BROWNSVILLE
PUBLIC UTILITIES BOARD

Date: July 12, 2024
To: All Vendors
Subject: Addendum #2

REFERENCE: **B058-24 CONSTRUCTION OF AIRPORT SUBSTATION AND CONTROL BUILDING**

This Addendum forms part of the contract and clarifies, corrects or modifies original bid document.

Question 1: Will this project be a turnkey job?

Answer 1: Yes, it is a turnkey job. The awarded contractor will be responsible for the construction and installation of substation and control building.

Question 2: Who is going to be responsible for the site grading?

Answer 2: Brownsville PUB already has a contractor to do the site grading and preparation for the new installation of the substation and control building.

Question 3: Do you have a Geotechnical report ready and available?

Answer 3: Yes, attached is the Geotechnical report.

Question 4: Do you need any access road at this site?

Answer 4: No, it is not required.

Question 5: Will Brownsville PUB also be going out for bid on AFDE-138kV A-Frame Deadend Structure and 138kV Large Angle Dead-End? The Bid B058-24 states those structures will be furnished by owner (BPUB).

Answer 5: Brownsville PUB already purchased those units, and they will be provided at the time of the construction.

Question 6: Who is going to be responsible to tap the transmission lines to A-Frame deadend structures and to energize?

Answer 6: Brownsville PUB will be responsible.

Question 7: What are the calendar days to complete the project?

Answer 7: Brownsville PUB does not have a specific number of calendar days to complete the project. BPUB will consider it when reviewing/evaluating the bids.

Question 8: Is the contractor responsible to pick up, move, transport, and deliver the equipment to the job site? Will BPUB load our trucks with the owner furnished material or is it the responsibility of the contractor to load? What is the distance?

Answer 8: Yes, this project is a turnkey job, and the awarded contractor will be responsible to move the equipment to the job site. contractor will have to coordinate pickup with BPUB on Structural steel pickup and other equipment, and responsible to provide their own loading equipment (forklift, winch truck). The equipment is located at 1495 Robinhood Drive, Brownsville TX, and the travel distance is approximately 3 to 4 miles away. A second unit is located at the Airport Substation, 915 S. Central Avenue, Brownsville, TX about 500 ft away.

Question 9: What about if moving the equipment for the second time? Do we need to move it to the new foundation?

Answer 9: Yes, the awarded contractor will be responsible for moving the equipment the second time.

Question 10: Do you have the weight and dimensions of the equipment?

Answer 10: Yes, attached is a picture of the nameplate and manufacturer design as references.

Question 11: It was mentioned yesterday that the contractor is responsible for the top rock/insulating rock that gets placed inside the station. There is not a bid unit for that, where do we need to put the cost for this?

Answer 11: Yes, see attached Cost Sheet – "Additional Line Item" page 35 rev1 and complete it along with the original cost sheet provided when submitting bid response.
DO NOT FILL PRICING WHEN ACKNOWLEDGING RECEIPT OF THIS ADDENDUM.

The signature of the company agent, for the acknowledgement of this addendum, shall be required. **Complete information below and return via e-mail to: hlopez@brownsville-pub.com and to dsolitaire@brownsville-pub.com.**

I hereby acknowledge receipt of this addendum.

Company: ____

Agent Name: ____

Agent Signature: ____

Address: ____

City: __________________ **State:**__________________ **Zip:**________

Phone Number: ________________ **E-mail address:**______________________

If you have any further questions about the Bid, call 956-983-6375.

Hugo E. Lopez

BY: Hugo E. Lopez
Purchasing

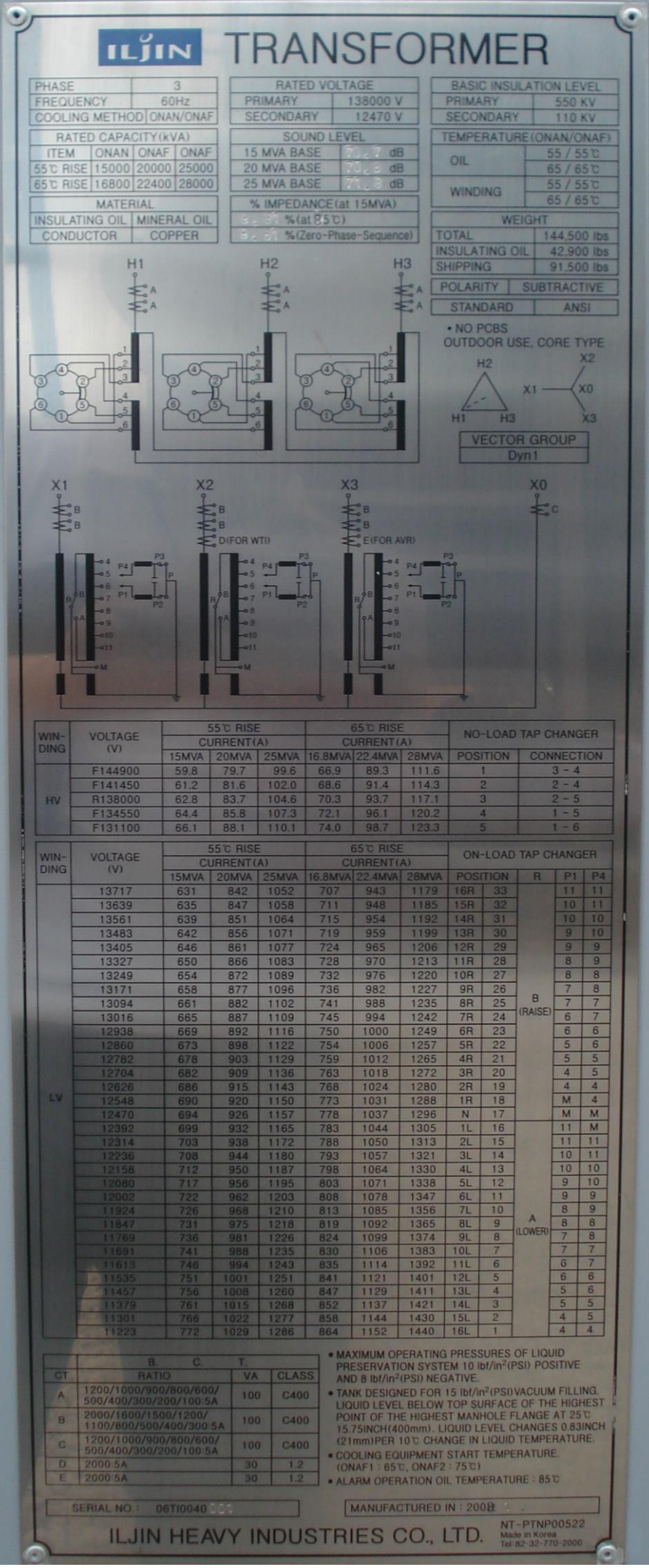
REVISED COST SHEET - Additional LineItem

DO NOT FILL PRICING WHEN ACKNOWLEDGING RECEIPT OF THIS ADDENDUM

Drawing Ref.	NAME AND DESCRIPTION OF CONSTRUCTION UNIT	Owner Furnished	NO. OF UNITS	LABOR PRICE		Material Price	
AP-Q4	**25kV Porcelain Insulator Painting-** Contractor is responsible for supplying labor, material, and equipment to apply 570 High Voltage Insulator Coating ("Seal Guard," Midsun Group, 1-800-4-MIDSUN) to prevent excess leakage current, tracking and flashover to new insulators. Seal Guard shall not be applied to anything made of polymer. The contractor is responsible to be fully trained or have a Midsun supervisor present during application so there is a full warranty in effect following application. The Midsun Insulator Coating is contractor furnished and WHITE in color. The porcelain insulators shall be painted in a dust-free environment (i.e. paint booth or other environment protected area.) **INSULATOR COATING SHALL BE ADDED TO ALL NEW STATION POST INSULATORS, INCLUDING INSULATORS MOUNTED ON NEW SWITCHES.**	N	1 lot				
				TOTAL, GROUP Q			
GROUP T - TESTING							
AP-T1	**Field Testing,** check-out and acceptable testing of the substation facilities as described in the Division FT of the "Contract Documents". The substation testing, check-out and acceptance will be performed by:	NA	1 lot				
				TOTAL, GROUP T			
TOTAL SUBSTATION BID AMOUNT			**$**				
	TOP ROCK/INSULATIN ROCK (INSIDE THE STATION)		1 LOT				

NOTE: LINE ITEM IN RED IS AN ADDITIONAL LINE ITEM

Airport New TRANS.



ILJIN TRANSFORMER

PHASE	3
FREQUENCY	60Hz
COOLING METHOD	ONAN/ONAF

RATED VOLTAGE	
PRIMARY	138000 V
SECONDARY	12470 V

BASIC INSULATION LEVEL	
PRIMARY	550 KV
SECONDARY	110 KV

RATED CAPACITY(kVA)			
ITEM	ONAN	ONAF	ONAF
55℃ RISE	15000	20000	25000
65℃ RISE	16800	22400	28000

SOUND LEVEL	
15 MVA BASE	70.7 dB
20 MVA BASE	70.8 dB
25 MVA BASE	71.8 dB

TEMPERATURE(ONAN/ONAF)	
OIL	55 / 55℃
	65 / 65℃
WINDING	55 / 55℃
	65 / 65℃

MATERIAL	
INSULATING OIL	MINERAL OIL
CONDUCTOR	COPPER

% IMPEDANCE(at 15MVA)	
8.31	%(at 85℃)
8.61	%(Zero-Phase-Sequence)

WEIGHT	
TOTAL	144,500 lbs
INSULATING OIL	42,900 lbs
SHIPPING	91,500 lbs

POLARITY	SUBTRACTIVE
STANDARD	ANSI

- NO PCBS

OUTDOOR USE, CORE TYPE

VECTOR GROUP
Dyn1

WIN-DING	VOLTAGE (V)	55℃ RISE CURRENT(A)			65℃ RISE CURRENT(A)			NO-LOAD TAP CHANGER	
		15MVA	20MVA	25MVA	16.8MVA	22.4MVA	28MVA	POSITION	CONNECTION
HV	F144900	59.8	79.7	99.6	66.9	89.3	111.6	1	3 - 4
	F141450	61.2	81.6	102.0	68.6	91.4	114.3	2	2 - 4
	R138000	62.8	83.7	104.6	70.3	93.7	117.1	3	2 - 5
	F134550	64.4	85.8	107.3	72.1	96.1	120.2	4	1 - 5
	F131100	66.1	88.1	110.1	74.0	98.7	123.3	5	1 - 6

WIN-DING	VOLTAGE (V)	55℃ RISE CURRENT(A)			65℃ RISE CURRENT(A)			ON-LOAD TAP CHANGER				
		15MVA	20MVA	25MVA	16.8MVA	22.4MVA	28MVA	POSITION		R	P1	P4
LV	13717	631	842	1052	707	943	1179	16R	33	B (RAISE)	11	11
	13639	635	847	1058	711	948	1185	15R	32		10	11
	13561	639	851	1064	715	954	1192	14R	31		10	10
	13483	642	856	1071	719	959	1199	13R	30		9	10
	13405	646	861	1077	724	965	1206	12R	29		9	9
	13327	650	866	1083	728	970	1213	11R	28		8	9
	13249	654	872	1089	732	976	1220	10R	27		8	8
	13171	658	877	1096	736	982	1227	9R	26		7	8
	13094	661	882	1102	741	988	1235	8R	25		7	7
	13016	665	887	1109	745	994	1242	7R	24		6	7
	12938	669	892	1116	750	1000	1249	6R	23		6	6
	12860	673	898	1122	754	1006	1257	5R	22		5	6
	12782	678	903	1129	759	1012	1265	4R	21		5	5
	12704	682	909	1136	763	1018	1272	3R	20		4	5
	12626	686	915	1143	768	1024	1280	2R	19		4	4
	12548	690	920	1150	773	1031	1288	1R	18		M	4
	12470	694	926	1157	778	1037	1296	N	17		M	M
	12392	699	932	1165	783	1044	1305	1L	16	A (LOWER)	11	M
	12314	703	938	1172	788	1050	1313	2L	15		11	11
	12236	708	944	1180	793	1057	1321	3L	14		10	11
	12158	712	950	1187	798	1064	1330	4L	13		10	10
	12080	717	956	1195	803	1071	1338	5L	12		9	10
	12002	722	962	1203	808	1078	1347	6L	11		9	9
	11924	726	968	1210	813	1085	1356	7L	10		8	9
	11847	731	975	1218	819	1092	1365	8L	9		8	8
	11769	736	981	1226	824	1099	1374	9L	8		7	8
	11691	741	988	1235	830	1106	1383	10L	7		7	7
	11613	746	994	1243	835	1114	1392	11L	6		6	7
	11535	751	1001	1251	841	1121	1401	12L	5		6	6
	11457	756	1008	1260	847	1129	1411	13L	4		5	6
	11379	761	1015	1268	852	1137	1421	14L	3		5	5
	11301	766	1022	1277	858	1144	1430	15L	2		4	5
	11223	772	1029	1286	864	1152	1440	16L	1		4	4

	B. C. T.		
CT	RATIO	VA	CLASS
A	1200/1000/900/800/600/ 500/400/300/200/100:5A	100	C400
B	2000/1600/1500/1200/ 1100/800/500/400/300:5A	100	C400
C	1200/1000/900/800/600/ 500/400/300/200/100:5A	100	C400
D	2000:5A	30	1.2
E	2000:5A	30	1.2

- MAXIMUM OPERATING PRESSURES OF LIQUID PRESERVATION SYSTEM 10 lbf/in^2(PSI) POSITIVE AND 8 lbf/in^2(PSI) NEGATIVE.
- TANK DESIGNED FOR 15 lbf/in^2(PSI)VACUUM FILLING. LIQUID LEVEL BELOW TOP SURFACE OF THE HIGHEST POINT OF THE HIGHEST MANHOLE FLANGE AT 25℃ 15.75INCH(400mm). LIQUID LEVEL CHANGES 0.83INCH (21mm)PER 10℃ CHANGE IN LIQUID TEMPERATURE.
- COOLING EQUIPMENT START TEMPERATURE. (ONAF1 : 65℃, ONAF2 : 75℃)
- ALARM OPERATION OIL TEMPERATURE : 85℃

SERIAL NO. : 06TI0040[illegible]

MANUFACTURED IN : 2008 [illegible]

ILJIN HEAVY INDUSTRIES CO., LTD.

NT-PTNP00522
Made in Korea
Tel:82-32-770-2000

ITEMS:
1. PROVISION ON BASE FOR SKIDDING WITH VENTILATION HOLES
2. TRANSFORMER LIFTING LUGS
3. STAINLESS STEEL 4 HOLE NEMA GROUND PADS, ON EACH CORNER OF TANK
4. STAINLESS STEEL DIAGRAMMATIC NAMEPLATE
5. 24" DIA, MANHOLE (2) WITH COVER (BOLTED AND GASKETED)
6. WELDED TOP COVER WITH LIFTING EYES (4) FOR COVER ONLY, SLOPED FOR DRAINAGE
7. COOLING RADIATORS (6) WITH ONE ADDITIOANL RADIATOR MOUNTING PROVISION, HOT DIPPED GALVANIZED, UNPAINTED, DEMOUNTABLE WITH ISOLATION VALVES, LIFTING EYES, AND 1/2" DRAIN/VENT BRASS PLUGS.
8. HV DRAWLEAD BUSHING, 138 kV, 650 kV BIL (3) WITH 4 HOLE NEMA PAD
9. LV BOTTOM CONNECTED BUSHING, 25 kV, 150 kV BIL, (4) WITH 4 HOLE NEMA PAD
10. 2" COMBINATION LOWER DRAIN AND FILTER VALVE WITH SAMPLER AND BRASS PLUG
11. 1" UPPER FILTER VALVE AND BRASS PLUG WITH SPLASH BAFFEL INSIDE
12. VTC PRESSURIZATION TEST POINT WITH 1/2" BALL VALVE AND BRASS PLUG
13. LIQUID LEVEL GAUGE WITH CONTACTS, GAUGE CENTER IS AT 25deg C OIL LEVEL
14. LIQUID TEMPERATURE GAUGE WITH CONTACTS
15. PRESSURE VACUUM GAUGE, INSIDE NITROGEN BOX, WITH CONTACTS AND BLEEDER
16. PRESSURE RELIEF DEVICE WITH CONTACTS AND FLAG
17. DE-ENERGIZED NO LOAD MANUAL TAP CHANGER WITH PROVISION FOR PADLOCKING
18. CONTROL BOX, NEMA 4X, 48" x 60" x 18", WITH BOLTED BOTTOM PLATE △1
19. JACK PADS(4) WITH PULLING EYES
20. BOX FOR LV CT TERMINALS AND AUTO TRANSFORMER CORE GROUND BUSHING
21. COOLING FANS (8) MOUNTED ON GALVANIZED STEEL BRACKET
22. WINDING TEMPERATURE GAUGE, SIMULATION SYSTEM, WITH CONTACTS
23. 1" COUPLING AND PLUG
24. THERMOWELLS FOR TEMPERATURE GAUGES
25. SUDDEN PRESSURE RELAY WITH SEAL-IN RELAY, MOUNTED BALL TYPE SHUT OFF VALVE
26. HV STATION CLASS ARRESTER, PORCELAIN, 108 kV, 84 kV MCOV
27. LV STATION CLASS ARRESTER, PORCELAIN, 15 kV, 12.7 kV MCOV
28. PREVENTIVE AUTO TRANSFORMER, LOCATED INSIDE MAIN TRANSFORMER TANK
29. BOX FOR HV CT TERMINALS AND MAIN CORE GROUND BUSHING
30. LOAD TAP CHANGER SWITCH COMPARTMENT, TYPE RMV-II-1500A
31. LTC DE-HYDRATING BREATHER, WITH TUBING AND SHUT OFF VALVE
32. 1" LTC OIL FILL VALVE AND BRASS PLUG
33. 2" LTC VACUUM FILLING NIPPLE AND CAP
34. LTC POSITION INDICATOR WITH DRAG HAND
35. 2" LTC GLOBE TYPE, BRONZE, DRAIN VALVE WITH 3/8" SAMPLER AND BRASS PLUG
36. LTC HAND CRANK OPERATING LOCATION
37. LTC LIQUID LEVEL GAUGE WITH CONTACTS
38. LTC LIQUID TEMPERATURE GAUGE WITH CONTACTS
39. FALL PROTECTION MOUNTING PLATE FOR TOWER
40. BOX FOR NITROGEN BOTTLE AND CONTROLS WITH 2 STAGE REGULATOR
41. ELECTRONIC TEMPERATURE MONITOR, LOCATED INSIDE CONTROL BOX
42. CLAMP TYPE GROUND CONNECTOR (2) SUITABLE FOR 1-0 TO 500 MCM CONDUCTOR
43. 1" VACUUM CONNECTION VALVE AND BRASS PLUG
44. 4/O BARE COPPER CABLES FOR NEUTRAL BUSHING AND LV ARRSTERS TO BOTTOM TANK GROUND PAD △1
45. LTC PRESSURE RELIEF DEVICE WITH CONTACT AND FLAG
46. 4/O BARE COPPER CABLES FOR HV ARRESTERS TO BOTTOM TANK GROUND PAD △1

NOTES:
1. TYPE II MINERAL OIL FILLED TRANSFORMER, APPROXIMATELY 4126 GALLONS
2. OUTDOOR SERVICE
3. PAINT: ANSI-70, ZINC RICH PRIMER, URETHANE OVER EPOXY (VTC PAINT SYSTEM IV), MIN. 10 MIL THK. COATING, TANK INSIDE AND CORE CLAMPS PAINTED WHITE, TOP COVER WITH ANTI-SKID COATING, BASE UNDERCOATED WITH COAL-TAR EPOXY
4. TOUCH UP PAINT KIT PROVIDED
5. UNIT DESIGNED FOR INERT GAS TYPE OIL PRESERVATION SYSTEM
6. SEE 20 SERIES SHEETS FOR SCHEMATIC
7. ACCESSORY WIRING IN RIGID GALVANIZED STEEL CONDUIT; FINAL SHORT RUNS MAY BE FLEXIBLE LIQUID TIGHT CONDUIT; FAN POWER VIA WEATHERPROOF CORDS AND PLUGS
8. CG1 IS FULLY ASSEMBLED, CG2 IS AS SHIPPED
9. UNIT DESIGNED FOR FULL VACUUM FILLING
10. UNIT SHIPS WITH FOLLOWING ITEMS DEMOUNTED;

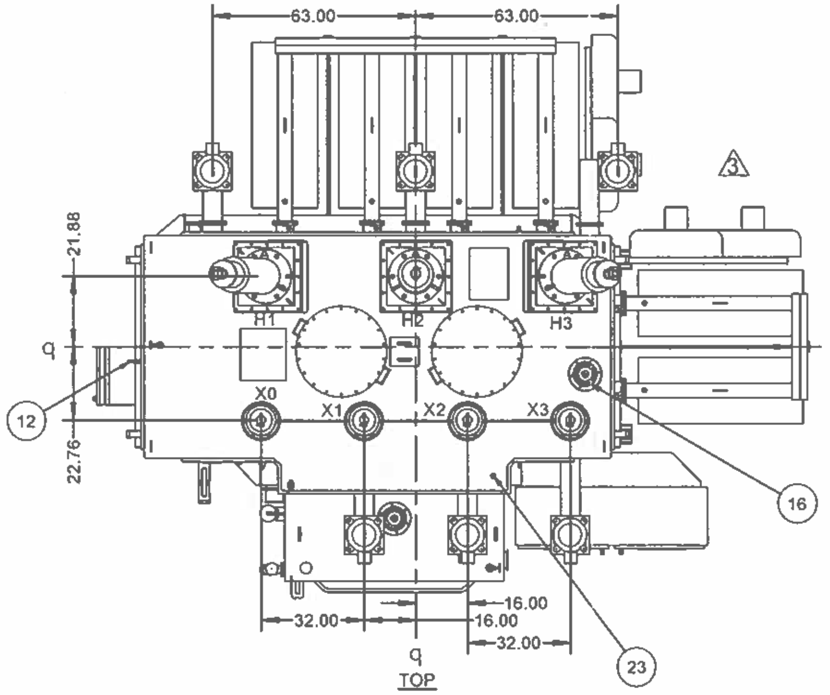
ITEM:	SHIPPING WEIGHT:
HV BUSHINGS/ HV AND LV PADS	1,025 LBS
HV AND LV ARRESTERS WITH HV BRACKET	1,000 LBS
RADIATORS AND FANS	11,250 LBS
OIL FOR RADS (330 GALLONS OF OIL IN TOTE)	2,475 LBS
MAIN UNIT	86,250 LBS

78 GAL OF RAD OIL SHIPS IN GAS SPACE= 1.97" ABOVE 25deg C LEVEL

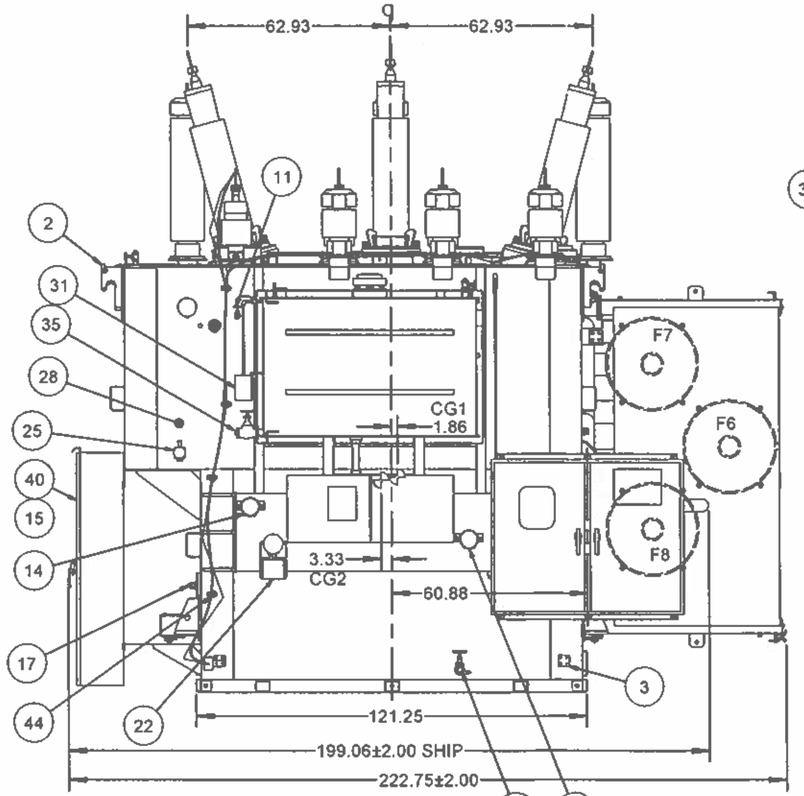
11. UNIT DESIGNED FOR OPERATION AT MINIMUM AMBIENT - 20deg C, 3300 FT ELEVATION
12. GASKET COMPRESSION CONTROL VIA MACHINED GROOVE FLANGES OR METAL TO METAL STOPS EXCEPT FOR ITEMS MOUNTED IN BOXES
13. ALL EXTERNAL HARDWARE IS STAINLESS STEEL
14. CONTRACTED DOCUMENTS SHIP INSIDE CONTROL BOX
15. UNIT SHIPS WITH IMPACT RECORDER
16. TANK SEAMS ARE WELDED INSIDE AND OUTSIDE-NO CORNER WELDS, NO LESS THAN 6" OF CORNER △1
17. SWITCHING IMPULSE TEST REQUIRED
18. 5 YEAR WARRANTY
19. CENTERLINE OF THE TANK TO BE PERMANENTLY MARKED NEAR BASE ON ALL FOUR SIDE OF TANK
20. 3/4" RAISED FLANGES FOR COVER MOUNTED ACCESSORIES
21. CORE AND COIL UNTANKING HEIGHT 250" EXCLUDING SLINGS

△1

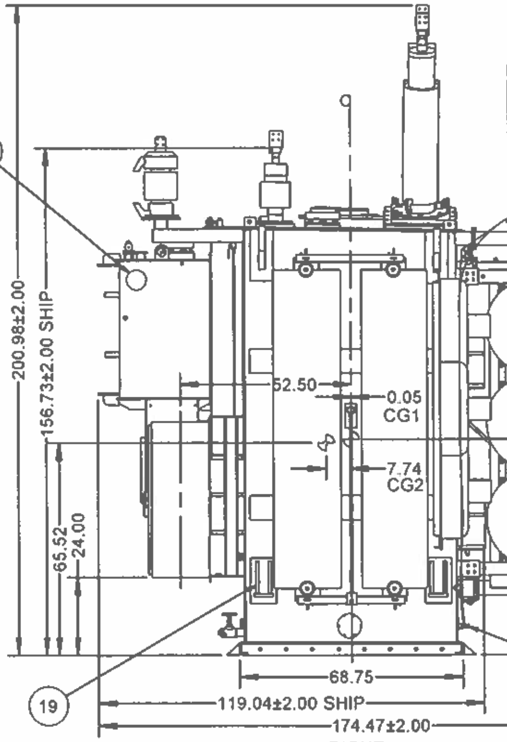
23. UNIT SHIPS WITH FOLLOWING SPARES PER VTC JOB# C872I FOR UNIT C872A; (1) HV BUSHING, (1) LV BUSHING, (1) FAN, (1) GASKET SET
24. UNIT SHIPS WITH FOLLOWING SPARES PER VTC JOB# C872J FOR UNIT C872B; (1) HV BUSHING, (1) LV BUSHING, (1) FAN, (1) GASKET SET



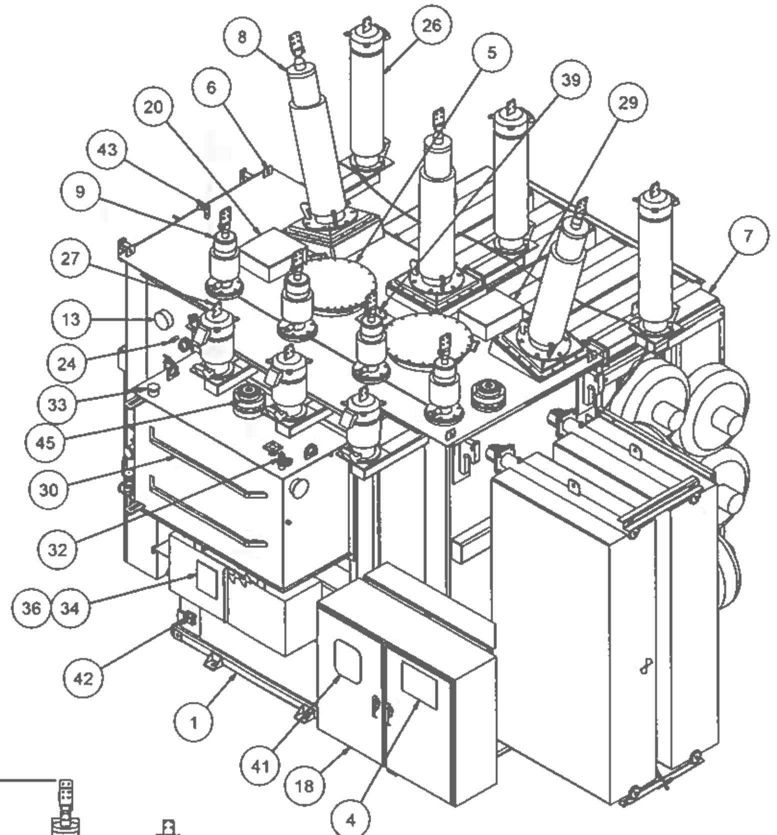
TOP



FRONT



RIGHT



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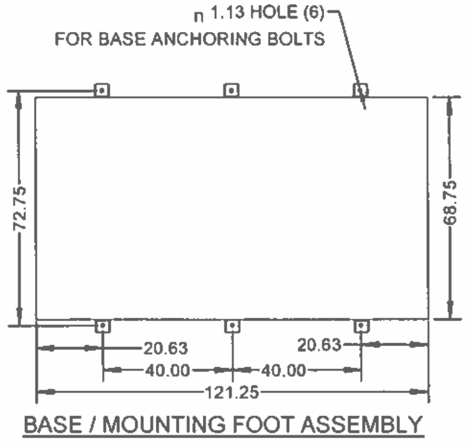


BASE / MOUNTING FOOT ASSEMBLY

Liquid Filled Transformer Data:
MOD/SN: 48015MA067 MVA: 15/20/25 AT 55°C RISE
MVA: 16.8/22.4/28 AT 65°C RISE
3 PHASE, 60 Hz, CLASS: ONAN/ONAF/ONAF
IMP: 9.5 %, +/- 2.0% WT: 102,000 LBS
WINDINGS: COPPER
HV DE-ENERGIZED TAPS: ' 2 X 2.5 %
LV LOAD TAPS: ±16 X 0.625%
HV: 138,000 DELTA, 550 kV BIL, 117 A NOM @ 28 MVA
LV: 12,470 GrdY/7,200V, 110 kV BIL, 1296 A @ 28 MVA

Customer: BROWNSVILLE PUB
Project: RIO GRANDE SUBSTATION

Warranty Field Work:
If, at the job site, the equipment is found to have not conformed to specifications or needs re-work covered under warranty, all parties concerned shall provide full access to Virginia Transformer Corp. or their representatives to work on the unit(s) at the job site. The method of repair/re-work will be determined solely by Virginia Transformer Corp.

TOLERANCES
IF NO TOLERANCES SHOWN ±0.5(12.7) OTHERWISE:
Δ ±0.25(6.3)
o ±1.0(25.4)

ALL DIMENSIONS IN INCHES & IN mm IF SHOWN IN PARENTHESIS

THIS DOCUMENT IS INTENDED FOR COORDINATION PURPOSES ONLY OTHER USES ARE PROHIBITED EXCEPT BY WRITTEN PERMISSION OF VTC.
C872A-101.idw

1	2	3
ITEM 18 REVISED PER CUST COMMENTS MTR 01/26/18	REVISED PER FINAL DESIGN GGA 03/08/18	ADDED FAN BRACKET GGA 04/17/18

VT
VIRGINIA TRANSFORMER CORP.
220 GLADE VIEW DR., N.E. ROANOKE, VA 24012
(540) 345-9892

TITLE: DIMENSIONAL OUTLINE JOB # C872A,B
DWN: PCP CHK: CAM DATE: 01/10/18
D 48015MA067 SHEET 101 REVISION 3

15.00

AUTOMATIC LOAD-TAP-CHANGING LIQUID FILLED TRANSFORMER

SERIAL NUMBER: 48015MA067-
PHASES: 3
CLASS: ONAN/ONAF/ONAF
FREQUENCY: 60 Hz
kVA: 15000/20000/25000 AT 55°C RISE
IMPEDANCE: AT 15000 kVA
kVA: 16800/22400/28000 AT 65°C RISE
LIQUID: TYPE II MINERAL OIL
HV: 138000 BIL: 550 kV COND. MATERIAL: COPPER
MONTH/YEAR OF MANUFACTURE:
LV: 12470 GrdY/7200 BIL: 110 kV COND. MATERIAL: COPPER

APPROXIMATE WEIGHT IN LBS

CORE & COILS	36400
TANK & FITTINGS	33850
LIQUID:	
MAIN TANK 3858 U.S. GALS.	29290
LTC TANK 268 U.S. GALS.	2040
TOTAL WEIGHT	102000
UNTANKING WEIGHT (HEAVIEST PIECE)	36820

MAX. OPERATING PRESSURES OF LIQUID PRESERVATION SYSTEM 9 lbf/in^2 POSITIVE, 7 lbf/in^2 NEGATIVE.
TANK DESIGNED FOR 15 lbf/in^2 VACUUM FILLING.
25°C OIL LEVEL TO TOP FLANGE OF MANHOLE, 16.38 IN.
LIQUID LEVEL CHGS. 0.82 IN. PER 10°C CHG. IN LIQ. TEMP.

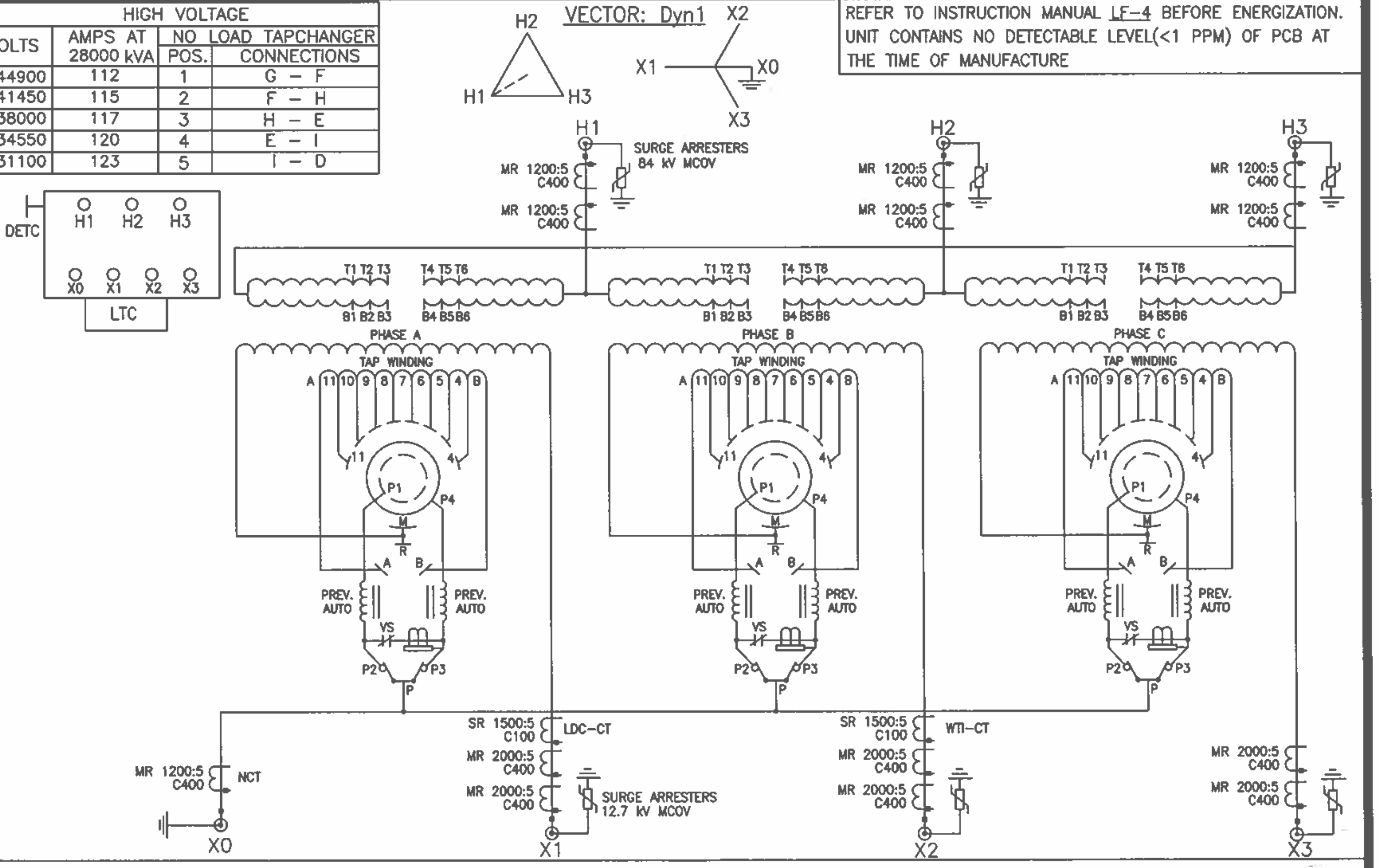
REFER TO INSTRUCTION MANUAL LF-4 BEFORE ENERGIZATION.
UNIT CONTAINS NO DETECTABLE LEVEL(<1 PPM) OF PCB AT THE TIME OF MANUFACTURE

LOW VOLTAGE, LTC: REINHAUSEN, RMV-II

LOAD TAP CHANGER				VOLTS	AMPS AT MAX. KVA
P4 ON	P1 ON	R ON	POS.		
11	11	B	16R	13767	1174
11	10		15R	13717	1179
10	10		14R	13667	1183
10	9		13R	13567	1192
9	9		12R	13468	1200
9	8		11R	13368	1209
8	8		10R	13268	1218
8	7		9R	13218	1223
7	7		8R	13168	1228
7	6		7R	13069	1237
6	6		6R	12969	1247
6	5		5R	12869	1256
5	5		4R	12769	1266
5	4		3R	12719	1271
4	4		2R	12670	1276
4	M		1R	12570	1286
M	M		NOM.	12470	1296
M	11	A	1L	12370	1296
11	11		2L	12270	1296
11	10		3L	12221	1296
10	10		4L	12171	1296
10	9		5L	12071	1296
9	9		6L	11971	1296
9	8		7L	11871	1296
8	8		8L	11772	1296
8	7		9L	11722	1296
7	7		10L	11672	1296
7	6		11L	11572	1296
6	6		12L	11472	1296
6	5		13L	11373	1296
5	5		14L	11273	1296
5	4		15L	11223	1296
4	4		16L	11173	1296

HIGH VOLTAGE

VOLTS	AMPS AT 28000 kVA	NO LOAD TAPCHANGER	
		POS.	CONNECTIONS
144900	112	1	G – F
141450	115	2	F – H
138000	117	3	H – E
134550	120	4	E – I
131100	123	5	I – D



VIRGINIA TRANSFORMER CORP.
ROANOKE, VA, USA

CAUTION
OPERATE MANUAL TAP CHANGER ONLY WHEN TRANSFORMER IS DE-ENERGIZED

11.00
0.19
0.19

MATERIAL: 0.048 STAINLESS STEEL
NON-CORROSIVE OUTDOOR BLACK
LETTER ENGRAVED PROTECTIVE
CLEAR PLASTIC FILM
0.1875 DIA. HOLES (4)

NOTES:

MONTH/YEAR OF MANUFACTURE
FINAL IMPEDANCE, WEIGHTS AND
PRESSURE VALUES WILL BE ENTERED
ON NAMEPLATE AFTER TESTING.
FOR NOMINAL DESIGN IMPEDANCE
SEE OUTLINE DRAWING.

ALL DIMENSIONS IN INCHES & IN mm IF SHOWN IN PARENTHESIS

1	CT RATINGS WERE CORRECTED CAM 2/1/18	2	ADDED WEIGHTS, LEVELS AND PRESSURES GGA 03/09/18

VIRGINIA TRANSFORMER CORP.
220 GLADE VIEW DR., N.E., ROANOKE, VA 24012
(540) 345-9892

TITLE: NAME PLATE (RMV-II LTC)
JOB# C872A,B
DWN: CAM
CHK:3NAD
DATE: 1/2/18
DWG SCALE: 1:1
PLOT SCALE: 1:1
C
48015MA067
SHEET 13
REV 2

Geotechnical Engineering Report

Airport Distribution Substation
Brownsville, Texas

May 18, 2020
Terracon Project No. 88205026

Prepared for:
Brownsville Public Utilities Board
Brownsville, Texas

Prepared by:
Terracon Consultants, Inc.
Pharr, Texas

Terracon
GeoReport

May 18, 2020

Brownsville Public Utilities Board (BPUB)
1425 Robinhood Street
Brownsville, Texas 78521

Attn: Emmanuel Benitez, P.E.
P: [956] 983-6216
E: ebenitez@brownsville-pub.com

Re: Geotechnical Engineering Report
Airport Distribution Substation
Billy Mitchel Blvd. and S. Central Ave.
Brownsville, Texas
Terracon Project No. 88205026

Dear Mr. Benitez:

We have completed the Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. P88205026 dated January 28, 2020. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations for the proposed project.

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, please contact us.

Sincerely,
Terracon Consultants, Inc.
(Texas Firm Registration No.: F-3272)

for: Stephany Chacón, E.I.T.
Staff Engineer

ALFONSO A. SOTO
94153
5/18/2020

Alfonso A. Soto, P.E., D.GE
Principal

REPORT TOPICS

Note: This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the ***GeoReport*** logo will bring you back to this page. For more interactive features, please view your project online at client.terracon.com.

ATTACHMENTS

Note: Refer to each individual Attachment for a listing of contents.

REPORT SUMMARY

Topic [1]	Overview Statement [2]
Project Description	The project will include the construction of substation and transmission line related equipment.
Geotechnical Characterization	■ Groundwater was encountered at depths between 7 and 34 feet below existing grade during drilling operations. ■ The subsurface soils at this site generally consist of Fat Clay (CH) and Silty Sand (SM).
Potential Vertical Rise (PVR)	The existing Potential Vertical Rise (PVR) of the soils within the proposed building area in present condition is about 1 to 2 inches.
Seismic Site Classification	The subsurface conditions within the site are consistent with the characteristics of Site Class D as defined in the International Building Code (IBC) Site Classification.
Earthwork	The subgrade should be prepared as noted in **Earthwork**
Foundations	A shallow or deep foundation system would be appropriate to support the structural loads of the proposed structures, provided the pads are prepared as recommended in this report.
General Comments	This section contains important information about the limitations of this geotechnical engineering report.

1. If the reader is reviewing this report as a pdf, the topics above can be used to access the appropriate section of the report by simply clicking on the topic itself.
2. This summary is for convenience only. It should be used in conjunction with the entire report for design purposes.

Geotechnical Engineering Report

Airport Distribution Substation
Billy Mitchel Blvd. and S. Central Ave.
Brownsville, Texas
Terracon Project No. 88205026
May 18, 2020

INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed additions to the existing Airport Distribution Substation located at Billy Mitchel Blvd. and S. Central Ave. in Brownsville, Texas. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil conditions
- Groundwater conditions
- Site preparation and earthwork
- Excavation considerations
- Foundation design and construction
- Floor slab design and construction
- Seismic site class per IBC

The geotechnical engineering Scope of Services for this project included the advancement of 3 test borings to depths of approximately 50 feet below existing site grades.

Maps showing the site and boring locations are presented in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil samples obtained from the site during the field exploration are included on the boring logs in the **Exploration Results** section.

SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project site is located south of the intersection of Billy Mitchel Blvd. and S. Central Ave. in Brownsville, Texas. Latitude/Longitude: 25.906247°, -97.447431° See **Site Location**
Existing Improvements	Currently energized and operational substation
Current Ground Cover	Caliche
Existing Topography	Relatively flat and level.

Item	Description
Geology	Based on the Geologic Atlas of Texas, McAllen – Brownsville prepared by The University of Texas, the site is located on the Alluvium Formation of the Holocene (Recent) Period of the Quaternary Age. Floodplain deposits, lower course of Rio Grande, are divided into areas dominantly mud and areas dominantly silt and sand. All other areas are alluvium undivided, except for some areas where tidal flat areas are mapped. The soils are mostly composed of clay, silt, sand, gravel and organic matter. The silt and sand are described as calcareous and dark gray to dark brown in color. The sand is mostly quartz and the gravel along Rio Grande include sedimentary rocks from the Cretaceous and Tertiary and a wide variety of igneous and sedimentary rocks from Trans-Pecos Texas, Mexico, and New Mexico including agate. The gravel in side streams of the Rio Grande is mostly Tertiary rocks and chert derived from Uvalde Gravel which caps divide.

PROJECT DESCRIPTION

Item	Description
Information Provided	*Technical Specifications for the Scope of Work* provided by Brownsville Public Utilities Board via email on 01/24/2020.
Project Description	The project will include the construction of substation and transmission line related structures and equipment.
Construction Type	The proposed structures may be supported by a shallow (grade-supported pads and mats) and/or deep (straight-sided drilled shafts or direct embedded poles) foundation system.

GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of site preparation and foundation options. Conditions encountered at each exploration point are indicated on the individual logs. The individual logs and the GeoModel can be found in the **Exploration Results** section of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at each boring location, refer to the GeoModel.

Model Layer	Layer Name	General Description
1	**CLAY**	Fat Clay (CH) Soft to hard
2	**SAND**	Silty Sand (SM) Loose to very dense

Groundwater Conditions

The boreholes were observed during and after completion of drilling for the presence and level of groundwater. The water levels observed are noted on the attached boring logs, and are summarized below.

Location	Depth to groundwater (feet)		
	During drilling	15 minutes after initial groundwater reading	After boring completion
B-1	34	34	7
B-2	16	12	7½
B-3	13	8	8

The Silty Sand (SM) soils are considered volumetrically stable and due to their granular nature may transmit water easily during rainfall seasons. Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. 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 boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project. The boreholes were backfilled with cement-bentonite grout after completion of the groundwater level observations.

GEOTECHNICAL OVERVIEW

Our findings indicate the proposed building structure can be supported on a shallow or deep foundation system. The desired foundation system may be used at this site provided the site and foundation are designed and constructed as recommended in this report.

The suitability and performance of a soil supported foundation for a structure depends on many factors including the magnitude of soil movement expected, the type of structure, the intended use of the structure, the construction methods available to stabilize the soils, and our understanding of the owner’s expectations of the completed structure's performance.

Expansive soils and soft compressible soils are present on this site. This report provides recommendations to help mitigate the effects of soil settlement, shrinkage and expansion. However, even if these procedures are followed, some movement in the structure should be anticipated. Eliminating the risk of movement may not be feasible, but it may be possible to further reduce the risk of movement if significantly more expensive measures are used during construction. We would be pleased to discuss other construction alternatives with you upon request.

Geotechnical engineering recommendations for foundation systems and other earth connected phases of the project are outlined below. The recommendations contained in this report are based upon the results of data presented herein, engineering analyses, and our current understanding of the proposed project.

The **General Comments** section provides an understanding of the report limitations.

Swell Test Results

To further evaluate the expansive characteristics of the clayey soil, one-dimensional vertical swell tests were conducted on selected specimens. The results of these tests are shown in the following table.

Swell Test Results

Boring	Depth (feet)	Surcharge (psf)	Initial Moisture (%)	Final Moisture (%)	Percent Swell (%)
B-1	5.0	100	25.5	27.3	0.8
B-1	5.0	700 [1]	24.5	26.0	0.1

1. Swell test specimens were applied a surcharge pressure during testing that approximated the existing soil overburden.

The test results indicate that the onsite soils have a moderate swell potential in their existing condition. However, these soils, if they were allowed to dry out, could have greater potential for volumetric changes.

EARTHWORK

Earthwork will include clearing and grubbing, excavations and fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria as necessary to render the site in the state considered in our geotechnical engineering evaluation for foundations and pavements.

Site Preparation

Construction areas should be stripped of all caliche, topsoil and other unsuitable material. Additional excavation as recommended in this report or as needed should be performed within the proposed building area. Once final subgrade elevation has been achieved, the exposed subgrade should be carefully proofrolled with a 15-ton pneumatic roller or a fully loaded dump truck to detect weak zones in the subgrade. Special care should be exercised when proofrolling the fill soils to detect soft/weak areas. Weak areas detected during proofrolling, as well as zones of fill containing organic matter and/or debris should be removed and replaced with select fill in the proposed building area. Proper site drainage should be maintained during construction, so that ponding of surface runoff does not occur and cause construction delays and/or inhibit site access.

Subsequent to proofrolling, and just prior to placement of fill, the exposed subgrade within the construction area should be evaluated for moisture and density. If the moisture, density, and/or the requirements do not meet the criteria described in the table below, the subgrade should be scarified to a minimum depth of 8 inches, moisture adjusted and compacted to at least 95 percent of the Standard Effort (ASTM D 698) maximum dry density. Select fill should meet the following criteria.

Fill Material Types

Engineered fill should consist of approved materials, free of organic material, debris and particles larger than about 2 inches. The maximum particle size criteria may be relaxed by the geotechnical engineer of record depending on construction techniques, material gradation, allowable lift thickness and observations during fill placement. Soils for use as engineered fill material should conform to the following specifications:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Aggregate Base Course [2]	SC, GC, Caliche, Crushed Limestone, Crushed Concrete	Top 6 inches of pad areas.
Select Fill	CL and/or SC (7≤PI≤20)	Must be used to construct the pads under the structures and all grade adjustments.
On-Site Soils	CL/CH	On-site CL soils may be suitable for use as fill within the structure areas as long as they are free from organics, cohesive and have a PI between 7 and 20.

1. Prior to any filling operations, samples of the proposed borrow and on-site materials should be obtained for laboratory moisture-density testing. The tests will provide a basis for evaluation of fill compaction by in-place density testing. A qualified soil technician should perform sufficient in-place density tests during the

filling operations to evaluate that proper levels of compaction, including dry unit weight and moisture content, are being attained.

2. Crushed limestone and crushed concrete material should meet the requirements of 2014 TxDOT Item 247, Type A, or D, Grades 1-2 and 3. The select fill materials should be free of organic material and debris, and should not contain stones larger than 2 inches in the maximum dimension. The clayey gravel and caliche materials should meet the gradation requirements of Item 247, Type B, Grades 1-2 and 3 as specified in the 2014 TxDOT Standard Specifications Manual and a Plasticity Index between 7 and 20.

Fill Compaction Requirements

Structural and general fill should meet the following compaction requirements.

Item	Description
Fill Lift Thickness	The fill should be placed in thins; loose lifts of about 8 inches, with compacted thickness not exceeding 6 inches.
Compaction Requirements (on-site soils)	The on-site soils should be compacted to at least 95 percent of the Standard Effort (ASTM D698) maximum dry density within 4 percentage points above the optimum moisture content.
Compaction Requirements (select fill)	The select fill should be compacted to at least 95 percent of the Standard Effort (ASTM D698) maximum dry density within 2 percentage points of the optimum moisture content.

Wet Weather/Soft Subgrade Conditions

Construction operations may encounter difficulties due to the wet or soft surface soils becoming a general hindrance to equipment due to rutting and pumping of the soil surface, especially during and soon after periods of wet weather.

If the subgrade cannot be adequately compacted to minimum densities as described above, one of the following measures will be required: 1) removal and replacement with select fill, 2) chemical treatment of the soil to dry and increase the stability of the subgrade, or 3) drying by natural means if the schedule allows.

In our experience with similar soils in this area, chemical treatment is an efficient and effective method to increase the supporting value of wet and weak subgrade. Terracon should be contacted for additional recommendations if chemical treatment of the soils is needed.

Prior to placing any fill, all surface vegetation, topsoil, possible fill material and any otherwise unsuitable materials should be removed from the construction areas. Wet or dry material should either be removed or moisture conditioned and recompacted. After stripping and grubbing, the subgrade should be proof-rolled where possible to aid in locating loose or soft areas. Proof-rolling can be performed with a 15-ton roller or fully loaded dump truck. Soft, dry and low-density soil should be removed or compacted in place prior to placing fill.

Grading and Drainage

It is important that positive drainage be established during construction such that water will not pond around the structures during or following the construction period.

All grades must be adjusted to provide positive drainage away from the structures. Where paving or flatwork abuts the structures, care should be taken that the joint is properly sealed and maintained. Roof drains should discharge away from the control building.

Earthwork Construction Considerations

Shallow excavations, for the proposed structure, are anticipated to be accomplished with conventional construction equipment. Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of floor slabs. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over, or adjacent to construction area should be removed. If the subgrade freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted, prior to floor slab construction.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, “Excavations” and its appendices, and in accordance with any applicable local, and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

Construction Observation and Testing

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of vegetation and top soil, proof-rolling and mitigation of areas delineated by the proof-roll to require mitigation.

Each lift of compacted fill should be tested, evaluated, and reworked as necessary until approved by the Geotechnical Engineer prior to placement of additional lifts. Each lift of fill should be tested for density and water content at a frequency of at least one test for every 2,500 square feet of compacted fill in the building area and 5,000 square feet in pavement areas. One density and water content test for every 50 linear feet of compacted utility trench backfill.

In areas of foundation excavations, the bearing subgrade should be evaluated under the direction of the Geotechnical Engineer. In the event unanticipated conditions are encountered, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.

Corrosion Considerations

The table below lists the results of laboratory soluble sulfate, soluble chloride, pH and resistivity testing. The values may be used to estimate potential corrosive characteristics of the on-site soils with respect to contact with the various underground materials which will be used for project construction.

Corrosivity Test Results Summary

Boring	Sample Depth (feet)	Soil Description	Soluble Sulfate (%)	Soluble Chloride (%)	pH	Resistivity (ohm-cm)
B-3	6 - 8	Fat Clay (CH)	4,817	2,475	7.6	116

Results of soluble sulfate testing indicate samples of the on-site soils tested possess severe sulfate concentrations when classified in accordance with Table 4.3.1 of the ACI Design Manual. Concrete should be designed in accordance with the provisions of the ACI Design Manual, Section 318, Chapter 4. To improve sulfate resistance of concrete in severe sulfate exposure when Type V cement is not available, the following should be considered:

- Use of Type I-II modified cement for sulfate resistance
- Cement should have a tricalcium aluminate content of not more than 8%.
- Concrete mixture should contain at least 20% Class F fly ash.
- Provide air-entrainment of 4% to 7% by volume.
- Lower the water to cement ratio to 0.4 to 0.45.

Thermal Resistivity Testing

A laboratory thermal resistivity (TR) was performed on a remolded specimen of representative soils from the native soils. The bulk sample was recovered from the upper 5 feet of soil in the vicinity of boring B-2. The results of TR testing are included in **Exploration Results**.

Electrical Earth Resistivity Testing (EER)

Terracon performed two (2) field EER survey alignments at location selected by the client following ASTM G-57, using the Four-Electrode Wenner method. The results of EER testing are included in **Exploration Results**.

FOUNDATIONS SYSTEMS

The proposed structures, depending on the load requirements and expected performance, can be supported on a variety of foundations which include drilled piers, mats, and slabs. Near-surface foundations, such as the equipment pads and the slab foundations may be sensitive to movement. If a structure can withstand the anticipated movement presented in this report, then spread footings may be utilized.

A slab foundation would be appropriate for the proposed building-type structures. However, spread footings should not be utilized for buildings or structures sensitive to movement because of the increased risk of differential movement. Thickened and widened sections of the slab could be constructed for areas of concentrated loads.

A deep foundation system, such as drilled piers, would be appropriate to support the structural loads of dead-end structures, and those structures requiring more capacity than a shallow foundation can provide. Recommendations for these types of foundation systems are provided in the following sections, along with other geotechnical considerations for this project.

Design Parameters – Slab-on-Grade Foundation

The foundation design parameters presented below are based on our evaluation using published theoretical and empirical design methods.

These were developed based on our understanding of the proposed project, our interpretation of the information and data collected as a part of this study, our area experience and the results of our evaluation. The structural engineer should select the appropriate slab design method and code for the amount of anticipated slab movement indicated.

The slab-on-grade foundation may be designed using the following parameters provided the subgrade is prepared as outlined in the **Earthwork** and **Floor Slabs** sections of this report:

Item	Description
Select Fill Pad	Minimum 2 feet of select fill over 8 inches of moisture conditioned and compacted on-site soils.

Item	Description
Allowable Bearing Pressure [1] ■ **Compacted select fill**	Net Total Load - 2,500 psf
Climatic Rating	15
Design Plasticity Index	24
Soil Support Index	0.90
Estimated PVR [2]	About 1 inch
Approximate total settlement [3]	About 1 inch
Estimated Differential Settlement [3]	Approximately ½ of total settlement
Min. perimeter grade beam embedment [4]	18 inches below finished grade

1. The net allowable bearing pressure provided above include a factor of safety of at least 2.
2. The slab-on-grade foundation system should be designed to tolerate the anticipated soil movement and provide satisfactory support to the proposed structure. The foundation should have adequate exterior and interior grade beams to provide sufficient rigidity to the foundation system such that the slab deflections that result are considered tolerable to the supported structure.
3. This estimated post-construction settlement is assuming proper construction practices are followed. Settlement response of a select fill supported slab is influenced more by the quality of construction than by soil-structure interaction. Therefore, it is essential that the recommendations for foundation construction be strictly followed during the construction phases of the building pad and foundation.
4. To bear within the select fill or moisture conditioned and recompacted on-site soils. The grade beams may be thickened and widened where necessary to support column loads.

Construction Considerations for Slab-on-Grade Foundation

Excavations for grade beams should be performed with equipment capable of providing a relatively clean bearing area. The bottom 6 inches of the excavations should be completed with a smooth-mouthed bucket or by hand labor. The excavations should be neatly excavated and properly formed. Debris in the bottom of the excavation should be removed prior to reinforcing steel placement. Water should not be allowed to accumulate at the bottom of the excavation. Due to the presence of dry soils, caving of grade beam excavation may occur. Therefore, the foundation contractor should be prepared to use forms.

To reduce the potential for groundwater seepage into the excavations and to minimize disturbance to the bearing area, we recommend that concrete and reinforcing steel be placed as soon as possible after the excavations are completed. Excavations should not be left open for more than 36 hours. The bearing surface of the grade beams should be evaluated after excavation is completed and immediately prior to placing concrete.

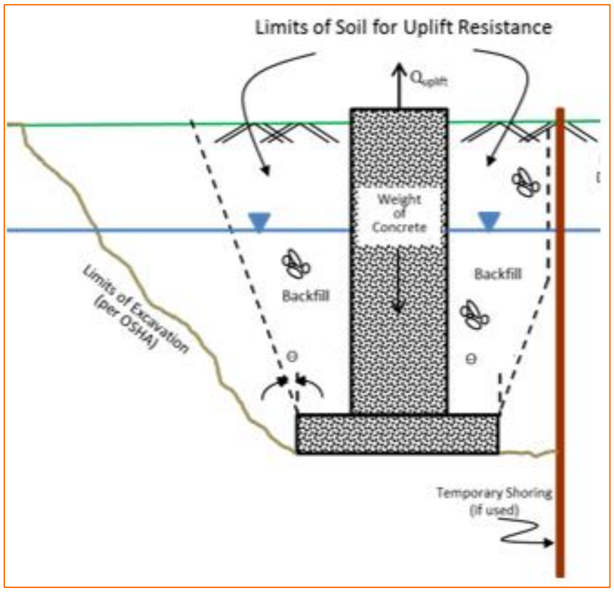
Design Recommendations – Spread Footing Foundation

A spread footing foundation system may be used to support some of the planned structures that are not sensitive to movement. On-site clay soils have a moderate to high potential for shrink/swell movements. The PVR of the soils in the general area of the substation is expected to be about 1 to 2 inches. Some industrial structures may not be affected by movements of this magnitude and shallow spread footings might be a cost-effective foundation option.

Spread footings may be considered in the design of the foundations to support the main column loads. Lateral loads transmitted to the footings should be resisted by a combination of soil-concrete friction on the base of the footing and passive pressure on the side of the footing. To resist lateral forces, a net allowable passive resistance may be utilized for portions of footings extending at least 30 inches below finished grade. If the footing is formed during construction, the open space between the footing and the in-situ soils should be backfilled with soils. Also, care should be taken to avoid disturbance of the footing bearing area since loose material could increase settlement and decrease resistance to lateral loading.

The spread footings can provide some uplift resistance for those structures subjected to wind or other induced structural loading.

Uplift resistance of spread footings can be developed from the effective weight of the footing and the overlying soils. As illustrated on the subsequent figure, the effective weight of the soil prism defined by diagonal planes extending up from the top of the perimeter of the foundation to the ground surface at an angle, θ, of 20 degrees from the vertical can be included in uplift resistance. The maximum allowable uplift capacity should be taken as a sum of the effective weight of soil plus the dead weight of the foundation, divided by an appropriate factor of safety. A soil unit weight of 120 pcf should be used for the backfill. This unit weight should be reduced to 58 pcf for portions of the backfill or natural soils below the groundwater elevation.



Design values for the footings are presented below.

Item	Description
Minimum Embedment Below Finished Grade [1]	2½ feet
Net Allowable Bearing Pressure [7]	Total Load - 2,500 psf
Approximate total settlement [2]	About 1 inch
Estimated Differential Settlement [3]	Approximately ½ of total settlement
Allowable Passive Pressure [4]	650 psf (if considered)
Coefficient of Sliding Friction [5]	0.40
Uplift Resistance [6]	Foundation Weight (150 pcf) & Soil Weight (120 pcf)

1. To bear within the native soils or select fill.
2. This estimated post-construction settlement of the shallow footings is without considering the effect of stress distribution from adjacent foundations and assuming proper construction practices are followed. A clear distance between the footings of one footing size should not produce overlapping stress distributions and would essentially behave as independent foundations.
3. Differential settlement may result from variances in subsurface conditions, loading conditions and construction procedures. The settlement response of the footings will be more dependent upon the quality of construction than upon the response of the subgrade to the foundation loads. We estimate that the differential settlement should be approximately one-half of the total settlement. Settlement of footings will be more sensitive to installation techniques than to soil-structure interaction.
4. The passive pressure along the exterior of the footings should be neglected unless pavement is provided up to the edge of the structure. For interior footings, the allowable passive pressure may be used for the entire depth of the footing. The passive pressure provided above includes a factor of safety of at least 3.
5. Lateral loads transmitted to the footings will be resisted by a combination of soil-concrete friction on the base of the footings and passive pressure on the side of the footings.
6. The ultimate uplift capacity of shallow footings should be reduced by an appropriate factor of safety to compute allowable uplift capacity.
7. The net allowable bearing pressure provided above include a factor of safety of at least 2.

Construction Considerations for Spread Footing Foundations

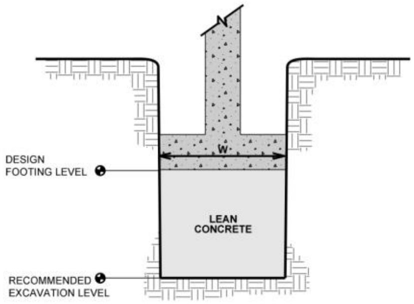
As noted in **Earthwork**, the footing excavations should be evaluated under the direction of the Geotechnical Engineer. The base of all foundation excavations should be free of water and loose soil, prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Care should be taken to prevent wetting or drying of the bearing materials during construction. Excessively wet or dry material or any loose/disturbed material in the bottom of the footing excavations should be removed/reconditioned before foundation concrete is placed. Due to the presence of dry soils, caving of excavation may occur. Therefore, the foundation contractor should be prepared to use forms.

Excavation should be accomplished with a smooth-mouthed bucket. If a toothed bucket is used, excavation with this bucket should be stopped 6 inches above the final bearing surface and the excavation completed with a smooth-mouthed bucket or by hand labor.

If the footing foundations are over-excavated and formed, the backfill around the foundation sides should be achieved with compacted select fill, lean concrete, compacted cement stabilized sand (two sacks cement to one cubic yard of sand) or flowable fill. Compaction of select fill should be as described later in this section of the report.

The bearing surface should be excavated with a slight slope to create an internal sump for runoff water collection and removal. If surface runoff water in excess of 2 inches accumulates at the bottom of the excavation, it should be pumped out prior to concrete placement. Under no circumstances should water be allowed to adversely affect the quality of the bearing surface. If the spread footing is buried, backfill above the foundation may be the excavated on-site soils or select fill soils. Backfill soils should be compacted to at least 95 percent of the maximum dry density as determined by the standard moisture/density relationship test (ASTM D 698). Moisture contents for on-site soils and imported select fill soils should be within 2 percentage points of the optimum moisture content. The backfill should be placed in thin, loose lifts of about 8 inches, with compacted thickness not to exceed 6 inches.

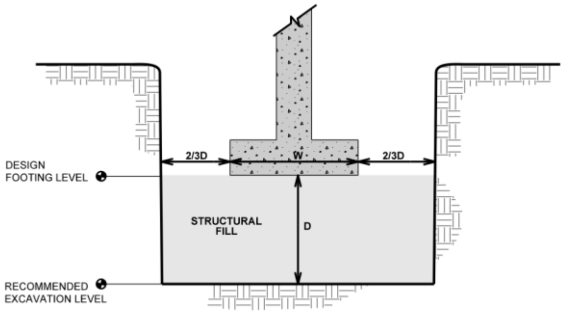
If unsuitable bearing soils are encountered at the base of the planned footing excavation, the excavation should be extended deeper to suitable soils, and the footings could bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. This is illustrated on the sketch below.



LEAN CONCRETE BACKFILL

NOTE: EXCAVATIONS ARE SHOWN VERTICAL; HOWEVER, THE SIDEWALLS SHOULD BE SLOPED AS NECESSARY FOR SAFETY

Over-excavation for structural fill placement below footings should be conducted as shown below. The over-excavation should be backfilled up to the footing base elevation, with select fill placed, as recommended in the **Earthwork** section.



OVER-EXCAVATION / BACKFILL ZONE

NOTE: EXCAVATIONS ARE SHOWN VERTICAL; HOWEVER, THE SIDEWALLS SHOULD BE SLOPED AS NECESSARY FOR SAFETY

Design Recommendations – Mat Foundation

A mat foundation may be utilized for some of the structures at the site. The Potential Vertical Rise (PVR) of the soils encountered at the site is about 1 to 2 inches in present condition. Based on the stiffness of a mat foundation, we anticipate that a PVR of about 1 inch, the typical design movement for these types of structures, can be tolerated.

The mat can be designed as a uniform thick concrete member extending above final grade or can be designed as a less thick member with the main mat portion buried and skids extending above final grade to support the structure.

The mat should be analyzed using a soil-structure interaction program to identify areas of high contact stresses, excessive movements and large moments. The subgrade and select fill soils should be prepared as outlined in the **Earthwork** section of this report, which contains material and placement requirements for select fill, as well as other subgrade preparation recommendations.

Item	Description
Select Fill Pad	As needed (Min. 2 feet)
Minimum Mat Embedment Depth [1]	8 inches below final grade
Maximum Contact Pressures	2,500 psf
Modulus of Subgrade Reaction	75 pounds per cubic inch (pci)
Soil Unit Weight [2]	100 pounds per cubic foot (pcf)
Estimated PVR [3]	About 1 inch

Item	Description
Approximate total settlement [4]	About 1 inch
Estimated differential settlement [4]	Approximately ½ of total settlement

1. To bear within the select fill.
2. A buried mat would provide more resistance to uplift than the uniform thick mat since the weight of the soil overlying the mat would also be included in the uplift resistance computations. In addition to the weight of foundation and structure, any soil directly overlying the foundation may also be considered. The soil unit weight provided above may be assumed for the on-site soils placed above the footing, provided the fill is properly compacted.
3. The buried mat foundation system should be designed to tolerate the anticipated soil movement and provide satisfactory support to the proposed structures.
4. This estimated post-construction settlement is assuming proper construction practices are followed.

Construction Considerations for Mat Foundations

Excavations for a mat foundation should be performed with equipment capable of providing a relatively clean bearing area. The bottom 6 inches of the excavations should be completed with a smooth-mouthed bucket or by hand labor.

The excavations should be neatly excavated and properly formed. If neat excavation is not possible then the foundation should be over-excavated and formed. All loose materials should be removed from the over-excavated areas and filled with lean concrete, compacted cement stabilized sand (two sacks cement to one cubic yard of sand) or flowable fill (ACI-229R).

Steel should be placed and the foundation poured the same day of excavation. If not, a seal slab consisting of lean concrete should be poured on the same day the contractor achieves the final bearing level in order to protect the exposed foundation soils. The bearing surface should be excavated with a slight slope to create an internal sump for runoff water collection and removal. If surface runoff water in excess of 2 inches accumulates at the bottom of the excavation, it should be pumped out prior to concrete placement. Under no circumstances should water be allowed to adversely affect the quality of the bearing surface.

The bearing surface of the foundation should be evaluated after excavation is completed and immediately prior to placing concrete.

Design Parameters - Drilled Pier Foundation

Axial compressive loads for the structures may be supported on straight-sided (non-under-reamed) piers. Due to the presence of subsurface water at relatively shallow depth, under-reamed drilled piers should not be considered for this site.

For the purposes of evaluating the subsoils for use in foundation analyses, we have developed soil parameters for axial capacity analysis for foundation design which are provided in **Exploration Results**.

Straight-sided drilled pier foundations may be designed using the following equations to evaluate the pier foundation sizes for both compressive and tensile (uplift) axial loading:

Ultimate skin friction capacity [1,5]	$Q_s = \pi d\,(f_s)(h)$
Ultimate end bearing capacity [1,5]	$Q_b = 0.25\pi d^2(q_{eb})$
Ultimate pier capacity in compression [5]	$Q_c = Q_s + Q_b$
Ultimate pier capacity in tension (uplift) [1,5]	$Q_t = \pi d\,(f_s)(h)(R)+W$
Ultimate skin friction [2,4]	$f_s = \alpha c_u$
Ultimate skin friction [3,4]	$f_s = \sigma' K \tan\delta$
Ultimate end bearing pressure [2,4]	$q_{eb} = c_u N_c$
Ultimate end bearing pressure [3,4]	$q_{eb} = \sigma' N_q$
Estimated uplift pressure (kips) [10]	$Up = 5 \bullet d$
Ultimate uplift resistance (kips) [1,6]	$Q_r = 2.0 \bullet d(\text{ft.}) \bullet h(\text{ft.}) + W(\text{kips}) + P_{DL}(\text{kips})$
Minimum percentage of steel [7]	As required by structural engineer
Maximum embedment depth	45 feet below existing grade
Approximate total settlement [8]	About 1 inch
Estimated differential settlement [9]	Approximately ½ of total settlement

1. Definitions: d = pier diameter; h = pier segment length; R = uplift reduction factor (equal to 0.7 for sands, 0.9 for clays); W = effective weight of the pier foundation; P_{DL} = dead load acting on the drilled pier
2. Ultimate value for cohesive soils only.
3. Ultimate value for cohesionless soils only.
4. Soil parameters provided in **Exploration Results**: α = skin friction adhesion factor (strength reduction factor).

   (equal to zero with the top 5 feet and one shaft diameter of the base of the pier); c_u = undrained shear strength of the soil; N_c = end bearing capacity factor for clay soil; σ' = effective overburden pressure; K = horizontal stress coefficient; δ = soil to pier friction angle (equal to soil angle of internal friction (ϕ) for concrete piers); N_q = end bearing capacity factor for granular soils
5. A factor of safety of 3 should be applied to ultimate end bearing, 2 to side shear (skin friction), and 2 to uplift (tension).
6. A factor of safety of at least 2 should be applied to the computed ultimate uplift force.
7. The piers should contain sufficient vertical reinforcing steel throughout the entire shaft length to resist uplift (tensile) forces due to post-construction heave of the clay soils. The amount of reinforcing steel required can be computed by assuming that the dead load of the structure surcharges the pier and that the above estimated tensile force acts vertically on the shaft.
8. Provided proper construction practices are followed. A clear distance between the piers of three times the pier diameter should be provided to develop the recommended bearing pressures and to control settlements. If this clearance cannot be maintained in every case,

   Terracon should be contacted so that we may determine the reduced capacities. Settlements provided for single, isolated piers/piles only.
9. Will result from variances in subsurface conditions, loading conditions and construction procedures, such a

cleanliness of the bearing area or flowing water in the shaft. Settlements provided for for single, isolated piers only.

10. U_p = uplift load, kips; d = shaft diameter, feet.

Drilled Pier Lateral Loading

Lateral Loading: The proposed structure(s) supported on drilled piers may be subject to lateral loading, the criteria for lateral load analysis is presented in **Exploration Results** are for use with the computer programs LPILE and FAD Tools. Several methods, including hand solutions and computer programs, are available for calculating the lateral behavior of piles and drilled piers. Most of these methods rely on “key” soil parameters such as soil elastic properties (E and ks), strain at 50 percent of the principal stress difference (ε50), undrained shear strength (c), and load-deflection (p-y) criteria. The p-y criteria, which are commonly used to model soil reaction, were developed from instrumented load tests and are generally considered to provide the best model of soil behavior under short-term lateral loading.

The foundations will need to be designed to resist high loads due to the structure height and the imposed forces from wind loading. Generally, four (4) load cases are applied to this type of structures; axial compressive loading, axial uplift (tensile) loading, lateral loading, and rotational. The foundations experience high lateral and rotational loading, which nearly always controls the foundation design. Axial loading of the foundation is relatively low and seldom controls the foundation design. However, the foundation should always be analyzed for the four (4) load cases to establish the controlling load case.

Factors of safety are not generally applied to the lateral load analysis. A performance criterion, or “limit state”, are usually considered. For most foundations subjected to lateral loads, the pier foundation is designed with a limit of 1 inch of deflection at the top of the pier and 1 degree of rotation as measured from the vertical axis of the pier. The analysis is generally conducted using the working loads and the limit state values. The applied loads are then doubled to evaluate the deflection and rotation at the top of the pier to determine if the foundation will topple over under extreme overload. This overload condition may indicate that the foundation would deflect or rotate such that the structure(s) will tilt, but the foundation will not experience failure. Structural limits, such as moment capacity and shear, may control the design and should be evaluated by the Structural Engineer.

Construction Considerations for Drilled Pier Foundation

Drilled excavations to a maximum depth of 45 feet below existing grade (grade at the time of our field activities) may be performed for installation of the drilled piers for the proposed structures at this site.

Groundwater was observed in the borings between 7 and 34 feet bgs during drilling operations and after drilling activities. Depending on weather conditions, groundwater levels may vary from the levels observed during our field program. Water must not be allowed to accumulate in the bottom of the pier excavations.

As previously discussed, subsurface water and sand soils were observed within the explored depths in the borings. Sloughing is likely to occur below the subsurface water table during construction. Therefore, the contractor should be prepared to remove water from the drilled piers if necessary. We recommend that slurry or casing drilling techniques be used to control sloughing of the subsurface soils during pier construction. Casing should only be used in drilled piers terminating in the Clay soils. Slurry drilling techniques are appropriate for piers terminating in all soil types encountered in the borings.

> <u>Slurry Method-</u> Water or a weighted drilling fluid may be considered to install the pier foundations. Slurry displacement drilling can only prevent sloughing and water influx but cannot control sloughing once it has occurred. Therefore, slurry displacement drilling techniques must begin at the ground surface, not after sloughing materials are encountered.
>
> Typical drilling fluids include those which contain polymers or bentonite. If a polymer is used with “hard” mixing water, a water softening agent may be required to achieve intimate mixing and the appropriate viscosity. The polymer manufacturer should be consulted concerning proper use of the polymer. If bentonite slurry is used, the bentonite should be mixed with water several hours before placing in the pier excavation. Prior mixing gives the bentonite sufficient time to hydrate properly. The drilling fluid should only be of sufficient viscosity to control sloughing of the excavation walls and subsurface water flow into the excavation.
> Care should be exercised while extracting the auger so that suction does not develop and cause disturbance or create “necking” in the excavation walls as described above. Casing should not be employed in conjunction with the slurry drilling technique due to possible trapping of loose soils and slurry between the concrete and natural soil.
>
> The use of weighted drilling fluid when installing drilled pier foundations requires extra effort to ensure an adequate bearing surface is obtained. A clean-out bucket should be used just prior to pier completion in order to remove any cuttings and loose soils which may have accumulated in the bottom of the excavation. Reinforcing steel and concrete should be placed in the excavation immediately after pier completion. A closed-end tremie should be used to place the concrete completely to the bottom of the excavation in a controlled manner to effectively displace the slurry during concrete placement.

When the pier excavation depth is achieved, and the bearing area has been cleaned, steel and concrete should then be placed immediately in the excavation. The concrete should be placed completely to the bottom of the excavation with a closed-end tremie in the pier excavation if more than 3 inches of water is ponded on the bearing surface or the slurry drilling technique is used. A short tremie may be used if the excavation has less than 3 inches of ponded water or if the water is pumped out prior to concrete placement. The fluid concrete should not be allowed to strike the pier reinforcement, temporary casing (if required) or excavation sidewalls during concrete placement.

Casing Method - Casing will provide stability of the excavation walls and will reduce water influx; however, casing may not completely eliminate subsurface water influx potential. In order for the casing to be effective, a “water tight” seal must be achieved between the casing and surrounding soils. The drilling subcontractor should determine casing depths and casing procedures. Water that accumulates in excess of 3 inches in the bottom of the pier excavation should be pumped out prior to reinforcing steel and concrete placement. If the water is not pumped out, a closed-end tremie should be used to place the concrete completely to the bottom of the pier excavation in a controlled manner to effectively displace the water during concrete placement. If water is not a factor, concrete should be placed with a short tremie so the concrete is directed to the bottom of the pier excavation. The concrete should not be allowed to ricochet off the walls of the pier excavation nor off the reinforcing steel. If this operation is not successful or to the satisfaction of the foundation contractor, the pier excavation should be flooded with fresh water to offset the differential water pressure caused by the unbalanced water levels inside and outside of the casing. The concrete should be tremied completely to the bottom of the excavation with a closed-end tremie.

Removal of casing should be performed with extreme care and under proper supervision to reduce mixing of the surrounding soil and water with the fresh concrete. Rapid withdrawal of casing or the auger may develop suction that could cause the soil to intrude into the excavation. An insufficient head of concrete in the casing during its withdrawal could also allow the soils to intrude into the wet concrete. Both of these conditions may induce “necking”, a section of reduced diameter, in the pier.

All aspects of concrete design and placement should comply with the American Concrete Institute (ACI) 318-08 Code Building Code Requirements for Structural Concrete; ACI 336.1-01 entitled Reference Specification for the Construction of Drilled Piers, and ACI 336.3R-93 (Reapproved 2006) entitled Design and Construction of Drilled Piers. Concrete should be designed to achieve the specified 28-day strength when placed at a 7-inch slump with a ±1 inch tolerance. Adding water to a mix that has been designed for a lower slump does not meet the intent of this recommendation. If a high range water reducer is used to achieve this slump, the span of slump retention for the specific admixture under consideration should be thoroughly investigated. Compatibility with other concrete admixtures should also be considered. A technical representative of the admixture supplier should be consulted on these matters.

Concrete aggregates in the area could have a history of problems associated with Alkali Silica Reactivity (ASR). If aggregates are known to have a history of ASR, then one of the following should be incorporated in the concrete used for the foundations:

Option 1: Replace 20 to 35% of the cement with Class C or Class F fly ash. However, if sulfate resistant concrete is required, do not use a Class C fly ash and do not use Type I Portland cement.

Option 2: Use a lithium nitrate admixture at a minimum dosage of 0.55 gallons of 30% lithium nitrate solution per pound of alkalies present in the portland cement. Coordinate with admixture supplier.

Option 3: When using portland cement only, ensure that the total alkali contribution from the cement in the concrete does not exceed 4.00 lb. per cubic yard of concrete when calculated as follows:

Pounds of alkali per cu yd. = (pounds of cement per cu yd) x (%Na2O equivalent in cement)/100.

In the above calculation, use the maximum cement alkali content reported on the cement mill certificate.

Option 4: Test both coarse and fine aggregate separately, in accordance with ASTM C 1260, using 440g of the proposed cementitious material in the same proportions of portland cement to supplementary cementing material to be used in the mix. Before use of the mix, provide the certified test report, signed and sealed by a licensed professional engineer, demonstrating that the ASTM C 1260 test result for each aggregate does not exceed 0.10% expansion.

Successful installation of drilled piers is a coordinated effort involving the general contractor, design consultants, subcontractors and suppliers. Each must be properly equipped and prepared to provide their services in a timely fashion. Several key items of major concern are:

- Proper drilling rig with proper equipment (including casing and augers);
- Reinforcing steel cages tied to meet project specifications;
- Proper scheduling and ordering of concrete for the piers; and

- Monitoring of installation by design professionals.

Pier construction should be carefully monitored to assure compliance of construction activities with the appropriate specifications. Particular attention to the referenced publication is warranted for pier installation. A number of items of concern for pier installation include those listed below.

- Pier locations
- Vertical alignment
- Competent bearing
- Reinforcement steel placement
- Concrete properties and placement
- Proper casing seal for groundwater control
- Slurry viscosity
- Casing removal

If the contractor has to deviate from the recommended foundations, Terracon should be notified immediately so additional engineering recommendations can be provided for an appropriate foundation type.

SEISMIC CONSIDERATIONS

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC). Based on the soil properties encountered at the site and as described on the exploration logs and results, it is our professional opinion that the **Seismic Site Classification is D**. Subsurface explorations at this site were extended to a maximum depth of 50 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

FLOOR SLABS

Floor Slab Design Parameters

The subsurface soils at this site generally exhibit moderate to high expansion potential. Based on the information developed from our field and laboratory programs and on method TEX-124-E in the Texas Department of Transportation (TxDOT) Manual of Testing Procedures, we estimate that the subgrade soils at this site exhibit a Potential Vertical Rise (PVR) of about 1 to 2 inches in present condition.

The actual movements could be greater if poor drainage, ponded water, and/or other sources of moisture are allowed to infiltrate beneath the structure after construction. We have provided recommendations to reduce the site PVR to about 1 inch. In addition, positive structure perimeter drainage should be carefully observed.

After site stripping and over-excavation activities as recommended, re-used on-site soil (that meet select fill criteria) or select fill over 8 inches of moisture conditioned and compacted subgrade soils should be constructed directly below the floor slab and should also extend a minimum of 3 feet beyond the edge of the proposed building area, including any movement sensitive flatwork that abuts the structure such as sidewalks. The final exterior grade adjacent to the building should be sloped to promote positive drainage away from the structure.

The subgrade and select fill soils should be prepared as outlined in the **Earthwork** section of this report, which contains material and placement requirements for select fill, as well as other subgrade preparation recommendations. The floor slab should be designed using the following recommendations.

Item	Description
Excavation	Minimum 6 inches.
Floor Slab Support [1]	Min. 8 inches of moisture conditioned and compacted native soils plus 2 feet of select fill (plus additional if needed to achieve Finished Pad Elevation).
Estimated Modulus of Subgrade Reaction [2]	100 pounds per square inch per inch (psi/in) for point loads.
Estimated Potential Vertical Rise (PVR)	About 1 inch

1. Floor slabs should be structurally independent of building footings or walls to reduce the possibility of floor slab cracking caused by differential movements between the slab and foundation. This recommendation applies to building area and movement-sensitive flatwork that abuts the structure.
2. Modulus of subgrade reaction is an estimated value based upon our experience with the subgrade condition, the requirements noted in **Earthwork**, and the floor slab support as noted in this table. It is provided for point loads. For large area loads the modulus of subgrade reaction would be lower.

Floor Slab Construction Considerations

Finished subgrade within and for at least 10 feet beyond the floor slab should be protected from traffic, rutting, or other disturbance and maintained in a relatively moist condition until floor slabs are constructed. If the subgrade should become damaged or desiccated prior to construction of floor slabs, the affected material should be removed and structural fill should be added to replace the resulting excavation. Final conditioning of the finished subgrade should be performed immediately prior to placement of the floor slab support course.

The Geotechnical Engineer should approve the condition of the floor slab subgrades immediately prior to placement of the floor slab support course, reinforcing steel and concrete. Attention should be paid to high traffic areas that were rutted and disturbed earlier, and to areas where backfilled trenches are located.

GENERAL COMMENTS

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur between exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

Our services and any correspondence or collaboration through this system are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client, and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES

Field Exploration

Number of Borings	Boring Depth (feet) [1]	Location
3	50	Proposed Structures

1. Below ground surface

Boring Layout and Elevations: Terracon personnel provided the boring layout. Coordinates were obtained with a handheld GPS unit (estimated horizontal accuracy of about ±10 feet).

Subsurface Exploration Procedures: We advanced the soil borings with a truck-mounted drill rig using continuous flight augers (solid stem and/or hollow stem as necessary depending on soil conditions). Five samples were obtained in the upper 10 feet of the borings and at intervals of 5 feet thereafter. Soil sampling was performed using thin-wall tube and/or split-barrel sampling procedures. We observed and recorded groundwater levels during drilling and sampling. For safety purposes, the borings were backfilled with cement-bentonite grout after their completion.

The sampling depths, penetration distances, and other sampling information were recorded on the field boring logs. The samples were placed in appropriate containers and taken to our soil laboratory for testing and classification by a geotechnical engineer. Our exploration team prepared field boring logs as part of the drilling operations. The field logs included visual classifications of the materials encountered during drilling and our interpretation of the subsurface conditions between samples. Final boring logs were prepared from the field log. The final boring logs represent the geotechnical engineer's interpretation of the field logs and include modifications based on observations and tests of the samples in our laboratory.

Laboratory Testing

The project engineer reviewed the field data and assigned various laboratory tests to better understand the engineering properties of the various soil strata as necessary for this project.

- ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D422 Standard Test Method for Particle-Size Analysis of Soils
- ASTM D2166/D2166M Standard Test Method for Unconfined Compressive Strength of Cohesive Soil

- ASTM D4546 Standard Test Methods for One-Dimensional Swell or Collapse of Soils
- ASTM D512 Standard Test Methods for Chloride Ion in Water
- ASTM C1580 Standard Test Method for Water-Soluble Sulfate in Soil
- ASTM G 51 Standard Test Method for pH of Soils

The laboratory testing program often included examination of soil samples by an engineer. Based on the material’s texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System (USCS).

SITE LOCATION AND EXPLORATION PLANS

Contents:

SITE LOCATION

Airport Distribution Substation ■ Brownsville, Texas
May 18, 2020 ■ Terracon Project No. 88205026

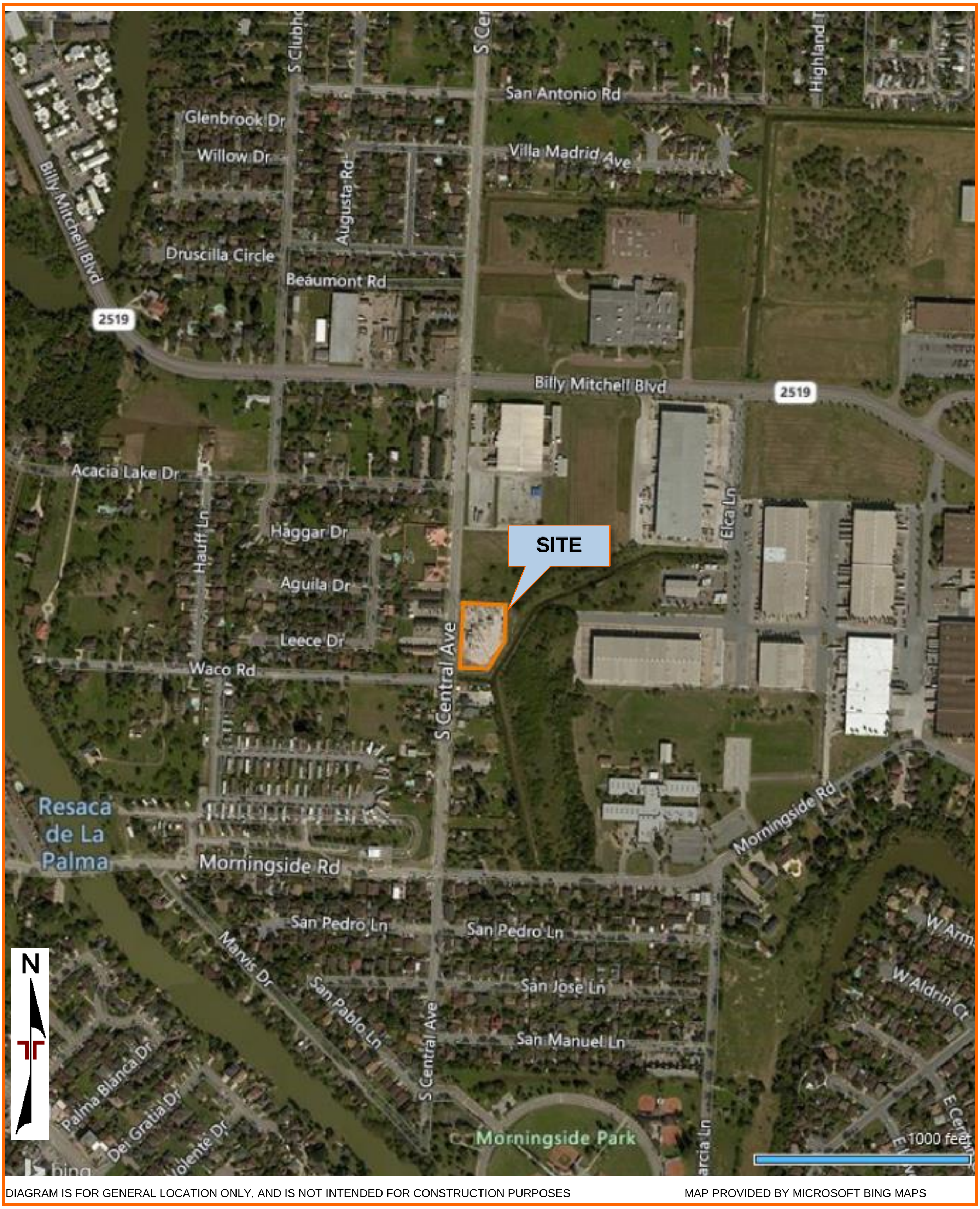


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION PLAN

Airport Distribution Substation ■ Brownsville, Texas
May 18, 2020 ■ Terracon Project No. 88205026

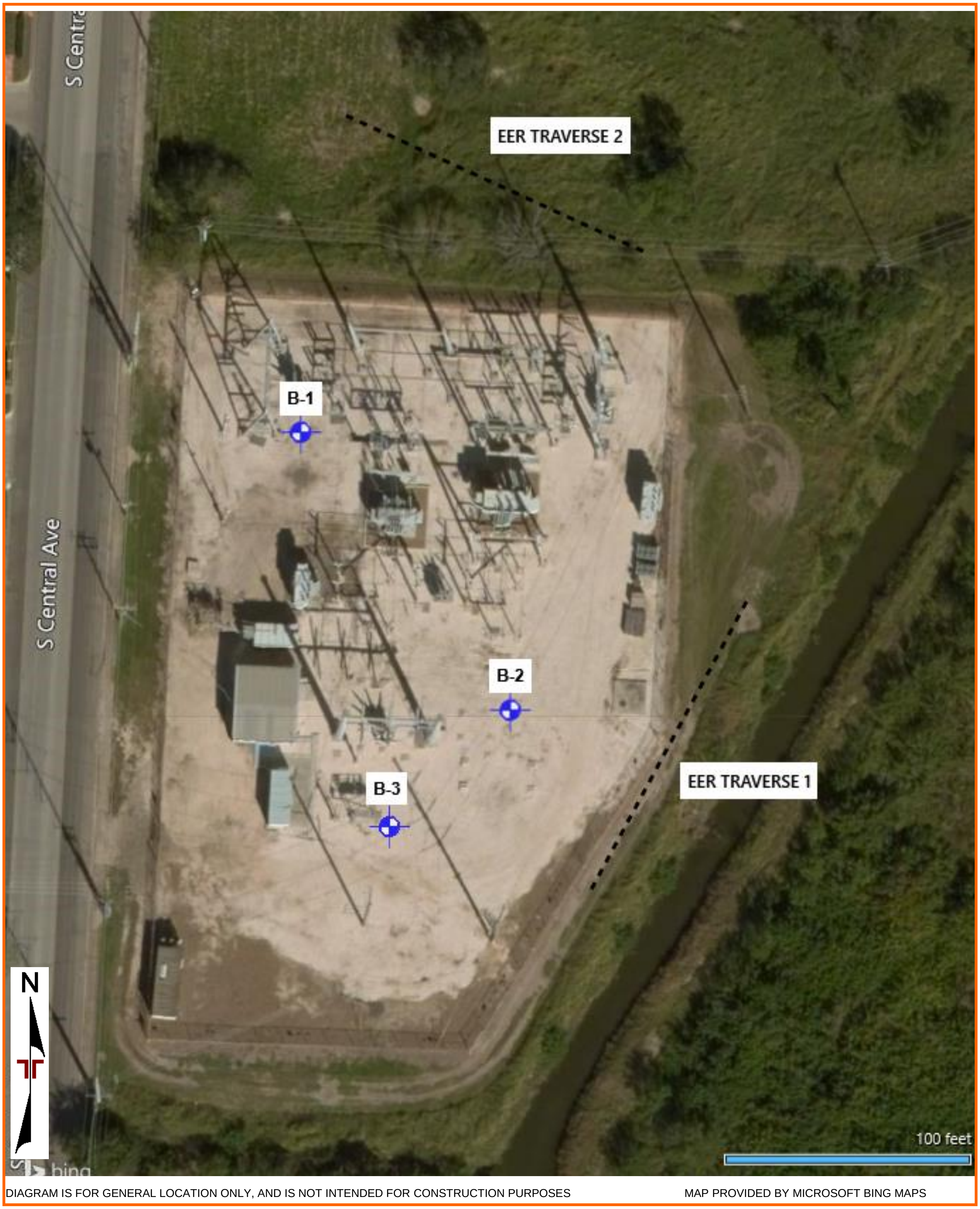


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

MAP PROVIDED BY MICROSOFT BING MAPS

EXPLORATION RESULTS

Contents:

Boring Logs
GeoModel
Thermal Resistivity Test Results
Electrical Earth Resistivity Test Results
Lateral and Axial Design Parameters for Undrained Condition

BORING LOG NO. B-1

Page 1 of 1

PROJECT: Airport Distribution Substation

CLIENT: Brownsville Public Utilities Board
Brownsville, TX

SITE: **Billy Mitchel Blvd and S. Central Avenue**
Brownsville, TX

MODEL LAYER	GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 25.9065° Longitude: -97.4476° DEPTH	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1	▨	**FAT CLAY (CH)**, dark grayish brown to light brown, stiff to hard			☒	3-5-6 N=11				21			
	▨				☒	4-5-6 N=11				27		58-20-38	
	▨		5		■	1.5 (HP)				23			87
	▨			▼	■	1.5 (HP)		0.81	10	22	105		
	▨	- with non-plastic Sandy Silt (ML) seams at 8 feet			■	SAMPLE DISTURBED				23		NP	
	▨		10										
	▨	- sandy at 13½ feet	15		☒	2-4-6 N=10				18			67
	▨		20		■	1.5 (HP)		1.90	10	20	110		
	▨		25		■	4.5 (HP)				24		77-25-52	99
	▨		30		■	3.5 (HP)		2.58	8	30	95		
	▨		35	▽	■	4.5+ (HP)				32			
	▨		40		■	3.75 (HP)				27		72-27-45	
	▨		45		■	4.5 (HP)		2.59	4.2	28	95		
	▨	50.0 - with Silty Sand (SM) seams at 48 feet	50		■	SAMPLE DISTURBED				24			
		Boring Terminated at 50 Feet											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Hollow-stem augered to termination depth.

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *While drilling*
▽ *After 15 minutes*
▼ *At completion of drilling*

1506 Mid Cities Dr
Pharr, TX

Boring Started: 04-16-2020	Boring Completed: 04-16-2020
Drill Rig: CME-75	Driller: EnviroCore
Project No.: 88205026	

BORING LOG NO. B-2

Page 1 of 1

PROJECT: Airport Distribution Substation

CLIENT: Brownsville Public Utilities Board
Brownsville, TX

SITE: Billy Mitchel Blvd and S. Central Avenue
Brownsville, TX

LOCATION See Exploration Plan

Latitude: 25.9062° Longitude: -97.4473°

MODEL LAYER	GRAPHIC LOG	DEPTH	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST: TEST TYPE	STRENGTH TEST: COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST: STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1	▨	**FAT CLAY (CH)**, dark gray, medium stiff to stiff, with Lean Clay (CL) seams to 2 feet			☒	3-5-6 N=11				27		48-19-29	
	▨				■	1.5 (HP)				19			90
	▨		5		■	0.5 (HP)				34		50-22-28	
	▨			▼	■	0.5 (HP)		0.48	10	48	73		
	▨				■	1.25 (HP)				40		98-33-65	99
	▨		10	∇									
	▨				■	2.0 (HP)		1.53	9	30	92		
	▨		15	∇									
	▨	20.0			☒	3-5-6 N=11				33			
2	⁘	**SILTY SAND (SM)**, brown, medium dense to dense	20										
	⁘		25		☒	5-7-12 N=19				28			37
	⁘		30		☒	6-12-18 N=30				26			
	⁘	- with Poorly Graded Sand with Silt (SP-SM) seams at 33½ feet 35.0			☒	7-18-19 N=37				25			7
1	▨	**FAT CLAY (CH)**, reddish brown, very stiff to hard	35										
	▨		40		☒	7-8-11 N=19				29		66-21-45	
	▨		45		■	4.5+ (HP)		2.96	6.3	26	95		
	▨	50.0			■	4.25 (HP)				23			
		Boring Terminated at 50 Feet	50										

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Hollow-stem augered to termination depth.

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

∇ *While drilling*
∇ *After 15 minutes*
▼ *At completion of drilling*

Terracon
1506 Mid Cities Dr
Pharr, TX

Boring Started: 04-16-2020	Boring Completed: 04-16-2020
Drill Rig: CME-75	Driller: EnviroCore
Project No.: 88205026	

BORING LOG NO. B-3

Page 1 of 1

PROJECT: Airport Distribution Substation

CLIENT: Brownsville Public Utilities Board
Brownsville, TX

SITE: **Billy Mitchel Blvd and S. Central Avenue**
Brownsville, TX

MODEL LAYER	GRAPHIC LOG	LOCATION See Exploration Plan Latitude: 25.9061° Longitude: -97.4475° DEPTH	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	STRENGTH TEST TEST TYPE	STRENGTH TEST COMPRESSIVE STRENGTH (tsf)	STRENGTH TEST STRAIN (%)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1		**FAT CLAY (CH)**, dark gray to brown and gray, soft - with very stiff to stiff Lean Clay (CL) seams to 4 feet			☒	9-9-11 N=20				22			
					☒	4-3-5 N=8				20		35-16-19	
			5		☒	1-1-2 N=3				40			89
				▼	☒	0-2-1 N=3				25			
			10		☒	1-1-1 N=2				38		99-31-68	
				▽									
			15		☒	0-0-2 N=2				25			
		18.0											
2		**SILTY SAND (SM)**, brown, loose to very dense	20		☒	9-16-20 N=36				28			22
			25		☒	2-3-6 N=9				27			
			30		☒	8-12-38 N=50				23			
		35.0			☒	4-5-6 N=11				24			19
1		**FAT CLAY (CH)**, reddish brown, stiff	35										
			40		☒	4-3-5 N=8				29		57-24-33	
			45		☒	3-4-5 N=9				29			98
		with Lean Clay (CL) seams at 48½ feet 50.0	50		☒	5-6-8 N=14				23		35-18-17	
		Boring Terminated at 50 Feet											

Stratification lines are approximate. In-situ, the transition may be gradual.

Hammer Type: Automatic

Advancement Method:
Hollow-stem augered to termination depth.

Abandonment Method:
Boring backfilled with cement-bentonite grout upon completion.

See Exploration and Testing Procedures for a description of field and laboratory procedures used and additional data (If any).

See Supporting Information for explanation of symbols and abbreviations.

Notes:

WATER LEVEL OBSERVATIONS

▽ *While drilling*

▽ *After 15 minutes*

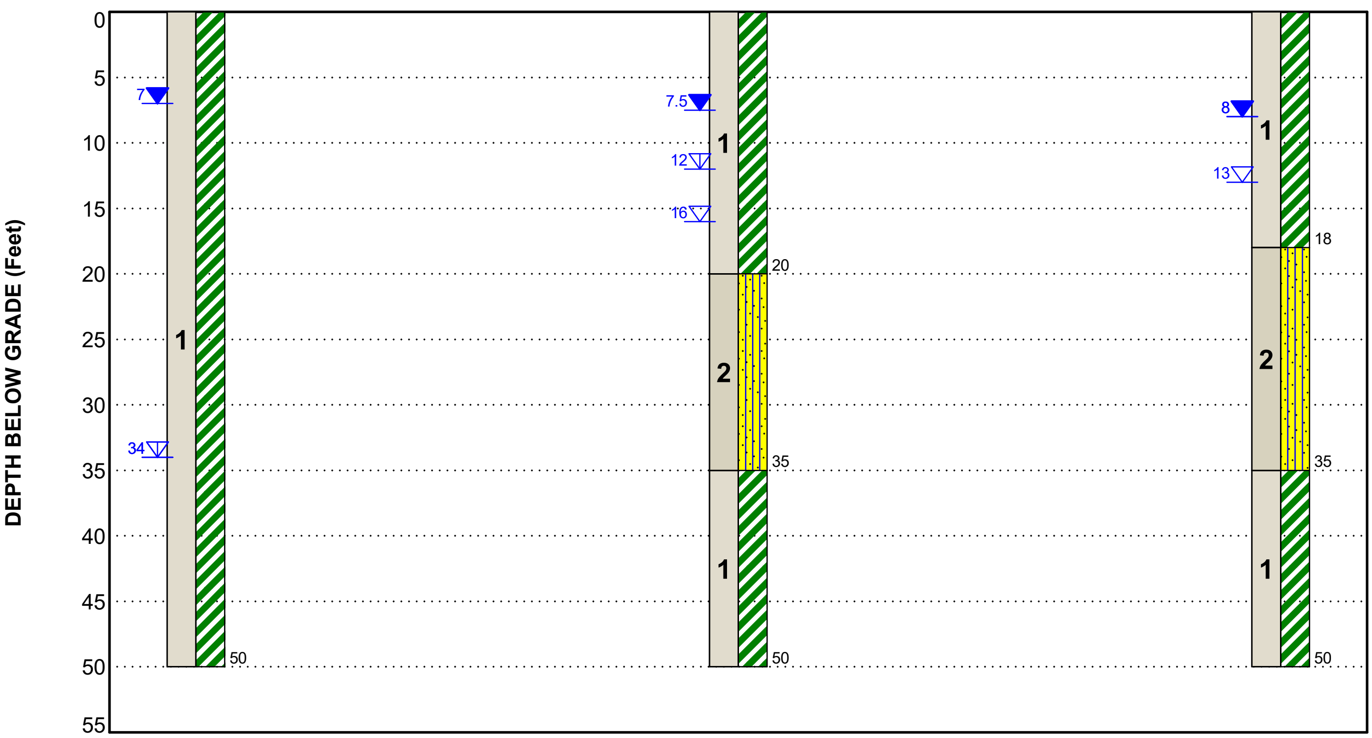
▼ *At completion of drilling*

Terracon
1506 Mid Cities Dr
Pharr, TX

Boring Started: 04-16-2020	Boring Completed: 04-16-2020
Drill Rig: CME-75	Driller: EnviroCore
Project No.: 88205026	

GEOMODEL

Airport Distribution Substation ■ Brownsville, TX
Terracon Project No. 88205026



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

Model Layer	Layer Name	General Description
1	CLAY	Fat Clay (CH) Soft to hard
2	SAND	Silty Sand (SM) Loose to very dense

LEGEND

🟩 Fat Clay

▨ Silty Sand

▽ First Water Observation
▽ Second Water Observation
▼ Third Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time.
Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

NOTES:
Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project.
Numbers adjacent to soil column indicate depth below ground surface.

Geotherm USA

21239 FM529 Rd., Bldg. F
Cypress, TX 77433
Tel: 281-985-9344
Fax: 832-427-1752
info@geothermusa.com
http://www.geothermusa.com

May 5, 2020

Terracon Consultants
1506 Mid Cities Drive
Pharr, Texas 78577
Attn: Stephany Chacon, E.I.T.

Re: Thermal Analysis of Native Soil Sample
Airport Distribution Substation – Brownsville, TX (Project No. 88205026)

The following is the report of thermal dryout characterization tests conducted on one (1) sample of native soil from the referenced project sent to our laboratory.

Thermal Resistivity Tests: The sample was compacted at its 'optimum' moisture content and at 95% of the maximum dry density ***provided by Terracon.*** The tests were conducted in accordance with the IEEE standard 442-2017. The results are tabulated below and the thermal dry out curve is presented in **Figure 1.**

Sample ID, Description, Thermal Resistivity, Moisture Content and Density

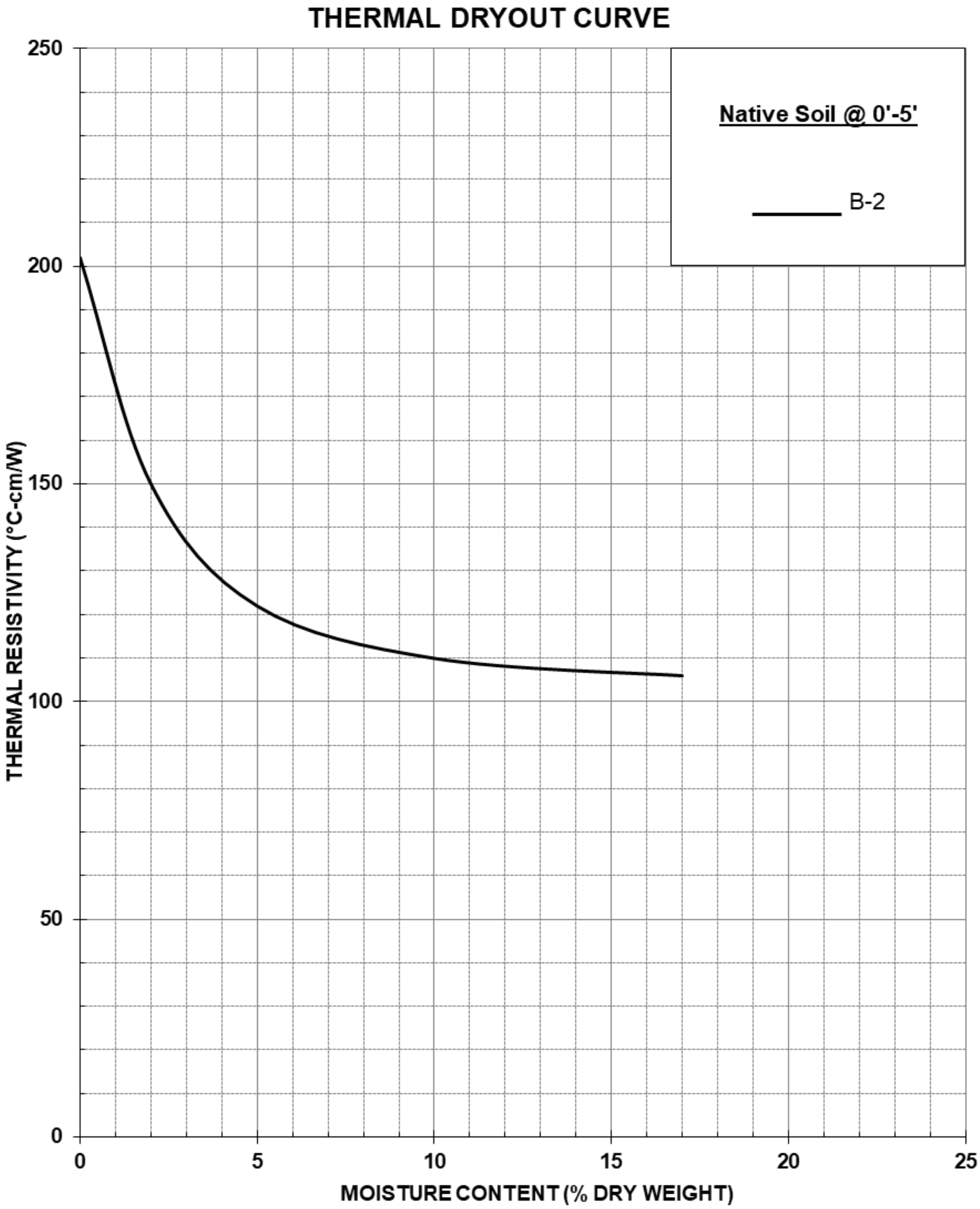
Sample ID @ 0' – 5'	Description (Terracon)	Thermal Resistivity (°C-cm/W)		Moisture Content (%)	Dry Density (lb/ft^3)
		Wet	Dry		
B-2	Lean Clay (CL) w/ Sand	106	202	17	97

Comments: The thermal characteristic depicted in the dry out curve applies for the soil at its respective test dry density.

Please contact us if you have any questions or if we can be of further assistance.

Geotherm USA

Nimesh Patel



Terracon Consultants (Project No. 88205026)

Thermal Analysis of Native Soil Sample

Airport Distribution Substation – Brownsville, TX

May 2020 **Figure 1**

ELECTRICAL EARTH RESISTIVITY TESTING

Project Name: Airport Distribution Substation

Project No.: 88205026

Date: 4/16/2020

Personnel: David Portillo

Manufacturer: AEMC

Model No.: 4620

Calibration Date: 3/9/2020 - 3/9/2021

TRAVERSE 1 (NORTHEAST-SOUTHWEST)

Location: 25.906148, -97.477100

Test No.	A Spacing (feet)	Meter Reading	Scale	Resistance Apparent	Multiplier	Earth Resistivity OHM-CM
1	2.5	1.28	1	1.28	479	613
2	5	0.22	1	0.22	958	211
3	10	0.08	1	0.08	1,915	153
4	20	0.03	1	0.03	3,830	115
5	40	0.01	1	0.01	7,660	77

* Significant readings beyond "a" spacing of 40 feet were not obtained.

TRAVERSE 2 (NORTHWEST-SOUTHEAST)

Location: 25.906756, -97.447289

Test No.	A Spacing (feet)	Meter Reading	Scale Ω	Resistance Apparent	Multiplier	Earth Resistivity OHM-CM
1	2.5	4.47	1	4.47	479	2,140
2	5	0.73	1	0.73	958	699
3	10	0.12	1	0.12	1,915	230
4	20	0.04	1	0.04	3,830	153
5	40	0.01	1	0.01	7,660	77

* Significant readings beyond "a" spacing of 40 feet were not obtained.

B-1

AXIAL CAPACITY ANALYSES DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS

Airport Distribution Substation

Brownsville, Texas

Soil Layer	Depth to Bottom of Soil Layer (feet)	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Adhesion Factor (-)	Friction Angle (degrees)	Horizontal Stress Coefficient (-)	Bearing Capacity Factors $N_c{}^4$ (-)	N_q (-)	N_g (-)
1	10	115	1,000	0.72	0	----	6	1	0
2	20	56	1,500	0.58	0	----	6	1	0
3	50	60	2,500	0.44	0	----	9	1	0

NOTES:

1. Design depth to subsurface water is about 10 feet.
2. For uplift conditions, the computed skin friction should be multiplied by 0.7 for sands and 0.9 for clay.
3. The unit allowable end bearing should not exceed 100 kips per square foot.
4. The N_c value of 9 for non-granular soils is for D/B ratios greater than 4. Otherwise, use $N_c = 6$.

B-2
AXIAL CAPACITY ANALYSES
DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS
Airport Distribution Substation
Brownsville, Texas

Soil Layer	Depth to Bottom of Soil Layer (feet)	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Adhesion Factor (-)	Friction Angle (degrees)	Horizontal Stress Coefficient (-)	Bearing Capacity Factors N_c[4] (-)	N_q (-)	N_g (-)
1	4	115	1,000	----	0	----	6	1	0
2	10	107	500	1.00	0	----	6	1	0
3	20	56	1,500	0.58	0	----	6	1	0
4	28	60	0	----	33	0.75	39	26	35
5	35	66	0	----	35	0.75	46	33	48
6	50	63	3,000	0.40	0	----	9	1	0

NOTES:

1. Design depth to subsurface water is about 10 feet.
2. For uplift conditions, the computed skin friction should be multiplied by 0.7 for sands and 0.9 for clay.
3. The unit allowable end bearing should not exceed 100 kips per square foot.
4. The N_c value of 9 for non-granular soils is for D/B ratios greater than 4. Otherwise, use N_c = 6.

B-3

AXIAL CAPACITY ANALYSES DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS

Airport Distribution Substation

Brownsville, Texas

Soil Layer	Depth to Bottom of Soil Layer (feet)	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Adhesion Factor (-)	Friction Angle (degrees)	Horizontal Stress Coefficient (-)	Bearing Capacity Factors		
							N_c^4 (-)	N_q (-)	N_g (-)
1	4	115	1,000	----	0	----	6	1	0
2	8	107	400	1.00	0	----	6	1	0
3	18	43	250	1.00	0	----	6	1	0
4	25	56	0	----	31	0.75	33	21	26
5	35	60	0	----	33	0.75	39	26	35
6	50	56	1,500	0.58	0	----	9	1	0

NOTES:

1. Design depth to subsurface water is about 8 feet.
2. For uplift conditions, the computed skin friction should be multiplied by 0.7 for sands and 0.9 for clay.
3. The unit allowable end bearing should not exceed 100 kips per square foot.
4. The N_c value of 9 for non-granular soils is for D/B ratios greater than 4. Otherwise, use N_c = 6.

B-1

LATERAL CAPACITY ANALYSES
DESIGN SOIL PARAMETERS FOR
UNDRAINED CONDITIONS

Airport Distribution Substation
Brownsville, Texas

				LPILE				**LPILE**	**MFAD**	
Soil Layer	**LPILE** Soil Type	Depth to Soil Layer Top (feet)	Bottom (feet)	Soil Modulus k (pci)	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Internal Friction Angle (degrees)	Soil Strain Factor e_{50}	Strength Reduction Factor (--)	Deformation Modulus (ksi)
1	Stiff Clay without Free Water	0	10	428	115	1,000	0	0.010	0.72	0.60
2	Stiff Clay without Free Water	10	20	525	56	1,500	0	0.008	0.58	0.90
3	Stiff Clay without Free Water	20	50	718	60	2,500	0	0.006	0.44	1.50

NOTES:

1. Design depth to subsurface water is about 10 feet.
2. MFAD deformation moduli values based on *MFAD 5.1 User Guide, October 2010*

B-2

LATERAL CAPACITY ANALYSES DESIGN SOIL PARAMETERS FOR UNDRAINED CONDITIONS

Airport Distribution Substation

Brownsville, Texas

		Depth to Soil Layer		LPILE				LPILE	MFAD	
Soil Layer	**LPILE** Soil Type	Top (feet)	Bottom (feet)	Soil Modulus k (pci)	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Internal Friction Angle (degrees)	Soil Strain Factor e_{50}	Strength Reduction Factor (--)	Deformation Modulus (ksi)
1	Stiff Clay without Free Water	0	4	428	115	1,000	0	0.010	----	0.60
2	Stiff Clay without Free Water	4	10	332	107	500	0	0.015	1.00	0.30
3	Stiff Clay without Free Water	10	20	525	56	1,500	0	0.008	0.58	0.90
4	Sand	20	28	91	60	0	33	----	----	1.80
5	Sand	28	35	111	66	0	35	----	----	4.90
6	Stiff Clay without Free Water	35	50	815	63	3,000	0	0.006	0.40	1.80

NOTES:

1. Design depth to subsurface water is about 10 feet.
2. MFAD deformation moduli values based on *MFAD 5.1 User Guide, October 2010*

B-3

LATERAL CAPACITY ANALYSES DESIGN SOIL PARAMETERS FOR <u>UNDRAINED CONDITIONS</u>

Airport Distribution Substation

Brownsville, Texas

		Depth to Soil Layer		**LPILE**				**LPILE**	**MFAD**	
Soil Layer	**LPILE** Soil Type	Top (feet)	Bottom (feet)	Soil Modulus k (pci)	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Internal Friction Angle (degrees)	Soil Strain Factor e_{50}	Strength Reduction Factor (--)	Deformation Modulus (ksi)
1	Stiff Clay without Free Water	0	4	428	115	1,000	0	0.010	----	0.60
2	Stiff Clay without Free Water	4	8	312	107	400	0	0.017	1.00	0.25
3	Stiff Clay without Free Water	8	18	283	43	250	0	0.023	1.00	0.15
4	Sand	18	25	71	56	0	31	----	----	0.85
5	Sand	25	35	91	60	0	33	----	----	1.00
6	Stiff Clay without Free Water	35	50	525	56	1,500	0	0.008	0.58	0.90

NOTES:

1. Design depth to subsurface water is about 8 feet.
2. MFAD deformation moduli values based on *MFAD 5.1 User Guide, October 2010*

SUPPORTING INFORMATION

Contents:

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING

■ Shelby Tube ☒ Split Spoon

WATER LEVEL

▽	**Water Initially Encountered**
▽	**Water Level After a Specified Period of Time**
▼	**Water Level After a Specified Period of Time**

Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.

FIELD TESTS

N	**Standard Penetration Test Resistance (Blows/Ft.)**
(HP)	**Hand Penetrometer**
(T)	**Torvane**
(DCP)	**Dynamic Cone Penetrometer**
UC	**Unconfined Compressive Strength**
(PID)	**Photo-Ionization Detector**
(OVA)	**Organic Vapor Analyzer**

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil 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.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance		**CONSISTENCY OF FINE-GRAINED SOILS** (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance		
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength Qu, (tsf)**	**Standard Penetration or N-Value Blows/Ft.**
Very Loose	0 - 3	Very Soft	less than 0.25	0 - 1
Loose	4 - 9	Soft	0.25 to 0.50	2 - 4
Medium Dense	10 - 29	Medium Stiff	0.50 to 1.00	4 - 8
Dense	30 - 50	Stiff	1.00 to 2.00	8 - 15
Very Dense	> 50	Very Stiff	2.00 to 4.00	15 - 30
		Hard	> 4.00	> 30

RELATIVE PROPORTIONS OF SAND AND GRAVEL

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

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	**Percent of Dry Weight**
Trace	<5
With	5-12
Modifier	>12

GRAIN SIZE TERMINOLOGY

Major Component of Sample	**Particle Size**
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
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)

PLASTICITY DESCRIPTION

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

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 ≥ 4 and 1 ≤ Cc ≤ 3 [E]		GW	Well-graded gravel [F]
			Cu < 4 and/or [Cc<1 or Cc>3.0] [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 [D]	Cu ≥ 6 and 1 ≤ Cc ≤ 3 [E]		SW	Well-graded sand [I]
			Cu < 6 and/or [Cc<1 or Cc>3.0] [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”		CL	Lean clay [K, L, M]
			PI < 4 or plots below “A” line [J]		ML	Silt [K, L, M]
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay [K, L, M, N]
			Liquid limit - not dried			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	< 0.75	OH	Organic clay [K, L, M, P]
			Liquid limit - not dried			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-inch (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] $Cu = D_{60}/D_{10} \qquad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[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.

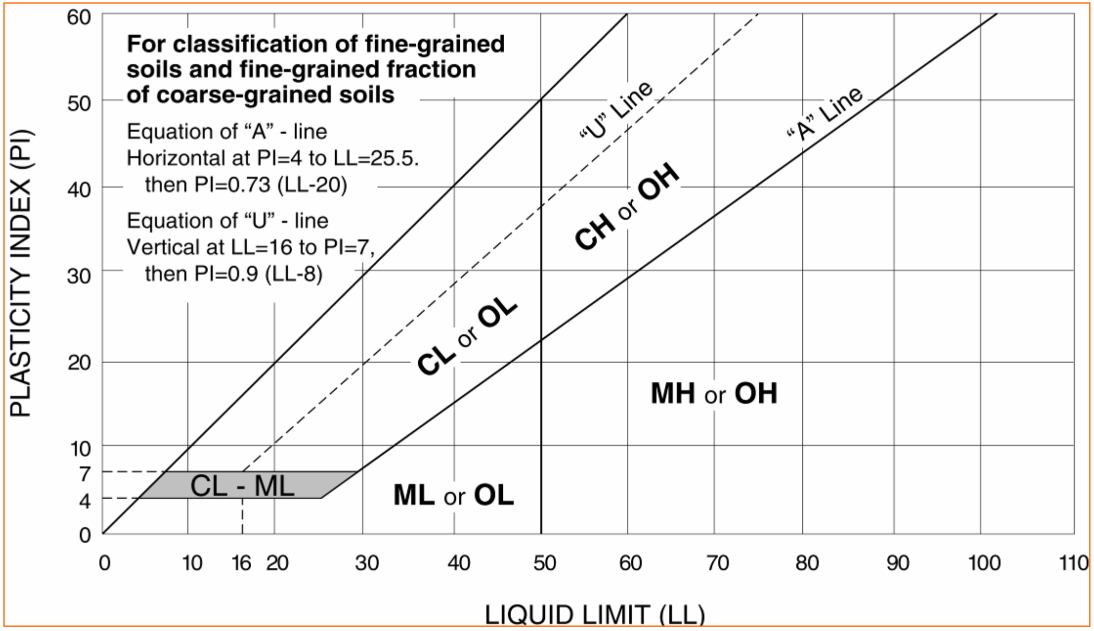
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

[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.



For classification of fine-grained soils and fine-grained fraction of coarse-grained soils

Equation of “A” - line
Horizontal at PI=4 to LL=25.5.
then PI=0.73 (LL-20)

Equation of “U” - line
Vertical at LL=16 to PI=7,
then PI=0.9 (LL-8)