09
1E-10
0.1
1.0
10.0
100.0
Peak Ground Acceleration, (g)

NFE-V-08 DEVELOPMENT Hazard by Seismic Source - 0.20 s -
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component



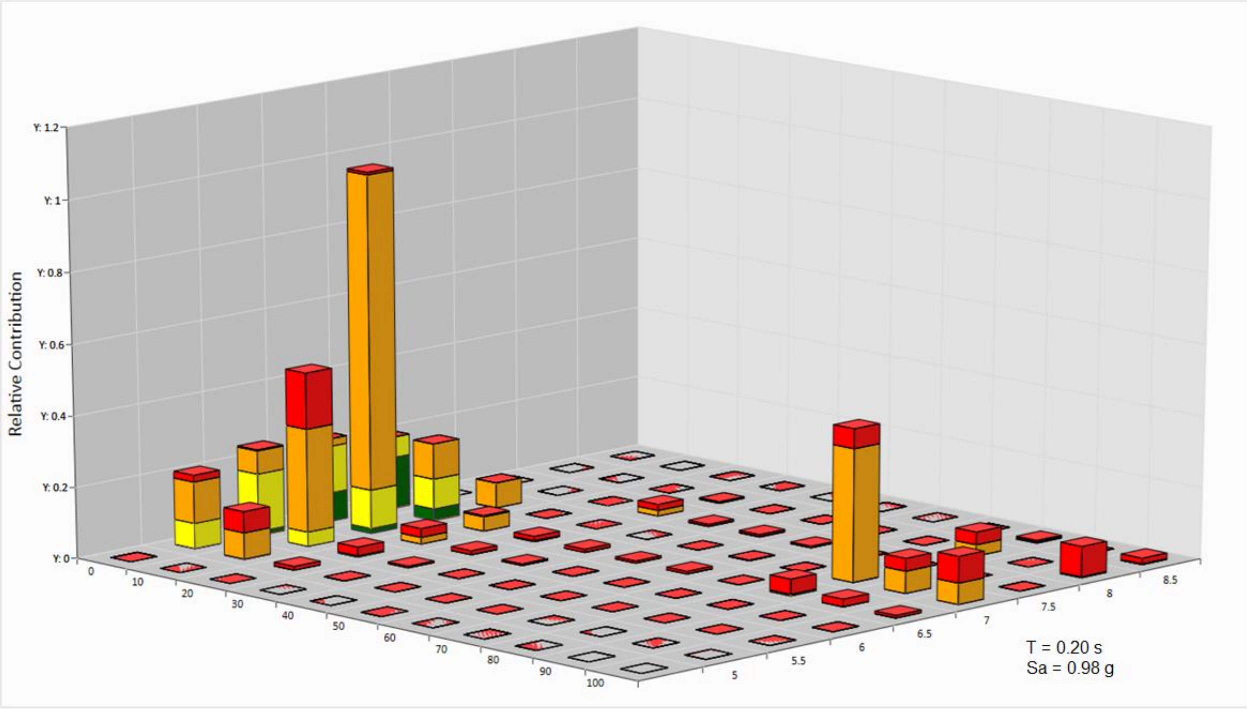
NFE-V-08 DEVELOPMENT Hazard by Seismic Source - 1 s -
Spectral Response @ 5% Damping - Maximum Rotated Horizontal Component





NFE-V-08 DEVELOPMENT

Magnitude-Distance-Epsilon Deaggregation
Spectral Response @ 5% Damping - Average Horizontal Component

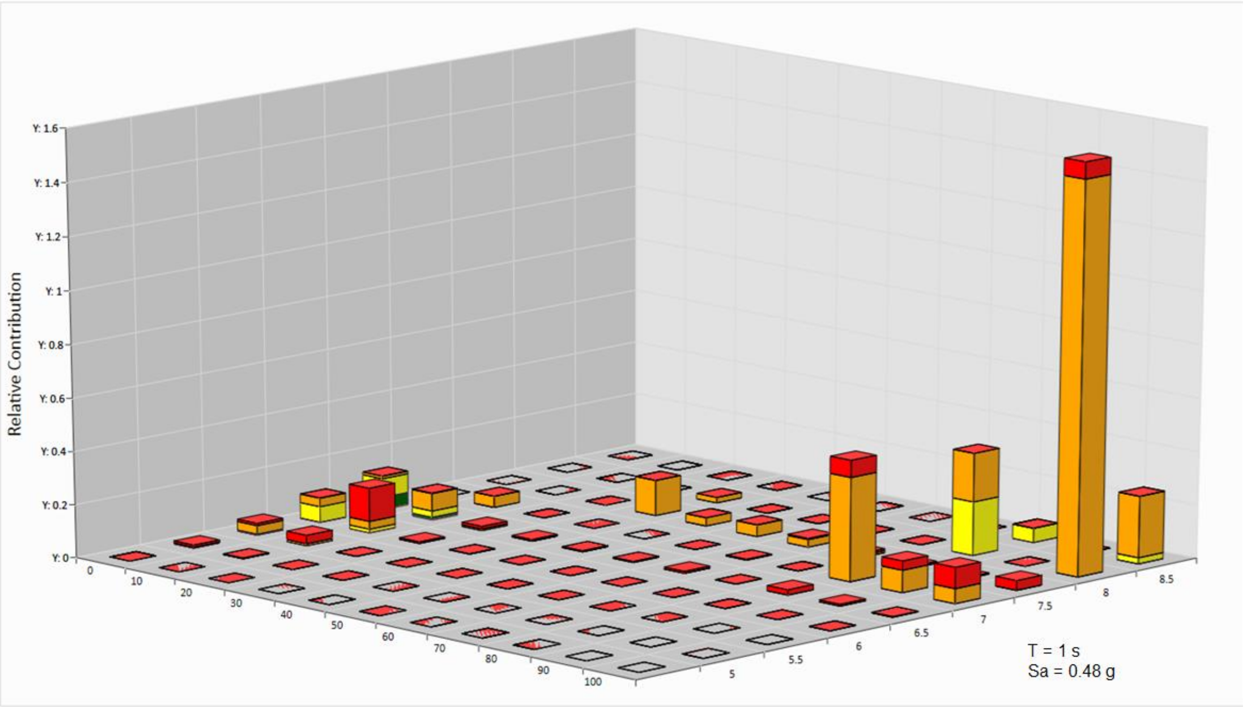


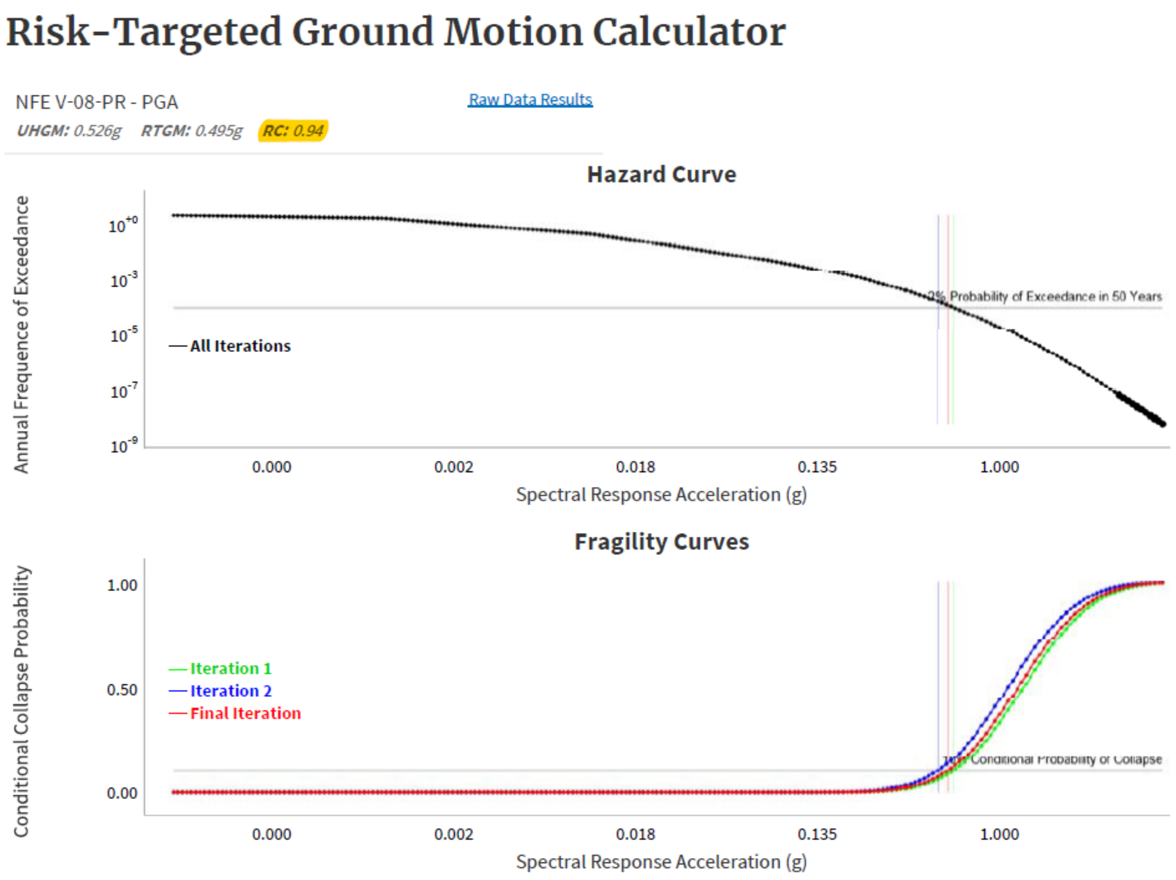
NFE-V-08 DEVELOPMENT

Magnitude-Distance-Epsilon Deaggregation
Spectral Response @ 5% Damping - Average Horizontal Component

NFE-V-08 DEVELOPMENT

Magnitude-Distance-Epsilon Deaggregation
Spectral Response @ 5% Damping - Average Horizontal Component



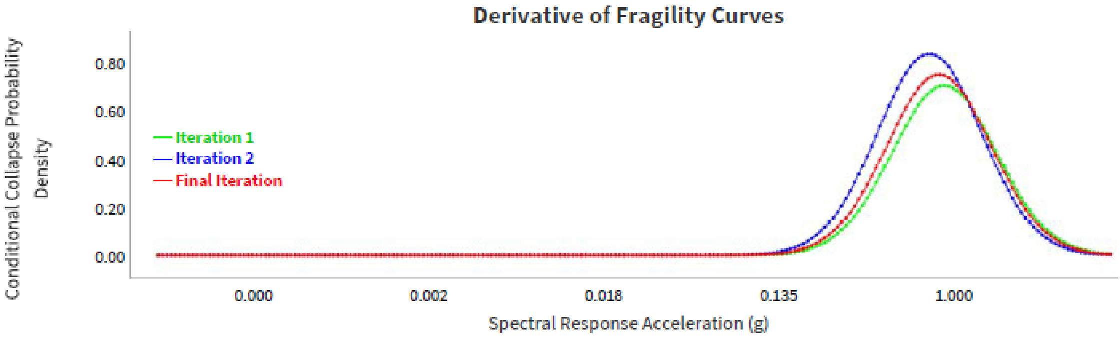


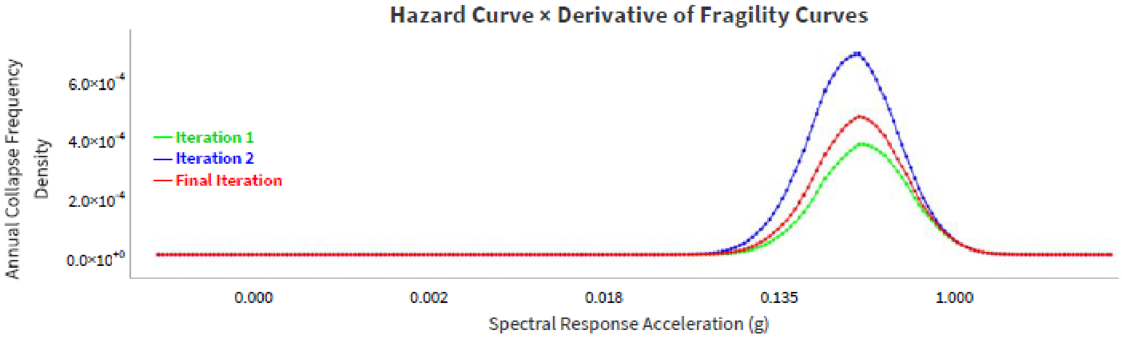
Risk-Targeted Ground Motion Calculator

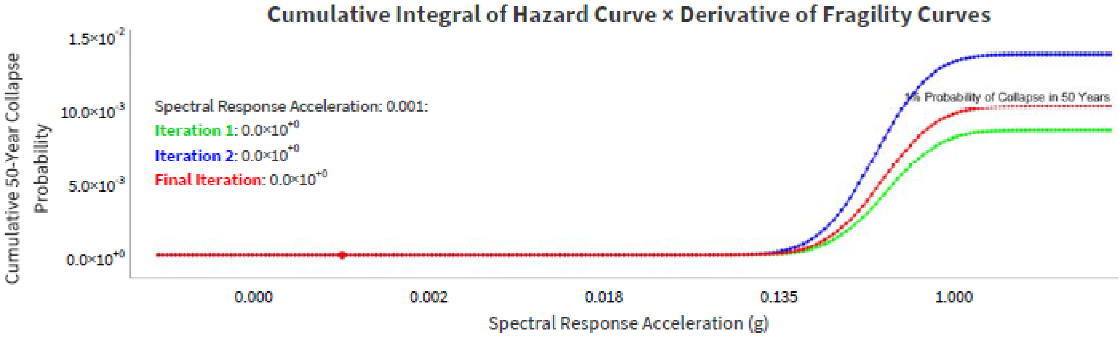
NFE V-08-PR - PGA

Raw Data Results

UHGM: *0.526g* ***RTGM:*** *0.495g* ***RC:*** *0.94*


Derivative of Fragility Curves
Conditional Collapse Probability Density
0.80
0.60
0.40
0.20
0.00
Iteration 1
Iteration 2
Final Iteration
0.000
0.002
0.018
0.135
1.000
Spectral Response Acceleration (g)

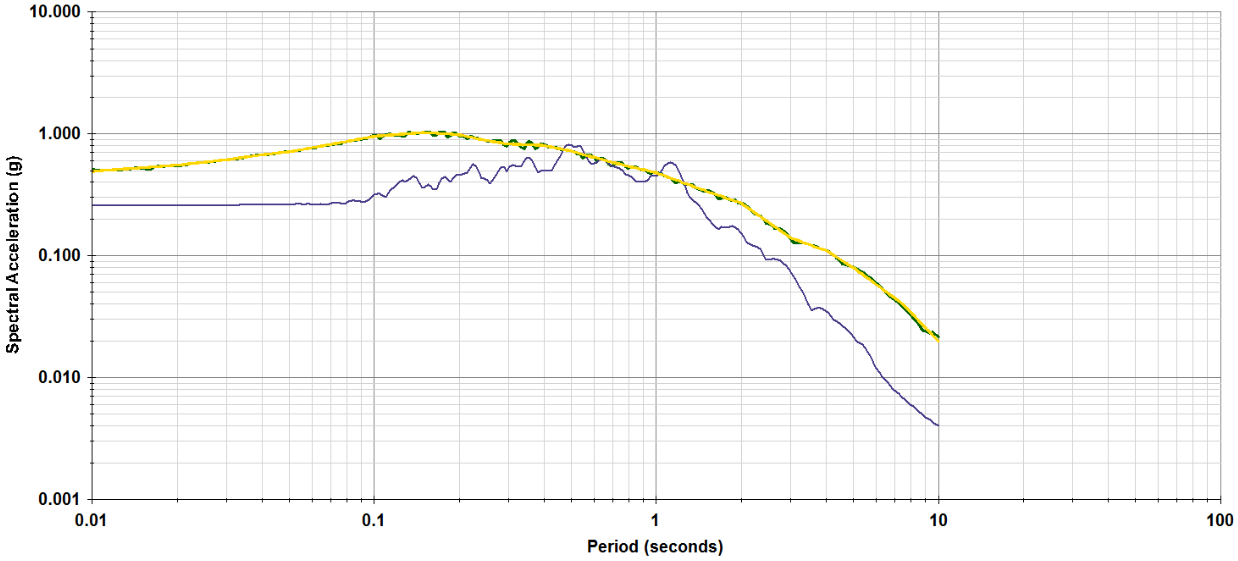

Hazard Curve × Derivative of Fragility Curves
Annual Collapse Frequency Density
6.0×10^{-4}
4.0×10^{-4}
2.0×10^{-4}
$0.0\times10^{+0}$
Iteration 1
Iteration 2
Final Iteration
0.000
0.002
0.018
0.135
1.000
Spectral Response Acceleration (g)


Cumulative Integral of Hazard Curve × Derivative of Fragility Curves
Cumulative 50-Year Collapse Probability
1.5×10^{-2}
10.0×10^{-3}
5.0×10^{-3}
$0.0\times10^{+0}$
Spectral Response Acceleration: 0.001:
Iteration 1: $0.0\times10^{+0}$
Iteration 2: $0.0\times10^{+0}$
Final Iteration: $0.0\times10^{+0}$
1% Probability of Collapse in 50 Years
0.000
0.002
0.018
0.135
1.000
Spectral Response Acceleration (g)

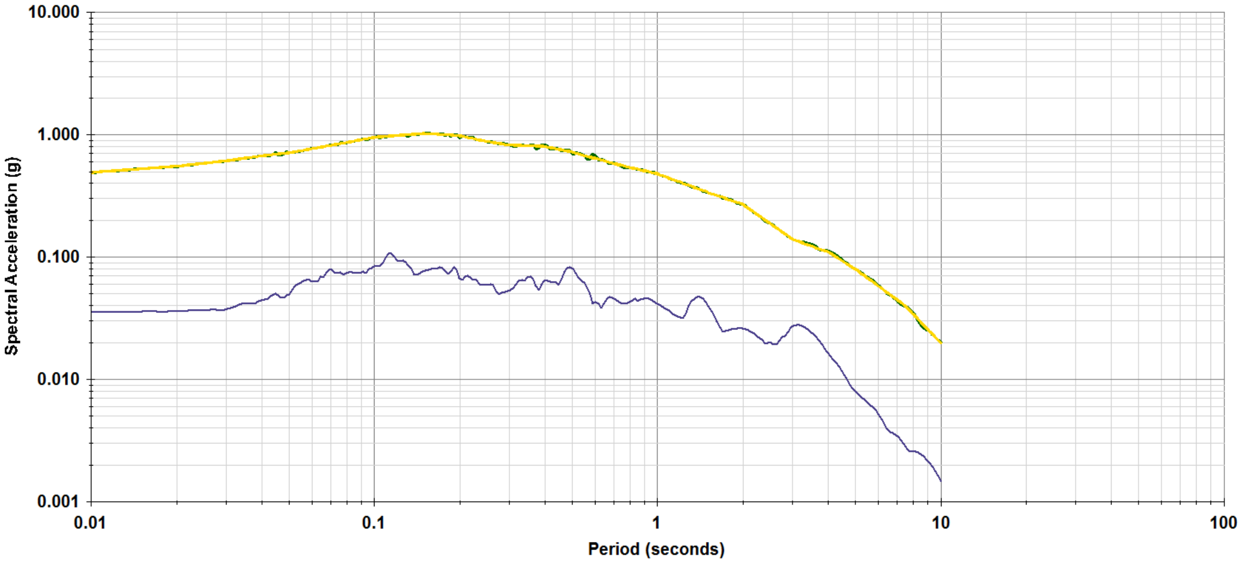
Appendix 2

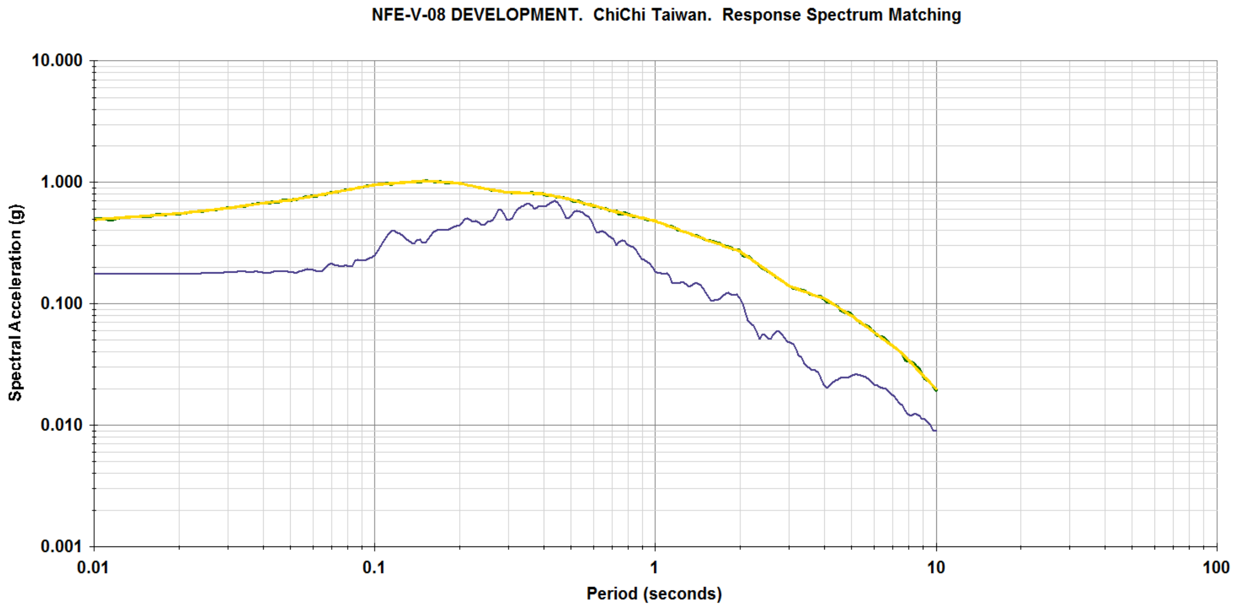
Response Spectrum Matching

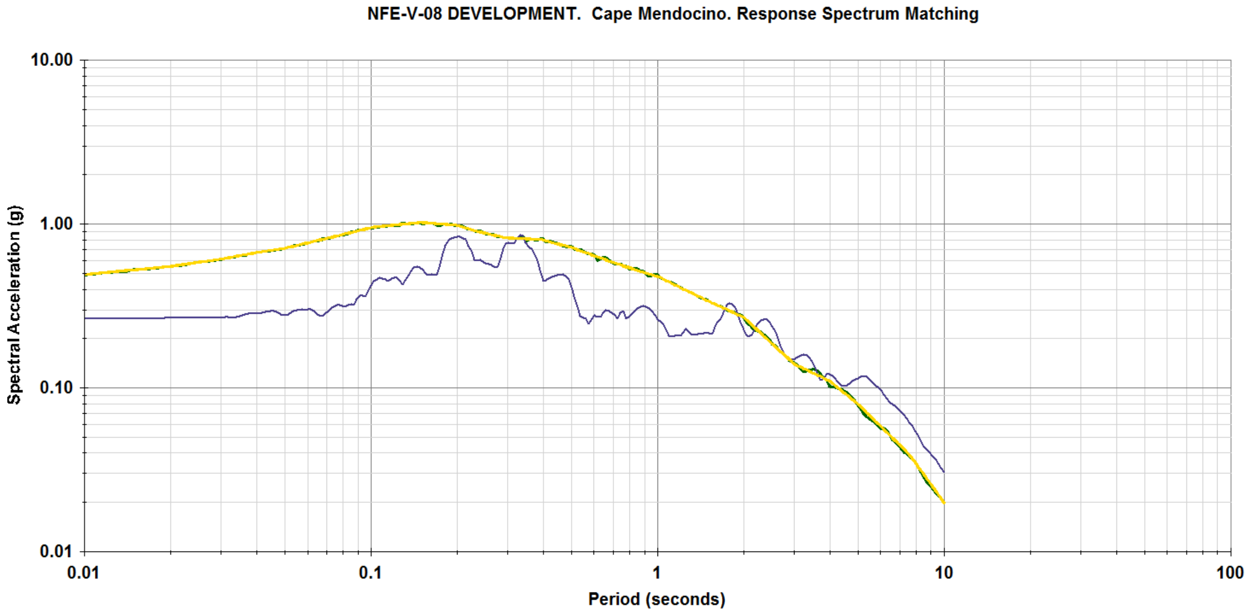
NFE-V-08 DEVELOPMENT. Loma Prieta. Response Spectrum Matching

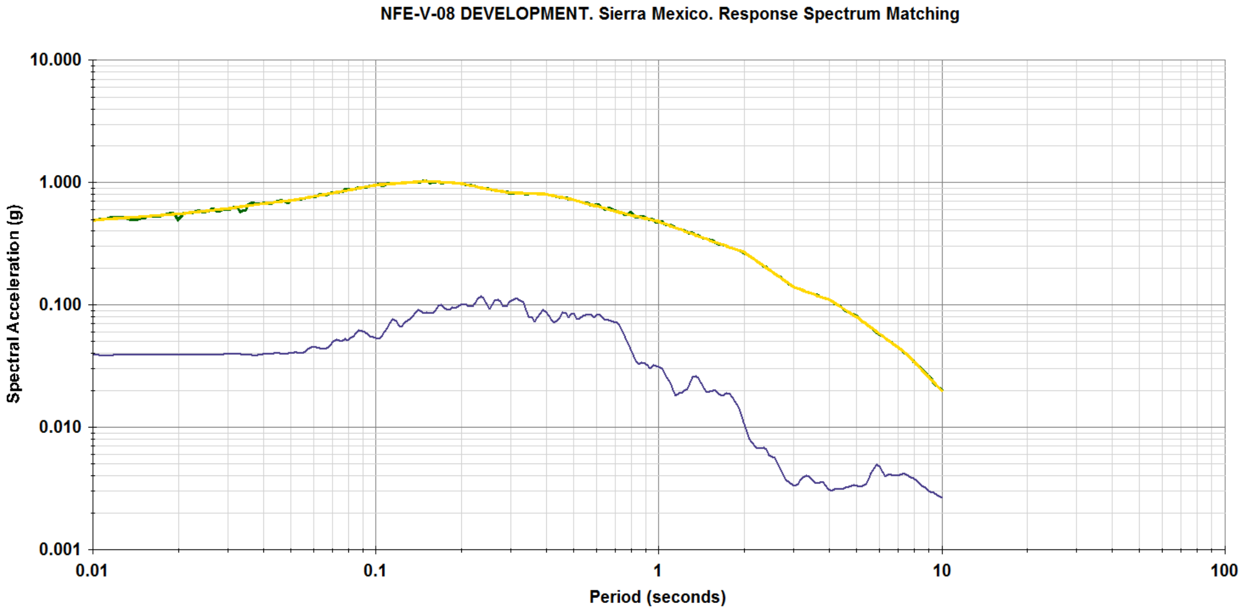


NFE-V-08 DEVELOPMENT. Hector Mine. Response Spectrum Matching



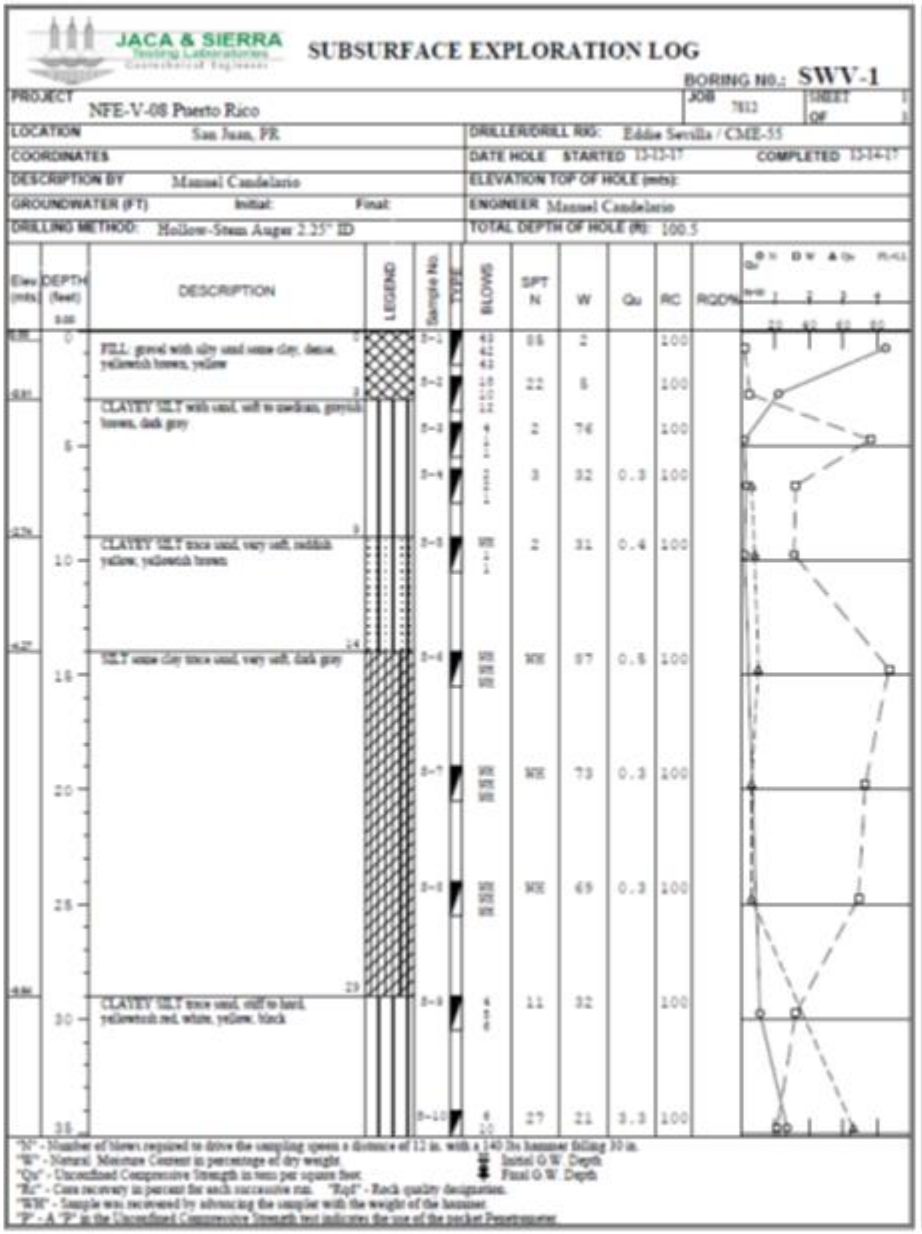

NFE-V-08 DEVELOPMENT. ChiChi Taiwan. Response Spectrum Matching
10.000
1.000
0.100
0.010
0.001
Spectral Acceleration (g)
0.01
0.1
1
10
100
Period (seconds)


NFE-V-08 DEVELOPMENT. Cape Mendocino. Response Spectrum Matching
10.00
1.00
0.10
0.01
Spectral Acceleration (g)
0.01
0.1
1
10
100
Period (seconds)


NFE-V-08 DEVELOPMENT. Sierra Mexico. Response Spectrum Matching

Appendix 3

Geotechnical and Geophysics Surveys



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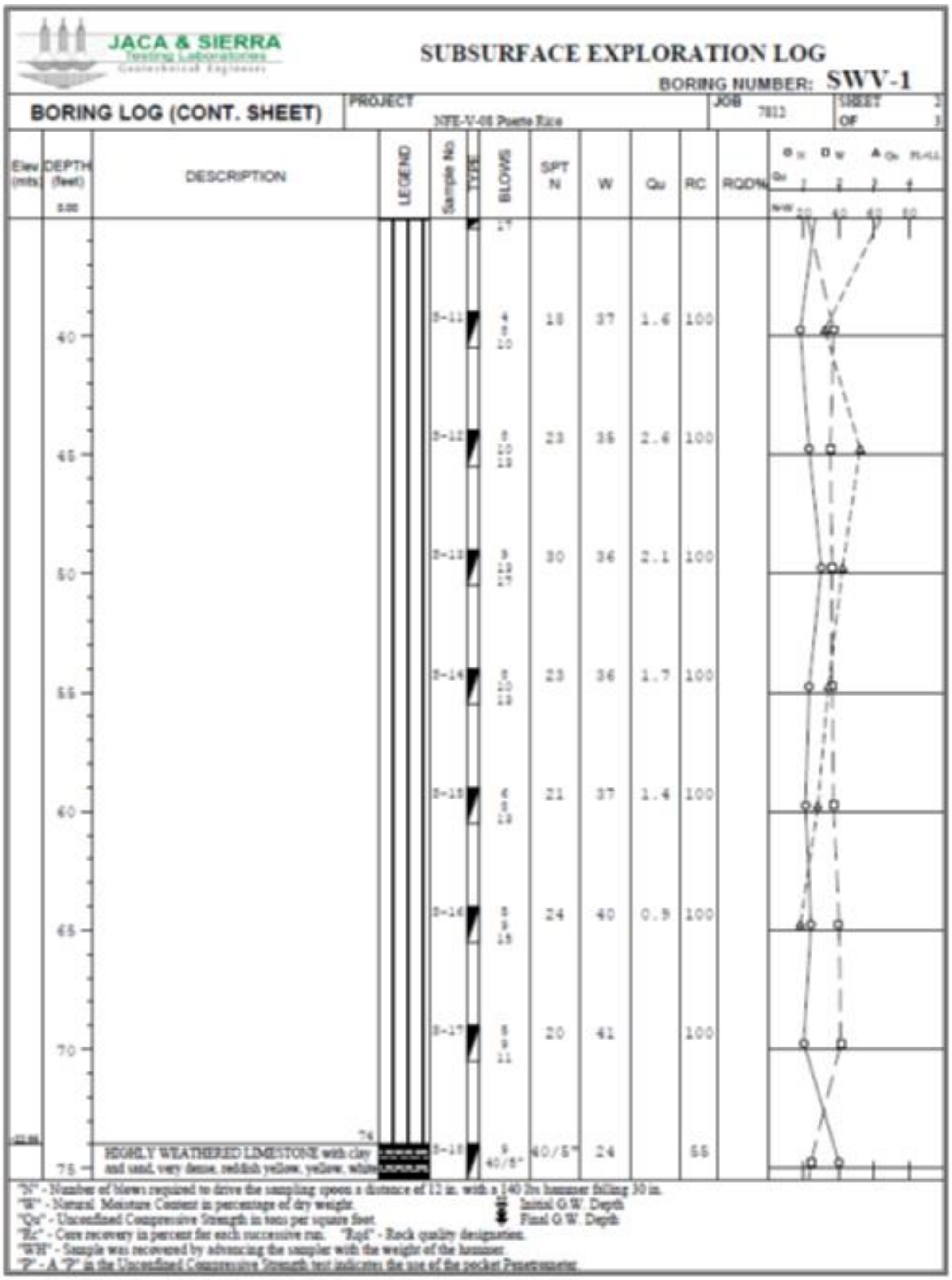
SUBSURFACE EXPLORATION LOG

BORING NO.: SWV-1

PROJECT NFE-V-08 Puerto Rico		**JOB** 7812	**SHEET** 1 **OF** 1
LOCATION San Juan, PR	**DRILLER/DRILL RIG:** Eddie Sevilla / CME-55		
COORDINATES	**DATE HOLE STARTED** 12-12-17	**COMPLETED** 12-14-17	
DESCRIPTION BY Manuel Candelario	**ELEVATION TOP OF HOLE (mts):**		
GROUNDWATER (FT) Initial: Final:	**ENGINEER** Manuel Candelario		
DRILLING METHOD: Hollow-Stem Auger 2.25" ID	**TOTAL DEPTH OF HOLE (ft):** 100.5		

Elev (mts)	DEPTH (feet)	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	0	FILL: gravel with silty sand some clay, dense, yellowish brown, yellow	▨	S-1		42 42 42	85	2		100	
				S-2		18 10 12	22	8		100	
	3	CLAYEY SILT with sand, soft to medium, greyish brown, dark grey		S-3		4 1 1 1	2	76		100	
	5			S-4		[illegible]	3	32	0.3	100	
	9	CLAYEY SILT trace sand, very soft, reddish yellow, yellowish brown		S-5		WH 1 1	2	31	0.4	100	
	10										
	14	SILT some clay trace sand, very soft, dark grey	▨	S-6		WH WH WH	WH	87	0.5	100	
	15										
	20			S-7		WH WH WH	WH	73	0.3	100	
	25			S-8		WH WH WH	WH	69	0.3	100	
	29	CLAYEY SILT trace sand, stiff to hard, yellowish red, white, yellow, black		S-9		4 5 6	11	32		100	
	30										
	35			S-10		6 10	27	21	3.3	100	

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square feet.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.
Initial G.W. Depth
Final G.W. Depth



SUBSURFACE EXPLORATION LOG

BORING NUMBER: **SWV-1**

BORING LOG (CONT. SHEET)

PROJECT: NFE-V-08 Puerto Rico

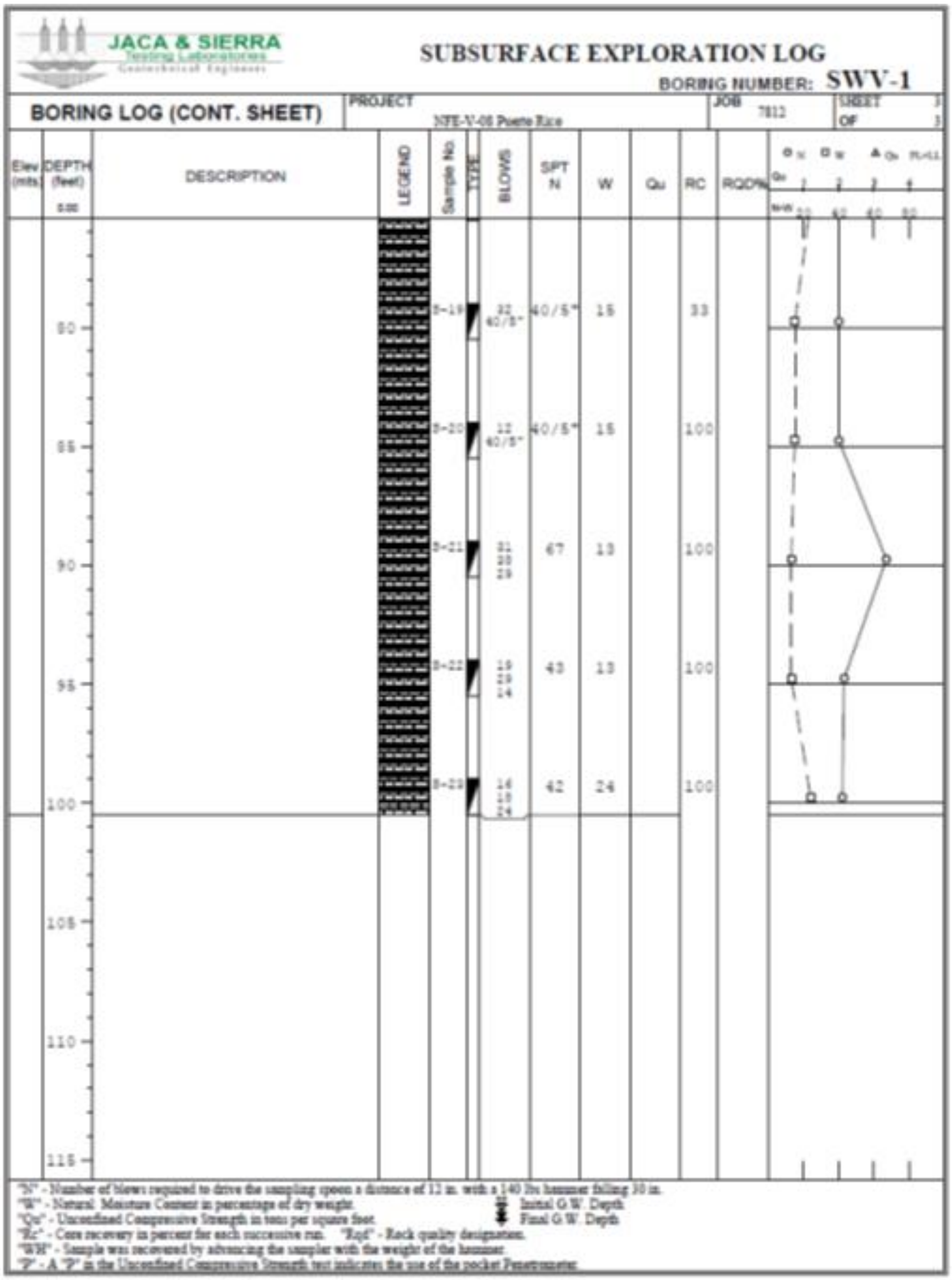
JOB: 7812

SHEET 2 OF 3

Elev (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
						17					
				S-11		4 8 10	18	37	1.6	100	
				S-12		8 10 13	23	35	2.6	100	
				S-13		9 13 17	30	36	2.1	100	
				S-14		8 10 13	23	36	1.7	100	
				S-15		6 8 13	21	37	1.4	100	
				S-16		8 9 15	24	40	0.9	100	
				S-17		5 9 11	20	41		100	
22.86	74	HIGHLY WEATHERED LIMESTONE with clay and sand, very dense, reddish yellow, yellow, white		S-18		9 40/5"	40/5"	24		55	

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square feet.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

Initial G.W. Depth
Final G.W. Depth



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SUBSURFACE EXPLORATION LOG

BORING NUMBER: SWV-1

BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 3 OF 3

Elev (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
				S-19		32 40/5"	40/5"	15		33	
				S-20		12 40/5"	40/5"	15		100	
				S-21		31 38 29	67	13		100	
				S-22		19 29 14	43	13		100	
				S-23		16 18 24	42	24		100	

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square feet.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

Initial G.W. Depth
Final G.W. Depth

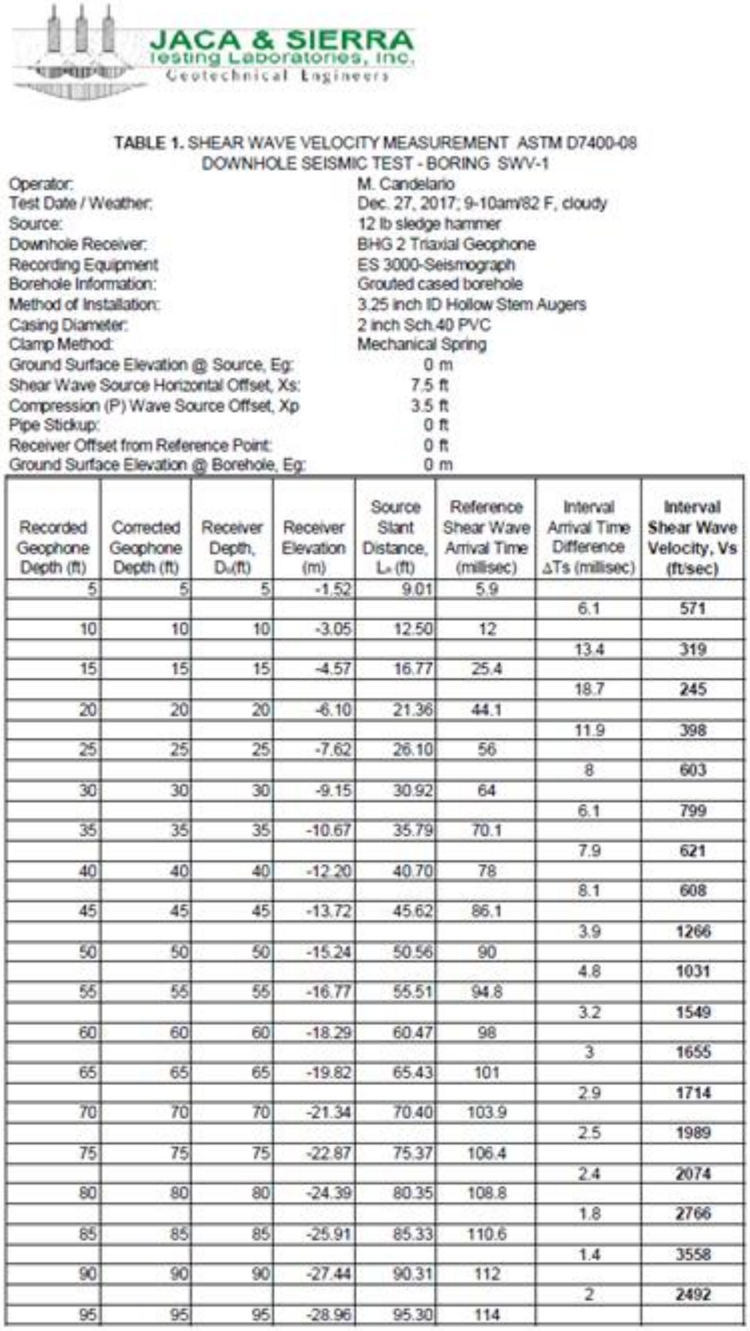

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TABLE 1. SHEAR WAVE VELOCITY MEASUREMENT ASTM D7400-08
DOWNHOLE SEISMIC TEST - BORING SWV-1

Operator:	M. Candelario
Test Date / Weather:	Dec. 27, 2017; 9-10am/82 F, cloudy
Source:	12 lb sledge hammer
Downhole Receiver:	BHG 2 Triaxial Geophone
Recording Equipment	ES 3000-Seismograph
Borehole Information:	Grouted cased borehole
Method of Installation:	3.25 inch ID Hollow Stem Augers
Casing Diameter:	2 inch Sch.40 PVC
Clamp Method:	Mechanical Spring
Ground Surface Elevation @ Source, Eg:	0 m
Shear Wave Source Horizontal Offset, Xs:	7.5 ft
Compression (P) Wave Source Offset, Xp	3.5 ft
Pipe Stickup:	0 ft
Receiver Offset from Reference Point:	0 ft
Ground Surface Elevation @ Borehole, Eg:	0 m

Recorded Geophone Depth (ft)	Corrected Geophone Depth (ft)	Receiver Depth, D_R(ft)	Receiver Elevation (m)	Source Slant Distance, L_R (ft)	Reference Shear Wave Arrival Time (millisec)	Interval Arrival Time Difference ΔTs (millisec)	**Interval Shear Wave Velocity, Vs (ft/sec)**
5	5	5	-1.52	9.01	5.9		
						6.1	571
10	10	10	-3.05	12.50	12		
						13.4	319
15	15	15	-4.57	16.77	25.4		
						18.7	245
20	20	20	-6.10	21.36	44.1		
						11.9	398
25	25	25	-7.62	26.10	56		
						8	603
30	30	30	-9.15	30.92	64		
						6.1	799
35	35	35	-10.67	35.79	70.1		
						7.9	621
40	40	40	-12.20	40.70	78		
						8.1	608
45	45	45	-13.72	45.62	86.1		
						3.9	1266
50	50	50	-15.24	50.56	90		
						4.8	1031
55	55	55	-16.77	55.51	94.8		
						3.2	1549
60	60	60	-18.29	60.47	98		
						3	1655
65	65	65	-19.82	65.43	101		
						2.9	1714
70	70	70	-21.34	70.40	103.9		
						2.5	1989
75	75	75	-22.87	75.37	106.4		
						2.4	2074
80	80	80	-24.39	80.35	108.8		
						1.8	2766
85	85	85	-25.91	85.33	110.6		
						1.4	3558
90	90	90	-27.44	90.31	112		
						2	2492
95	95	95	-28.96	95.30	114		

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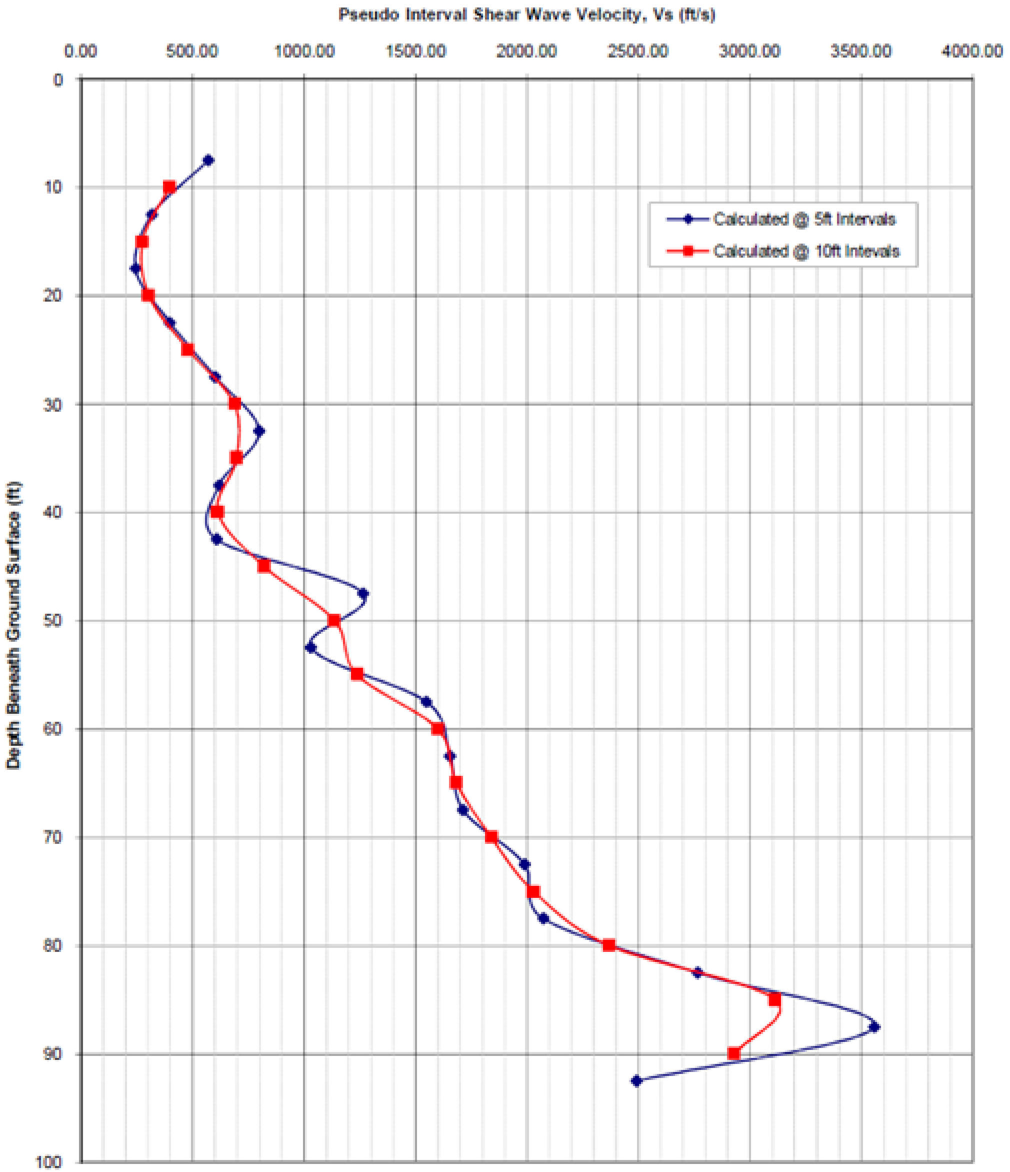
Downhole Seismic Test - Boring no. SWV-1

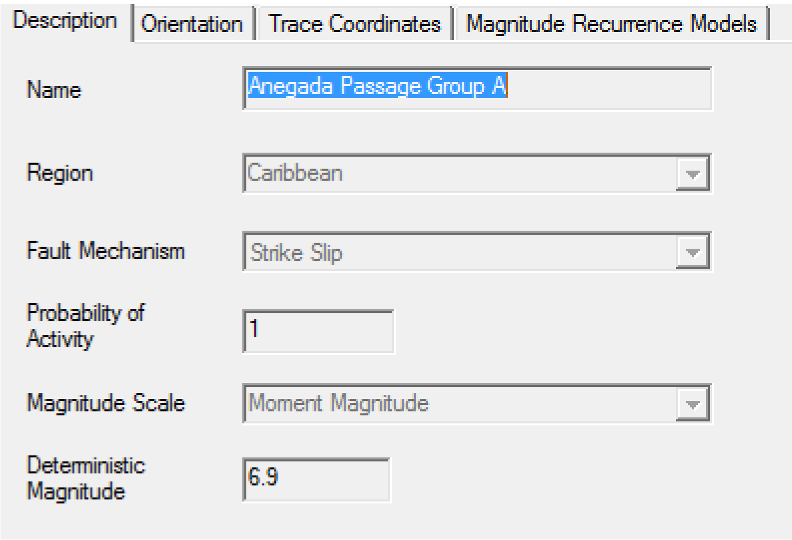


Appendix 4

Seismic Main Sources Parameters

ANEGADA PASSAGE

1.- ANEGADA PASSAGE



Name: Anegada Passage Group A

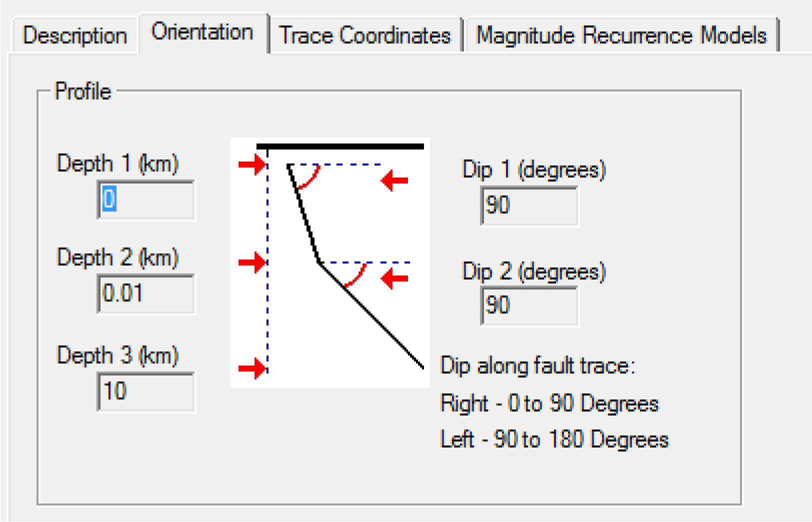
Region: Caribbean

Fault Mechanism: Strike Slip

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 6.9



Depth 1 (km): 0

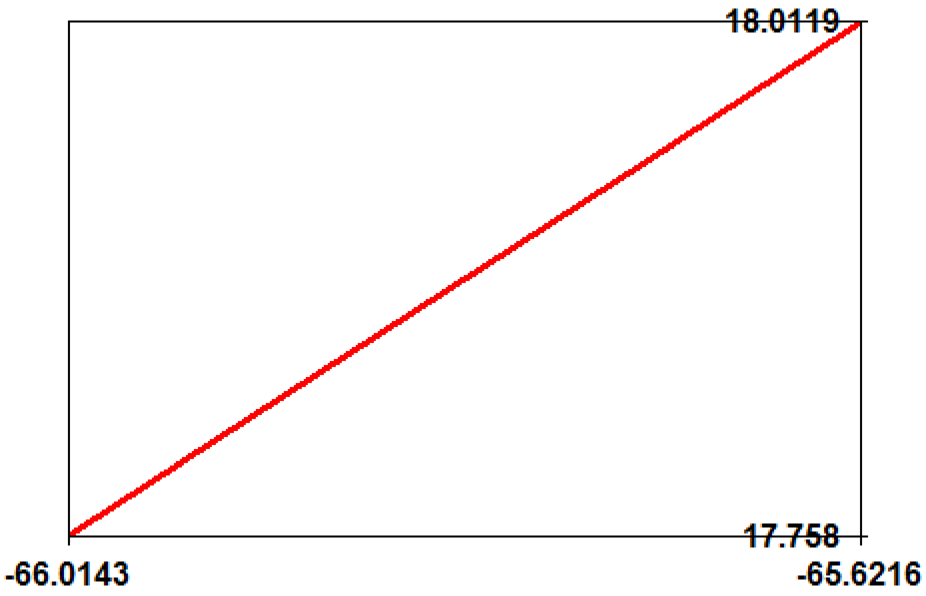
Depth 2 (km): 0.01

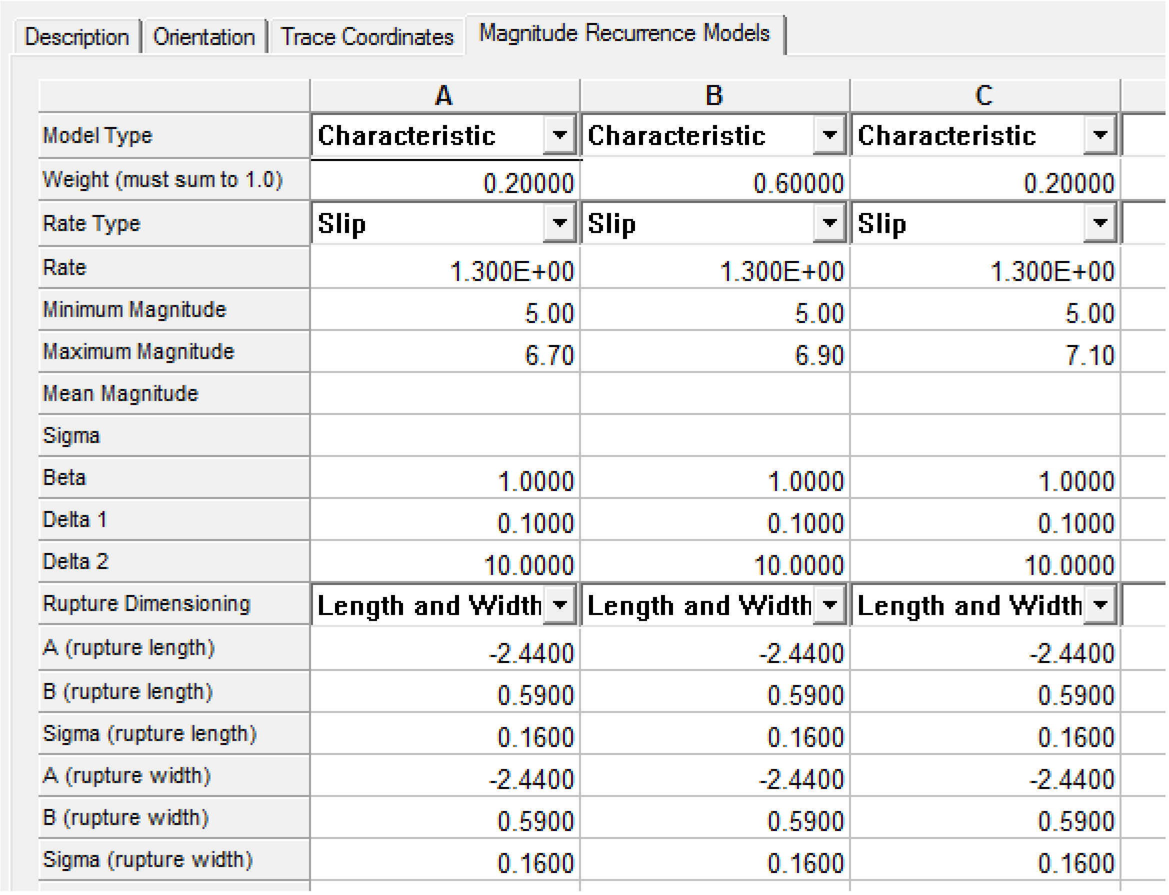
Depth 3 (km): 10

Dip 1 (degrees): 90

Dip 2 (degrees): 90

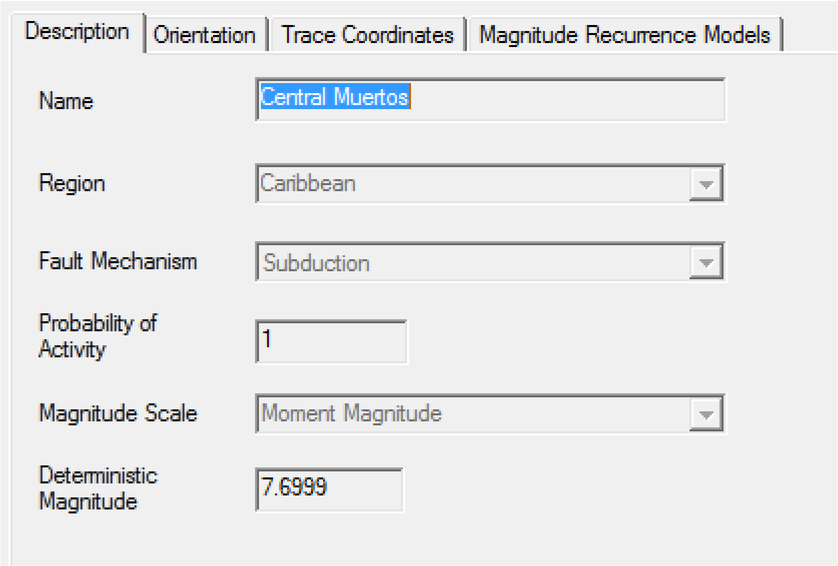
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees



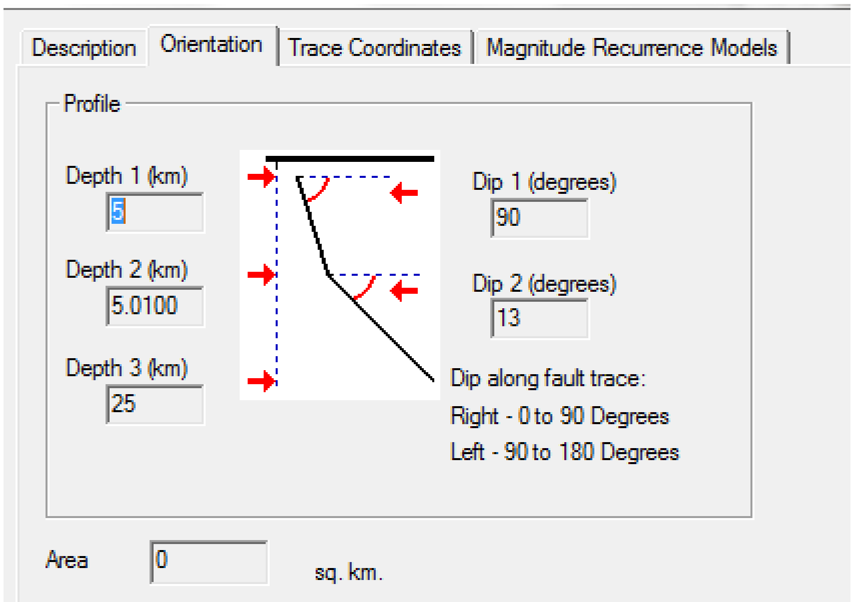


	A	B	C
Model Type	Characteristic	Characteristic	Characteristic
Weight (must sum to 1.0)	0.20000	0.60000	0.20000
Rate Type	Slip	Slip	Slip
Rate	1.300E+00	1.300E+00	1.300E+00
Minimum Magnitude	5.00	5.00	5.00
Maximum Magnitude	6.70	6.90	7.10
Mean Magnitude			
Sigma			
Beta	1.0000	1.0000	1.0000
Delta 1	0.1000	0.1000	0.1000
Delta 2	10.0000	10.0000	10.0000
Rupture Dimensioning	Length and Width	Length and Width	Length and Width
A (rupture length)	-2.4400	-2.4400	-2.4400
B (rupture length)	0.5900	0.5900	0.5900
Sigma (rupture length)	0.1600	0.1600	0.1600
A (rupture width)	-2.4400	-2.4400	-2.4400
B (rupture width)	0.5900	0.5900	0.5900
Sigma (rupture width)	0.1600	0.1600	0.1600

CENTRAL MUERTOS



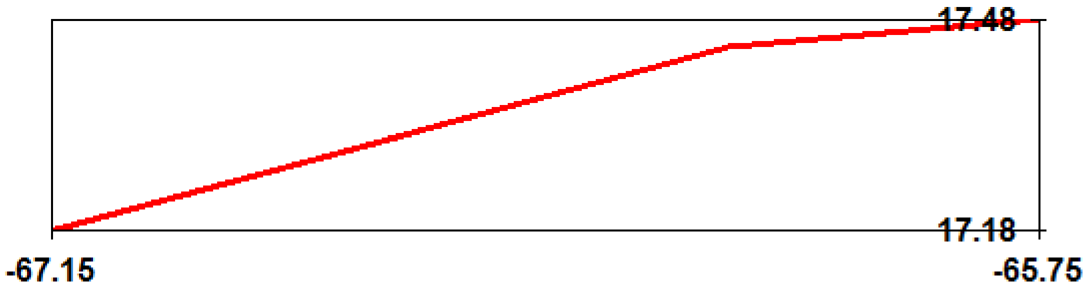
Name: Central Muertos
Region: Caribbean
Fault Mechanism: Subduction
Probability of Activity: 1
Magnitude Scale: Moment Magnitude
Deterministic Magnitude: 7.6999

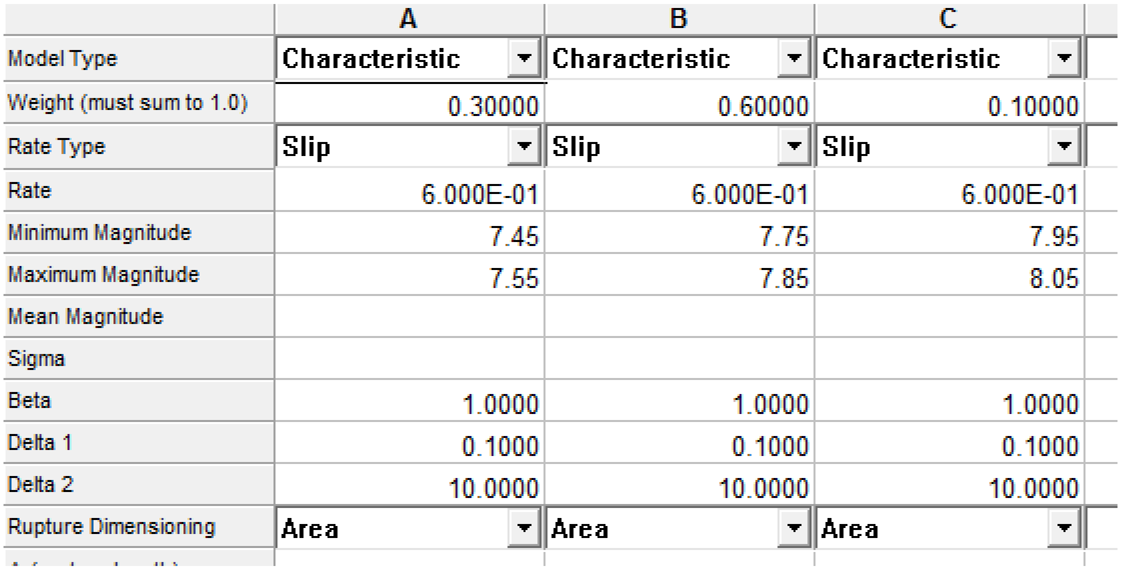


Depth 1 (km): 5
Depth 2 (km): 5.0100
Depth 3 (km): 25
Dip 1 (degrees): 90
Dip 2 (degrees): 13

Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees

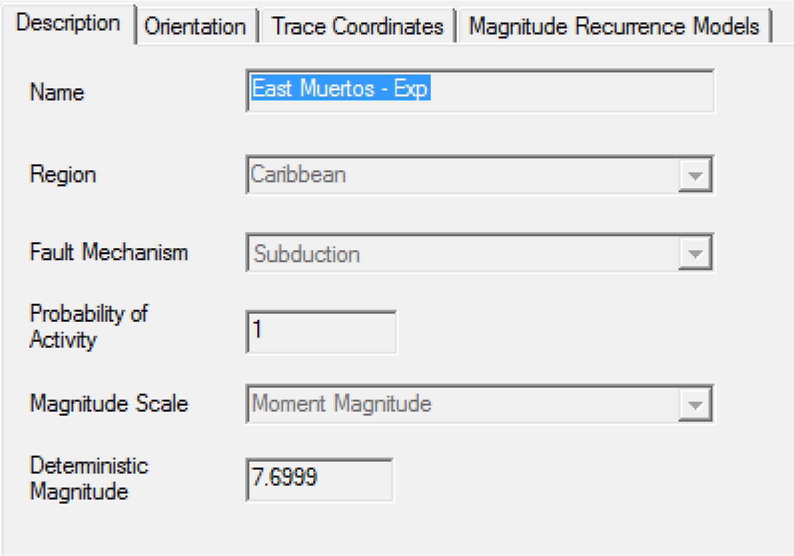
Area: 0 sq. km.





	A	B	C
Model Type	Characteristic	Characteristic	Characteristic
Weight (must sum to 1.0)	0.30000	0.60000	0.10000
Rate Type	Slip	Slip	Slip
Rate	6.000E-01	6.000E-01	6.000E-01
Minimum Magnitude	7.45	7.75	7.95
Maximum Magnitude	7.55	7.85	8.05
Mean Magnitude			
Sigma			
Beta	1.0000	1.0000	1.0000
Delta 1	0.1000	0.1000	0.1000
Delta 2	10.0000	10.0000	10.0000
Rupture Dimensioning	Area	Area	Area

EAST MUERTOS



Name: East Muertos - Exp

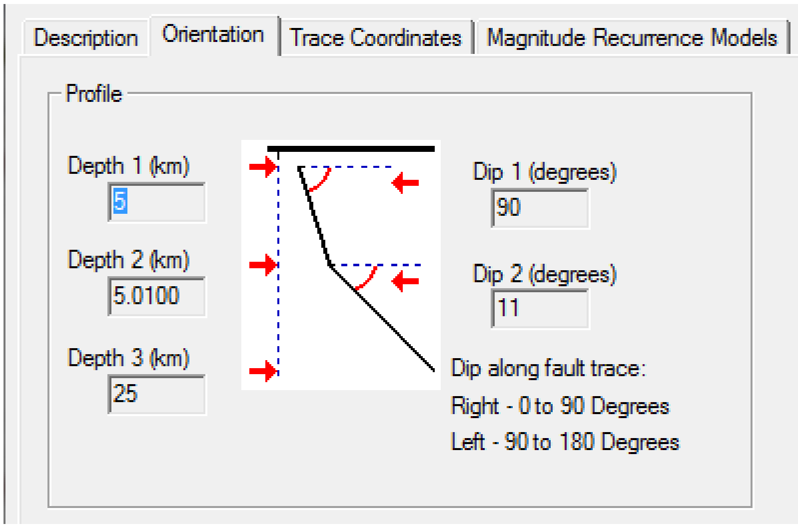
Region: Caribbean

Fault Mechanism: Subduction

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 7.6999



Depth 1 (km): 5

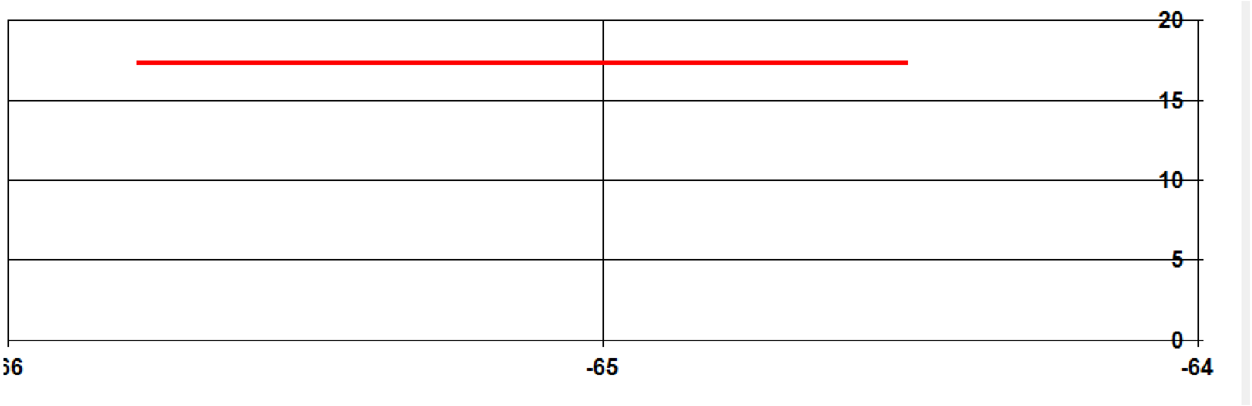
Depth 2 (km): 5.0100

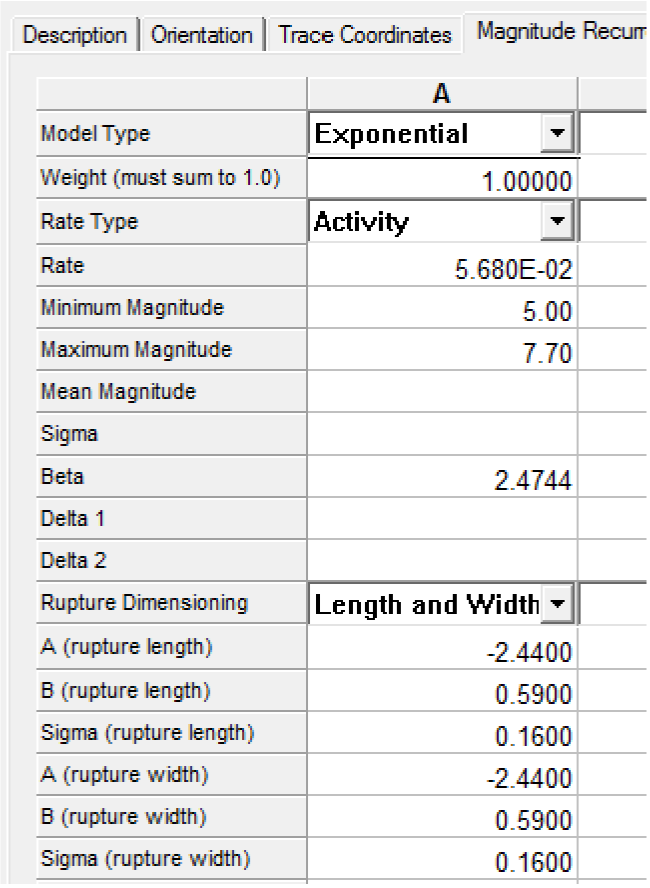
Depth 3 (km): 25

Dip 1 (degrees): 90

Dip 2 (degrees): 11

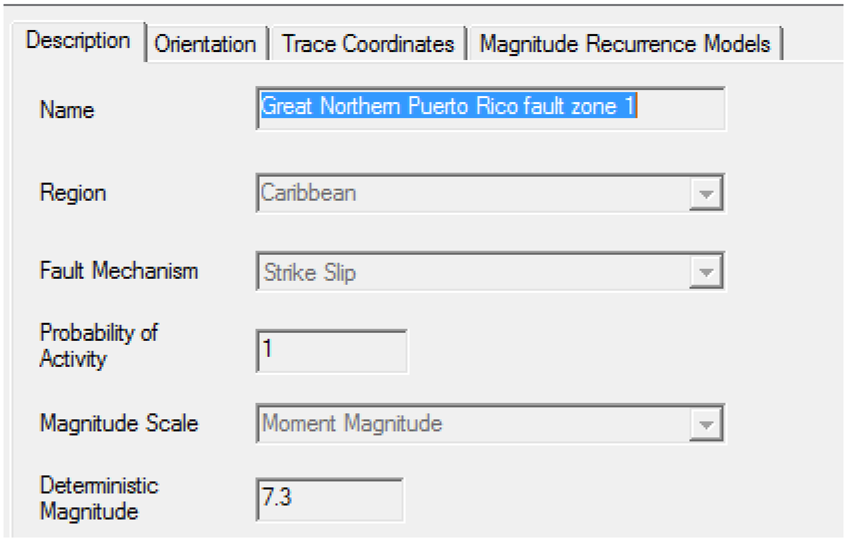
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A
Model Type	Exponential
Weight (must sum to 1.0)	1.00000
Rate Type	Activity
Rate	5.680E-02
Minimum Magnitude	5.00
Maximum Magnitude	7.70
Mean Magnitude	
Sigma	
Beta	2.4744
Delta 1	
Delta 2	
Rupture Dimensioning	Length and Width
A (rupture length)	-2.4400
B (rupture length)	0.5900
Sigma (rupture length)	0.1600
A (rupture width)	-2.4400
B (rupture width)	0.5900
Sigma (rupture width)	0.1600

GNPR FAULT ZONE 1



Name: Great Northern Puerto Rico fault zone 1

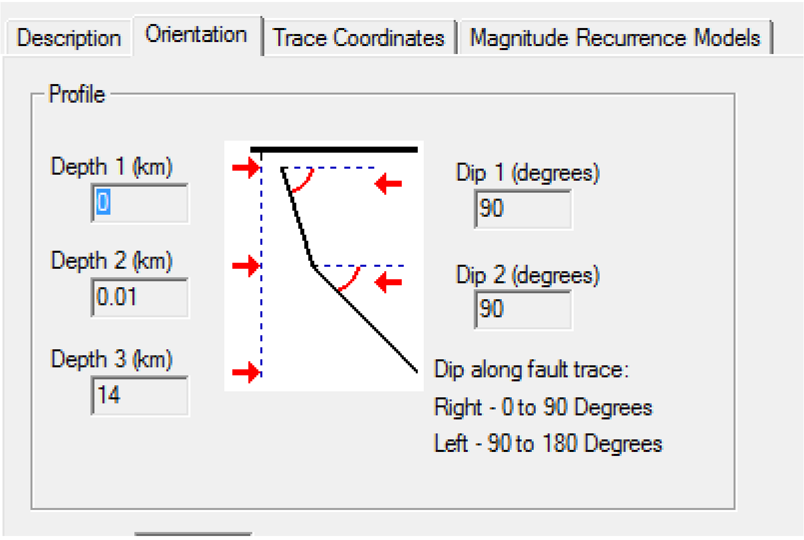
Region: Caribbean

Fault Mechanism: Strike Slip

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 7.3



Depth 1 (km): 0

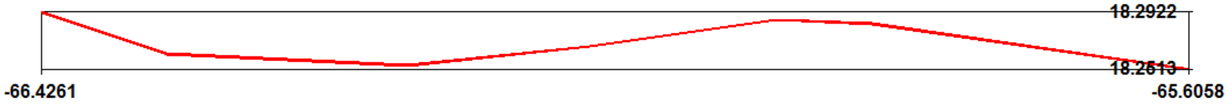
Depth 2 (km): 0.01

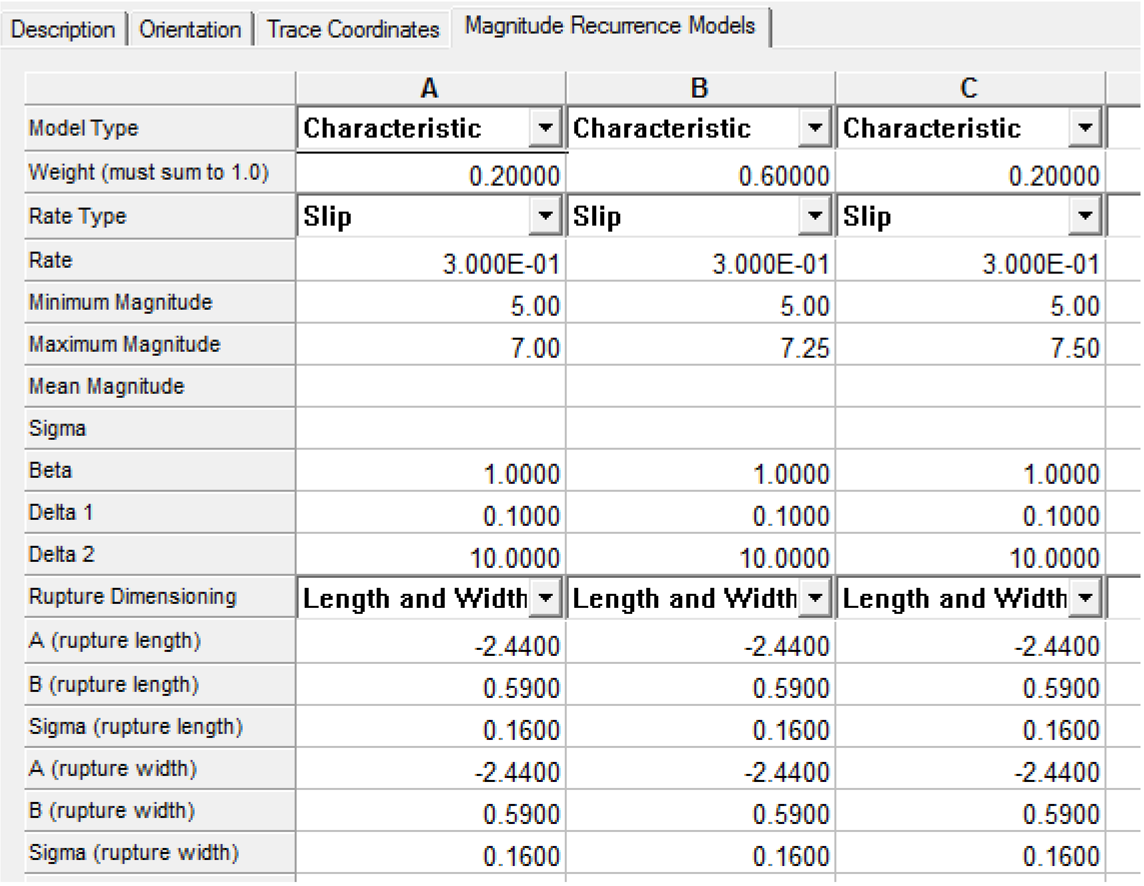
Depth 3 (km): 14

Dip 1 (degrees): 90

Dip 2 (degrees): 90

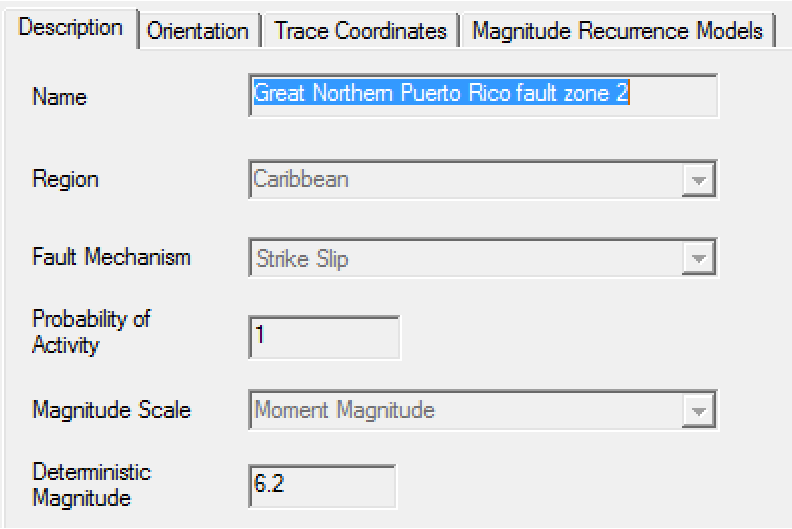
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A	B	C
Model Type	Characteristic	Characteristic	Characteristic
Weight (must sum to 1.0)	0.20000	0.60000	0.20000
Rate Type	Slip	Slip	Slip
Rate	3.000E-01	3.000E-01	3.000E-01
Minimum Magnitude	5.00	5.00	5.00
Maximum Magnitude	7.00	7.25	7.50
Mean Magnitude			
Sigma			
Beta	1.0000	1.0000	1.0000
Delta 1	0.1000	0.1000	0.1000
Delta 2	10.0000	10.0000	10.0000
Rupture Dimensioning	Length and Width	Length and Width	Length and Width
A (rupture length)	-2.4400	-2.4400	-2.4400
B (rupture length)	0.5900	0.5900	0.5900
Sigma (rupture length)	0.1600	0.1600	0.1600
A (rupture width)	-2.4400	-2.4400	-2.4400
B (rupture width)	0.5900	0.5900	0.5900
Sigma (rupture width)	0.1600	0.1600	0.1600

GNPR FAULT ZONE 2



Name: Great Northern Puerto Rico fault zone 2

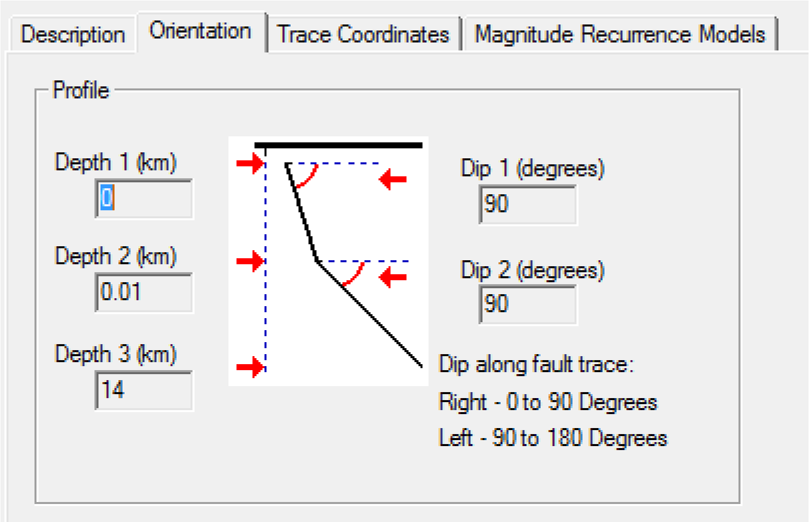
Region: Caribbean

Fault Mechanism: Strike Slip

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 6.2



Depth 1 (km): 0

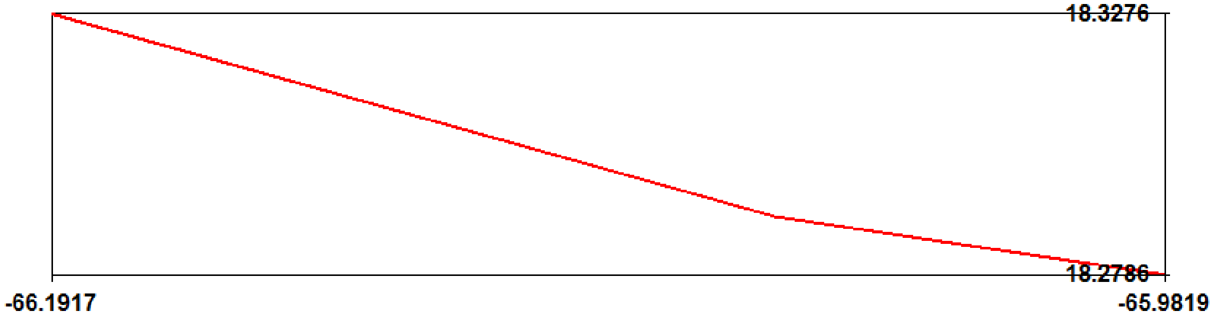
Depth 2 (km): 0.01

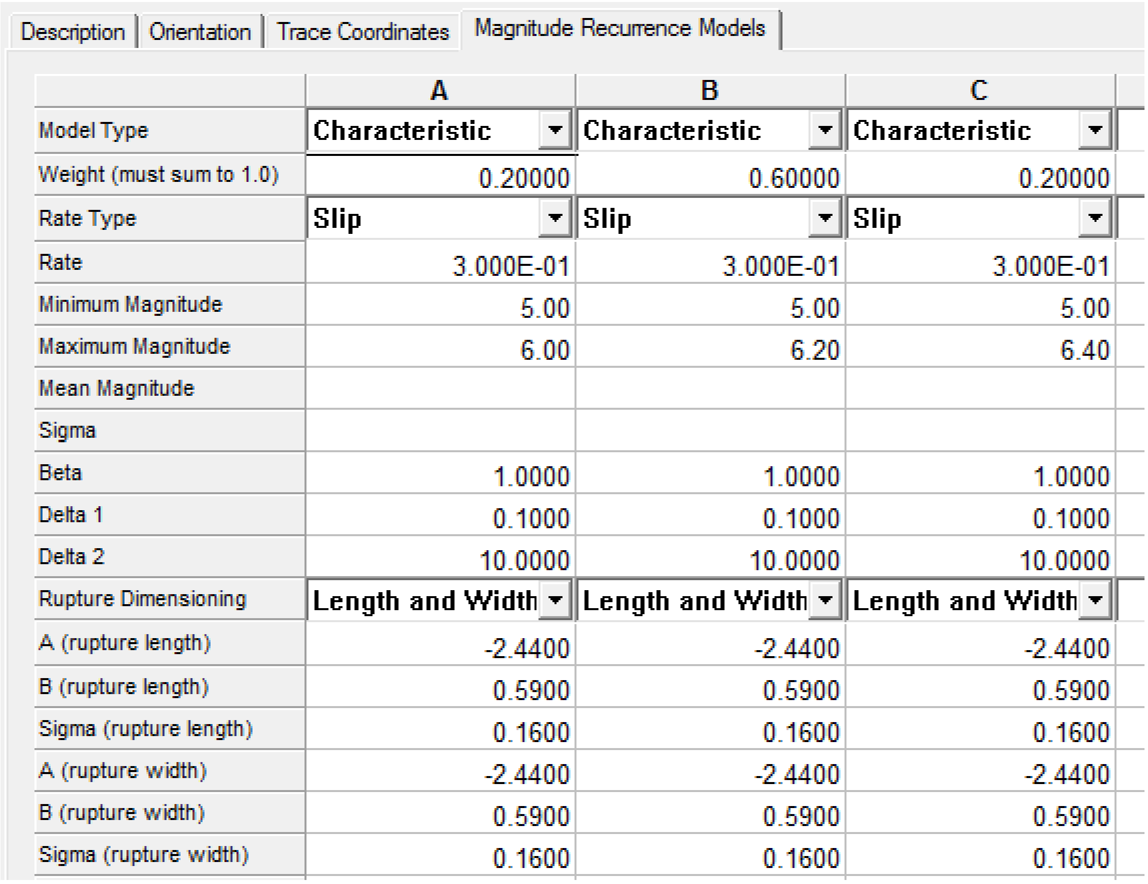
Depth 3 (km): 14

Dip 1 (degrees): 90

Dip 2 (degrees): 90

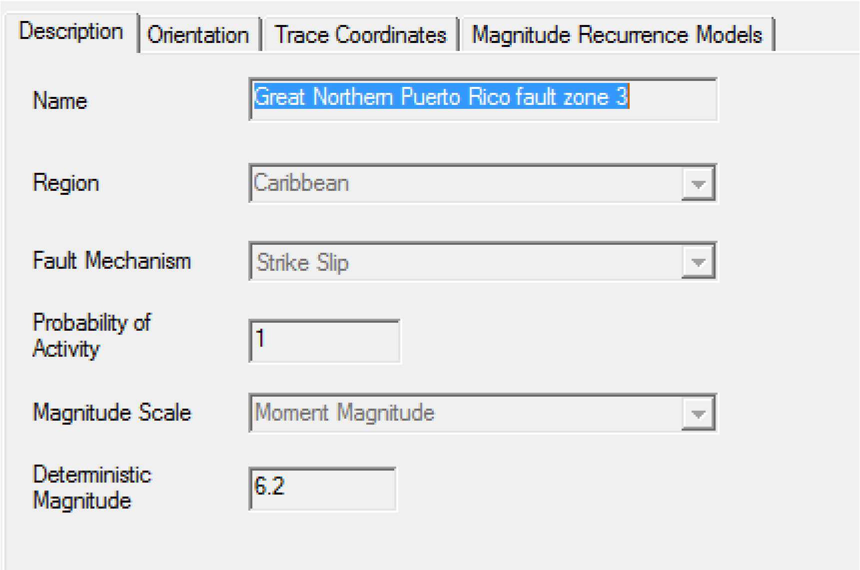
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A	B	C
Model Type	Characteristic	Characteristic	Characteristic
Weight (must sum to 1.0)	0.20000	0.60000	0.20000
Rate Type	Slip	Slip	Slip
Rate	3.000E-01	3.000E-01	3.000E-01
Minimum Magnitude	5.00	5.00	5.00
Maximum Magnitude	6.00	6.20	6.40
Mean Magnitude			
Sigma			
Beta	1.0000	1.0000	1.0000
Delta 1	0.1000	0.1000	0.1000
Delta 2	10.0000	10.0000	10.0000
Rupture Dimensioning	Length and Width	Length and Width	Length and Width
A (rupture length)	-2.4400	-2.4400	-2.4400
B (rupture length)	0.5900	0.5900	0.5900
Sigma (rupture length)	0.1600	0.1600	0.1600
A (rupture width)	-2.4400	-2.4400	-2.4400
B (rupture width)	0.5900	0.5900	0.5900
Sigma (rupture width)	0.1600	0.1600	0.1600

GNPR FAULT ZONE 3



Name: Great Northern Puerto Rico fault zone 3

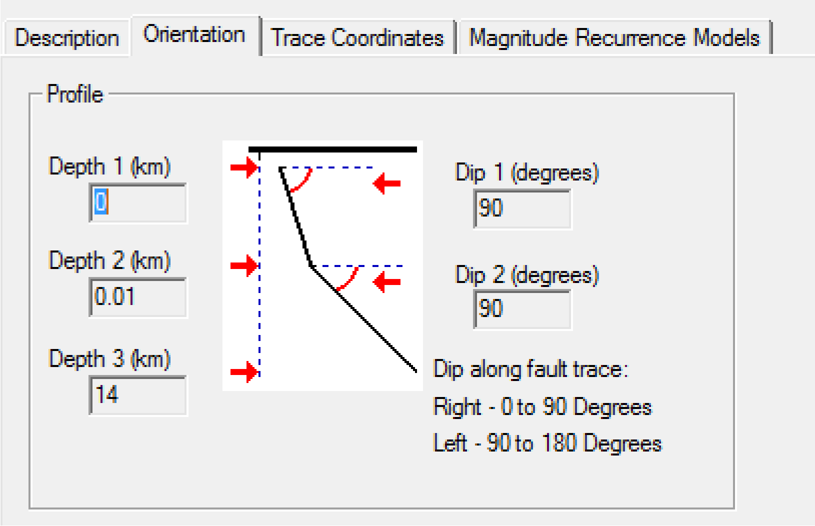
Region: Caribbean

Fault Mechanism: Strike Slip

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 6.2



Depth 1 (km): 0

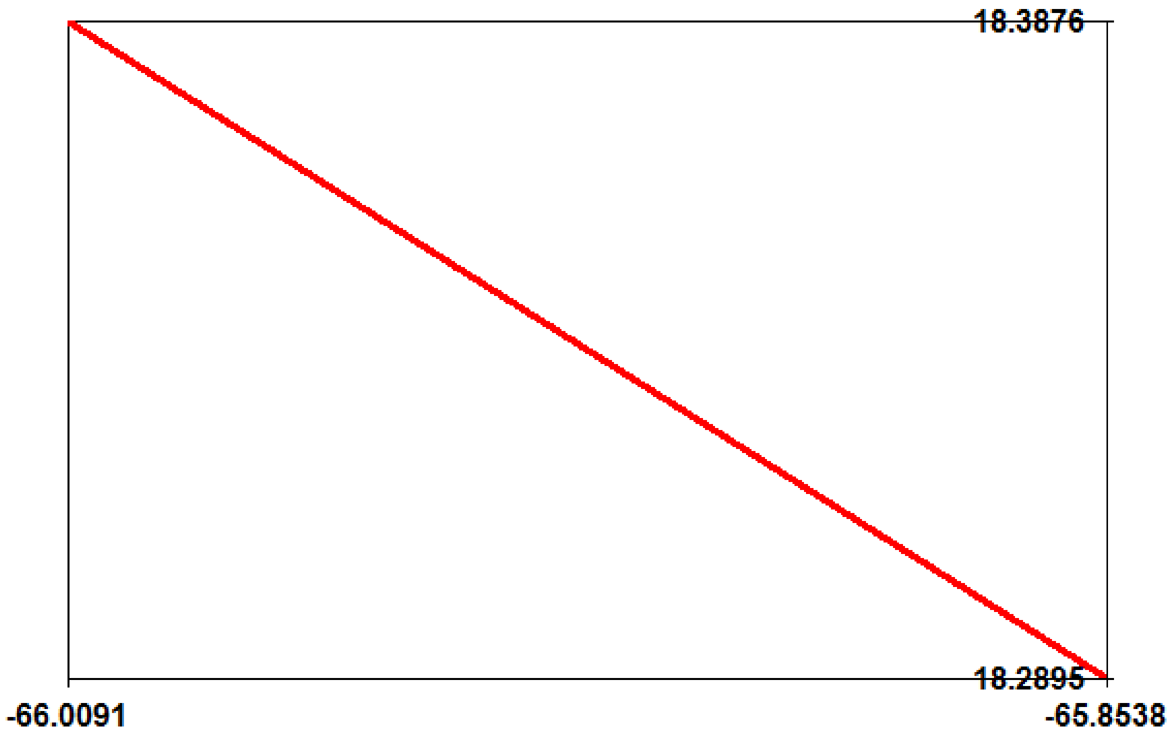
Depth 2 (km): 0.01

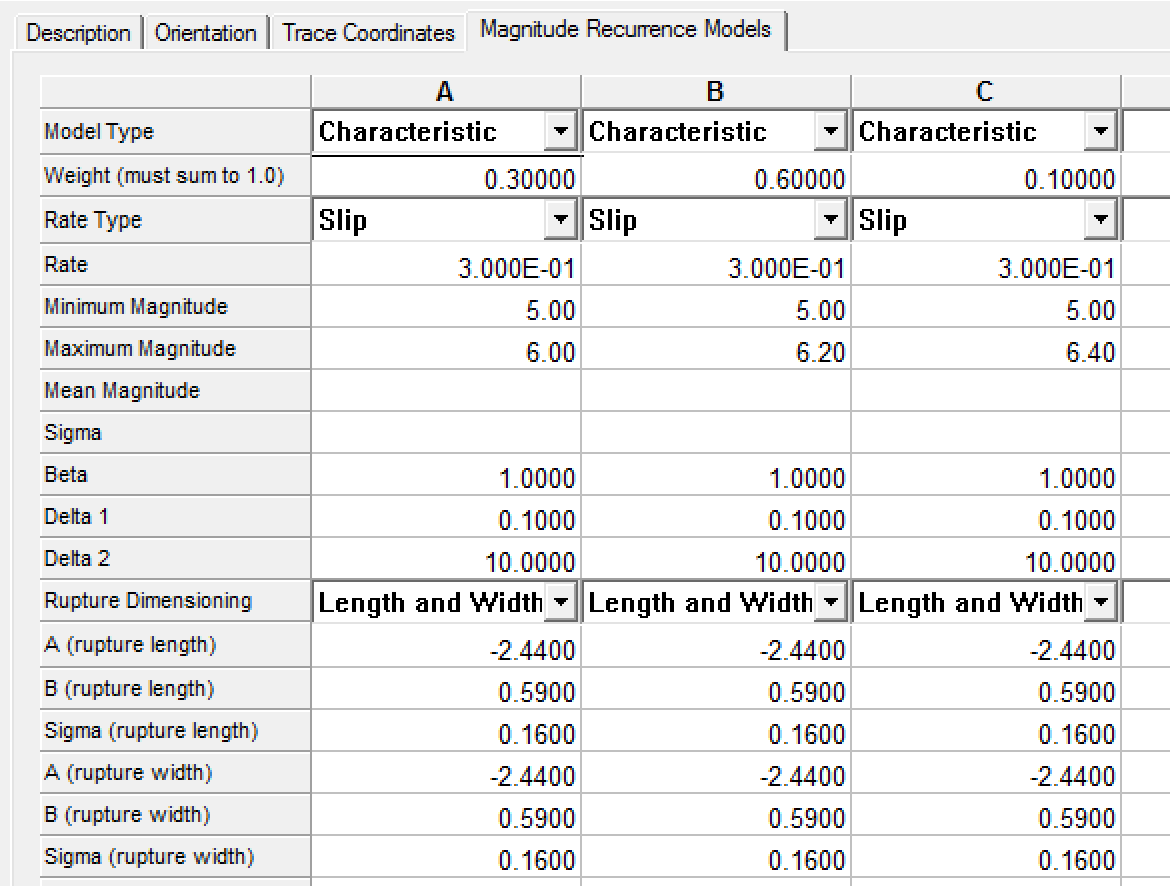
Depth 3 (km): 14

Dip 1 (degrees): 90

Dip 2 (degrees): 90

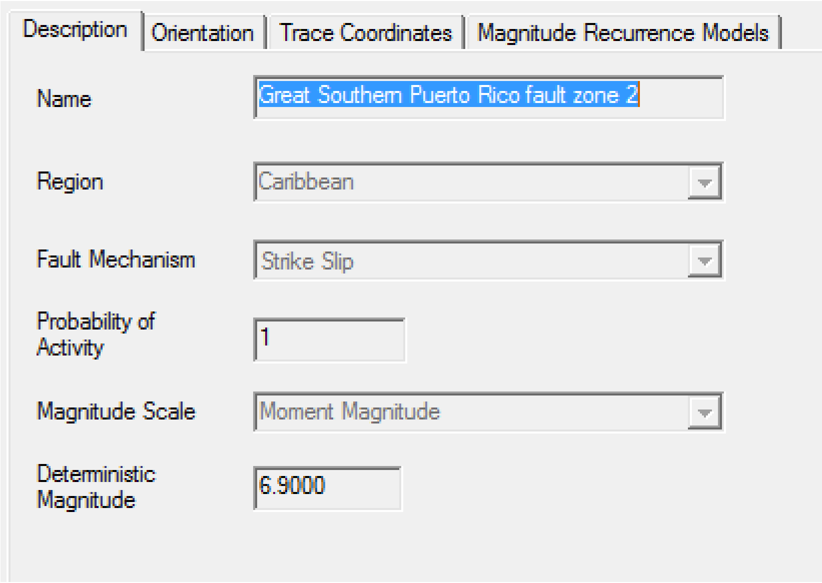
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A	B	C
Model Type	Characteristic	Characteristic	Characteristic
Weight (must sum to 1.0)	0.30000	0.60000	0.10000
Rate Type	Slip	Slip	Slip
Rate	3.000E-01	3.000E-01	3.000E-01
Minimum Magnitude	5.00	5.00	5.00
Maximum Magnitude	6.00	6.20	6.40
Mean Magnitude			
Sigma			
Beta	1.0000	1.0000	1.0000
Delta 1	0.1000	0.1000	0.1000
Delta 2	10.0000	10.0000	10.0000
Rupture Dimensioning	Length and Width	Length and Width	Length and Width
A (rupture length)	-2.4400	-2.4400	-2.4400
B (rupture length)	0.5900	0.5900	0.5900
Sigma (rupture length)	0.1600	0.1600	0.1600
A (rupture width)	-2.4400	-2.4400	-2.4400
B (rupture width)	0.5900	0.5900	0.5900
Sigma (rupture width)	0.1600	0.1600	0.1600

GSPR FAULT ZONE 2



Name: Great Southern Puerto Rico fault zone 2

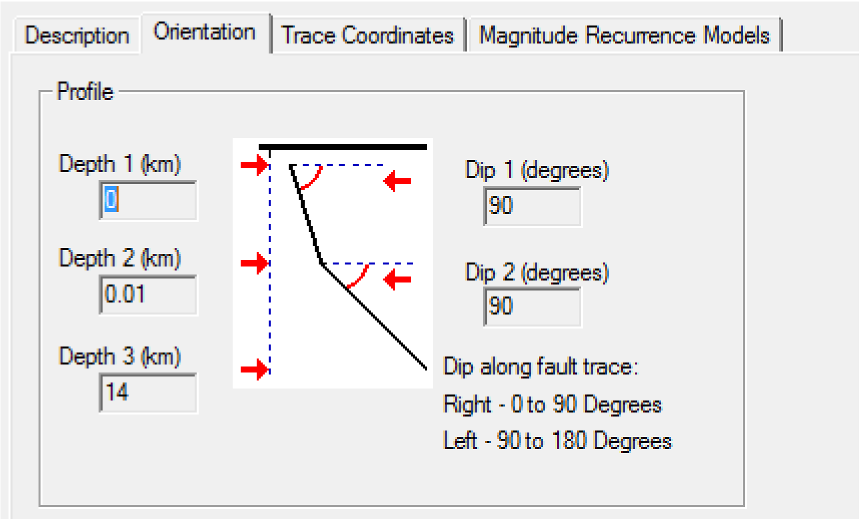
Region: Caribbean

Fault Mechanism: Strike Slip

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 6.9000



Depth 1 (km): 0

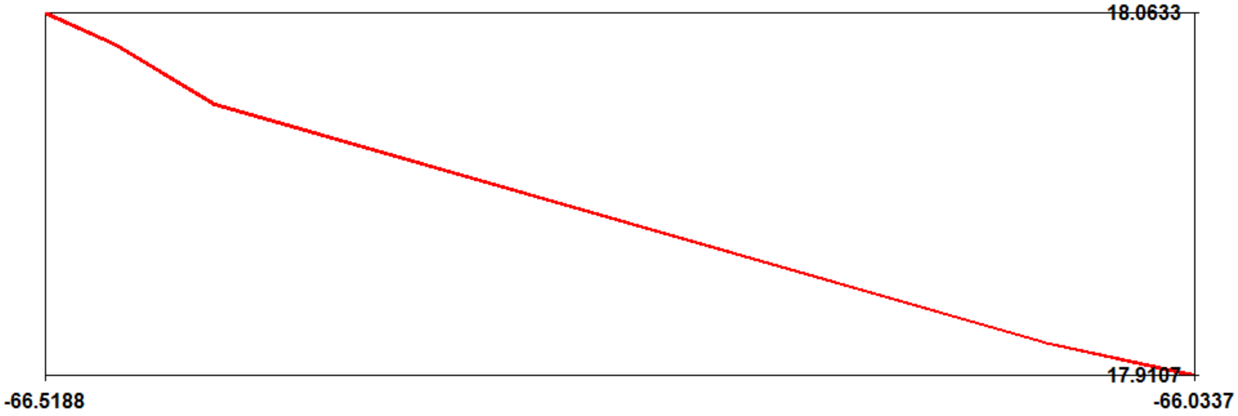
Depth 2 (km): 0.01

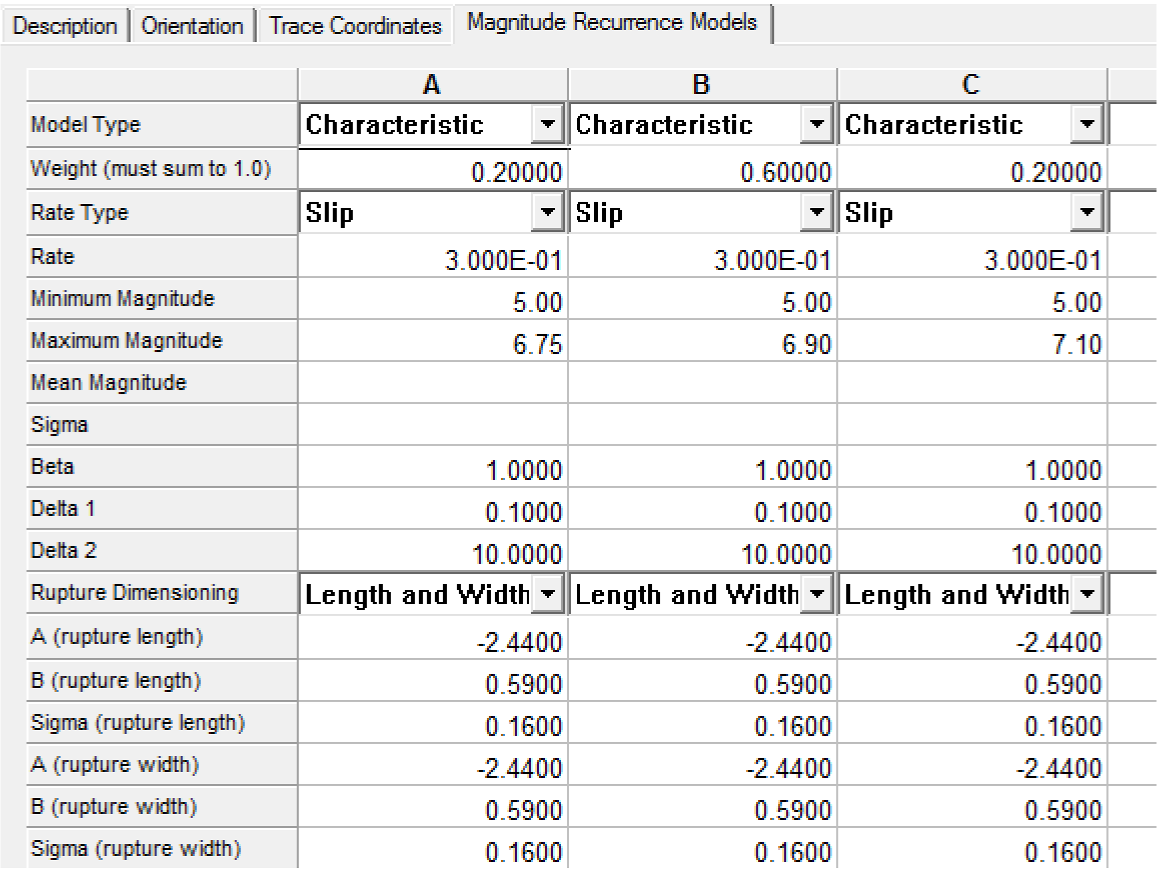
Depth 3 (km): 14

Dip 1 (degrees): 90

Dip 2 (degrees): 90

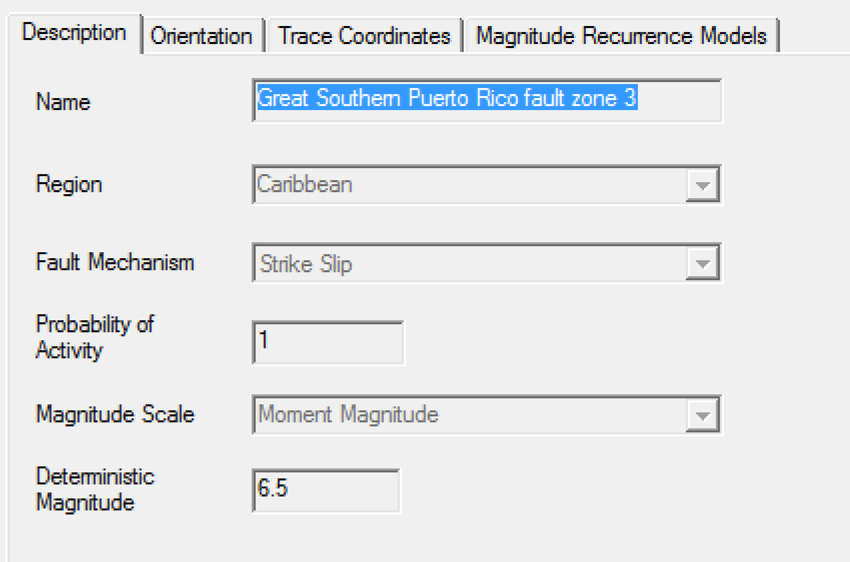
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A	B	C
Model Type	Characteristic	Characteristic	Characteristic
Weight (must sum to 1.0)	0.20000	0.60000	0.20000
Rate Type	Slip	Slip	Slip
Rate	3.000E-01	3.000E-01	3.000E-01
Minimum Magnitude	5.00	5.00	5.00
Maximum Magnitude	6.75	6.90	7.10
Mean Magnitude			
Sigma			
Beta	1.0000	1.0000	1.0000
Delta 1	0.1000	0.1000	0.1000
Delta 2	10.0000	10.0000	10.0000
Rupture Dimensioning	Length and Width	Length and Width	Length and Width
A (rupture length)	-2.4400	-2.4400	-2.4400
B (rupture length)	0.5900	0.5900	0.5900
Sigma (rupture length)	0.1600	0.1600	0.1600
A (rupture width)	-2.4400	-2.4400	-2.4400
B (rupture width)	0.5900	0.5900	0.5900
Sigma (rupture width)	0.1600	0.1600	0.1600

GSPR FAULT ZONE 3



Name: Great Southern Puerto Rico fault zone 3

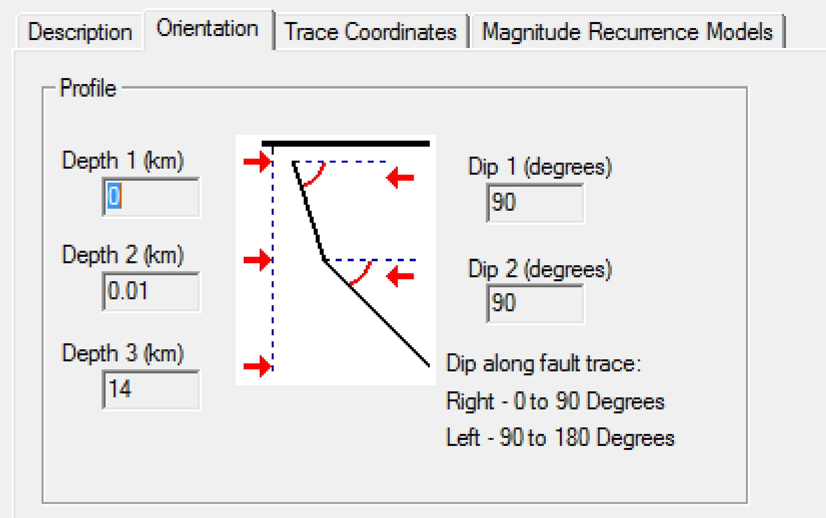
Region: Caribbean

Fault Mechanism: Strike Slip

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 6.5



Depth 1 (km): 0

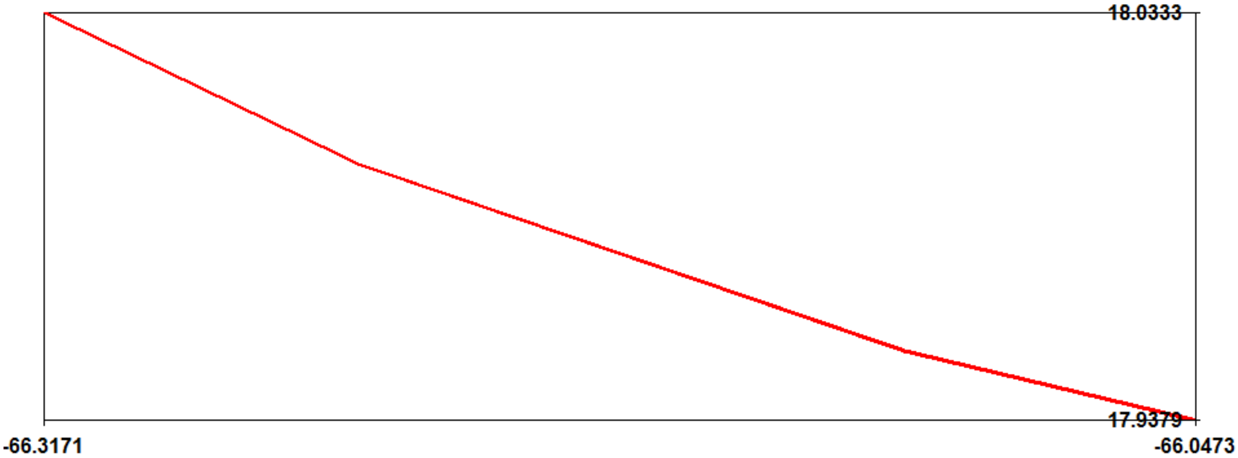
Depth 2 (km): 0.01

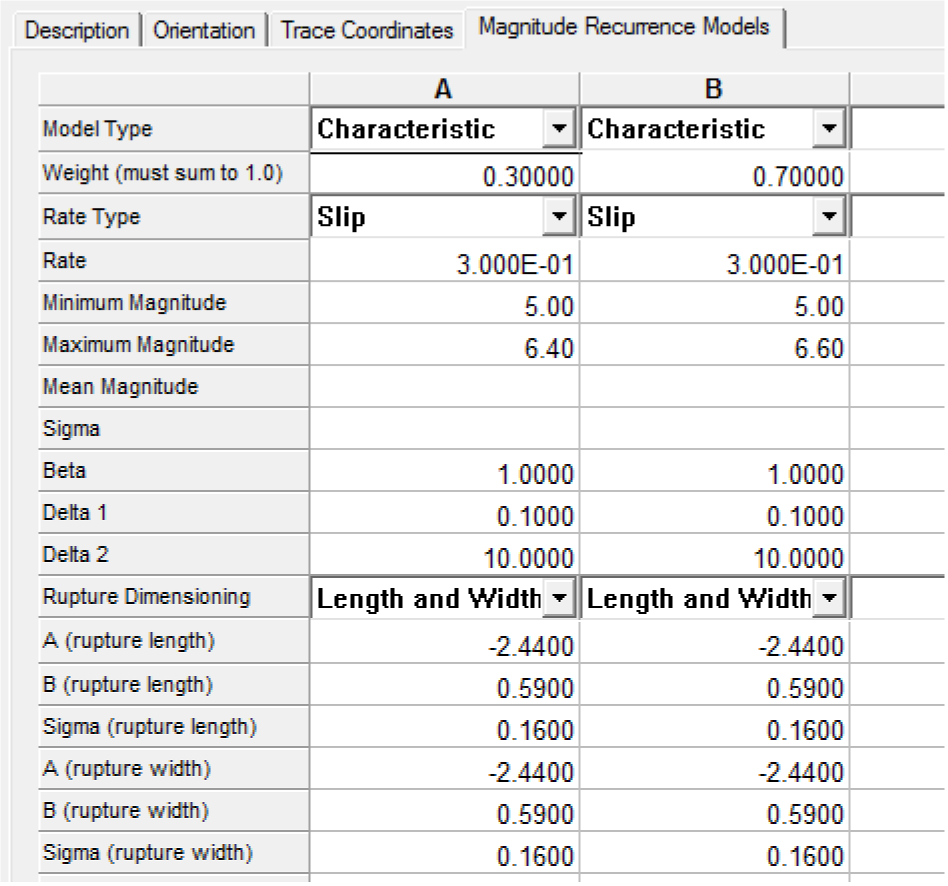
Depth 3 (km): 14

Dip 1 (degrees): 90

Dip 2 (degrees): 90

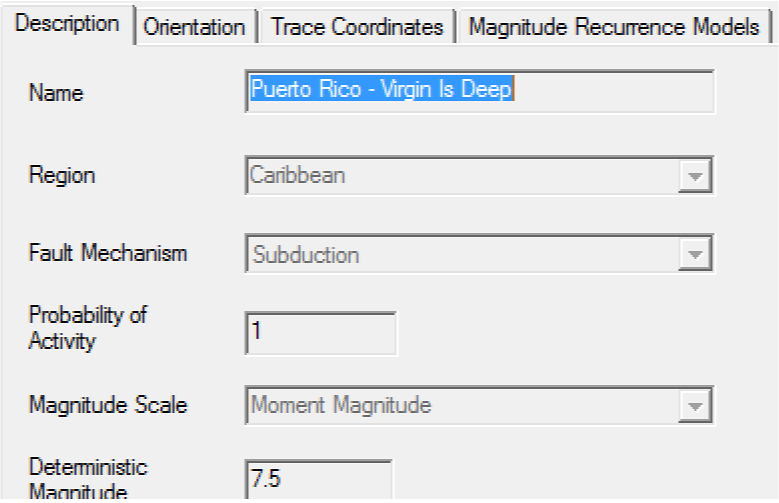
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A	B
Model Type	Characteristic	Characteristic
Weight (must sum to 1.0)	0.30000	0.70000
Rate Type	Slip	Slip
Rate	3.000E-01	3.000E-01
Minimum Magnitude	5.00	5.00
Maximum Magnitude	6.40	6.60
Mean Magnitude		
Sigma		
Beta	1.0000	1.0000
Delta 1	0.1000	0.1000
Delta 2	10.0000	10.0000
Rupture Dimensioning	Length and Width	Length and Width
A (rupture length)	-2.4400	-2.4400
B (rupture length)	0.5900	0.5900
Sigma (rupture length)	0.1600	0.1600
A (rupture width)	-2.4400	-2.4400
B (rupture width)	0.5900	0.5900
Sigma (rupture width)	0.1600	0.1600

PUERTO RICO-VIRGIN ISLANDS DEEP



Name: Puerto Rico - Virgin Is Deep

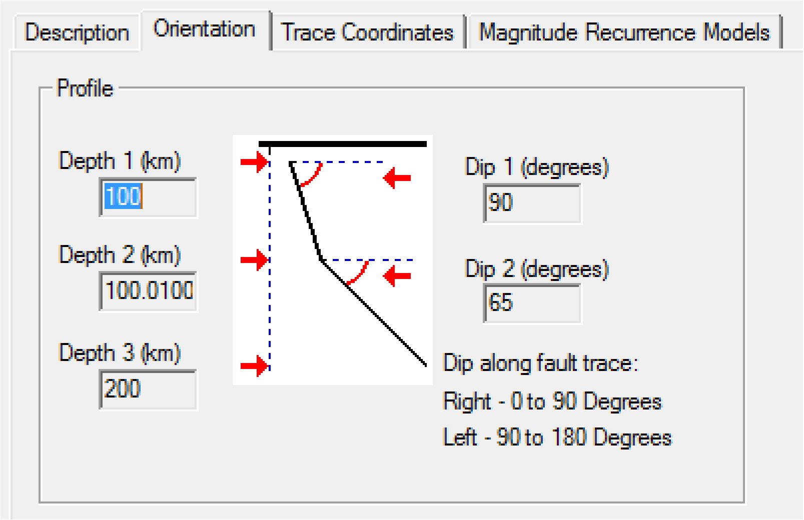
Region: Caribbean

Fault Mechanism: Subduction

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 7.5



Depth 1 (km): 100

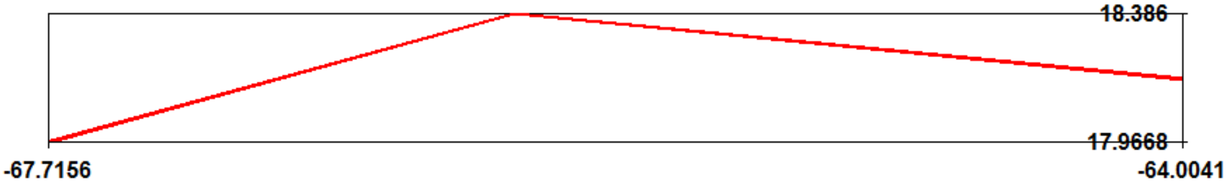
Depth 2 (km): 100.0100

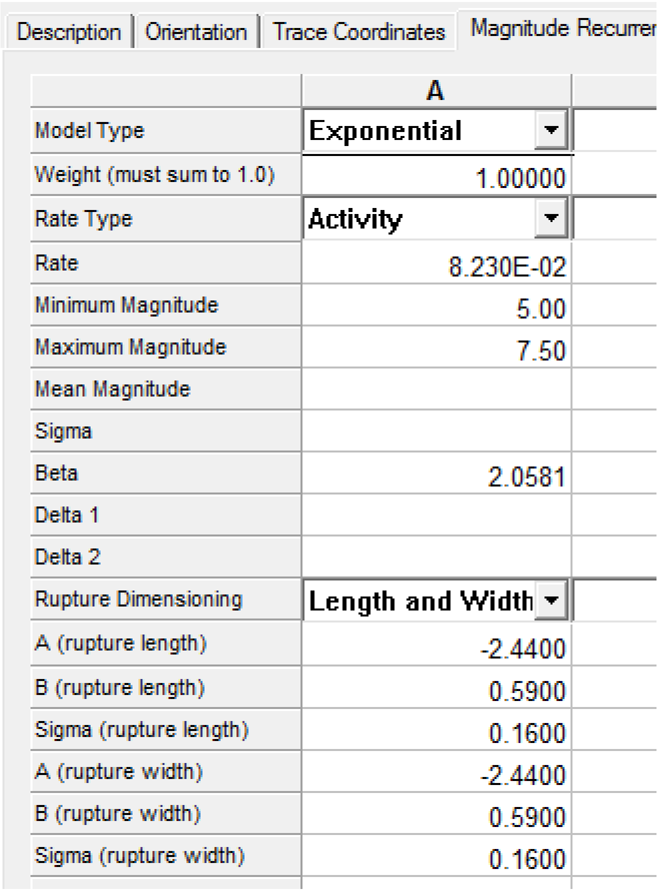
Depth 3 (km): 200

Dip 1 (degrees): 90

Dip 2 (degrees): 65

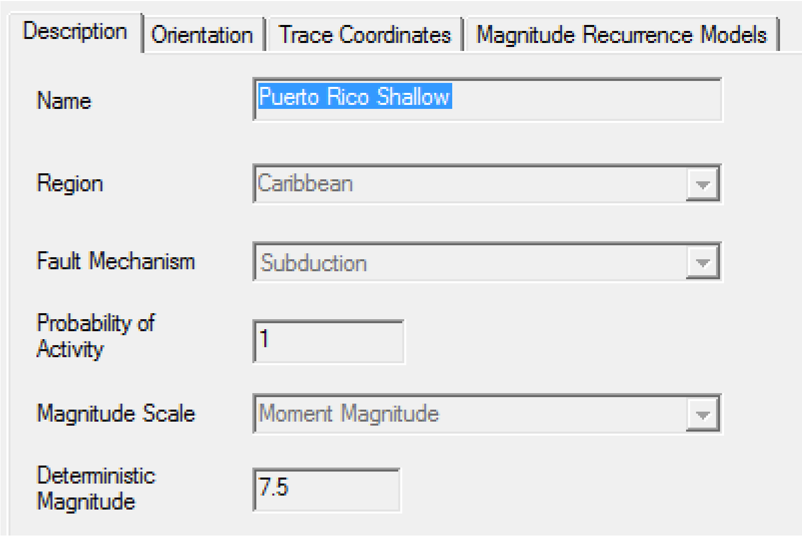
Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees





	A
Model Type	Exponential
Weight (must sum to 1.0)	1.00000
Rate Type	Activity
Rate	8.230E-02
Minimum Magnitude	5.00
Maximum Magnitude	7.50
Mean Magnitude	
Sigma	
Beta	2.0581
Delta 1	
Delta 2	
Rupture Dimensioning	Length and Width
A (rupture length)	-2.4400
B (rupture length)	0.5900
Sigma (rupture length)	0.1600
A (rupture width)	-2.4400
B (rupture width)	0.5900
Sigma (rupture width)	0.1600

PUERTO RICO SHALLOW



Name: Puerto Rico Shallow

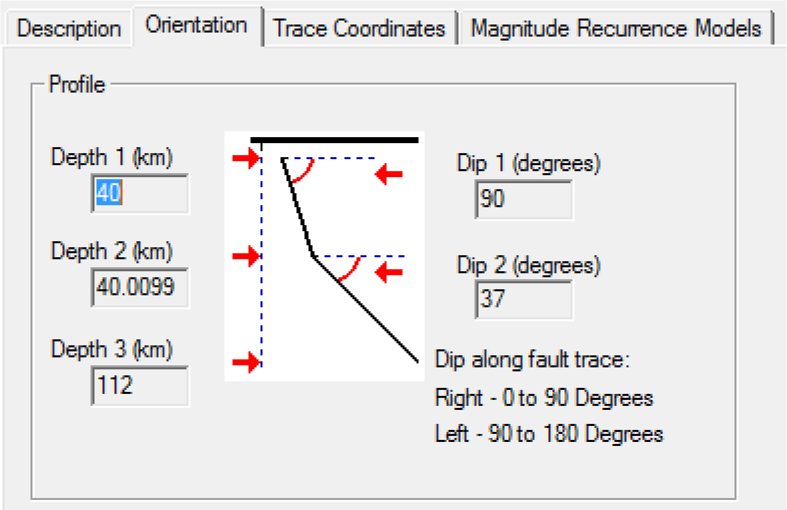
Region: Caribbean

Fault Mechanism: Subduction

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 7.5



Depth 1 (km): 40

Depth 2 (km): 40.0099

Depth 3 (km): 112

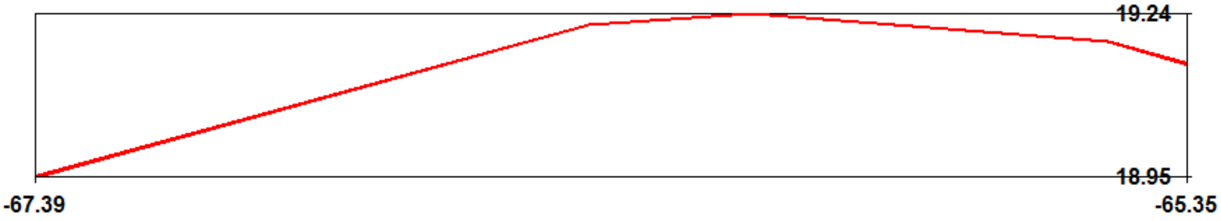
Dip 1 (degrees): 90

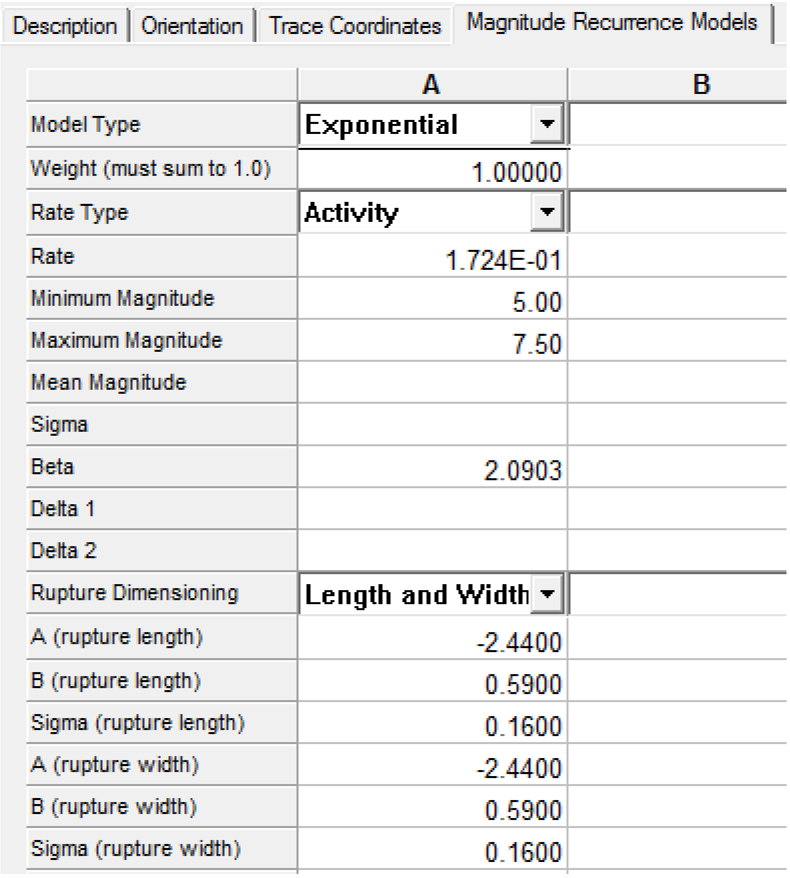
Dip 2 (degrees): 37

Dip along fault trace:

Right - 0 to 90 Degrees

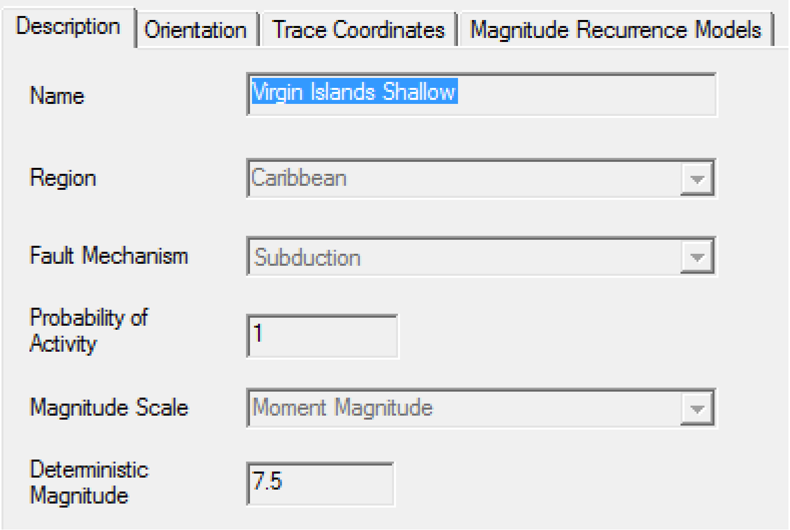
Left - 90 to 180 Degrees





	A	B
Model Type	Exponential	
Weight (must sum to 1.0)	1.00000	
Rate Type	Activity	
Rate	1.724E-01	
Minimum Magnitude	5.00	
Maximum Magnitude	7.50	
Mean Magnitude		
Sigma		
Beta	2.0903	
Delta 1		
Delta 2		
Rupture Dimensioning	Length and Width	
A (rupture length)	-2.4400	
B (rupture length)	0.5900	
Sigma (rupture length)	0.1600	
A (rupture width)	-2.4400	
B (rupture width)	0.5900	
Sigma (rupture width)	0.1600	

VIRGIN ISLANDS SHALLOW



Name: Virgin Islands Shallow

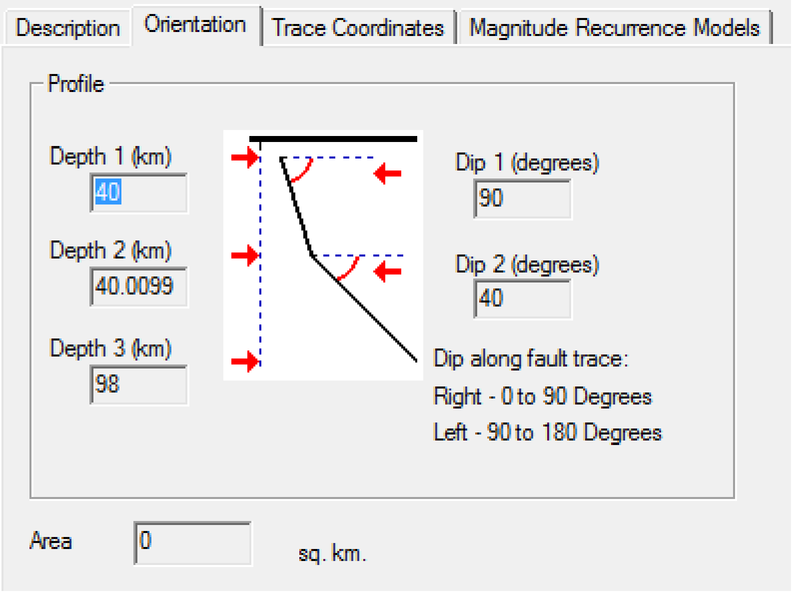
Region: Caribbean

Fault Mechanism: Subduction

Probability of Activity: 1

Magnitude Scale: Moment Magnitude

Deterministic Magnitude: 7.5



Depth 1 (km): 40

Depth 2 (km): 40.0099

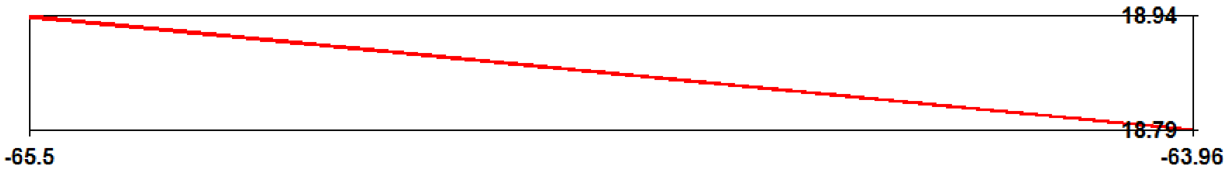
Depth 3 (km): 98

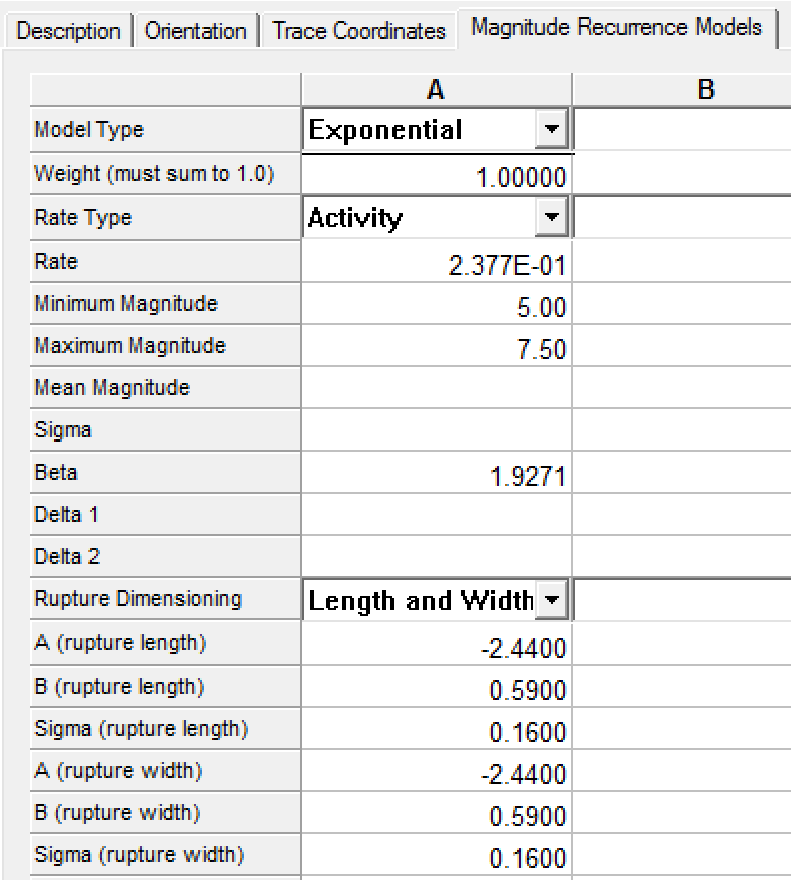
Dip 1 (degrees): 90

Dip 2 (degrees): 40

Dip along fault trace:
Right - 0 to 90 Degrees
Left - 90 to 180 Degrees

Area: 0 sq. km.



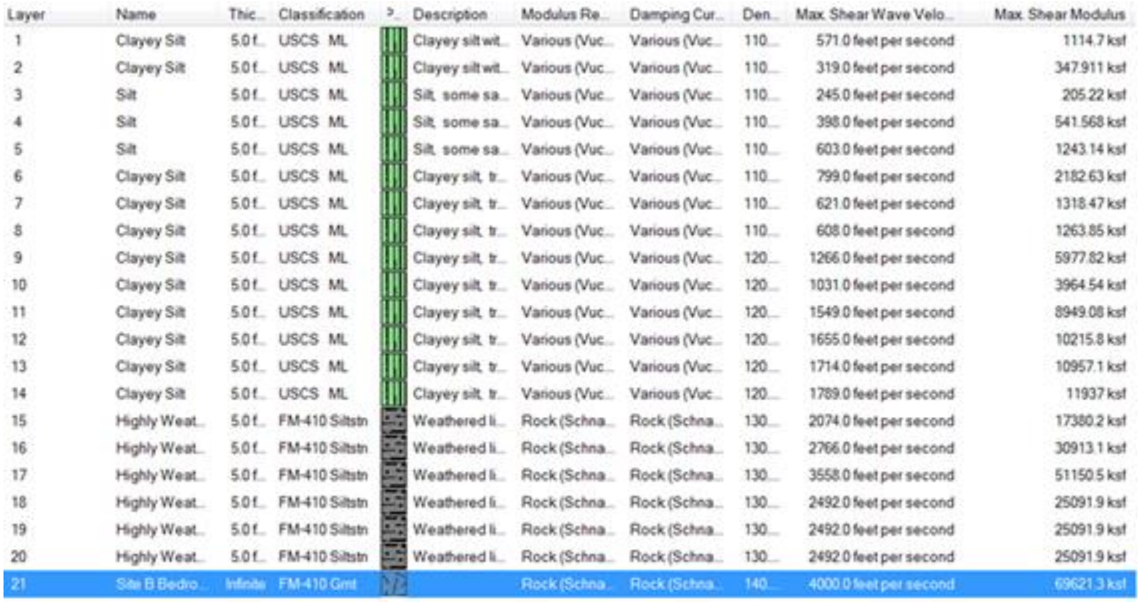


	A	B
Model Type	Exponential	
Weight (must sum to 1.0)	1.00000	
Rate Type	Activity	
Rate	2.377E-01	
Minimum Magnitude	5.00	
Maximum Magnitude	7.50	
Mean Magnitude		
Sigma		
Beta	1.9271	
Delta 1		
Delta 2		
Rupture Dimensioning	Length and Width	
A (rupture length)	-2.4400	
B (rupture length)	0.5900	
Sigma (rupture length)	0.1600	
A (rupture width)	-2.4400	
B (rupture width)	0.5900	
Sigma (rupture width)	0.1600	

Appendix 5

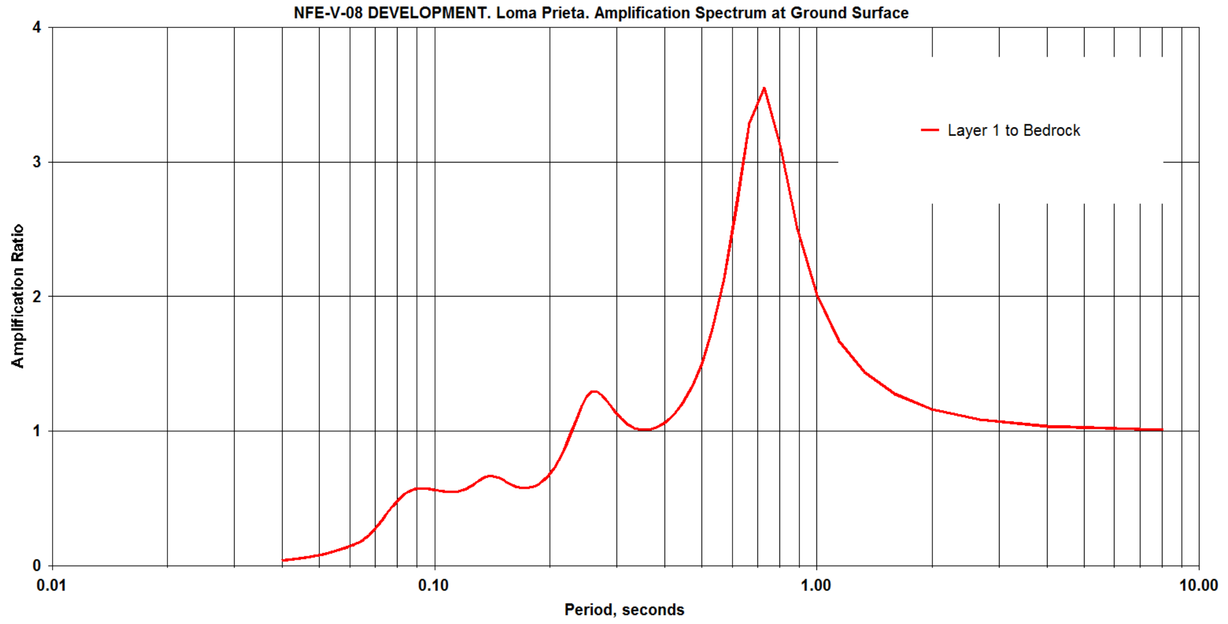
Site Response. Shake Analyses

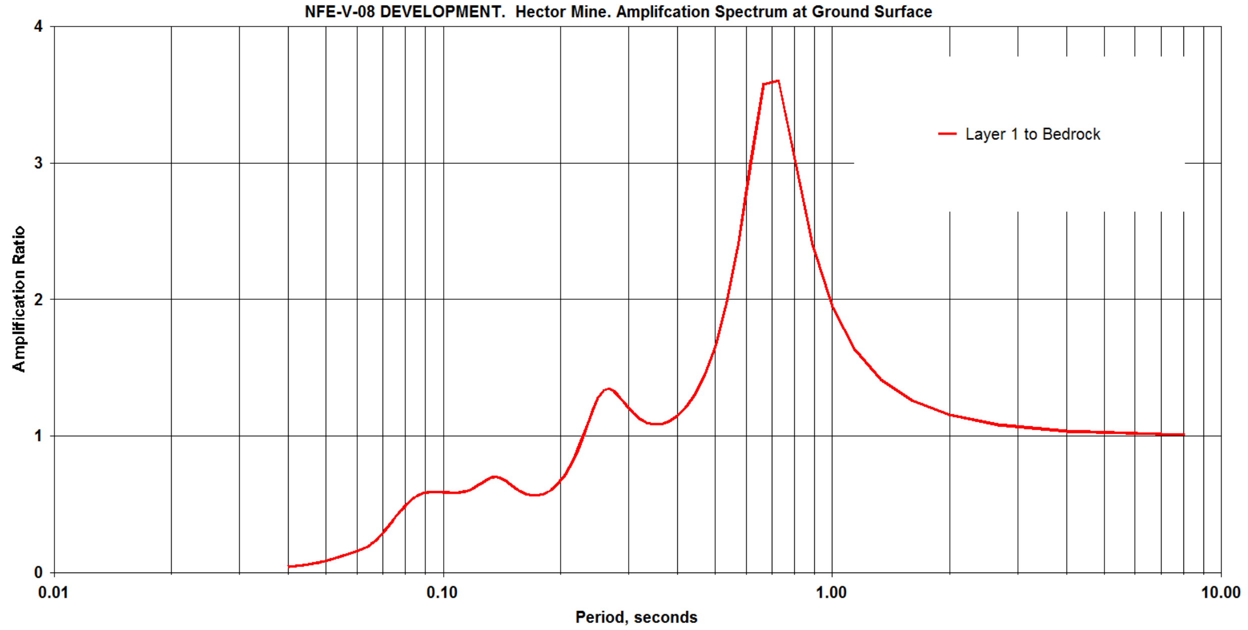
SHAKE COLUMN



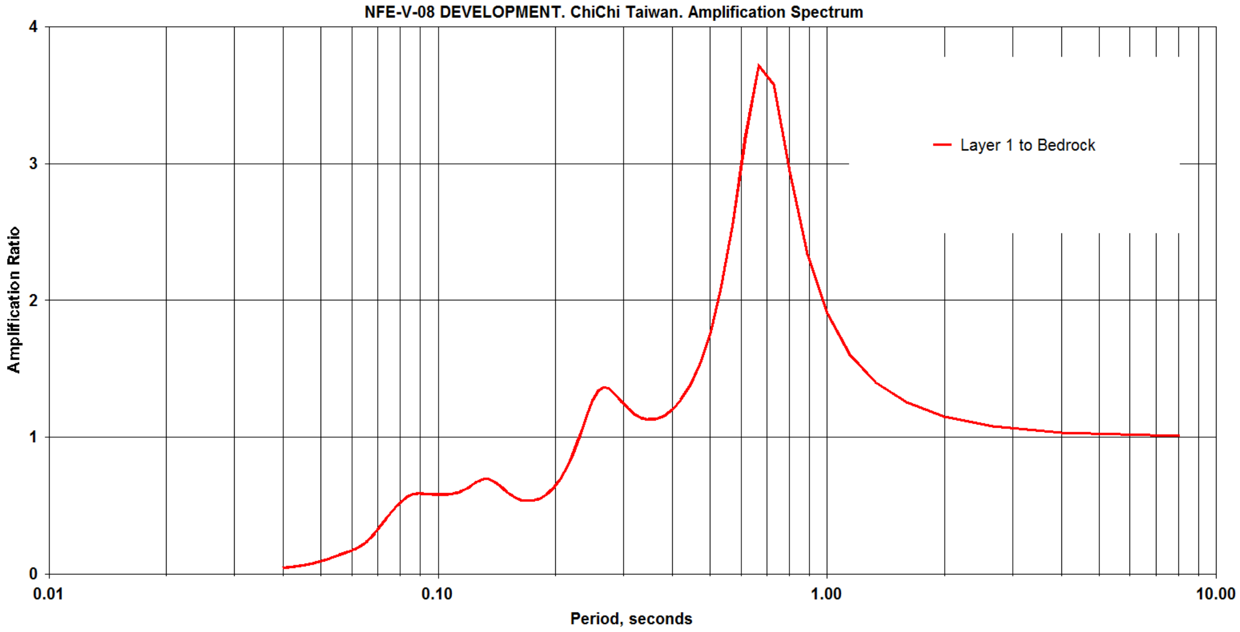
Layer	Name	Thic…	Classification	>…	Description	Modulus Re…	Damping Cur…	Den…	Max. Shear Wave Velo…	Max. Shear Modulus
1	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt wit…	Various (Vuc…	Various (Vuc…	110…	571.0 feet per second	1114.7 ksf
2	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt wit…	Various (Vuc…	Various (Vuc…	110…	319.0 feet per second	347.911 ksf
3	Silt	5.0 f…	USCS ML	🟩	Silt, some sa…	Various (Vuc…	Various (Vuc…	110…	245.0 feet per second	205.22 ksf
4	Silt	5.0 f…	USCS ML	🟩	Silt, some sa…	Various (Vuc…	Various (Vuc…	110…	398.0 feet per second	541.568 ksf
5	Silt	5.0 f…	USCS ML	🟩	Silt, some sa…	Various (Vuc…	Various (Vuc…	110…	603.0 feet per second	1243.14 ksf
6	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	110…	799.0 feet per second	2182.63 ksf
7	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	110…	621.0 feet per second	1318.47 ksf
8	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	110…	608.0 feet per second	1263.85 ksf
9	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	120…	1266.0 feet per second	5977.82 ksf
10	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	120…	1031.0 feet per second	3964.54 ksf
11	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	120…	1549.0 feet per second	8949.08 ksf
12	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	120…	1655.0 feet per second	10215.8 ksf
13	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	120…	1714.0 feet per second	10957.1 ksf
14	Clayey Silt	5.0 f…	USCS ML	🟩	Clayey silt, tr…	Various (Vuc…	Various (Vuc…	120…	1789.0 feet per second	11937 ksf
15	Highly Weat…	5.0 f…	FM-410 Siltstn	▦	Weathered li…	Rock (Schna…	Rock (Schna…	130…	2074.0 feet per second	17380.2 ksf
16	Highly Weat…	5.0 f…	FM-410 Siltstn	▦	Weathered li…	Rock (Schna…	Rock (Schna…	130…	2766.0 feet per second	30913.1 ksf
17	Highly Weat…	5.0 f…	FM-410 Siltstn	▦	Weathered li…	Rock (Schna…	Rock (Schna…	130…	3558.0 feet per second	51150.5 ksf
18	Highly Weat…	5.0 f…	FM-410 Siltstn	▦	Weathered li…	Rock (Schna…	Rock (Schna…	130…	2492.0 feet per second	25091.9 ksf
19	Highly Weat…	5.0 f…	FM-410 Siltstn	▦	Weathered li…	Rock (Schna…	Rock (Schna…	130…	2492.0 feet per second	25091.9 ksf
20	Highly Weat…	5.0 f…	FM-410 Siltstn	▦	Weathered li…	Rock (Schna…	Rock (Schna…	130…	2492.0 feet per second	25091.9 ksf
21	Site B Bedro…	Infinite	FM-410 Grnt	▨		Rock (Schna…	Rock (Schna…	140…	4000.0 feet per second	69621.3 ksf

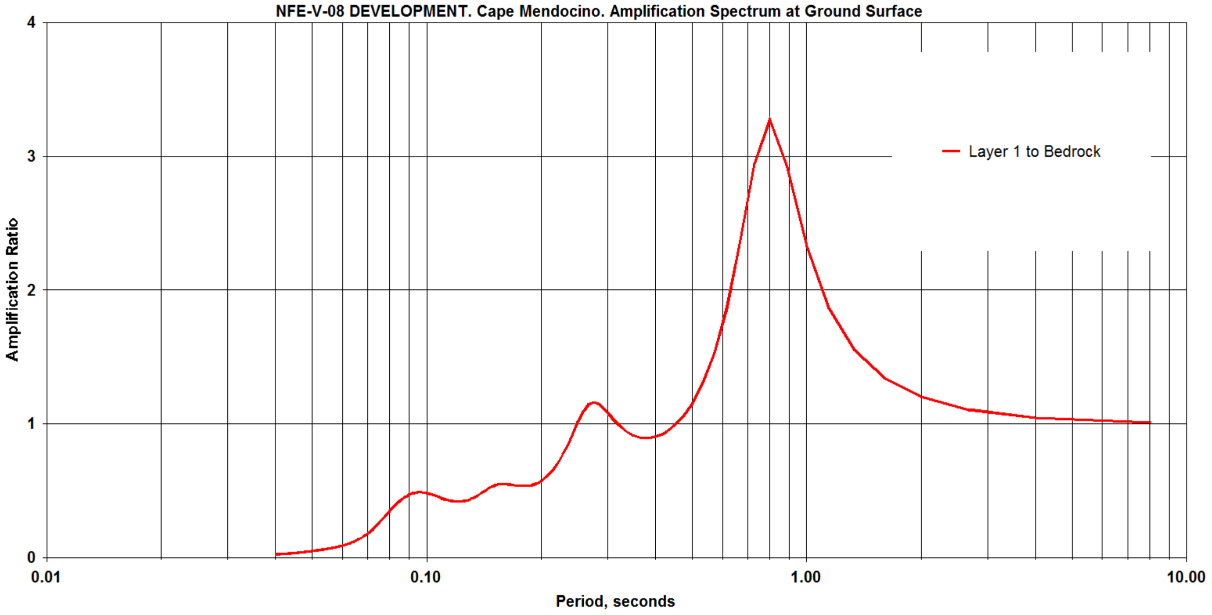
AMPLIFICATION SPECTRA AT GROUND SURFACE

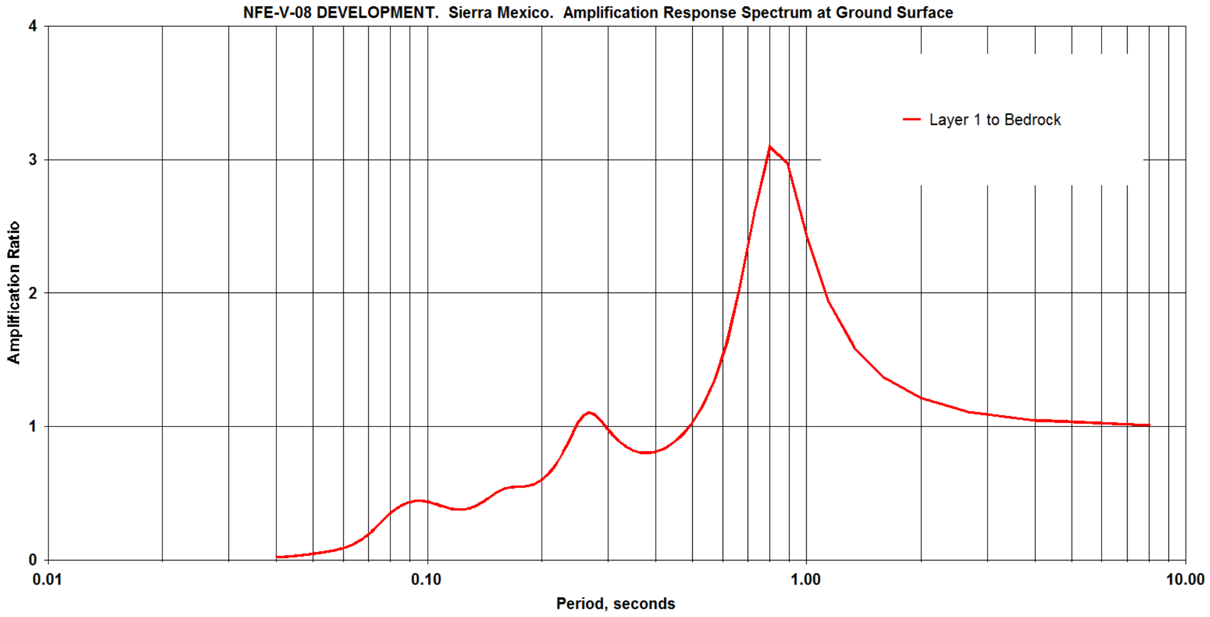




Public

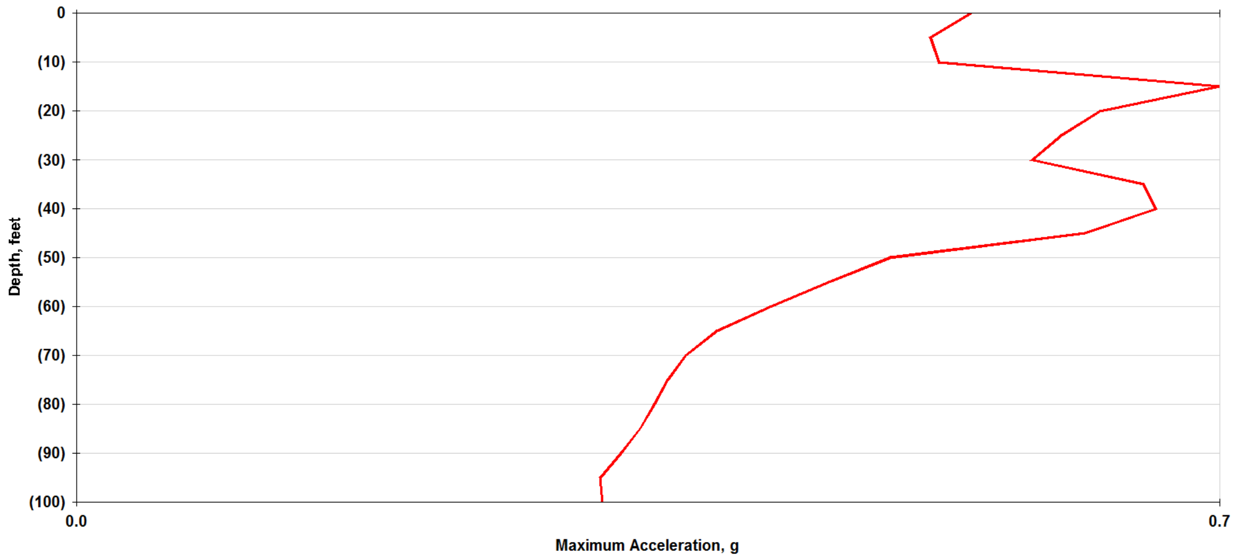

NFE-V-08 DEVELOPMENT. ChiChi Taiwan. Amplification Spectrum
Amplification Ratio
4
3
2
1
0
0.01
0.10
1.00
10.00
Period, seconds
Layer 1 to Bedrock


NFE-V-08 DEVELOPMENT. Cape Mendocino. Amplification Spectrum at Ground Surface
Amplification Ratio
4
3
2
1
0
0.01
0.10
1.00
10.00
Period, seconds
Layer 1 to Bedrock

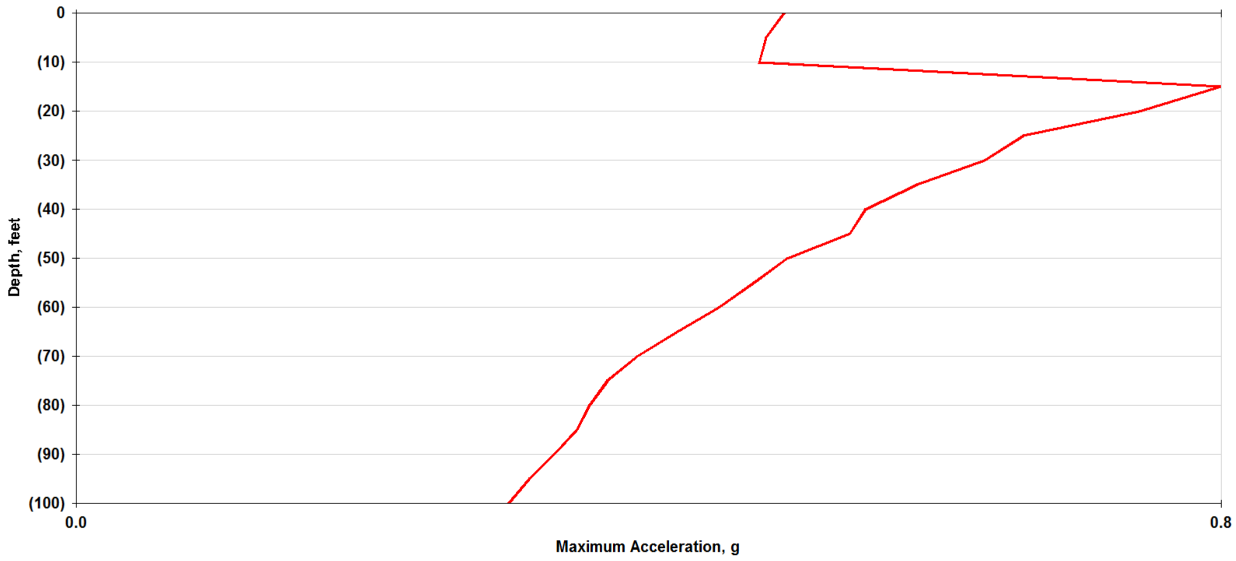

NFE-V-08 DEVELOPMENT. Sierra Mexico. Amplification Response Spectrum at Ground Surface
Amplification Ratio
4
3
2
1
0
0.01
0.10
1.00
10.00
Period, seconds
Layer 1 to Bedrock

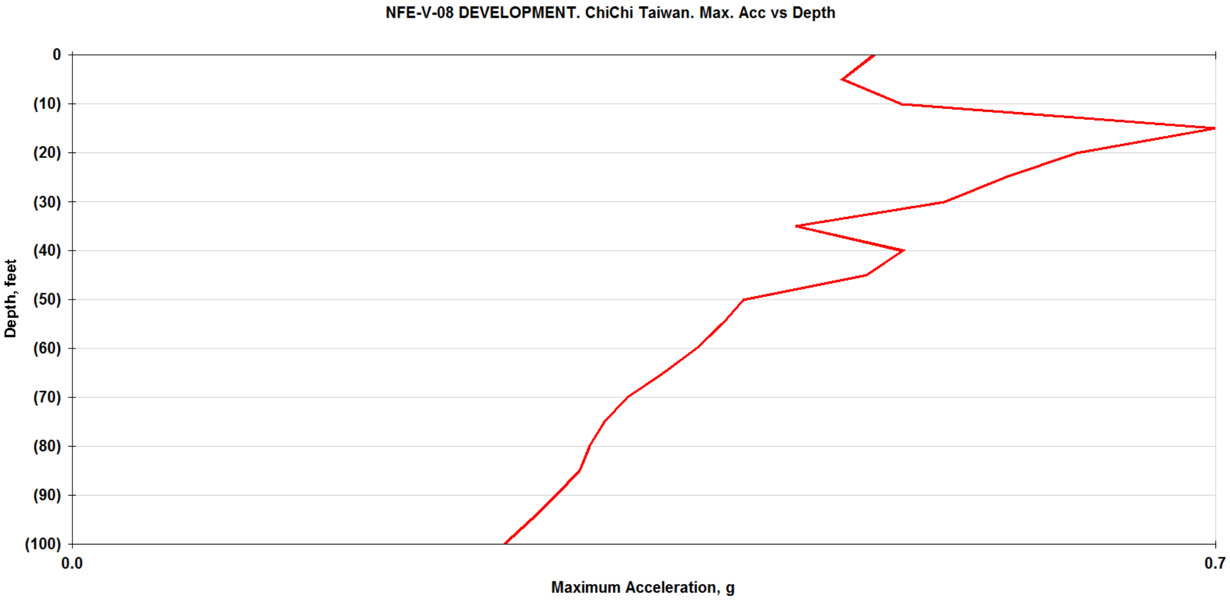
MAXIMUM GROUND MOTION ACCELERATION VS DEPTH

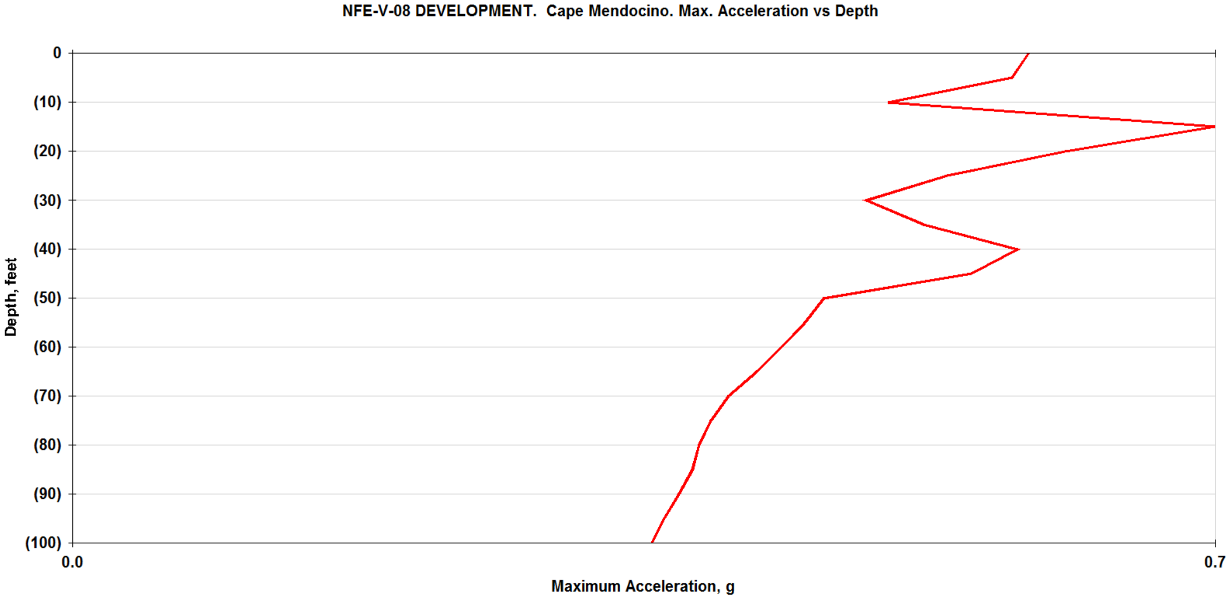
NFE-V-08 DEVELOPMENT. Loma Prieta. Max. Acc. vs Depth

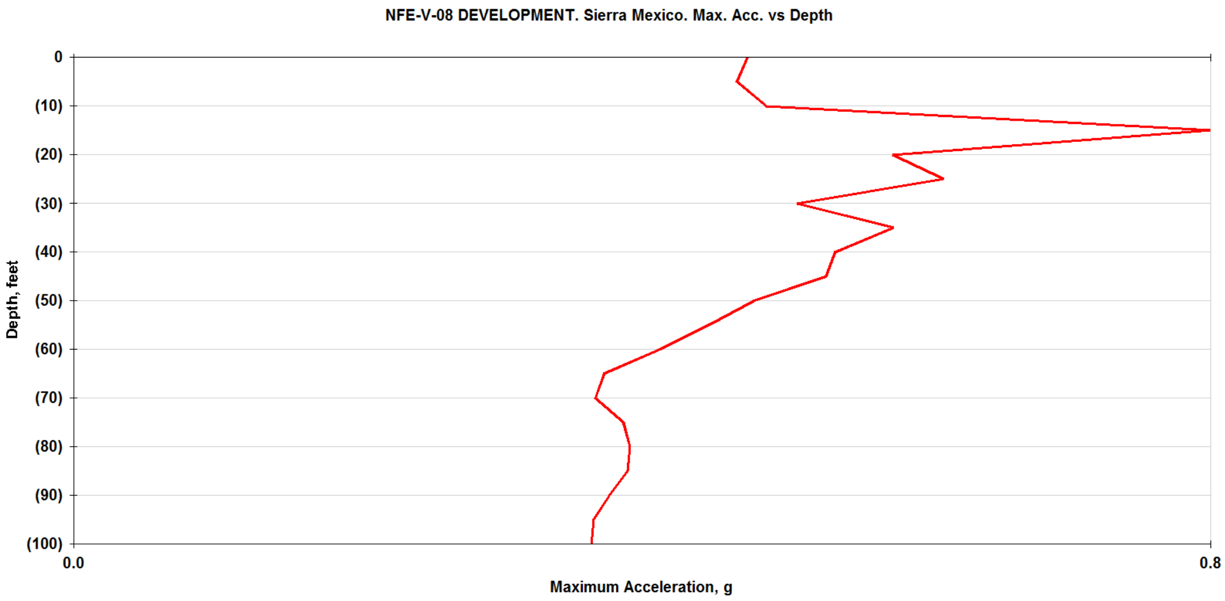


NFE-V-08 DEVELOPMENT. Hector Mine. Max. Acc. vs Depth

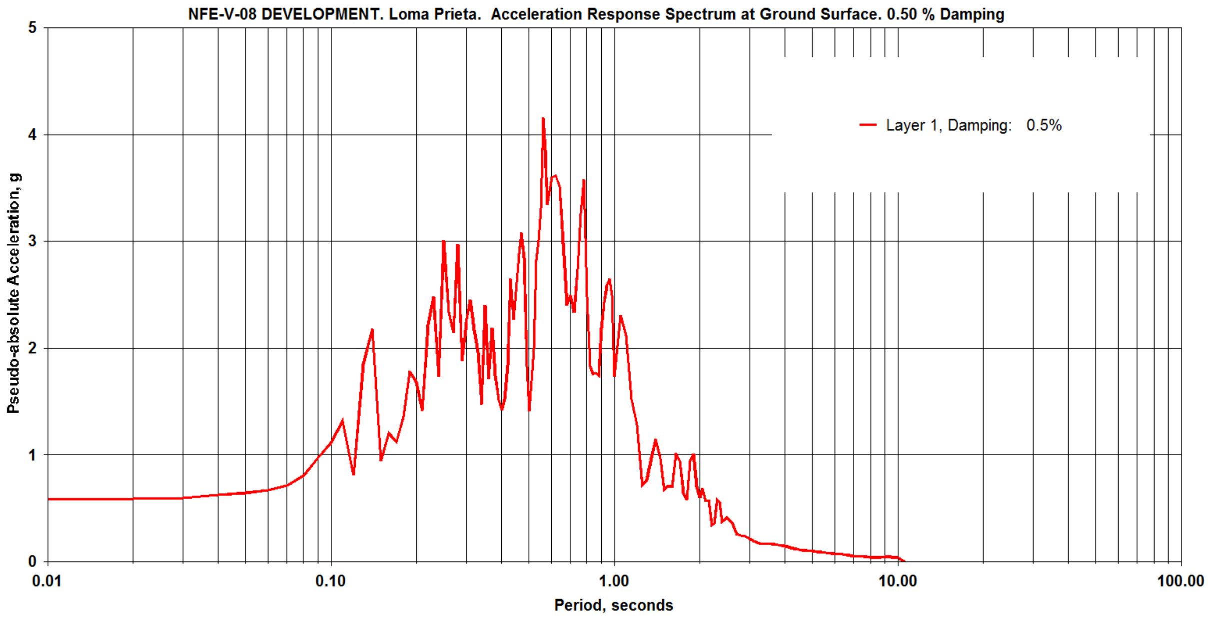


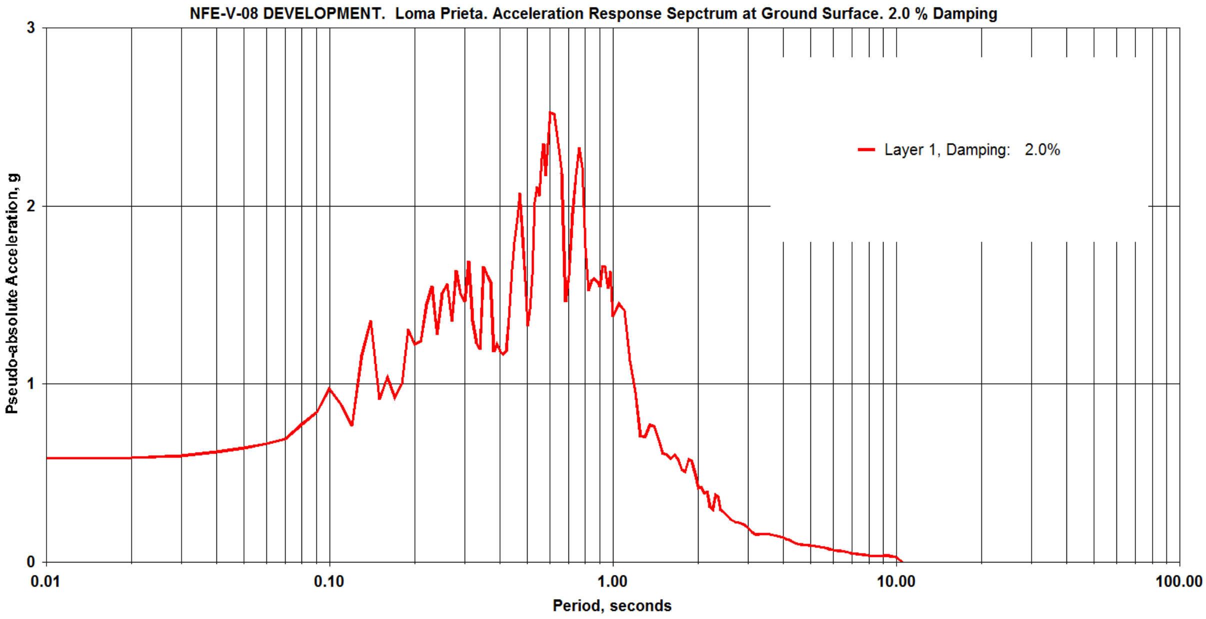

NFE-V-08 DEVELOPMENT. ChiChi Taiwan. Max. Acc vs Depth
0
(10)
(20)
(30)
(40)
(50)
(60)
(70)
(80)
(90)
(100)
Depth, feet
0.0
0.7
Maximum Acceleration, g

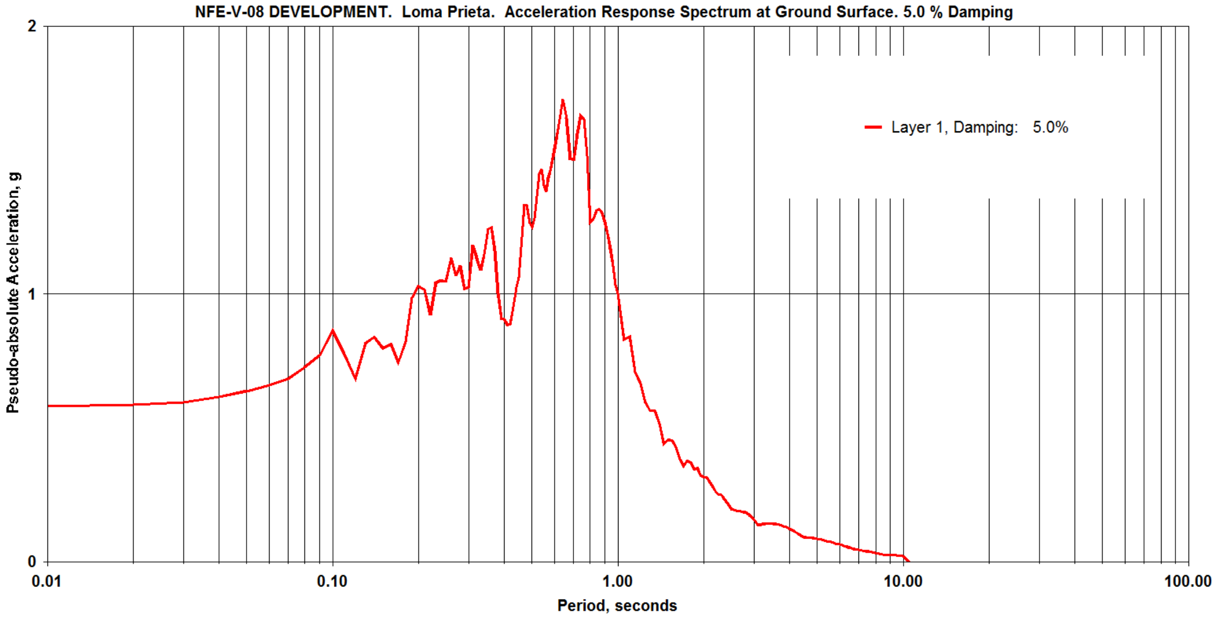

NFE-V-08 DEVELOPMENT. Cape Mendocino. Max. Acceleration vs Depth
0
(10)
(20)
(30)
(40)
(50)
(60)
(70)
(80)
(90)
(100)
Depth, feet
0.0
0.7
Maximum Acceleration, g


NFE-V-08 DEVELOPMENT. Sierra Mexico. Max. Acc. vs Depth
0
(10)
(20)
(30)
(40)
(50)
(60)
(70)
(80)
(90)
(100)
Depth, feet
0.0
0.8
Maximum Acceleration, g

RESPONSE SPECTRA AT GROUND SURFACE



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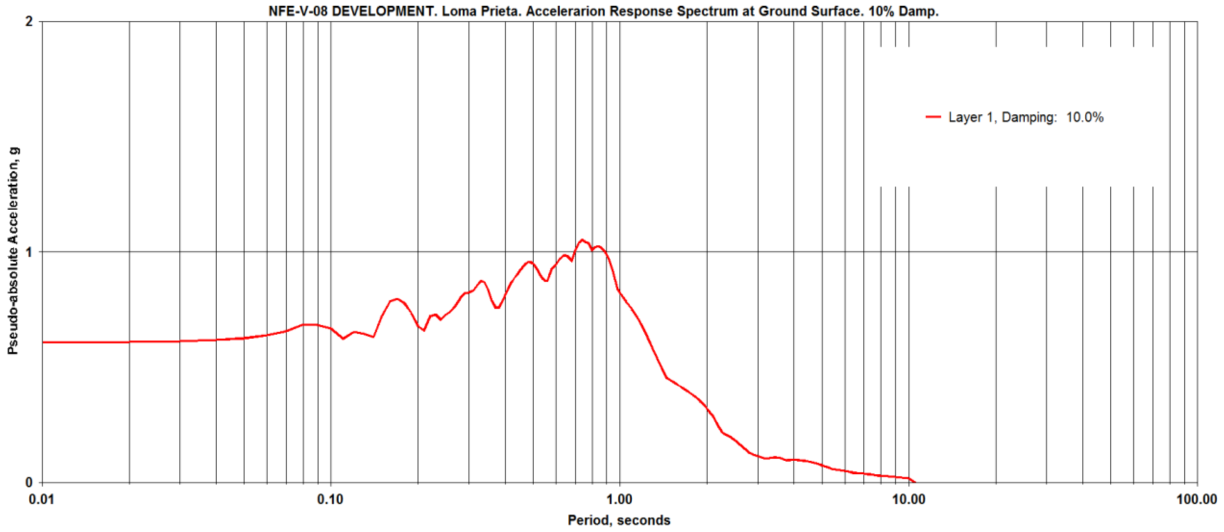
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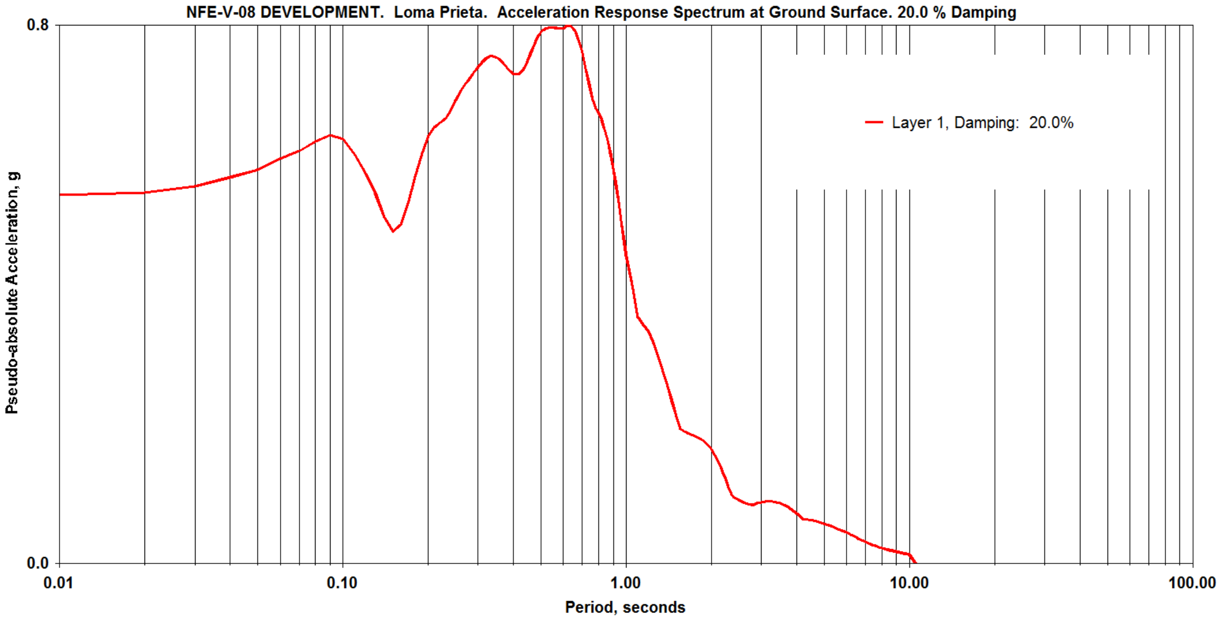
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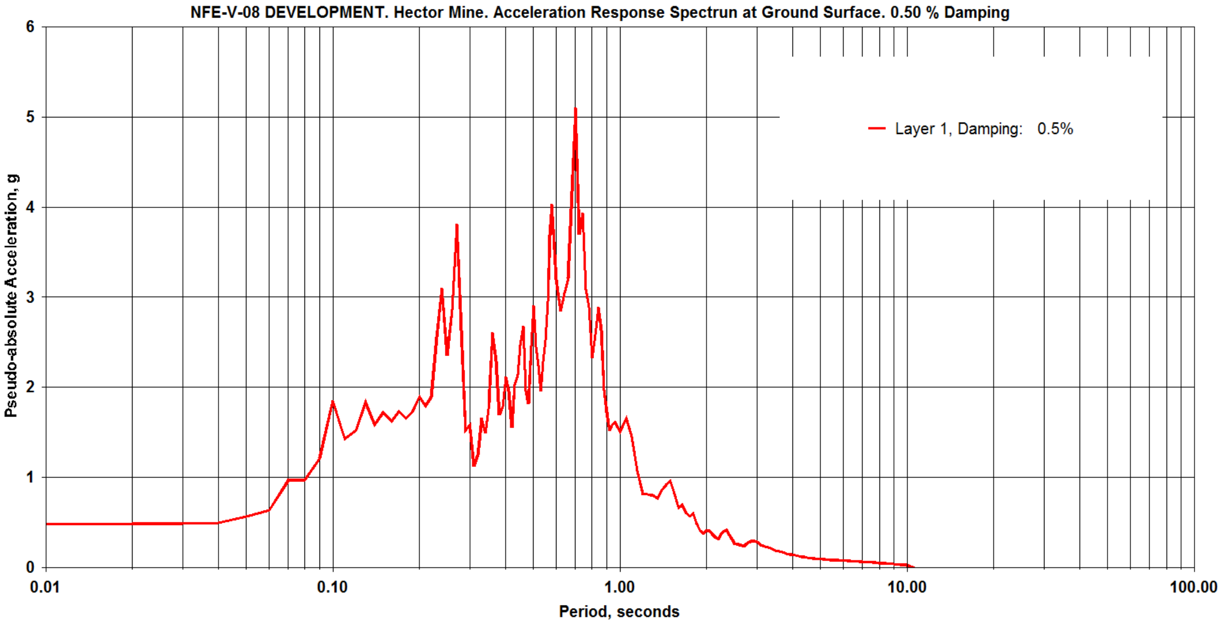
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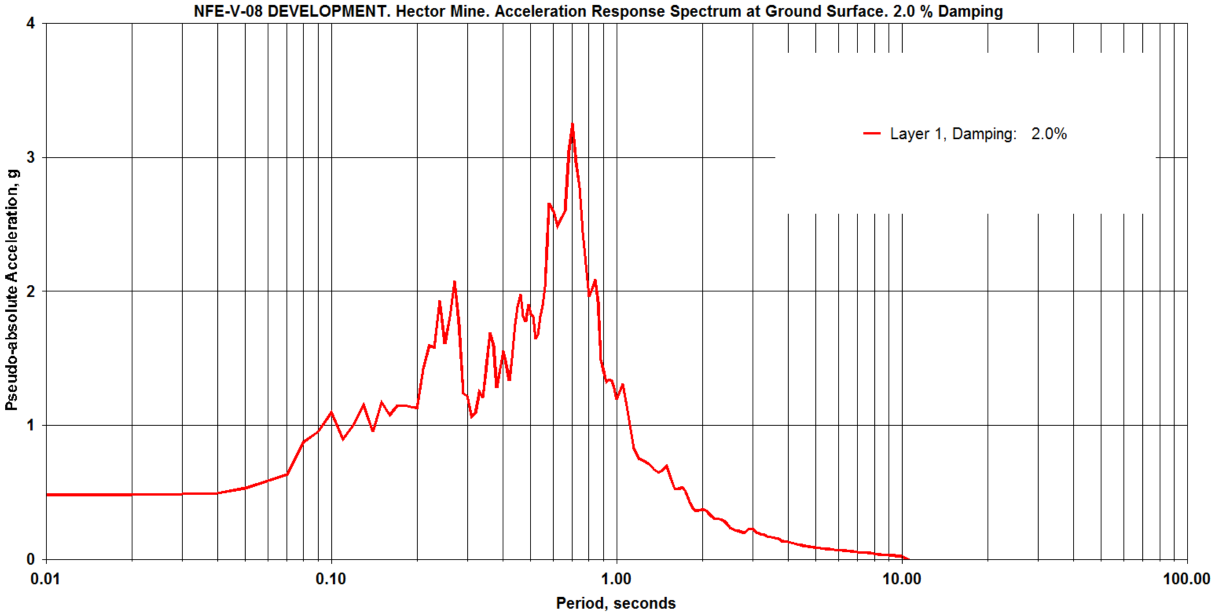
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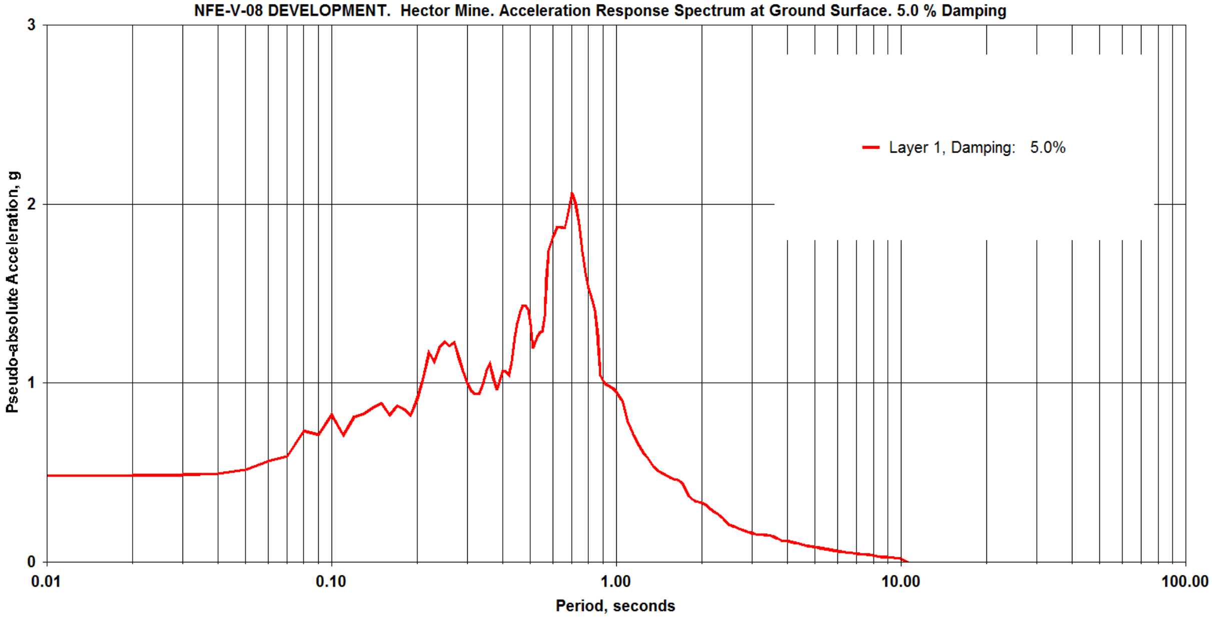
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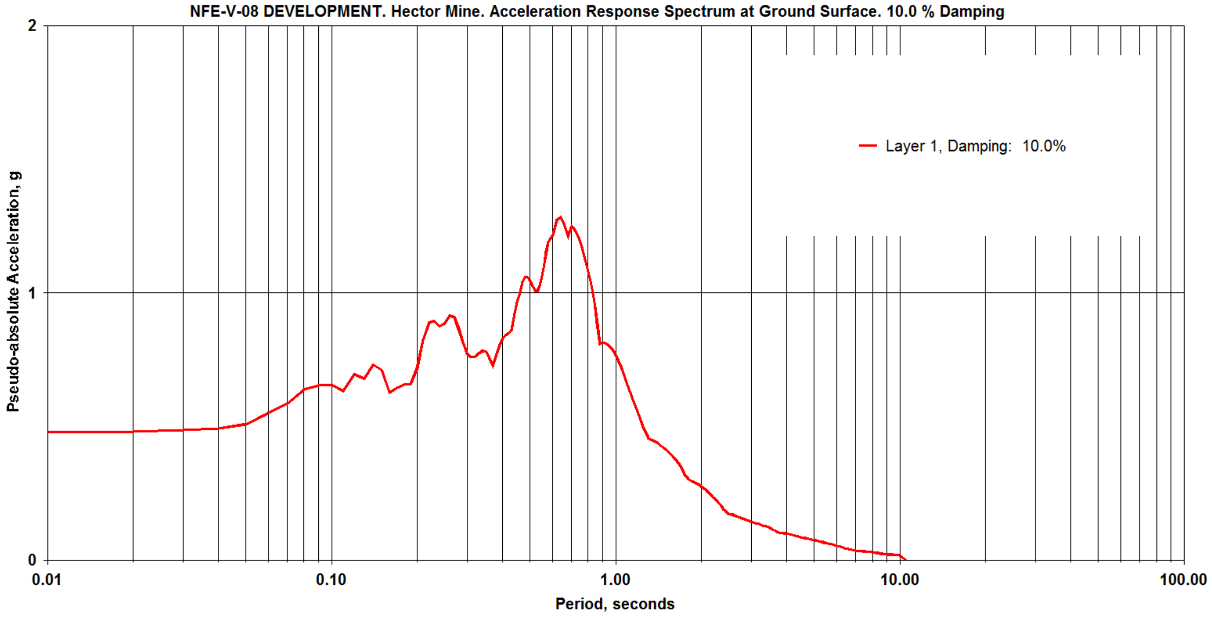
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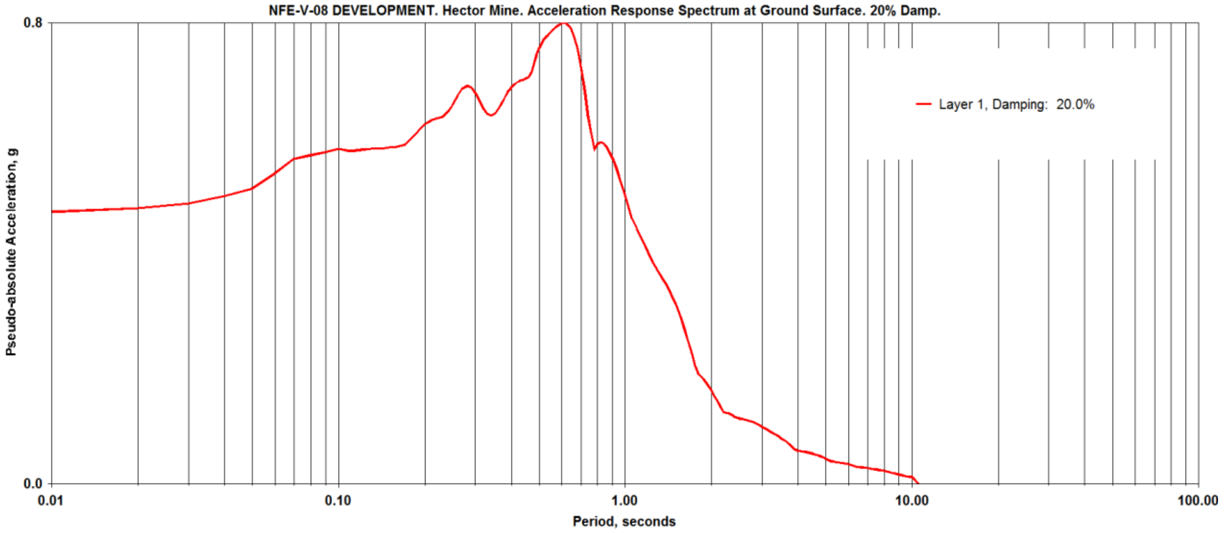
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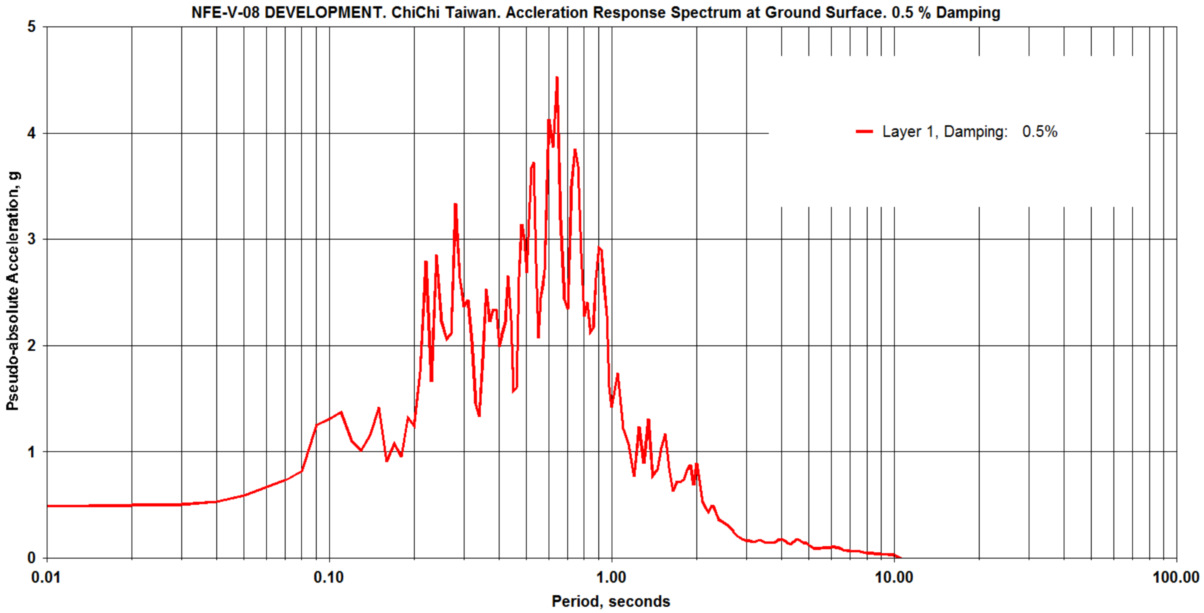
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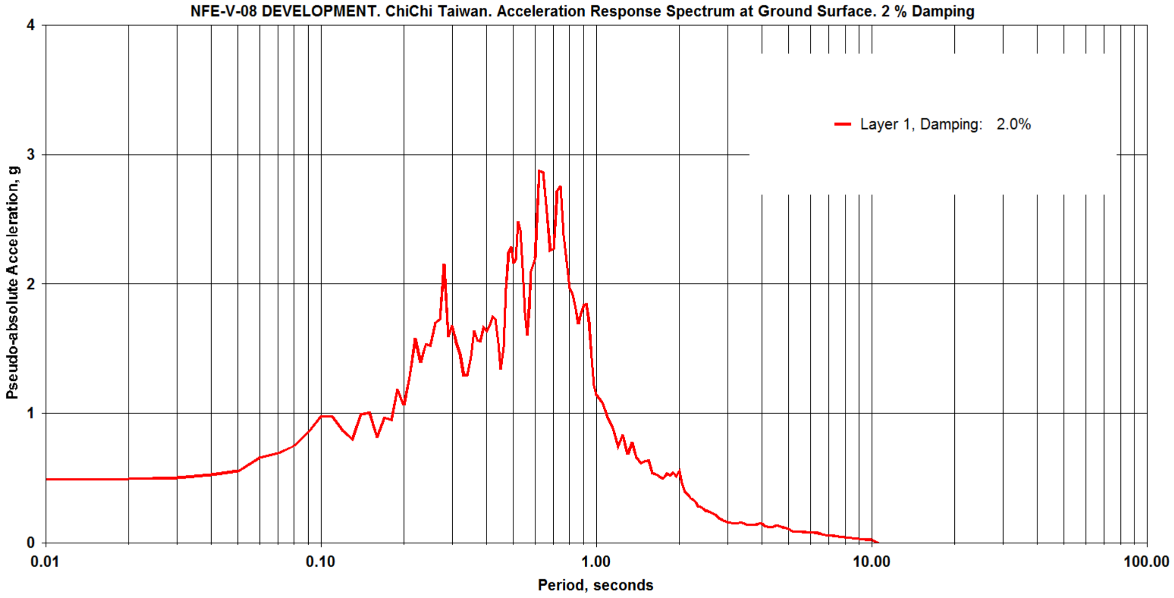
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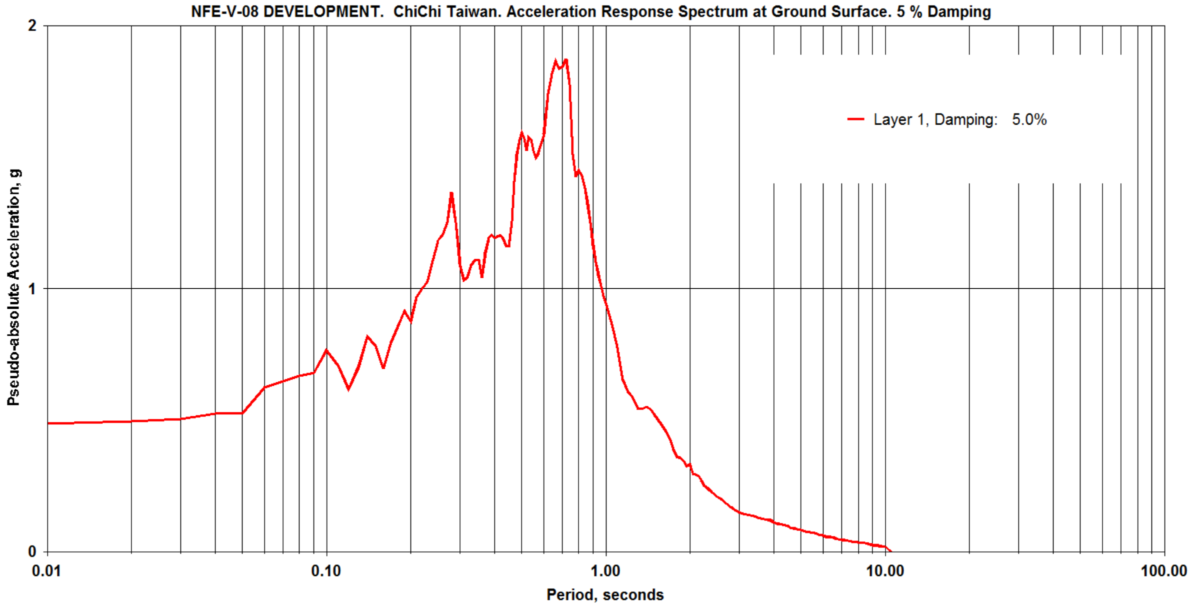
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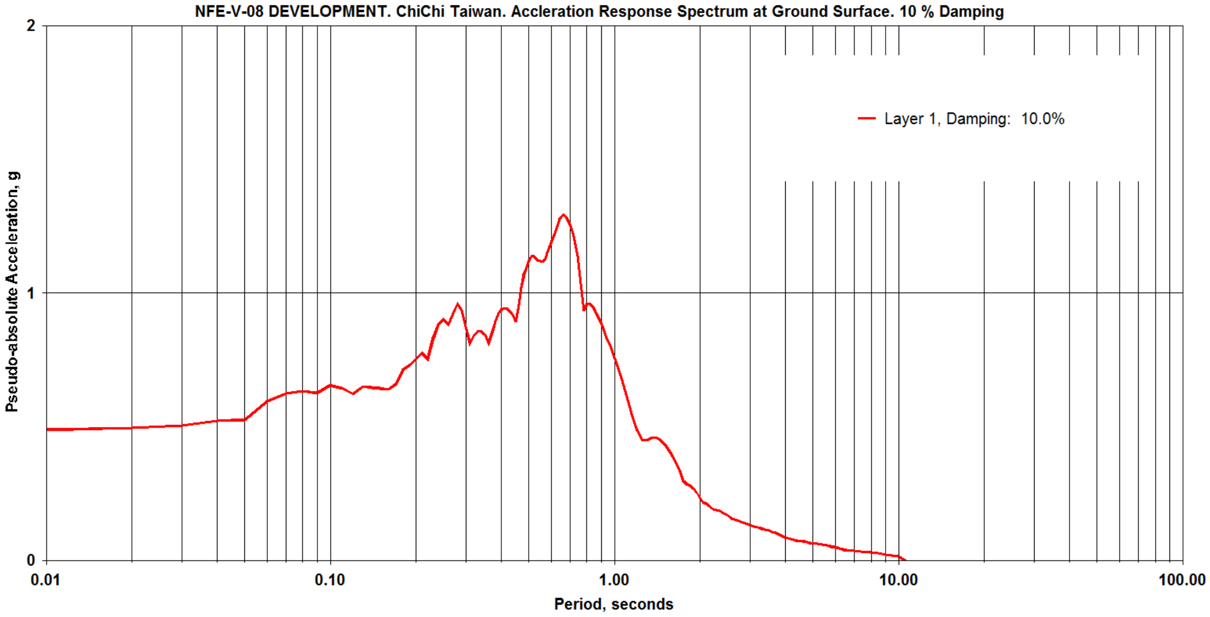
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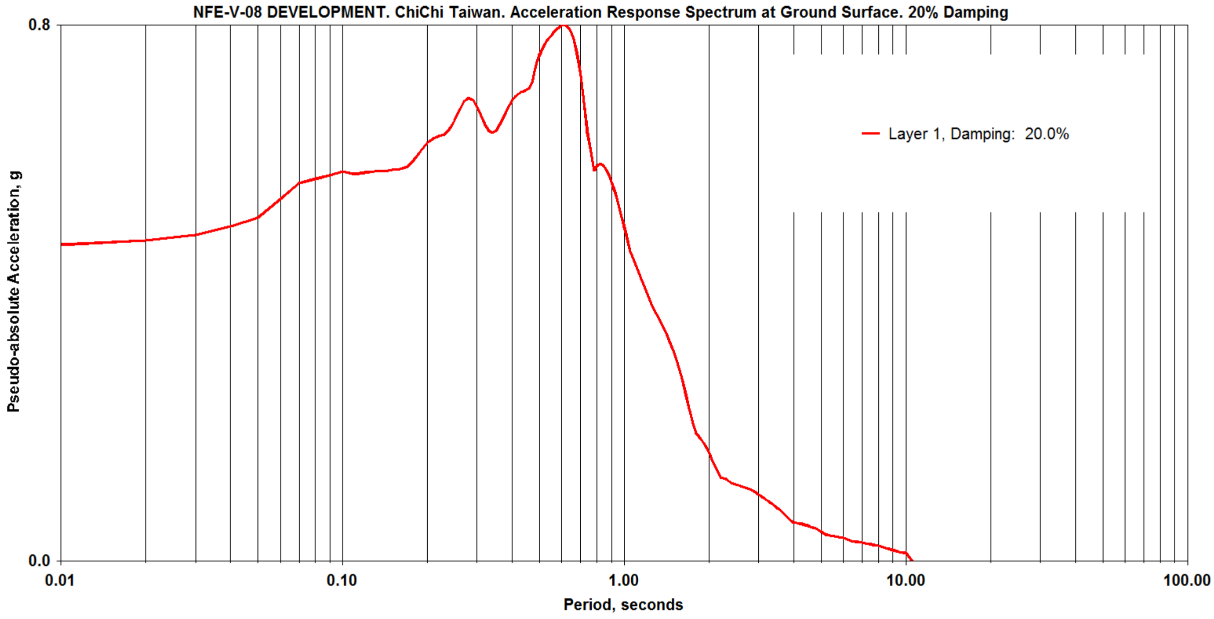
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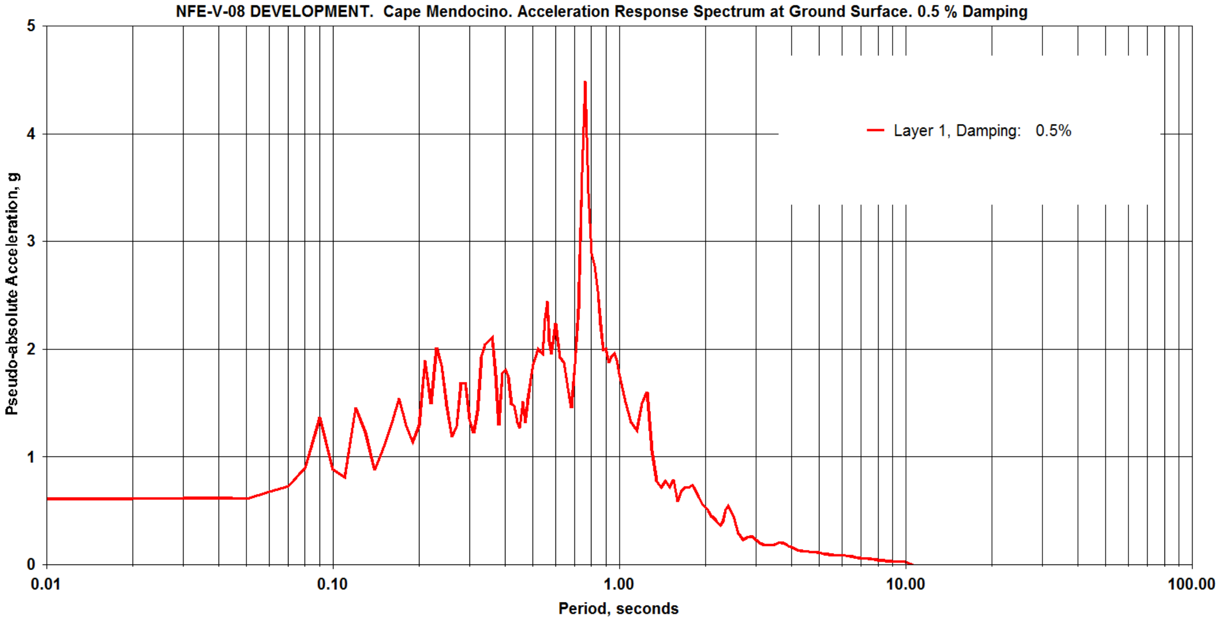
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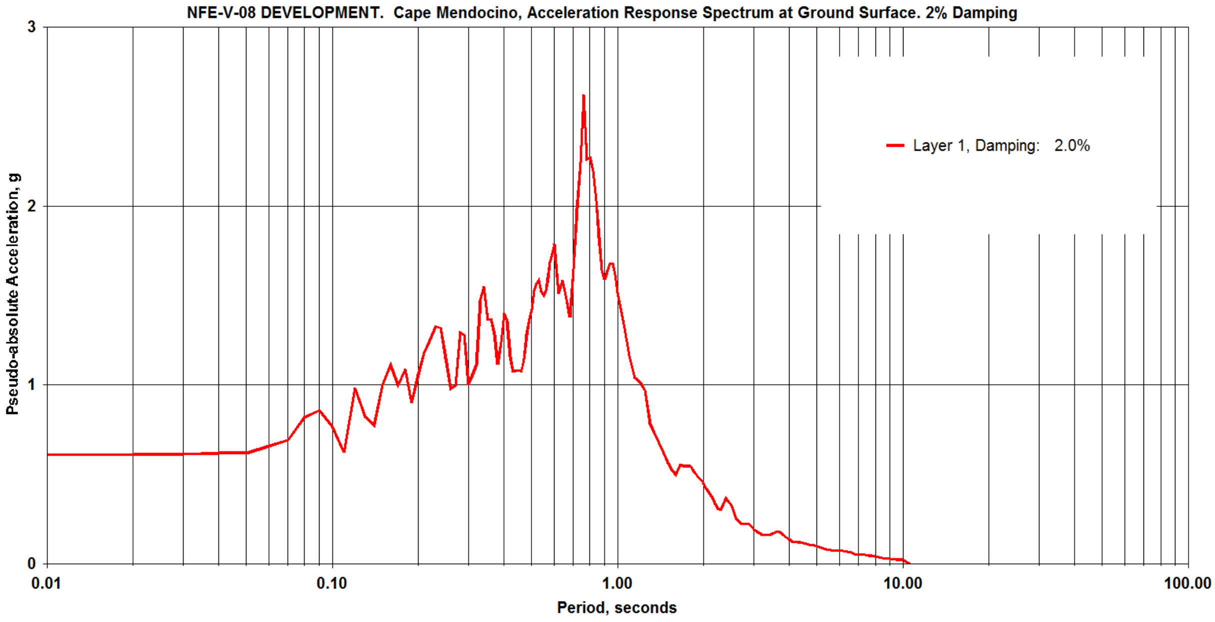
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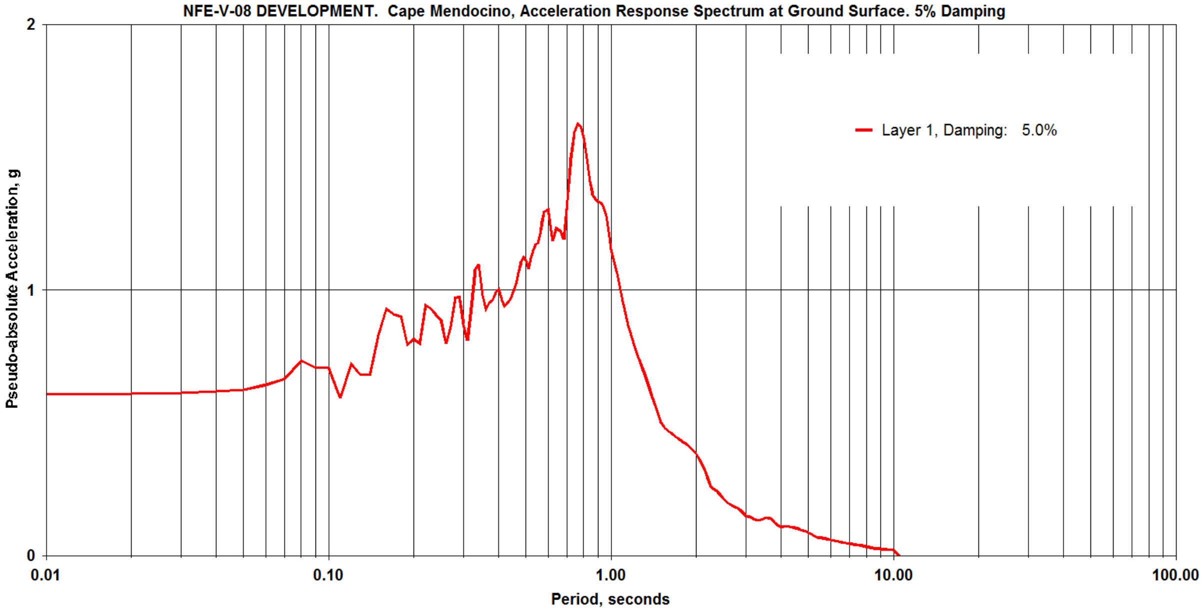
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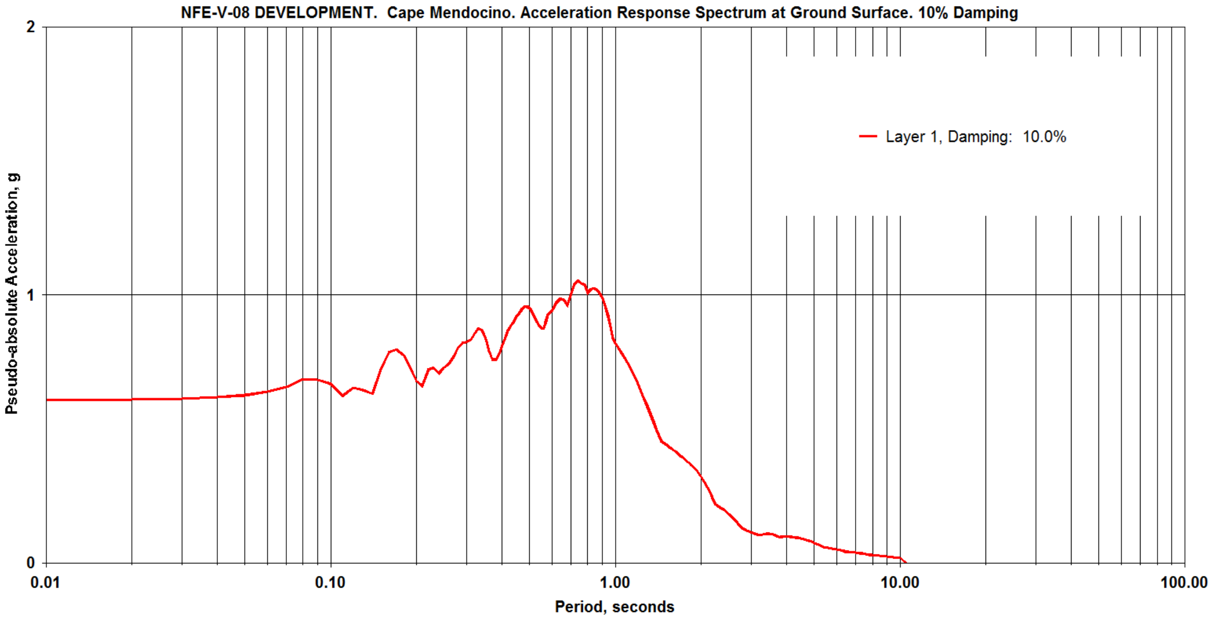
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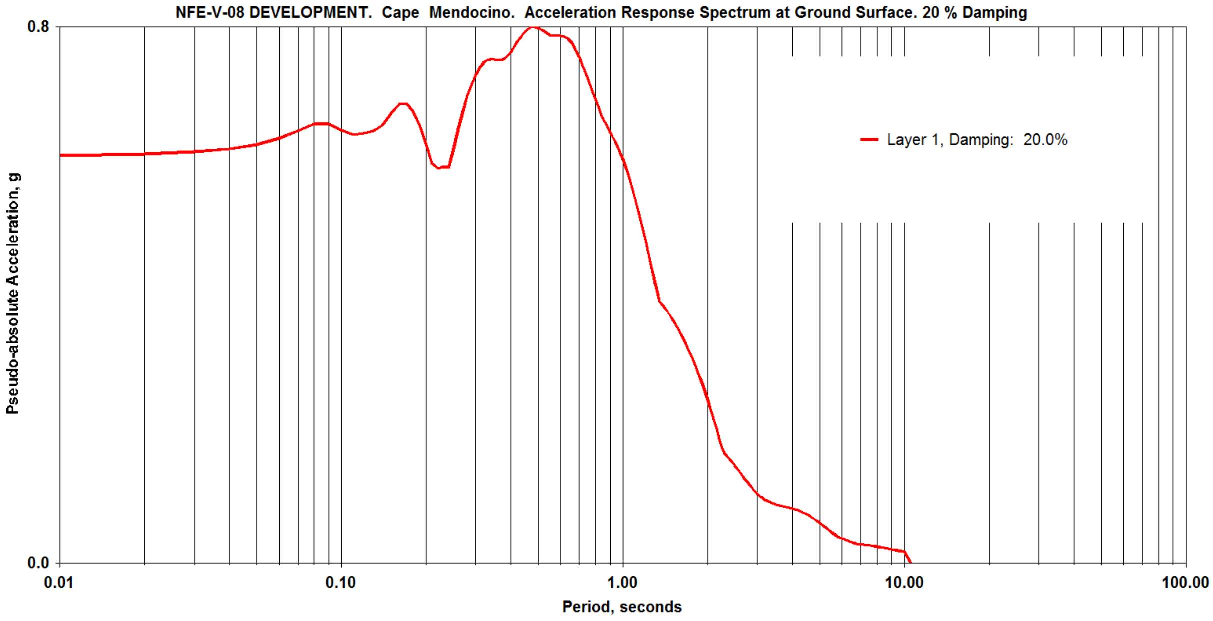
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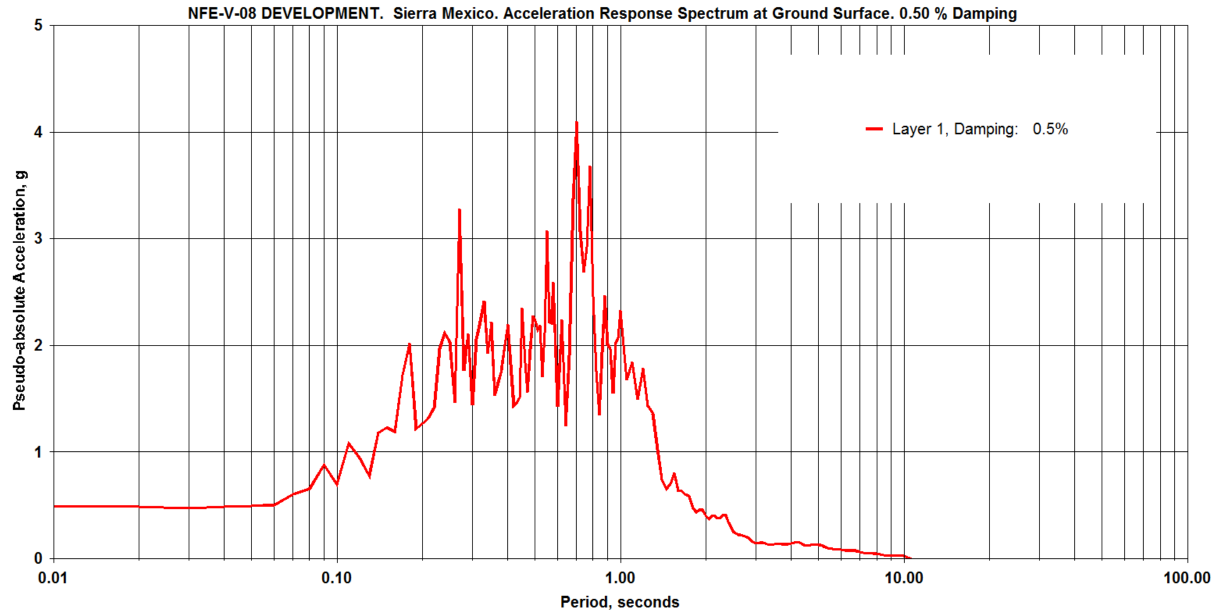
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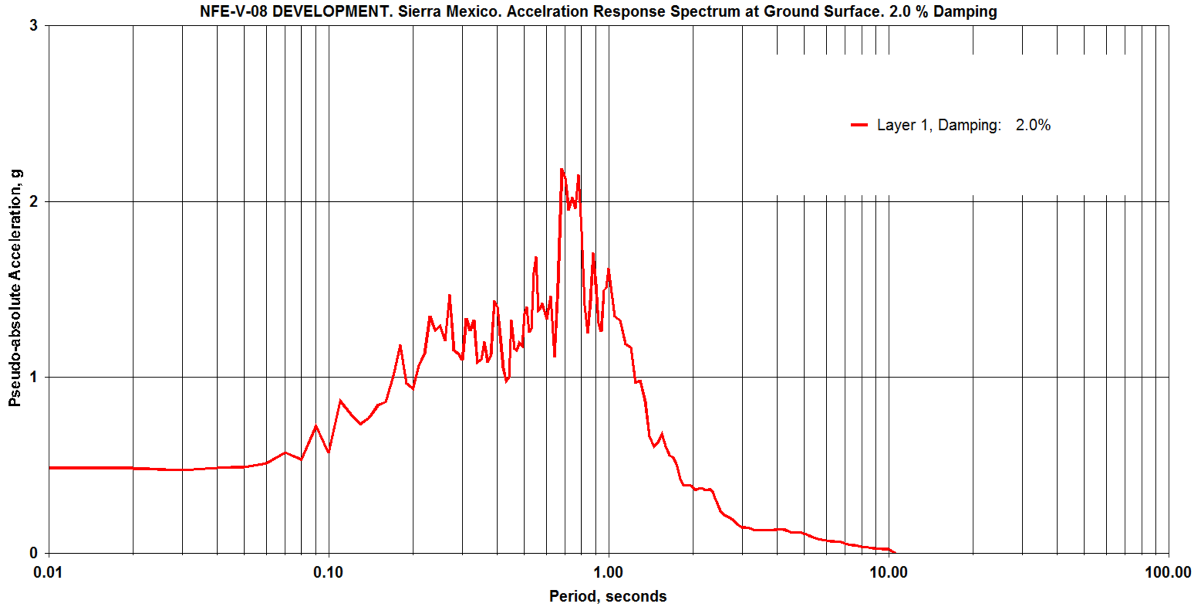
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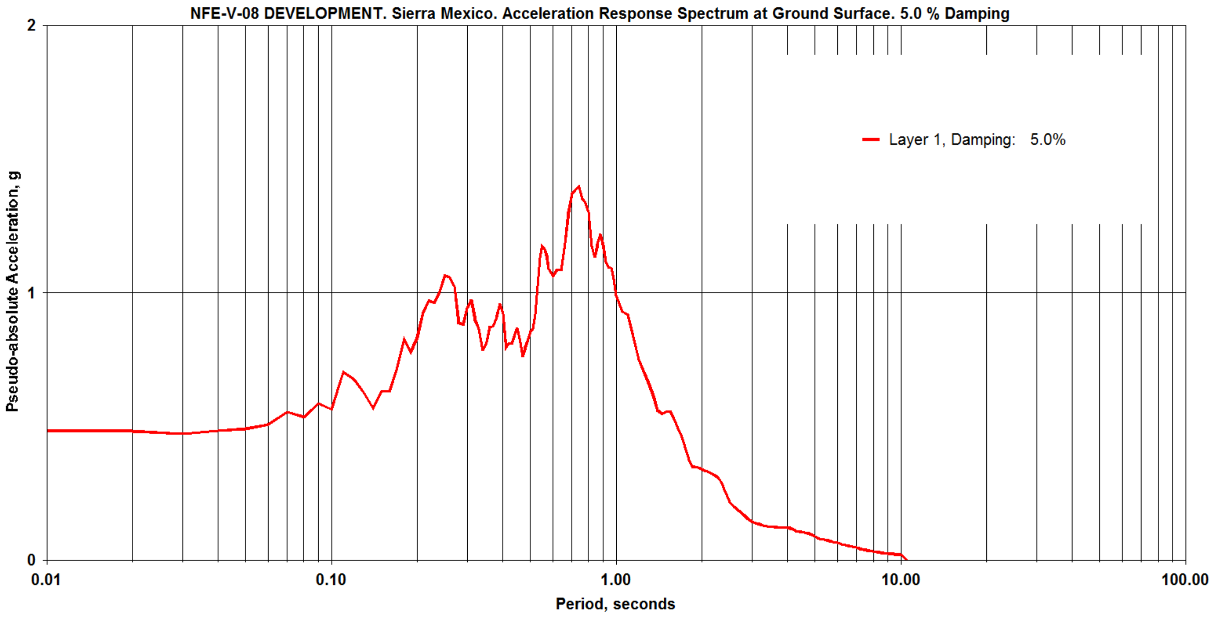
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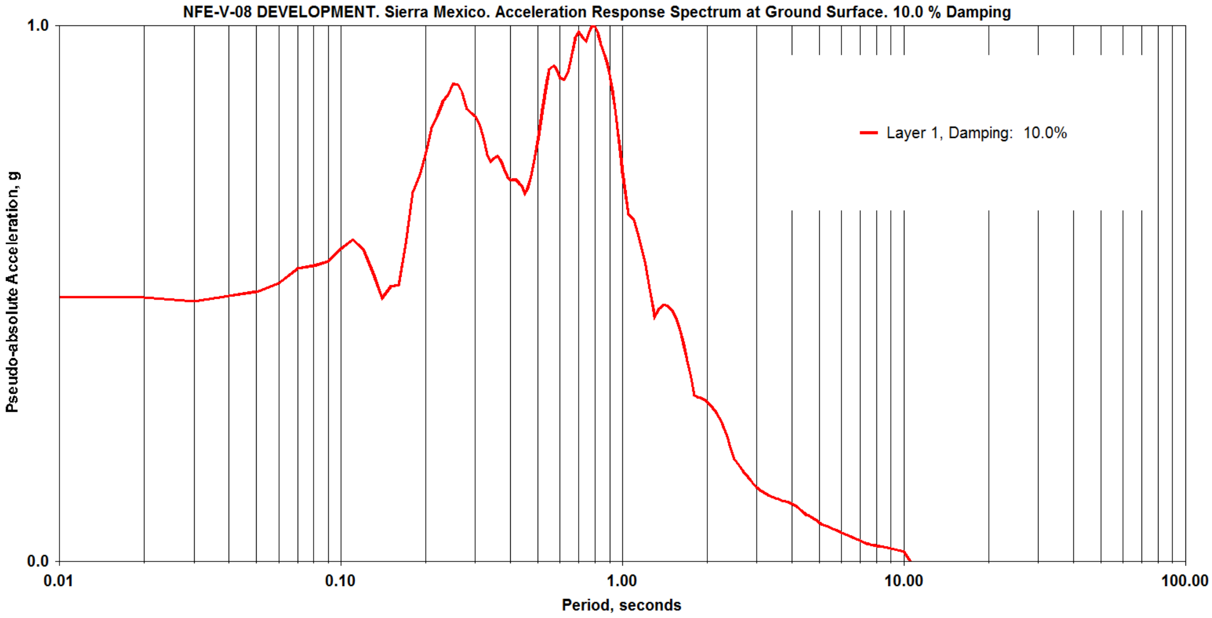
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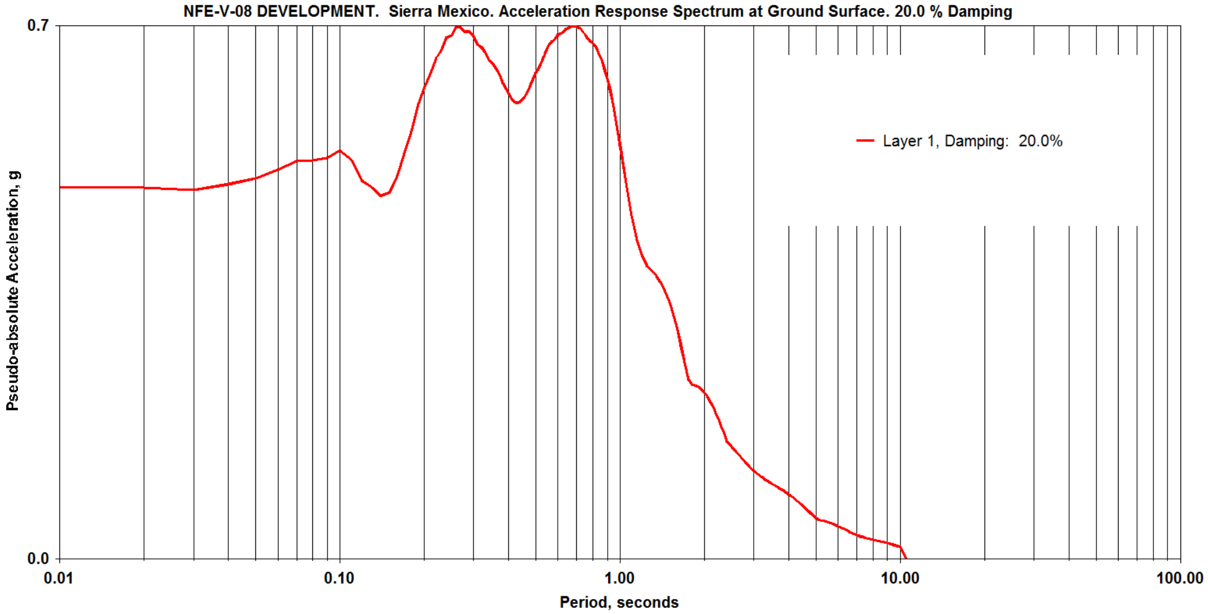
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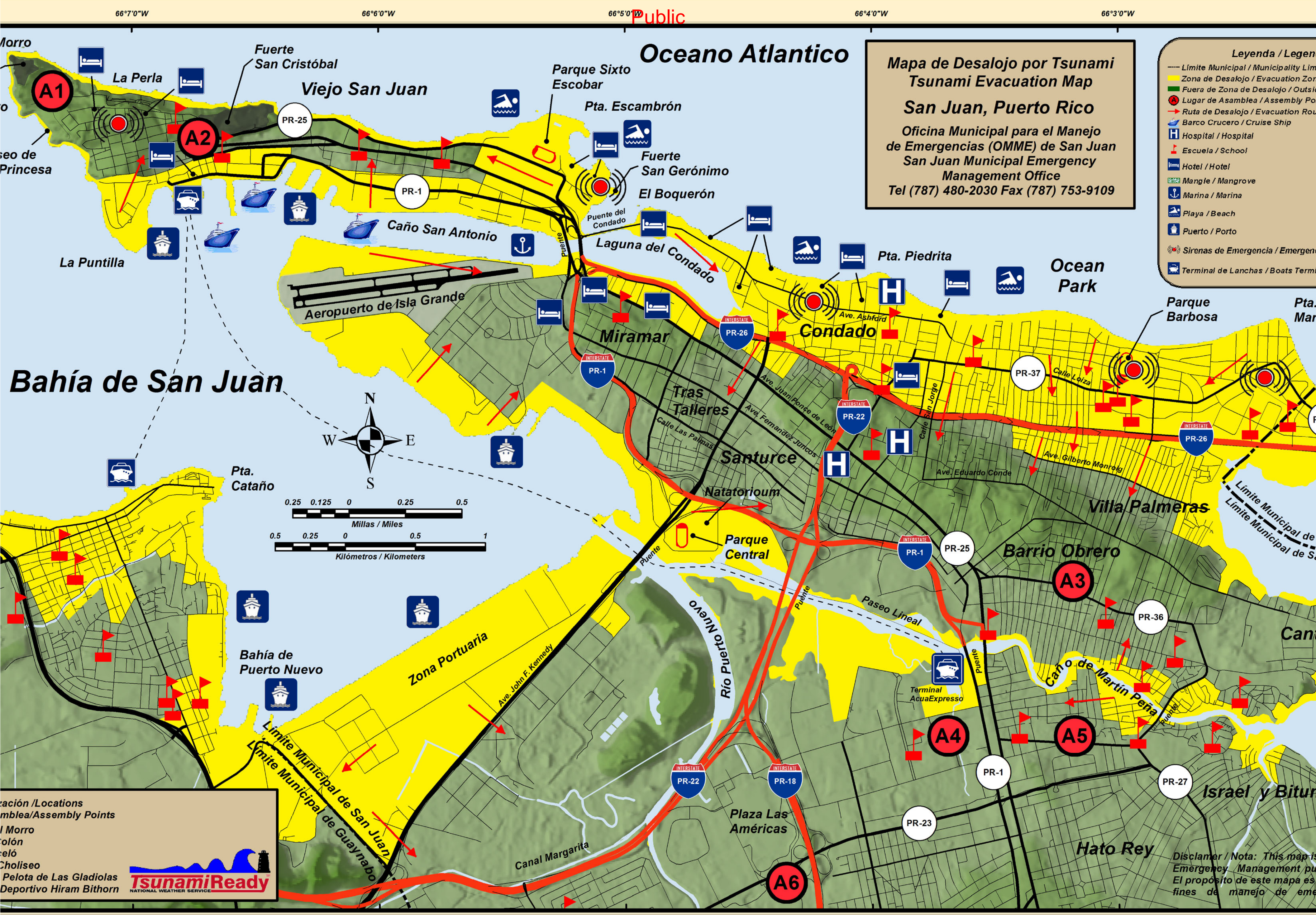
Appendix I.2



Mapa de Desalojo por Tsunami
Tsunami Evacuation Map
San Juan, Puerto Rico
Oficina Municipal para el Manejo
de Emergencias (OMME) de San Juan
San Juan Municipal Emergency
Management Office
Tel (787) 480-2030 Fax (787) 753-9109

Leyenda / Legen
---- Límite Municipal / Municipality Lim
🟨 Zona de Desalojo / Evacuation Zon
🟩 Fuera de Zona de Desalojo / Outsi
Ⓐ Lugar de Asamblea / Assembly Po
→ Ruta de Desalojo / Evacuation Rou
Barco Crucero / Cruise Ship
H Hospital / Hospital
Escuela / School
Hotel / Hotel
Mangle / Mangrove
Marina / Marina
Playa / Beach
Puerto / Porto
Sirenas de Emergencia / Emergen
Terminal de Lanchas / Boats Termi

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l Morro
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Choliseo
Pelota de Las Gladiolas
Deportivo Hiram Bithorn

TsunamiReady
NATIONAL WEATHER SERVICE

Disclamer / Nota: This map is
Emergency Management pu
El propósito de este mapa es
fines de manejo de eme

zación

Agencia Estatal para el Manejo de Emergencias
y Administración de Desastres (AEMEAD) Zona 1
Puerto Rico Emergency Management Agency (PREMA) Zone 1
Tel (787) 294-0277; Fax (787) 294-1165

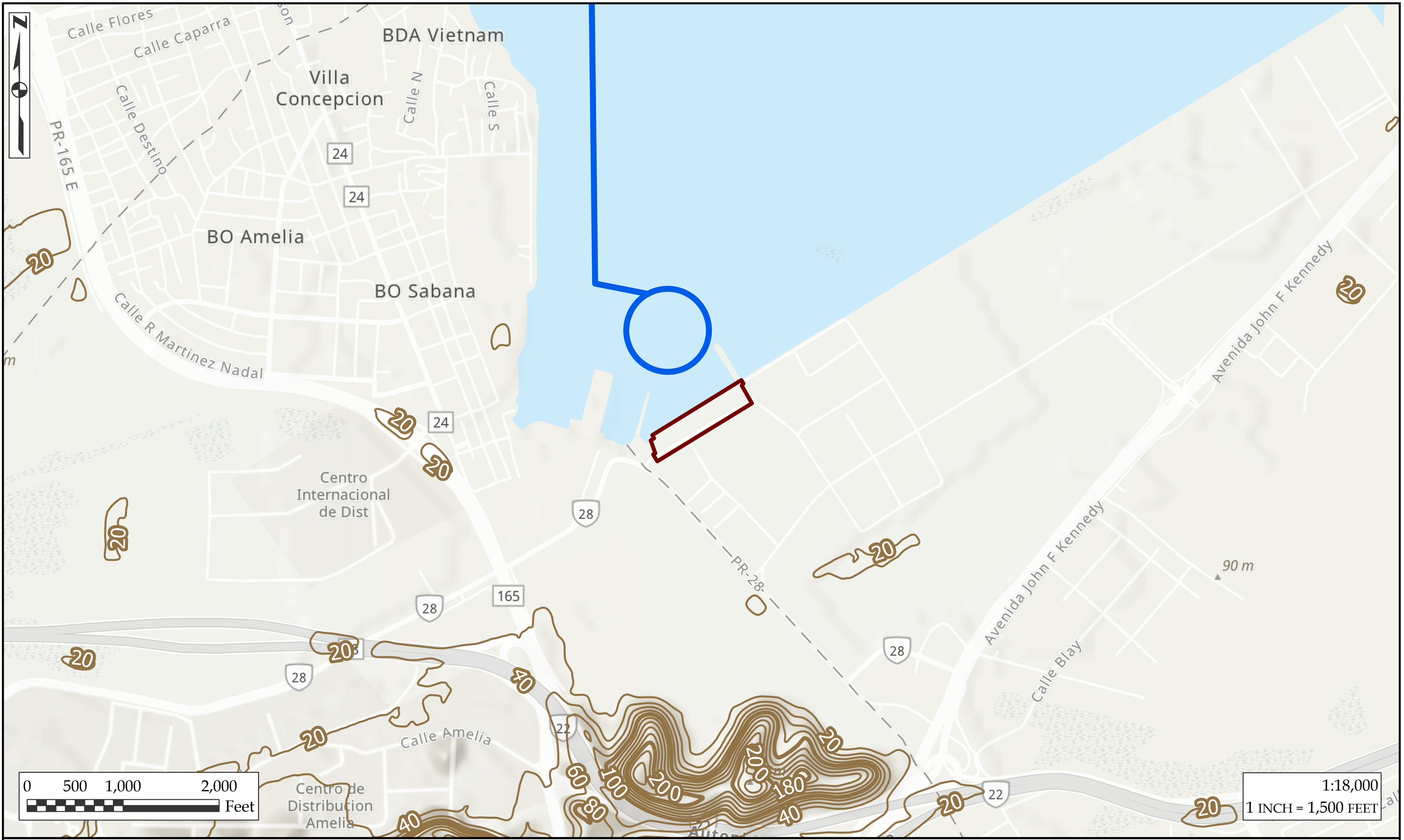
Appendix J.1

APRX Path | Layout Name: \\usbdcfs02\data\Boston\Team\DMMV\Clients_L_P\New_Fortress_Energy\Puerto_Rico_FERC\APRX\2021\2021_06_New_Fortress_FERC_Analysis\2021_06_New_Fortress_FERC_Analysis.aprx | Topographic_Map

Map Author: CAL.WILSON

Revised: 06/23/2021 | Scale: 1:18,000 when printed at 8.5"x11"

COORDINATE SYSTEM: WGS 1984 Web Mercator Auxiliary Sphere



Topographic Contours

100-ft Contours

20-ft Contours

Shuttle Vessel Route

Site Boundary

Data Citations

1. U.S. Geological Survey, National Geospatial Technical Operations Center, 20190306, USGS Topo Map Vector Data (Vector) 39644 San Juan, Puerto Rico 20190306 for 7.5 x 7.5 minute FileGDB 10.1: U.S. Geological Survey.
2. Puerto Rico Centro de Recaudación de Ingresos Municipales

Figure 1-2

Topographic Contour Map

San Juan Micro-Fuel Handling Facility - NFEnergía, LLC
San Juan, Puerto Rico

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This information is for environmental review purposes only.

Appendix J.4

JACA & SIERRA
Testing Laboratories
Geotechnical Engineers

REPORT

ON THE GEOTECHNICAL EXPLORATION PERFORMED AT THE SITE OF THE PROPOSED NFE MICROFUEL HANDLING FACILITY PUERTO NUEVO WHARF, SAN JUAN, PR

Submitted to:

Mr. Winnie Irizarry

NFEnergia

Prepared by:
Carlos R. Sierra Del Llano MSCE, PE
Jaca & Sierra Engineering, PSC

CARLOS SIERRA DEL LLANO
INGENIERO LICENCIADO
LIC.#18664

Date:
March 8, 2019
Job No. 7812A

This report contains 160 pages including cover

Table of Contents:

1.0 INTRODUCTION: 2
2.0 SCOPE OF WORK: 3
  2.1 Field Work: 3
  2.2 Laboratory Work: 4
3.0 SUBSOIL GENERALIZED CONDITIONS: 5
  3.1 Geology: 5
  3.3 Groundwater: 9
4.0 GEOTECHNICAL RECOMMENDATIONS: 10
  4.1 Liquefaction Potential and Seismic Settlements: 10
    4.1.2 Liquefaction Induced Lateral Spreading Concern: 12
    4.1.3 Liquefaction Mitigation: 13
  4.2 Deep Foundations: 13
    4.2.1 Field loading Tests and Quality Monitoring: 15
  4.3 Truck Scales, Truck Loading Skid and Pipe Racks: 16
  4.4 Existing Bulkhead Evaluation: 19
    4.4.1 Parallel Seismic Survey-Existing Bulkhead Depth Estimate: 19
    4.4.2 Earth Pressure Parameters on the Bulkhead: 21
    4.4.3 Pipe Pile "A" Frame for Lateral Support of the Bulkhead: 23
    4.4.4 Tieback anchors for Lateral Support of the Bulkhead: 24
  4.5 38 KV Electrical Substation: 25
  4.5 Impoundment Structure: 27
  4.6. Fill Placement Guidelines: 29
  4.7 Pavement Design Recommendations: 30
    4.7.1 Subgrade: 32
    4.7.2 Subbase: 33
    4.7.3 Base Course: 33
    4.7.4 Light Duty Asphalt Section: 34
    4.7.5 Heavy Duty Asphalt Section: 34
    4.7.6 Heavy Duty Asphalt Section II- Reinforced Section: 35
    4.7.6 Concrete Section: 36
5.0 ADDITIONAL COMMENTS: 36

REPORT

ON THE GEOTECHNICAL EXPLORATION PERFORMED AT THE SITE OF THE PROPOSED NFE MICROFUEL HANDLING FACILITY PUERTO NUEVO WHARF, SAN JUAN, PR

1.0 INTRODUCTION:

The present report covers the results of the geotechnical exploration conducted at the site of the proposed energy facilities at berths A, B and C in Puerto Nuevo Wharf, San Juan, PR.

Jaca & Sierra Engineering, PSC was contracted by **NFEnergia, LLC** to perform site investigations and prepare geotechnical recommendations for the purpose of developing design drawings for the reference project.

The geotechnical exploration program was directed to obtain subsurface soil information to be utilized in the formulation of the pertinent recommendations for the intended structure foundation system.

This report references the following documents:

1. Probabilistic Seismic Hazard Analysis (PSHA) and Site Specific Response Spectrum report for NFE V-08 by Terratec, Inc dated February 2018

2. 75% design drawings submittal by Moffat and Nichol (M&N) titled NFE V-08 Berth Repair dated 2018-12-06

This subsurface investigation was conducted as a function of information given by Moffatt & Nichol (M&N), project's civil designers.

This soil report has been prepared for the exclusive use of the owner, their architects, engineers and others involved in the preparation of the design plans and specifications of the project.

2.0 SCOPE OF WORK:

2.1 Field Work:

Test borings were made in different phases, the first completed on December 2017 and the second phase in December of 2018. The first phase of fieldwork consisted of drilling seven (7) test borings: Four (4) were drilled up to 60-70 ft depth (B-1 thru B-4); two (2) to 120 ft depth (C-1 and C-2); and one (1) to 100 ft depth (SWV-1). At the location of SWV-1 a Down Hole Seismic (DHS)-ASTM D5400- test was performed. Additional field works included three (3) Cone Penetrations Test (CPT) near the locations of borings no. C-1, C-2 and B4 and a parallel seismic survey near the bulkhead at the vicinity of C-1. In addition, a total of eight (8) Shelby tube samples were extracted from cohesive soils within the upper 30 ft for performance of specialized soil mechanics laboratory testing, such as triaxial shear and consolidation tests.

The second phase of investigation consisted of 10 shallow borings to complete a pavement design assessment: one (1) 80 ft deep boring for the impoundment pond; one (1) 60 ft boring for the electrical substation; and two (2) borings to 30 ft depth at the proposed truck scales. In addition, ten (10) borings to 10 ft depth were made for pavement evaluation purposes. Also an additional boring was performed on the water side within the existing pile supported wharf deck. Field work also included a parallel seismic test conducted near the existing bulkhead to verify probable depth of the existing sheet piles.

In situ testing and soil sampling were achieved by means of the universally adopted Standard Penetration Test (SPT) and split spoon sampler method according to ASTM D 1586. Subsurface drilling was executed by means of the power auger method as per ASTM D 1452 using a CME-55 drill rig to drive a 3 inches ID helical auger into the ground. SPT sampling was completed with an automatic SPT hammer.

2.2 Laboratory Work:

The soil samples were saved in jars and transported to our laboratory for visual and manual description by an engineer. In the laboratory, the soil composition was identified and the presence of any organic matter or characteristic that may be unsuitable for the proposed structure was observed. The laboratory tests performed were the following: moisture contents, unconfined strength, unit weight, soil classification (sieve analyses and Atterberg limits), consolidation tests, organic content, unconsolidated undrained (UU) and Consolidated Undrained (CU) triaxial tests.

The field and laboratory information was collected to prepare boring logs, which reveal the stratigraphy and soil properties at each boring explored. This report was based on the information obtained in the boring logs, laboratory tests and information submitted to us.

3.0 SUBSOIL GENERALIZED CONDITIONS:

3.1 Geology:

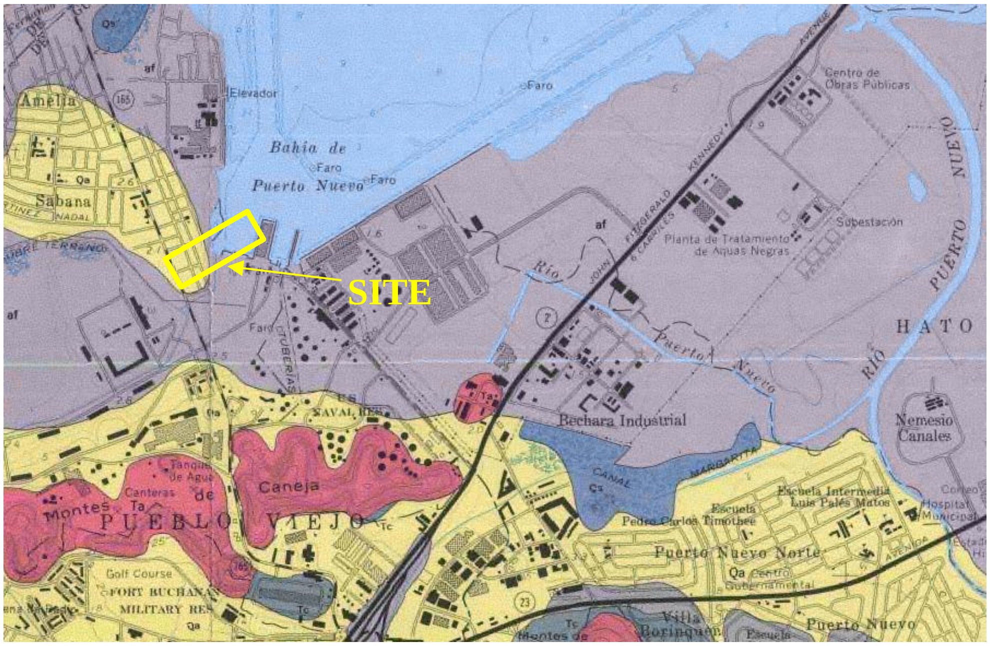

Figure 1: Site location in USGS geology map

According to the U.S. Geological Survey (USGS) geologic map of the San Juan Quadrangle[1], the surface geology of the explored area consists of Artificial (Af) (see Figure 1). The USGS describes the mentioned deposit as follows:

Af – Artificial Fill (Holocene) *"Sand, limestone and volcanic rock as fill in valleys, swamps and locally a part of Bahia de San Juan."*

Based on our interpretation of the stratigraphy the following units are also present below surface in the order of mention:

Qs- Swamp Deposits (Holocene)-*"Sand, muck and clayey sand; generally underlain by peat formed in mangrove swamps. Most areas mapped as artificial fill are underlain by swamp deposits."*

QTt- Older Alluvial and Terrace Deposits (Pleistonce and Pliocene)- "*Clay, silty and sandy, mainly red or mottled red and light gray."*

Tc-Cibao Formation (*Miocene and Oligocene****) "****Chalk, soft, pale gray limestone and very pale orange sandy clay."*

---

[1] MH Pease Jr. and W.H. Monroe. (1977) Geologic Map of the San Juan Quadrangle, Puerto Rico. United States Geological Survey(USGS), Department of Interior, Reston, VA-Map I 1010

3.2 Stratigraphy:

In general, soil stratigraphy is characterized by an upper man-made fill, underlain by soft clayey swamp deposits with occurring sand lenses or pockets of variable thickness, followed by older alluvial and terrace deposits found in consolidated state. The limestone horizon, interpreted to consist of the Cibao formation, occurred at depths of 70 to 80 ft and extending to the bottom of the deepest boring of 120 ft beneath ground surface.

Stratum no. 1: *Man Made Fill/Hydraulic Fill*

The upper stratum consists of man-made fill. This upper fill can be subdivided into two different descriptions, the granular surface fill comprised of gravelly sand mix used for pavement base and sub-base and the underlying sandy hydraulic dredge fill used to reclaim land over the wharf area. The upper coarse granular fill had variable thickness from 2 to 4 ft thick. The SPT N values, which were typically over 20 blows/ft, indicated medium to dense relative density.

The hydraulic fill consists of sandy material extracted from the Bay of San Juan during dredging and deposited within areas to be reclaimed. Our subsurface investigation uncovered that the dredge fill has a thickness in the order of 30 ft near the existing bulkhead and about 9 to 10 ft in other further inland parts of the site. SPT N values recorded were variable from values in the order of WH to 10 blows/ft. The SPT N values generally had a decreasing pattern with the depth. High SPT values occurring at certain depths are due to the presence of shell and coral fragments larger than the sampler size which cause an unrealistic high value which is not necessarily a representation of fill material density.

Stratum no. 2: *Soft Deposits- Silt, Clay and Sand*

The second stratum is mainly composed of swamp or bay bottom deposits. This stratum chiefly occurs as a very-soft to soft consistency clayey silt to silty clay with traces of organic matter. Sand and shell fragments were detected mostly as lenses or pockets. This stratum tends to have medium consistency or certain degree of over-consolidation near the transition with the upper fill and likewise below near the older alluvial deposits below. Elsewhere within this horizon, the soil was found to be very soft and unconsolidated. SPT N values for this stratum ranged from Weight of Hammer (WH) to values typically below 10 blows/ft. Shelby tube samples were extracted mostly from this stratum for the evaluation of its consolidation properties. Moisture contents for this unit varied from about 40% to 80%, with most values in the range of 60% to 80%, which is an indication of potential for soil compressibility.

Stratum no. 3: *Stiff Silty Clay, Sandy Clay, Clayey sand*

The third stratum is mainly composed of older consolidated alluvial or terrace deposits. This stratum was found a stiff to very stiff clayey silt, sandy clay, clayey sand to silty clay. SPT N values ranged from about 10 to 30 blows/ft. This unit ranged in depth mostly between 30 to 70 ft depth.

Stratum no. 4: *Weak Limestone*

The above described layers are overlain by a weathered limestone formation found at depths in the order to 70 and 75 ft beneath ground surface, at the locations of borings no. 1, C-2 and SWV-1. SPT N values for this unit varied widely mainly due to weak strength characteristic of the formation, high level of weathering and solution voids and soil filled cavities. Blow counts were found to range from values in the high 10s to over 100 blows/ft (ie.50 blows/4”). This limestone was found in a very weak state. Coring was attempted, but no recovery was obtained. The composition of the formation is that of a partly and moderately cemented limestone gravel, sand and silt rather than rock. This unit shall not be regarded as bedrock.

3.3 Groundwater:

According to the observations made during the subsoil exploration, groundwater was found at depths of 6 to 8 ft beneath existing paved surface. Groundwater level may rise during and after prolonged rain events and tidal fluctuations. It is interpreted that ground water is within 1-3 ft above mean sea level. Perched ground water will occur within sand pockets overlying clayey soils. Furthermore, it is our opinion that ground water level will rise to near ground level during storm related surge and heavy rains

The above information corresponds to a general description of the subsoil conditions of the area explored. However, for detailed description regarding the soil profile, please refer to the enclosed boring logs on Appendix A.

4.0 GEOTECHNICAL RECOMMENDATIONS:

Based on information obtained from the test borings concept, it is understood that the site will be developed with industrial structures. As will be explained in the following sections, the potential for liquefaction and settlement prone soils will require for all heavy structures to be supported over deep foundations. Any light ground bearing structure will need to be evaluated in a case by case basis. Nevertheless, regardless of the structure weight, the ground will be prone to significant subsidence during strong ground motions.

4.1 Liquefaction Potential and Seismic Settlements:

Analysis of liquefaction was made using SPT and CPT data. Based on the site specific seismic hazard assessment, the PGA for 10% probability of exceedance in 50 years (5 % damping) is 0.26 g. Analysis was made using Seed et al (2004) criteria for liquefaction exhibiting potential for liquefaction for depths within the upper 20 to 30 ft within the zone near the existing bulkhead that was backfilled with sandy hydraulic fills. Effects of liquefaction include excessive ground settlement and lateral spreading. The liquefaction potential with regards to boring location is described in table no.1, below:

Table 1: Liquefaction Potential per Boring

Boring no.	Liquefaction Potential	Depth Range of Liquefaction	Comments
SWV-1	Moderate	14-29	Soft Silt may exhibit seismic settlement; high fines content reduces potential for liquefaction
B-1	Low to Moderate		Soft Silty soils may exhibit seismic settlement
B-2	Moderate to high	10-19	High potential within saturated loose hydraulic fill
B-3	High	5-34	High potential within saturated loose hydraulic fill-Near Bulkhead
B-4	High	10-35	High potential within saturated loose hydraulic fill-Near Bulkhead
C-1	High	5-29	High potential within saturated loose hydraulic fill-Near Bulkhead
C-2	High	6-30	High potential within saturated loose hydraulic fill-Near bulkhead
SC-1	High	6-30	High potential within saturated loose hydraulic fill
SC-2	Moderate	15-25	Soft Silty soils may exhibit seismic settlement; high fines content reduces potential for liquefaction; sand layer 19-24 ft
B-5	Low		Mostly clayey soils below mudline
B-6	Moderate to low	6-14	Dense sands with SPT N>25 exhibit conditions that will mitigate potential of occurrence
B-7	Low	4-6	Thin loose sand layer 1-2 ft over ground water level. Profile is governed by clayey soils

4.1.2 Liquefaction Induced Lateral Spreading Concern:

Liquefaction prone soils are mostly found close the existing bulkhead area where hydraulic fills from dredging where deposited. At most locations it is noted that the subsurface profiles have an increased depth of liquefaction prone sand towards the existing bulkhead. This creates the situation that as the sandy soils liquefy, by losing their internal friction, these would displace laterally by gravity over the underlying inclined soft clay layer causing ground surface to exhibit extension cracks parallel to the bulkhead (perpendicular to slope direction). This would also cause a great overstress on the bulkhead that may lead to its failure.

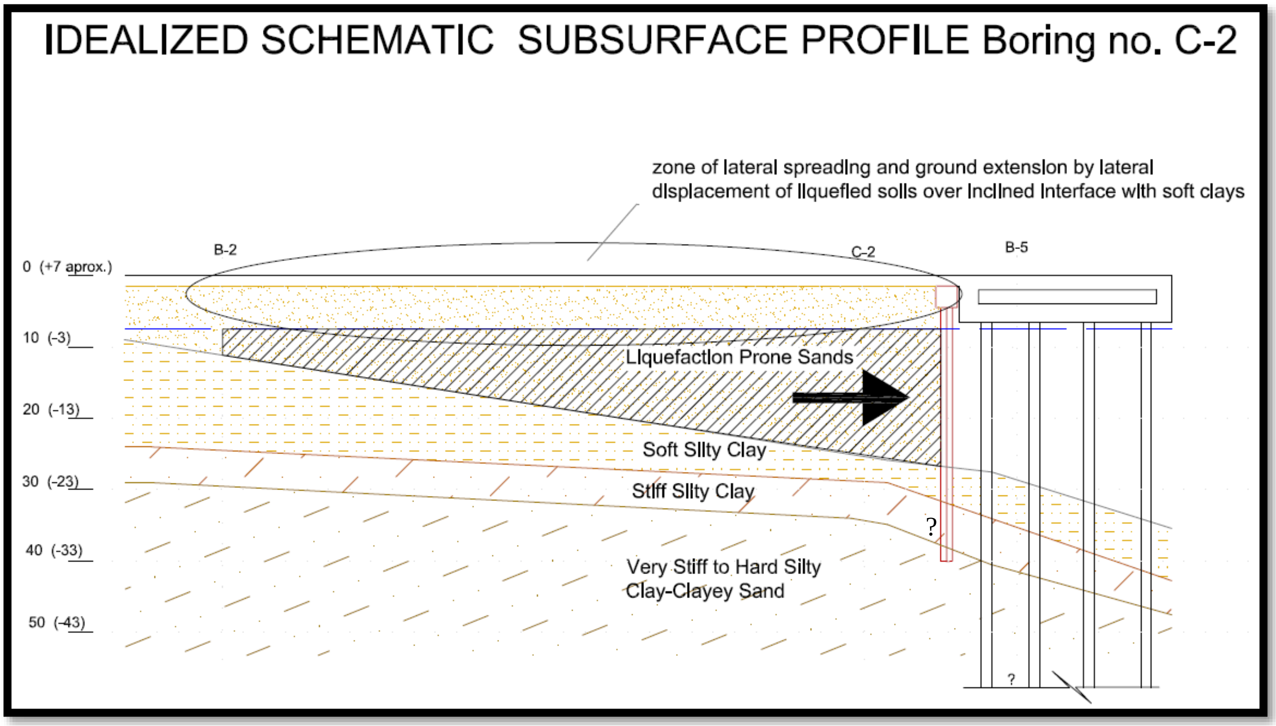

Figure 2: Schematic subsurface profile exhibiting conditions for lateral spreading

4.1.3 Liquefaction Mitigation:

Liquefaction shall be mitigated by ground improvement methods such as stone columns (vibro-replacement) or rammed aggregate pier methods such as Impact Piers by Tensar's Geopier patented methods, where deemed necessary to protect wharf infrastructure and seismic safety of the facilities. These methods commonly entail stone columns arranged in an array having center to center spacing ranging from 6 to 9 ft. The effectiveness of ground improvement is verified by performing pre and post treatment Cone Penetration Tests (CPT) or Standard Penetration Tests (SPT) made to validate adequacy of stone column or aggregate spacings. If any of these methods are implemented, at least two (2) test areas shall be established by geotechnical engineer prior to proceeding with ground improvement.

4.2 Deep Foundations:

Heavy loaded structures or any structure that is important and should remain safe against settling excessively or displacing due to seismic liquefaction, should be supported over deep foundations. **These structures are understood to consist of the truck loading suction drum, gas combustion units, regasification suction drum, fire water tanks, gas fired vaporizers, operations building and other structures. Any structure supported over shallow foundation will likely lose foundation support and become ruined during seismic liquefaction.**

Pile size will be a function of axial and lateral loads. The proposed piles will develop most of their capacity in friction within stiff clays and weak limestone horizon.

Based on the current 75% project plans, the existing pile supported berth will be increased of its capacity by installing new 36 inch diameter steel pipe piles over the existing concrete piles. We have been informed by M&N that, based on a diver survey commissioned by the owner, there should not be any rocks or obstruction that would impede pile installation beneath the existing berth. The new 36 inch diameter (t=0.5 inches) steel pipe pile depths are estimated to be 70 ft depth with 232 kips allowable compression and 50 kips allowable tension.

Inland structures can be supported by driven precast concrete piles with minimum diameter of 12 inches.

The ultimate axial resistance in skin friction for different driven piles was evaluated using *Ensoft APile v2018* software. The results are shown in Appendix C. In order to obtain allowable design loads a Factor of Safety of 2 can be considered for the provided ultimate loads.

4.2.1 Field loading Tests and Quality Monitoring:

The suitability of the pile driving hammer should be verified before construction by performing a Wave Equation Analysis (WEAP), which can also guide on the possibility of pile damage during installation.

The pile driving operations are to be preceded by the installation of at least two (2) indicator piles. The indicator piles shall be selected from the production pile clusters and should not be judged as a separate item from production piles. We should be contacted before test pile installation to select which test piles will yield the most relevant information. **Initially, indicator piles should be driven up to the depths coordinated with the geotechnical engineer in consideration of the final chosen pile type, capacity and location.**

A **field load testing program** shall be planned to confirm axial capacity of driven piles. We recommend a minimum of two (2) test piles distributed per each pile type and per each structure. The test piles shall be subjected to high strain dynamic pile testing as per ASTM D4945 with Pile Driving Analyzer (PDA) system. The PDA test locations shall be selected by the geotechnical engineer based on the results of the indicator pile installation. Based on the results of the above field testing, the geotechnical engineer will prepare a pile installation criteria.

Production pile installation shall be monitored continuously by a geotechnical engineering technician following guidance from a geotechnical engineer for the implementation of the pile installation criteria developed for each pile type and structure.

4.3 Truck Scales, Truck Loading Skid and Pipe Racks:

Two (2) borings were completed at the site of the propose truck scales. These were labeled as boring no. SC-1 and SC2. The borings exhibit varying conditions. SC-1 (closer to the berth area shows an upper granular fill material with dense relative density followed by a loose sand (hydraulic fill) with SPT N values ranging from 3 to 4 blows/ft indicating loose relative density extending to 20 ft beneath ground surface. This lose sand is followed by a soft silty clay extending up to 29 ft bgs where a stiff sandy clay is found.

On the other hand, boring no. SC 2 had 8ft of sandy clay and gravel (not hydraulic fill) followed by a very soft compressible silty clay with Weight Hammer (WH) N value from 8 to 19 ft BGS. This unit is underlain by 5 ft of loose sand and then a medium dense clayey sand at 24 ft depth BGS.

In this profile, boring no. SC-1 poses risk for seismic liquefaction from 5 to 20 ft depth and SC-2 exhibit potential for consolidation settlements from soft layers found from 8 to 20 ft depths.

Ground water at both borings was detected at 6 ft beneath ground surface.

Based on information provided to us by M&N, the structure is proposed to be supported over continuous foundations with 1,000 psf (foundation labeled 2 and 3 in figure above) and other foundations (1 and 4) with higher contact pressures. In consideration of the conditions, it is our opinion that the foundations 1-4 shall be sized to not exceed a bearing pressure of 2,000 psf.

In order to improve soil conditions at the site, which have been affected by demolition and excavation of utilities and underground structures, we recommend the following:

1. Perform 2.5 ft undercut below proposed footings extending 3 ft beyond the foundations;
2. Compact and stabilize exposed grade, if necessary, use gabion size stone beds at weak spots;
3. Place a geogrid BX 1100 or equivalent;
4. Place engineered fill up to final grade per fill placement guidelines.

Notwithstanding of the superficial ground improvements, long term settlements from deeper soft soils consolidation could occur at estimated magnitudes of 1 to 2 inches with an approximated 50% being differential subsidence.

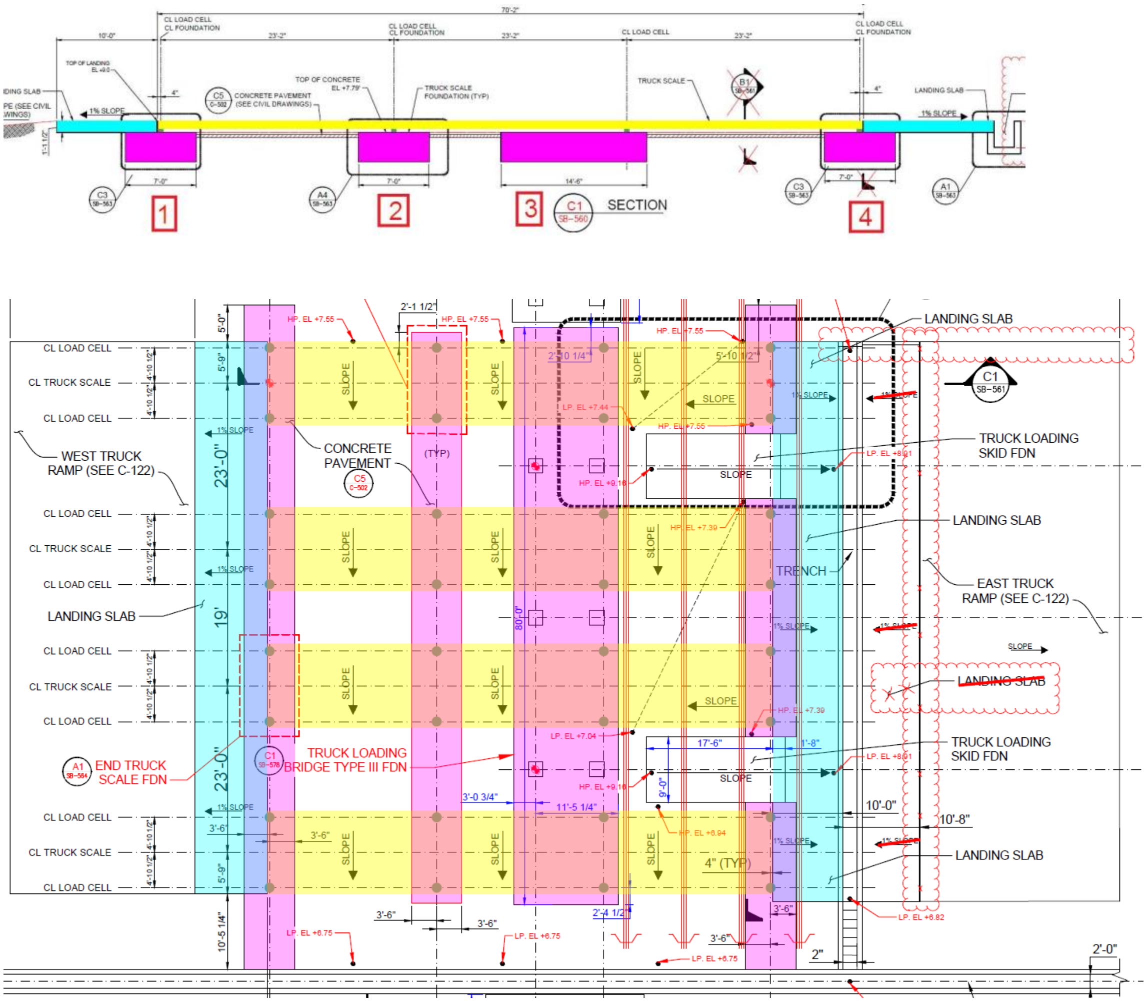

Figure 3: Proposed foundations for the Truck Scales structure

The owner and project designer should understand that this and any structure over shallow foundations on this site will experiment settlement and distortion to the extent of being ruined during a strong ground motion event producing liquefaction.

If this is not acceptable, the site can be improved with stone columns or aggregate piers to mitigate the occurrence of liquefaction. Also, the structure can be supported over deep foundations. Nevertheless, lateral spreading will cause differential lateral pile deflection that would cause damage to the structure as the spreading ground drags the piles with it.

4.4 Existing Bulkhead Evaluation:

Based on information provided to us by M&N, the existing bulkhead section consists of a MZ 38 sheet pile section that is laterally restrained in the top against lateral movement by the existing pile supported berth.

4.4.1 Parallel Seismic Survey-Existing Bulkhead Depth Estimate:

A Parallel Seismic Test is a non-destructive methodology that is used to define the length of deep foundations in cases where construction plans are not available or when other techniques such as Pile Integrity Testing (PIT) cannot be implemented due to the length and slenderness of the foundations.

This technique consists on generating an elastic wave through the foundation by impacting the top of the element with a 12 lb hammer. A geophone or receiver was placed down the borehole parallel to the bulkhead at a distance of about 3 ft in order to take measurements of the first arrivals of the elastic P-waves generated by the hammer impact. Measurements are taken at 3 ft intervals. The recorded travel times are then plotted with the corresponding receiver depth.

The energy generated by the hammer impact generates a wave in the soil similar to a velocity of a wave traveling through steel (sheet pile). Below the tip of the sheet pile, the first arrival is delayed due to the wave traveling through soil at a lower velocity. In a technique known as ray-tracing, wave travel times are plotted versus receiver depth. Any change in slope that occurs in the plot is a result of the pile tip acting as a point diffractor, which indicates the end of the pile. The results are shown in figure 4, below.

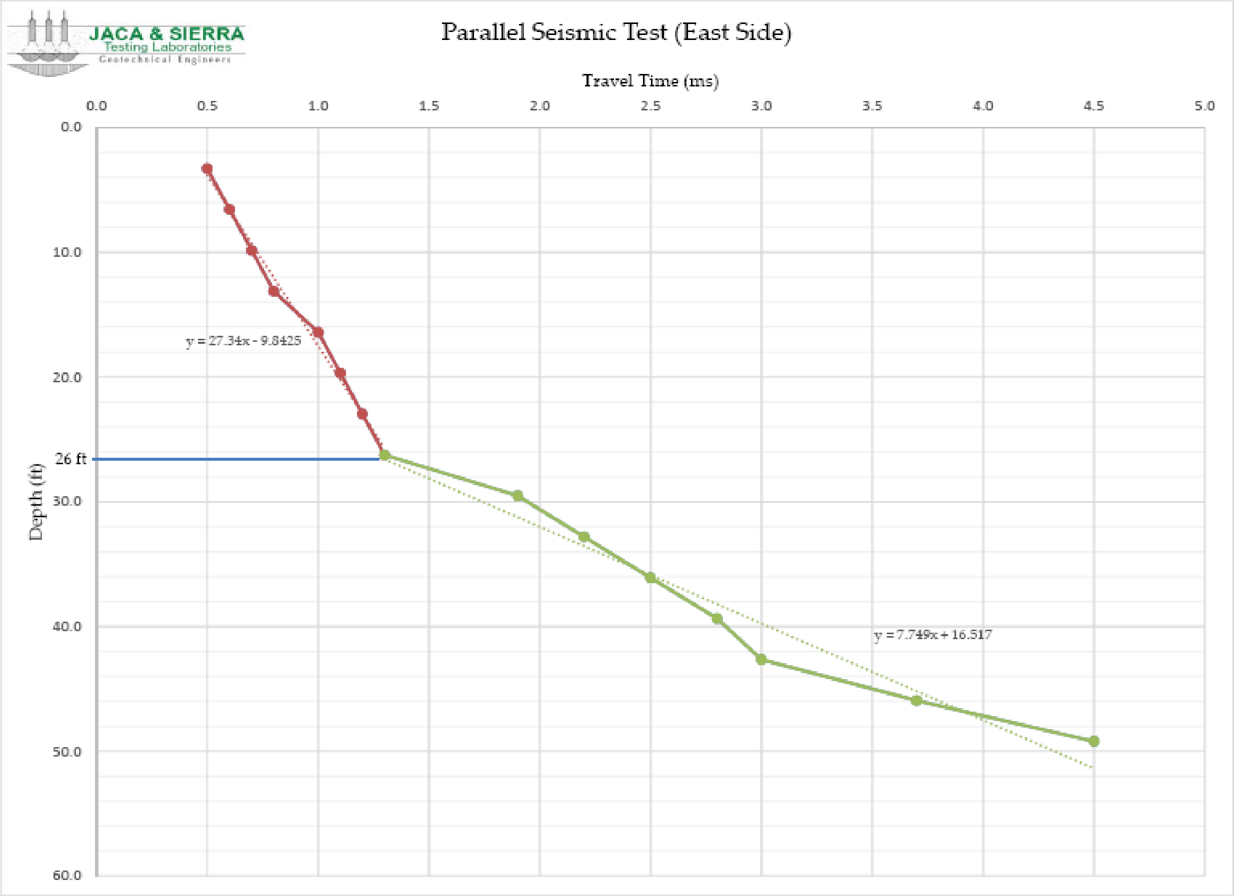

Figure 4: Parallel Seismic Test Result

The upper part (shown in red) corresponds to the higher wave velocities traveling through the steel element, while the lower portion (shown in green) corresponds to the lower wave velocities understood to be traveling through soil. As observed on the results shown above, there is a marked change in slope at an approximate depth of 26 ft which could potentially be the bottom of the sheet pile, but seems to be too short. With the present scope and its inherent physical limitations, we could not confirm existence of sheet pile below 26 ft depth at two (2) test locations. Further studies are recommended since the sheet pile should be 40 ft or deeper to meet criteria for stability. Additional testing may consist of Crosshole Seismic from land and sea side or parallel seismic from sea side (if possible).

4.4.2 Earth Pressure Parameters on the Bulkhead:

In order to evaluate the effects of static earth pressures with surcharge for temporary (during construction), permanent conditions, seismic pseudo static and liquefaction, the following parameters are recommended:

Table 2: Active Side Earth Pressure Parameters (conditions in the vicinity of borings C-1, C-2, and B-5)

Stratum	Depth beneath ground surface(ft)	Cohesion (psf)	Angle of Internal friction	Effective Unit Weight (pcf)
Fill: Sand and Gravel	0-7	0	28	115
Hydraulic Fill: Loose Sand and Silt	7-35	0	28	40
Clayey Sand	35-45	0	32	50
Very stiff Silty Clay	45-70	150	30	55
Weathered Limestone	70+	500	40	70

- Water level behind bulkhead at 7 ft beneath top of bulkhead or ground surface;
- Seismic Kh=0.26; Kv=0.13;
- Liquefaction up to 35 ft (liquefied mass density 95 pcf, c=0, phi=0);
- Ground surface assumed at +7.25 per project drawings.

Table 3: Passive Side Earth Pressure (Drained Parameters)

Stratum	Depth beneath Berth surface (ft)(+7.25ft)	Cohesion (psf)	Angle of Internal friction	Effective Unit Weight (pcf)
Soft-Med Stiff Clay	22-34	0	27	35
Med Stiff Silty Clay	34-40	100	28	50
Very Stiff Silty Clay	40-60	500	28	55

The following comments and recommendations are provided for bulkhead analysis:

- For seismic pseudo static analysis the PGA value for 10% probability of exceedance in 50 years is 0.26g;
- The water level can be assumed at 6 ft on both sides (active and passive);
- Liquefaction condition considered up to 35 ft depth, unless ground improvement is performed.
- Soil depth at mudline level currently at -22 ft elevation under existing berth should consider projection of scour depth. The upper 4-6 ft below mudline consist of very soft drift sediments.

4.4.3 Pipe Pile "A" Frame for Lateral Support of the Bulkhead:

The project design team has proposed a deadman supported by A frame with pipe piles as an option for anchoring the bulkhead structure. This deadman will act to restrain the top of the bulkhead against lateral displacement. Axial and lateral capacity for the proposed A frame battered piles is provided in Appendix A. Pile length shall be designed per corresponding required axial compression and tension loads. Pile drivability shall be confirmed by Wave Equation analysis. Pile capacity shall be confirmed by doing at least (2) PDA Tests on production piles.

4.4.4 Tieback anchors for Lateral Support of the Bulkhead:

During project design development, tie back anchors were considered, but the design team selected the A frame concept since the load required resulted to be relatively high and soil liquefaction and deep soft soils made required for relatively long tieback anchor elements which would also tend to have high elastic deformation due to steel rod lengths. Nevertheless, we supply the following recommendations for tie back anchors in case it is considered.

1. The recommended angle of installation should be 30 degrees from horizontal
2. The minimum un-bonded length should be 50 ft to maintain bond zone away from liquefaction prone soils and soft strata.
3. The bond length zone shall be constructed with temporary casing and pressure grouting method.
4. The bond strength will greatly depend on the drilling and grouting techniques. Average ultimate bond strengths of 20 to 40 psi are achievable on the stiff to very stiff silty clay found at elevations of -30 ft or deeper. Values of 100 to 150 psi are achievable on the weathered limestone at near -70 ft elevation (at 30 degrees anchor lengths over 140 ft). Final anchors lengths shall be obtained by testing.
5. Anchor Testing shall be in accordance to Post Tensioning Institute Recommendations for Prestressed Rock and Soil Anchors (PTI DC35.1-14). A minimum of two (2) performance tests shall be made to establish final anchor lengths on sacrificial anchors. Also, proof test shall be completed on 15% of the production piles.

6. A minimum safety factor of 2 shall be considered for permanent anchors.

4.5 38 KV Electrical Substation:

A 38 KV Electrical Substation is proposed at the projects southwest side near the project entrance (Figure 5). It will include a transformer and post supported substation. Per information supplied by Lord Electric (email from Mr. Javier Perez dated Jan 28, 2019) the proposed transformer will weigh 31,000 lbs and has a surface contact area of 83 inches by 67 inches. The transformer will have concrete base understood to be larger than the support base. Assuming the support base area, the contact stress will be near 800 psf. The electrical substation frame will have post supports weighing 8,425 lbs.

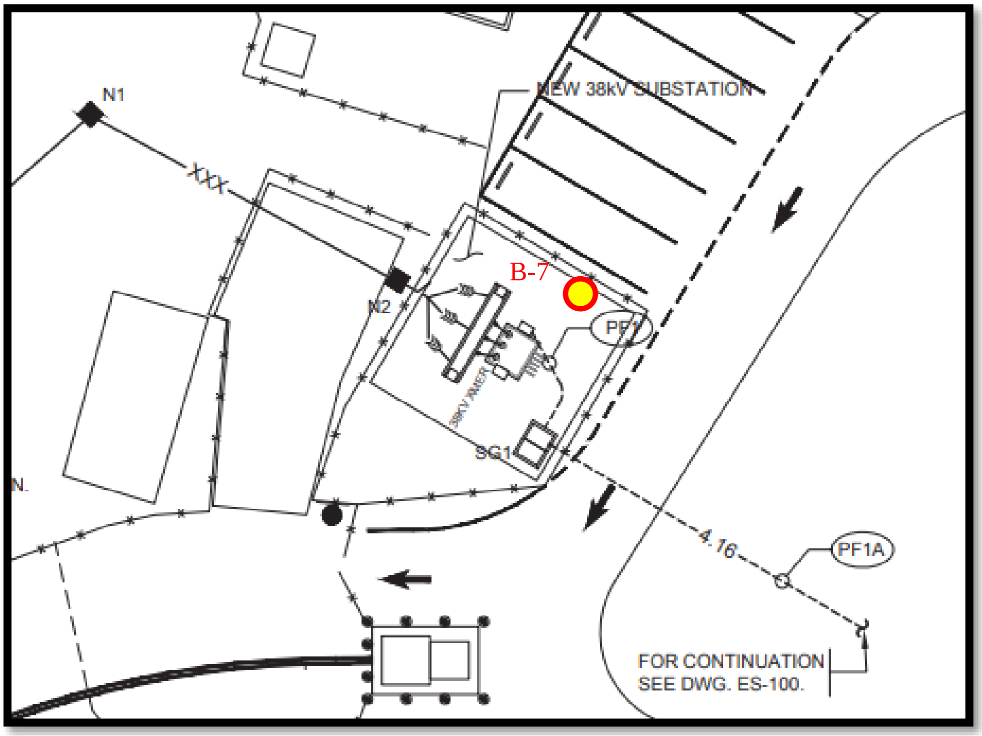

Figure 5: Electrical Substation location and test boring

Boring no. B-7 was completed near the electrical substation (figure 5). This boring uncovered a gravelly sand fill extending to 2 ft depth followed by a silty clay with shell fragments having medium consistency up to 4 ft. Then a 2 ft sand with shell fragments was detected from 4 to 6 ft depth. This stratum overlies a very soft silty clay from 6 to 24 ft depth followed by a stiff to very stiff silty to sandy clay up to the end of boring at 60 ft. The ground water was found at 5 ft depth.

The soil conditions from 4 ft to 24 ft have poor supporting capacity and will consolidate upon increase in stresses. Nevertheless, the proposed structure are relatively light. The ground elevation at that site is near 8 ft, and is expected to remain near that level. The following recommendations are provided for foundation support and ground improvement:

The transformer pad and any other foundation for light structures shall be designed for a contact pressure not exceeding 500 psf. We recommend an undercut of 1 ft beneath bottom of foundation pad and replacement with engineered fill per fill placement guidelines. The substation posts can be designed for shallow pylons or foundations. The skin friction of the ground within the upper 5 ft can be taken as 300 psf. Discard the upper 2 ft. The ground water is at 5 ft and any excavation below 4 ft will have a tendency to collapse.

4.5 Impoundment Structure:

The impoundment structure consists of a 15 ft by 30 ft outer dimension pit made of reinforced concrete walls and bottom foundation. The proposed bottom of foundation is at -7.55 ft elevation. Therefore, the below ground foundation depth will be 15.55 ft. Test boring no. 6 was completed at the proposed structure location. The soil profile is defined by an upper sandy gravel fill followed by dense sand layers up to 14 ft depth. This sand unit is followed by a soft silty clay which extends to 34 ft beneath ground surface which us underlain by a stiff to very stiff silty clay extending to the end of boring at 80 ft depth. The ground water was found at near 5 ft beneath ground surface or at elevation +3.

The bottom of foundation will occur over a very soft silty clay. The ground water level at this location was found 11 ft over the base of the impoundment structure. For design purposes, we recommend to assume groundwater at +7 ft or 1 ft beneath ground surface accounting for extreme storm related surge and heavy rain. With this in consideration, the hydrostatic pressure acting at the base of the impoundment will be 15 ft water head or 936 psf (421.2 kips gross uplift force). The structure shall be designed to counteract net buoyancy, as well as the unbalanced hydrostatic pressure acting against the side walls for the condition of the impoundment being empty. In order to counteract net buoyancy uplift loads, the structure can be supported over deep foundation such as

12 inch or 14 inch diameter precast concrete piles, anchoring the excavation sheet pile wall(permanent) or providing and extension of the foundations beyond the perimeter to create a key. For the perimeter foundation key option, the backfill unit weight shall be taken as 45 pcf for the fully submerged extreme condition.

For construction, a sheet pile will be required with a minimum embedment of 35 ft beneath ground surface. The sheet pile shall be designed considering water table at +2 level (4 ft beneath ground surface) and using the following earth pressure parameters for temporary condition:

Table 4: Temporary sheet pile wall earth pressure parameters for the impoundment structures

Stratum	Depth beneath ground surface (ft)	Cohesion (psf)	Angle of Internal friction	Effective Unit Weight (pcf)
Moist Sandy Fill	0-4	0	30	125
Saturated Fill	4-14		28	55
Soft Silty Clay	14-34	250	0	40
Stiff Silty Clay	34+	2000	0	65

For the permanent condition an equivalent pressure of 83 lb/sq.ft/ft can be considered for the extreme condition, which values includes hydrostatic earth pressure and soil pressures for saturated backfill and elevated ground water table.

4.6. Fill Placement Guidelines:

The site was occupied by various structures including warehouses, slabs and utilities. Once the required excavations have been completed and general site clearing has been achieved including pavement and unsuitable soil removal, a proof rolling must be performed with a loaded truck within the footprint areas of the structures and surfaces to be paved in order to detect weak spots. Any weak spot must be excavated and replaced with engineered fill. The exposed grade must then be compacted to an unyielding surface. Engineered fill shall then be placed up to final grade following the fill placement guidelines provided herein:

1. The fill material shall consist of well graded granular soil complying with AASHTO Classification A-2-4 or A-1 (GM, GW, SW or SM according to Unified Soil Classification). This material should be approved by the consultant geotechnical engineer.
2. Fill material shall be placed in layers not exceeding eight (8) inches of thickness (as measured before compaction) on a surface free of water and each layer shall be compacted to a minimum of 95% based on its maximum dry density determined from a Modified Proctor Compaction Test, according ASTM D 1557. If portable compaction equipment (walk-behind rollers, plate compactors, among others) will be used, the thickness of the fill lift layers

should be reduced to 4 inches. This is required due to its relatively low compaction energy.

The construction of the fill layer shall be made monitored by third party geotechnical laboratory. The presence of a field soil technician shall be continuous from the initiation of site clearing until the final grade is reached.

4.7 Pavement Design Recommendations:

Following requests and approved scope of work by Moffat and Nichol, we have completed pavement evaluation and design sections for the project. This evaluation is based on the following documents provided to us:

1. Traffic Plan Sketch by M&N;
2. Traffic Loading information provided by M&N (email from Adam Crouch dated Dec. 7, 2018);
3. Project Civil Drawings by M&N; 75% delivery dated Dec. 06, 2018.

Based on document reference no.2, above, the design loads provided and considered for this design are as follows:

- 96 trucks/day @ 80,000 lbs loaded (25,000lbs unloaded);
- 20-ton mobile crane (occasional for equipment maintenance).

A total of ten (10) borings to 10 ft depth were completed at different areas of the site which were expected to have traffic base. The borings made for pavement assessment are labeled as #-P (ie. 5-P). Refer to boring logs and boring locations plan in Appendix B for further details. At each boring location, the asphalt thickness was measured by coring and a Dynamic Cone Penetrometer (DCP) test were performed at sub-base level.

Table 5: Existing Pavement Thickness Determination and DCP Test Results

ID	Surface Material	Thickness (inches)	DCP Penetration Depth measured from the surface	Average CBR as per DCP Tests
1	Asphalt	8.0	11.25*	99+
2	Asphalt	6.0	9.75*	99+
3	Asphalt	2.0	18.5	35
4	Asphalt	2.0	4.75*	99+
5	Concrete	4.0	6.25*	99+
6	Concrete	4.0	5.5*	99+
7	Concrete	3.0	7.0*	99+
8	Asphalt	12.0	16.5*	99+
9	Asphalt	-	1.5*	99+
10	Asphalt	12.0	15.75*	99+

Dash Symbol (-) indicates the surface was exposed
Asterisk Symbol (*) indicates DCP Refusal

From the obtained information of the boring logs as well as the DCP tests we can consider that the existing sandy fill is suitable for the construction of the proposed pavement and other elements of the project. The following sections provide our recommendations and strength parameters for the design.

The soil samples obtained uncovered that the pavement structure is constructed over a heterogeneous sub-grade consisting mostly of a granular man-made fill profile ranging from A-2-6, A-2-4 to A-1. . As shown above, on table 1, field CBR test results exhibit values higher than 90 with the exception of number 3. All CBR values were obtained using the DCP correlations as per ASTM D6951. According to the collected data and analysis a CBR of 30 may be used for design purposes. This is applicable as long as these are densified to at least 95% of the maximum dry density and corresponding optimum moisture content as per ASTM D1557. In the event that a rigid pavement will be designed a Modulus of Subgrade Reaction (k) a value of 350 pci as a lower bound value and 450 as an upper bound value. In consideration of limited observations and heterogeneity, lower bound values are recommended unless further tests are performed.

Based on the obtained results and performed tests, a subgrade CBR value of 20 can be assumed for compacted subgrade soils under the design pavement section.

4.7.1 Subgrade:

After the initial site clearing and fill placement guidelines have been completed, the exposed grade along the site will consist of insitu man-made fill soils. For most cases the subgrade should consist of medium dense sands, a CBR value of 20 or a modulus of subgrade reaction, k, of 100 psi/in of can be considered.

4.7.2 Subbase:

Subbase may consist of a material with an AASHTO classification of A-1 to A-2-4. The fill must be compacted to 95% of its Modified Proctor (ASTM D1557) maximum dry density. In-situ soils can be used for this purpose provided their AASHTO soil classification complies with the above requirement. Subbase course should yield a minimum CBR value of 20.

4.7.3 Base Course:

Aggregate base course should consist of crushed rock or gravel with a minimum size no larger than 2 inches. Gradation should not exceed 50% of sand and fine content should not exceed 5%. Base course shall be compacted to 97% of the Modified Proctor maximum dry density (ASTM D1557) and placed as per fill placement recommendations in this report. The table below provides the gradation requirements for the recommended base course material as per the standard specifications of the Puerto Rico Highway and Transportation Authority. Class A or B are acceptable.

Table 6: Grading for aggregate base course

Sieve Designation	Percentage of Weight Passing by Sieve	
Grading Class	**A**	**B**
2"	100	-
1-1/2"	-	100
1	50-80	-
1/2"	-	40-75
No. 4	20-50	30-60
No. 10	-	-
No. 200	5-12	5-12

4.7.4 Light Duty Asphalt Section:

LIGHT DUTY FLEXIBLE PAVEMENT (Un-Reinforced)

Pavement Layer	Thickness	Minimum Requirements
S-1 Asphalt Surface Course	1.5 in minimum	93%min-97%max field density per Laboratory Marshall
B-1 Asphalt Base Course	4 inch minimum	93-97% field density per Laboratory Marshall
Aggregate Base Course	8 in minimum	PRHTA Class A or B Aggregate Base Course compacted to 97% modified proctor
Subbase Course	AS REQUIRED TO ACHIEVE F.G.	Surface Compaction and Proof rolling up to a CBR of 15

4.7.5 Heavy Duty Asphalt Section:

This section is applicable to all areas where loaded and unloaded truck traffic is expected.

HEAVY DUTY FLEXIBLE PAVEMENT (Un-Reinforced)

Pavement Layer	Thickness	Minimum Requirements
S-1 Asphalt Surface Course	2 in minimum	93%min-97%max field density per Laboratory Marshall
B-1 Asphalt Base Course	6 inch minimum	93-97% field density per Laboratory Marshall
Aggregate Base Course	8 in minimum	PRHTA Class A or B Aggregate Base Course compacted to 97% modified proctor
Subbase Course	AS REQUIRED TO ACHIEVE F.G.	Surface Compaction and Proof rolling up to a CBR of 15

4.7.6 Heavy Duty Asphalt Section II- Reinforced Section:

This section is applicable to areas where:

1. Loaded truck and containers will standby or stop regularly;
2. Project Entrance near gate; from state road to gate house area and zone where loaded truck stop at exit gate;
3. Strip of land over existing PREPA intake systems and 6 ft beyond their perimeter.

HEAVY DUTY FLEXIBLE PAVEMENT (Reinforced)

Pavement Layer	Thickness	Minimum Requirements
S-1 Asphalt Surface Course	2 in minimum	93%min-97%max field density per Laboratory Marshall
B-1 Asphalt Base Course	6 inch minimum	93-97% field density per Laboratory Marshall
Aggregate Base Course	12 in minimum	PRHTA Class A or B Aggregate Base Course compacted to 97% modified proctor
Biaxial Geogrid Tensar BX 1100 or Equivalent/ 6 inch of A-2-4 or A-1 @ 95% Mod. Proctor		
Subbase Course	AS REQUIRED TO ACHIEVE F.G.	Surface Compaction and Proof rolling up to a CBR of 15

4.7.6 Concrete Section:

This section is applicable where necessary in substitution of heavy-duty asphalt mostly where abrasive action, chemical effects and point loading will make use of asphalt unfeasible.

Concrete Section

Pavement Layer	Thickness	Minimum Requirements
Concrete Surface Course	6 in minimum	4000 psi minimum compressive strength; 10 ft x 10 ft saw cut joints; 1¼" minimum depth
Aggregate Base Course	12 in minimum	PRHTA Class A or B Aggregate Base Course compacted to 97% modified proctor
Subbase Course	AS REQUIRED TO ACHIEVE F.G.	Surface Compaction and Proof rolling up to a CBR of 15

5.0 ADDITIONAL COMMENTS:

It is recommended that this submitted geotechnical report be carefully studied and evaluated to coordinate those pertinent office meetings during the project design stage, to discuss the various considered project design concepts and to clarify or include any other pertinent geotechnical design recommendations not covered in our soil report.

Note that the herein given recommendations are based on tests borings performed on spots, which are considered as representative of the subsoil conditions within the site. However, this fact does not guarantee that different conditions may be found during construction progress and/or excavations. In such instances, we shall be notified to proceed with a field visual inspection directed to formulate the corresponding solution.

We wish to thank you for the opportunity of submitting this geotechnical engineering report and remain.

Respectfully submitted,
JACA & SIERRA ENGINEERING, PSC

Carlos R. Sierra Del Llano, MSCE, PE

LIC.#18664

Revision D.

Enclosures

Appendix A: Boring logs and location plan

Appendix B: CPT and Downhole Seismic

Appendix C: Laboratory Test Reports

Appendix D: Pile Analysis

Appendix A

Boring Logs and Location Plan

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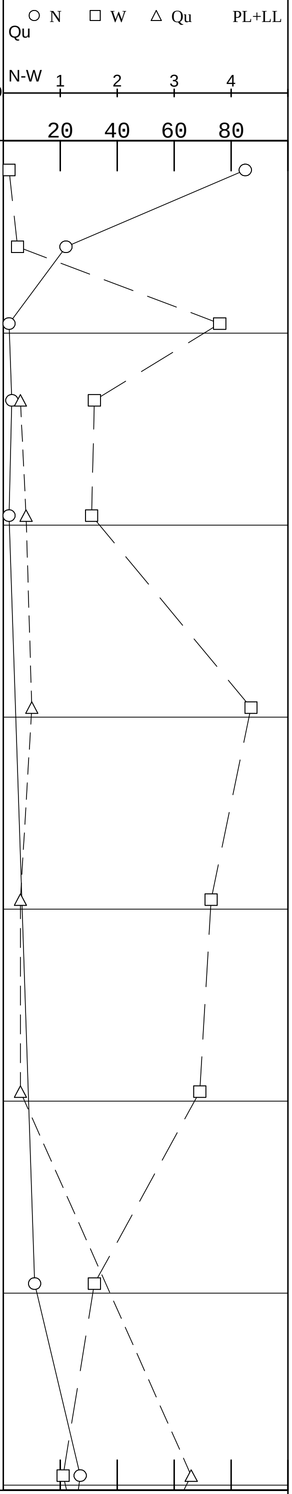
SUBSURFACE EXPLORATION LOG

BORING N0.: SWV-1

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 1 **OF** 3
LOCATION San Juan, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES
DATE HOLE STARTED 12-12-17 **COMPLETED** 12-14-17
DESCRIPTION BY Manuel Candelario
ELEVATION TOP OF HOLE (mts):
GROUNDWATER (FT) **Initial:** **Final:**
ENGINEER Manuel Candelario
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH OF HOLE (ft): 100.5

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
0.00	0	FILL: gravel with silty sand some clay, dense, yellowish brown, yellow	▩	S-1	◣	43 42 43	85	2		100	
				S-2	◣	18 10 12	22	5		100	
-0.91	3	CLAYEY SILT with sand, soft to medium, grayish brown, dark gray	▥	S-3	◣	4 1 1	2	76		100	
	5			S-4	◣	2 2 1	3	32	0.3	100	
-2.74	9	CLAYEY SILT trace sand, very soft, reddish yellow, yellowish brown	⋮	S-5	◣	WH 1 1	2	31	0.4	100	
	10										
-4.27	14	SILT some clay trace sand, very soft, dark gray	▨	S-6	◣	WH WH WH	WH	87	0.5	100	
	15										
	20			S-7	◣	WH WH WH	WH	73	0.3	100	
	25			S-8	◣	WH WH WH	WH	69	0.3	100	
-8.84	29	CLAYEY SILT trace sand, stiff to hard, yellowiush red, white, yellow, black	▥	S-9	◣	4 5 6	11	32		100	
	30										
	35			S-10	◣	6 10	27	21	3.3	100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: **SWV-1**

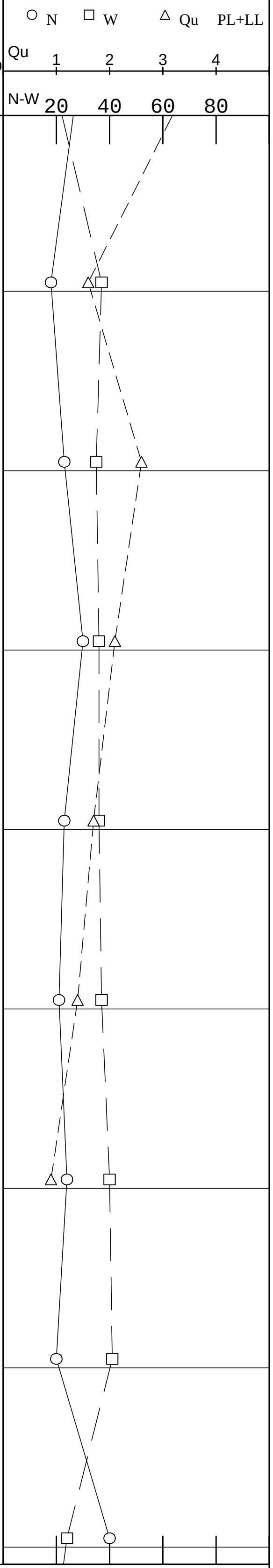
BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 2 **OF** 3

Elev. (mts)	DEPTH (feet)	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	0.00										
						17					
	40			S-11		4 8 10	18	37	1.6	100	
	45			S-12		8 10 13	23	35	2.6	100	
	50			S-13		9 13 17	30	36	2.1	100	
	55			S-14		8 10 13	23	36	1.7	100	
	60			S-15		6 8 13	21	37	1.4	100	
	65			S-16		5 9 15	24	40	0.9	100	
	70			S-17		5 9 11	20	41		100	
-22.56	74 75	HIGHLY WEATHERED LIMESTONE with clay and sand, very dense, reddish yellow, yellow, white		S-18		9 40/5"	40/5"	24		55	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
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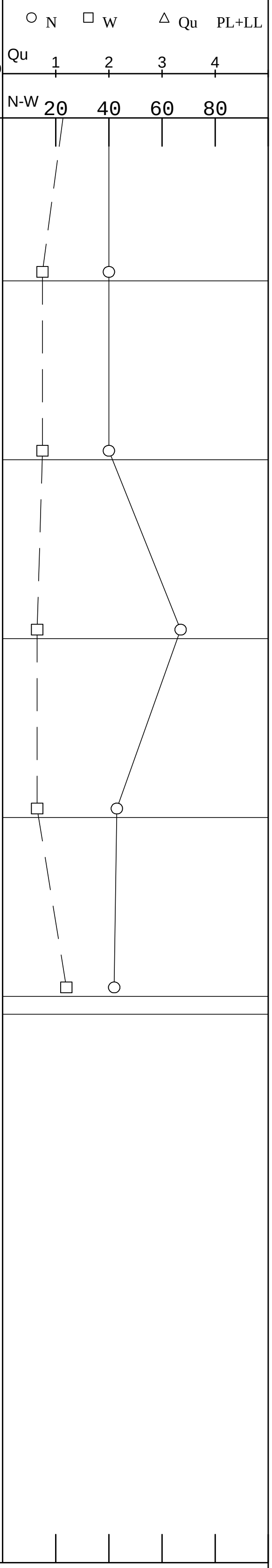
SUBSURFACE EXPLORATION LOG

BORING NUMBER: **SWV-1**

BORING LOG (CONT. SHEET)

PROJECT	JOB	SHEET	OF
NFE-V-08 Puerto Rico	7812	3	3

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	80			S-19		32 40/5"	40/5"	15		33	
	85			S-20		12 40/5"	40/5"	15		100	
	90			S-21		31 38 29	67	13		100	
	95			S-22		19 29 14	43	13		100	
	100			S-23		16 18 24	42	24		100	
	105										
	110										
	115										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
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"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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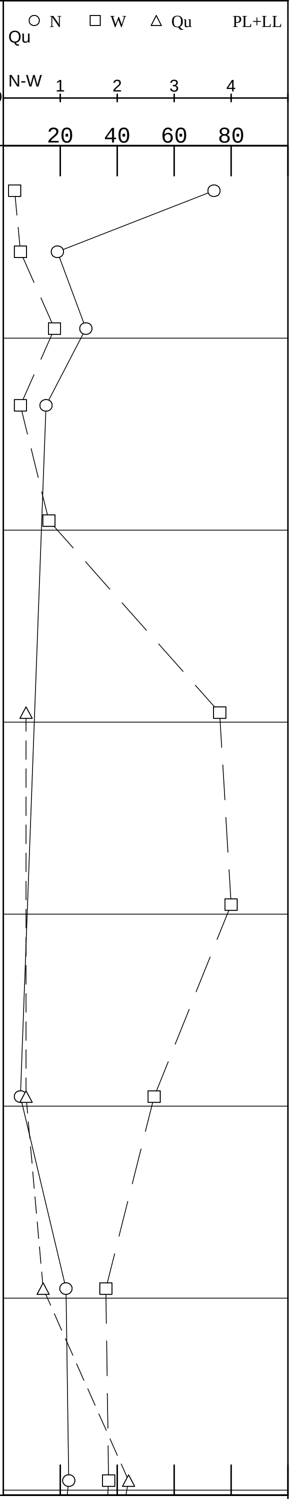
SUBSURFACE EXPLORATION LOG

BORING N0.: **B-1**

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 1 **OF** 2
LOCATION San Juan, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES
DATE HOLE STARTED 1-2-18 **COMPLETED** 1-2-18
DESCRIPTION BY Manuel Candelario
ELEVATION TOP OF HOLE (mts):
GROUNDWATER (FT) **Initial:** 8 **Final:**
ENGINEER Manuel Candelario
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH OF HOLE (ft): 70.5

Elev. (mts)	DEPTH (feet)	DESCRIPTION
0.00	0.00	
-0.13	0	Asphalt
-0.61	0.41	FILL: gravel with sand some silt, moist, brown and pale yellow
	2	FILL: silty clay some limestone fragments, moist, pale yellow, reddish brown Do... with limestone fragments, organic, moist to wet
-2.74	9	SILTY CLAY some and shell fragments, organic, very soft, wet, very dark brown to black Do... with shell fragments
-7.32	24	SILTY CLAY, soft, wet, brown, gray
-8.84	29	SILTY CLAY, very stiff, moist, dark brown to brown

Sample No.	BLOWS	SPT N	W	Qu	RC	RQD%
S-1	44 45 29	74	4		100	
S-2	19 9 10	19	6		100	
S-3	3 6 23	29	18		100	
S-4	15 10 5	15	6		100	
S-5	WH WH WH	WH	16		100	
S-6	WH WH WH	WH	76	0.4	100	
S-7	WH WH WH	WH	80		100	
S-8	WH 3 3	6	53	0.4	100	
S-9	7 9 13	22	36	0.7	100	
S-10	7 10	23	37	2.2	100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
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Initial G.W. Depth
Final G.W. Depth

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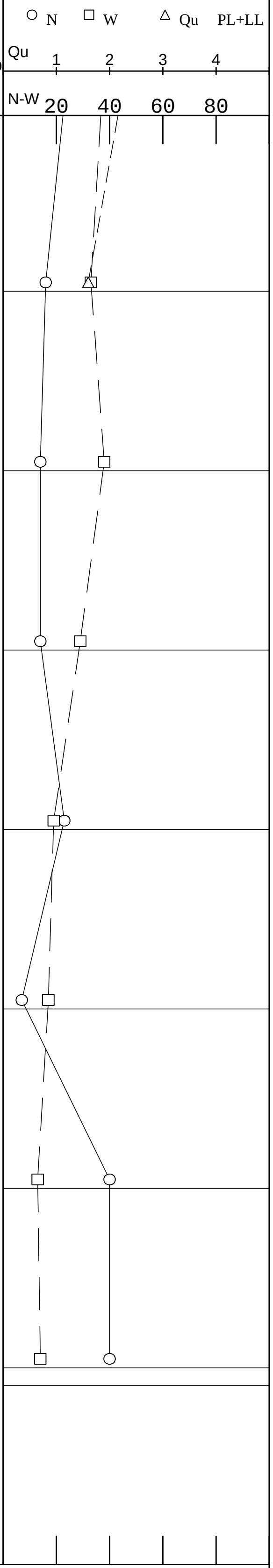
SUBSURFACE EXPLORATION LOG

BORING NUMBER: B-1

BORING LOG (CONT. SHEET)

PROJECT	JOB	SHEET	OF
NFE-V-08 Puerto Rico	7812	2	2

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	Sample No.	BLOWS	SPT N	W	Qu	RC	RQD%
				13					
	40		S-11	5 7 9	16	33	1.6	100	
-13.41	44	SILTY CLAY some sand, limestone fragments, stiff, light brown to pale yellow	S-12	7 8 6	14	38		77	
-14.94	49	LIMESTONE FRAGMENTS with sand some silt and clay, medium,	S-13	6 7 7	14	29		44	
	55		S-14	9 13 10	23	19		100	
	60	Do... loose	S-15	6 5 2	7	17		100	
	65	Do... hard	S-16	40/5"	40/5"	13		27	
	70		S-17	40/5"	40/5"	14		44	
	75								



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
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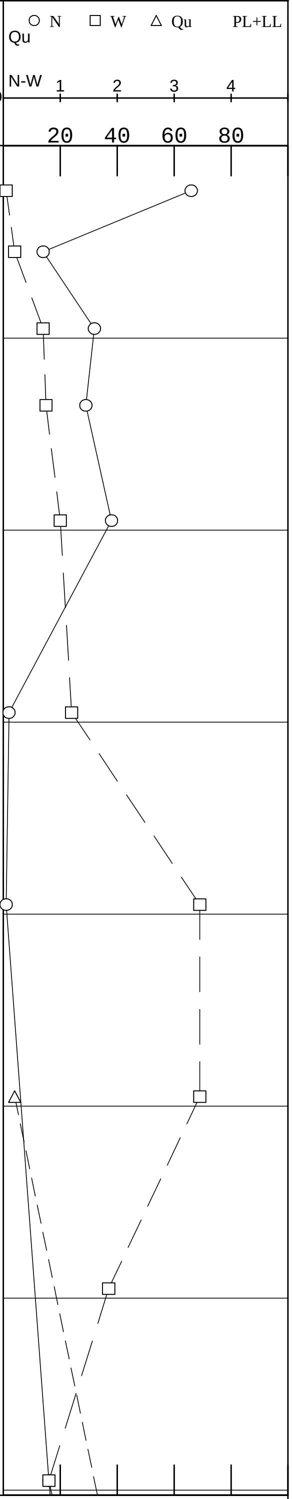
SUBSURFACE EXPLORATION LOG

BORING N0.: B-2

PROJECT NFE-V-08 Puerto Rico		**JOB** 7812	**SHEET** 1 **OF** 2
LOCATION San Juan, PR	**DRILLER/DRILL RIG:** Eddie Sevilla / CME-55		
COORDINATES	**DATE HOLE STARTED** 12-16-17 **COMPLETED** 12-16-17		
DESCRIPTION BY Manuel Candelario	**ELEVATION TOP OF HOLE (mts):**		
GROUNDWATER (FT) **Initial:** 7.5 **Final:**	**ENGINEER** Manuel Candelario		
DRILLING METHOD: Hollow-Stem Auger 2.25" ID	**TOTAL DEPTH OF HOLE (ft):** 60.5		

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
0.00 0.13	0	0 Asphalt 0.41		S-1		24 30 36	66	1		88	
-0.61		FILL: aggregate base gravel with sand, dry, brown, gray 2		S-2		12 7 7	14	4		100	
		FILL: sand, medium to dense, moist, brown		S-3		12 16 16	32	14		100	
	5			S-4		11 12 17	29	15		100	
	▽										
	10	Do... some silt, wet USCS: SP-SM AASHTO: A-3 SAND: 90% FINES: 10%		S-5		11 20 18	38	20		100	
	15	Do... with silty clay, very soft, wet 19		S-6		2 1 1	2	24		88	
-5.79	20	CLAYEY SILT some sand some organic material, very soft, wet, dark brown USCS: ML AASHTO: A-75(16) SAND: 16.3% FINES: 10% CLAY: 29.9% SILT: 53.8% LL: 47 PI: 17 24		S-7		WH WH 1	1	69		22	
-7.32	25			S-8		WH WH WH	WH	69	0.2	100	
	30	SILTY CLAY trace sand and shell fragments, organic, dark grayish brown to black streaks 34		S-9		WH WH WH	WH	37		100	
-10.37	35	SILTY CLAY with sand, stiff to very stiff,		S-10		6 7	16	16		100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

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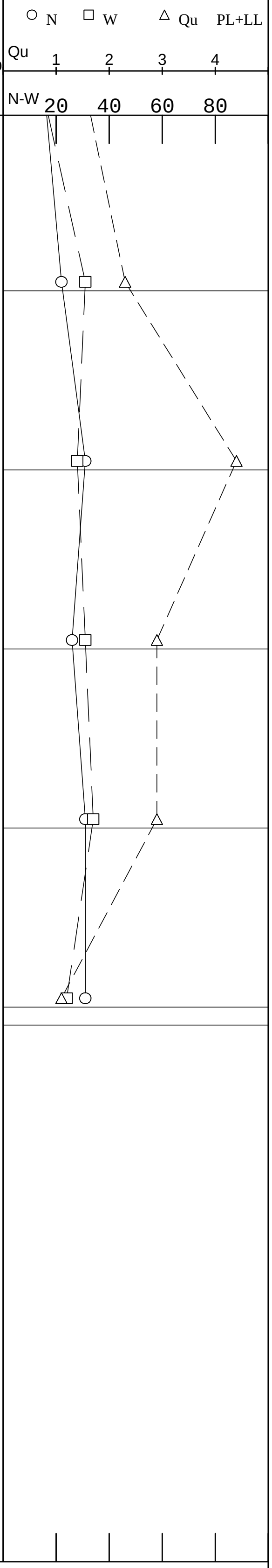
SUBSURFACE EXPLORATION LOG

BORING NUMBER: B-2

BORING LOG (CONT. SHEET)	PROJECT	JOB	SHEET 2
	NFE-V-08 Puerto Rico	7812	OF 2

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
		yellowish brown and gray	▨			9					
	40		▨	S-11		7 9 13	22	31	2.3	100	
	45	USCS: CH AASHTO: A-7-6 (43) SAND: 8% SILT: 47.3% CLAY: 50.9% LL: 64 PI: 38	▨	S-12		8 14 17	31	28	4.4	100	
-14.94		49	▨								
	50	SILTY CLAY, very stiff, yellowish brown and gray, streaks, moist	▨	S-13		9 11 15	26	31	2.9	100	
	55		▨	S-14		9 14 17	31	34	2.9	88	
	60	Do... reddish brown some sand	▨	S-15		10 16 15	31	24	1.1	100	
										100	
	65										
	70										
	75										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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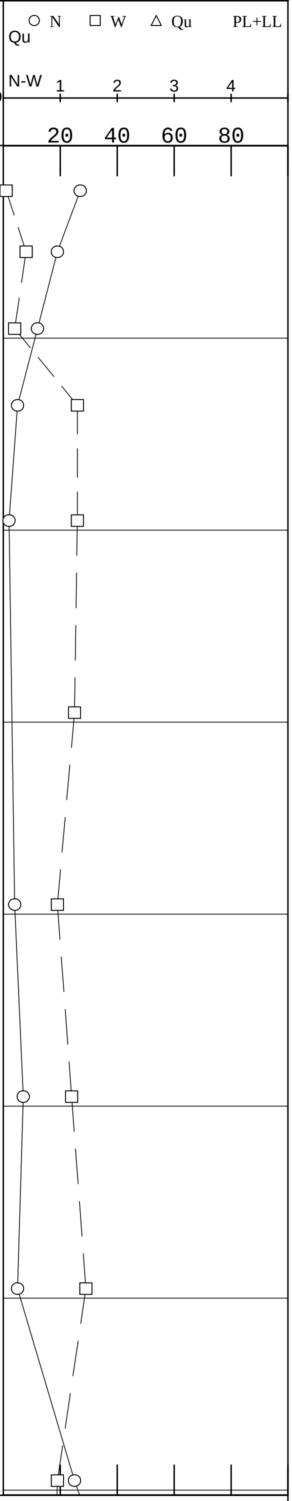
SUBSURFACE EXPLORATION LOG

BORING N0.: **B-3**

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 1 **OF** 2
LOCATION San Juan, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES
DATE HOLE **STARTED** 12-16-17 **COMPLETED** 12-16-17
DESCRIPTION BY Manuel Candelario
ELEVATION TOP OF HOLE (mts):
GROUNDWATER (FT) **Initial:** 7.5 **Final:**
ENGINEER Manuel Candelario
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH OF HOLE (ft): 60.5

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
0.00 -0.13	0	0 Asphalt 0.41		S-1		44 18 9	27	1		100	
-0.61		FILL: aggregate base gravel with sand, dry, brown, gray 2		S-2		10 10 9	19	8		100	
	5	FILL: sand occurring shell fragments, medium to loose, moist, brown		S-3		4 6 6	12	4		100	
				S-4		3 3 2	5	26		100	
	10	Do... very loose		S-5		WH WH 2	2	26		100	
	15			S-6		WH 1 WH	WH	25		100	
	20			S-7		6 3 1	4	19		100	
	25			S-8		3 3 4	7	24		55	
-8.84	30	29 SAND with shell fragments and silty clay, loose, dark gray		S-9		1 3 2	5	29		55	
-10.37	35	34 SAND trace silt, medium to dense, brown		S-10		7 10	25	19		100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: **B-3**

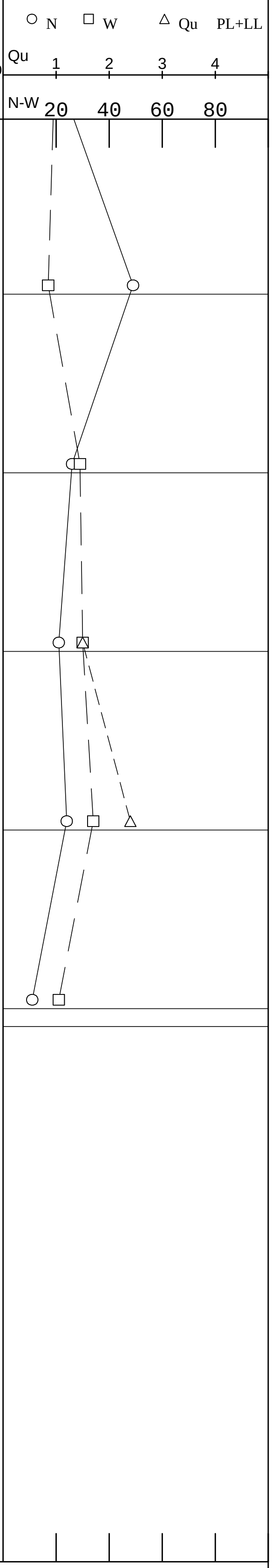
BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 2 **OF** 2

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
		LL: 52 PI: 33				15					
	40			S-11		17 28 21	49	17		100	
-13.41	44 45	SILTY CLAY some sand, very stiff, moist, reddish brown		S-12		11 11 15	26	29		100	
	50			S-13		7 9 12	21	30	1.5	100	
	55	Do... some sand, wet SAND: 19% FINES: 81.0%		S-14		7 9 15	24	34	2.4	100	
-17.99	59 60	SAND with silty clay, medium reddish brown		S-15		2 5 6	11	21		100	
	65										
	70										
	75										



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"W" - Natural Moisture Content in percentage of dry weight.
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"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING N0.: B-4

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 1 **OF** 2

LOCATION San Juan, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

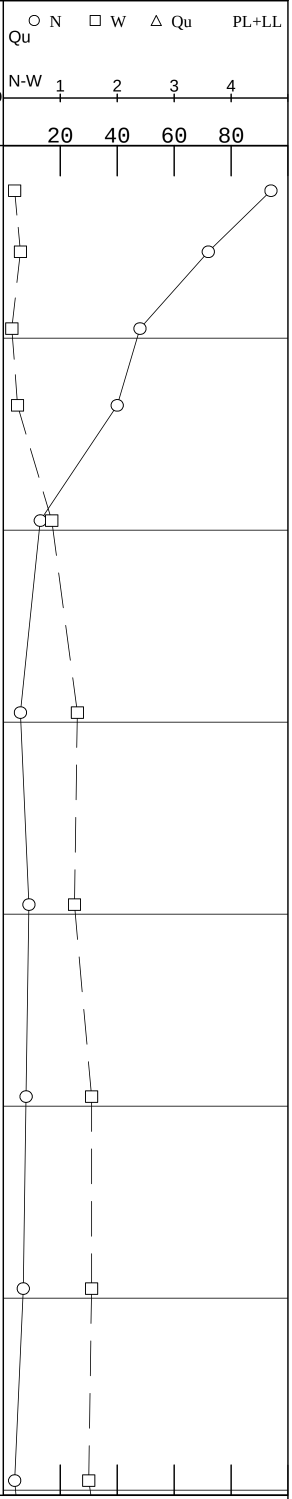
COORDINATES
DATE HOLE STARTED 12-15-17 **COMPLETED** 12-15-17

DESCRIPTION BY Manuel Candelario
ELEVATION TOP OF HOLE (mts):

GROUNDWATER (FT) **Initial:** 10 **Final:**
ENGINEER Manuel Candelario

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH OF HOLE (ft): 60.5

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
0.00 -0.13	0	0 Asphalt 0.41	■ ▨	S-1		68 58 36	94	4		100	
-0.61		FILL: silty clay some sand and gravel, moist, grayish brown to brown 2	▨	S-2		23 40 32	72	6		100	
	5	FILL: sand, very loose to loose, moist, brown	▨	S-3		14 26 22	48	3		100	
			▨	S-4		40/3"	40/3"	5		0.05	
	▽10		▨	S-5		6 7 6	13	17		88	
	15		▨	S-6		WH 2 4	6	26		83	
	20		▨	S-7		4 4 5	9	25		100	
-7.32		24	▨								
	25	SAND with coral and shell fragments some silty clay, very loose to loose, wet, dark gray	⁙	S-8		2 4 4	8	31		66	
	30		⁙	S-9		2 3 4	7	31		100	
	35		⁙	S-10		5 1	4	30		100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot.
▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
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SUBSURFACE EXPLORATION LOG

BORING NUMBER: B-4

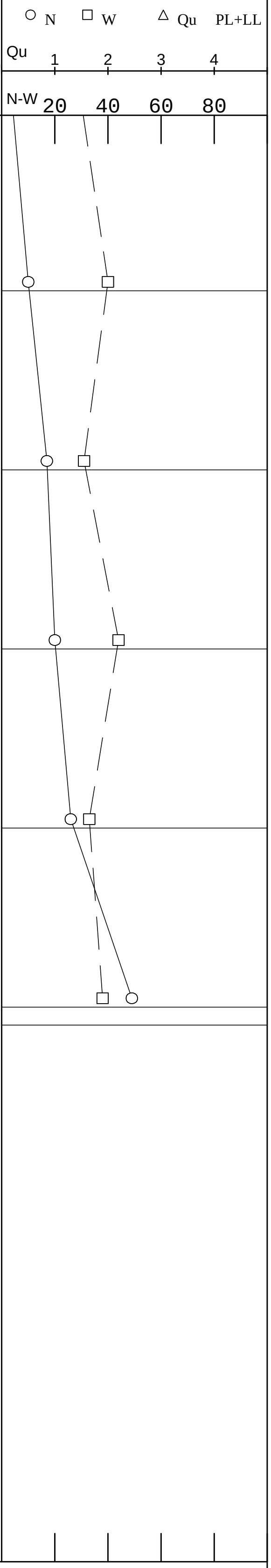
BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 2 **OF** 2

Elev. (mts)	DEPTH (feet)	DESCRIPTION	Sample No.	BLOWS	SPT N	W	Qu	RC	RQD%
	0.00			3					
-11.89	39								
	40	SILTY CLAY some sand, medium, yellowish brown, moist	S-11	6 5 5	10	40		55	
	45	Do... some limestone fragments	S-12	5 10 7	17	31		61	
	50		S-13	13 7 13	20	44		55	
	55	Do... with limestone fragments	S-14	12 12 14	26	33		50	
	60		S-15	32 38 11	49	38		77	
	65								
	70								
	75								



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "Rqd" - Rock quality designation.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING N0.: C-1

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 1 **OF** 4

LOCATION San Juan, PR

DRILLER/DRILL RIG: Eddie Sevilla / CME-55

COORDINATES

DATE HOLE STARTED 1-19-18 **COMPLETED** 1-19-18

DESCRIPTION BY Manuel Candelario

ELEVATION TOP OF HOLE (mts):

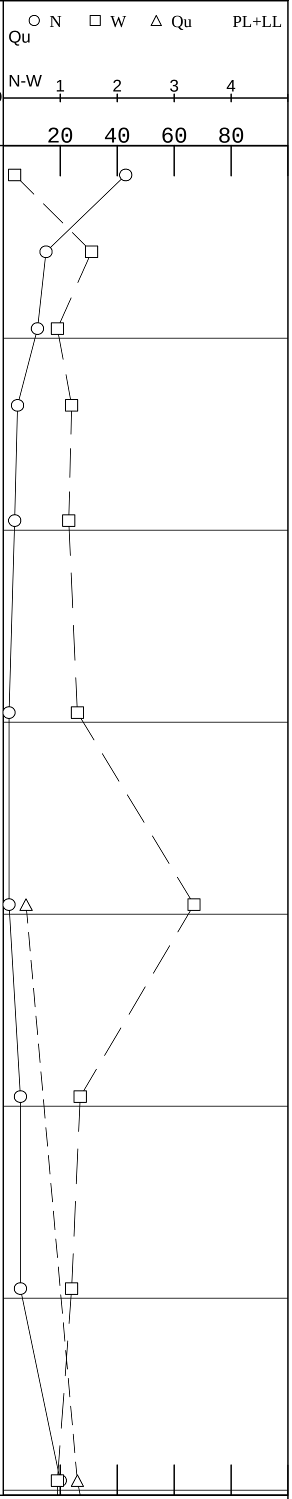
GROUNDWATER (FT) **Initial:** 5 **Final:**

ENGINEER Manuel Candelario

DRILLING METHOD: Hollow-Stem Auger 2.25" ID

TOTAL DEPTH OF HOLE (ft): 120.5

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
0.00	0	FILL: sandy silt with gravel, brown, yellowish brown	☒	S-1		20 31 12	43	4		95	
-0.61	2	Hydraulic FILL: sand some silt, medium dense to loose, moist, brown	☒	S-2		12 8 7	15	31		100	
				S-3		6 7 5	12	19		100	
	5			S-4		2 2 3	5	24		100	
	10			S-5		4 2 2	4	23		100	
	15	Do... loose to very loose		S-6		1 1 1	2	26		100	
-5.79	19	CLAYEY SILT, soft, dark gray		S-7		2 1 1	2	67	0.4	100	
	25	Do... ocurring pockets or thin layers of sand		S-8		3 4 2	6	27		100	
-8.84	29	SANDY SILT with some clay, loose, gray		S-9		WH 2 4	6	24		98	
-10.37	34	CLAYEY SAND, medium dense to dense,		S-10		8 9	20	19	1.3	95	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
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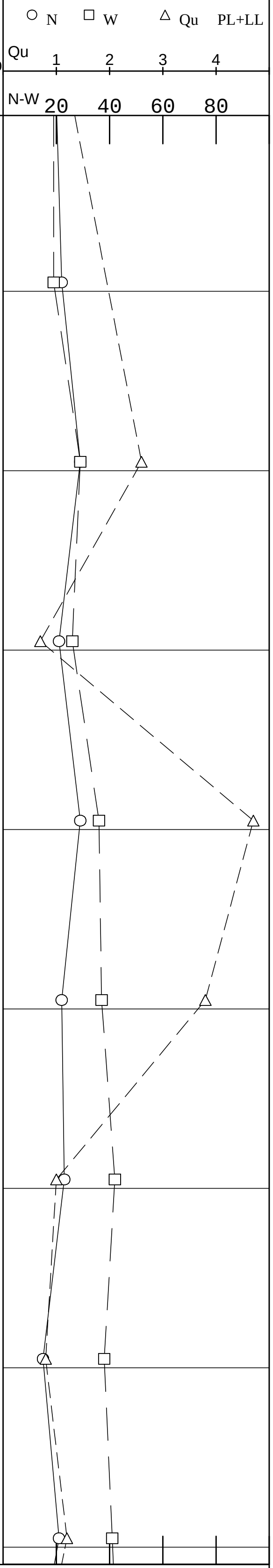
▽ Initial G.W. Depth
▼ Final G.W. Depth

SUBSURFACE EXPLORATION LOG

BORING NUMBER: C-1

BORING LOG (CONT. SHEET)	PROJECT NFE-V-08 Puerto Rico	JOB 7812	SHEET 2 OF 4

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
		yellowish red and white, silica sand	▨			11					
	40		▨	S-11		6 10 12	22	19		90	
-13.41	44										
	45	SILTY CLAY some sand, very stiff to hard, yellowish red, white mottled	▨	S-12		7 12 17	29	29	2.6	95	
	50		▨	S-13		6 8 13	21	26	0.7	88	
-16.46	54										
	55	SILTY CLAY trace sand, very stiff to hard, brownish red	▨	S-14		9 11 18	29	36	4.7	88	
	60		▨	S-15		7 9 13	22	37	3.8	90	
	65		▨	S-16		7 10 13	23	42	1.0	100	
	70		▨	S-17		4 6 9	15	38	0.8	98	
	75		▨	S-18		5 9	21	41	1.2	94	



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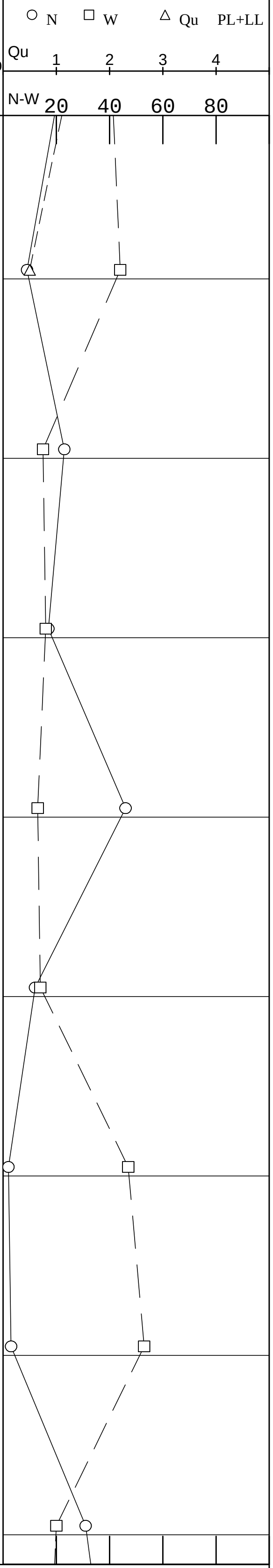
SUBSURFACE EXPLORATION LOG

BORING NUMBER: C-1

BORING LOG (CONT. SHEET)

PROJECT	JOB	SHEET	OF
NFE-V-08 Puerto Rico	7812	3	4

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	Sample No.	BLOWS	SPT N	W	Qu	RC	RQD%
				12					
	80		S-19	3 4 5	9	44	0.5	100	
-25.61	84	LIMESTONE GRAVEL with clay and sand, yellowish white, light yellow (very weak porous limestone or limestone collovium)							
	85		S-20	15 8 15	23	15		65	
	90		S-21	18 8 9	17	16		70	
	95		S-22	41 28 18	46	13		88	
	100		S-23	15 7 5	12	14		90	
-31.71	104	CLAYEY SILT with limestone fragments, soft, yellowish brown	S-24	4 WH 2	2	47		100	
	105								
	110		S-25	WH 1 2	3	53		100	
	115	Do... limestone gravel with clayey silt	S-26	7 14 17	31	20		100	



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▼ Final G.W. Depth

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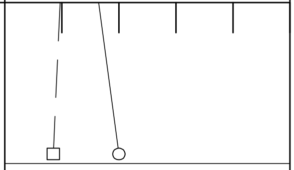
SUBSURFACE EXPLORATION LOG

BORING NUMBER: C-1

BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 4
OF 4

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%	○ N □ W △ Qu PL+LL Qu 1 2 3 4 N-W 20 40 60 80
-36.28	119											
	120	WEAK POROUS LIMESTONE sampled as gravel and silt		S-27		15 8 40/5"	40/5"	17		100		
	125											
	130											
	135											
	140											
	145											
	150											
	155											

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SUBSURFACE EXPLORATION LOG

BORING N0.: C-2

PROJECT NFE-V-08 Puerto Rico
JOB 7812
SHEET 1 **OF** 4

LOCATION San Juan, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

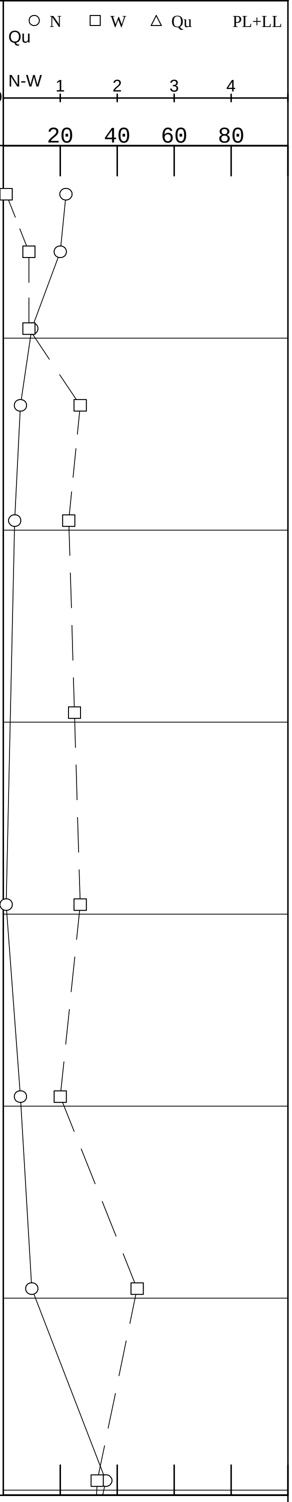
COORDINATES
DATE HOLE STARTED 12-19-17 **COMPLETED** 12-19-17

DESCRIPTION BY Manuel Candelario
ELEVATION TOP OF HOLE (mts):

GROUNDWATER (FT) **Initial:** 6 **Final:**
ENGINEER Manuel Candelario

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH OF HOLE (ft): 120.5

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
0.00 -0.15	0	0 Asphalt 0.50		S-1		53 11 11	22	1		77	
-0.61		FILL: aggregate base gravel with sand, dry, brown, gray 2		S-2		11 9 11	20	9		100	
	5	FILL: sand, medium to very loose, moist, brown		S-3		6 5 5	10	9		100	
	▽	Do... gray to brown wet, very loose to loose		S-4		3 3 3	6	27		100	
	10			S-5		1 2 2	4	23		100	
	15			S-6		2 WH WH	WH	25		77	
	20			S-7		1 WH 1	1	27		77	
	25			S-8		1 2 4	6	20		100	
-8.84	30	29 SILTY CLAY some sand, trace organics, medium, moist, very dark brown to black		S-9		5 5 5	10	47		100	
-10.37	35	34 SILTY CLAY trace sand, stiff to hard, reddish		S-10		10 15	36	33		100	



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▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: C-2

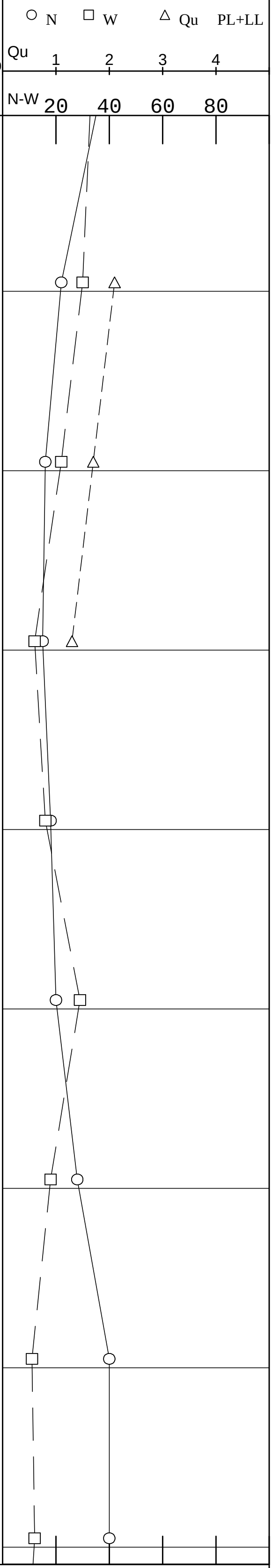
BORING LOG (CONT. SHEET)

PROJECT NFE-V-08 Puerto Rico

JOB 7812

SHEET 2 OF 4

Elev. (mts)	DEPTH (feet)	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	0.00										
		brown, gray streaks				21					
	40			S-11		6 10 12	22	30	2.1	100	
	45			S-12		4 6 10	16	22	1.7	100	
	50			S-13		5 5 10	15	12	1.3	100	
	55	Do... some sand		S-14		8 8 10	18	16		77	
-17.99	59										
	60	SAND trace fines, medium, yellowish brown		S-15		5 8 12	20	29		77	
-19.51	64										
	65	SILTY CLAY some sand, limestone fragments, stiff, light brown to pale yellow		S-16		15 14 14	28	18		100	
-21.04	69										
	70	HEAVILY WEATHERED LIMESTONE FRAGMENTS with sand some silt and clay, medium,		S-17		14 14 40/1"	40/1"	11		66	
	75			S-18		40/5"	40/5"	12		27	



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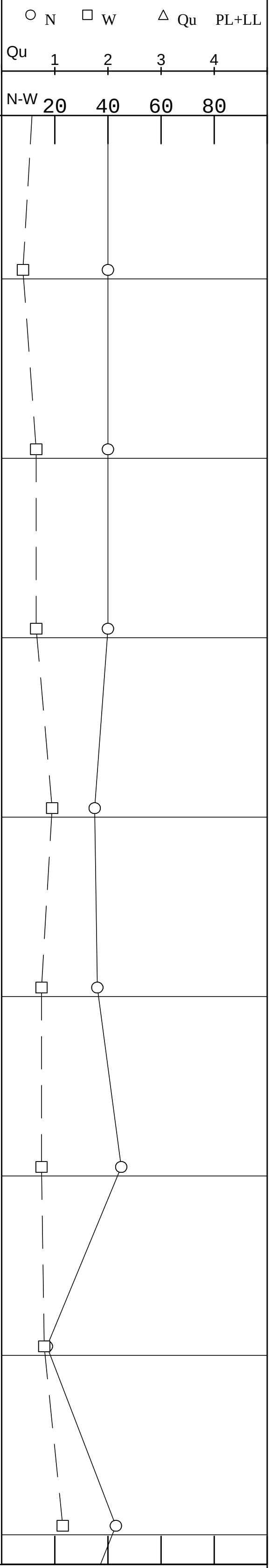
SUBSURFACE EXPLORATION LOG

BORING NUMBER: C-2

BORING LOG (CONT. SHEET)

PROJECT	JOB	SHEET
NFE-V-08 Puerto Rico	7812	3 OF 4

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	80			S-19		40/2"	40/2"	8		13	
	85			S-20		34 40/4"	40/4"	13		66	
	90			S-21		40/4"	40/4"	13		16	
	95			S-22		25 23 12	35	19		100	
	100			S-23		9 16 20	36	15		18	
	105			S-24		26 28 17	45	15		100	
	110			S-25		15 7 10	17	16		77	
	115			S-26		37 22 21	43	23		72	



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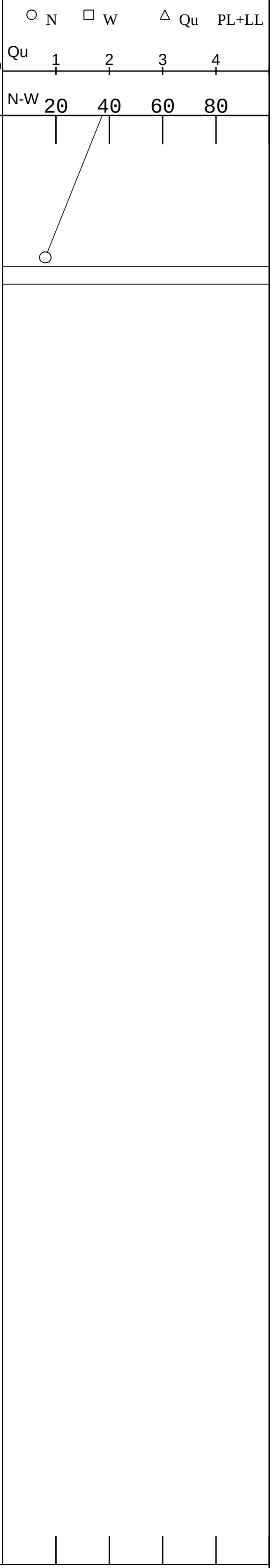
SUBSURFACE EXPLORATION LOG

BORING NUMBER: C-2

BORING LOG (CONT. SHEET)	**PROJECT** NFE-V-08 Puerto Rico	**JOB** 7812	SHEET 4 **OF** 4

Elev. (mts)	DEPTH (feet) 0.00	DESCRIPTION	LEGEND	Sample No.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
			▦	S-27	◣	10 10 6	16			100	
	120										
	125										
	130										
	135										
	140										
	145										
	150										
	155										



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∇ Initial G.W. Depth
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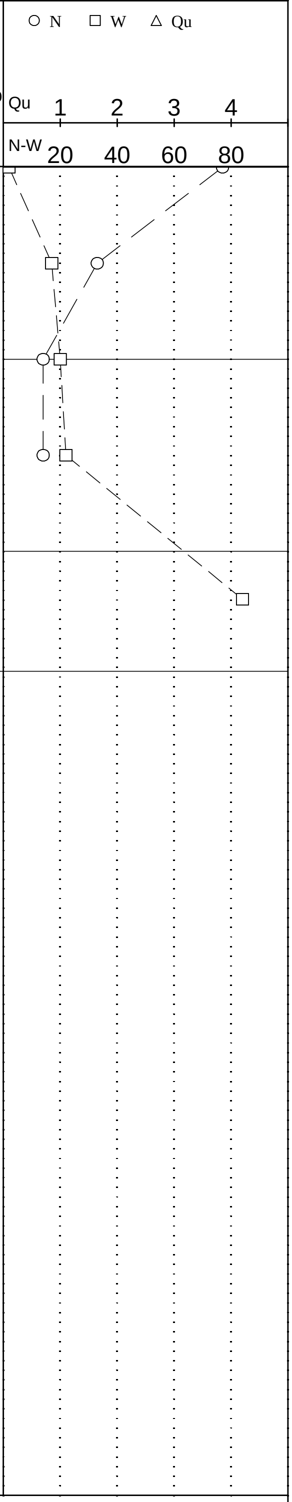
SUBSURFACE EXPLORATION LOG

BORING No.: 1-P

PROJECT: NFE V-08 Microfuel Handling Facilites		**JOB:** 7812-P	**SHEET** 1 **OF** 1
LOCATION: Cataño, PR		**DRILLER/DRILL RIG:** Eddie Sevilla / CME-55	
COORDINATES:		**DATE STARTED:** 12-10-18	**DATE COMPLETED:** 12-10-18
DESCRIPTION BY: Carlos R. Sierra Del Llano		**SURFACE ELEVATION (ft):** 7	
GROUNDWATER (ft):	**Initial:** 7 **Final:** 6	**ENGINEER:** Carlos R. Sierra Del Llano	
DRILLING METHOD: Hollow-Stem Auger 2.25" ID		**TOTAL DEPTH (ft):** 10.5	

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
7.00	0	FILL: sand and gravel, asphalt pavements 0 2	▨	S-1	◣	88 56 21	77	2		91	
5.00		FILL: sand with limestone fragments	▨	S-2	◣	15 18 15	33	17		83	
	4		▨	S-3	◣	3 7 7	14	20		98	
1.00	▼ ▽	6 FILL: silty clay some sand, Strong Hidrocarbon Odor, wet	▨	S-4	◣	4 5 9	14	22		100	
	8		▨								
-2.00		9 SILTY CLAY, very soft, very dark, grayish brown	▥	S-5	◣	WH WH WH	WH	84		96	
	12										
	16										
	20										
	24										



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"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
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SUBSURFACE EXPLORATION LOG

BORING No.: 2-P

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 1

LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

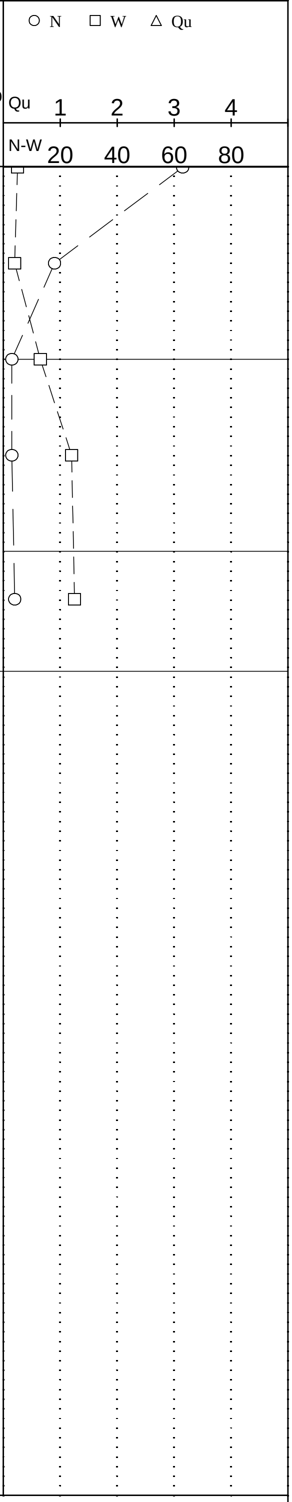
COORDINATES:
DATE STARTED: 12-11-18 **DATE COMPLETED:** 12-11-18

DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 5

GROUNDWATER (ft): **Initial:** 8 **Final:** 7
ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
5.00	0	FILL: sand and gravel, asphalt pavements (0 – 2)	⊠	S-1	◣	42 32 31	63	5		88	
3.00		FILL: sand with limestone fragments	⊠	S-2	◣	25 11 7	18	4		73	
	4	(5)	⊠	S-3	◣	3 2 1	3	13		81	
0.00		SAND trace silt, loose, wet, yellowish brown	⁘	S-4	◣	2 1 2	3	24		91	
	8	Do... some gravel	⁘	S-5	◣	2 2 2	4	25		79	
	12										
	16										
	20										
	24										



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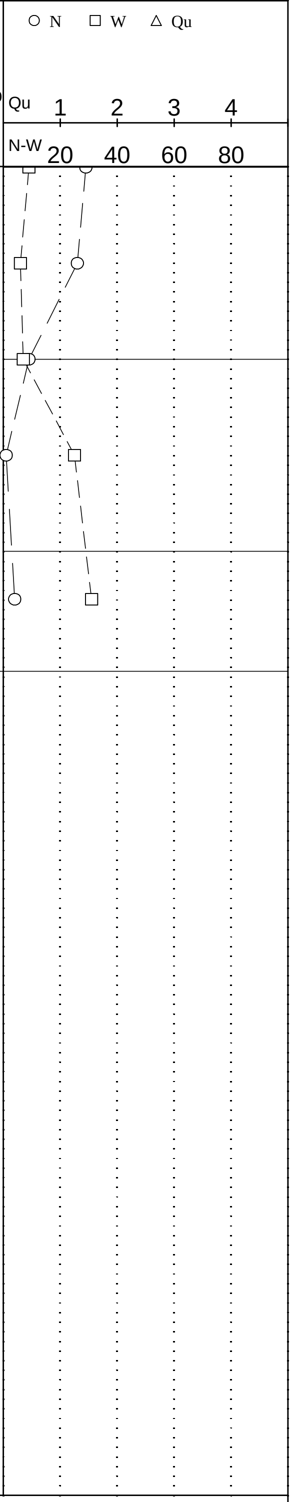
SUBSURFACE EXPLORATION LOG

BORING No.: 3-P

PROJECT: NFE V-08 Microfuel Handling Facilites	**JOB:** 7812-P	**SHEET** 1 **OF** 1

LOCATION: Cataño, PR	**DRILLER/DRILL RIG:** Eddie Sevilla / CME-55
COORDINATES:	**DATE STARTED:** 12-11-18 **DATE COMPLETED:** 12-11-18
DESCRIPTION BY: Carlos R. Sierra Del Llano	**SURFACE ELEVATION (ft):** 8
GROUNDWATER (ft): **Initial:** 7 **Final:** 5.5	**ENGINEER:** Carlos R. Sierra Del Llano
DRILLING METHOD: Hollow-Stem Auger 2.25" ID	**TOTAL DEPTH (ft):** 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	FILL: sand and gravel, asphalt pavements 0	▨	S-1	◣	24 14 15	29	9		75	
6.00		2 SAND some silt, loose, wet, gray, brown	⁙	S-2	◣	11 13 13	26	6		93	
	4		⁙	S-3	◣	6 5 4	9	7		89	
	▼		⁙								
		Do... very loose	⁙	S-4	◣	2 WH 1	1	25		73	
	▽		⁙								
	8		⁙								
		Do... brown, wet	⁙	S-5	◣	2 2 2	4	31		97	
	12										
	16										
	20										
	24										



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"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: 4-P

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 1

LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

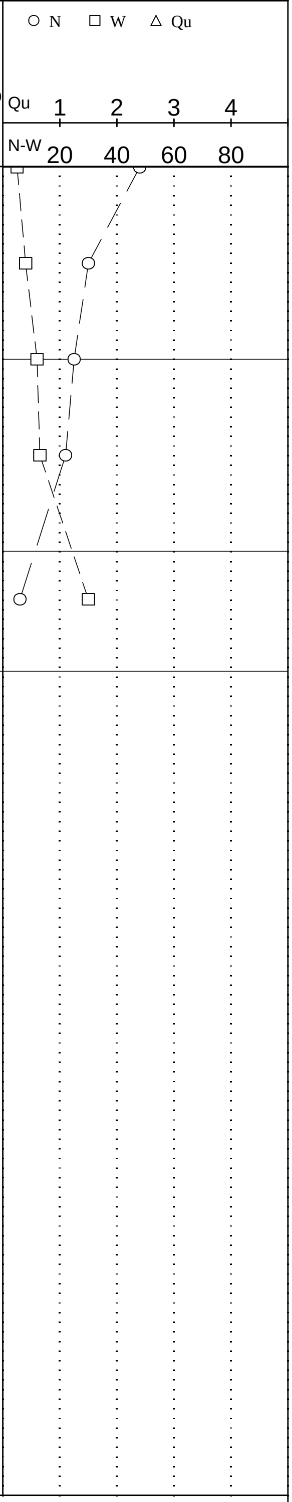
COORDINATES:
DATE STARTED: 12-11-18 **DATE COMPLETED:** 12-11-18

DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8

GROUNDWATER (ft): **Initial:** 10 **Final:** 8
ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: sand and gravel, asphalt pavements 2	▩	S-1	◤	18 19 29	48	5		98	
6.00		SAND some silt, loose, wet, gray, brown	⁘	S-2	◤	13 15 15	30	8		93	
	4		⁘	S-3	◤	6 12 13	25	12		97	
		Do... wet	⁘	S-4	◤	11 13 9	22	13		88	
	▼ 8	9	⁘								
-1.00	▽	SAND trace silt, loose, gray	⁘	S-5	◤	3 3 3	6	30		83	
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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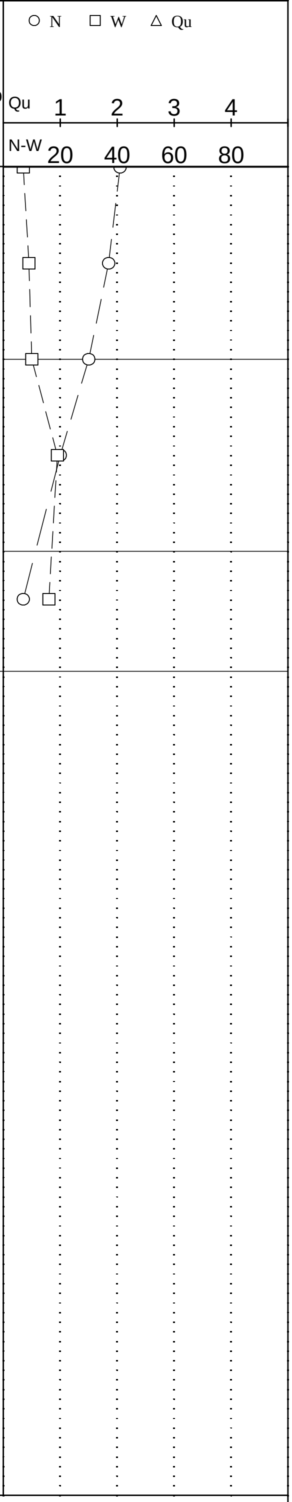
SUBSURFACE EXPLORATION LOG

BORING No.: 5-P

PROJECT: NFE V-08 Microfuel Handling Facilites	**JOB:** 7812-P	**SHEET** 1 **OF** 1
LOCATION: Cataño, PR	**DRILLER/DRILL RIG:** Eddie Sevilla / CME-55	
COORDINATES:	**DATE STARTED:** 12-11-18	**DATE COMPLETED:** 12-11-18
DESCRIPTION BY: Carlos R. Sierra Del Llano	**SURFACE ELEVATION (ft):** 8	
GROUNDWATER (ft): **Initial:** 10 **Final:** 8	**ENGINEER:** Carlos R. Sierra Del Llano	
DRILLING METHOD: Hollow-Stem Auger 2.25" ID	**TOTAL DEPTH (ft):** 10.5	

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: sandy gravel with traces silt, gray, brown 2	▦	S-1	◣	36 22 19	41	7		77	
6.00		SAND trace silt, dense to medium dense, brown	⁙	S-2	◣	14 21 16	37	9		91	
	4		⁙	S-3	◣	9 21 9	30	10		87	
		Do... wet	⁙	S-4	◣	5 8 12	20	19		81	
	▼ 8	9	⁙								
-1.00	▽	CLAYEY SAND with coral and shell fragments, loose, yellowish brown	▨	S-5	◣	2 4 3	7	16		100	
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: 6-P

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 1

LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

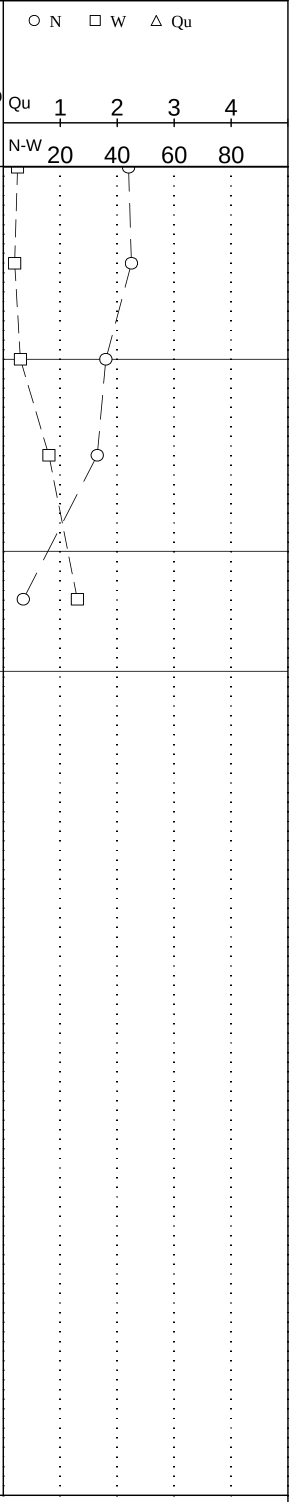
COORDINATES:
DATE STARTED: 12-11-18 **DATE COMPLETED:** 12-11-18

DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8

GROUNDWATER (ft): **Initial:** 10 **Final:** 8
ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: gravelly sand lense, brown, gray 2	⊠	S-1	▲	24 21 23	44	5		89	
6.00		SAND trace silt, dense, brown, gray	⁘	S-2	▲	21 22 23	45	4		91	
	4		⁘	S-3	▲	14 18 18	36	6		94	
		Do... some silt, wet	⁘	S-4	▲	11 14 19	33	16		84	
	▼ 8	9	⁘								
-1.00	▽	SAND trace organic matter, loose, light gray	⁘	S-5	▲	3 4 3	7	26		86	
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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SUBSURFACE EXPLORATION LOG

BORING No.: 7-P

PROJECT: NFE V-08 Microfuel Handling Facilites

JOB: 7812-P

SHEET 1 **OF** 1

LOCATION: Cataño, PR

DRILLER/DRILL RIG: Eddie Sevilla / CME-55

COORDINATES:

DATE STARTED: 12-11-18 **DATE COMPLETED:** 12-11-18

DESCRIPTION BY: Carlos R. Sierra Del Llano

SURFACE ELEVATION (ft): 8

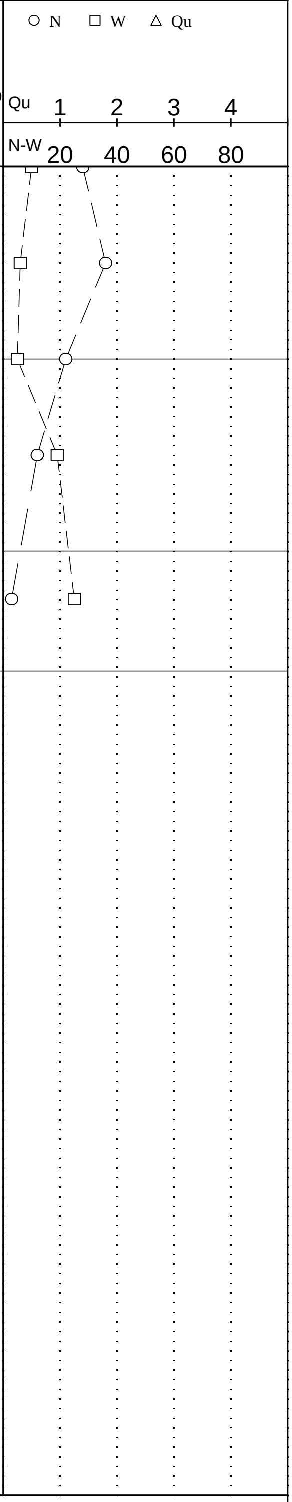
GROUNDWATER (ft): **Initial:** 8 **Final:** 7.5

ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID

TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: gravelly sand lense, brown, gray 2	▨	S-1		20 12 16	28	10		91	
6.00		SAND trace silt, dense, brown, gray	░	S-2		13 18 18	36	6		93	
	4		░	S-3		13 11 11	22	5		97	
		Do... wet	░	S-4		9 6 6	12	19		88	
	8		░								
		Do... loose	░	S-5		2 1 2	3	25		85	
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: 8-P

PROJECT: NFE V-08 Microfuel Handling Facilites

JOB: 7812-P

SHEET 1 **OF** 1

LOCATION: Cataño, PR

DRILLER/DRILL RIG: Eddie Sevilla / CME-55

COORDINATES:

DATE STARTED: 12-11-18 **DATE COMPLETED:** 12-11-18

DESCRIPTION BY: Carlos R. Sierra Del Llano

SURFACE ELEVATION (ft): 7

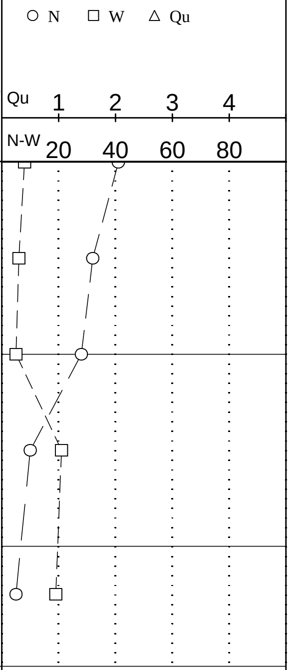
GROUNDWATER (ft): **Initial:** 10 **Final:** 8

ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID

TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
7.00	0	SANDY GRAVEL, dense, brown, yellow, gray 0		S-1		30 21 20	41	8		71	
				S-2		13 16 16	32	6		63	
4.00		3									
		SAND trace silt, dense, brown, gray									
	4			S-3		9 14 14	28	5		93	
		Do... wet		S-4		7 5 5	10	21		89	
	▼ 8										
		Do... loose		S-5		2 3 2	5	19		85	
	▽										
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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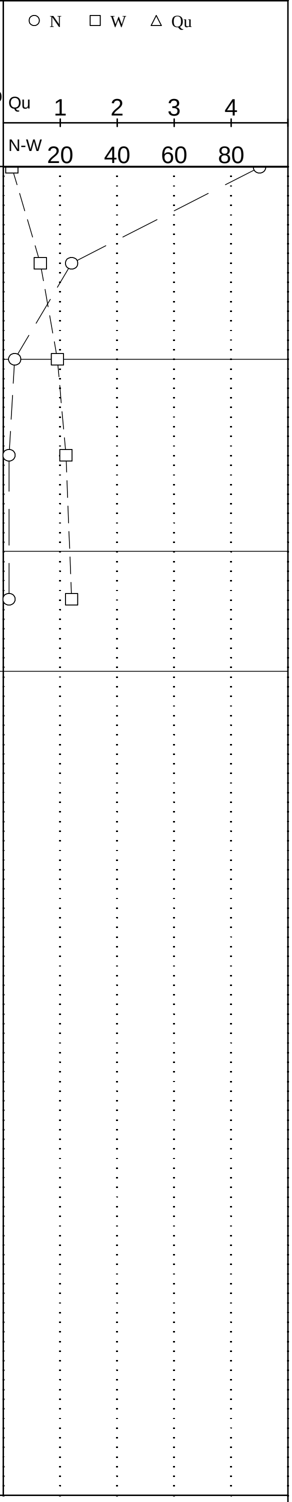
SUBSURFACE EXPLORATION LOG

BORING No.: 9-P

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 1
LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES:
DATE STARTED: 12-12-18
DATE COMPLETED: 12-12-18
DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8
GROUNDWATER (ft): **Initial:** 10 **Final:** 7
ENGINEER: Carlos R. Sierra Del Llano
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	FILL: sand some clay and gravel, dense, gray brown 0	▩	S-1	◣	65 45 45	90	3		87	
			▩	S-2	◣	15 13 11	24	13		98	
4.00	4	4 SAND, loose, brown, light gray	░	S-3	◣	2 2 2	4	19		81	
			░	S-4	◣	3 1 1	2	22		87	
	▼ 8		░								
	▽	Do... very loose, wet	░	S-5	◣	1 1 1	2	24		93	
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot.
▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
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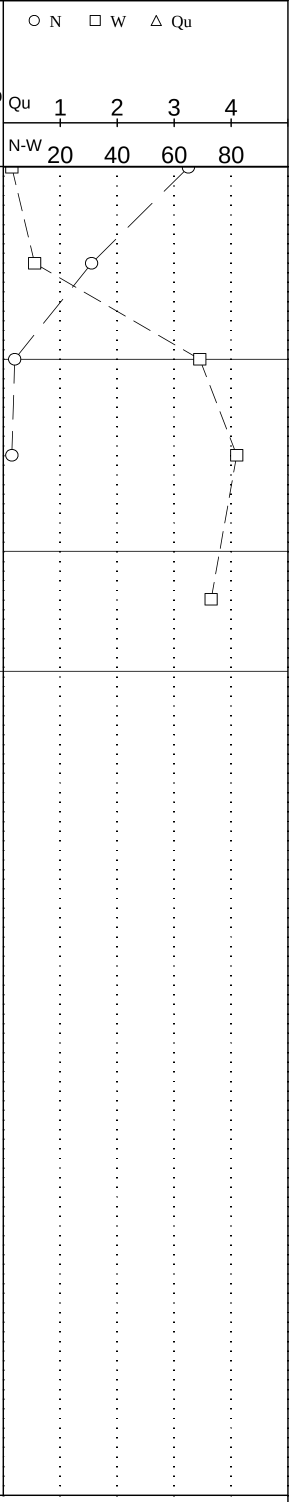
SUBSURFACE EXPLORATION LOG

BORING No.: 10-P

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 1
LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES:
DATE STARTED: 12-10-18 **DATE COMPLETED:** 12-10-18
DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8
GROUNDWATER (ft): **Initial:** Not Found **Final:**
ENGINEER: Carlos R. Sierra Del Llano
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 10.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: sand some clay and gravel, dense, gray, brown	▨	S-1	◣	30 34 31	65	3		88	
			▨	S-2	◣	9 16 15	31	11		93	
4.00	4	4 CLAYEY SILT with shell fragments, dark gray	▥	S-3	◣	3 2 2	4	69		98	
			▥	S-4	◣	2 2 1	3	82		97	
	8		▥								
		Do... very soft	▥	S-5	◣	WH WH WH	WH	73		91	
	12										
	16										
	20										
	24										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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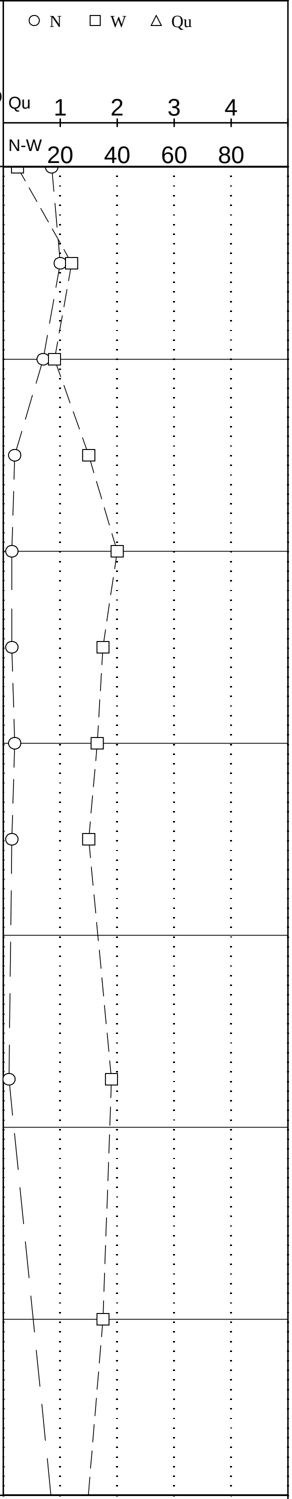
SUBSURFACE EXPLORATION LOG

BORING No.: SC-1

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 2
LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55
COORDINATES:
DATE STARTED: 1-30-19
DATE COMPLETED: 1-30-19
DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8
GROUNDWATER (ft): **Initial:** 7 **Final:** 6
ENGINEER: Carlos R. Sierra Del Llano
DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 30.5

ELEV (ft)	DEPTH (ft)	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	0.00										
8.00	0	0 FILL: SILTY SAND with gravel, brown		S-1		5 9 8 10	17	5		93	
		3		S-2		7 9 11 11	20	24		88	
5.00		DREDGE FILL: SILTY SAND, medium dense, gray								97	
	4			S-3		7 8 6 4	14	18		85	
		Do... loose, trace organic matter (wet)		S-4		3 2 2 2	4	30		83	
	8			S-5		2 1 2 2	3	40		83	
				S-6		2 1 2 2	3	35		88	
	12			S-7		2 2 2 2	4	33		85	
				S-8		2 2 1 1	3	30		81	
	16										
-11.00		19 SILTY CLAY trace sand, soft, dark gray		S-9		1 1 1 1	2	38		90	
	20										
	24	Do... some sand		S-10		2 1 WH	WH	35		94	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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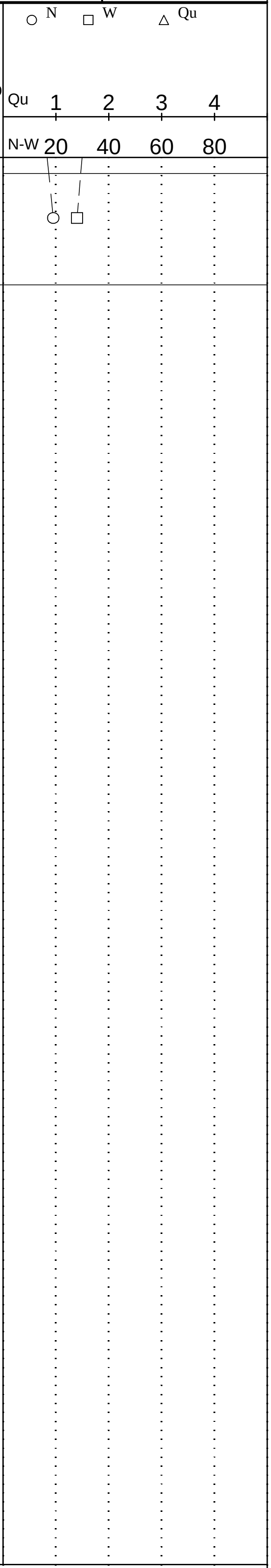
SUBSURFACE EXPLORATION LOG

BORING NUMBER: SC-1

BORING LOG (CONT. SHEET)	PROJECT NFE V-08 Microfuel Handling Facilites	JOB 7812-P	SHEET 2 OF 2

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	28	29									
-21.00		SANDY CLAY some silt, stiff to very stiff, red, brown, white		S-11		5 9 10	19	28		100	
	32										
	36										
	40										
	44										
	48										
	52										
	56										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: SC-2

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 1

LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

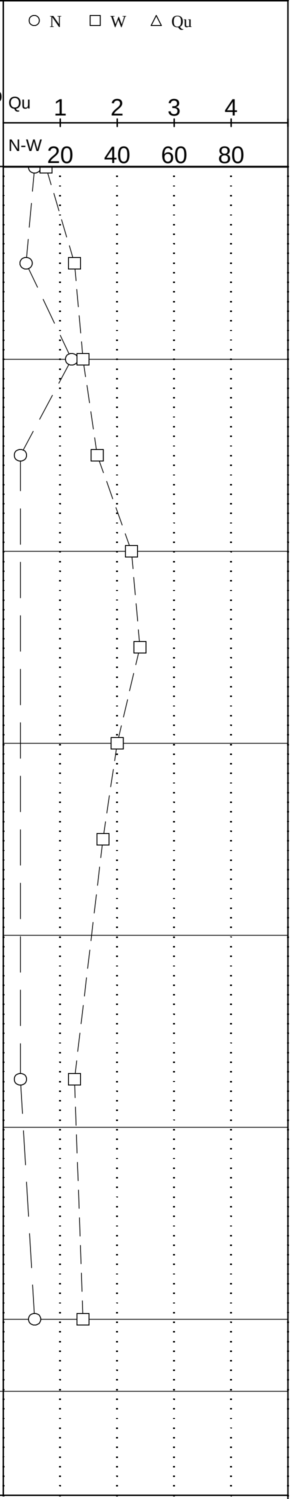
COORDINATES:
DATE STARTED: 1-30-19 **DATE COMPLETED:** 1-30-19

DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8

GROUNDWATER (ft): **Initial:** 6 **Final:** 7
ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 25.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: silty sand with gravel, brown		S-1		12 8 3 4	11	15		93	
				S-2		3 3 5 2	8	25		89	
5.00	4	3 FILL: sandy clay with limestone gravel, brown, yellow		S-3		4 16 8 8	24	28		93	
	▽ ▼	Do... wet		S-4		4 3 3 3	6	33		98	
0.00	8	8 SILTY CLAY trace sand, very soft, dark gray		S-5		3 1 WH WH	WH	45		77	
				S-6		WH WH WH WH	WH	48		85	
	12			S-7		WH WH WH WH	WH	40		82	
		Do... trace shell fragments		S-8		WH WH WH WH	WH	35		80	
	16										
-11.00	20	19 SILTY SAND with coral fragments, loose, gray		S-9		4 4 2	6	25		89	
-16.00	24	24 CLAYEY SAND, medium dense, red, gray, white		S-10		1 4 7	11	28		100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
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"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: B-5

PROJECT: NFE V-08 Microfuel Handling Facilites

JOB: 7812-P

SHEET 1 **OF** 3

LOCATION: Cataño, PR

DRILLER/DRILL RIG: Eddie Sevilla / CME-55

COORDINATES:

DATE STARTED: 1-30-19 **DATE COMPLETED:** 1-30-19

DESCRIPTION BY: Carlos R. Sierra Del Llano

SURFACE ELEVATION (ft): 7

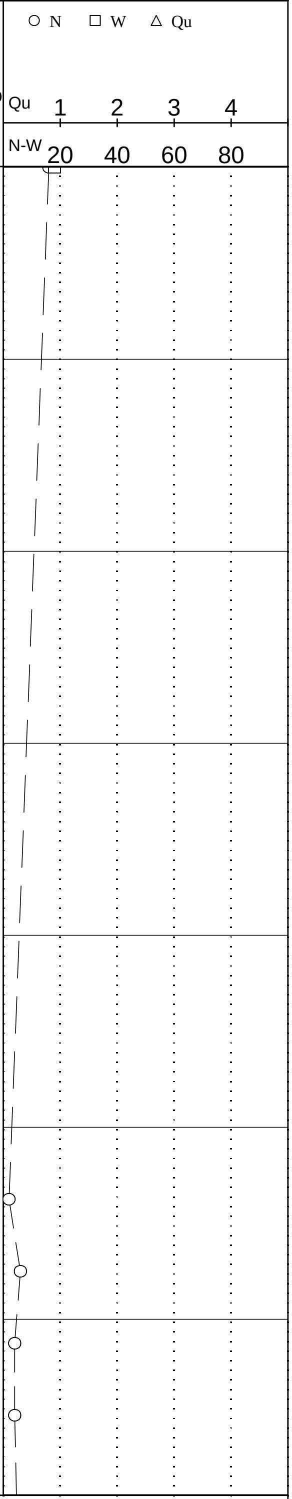
GROUNDWATER (ft): **Initial:** 6.5 **Final:** 15.5

ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD:

TOTAL DEPTH (ft): 65.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
7.00	0	Concrete Slab 8 inch.	■			8 9 7	16	18			
6.34	0.66	SILTY SAND with gravel, brown	⁘								
4.00	3	Concrete Slab 2.5 feet	■								
1.50	5.5										
0.50	6.5	Water	≈								
-14.50	21.5	SILTY CLAY trace sand and shell fragments, dark gray	▨	S-1		2 1 1	2			93	
				S-2		3 3 3	6			97	
				S-3		3 2 2	4			100	
				S-4		1 2 2	4			100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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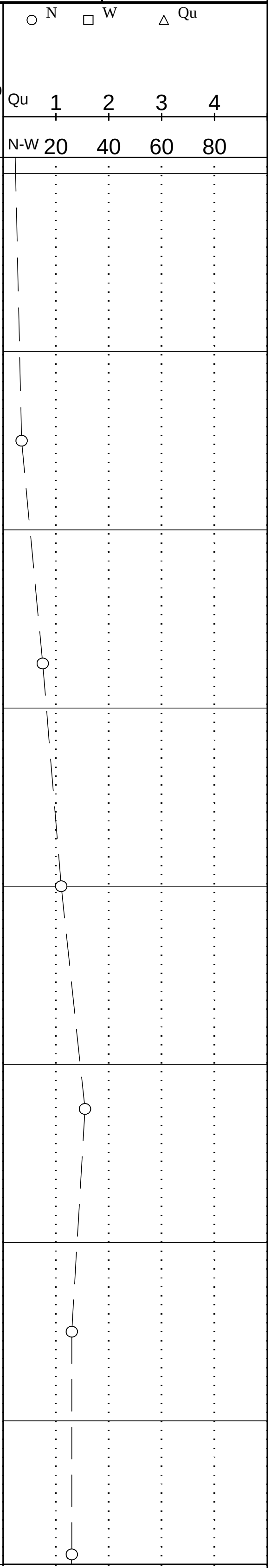
SUBSURFACE EXPLORATION LOG

BORING NUMBER: B-5

BORING LOG (CONT. SHEET)	PROJECT	JOB	SHEET
	NFE V-08 Microfuel Handling Facilites	7812-P	2 OF 3

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	28		▨								
	32		▨								
-27.00		34	▨								
		SILTY CLAY with some sand, stiff, red, reddish yellow, white	▨	S-5		5 2 5	7			100	
	36		▨								
		Do... very stiff	▨	S-6		4 6 9	15			100	
	40		▨								
	44	Do... hard	▨	S-7		7 9 13	22			100	
	48		▨	S-8		7 13 18	31			100	
	52		▨								
		Do... some fine gravel fragments	▨	S-9		6 9 17	26			96	
	56		▨								
-52.00		59	▨								



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: **B-5**

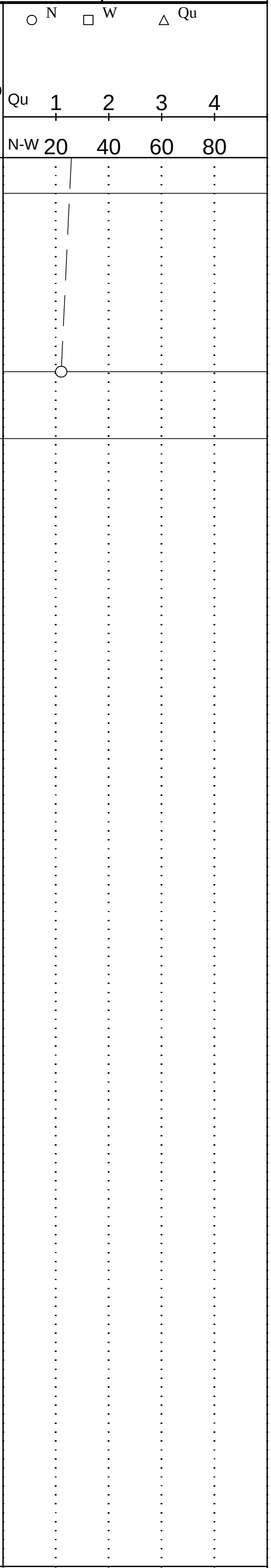
BORING LOG (CONT. SHEET)

PROJECT NFE V-08 Microfuel Handling Facilites

JOB 7812-P

SHEET 3 **OF** 3

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	60	CLAYEY SAND some silt, dense, brownish red 64	▨	S-10	◣	6 9 17	26			98	
-57.00	64	SILTY CLAY trace sand, very stiff, brownish red	▨	S-11	◣	7 10 12	22			100	
	68										
	72										
	76										
	80										
	84										
	88										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: B-6

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 3

LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

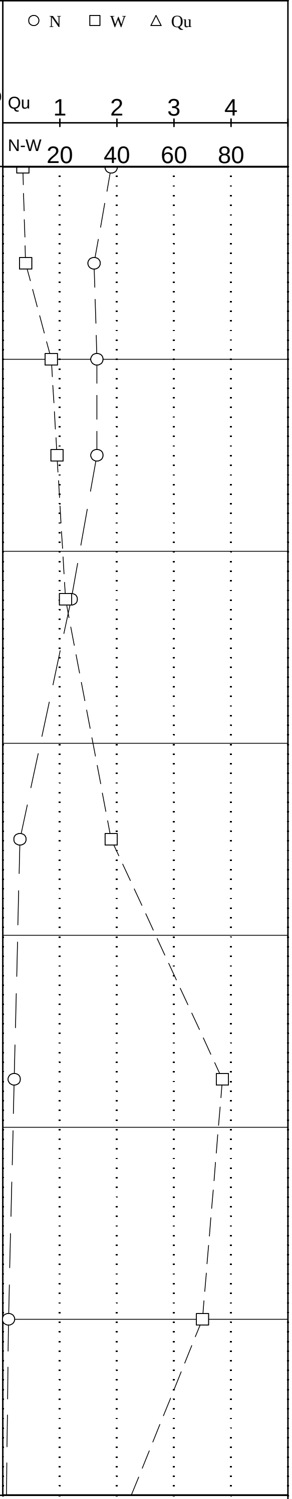
COORDINATES:
DATE STARTED: 12-20-18 **DATE COMPLETED:** 12-20-18

DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8

GROUNDWATER (ft): **Initial:** 6 **Final:** 5.5
ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 80.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	0 FILL: sand with gravel some clay, medium, moist, dark graish	☒	S-1		10 12 26	38	7		83	
			☒	S-2		10 14 18	32	8		88	
4.00	4	4 SAND some gravel trace silt, medium, moist, light brown	⁚	S-3		10 14 19	33	17		95	
	▼ ▽		⁚	S-4		10 16 17	33	19		91	
	8		⁚								
		Do... very dark brown to dark gray, moist	⁚	S-5		5 14 10	24	22		98	
	12		⁚								
-6.00		14 SILTY CLAY some sand with rock fragments, soft, wet, dark gray	▨	S-6		3 4 2	6	38		100	
	16		▨								
-11.00		19 SILTY CLAY trace sand, soft to soft, very dark gray to dark brown	▨	S-7		WH 2 2	4	77		93	
	20		▨								
	24	Do... trace shells and rock fragments	▨	S-8		WH WH 2	2	70		91	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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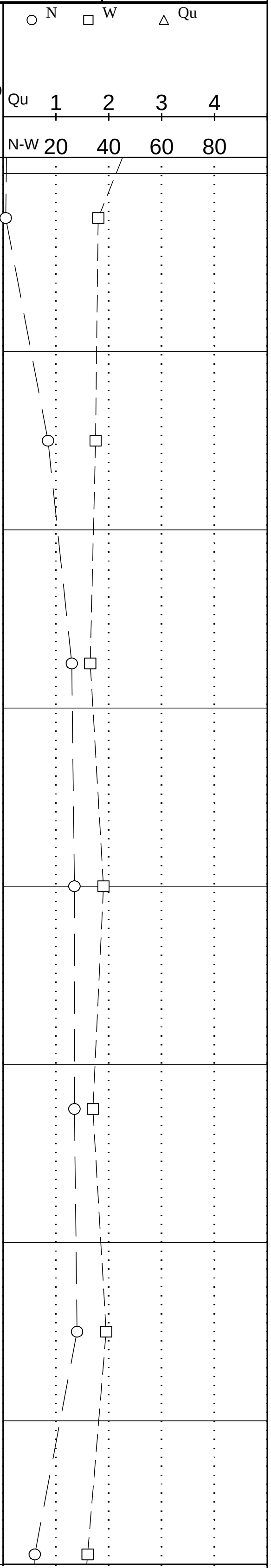
SUBSURFACE EXPLORATION LOG

BORING NUMBER: **B-6**

BORING LOG (CONT. SHEET)

PROJECT	JOB	SHEET	OF
NFE V-08 Microfuel Handling Facilites	7812-P	2	3

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	28										
				S-9		WH WH 1	1	36		89	
	32										
-26.00		34									
		CLAY some silt, very stiff, reddish brown and gray		S-10		3 7 10	17	35		100	
	36										
		Do... red, reddish brown		S-11		7 12 14	26	33		100	
	40										
	44	Do... yellowish brown		S-12		7 11 16	27	38		100	
	48										
-41.00		49									
		SILTY CLAY with rock fragments trace sand, very stiff, moist, yellowish brown to reddish yellow		S-13		7 11 16	27	34		100	
	52										
				S-14		11 14 14	28	39		100	
	56										
-51.00		59									



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: **B-6**

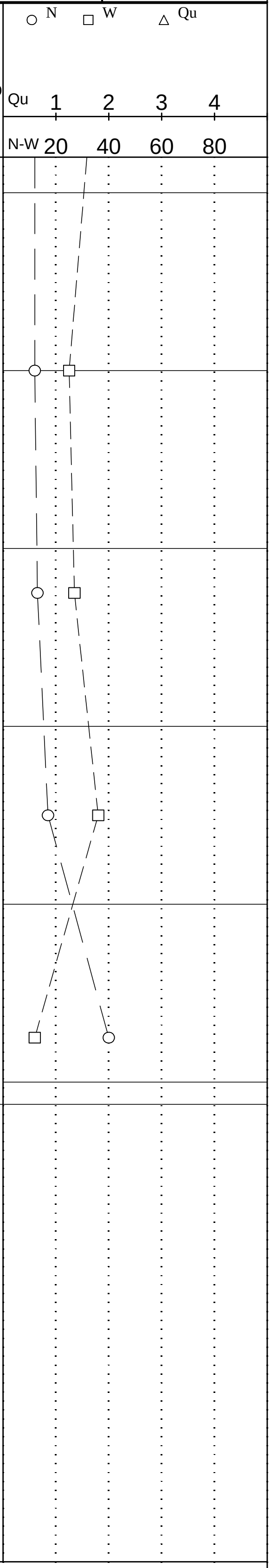
BORING LOG (CONT. SHEET)

PROJECT NFE V-08 Microfuel Handling Facilites

JOB 7812-P

SHEET 3 **OF** 3

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	60	SILTY CLAY some sand, stiff, wet, yellowish brown	▨	S-15	◤	5 5 7	12	32		100	
	64	Do... some limestone weathered fragments	▨	S-16	◤	8 6 6	12	25		95	
	68		▨								
			▨	S-17	◤	5 5 8	13	27		100	
	72		▨								
			▨	S-18	◤	5 7 10	17	36		100	
	76		▨								
			▨	S-19	◤	26 40/4"	40/4"	12		30	
	80										
	84										
	88										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
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▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING No.: B-7

PROJECT: NFE V-08 Microfuel Handling Facilites
JOB: 7812-P
SHEET 1 **OF** 3

LOCATION: Cataño, PR
DRILLER/DRILL RIG: Eddie Sevilla / CME-55

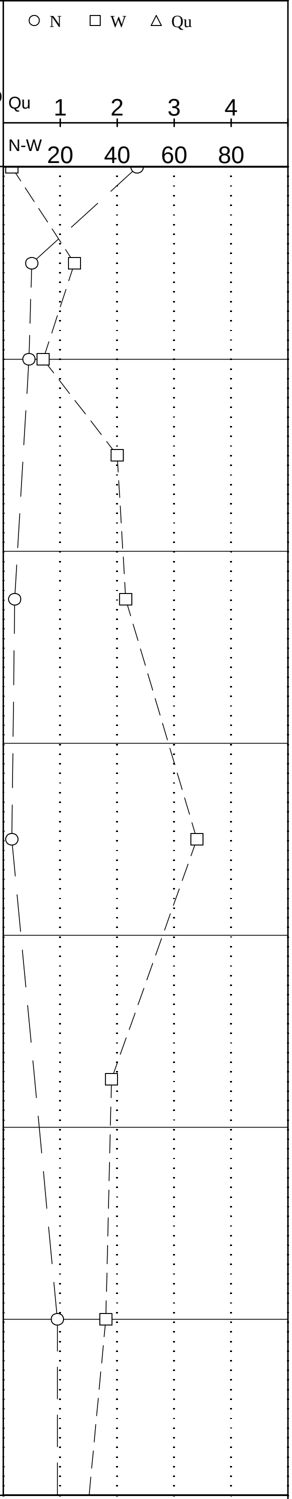
COORDINATES:
DATE STARTED: 1-11-18 **DATE COMPLETED:** 1-11-18

DESCRIPTION BY: Carlos R. Sierra Del Llano
SURFACE ELEVATION (ft): 8

GROUNDWATER (ft): **Initial:** 7 **Final:** 5
ENGINEER: Carlos R. Sierra Del Llano

DRILLING METHOD: Hollow-Stem Auger 2.25" ID
TOTAL DEPTH (ft): 60.5

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
8.00	0	FILL: sand with gravel some silty clay, dark brown		S-1		25 18 29	47	3		87	
6.00	2	SILTY CLAY some sand trace of shell fragments, medium, moist, reddish brown		S-2		6 5 5	10	25		100	
4.00	4	SAND some coral and shell fragments, loose, grayish brown		S-3		10 6 3	9	14		91	
2.00	6	SILTY CLAY with sand, very soft, moist, yellowish brown		S-4		1 WH 1	WH	40		92	
-1.00	9	SILTY CLAY trace sand, very soft, yellowish brown and gray		S-5		1 1 3	4	43		100	
-6.00	14	SILTY CLAY with shell fragments some sand, soft, moist, dark gray to black		S-6		1 2 1	3	68		100	
-11.00	19	SILTY CLAY trace sand, very soft, yellowish brown to dark brown		S-7		WH WH WH	WH	38		95	
-16.00	24	SILTY CLAY with some sand, very stiff, brownish red, light gray, yellow		S-8		3 9 10	19	36		100	



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot.
▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: B-7

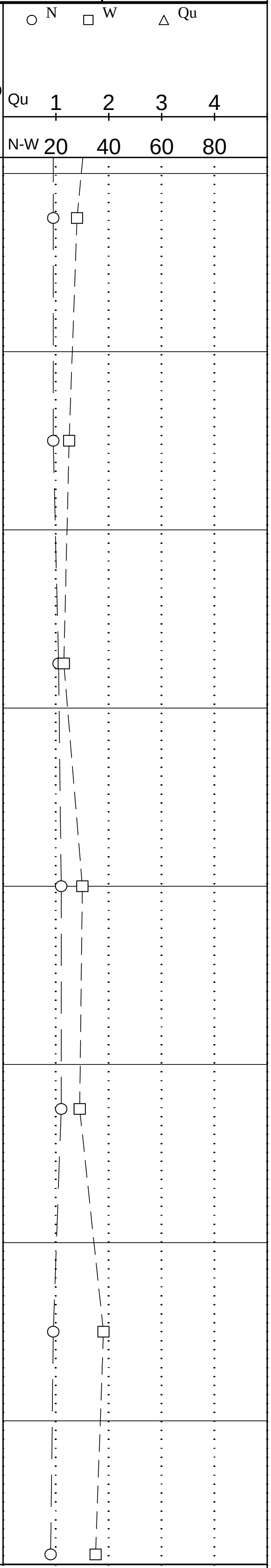
BORING LOG (CONT. SHEET)

PROJECT NFE V-08 Microfuel Handling Facilites

JOB 7812-P

SHEET 2 **OF** 3

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%
	28										
				S-9		3 9 10	19	28		100	
	32										
		Do... reddish yellow		S-10		4 9 10	19	25		100	
	36										
				S-11		5 9 12	21	23		100	
	40										
	44			S-12		4 10 12	22	30		100	
	48										
				S-13		4 10 12	22	29		100	
	52										
				S-14		6 8 11	19	38		100	
	56										



"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight.
"Qu" - Unconfined Compressive Strength in tons per square foot.
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

▽ Initial G.W. Depth
▼ Final G.W. Depth

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SUBSURFACE EXPLORATION LOG

BORING NUMBER: B-7

BORING LOG (CONT. SHEET)	PROJECT NFE V-08 Microfuel Handling Facilites	JOB 7812-P	SHEET 3 OF 3

ELEV (ft)	DEPTH (ft) 0.00	DESCRIPTION	LEGEND	SAMPLE NO.	TYPE	BLOWS	SPT N	W	Qu	RC	RQD%	○ N □ W △ Qu Qu 1 2 3 4 N-W 20 40 60 80
	60		▨	S-15	◣	6 8 10	18	35		100		
	64											
	68											
	72											
	76											
	80											
	84											
	88											

"N" - Number of blows required to drive the sampling spoon a distance of 12 in. with a 140 lbs hammer falling 30 in.
"W" - Natural Moisture Content in percentage of dry weight. ▽ Initial G.W. Depth
"Qu" - Unconfined Compressive Strength in tons per square foot. ▼ Final G.W. Depth
"Rc" - Core recovery in percent for each successive run. "RQD" - Rock quality designation.
"WH" - Sample was recovered by advancing the sampler with the weight of the hammer.
"P" - A "P" in the Unconfined Compressive Strength test indicates the use of the pocket Penetrometer.

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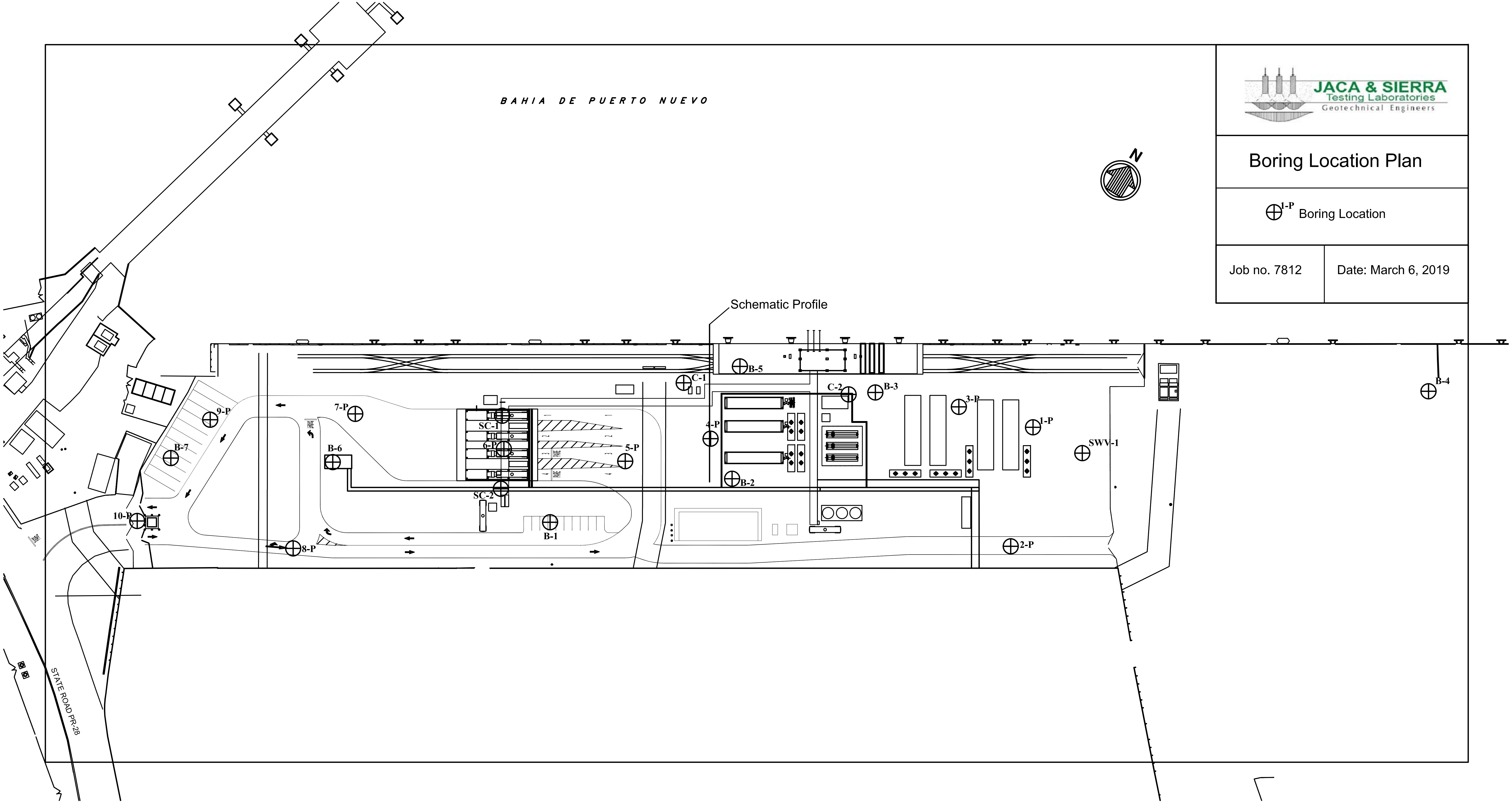
Boring Location Plan

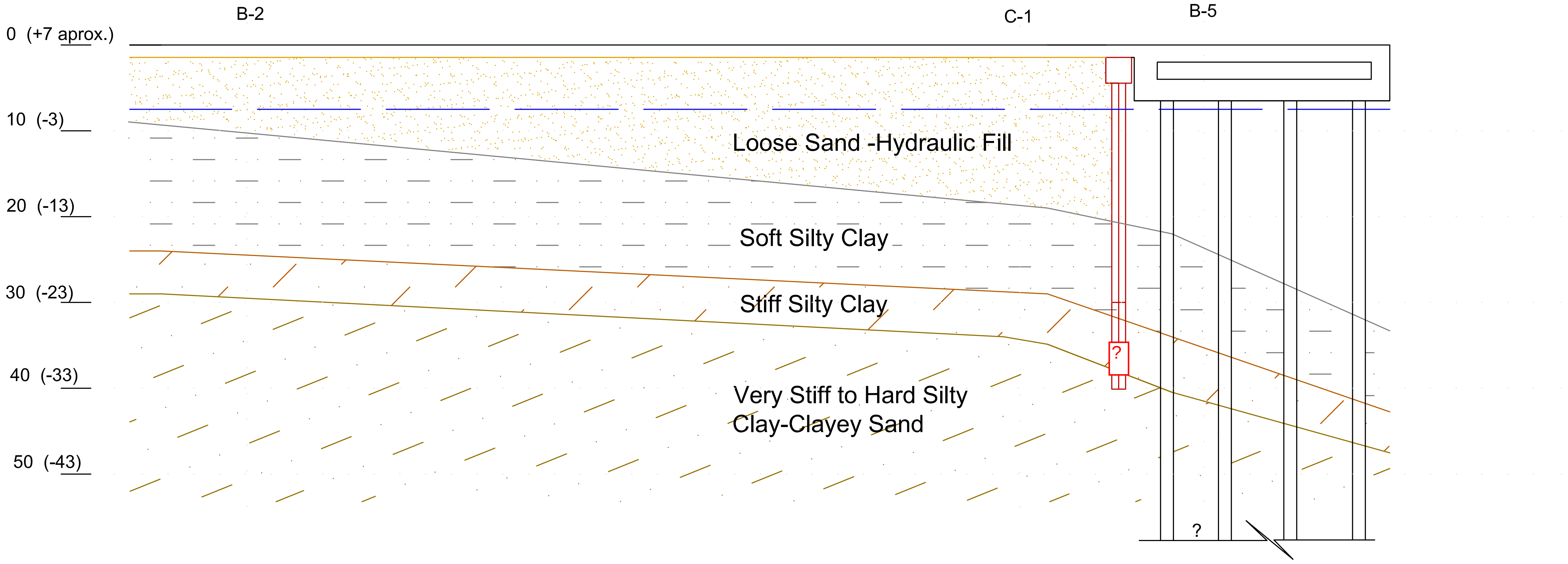
⊕ 1-P Boring Location

Job no. 7812

Date: March 6, 2019



IDEALIZED SCHEMATIC SUBSURFACE PROFILE



Appendix B

Cone Penetration Tests and Downhole Seismic Test

PROJECT: NFE-V-08 PR Concept Development Project Exhibit
TEST ID: CPT-1
TOTAL DEPTH: 54.029 ft
LOCATION: San Juan, PR
TEST DATE: Fri 26/Jan/2018

OPERATOR: M. Candelario
CREW: E.Sevilla/F.Villegas
FILENAME: combined-file-for-CPT-1.dat
PROBE ID: 3045.115XX

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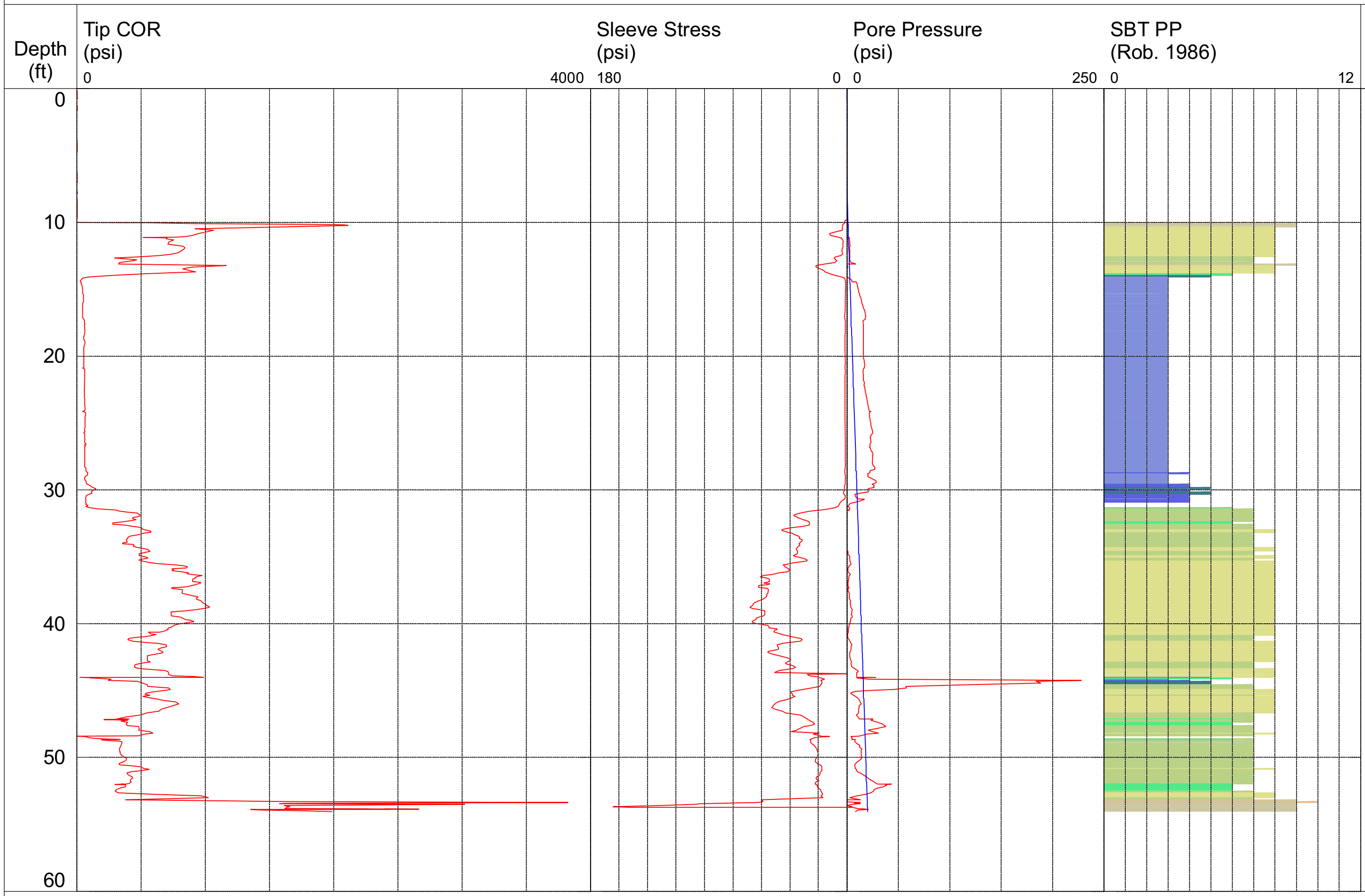

REMARKS

SOUNDING

🟥 1 Sensitive fine grained
🟥 2 Organic material
🟦 3 Clays
🟦 4 Silty clay to clay
🟩 5 Clayey silt to silty clay
🟩 6 Sandy silt to clayey silt
🟩 7 Silty sand to sandy silt
🟨 8 sand to silty sand
🟫 9 Sand
🟧 10 Gravelly sand to sand
⬜ 11 Very stiff fine grained **
⬛ 12 Sand to clayey sand **

*SBT: Robertson 1986; **Overconsolidated or Cemented; *SBT/SPT CORRELATION: UBC-1983

PROJECT: NFE-V-08 PR Concept Development Project Exhibit
TEST ID: CPT-2
TOTAL DEPTH: 67.683 ft
LOCATION: San Juan, PR
TEST DATE: Fri 26/Jan/2018

OPERATOR: M. Candelario
CREW: E.Sevilla/F.Villegas
FILENAME: combined-file-CPT-2.dat
PROBE ID: 3045.115XX

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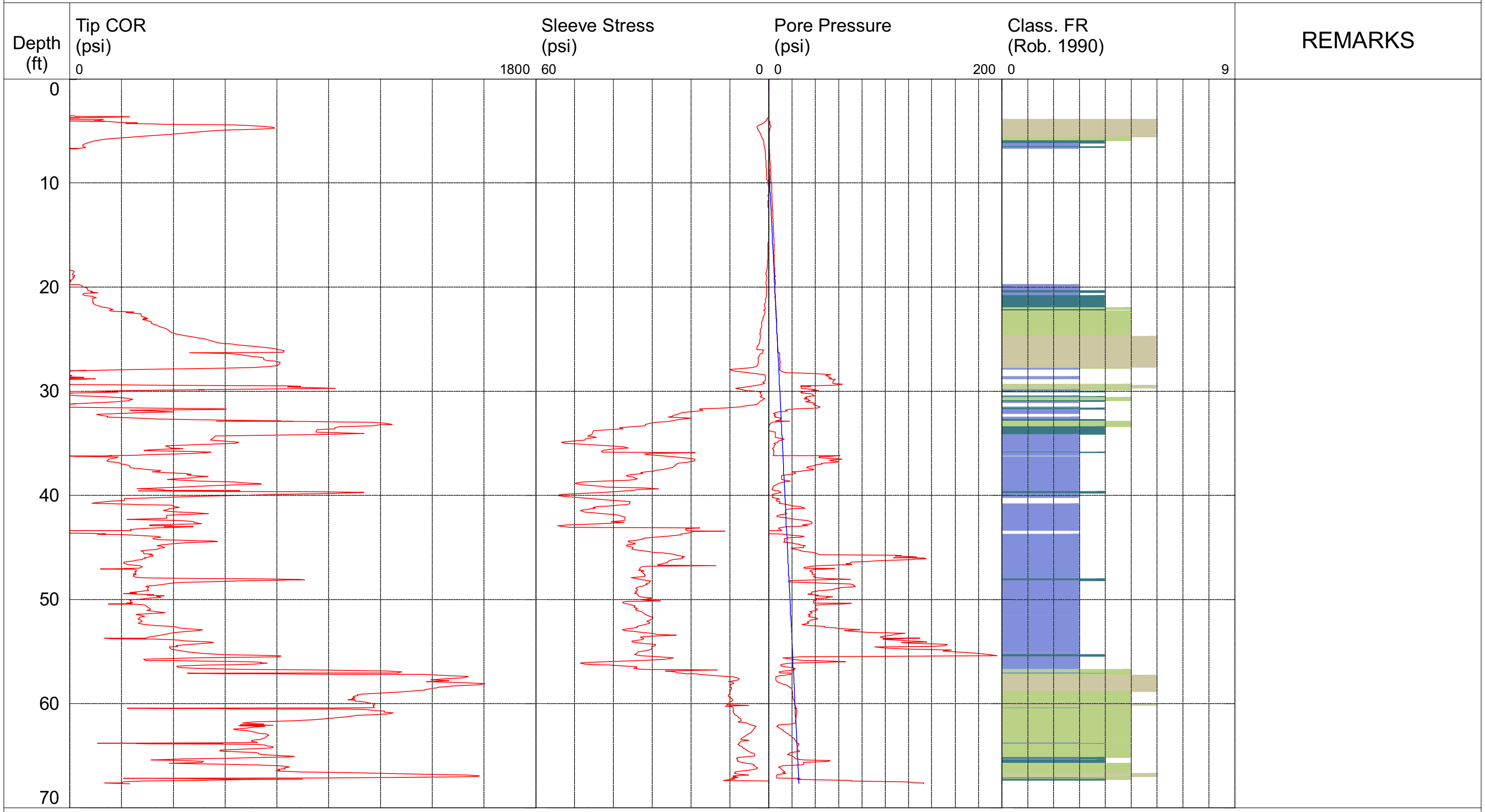

SOUNDING

🟥 1 Sensitive, fine grained
🟥 2 Organic soils - peats
🟦 3 Clays - clay to silty clay
🟦 4 Silt mixtures - clayey silt to silty clay
🟩 5 Sand mixtures - silty sand to sandy silt
🟫 6 Sands - clean sand to silty sand
🟧 7 Gravelly sand to sand
⬛ 8 Very stiff sand to clayey sand **
⬜ 9 Very stiff, fine grained **

*SBT: Robertson 1990; **Overconsolidated or Cemented; *SBT/SPT CORRELATION: UBC-1983

PROJECT: NFE-V-08 PR Concept Development Project Exhibit
TEST ID: CPT-3
TOTAL DEPTH: 42.824 ft
LOCATION: San Juan, PR
TEST DATE: Thu 25/Jan/2018

OPERATOR: M. Candelario
CREW: E.Sevilla/F.Villegas
FILENAME: 2CME-5525J1805C.DAT
PROBE ID: 3045.115XX

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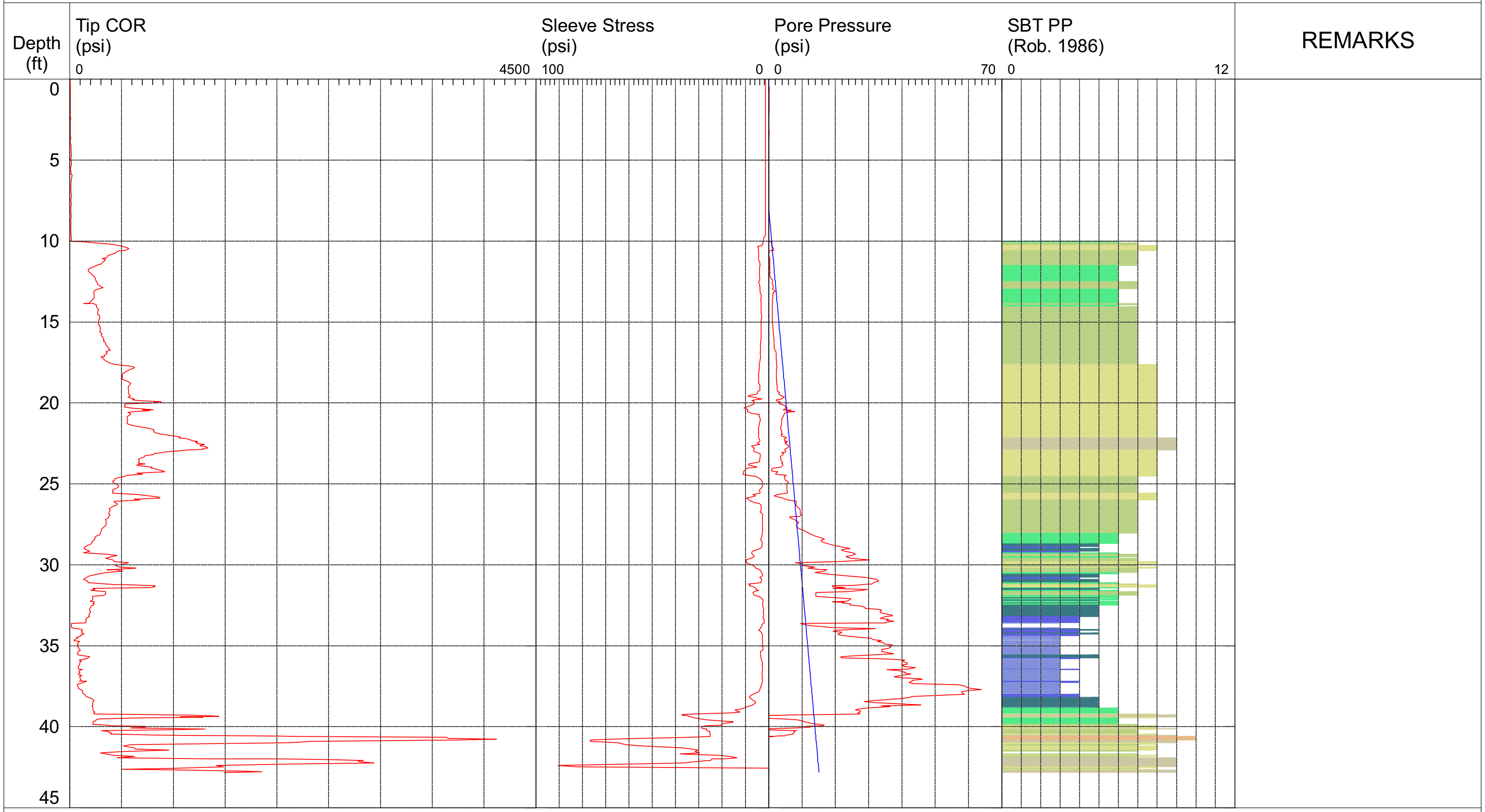

SOUNDING

🟥 1 Sensitive, fine grained
🟥 2 Organic soils - peats
🟦 3 Clays - clay to silty clay
🟦 4 Silt mixtures - clayey silt to silty clay
🟩 5 Sand mixtures - silty sand to sandy silt
🟫 6 Sands - clean sand to silty sand
🟧 7 Gravelly sand to sand
⬛ 8 Very stiff sand to clayey sand **
⬜ 9 Very stiff, fine grained **

*SBT: Robertson 1990; **Overconsolidated or Cemented; *SBT/SPT CORRELATION: UBC-1983

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Downhole Seismic Test - Boring no. SWV-1

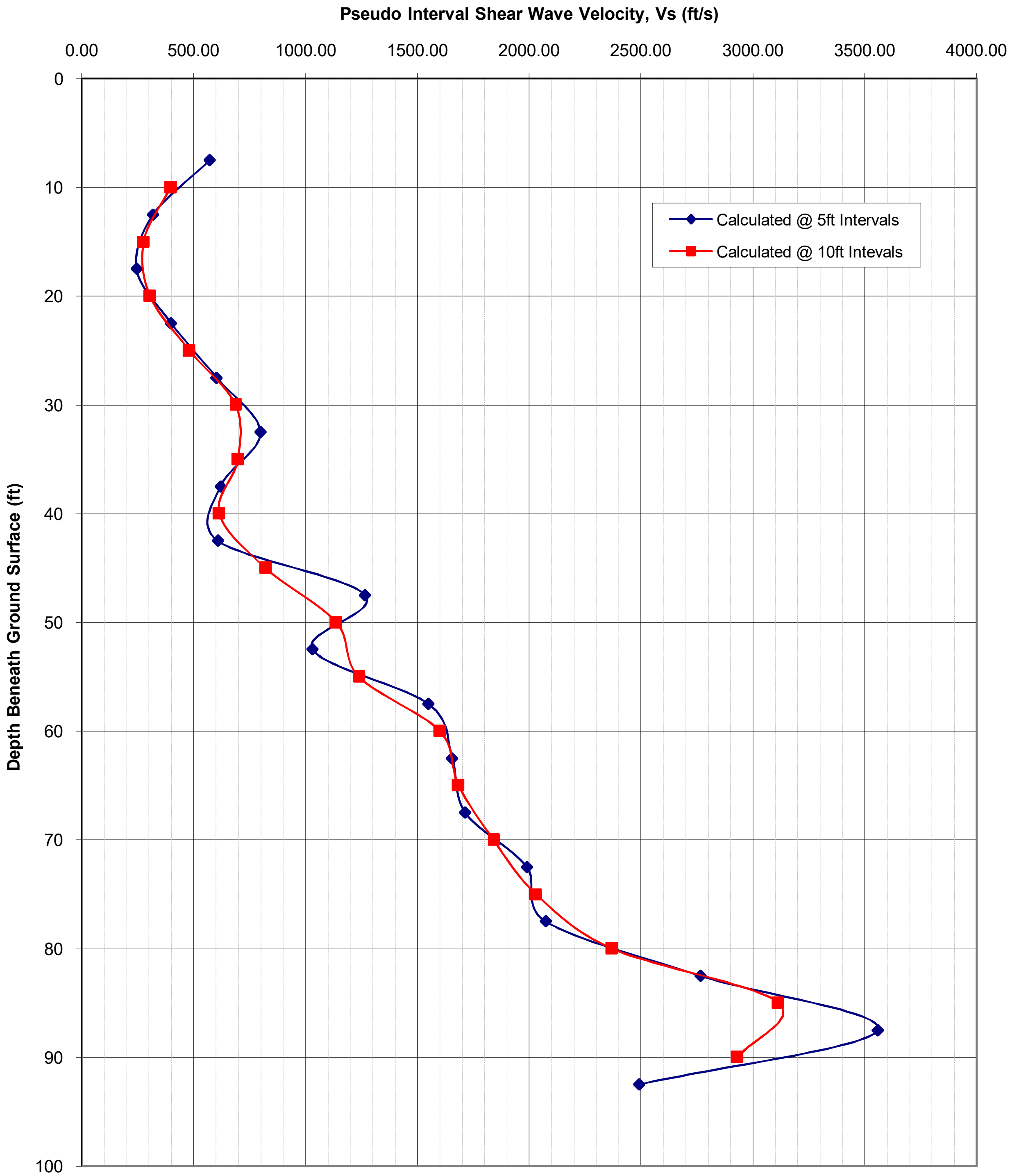

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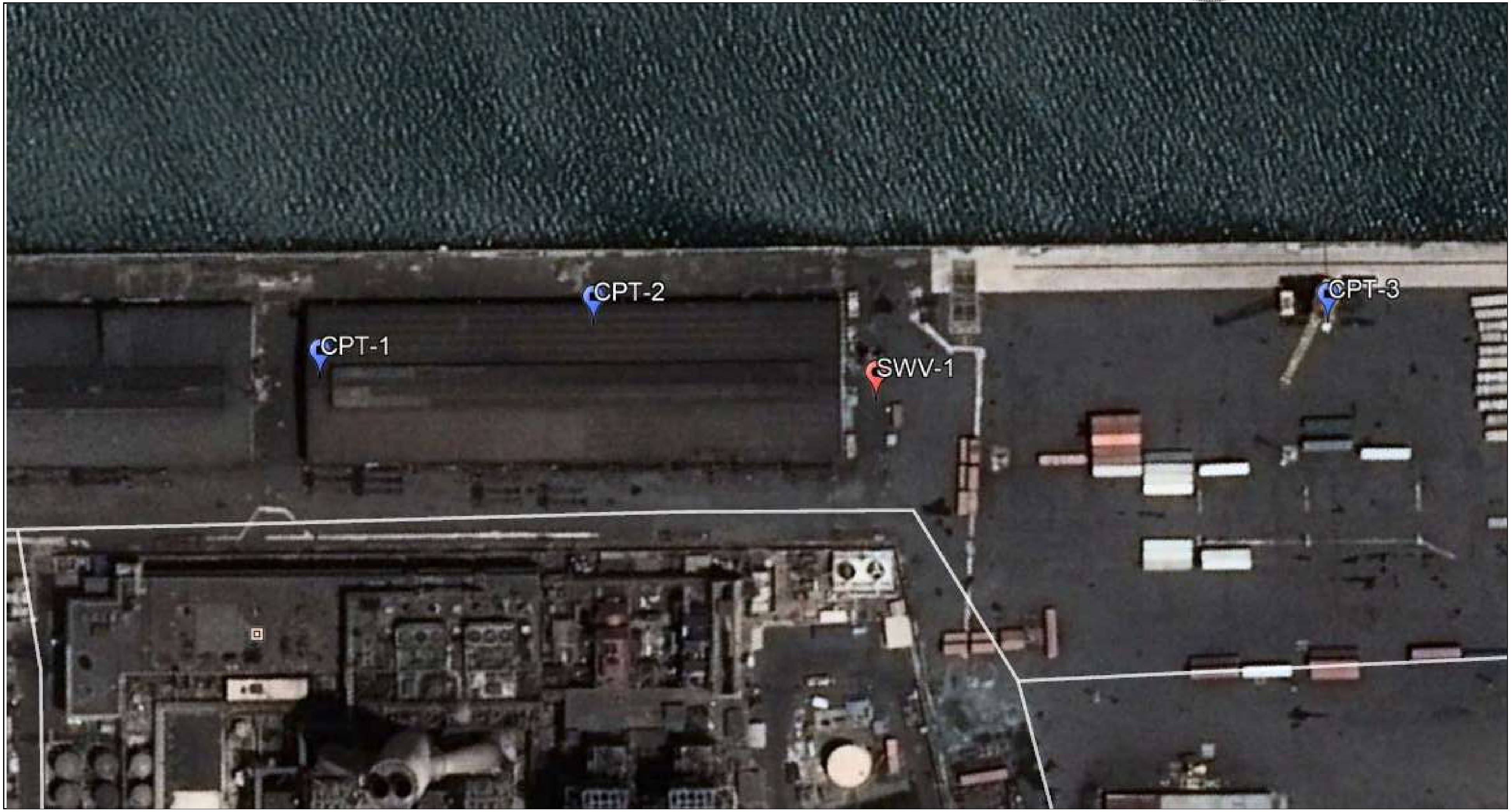
TABLE 1. SHEAR WAVE VELOCITY MEASUREMENT ASTM D7400-08
DOWNHOLE SEISMIC TEST - BORING SWV-1

Operator:	M. Candelario
Test Date / Weather:	Dec. 27, 2017; 9-10am/82 F, cloudy
Source:	12 lb sledge hammer
Downhole Receiver:	BHG 2 Triaxial Geophone
Recording Equipment	ES 3000-Seismograph
Borehole Information:	Grouted cased borehole
Method of Installation:	3.25 inch ID Hollow Stem Augers
Casing Diameter:	2 inch Sch.40 PVC
Clamp Method:	Mechanical Spring
Ground Surface Elevation @ Source, Eg:	0 m
Shear Wave Source Horizontal Offset, Xs:	7.5 ft
Compression (P) Wave Source Offset, Xp	3.5 ft
Pipe Stickup:	0 ft
Receiver Offset from Reference Point:	0 ft
Ground Surface Elevation @ Borehole, Eg:	0 m

Recorded Geophone Depth (ft)	Corrected Geophone Depth (ft)	Receiver Depth, D_G(ft)	Receiver Elevation (m)	Source Slant Distance, L_R (ft)	Reference Shear Wave Arrival Time (millisec)	Interval Arrival Time Difference ΔTs (millisec)	**Interval Shear Wave Velocity, Vs (ft/sec)**
5	5	5	-1.52	9.01	5.9		
						6.1	**571**
10	10	10	-3.05	12.50	12		
						13.4	**319**
15	15	15	-4.57	16.77	25.4		
						18.7	**245**
20	20	20	-6.10	21.36	44.1		
						11.9	**398**
25	25	25	-7.62	26.10	56		
						8	**603**
30	30	30	-9.15	30.92	64		
						6.1	**799**
35	35	35	-10.67	35.79	70.1		
						7.9	**621**
40	40	40	-12.20	40.70	78		
						8.1	**608**
45	45	45	-13.72	45.62	86.1		
						3.9	**1266**
50	50	50	-15.24	50.56	90		
						4.8	**1031**
55	55	55	-16.77	55.51	94.8		
						3.2	**1549**
60	60	60	-18.29	60.47	98		
						3	**1655**
65	65	65	-19.82	65.43	101		
						2.9	**1714**
70	70	70	-21.34	70.40	103.9		
						2.5	**1989**
75	75	75	-22.87	75.37	106.4		
						2.4	**2074**
80	80	80	-24.39	80.35	108.8		
						1.8	**2766**
85	85	85	-25.91	85.33	110.6		
						1.4	**3558**
90	90	90	-27.44	90.31	112		
						2	**2492**
95	95	95	-28.96	95.30	114		



Approximate Locations of Cone Penetrometer Tests and Downhole Seismic Test

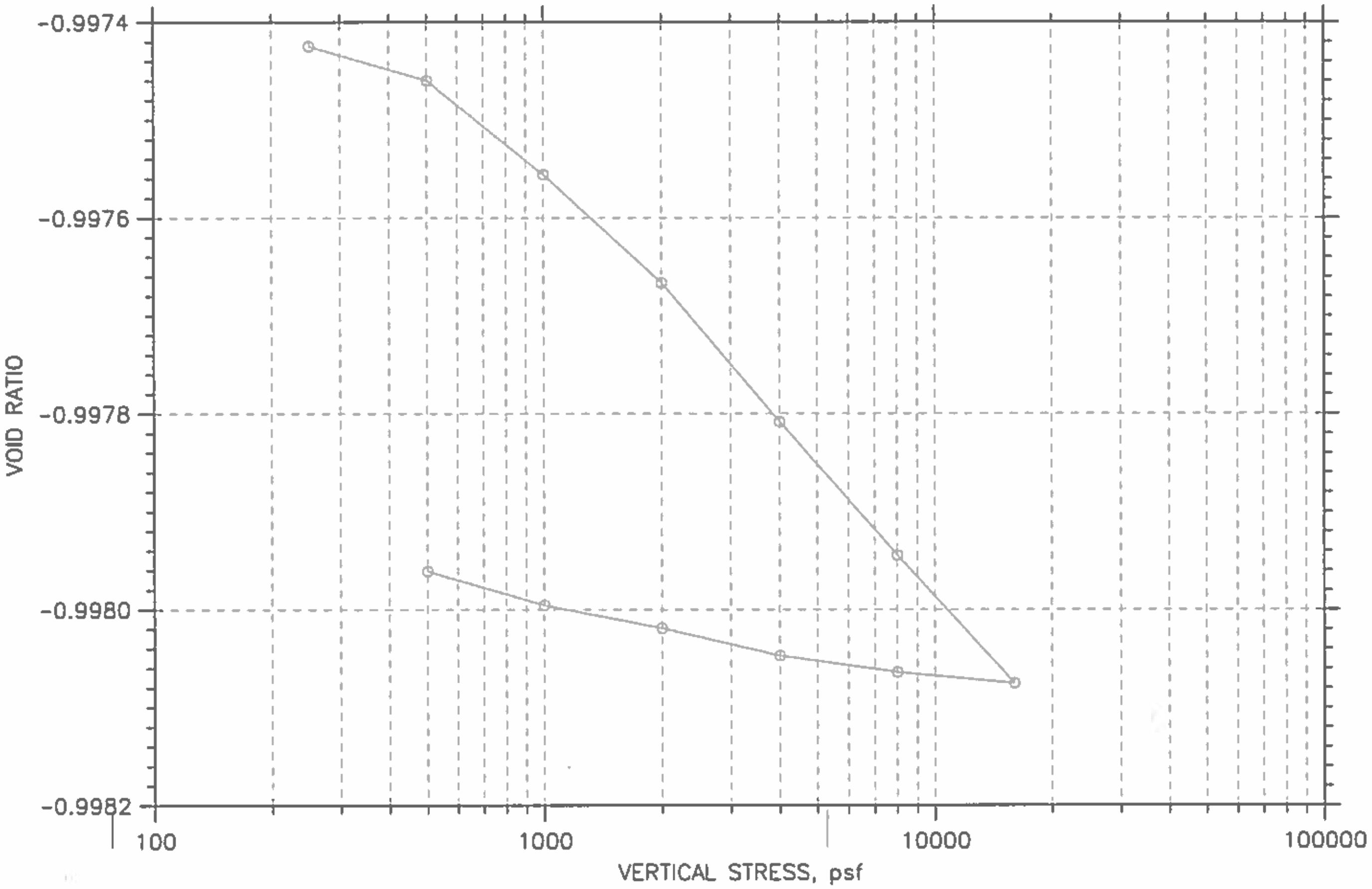
NFE-V-08 Puerto Rico Concept Development Project Exhibit

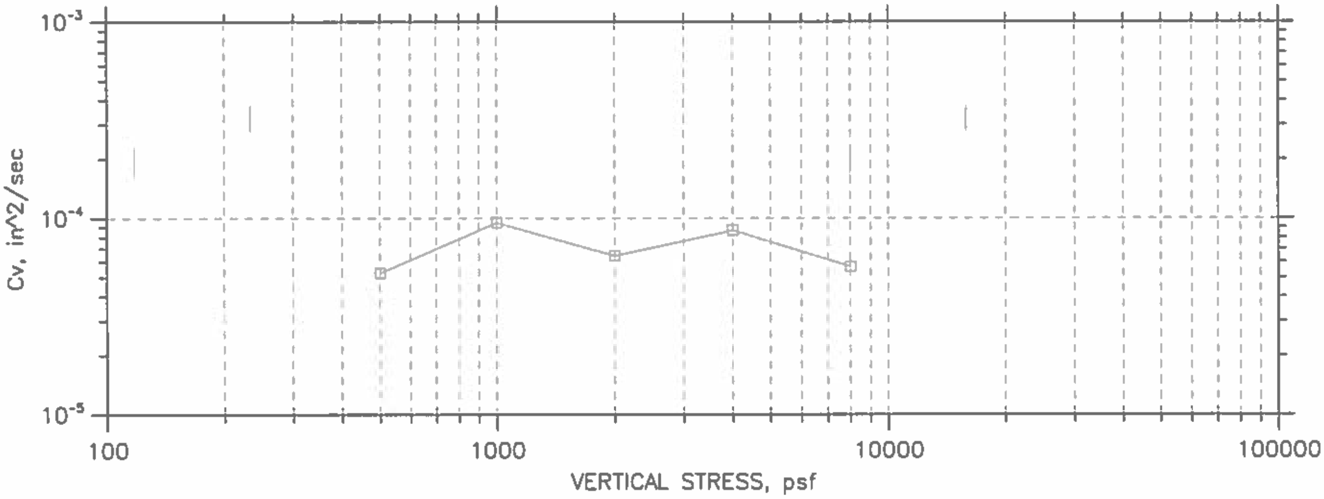
Appendix C

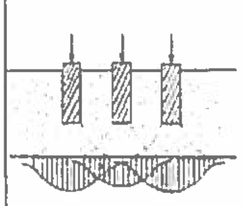
Laboratory Test Reports

CONSOLIDATION TEST DATA

SUMMARY REPORT



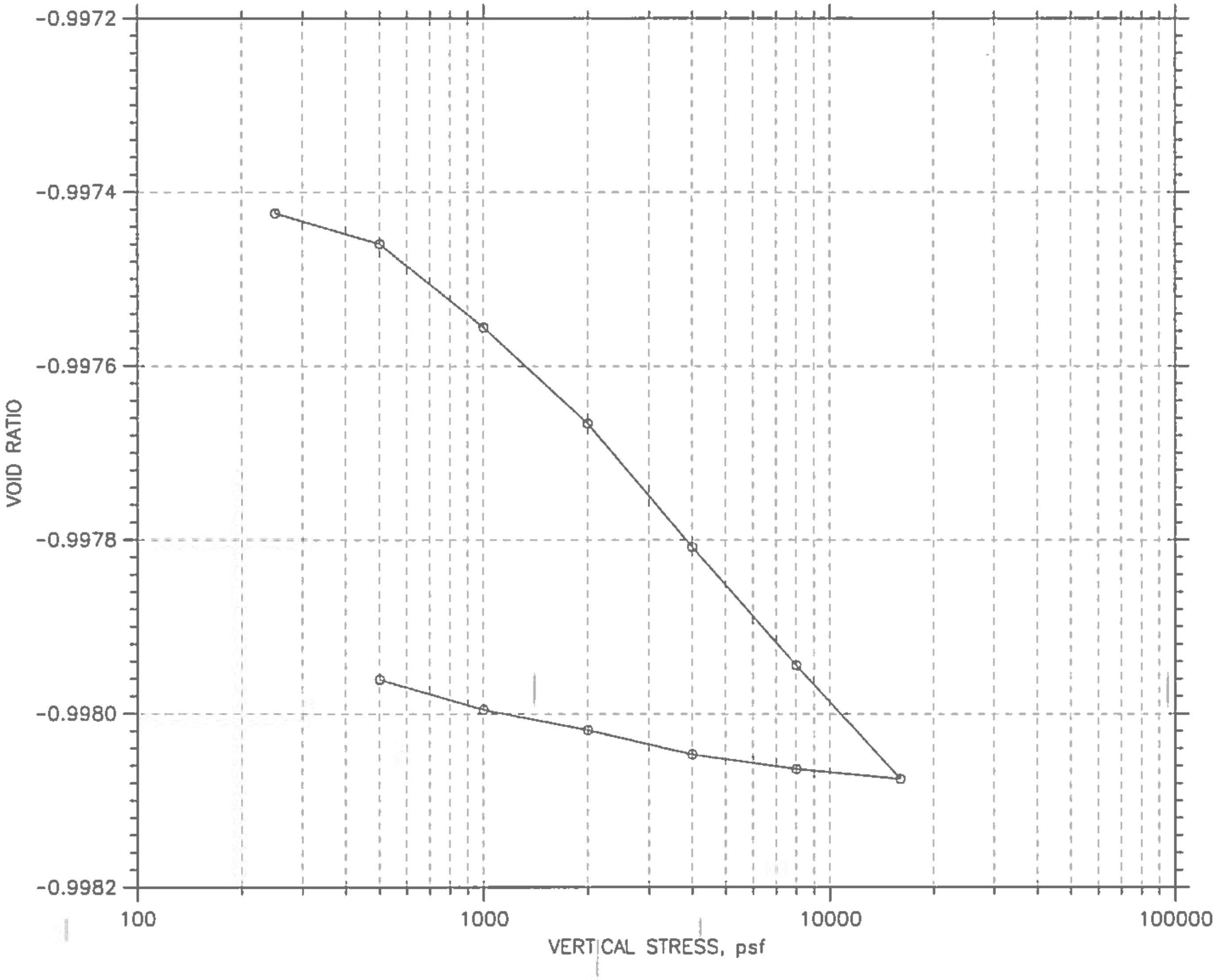


	Project: Berth A, B, C	Location: San Juan	Project No.:
	Boring No.: B-1	Tested By: MGMR	Checked By: MGMR
	Sample No.: 1	Test Date: 01-26-18	Depth: 20-22
	Test No.: 1	Sample Type: Undisurbed	Elevation: -
	Description:		
	Remarks: -		

Sun, 04-FEB-2018 10:12:03

CONSOLIDATION TEST DATA

SUMMARY REPORT



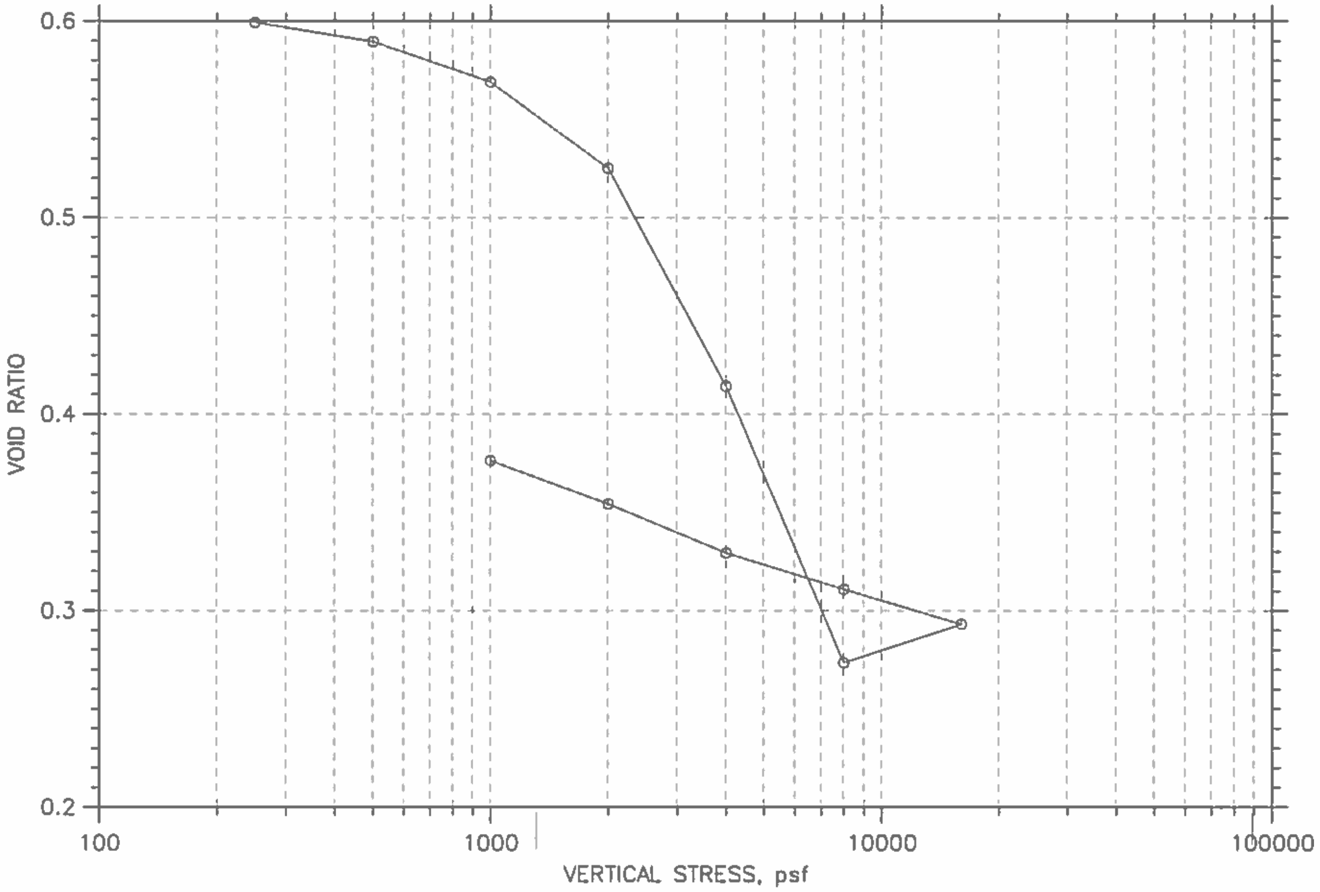
					Before Test	After Test
Overburden Pressure: 1 psf				Water Content, %	62.42	43.44
Preconsolidation Pressure: 2 psf				Dry Unit Weight, pcf	62230	79600
Compression Index: 0.26				Saturation, %	-162.72	-113.17
Diameter: 2.5 in		Height: 1 in		Void Ratio	-1.00	-1.00
LL: ---	PL: ---	PI: ---	GS: 2.60			

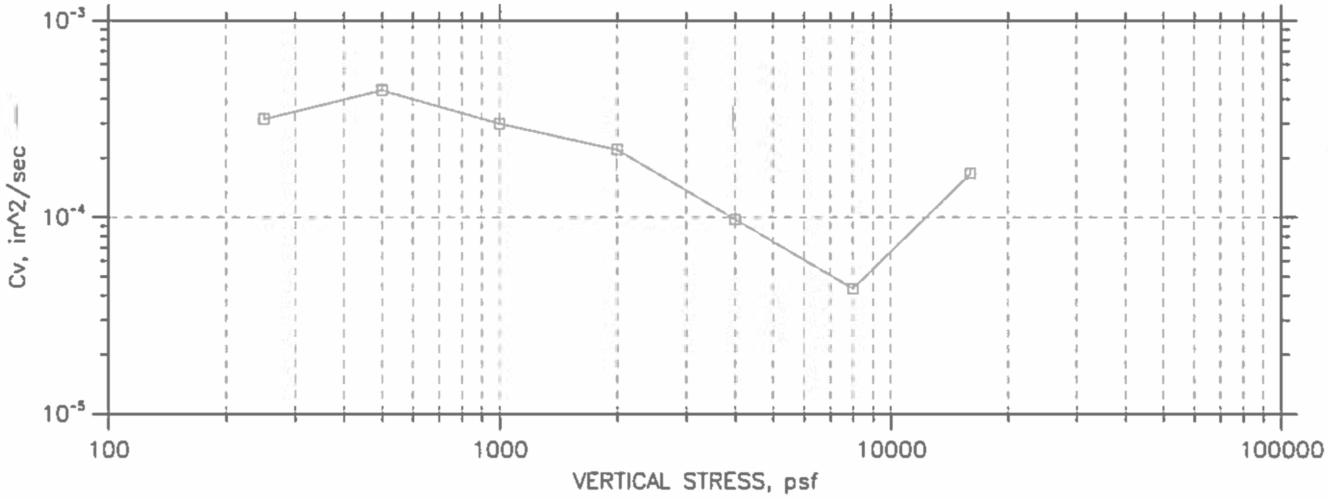
Project: Berth A, B, C	Location: San Juan	Project No.:
Boring No.: B-1	Tested By: MGMR	Checked By: MGMR
Sample No.: 1	Test Date: 01-26-18	Depth: 20-22
Test No.: 1	Sample Type: Undisurbed	Elevation: -
Description:		
Remarks: -		

Sun, 04-FEB-2018 10:12:03

CONSOLIDATION TEST DATA

SUMMARY REPORT



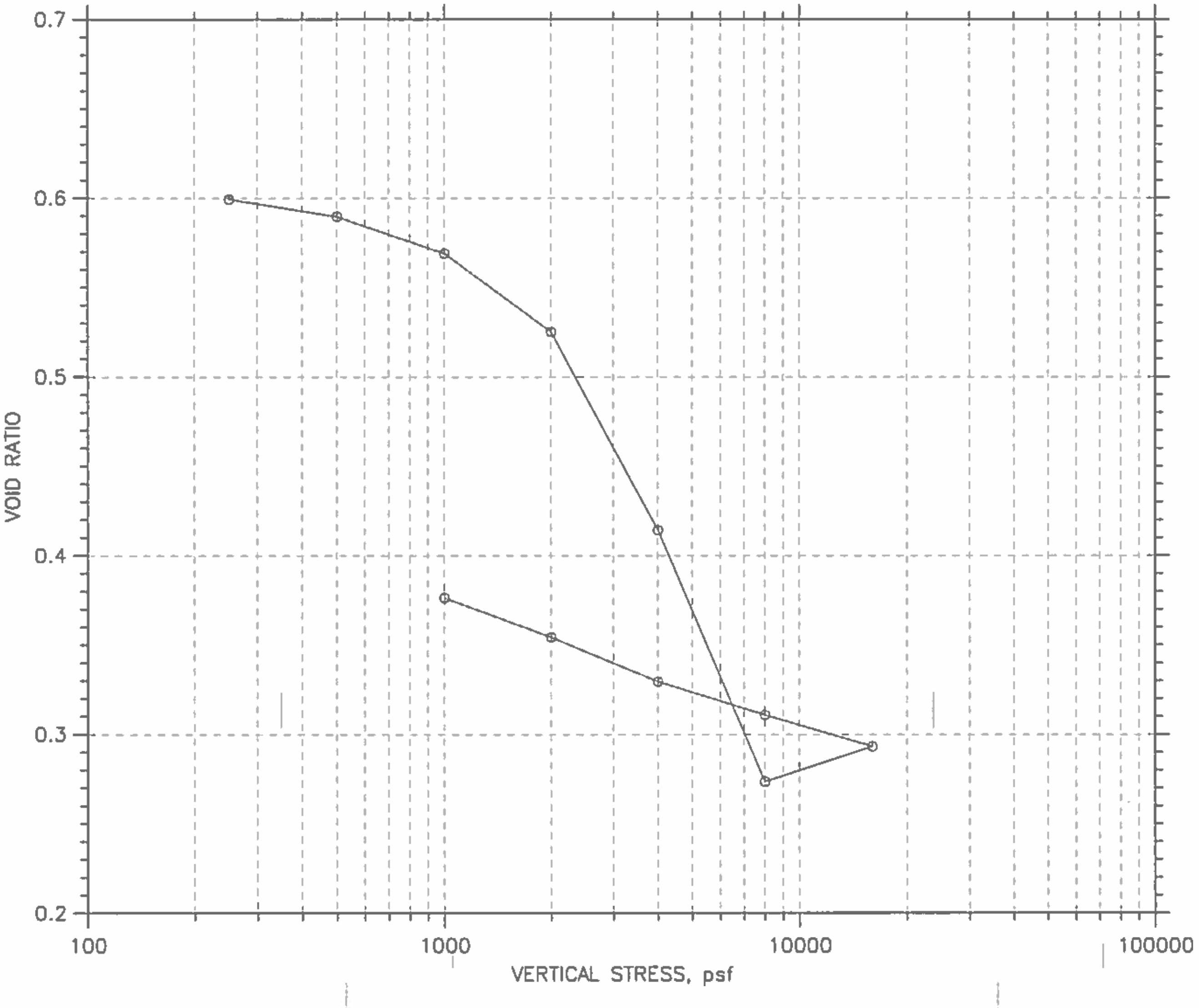


Project: Berth A, B, C	Location: San Juan	Project No.:
Boring No.: B-2	Tested By: J. Garcia	Checked By: J. Garcia
Sample No.: 1	Test Date: 01-18-18	Depth: 15-17
Test No.: 1	Sample Type: Undisurbed	Elevation: -
Description: Organic Silt with sand.		
Remarks: -		

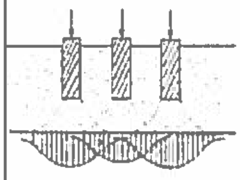
Sun, 04-FEB-2018 10:12:26

CONSOLIDATION TEST DATA

SUMMARY REPORT

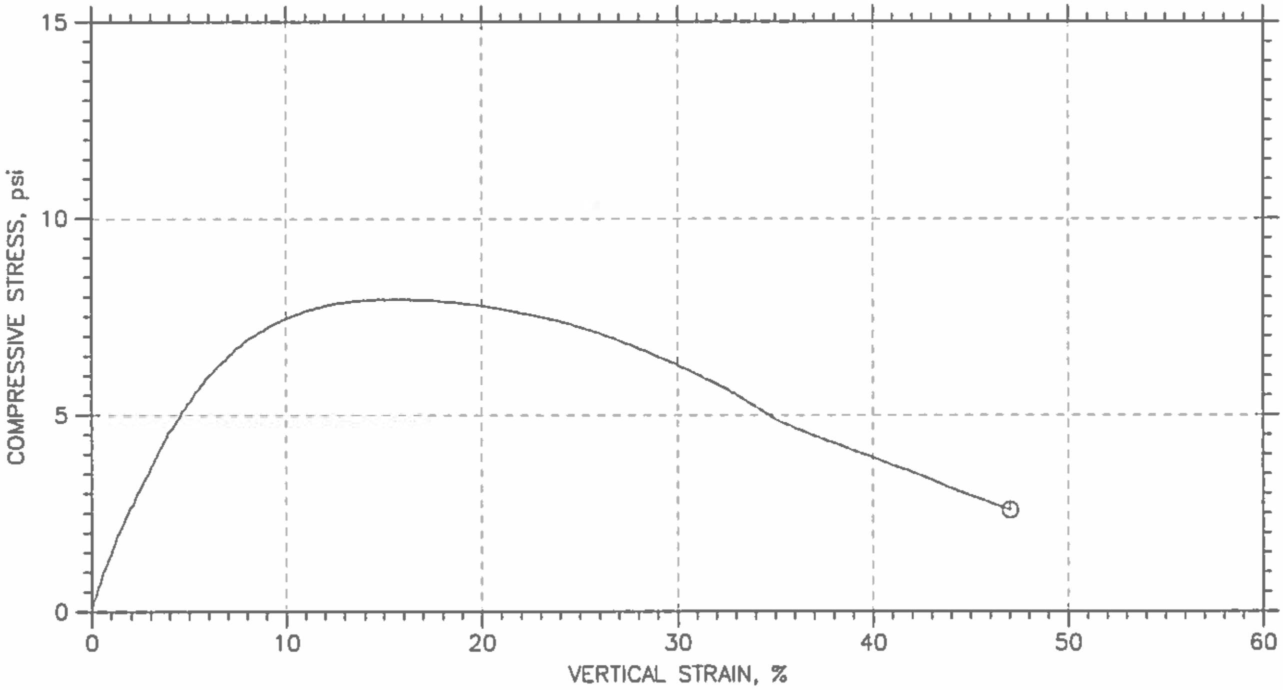


					Before Test	After Test
Overburden Pressure: 1 psf				Water Content, %	857.85	18.65
Preconsolidation Pressure: 2 psf				Dry Unit Weight, pcf	101.4	117.9
Compression Index: 0.26				Saturation, %	3714.31	128.81
Diameter: 2.45 in		Height: 1 in		Void Ratio	0.60	0.38
LL: ---	PL: ---	PI: ---	GS: 2.60			

	Project: Berth A, B, C	Location: San Juan	Project No.:
	Boring No.: B-2	Tested By: J. Garcia	Checked By: J. Garcia
	Sample No.: 1	Test Date: 01-18-18	Depth: 15-17
	Test No.: 1	Sample Type: Undisurbed	Elevation: -
	Description: Organic Silt with sand.		
	Remarks: -		

Sun, 04-FEB-2018 10:12:26

UNCONFINED COMPRESSION TEST REPORT

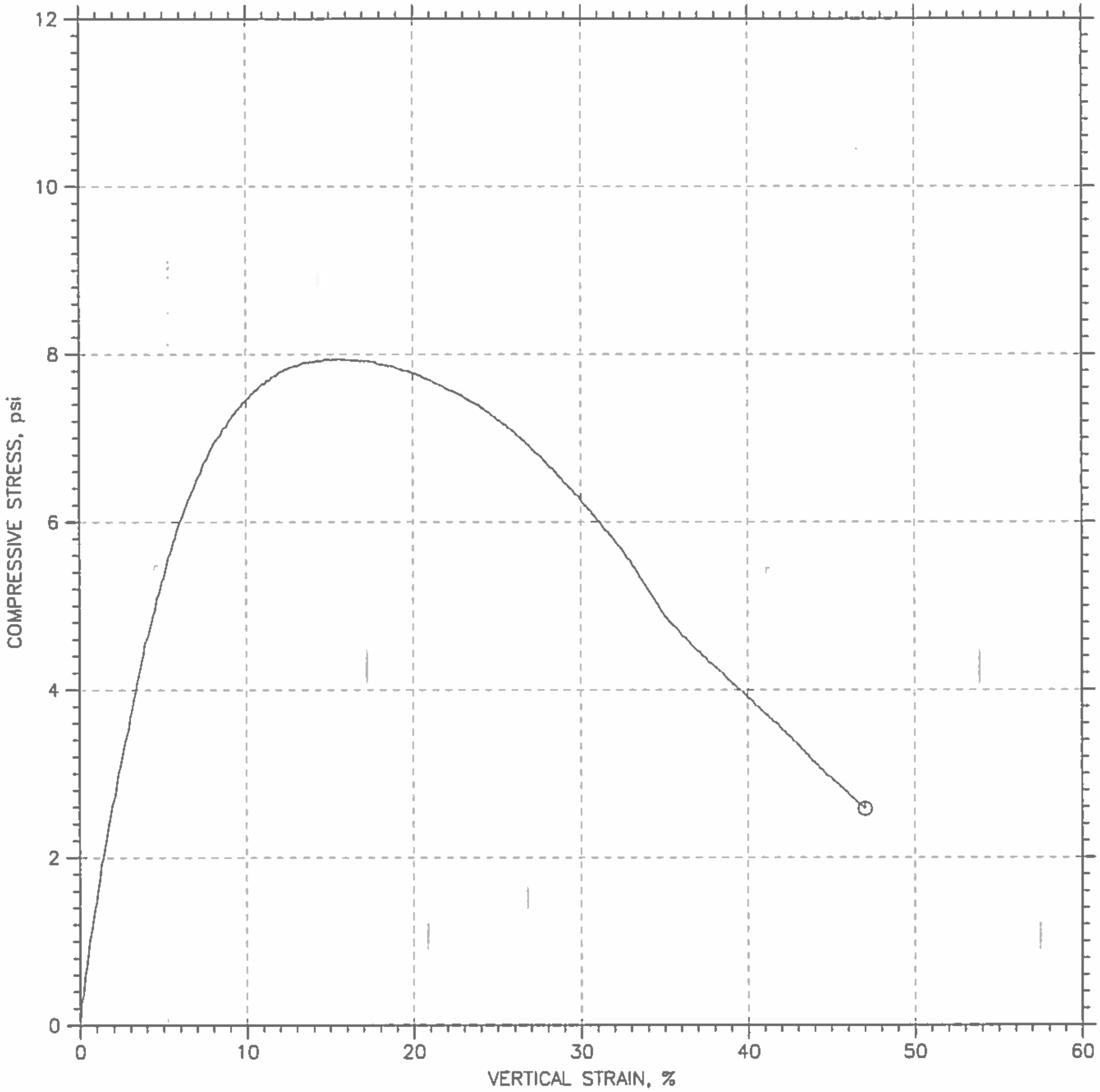


Symbol		○			
Test No.		1			
Initial	Diameter, in	2.856			
	Height, in	6.005			
	Water Content, %	28.97			
	Dry Density, pcf	74.52			
	Saturation, %	62.94			
	Void Ratio	1.22			
Unconfined Compressive Strength, psi		7.943			
Undrained Shear Strength, psi		3.972			
Time to Failure, min		4.0032			
Strain Rate, %/min		1			
Estimated Specific Gravity		2.65			
Liquid Limit		---			
Plastic Limit		---			
Plasticity Index		---			
Failure Sketch					

Project: RPN, Berth A,B,C
Location: San Juan , PR
Project No.: -
Boring No.: 2
Sample Type: Undisturbed
Description: Very dark Brown Silt some clay, Organic
Remarks:

Sun, 04-FEB-2018 10:17:01

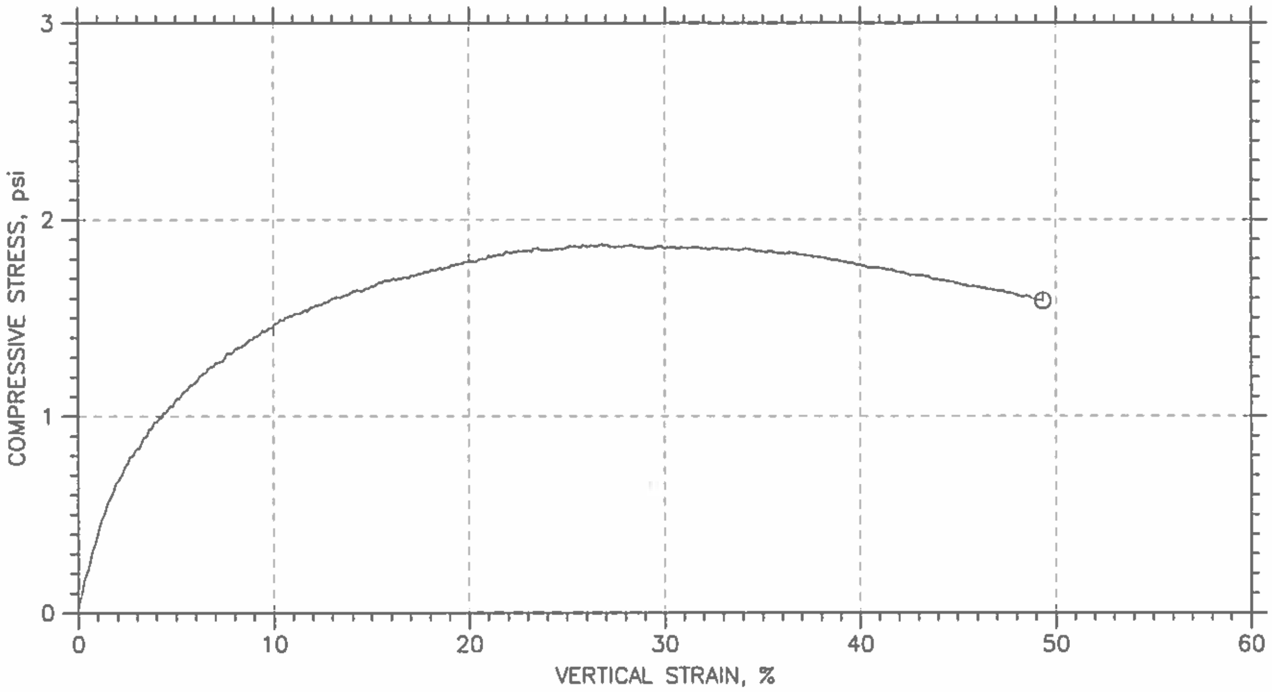
UNCONFINED COMPRESSION TEST REPORT



Project: RPN, Berth A,B,C	Location: San Juan , PR	Project No.: -
Boring No.: 2	Tested By: JAGB	Checked By: JAGB
Sample No.: 1	Test Date: 01-23-18	Depth: 15-17 ft
Test No.: 1	Sample Type: Undisturbed	Elevation: -
Description: Very dark Brown Silt some clay, Organic		
Remarks:		

Sun, 04-FEB-2018 10:17:01

UNCONFINED COMPRESSION TEST REPORT

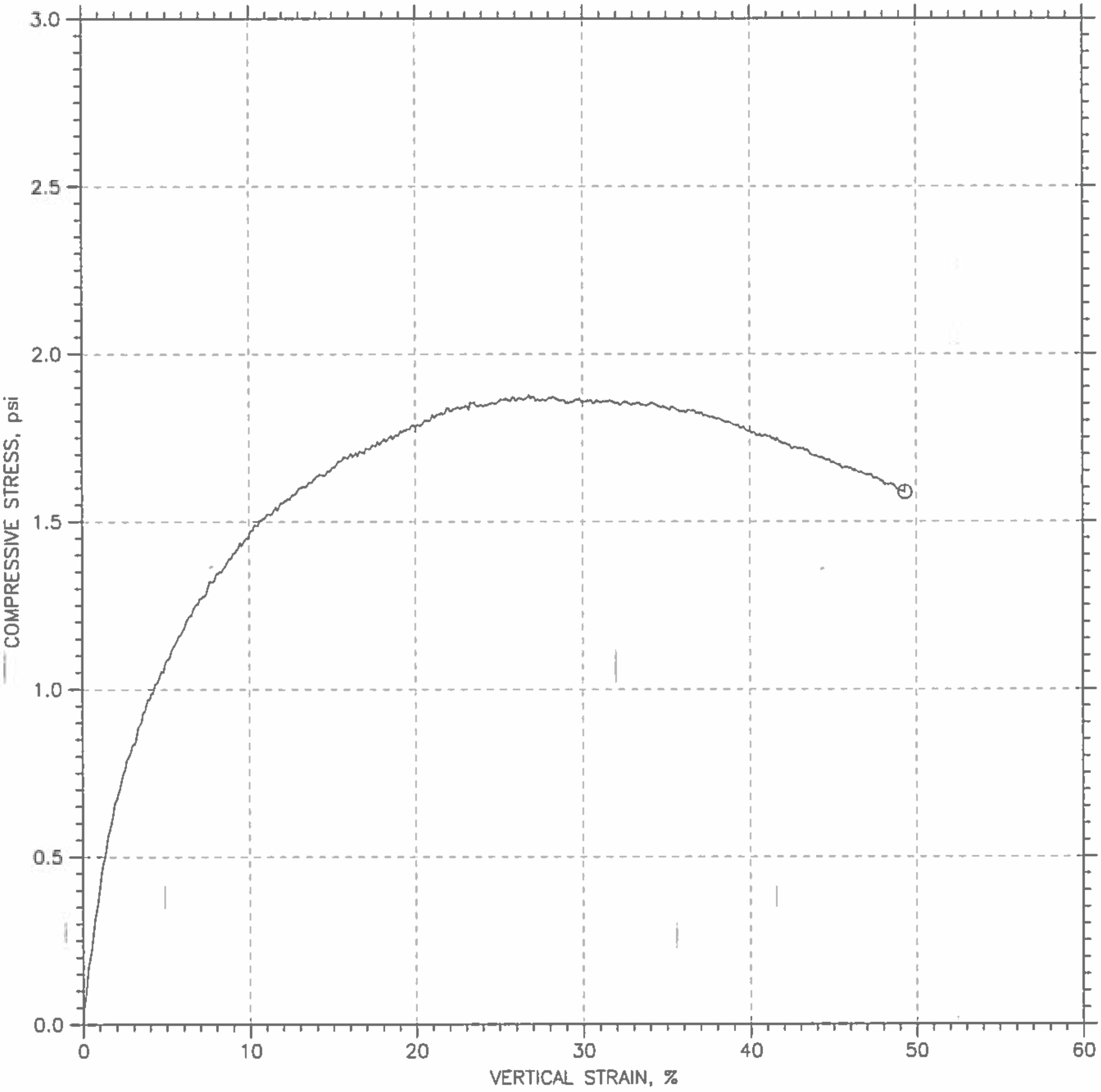


Symbol		⌽			
Test No.		1			
Initial	Diameter, in	2.844			
	Height, in	5.987			
	Water Content, %	76.71			
	Dry Density, pcf	55.36			
	Saturation, %	102.23			
	Void Ratio	1.99			
Unconfined Compressive Strength, psi		1.877			
Undrained Shear Strength, psi		0.9385			
Time to Failure, min		6.8048			
Strain Rate, %/min		1			
Estimated Specific Gravity		2.65			
Liquid Limit		---			
Plastic Limit		---			
Plasticity Index		---			
Failure Sketch					

Project: RPN, Berth A,B,C
Location: San Juan , PR
Project No.: -
Boring No.: 1
Sample Type: Undisturbed
Description: Very dark Brown Silt some clay.
Remarks:

Sun, 04-FEB-2018 10:19:12

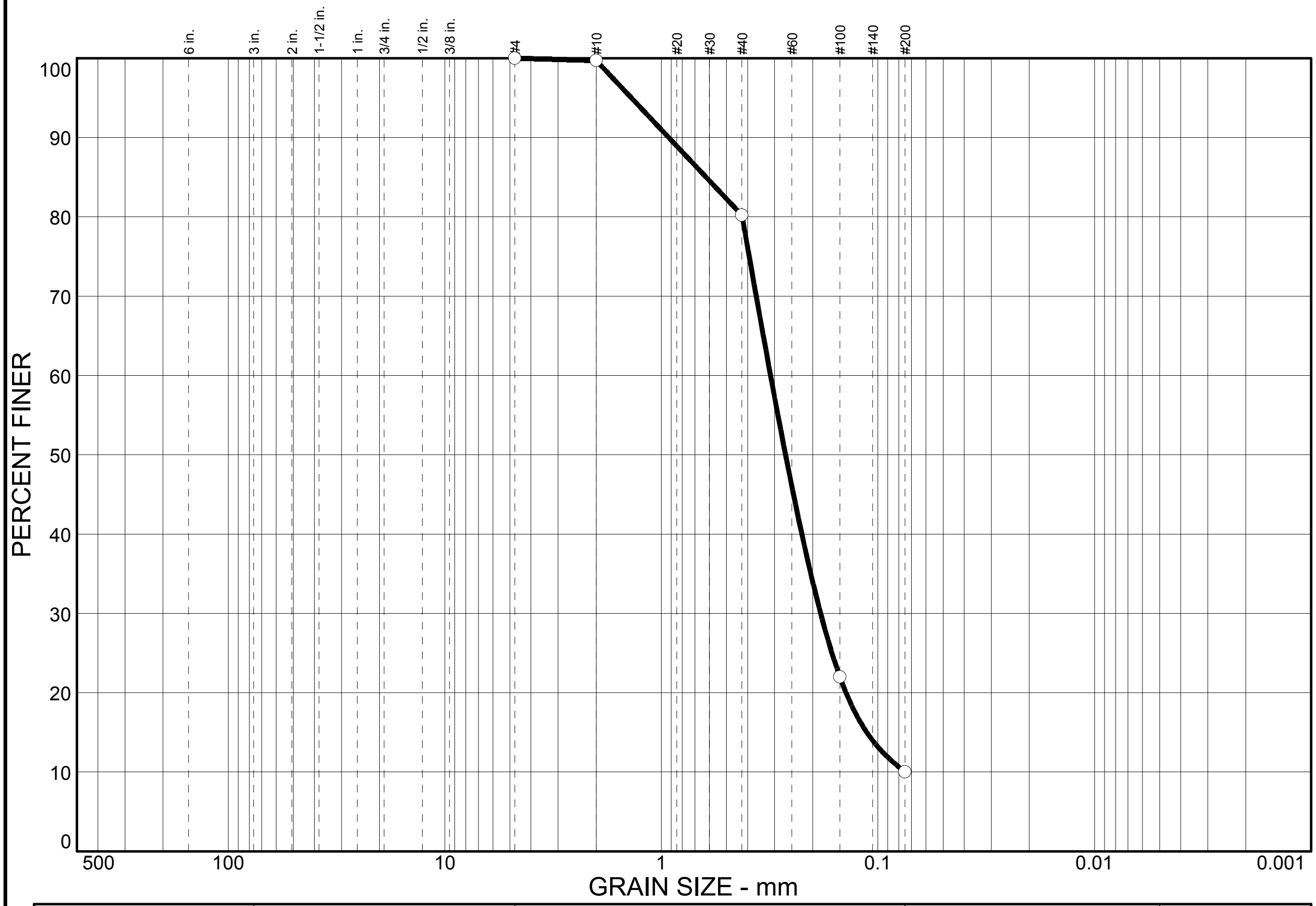
UNCONFINED COMPRESSION TEST REPORT



Project: RPN, Berth A,B,C	Location: San Juan , PR	Project No.: -
Boring No.: 1	Tested By: MGMR	Checked By: MGMR
Sample No.: 1	Test Date: 01-25-18	Depth: 15-17 ft
Test No.: 1	Sample Type: Undisturbed	Elevation: -
Description: Very dark Brown Silt some clay.		
Remarks:		

Sun, 04-FEB-2018 10:19:12

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	90.0	10.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.7		
#40	80.2		
#100	22.0		
#200	10.0		

* (no specification provided)

Material Description

Poorly graded sand with silt.

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 0.622 D_{60}= 0.314 D_{50}= 0.267
D_{30}= 0.184 D_{15}= 0.113 D_{10}= 0.0750
C_u= 4.18 C_c= 1.44

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Tested by: A. Perez
Checked by: Jose A. Garcia Betancourt, MECE, PE
F.M.=0.78

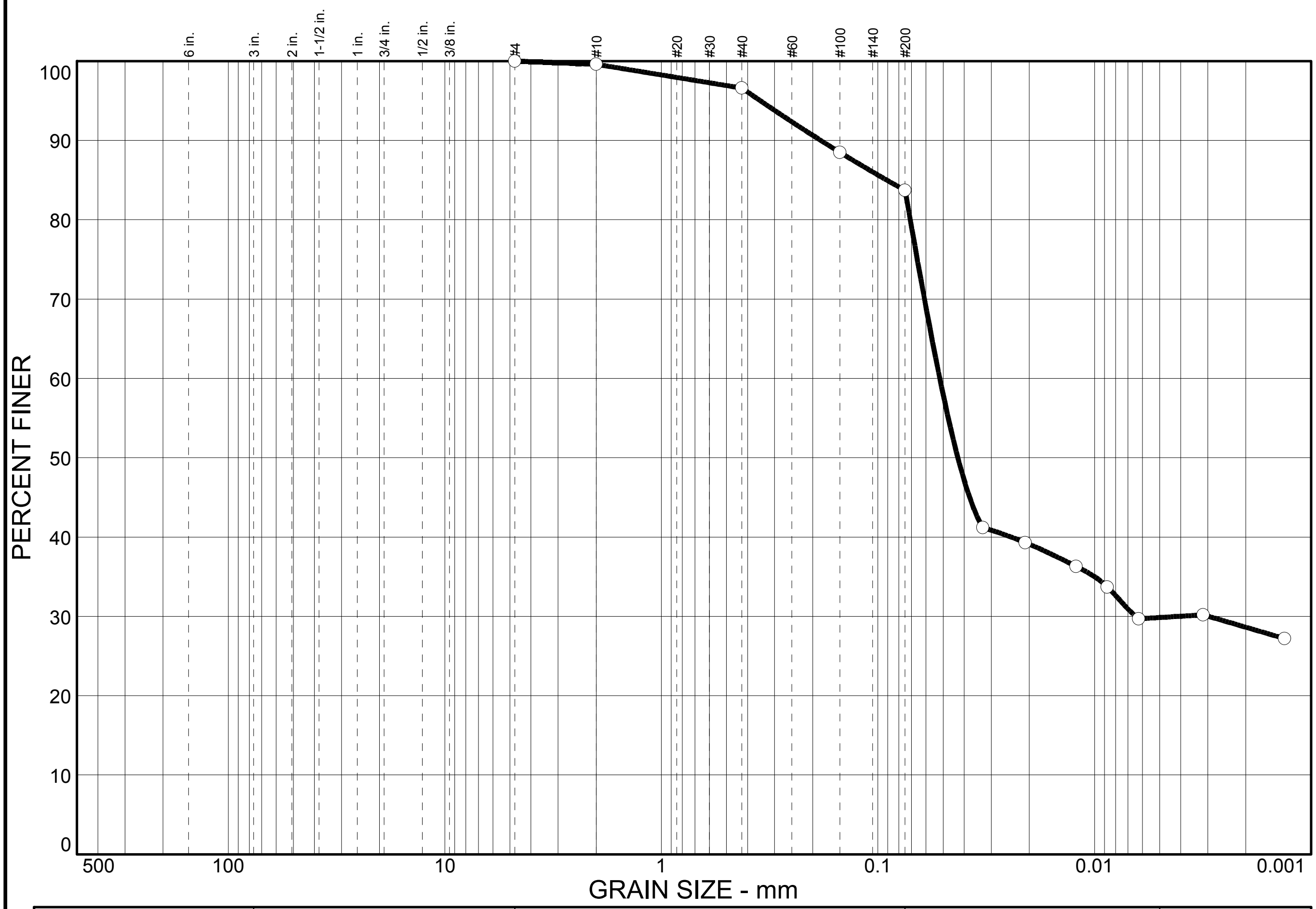
Sample No.: Bo. 2 **Source of Sample:** Project Site **Date:** 1/8/18
Location: San Juan, PR **Elev./Depth:** 10'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	16.3	53.8	29.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.6		
#40	96.6		
#100	88.5		
#200	83.7		

* (no specification provided)

Material Description

Silt with sand.

Atterberg Limits

PL= 30 LL= 47 PI= 17

Coefficients

D_{85}= 0.0911 D_{60}= 0.0519 D_{50}= 0.0428
D_{30}= 0.0030 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-7-5(16)

Remarks

Tested by: A. Perez
Checked by: Jose A. Garcia Betancourt, MECE, PE
F.M.=0.12

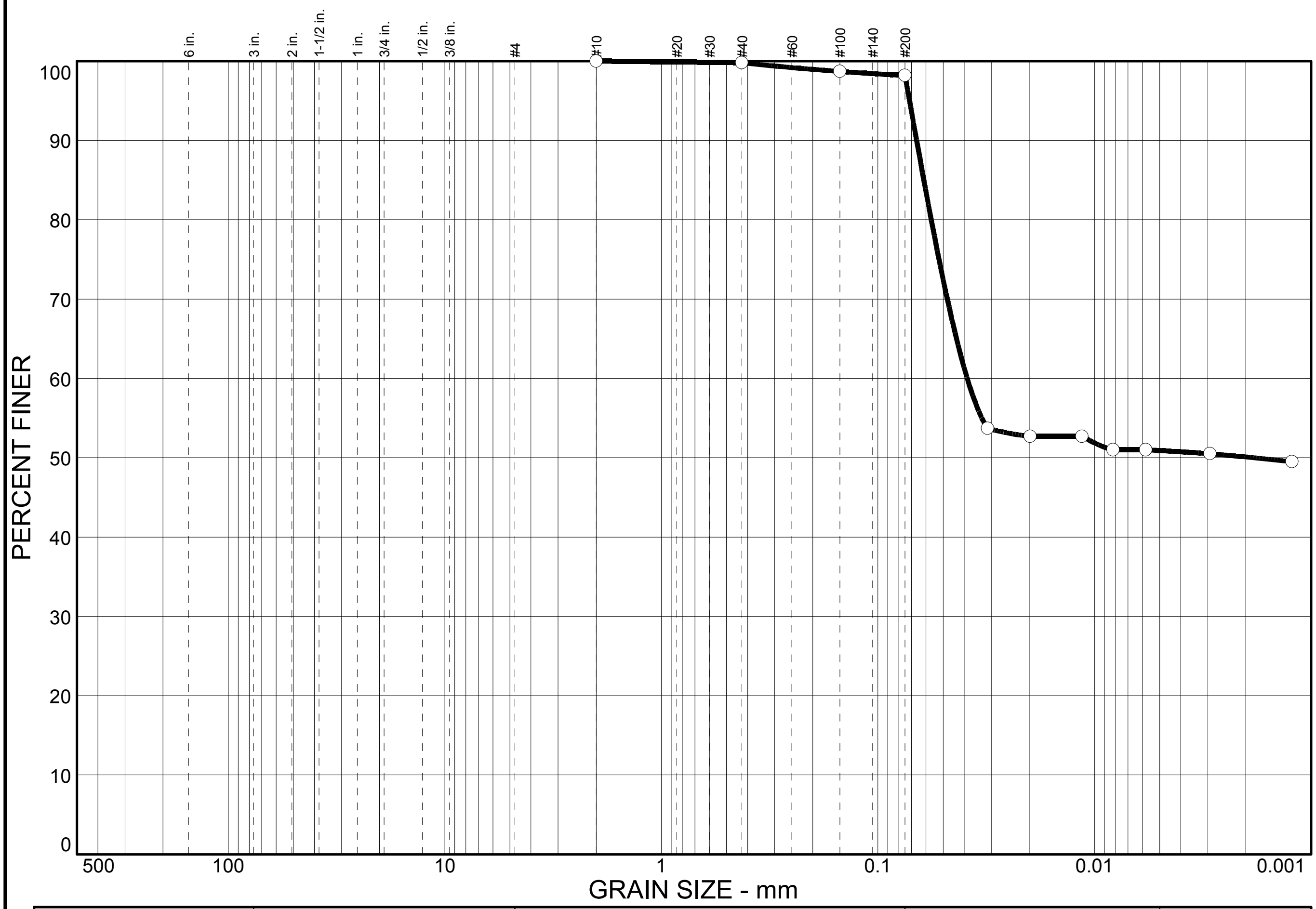
Sample No.: Bo. 2 **Source of Sample:** Project Site **Date:** 1/12/18
Location: San Juan, PR **Elev./Depth:** 19'-20'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	1.8	47.3	50.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	99.8		
#100	98.7		
#200	98.2		

* (no specification provided)

Material Description

Fat clay.

Atterberg Limits

PL= 26 LL= 64 PI= 38

Coefficients

D_{85}= 0.0615 D_{60}= 0.0387 D_{50}= 0.0018
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO= A-7-6(43)

Remarks

Tested by: A. Perez
Checked by: Jose A. Garcia Betancourt, MECE, PE
F.M.=0.01

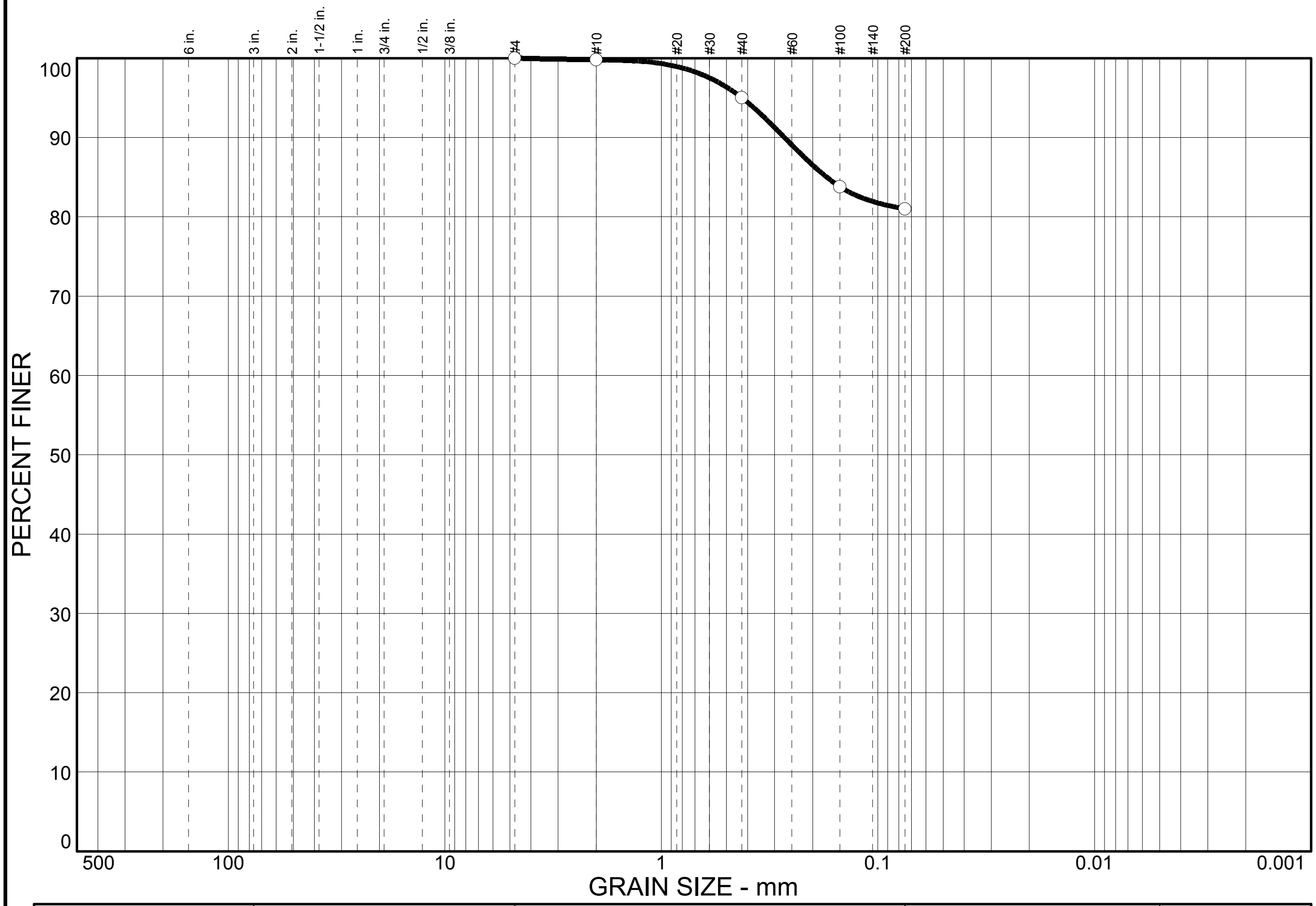
Sample No.: Bo. 2 **Source of Sample:** Project Site **Date:** 1/11/18
Location: San Juan, PR **Elev./Depth:** 44'-45.5'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	19.0	81.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.8		
#40	95.0		
#100	83.8		
#200	81.0		

* (no specification provided)

Material Description

Silty with sand.

Atterberg Limits

PL= - LL= - PI= -

Coefficients

D_{85}= 0.173 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Tested by: J. Cordova
Checked by: Jose A. Garcia Betancourt, MECE, PE
F.M.=0.16

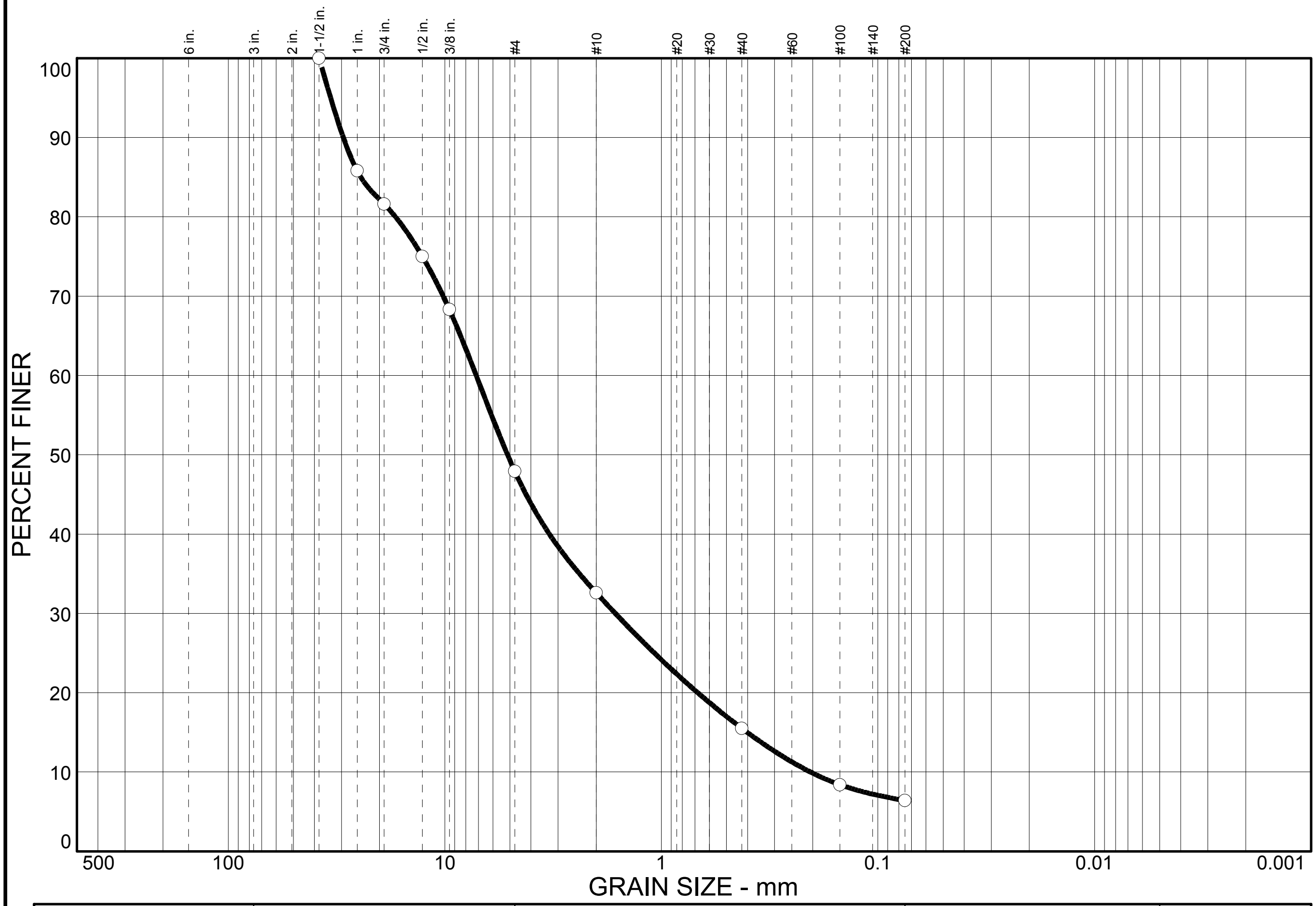
Sample No.: Bo. 3 **Source of Sample:** Project Site **Date:** 1/4/18
Location: San Juan, PR **Elev./Depth:** 55'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	52.1	41.5	6.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5 in.	100.0		
1 in.	85.8		
.75 in.	81.6		
.5 in.	75.0		
.375 in.	68.3		
#4	47.9		
#10	32.6		
#40	15.5		
#100	8.4		
#200	6.4		

* (no specification provided)

Material Description

Well-graded gravel with silt and sand.

Atterberg Limits

PL= -
LL= -
PI= -

Coefficients

D_{85}= 24.4
D_{60}= 7.17
D_{50}= 5.14
D_{30}= 1.63
D_{15}= 0.402
D_{10}= 0.205
C_u= 34.97
C_c= 1.81

Classification

USCS=
AASHTO=

Remarks

Tested by: J. Cordova
Checked by: Jose A. Garcia Betancourt, MECE, PE
F.M.=1.94

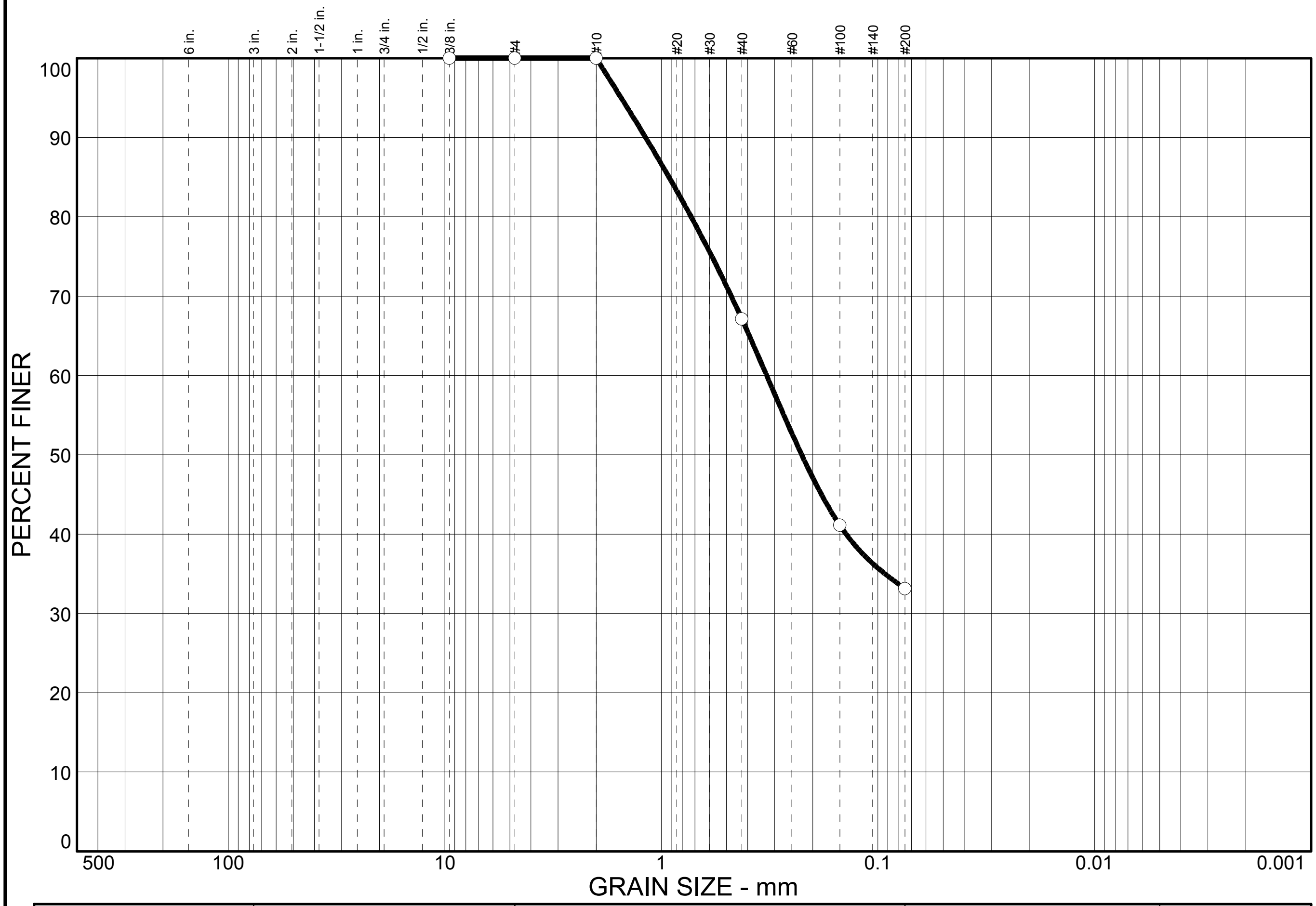
Sample No.: Bo. C-2
Source of Sample: Project Site
Date: 1/4/18
Location: San Juan, PR
Elev./Depth: 0'-1.5'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	66.9	33.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.375 in.	100.0		
#4	100.0		
#10	100.0		
#40	67.1		
#100	41.1		
#200	33.1		

* (no specification provided)

Material Description

Clayey sand.

Atterberg Limits

PL= 13 LL= 32 PI= 19

Coefficients

D_{85}= 0.923 D_{60}= 0.327 D_{50}= 0.225
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SC AASHTO= A-2-6(2)

Remarks

Tested by: A. Perez
Checked by: Jose A. Garcia Betancourt, MECE, PE
F.M.=0.59

Sample No.: Bo. C-2 **Source of Sample:** Project Site **Date:** 1/8/18
Location: San Juan, PR **Elev./Depth:** 55'

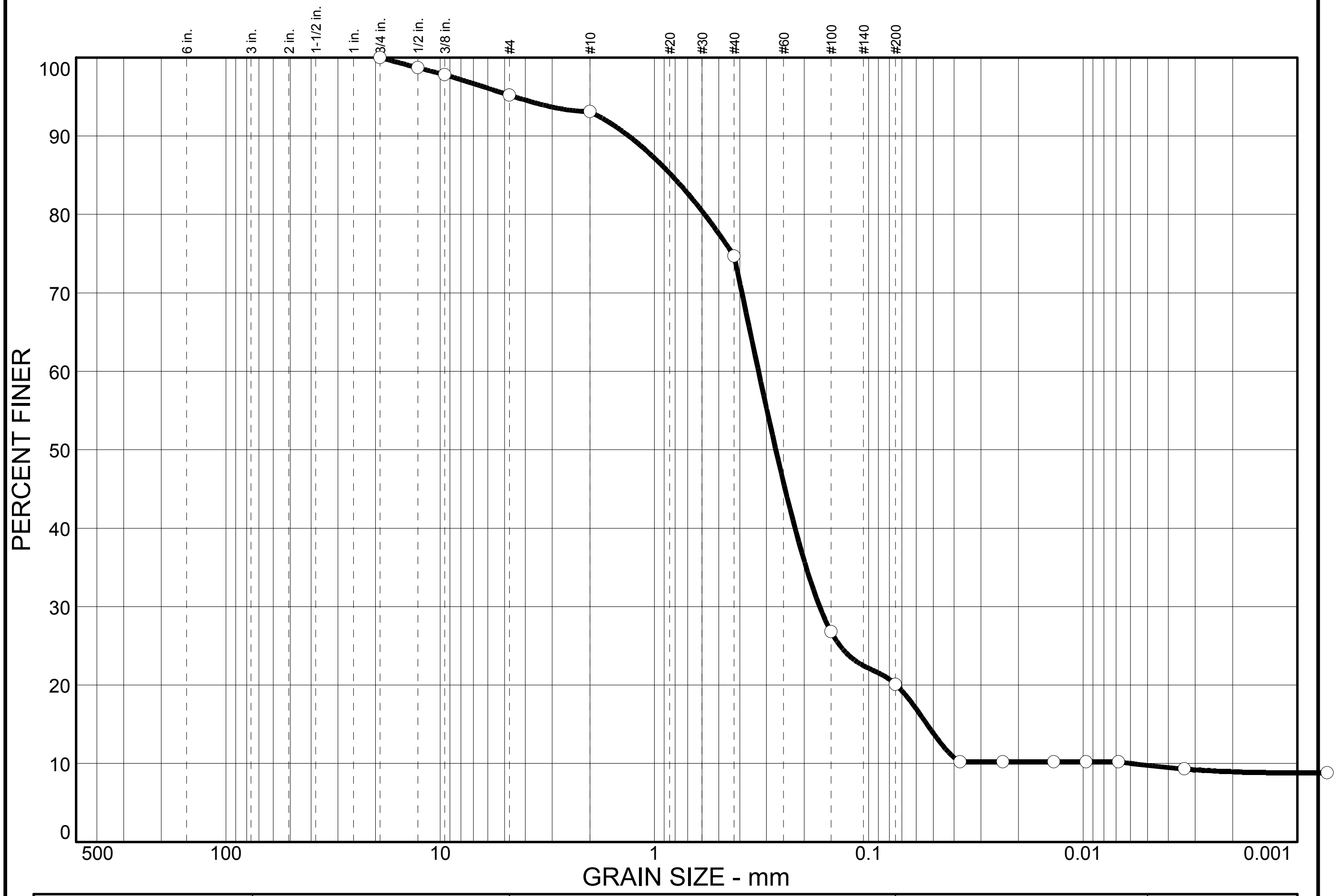
JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Public

Particle Size Distribution Report



% +75 MM	% GRAVEL	% SAND	% SILT	% CLAY
0.0	4.8	75.1	10.3	9.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.5 in.	98.7		
.375 in.	97.8		
#4	95.2		
#10	93.1		
#40	74.7		
#100	26.8		
#200	20.1		

* (no specification provided)

Material Description

Silty sand.

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 0.833 D_{60}= 0.327 D_{50}= 0.272
D_{30}= 0.170 D_{15}= 0.0535 D_{10}= 0.0059
C_u= 55.11 C_c= 14.80

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Tested by: L. Medina
Checked by: Carlos Sierra del Llano, MSCE, PE
F.M.=0.80

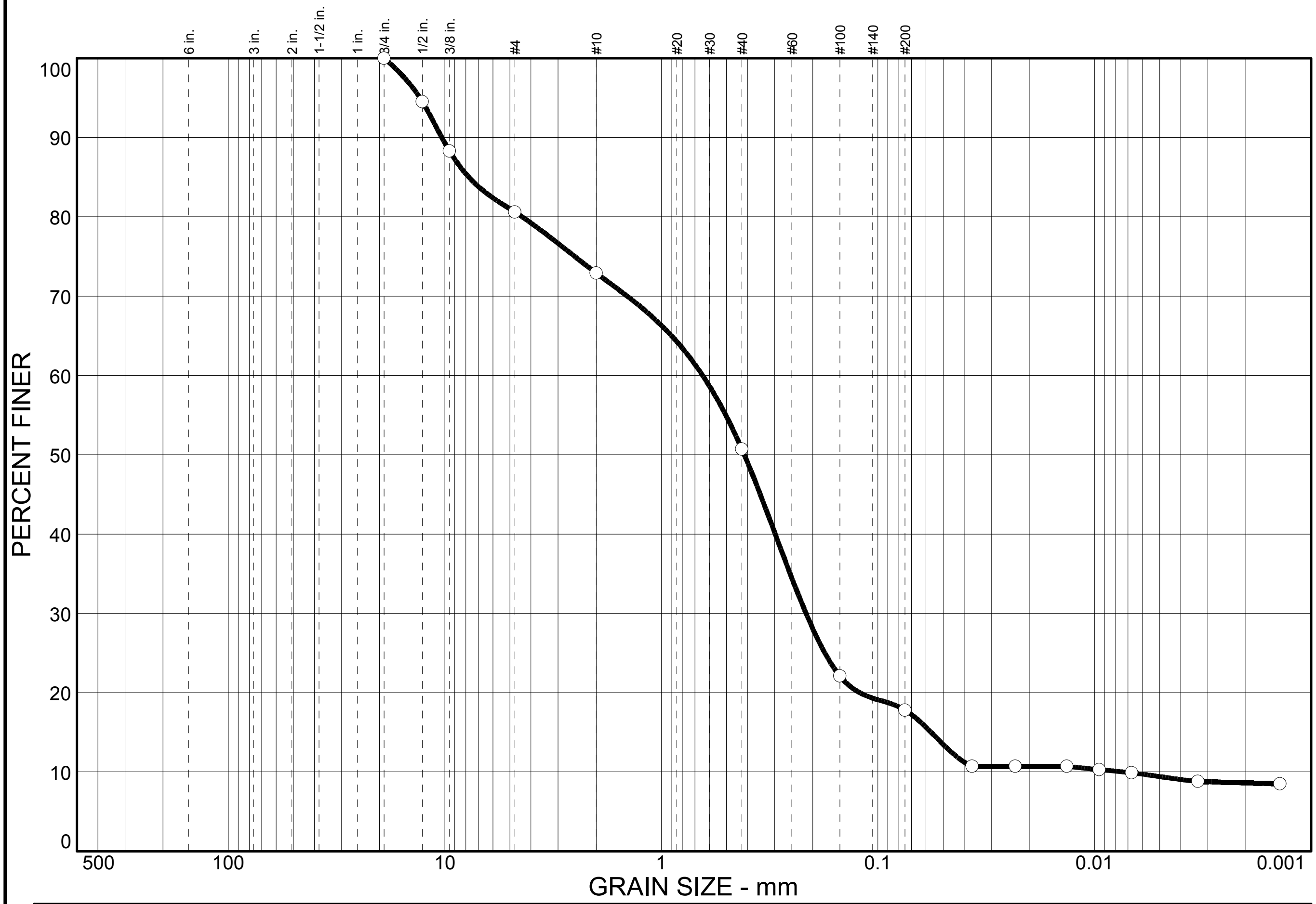
Sample No.: Bo. 4 **Source of Sample:** Project Site **Date:** 10/10/18
Location: San Juan, PR **Elev./Depth:** 9-15.6'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% +75 MM	% GRAVEL	% SAND	% SILT	% CLAY
0.0	19.4	62.8	8.4	9.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.75 in.	100.0		
.5 in.	94.5		
.375 in.	88.3		
#4	80.6		
#10	72.9		
#40	50.7		
#100	22.1		
#200	17.8		

* (no specification provided)

Material Description

Silty sand with gravel.

Atterberg Limits

PL= - LL= - PI= -

Coefficients

D_{85}= 7.76 D_{60}= 0.646 D_{50}= 0.414
D_{30}= 0.215 D_{15}= 0.0569 D_{10}= 0.0073
C_u= 88.70 C_c= 9.83

Classification

USCS= AASHTO=

Remarks

Tested by: F. Santos
Checked by: Carlos Sierra del Llano, MSCE, PE
F.M.=1.09

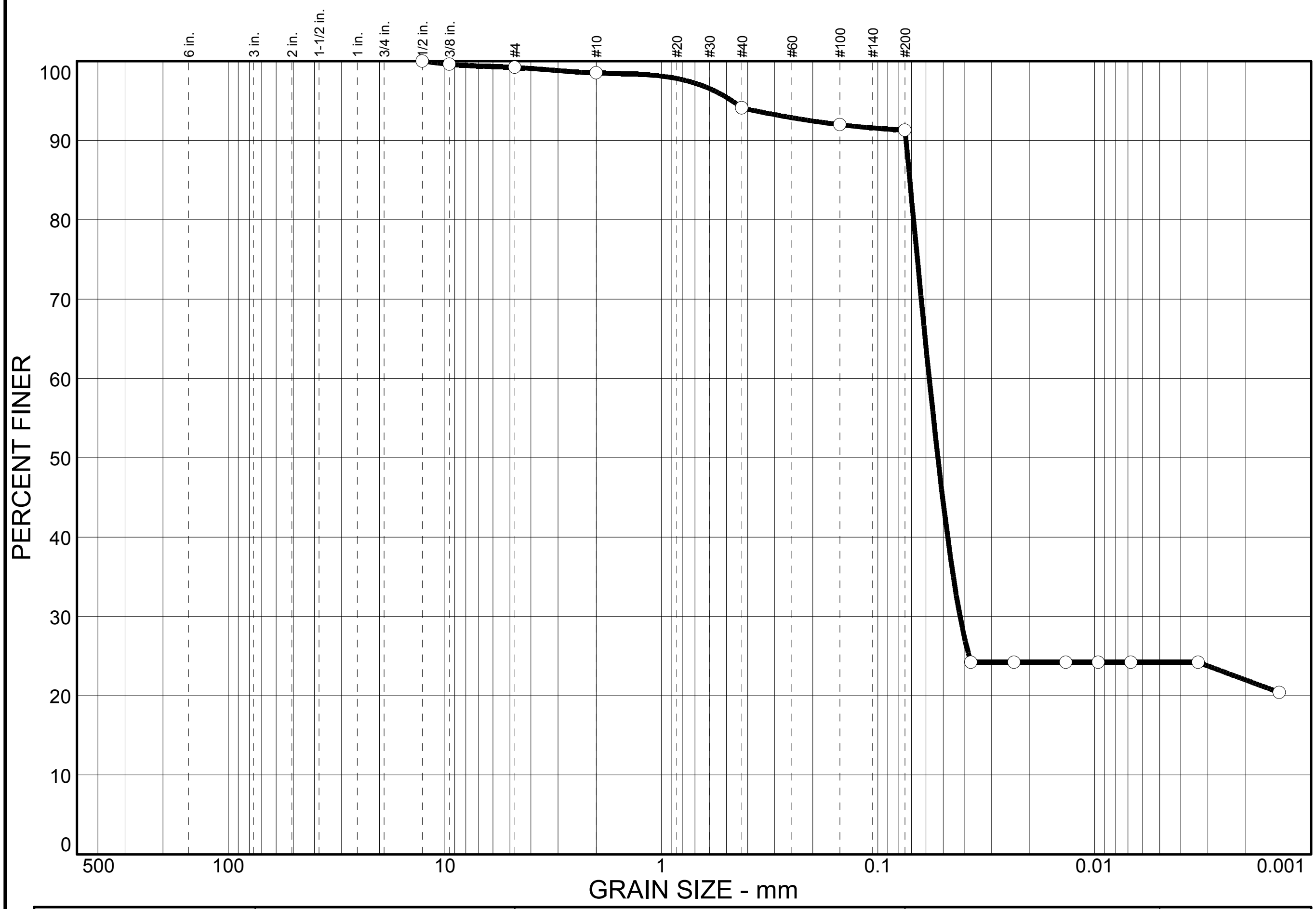
Sample No.: Bo. 4 **Source of Sample:** Project Site **Date:** 10/17/18
Location: san Juan, PR **Elev./Depth:** 24-25.6'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% +75 MM	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.8	7.9	67.1	24.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
.5 in.	100.0		
.375 in.	99.6		
#4	99.2		
#10	98.5		
#40	94.1		
#100	92.0		
#200	91.3		

* (no specification provided)

Material Description

Fat clay.

Atterberg Limits

PL= 32
LL= 71
PI= 39

Coefficients

D_{85}= 0.0713
D_{60}= 0.0580
D_{50}= 0.0529
D_{30}= 0.0418
D_{15}=
D_{10}=
C_u=
C_c=

Classification

USCS= CH
AASHTO= A-7-5(42)

Remarks

Tested by: L. Medina
Checked by: Carlos Sierra del Llano, MSCE, PE
F.M.=0.09

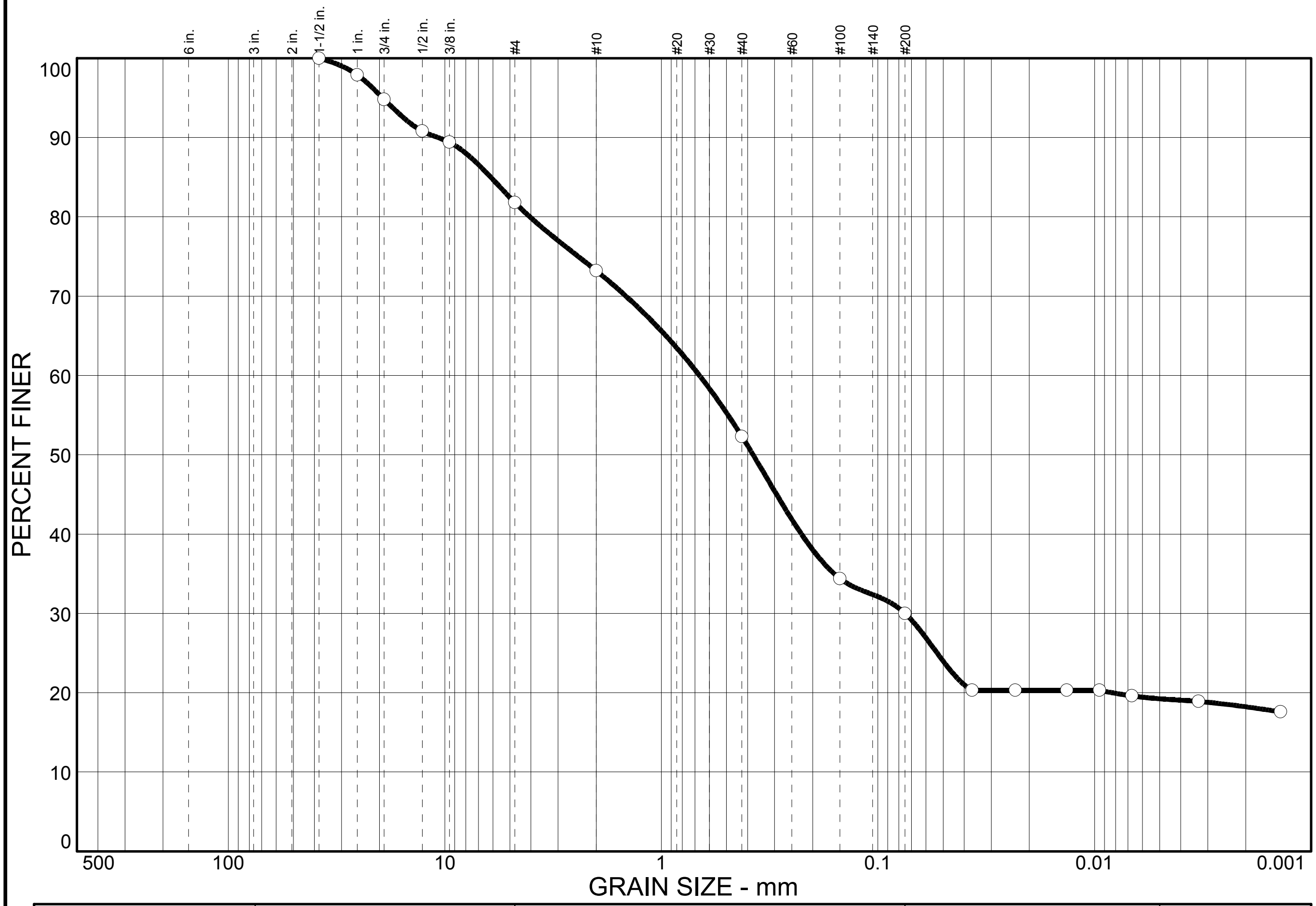
Sample No.: SWN-1
Source of Sample: Project Site
Date: 10/10/10
Location: San Juan, PR
Elev./Depth: 19-25.6'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812
Figure

Particle Size Distribution Report



% +75 MM	% GRAVEL	% SAND	% SILT	% CLAY
0.0	18.2	51.8	10.8	19.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5 in.	100.0		
1 in.	97.9		
.75 in.	94.8		
.5 in.	90.8		
.375 in.	89.4		
#4	81.8		
#10	73.2		
#40	52.3		
#100	34.4		
#200	30.0		

* (no specification provided)

Material Description

Clayey sand with gravel.

Atterberg Limits

PL= 20 LL= 33 PI= 13

Coefficients

D_{85}= 6.14 D_{60}= 0.668 D_{50}= 0.378
D_{30}= 0.0750 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SC AASHTO= A-2-6(0)

Remarks

Tested by: L. Medina
Checked by: Carlos Sierra del Llano, MSCE, PE
F.M.=1.00

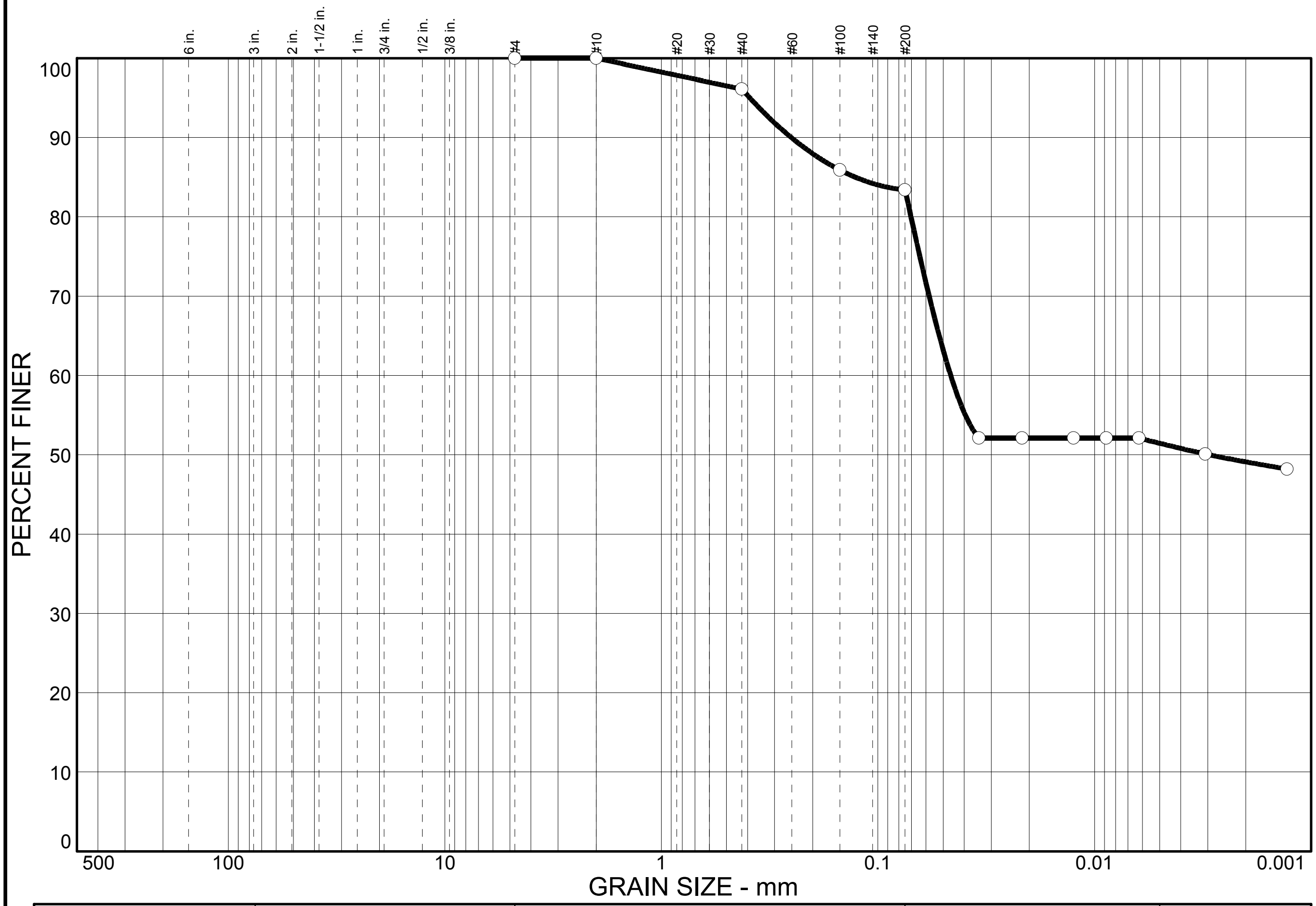
Sample No.: Bo. 4 **Source of Sample:** Project Site **Date:** 10/10/18
Location: San Juan, PR **Elev./Depth:** 29-35.6'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

Particle Size Distribution Report



% +75 MM	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	16.6	32.0	51.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	100.0		
#40	96.1		
#100	85.9		
#200	83.4		

* (no specification provided)

Material Description

Fat clay with sand.

Atterberg Limits

PL= 28
LL= 62
PI= 34

Coefficients

D_{85}= 0.127
D_{60}= 0.0462
D_{50}= 0.0030
D_{30}=
D_{15}=
D_{10}=
C_u=
C_c=

Classification

USCS=
AASHTO= A-7-6(31)

Remarks

Tested by: L. Medina
Checked by: Carlos Sierra del Llano, MSCE, PE
F.M.=0.14

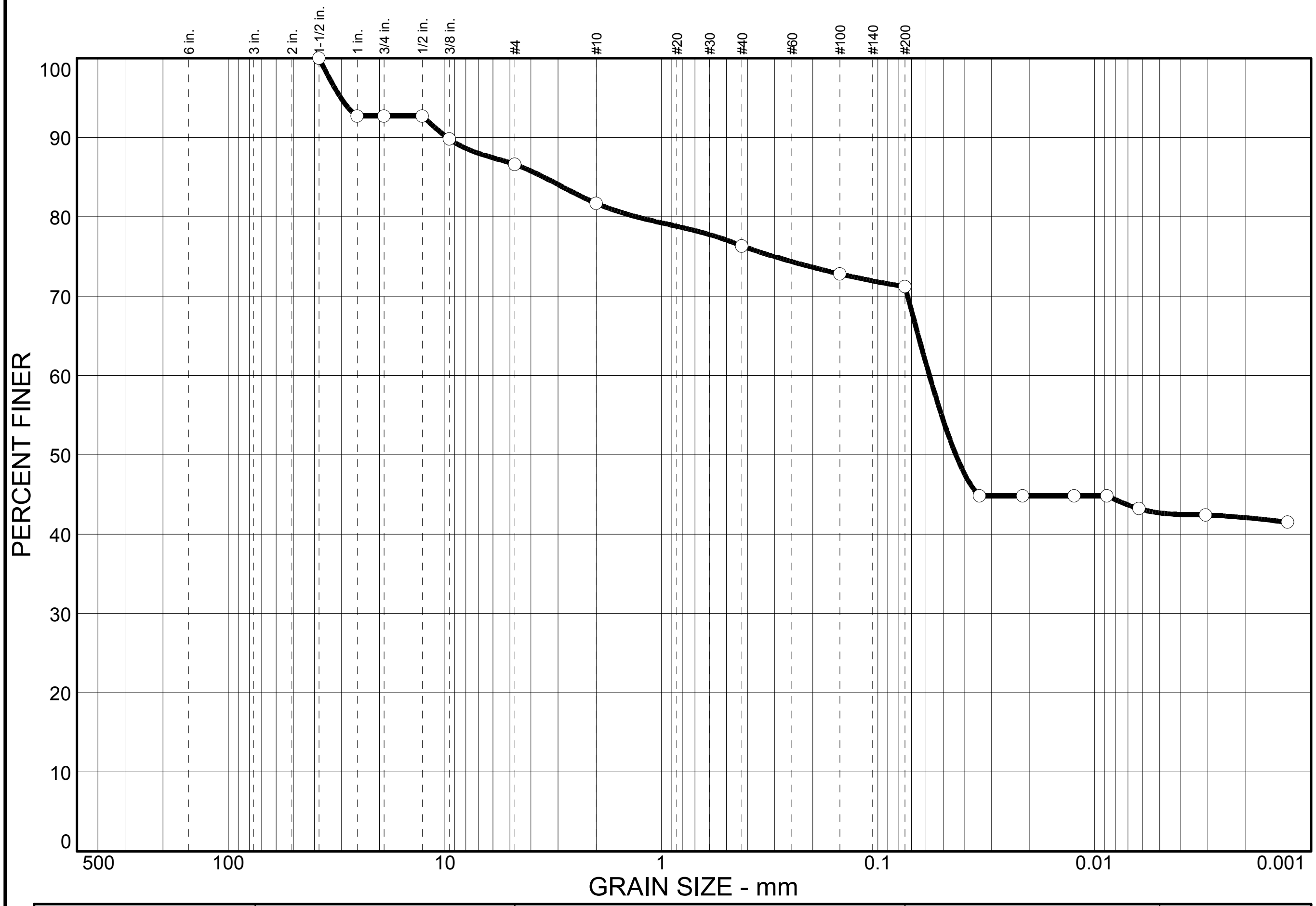
Sample No.: SWN-1
Source of Sample: Project Site
Date: 10/18/18
Location: San Juan, PR
Elev./Depth: 29-35.6'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812
Figure

Particle Size Distribution Report



% +75 MM	% GRAVEL	% SAND	% SILT	% CLAY
0.0	13.4	15.4	28.5	42.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5 in.	100.0		
1 in.	92.7		
.75 in.	92.7		
.5 in.	92.7		
.375 in.	89.8		
#4	86.6		
#10	81.7		
#40	76.3		
#100	72.8		
#200	71.2		

* (no specification provided)

Material Description

Fat clay with sand.

Atterberg Limits

PL= 30 LL= 80 PI= 50

Coefficients

D_{85}= 3.49 D_{60}= 0.0579 D_{50}= 0.0437
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO= A-7-5(37)

Remarks

Tested by: L. Medina
Checked by: Carlos Sierra del Llano, MSCE, PE
F.M.=0.58

Sample No.: SWN-1 **Source of Sample:** Project Site **Date:** 10/10/18
Location: San Juan, PR **Elev./Depth:** 64-70.6'

JACA & SIERRA
TESTING LABORATORIES
San Juan, Puerto Rico

Client: Moffat & Nichol
Project: PR Fuel Facilities-San Juan

Project No: 7812 **Figure**

JACA & SIERRA
Testing Laboratories
Geotechnical Engineers

Job No.: 7812
Date of Report: January 18, 2018
Page 1/1

LABORATORY TESTING SERVICES

Client:	Moffat & Nichol	Transported by:	Jaca & Sierra
Source of Samples:	Project Site-San Juan PR - Provided by Client	Date of Sample Receipt:	2-Jan-18
		Date of Testing:	4-Jan-18
Project:	PR Fuel Facilities	Standard Test Methods:	ASTM D 4318
Location:	San Juan, PR		

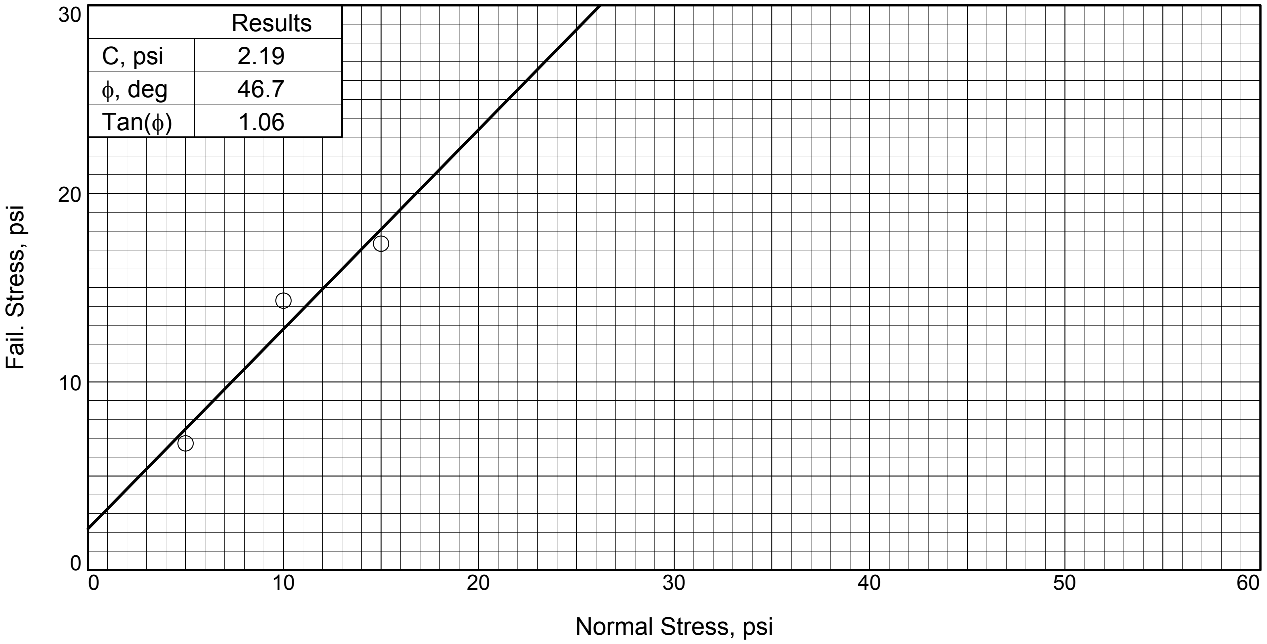
RESULTS

Sample ID	Liquid Limit, LL	Plasticity Index, PI
Boring 3 35'	52	33
Boring 3 15'	NP	NP

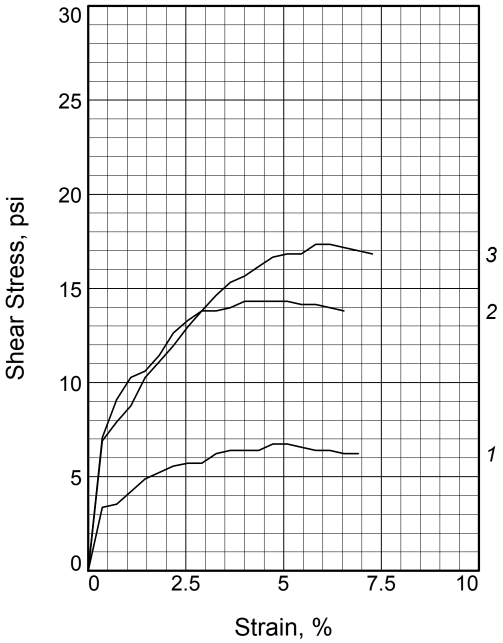
COMMENTS:
No additional comments

Respectfully Submitted,
JACA & SIERRA ENGINEERING, PSC

Carlos R. Sierra Del Llano, MSCE, PE
Geotechnical Engineering



	Results
C, psi	2.19
ϕ, deg	46.7
Tan(ϕ)	1.06



	Sample No.	1	2	3
Initial	Water Content, %	20.1	17.9	19.1
	Dry Density, pcf	80.7	82.4	81.7
	Saturation, %	50.7	47.0	49.4
	Void Ratio	1.0488	1.0082	1.0246
	Diameter, in.	2.75	2.75	2.75
	Height, in.	0.72	0.72	0.72
At Test	Water Content, %	22.2	20.1	19.8
	Dry Density, pcf	80.7	82.4	81.7
	Saturation, %	56.1	52.8	51.1
	Void Ratio	1.0488	1.0082	1.0246
	Diameter, in.	2.75	2.75	2.75
	Height, in.	0.72	0.72	0.72
	Normal Stress, psi	5.00	10.00	15.00
	Fail. Stress, psi	6.73	14.31	17.34
	Strain, %	4.7	4.0	5.8
	Ult. Stress, psi			
	Strain, %			
	Strain rate, in./min.	0.01	0.01	0.01

Sample Type:

Description:

Assumed Specific Gravity= 2.65

Remarks:

Figure ________

Client: Moffat & Nichol

Project: PR Fuel Facilities-San Juan

Location: San Juan, PR

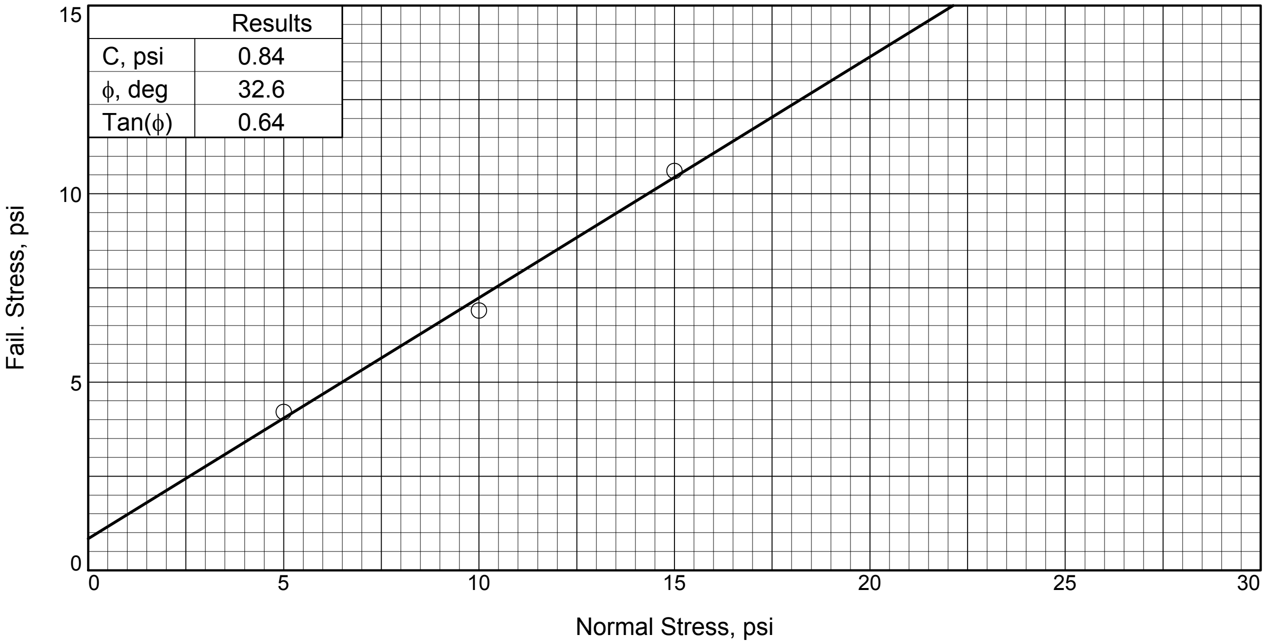
Sample Number: SWN-1 **Depth:** 4-7.5'

Proj. No.: 7812 **Date:**

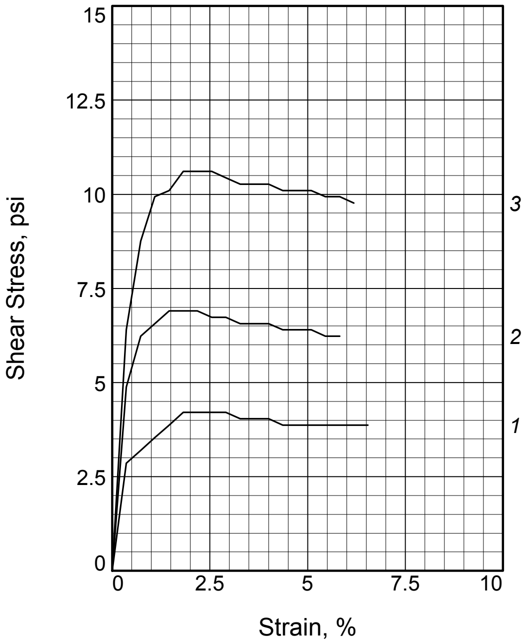
DIRECT SHEAR TEST REPORT

JACA & SIERRA TESTING LABORATORIES

Tested By: A. Perez **Checked By:** C. Sierra



	Results
C, psi	0.84
ϕ, deg	32.6
Tan(ϕ)	0.64



	Sample No.	1	2	3
Initial	Water Content, %	7.2	8.5	7.8
	Dry Density, pcf	83.6	83.0	83.1
	Saturation, %	19.5	22.7	20.8
	Void Ratio	0.9791	0.9932	0.9909
	Diameter, in.	2.75	2.75	2.75
	Height, in.	0.72	0.72	0.72
At Test	Water Content, %	23.2	21.9	21.3
	Dry Density, pcf	83.6	83.0	83.1
	Saturation, %	62.8	58.4	57.0
	Void Ratio	0.9791	0.9932	0.9909
	Diameter, in.	2.75	2.75	2.75
	Height, in.	0.72	0.72	0.72
	Normal Stress, psi	5.00	10.00	15.00
	Fail. Stress, psi	4.21	6.90	10.61
	Strain, %	1.8	1.5	1.8
	Ult. Stress, psi			
	Strain, %			
	Strain rate, in./min.	0.01	0.01	0.01

Sample Type:

Description:

Assumed Specific Gravity= 2.65

Remarks:

Figure ________

Client: Moffat & Nichol

Project: PR Fuel Facilities-San Juan

Location: San Juan, PR

Sample Number: Bo. 2 **Depth:** 2-10.5

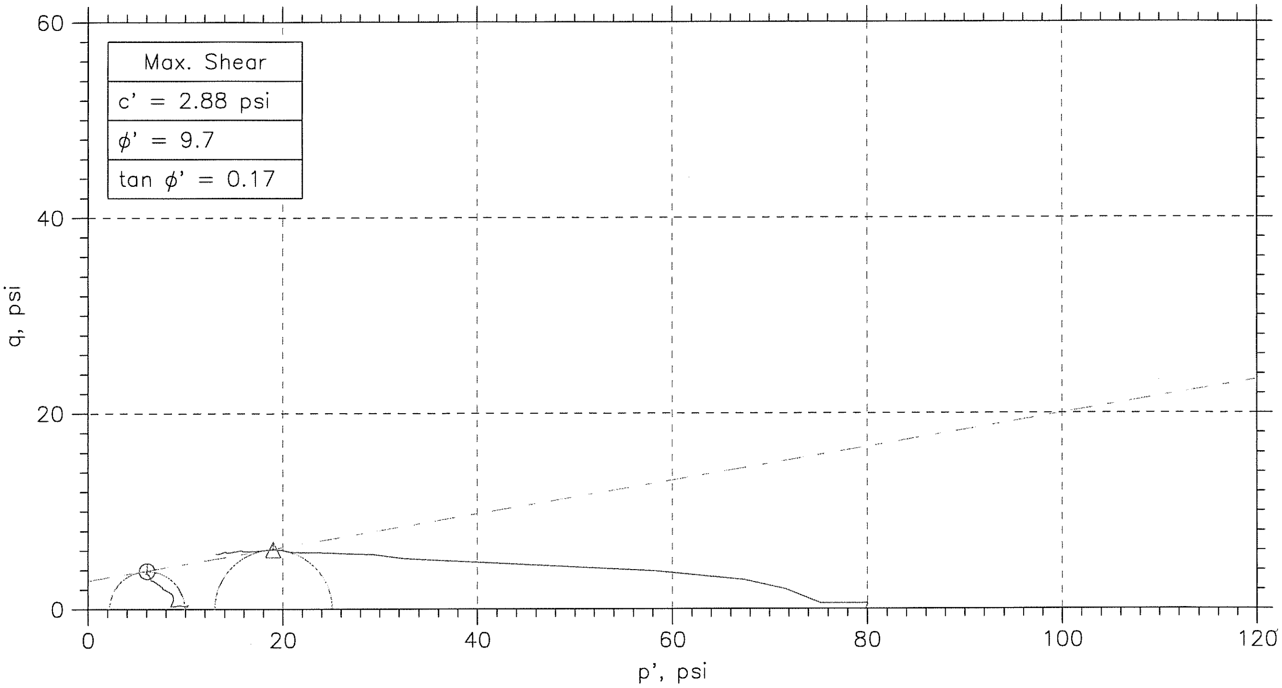
Proj. No.: 7812 **Date:**

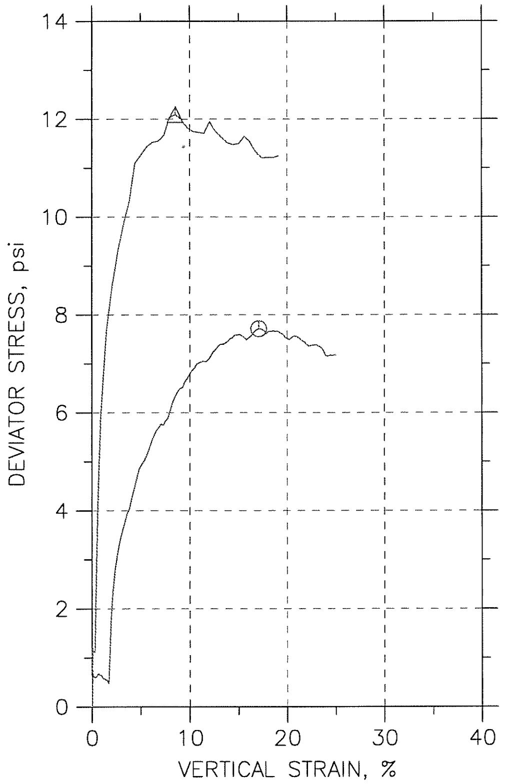
DIRECT SHEAR TEST REPORT

JACA & SIERRA TESTING LABORATORIES

Tested By: A. Perez **Checked By:** C. Sierra

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





Symbol		⦶	△		
Sample No.		2	3		
Test No.		1	1		
Depth		15'-17'	15'-17'		
Initial	Diameter, in	2.592	2.582		
	Height, in	4.815	5.422		
	Water Content, %	70.1	78.0		
	Dry Density, pcf	58.46	51.19		
	Saturation, %	101.5	92.6		
	Void Ratio	1.83	2.23		
Before Shear	Water Content, %	53.7	78.1		
	Dry Density, pcf	68.29	50.99		
	Saturation*, %	100.0	92.2		
	Void Ratio	1.42	2.24		
	Back Press., psi	20.99	21.02		
Ver. Eff. Cons. Stress, psi		9.951	79.87		
Shear Strength, psi		3.854	6.044		
Strain at Failure, %		17.1	8.49		
Strain Rate, %/min		0.1	0.3		
B-Value		0.98	---		
Estimated Specific Gravity		2.65	2.65		
Liquid Limit		---	---		
Plastic Limit		---	---		

Project: M&N

Location:

Project No.: 7812

Boring No.: B1

Sample Type: Undisturbed

Description: Dark Gray Clay

Remarks:

Phase calculations based on start and end of test.

* Saturation is set to 100% for phase calculations.

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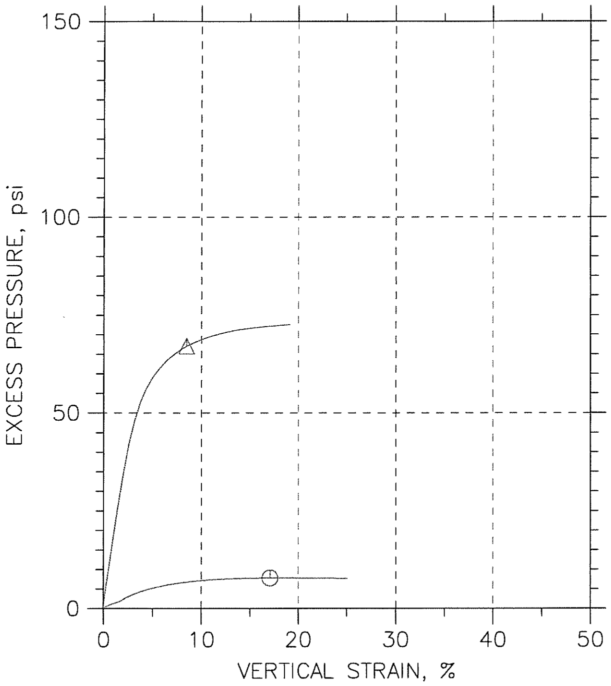
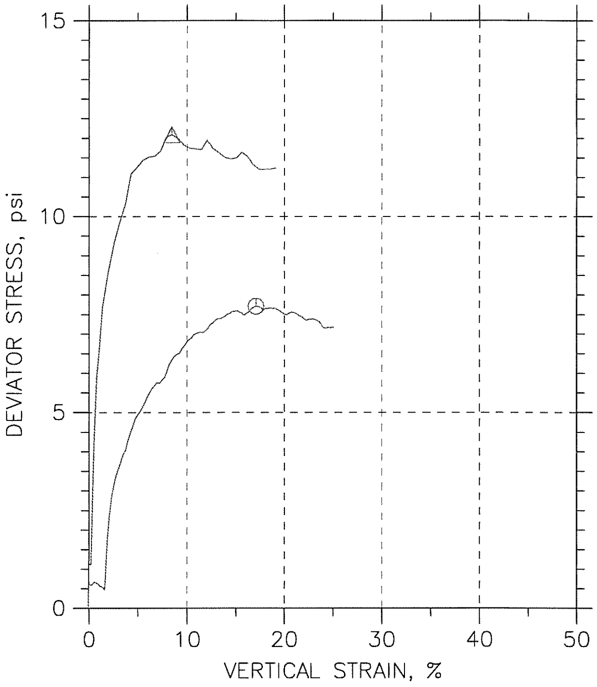
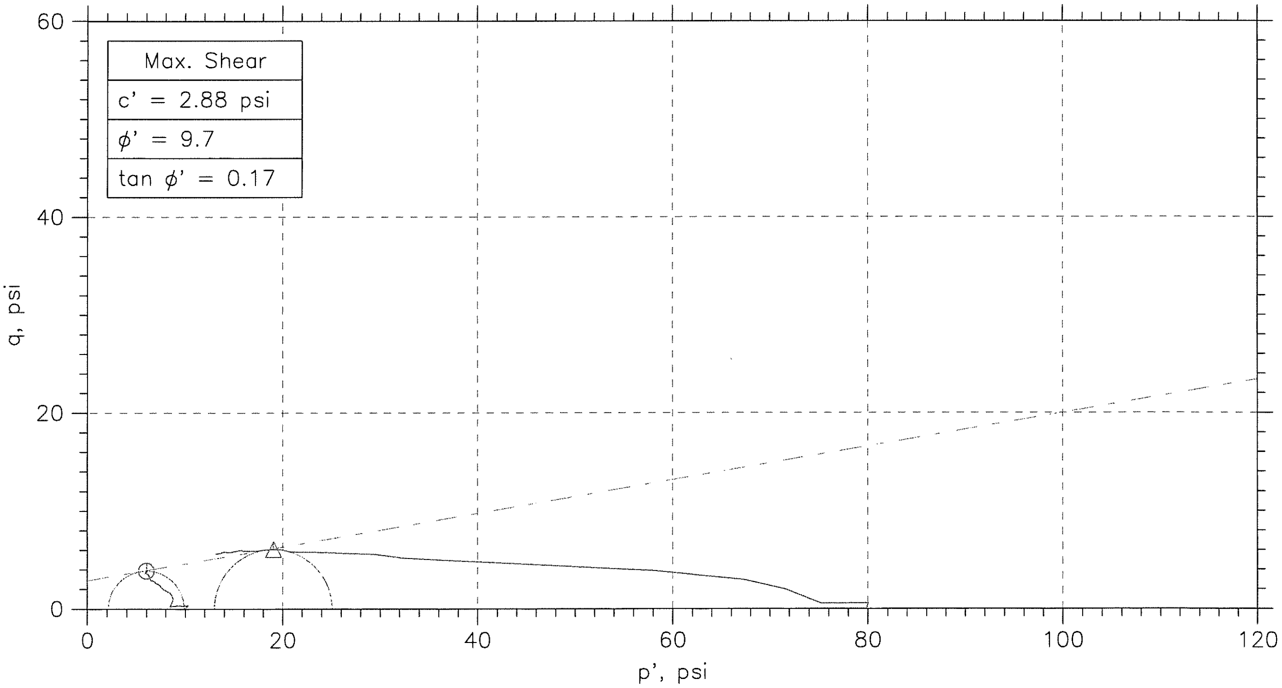
CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767







	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⦶	2	1	15'-17'	JAGB	16-Nov-18	JAGB		7812 M&N B1 15-17 s1.dat
△	3	1	15'-17'	JAGB	20-Nov-18	JAGB		7812 M&N B1 15-17 s3-UU Mo

Project: M&N	Location:	Project No.: 7812
Boring No.: B1	Sample Type: Undisturbed	
Description: Dark Gray Clay		
Remarks:		

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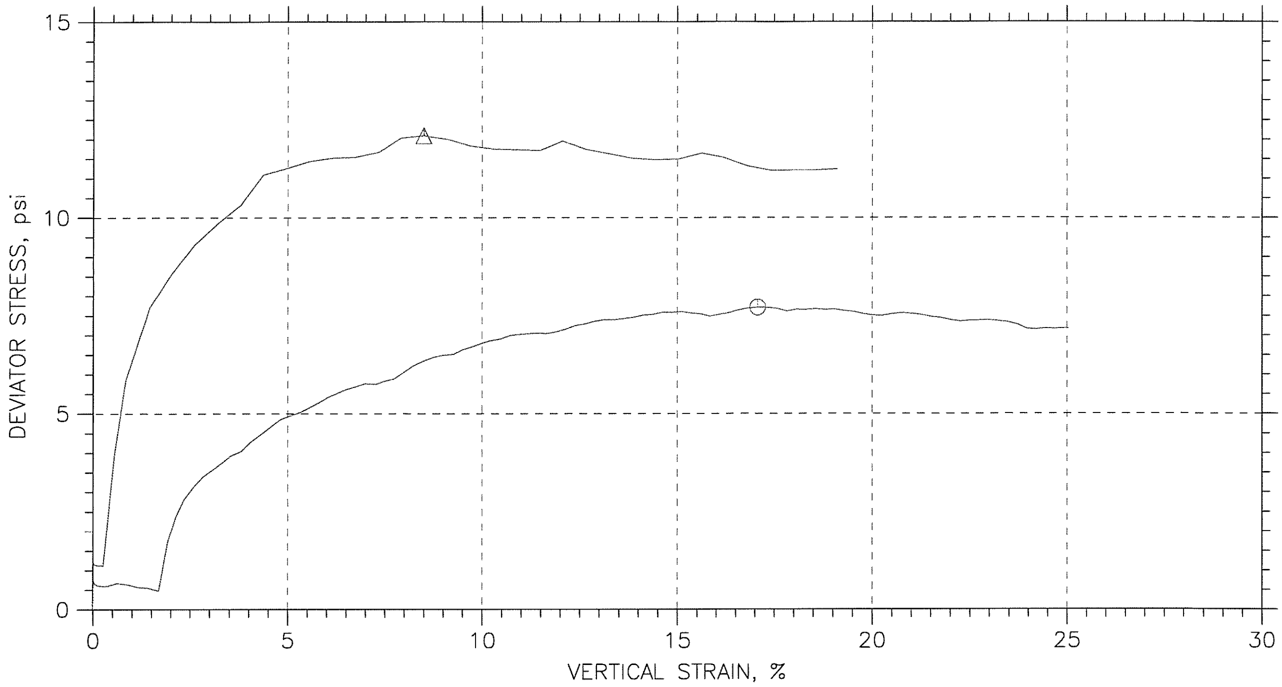
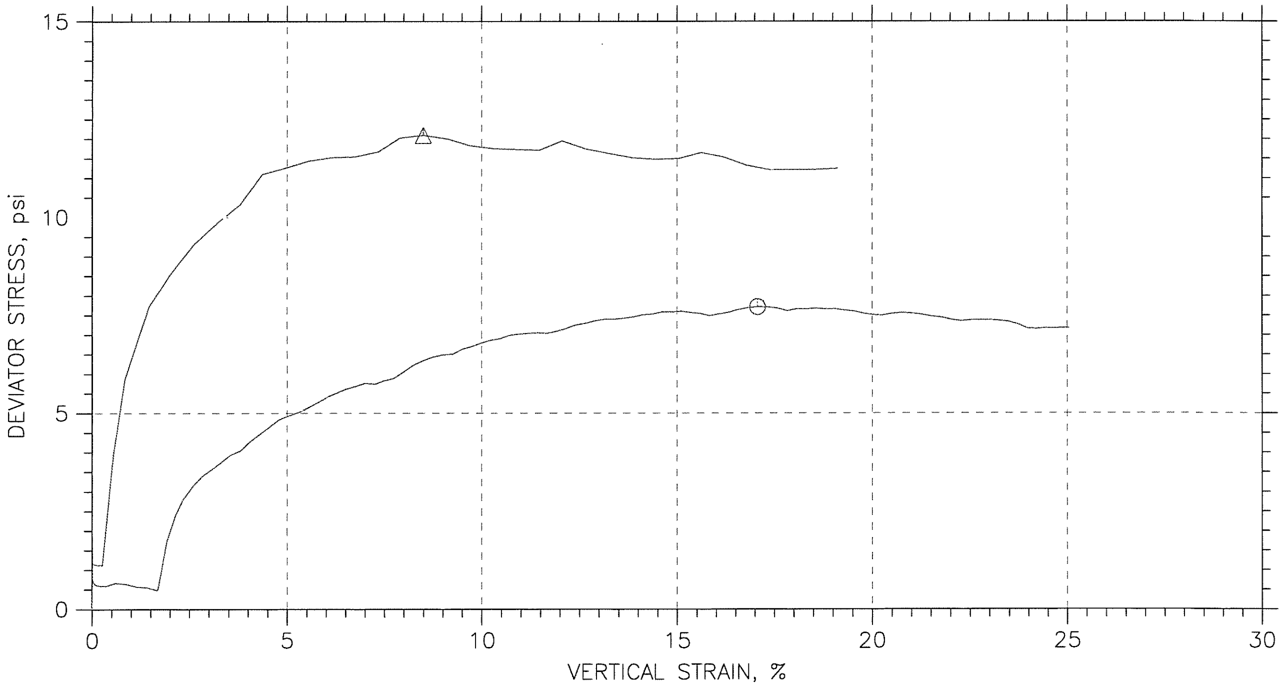
Public

CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⦶	2	1	15'-17'	JAGB	16-Nov-18	JAGB		7812 M&N B1 15-17 s1.dat
△	3	1	15'-17'	JAGB	20-Nov-18	JAGB		7812 M&N B1 15-17 s3-UU Mo

Project: M&N	Location:	Project No.: 7812
Boring No.: B1	Sample Type: Undisturbed	
Description: Dark Gray Clay		
Remarks:		

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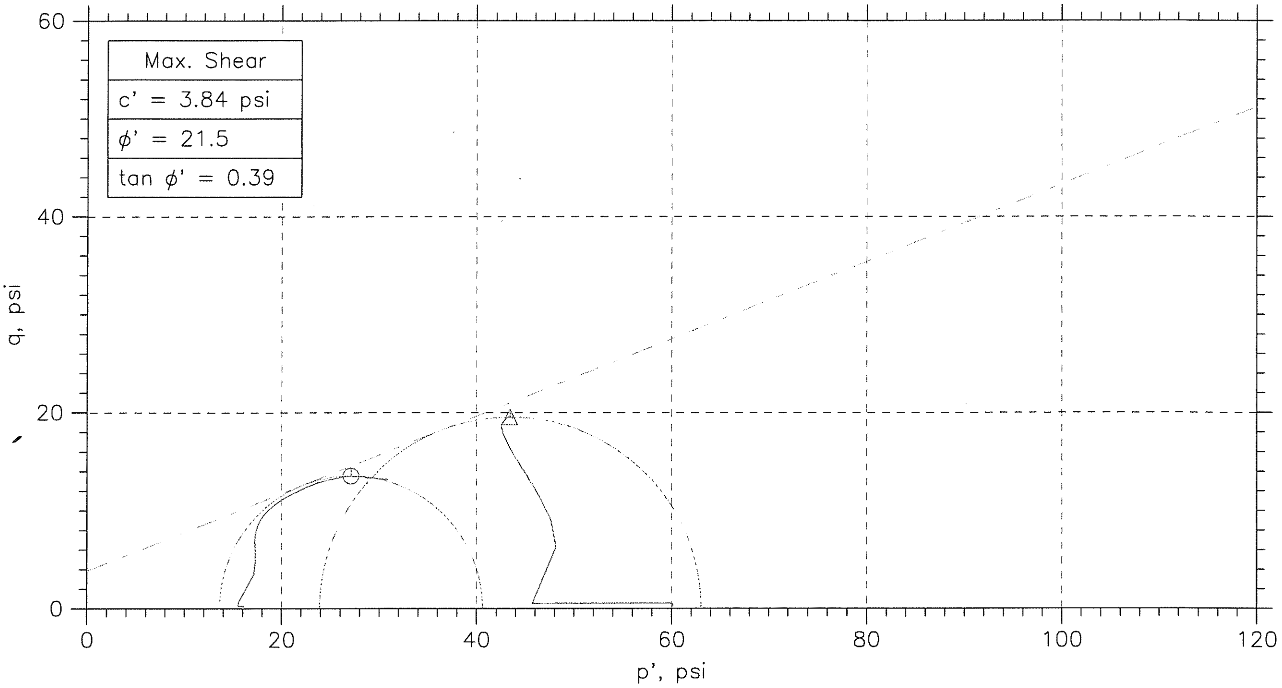
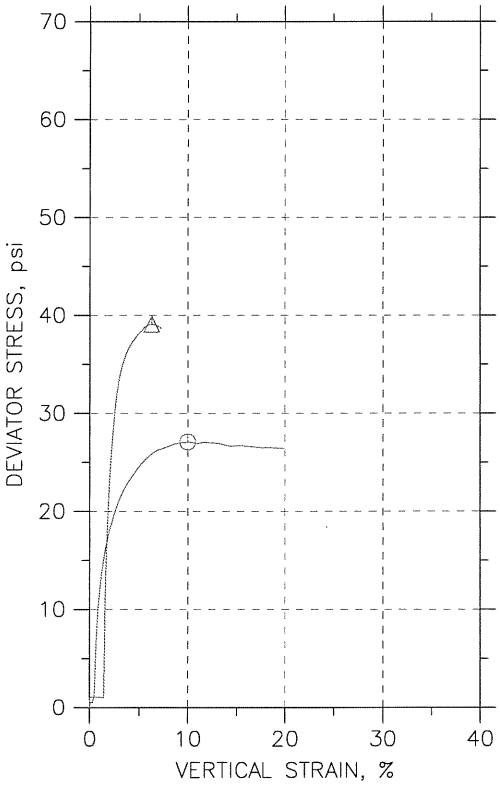
CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





Symbol		○	△		
Sample No.		1	2		
Test No.		1	1		
Depth		25'-27'	25'-27'		
Initial	Diameter, in	2.875	2.869		
	Height, in	5.995	6.037		
	Water Content, %	25.5	27.0		
	Dry Density, pcf	96.32	93.99		
	Saturation, %	94.2	94.1		
	Void Ratio	0.718	0.76		
Before Shear	Water Content, %	29.1	27.5		
	Dry Density, pcf	93.37	95.76		
	Saturation*, %	100.0	100.0		
	Void Ratio	0.772	0.728		
	Back Press., psi	21.	36.01		
Ver. Eff. Cons. Stress, psi		15.99	59.96		
Shear Strength, psi		13.53	19.53		
Strain at Failure, %		9.99	6.25		
Strain Rate, %/min		0.1	0.1		
B-Value		0.95	0.96		
Estimated Specific Gravity		2.65	2.65		
Liquid Limit		---	---		
Plastic Limit		---	---		

Project: M&N
Location:
Project No.: 7812
Boring No.: B1
Sample Type: Undisturbed
Description:
Remarks:
Phase calculations based on start and end of test.
* Saturation is set to 100% for phase calculations.

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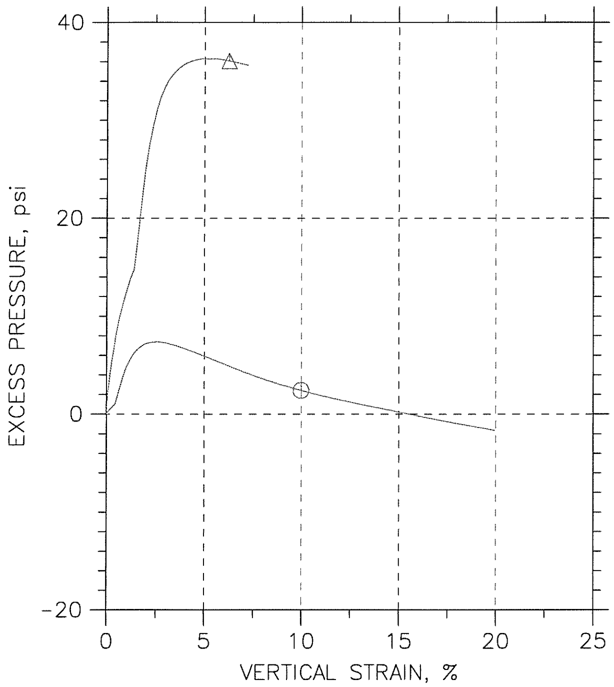
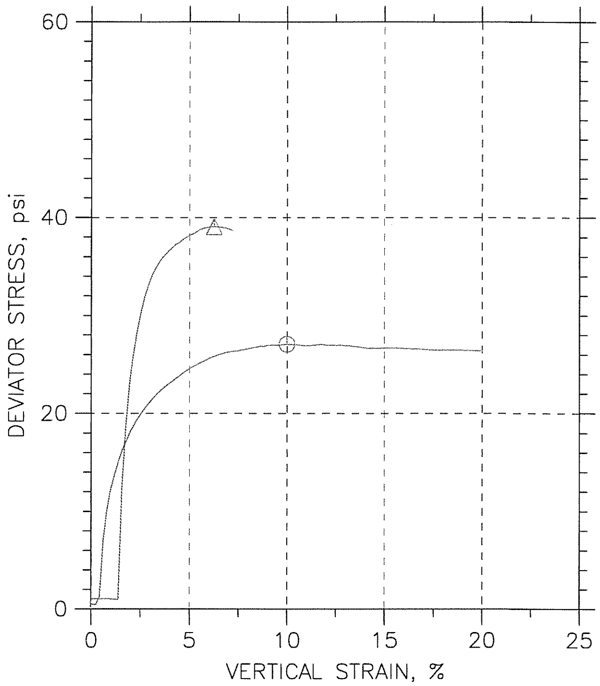
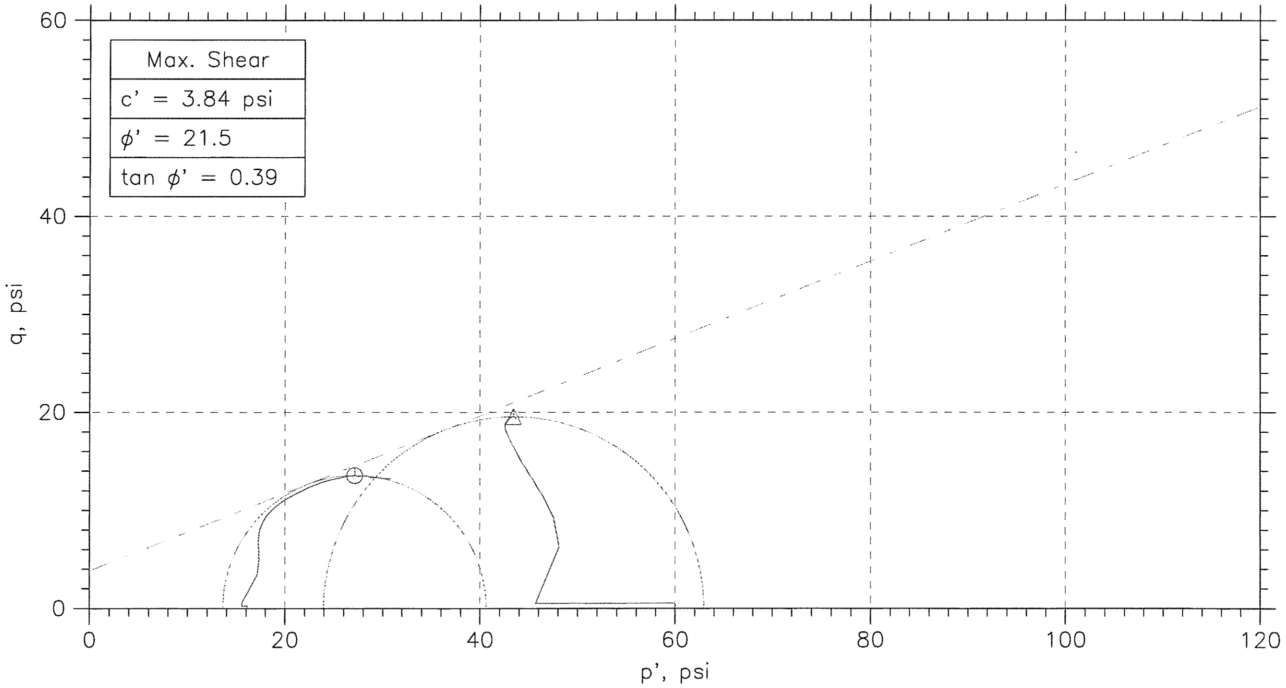
CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767







	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⦶	1	1	25'-27'	JAGB	12-Nov-18	JAGB		7812 M&N B1 25-27 s1.dat
△	2	1	25'-27'	JAGB	13-Nov-18	JAGB		7812 M&N B1 25-27 s2.dat

Project: M&N
Location:
Project No.: 7812
Boring No.: B1
Sample Type: Undisturbed
Description:
Remarks:

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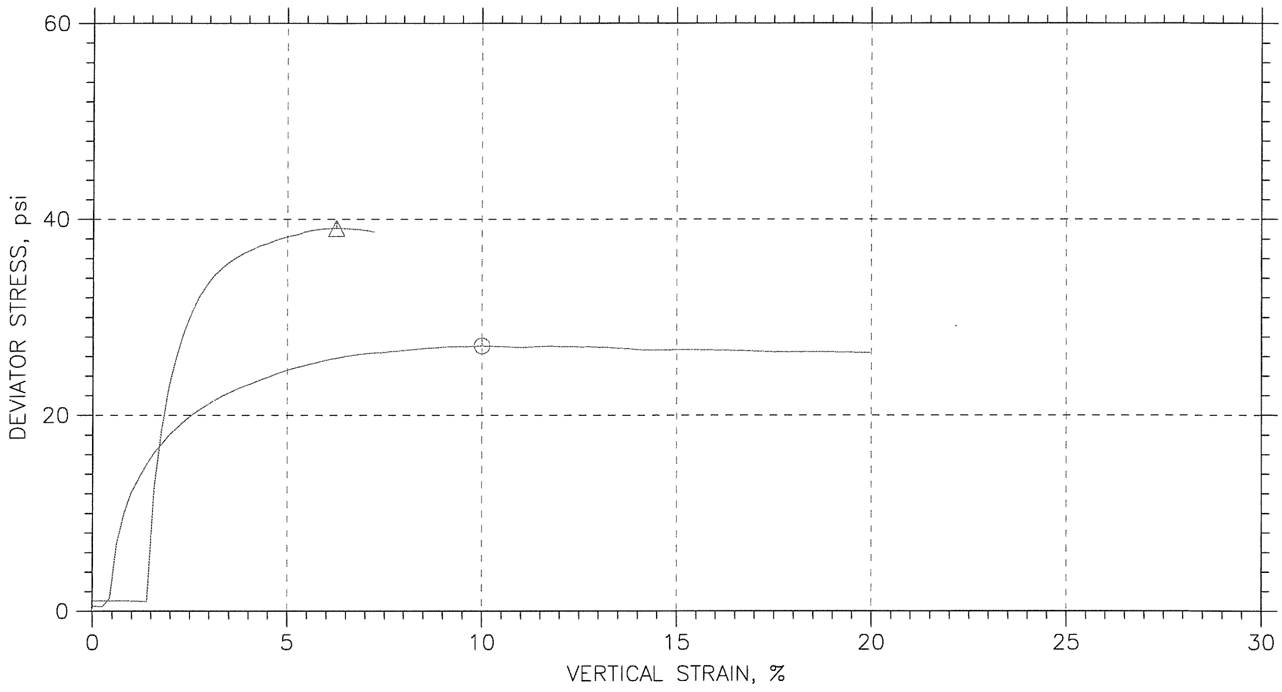
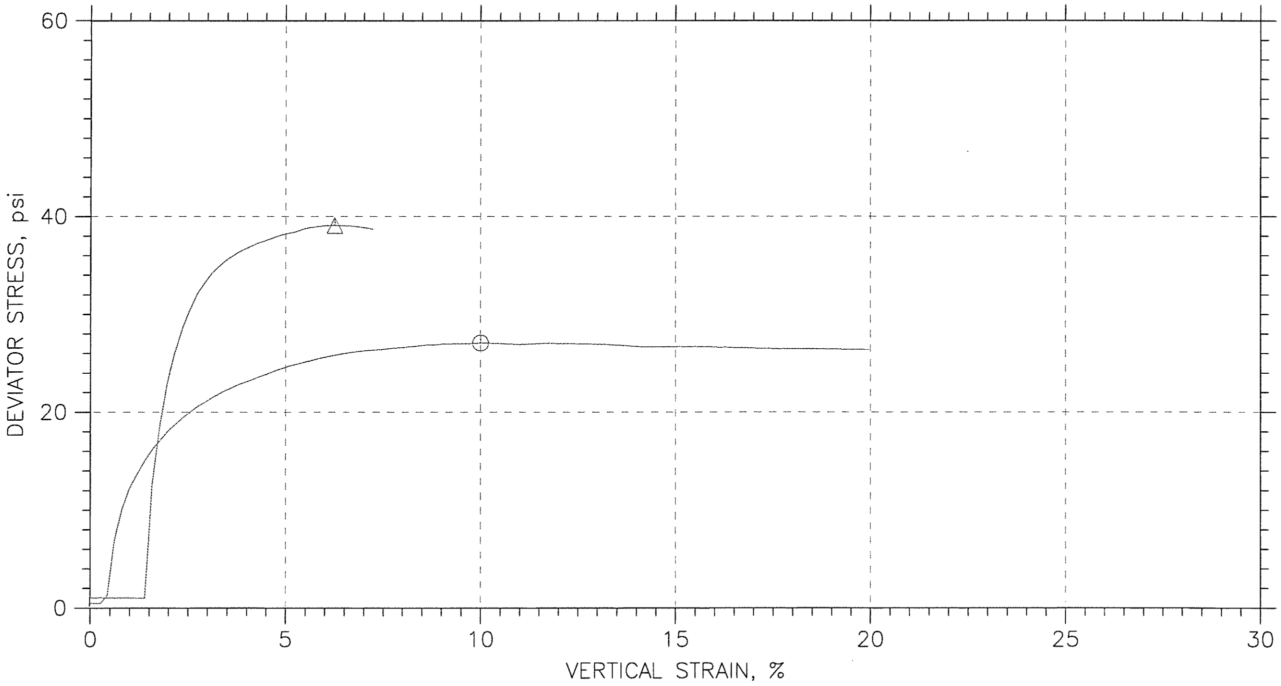
CONSOLIDATED UNDRAINED TRIAXIAL TEST by ASTM D4767





	Sample No.	Test No.	Depth	Tested By	Test Date	Checked By	Check Date	Test File
⦶	1	1	25'-27'	JAGB	12-Nov-18	JAGB		7812 M&N B1 25-27 s1.dat
△	2	1	25'-27'	JAGB	13-Nov-18	JAGB		7812 M&N B1 25-27 s2.dat

Project: M&N
Location:
Project No.: 7812
Boring No.: B1
Sample Type: Undisturbed
Description:
Remarks:

Mon, 04-MAR-2019 09:11:30

JACA & SIERRA
Testing Laboratories
Geotechnical Engineers

Appendix D

Axial and Lateral Capacity Analysis of Deep Foundations; and Liquefaction Analysis Report

JACA & SIERRA
Engineering | since 1967
Consulting | Testing | Geo-Construction

NFE Microfuel Handling Facility- Pile Capacity Analysis

Axial Pile Capacity Analysis Summary:

		Static Condition FS=2		FS reduction with Liquefaction		Liquefaction with FS=2	
Pile Type	**Depth (ft)**	**Allowable Axial Compression (tons)**	**Allowable Axial Tension (tons)**	**Ultimate Axial Compression with liquefaction (tons)**	**FS compared to allowable compression load static case**	**Allowable Axial Compression (tons)**	**Allowable Axial Tension (tons)**
12 inch diameter precast concrete pile	90	75	45	120	1.60	60	33
14 inch diameter precast concrete pile	90	85	50	138	1.62	69	36
HP 14 x 117	90	105	68	170	1.62	85	50
18 inch Pipe Pile; t=0.5"	90	120	68	195	1.63	97.5	48
24 inch Pipe Pile; t=0.5"	70	105	60	190	1.81	95	55

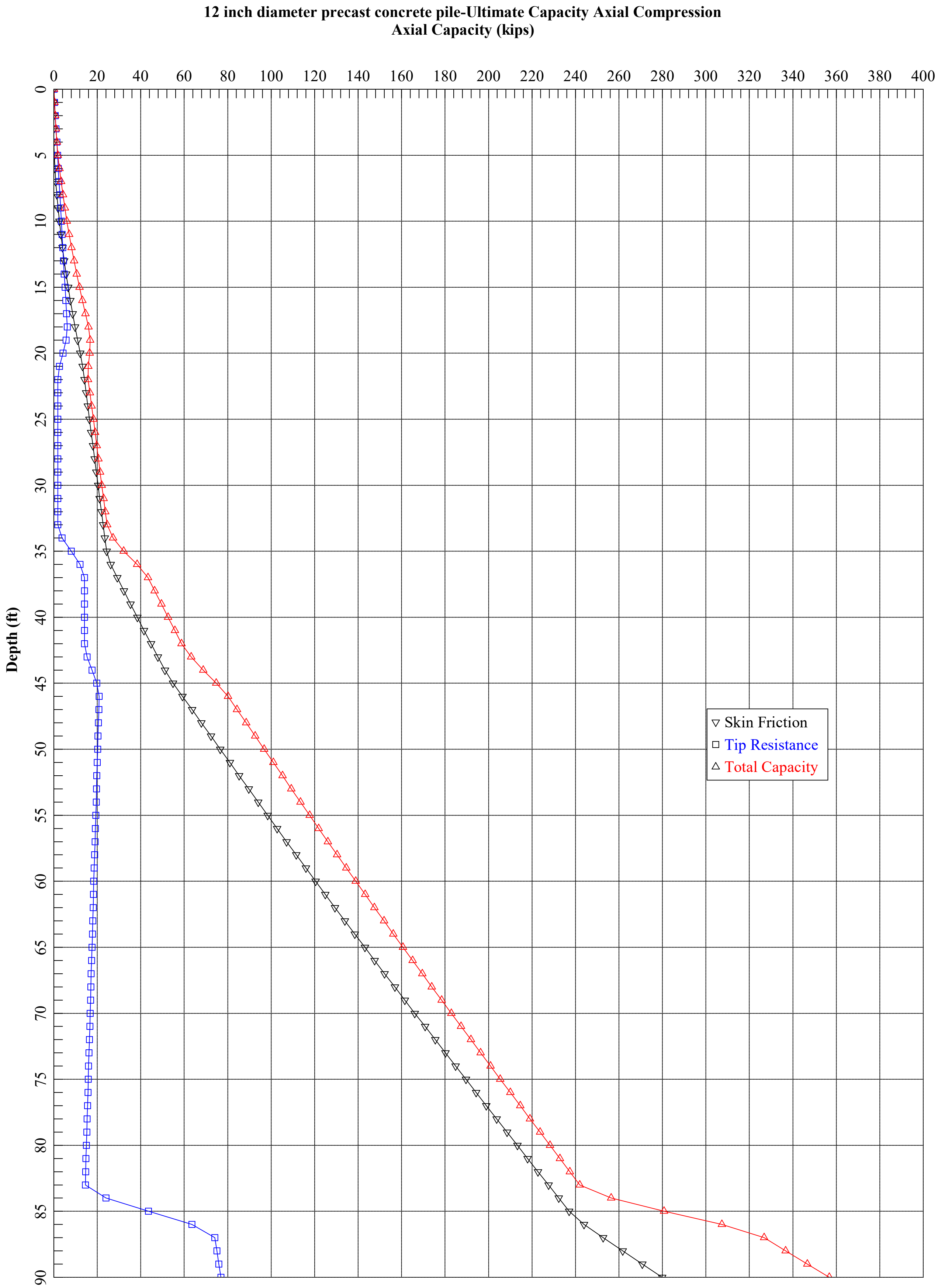
Lateral Loading Analysis Parameters (Lpile): STATIC CONDITIONS + WIND LOADS

Soils Stratum	**Lpile Model P-Y Curve**	**Depth below pile head to top of layer(ft)**	**Depth below pile head to bottom of layer(ft)**	**Effective Unit Weight (pcf)**	**Cohesion/Su (psf)**	**Angle of Internal Friction**	**k and strain factor**
Loose Sand (Hyd. Fill)	API Sand (Oneill)	0	15	38		28	default
Soft Clayey Silt/Silty Clay	Soft Clay (Matlock)	15	30	33	150		default
Stiff Silty Clay	Stiff Clay with Free Water	30	60	53	1500-3000		default

Lateral Loading Analysis Parameters (Lpile): SEISMIC LIQUEFACTION

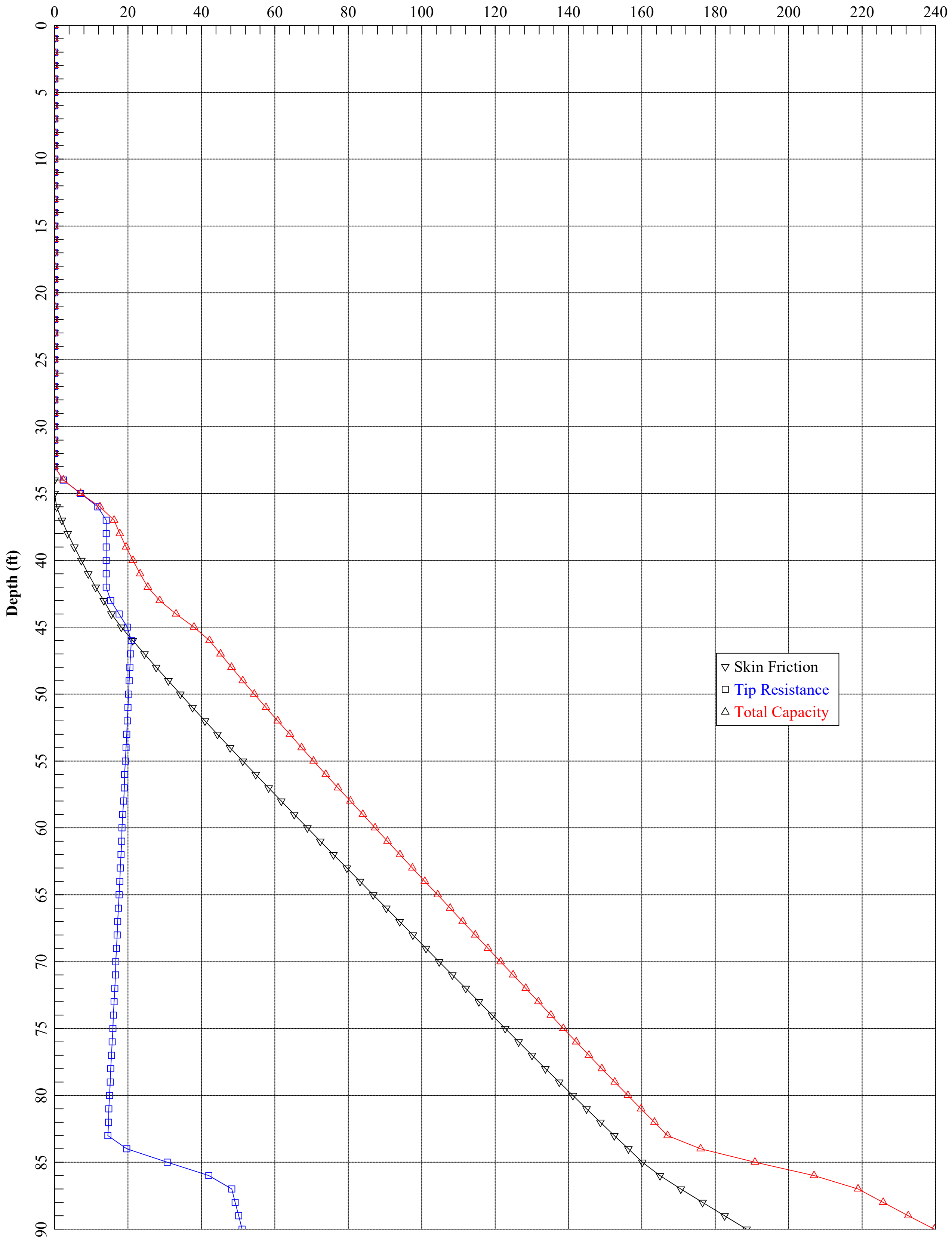
Soils Stratum	**Lpile Model P-Y Curve**	**Depth below pile head to top of layer(ft)**	**Depth below pile head to bottom of layer(ft)**	**Effective Unit Weight (pcf)**	**Cohesion;Su (psf)**	**SPT Blow Count input**	**k and strain factor**
Loose Sand (Liquefaction)	Hybrid Model Liquefied Sand	0	30	38	2	2	default
Stiff Silty Clay	Stiff Clay with Free Water	30	60	53	1500-3000		default

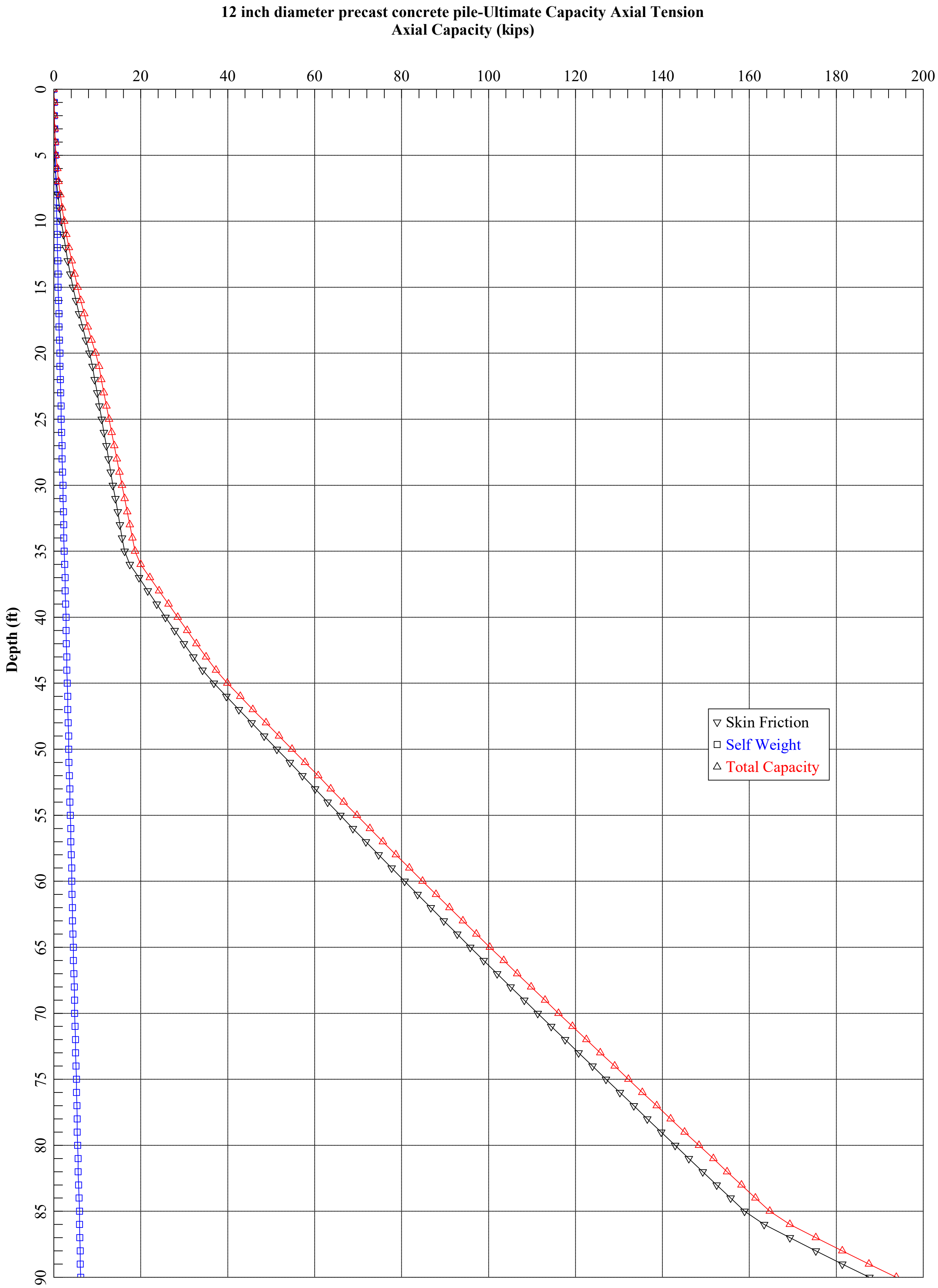
Date: 11-9-18 by Carlos R. Sierra, MSCE, PE


12 inch diameter precast concrete pile-Ultimate Capacity Axial Compression
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Tip Resistance
△ Total Capacity

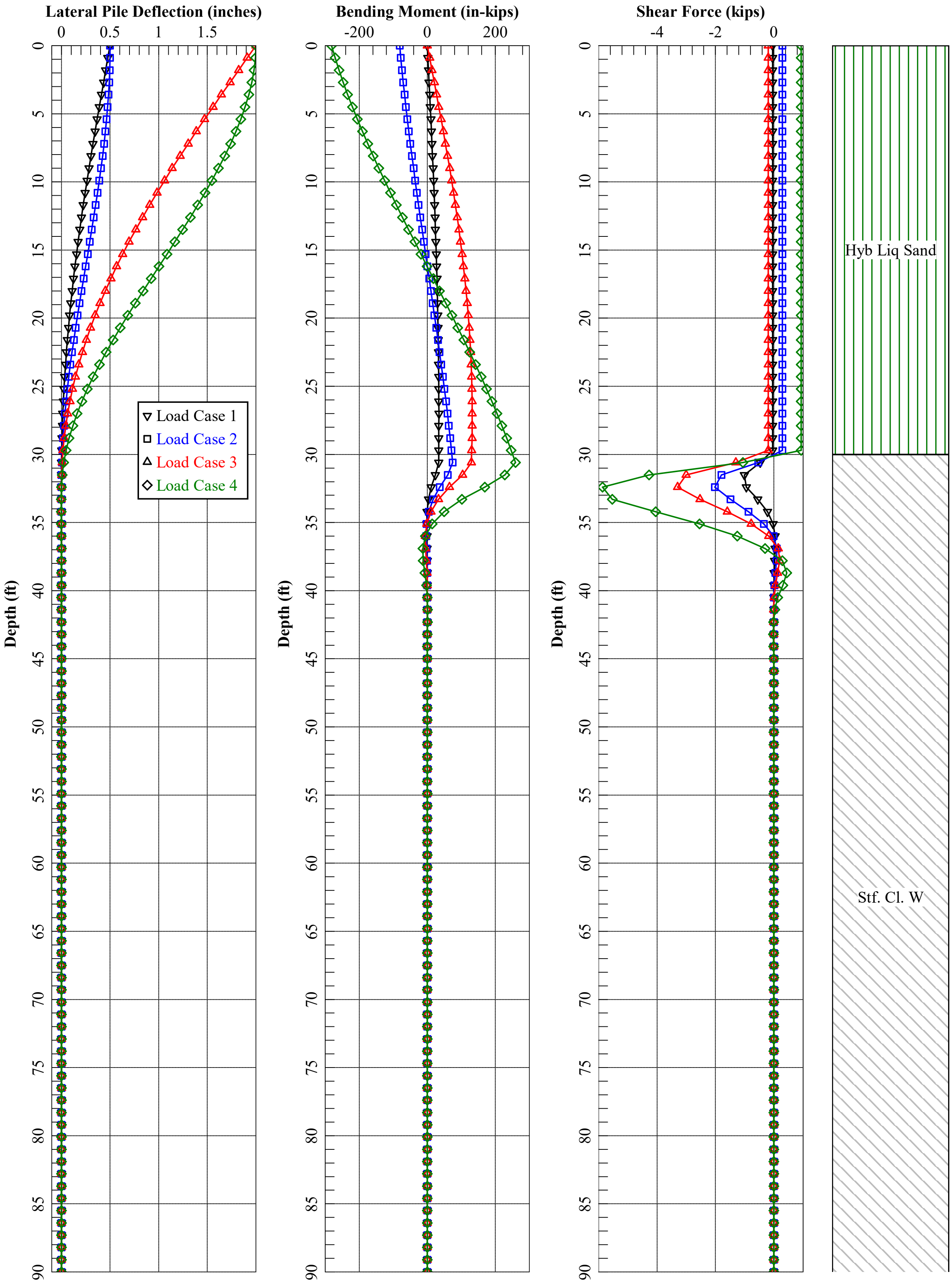
Public

12 inch diameter precast concrete pile-Ultimate Capacity Axial Compression
Axial Capacity (kips)

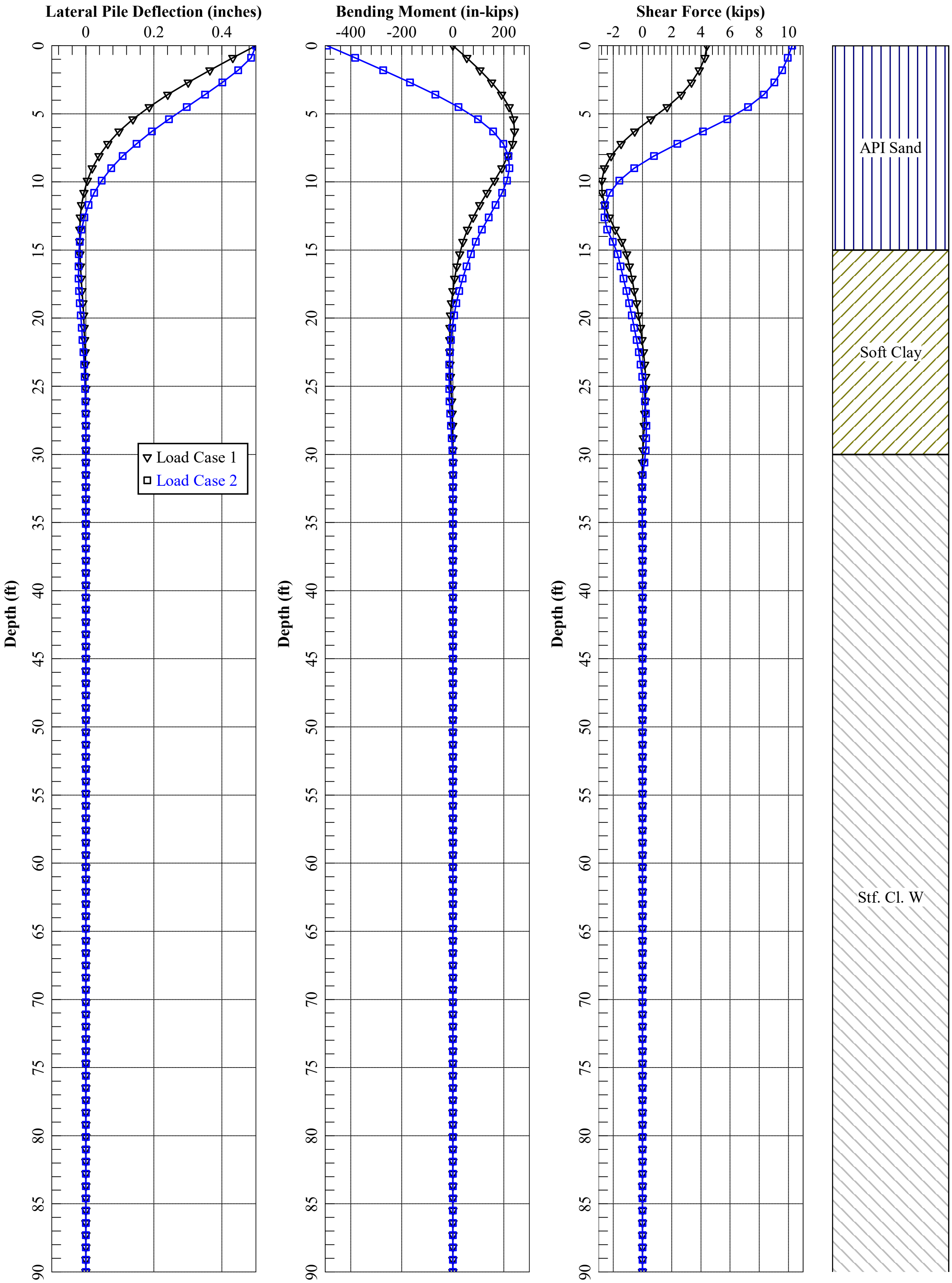



12 inch diameter precast concrete pile-Ultimate Capacity Axial Tension
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Self Weight
△ Total Capacity

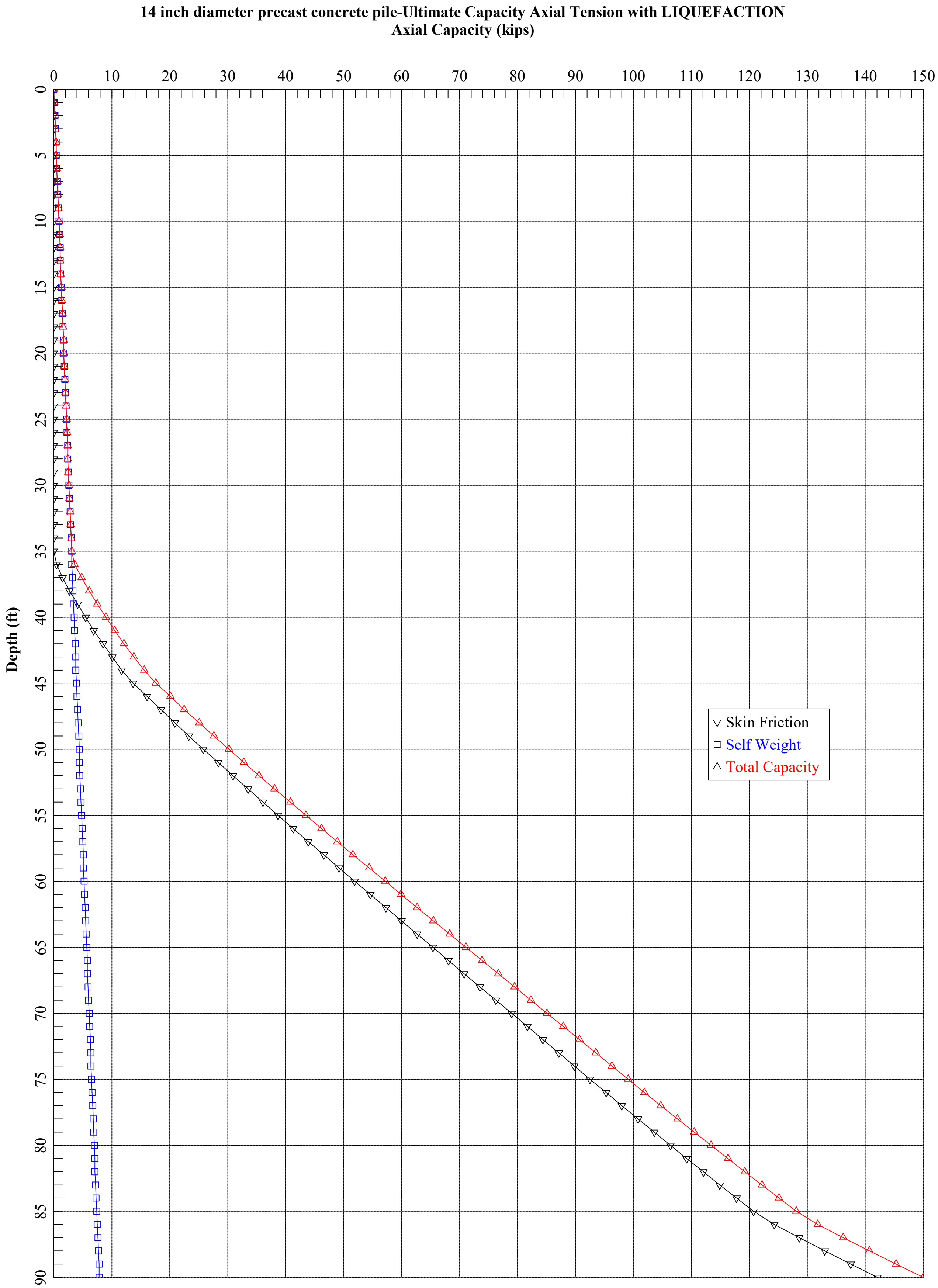
12 inch precast concrete pile B-2: LIQUEFACTION



12 inch precast concrete pile B-2: Static Condition

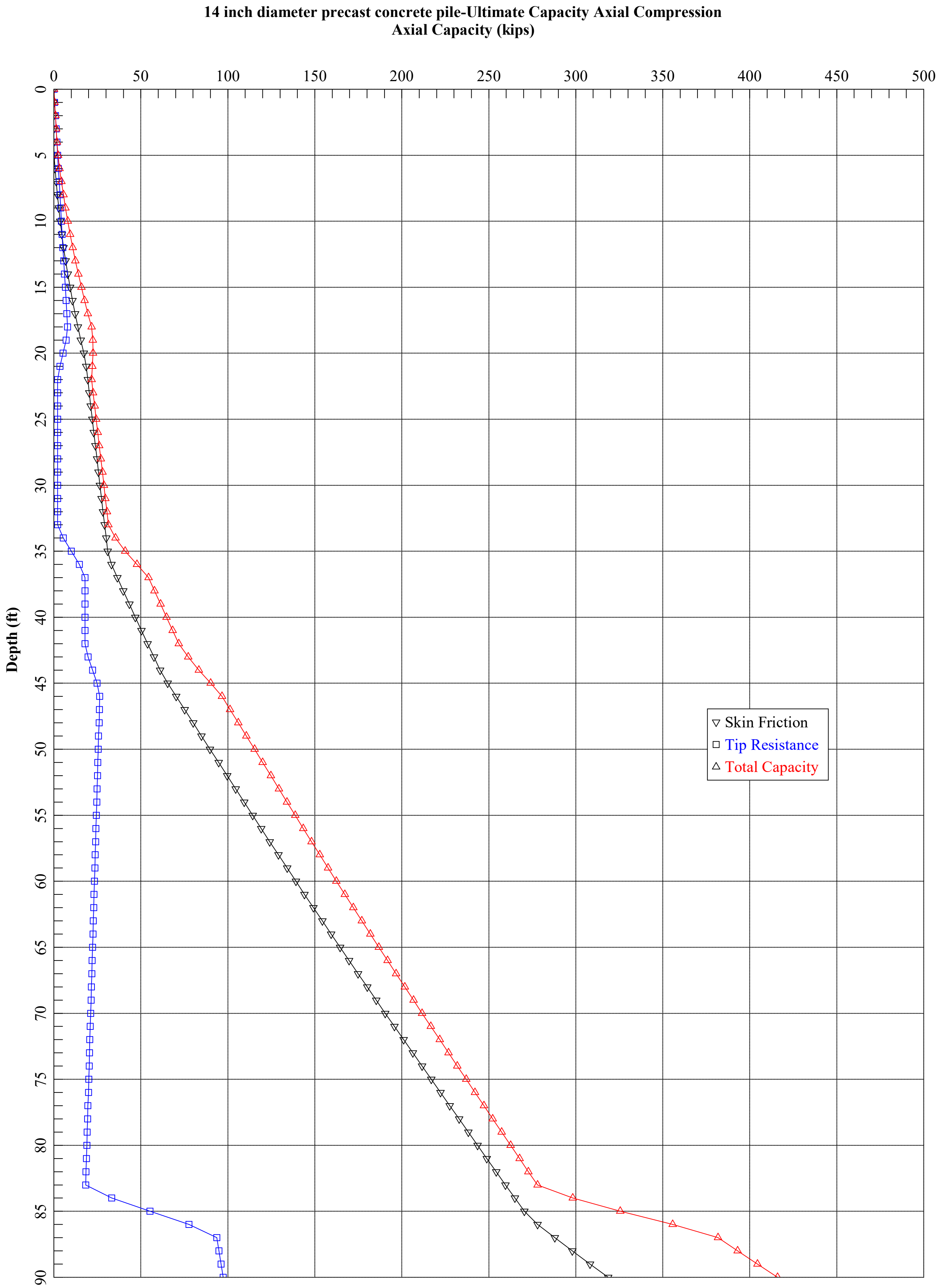


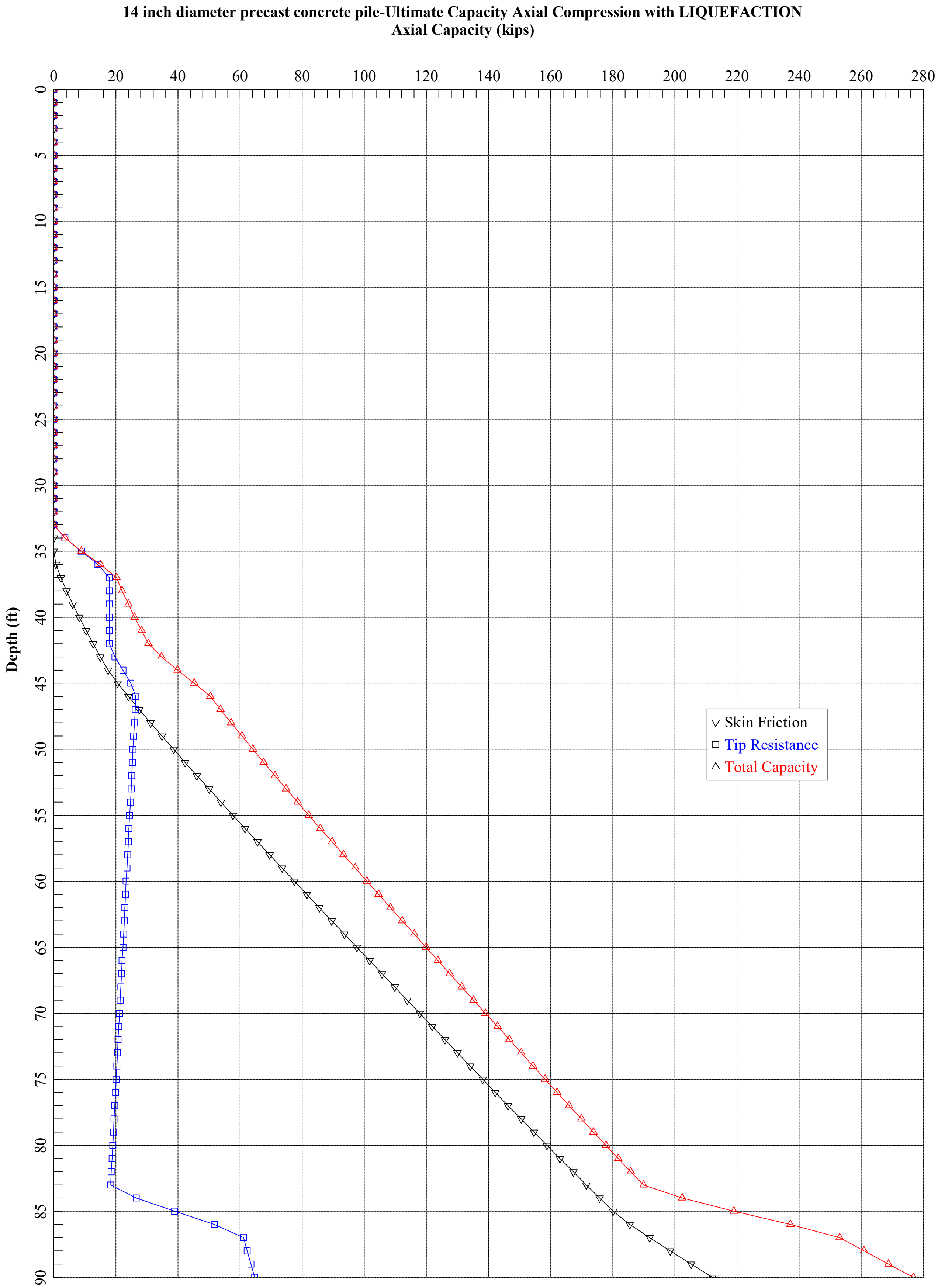
Public



14 inch diameter precast concrete pile-Ultimate Capacity Axial Tension with LIQUEFACTION
Axial Capacity (kips)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Self Weight
△ Total Capacity

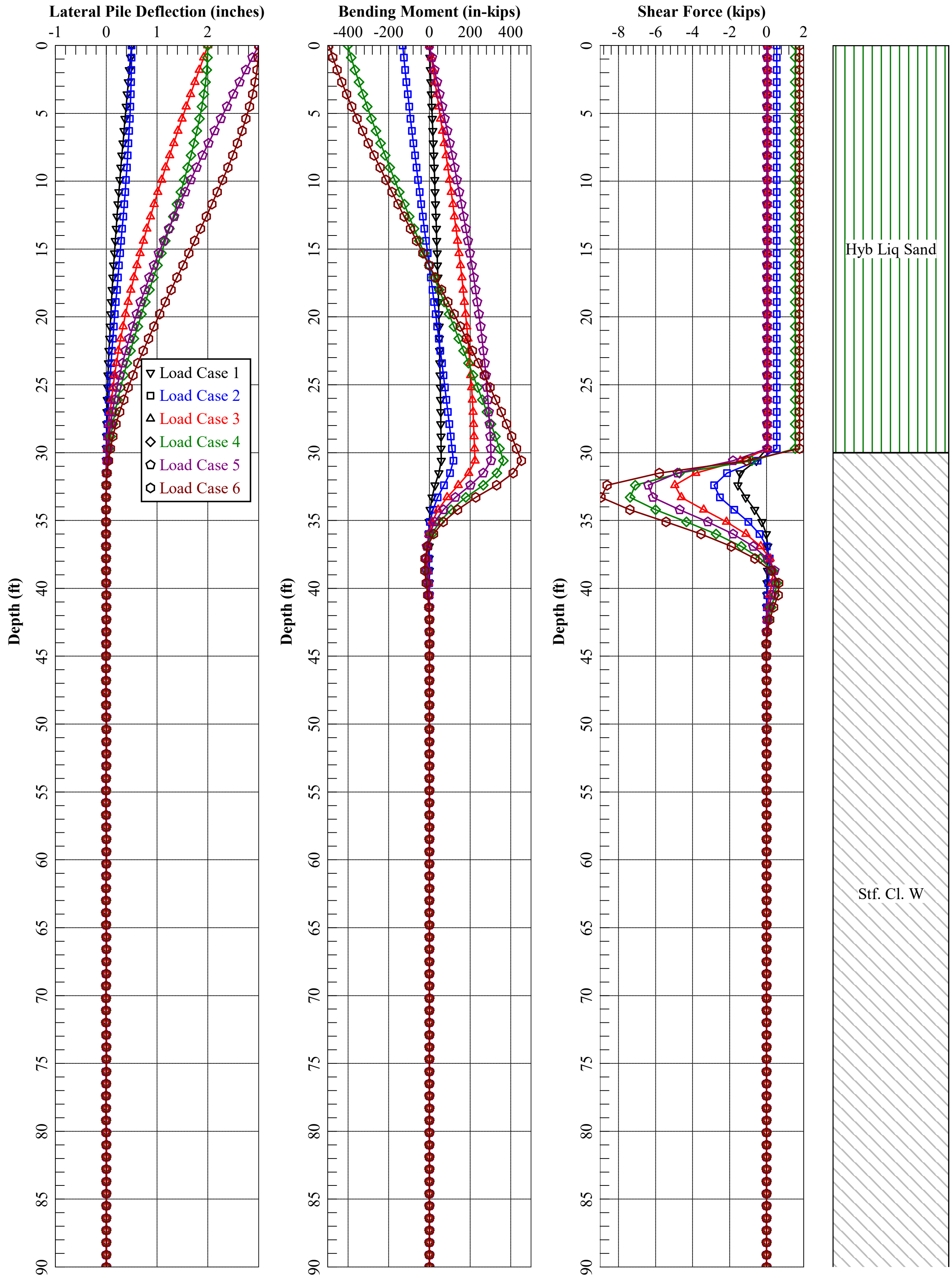
Public

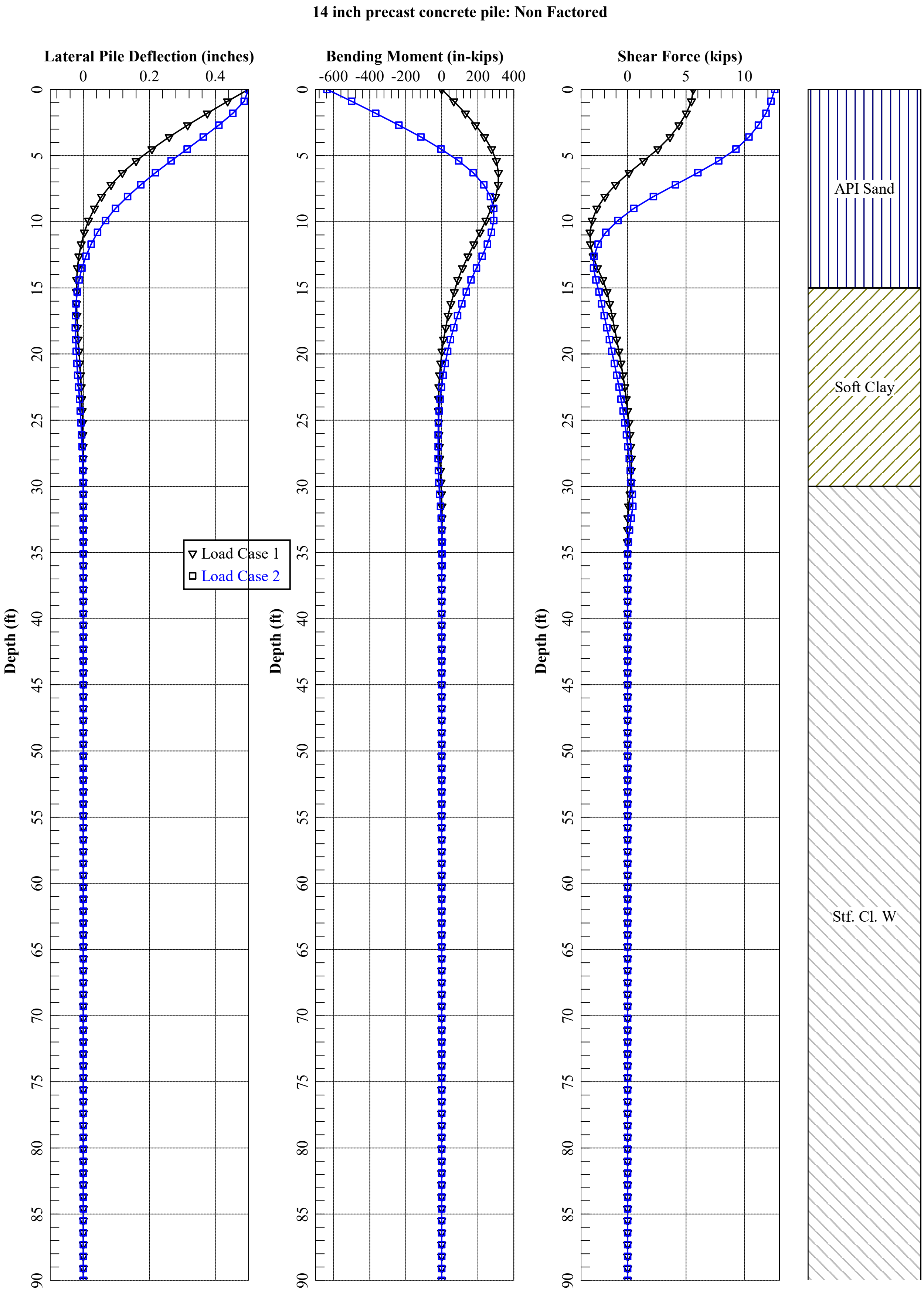

14 inch diameter precast concrete pile-Ultimate Capacity Axial Compression
Axial Capacity (kips)
0
50
100
150
200
250
300
350
400
450
500
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Tip Resistance
△ Total Capacity


14 inch diameter precast concrete pile-Ultimate Capacity Axial Compression with LIQUEFACTION
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Tip Resistance
△ Total Capacity

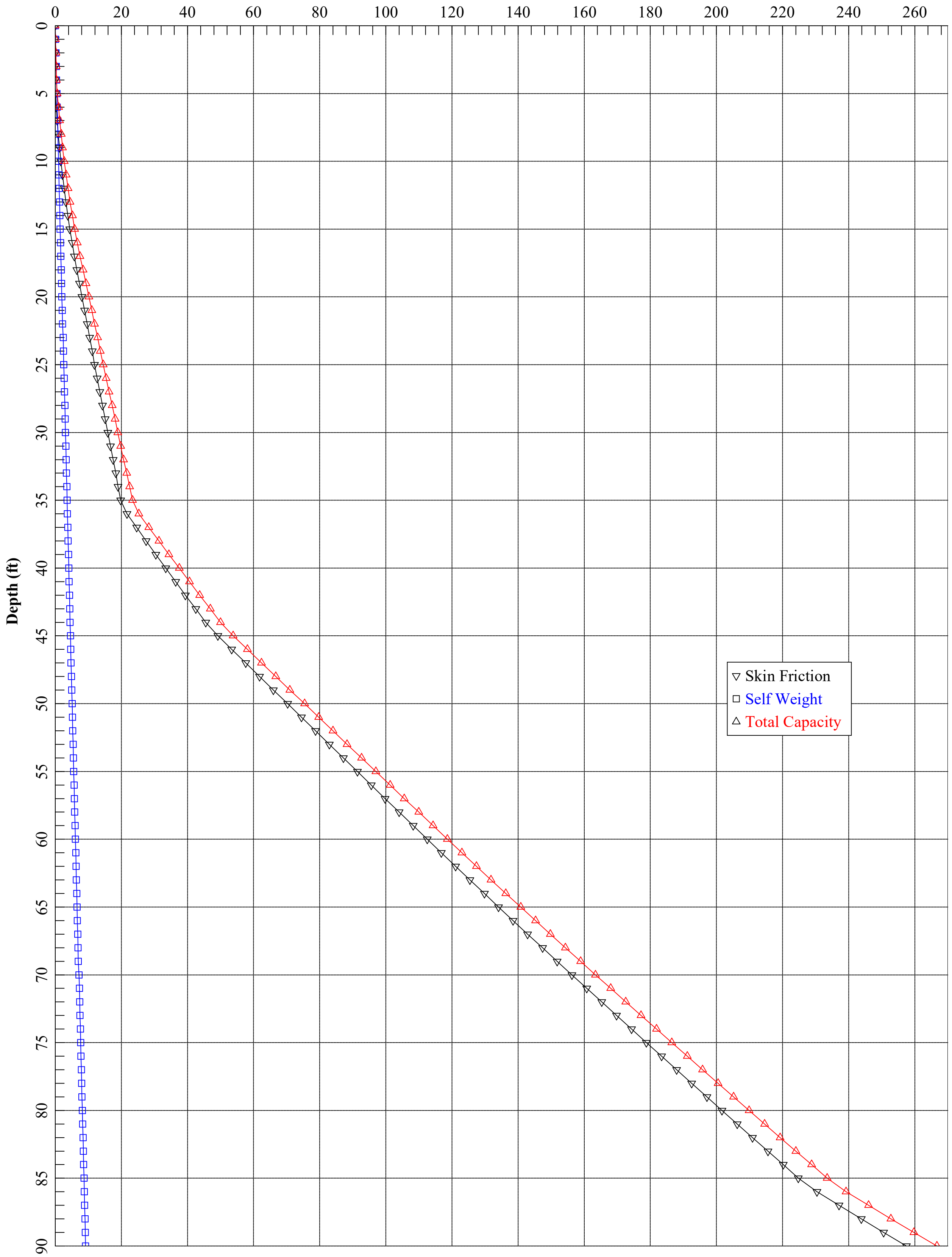
Public

13.5 inch precast concrete pile B-2: LIQUEFACTION

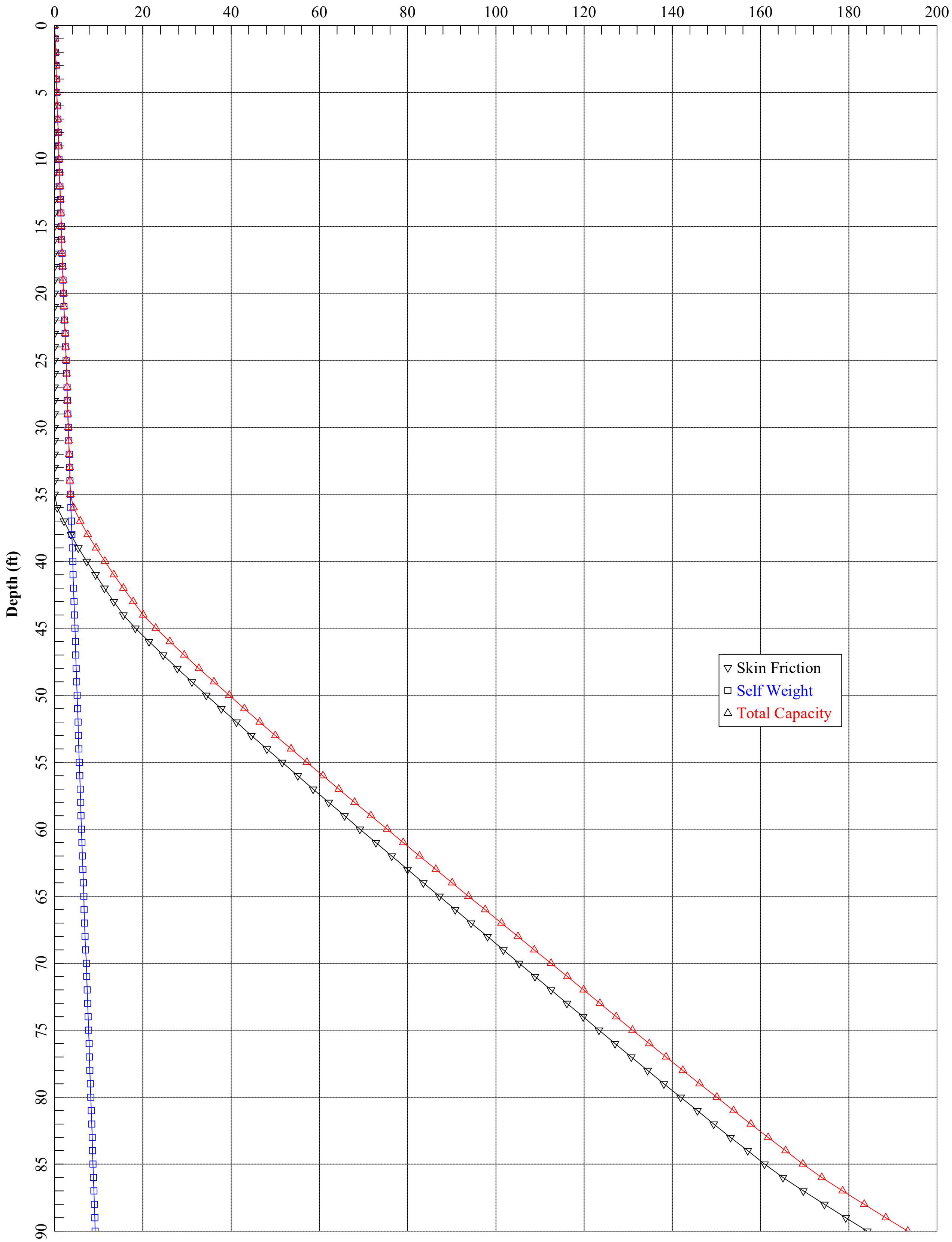


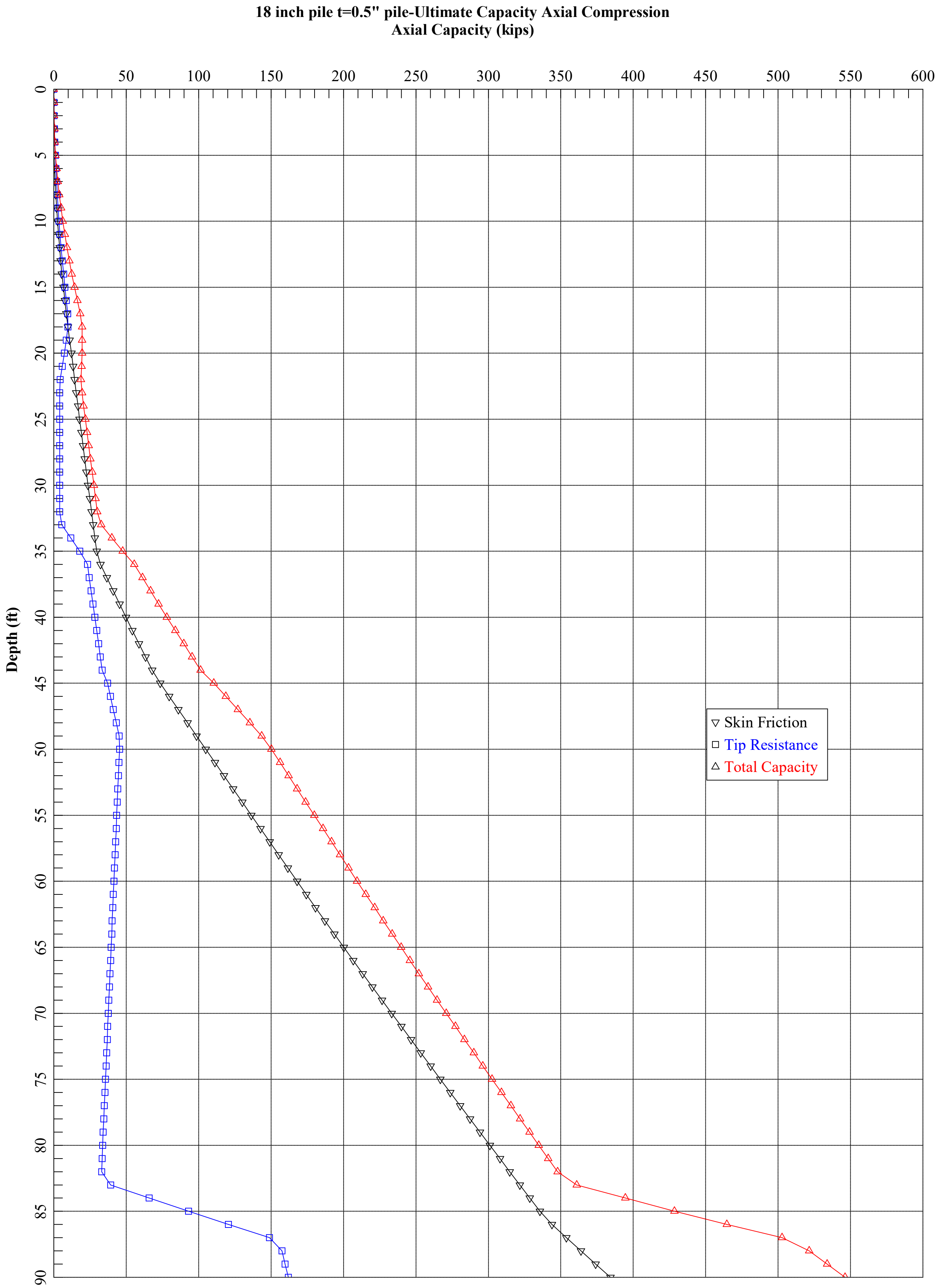

14 inch precast concrete pile: Non Factored
Lateral Pile Deflection (inches)
0
0.2
0.4
Bending Moment (in-kips)
-600
-400
-200
0
200
400
Shear Force (kips)
0
5
10
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
Load Case 1
Load Case 2
API Sand
Soft Clay
Stf. Cl. W

18 inch pile t=0.5" pile-Ultimate Capacity Axial Tension

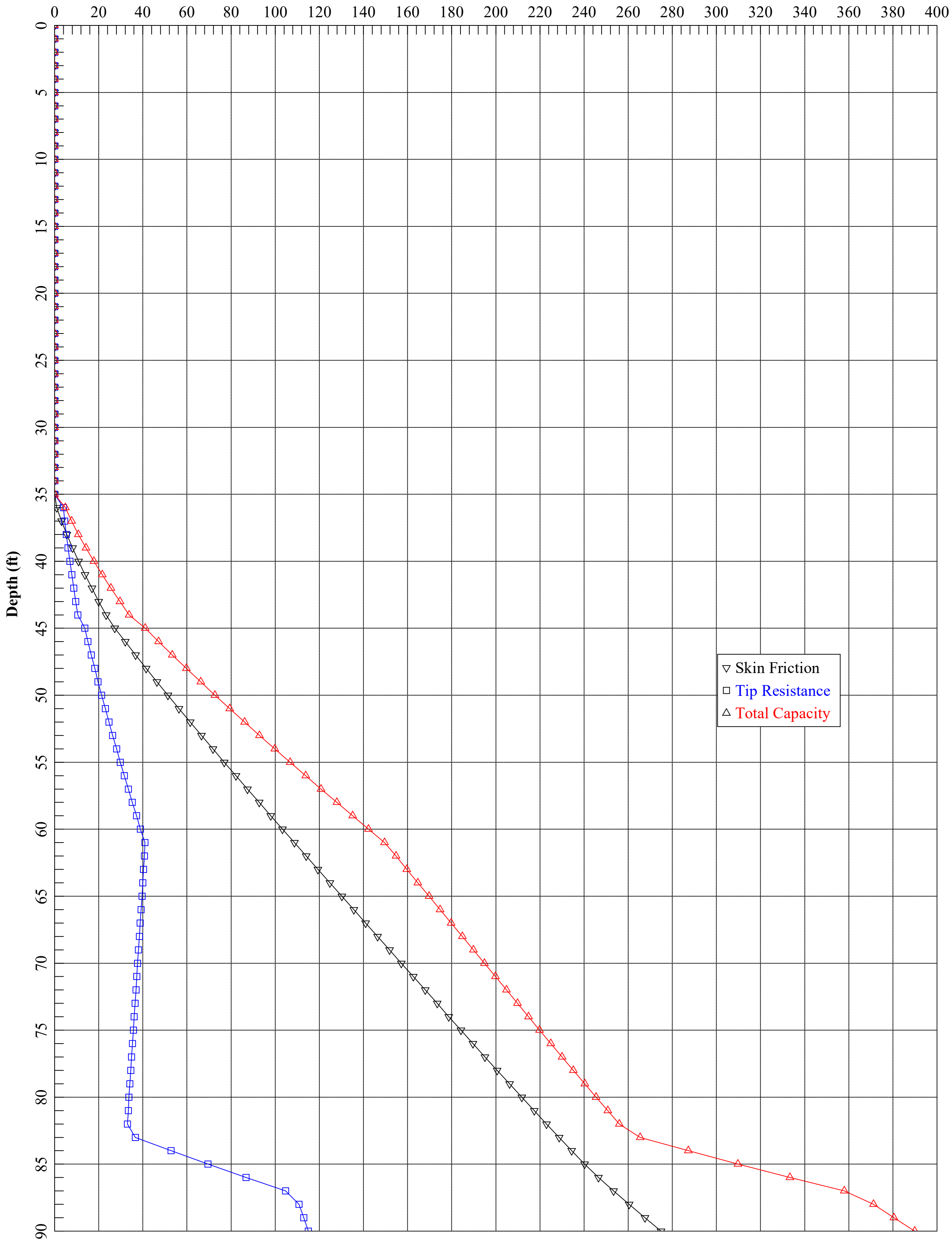


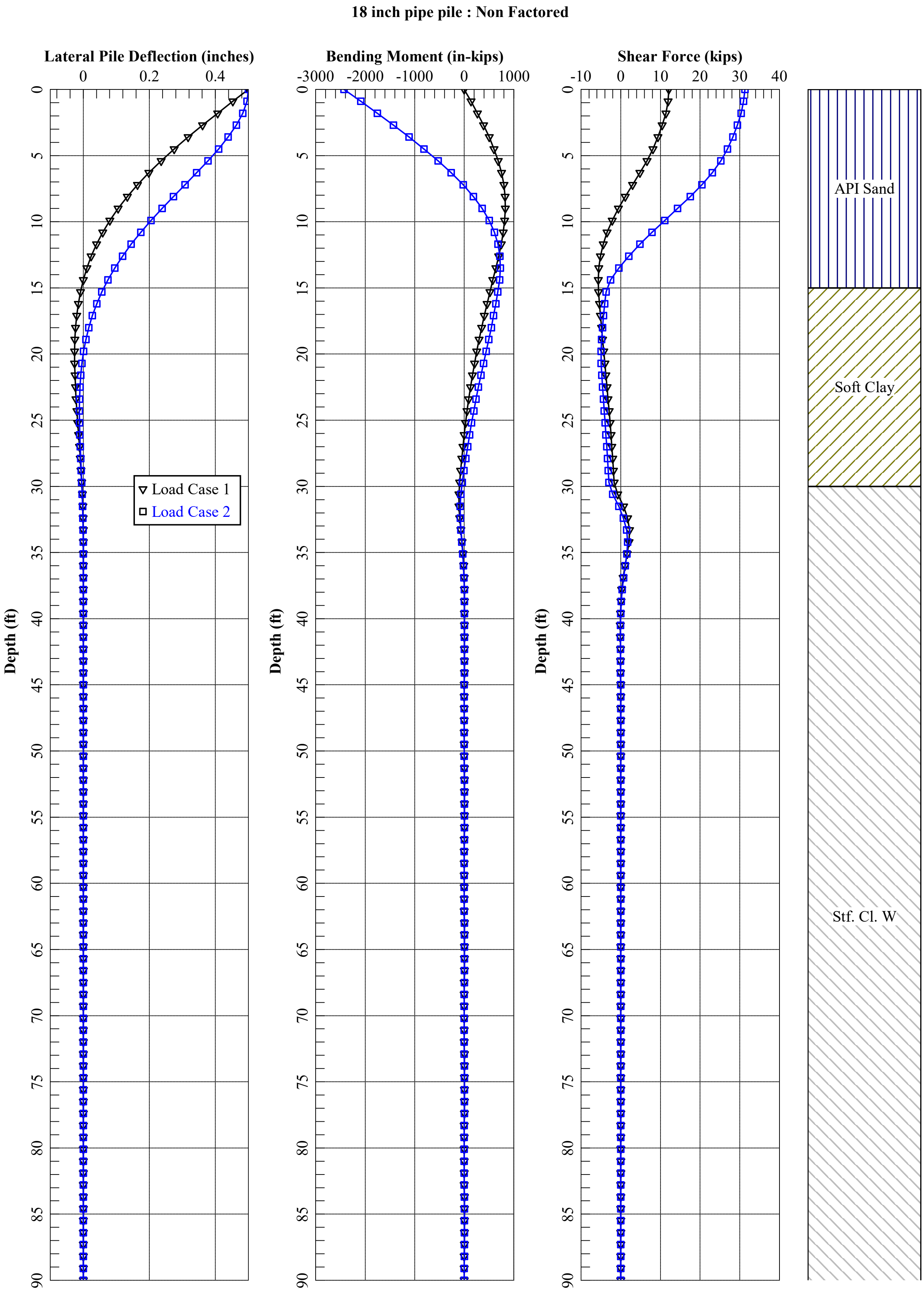
18 inch pile t=0.5" pile-Ultimate Capacity Axial Tension Liquefaction



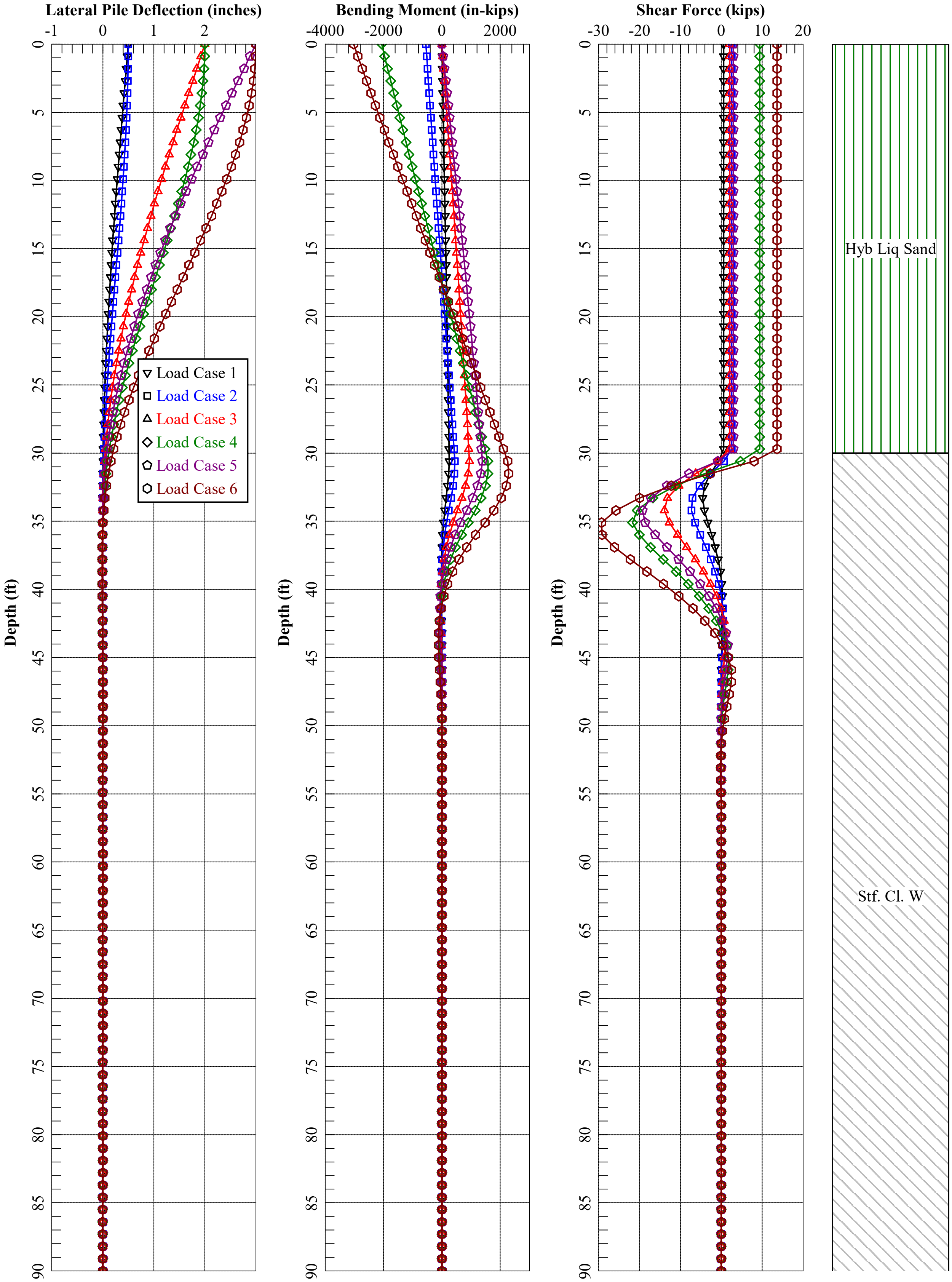

18 inch pile t=0.5" pile-Ultimate Capacity Axial Compression
Axial Capacity (kips)
0
50
100
150
200
250
300
350
400
450
500
550
600
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Tip Resistance
△ Total Capacity

18 inch pile t=0.5" pile-Ultimate Capacity Axial Compression Liquefaction
Axial Capacity (kips)



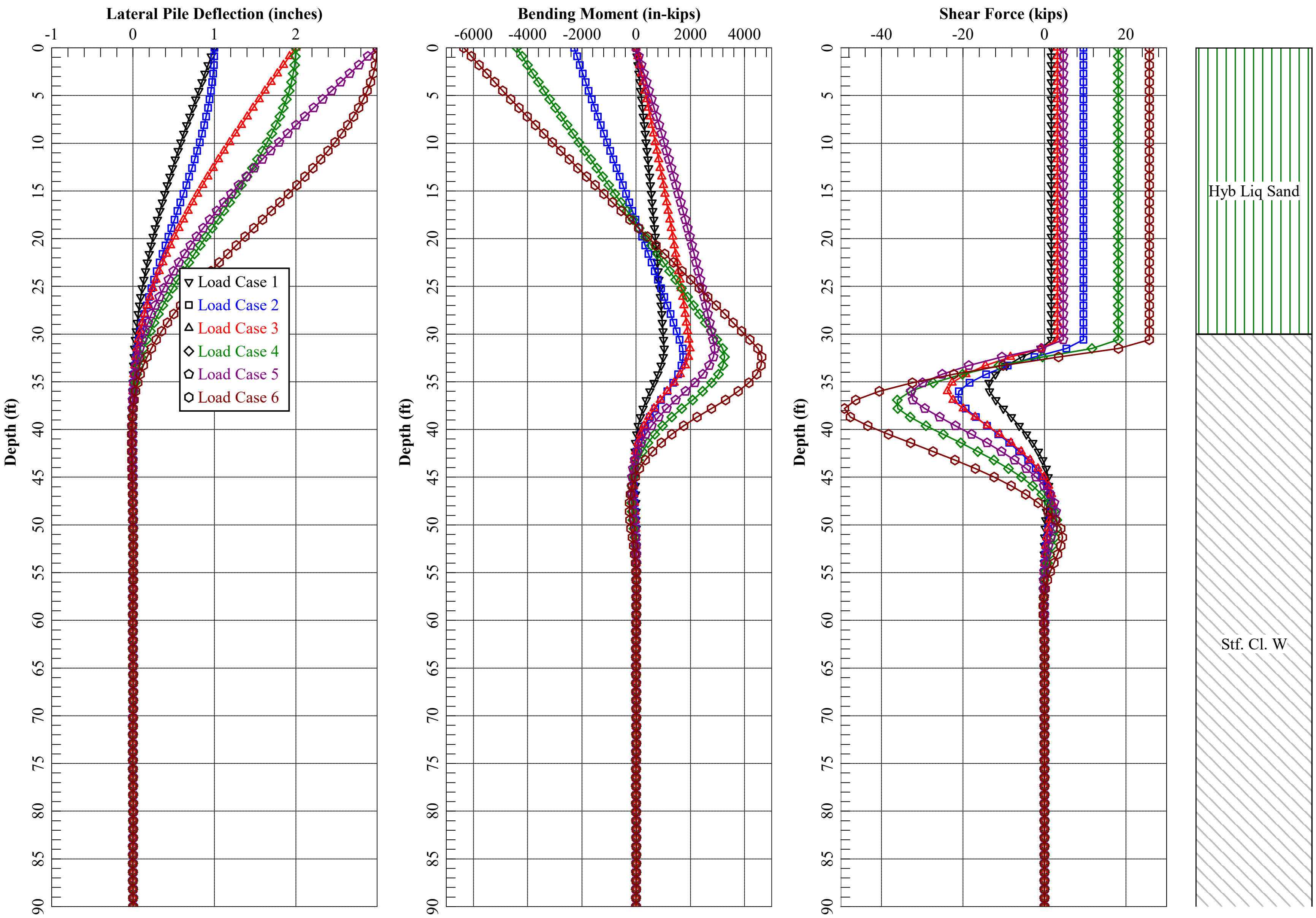

18 inch pipe pile : Non Factored
Lateral Pile Deflection (inches)
0
0.2
0.4
Bending Moment (in-kips)
-3000
-2000
-1000
0
1000
Shear Force (kips)
-10
0
10
20
30
40
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
Load Case 1
Load Case 2
API Sand
Soft Clay
Stf. Cl. W

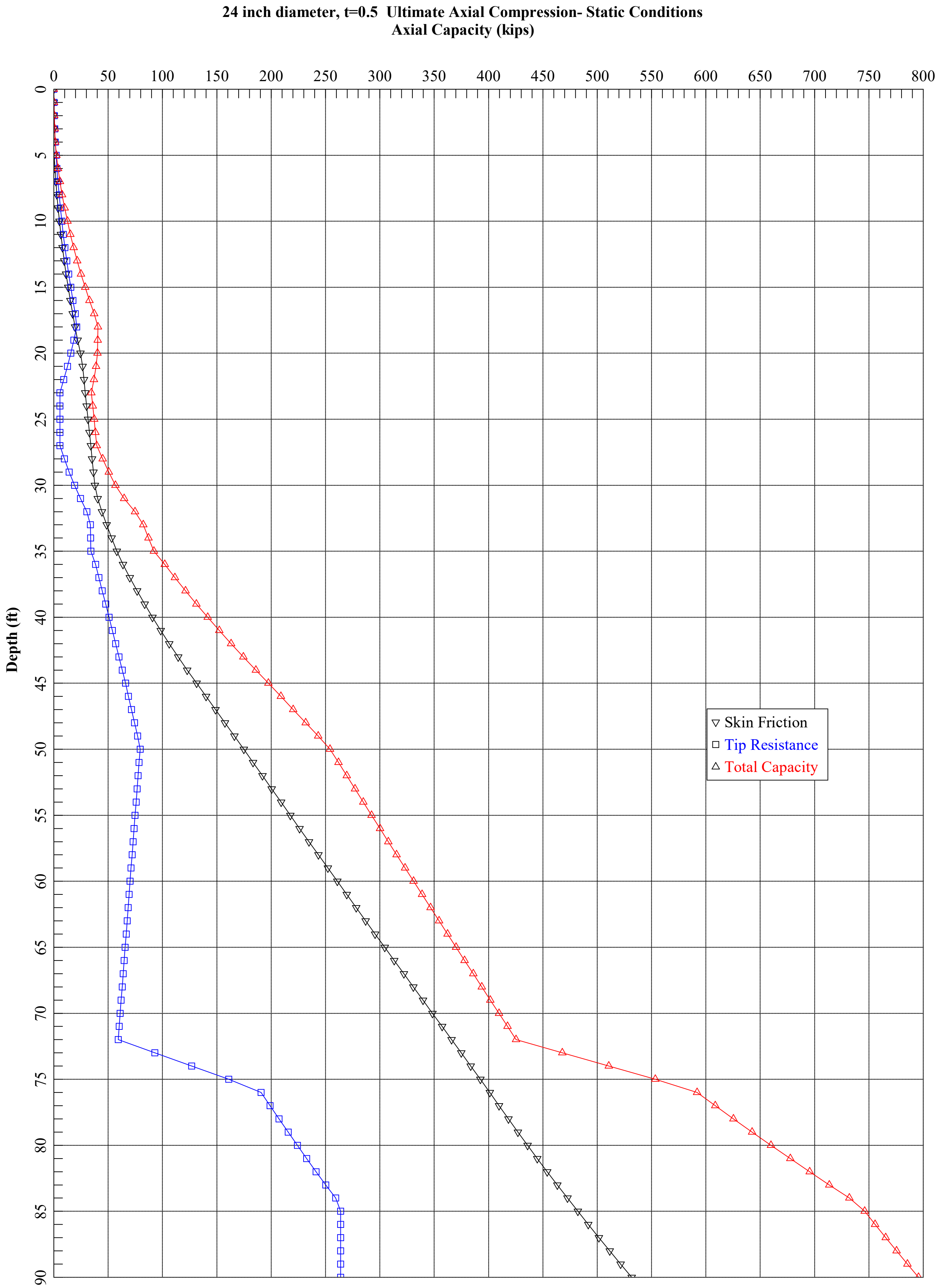
18 inch pipe pile; t=0.5 B-2: LIQUEFACTION

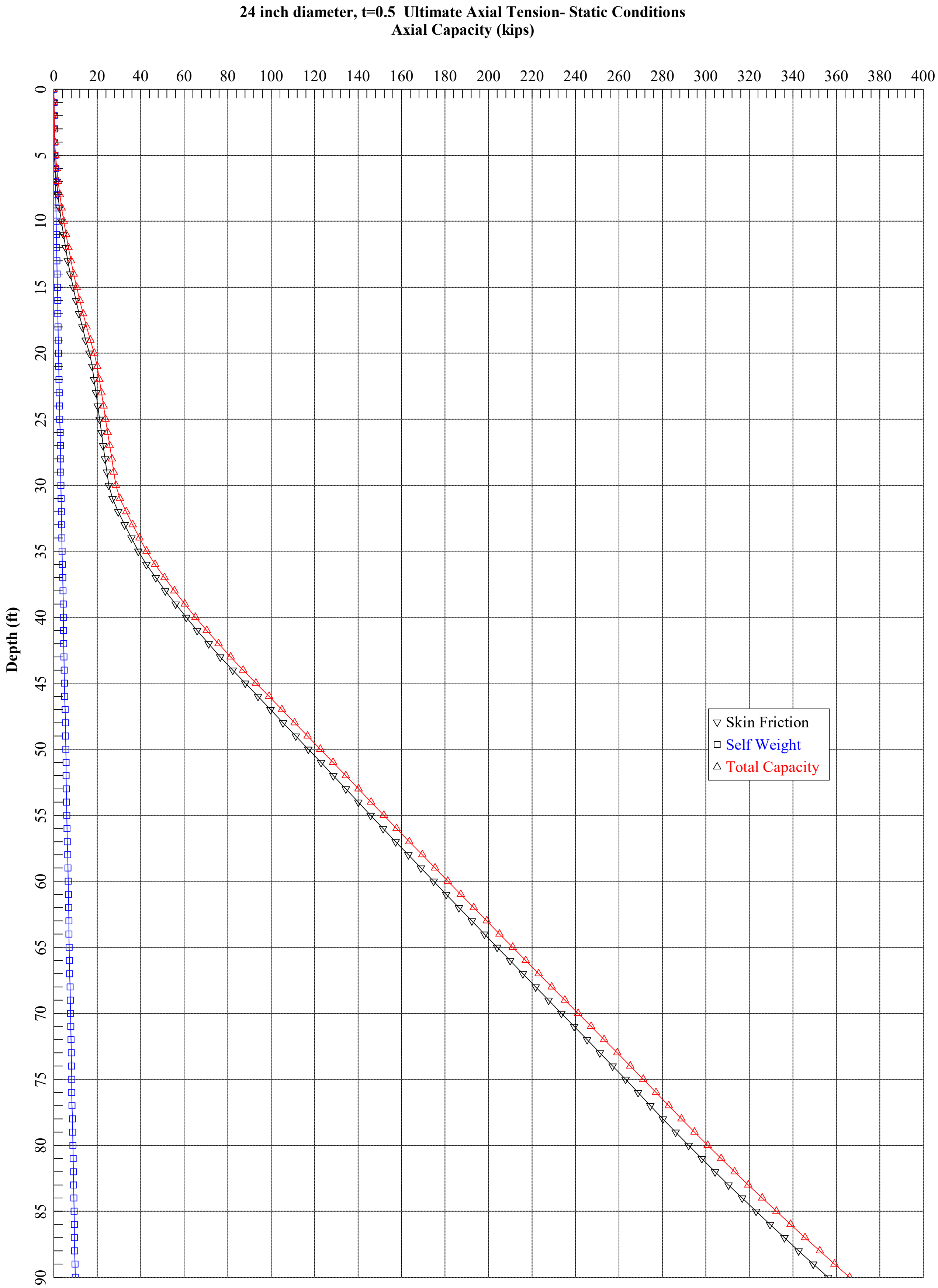


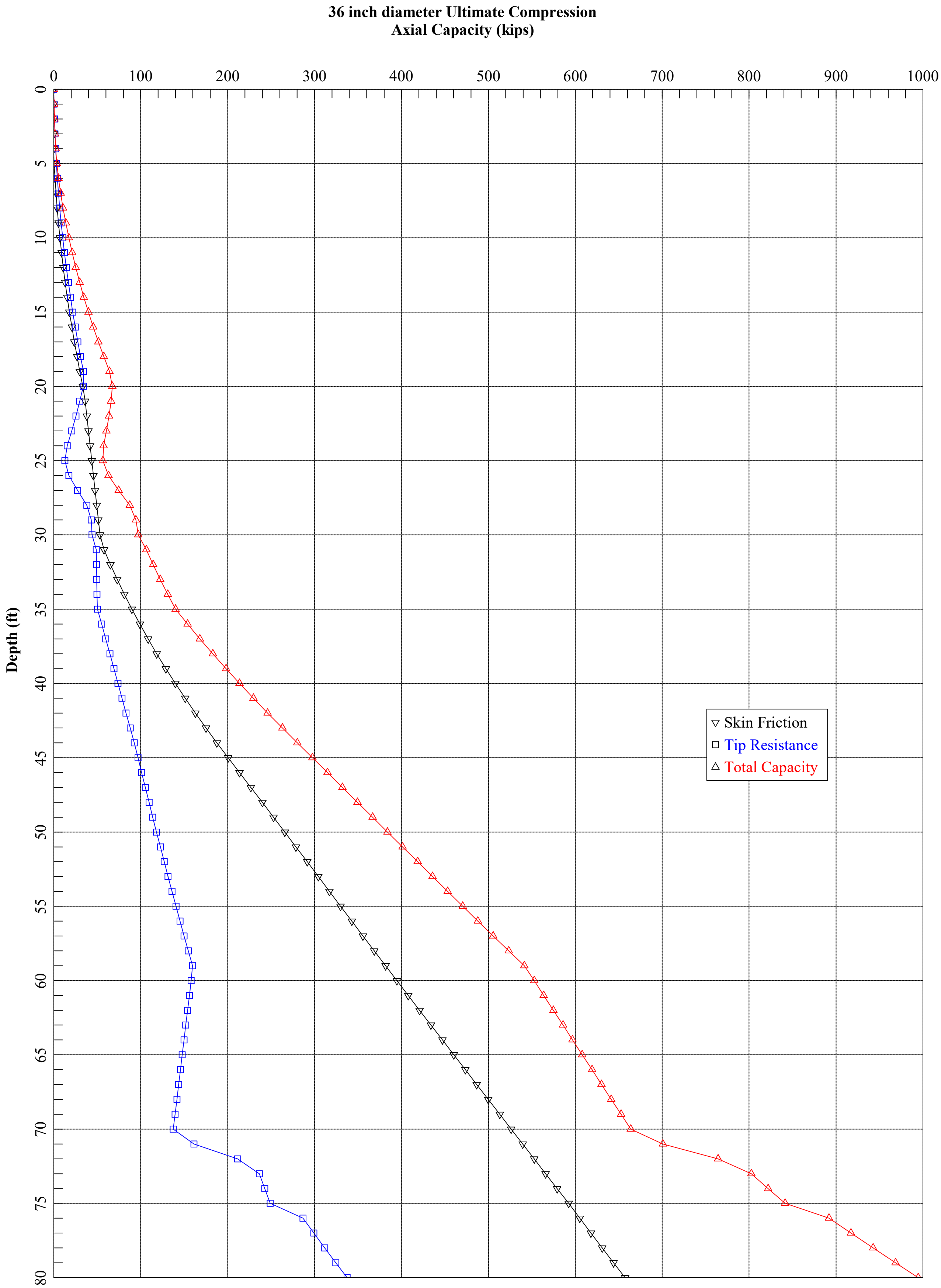
Public

24 inch diameter 15 deg battered pile with liquefaction

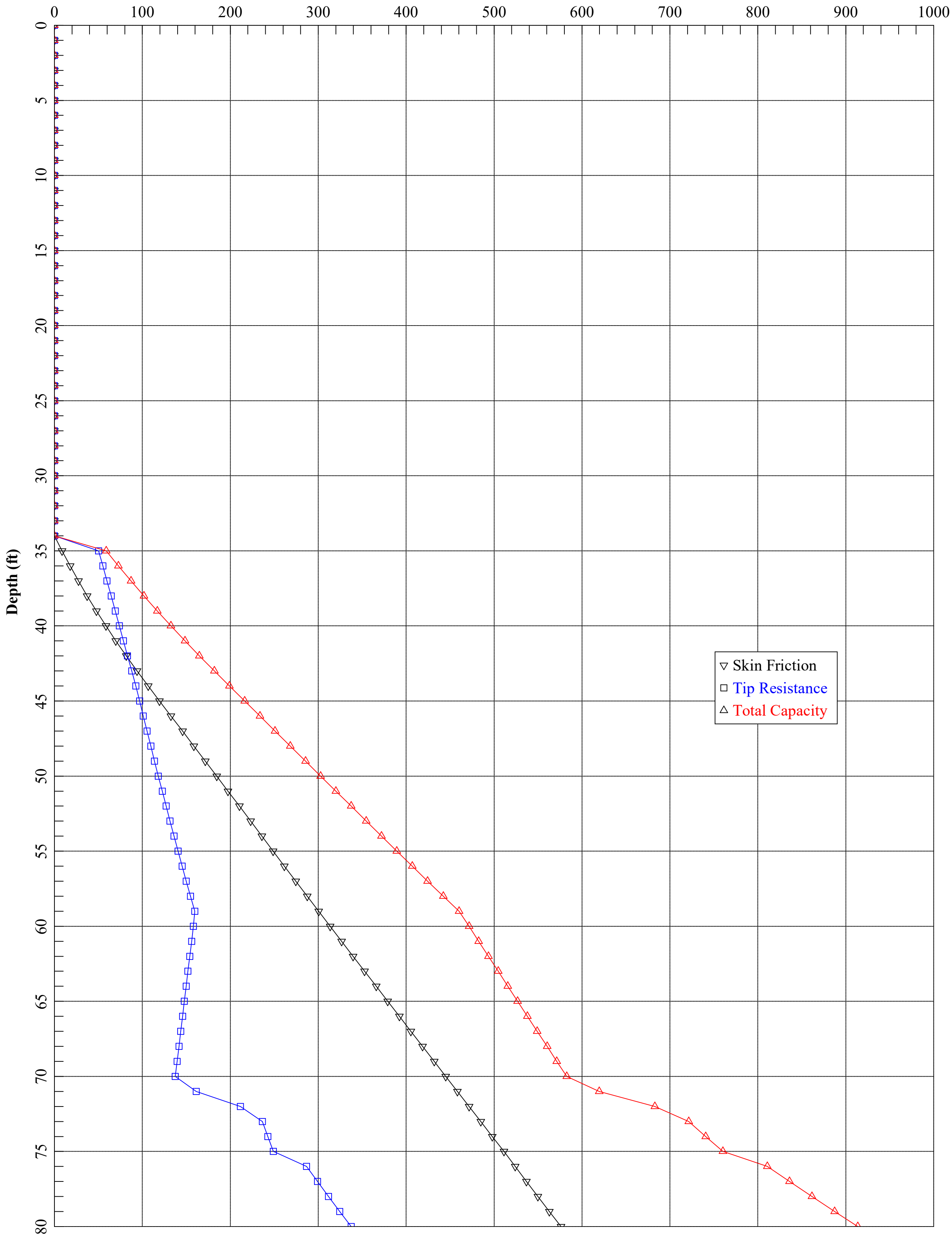


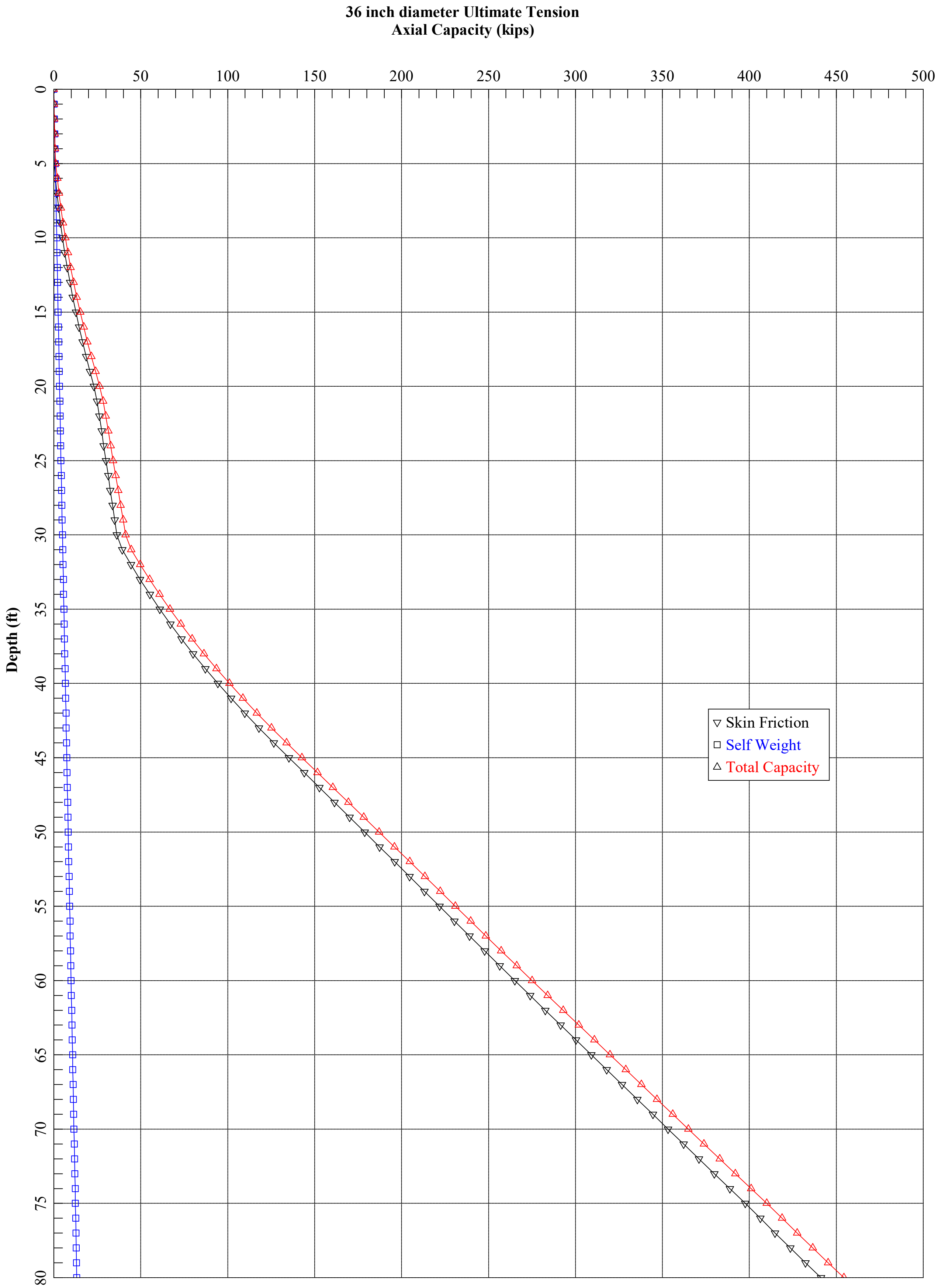

24 inch diameter, t=0.5 Ultimate Axial Compression- Static Conditions
Axial Capacity (kips)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Tip Resistance
△ Total Capacity


24 inch diameter, t=0.5 Ultimate Axial Tension- Static Conditions
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Self Weight
△ Total Capacity


36 inch diameter Ultimate Compression
Axial Capacity (kips)
0
100
200
300
400
500
600
700
800
900
1000
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Depth (ft)
▽ Skin Friction
□ Tip Resistance
△ Total Capacity

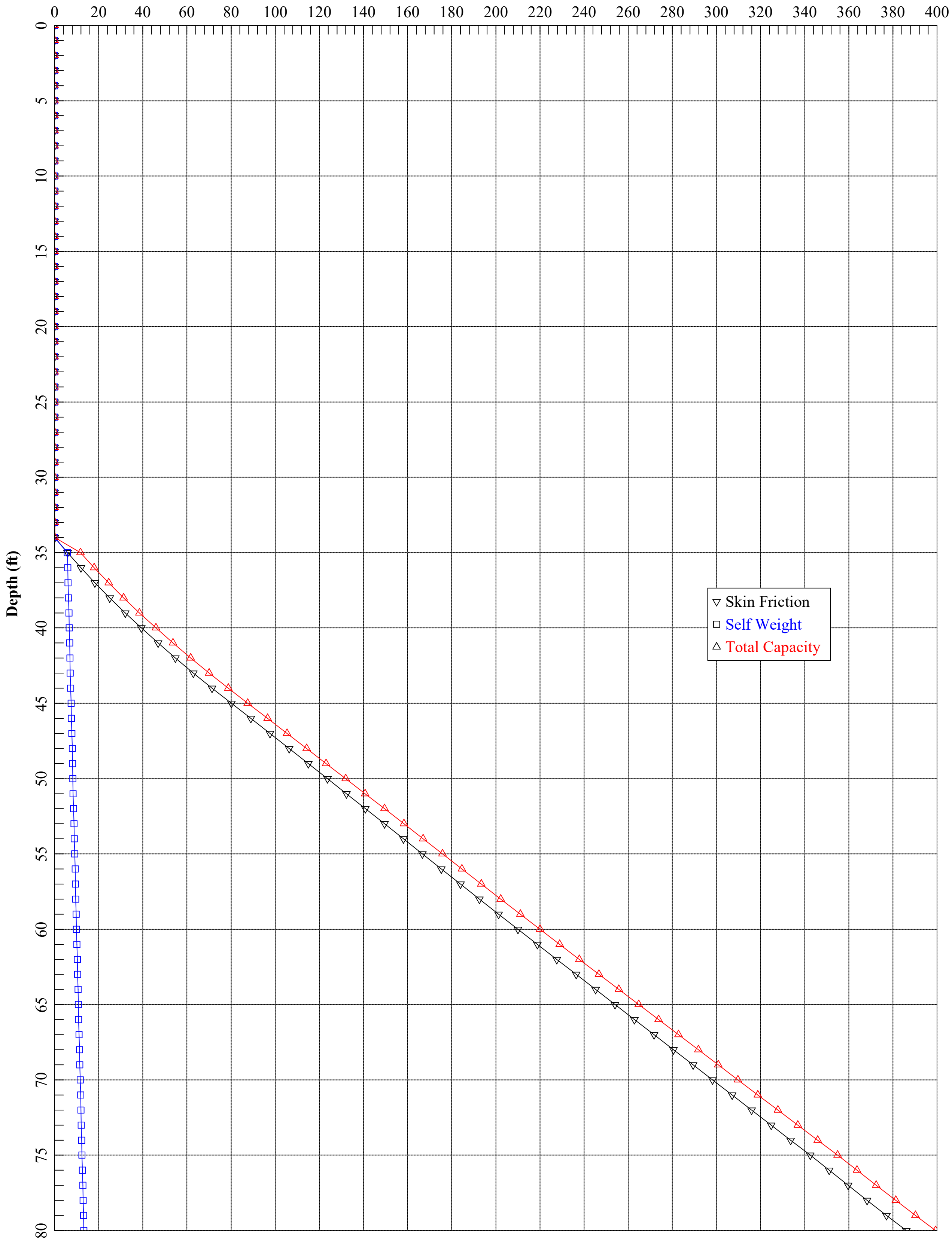
36 inch diameter Ultimate Compression-Liquefaction
Axial Capacity (kips)

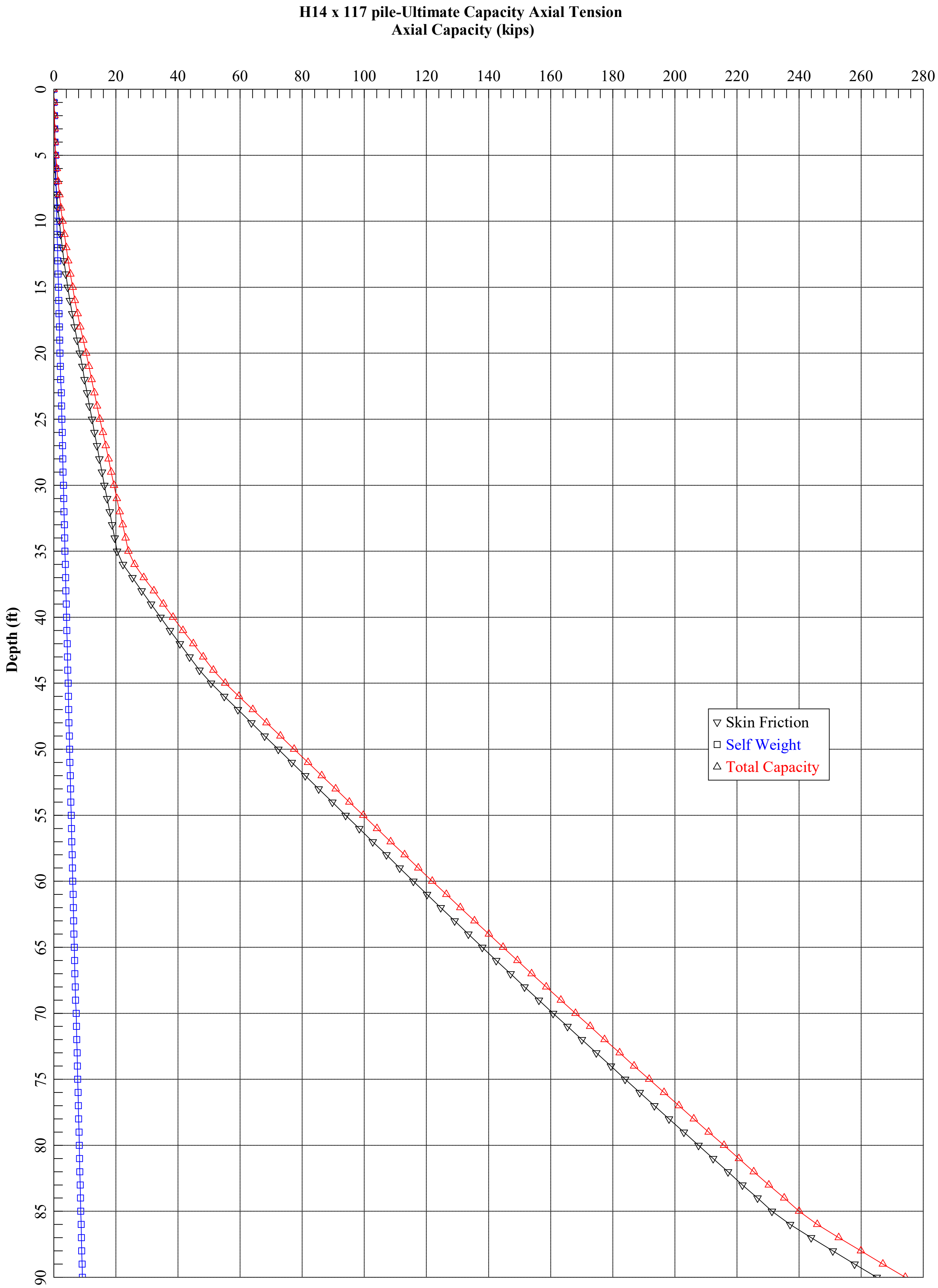



36 inch diameter Ultimate Tension
Axial Capacity (kips)
0
50
100
150
200
250
300
350
400
450
500
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
▽ Skin Friction
□ Self Weight
△ Total Capacity

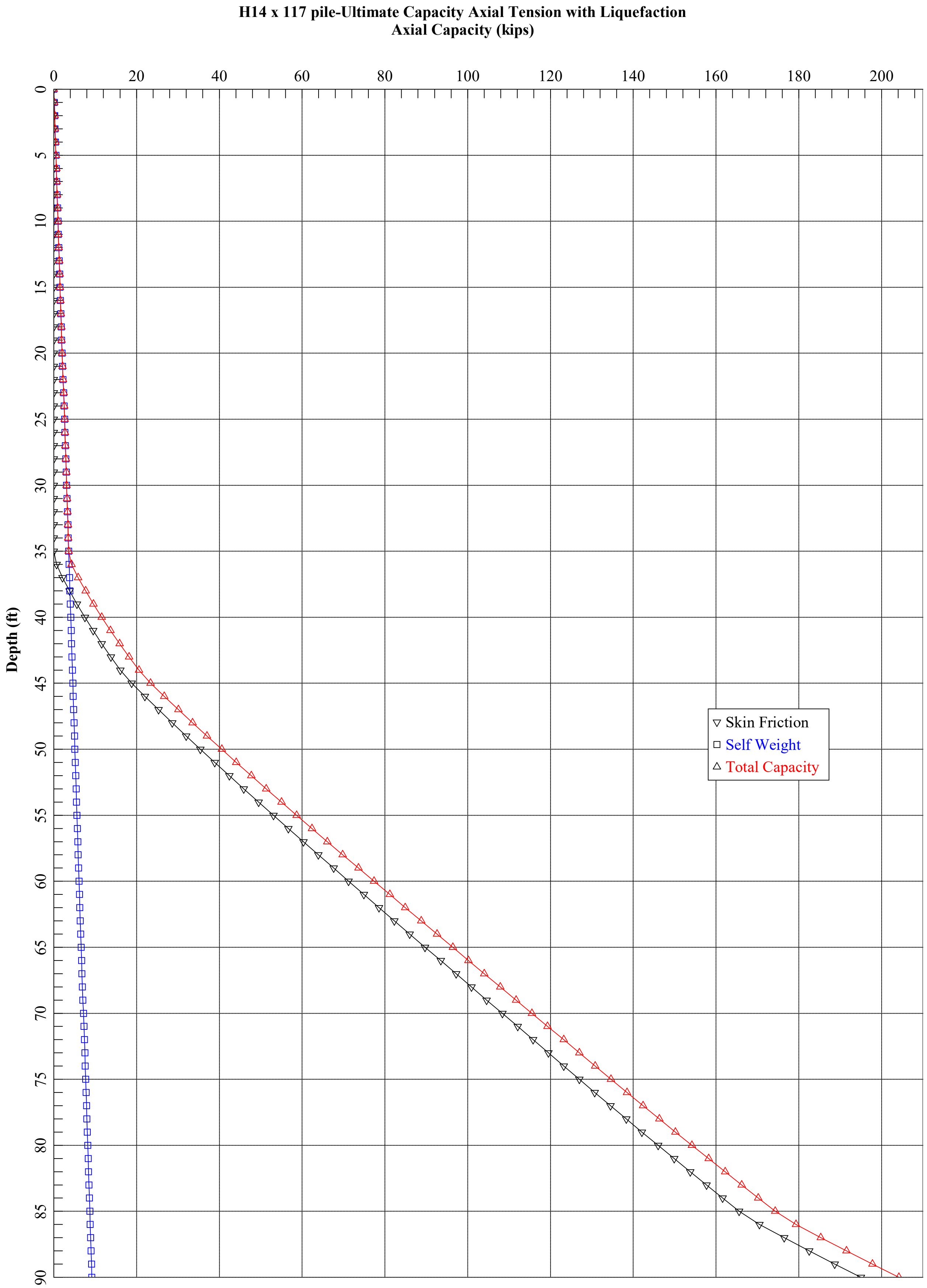
Public

36 inch diameter pipe pile, t=0.5 inches; Ultimate Axial Tension-Liquefaction

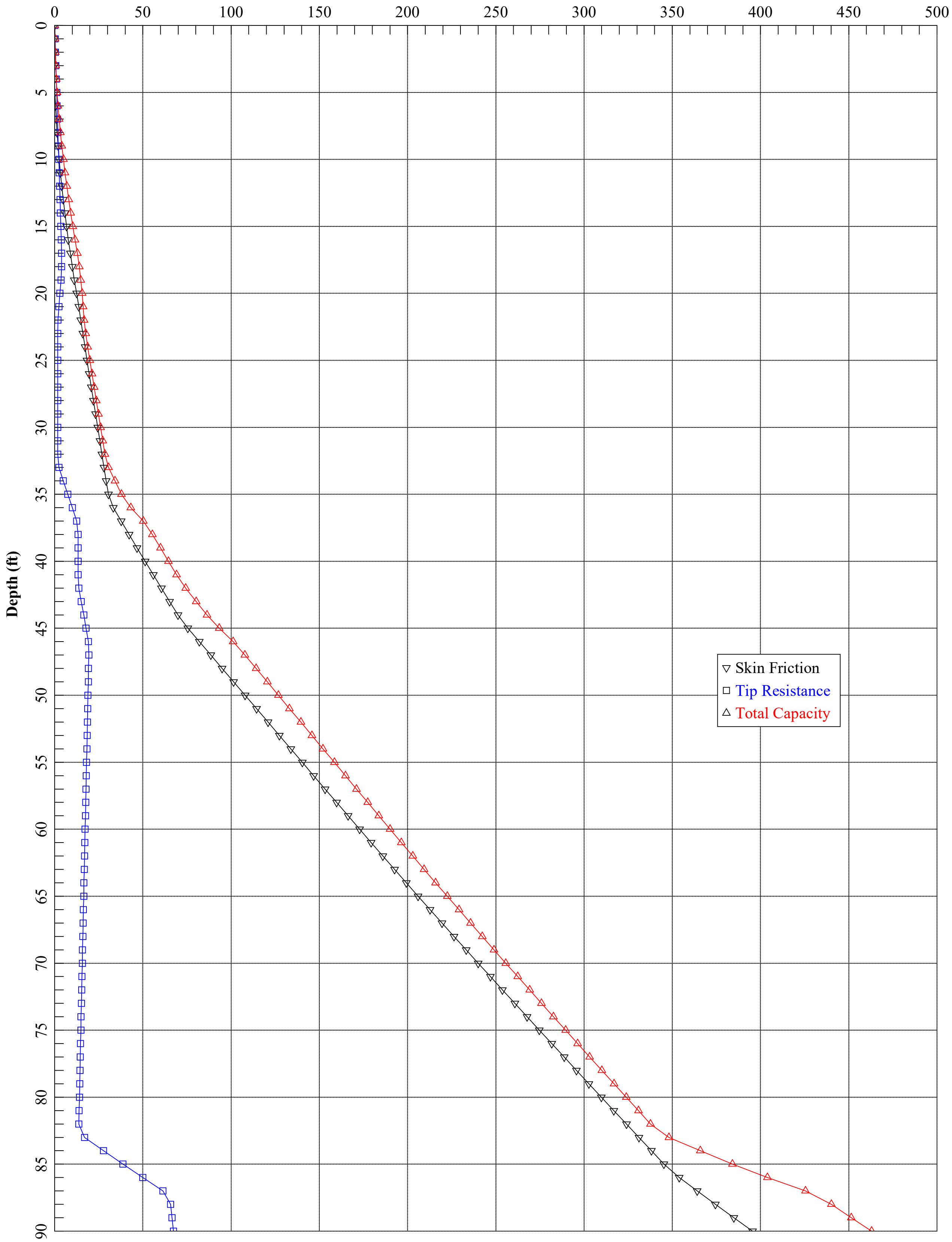



H14 x 117 pile-Ultimate Capacity Axial Tension
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Self Weight
△ Total Capacity

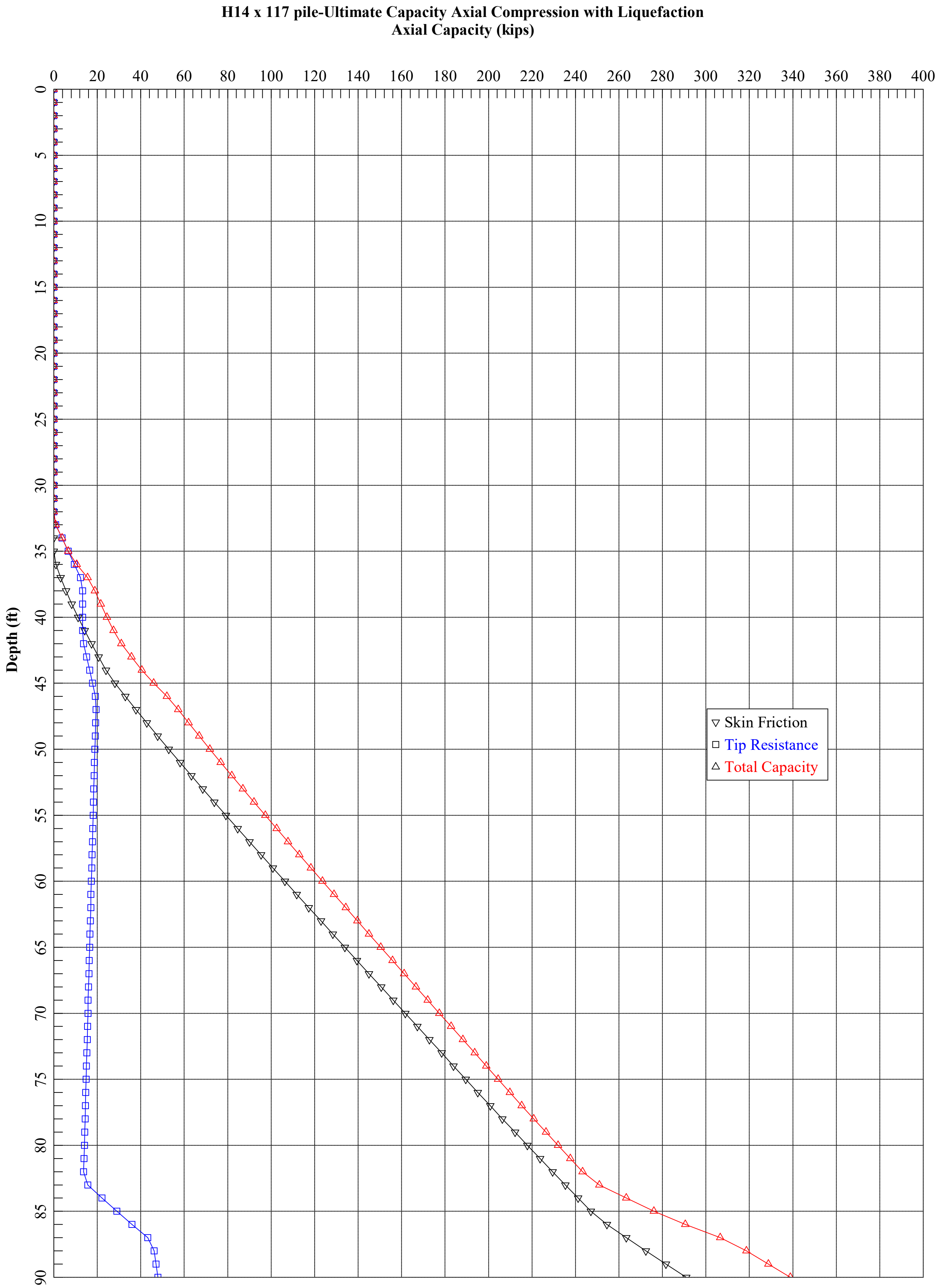
Public


H14 x 117 pile-Ultimate Capacity Axial Tension with Liquefaction
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Self Weight
△ Total Capacity

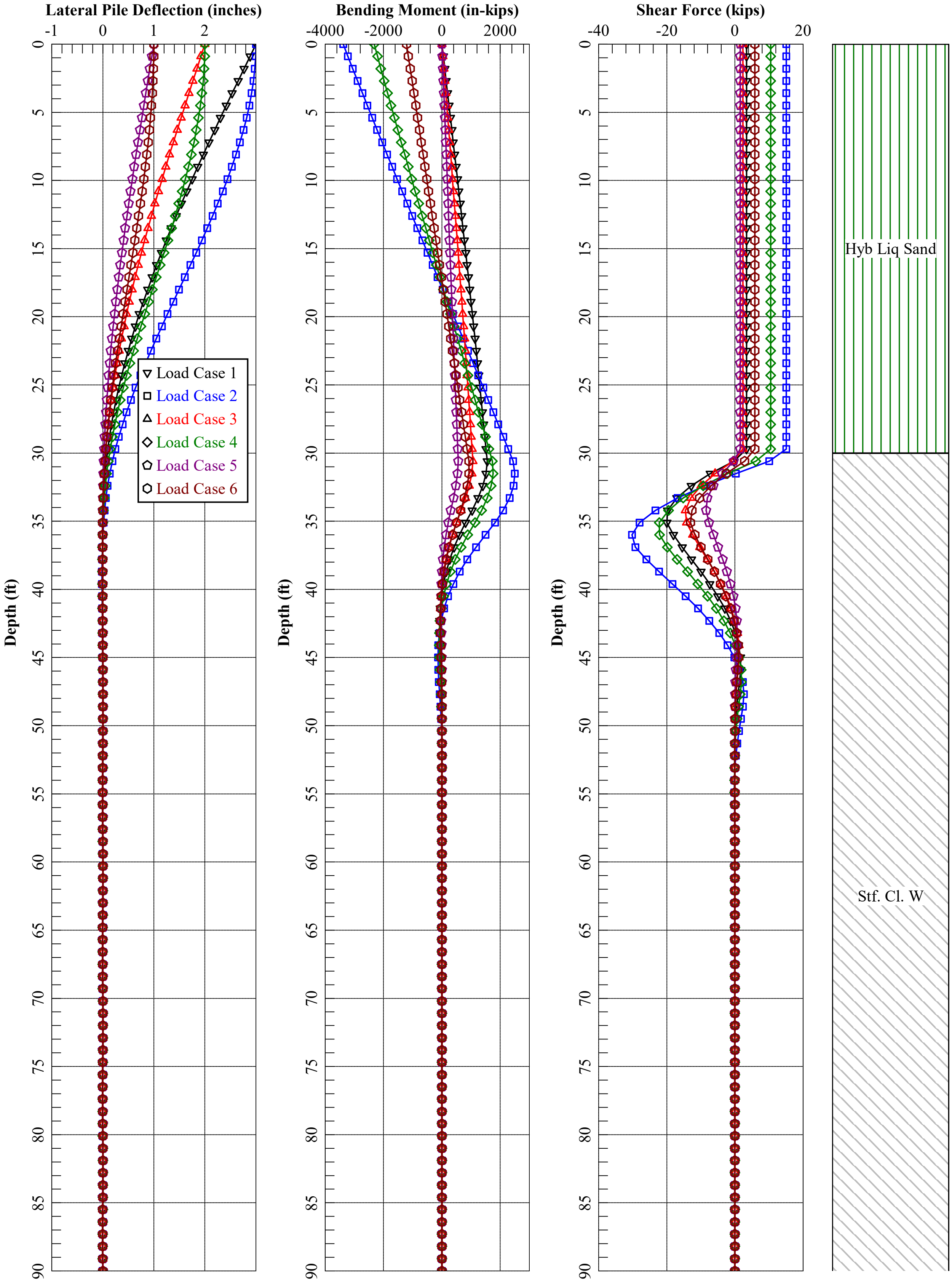
H14 x 117 pile-Ultimate Capacity Axial Compression



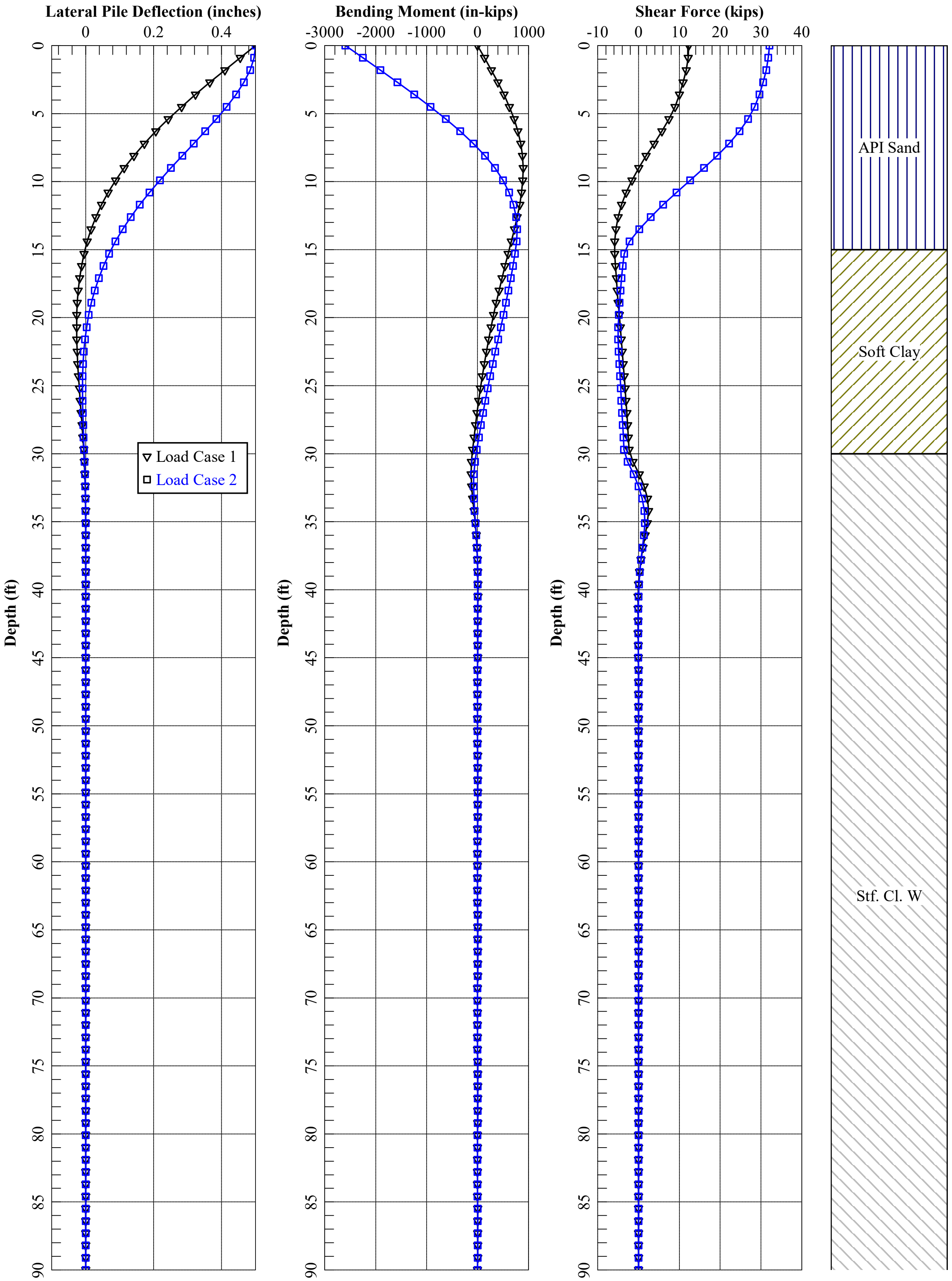
Public

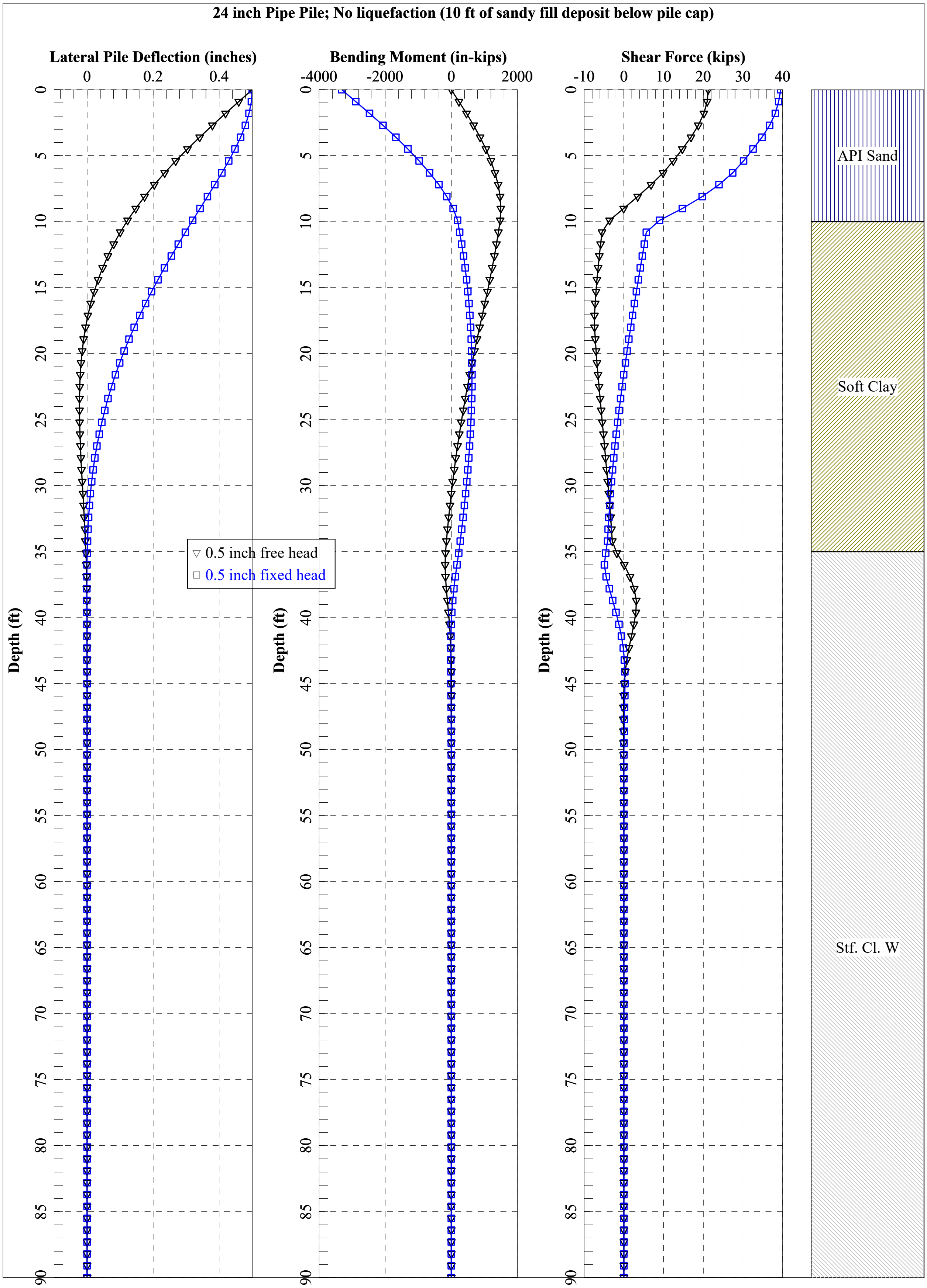

H14 x 117 pile-Ultimate Capacity Axial Compression with Liquefaction
Axial Capacity (kips)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ Skin Friction
□ Tip Resistance
△ Total Capacity

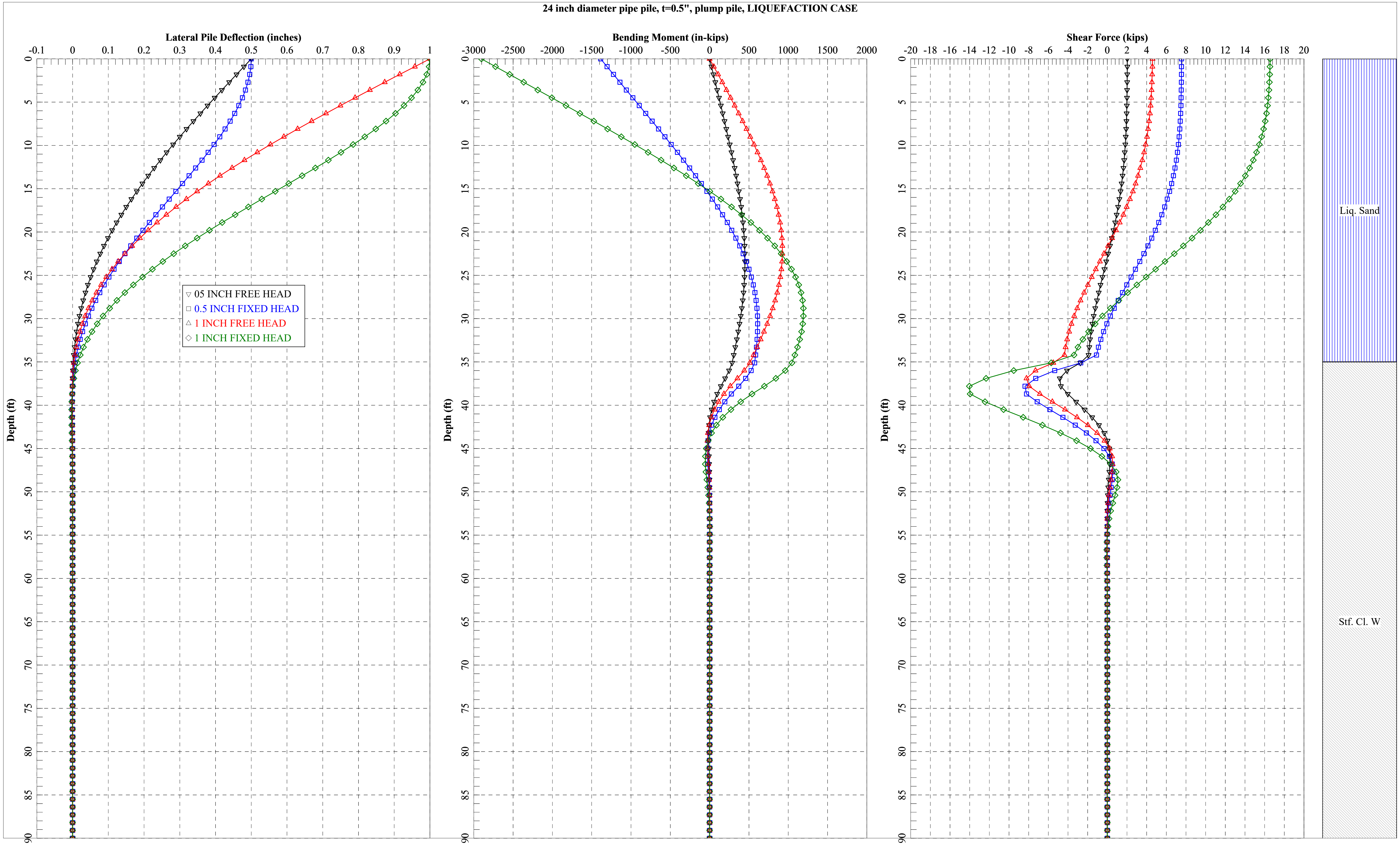
H14 x 117 B-2: LIQUEFACTION

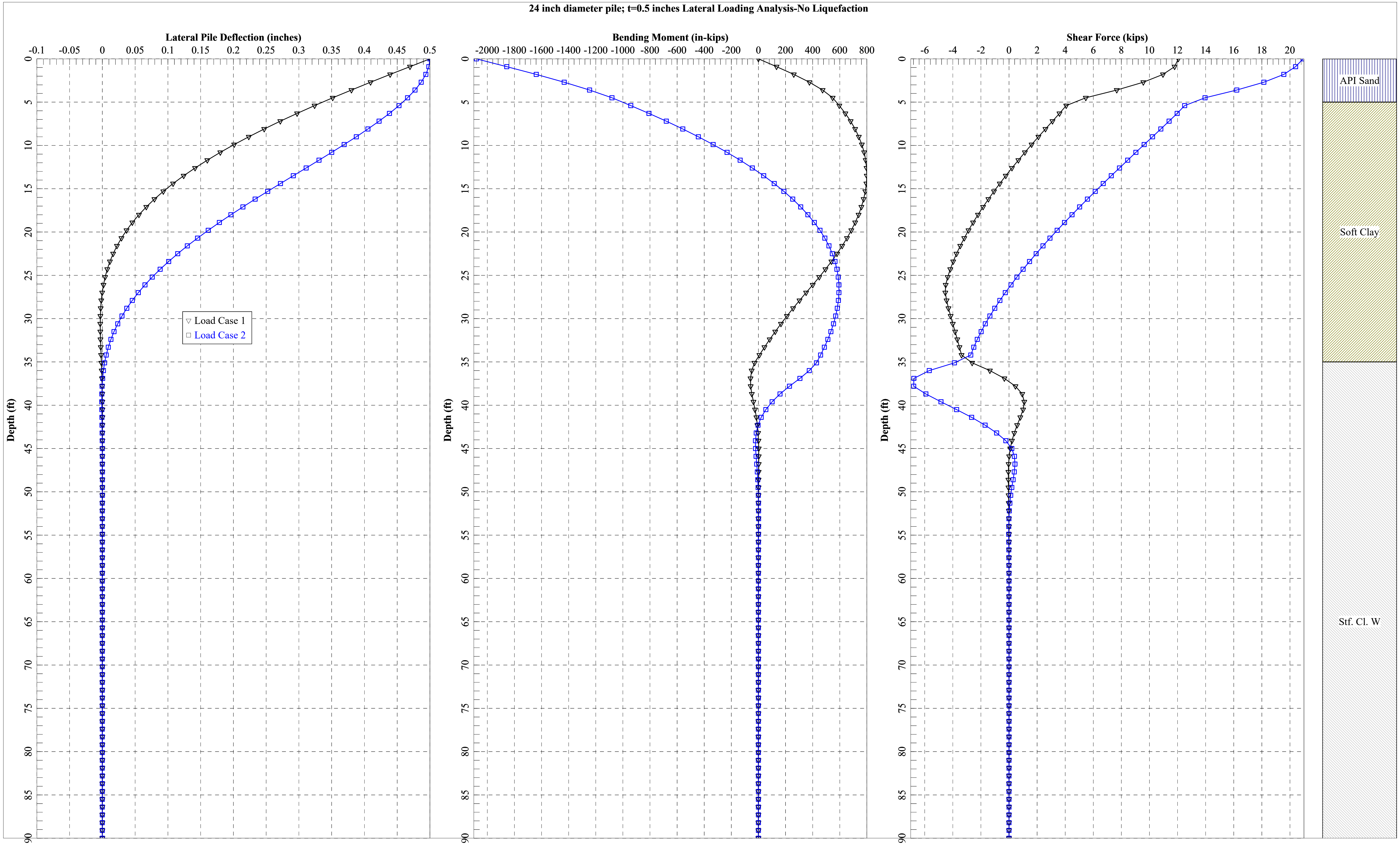


H14 X 117 pile LIQUEFACTION : Non Factored

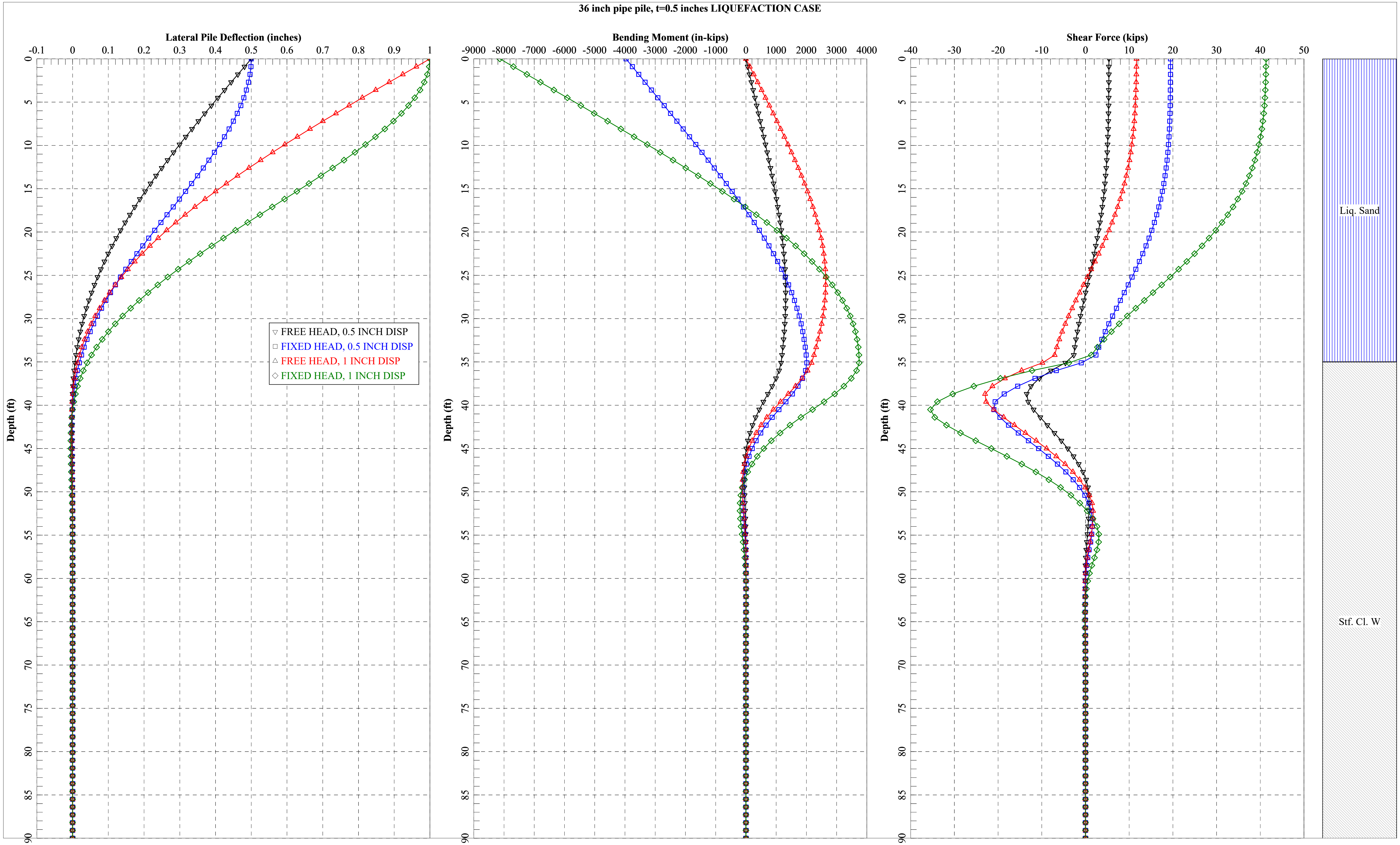


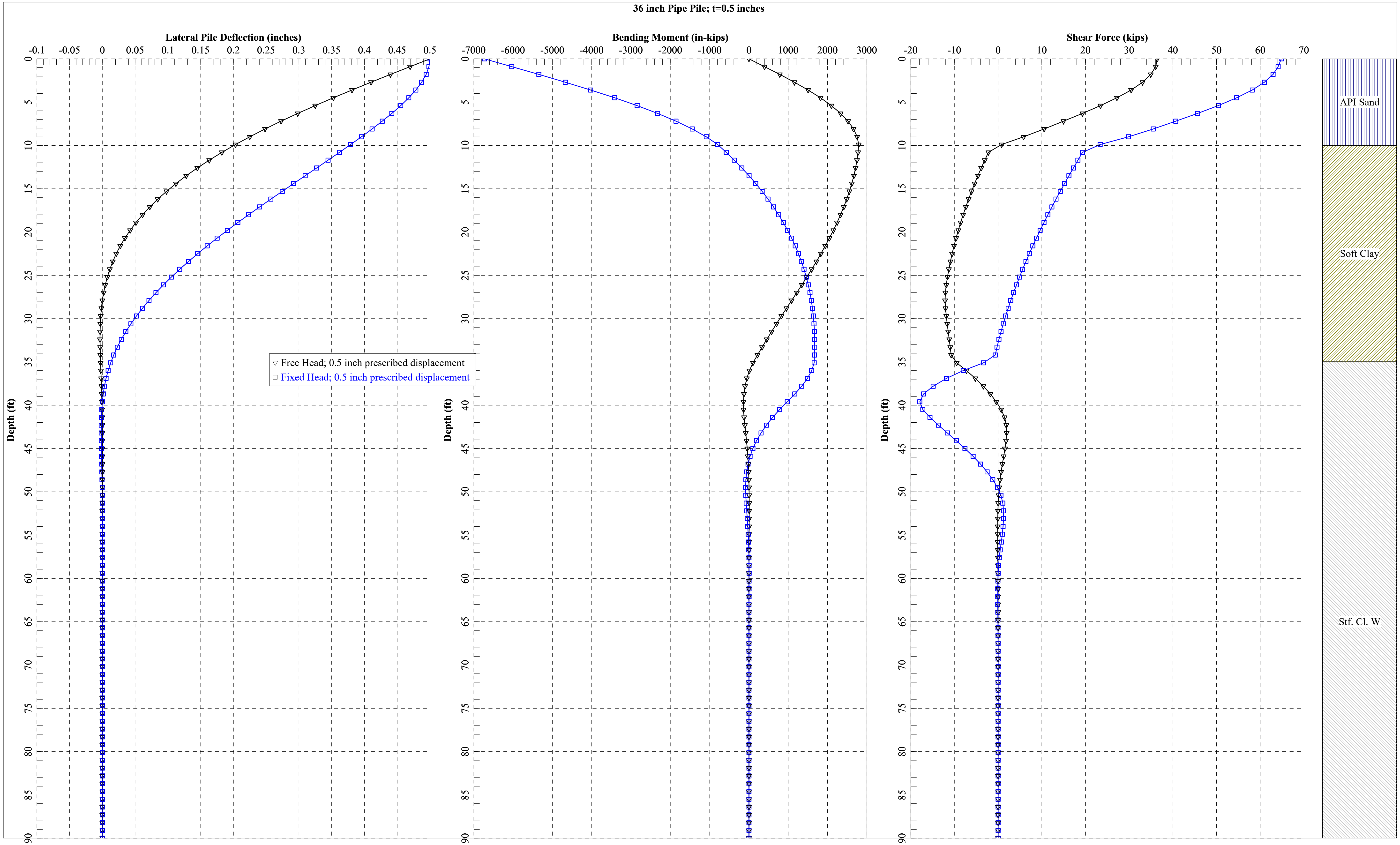

24 inch Pipe Pile; No liquefaction (10 ft of sandy fill deposit below pile cap)
Lateral Pile Deflection (inches)
0
0.2
0.4
Bending Moment (in-kips)
-4000
-2000
0
2000
Shear Force (kips)
-10
0
10
20
30
40
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ 0.5 inch free head
□ 0.5 inch fixed head
API Sand
Soft Clay
Stf. Cl. W


24 inch diameter pipe pile, t=0.5", plump pile, LIQUEFACTION CASE
Lateral Pile Deflection (inches)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Bending Moment (in-kips)
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
Shear Force (kips)
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ 05 INCH FREE HEAD
□ 0.5 INCH FIXED HEAD
△ 1 INCH FREE HEAD
◇ 1 INCH FIXED HEAD
Liq. Sand
Stf. Cl. W



24 inch diameter pile; t=0.5 inches Lateral Loading Analysis-No Liquefaction


36 inch pipe pile, t=0.5 inches LIQUEFACTION CASE
Lateral Pile Deflection (inches)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Bending Moment (in-kips)
-9000
-8000
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
Shear Force (kips)
-40
-30
-20
-10
0
10
20
30
40
50
Depth (ft)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
▽ FREE HEAD, 0.5 INCH DISP
□ FIXED HEAD, 0.5 INCH DISP
△ FREE HEAD, 1 INCH DISP
◇ FIXED HEAD, 1 INCH DISP
Liq. Sand
Stf. Cl. W


36 inch Pipe Pile; t=0.5 inches
Lateral Pile Deflection (inches)
-0.1 -0.05 0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5
Bending Moment (in-kips)
-7000 -6000 -5000 -4000 -3000 -2000 -1000 0 1000 2000 3000
Shear Force (kips)
-20 -10 0 10 20 30 40 50 60 70
Depth (ft)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
▽ Free Head; 0.5 inch prescribed displacement
□ Fixed Head; 0.5 inch prescribed displacement
API Sand
Soft Clay
Stf. Cl. W

SPT BASED LIQUEFACTION ANALYSIS REPORT

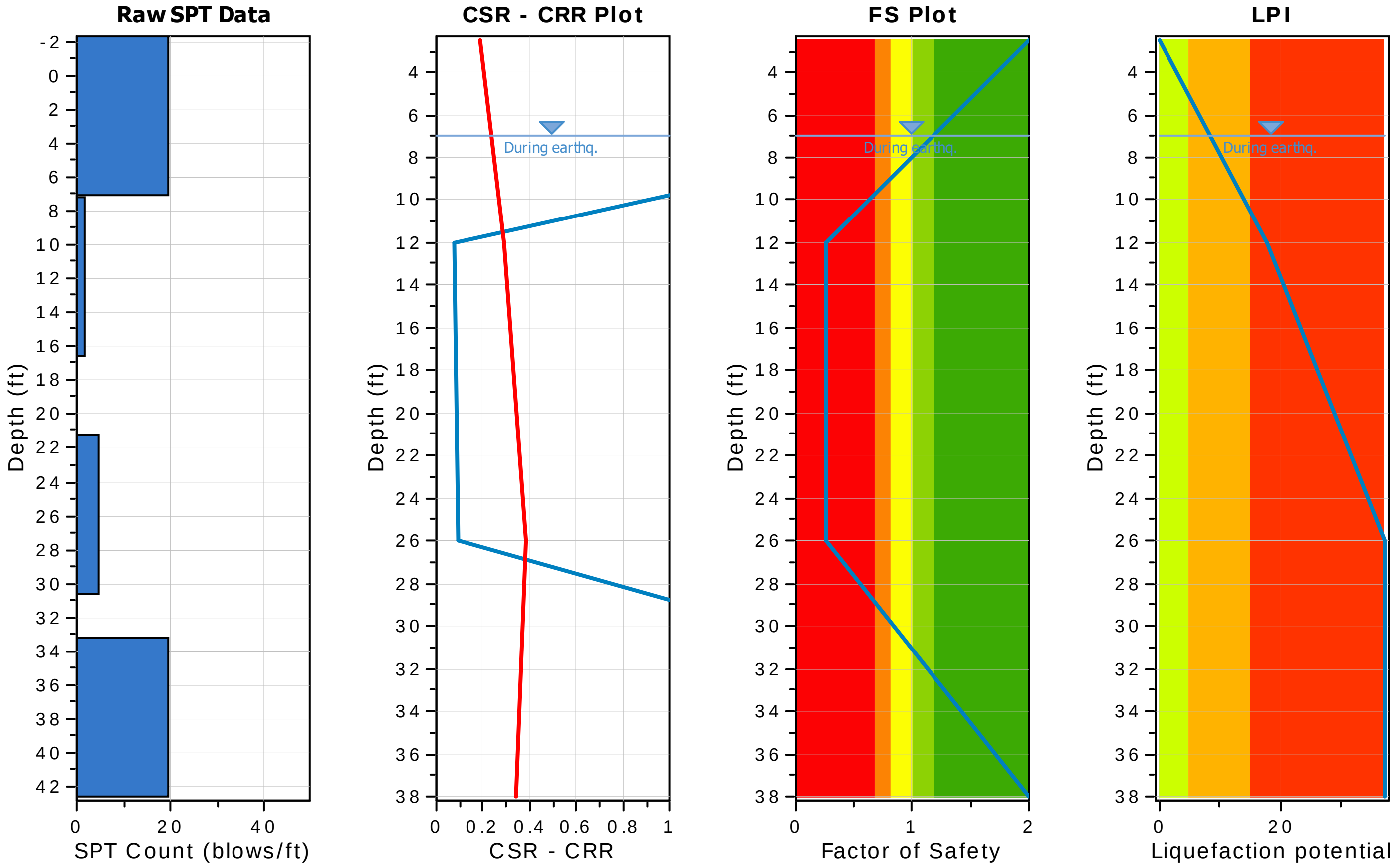
Project title : NFE-V-08 Puerto Rico **SPT Name: Boring no.3**

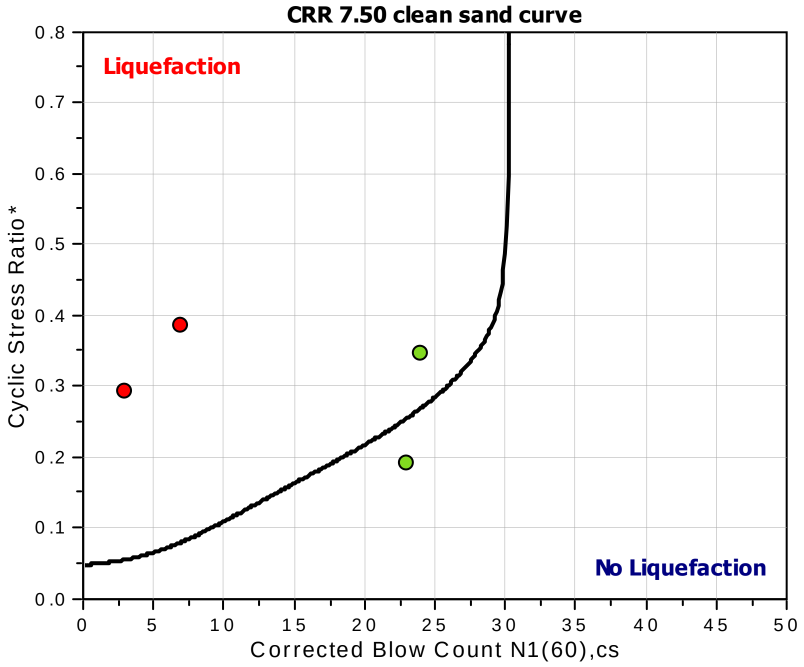
Location : San Juan, PR

:: Input parameters and analysis properties ::

Analysis method: Boulanger & Idriss, 2014
Fines correction method: Boulanger & Idriss, 2014
Sampling method: Standard Sampler
Borehole diameter: 65mm to 115mm
Rod length: 3.28 ft
Hammer energy ratio: 0.90

G.W.T. (in-situ): 0.00 ft
G.W.T. (earthq.): 7.00 ft
Earthquake magnitude M_w: 7.00 ft
Peak ground acceleration: 0.36 g
Eq. external load: 0.00 tsf

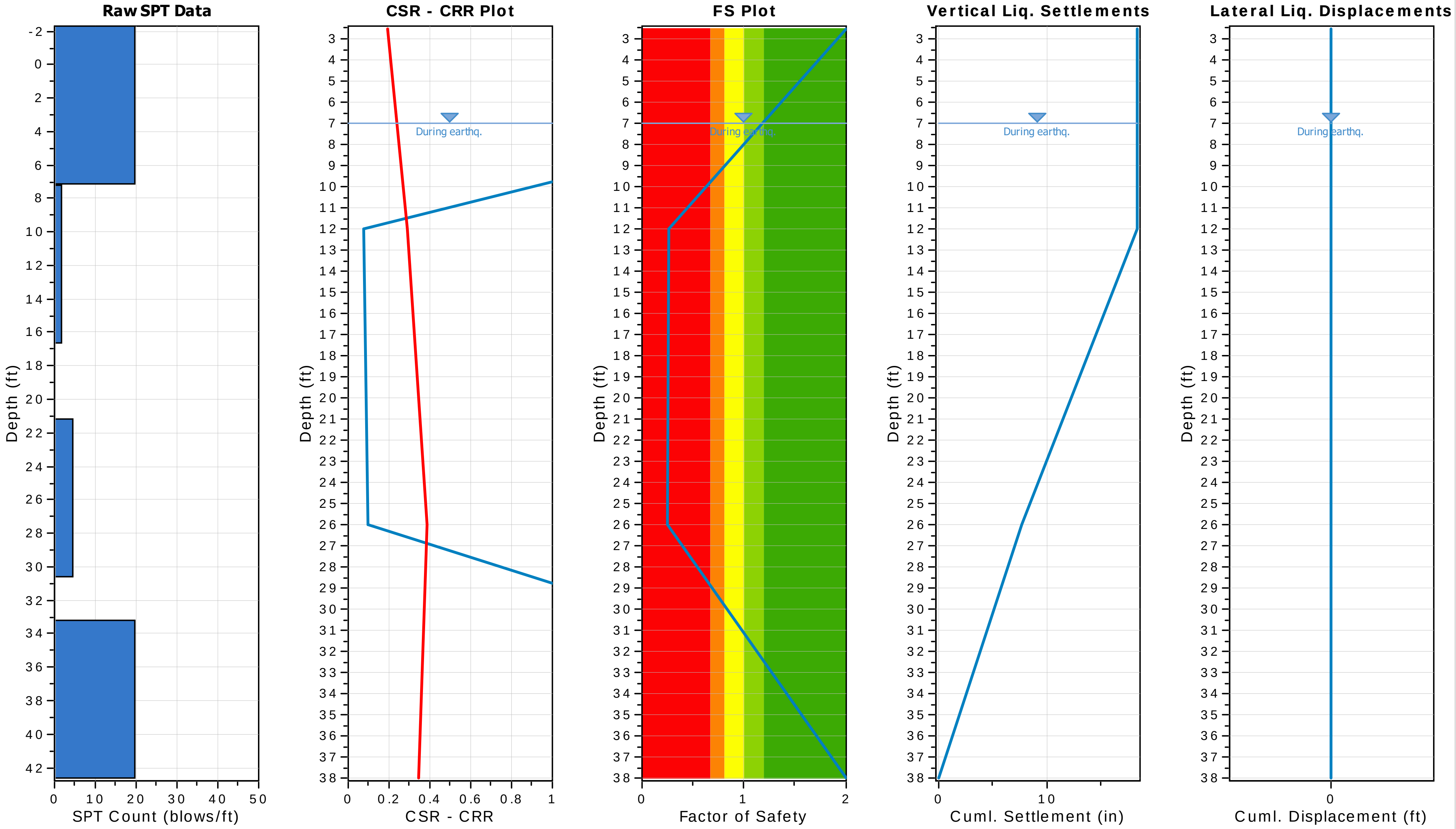




F.S. color scheme
- 🟥 Almost certain it will liquefy
- 🟧 Very likely to liquefy
- 🟨 Liquefaction and no liq. are equally likely
- 🟩 Unlike to liquefy
- 🟩 Almost certain it will not liquefy

LPI color scheme
- 🟥 Very high risk
- 🟧 High risk
- 🟨 Low risk

:: Overall Liquefaction Assessment Analysis Plots ::



:: Field input data ::

Test Depth (ft)	SPT Field Value (blows)	Fines Content (%)	Unit Weight (pcf)	Infl. Thickness (ft)	Can Liquefy
2.50	20	5.00	110.00	5.00	Yes
12.00	2	5.00	85.00	14.00	Yes
26.00	5	5.00	95.00	14.00	Yes
38.00	20	15.00	120.00	10.00	No

Abbreviations

Depth:	Depth at which test was performed (ft)
SPT Field Value:	Number of blows per foot
Fines Content:	Fines content at test depth (%)
Unit Weight:	Unit weight at test depth (pcf)
Infl. Thickness:	Thickness of the soil layer to be considered in settlements analysis (ft)
Can Liquefy:	User defined switch for excluding/including test depth from the analysis procedure

:: Cyclic Resistance Ratio (CRR) calculation data ::

Depth (ft)	SPT Field Value	Unit Weight (pcf)	σ_v (tsf)	u_o (tsf)	σ'_{vo} (tsf)	m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	FC (%)	$\Delta(N_1)_{60}$	$(N_1)_{60cs}$	$CRR_{7.5}$
2.50	20	110.00	0.14	0.08	0.06	0.42	1.70	0.90	1.00	0.75	1.00	23	5.00	0.00	23	4.000
12.00	2	85.00	0.54	0.37	0.17	0.66	1.70	0.90	1.00	0.85	1.00	3	5.00	0.00	3	0.075
26.00	5	95.00	1.21	0.81	0.39	0.58	1.70	0.90	1.00	0.95	1.00	7	5.00	0.00	7	0.098
38.00	20	120.00	1.93	1.19	0.74	0.43	1.17	0.90	1.00	1.00	1.00	21	15.00	3.26	24	4.000

Abbreviations

σ_v:	Total stress during SPT test (tsf)
u_o:	Water pore pressure during SPT test (tsf)
σ'_{vo}:	Effective overburden pressure during SPT test (tsf)
m:	Stress exponent normalization factor
C_N:	Overburden corretion factor
C_E:	Energy correction factor
C_B:	Borehole diameter correction factor
C_R:	Rod length correction factor
C_S:	Liner correction factor
$N_{1(60)}$:	Corrected N_{SPT} to a 60% energy ratio
$\Delta(N_1)_{60}$	Equivalent clean sand adjustment
$N_{1(60)cs}$:	Corected $N_{1(60)}$ value for fines content
$CRR_{7.5}$:	Cyclic resistance ratio for M=7.5

:: Cyclic Stress Ratio calculation (CSR fully adjusted and normalized) ::

Depth (ft)	Unit Weight (pcf)	$\sigma_{v,eq}$ (tsf)	$u_{o,eq}$ (tsf)	$\sigma'_{vo,eq}$ (tsf)	r_d	α	CSR	MSF_{max}	$(N_1)_{60cs}$	MSF	$CSR_{eq,M=7.5}$	K_{sigma}	CSR^*	FS	
2.50	110.00	0.14	0.00	0.14	1.00	1.00	0.234	1.62	23	1.11	0.211	1.10	0.192	2.000	🟢
12.00	85.00	0.54	0.16	0.39	0.97	1.00	0.318	1.10	3	1.02	0.312	1.07	0.292	0.258	🔴
26.00	95.00	1.21	0.59	0.61	0.90	1.00	0.414	1.14	7	1.02	0.404	1.04	0.387	0.254	🔴
38.00	120.00	1.93	0.97	0.96	0.83	1.00	0.392	1.67	24	1.12	0.351	1.02	0.345	2.000	🟢

Abbreviations

$\sigma_{v,eq}$:	Total overburden pressure at test point, during earthquake (tsf)
$u_{o,eq}$:	Water pressure at test point, during earthquake (tsf)
$\sigma'_{vo,eq}$:	Effective overburden pressure, during earthquake (tsf)
r_d:	Nonlinear shear mass factor
α:	Improvement factor due to stone columns
CSR :	Cyclic Stress Ratio
MSF :	Magnitude Scaling Factor
$CSR_{eq,M=7.5}$:	CSR adjusted for M=7.5
K_{sigma}:	Effective overburden stress factor
CSR^*:	CSR fully adjusted
FS:	Calculated factor of safety against soil liquefaction

:: Liquefaction potential according to Iwasaki ::

Depth (ft)	FS	F	wz	Thickness (ft)	I_L
2.50	2.000	0.00	9.62	9.50	0.00
12.00	0.258	0.74	8.17	9.50	17.57
26.00	0.254	0.75	6.04	14.00	19.22
38.00	2.000	0.00	4.21	12.00	0.00

Overall potential I_L : 36.79

I_L = 0.00 - No liquefaction
I_L between 0.00 and 5 - Liquefaction not probable
I_L between 5 and 15 - Liquefaction probable
I_L > 15 - Liquefaction certain

:: Vertical settlements estimation for dry sands ::

Depth (ft)	$(N_1)_{60}$	τ_{av}	p	G_{max} (tsf)	α	b	γ	ε_{15}	N_c	ε_{Nc} (%)	Δh (ft)	ΔS (in)
2.50	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.000

Cumulative settlemetns: 0.000

Abbreviations

τ_{av}:	Average cyclic shear stress
p:	Average stress
G_{max}:	Maximum shear modulus (tsf)
α, b:	Shear strain formula variables
γ:	Average shear strain
ε_{15}:	Volumetric strain after 15 cycles
N_c:	Number of cycles
ε_{Nc}:	Volumetric strain for number of cycles N_c (%)
Δh:	Thickness of soil layer (in)
ΔS:	Settlement of soil layer (in)

:: Vertical & Lateral displ.acements estimation for saturated sands ::

Depth (ft)	$(N_1)_{60cs}$	γ_{lim} (%)	F_α	FS_{liq}	γ_{max} (%)	e_v (%)	dz (ft)	S_{v-1D} (in)	LDI (ft)
12.00	3	100.00	0.95	0.258	100.00	6.33	14.00	10.640	0.00
26.00	7	66.51	0.95	0.254	66.51	4.52	14.00	7.594	0.00
38.00	24	0.00	0.00	2.000	0.00	0.00	10.00	0.000	0.00

Cumulative settlements: 18.234 0.00

Abbreviations

γ_{lim}:	Limiting shear strain (%)
F_α/N:	Maximun shear strain factor
γ_{max}:	Maximum shear strain (%)
e_v::	Post liquefaction volumetric strain (%)
S_{v-1D}:	Estimated vertical settlement (in)
LDI:	Estimated lateral displacement (ft)

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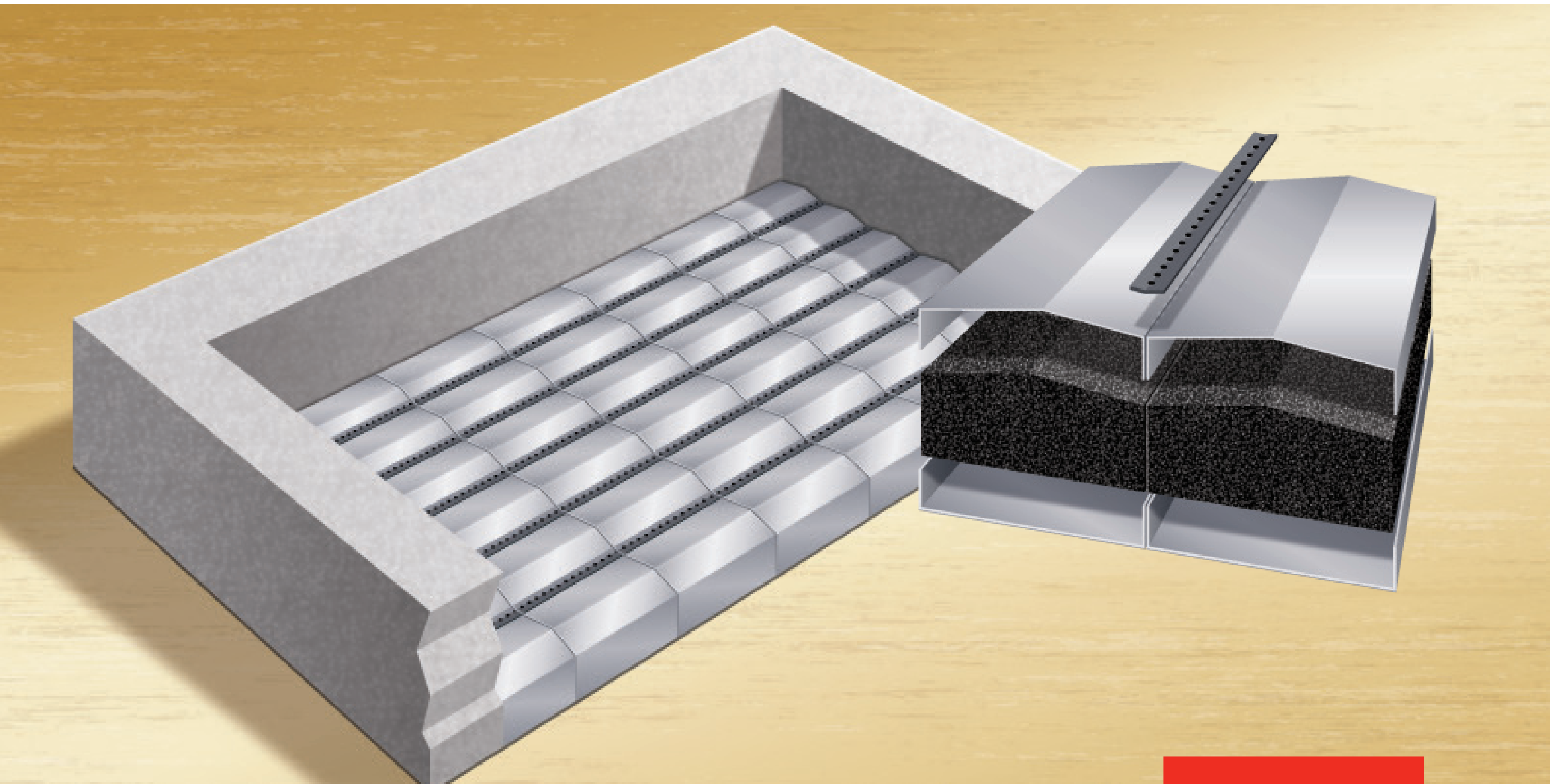
Appendix S.4

FOAMGLAS® PFS™ SYSTEM
POOL FIRE SUPPRESSANT · GENERATION 2

U.S. PATENT NO. 9,925,401



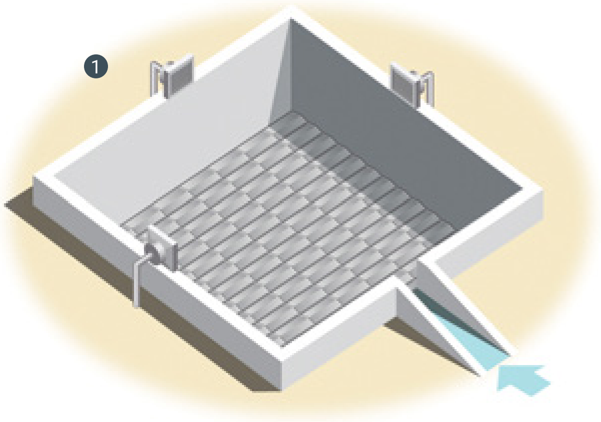
FOAMGLAS® PFS™ SYSTEM GENERATION 2

FOR POOL FIRE SUPPRESSION

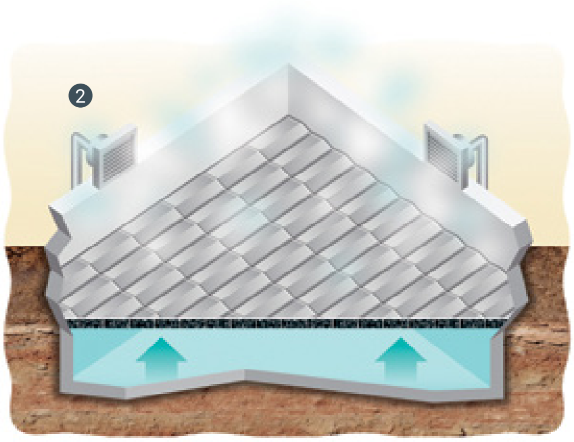
Industrial fire safety is more important now than ever before. Production demands require oil and gas facilities to run continuously without fear of costly safety issues. Many companies are also assigning a greater priority to communicating their successful safety records both internally and externally.

After widespread adoption of the Generation 1 system, the FOAMGLAS® PFS™ Generation 2 pool fire suppression system addresses requirements for extended resistance to weathering and poor climatic conditions, as well as improve the working surface to ease snow removal. This system complements safety programs by delivering a reliable, low-maintanance passive solution for the reduction of thermal radiation and flame height in contained liquid natural gas (LNG) fires. FOAMGLAS® PFS™ system is easy to install and can provide immediate mitigation of the thermal flux, rate of combustion, view and overall size of an LNG pool fire.

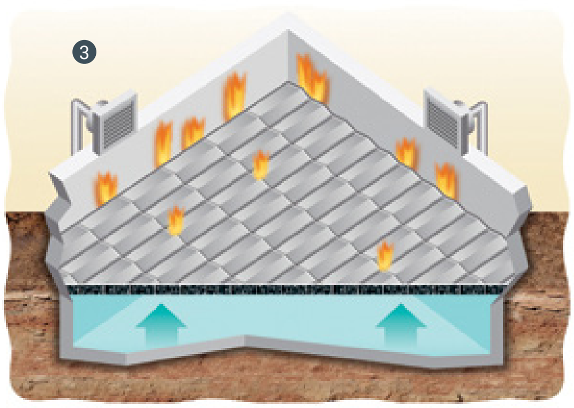
HOW IT WORKS.



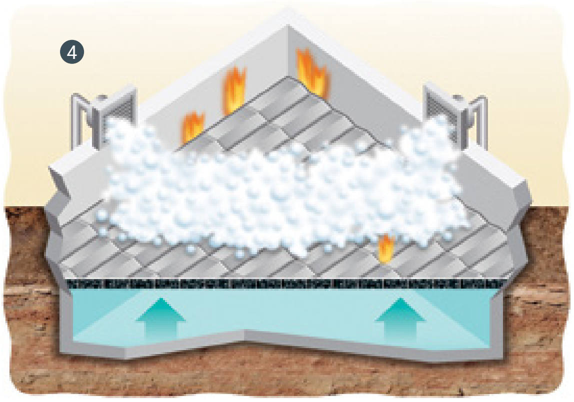
The FOAMGLAS® PFS™ system is a passive system that remains in place to assist in providing immediate and automatic control of LNG pool fires without deployment delays.



Because FOAMGLAS® PFS™ system is highly buoyant, the pool fire suppressant modules rise immediately to the surface of the LNG to provide an insulating cap that can aid in reducing vaporization.



In the event of ignition, the FOAMGLAS® PFS™ system modules quickly limit thermal radiation and flame height.



The system works in conjunction with fire fighting foams.


LNG

EASY TO INSTALL

FOAMGLAS® PFS™ system modules are constructed of a cladded insulation core which are bridged together to uniformly cover an impounding sump or other containment area. These units are easily installed on site and do not require any specialized skills or equipment to install or maintain. The product is packed on standard pallets so no special shipping or handling is required.

IMMEDIATE CONTROL AND PROVEN RESULTS WITH CELLULAR GLASS SYSTEMS

Vapor and Fire Control Testing commissioned by TOTAL and conducted under the supervision of Resource Protection International at the Centro Jovellanos concluded that the the FOAMGLAS® PFS™ system was effective in reducing radiant heat flux and controlling fire from LNG and LPG pool fires.

In scale tests conducted by Shell Research Ltd, a depth of 200 mm (8 inches) of FOAMGLAS® PFS™ system cubes, assisted in providing an immediate and automatic control of the fire at a level comparable with that provided of 1-2 meters (3.3-6.6 ft.) of high-expansion foam.

Results of large scale experiments performed at the Emergency Services Training Institute of Texas A&M University have shown that the view factor of an LNG pool fire suppressed by FOAMGLAS® PFS™ system is comparatively lower than that of high expansion foam, providing real protection from thermal radiation for exposed equipment or personnel. With maximum flame height significantly reduced at a steady state, the thermal radiation is limited to the visible fire within the much lower temperature range of 200˚C to 500˚C (392˚F to 932˚F).

Field extinguishing trials conducted were successful in demonstrating the system's performance. These trials, performed on an LNG test pit of 100 square feet, showed that firefighters equipped with a single 20 lb. dry chemical extinguisher were able to directly approach the edge of the containment pit and extinguish the flames within seconds with only a partial charge.

Liquefied Natural Gas pool fires are considered one of the main hazards of LNG facilities. Suppression methods for potential fires are designed to reduce hazards such as radiant heat and flame height. Based on past research, high expansion foam was regarded as the primary technology in suppressing LNG pool fires. FOAMGLAS® PFS™ pool fire suppression systems assist in providing immediate and automatic control of LNG pool fires. The FOAMGLAS® PFS™ pool fire suppression system has been tested to show that both radiant heat and flames were significantly reduced when used as a passive system prior to a gas leak when compared to traditional foam suppression systems used as the only method to attenuate pool fires. In order to help protect a facility from fire and smoke, the use of cellular glass makes sound technical sense.

UNIQUE PHYSICAL PROPERTIES

The FOAMGLAS® PFS™ system contains specially formulated low-density cellular glass that has a combination of physical properties not found in traditional fire suppressant foams. Made of cellular glass, the material is both extremely buoyant and nonflammable. The pool fire suppressant module system is non-corrosive and resistant to water and vermin. It is also fiber-free, and has a high compressive strength. The FOAMGLAS® PFS™ system works in conjunction with fire fighting foams. Damaged or post-incident waste materials can be disposed of as standard refuse, and can be compacted for reduced waste volume.

Closed-cell structure of FOAMGLAS® cellular glass insulation.

FOAMGLAS® PFS™ SYSTEM POOL FIRE SUPPRESSANT GENERATION 2

The FOAMGLAS® PFS™ Pool Fire Suppressant System Generation 2 complements safety programs by delivering a reliable, low-maintenance passive protective solution for the reduction of thermal radiation and flame height in contained liquid natural gas (LNG) fires. The FOAMGLAS® PFS™ system is easy to install and can provide immediate mitigation of the thermal flux, rate of combustion, view, and overall size of an LNG pool fire.

BENEFITS

- Easy to install
- Continous protection & immediate control
- Passive & reliable
- Low maintainance
- Long term resistence to weathering and poor climatic conditions
- Customized design to match the containment area
- May reduce mandated exclusion zone for your facility

PROJECT REFERENCES[1]:

PORI LNG
YAMAL LNG
NATIONAL PETROLEUM CORP - BARBADOS
SINGAPORE LNG
ELENGY - FRANCE
LNG MIAMI
LYSEKIL LNG
BINTULU MLNG
FERUS NATURAL GAS FUELS
APA GROUP - AUSTRALIA
SAMSUNG - KOREA
TOTAL PETROCHEMICALS - FRANCE
ADGAS - UAE
EG LNG
BOC - AUSTRALIA
ISLE OF GRAIN LNG
RISAVIKA LNG
CLEAN ENERGY HIGH DESERT LNG
GASREC LIQUID BIOMETHANE - UK
FREEPORT LNG
YEMEN LNG
PANIGAGLIA LNG

FIRE CREDENTIALS FOR FOAMGLAS® INSULATION

Der Norske Verita Type Approval
Lloyd's Register
USGG Approval for Non-combustible Inspections

Material Tests:
EN ISO 1182 (Class A1)
ASTM E136 (noncombustible)
ASTM E 84 - Flame-spread (0) Smoke Development (0)

Application Tests[1]:
FOAMGLAS® Insulation on LNG. MKOPSC.
Texas A&M University.

Fire & Vapor Control Testing. Resource Protection International. Centro Jovellanos.

Extinguishing Trials at Brayton Fire Training Filed.

A Novel Method for Controlling Pool Fires.
Fire Technology Journal. Shell Research Limited.
Thorton Research Centre.

REGULATORY OVERVIEW

- National Fire Protection Association 59A, Standard for the Production, Storage, and Handling of LNG, has contributed to the conditional withholding and final denial of regulatory approval for several LNG projects by the Federal Energy Regulatory Committee.
- Requirements for exclusion zones can impact overall site layout and design - with direct impact on land acquisition and construction costs for facility owners.
- Mandated exclusion zones for LNG facilities include parameters for both vapor dispersion and thermal radiation (radiant thermal flux).
- NFPA 59A allows for the use of passive fire mitigation techniques in the calculation of radiant heat distances, subject to the approval of the agency having jurisdiction.

1. Includes Generation 1 Systems

OWENS CORNING® FOAMGLAS®

Pittsburgh Corning, LLC
One Owens Corning Pkwy
Toledo, OH 43659

For web-based Sales and Technical Service inquiries,
please visit www.foamglas.com

To contact by phone or email:

Industrial & Commercial Sales

Americas
+1 800 327 6126

Asia-Pacific
Singapore: +65 9635 9184
China: +86 (0) 21 6101 7179
Japan: +81 3 6365 4307

Europe, Middle East & Africa
+32 13 661 721

Technical Services

Americas & Asia Pacific
+1 800 327 6126
Foamglastechnical@owenscorning.com

Europe, Middle East & Africa
+32 13 611 468
Industrytechnical@foamglas.com

Pub. No. 10023721

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