GPD GROUP
Professional Corporation

GPD# 2016777.829171.01
July 29, 2016

GEOTECHNICAL REPORT

BU Number: **829171**
Site Name: **WWeber_Baugh**

Site Data: **4311 West 1200 South**
West Weber (Weber County), Utah 84404
Latitude 41° 14' 39.5'' N, Longitude 112° 05' 16.1'' W
Existing 119-ft SABRE Monopole

GPD Group is pleased to submit this **Geotechnical Report** for the aforementioned tower. The purpose of the following report is to summarize the soil/rock conditions encountered during the subsurface exploration at this site and provide geotechnical engineering parameters for structural evaluation of the existing tower foundation system.

We at *GPD Group* appreciate the opportunity to provide continuing professional services to you. Please feel free to contact us with any questions or if you need additional assistance.

Respectfully Submitted,

Dustin Vincent, E.I.T.
Geotechnical Specialist

PROFESSIONAL ENGINEER
No. 8255903-2202
HEWITT T. WILKINSON
STATE OF UTAH

Chip Wilkinson, P.E.
Principal
Utah P.E. License #8255903-2202

Attachments:
Site Location Map
Satellite Photograph
Topographic Map
Boring Location Plan
Boring Log
Atterberg Limits' Results
Grain Size Distribution Results
Photographs
Unified Soil Classification System
General Notes
Previous Boring Log - Terracon

REGIONAL AND SITE GEOLOGY

The United States Department of Agriculture ("USDA") Soil Survey of Weber County, Utah, and the United States Geological Survey ("USGS") maps were reviewed to assess the subsurface geology and sedimentary makeup of the site location, as well as the topography of the region. The site is located in an open field near a railroad and the ground surface is relatively flat. The surrounding area is comprised of relatively flat agricultural fields and few residential dwellings. The site elevation ranges from about 4,239 to 4,242 feet above sea level. The frost depth in this region is 50 inches per NAVFAC DM 7.01.

According to the USGS, the surficial soils in this area consist primarily of silt loam from the Airport soil group. The silt loam indicates a high concentration of silt with some sand and clay. Recent deposits of sand and gravel are also present throughout the area depending on the proximity to rivers and streams. USGS maps show that deep Quaternary alluvium and colluvium deposits of clay, silt, sand, and some gravel created from streams and eroding mountains and hillsides lie below the surficial soils.

SEISMIC SITE CLASSIFICATION

Based on the results of the test boring and following the calculation procedure in the 2012 International Building Code/ASCE 7-10, the Site Soil Classification is Site Class "E." Based on the soils encountered during this geotechnical investigation, the liquefaction potential of the site is considered high.

GEOTECHNICAL EXPLORATION

Drilling and soil sampling was performed by ConeTec using a truck-mounted Marl M-10 drill rig with hollow-stem augers and an automatic SPT hammer. The automatic SPT hammer has an efficiency rating of 84.1% as provided by the drilling company. One (1) sample boring was drilled near the existing tower foundation to a depth of about sixty-one and one-half (61.5) feet. The boring location was laid out by the driller using a measuring tape and pacing methods. The location of the boring should be considered accurate only to the degree implied by the means and methods used to define them. Refer to the attached Boring Location Plan for more information.

Representative samples were obtained by the split-barrel sampling procedure in general accordance with appropriate ASTM standards. In the split-barrel sampling procedure, the number of blows required to advance a standard 2-inch O.D. split-barrel sampler the last 12 inches of the typical total 18-inch penetration by means of a 140-pound hammer with a free fall of 30 inches, is the standard penetration resistance value (N). Sampling depths and penetration distance, plus the standard penetration resistance values, are shown on the attached boring log. The samples were sealed and mailed to our laboratory for soil classification in general accordance with ASTM D-4220.

The subsurface conditions encountered at the boring location are indicated on the attached boring log. The stratification boundaries on the boring log represent the approximate location of changes in soil/rock types; in-situ, the transition between materials may be gradual. The boring log includes visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples.

LABORATORY TESTING

The samples were classified in the laboratory based on visual observation, texture and plasticity. The descriptions of the soils indicated on the boring log are in accordance with the enclosed General Notes and the Unified Soil Classification System. Estimated group symbols according to the Unified Soil Classification System are given on the boring log. A brief description of this classification system is attached to this report.

The laboratory testing program consisted of performing the following tests:

- Natural water content tests (ASTM D-2216)
- Washing soils through #200 Sieve (ASTM D-1140)
- Atterberg limits tests (ASTM D-4318)
- Grain size analysis (ASTM D-422)
- Soil Resistivity Test (ASTM G187-12A)
- Soil pH Test (ASTM D-4972)

It should be noted that torvane testing for Samples 8, 10, and 11 and pocket penetrometer testing for Sample 10 and 11 were unable to be completed due to the condition of the received samples.

Information from these tests was used in conjunction with field penetration test data to evaluate soil strength in-situ and soil classification. Results of these tests are attached and provided on the boring log.

SOIL RESISTIVITY AND REACTIVITY

Soil resistivity and pH testing was performed as a part of the geotechnical investigation at this site. A composite sample was obtained within the upper 10-ft for laboratory testing. Laboratory resistivity measurements were obtained using a MILLER-400A implementing the 2-electrode method in conjunction with an electrolyte box in accordance with ASTM G187-12A. It should be noted that the soil samples were saturated for this testing procedure. Based on the laboratory test results, most of the soil is rated "Highly Corrosive" with resistivity measurements on average of about **1,600 ohm-cm** (refer to Table below). Additionally, soil pH tests were conducted in accordance with ASTM D-4972. An average soil pH of **8.0** was measured at **26°C** for the surficial soils at the project location.

Soil Resistivity

Resistivity (Ohm-cm)	Soil Type	Corrosion Rating
0 to 1,000	Moist Clay	Extremely Corrosive
1,000 to 3,000	Moist Clay	Highly Corrosive
3,000 to 5,000	Clay	Corrosive
5,000 to 10,000	Silty Clay/Clayey Silt	Moderately Corrosive
10,000 to 20,000	Sandy Silt	Mildly Corrosive
>20,000	Sand/Gravel/Rock	Non-Corrosive

GROUNDWATER

Groundwater was encountered during drilling operations at a depth of about 7 feet below grade as noted on the attached boring log. Groundwater was found in the previous geotechnical study (Terracon Project No. 61005455 dated January 11, 2001) at a depth of 5 feet below grade. Therefore, buoyant unit weights should be utilized below a depth of 5 feet. It should be noted that fluctuations in the groundwater level can occur and perched water can develop over low permeability soil or rock strata following periods of heavy or prolonged precipitation. Long term monitoring in cased holes or piezometers would be necessary to accurately evaluate the potential range of groundwater conditions on the site.

PREVIOUS GEOTECHNICAL STUDY

A geotechnical report was previously completed by Terracon (Terracon Project No. 61005455 dated January 11, 2001). The boring log from this study has been included as an appendix.

EXISTING FOUNDATION SYSTEM

Based on the Foundation Design by Boyd Tangren, PE/CSE (dated May 28, 2002) the foundation system is reportedly comprised of a 6-ft diameter Drilled Pier (Caisson) extending to a depth of 40 feet below grade.

GEOTECHNICAL RECOMMENDATIONS

Based on the results of this study, the following ultimate design parameters may be used evaluate the capacity of the existing foundation system. The cohesion, internal angle of friction and total unit weight parameters along with the horizontal modulus of subgrade reaction and soil strain values given in the following table are based on the results of the sample boring, lab testing, published values and our past experience with similar soil/rock types. These values should, therefore, be considered approximate.

Monopole – Drilled Pier – Ultimate Design Parameters

Depth (feet)	USCS	Total Unit Weight (pcf)	Horizontal Modulus of Subgrade Reaction (pci)	ε_{50}	Ultimate Gross Bearing Pressure (psf)	Internal Angle of Friction (Degrees)	Cohesive Strength (psf)
0 – 4.5*	CL	115	Ignore*	0.01	Ignore*	0	750
4.5 – 7	SC	105	20	-	Ignore	26	0
7 – 10	SP-SM	115	60	-	4,500	30	0
10 – 13	CL	110	40	0.01	4,500	0	500
13 – 18	SP-SM	105	20	-	5,000	26	0
18 – 26	SP-SM	110	60	-	6,500	30	0
26 – 38	CL	115	40	0.01	6,500	0	500
38 – 43	CL	115	40	0.01	7,000	0	500
43 – 48	CL	125	160	0.007	9,000	0	2,000
48 – 61.5	CL	110	40	0.01	7,500	0	500

*The upper 4.5 feet of soil should be ignored due to potential frost effects (NAVFAC DM 7.01).

The above bearing pressure, horizontal modulus of subgrade reaction, and soil strain values are provided for the evaluation of the existing tower foundation system. In the event that modifications or new tower construction is required, these parameters are not considered valid and GPD Group should be notified immediately to provide appropriate design parameters, as warranted.

QUALIFICATIONS

The analysis and recommendations presented in this report are based upon the data obtained from the boring performed at this site and from other information discussed in this report. This report does not reflect variations that may occur across the site or due to the modifying effects of weather.

This report has been prepared for the exclusive use of **Crown Castle** for specific application to the project discussed herein and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. In the event that changes in the nature or design as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless ***GPD Group*** reviews the changes and either verifies or modifies the conclusions of this report in writing.

The scope of services for this project does not include either specifically or by implication any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken.

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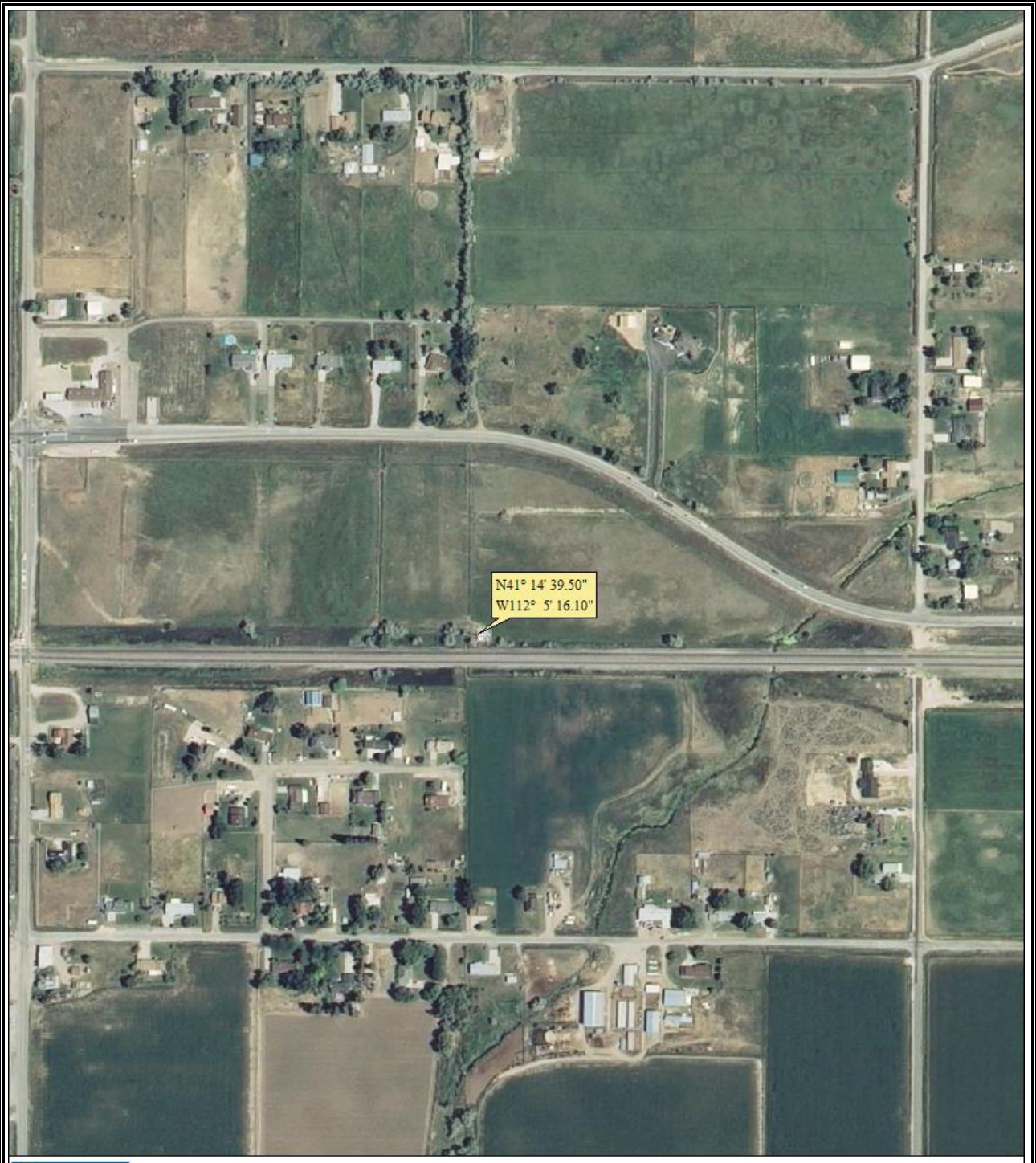
SITE LOCATION MAP

Site Name: WWeber_Baugh
BU Number: 829171
GPD Job Number: 2016777.829171.01
Date: July 2016



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MN (11.6° E)

0 160 320 480 640 800 ft
Data Zoom 15-2

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SATELLITE PHOTOGRAPH

Site Name: WWeber_Baugh
BU Number: 829171
GPD Job Number: 2016777.829171.01
Date: July 2016

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www.delorme.com

MN (11.6° E)

0 600 1200 1800 2400 3000 3600 ft
Data Zoom 13-1

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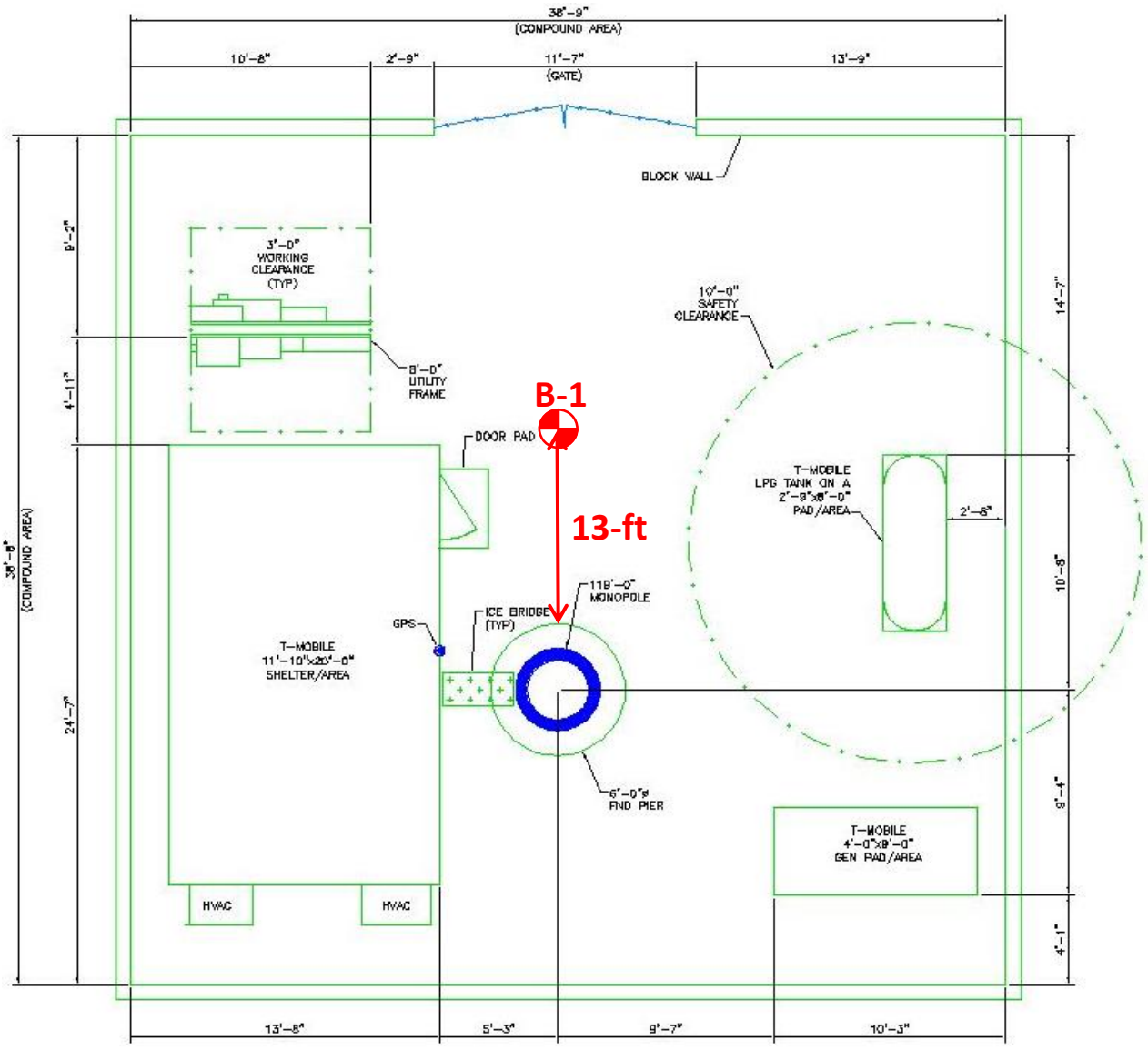
TOPOGRAPHIC MAP

Site Name: WWeber_Baugh
BU Number: 829171
GPD Job Number: 2016777.829171.01
Date: July 2016

Boring Location: 41.24433 N, 112.08776 W



The location of the previous boring (Terracon Project No. 61005455 dated January 11, 2001) was not available at the time of this report.

NOT TO SCALE

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BORING LOCATION PLAN

Site Name: WWeber_Baugh
BU Number: 829171
GPD Job Number: 2016777.829171.01
Date: July 2016

Boring Number: B-1

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CLIENT Crown Castle
PROJECT NAME WWeber_Baugh
PROJECT NUMBER 2016777.829171.01
PROJECT LOCATION West Weber, Utah
DATE STARTED July 13, 2016 **COMPLETED** July 13, 2016
GROUND ELEVATION _____ **HOLE SIZE** 7.5 in
DRILLING CONTRACTOR ConeTec
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Auger
AT TIME OF DRILLING 7.00 ft
LOGGED BY Dustin Vincent **CHECKED BY** Nicholas Zadd
AT END OF DRILLING 7.00 ft
NOTES Marl M-10 Drill Rig with Automatic SPT Hammer

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	TORVANE (kg/cm²)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0		Gravel										
		Medium Stiff brown SANDY CLAY (CL) with silt	SS 1	44	3-3-2 (5)	2.0	0.6	20				
		Very Loose brown fine CLAYEY SAND (SC)	SS 2	89	2-1-2 (3)			29				
		Medium Dense brown fine to medium SAND (SP-SM) with silt	SS 3	100	3-5-5 (10)			30				8
10		Soft brown LEAN CLAY (CL) with silt and fine sand	SS 4	44	1-1-2 (3)	0.5	0.6	30				
		Very Loose dark grayish brown fine to medium SAND (SP-SM) with silt	SS 5	33	2-1-1 (2)			28				5
		Medium dense below 18 feet										
20			SS 6	0	1-2-8 (10)							
		Loose below 23 feet										
		Medium Stiff dark grayish brown LEAN CLAY (CL) with trace sand	SS 7	44	1-4-2 (6)			31				
		Soft below 28 feet										
30			SS 8	100	0-1-2 (3)	0.5		38	41	19	22	98
		Soft to medium stiff and gray and brown below 33 feet	SS 9	100	1-2-2 (4)	0	0.25	55				
40			SS 10	78	2-2-2 (4)			45	40	19	21	96
		Hard brown SANDY CLAY (CL)	SS 11	89	5-13-23 (36)			20				54
		Medium Stiff brown LEAN CLAY (CL) with some silt										
50			SS 12	100	2-3-2 (5)	0.25	0.25	43				
		Very soft to soft and dark gray and brown below 53 feet	SS 13	100	0-0-2 (2)	0.25	0.5	43				
		Medium stiff and gray below 58 feet										
60			SS 14	100	0-2-3 (5)	0.25	0.5	46				
		Boring terminated at 61.5 feet										

WITH TORVANE VALUE - GINT STD US LAB.GDT - 7/29/16 07:29 - O:\GEOTECH\GINT PROJECTS (STARTED AFTER 032414)\GINT PROJECTS 2015\829171 WWEBER_BAUGH.GPJ

ATTERBERG LIMITS' RESULTS

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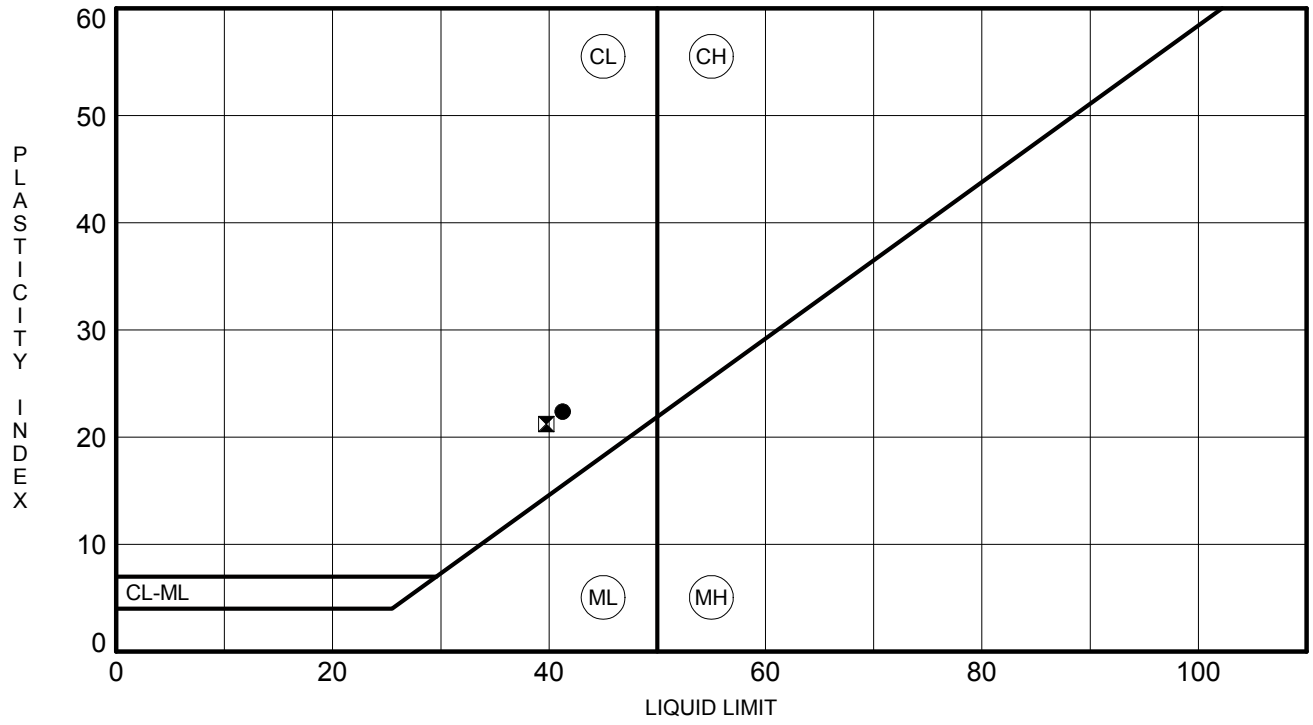
CLIENT Crown Castle **PROJECT NAME** WWeber_Baugh

PROJECT NUMBER 2016777.829171.01 **PROJECT LOCATION** West Weber, Utah



	BOREHOLE	DEPTH	LL	PL	PI	Fines	Classification
●	**B-1**	**30.0**	**41**	**19**	**22**	**98**	**LEAN CLAY (CL)**
⧓	**B-1**	**40.0**	**40**	**19**	**21**	**96**	**LEAN CLAY (CL)**

GRAIN SIZE DISTRIBUTION

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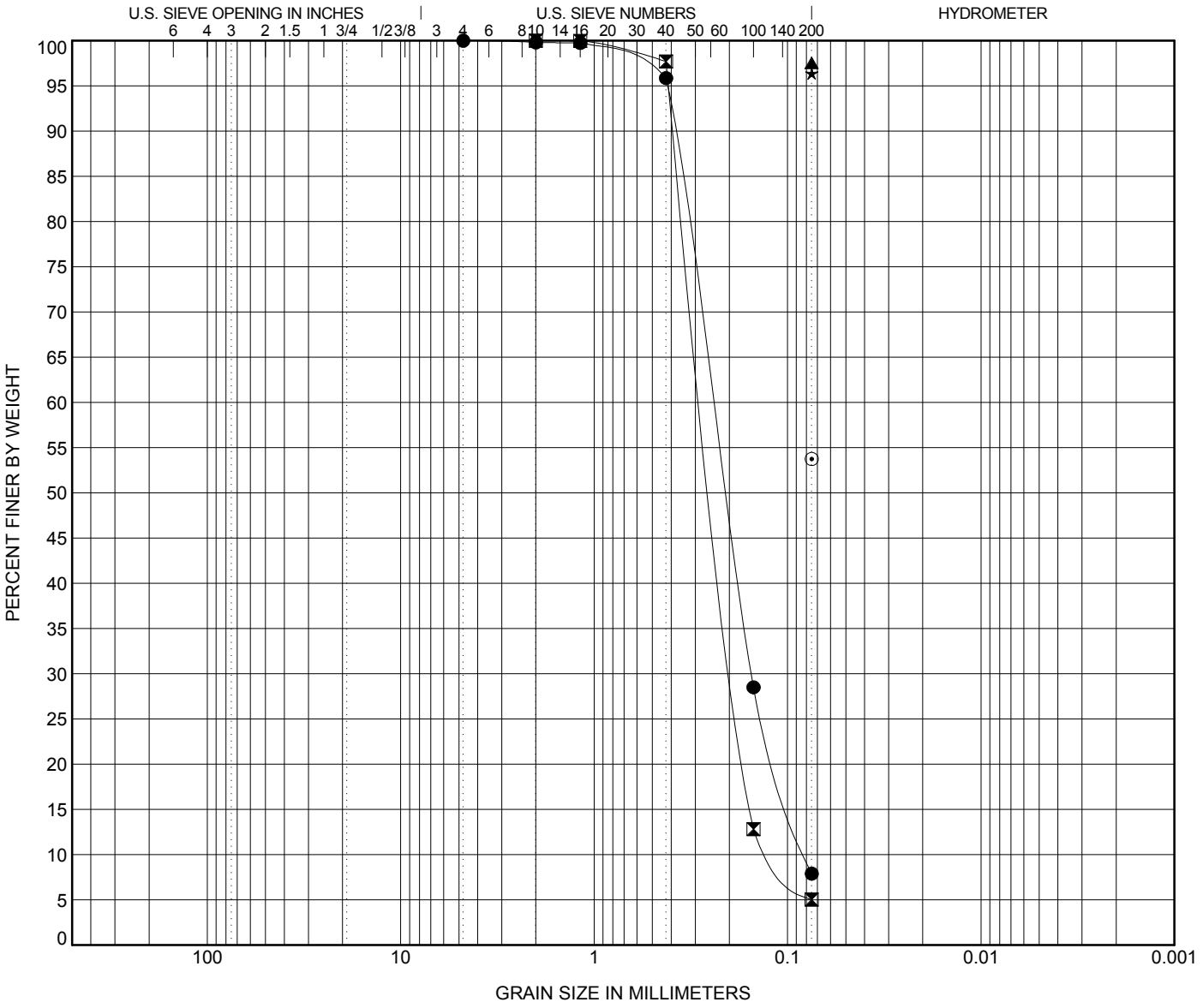
CLIENT Crown Castle **PROJECT NAME** WWeber_Baugh

PROJECT NUMBER 2016777.829171.01 **PROJECT LOCATION** West Weber, Utah



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	B-1	7.5	SAND (SP-SM) with silt				1.20	3.03
⧓	B-1	15.0	SAND (SP-SM) with silt				1.10	2.29
▲	B-1	30.0	LEAN CLAY (CL)	41	19	22		
★	B-1	40.0	LEAN CLAY (CL)	40	19	21		
⊙	B-1	45.0	SANDY CLAY (CL)					

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	B-1	7.5	4.75	0.244	0.154	0.081	0.0	92.1	7.9	
⧓	B-1	15.0	2	0.268	0.185	0.117	0.0	95.0	5.0	
▲	B-1	30.0	0.075						97.6	
★	B-1	40.0	0.075						96.4	
⊙	B-1	45.0	0.075						53.7	

1) SOIL SAMPLES 1 THROUGH 4

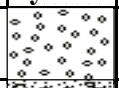
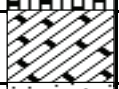
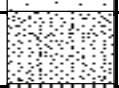
2) SOIL SAMPLES 5 THROUGH 8

3) SOIL SAMPLES 9 THROUGH 12

4) SOIL SAMPLES 13 AND 14

5) DRILL RIG DURING DRILLING

Unified Soil Classification System

Major Divisions			Letter	Symbol	Description
Coarse-grained Soils More than ½ retained on the No. 200 Sieve	**Gravels** More than ½ coarse fraction retained on the No. 4 sieve	Clean Gravels	GW		Well-graded gravels and gravel-sand mixtures, little or no fines.
			GP		Poorly-graded gravels and gravel-sand mixtures, little or no fines.
		Gravels With Fines	GM		Silty gravels, gravel-sand-silt mixtures.
			GC		Clayey gravels, gravel-sand-clay mixtures.
	Sands More than ½ passing through the No. 200 sieve	Clean Sands	SW		Well-graded sands and gravelly sands, little or no fines.
			SP		Poorly-graded sands and gravelly sands, little or no fines.
		Sands With Fines	SM		Silty sands, sand-silt mixtures
			SC		Clayey sands, sandy-clay mixtures.
Fine-grained Soils More than ½ passing through the No. 200 Sieve	**Silts and Clays** Liquid Limit less than 50%		ML		Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL		Organic clays of medium to high plasticity.
	Silts and Clays Liquid Limit greater than 50%		MH		Inorganic silts, micaceous or diatomaceous fines sands or silts, elastic silts.
			CH		Inorganic clays of high plasticity, fat clays.
			OH		Organic clays of medium to high plasticity.
Highly Organic Soils			PT		Peat, muck, and other highly organic soils.

Consistency Classification

Granular Soils			*Cohesive Soils*		
Description - Blows Per Foot (Corrected)			Description - Blows Per Foot (Corrected)		
	MCS	SPT		MCS	SPT
Very loose	<5	<4	Very soft	<3	<2
Loose	5 - 15	4 - 10	Soft	3 - 5	2 - 4
Medium dense	16 - 40	11 - 30	Firm	6 - 10	5 - 8
Dense	41 - 65	31 - 50	Stiff	11 - 20	9 - 15
Very dense	>65	>50	Very Stiff	21 - 40	16 - 30
			Hard	>40	>30

MCS = Modified California Sampler SPT = Standard Penetration Test Sampler

GENERAL NOTES

SAMPLE IDENTIFICATION

The Unified Soil Classification System (USCS), AASHTO 1988 and ASTM designations D2487 and D-2488 are used to identify the encountered materials unless otherwise noted. Coarse-grained soils are defined as having more than 50% of their dry weight retained on a #200 sieve (0.075mm); they are described as: boulders, cobbles, gravel or sand. Fine-grained soils have less than 50% of their dry weight retained on a #200 sieve; they are defined as silts or clay depending on their Atterberg Limit attributes. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size.

DRILLING AND SAMPLING SYMBOLS

SFA: Solid Flight Auger - typically 4" diameter flights, except where noted.
HSA: Hollow Stem Auger - typically 3¼" or 4¼ I.D. openings, except where noted.
M.R.: Mud Rotary - Uses a rotary head with Bentonite or Polymer Slurry
R.C.: Diamond Bit Core Sampler
H.A.: Hand Auger
P.A.: Power Auger - Handheld motorized auger

SS: Split-Spoon - 1 3/8" I.D., 2" O.D., except where noted.
ST: Shelby Tube - 3" O.D., except where noted.
BS: Bulk Sample
PM: Pressuremeter
CPT-U: Cone Penetrometer Testing with Pore-Pressure Readings

SOIL PROPERTY SYMBOLS

N: Standard "N" penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2-inch O.D. Split-Spoon.
N_{60}: A "N" penetration value corrected to an equivalent 60% hammer energy transfer efficiency (ETR)
Q_u: Unconfined compressive strength, TSF
Q_p: Pocket penetrometer value, unconfined compressive strength, TSF
w%: Moisture/water content, %
LL: Liquid Limit, %
PL: Plastic Limit, %
PI: Plasticity Index = (LL-PL),%
DD: Dry unit weight, pcf
▼,▽,▼ Apparent groundwater level at time noted

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	N - Blows/foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	50 - 80
Extremely Dense	80+

ANGULARITY OF COARSE-GRAINED PARTICLES

Description	Criteria
Angular:	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular:	Particles are similar to angular description, but have rounded edges
Subrounded:	Particles have nearly plane sides, but have well-rounded corners and edges
Rounded:	Particles have smoothly curved sides and no edges

GRAIN-SIZE TERMINOLOGY

Component	Size Range
Boulders:	Over 300 mm (>12 in.)
Cobbles:	75 mm to 300 mm (3 in. to 12 in.)
Coarse-Grained Gravel:	19 mm to 75 mm (¾ in. to 3 in.)
Fine-Grained Gravel:	4.75 mm to 19 mm (No.4 to ¾ in.)
Coarse-Grained Sand:	2 mm to 4.75 mm (No.10 to No.4)
Medium-Grained Sand:	0.42 mm to 2 mm (No.40 to No.10)
Fine-Grained Sand:	0.075 mm to 0.42 mm (No. 200 to No.40)
Silt:	0.005 mm to 0.075 mm
Clay:	<0.005 mm

PARTICLE SHAPE

Description	Criteria
Flat:	Particles with width/thickness ratio > 3
Elongated:	Particles with length/width ratio > 3
Flat & Elongated:	Particles meet criteria for both flat and elongated

RELATIVE PROPORTIONS OF FINES

Descriptive Term	% Dry Weight
Trace:	< 5%
With:	5% to 12%
Modifier:	>12%

GENERAL NOTES

(Continued)

CONSISTENCY OF FINE-GRAINED SOILS

Q_U - TSF	N - Blows/foot	Consistency
0 - 0.25	0 - 2	Very Soft
0.25 - 0.50	2 - 4	Soft
0.50 - 1.00	4 - 8	Firm (Medium Stiff)
1.00 - 2.00	8 - 15	Stiff
2.00 - 4.00	15 - 30	Very Stiff
4.00 - 8.00	30 - 50	Hard
8.00+	50+	Very Hard

MOISTURE CONDITION DESCRIPTION

Description	Criteria
Dry:	Absence of moisture, dusty, dry to the touch
Moist:	Damp but no visible water
Wet:	Visible free water, usually soil is below water table

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term	% Dry Weight
Trace:	< 15%
With:	15% to 30%
Modifier:	>30%

STRUCTURE DESCRIPTION

Description	Criteria
Stratified:	Alternating layers of varying material or color with layers at least ¼-inch (6 mm) thick
Laminated:	Alternating layers of varying material or color with layers less than ¼-inch (6 mm) thick
Fissured:	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided:	Fracture planes appear polished or glossy, sometimes striated
Blocky:	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed:	Inclusion of small pockets of different soils
Layer:	Inclusion greater than 3 inches thick (75 mm)
Seam:	Inclusion 1/8-inch to 3 inches (3 to 75 mm) thick extending through the sample
Parting:	Inclusion less than 1/8-inch (3 mm) thick

SCALE OF RELATIVE ROCK HARDNESS

Q_U - TSF	Consistency
2.5 - 10	Extremely Soft
10 - 50	Very Soft
50 - 250	Soft
250 - 525	Medium Hard
525 - 1,050	Moderately Hard
1,050 - 2,600	Hard
>2,600	Very Hard

ROCK BEDDING THICKNESSES

Description	Criteria
Very Thick Bedded	Greater than 3-foot (>1.0 m)
Thick Bedded	1-foot to 3-foot (0.3 m to 1.0 m)
Medium Bedded	4-inch to 1-foot (0.1 m to 0.3 m)
Thin Bedded	1¼-inch to 4-inch (30 mm to 100 mm)
Very Thin Bedded	½-inch to 1¼-inch (10 mm to 30 mm)
Thickly Laminated	1/8-inch to ½-inch (3 mm to 10 mm)
Thinly Laminated	1/8-inch or less "paper thin" (<3 mm)

ROCK VOIDS

Voids	Void Diameter
Pit	<6 mm (<0.25 in)
Vug	6 mm to 50 mm (0.25 in to 2 in)
Cavity	50 mm to 600 mm (2 in to 24 in)
Cave	>600 mm (>24 in)

GRAIN-SIZED TERMINOLOGY

(Typically Sedimentary Rock)

Component	Size Range
Very Coarse Grained	>4.76 mm
Coarse Grained	2.0 mm - 4.76 mm
Medium Grained	0.42 mm - 2.0 mm
Fine Grained	0.075 mm - 0.42 mm
Very Fine Grained	<0.075 mm

ROCK QUALITY DESCRIPTION

Rock Mass Description	RQD Value
Excellent	90 -100
Good	75 - 90
Fair	50 - 75
Poor	25 -50
Very Poor	Less than 25

DEGREE OF WEATHERING

Slightly Weathered: Rock generally fresh, joints stained and discoloration extends into rock up to 25 mm (1 in), open joints may contain clay, core rings under hammer impact.

Weathered: Rock mass is decomposed 50% or less, significant portions of the rock show discoloration and weathering effects, cores cannot be broken by hand or scraped by knife.

Highly Weathered: Rock mass is more than 50% decomposed, complete discoloration of rock fabric, core may be extremely broken and gives clunk sound when struck by hammer, may be shaved with a knife.

Master Index

LOG OF BORING NO. B-1

CLIENT: VoiceStream Wireless

ARCHITECT/ENGINEER:

SITE: 1150 South 4700 West, Ogden, Utah

PROJECT: Monopole Tower, 12th Street Site - SL-1312

Location: See Site Vicinity Map

GRAPHIC LOG	DESCRIPTION	DEPTH (FT.)	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, INCHES	SAMPLES SPT - N BLOWS / FT.	TESTS MOISTURE, %	TESTS DRY DENSITY PCF	TESTS UNCONFINED STRENGTH, PSF	
	1.0 **TOPSOIL:** organic material										
	SILT (ML); dark brown to light brown, medium stiff, moist		ML	1	SS	12	6	24			pH=9.0, Res.= 600 ohm-cm, Sulfate= 0.006%
	--- soft, wet at 5 feet ▽	5	ML	2	SS	12	4	33			
	7.0 **SILTY SAND (SM);** light brown to dark gray, medium dense, wet		SM	3	SS	12	14	27			
	--- loose below 10 feet	10	SM	4	SS	12	8	33			
		15	SM	5	SS	10	15	25			
	--- black below 20 feet --- white lense at 21 feet	20	SM	6	SS	12	10	28			
	22.5 **LEAN CLAY (CL);** black, medium stiff, wet	25	CL	7	SS	12	5	37			
		30	CL	8	SS	14	6	23			
	31.5 Bottom of boring at 31.5 feet										

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	▽ 5 ft. WD	▼
WL		
WL		

Terracon

BORING STARTED	1-4-01		
BORING COMPLETED	1-4-01		
RIG	CME-55	FOREMAN	AHS
APPROVED	WGT	JOB #	61005455

GEOTECHNICAL ENGINEERING REPORT

PROPOSED MONOPOLE COMMUNICATIONS TOWER
12TH STREET - SITE SL-1312
1150 SOUTH 4700 WEST
OGDEN, UTAH

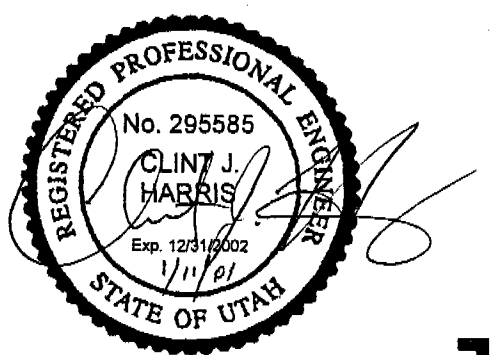
Terracon Project No. 61005455
January 11, 2001

Prepared for:

VOICESTREAM
Salt Lake City, Utah

Prepared by:

TERRACON
Consulting Geotechnical Engineers
Salt Lake City, Utah



Terracon

January 11, 2001

Terracon
12217 South Lone Peak Parkway, Suite 100
Draper, Utah 84020
(801) 545-8500 Fax: (801) 545-8600

VoiceStream
1497 South 700 West
Salt Lake City, Utah 84104

Attention: Jerome Gourley

Re: Geotechnical Engineering Report
Proposed Monopole Communications Tower
12th Street - Site SL-1312
1150 South 4700 West
Ogden, Utah
Terracon Project No. 61005455

Dear Mr. Gourley,

We are submitting, herewith, our Geotechnical Engineering Report for the referenced project. The purpose of this exploration was to obtain information on subsurface conditions at the proposed project site and provide geotechnical recommendations regarding design of foundations for the tower and ancillary structures. Results of the field exploration indicate the site contains approximately 7 feet of silt overlying loose sand and very soft silty/clayey soils extending to the maximum depth explored of 31.5 feet below the ground surface. In our opinion, the proposed tower can be supported on a drilled pier foundation, **but there are some concerns with the loose/very soft soils in providing adequate capacity. Note that liquefaction during a major seismic event is likely in the loose sandy soils from a depth of 7 to 22.5 feet. We also anticipate that casing will likely be required below groundwater because of the possibility of the sidewalls caving or squeezing in during installation of the drilled pier.** The accompanying report presents our findings, analyses and recommendations for the subject project. Also, samples obtained during our field exploration will be discarded 30 days from the issuance of this report, unless otherwise requested.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service to you in any way, please contact us.

Sincerely,
TERRACON

Clint J. Harris, P.E.
Geotechnical Engineer

William G. Turner, P.E.
Sr. Geotechnical Engineer

n:\geo\2000\5455rpt.doc
Copies To: Addressee (2)

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GEOTECHNICAL ENGINEERING REPORT

PROPOSED MONOPOLE COMMUNICATIONS TOWER
12TH STREET - SITE SL-1312
1150 SOUTH 4700 WEST
OGDEN, UTAH

Terracon Project No. 61005455
January 11, 2001

INTRODUCTION

This geotechnical engineering report presents subsurface exploration results for the proposed monopole communications tower to be located near the southeast corner of the intersection of 1150 South Street and 4700 West Street in Ogden, Utah. The approximate location of the site is shown on the attached Project Vicinity Map. One boring was drilled to a depth of about 31.5 feet below the existing ground surface near the proposed site to obtain subsurface information. The boring log is included with this report in the Appendix.

The purpose of this report is to describe the subsurface materials and conditions encountered in the boring, analyze and evaluate the field and test data, and provide geotechnical recommendations regarding design of the foundations for the tower and ancillary structures for the referenced project.

PROJECT DESCRIPTION

We understand the proposed project will consist of constructing a self-supporting 60- to 80-foot high tower and ancillary support equipment. The tower will be supported on a drilled shaft foundation. Ancillary equipment will be supported on reinforced concrete slab-on-grade pedestals.

Based on previous tower projects for VoiceStream, we understand governing reactions at the base of the monopole tower will consist of vertical compressive forces and shear forces of about 13 kips and an overturning moment of about 11,200 in-kips. We have assumed concrete slab loads will not exceed 500 psf.

If the information or proposed construction varies significantly from that described above, we should be notified immediately so that the applicability of the recommendations presented herein can be re-evaluated.

SITE EXPLORATION PROCEDURES

Field Exploration

The site location was selected by VoiceStream and field located by Terracon. The location of the boring was determined by tape measurements from prominent features in the field. The elevation of the ground surface at the boring location was not determined. The location of the soil boring should be considered accurate only to the degree implied by the means and methods used to define it.

The boring was drilled with a CME 75 truck-mounted rotary drill rig, equipped with a hydraulic head employed in drilling and sampling operations, using continuous flight hollow-stem augers to advance the borings. Representative samples were obtained using the split-barrel sampling procedure (Standard Penetration Test).

In the split-barrel sampling procedure (SPT), disturbed samples are obtained by driving a standard 2-inch outside diameter (OD) split-barrel sampler into the ground with a 140-pound hammer falling a distance of 30 inches. The number of blows required to advance the sampler the last 12 inches, or the interval indicated, of a typical 18-inch penetration is recorded as the standard penetration resistance value (N-value). The N-value provides a reasonable indication of the in-place density of sandy type materials, but only provides an indication of the relative stiffness of cohesive materials since the blow count in these soils is a function of the moisture content. N-values are indicated on the boring log at the SPT depth. The SPT samples were placed and sealed in plastic bags.

Subsurface materials were visually classified and logged in the field by Terracon personnel. The Log of Boring included in the Appendix of this report represents an interpretation of the field log and includes modifications based on laboratory observations and tests of the samples obtained. The log also includes sampling intervals and depths, N-values, graphical material descriptions and encountered water levels, as appropriate. The field exploration and sampling were performed in general accordance with applicable ASTM procedures.

Laboratory Testing

Samples obtained during the field exploration were taken to the laboratory where they were initially classified by a geotechnical engineer based on visual observation, texture, and plasticity in general accordance with the enclosed General Notes and the Unified Soil Classification System. The soil descriptions and estimated group symbols according to the

Unified Soil Classification System are shown on the log for the soils encountered. A brief description of the Unified System is included after the logs.

Representative samples were selected for testing to determine the engineering and physical properties of the soil in general accordance with ASTM or other approved procedures. Following are the laboratory tests performed and a brief description of the purpose for each test:

Natural Water Content: Water (moisture) content representative of field conditions at the time samples were taken; used for classification and general analysis purposes.

Sulfate Content: The potential of the soil to deteriorate normal concrete with Type I Portland cement; used to recommend cement type for concrete adjacent to soil.

Resistivity and pH: The potential of the soil to corrode metal and deteriorate concrete; used to evaluate life of metals and concrete in contact with soil.

Results of the laboratory tests are summarized on the log included in the Appendix. These data, along with the field information, were also used to prepare the exploratory boring log, as appropriate.

SITE AND SUBSURFACE CONDITIONS

Site Description and Local Geology

The proposed tower site is located in the northwest corner of an agricultural field near the southeast corner of the intersection of 1150 South Street and 4700 West Street in Ogden, Utah. At the time of our field exploration, the site consisted of a fenced-off plowed agricultural field. The proposed site is bounded on the north by 1150 South Street, on the east and on the south by additional farm fields, and on the west by 4700 South Street. The ground surface is relatively flat at the site.

According to available geologic maps from the Utah Geologic Survey, the surficial geologic deposits in the immediate area of the site consist of lakebed sediments. The lakebed deposits are typically comprised of an upper desiccated clay crust underlain by interbedded clay, silt and sand lenses.

According to available liquefaction potential maps for Weber County, the proposed site is located in an area designated as high in liquefaction potential.

Subsurface Conditions

Subsurface conditions encountered at the boring location are indicated on the boring log included in the Appendix. Stratification boundaries shown on the log represent the approximate location of changes in material types. In-situ, the transitions between materials may be gradual.

In general the subsurface materials at the site may be described as topsoil overlying silt, sand and clay soils. These materials may be generally described as follows:

Topsoil/roots: About 1 foot of organic clayey soil with roots was encountered at the surface of the boring.

Silt: Silt (ML) soils were encountered beneath the topsoil in the boring, from depths of 1 to 7 feet below the existing grade. These silty soils were generally medium stiff, with N-values ranging from 4 to 6. The natural water content varies from 24 to 33 percent. Test results of a representative sample indicates the sand has a pH of 9.0, a laboratory resistivity of 600 ohm-cm, and a water soluble sulfate content of about 0.006 percent.

Sand: Silty sand (SM) soils were encountered beneath the silt in the boring, from depths of 7 to 22.5 feet below existing grade. These sand soils were generally loose to medium dense with N-values ranging from 8 to 15. The fine portion (percent passing No. 40 sieve) of these soils visually appears to be non-plastic. The natural water content varies from 25 to 33 percent.

Clay: Lean clay (CL) soils were encountered below the sand soil from depths of 22.5 to 31.5 feet (maximum depth explored) below existing grade. The consistency of these clayey soils was generally medium stiff, with N-values in the range of 5 to 6. They visually appear to be moderately to highly plastic. The natural water content varies from 23 to 37 percent.

Groundwater Conditions

The boring was monitored during drilling for the presence and level of groundwater. At the time of our field exploration, water was encountered at a depth of about 5 feet below the ground surface.

It should be recognized that fluctuations of the groundwater table may occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the boring was performed. The evaluation of these factors is beyond the scope of this report. Therefore, groundwater levels during construction, or at other times in the life of the structure, may be higher or lower than the levels indicated on the log. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

ENGINEERING ANALYSIS AND RECOMMENDATIONS

Tower Foundations

In our opinion, the tower can be supported on a drilled pier foundation. Recommended values for allowable end bearing pressure and skin friction are presented in Table 1. These values assume drilled piers having concrete cast in direct contact with adjacent soil (uncased). The allowable bearing end pressure values include a factor of safety of 3. Allowable skin friction values include a factor of safety of 2. We recommend neglecting the upper 3 feet of the subsurface profile because freeze-thaw, cyclic loading, and wet-dry cycles in this zone will loosen supporting material around the tower foundations and will provide very little lateral or vertical support for the tower foundation.

The capacity of a drilled pier foundation has two components, end bearing and skin friction. Piers embedded in the native soils at least 23 feet below the ground surface will develop resistance primarily through skin friction along the side of the pier, with a small contribution from end bearing. Resistance to uplift is derived from skin friction only. Settlement is expected to be less than 1 inch for a drilled pier supporting axial loads of up to 13 kips, and sized using the appropriate allowable bearing pressure values presented in Table 1 below. Note that allowable lateral deflection may govern the design of the pier. Recommended horizontal modulus of subgrade reaction values (k_h), for calculating the lateral load carrying capacity of the pier, are presented in Table 1 below.

Drilling to design depths should be possible with a large single-flight power auger. Due to the very soft soils encountered in our boring, **we anticipate that temporary steel casing or use of the slurry displacement method will likely be required to prevent sloughing and/or caving of the sidewalls and disturbance of the soils for the portion of the drilled pier below groundwater**. Groundwater should be removed from the pier shaft prior to concrete placement. Pier concrete should be placed immediately after completion of drilling and cleaning. If pier concrete cannot be placed in dry conditions, a tremie should be used for

concrete placement. Due to potential sloughing and raveling, foundation concrete quantities may exceed calculated geometric volumes.

If a casing is used for pier construction, it should be withdrawn in a slow, continuous manner maintaining a sufficient head of concrete to prevent infiltration of water or the creation of voids in pier concrete. Pier concrete should have a relatively high fluidity when placed in cased pier holes or through a tremie. Pier concrete with slump in the range of 5 to 7 inches is recommended.

Free-fall concrete placement in drilled shafts will only be acceptable if provisions are taken to avoid striking the concrete on the sides of the hole or reinforcing steel. The use of a bottom-dump hopper, or an elephant's trunk discharging near the bottom of the hole where concrete segregation will be minimized, is recommended.

Shaft bearing surfaces must be cleaned prior to concrete placement. A representative of the geotechnical engineer should observe the bearing surface and shaft configuration.

TABLE 1

SUMMARY OF RECOMMENDED DESIGN PARAMETERS

Layer No.	Depth (ft)	Layer Thickness, t (ft)	Effective Unit Weight of Soil, γ (pcf)	Friction Angle, ϕ (degrees)	Cohesion, c (psf)	Net Allowable Bearing Pressure, q (psf)	Allowable Skin Friction, Compression, S_d (psf)	Allowable Skin Friction, Uplift, S_u (psf)	Horizontal Modulus Of Subgrade Reaction, k_h (pci)
0[(a)]	0-3	3	115	--	--	--	--	--	--
1	3-7	3	115	0	750	650	90	60	20
2	7-22.5	8	120	30	0 **200[(b)]**	1550 **1300[(b)]**	230 **300[(b)]**	150 **200[(b)]**	25 **10[(b)]**
3	22.5-31.5	9	115	0	650	1550	285	190	40

Notes: (a) - Layer neglected due to frost action.
(b) – Use these <u>ultimate</u> values for seismic design due to possible liquefaction of layer.

Allowable pier capacity in compression (pounds) can be calculated by the following equation:

$$Q_{allow} = \pi(q)(d^2)/4 + \pi \sum_{i=1}^{n} (s_d)(d)(t_i) \quad \text{[pounds]}$$

Where: q = allowable bearing pressure (psf)
d = pier diameter (ft)

s_d = allowable skin friction in compression (psf)
t_i = i^{th} soil layer thickness in contact with pier (ft)
i = individual layer
n = total number of layers

The first and second terms in the above equation represent allowable end bearing and skin friction components of pier capacity, respectively. The allowable uplift capacity can be calculated by substituting s_u for s_d in the second term of the equation and neglecting the end bearing component.

Seismic Considerations

The project site is located in Seismic Risk Zone 3 of the Seismic Zone Map for the United States as indicated by the latest Uniform Building Code, Figure 16-2. Based on the results of our field and laboratory test results, we estimate the subsurface soil profile at the site is best represented by Soil Type S_E.

Based on our review of available geologic literature, the Weber-Davis segment of the Wasatch fault zone is located a little over 8.25 miles east of the subject site. The Wasatch fault is believed capable of producing an earthquake magnitude of 7.5 (Richter scale). Averaging the values obtained from Joyner and Boore (1988) and Campbell (1991) attenuation equations results in a peak horizontal ground acceleration at the site of 0.36***g*** for the Wasatch fault. Liquefaction is a concern in the sandy subsurface soils due to the loose conditions encountered in our boring. **Therefore, we recommend using reduced bearing pressure, frictional compression and uplift components, and modulus of subgrade reaction of this layer during a seismic event (see Table 1).**

Buried Metal Corrosion

The pH of on-site soils is about 9.0, with a corresponding resistivity value of 600 ohm-centimeters. Based on criteria presented in the *Handbook of Steel Drainage and Highway Construction Products* (published by the American Iron and Steel Institute), these pH and resistivity values indicate an acceptable service life of about 40 years for 18 gage galvanized steel exposed to on-site soils.

Sulfate Attack on Concrete

The water soluble sulfate content of on-site soils is on the order of 0.006 percent which represents a negligible degree of sulfate attack on concrete exposed to these materials. The degree of attack is based on a range of negligible, moderate, severe and very severe as

presented by the American Concrete Institute Standard 318. These results indicate Type 1 cement can be used for concrete in contact with the on-site soils.

Drainage

Positive drainage should be provided during construction and maintained throughout the life of the proposed project. We recommend the ground surface be graded to slope away from the proposed structures at a minimum gradient of 5 percent for a distance of at least 10 feet.

GENERAL COMMENTS

The analysis and recommendations presented in this report are based upon the data obtained from the boring performed at the indicated location and from other information discussed in this report. This report does not reflect variations that may occur across the site. The nature and extent of such variations may not become evident until construction. If variations appear, it will be necessary to re-evaluate the recommendations of this report.

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of the geotechnical recommendations contained herein with respect to the design and specifications. Terracon should also be retained to provide testing and observation during excavation, grading, foundation and construction phases of the project.

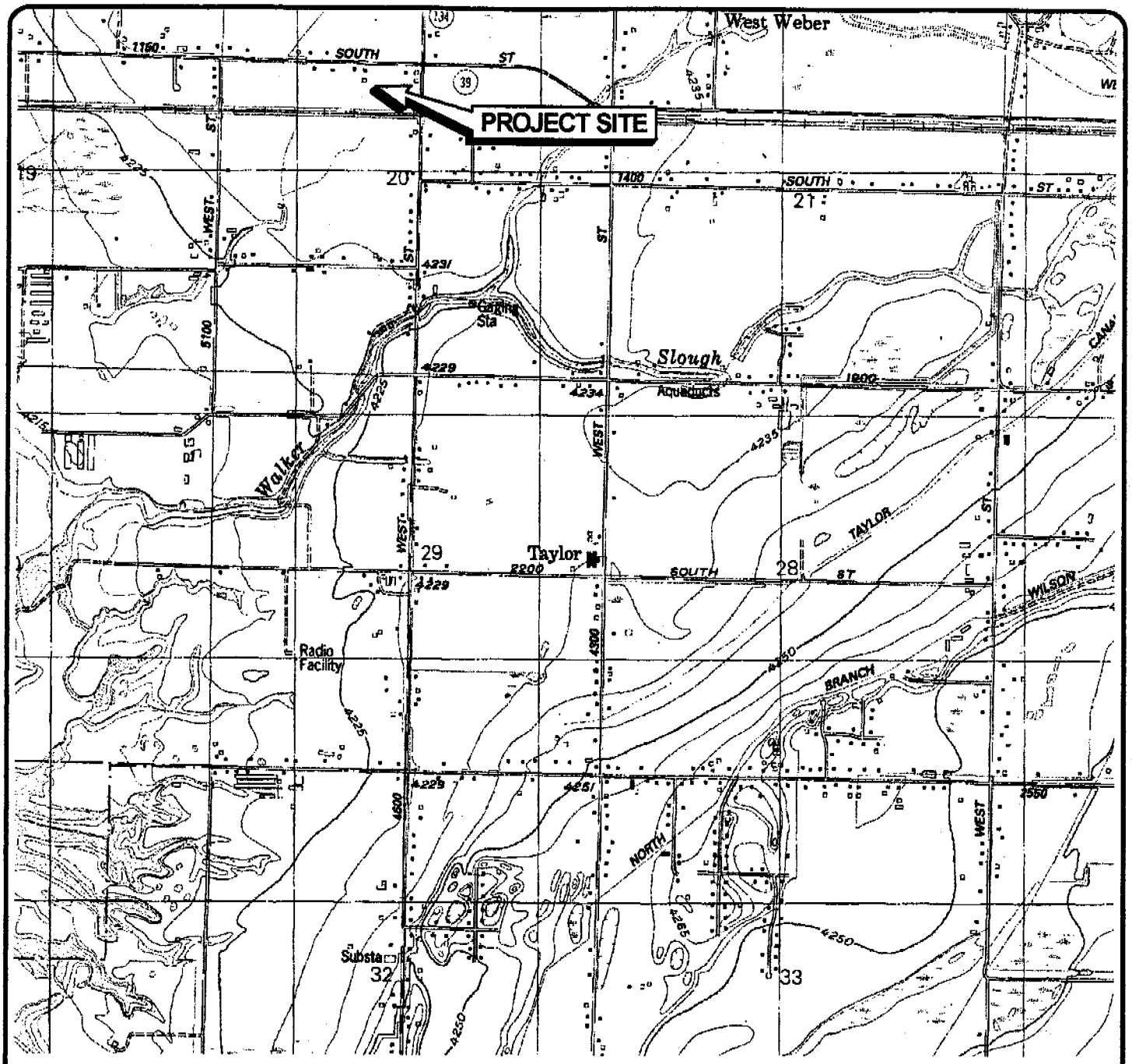
The scope of services for this project does not include, either specifically or by implication, any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes, and either verifies or modifies the conclusions of this report in writing.

REFERENCES

Campbell, K.W., 1991, "*Analysis of Ground-Shaking Hazard and Risk for Lifeline Systems,*" *Lifeline Earthquake Engineering*, Cassaro, M.A., editor: New York, American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering Monograph No. 4, p. 581-590.

Joyner, W.B., and Boore, D.M., 1988, "*Measurement, Characterization, and Prediction of Strong Ground Motion,*" *Earthquake Engineering and Soil Dynamics II – Recent Advances in Ground-Motion Evaluation*, Von Thun, J.L., editor: New York, American Society of Civil Engineers Geotechnical Special Publication No. 20, p. 43-102.



Reference: USGS 7.5-Minute Quadrangles for Roy, Utah

SCALE 1:24,000

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

N

CONTOUR INTERVAL 5 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

PROJECT VICINITY MAP

12TH STREET – SITE SL-1312

OGDEN, UT

Job No. 61005455	Date: Jan. 2001	Drawn By: CJH

Terracon

APPENDIX

LOG OF EXPLORATORY BORING
GENERAL NOTES
UNIFIED SOIL CLASSIFICATION SYSTEM

LOG OF BORING NO. B-1

CLIENT: VoiceStream Wireless

ARCHITECT/ENGINEER:

SITE: 1150 South 4700 West, Ogden, Utah

PROJECT: Monopole Tower, 12th Street Site - SL-1312

Location: See Site Vicinity Map

GRAPHIC LOG	DESCRIPTION	DEPTH (FT.)	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, INCHES	SAMPLES SPT - N BLOWS / FT.	TESTS MOISTURE, %	TESTS DRY DENSITY PCF	TESTS UNCONFINED STRENGTH, PSF	
	1.0 **TOPSOIL:** organic material										
	SILT (ML); dark brown to light brown, medium stiff, moist		ML	1	SS	12	6	24			pH=9.0, Res.= 600 ohm-cm, Sulfate= 0.006%
	--- soft, wet at 5 feet ▽	5	ML	2	SS	12	4	33			
	7.0										
	SILTY SAND (SM); light brown to dark gray, medium dense, wet		SM	3	SS	12	14	27			
	--- loose below 10 feet	10	SM	4	SS	12	8	33			
		15	SM	5	SS	10	15	25			
	--- black below 20 feet --- white lense at 21 feet	20	SM	6	SS	12	10	28			
	22.5										
	LEAN CLAY (CL); black, medium stiff, wet	25	CL	7	SS	12	5	37			
		30	CL	8	SS	14	6	23			
	31.5										
	Bottom of boring at 31.5 feet										

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	▽ 5 ft. WD	▼
WL		
WL		

Terracon

BORING STARTED	1-4-01		
BORING COMPLETED	1-4-01		
RIG	CME-55	FOREMAN	AHS
APPROVED	WGT	JOB #	61005455

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon - 1-3/8" I.D., 2" O.D., unless otherwise noted	HS:	Hollow Stem Auger
ST:	Thin-Walled Tube - 3" O.D., unless otherwise noted	PA:	Power Auger
RS:	Ring Sampler - 2.42" I.D., 3" O.D., unless otherwise noted	HA:	Hand Auger
DB:	Diamond Bit Coring - 4", N, B	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	WB:	Wash Boring or Mud Rotary

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value". For 3" O.D. ring samplers (RS) the penetration value is reported as the number of blows required to advance the sampler 12 inches using a 140-pound hammer falling 30 inches, reported as "blows per foot," and is not considered equivalent to the "Standard Penetration"or "N-value".

WATER LEVEL MEASUREMENT SYMBOLS:

WL:	Water Level	WS:	While Sampling
WCI:	Wet Cave in	WD:	While Drilling
DCI:	Dry Cave in	BCR:	Before Casing Removal
AB:	After Boring	ACR:	After Casing Removal

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	<2	Very Soft
500 – 1,000	2-3	Soft
1,001 – 2,000	4-6	Medium Stiff
2,001 – 4,000	7-12	Stiff
4,001 – 8,000	13-26	Very Stiff
8,000+	26+	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	Ring Sampler (RS) Blows/Ft.	Relative Density
0 – 3	0-6	Very Loose
4 – 9	7-18	Loose
10 – 29	19-58	Medium Dense
30 – 49	59-98	Dense
50+	99+	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 – 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifiers	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1-10
Medium	11-30
High	30+

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UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well-graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel[F, G, H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[E]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			$Cu < 6$ and/or $1 > Cc > 3$[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G, H, I]
			Fines classify as CL or CH	SC	Clayey sand[G, H, I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K, L, M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K, L, M]
		organic	Liquid limit — oven dried / Liquid limit — not dried < 0.75	OL	Organic clay[K, L, M, N] / Organic silt[K, L, M, O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K, L, M]
			PI plots below "A" line	MH	Elastic silt[K, L, M]
		organic	Liquid limit — oven dried / Liquid limit — not dried < 0.75	OH	Organic clay[K, L, M, P] / Organic silt[K, L, M, Q]
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

[A]Based on the material passing the 3-in. (75-mm) sieve.

[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C]Gravels with 5 to 12% fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

[D]Sands with 5 to 12% fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

[E]$Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains ≥ 15% sand, add "with sand" to group name.

[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H]If fines are organic, add "with organic fines" to group name.

[I]If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J]If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K]If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

[L]If soil contains ≥ 30% plus. No. 200 predominantly sand, add "sandy" to group name.

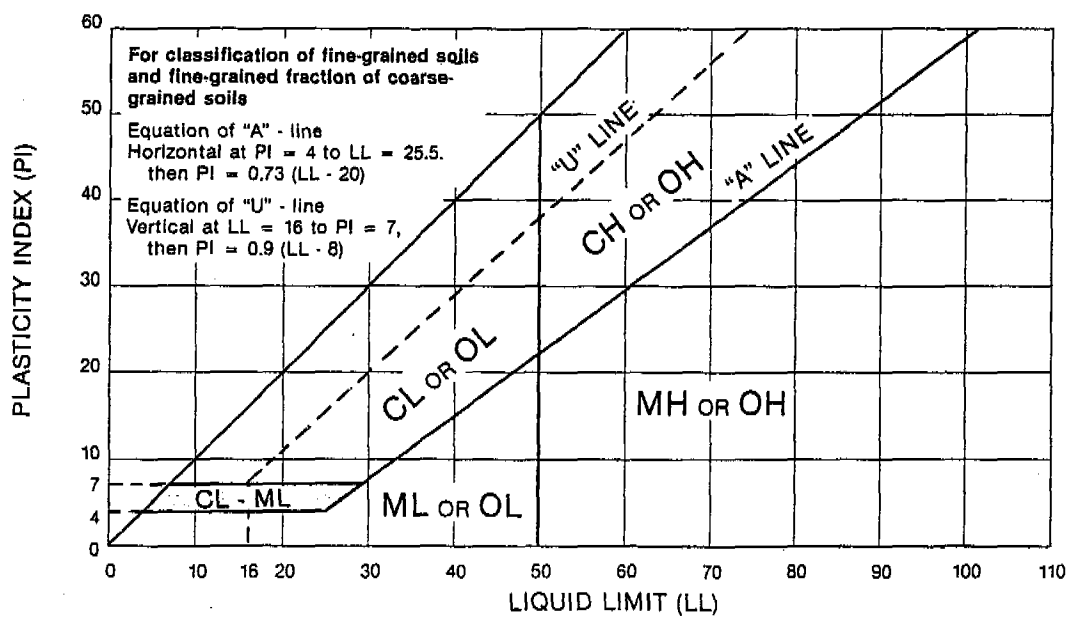
[M]If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N]PI ≥ 4 and plots on or above "A" line.

[O]PI < 4 or plots below "A" line.

[P]PI plots on or above "A" line.

[Q]PI plots below "A" line.



Terracon

Form 111—6-85