Development of a Wireline CPT System for Multiple Tool Usage

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Introduction

Over the past five years, the Department of Energy (DOE) has invested in the development of Cone Penetrometer Technology (CPT) to reduce both time and costs associated with site characterization efforts. To date CPT has been effectively demonstrated at nearly all DOE facilities and is a technology that is being routinely used at all of the larger DOE sites (i.e., SRS, Hanford, Fernald, etc.). Prior to development of the innovative Wireline CPT system, the use of multiple CPT tools during a site characterization (i.e., piezometric cone, chemical sensors, core sampler, grouting tool) was accomplished by withdrawing the entire penetrometer rod string to change tools. This procedure results in multiple penetrations being required to collect the data and samples that may be required during characterization of a site, and to subsequently seal the resulting holes with grout. The Wireline CPT system being developed allows multiple CPT tools to be interchanged during a single penetration, without withdrawing the CPT rod string from the ground. This innovation will allow more work to be accomplished, and reduce overall costs as time is not wasted pulling rods back into the truck to change tools.

By reducing the number of penetrations and thus the time required to perform typical site characterization tasks, the development of the Wireline CPT system significantly reduces the cost of CPT operations. In addition to the cost savings, Wireline CPT promises simpler deployment of sensor technologies that have been complicated and difficult to package for use with conventional CPT in the past. These include Laser-Induced Breakdown Spectroscopy, cone permeameter, beta and gamma radiation detectors, and X-Ray Fluorescence. Overall, the Wireline CPT system is expected to significantly enhance site characterization and monitoring activities at most DOE facilities.

Objective

The objective of the project was to design, fabricate and test a wireline system for cone penetration testing that will allow the deployment of several tools during a single penetration. This approach saves time and money by decreasing the number of penetrations required to perform the analyses and collect multiple media samples that may be required from a single sounding location during site characterization.

The success criteria for the Wireline CPT development project were to:

- demonstrate the ability to advance a piezocone to refusal depth at Savannah River Site (SRS) using the DOE SCAPS rig; with the rod string in place, replace the piezocone with a grouting tool; and subsequently grout the hole upon withdrawal of the rod string.

- develop and demonstrate a wireline soil sampler for collecting multiple depth samples in a single penetration;
- document the time savings afforded by the new soil sampler for collection of contiguous soil cores; and
- evaluate the utility of the wireline soil sampler, combined with the sonic CPT system to enhance penetration through difficult low-porosity layers by cutting out and removing obstructive material.

Accomplishments achieved in addition to these criteria included:

- validation of the wireline piezocone performance against ASTM standard geometry cones (1.44-inch and 1.75-inch diameter);
- demonstration of the reliability of retrieval and re-deployment of the developed wireline tools at multiple depths and in multiple geologies; and
- comparison of production time with that of conventional CPT for geotechnical characterization.

While the Wireline CPT alone proved useful for enhancing penetration in one demonstration, the utility of combining the Wireline CPT with a sonic CPT system to enhance penetration of a difficult layer at the site chosen for that evaluation was marginal. The lack is significant performance enhancement is attributable to site specific conditions.

Technology

The Wireline CPT system consists of six major components:

(1) segmented rod string;
(2) tool and lock housing (including cutting mouth);
(3) tool locking and retrieval mechanism;
(4) piezocone tool;
(5) soil sampler; and
(6) grouting tool.

The locking mechanism is the heart of the Wireline CPT system. It provides a unique functionality that enables all other innovations. The locking mechanism is identical for each individual wireline tool, to allow interchangeability. A schematic of the mechanism appears below.

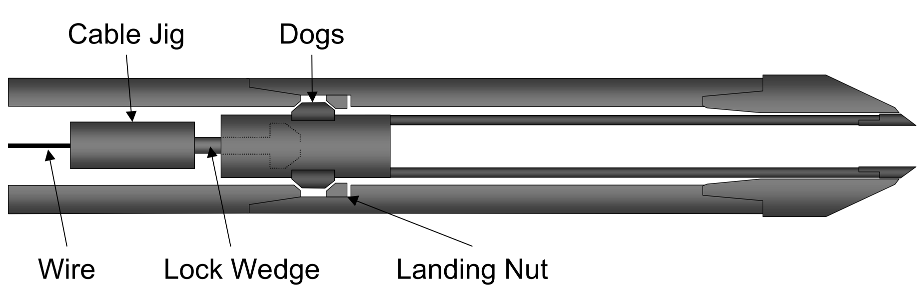

Figure 1. Schematic of Wireline CPT locking mechanism with soil sampler in place.

The lock mechanism utilizes two horizontally opposed, horizontally rotating locking "dogs" which, when engaged, occupy a slot formed in the interior of a rod segment. A circular cross-section locking wedge slides vertically between the dogs to push them radially outward and into the slot. The locking wedge is spring loaded, so outward pressure is applied to the dogs, centering the tool as it slides down the interior of the rod string during deployment. The locking dogs have chamfered upper and lower contact surfaces to allow them to slide smoothly over rod joints and other potential obstructions to vertical travel. The slot into which the locking dogs engage is actually formed by threading a cylindrical landing nut into the expanded bore at the end of a typical rod segment. This approach greatly reduces manufacturing cost by eliminating the need to mill a slot internal to the rods, and allows easy replacement of the bearing surface (i.e., the landing nut) to repair routine wear. A lock housing, incorporating pinned dog connections and a retaining ring, contains the locking wedge, compression spring, and locking dogs and constrains their paths of travel. A photograph of the assembled and disassembled locking mechanism is shown below.

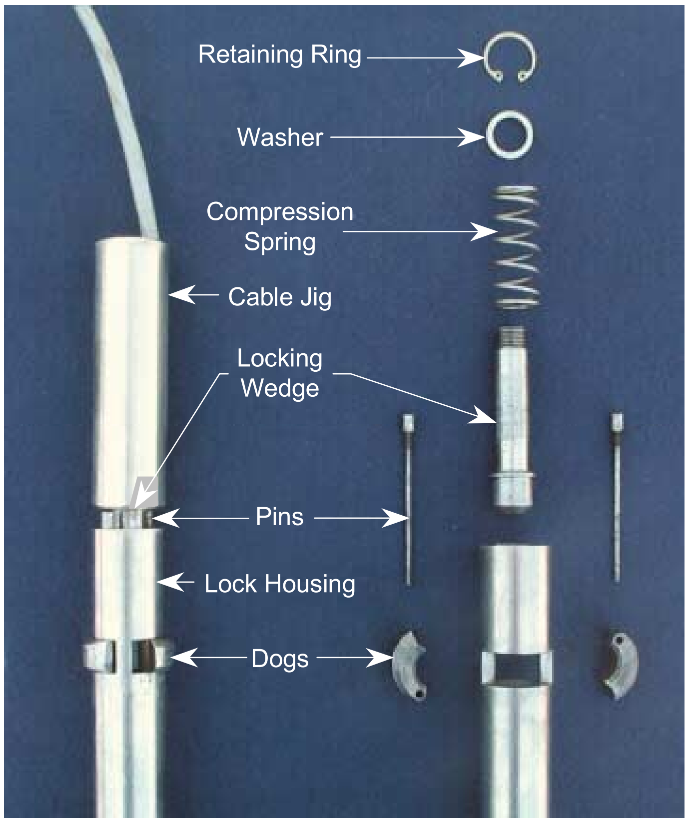

Figure 2. Photograph of assembled locking mechanism and individual components.

When upward force is applied to the locking wedge via tension on a retrieval wire, the wedge slides upward allowing the dogs to move freely inward. The dogs retract into the lock housing under the force transferred to them through their 45-degree inclined upper bearing surface contacting the matching surface of the receiving groove inside the lock and tool housing. This allows the tool to be retrieved to ground surface.

The soil sampler was developed under a contract option, and is the focus of this paper. A prior publication by Farrington and Gildea (1999) focuses in depth on development and testing of the other wireline components. The soil sampling tool is depicted in Figure 3. The sampler allows the collection and retrieval of core samples from multiple depths during a penetration without requiring retraction of the CPT rods from the ground. The sample barrel produces a 1-inch diameter, 12-inch long core of soil, accommodates the use of a plastic retainer basket (for loose soils), and is easily separable from the locking mechanism and basket retainer nut. Either end of the barrel connects to these other parts, or to end plugs used for sealing the sample. A replaceable cutting lip prevents wear or damage to the leading edge of the core barrel and also serves to hold the sample retainer basket in place.

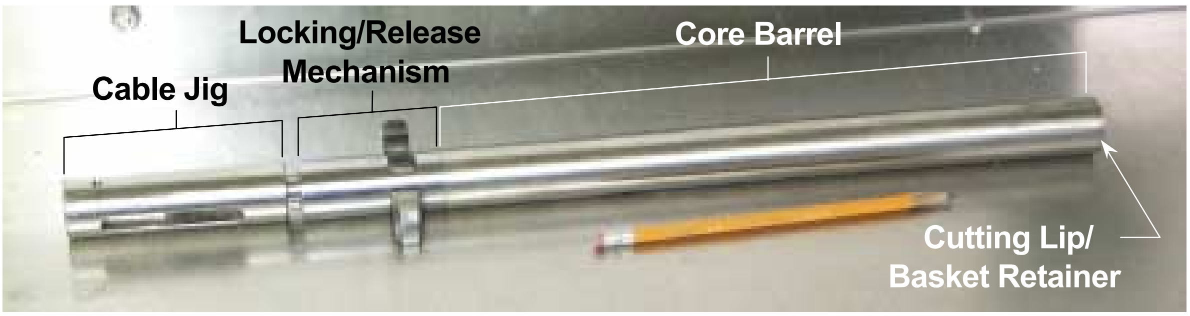

Figure 3. Photograph of the Wireline CPT retrievable soil sampler, with parts labeled.

The impact of procedural issues on the design of the system was carefully assessed. Ordinarily, an entire CPT rod string is pre-threaded with the piezocone and chemical sensor umbilical lines and remains so during the course of operations. The interchange of tools during a penetration will allow a number of rods (those in the ground) to be unthreaded, and additional rods to be inserted in the string before re-threading by sending a tool down the hole. This creates the potential for the entire rod string to require re-threading between penetrations – a time-consuming procedure which would eliminate the time savings afforded by the wireline system. Therefore the design of the system had to allow for operational procedures which eliminate any potential need for re-threading the rod string. This was accomplished by deciding that the grout tube and piezocone cables would be integrated into one umbilical which readily attaches to and detaches from either the piezocone or the grouting tool. The retrieval wire for these tools and the soil sampler remain attached only during retrieval or replacement of the tools, so that threading it is not an issue.

Results

Preliminary testing of the Wireline CPT was conducted in Vermont, prior to field evaluation at a DOE facility to assure the smoothest possible system operation and ultimate project success. The first tests were conducted in March and April of 1999, immediately following fabrication of the major components. These tests consisted of above-ground testing of the locking mechanism and its ability to sustain free-fall re-deployment through the rod string. Two field testing events followed. In addition, a deflection tolerance study was undertaken to ensure that geometry of individual wireline tools would allow them to pass reliably through an embedded rod string that may be deflected due to encounters with boulders, hard layers, or other obstructions during penetration. Findings from these tests guided further, minor modifications to the system design and operating procedures.

During April and May 1999, field testing continued at SRS, using the refined locking component, the fully instrumented piezocone tool, and the grouting tool. This field evaluation was carefully designed to gather the information necessary for evaluating the following functional concerns:

- performance of the tool locking mechanism;
- adequacy of operational procedures developed;
- system survivability;
- refusal depth versus conventional CPT;
- piezocone performance versus ASTM standard piezocone; and
- production rate versus conventional CPT.

During this testing, the piezocone tool was deployed and retrieved repeatedly at every one-meter increment of depth between 0 and 40 feet. In all trials, the tool was removed from the rod string, pulled up-hole, and re-deployed successfully without event. Cost estimates, penetration depths, and geotechnical characterization data were gathered for comparison to conventional techniques.

Data obtained from the first field evaluation at SRS were used to validate the wireline piezocone against the ASTM standard 1.75-in diameter cone. The data collected at the SRS site using the wireline 1.125-in cone and the 1.75-in cone were statistically analyzed using the "Student t" test statistical method. Refusal depth of the wireline system was compared to that of conventional CPT under identical conditions during the field evaluation at M-basin, SRS. The performance of the wireline system far exceeded expectations, and at the first SRS field evaluation, refusal was not encountered before running out of rods. Returning to the M-Basin in April of 2000, with additional rods, we found the wireline system to penetrate as deeply as had the conventional system a year earlier. The table below compares refusal depth of the wireline system (2.00-inch diameter rods) to that of conventional CPT (1.75-inch diameter rods) at SRS M-Basin. Data are included from two evaluation/demonstration events. Details of the findings of the first field evaluation at SRS, including the statistical validation of the wireline piezocone, are discussed in a prior publication (Farrington and Gildea, 1999).

Table 1. Refusal depth of Wireline CPT compared to conventional (1.75-inch) CPT at SRS M-Basin.

Penetration	System	Depth to Refusal
Field Test (5/99)	Conventional	44.5 m (146 ft)
Field Test (5/99)	Wireline	> 33.2 m (109 ft)*
Demonstration (4/00)	Wireline	46.0 m (151 ft)

*Ran out of rods at first field test

As with the other components, the soil sampler was subjected to preliminary operational testing at ARA's New England facilities during development. This occurred in January 2000. The objective of the testing was to evaluate reliability of the first prototype design in terms of sample recovery, tool retrieval and deployment, and survivability. Tests consisted of two penetrations into a formation characterized by nonindurated glaciofluvial deposits of fine sands, silts, and clays. Sampling was attempted at multiple, contiguous depths during each penetration. During the first penetration, sample recoveries were inconsistent. This was due to initial difficulty in reliably detecting when the sampler was not properly locked in place. However, once operator familiarity with the tool was established, the sample recovery rate increased dramatically. On the second penetration, four contiguous samples were collected between the depths of 16 and 20 feet, each yielding 100% recovery as shown in Figure 4 below. The water table was encountered between 20 and 21 feet, as indicated by the (partial) recovery of a saturated sample. Three subsequent sampling attempts below the water table yielded no recovery. This result was likely due to the absence of a sample retainer basket, the mold for which had not yet been fabricated. During the tests, production speed was estimated at four to five times conventional CPT soil sampling, because there was no need to retract the rods and re-penetrate. While substantially positive results were obtained, the initial testing did reveal the need to increase the weight of the sampler package to ensure more reliable locking upon deployment in an embedded rod string.

(a) **(b)**

Figure 4. Recovery of a soil sample during field testing in Vermont. The cutting lip/basket retainer and tool locking mechanism are visible in (a). In (b) the core barrel has been separated from the other sampler parts and the specimen is being removed.

A second field evaluation and demonstration of the Wireline CPT soil sampler was conducted at SRS from April 5-20, 2000 in conjunction with ongoing environmental restoration work. Three deployments were accomplished during the evaluation period, and a fourth was accomplished following the demonstration. Deployments during the evaluation period included successful use of the wireline system for:

- piezocone characterization in combination with soil gas sampling;
- piezocone characterization in combination with ribbon DNAPL sampling; and
- continuous soil sampling, in addition to cutting through a geologic layer that initially caused refusal at the A14 outfall.

In addition, we were prepared to install permanent soil gas monitoring points through the wireline system had the results of gas sampling indicated any zones of concern. In the fourth deployment, the Wireline CPT system was used for continuous soil sampling at the Chemical Metals and Pesticides (CMP) Pits site.

Field evaluations and demonstrations were also conducted at the DOE's Hanford site, in two intervals. The wireline soil sampler was demonstrated at the Sisson and Lu site of 200 East on July 21 and 24, 2000. Evaluation in conjunction with ARA's sonic CPT system occurred on August 1-4, 2000 at the Ash Pit of 100 F. The objective of the tests conducted at the Sisson and Lu site was to compare the performance of the Wireline CPT soil sampler to that of a conventional CPT soil sampler. The objective of the demonstration at the 100F Ash Pit was to evaluate the use the wireline soil sampler with the sonic vibratory head as a means of enhancing penetrability in difficult geologic conditions.

At Sisson and Lu, both samplers were used to retrieve continuous soil samples over an extended depth. Close monitoring of the time required to retrieve samples, as well as sample recovery, was conducted. Samples collected using the Wireline CPT soil sampler took an average of two minutes each to retrieve (about 10 seconds per inch of sample). In contrast, using the conventional CPT soil sampler took an average of 18 minutes to retrieve each 18-inch sample (about one minute per inch of sample). Both samplers worked as expected and no problems were encountered. Recovery for each sample using the Wireline CPT system was greater than 80%, with most being greater than 90%, while recovery for each sample using the conventional sampler was between 70% and 80%.

Push forces of 20,000 lbs were typical using the Wireline CPT system; the maximum force was approximately 32,700 lbs. In contrast, push forces exceeding 40,200 lbs were reached when using the conventional sampler. This was due to rocks and debris falling down the open borehole while removing and reinserting the push rods. Site stratigraphy (hard layers) did not adversely impact the operation of either sampler.

Benefits

The primary benefit of the Wireline CPT innovation is a reduction in time and cost for completing typical site characterization activities. In the first tests at SRS a 24% time savings was documented for conducting piezocone geotechnical characterization followed by grouting out the hole. Substantially greater time savings were demonstrated for contiguous soil sampling during subsequent demonstrations at SRS and Hanford, as described below.

Based on the data obtained from the Hanford demonstration and from operations and demonstrations at SRS M-Basin, a cost model was developed to predict the reduction in cost of contiguous soil sampling afforded by use of the Wireline CPT system. The cost model accounted for: (1) the time required to set up over each sampling location; (2) the rate at which a dummy tip can be advanced to the depth at which samples are desired; and (3) the rate of retrieving and recovering a sample from each apparatus. In addition, the model also considered fixed costs associated with consumables associated with each of the two sampling methods.

Times calculated for conducting contiguous sampling operations by each of the two methods were multiplied by a composite crew and equipment rate representing a two-person crew using a heavyweight (20-30 tons) CPT rig. The table below presents the inputs to the cost model.

Table 2. Inputs to the cost model for contiguous CPT soil sampling.

Activity	Units	Wireline CPT	Conventional
Initial Penetration Rate	feet per minute	5	5
Fixed Time Per Sample	minutes	1.5	5
Sample Retrieval Rate ("Tripping")	feet of sample depth per minute (round trip)	25	2.5
Set-up time per hole	hours	30	30
Crew & Equipment Rate	dollars per hour	312	312
Consumables	dollars per sample	50	10
Length of Sample	feet	1.5	1.75

The rate at which a sample is retrieved, also called "tripping", applies to the round trip rate for pulling the loaded sample apparatus to the surface and re-deploying it to the previous depth. For the wireline system, the apparatus includes only the sampling tool and soil. For conventional sampling, the apparatus includes the rod string. The fixed time per sample is the up-hole time required to remove the sample from the apparatus and re-assemble the apparatus to ready it for collection of the next sample. Other assumptions applied to the cost model included the following:

- The consumables cost for wireline sampling exceeded that of conventional sampling by $50 per sample (i.e. the retail value of a core barrel) because the core barrels can not be immediately re-used, since the sample collection rate exceeds the rate of removing a sample from the barrel, cataloging it, and cleaning the barrel for re-use;
- The conventional sampler recovered 21 inches of core at a time;
- The wireline system recovered 18 inches of core at a time (12, 18, and 24-inch core barrels are available);
- Set-up time over each sampling location, including subsequent grout mixing and cleanup, required 30 minutes.

Figure 5 illustrates the cost savings realized with a Wireline CPT system for contiguous soil sampling versus conventional CPT. The savings prediction considers the unit cost of collecting each sample under a variety of scenarios. The cost model was calibrated against actual cost data from field evaluations and operations at M-Basin of SRS and the Sisson and Lu site at Hanford 200 East. In the graph, the x-axis represents the length of the interval over which samples are collected. The y-axis represents percent savings, also per length interval. A line is presented for each of several starting depths for the interval. It should be noted that, although the graph includes scenarios involving samples from as deep as 200 feet, at the time of this writing, Wireline CPT soil sampling has been conducted no deeper than 151 feet.

While the cost savings demonstrated for contiguous soil sampling are remarkable, the greatest cost savings from use of the Wireline CPT system will probably be realized in mixed applications, such as a combination of sensor characterization and sampling. In these cases, in addition to reducing re-penetration, the wireline approach will eliminate the need to move the CPT rig to a new location each time a new process is initiated.

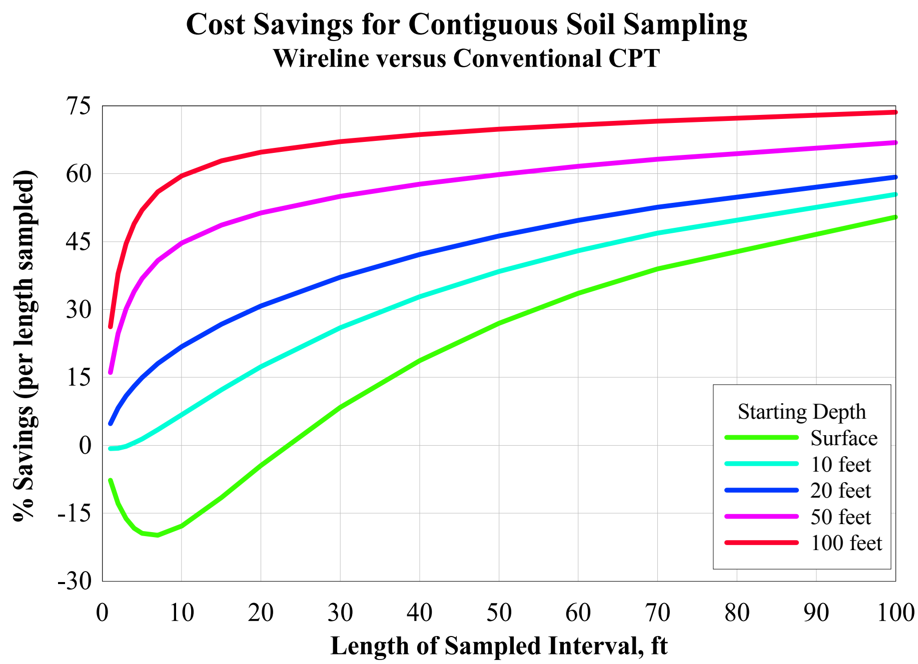

Figure 5. Modeled cost savings for contiguous soil sampling using the Wireline CPT system versus conventional CPT soil sampling.

In addition to the time and cost reductions afforded by the Wireline CPT system, further benefits of this innovation include penetration enhancement and ease of additional tool development. At SRS, the wireline system was demonstrated to enhance penetration at the A14 outfall, by "sampling through" a gravelly layer where conventional CPT had met refusal. During this deployment, we located DNAPL in soil beneath the gravelly layer using the wireline soil sampler. Combining the wireline soil system with the sonic CPT system to enhance penetration did not result in any significant advantage during the evaluation at the 100F Ash Pit site of Hanford. At that location, the addition of dynamic force using the sonic head only resulted in damage to exposed wireline system components.

Future Activities

Based on the demonstrated success of the wireline system in reducing the time and cost of a variety of site characterization operations, especially multiple depth soil sampling, we look forward to promotion of the system's use within DOE wherever the conditions are applicable. In addition, members of DOE's Environmental Restoration (ER) community have suggested additional wireline tools which could be developed in response to articulated ER needs. Among the tools that could be adapted to the wireline, we see the following technologies as the highest priority items for meeting present ER needs:

Saturated Zone Soil Sampler. Although the wireline soil sampler works exceptionally well in the vadose zone and under many saturated soil conditions, in situations with low effective soil stress (e.g., flowing sands) the open down-hole end of the Wireline CPT rod string can become clogged with formation material during retrieval of the most recent sample. SRS has expressed a need for protecting the system against infiltration of such material while conducting sampling below the water table. In addition, Hanford has expressed concern about the possibility of radiologically hazardous soil entering the open end of the rods during vadose zone characterization. Development of a method to keep formation material from entering the bottom of the rod string when CPT tools are not locked in place would satisfy both these site needs. We envision a possible trap-door type mechanism with a wiper seal, or the use of positive pressure within the rods to achieve this goal.

Wireline Deployable ConeSipper™. Development of a wireline-compatible implementation of the successful ConeSipper™, developed under a Cooperative Research and Development Agreement (CRADA) between SRS and ARA, will result in savings of time and cost associated with groundwater and soil gas sampling. Currently, the sample inlet screen of the ConeSipper™ is prone to clogging as it passes through fine-grained or clayey materials, and this can cross-contaminate samples by retaining residue from shallower strata on the sampling screen. When such clogging or cross-contamination occurs, the entire CPT rod string must be withdrawn in order to clean the tool. Although this problem can often be circumvented by continuously purging the tool with pressurized nitrogen, this solution adds cost and complexity, and is not effective in many situations. Implementation of a wireline-compatible ConeSipper™, which retracts into the rod string to protect the sampling screen during penetration between sampling events, would increase it's reliability and reduce costs. Also, if any clogging or cross-contamination does occur, the tool can be easily retrieved for cleaning without withdrawing the rods. This innovation will extend the remarkable speed and cost advantages of Wireline CPT soil sampling to multiple-depth groundwater sampling.

Complementary Wireline Gamma and Beta Radiation Sensors. A recent review of the technology need statements from the Site Technology Coordination Groups (STCG) at several DOE sites identified 14 separate needs for detection of beta-emitting radionuclides in the subsurface. The application of the Wireline CPT technology will permit direct interaction between the sensing volume of a beta sensor and the soils, without any casing materials such as CPT rods or well casing shielding the detector from the beta particles. This can be achieved by deploying the beta sensor out the open down-hole end of the CPT rod string upon retraction of the rods from depth. The initial penetration can be accomplished while deploying a gamma sensor, thus allowing both gamma and beta characterization in a single penetration. ARA has already deployed a CPT gamma sensor (sodium iodide crystal) tool that can readily be made compatible with the Wireline CPT system.

Wireline Video Cone. With the currently shrinking size of adequate resolution video cameras, ARA's highly useful and commercially successful videocone could be packaged as a 1.125-inch diameter Wireline CPT tool. This tool in it's conventional CPT form, sometimes combined with an optical chemical sensors, has proven invaluable in verifying soil classifications, mineralogy, moisture, and the presence of non-aqueous phase liquid contaminants.

References

Farrington, Stephen P., and Martin L. Gildea (1999). *Development of a Wireline CPT System for Multiple Tool Usage*. Proceedings of the Industry Partnerships to Deploy Environmental Technology Conference. Federal Energy Technology Center, US Department of Energy, Morgantown, West Virginia. October 1999.

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What Is The Baseline?

Conventional Cone Penetration Testing

Advantages

- Generates little or no IDW
- Results in little or no Worker Exposure
- Provides very detailed information

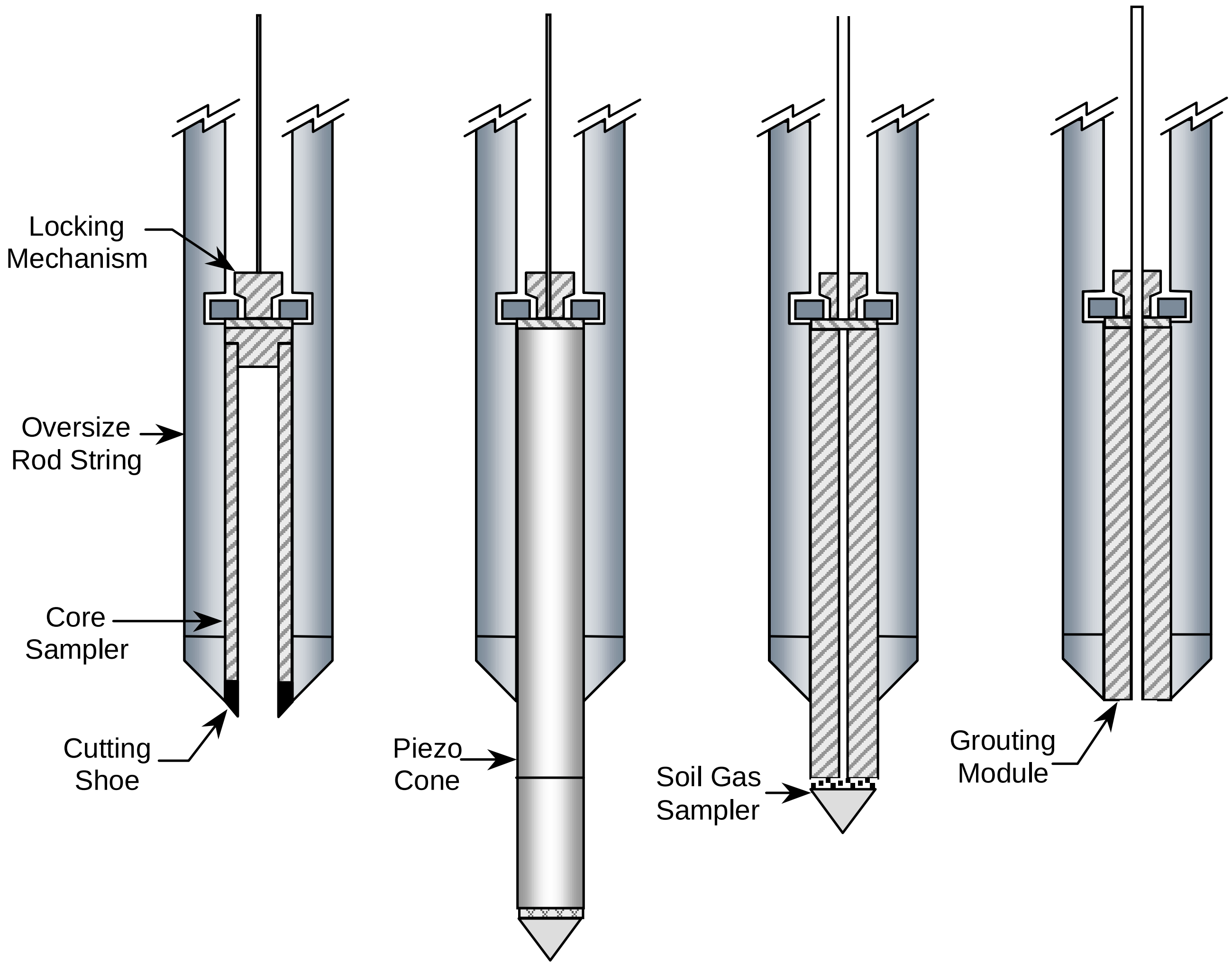
Limitations

- Incapacious
- Multiple pushes for multiple tasks
- Some geologies are resistant to penetration

What Does This Do?

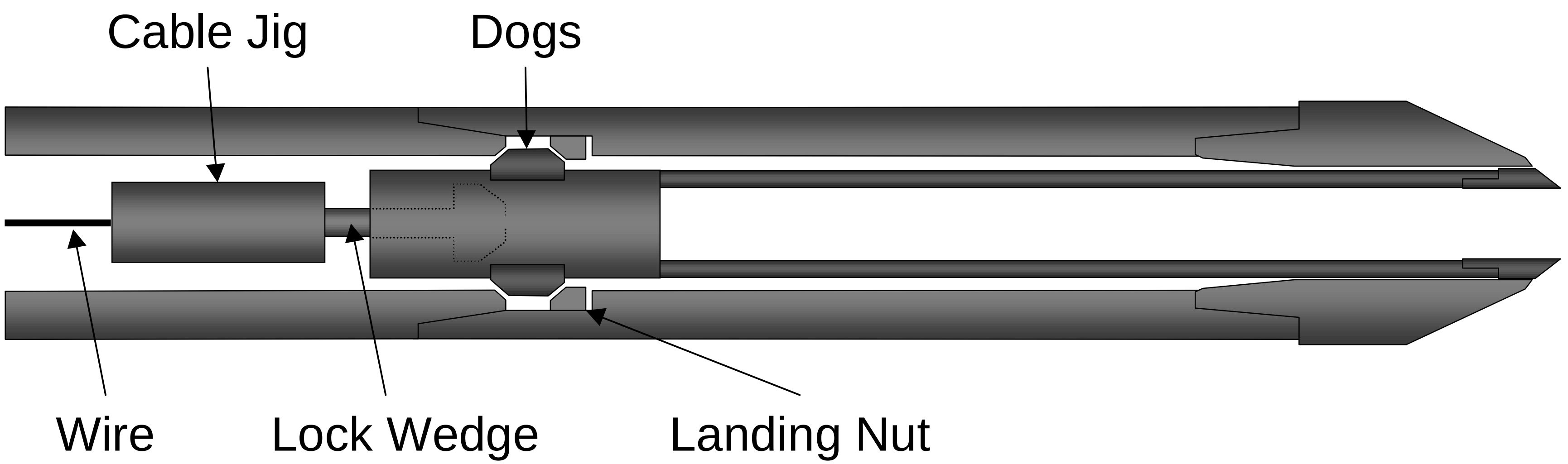
The wireline CPT system allows multiple subsurface characterization tools to be interchanged at the down-hole tip of a CPT rod string, while the rods remain embedded in the ground.

What Tools?



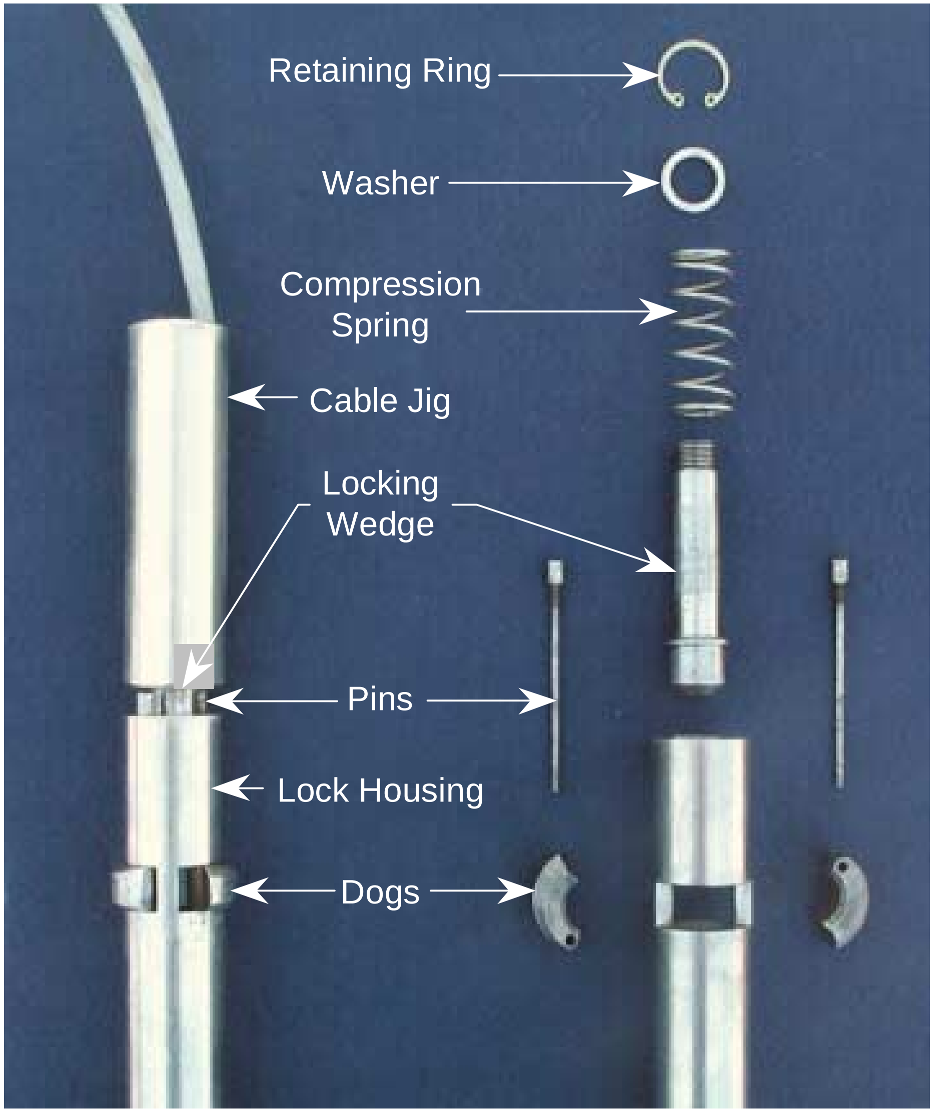
Locking
Mechanism
Oversize
Rod String
Core
Sampler
Cutting
Shoe
Piezo
Cone
Soil Gas
Sampler
Grouting
Module

How Does It Work?



Locking Mechanism

Dogs Retracted



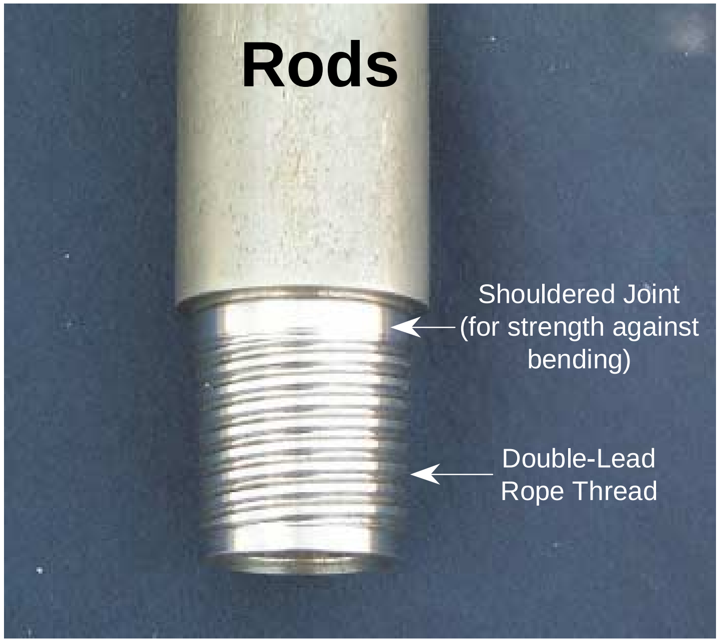
Dogs Extended

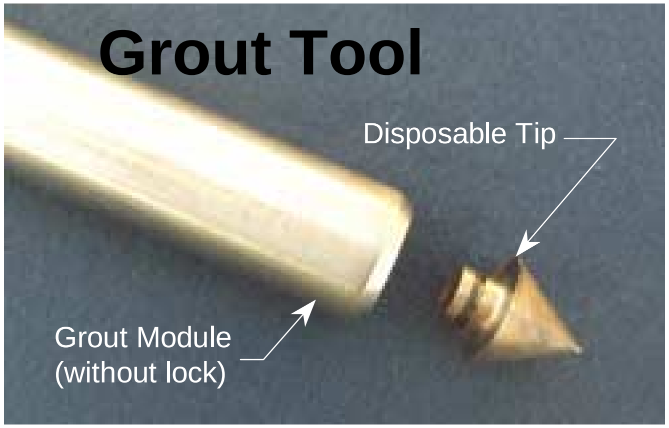
APPLIED RESEARCH ASSOCIATES, INC.

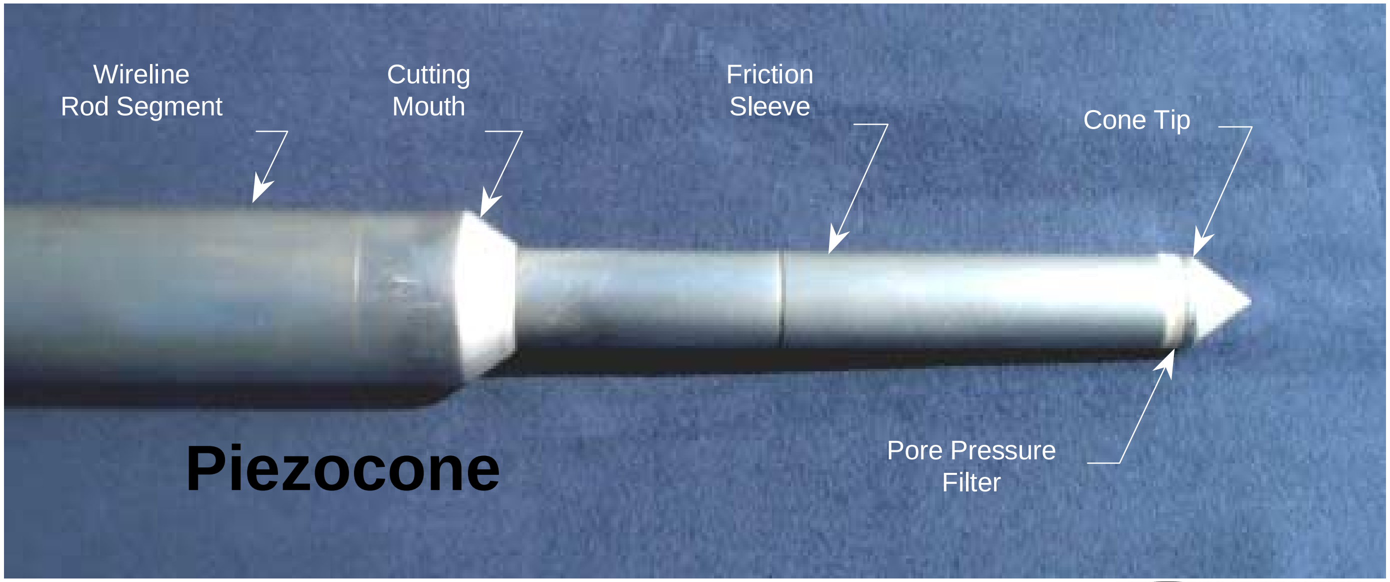
Wireline CPT System

Why Is This Better?

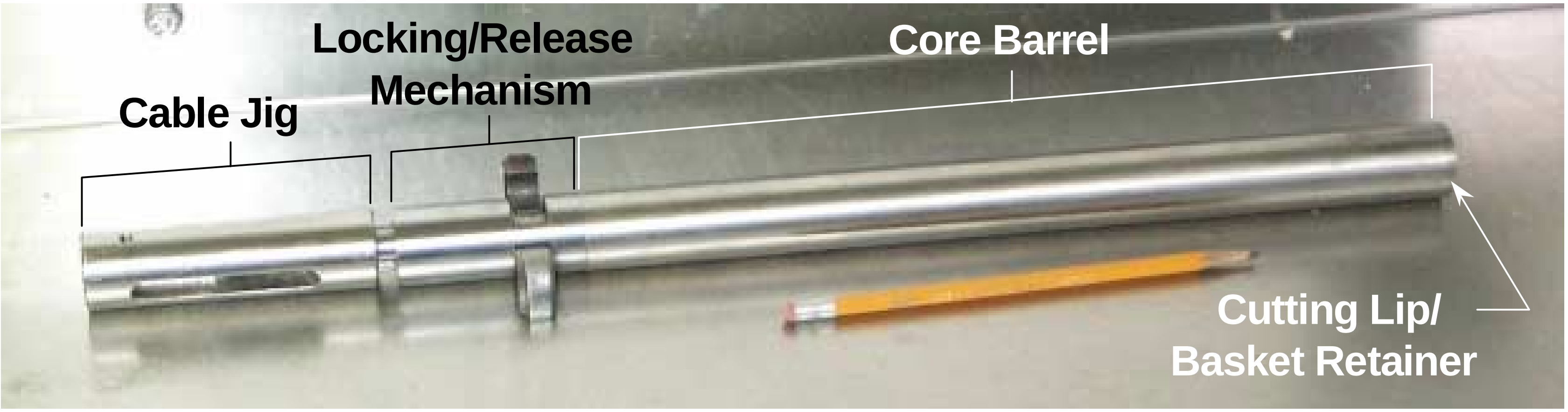
- **Reduced time/reduced cost**
  - Single penetration for sounding, sampling, sealing
  - Multiple samples from one penetration
  - Retrieve samples only, not all rods
- **Reduced risk**
  - Lower chance of drag-down during characterization
  - Fewer holes
  - Higher confidence that grout is placed in the original hole


Rods
Shouldered Joint (for strength against bending)
Double-Lead Rope Thread


Grout Tool
Disposable Tip
Grout Module (without lock)

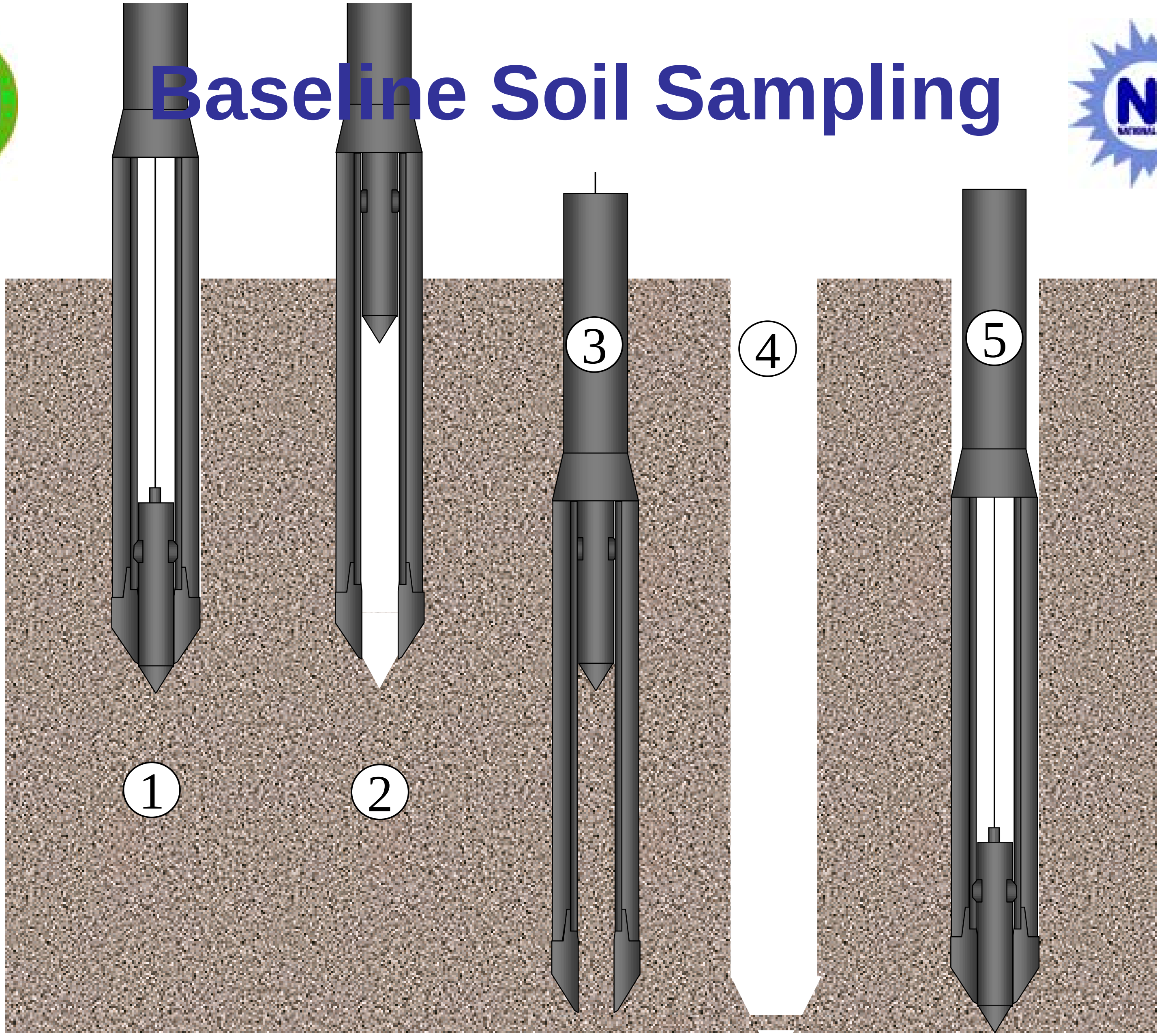

Wireline Rod Segment
Cutting Mouth
Friction Sleeve
Cone Tip
Pore Pressure Filter
Piezocone

Wireline Soil Sampler

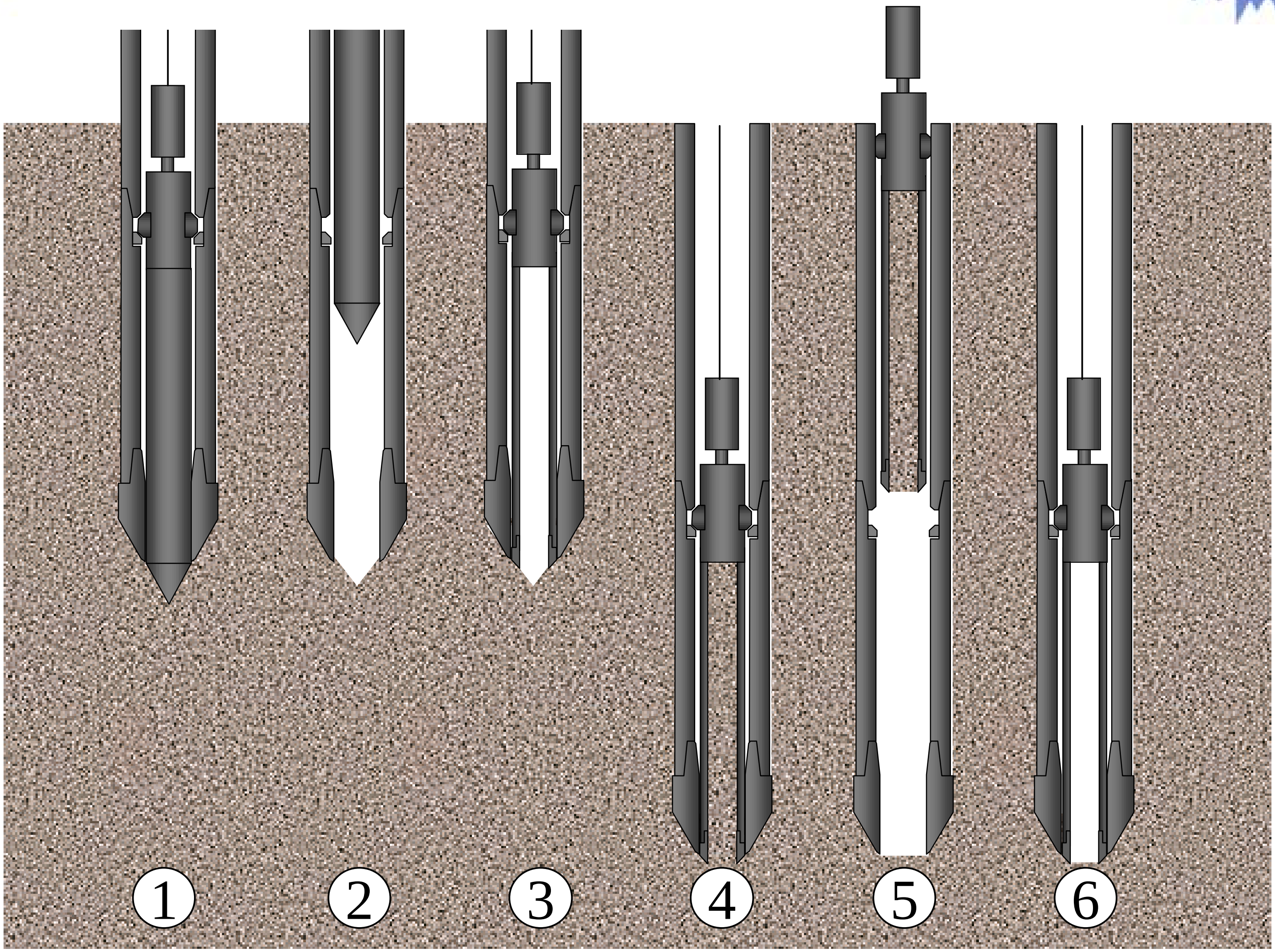


Soil Sampler

Baseline Soil Sampling



Wireline CPT Soil Sampling



How Much Better Is It?

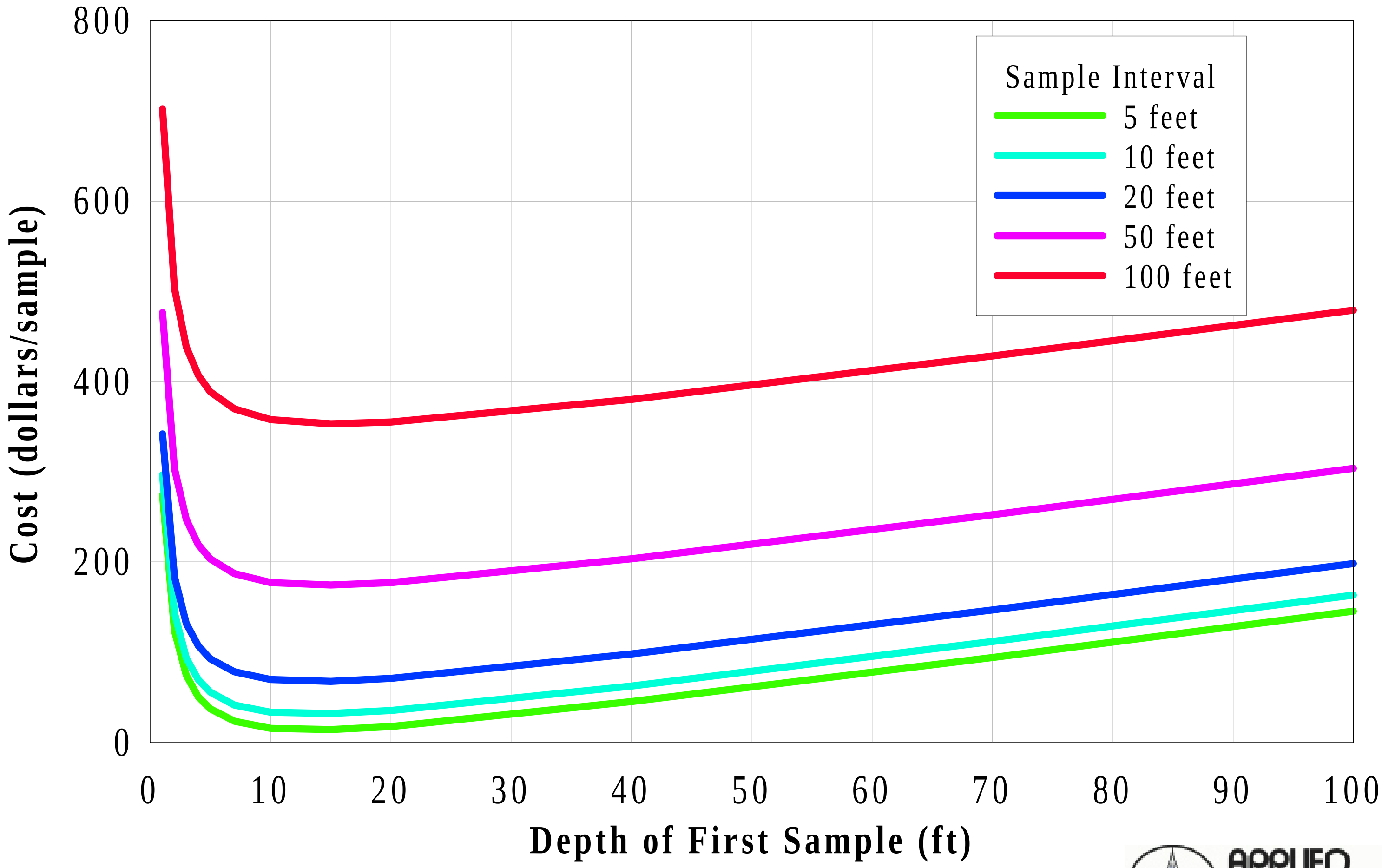
Conventional CPT Soil Sampling			Wireline CPT Soil Sampling		
Depth Interval	Cumulative Feet	Percent Re-penetration	Depth Interval	Cumulative Feet	Percent Re-penetration
20-21.5	21.5	0	20-21	21.0	0
21.5-23	44.5	93	21-22	22.0	0
23-24.5	69.0	182	22-23	23.0	0
24.5-26	95.0	265	23-24	24.0	0
26-27.5	122.5	345	24-25	25.0	0
27.5-29	151.5	422	25-26	26.0	0
29-30.5	182.0	497	26-27	27.0	0
30.5-32	214.0	569	27-28	28.0	0
Grout Out	246.0	669	28-29	29.0	0
			29-30	30.0	0
			30-31	31.0	0
			31-32	32.0	0
			Grout Out	32.0	0

How Much Better Is It?

Wireline CPT Cost Savings

Contiguous Soil Sampling

Wireline vs. Conventional CPT



How Much Better Is It?

Cost Model Assumptions

- Mobilization costs are equal and are not included
- 12-inch long wireline core barrel
- 18-inch long conventional core barrel
- Wireline material cost is $50/sample greater than conventional

How Do We Know It Works?

Field Evaluations &Demonstrations

- New England (ARA Test Site) - March-April 1999
- Savannah River Site - May 1999
- Savannah River Site - April 2000
- Hanford Reservation - July 2000
- Hanford Reservation - August 2000

How Well Does It Work?

Field Testing Results

- Penetrated sand, silt, gravel
- Exerted over 50,000 lbs. push force with no damage resulting
- Retrieved and deployed various tools down to 161 feet
- Re-deployment of tools consistently successful
- Wireline reached deeper than conventional at SRS A14 outfall
- Sonic CPT/Wireline combination did not help at Hanford 100F Ash Pits - very low porosity

How Well Does It Work?

Field Testing Results

- Penetrated SRS M-basin until out of rods (108 ft) in 1999, then to 151 feet in 2000
- 24% time savings vs. conventional CPT for piezocone characterization and grout-out only
- 83% time savings per foot of continuous soil sampling
- Consistent 80-90% recovery rate for sample cores
- No statistically significant difference between wireline piezocone data and ASTM standard cone data - site heterogeneity controls

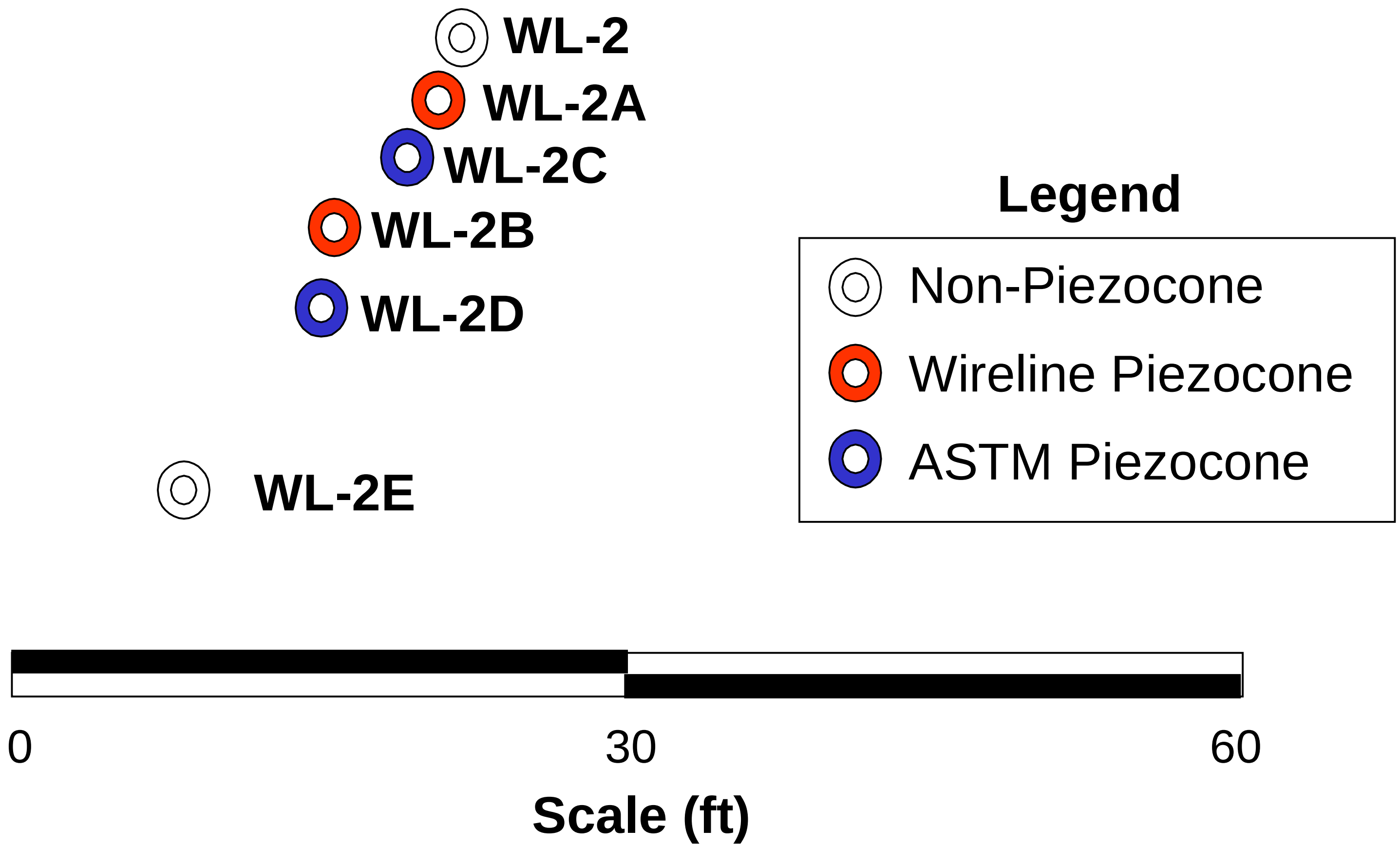
How Well Does It Work?

Refusal Depth at M-Basin

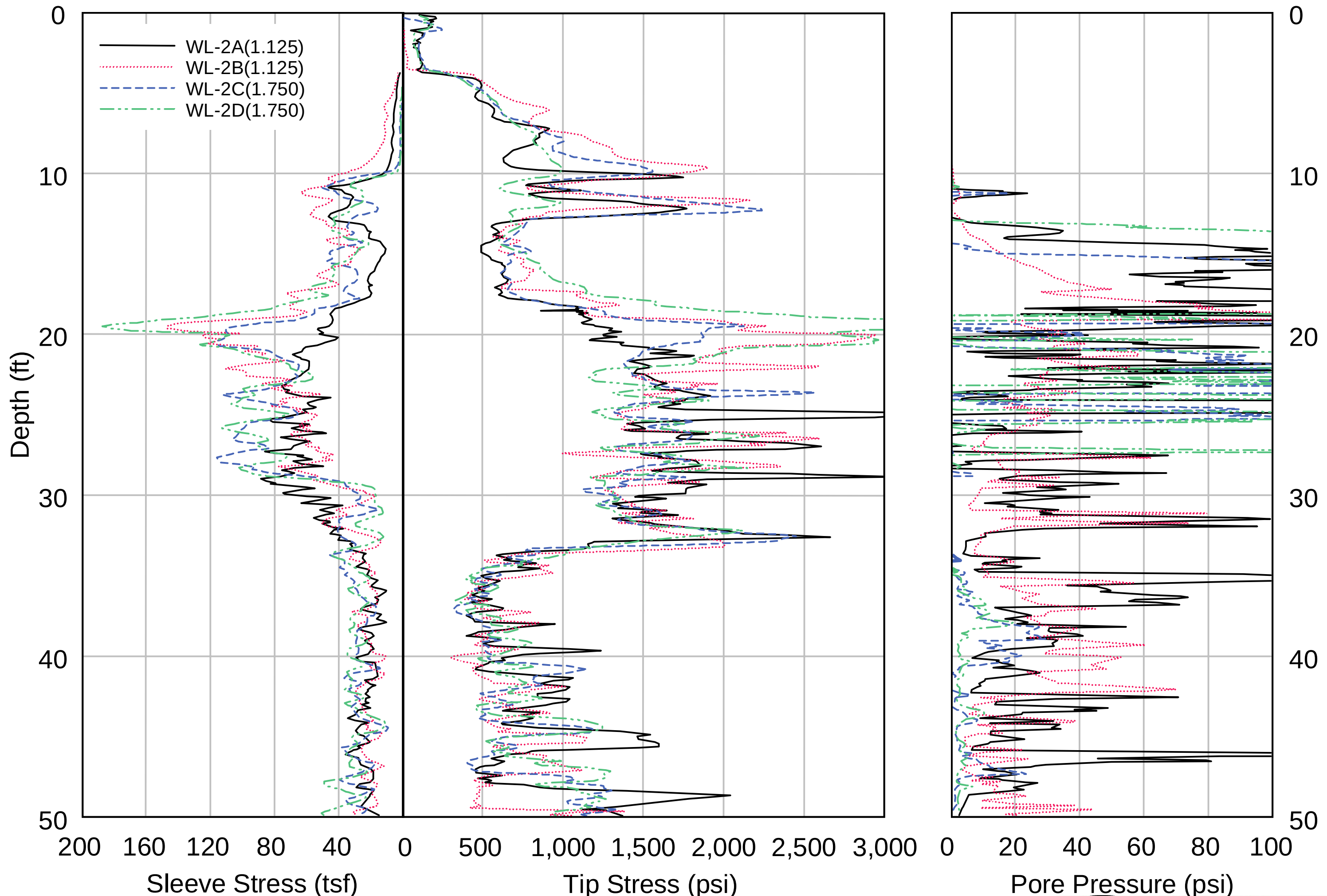
Penetration ID	System	Depth to Refusal
Field Test (5/99)	Conventional	44.5 m (146 ft)
Field Test (5/99)	Wireline	> 33.2 m (109 ft)*
Demonstration (4/00)	Wireline	46.0 m (151 ft)

*Ran out of rods at first field test

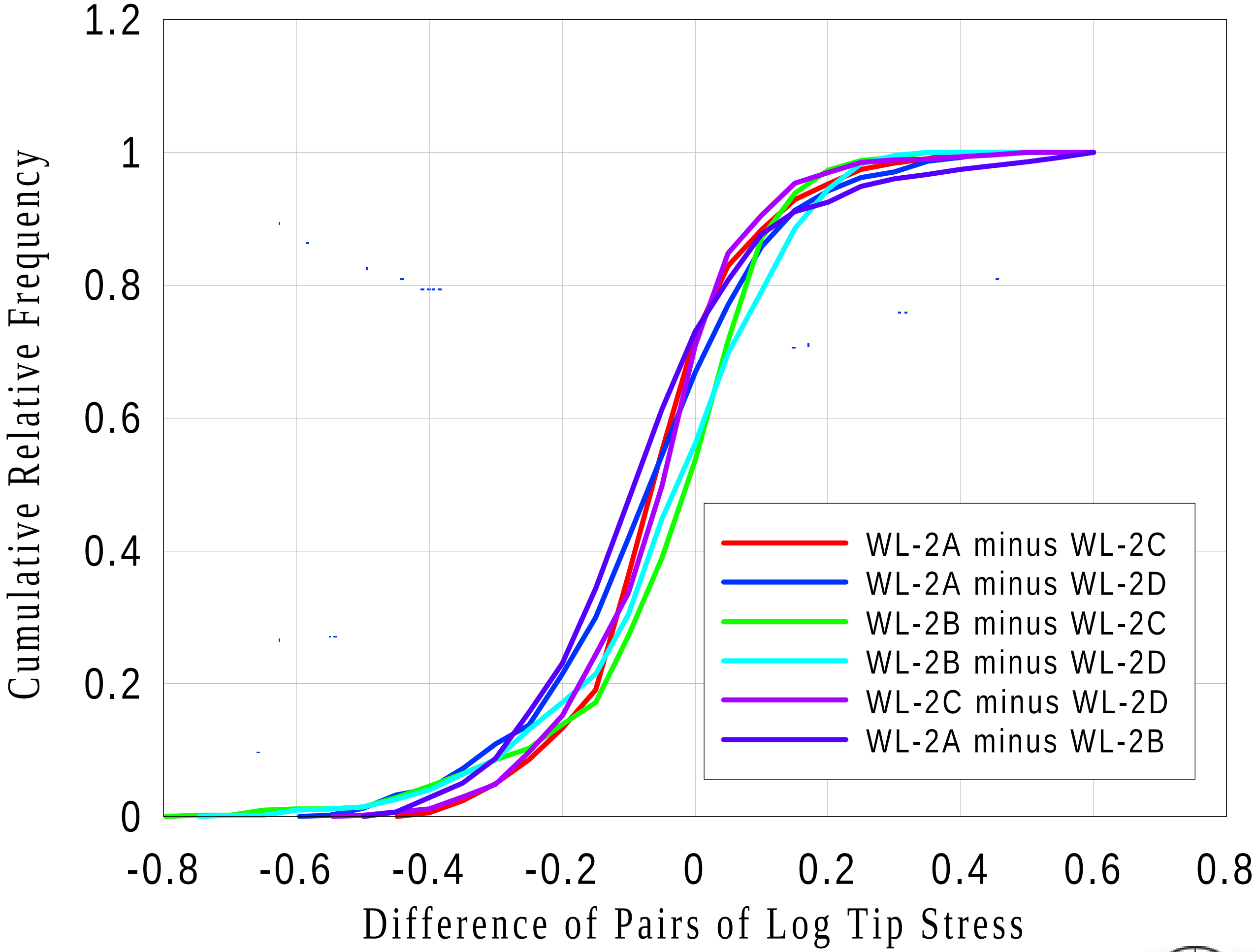
Piezocone Comparison, M-Basin SRS



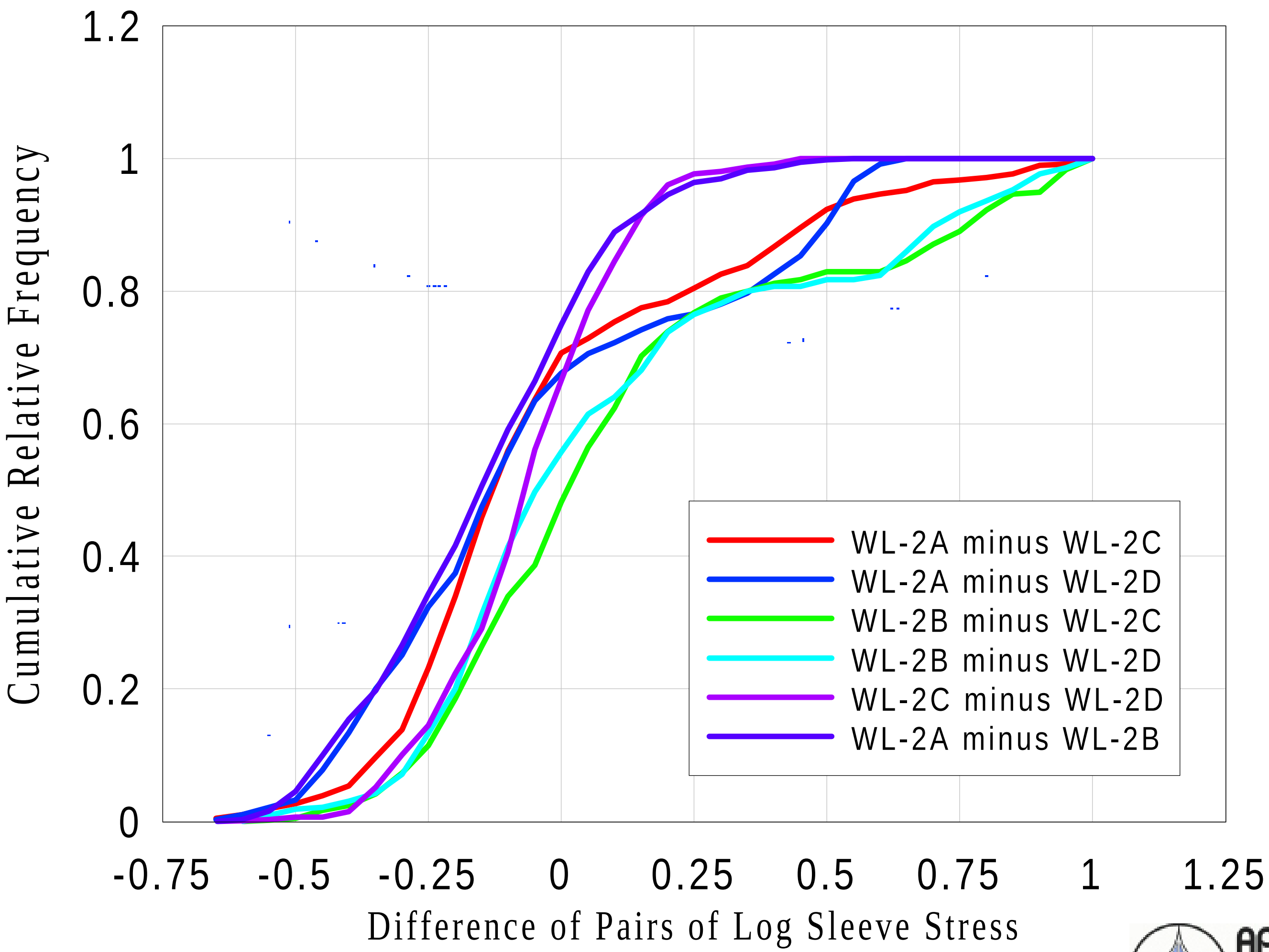
Piezocone Comparison, M-Basin SRS



Piezocone Comparison

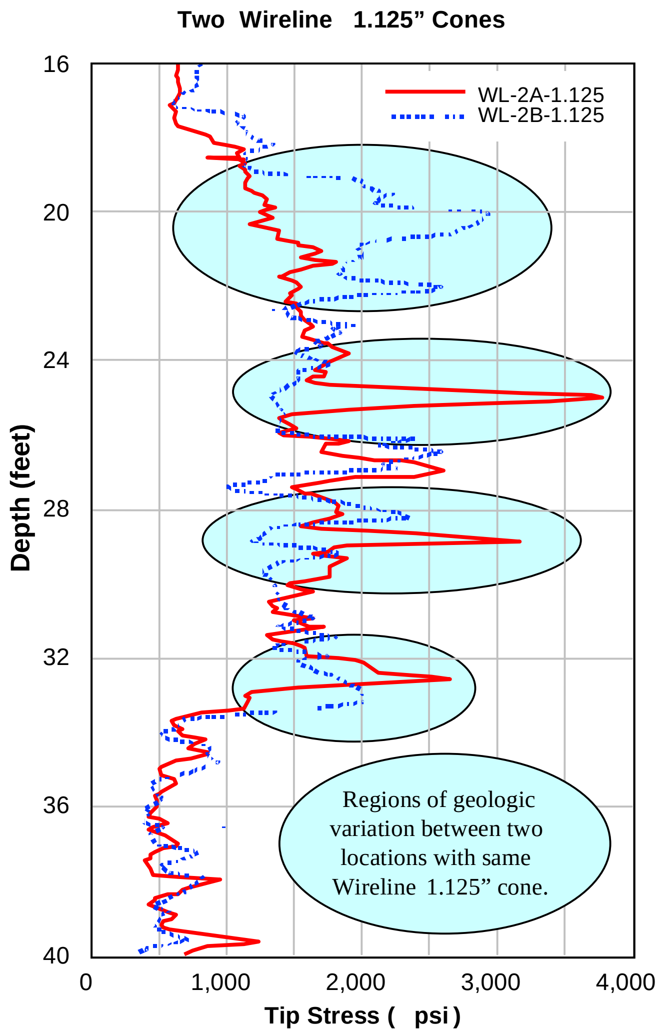


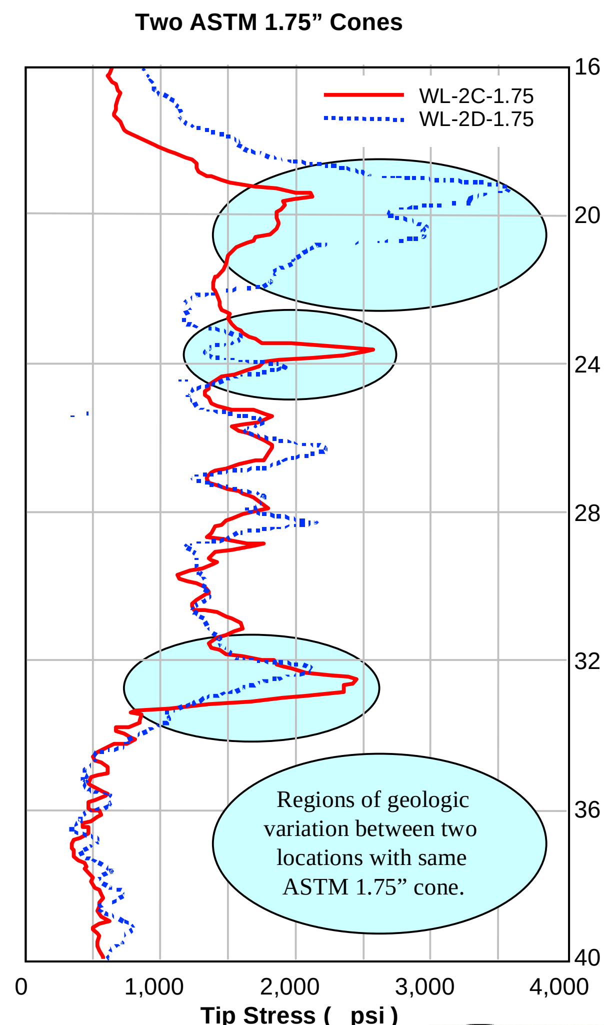
Piezocone Comparison



APPLIED RESEARCH ASSOCIATES, INC.

Piezocone Comparison, M-Basin SRS





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How Successful Is It?

- Cost Savings of up to 50%
- Time savings of 24-83%
- Can enhance access to tough spots by "cutting through" hard layers (A14 Outfall)
- Indistinguishable from ASTM cone for geotechnical characterization
- System is versatile, reliable, robust
- Wireline is single greatest advance in CPT utility

How Successful Is It?

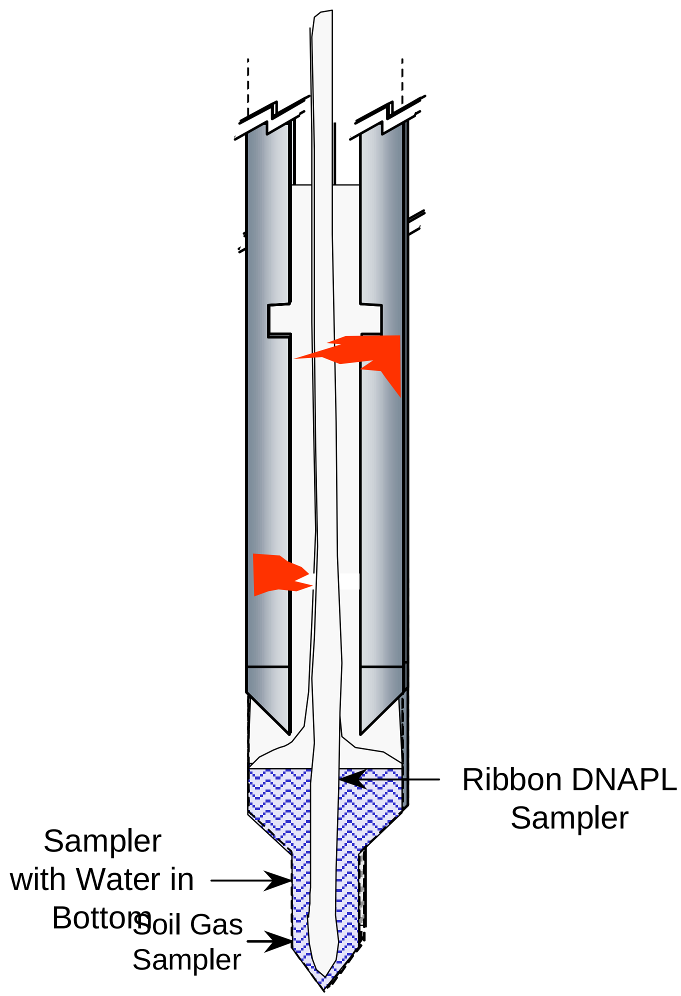
9 Deployments in 1999-2000

Savannah River Site

- A14 Outfall
- M-Area (soil sampling)
- D-Area (ribbon NAPL sampler)
- Chemical Metals Pesticides (CMP) Pits (twice)
- P-area Burning Rubble Pit (BRP) (twice)

Hanford Reservation

- 200 East - Sisson & Lu Site (twice)



Ribbon DNAPL Sampler
Sampler with Water in Bottom
Soil Gas Sampler

How Successful Is It?

User Feedback

"It's the most useful tool you guys have ever come up with..."

What's Next?

1. **More Deployments (We Hope)**
2. **Additional Tools (We Hope)**

Multiple Depth Water Sampler

- Multiple Depth system
- Adaptation of ConeSipper™

Saturated Zone Soil Sampler

- Keep Out Flowing Sands and/or Water

Beta and Gamma Sensors

- Scintillating fiber Beta
- Sodium Iodide or Zenon Gamma

Video Cone & Optical Sensors