Minnesota Department of Transportation
Office of Materials & Road Research
1400 Gervais Avenue, Maplewood, MN 55109

Memo

TO: Monty Hamri, Final Design Project Manager
Metro District, Waters Edge

FROM: Paul Martin, Assistant Foundations Engineer
Geotechnical Engineering Section

Paul Martin Digitally signed by Paul Martin Date: 2020.07.28 12:37:18 -05'00'

Concur: Rich Lamb, Foundations Engineer
Geotechnical Engineering Section

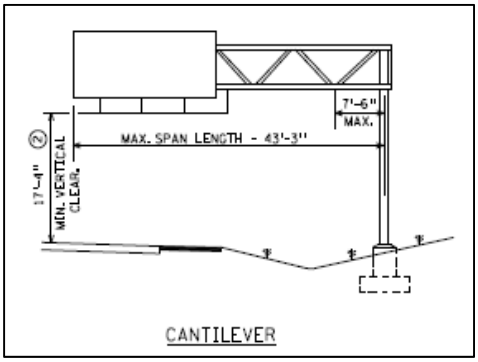
RAL

DATE: July 27, 2020

SUBJECT: SP 1928-71, US 52, Six Overhead Sign Structure Replacements
Subsurface Evaluation and Foundation Recommendation Memo REVISED

1.0 Project Summary

This revised report is provided in response to a request by the Metro District to provide a subsurface investigation and foundation recommendations for six proposed new overhead sign structures being constructed along US Hwy 52 in St Paul and Inver Grove Heights as part of a large pavement improvement project. The proposed sign structures include:



- Site 1, Cantilever Sign ID# US52-135
- Sites 5&6, Sign Bridge ID# US52-122
- Site 39, Monotube Sign ID# US52-132
- Site 41, Cantilever Sign ID# US52-131
- Site 42, Cantilever Sign ID# US52-137, and
- Site 45, Cantilever Sign ID# US52-138

After publication of our report dated July 22, 2020, we learned the sign structure at Site 39, US52-132, will have a design known as a monotube. This shaft foundation is 3 ft. dia., extends 15½ ft. below the surface and requires the same soil characteristics as the Design D standard plan.

2.0 Subsurface Investigation

The soils at or near the proposed sign locations were investigated using Cone Penetration Test Soundings (CPT) conducted on May 26, 2020. The CPT soundings were interpreted for general soil behavior type and estimated water table elevation. No soil samples were taken so the interpreted soil behavior type may not exactly match what soil is present, but should indicate how it behaves if compared to standard soils. Due to restrictions caused by guardrail and terrain, CPT c204a, at Site 41, was located greater than 30 feet away from the proposed overhead sign location.

Based on the results of the investigations we determined that the foundation soils at the proposed sign locations include loose to very dense sands and layered soft to stiff sandy loam, clay and silt soils. Groundwater was not positively indicated in any of the CPT soundings, but water that is trapped between layered soils might be encountered. Please refer to Tables 1 and 2 below and the attached sounding logs for more complete descriptions of the foundation soils.

Table 1, Sounding and Sign Location Descriptions

Sounding	Location Description
c200	Site 1, Sign ID US52-135, SB loop to EB 494, STA 338+66
c201 & c202	Sites 5&6, Sign ID US52-122, for Southview Blvd. exit NB 52, STA 365+10
c203	Site 39, Sign ID US52-132, SB ramp to Cesar Chavez St. SB52, STA 544+76
c204a	Site 41, Sign ID US52-131, for Cesar Chavez St exit SB 52, STA 551+67
c205	Site 42, Sign ID US52-137, exit to East Lafayette Frontage Road NB 52, STA 561+75
c206	Site 45, Sign ID US52-138, exit to West Lafayette Frontage Road SB 52, STA 585+59

Table 2, Summary of Estimated Soil Conditions

Depth	Indicated Soils	Penetration Resistance psi	N_{60} Range	Shear Strength Range psf
c200	**SB 52 STA 338+66 71' Lt**			
0 – 2'	Undefined, likely topsoil	123 - 1132	2 to 13	1322 - 6667
2 – 9.7'	Sand w/ Silty layers	237 - 1306	3 to 19	3717 - 6715
9.7 – 12.1'	Mostly Silt soils w/ a Clay layer	280 - 686	6 to 12	2257 - 5407
12.1 – 17.1'	Mostly Sand w/ Loamy layers	657 - 4788	13 to 60	5222 - 14886
17.1 – 19.2'	Silt, Sand and Clay layers	621 - 2217	13 to 34	4977 - 12341
19.2 - 25.4'	Sands w/ Silt and Clay layers	929 - 5106	18 to 68	7403 – 18797
25.4 – 27.4'	Silt, Sand and Clay layers	1506 - 3195	27 to 50	11933 - 18957
27.4 – 48.2'	Sand w/ a few Loamy layers	763 - 4695	14 to 68	
c201	**NB 52 STA 365+15 66' Rt**			
0 – 0.5'	Undefined, likely topsoil	63 - 2245		
0.5 – 5.3'	Sands w/thin loamy layers	527 - 3310	7 to 42	6702 - 24706
5.3 – 43.9'	Sands	1166 - 5757	15 to 81	
c202	**NB 52 STA 365+05 23' Lt**			
0 - 1.1'	Undefined, likely topsoil	285 - 1191	0 to 12	
1.1 - 5'	Sandy Loam w/Clay and Sand layers	939 - 3257	11 to 43	7230 - 24181
5 - 34.6'	Sands w/ a loamy layer	1164 - 5630	17 to 75	
34.6 - 39'	Clay w/ layers of Silt and Sand	493 - 3667	11 to 53	3974 - 19961
c203	**SB 52 STS 544+76 98' Lt**			
0 – 8.7'	Sand w/ Silt and Clay layers	117 - 2182	2 to 30	2815 - 16485
8.7 –9.8'	Silt and Clay layers	147 - 281	3 to 5	1189 - 2256
9.8 – 14.3'	Sands w/ Silt and Clay layers	144 - 2330	3 to 32	1164 – 5266
14.3 - 16.8'	Silt and Clay w/ Sand layers	142 - 286	3 to 5	1147 - 1990
16.8 – 19.4'	Sandy Loam w/ a Silt layer	278 - 812	5 to 12	2409 - 2779
19.4 - 23'	Silt, Clay and Sandy Loam layers	198 – 503	5 to 9	1592 - 4053
23 – 48.4	Layered Silt and Clay w/ Sand	121 - 4115	4 to 56	933 - 20050

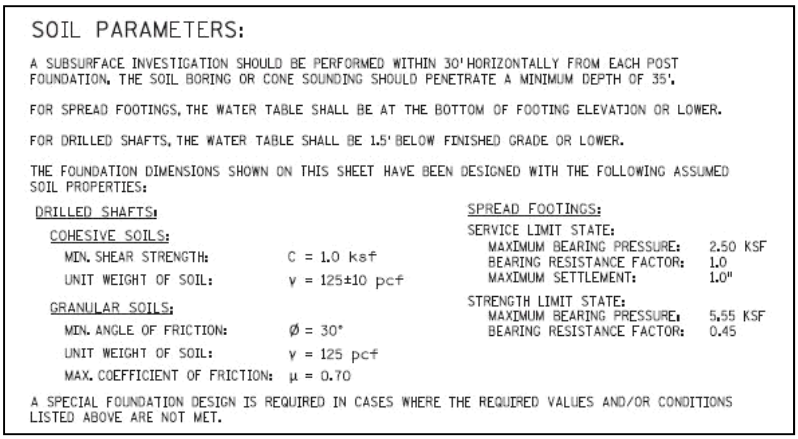
Depth		Penetration Resistance psi	N_{60} Range	Shear Strength Range psf
c204a	**SB 52 STA 551+67, 32' Lt**			
0 – 1.5’	Undefined Sand and Clay layers	1452 - 374	2 to 5	1139 - 2820
1.5 – 10.3'	Sand and Sandy Loam w/ Clay layers	237 – 2306	4 to 26	4378 – 9481
10.3 – 13'	Silt w/ Sand layers	148 – 308	3 to 6	1199 - 2366
13 – 19.4'	Sand	425 – 7494	7 to 86	
19.4 – 46.6'	Clay w/layers of Silt and Sand	378 – 5940	10 to 81	3031 - 29747
c205	**NB 52 STA 561+75, 36’ Rt**			
0 – 24.6’	Sandy Loam & Sand w/Silt and Clay layers	163 – 6013	3 to 72	1718 – 35210
24.6 – 48.1’	Clay w/ Silt and Sand layers	113 – 1522	3 to 24	848 - 5806
c206	**SB 52 STA 585+59, 38’ Lt**			
0 - 14’	Sand w/ Silt layers	250 - 3255	4 to 38	3828 -14966
14 – 40.4’	Layered Silt and Clay w/ Sand layers	156 - 7130	5 to 94	1168 - 50622

3.0 Foundation analysis

As part of the overhead sign standard plans, standard foundations were developed to support overhead signs. These standard foundations include consist of two spread footing and two drilled shaft designs to be used on the various sign post sizes (see Standard Plan 5-297.763, Standard Overhead Sign Structures - Design D Revised 05-26-2020) and Monotube.

- Spread Footings: 12 ½ ft. x 18 ft. or 9 ft. x 14 ft.
- Drilled Shafts: 3 ft. 6 in. diameter and 23 ft. deep or 4 ft. 3 in. diameter and 29 ft. deep
- Monotube Drilled Shaft: 3ft. diameter and 15.5 ft. deep

In addition, the Standard Plan Soil Parameters notes state the following requirements:



SOIL PARAMETERS:

A SUBSURFACE INVESTIGATION SHOULD BE PERFORMED WITHIN 30' HORIZONTALLY FROM EACH POST FOUNDATION. THE SOIL BORING OR CONE SOUNDING SHOULD PENETRATE A MINIMUM DEPTH OF 35'.

FOR SPREAD FOOTINGS, THE WATER TABLE SHALL BE AT THE BOTTOM OF FOOTING ELEVATION OR LOWER.

FOR DRILLED SHAFTS, THE WATER TABLE SHALL BE 1.5' BELOW FINISHED GRADE OR LOWER.

THE FOUNDATION DIMENSIONS SHOWN ON THIS SHEET HAVE BEEN DESIGNED WITH THE FOLLOWING ASSUMED SOIL PROPERTIES:

DRILLED SHAFTS:

COHESIVE SOILS:
- MIN. SHEAR STRENGTH: C = 1.0 ksf
- UNIT WEIGHT OF SOIL: γ = 125±10 pcf

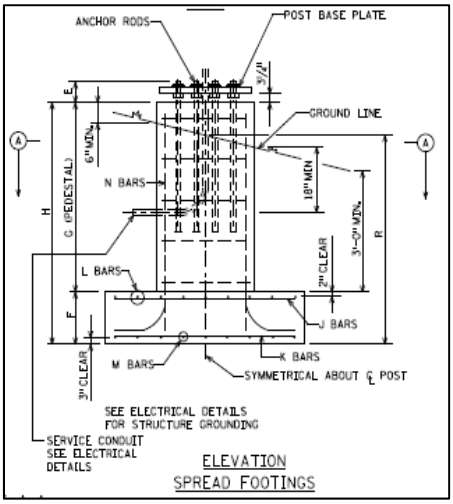
GRANULAR SOILS:
- MIN. ANGLE OF FRICTION: Ø = 30°
- UNIT WEIGHT OF SOIL: γ = 125 pcf
- MAX. COEFFICIENT OF FRICTION: μ = 0.70

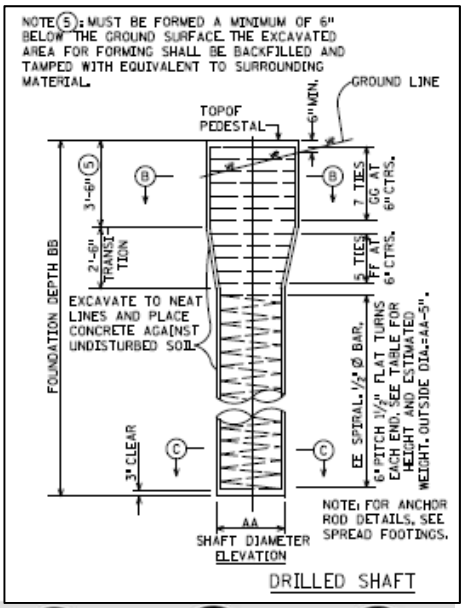
SPREAD FOOTINGS:

SERVICE LIMIT STATE:
- MAXIMUM BEARING PRESSURE: 2.50 KSF
- BEARING RESISTANCE FACTOR: 1.0
- MAXIMUM SETTLEMENT: 1.0"

STRENGTH LIMIT STATE:
- MAXIMUM BEARING PRESSURE: 5.55 KSF
- BEARING RESISTANCE FACTOR: 0.45

A SPECIAL FOUNDATION DESIGN IS REQUIRED IN CASES WHERE THE REQUIRED VALUES AND/OR CONDITIONS LISTED ABOVE ARE NOT MET.





The recommendations contained in the paragraphs below are based on our analysis. We recommend the new foundations consist of drilled shafts designed to meet the requirements of the current standard design tables. At many locations the soils in the shaft excavations will likely require support to prevent caving and loss-of-ground below nearby pavements, utilities or structures.

4.0 Foundation Recommendations
Based on review of the existing subsurface conditions and proposed structures, we recommend:

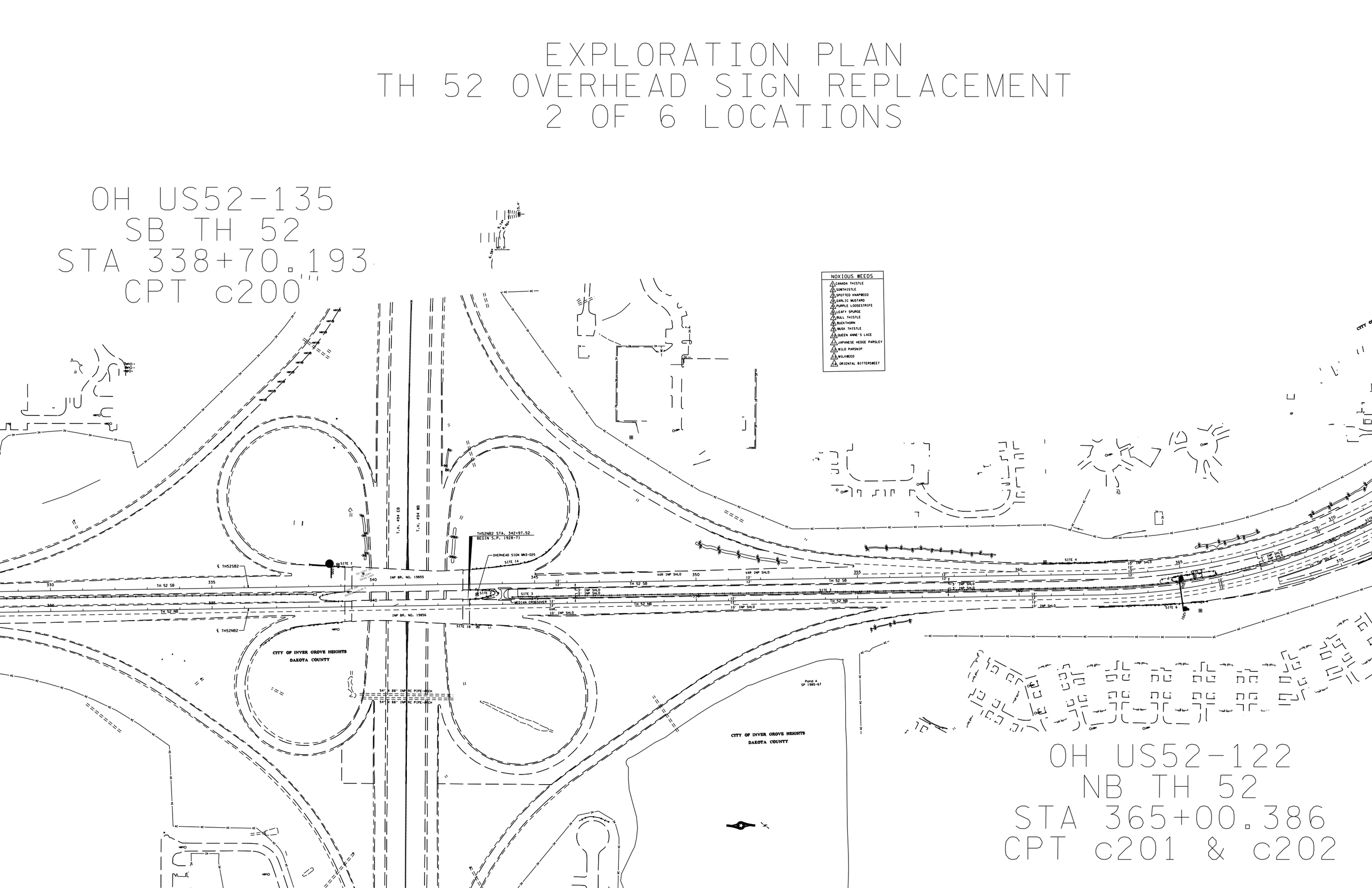
1. Overhead sign structures US52-135, US52-122, US52-131, US52-137, and US52-138 be supported with drilled shaft foundations as detailed in the typical Standard Plan 5-297.763, Standard Overhead Sign Structures - Design D. Overhead sign structure US52-132 be supported with a drilled shaft foundation as detailed in the typical Monotube Standard Plan.
2. This report, including Table 2 and a copy of the attached CPT Sounding Logs, be forwarded to the bidding contractors.
3. At Sign US52-137and Sign US52-138 the caving conditions and loss-or-ground caused by waterbearing sand layers be controlled to protect existing pavements, utilities and structures through the use of drilling fluid to balance the water pressure and/or temporary casing.

Attachments:
Soil Exploration Location Overview, 2 Sheets
Plan Drawings Sites 1, 5&6, 39, 41, 42 and 45
X-Section Drawings Sites 1, 5&6, 39, 41, 42 and 45
Sounding Logs c200 – c206, Unique Numbers 85032 - 85038
CPT Index Sheet

cc: E. Peterson, Metro Signing Design
G. Ashe, Construction Resident Engineer
B. Skow, Chief Geotechnical Engineer

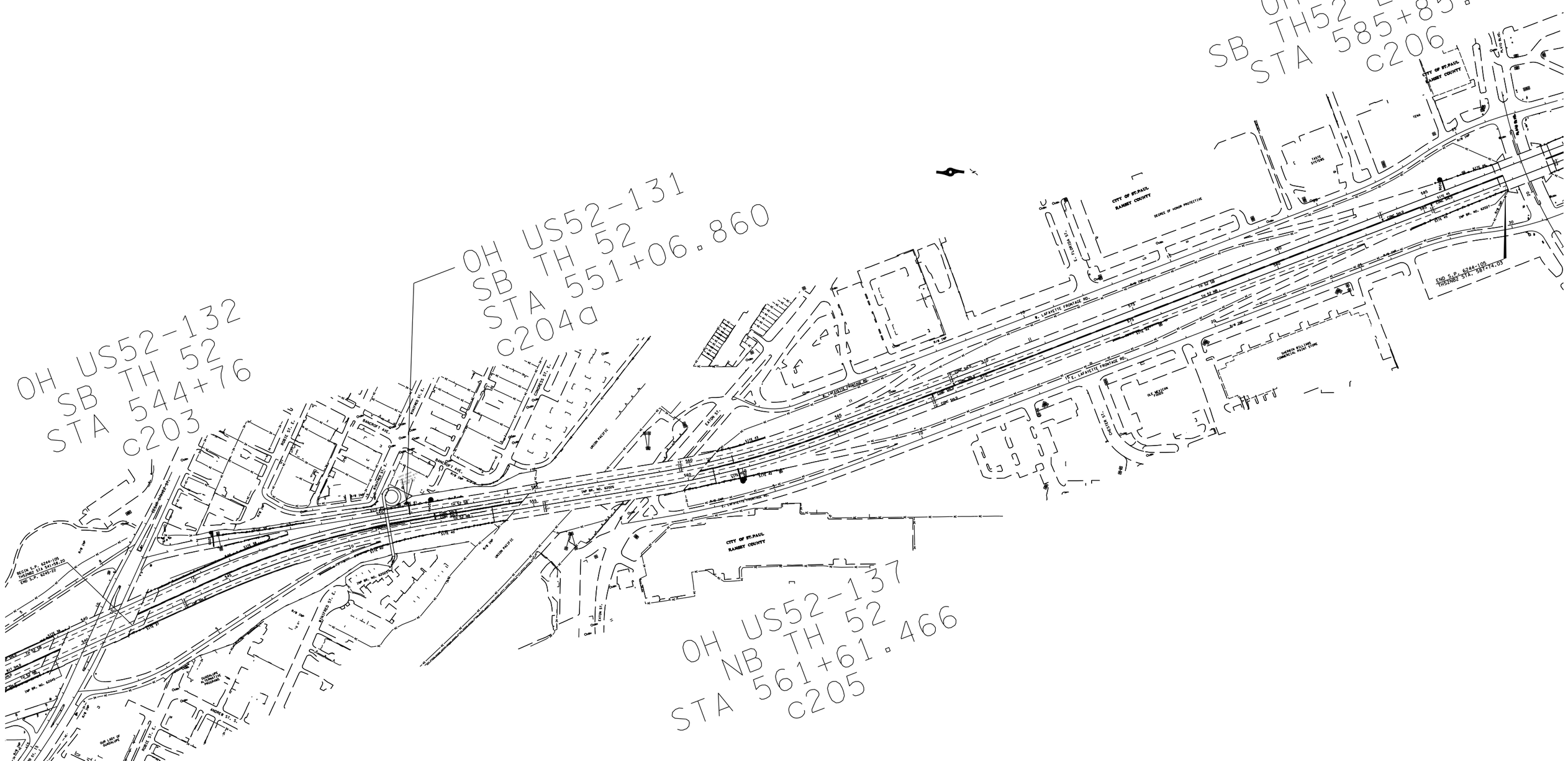
EXPLORATION PLAN
TH 52 OVERHEAD SIGN REPLACEMENT
2 OF 6 LOCATIONS

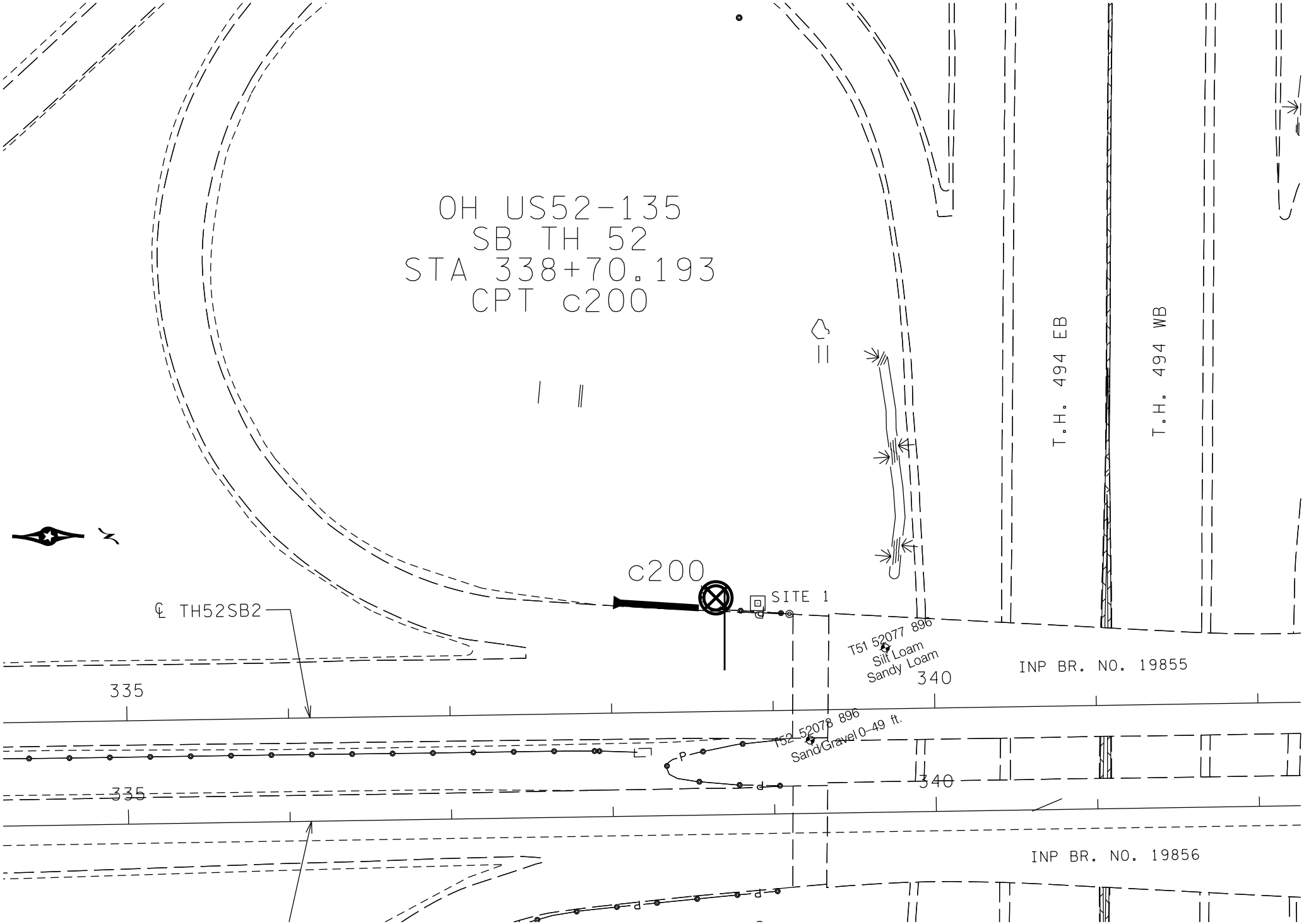
OH US52-135
SB TH 52
STA 338+70.193
CPT c200

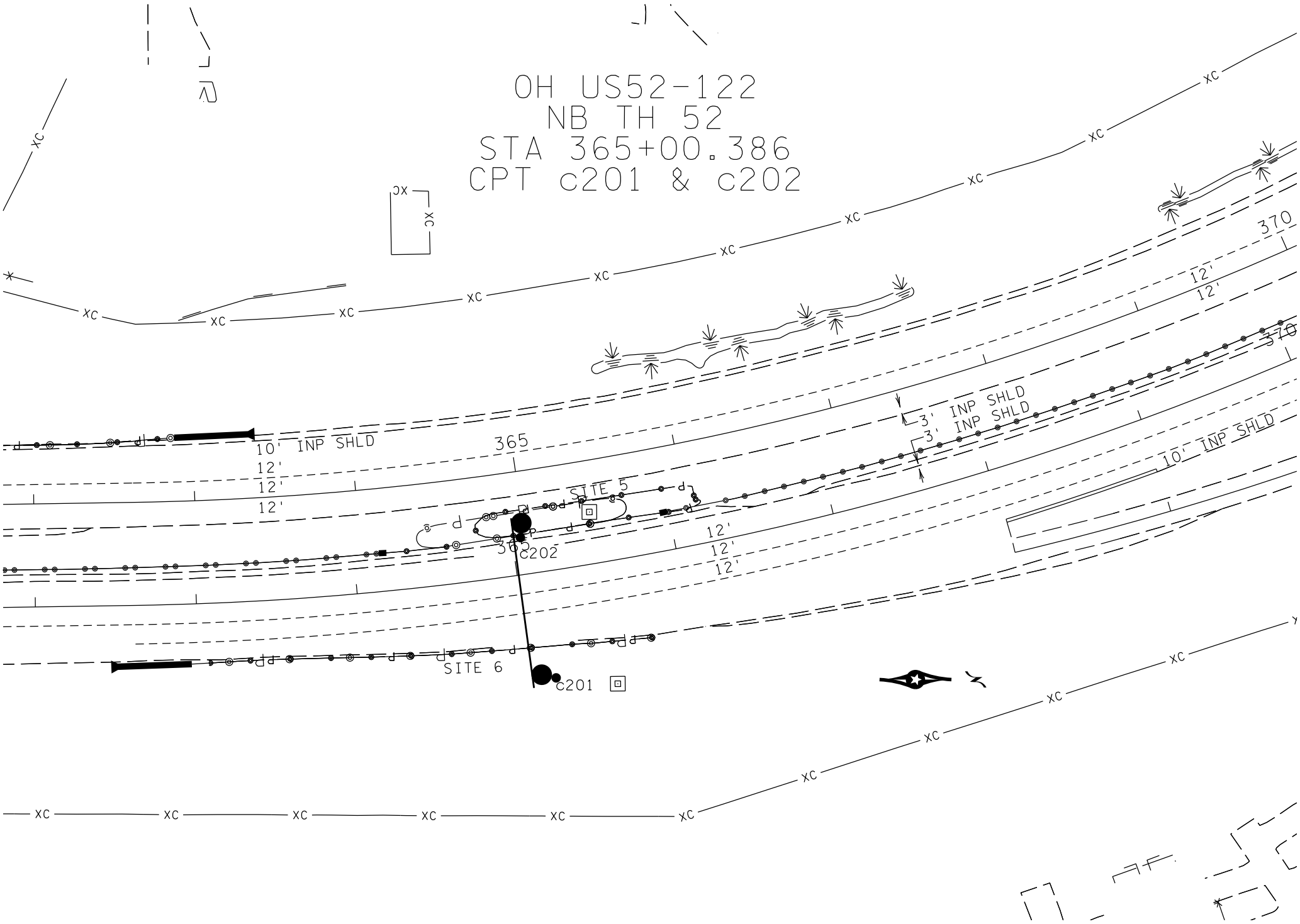


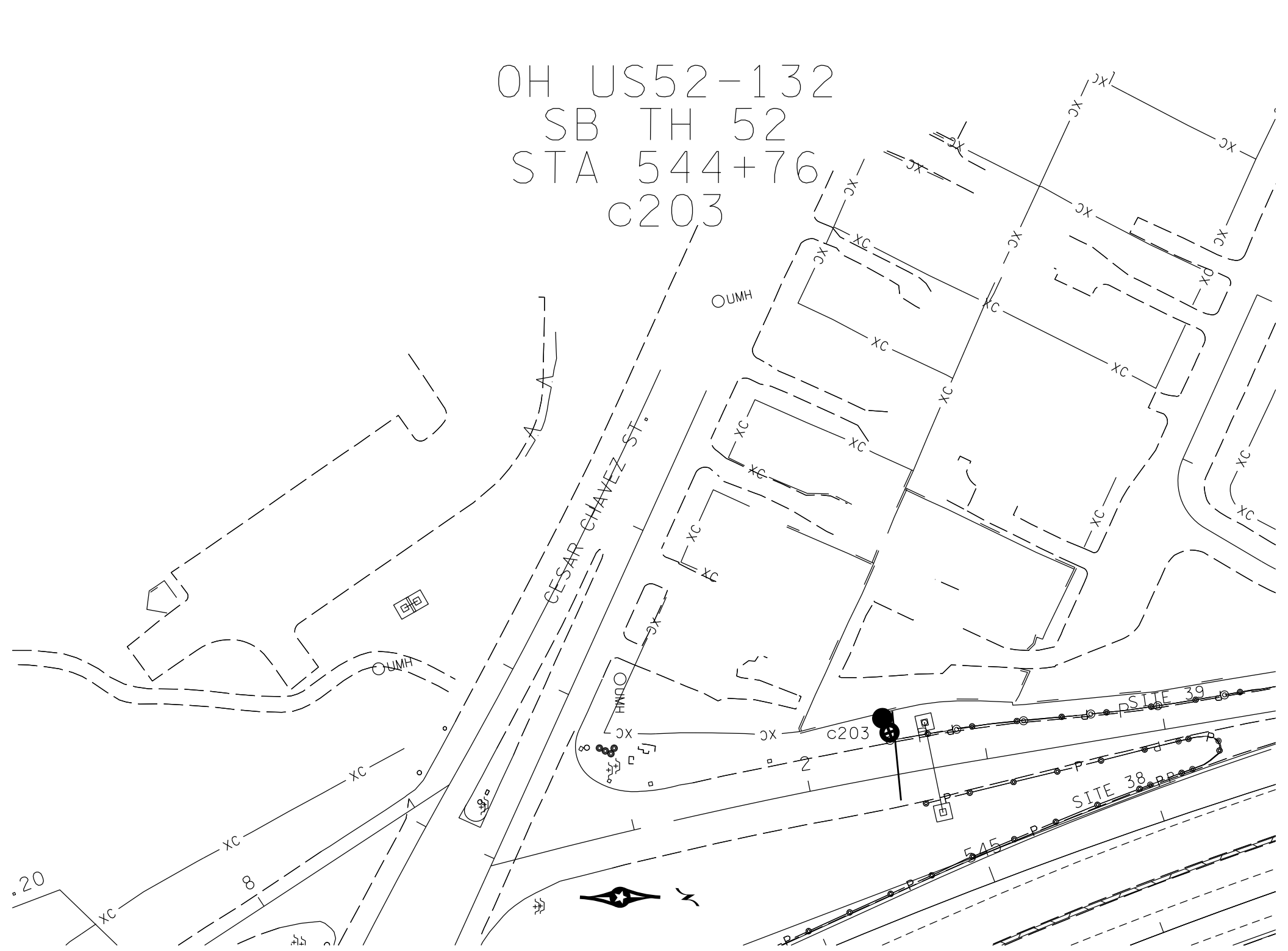
OH US52-122
NB TH 52
STA 365+00.386
CPT c201 & c202

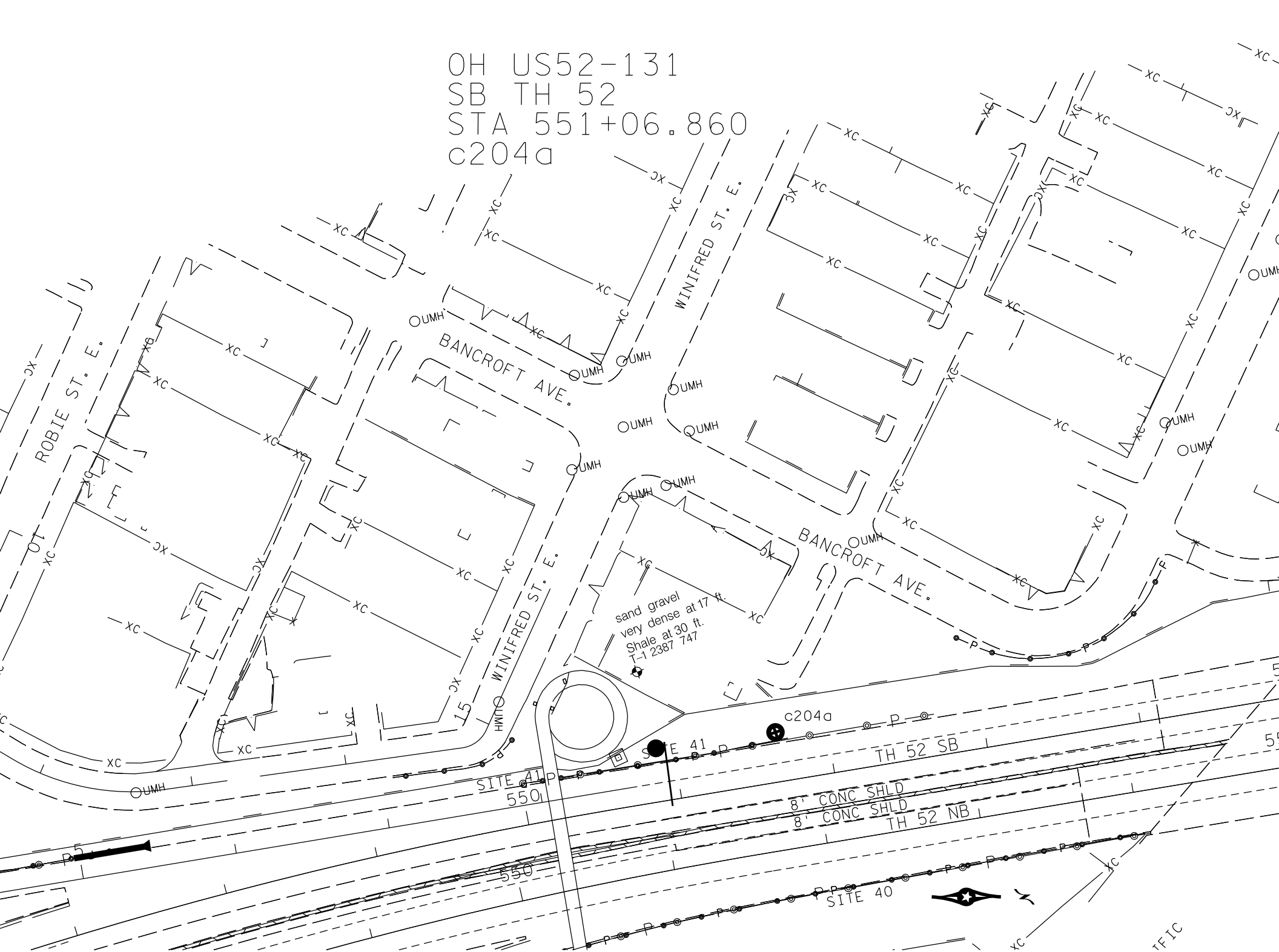
EXPLORATION PLAN
TH 52 OVERHEAD SIGN REPLACEMENT
4 OF 6 LOCATIONS

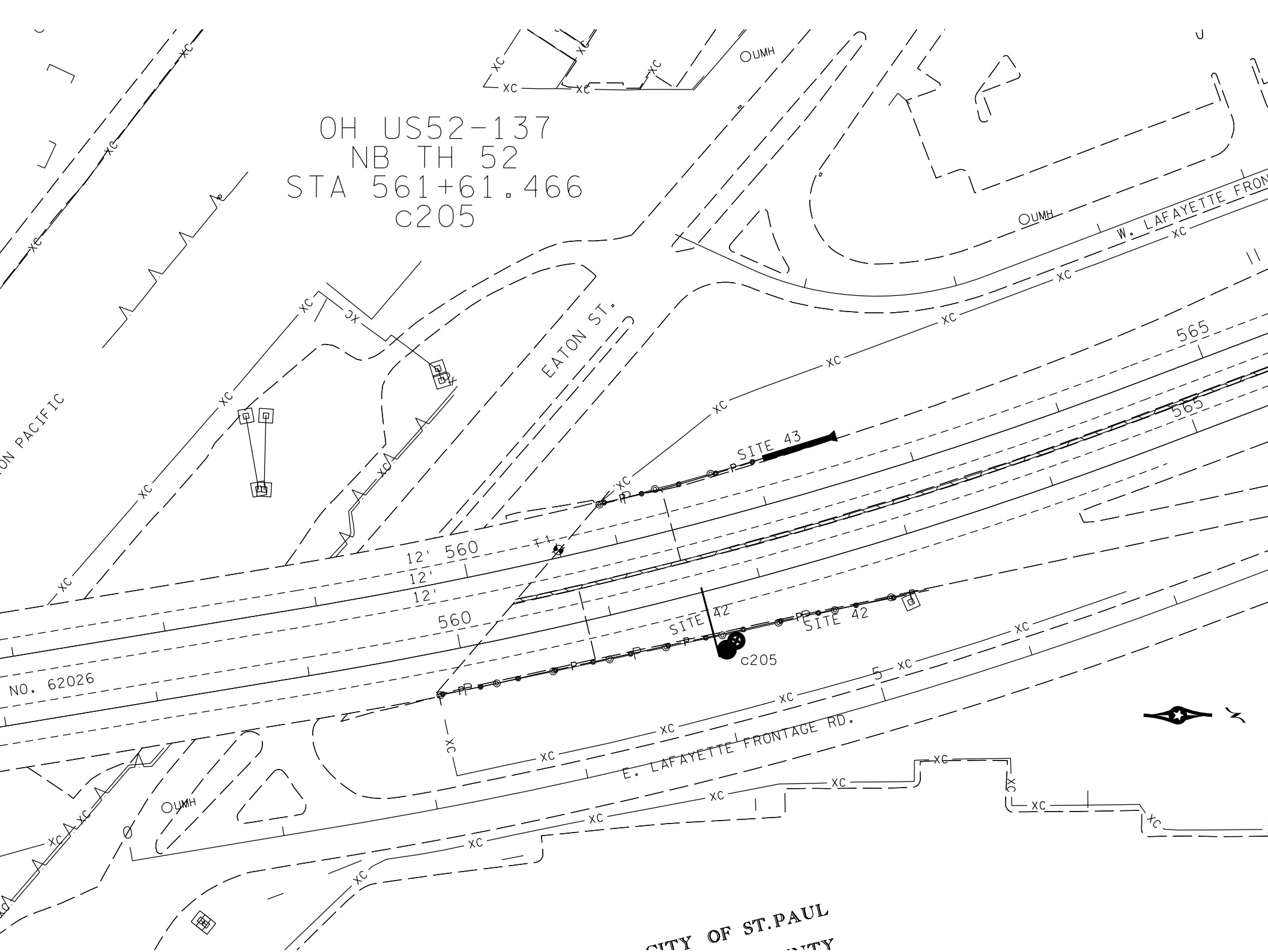


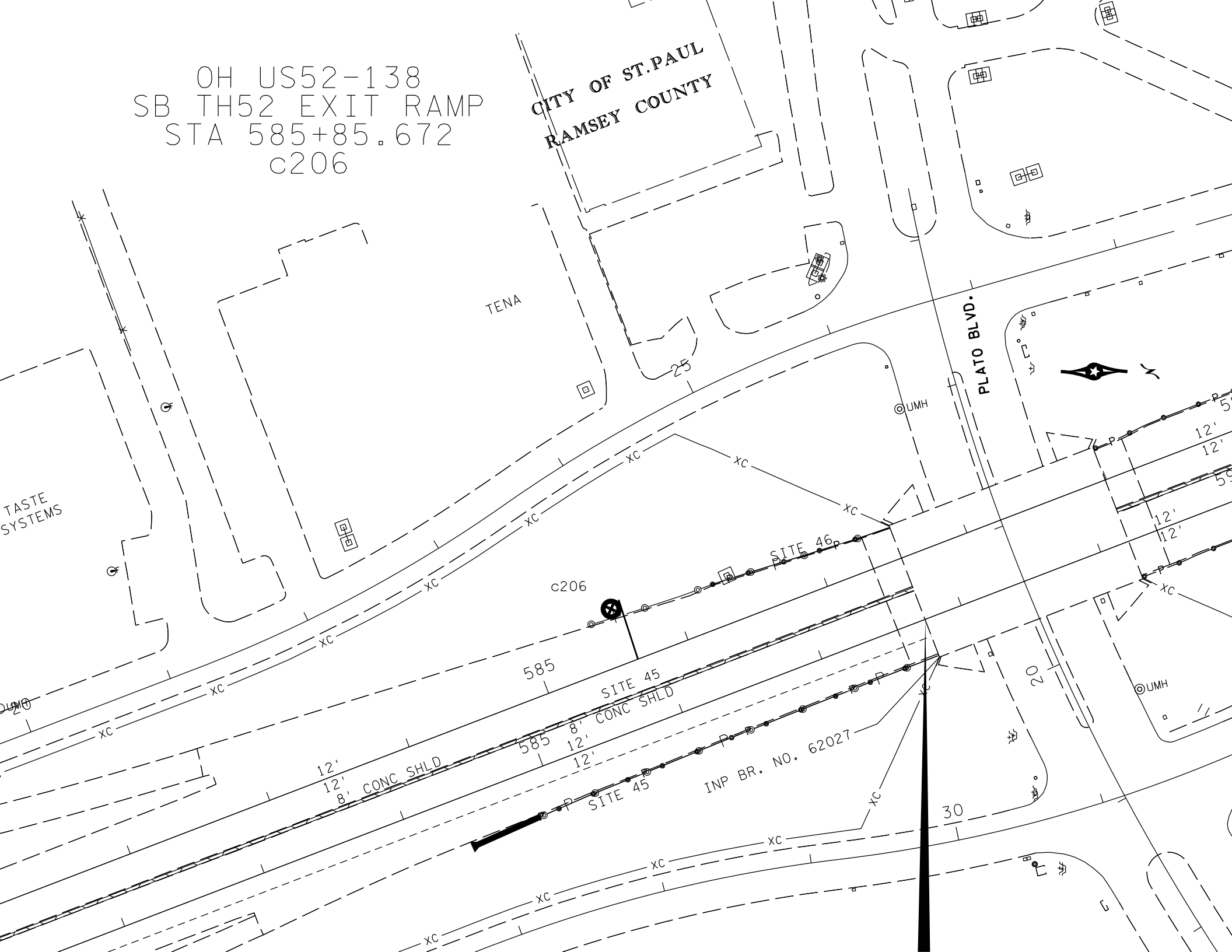

OH US52-135
SB TH 52
STA 338+70.193
CPT c200
T.H. 494 EB
T.H. 494 WB
c200
SITE 1
℄ TH52SB2
T51 52077 896
Silt Loam
Sandy Loam
INP BR. NO. 19855
335
340
T52 52078 896
Sand/Gravel 0-49 ft.
335
340
INP BR. NO. 19856


OH US52-122
NB TH 52
STA 365+00.386
CPT c201 & c202
10' INP SHLD
12'
12'
12'
365
SITE 5
C202
3' INP SHLD
3' INP SHLD
370
12'
12'
12'
10' INP SHLD
SITE 6
C201
XC

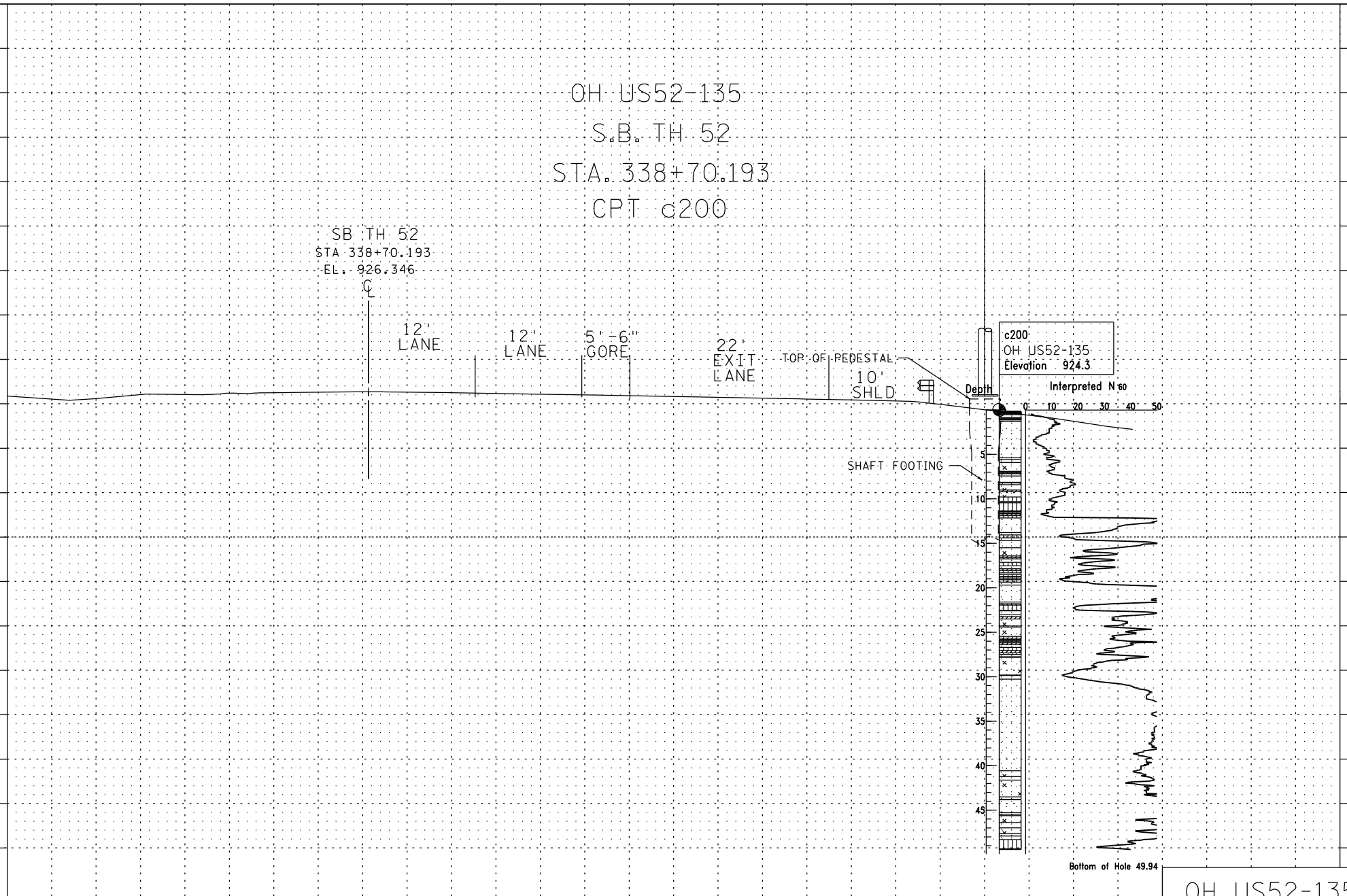

OH US52-132
SB TH 52
STA 544+76
c203
CESAR CHAVEZ ST.
OUMH
SITE 39
SITE 38
545
c203


OH US52-131
SB TH 52
STA 551+06.860
c204a
ROBIE ST. E.
WINIFRED ST. E.
BANCROFT AVE.
sand gravel
very dense at 17 ft.
Shale at 30 ft.
T-1 2387 747
c204a
SITE 41
TH 52 SB
8' CONC SHLD
8' CONC SHLD
TH 52 NB
SITE 40
550
550


OH US52-137
NB TH 52
STA 561+61.466
c205
EATON ST.
W. LAFAYETTE FRON
E. LAFAYETTE FRONTAGE RD.
SITE 43
SITE 42
SITE 42
c205
12' 560
12'
12'
560
565
565
NO. 62026
OUMH
OUMH
CITY OF ST.PAUL


OH US52-138
SB TH52 EXIT RAMP
STA 585+85.672
c206
CITY OF ST.PAUL
RAMSEY COUNTY
TENA
PLATO BLVD.
TASTE
SYSTEMS
UMH
UMH
25
30
585
585
c206
SITE 46
SITE 45
SITE 45
8' CONC SHLD
8' CONC SHLD
12'
12'
12'
12'
INP BR. NO. 62027
XC
P

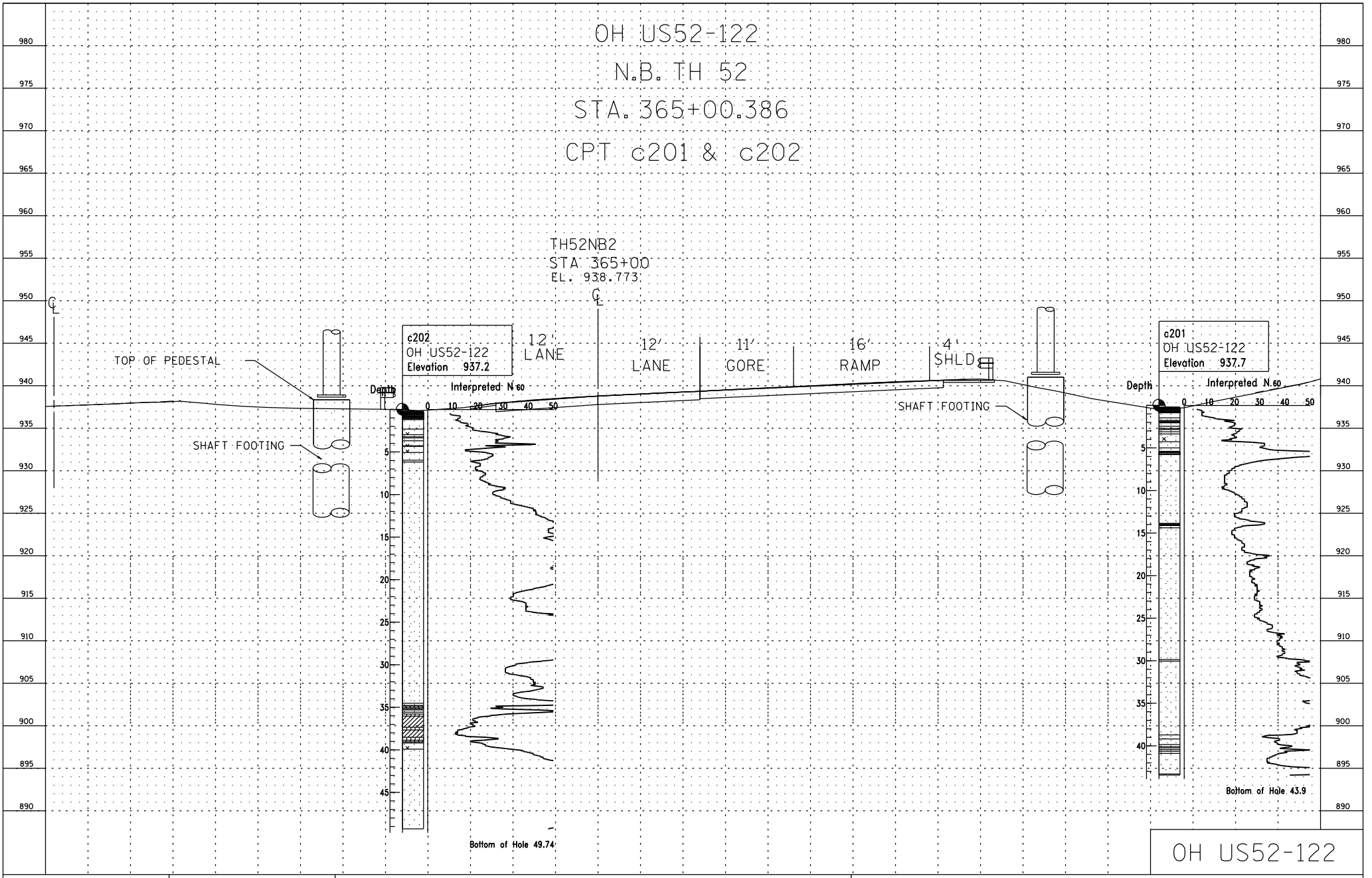
OH US52-135
S.B. TH 52
STA. 338+70.193
CPT c200



OH US52-135

DRAWN BY: PSM			STATE PROJ. NO. 1928-71 (TH 52)	SHEET NO. 1 OF 6 SHEETS

OH US52-122
N.B. TH 52
STA. 365+00.386
CPT c201 & c202



OH US52-122

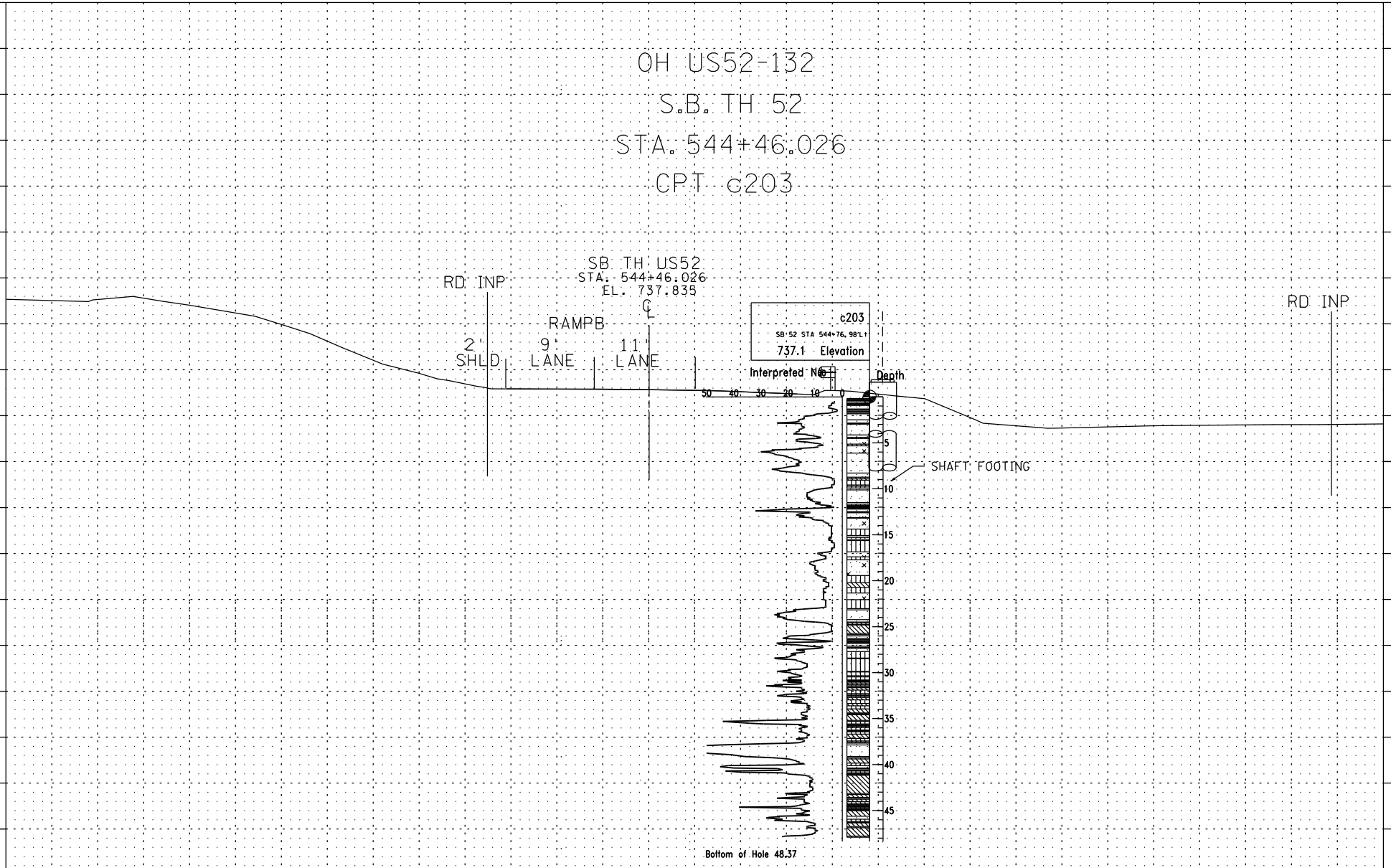
DRAWN BY: PSM			STATE PROJ. NO. 1928-71 (TH 52)	SHEET NO. 2 OF 6 SHEETS

OH US52-132

S.B. TH 52

STA. 544+46.026

CPT c203



OH US52-132

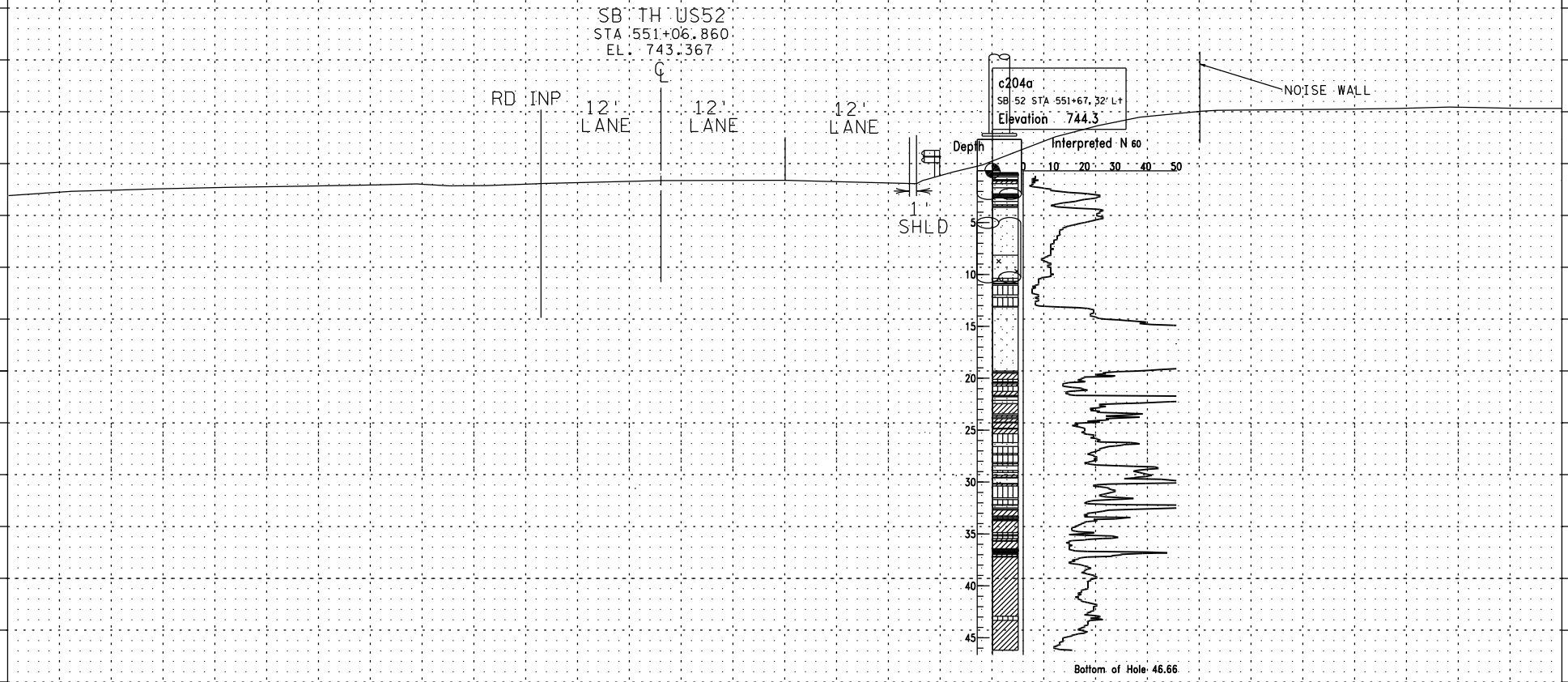
DRAWN BY: PSM			STATE PROJ. NO. 1928-71 (TH 52)	SHEET NO. 3 OF 6 SHEETS

OH US52-131

S.B. TH 52

STA. 551+06.860

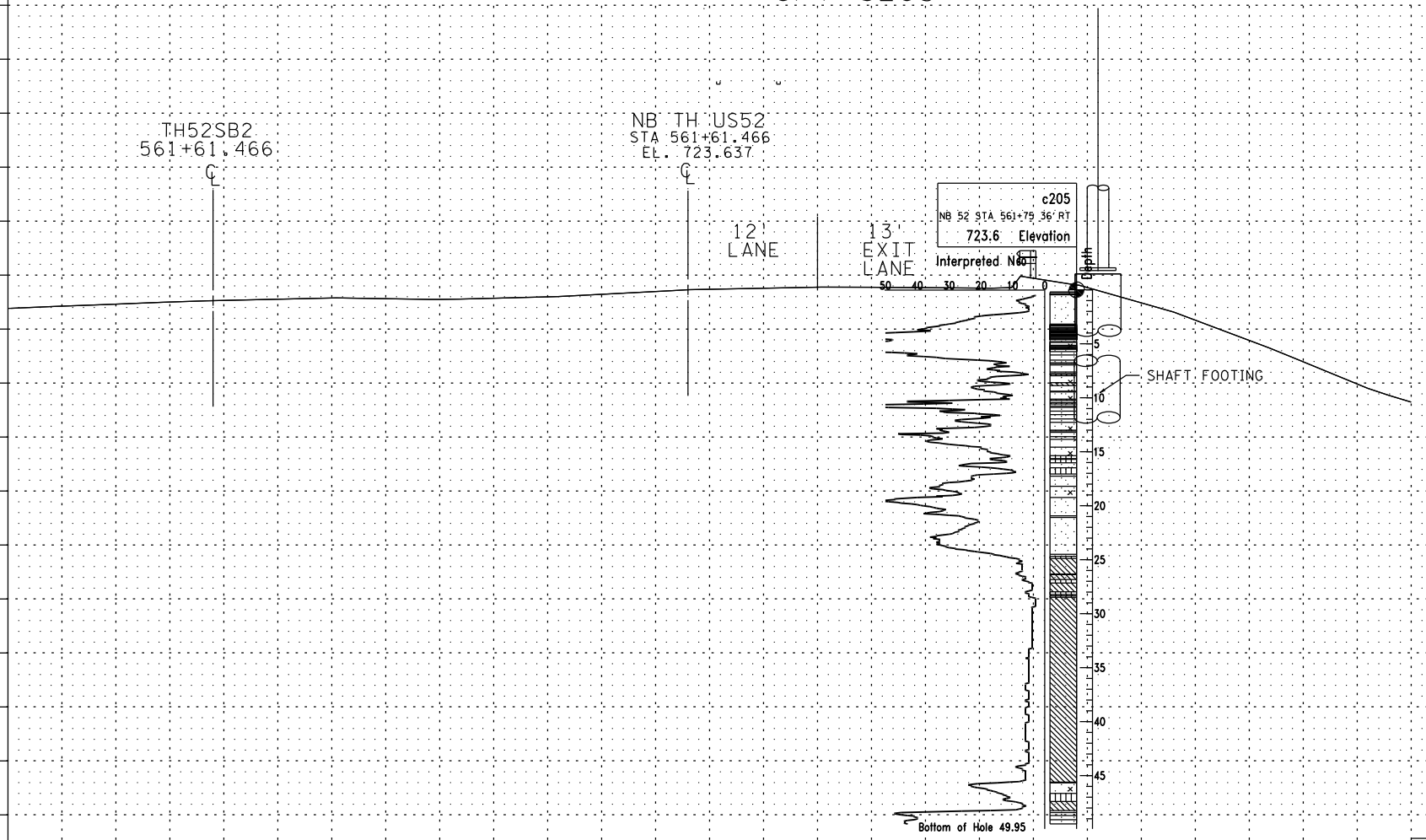
CPT c204a



OH US52-131

DRAWN BY: PSM			STATE PROJ. NO. 1928-71 (TH 52)	SHEET NO. 4 OF 6 SHEETS

OH US52-137
N.B. TH 52
STA. 561+61.466
CPT c205



OH US52-137

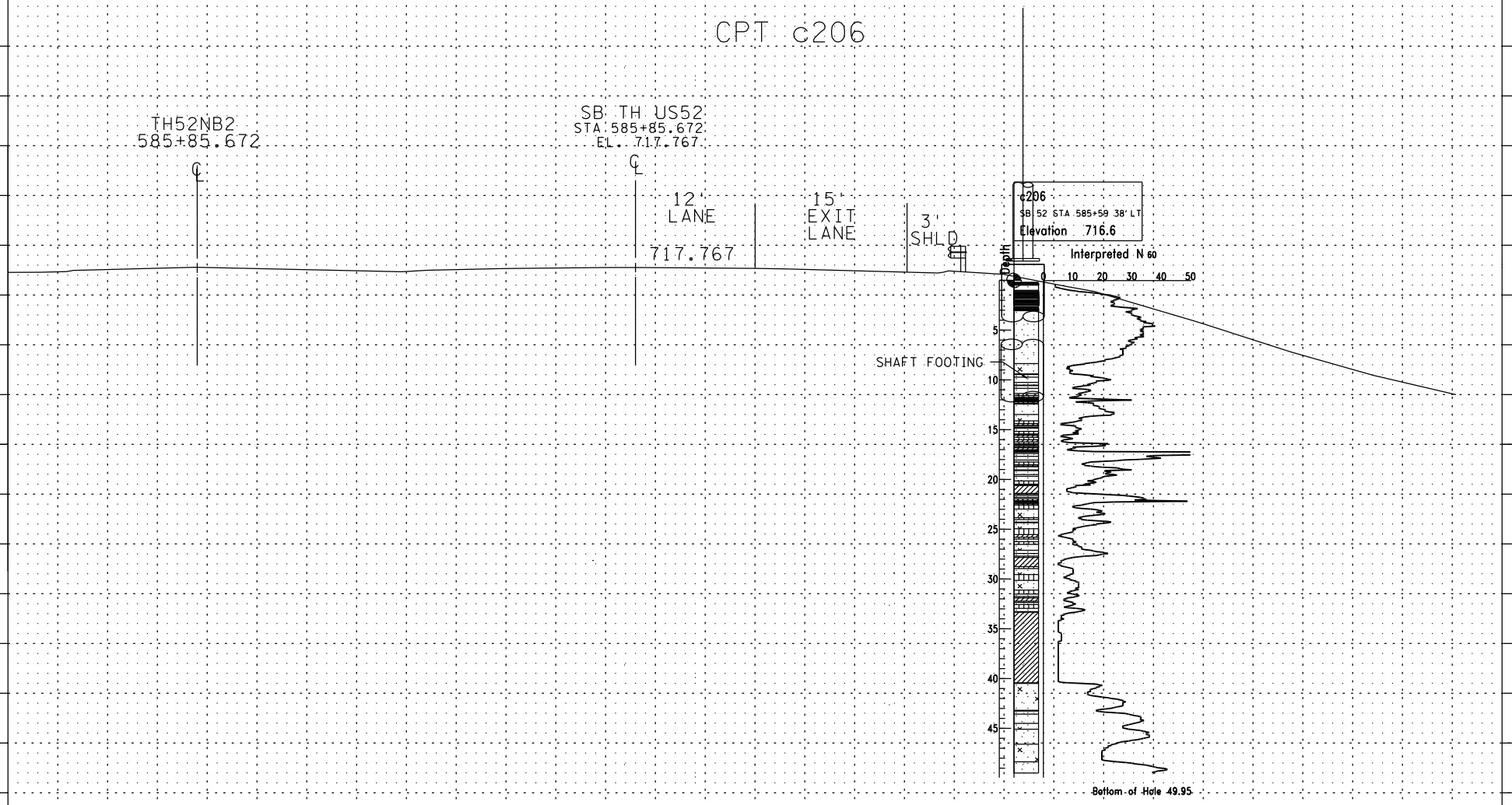
DRAWN BY: PSM			STATE PROJ. NO. 1928-71 (TH 52)	SHEET NO. 5 OF 6 SHEETS

OH US52-138

S.B. TH 52

STA. 585+85.672

CPT c206



OH US52-138

DRAWN BY: PSM			STATE PROJ. NO. 1928-71 (TH 52)	SHEET NO. 6 OF 6 SHEETS

DEPARTMENT OF TRANSPORTATION

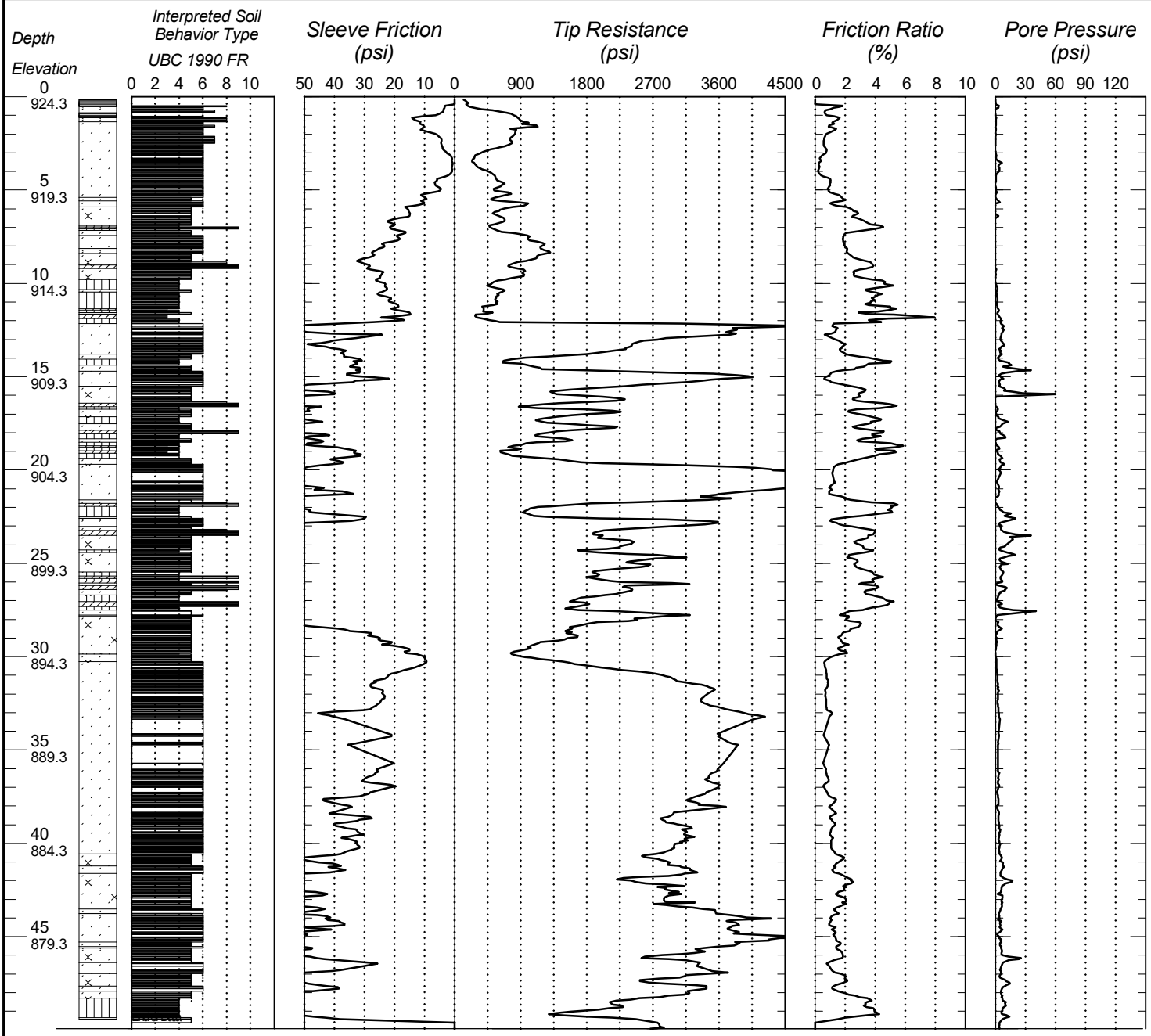
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85032

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-135**	**52**	**c200**	**924.3** *(DTM)*

Location Dakota County Coordinate System	*CPT Machine* **203094 CPT Truck**	*SHEET 1 of 1*
X=566262 Y=246728 *'SB 52 STA 338+66 71' Lt*	*CPT Operator* **ODonnel**	*Date Completed*
Latitude (North)=44°52'26.75" *Longitude (West)=93°03'39.91"*	*Hole Type* **CPT-STD**	**5/26/20**



Bottom of Hole 49.94

DEPARTMENT OF TRANSPORTATION

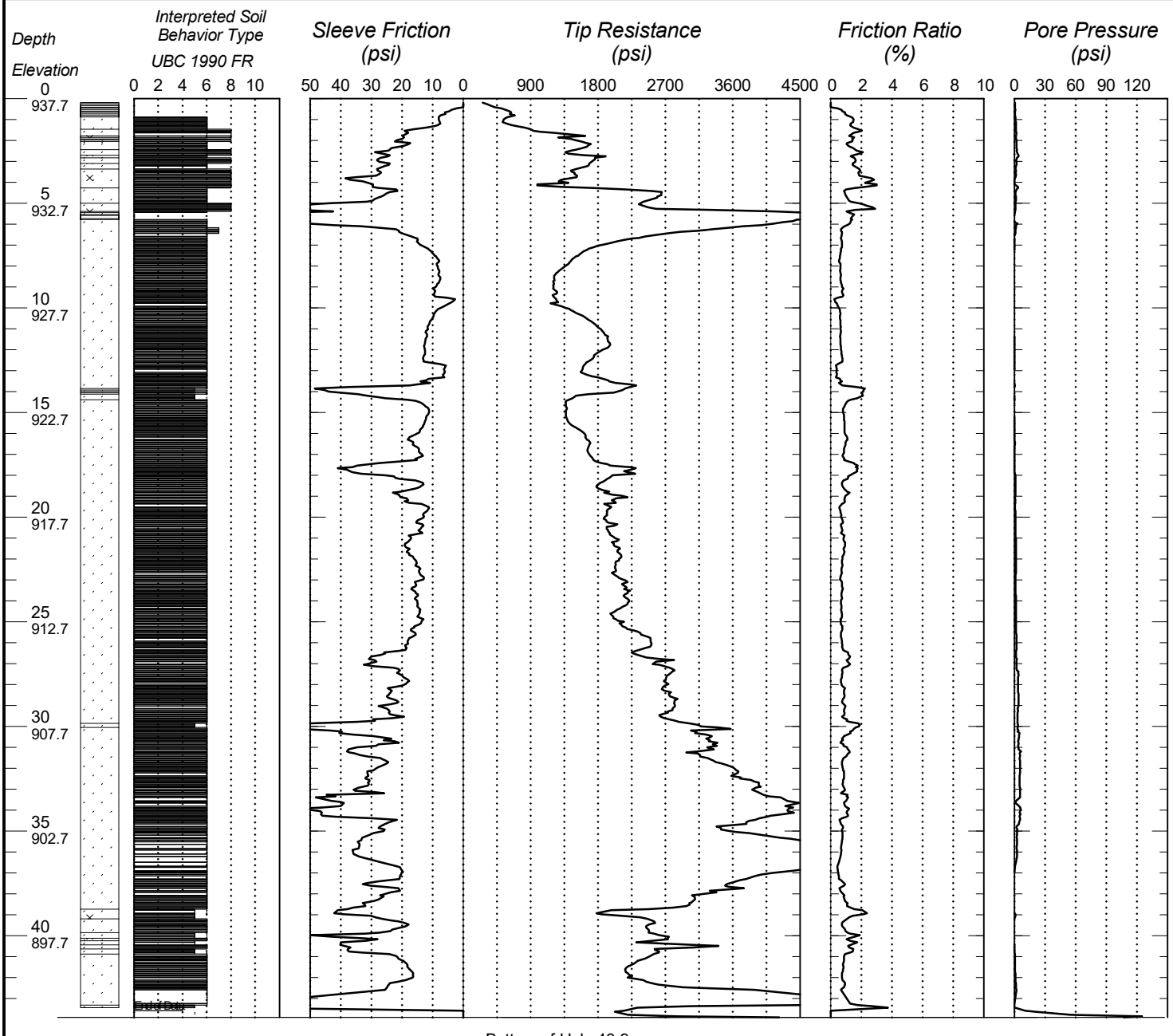
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85033

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-122**	**52**	**c201**	**937.7** *(DTM)*

Location Dakota County Coordinate System	*CPT Machine* **203094 CPT Truck**	*SHEET 1 of 1*
X=566391 Y=249389 *'NB 52 STA 365+15 66' Rt*	*CPT Operator* **ODonnel**	*Date Completed*
Latitude (North)=44°52'53.01" Longitude (West)=93°03'38"	*Hole Type* **CPT-STD**	**5/26/20**



Bottom of Hole 43.9

DEPARTMENT OF TRANSPORTATION

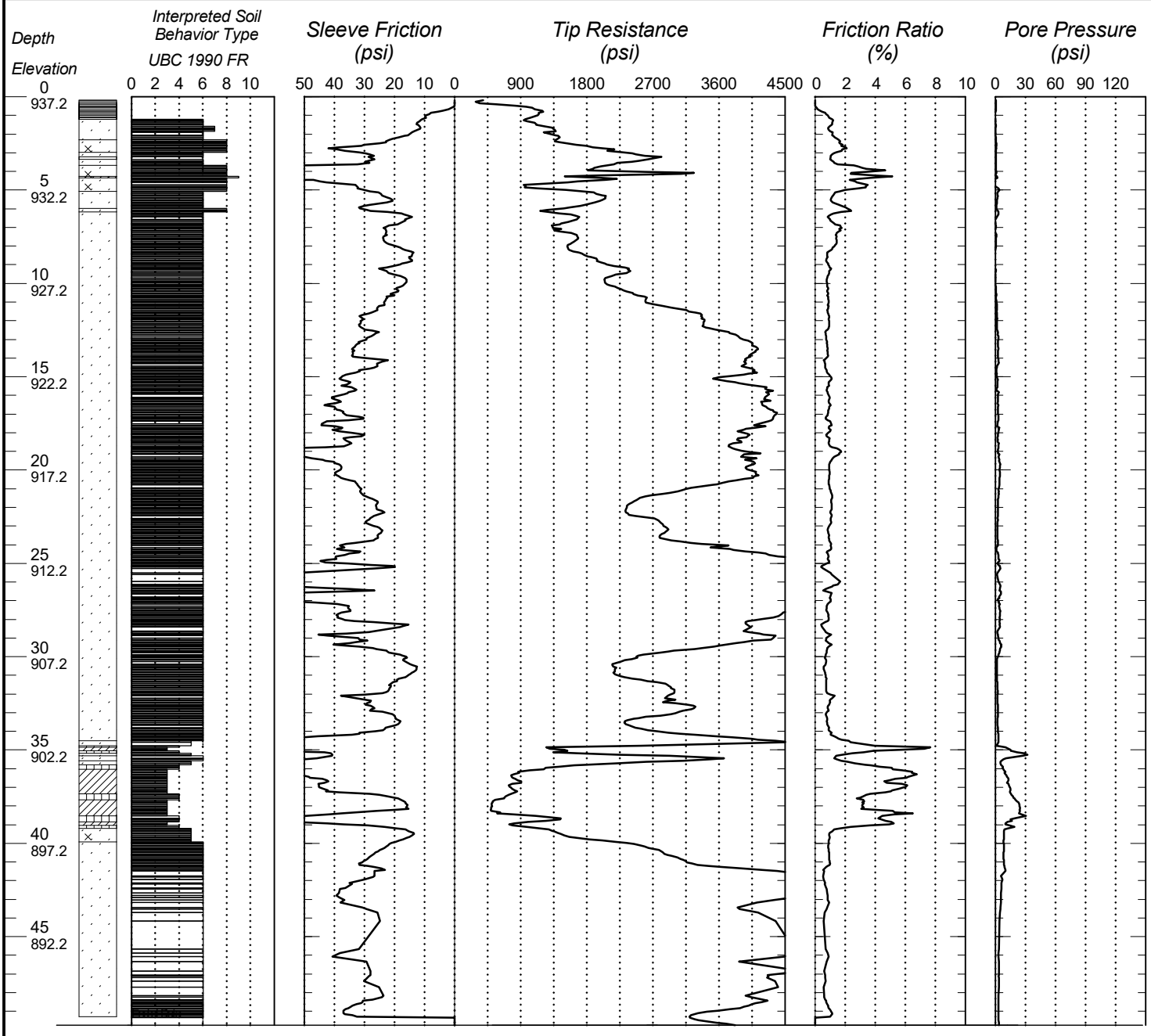
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85034

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-122**	**52**	**c202**	**937.2** *(DTM)*

Location		CPT Machine	SHEET 1 of 1
Dakota County Coordinate System		**203094 CPT Truck**	
X=566304 Y=249366 *'NB 52 STA 365+05 23' Lt*		CPT Operator **ODonnel**	Date Completed
Latitude (North)=44°52'52.79" *Longitude (West)=93°03'39.21"*		Hole Type **CPT-STD**	**5/26/20**



Bottom of Hole 49.74

DEPARTMENT OF TRANSPORTATION

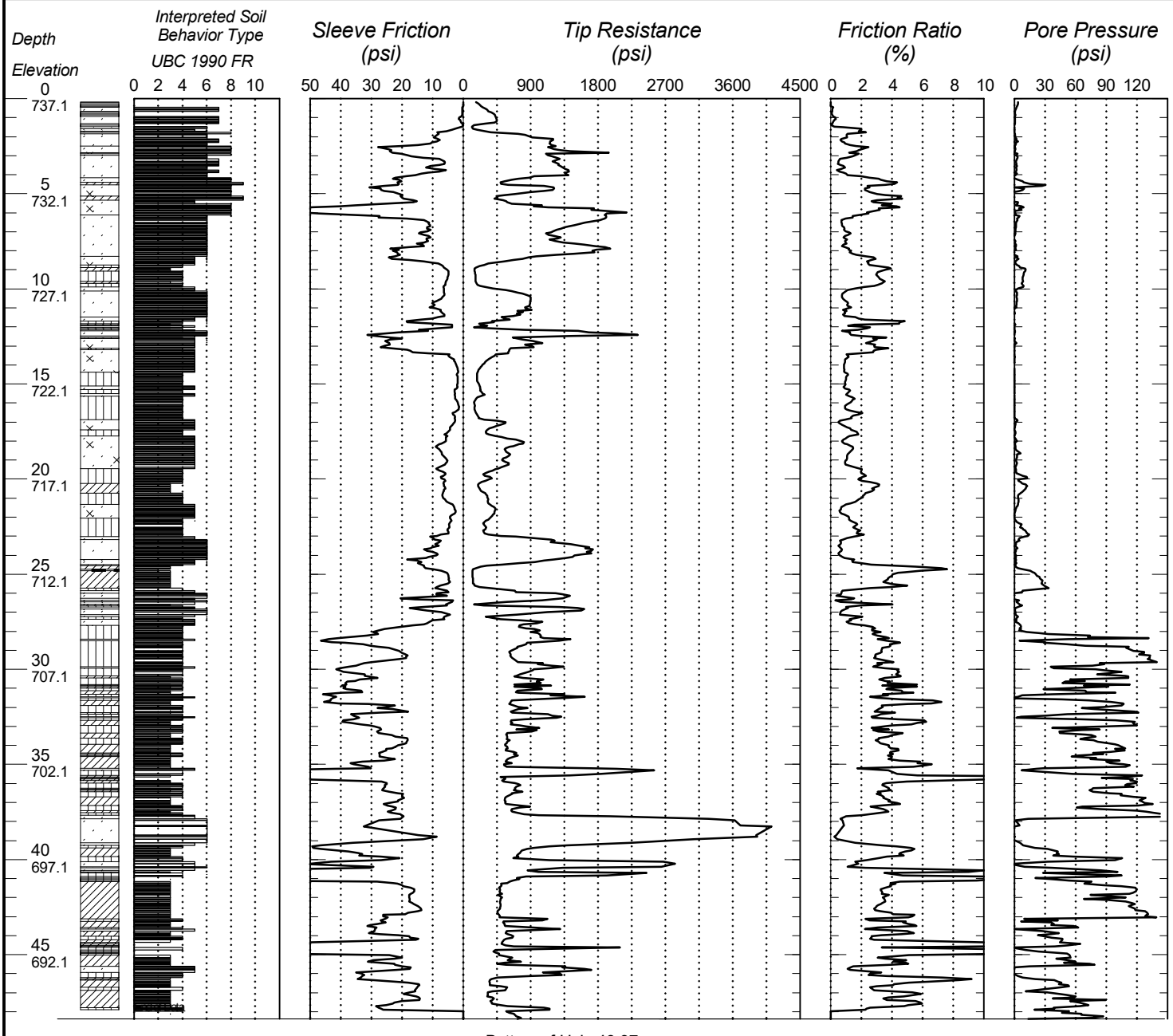
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85035

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-132**	**52**	**c203**	**737.1** *(DTM)*

Location	CPT Machine	SHEET 1 of 1
Dakota County Coordinate System	**203094 CPT Truck**	
X=563644 Y=266481 *'SB 52 STA 544+76 98' Lt*	CPT Operator **ODonnel**	Date Completed
Latitude (North)=44°55'41.85" Longitude (West)=93°04'15.43"	Hole Type **CPT-STD**	**5/26/20**



Bottom of Hole 48.37

DEPARTMENT OF TRANSPORTATION

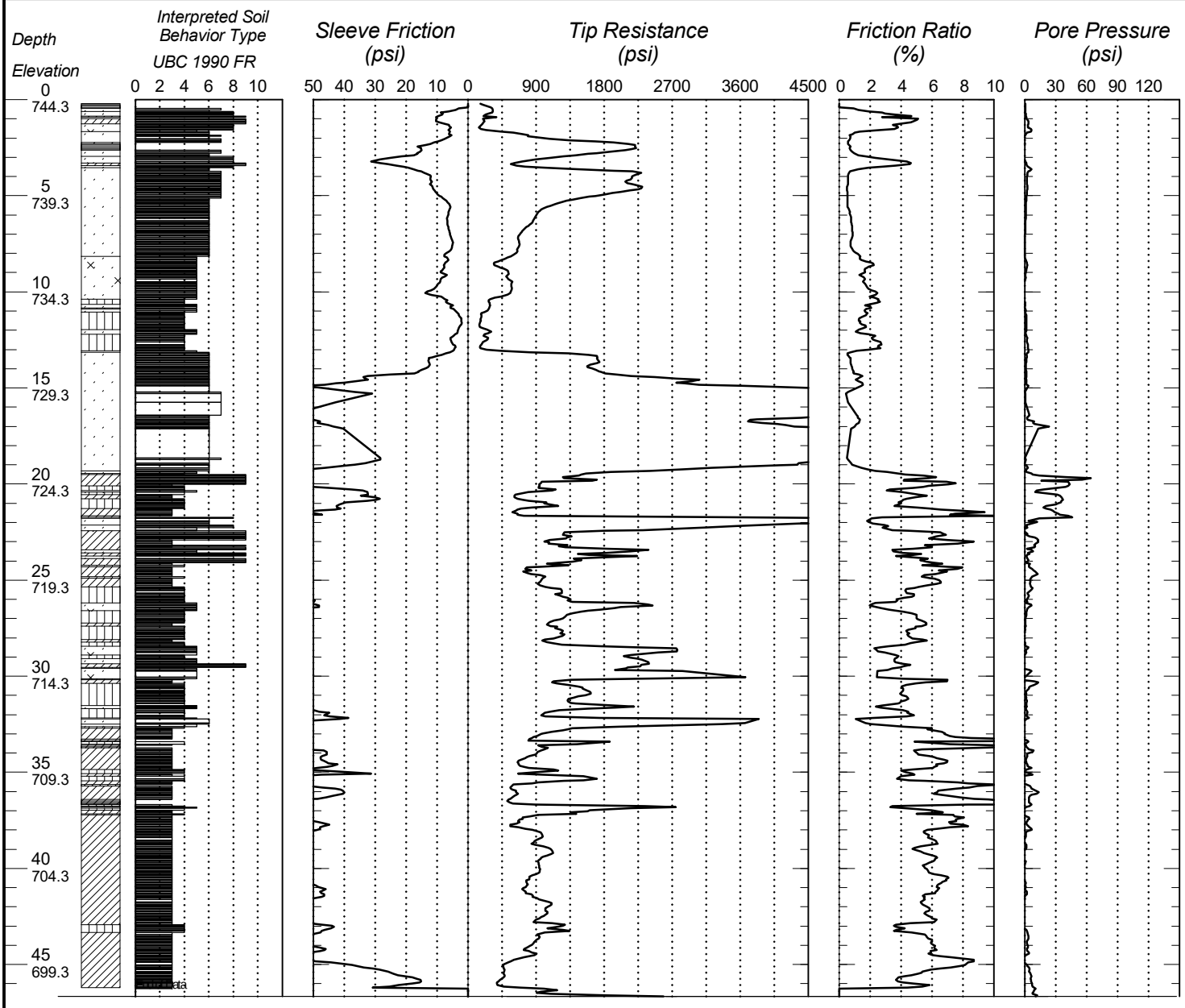
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85036

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-131**	**52**	**c204a**	**744.3** *(DTM)*

Location		CPT Machine	SHEET 1 of 1
Dakota County Coordinate System		**203094 CPT Truck**	
X=563528 Y=267178 *'SB 52 STA 551+67 32' Lt*		CPT Operator **ODonnel**	Date Completed
Latitude (North)=44°55'48.74" *Longitude (West)=93°04'17.01"*		Hole Type **CPT-STD**	**5/26/20**



Bottom of Hole 46.66

DEPARTMENT OF TRANSPORTATION

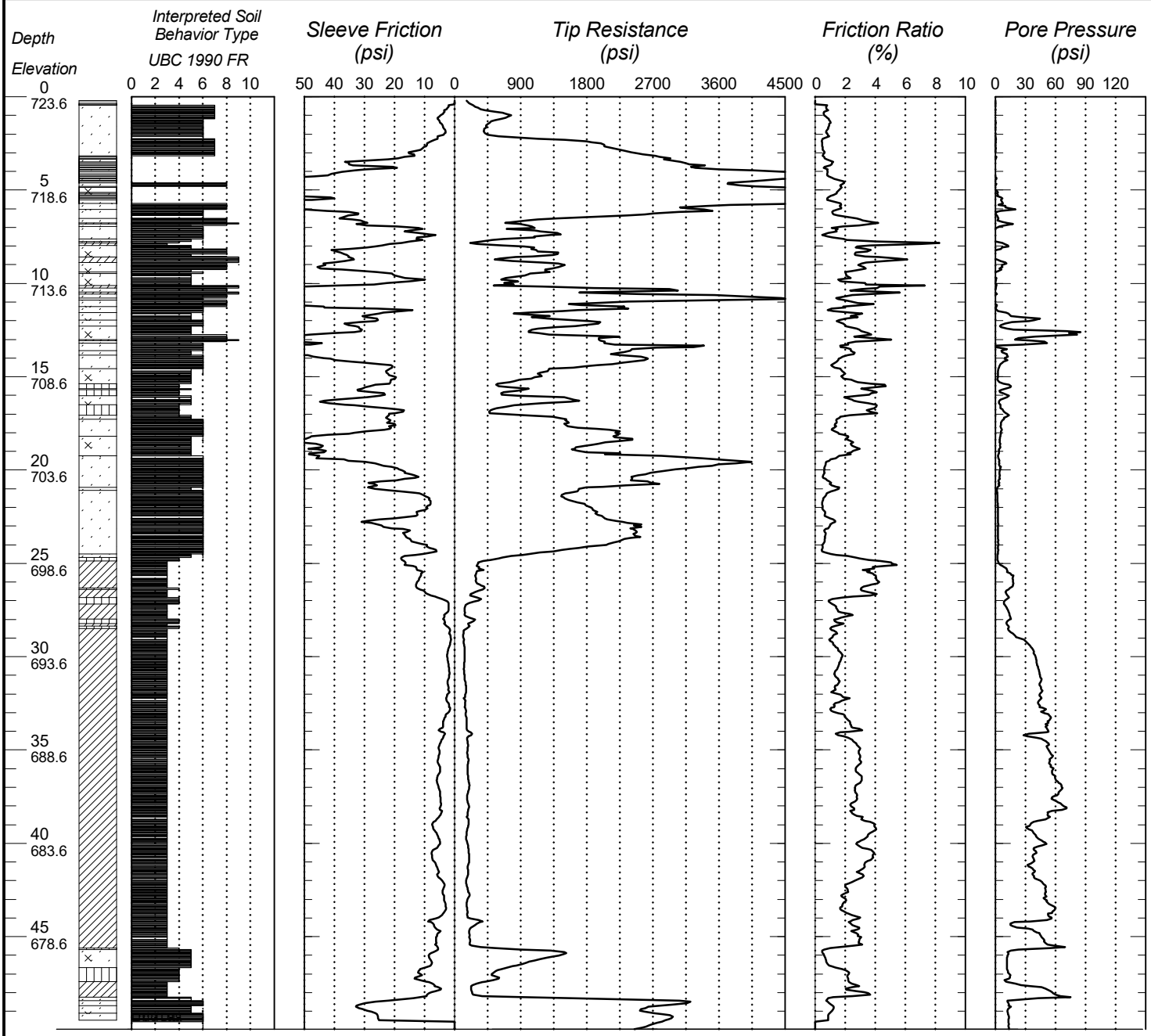
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85037

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-137**	**52**	**c205**	**723.6** *(DTM)*

Location Dakota County Coordinate System	*CPT Machine* **203094 CPT Truck**	*SHEET 1 of 1*
X=563458 Y=268180 *'NB 52 STA 561+75 36' Rt*	*CPT Operator* **ODonnel**	*Date Completed*
Latitude (North)=44°55'58.63" Longitude (West)=93°04'17.95"	*Hole Type* **CPT-STD**	**5/26/20**



Bottom of Hole 49.95

DEPARTMENT OF TRANSPORTATION

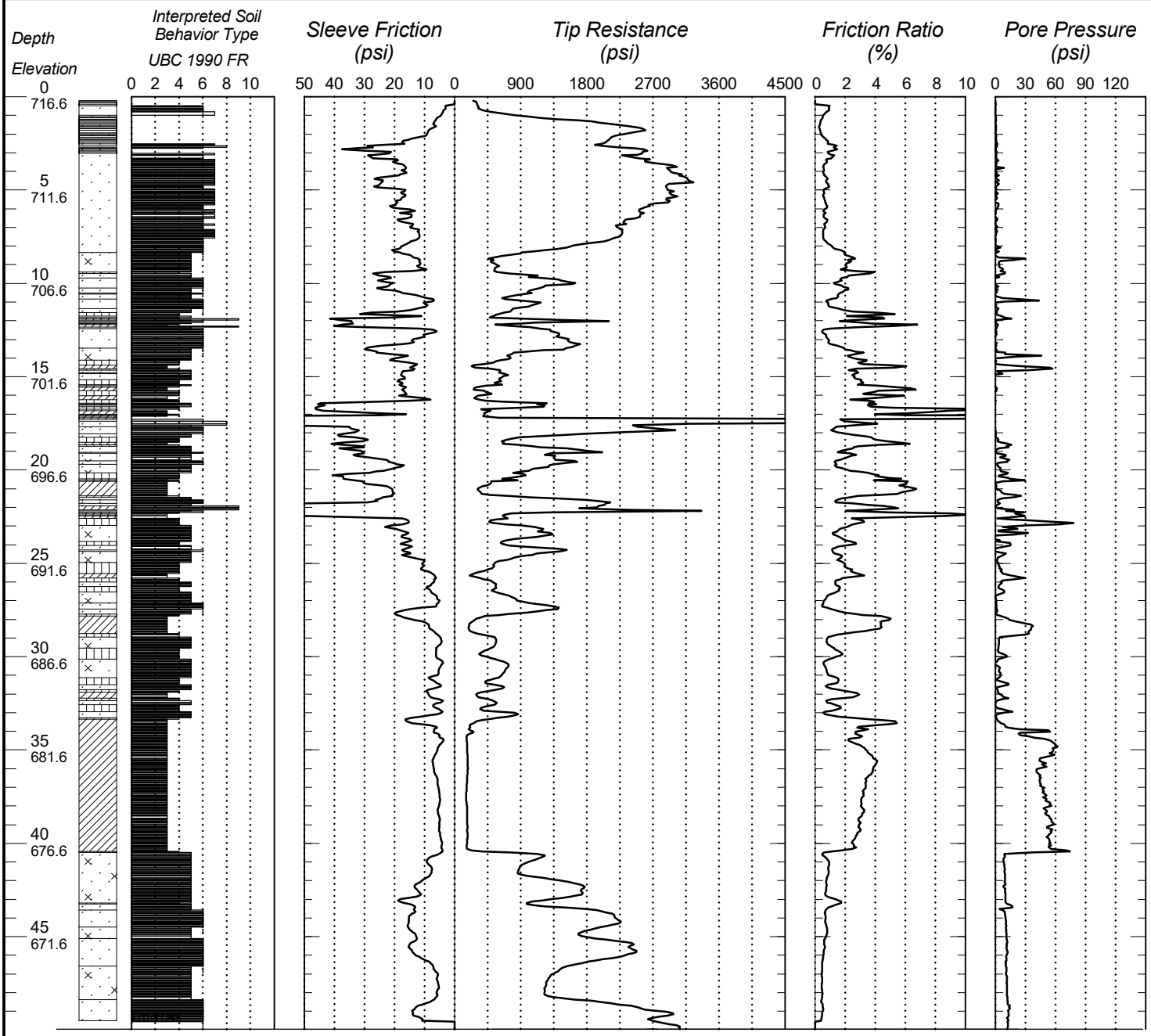
MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

CONE PENETRATION TEST RESULTS

UNIQUE NUMBER 85038

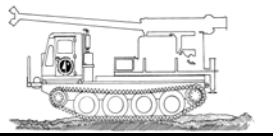
State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Sounding No.	Ground Elevation
1928-71	**OH SIGN US52-138**	**52**	**c206**	**716.6** *(DTM)*

Location Dakota County Coordinate System	*CPT Machine* **203094 CPT Truck**	*SHEET 1 of 1*
X=562493 Y=270389 *'SB 52 STA 585+59 38' Lt*	*CPT Operator* **ODonnel**	*Date Completed*
Latitude (North)=44°56'20.47" *Longitude (West)=93°04'31.27"*	*Hole Type* **CPT-STD**	**5/26/20**



Bottom of Hole 49.95

Minnesota Department of Transportation
Geotechnical Section
Cone Penetration Test Index Sheet 1.0 (CPT 1.0)



USER NOTES, ABBREVIATIONS AND DEFINITIONS

This Index sheet accompanies Cone Penetration Test Data. Please refer to the Boring Log Descriptive Terminology Sheet for information relevant to conventional boring logs.

This Cone Penetration Test (CPT) Sounding follows ASTM D 5778 and was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this sounding was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the conditions and materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this sounding.

Since subsurface conditions outside each CPT Sounding are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this sounding will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water pressure measurements and subsequent interpreted water levels shown on this log should be used with discretion since they represent dynamic conditions. Dynamic Pore water pressure measurements may deviate substantially from hydrostatic conditions, especially in cohesive soils. In cohesive soils, water pressures often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

CPT Terminology

CPT ..... Cone Penetration Test
CPTU..... Cone Penetration Test with Pore Pressure measurements
SCPTU..... Cone Penetration Test with Pore Pressure and Seismic measurements
Piezocone...Common name for CPTU test

(Note: This test is not related to the Dynamic Cone Penetrometer DCP)

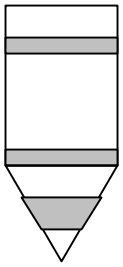
q_T TIP RESISTANCE
The resistance at the cone corrected for water pressure. Data is from cone with 60 degree apex angle and a 10 cm^2 end area.

f_s SLEEVE FRICTION RESISTANCE
The resistance along the sleeve of the penetrometer.

FR Friction Ratio
Ratio of sleeve friction over corrected tip resistance.
FR = fs/qt

V_s Shear Wave Velocity
A measure of the speed at which a siesmic wave travels through soil/rock.

PORE WATER MEASUREMENTS
Pore water measurements reported on CPT Log are representative of water pressures measured at the U2 location, just behind the cone tip, prior to the sleeve, as shown in the figure below. These measurements are considered to be dynamic water pressures due to the local disturbance caused by the cone tip. Dynamic water pressure decay and Static water pressure measurements are reported on a Pore Water Pressure Dissipation Graph.



SBT SOIL BEHAVIOR TYPE
Soil Classification methods for the Cone Penetration Test are based on correlation charts developed from observations of CPT data and conventional borings. Please note that these classification charts are meant to provide a guide to Soil Behavior Type and should not be used to infer a soil classification based on grain size distribution.

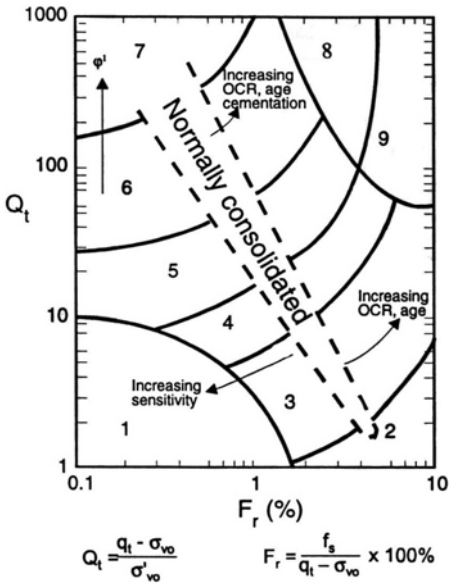
The numbers corresponding to different regions on the charts represent the following soil behavior types:

1. Sensitive, Fine Grained
2. Organic Soils - Peats
3. Clays - Clay to Silty Clay
4. Silt Mixtures - Clayey Silt to Silty Clay
5. Sand Mixtures - Silty Sand to Sandy Silt
6. Sands - Clean Sand to Silty Sand
7. Gravelly Sand to Sand
8. Very Stiff Sand to Clayey Sand
9. Very Stiff, Fine Grained

Note that engineering judgment, and comparison with conventional borings is especially important in the proper interpretation of CPT data in certain geo-materials.

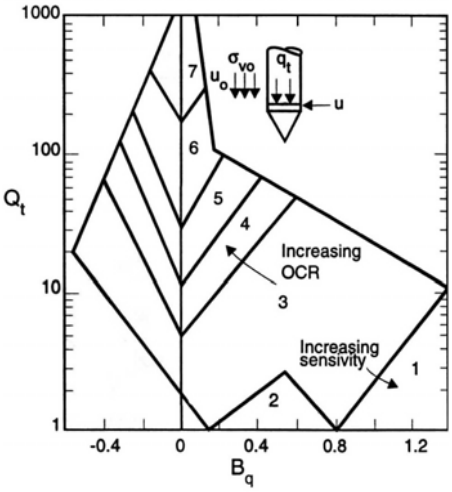
The following charts are used to provide a Soil Behavior Type for the CPT Data.

Robertson CPT 1990
Soil Behavior type based on friction ratio



$$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

Robertson CPTU 1990
Soil Behavior type based on pore pressure



$$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \qquad B_q = \frac{u_2 - u_o}{q_t - \sigma_{vo}}$$

where ...
Q_T ..... normalized cone resistance
B_q ..... pore pressure ratio
F_r ..... Normalized friction ratio
σ_{vo} ..... overburden pressure
σ'_{vo} ..... effective over burden pressure
u_2 ..... measured pore pressure
u_0 ..... equilibrium pore pressure