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Offices Covering all USA

A Practical Overview of Introducing a New Technology: Implementing the Cone Penetration Test (CPT) at Mn/DOT



Current Practice for Site Investigation at Mn/DOT



Field

Lab

Office



Drilling Equipment & Crews

- Typically operate 4 field crews, statewide
- Minnesota Soils:
 - Overconsolidated Clay Tills
 - Normally Consolidated Clays
 - Loose Sands
 - Dense Sands
 - Rock (soft, hard, light, classic...)
 - Peat
- Recover Split Tube, Thin Wall, Rock Core Samples
Typically find: N , M_c , S_u , unit weight, $[Q_u, E \text{ (rock)}]$





↑ Mobile B47 - - GEFCO F6 ↓



↑ CME 850 - - CME 850 ↓



Changing Times

- Workload is increasing
- For large corridors more preliminary site information is required, earlier.
- New interest in groundwater, stratigraphy, and, occasionally, instant response and results for “discoveries” at time of construction

Other Changes Taking Place

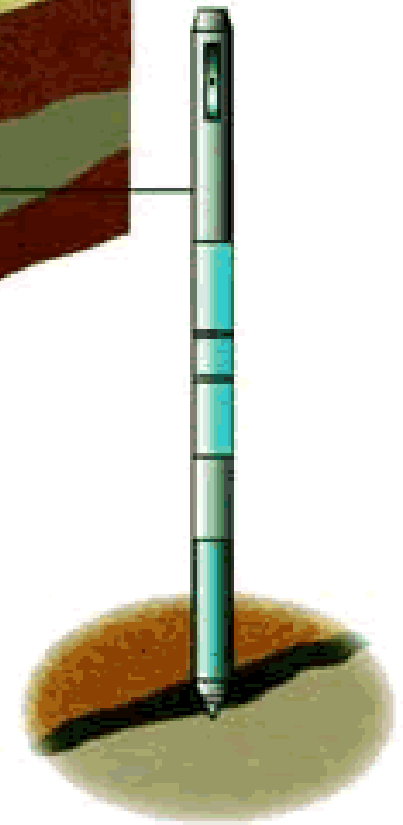
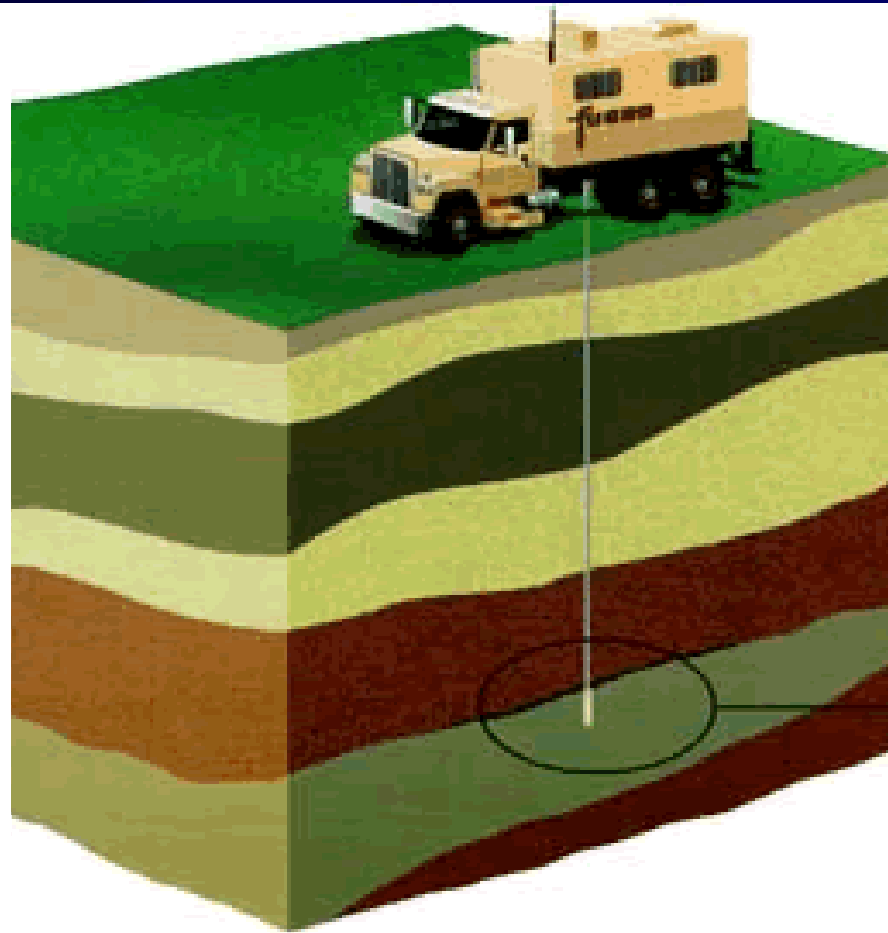
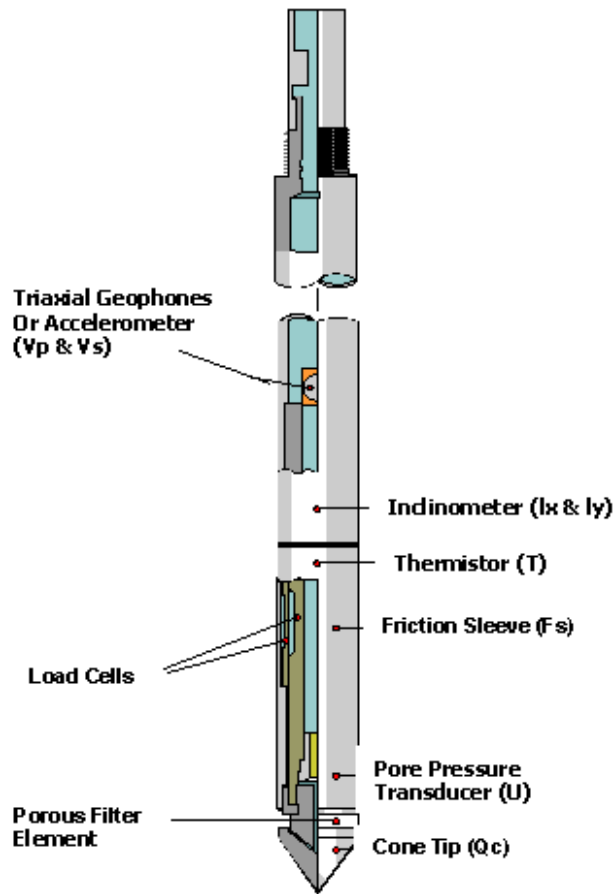
- New Engineers with New Ideas; New Technologies with New Automation
- The fall of “N60” as sufficient information to predict all things
- Money for Scientific Equipment
- The move to Load and Resistance Factor Design (LRFD)
- Within the Mn/DOT PSG- Promotions at the “OoMaRR” (us) and Retirements at the “OoBaS” (them)

The Stage is Now Set for a Change, an Improvement – But What?

- Something faster; some better method to log data, perhaps?
- Something less labor intensive; field crew personnel may not be replaced as retirements occur
- Something that provides useful information on what we need to know - water level, stratigraphy, soil type or behavior, strength
- Something that recognizes that taking more conventional borings isn't the answer

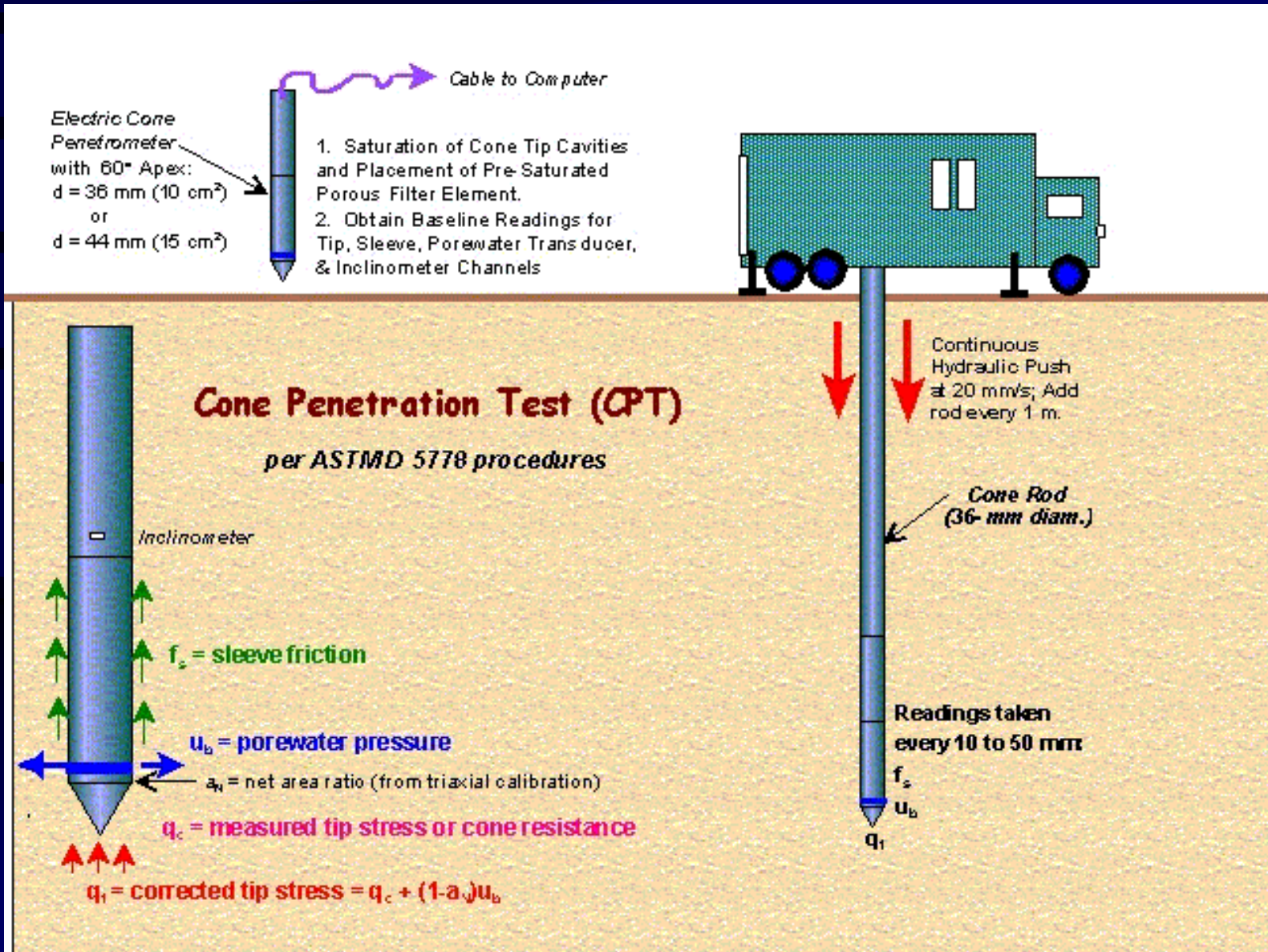
New Methods for New Needs

- “CPT”, “CPTU”, “Piezocone”, “Seismic Cone” begin to become increasingly common terms at conferences, seminars, and in articles, reports, and papers- even among colleagues.
- Geotechnical Engineers at Mn/DOT began to take interest in the “cone” and the wild claims of continuous profiling of multiple soil characteristics.



The “Cone”
Could this be the Answer?

Just What is a CPT?



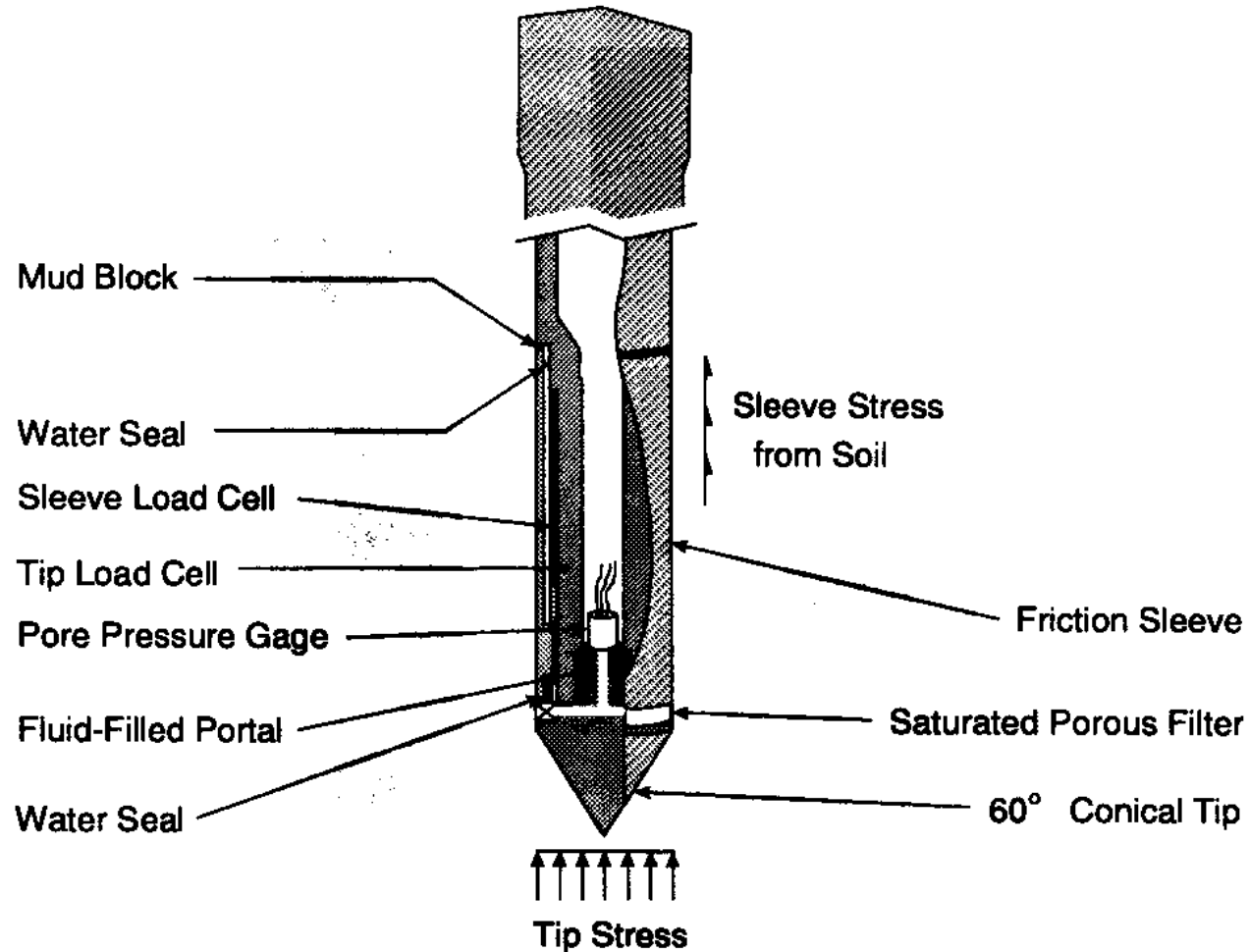
CPT System (ASTM D-5778-95)

- Instrumented Probe (penetrometer)
- Push System (rig and hydraulics)
- Data Acquisition (computer)
- CPTU / SCPTU etc...



The Piezocone (CPTU) Probe

Standard Piezo-CPT Probe



Push System

Reaction mass



Push rods



Hydraulic rams

Trailer Mounted (small)

Push Vehicles



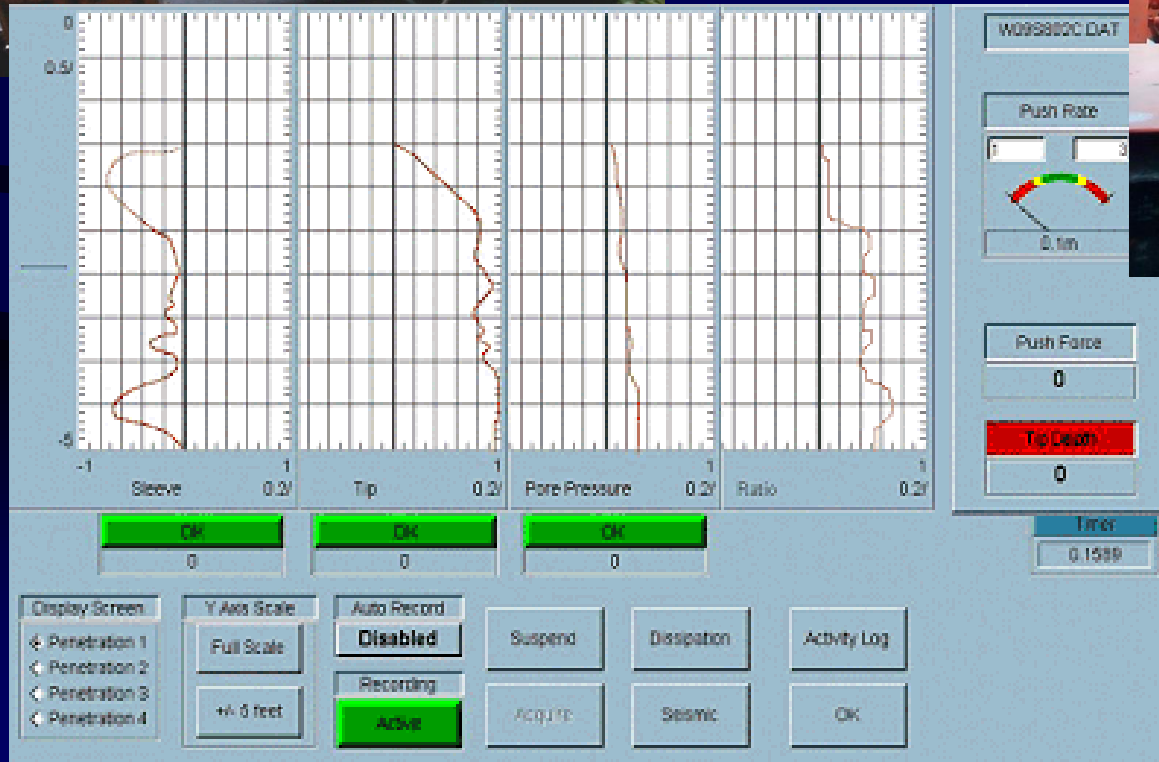
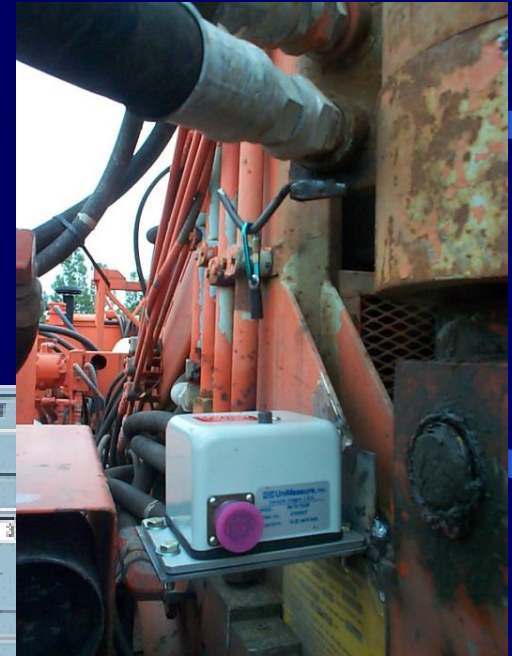
Tracked Carrier



Truck Mounted (big)



Data Acquisition

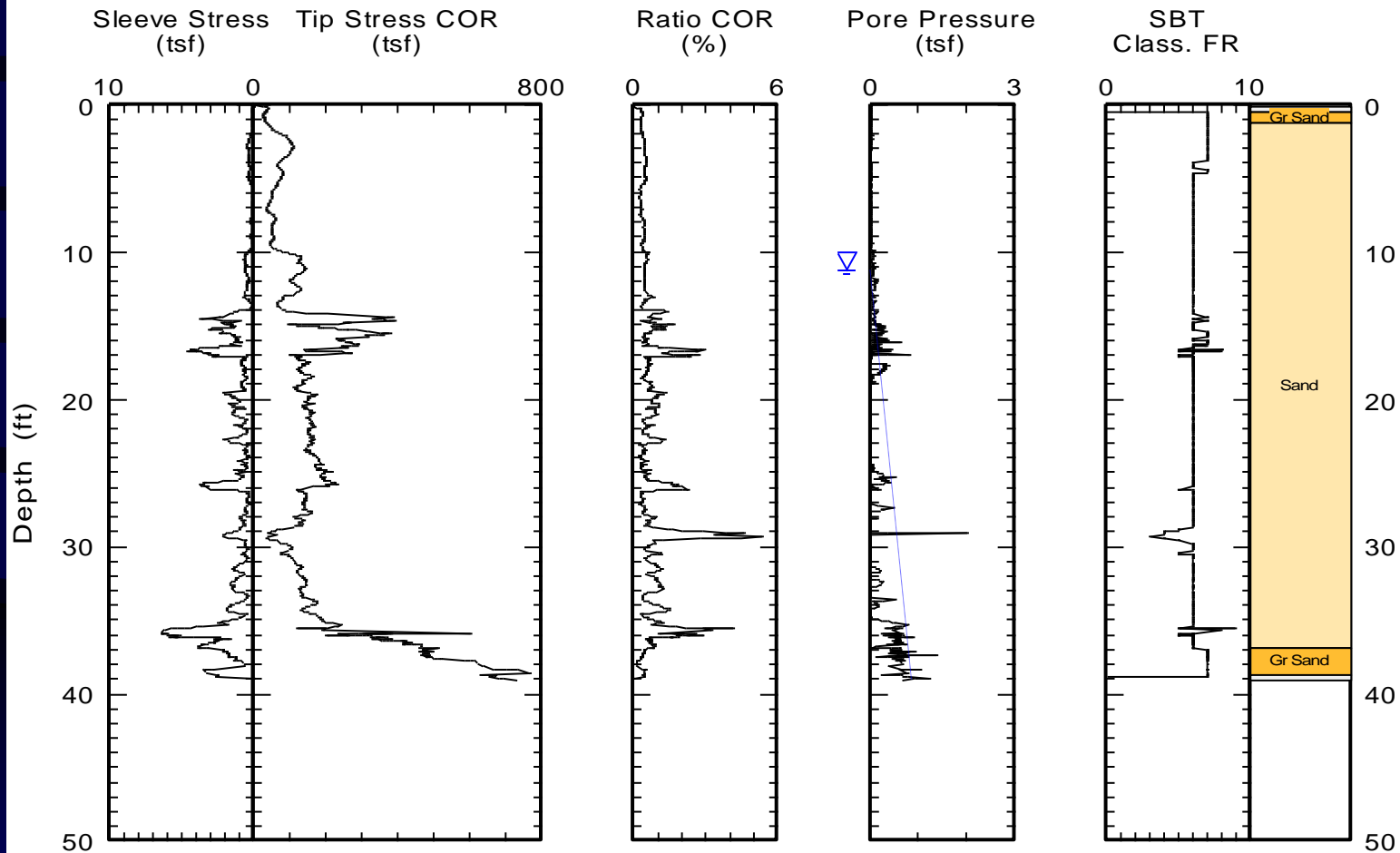


Data Presentation

Test ID: CT-134

Project: 5070

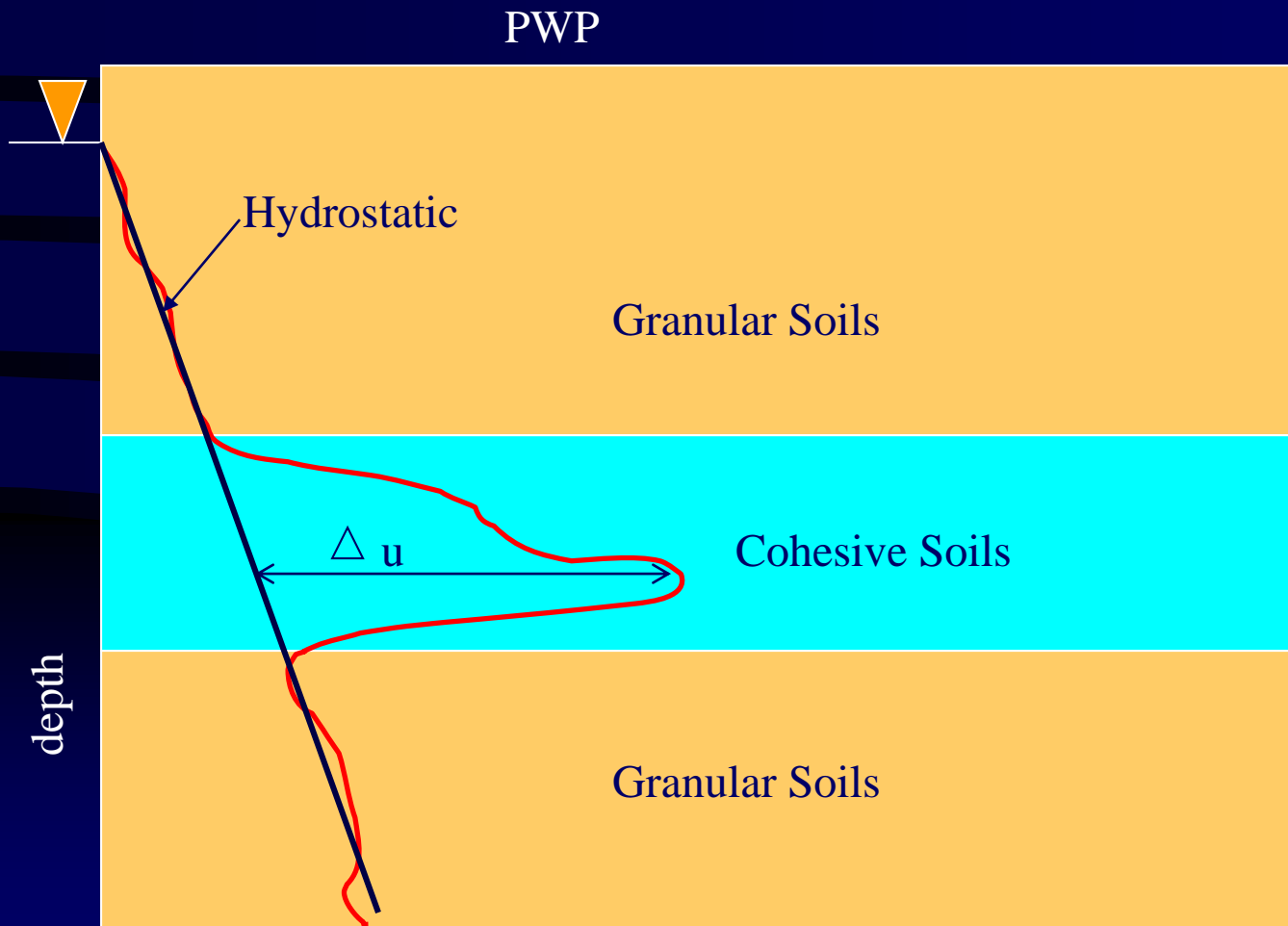
Date: 06/08/99



Class FR: Friction Ratio Classification (Ref: Robertson 1990)

▽ Estimated Phreatic Surface

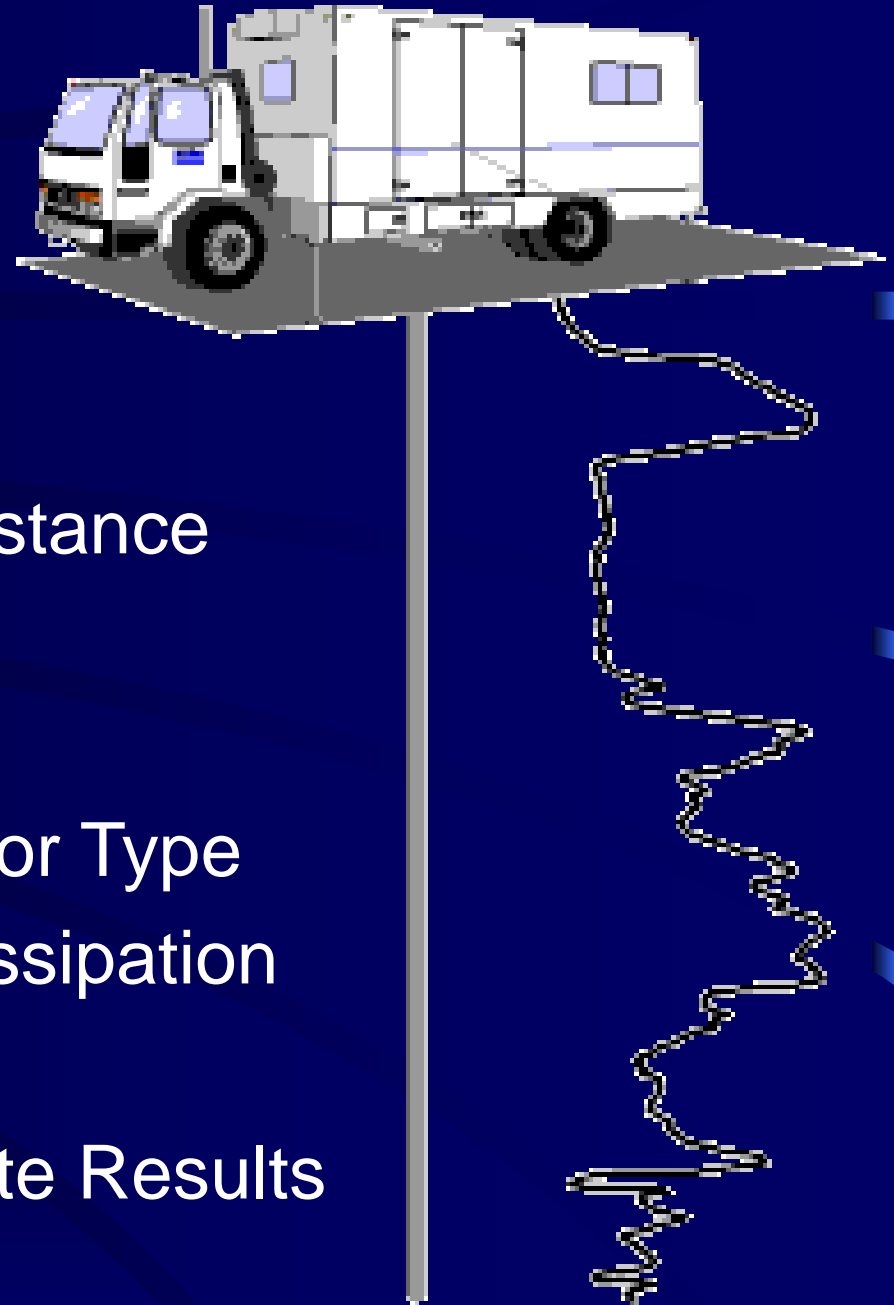
Dynamic Pore Water Pressure (U / PWP) Measurements



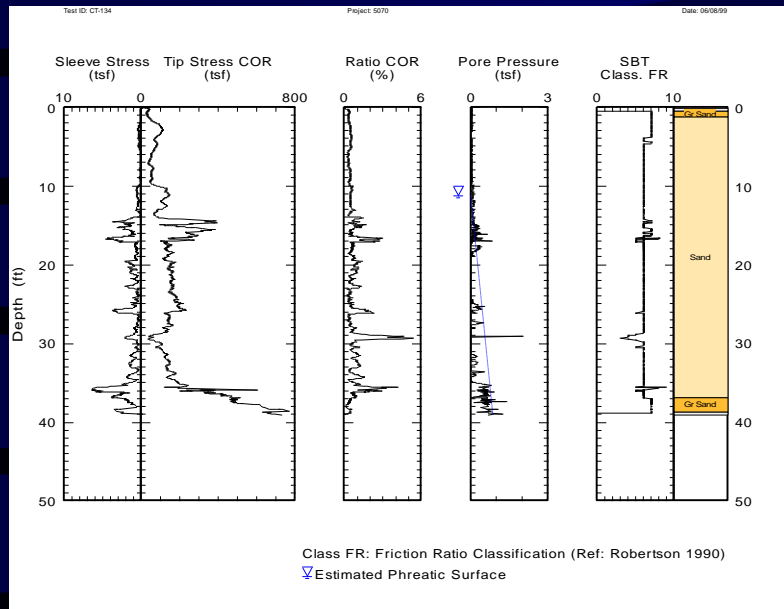
Back to our earlier question,

The “Cone”

Could this be the Answer?



- Direct readings of Tip Resistance
- Pore Water Pressure
- Continuous Stratigraphy
- Correlations to Soil Behavior Type
- Seismic Methods, PWP Dissipation
- Automated Data Logging
- Fast, Less Labor, Immediate Results



Yes, this is the answer.



Okay, The Cone Looks Like the Way to Go, But...

- Who uses it?
- Will it work in “Minnesota Soils”?
- Will it go deep enough?
- Will we be able to “sell” people on something new, something with no soil samples, something with no standard test values, and... no “N” ?

Who uses CPT?

- **Worldwide** (Europe, Asia, Indonesia, Japan, Americas)
- **Europe- Netherlands, leaders**
- **United States**
 - Fed. Govt.
 - EPA, DOE, USACOE, Navy, Army, Air Force
 - State DOT's
 - WA, LA, FL, PA, NY, VA, MO, MI, IL, MN, ...
 - VA and IN are in acquisition process
 - Private Sector

Applications

- define sub-surface stratigraphy
 - high resolution profiles
- estimate geotechnical parameters
 - friction angle (ϕ), S_u , others
- groundwater investigations
- environmental investigations
 - Contaminated soils, remediation studies

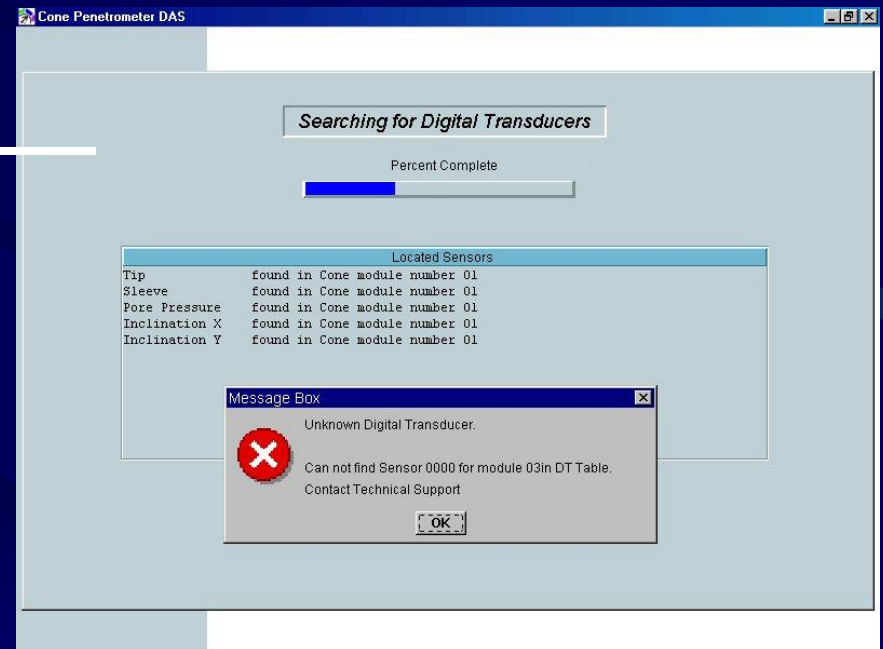
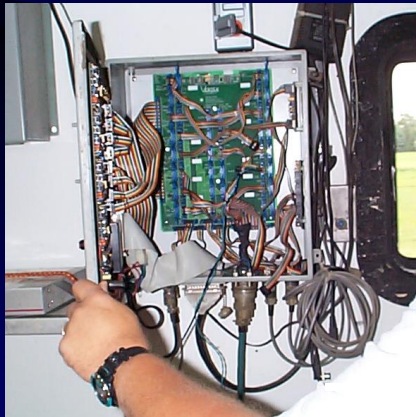
Advantages of CPT

- Immediate Results (no lab work)
- Footage (150-500 ft. day)
- Continuous Soil Profile (stratigraphy)
- Pore pressure measurements
- Great tool for preliminary investigations



Disadvantages

- No samples- How do I know what it is if I can't see it?
- Depth Limitations (friction, tip, buckling)
- Obstructions: rocks, concrete, rubble
- Highly trained technician or engineer needed
- Continuous Data
- Electronics!



Test Procedure

- Take initial baseline readings
- Saturate porous filter
- Push probe into ground at 2 cm/s
- Add on rods
- Stop for special tests
- Push until design depth or refusal
- Take final baseline readings



Direct Test Results

- q_c - tip resistance (tsf)
- f_s - sleeve friction (tsf)
- dynamic pore water pressure (psi)
- static pore water pressure (clays, dissipation test)
- V_s , shear wave velocity
- Friction Ratio = f_s/q_c

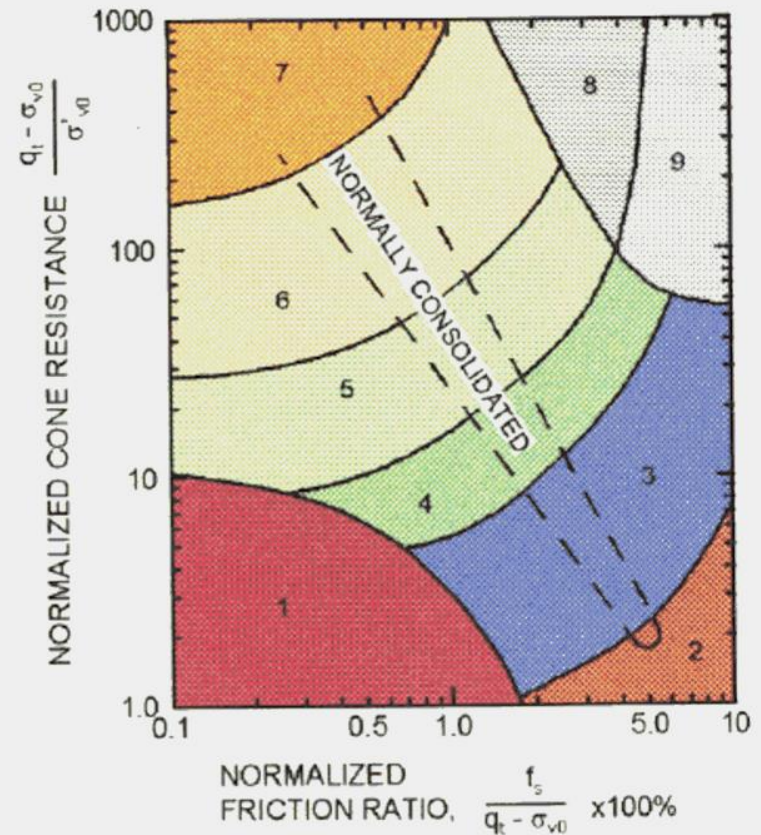
SBT number (soil behavior type) based on FR / U

Soil Behavior Type

Zone	Q_t/N	Description
1	2	Sensitive, Fine Grained
2	1	Organic Soils-Peats
3	1.5	Clays-Clay to Silty Clay
4	2	Silt Mixtures-Clayey Silt to Silty Clay
5	3	Sand Mixtures-Silty Sand to Sandy Silt
6	4.5	Sands-Clean Sand to Silty Sand
7	6	Gravelly Sand to Sand
8	1	Very Stiff Sand to Clayey Sand *
9	2	Very Stiff, Fine Grained *
		Undefined Soil Layer

(*) Heavily Overconsolidated or Cemented

Normalized Friction Ratio
Classification Chart



(Ref. Robertson, 1990)

Not a formal classification method

General Relationships

- Granular Soils - High tip resistance, high sleeve friction, low friction ratio
- Cohesive Soils - Low tip resistance, high sleeve friction, high friction ratio
- Organics - very low tip, very low sleeve, very high friction ratio

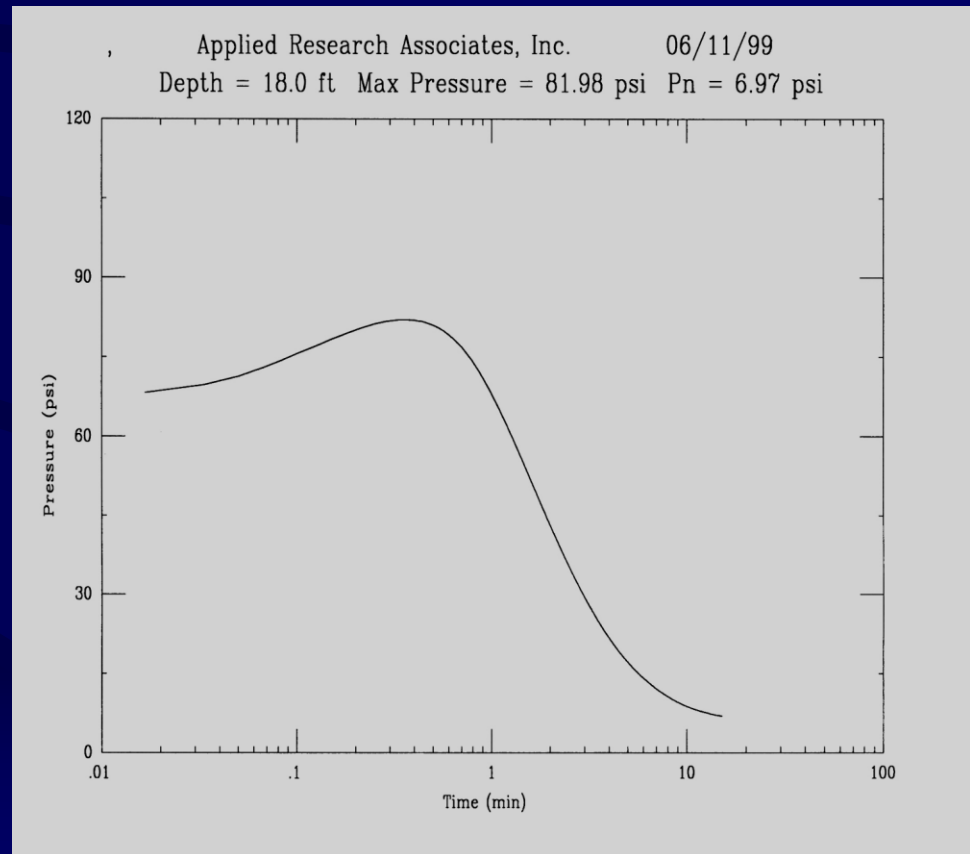
Indirect Test Results

Empirical & semi-empirical correlations

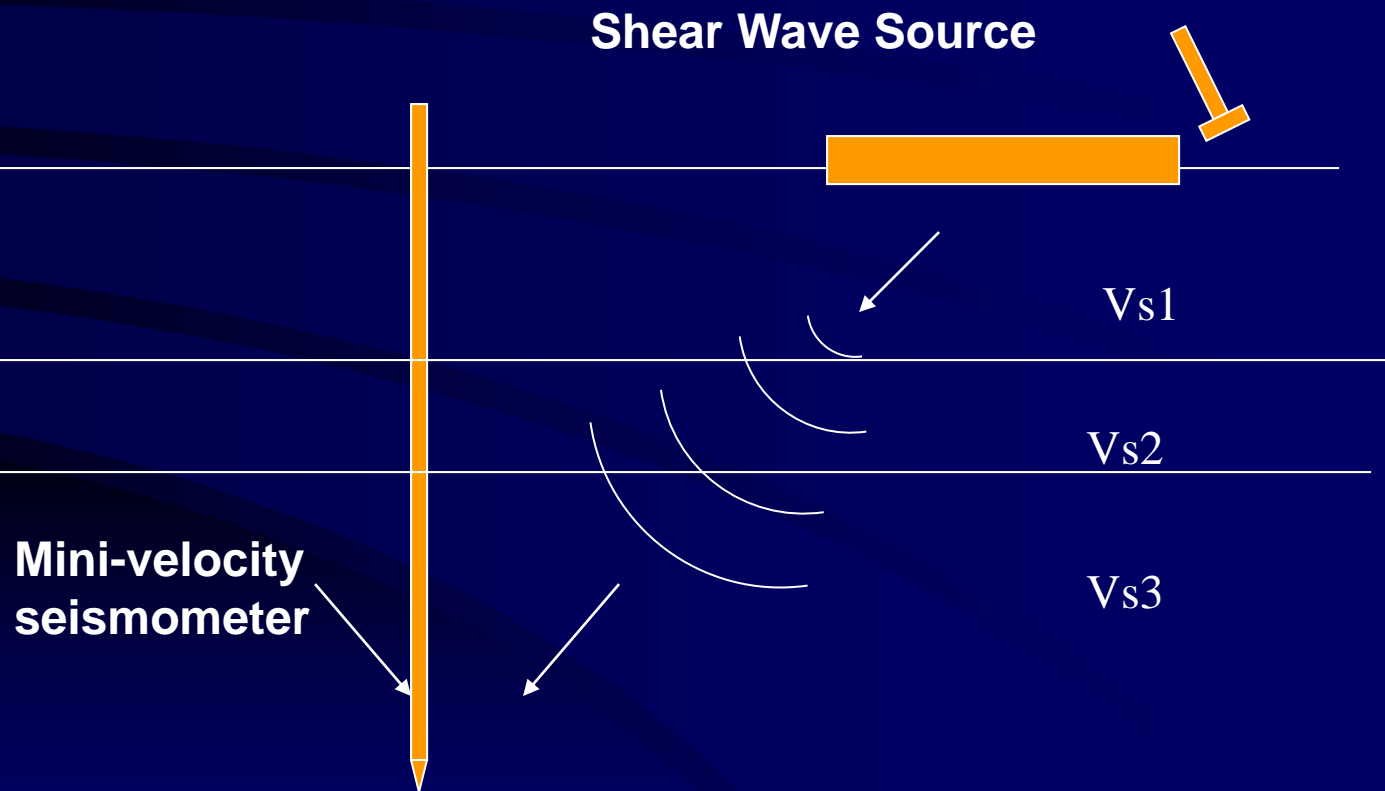
- relative density, D_r
- overconsolidation ratio (OCR)
- unit wt.
- Insitu horizontal stress, K_o
- Soil moduli, M , E_u , G_o
- N value and friction angle, ϕ
- undrained shear strength (S_u)
- Permeability (k)
- coefficient of consolidation (horiz.)

Pore Dissipation Tests

- Pore pressure response vs. time for cohesive soils
- hydrostatic level
- ground water table
- permeability (k_H)



Seismic CPT



Will it Work for Us?

- Initial interest (1996, GeoLogan)
- Research the Technology
- Investigate Equipment Manufacturers
- Demo Project (1999, Minnesota Sites)



Goals of Demo Project

- Learn about CPT operations
- Determine if CPT would work in Minnesota's glacial soils
- Determine depth and relative density limitations of CPT
- What we could use CPT data for
- What is best equipment for Mn/DOT

Plan

- Hire CPT Consultant
- Large CPT Rig (25 tons)
 - determine depth limits
- Push CPT next to existing borings
- Different Soils
 - sands, silts, clays, organics, etc.
- Good Access
 - traffic, flat terrain
- Metro Area (5 sites)
- Evaluate equipment and data



Conclusions from Demo

- CPT works in Minnesota Glacial Soils
- CPT for Bridge Borings?
- Data is overwhelming (software)
- Prelim. est. of geotechnical parameters
- Design: Should calibrate with conventional borings (lab tests, local geology) recognizing data is different- and better
- Great for swamps, shallow foundations and preliminary investigations

Added Benefits

- 2 man field crews (3 for drilling)
- No samples to process in lab
 - More time for advanced testing on fewer samples
- 1 m rods; less wear and tear
- Safety, no rotation
- Minimal spoil
- Comparatively fast 'turn-around' from investigation to reporting: ideally suited for construction problems that require solutions before their boss calls your boss.

Shopping

- Initial purchase: 1 new tracked drill rig and complete SCPTU system
- “Add-On” CPTU system for use with an existing standard drill rig
(intended to be the first system, but for a standard drill rig snafu)



Specifications: The Necessary Evil

- Do your homework
- Think of what you will need
- Get help from others
- Ask others what they needed
- Be comprehensive, but not prescriptive
- Include “back-up” items

Comparisons: Products and Costs: Vertek vs. Hogentogler

- Rigs, rods, cables, etc. fairly similar
- Push System / Anchoring System
- Digital vs. Analog Cone
- Rod Advance and Locking system
- Differences in Piezocone systems
- Real-time Data Display and Software
- Service and Warranty Issues (MTF)
- Testimonials from users

ARA Vertek CPT Track Rig

- Light weight and Mobile, 20,400 lbs. (4-5 psi)
- Added Reaction with Ground Anchors (2)
- Digital SCPTU Cone



- Pushed with 36,000 lbs. of force to 60 ft. during test run

Push System, Rods and Data Cable



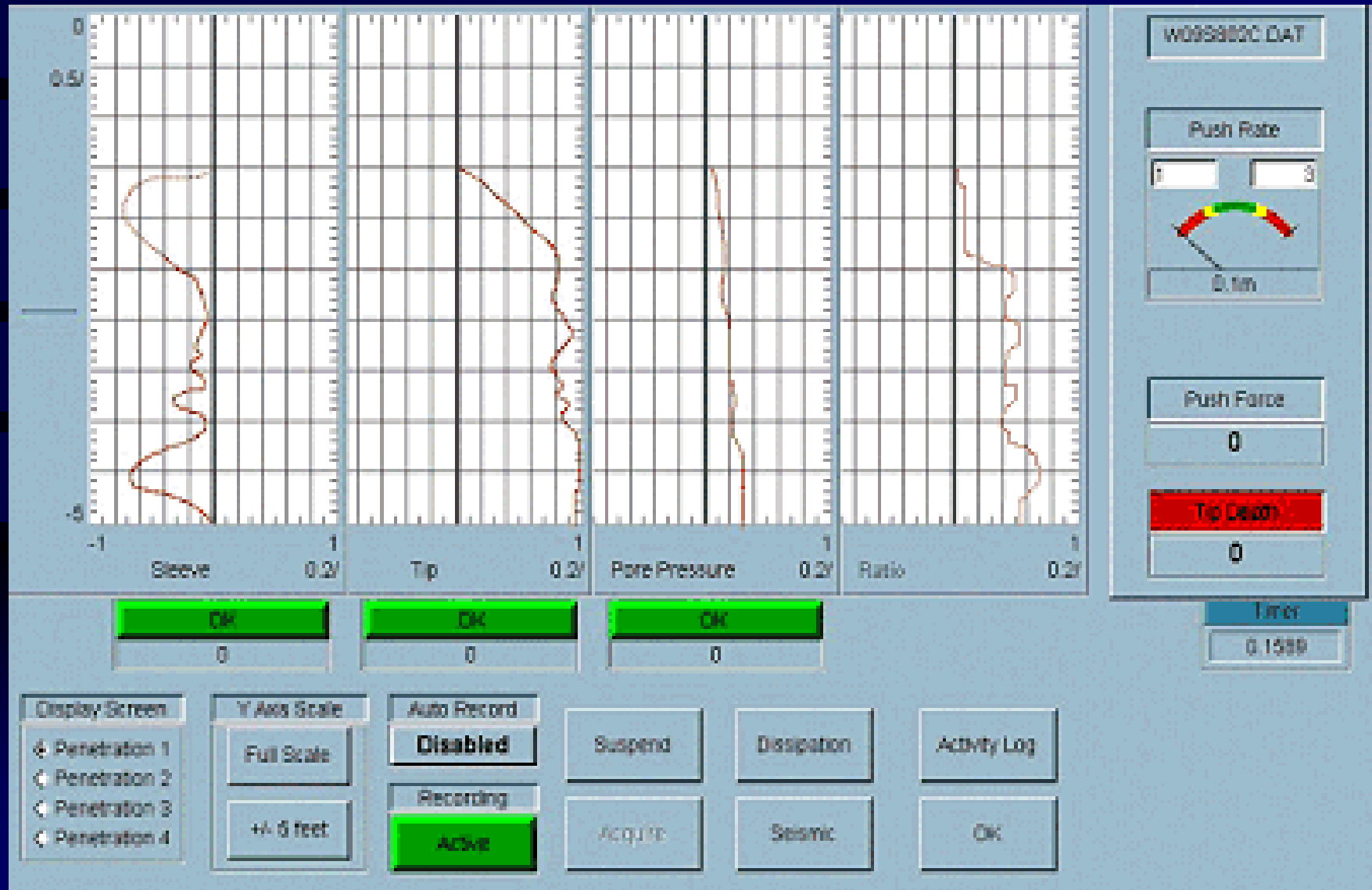
Laptop and Datapack



Anchoring System



Real Time Data Display of Soil Properties



CPT Track Rig

- Planned Uses

- Swamp delineation
- Areas where PWP dissipation is of interest
- Retaining Walls
- Culverts
- Trails
- Artesian Zones
- Road Fills
- Bridges*
- Preliminary
 - large projects



Modular Mix & Match

- Effort in Specs to maintain compatibility
- Same equipment for both systems
 - Allows greater user confidence/familiarity
 - Minimizes confusion, inventory, overall stupidity
 - One download/data transfer/presentation system
 - Interchangeable parts:
 - computers, D/A, probes, cable, parts, etc...

CPT “Add-On” Equipment

- Uses existing Drill Rig to push CPT rods
- Add on equipment
 - Digital CPTU probe, cable, CPT rods
 - CPT/SPT rod push/pull adapters (w/cable slot)
 - CPTU hardware and laptop computer
 - Depth Gage
- Holes can be drilled out to extend push depth
- Same crew can push both types of hole; 1 rig

CPT "Add-On" System



Current Status and Goals

- Beginning to use “Add-On” equipment
 - High profile Interstate Mississippi River crossing site; consultants
 - A successful push at C-43, a few feet from T-43 (1 production hole so far)
 - Fixing problems (bad cables, odd grounding fault, depth gage issue)
 - Now have automated download program operational
 - Continuing to refine CPT boring log templates in glNT, mostly complete
 - Developing Fence .dxf diagram for Microstation plotting
- Delivery of Track Rig by November 1 (2 months late)
- Fully operation systems by December 1
 - Soundings
 - Data Presentation, Interpretation, Reports bearing “Squiggly Lines”
 - Multiple projects queued for CPTU work

Abort, Ignore, Retry, Fail?

Cone Penetrometer DAS

Searching for Digital Transducers

Percent Complete

Located Sensors



Tip	found in Cone module number 01
Sleeve	found in Cone module number 01
Pore Pressure	found in Cone module number 01
Inclination X	found in Cone module number 01
Inclination Y	found in Cone module number 01

Message Box

Unknown Digital Transducer.

Can not find Sensor 0000 for module 03 in DT Table.
Contact Technical Support

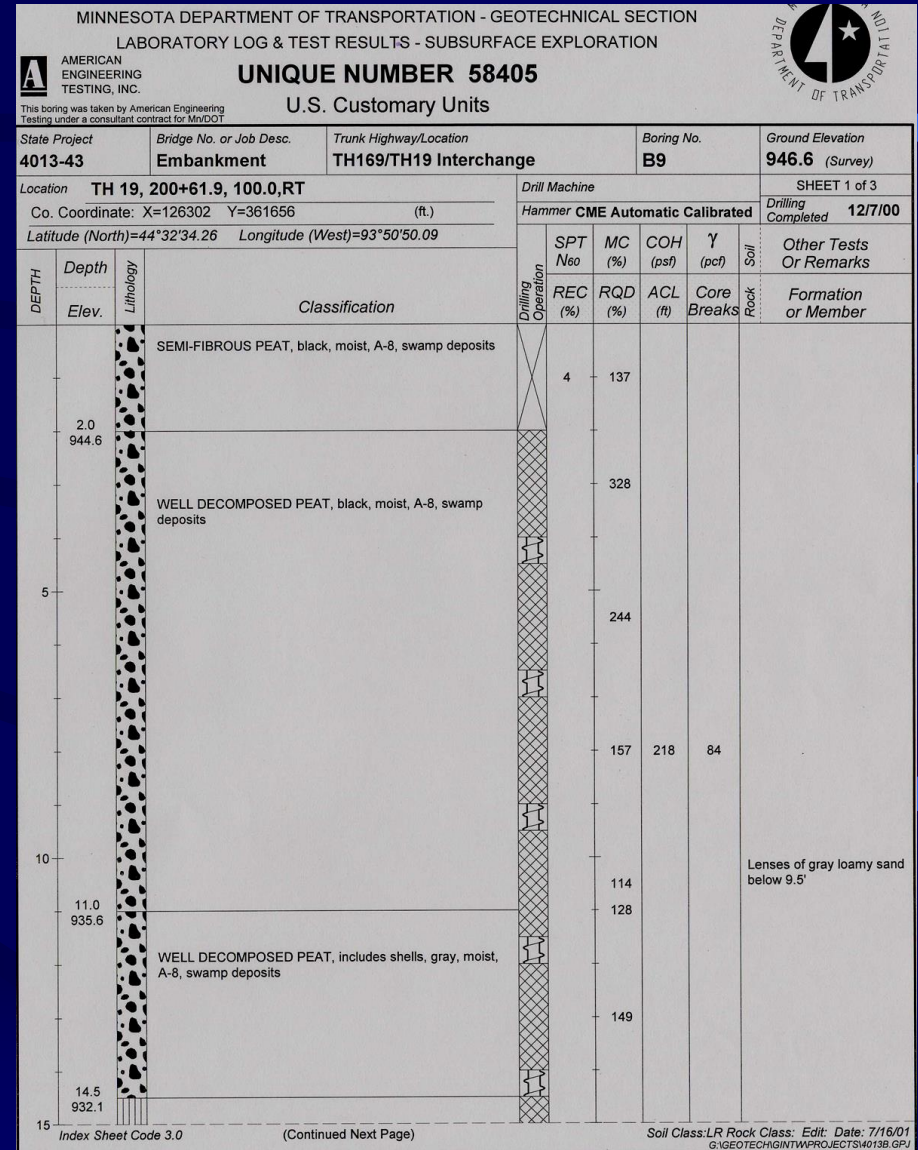
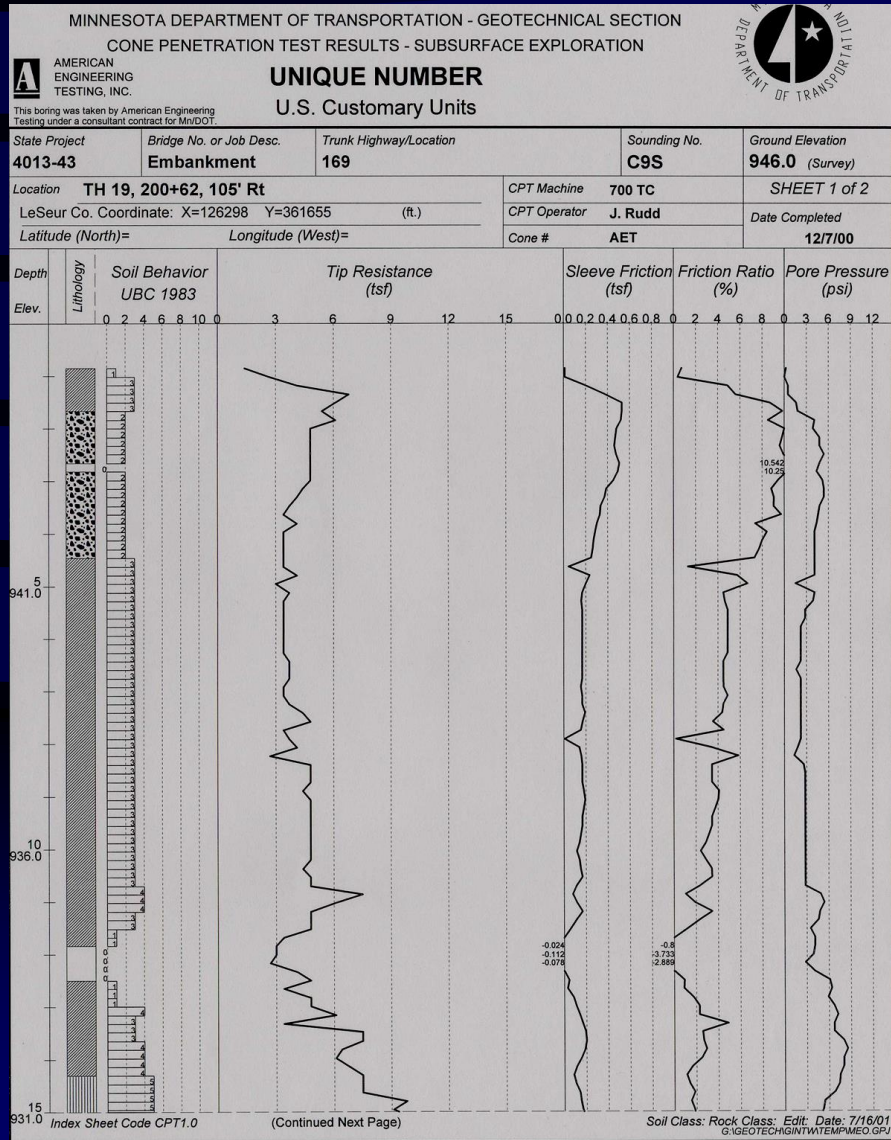
OK



The Future is Almost Here

- New Type of Boring Logs
- Different Information (squiggly lines)
 - Continuous Subsurface Profile
 - Derived Soil Behavior Type (SBT)
 - Tip Resistance, Sleeve Resistance, Friction Ratio*,
 - Pore Water Pressure, Push Pressure (at top)
 - Seismic V_s
 - PWP Dissipation Graphs
- Future: 1/3 SPT, 2/3 CPT rule of thumb

CPT Sounding / Boring Log



Things Left to Do

- New Design Methods
 - Shallow foundations, deep foundations
- Incorporate LRFD Benefit into reports
 - Less conservative reduction factors for CPT
- Adjust Field Operations
 - Staff, Fleet, Grouting, Maintenance Schedule
- Correlate
 - Standard Borings, Dynamic Pile Driving,
 - Load Tests, Lab Tests,
- Educate
 - Internal and External Customers, Contractors, Consultants, Our own staff

Big Projects - You Can Help!

- National CPT Users Group
 - Practical Information, Best Practices
 - Problems, Troubleshooting, Bug Fixes
 - Experience Knowledgebase
- Research and Development
 - Expansion of Louisiana Pile Design by CPT program (LTRC)?
 - Driven 2.0 with CPT data option?

Any Questions?

(before everyone races to the snack table for the break)



Artist's Visualization of Tracked CPT
Rig at an Actual Minnesota Project

7.26.2001

Thanks for your attention, and participation in the conference.