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Geotechnical, Environmental and Construction Materials Testing Professionals

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Offices Covering all USA

In-Situ Testing at Mn/DOT

What would you rather have? In-Situ Testing

- SPT
- Piezos

- SPT N_{60}
- CPTU
- Seismic CPT
- SMR-CPT
- CPT-Sampler
- Vision Cone
- CPT-Dissipation
- DMT
- DMT Dissipation
- Electrical Resistivity
- Push-in CPT piezos

How did we get here?

- Capital investment
- Upper Staff support
- Champion
- Willing to try new things
- Learning Curve

SPT

- Standard Penetration Tortoise

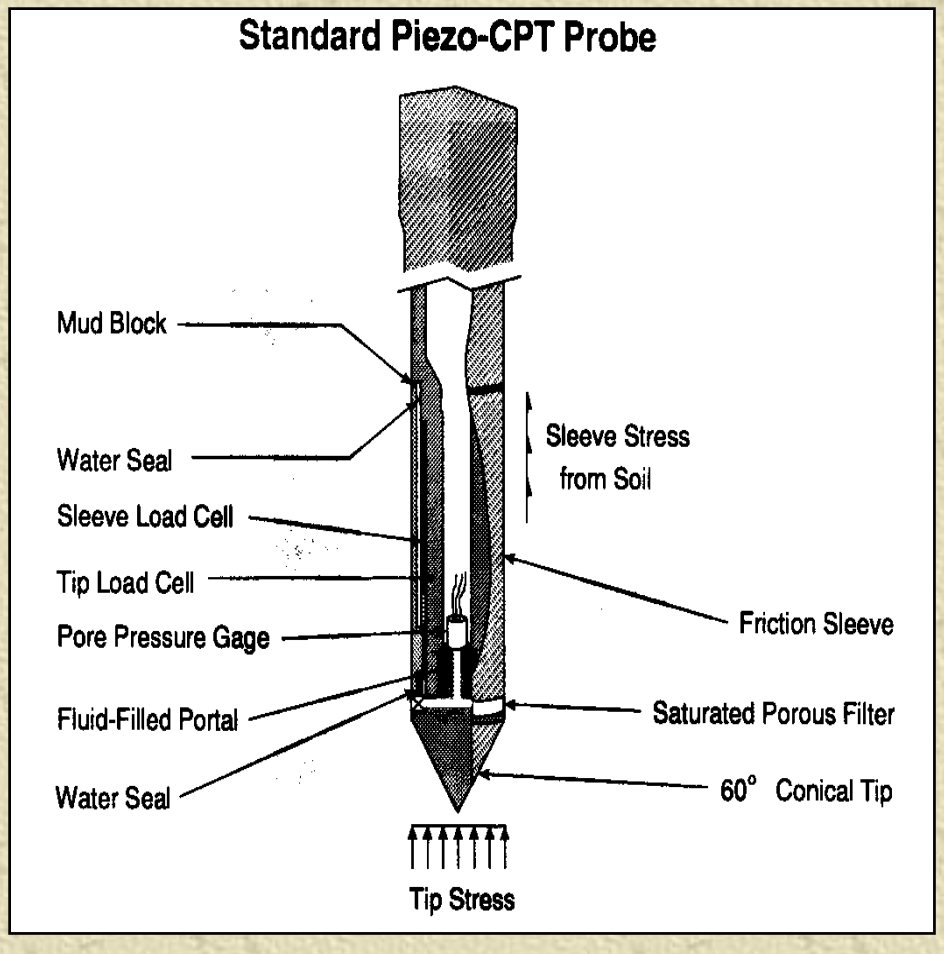
Mn/DOT Modified SPT

- All hammers calibrated to 60% efficiency
- Adjust stroke and/or hammer weight
- N_{60}
- Checked annually
- Consultants required to follow
- Still a poor test

CPT Menu

- CPTu
- CPT dissipation
- CPTu with soil samples
- Vision Cone
- SCPTu
- CPT push-in piezos
- SMR-CPTu (RCPTu)

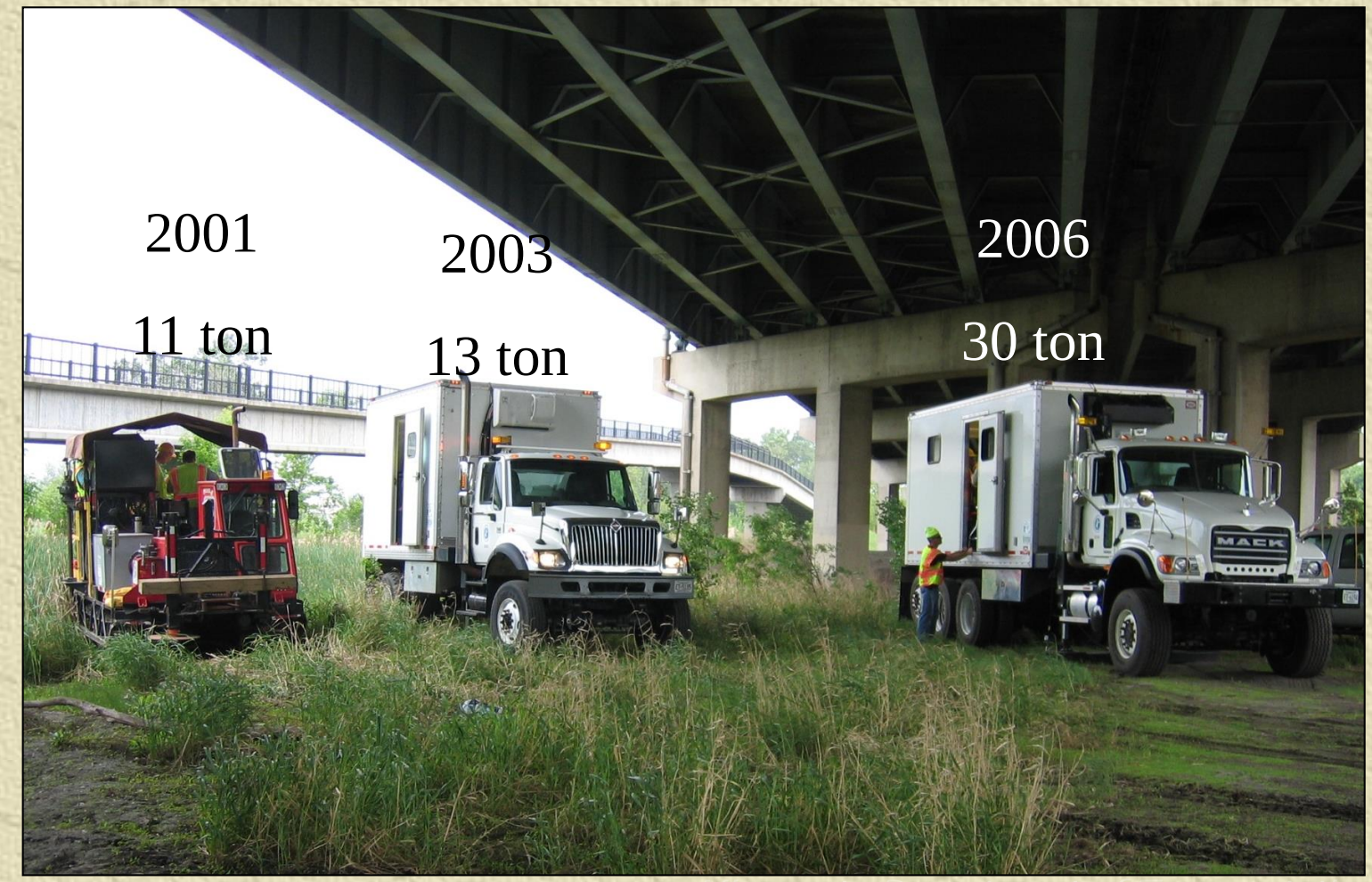
Cone Penetration Test (CPTu)



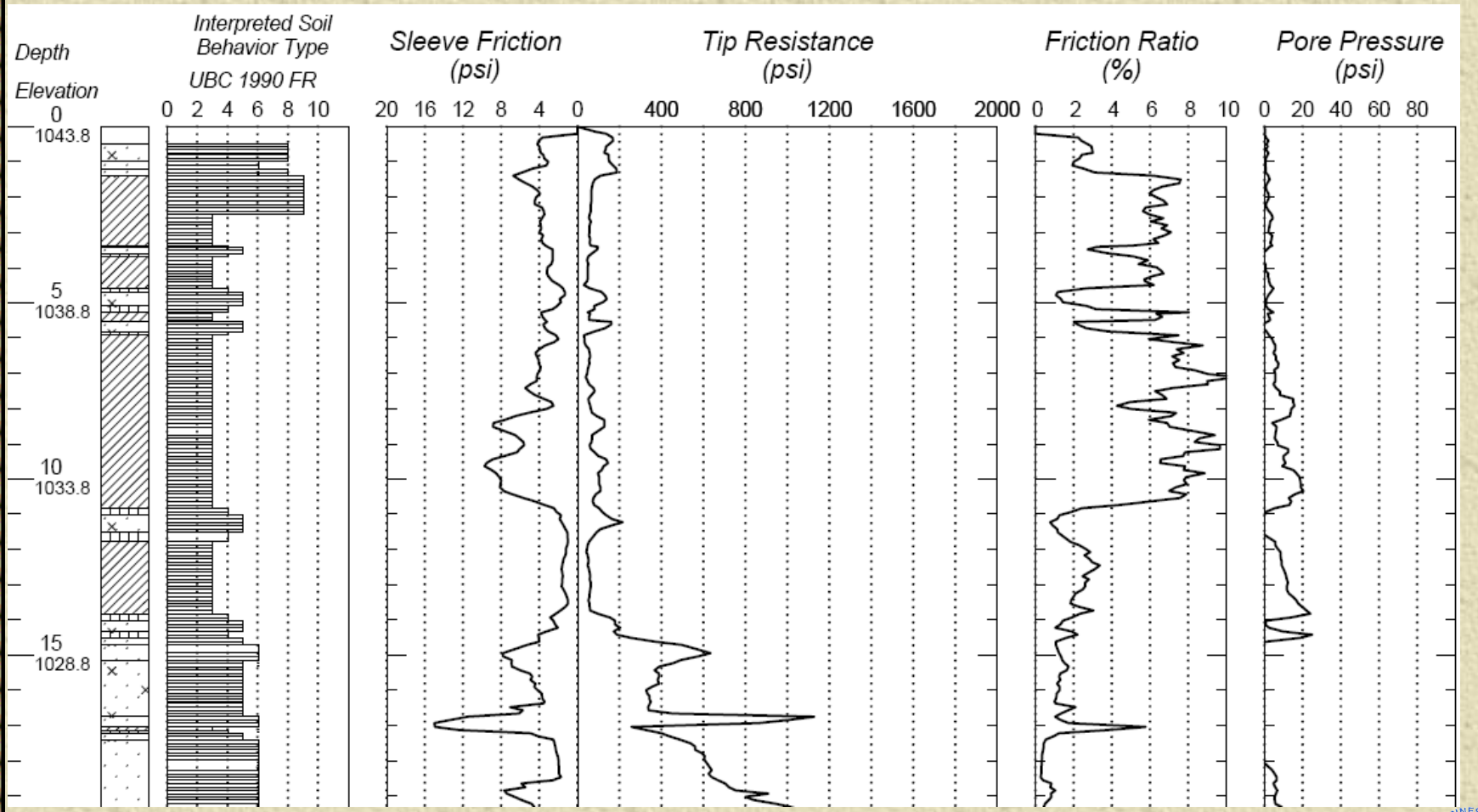
CPTu vs. SPT

- Good
  - 10 x faster
  - 100 x more data
  - 1/10 cost
- Bad
  - No samples for lab testing
  - Rock, boulders

Mn/DOT's CPT Fleet

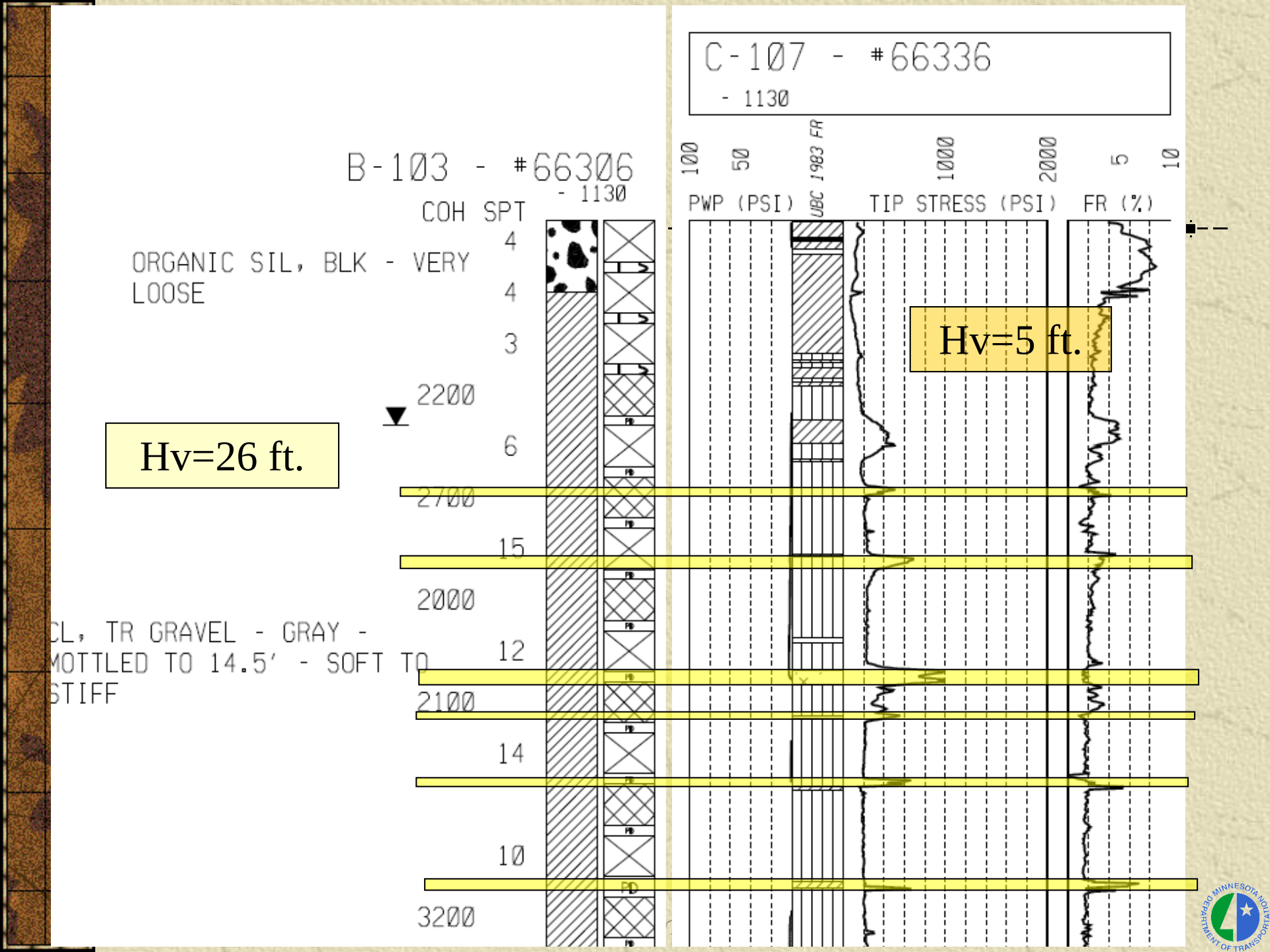


CPTu data

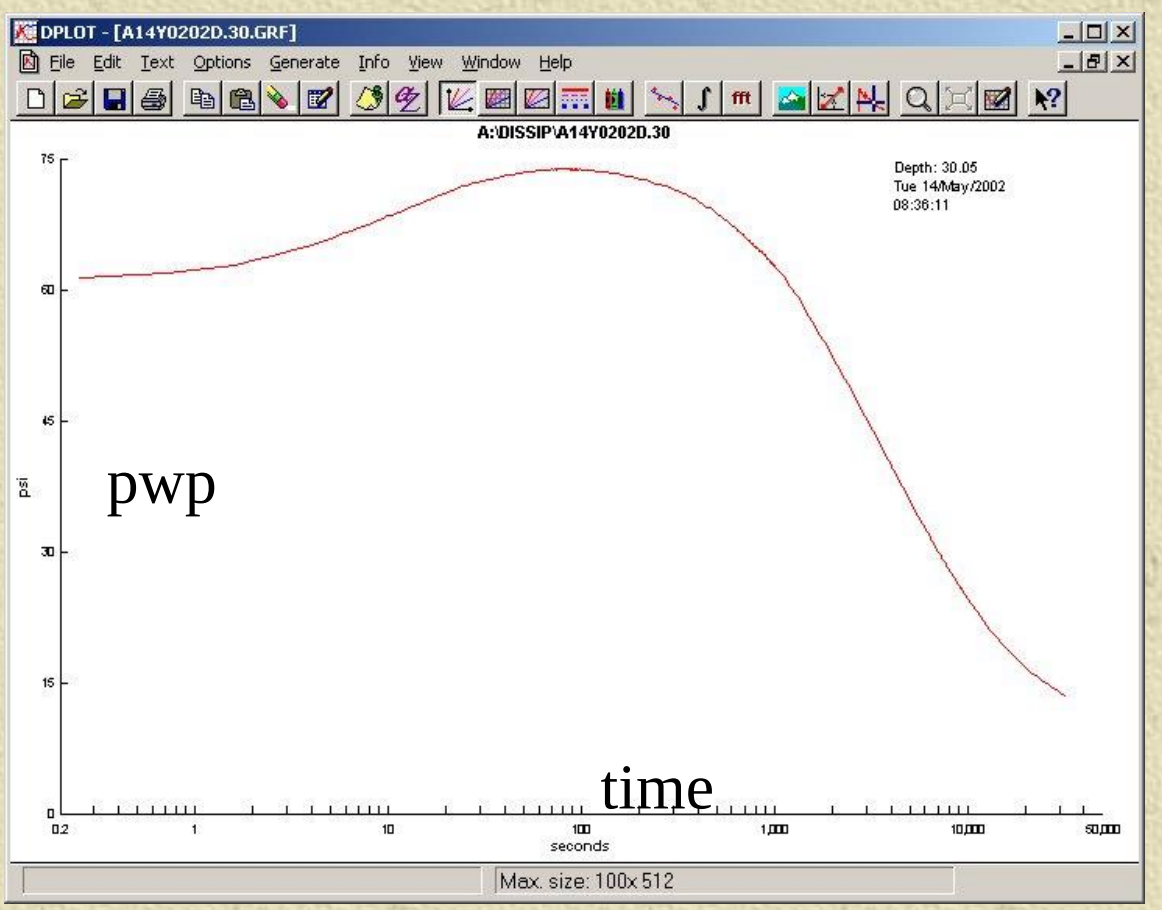

Depth
Elevation
0
1043.8
5
1038.8
10
1033.8
15
1028.8
Interpreted Soil Behavior Type
UBC 1990 FR
0 2 4 6 8 10
Sleeve Friction (psi)
20 16 12 8 4 0
Tip Resistance (psi)
0 400 800 1200 1600 2000
Friction Ratio (%)
0 2 4 6 8 10
Pore Pressure (psi)
0 20 40 60 80

CPTu Applications

- Swamp Delineation
- Define drainable layers (embankment settlement)
- Slope Stability
- Prelim. Info.
- Shallow and Deep foundation design
- Pavement design


C-107 - #66336
- 1130
B-103 - #66306
- 1130
COH SPT
ORGANIC SIL, BLK - VERY LOOSE
4
4
3
2200
6
2700
15
2000
CL, TR GRAVEL - GRAY - MOTTLED TO 14.5' - SOFT TO STIFF
12
2100
14
10
3200
100
50
UBC 1983 FR
1000
2000
5
10
PWP (PSI)
TIP STRESS (PSI)
FR (%)
Hv=26 ft.
Hv=5 ft.

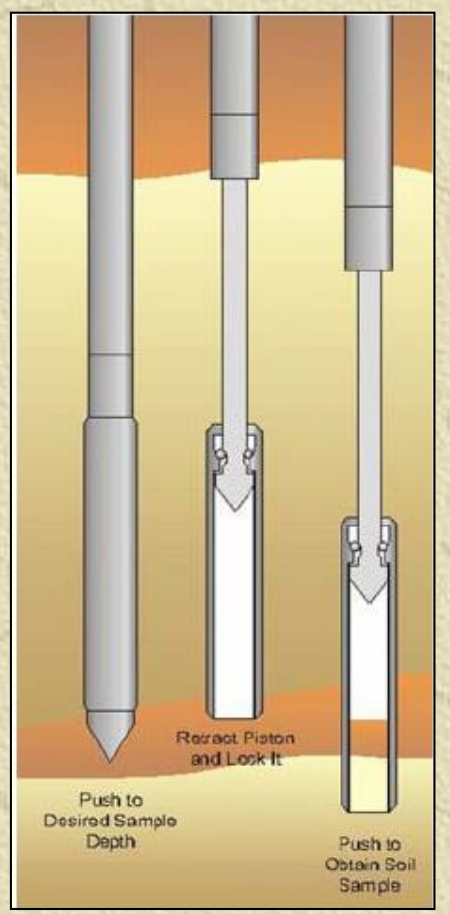
CPT – Dissipation Test



CPT Dissipation Test Applications

- Dissipation rate for plastic soils
  - Time rate of settlement
  - Pile set-up potential
- Aid in soil classification
- Water table determination

CPT-Sampler



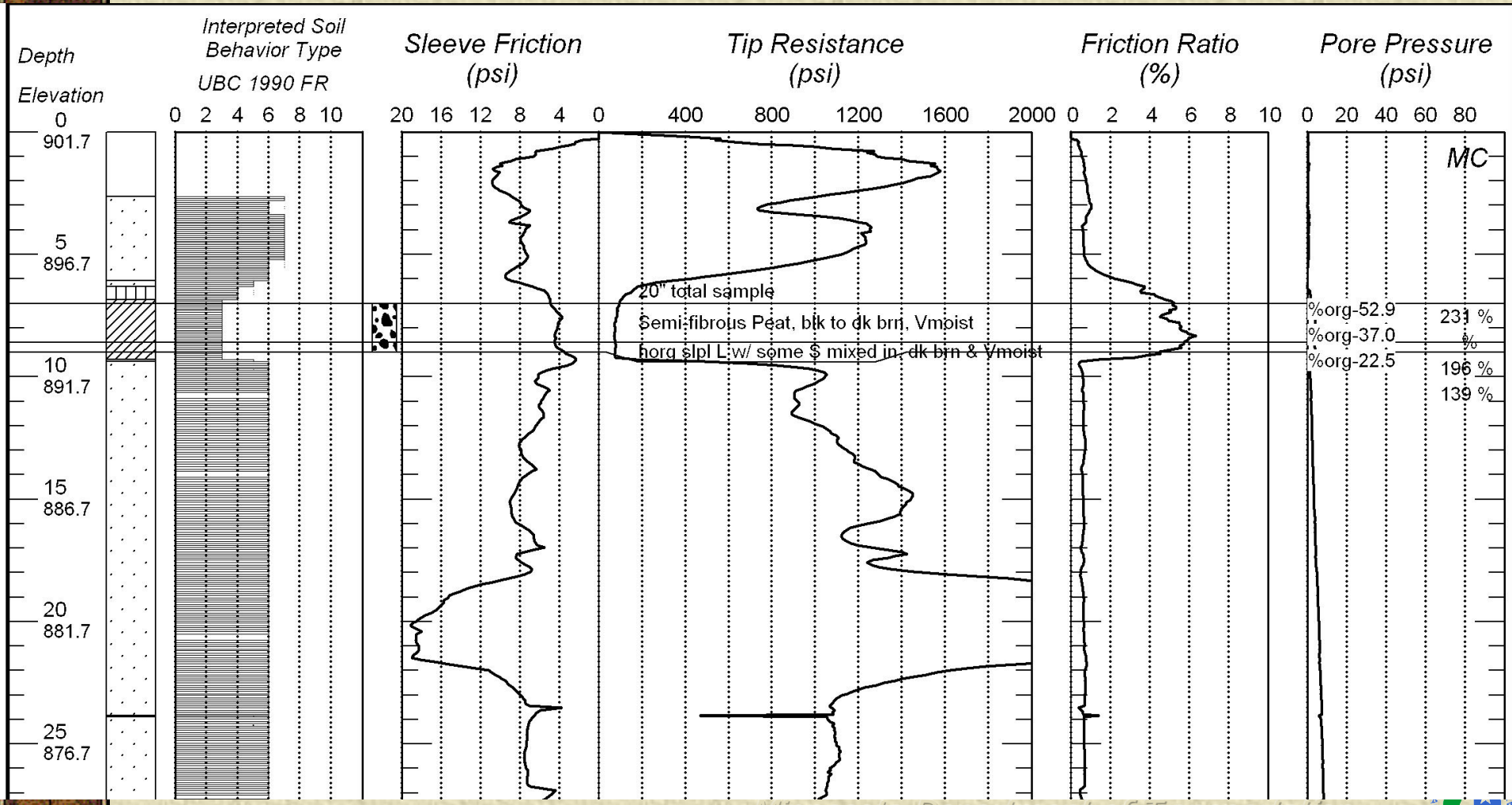
1 in.
diameter

24 in. long

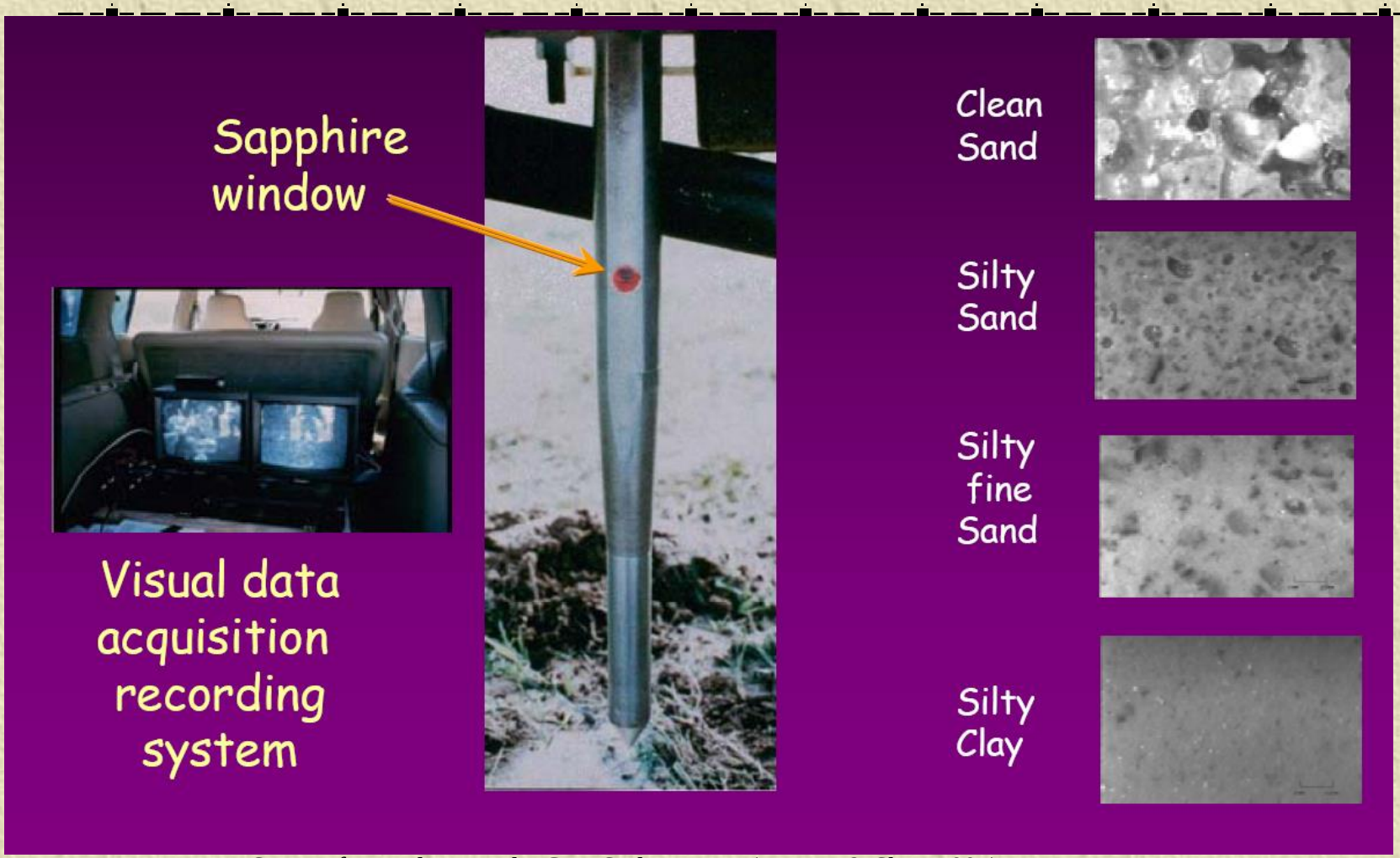
CPT - Sampler

- Soil Classification
- Moisture content
- Organic content
- Sieve Analysis

CPT Sample Log



Vision Cone

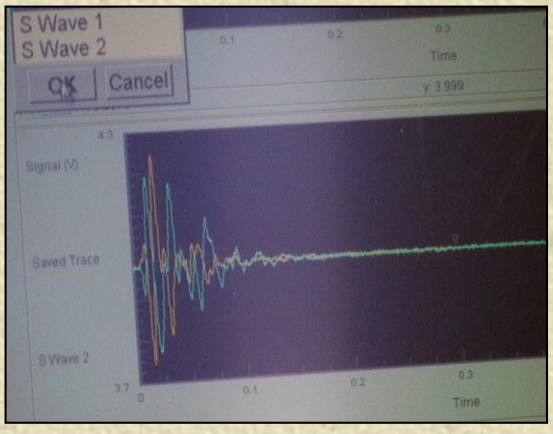


Vision Penetrometer System for Realtime VideoCam Soil Viewing (Hryciw & Shin, 2004)

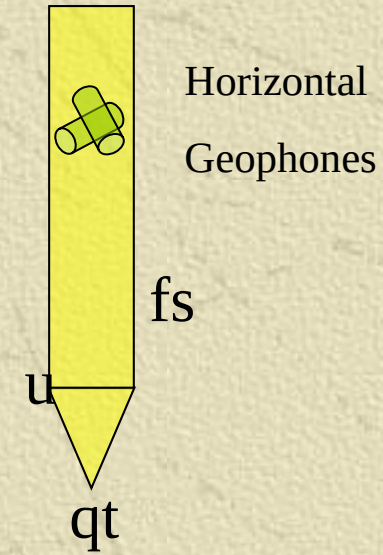
Vision Cone

Seismic CPT

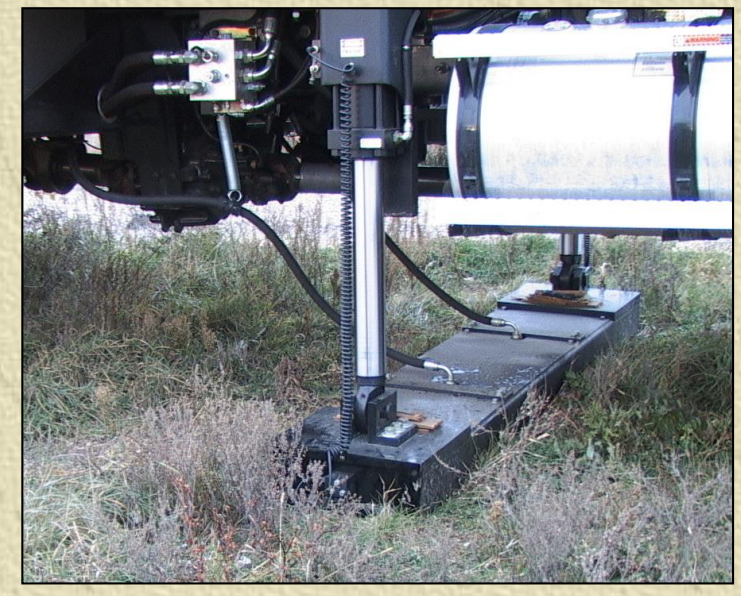
- Measures shear wave velocities (Vs) of soil
- Vs is directly related to low strain shear modulus and poisson's ratio
  - Stiffness parameters
- Data used to predict
  - Settlement
  - Liquefaction potential

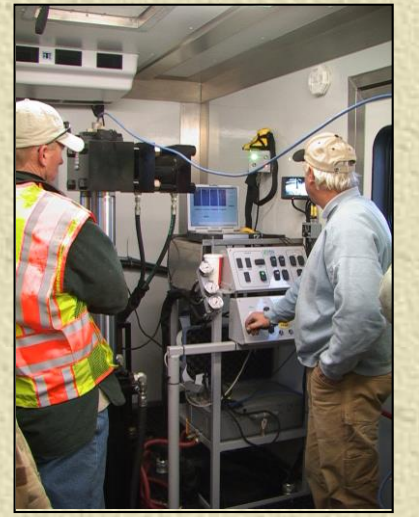


Seismic CPT Equipment

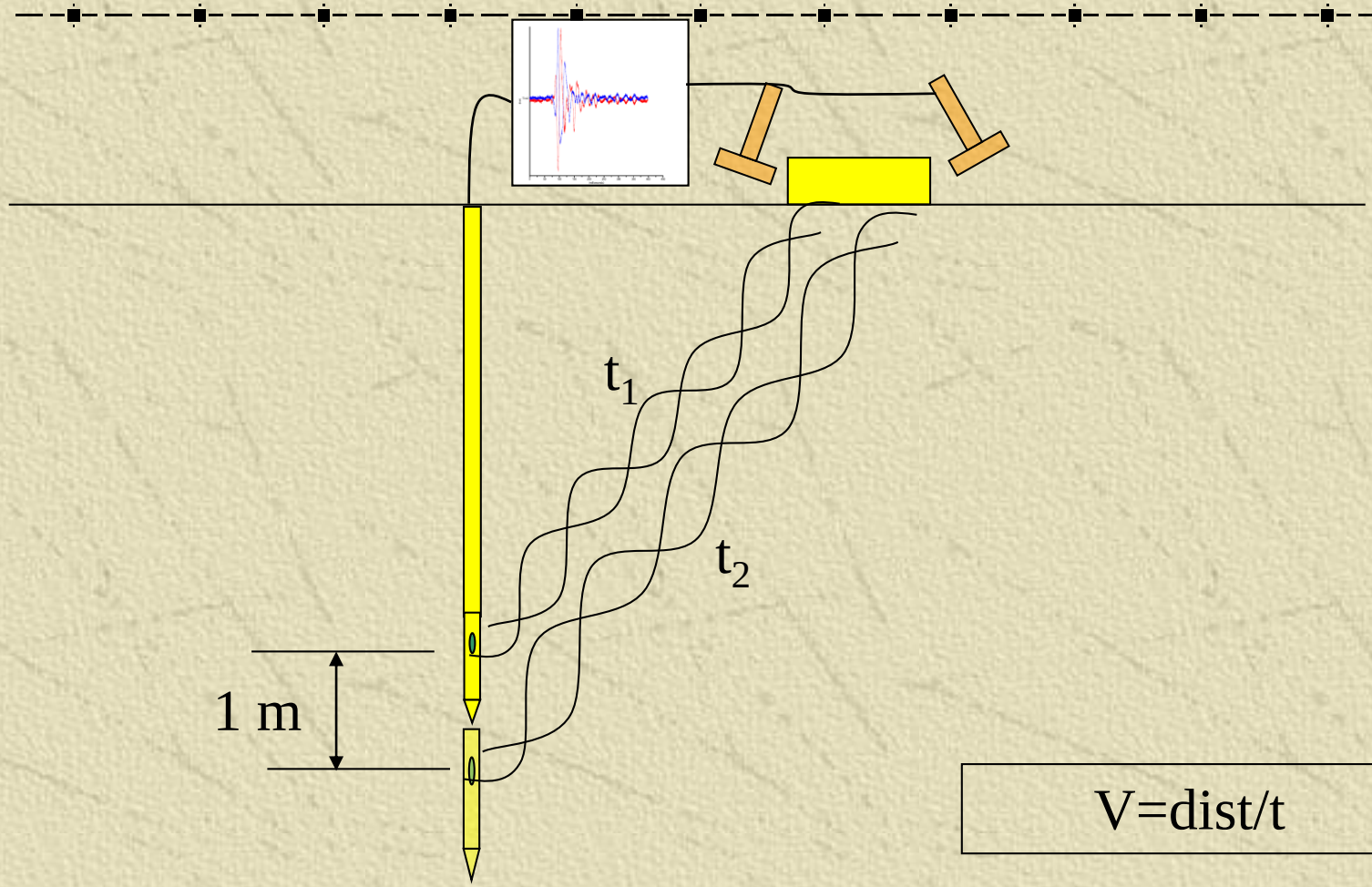


Seismic CPT Equipment



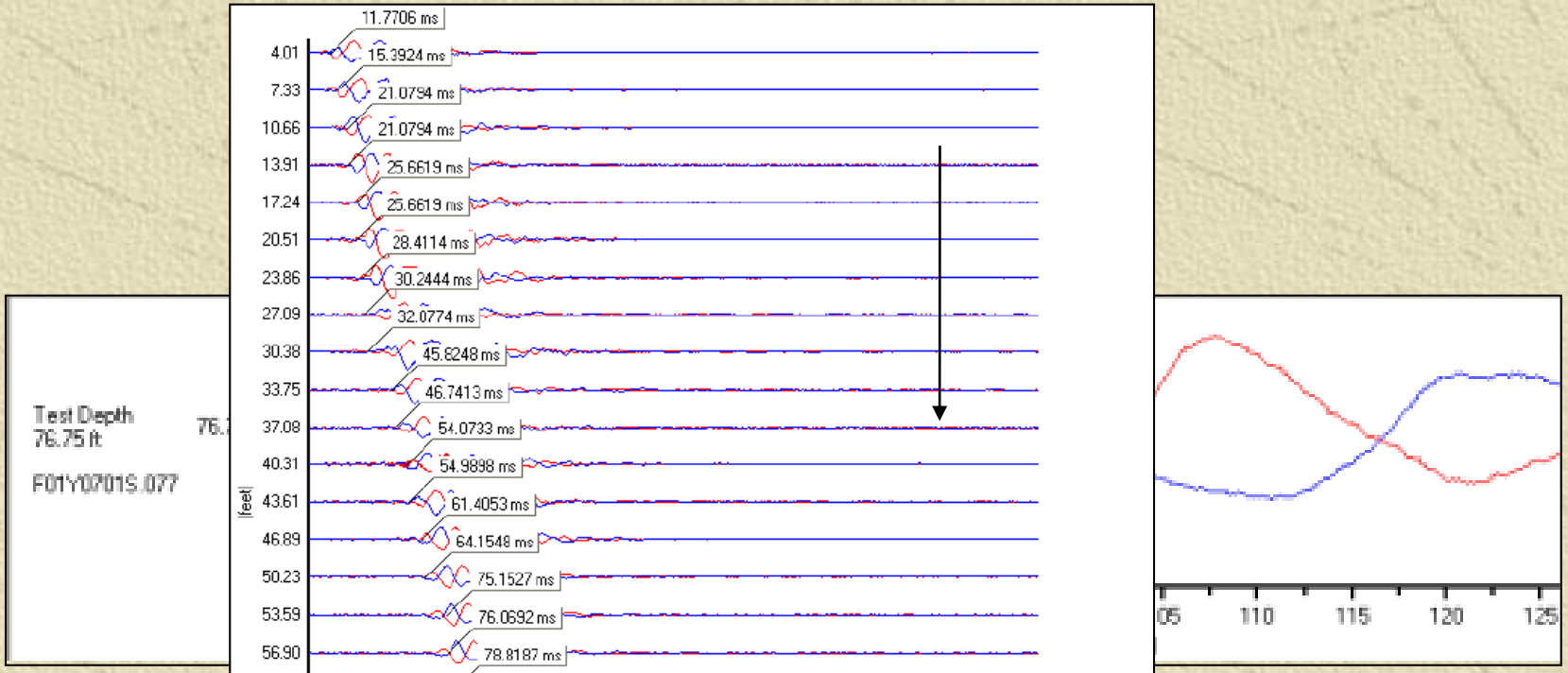


Seismic CPT Procedure



V=dist/t

Seismic CPT Procedure

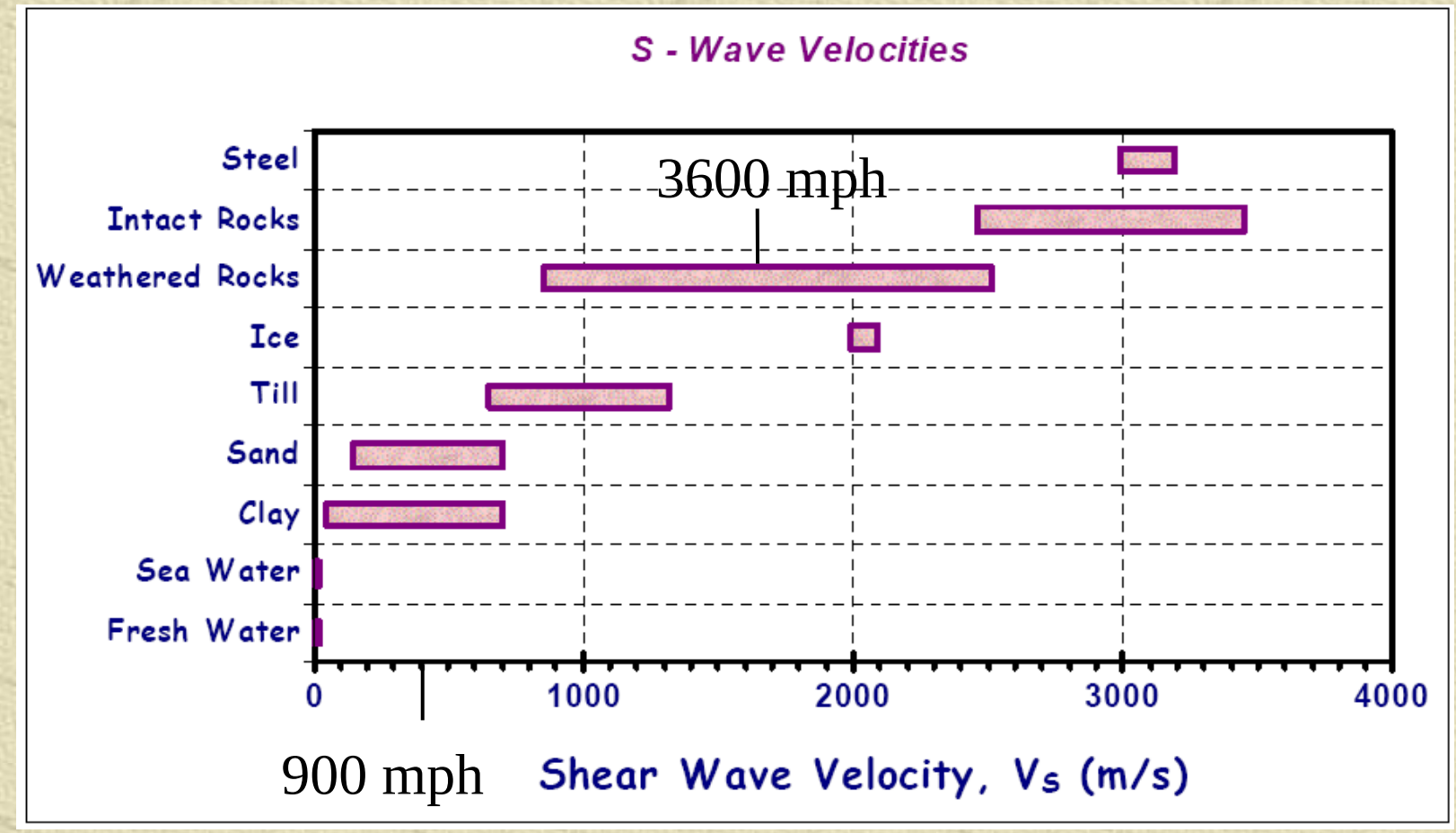


Seismic CPT Data

V=dist/t

Hole	depth (ft)	arrival (ms)	interval time (ms)	distance (ft)	Vs (ft/s)
c05	7.42	15.9215			
c05	10.51	20.7813	4.8598	3.09	
c05	13.8	25.7528	4.9715	3.29	661.77
c05	17.08	30.2706	4.5178	3.28	726.02
c05	20.39	35.2061	4.9355	3.31	670.65
c05	23.65	39.2397	4.0336	3.26	808.21
c05	26.99	42.7982	3.5585	3.34	938.60
c05	30.31	47.5043	4.7061	3.32	705.47
c05	33.59	51.0817	3.5774	3.28	916.87
c05	36.85	54.3943	3.3126	3.26	984.12
c05	40.18	59.3824	4.9881	3.33	667.59
c05	43.51	62.4703	3.0879	3.33	1078.40
c05	46.8	66.2708	3.8005	3.29	865.68
c05	50.08	67.696	1.4252	3.28	2301.43
c05	53.4	71.9715	4.2755	3.32	776.52
c05	56.68	74.5843	2.6128	3.28	1255.36
c05	59.98	77.4347	2.8504	3.3	1157.73

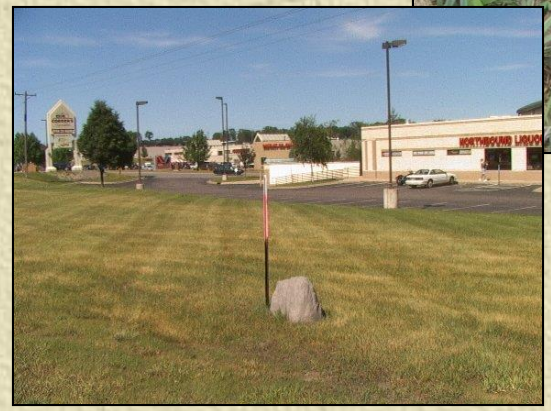
Seismic CPT Vs for soils



Source: GEC 5 (2002) Evaluation of Soil and Rock Properties

CPT- Piezos

- Push-in piezo



CPT Piezos - Applications

- Water Table Determination
- Pore pressure monitoring for embankment construction

SMR-CPT

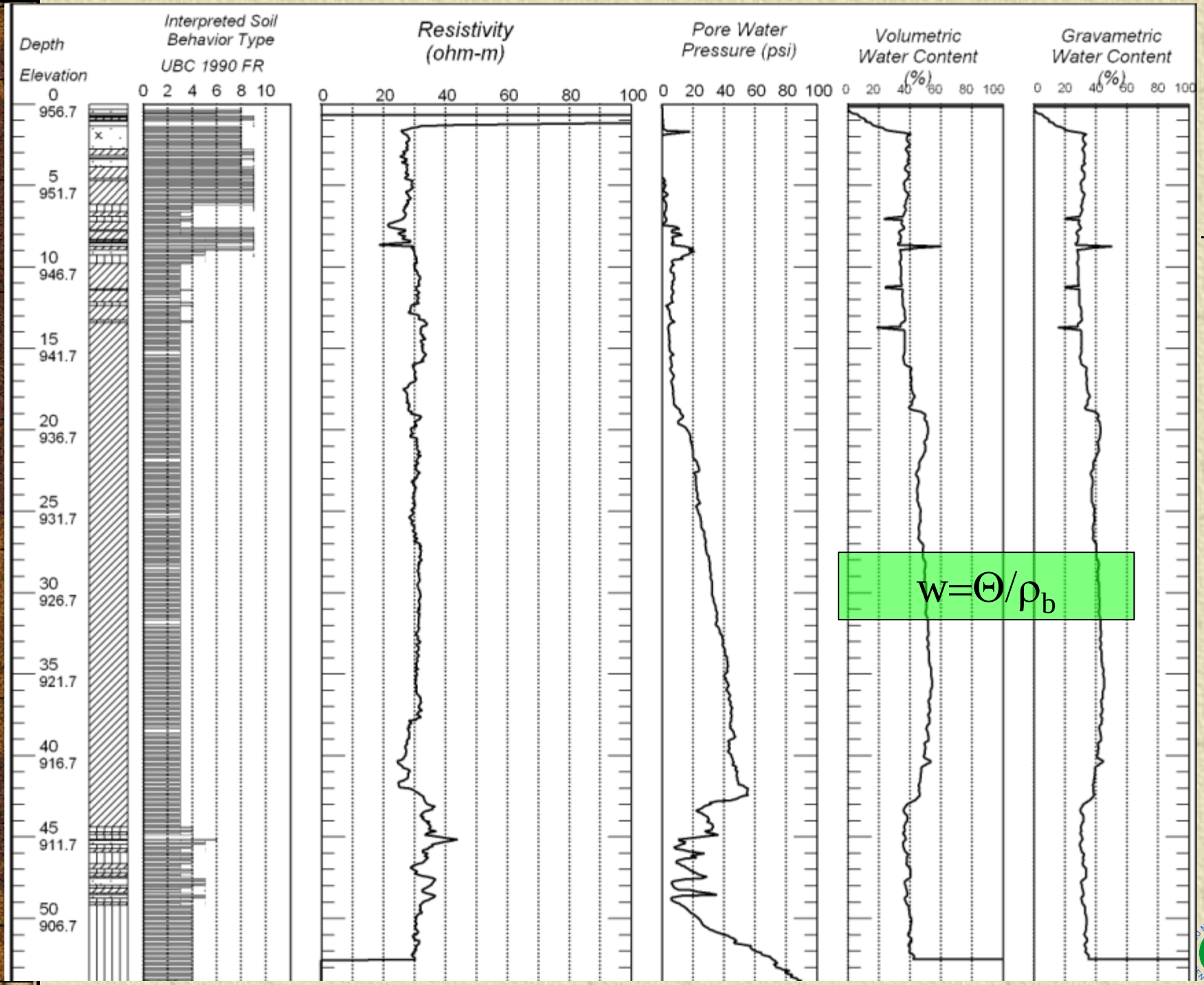
- Soil Moisture/Resistivity
- Electrical conductivity measurements
  - Stratigraphy
  - Ground Water Problems
  - Contaminates
  - Verify Electrical Resistivity measurements by Geologists

SMR-CPT Equipment

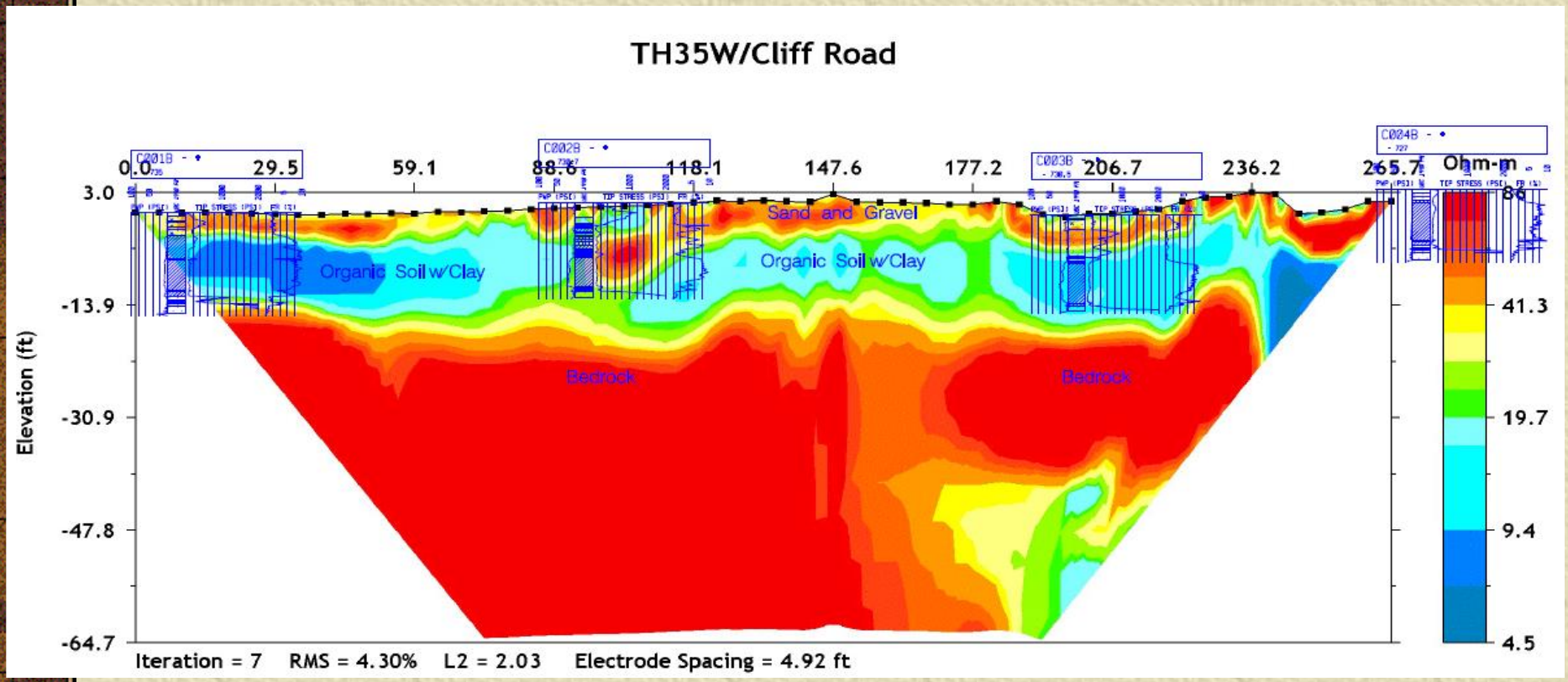
- Coupled to std. cone
- Four electrode array
  - Brass ring electrodes separated by plastic insulator

SMR-CPT Procedure

- Push standard CPTu
- High frequency AC sent across electrodes
- Voltage is measured
- Voltage converted to resistance (function of conductivity)
- Resistance multiplied by calibration factor to arrive at Resistivity value (ohlm-meter)


Depth
Elevation
Interpreted Soil Behavior Type
UBC 1990 FR
Resistivity (ohm-m)
Pore Water Pressure (psi)
Volumetric Water Content (%)
Gravametric Water Content (%)
0 2 4 6 8 10
0 20 40 60 80 100
0 956.7
5 951.7
10 946.7
15 941.7
20 936.7
25 931.7
30 926.7
35 921.7
40 916.7
45 911.7
50 906.7
$w=\Theta/\rho_b$

Electrical Resistivity Survey



Flat Plate Dilatometer Test (DMT)

- Developed by Silvano Marchetti in 1970s in Italy
- Introduced to N. America in 1980s
- Used today in over 40 countries
- ASTM D 6635
- Direct Push Test, no samples

DMT Advantages

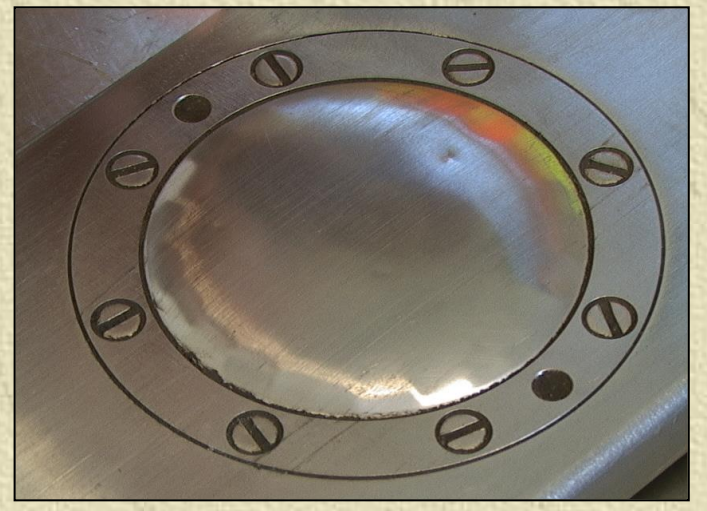
- Wide range of soils (not suitable for gravels)
- Quick, simple, reproducible test
- Primary use of data is to interpret common soil properties
  - Strength
  - Stiffness
- Settlement Analysis

DMT Equipment

0.6 in.

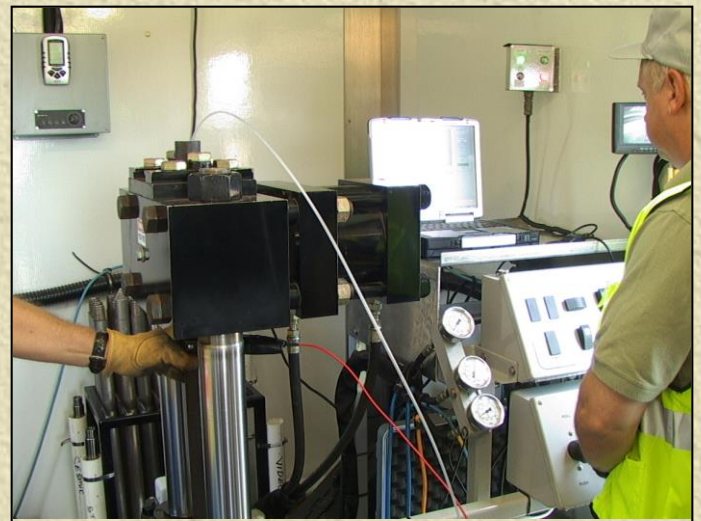
thick

4 in.



Flat, 2.4 in. diameter circular steel membrane (0.2 mm thick)

DMT Equipment

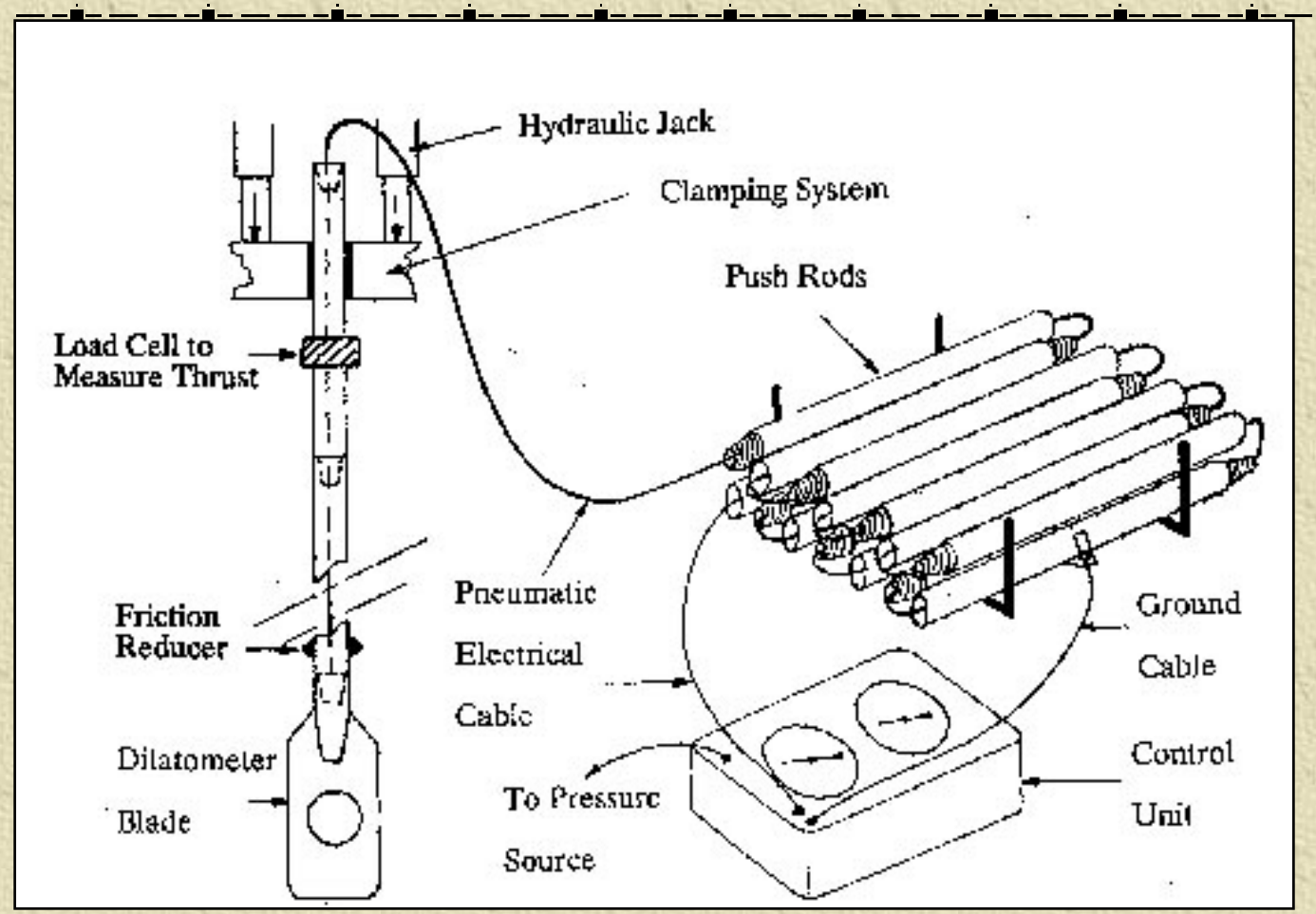


DMT Equipment

Control Box

Nitrogen

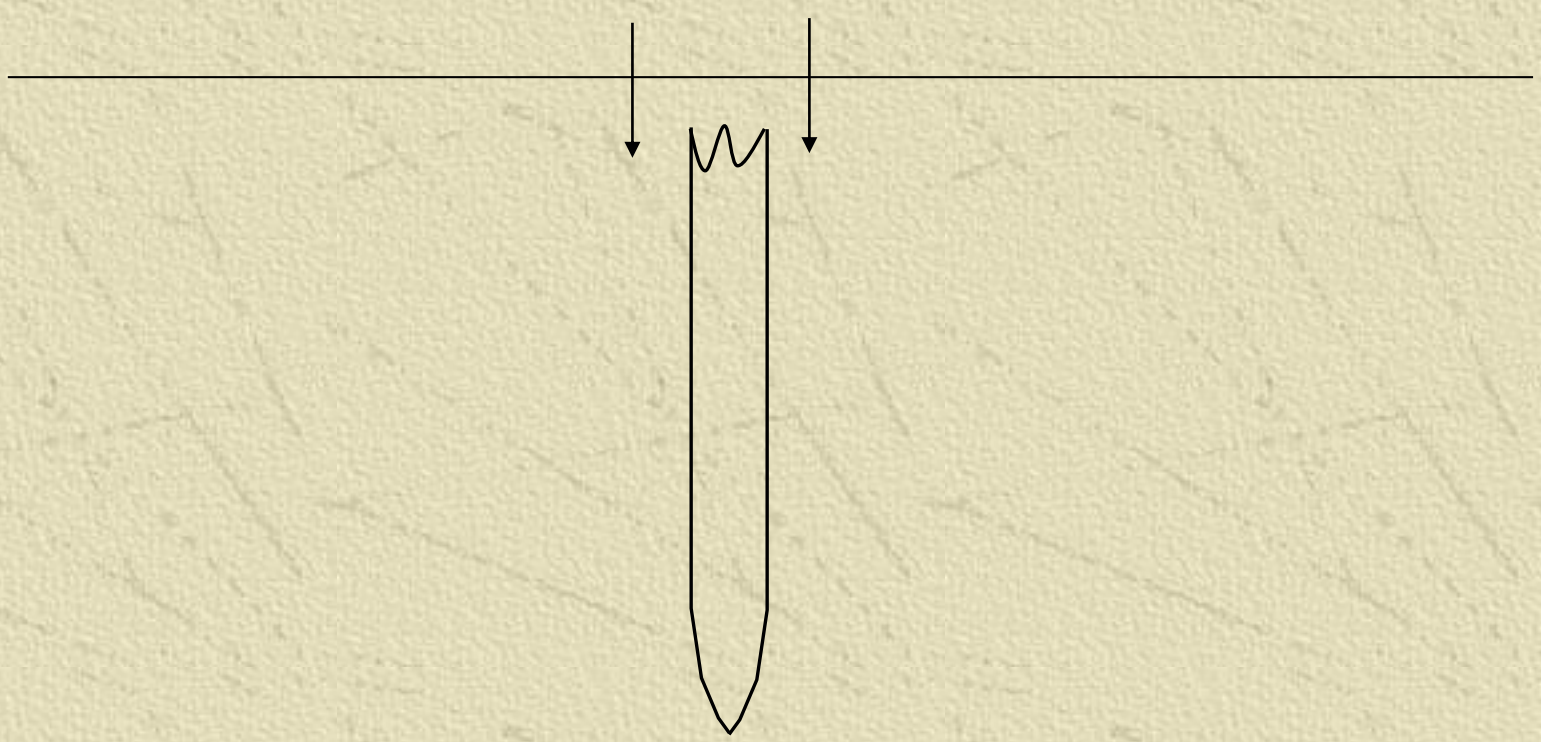
DMT Set-Up



Source: "The Flat Dilatometer Test (DMT) in Soil Investigations", Report of the ISSMGE Technical Committee 16 on Ground Property Characterization from In-Situ Testing 2001

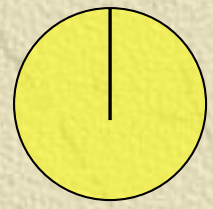
DMT Test Sequence

- 1st Step – Push in blade to test depth



DMT Sequence

- 2nd Step Start Inflating membrane

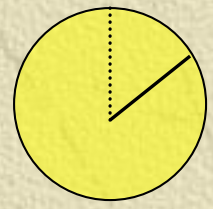


Pressure gauge

Membrane collapsed from earth pressure

DMT Sequence

- 3rd Step Continue to Inflate membrane
- Take A reading (Po) (lift-off pressure)



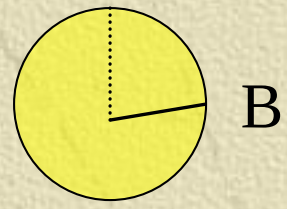
A

Pressure gauge

Membrane flush with blade face

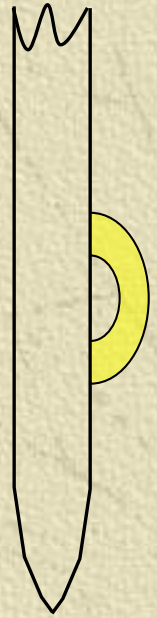
DMT Sequence

- 4th Step Continue to Inflate membrane
- Take B reading (P1) (expansion pressure)



B

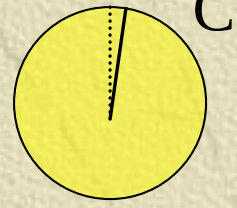
Pressure gauge



Membrane extended 1.1 mm

DMT Sequence

- 5th Step slowly deflate membrane
- Take C reading (P2) (penetration pore pressure)

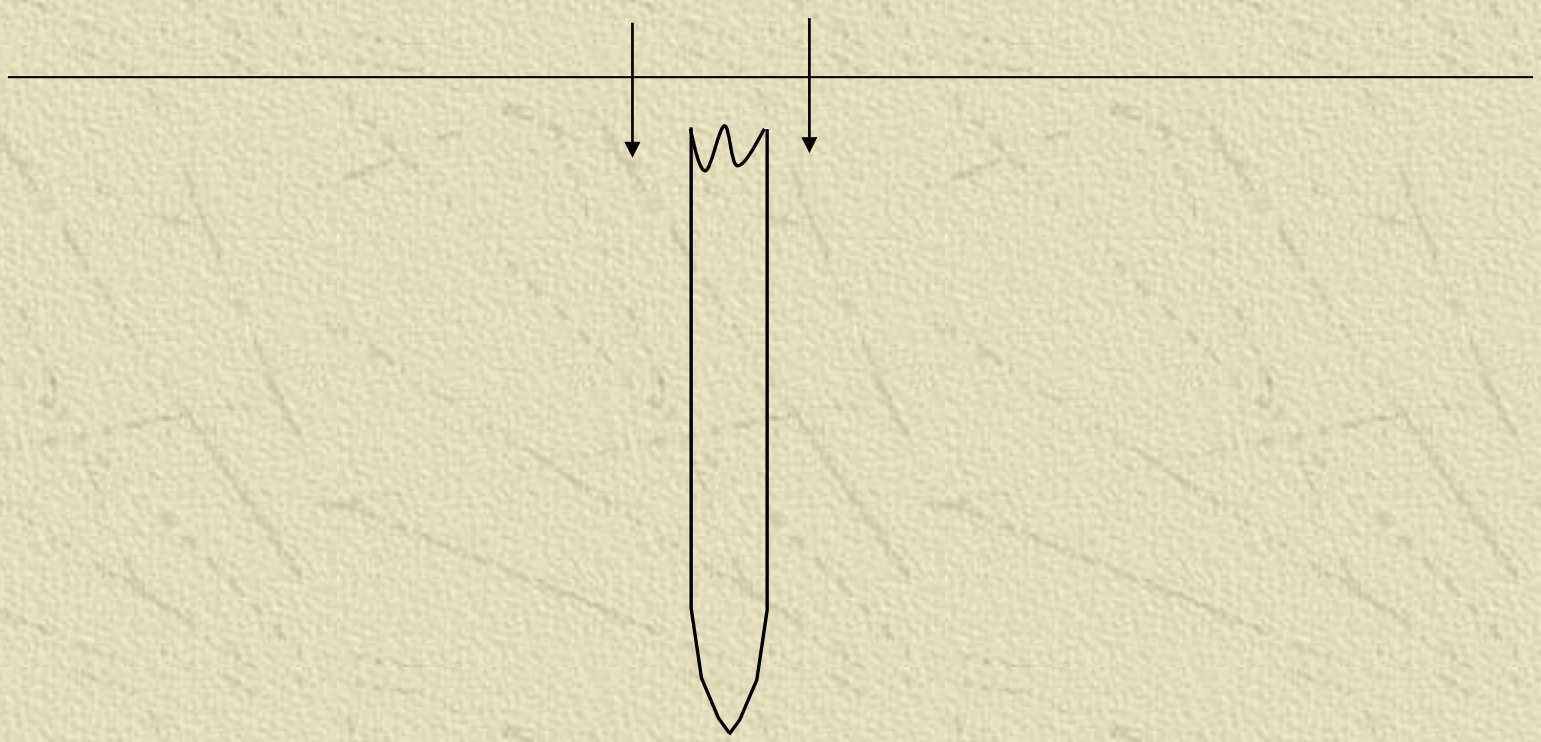


Pressure gauge

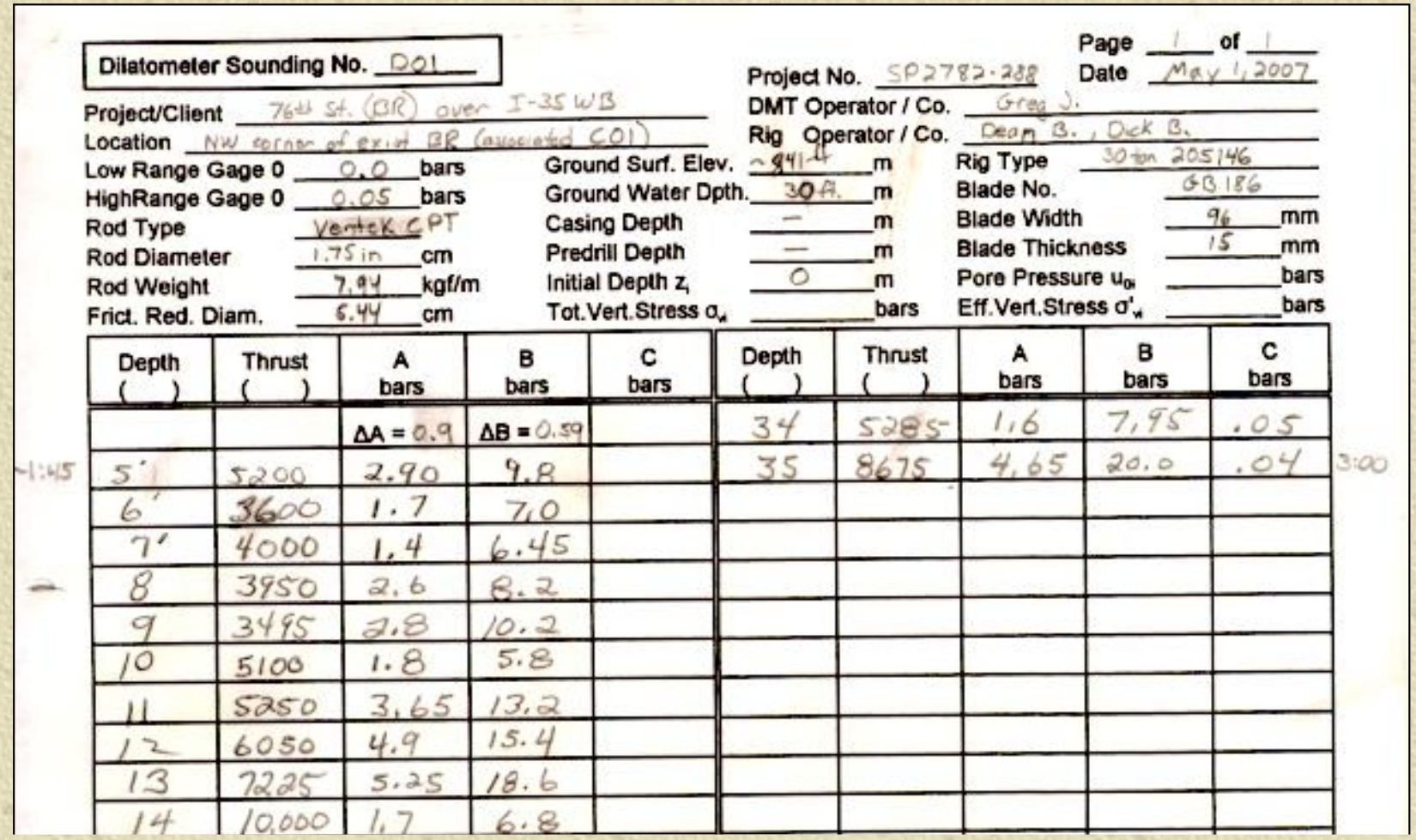
0.05 mm expansion

DMT Test Sequence

- 6th step – Push in blade to next test depth
  - 8 in. minimum interval



DMT Raw Data



Dilatometer Sounding No. DQ1

Page 1 of 1

Project/Client 76th St. (BR) over I-35 W B

Project No. SP2782-288

Date May 1, 2007

DMT Operator / Co. Greg J.

Location NW corner of exist BR (associated CO1)

Rig Operator / Co. Dean B., Dick B.

Low Range Gage 0	0.0	bars	Ground Surf. Elev.	~941	m	Rig Type	30 ton 205146
HighRange Gage 0	0.05	bars	Ground Water Dpth.	30A.	m	Blade No.	GB186
Rod Type	VertekC PT		Casing Depth	—	m	Blade Width	96 mm
Rod Diameter	1.75 in	cm	Predrill Depth	—	m	Blade Thickness	15 mm
Rod Weight	7.94	kgf/m	Initial Depth z_i	0	m	Pore Pressure u_o	bars
Frict. Red. Diam.	6.44	cm	Tot.Vert.Stress σ_v		bars	Eff.Vert.Stress σ'_v	bars

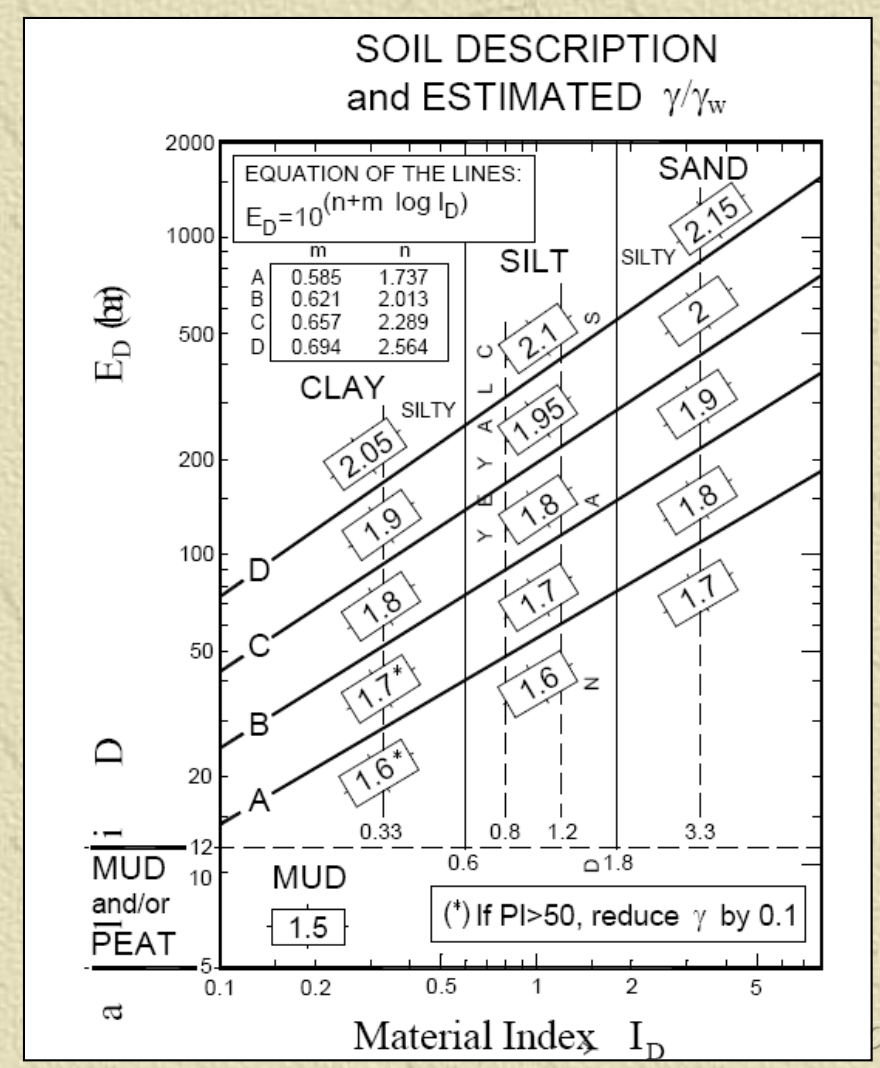
Depth ( )	Thrust ( )	A bars	B bars	C bars	Depth ( )	Thrust ( )	A bars	B bars	C bars
		ΔA = 0.9	ΔB = 0.59		34	5285	1.6	7.95	.05
5'	5200	2.90	9.8		35	8675	4.65	20.0	.04
6'	3600	1.7	7.0						
7'	4000	1.4	6.45						
8	3950	2.6	8.2						
9	3495	2.8	10.2						
10	5100	1.8	5.8						
11	5250	3.65	13.2						
12	6050	4.9	15.4						
13	7225	5.25	18.6						
14	10,000	1.7	6.8						

DMT Data Reduction

SYMBOL	DESCRIPTION	BASIC DMT REDUCTION FORMULAE	
p_0	Corrected First Reading	$p_0 = 1.05\ (A - Z_M + \Delta A) - 0.05\ (B - Z_M - \Delta B)$	Z_M = Gage reading when vented to atm. If ΔA & ΔB are measured with the same gage used for current readings A & B, set $Z_M = 0$ (Z_M is compensated)
p_1	Corrected Second Reading	$p_1 = B - Z_M - \Delta B$	
I_D	Material Index	$I_D = (p_1 - p_0) / (p_0 - u_0)$	u_0 = pre-insertion pore pressure
K_D	Horizontal Stress Index	$K_D = (p_0 - u_0) / \sigma'_{v0}$	σ'_{v0} = pre-insertion overburden stress
E_D	Dilatometer Modulus	$E_D = 34.7\ (p_1 - p_0)$	E_D is NOT a Young's modulus E. E_D should be used only AFTER combining it with K_D (Stress History). First obtain $M_{DMT} = R_M E_D$, then e.g. $E \approx 0.8\ M_{DMT}$
K_0	Coeff. Earth Pressure in Situ	$K_{0,DMT} = (K_D / 1.5)^{0.47} - 0.6$	for $I_D < 1.2$
OCR	Overconsolidation Ratio	$OCR_{DMT} = (0.5\ K_D)^{1.56}$	for $I_D < 1.2$
c_u	Undrained Shear Strength	$c_{u,DMT} = 0.22\ \sigma'_{v0}\ (0.5\ K_D)^{1.25}$	for $I_D < 1.2$
Φ	Friction Angle	$\Phi_{safe,DMT} = 28° + 14.6°\ \log K_D - 2.1°\ \log^2 K_D$	for $I_D > 1.8$
c_h	Coefficient of Consolidation	$c_{h,DMTA} \approx 7\ cm^2 / t_{flex}$	t_{flex} from A-log t DMT-A decay curve
k_h	Coefficient of Permeability	$k_h = c_h\ \gamma_w / M_h$ ($M_h \approx K_0\ M_{DMT}$)	
γ	Unit Weight and Description	(see chart in Fig. 16)	
M	Vertical Drained Constrained Modulus	$M_{DMT} = R_M E_D$ if $I_D \le 0.6$ $R_M = 0.14 + 2.36 \log K_D$ if $I_D \ge 3$ $R_M = 0.5 + 2 \log K_D$ if $0.6 < I_D < 3$ $R_M = R_{M,0} + (2.5 - R_{M,0}) \log K_D$ with $R_{M,0} = 0.14 + 0.15\ (I_D - 0.6)$ if $K_D > 10$ $R_M = 0.32 + 2.18 \log K_D$ if $R_M < 0.85$ set $R_M = 0.85$	
u_0	Equilibrium Pore Pressure	$u_0 = p_2 = C - Z_M + \Delta A$	In free-draining soils

Source: "The Flat Dilatometer Test (DMT) in Soil Investigations", Report of the ISSMGE Technical Committee 16 on Ground Property Characterization from In-Situ Testing 2001

DMT Material Index



MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

DILATOMETER (DMT) TEST RESULTS

UNIQUE NUMBER 68619

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	DMT Push No.	Ground Elevation
2782-288	27V98	I-35W	D01	841.2 (from Plan)

Location , , ft. LT

Hennepin Co. Coordinate: X=521795 Y=127241 (ft.)

Latitude (North)=44°51'56.85" Longitude (West)=93°17'57.41"

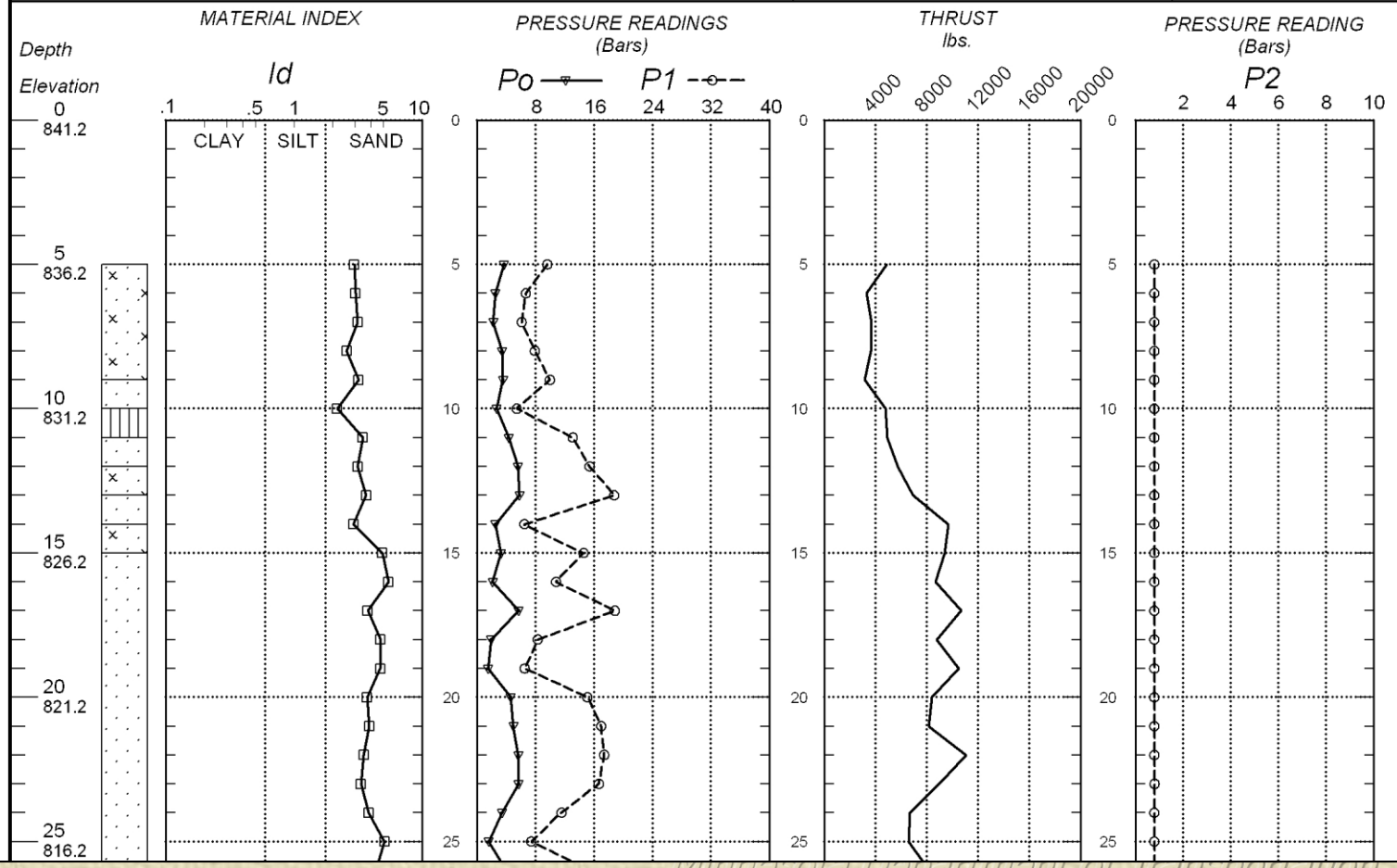
CPT Machine: 205146 CPT Truck (H)

DMT Operator: D. Brady

Hole Type: DMT

SHEET 1 of 1

Date Completed: 5/1/07



MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

DILATOMETER (DMT) TEST RESULTS

UNIQUE NUMBER 68619

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	DMT Push No.	Ground Elevation
2782-288	27V98	I-35W	D01	841.2 (from Plan)

Location , , ft. LT

Hennepin Co. Coordinate: X=521795 Y=127241 (ft.)

Latitude (North)=44°51'56.85" Longitude (West)=93°17'57.41"

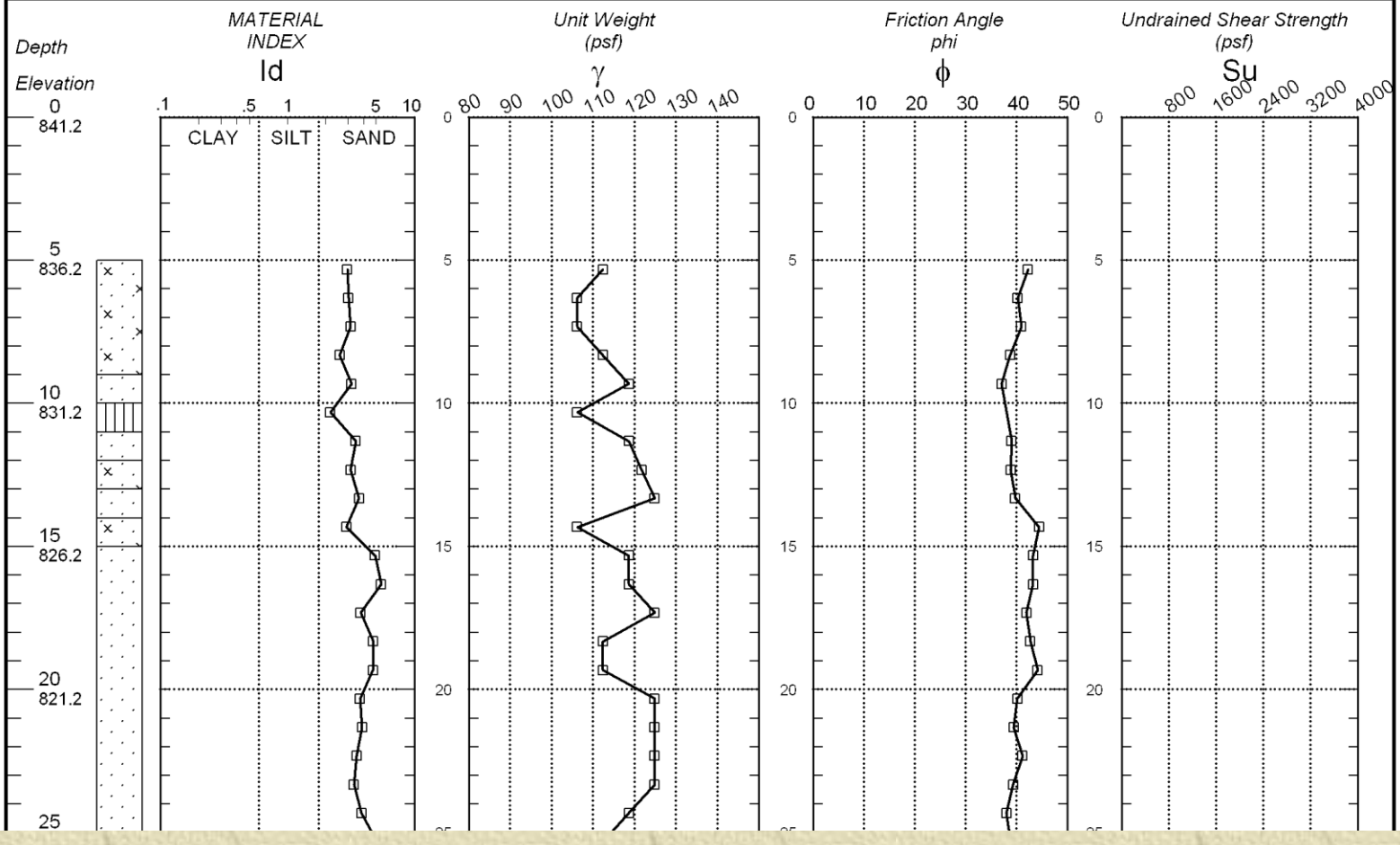
CPT Machine 205146 CPT Truck (H)

DMT Operator D. Brady

Hole Type DMT

SHEET 1 of 1

Date Completed 5/1/07



MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

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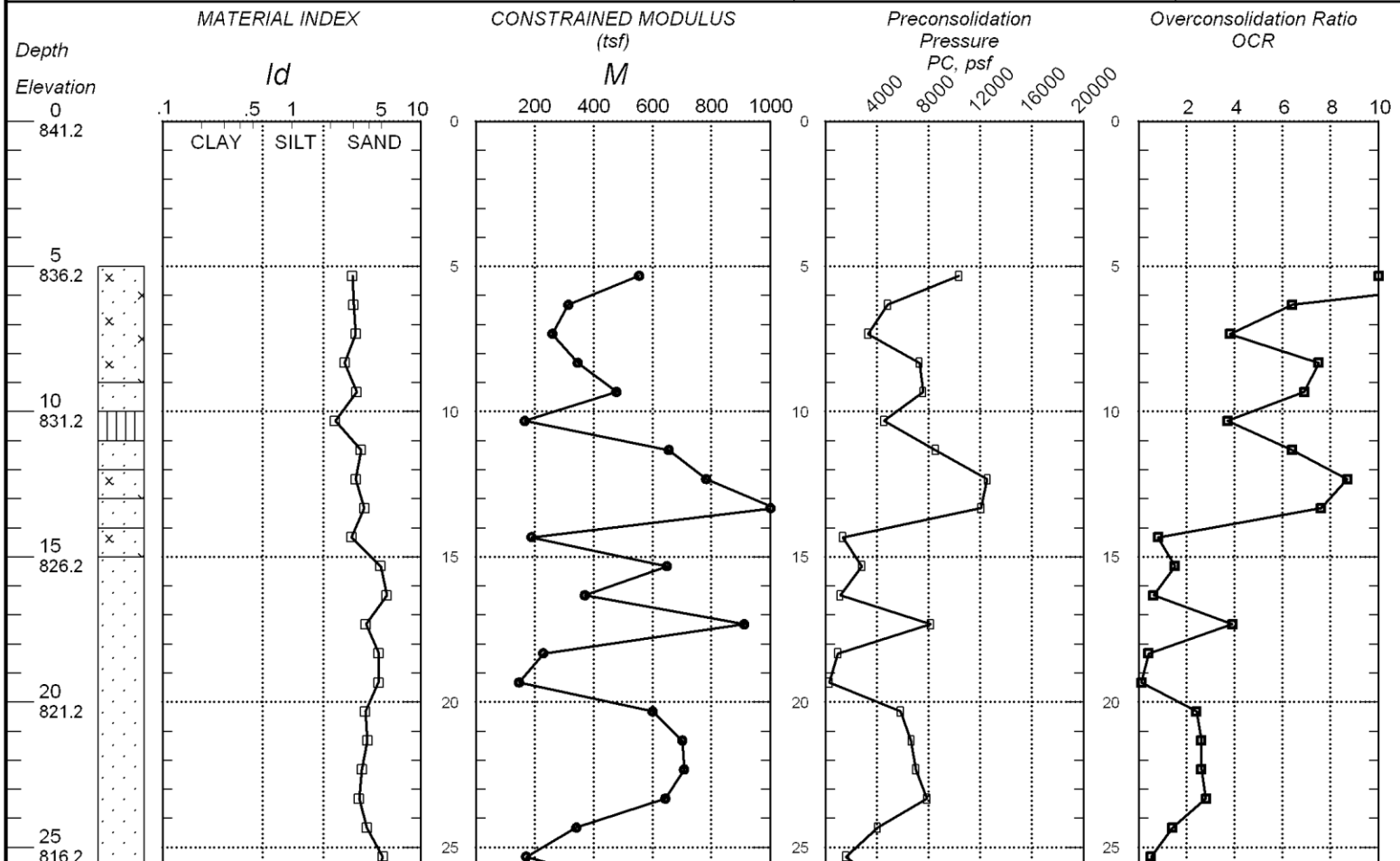
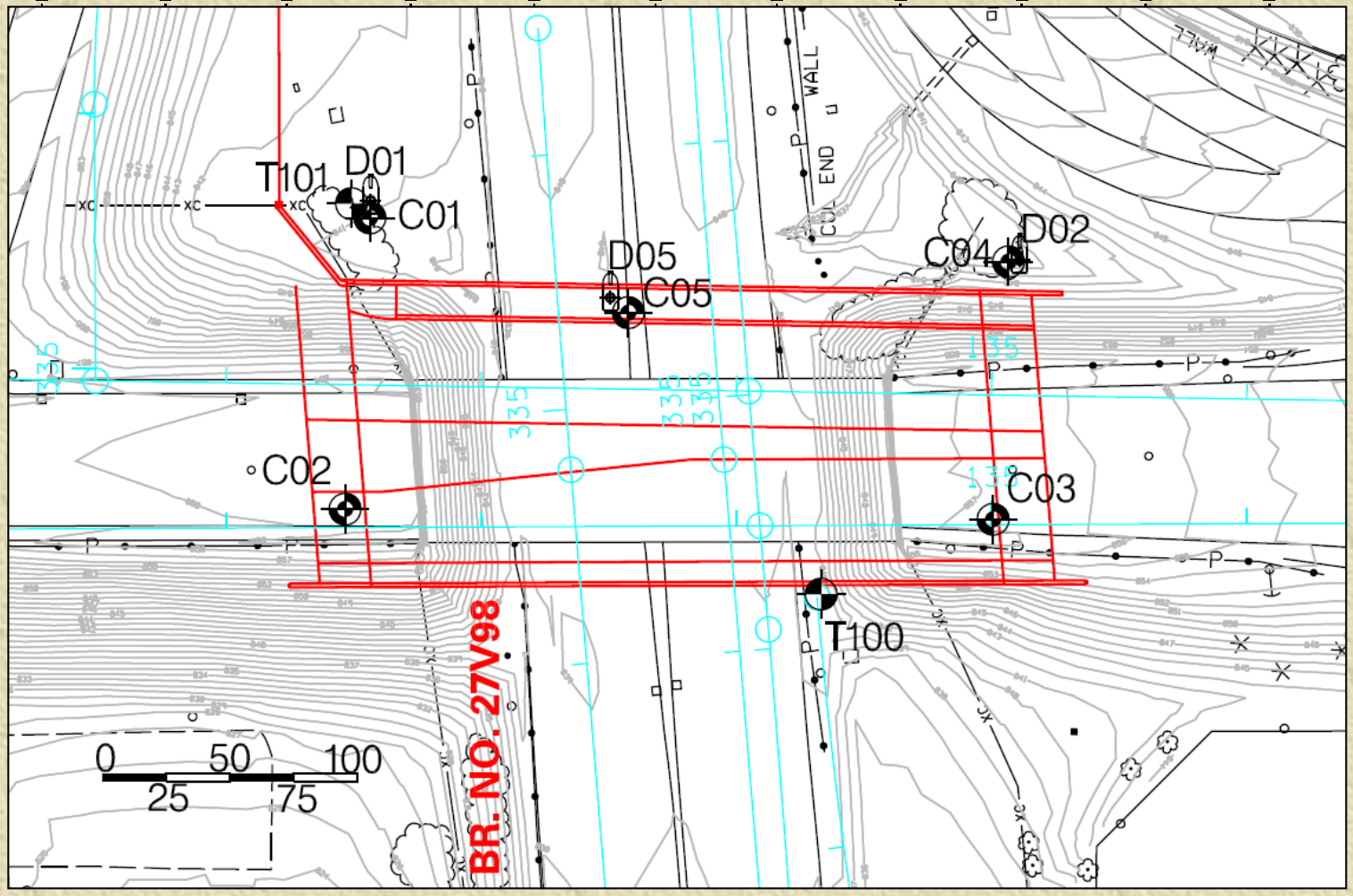
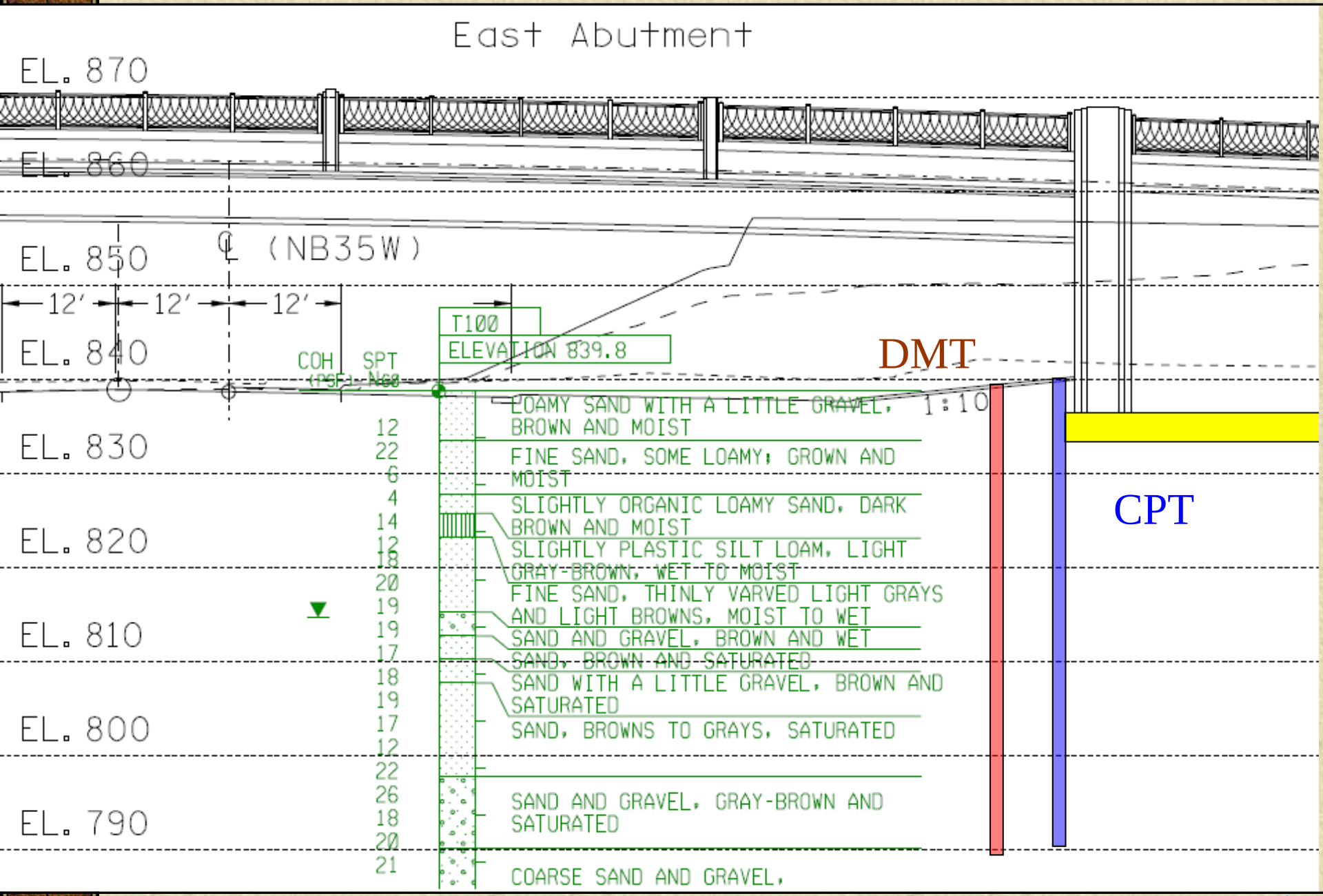
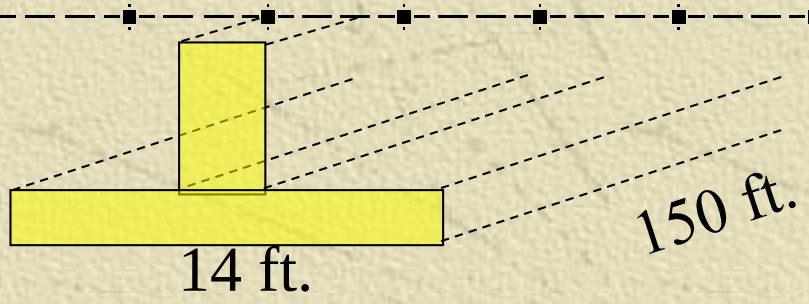


Case Study


T101
D01
C01
D05
C05
D02
C04
C02
C03
T100
BR. NO. 27V98
WALL
END
0
50
100
25
75


East Abutment
EL. 870
EL. 860
EL. 850
EL. 840
EL. 830
EL. 820
EL. 810
EL. 800
EL. 790
℄ (NB35W)
12'
12'
12'
T100
ELEVATION 839.8
COH (PSF)
SPT N60
DMT
CPT
1:10
LOAMY SAND WITH A LITTLE GRAVEL, BROWN AND MOIST
FINE SAND, SOME LOAMY; GROWN AND MOIST
SLIGHTLY ORGANIC LOAMY SAND, DARK BROWN AND MOIST
SLIGHTLY PLASTIC SILT LOAM, LIGHT GRAY-BROWN, WET TO MOIST
FINE SAND, THINLY VARVED LIGHT GRAYS AND LIGHT BROWNS, MOIST TO WET
SAND AND GRAVEL, BROWN AND WET
SAND, BROWN AND SATURATED
SAND WITH A LITTLE GRAVEL, BROWN AND SATURATED
SAND, BROWNS TO GRAYS, SATURATED
SAND AND GRAVEL, GRAY-BROWN AND SATURATED
COARSE SAND AND GRAVEL,
12
22
6
4
14
12
18
20
19
19
17
18
19
17
12
22
26
18
20
21

Footing Settlement



SLS Bearing Capacity (LRFD)		
	SPT	DMT
1 in. settlement	2.4 ksf	4.2 ksf
1.5 in. settlement	3.8 ksf	6.7 ksf

Thank You