Site Characterization and Analysis Penetrometer System (SCAPS): Assessing Site Contamination and *Sensors for SCAPS*

What the innovation is: A suite of cost-effective sensing and sampling technologies were developed and fielded under the SCAPS umbrella that provide the unique capability for in situ real-time determination of subsurface geophysical properties and the detection, discrimination, and quantification of a wide variety of subsurface contaminants in soil and groundwater.

Why it is innovative: The SCAPS provides for the first time the capability to provide real or near real-time screening of subsurface media (vadose and saturated zones) in situ for petroleum, oils and lubricants (POL), chlorinated solvents, volatile organic compounds (VOC), explosive compounds, metals, and radionuclide contamination. The ERDC has been awarded 13 patents for SCAPS related sensor and hybrid sensor/sampler probe technologies. Small < 2 inch diameter cone penetrometer contaminant sensor or hybrid sensor/sampler probes were developed that are hydraulically pushed to depths of approximately 50 m in nominally consolidated fine-grained soils. Geophysical (soil classification & stratigraphy) and/or contaminant specific sensor data are collected either continuously during the vertical push with 2 cm spacial resolution or at selected interrogation depths via onboard real-time data acquisition/processing system and provides 3-dimensional visualization of soil stratigraphy and contaminant plumes. SCAPS hybrid sensor/sampler probes provide the capability to detect and quantify analyte and contaminant vapors in situ when interfaced to onboard field portable analytical equipment such as an ion trap mass spectrometer or gas chromatograph. The SCAPS contaminant sensor probes also have the capability to prevent cross-layer contamination by sealing penetrometer holes during probe retraction using an ERDC developed grouting module attached to the sensor probe.

What it changed or replaced: Prior to the implementation of SCAPS technologies, monitoring wells were placed on grid patterns without knowing whether contaminants were present, near, or migrating; and soil and water samples were collected and sent offsite for costly and time-consuming chemical analysis. The use of SCAPS onsite contaminant sensing technologies minimizes the number of soil and water samples that are required for offsite chemical analysis, identifies the vertical and horizontal boundaries of contaminant plumes, and optimizes the placement of monitoring wells. SCAPS technologies typically save from 25-50% per site when compared to conventional drill and sampling techniques. Documented Savings: (1) $1M at the Point Loma Fleet Fuel Farm, CA, by determining areas free of contamination that were scheduled for excavation; (2) $300K at an Aberdeen Proving Ground, MD, VOC spill site versus conventional well installation and sampling technologies; and (3) >$800K for radionuclide detection in situ at the R-Reactor site, Savannah River Site, SC, versus offsite laboratory analysis. SCAPS POL and VOC technologies have been awarded California Environmental Technology and Interstate Technology Regulatory Council Certifications.

Where/when it originated, has been used, and is expected to be used in the future: The U.S. Army Engineer Research and Development Center (ERDC) originated the concept of SCAPS as an in situ subsurface geophysical and contaminant interrogation system in 1989 and developed SCAPS sensing and sampling capabilities in response to a critical need of the U.S. Government to characterize soil and groundwater conditions on military installations. The ERDC partnered with the U.S. Army Environmental Center (AEC) and the Strategic Environmental Research and Development Program / Environmental Strategic Technology Certification Program Office to demonstrate, validate, and transition SCAPS technologies. The SCAPS technologies have been used at more than 100 sites by the Corps of Engineers Kansas City, Savannah, and Tulsa Districts, and other DoD, DOE, and Army licensed commercial operators. It is expected to be used on active government installations, formerly used defense sites, base realignment and closure sites, and private sector sites.

If an innovative project, specifically identify each of its innovations: The innovations are the development of real-time data acquisition and processing software and the development of SCAPS small diameter sensor and hybrid sensor/sampler penetrometer probes for onsite in situ analysis of subsurface media for contamination. The ERDC developed the following probe technologies: the laser induced fluorescence petroleum, oil, and lubricant (POL) sensor detects fluorescing POL in soil or groundwater; the thermal desorption sampler is a hybrid sensor/sampler that provides near real-time detection of volatile organic compounds (VOCs) in soil; the hydrosparge sampler uses an ERDC repeat multi-port sampler or a commercial small diameter groundwater sampler interfaced to a direct sparging device to detect VOCs in groundwater; explosives (TNT, RDX, HMX) chemical sensor probe; chlorinated solvent chemical sensor probe; X-Ray Fluorescence (XRF) and Laser Induced Breakdown Spectroscopy probes to detect heavy metals; sodium iodide and high pressure xenon gas spectral gamma probes for radionuclide detection; and a multi-sensor isotopic XRF and spectral gamma probe.

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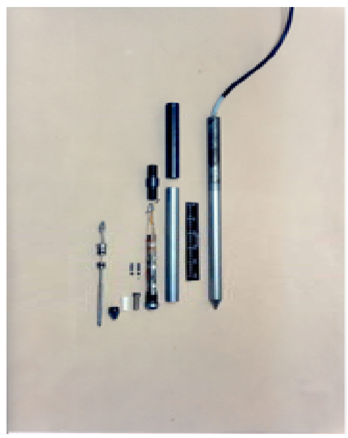
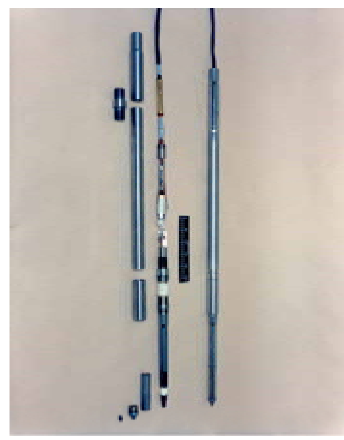
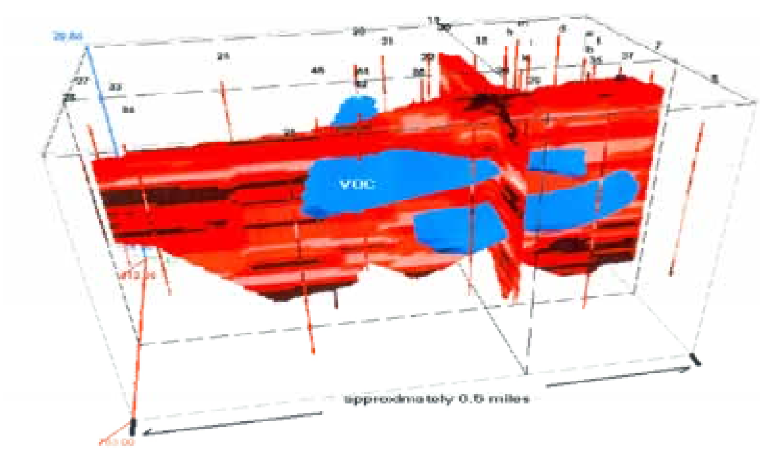
Site Characterization and Analysis Penetrometer System (SCAPS): Assessing Site Contamination* and *Sensors for SCAPS

SCAPS Truck Conducting Characterization SCAPS Real-Time Data
Acquisition
of Subsurface Soil Layering and Contamination and Onboard Data
Processing





Laser Induced
uorescence Thermal Desorption VOC Electro-Chemical Explosives
Petroleum (POL) Sensor Hybrid Sensor/Sampler (TNT, HMX, RDX)
ensor



INVESTIGATOR'S SUMMARY[1]

Nomination 2006-08
Investigator: Christine K. Meyers[2]

SITE SUBSURFACE CHARACTERIZATION/ANALYSIS

Site Characterization and Analysis Penetrometer System (SCAPS): Assessing Site Contamination and Sensors for SCAPS

The Innovation

Site Characterization and Analysis Penetrometer System (SCAPS) is a multi-faceted innovation developed by the United States Army Corps of Engineers within their Engineer Research and Development Center (ERDC). Development started in 1989 in response to a critical need of the U.S. government to characterize soil and groundwater conditions on military installations.[3] It consists of a "suite of cost-effective sensing and sampling technologies." These technologies are used to determine in situ real-time information about subsurface geophysical properties of soils and groundwater containing subsurface contaminants.

Figure 1. SCAPS Truck Photo with Trailer for Grouting

SCAPS is a specially designed mobile truck unit with off road 6-wheel drive capability. It contains two separate work spaces; the computer/instrumentation room where data is collected and the hydraulic control room where the penetrometer thrust system is located. The truck has a self-contained generator to run all equipment. All walls are stainless steel for ease of decontamination (if necessary). Pushes are made at the rate of 20 millimeters

[1] October 1, 2006
[2] Owner/Project Manager, Larkspur Construction, Inc., Victor, Idaho.
[3] NOVA Award Nomination form

PENETROMETER Definition: Apparatus for measuring the penetration number of a solid.

(mm)/second (s) or about 1.2 meters/minute. Push rods can be automatically decontaminated below the truck as they are withdrawn from the push hole, by a high pressure, high temperature cleaner. This arrangement minimizes crew exposure to potential contamination and crew downtime for equipment decontamination. This also minimizes the quantity of decontamination wash water that must be managed. The SCAPS platform also has survey and site-mapping equipment, as well as equipment for backfilling each penetrometer push cavity with grout.[4] Grouting the hole upon retraction of the penetrometer prevents cross-contamination.

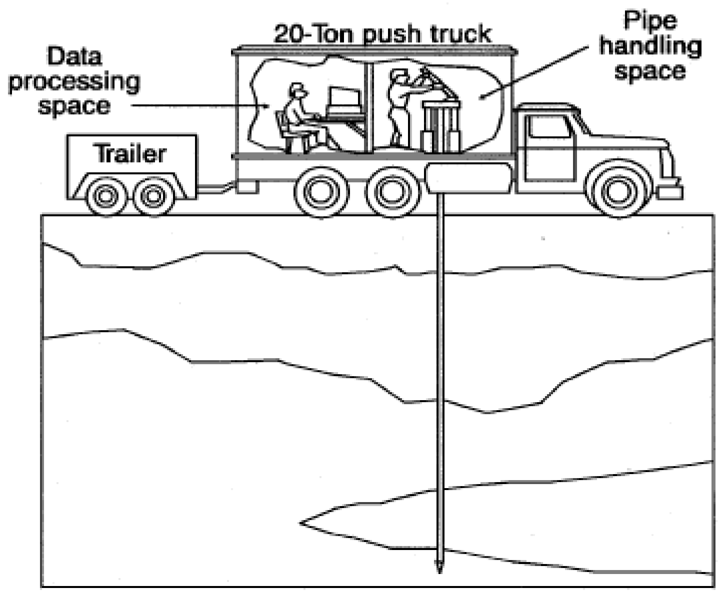


Figure 2. Diagram of SCAPS Truck and Workspace.

The SCAPS technology falls under the greater umbrella of Cone Penetrometer Technology (CPT). CPT is not new technology. The new technology is really the sensors developed by the Army Corp. In response to the question "What is innovative about the proposed technology? Is it an innovation or merely an evolution of existing technology?" Dr. Beth Fleming responded:

> The development of SCAPS sensor and hybrid sensor/sampler probe technologies for in situ evaluation of subsurface soil and groundwater for contamination (petroleum products; volatile organic compounds; explosive constituents such as TNT, RDX, HMX; heavy metals; and gamma emitting radionuclides) is truly innovative and not an evolution of existing technologies….The use of SCAPS innovative technologies revolutionizes in situ detection of contaminants in real-time

[4] www.spawar.navy.mil/sti/publications/pubs/td/2744rl/

or near real-time onsite analysis, drastically minimizing the number of soil and water samples that must be collected using conventional sampling techniques and sent offsite for laboratory analysis.

SCAPS Sensors

SCAPS uses the following Penetrometer sensors for site subsurface testing and discovery[5]:

1. Laser Induced Fluorescence (LIF) Petroleum, Oil, and Lubricant (POL) Sensor
The U.S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U.S. Army Environmental Center (AEC) patented the LIF POL sensor. The LIF POL sensor uses ultra violet laser energy to induce fluorescence in POL contaminants. The laser, mounted in the SCAPS truck (See Figure 3), is linked via fiber optic cables to a sampling "window" mounted on the side of a Penetrometer probe. Laser energy emitted through the window causes fluorescence in adjacent POL contaminated media. The fluorescent energy is returned to the surface via optical cables for real-time spectral data acquisition/processing (spectral analysis) in the SCAPS truck. The SCAPS LIF POL sensor has undergone numerous successful field investigations at various government facilities to determine soil classification layering and POL contaminant data. The SCAPS LIF POL sensor is currently undergoing EPA demonstration/validation investigations and has been licensed to private industry for commercialization.

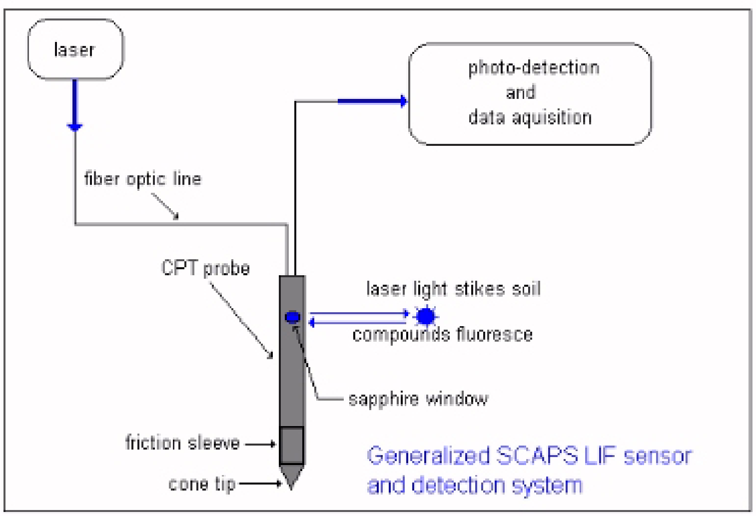


Figure 3. Schematic of LIF POL Sensor.

[5] This portion of the report describing the sensors can be found in the following reference: Adams, J.W., and Robiatille, G. (2000). "The Tri-Service Site Characterization and Analysis Penetrometer System-SCAPS: Innovative Environmental Technology from Concept to Commercialization." Report Number: SFIM-AEC-ET-TR-99073. U.S. Army Environmental Center, Aberdeen Proving Ground, MD.

2. Volatile Organic Compounds Sensing Tools

The basis for the very successful application of SCAPS probes for sensing Volatile Organic Compounds (VOCs) in soils is due to the use of Direct Sampling Ion Trap Mass Spectrometry (DSITMS). These probes work by bringing a sample of gas from soil or groundwater through a transport line to the DSITMS for analysis in the truck. Sample analysis takes 2 to 3 minutes and detection limits are typically in the range of 1 ppb or less. The ITMS field methodology (Method 8265) has been conditionally approved by the EPA.

A. Thermal Desorption Sampler (TDS)

The operation of the Thermal Desorption VOC Sampler is based on the capture of a known volume of soil (See Figure 4). The TDS is pushed to the desired ground depth and an interior rod retracts the penetrometer tip. The probe is then pushed further into the soil, collecting a 5 gm soil plug in the sample chamber. The soil plug is heated, releasing the VOC gases from the soil. The vapors are drawn to the surface by an inert carrier gas, where they are trapped on an adsorbent media. The trap is then thermally desorbed into an onboard, field portable ITMS where the contaminants are analyzed in near-real time.

The soil plug is then expelled from the sample chamber. The sample chamber is heated and purged to remove any residual contamination before the process is repeated at multiple depths during a single push. Upon completion of the push, grout is used to seal the penetrometer hole upon retraction.

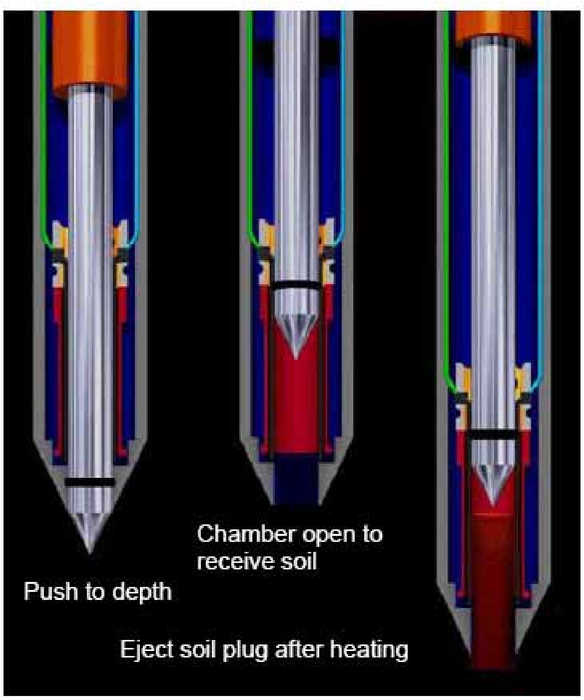


Figure 4. Schematic of the TDS Sensor.

B. Hydrosparge Sensor

The Hydrosparge VOC Sensor uses a commercially available Hydropunch or Powerpunch direct push groundwater sampling tool to access the groundwater. The Hydropunch sampler is pushed to the desired depth and the push pipes are retracted, exposing the screen to the groundwater. The water level is then allowed to come to equilibrium, which generally takes less than 15 to 20 minutes.

The in situ sparge module (See Figure 5), developed by Oak Ridge National Laboratory, is then lowered into the well to operate about 18 inches below the surface. The sparge module purges the VOC analytes in situ from the groundwater using Helium gas. The volatiles sparged out of the water are transported to an ITMS in the truck, where the contaminants are analyzed in real-time. When the in situ sparge module is interfaced with a mass flow meter, data may be acquired at various depths, ultimately producing a depth profile of the contaminant(s).

The reliability of in situ, direct sparging of VOC analytes from groundwater in concert with the ITMS has been successfully demonstrated at numerous sites where it has provided cost savings of at least 40% over conventional methods. The technology is currently being evaluated by the California Environmental Protection Agency Innovative Environmental Technology Certification Program and the U.S. EPA Office of Hazardous Waste.

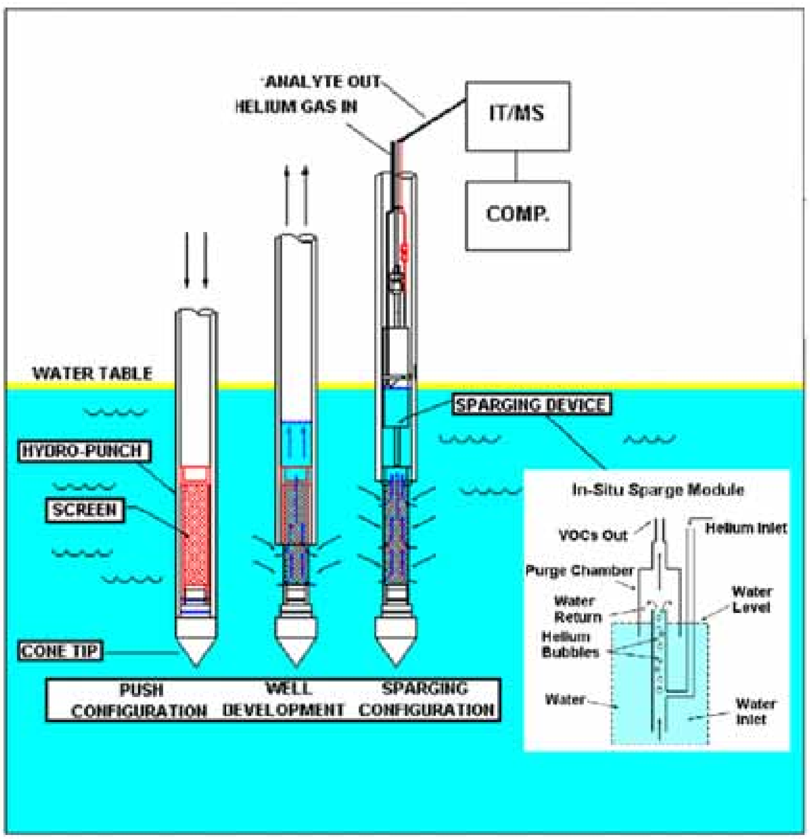


Figure 5. Schematic of the In Situ Sparge Sensor.

C. Vadose Sparge Sensor

The SCAPS vadose sparge sensor is a soil vapor probe that is deployed in conjunction with a DSITMS in the truck. This probe evolved from a probe that was designed for detecting chlorinated solvents by an electrochemical cell after the manufacturer of the cell discontinued its production.

The Vadose Sparge Sensor consists of a standard geophysical cone module and a sacrificial sleeve that protects vapor delivery and sampling port openings in the probe during a downward push. Data is taken during probe retraction. The sleeve falls off when the probe is pulled from the ground. A pumping system pushes air from the surface to ports at the bottom of the sampling module, and then outward from the probe. The air sweeps over a cylindrical soil surface area around the probe that corresponds to an area ~4 inches long by 1.75 inches diameter. Soil vapors are transferred to the purge gas and then captured by four intake valves. Vapors are delivered through the purge-gas tubing to an in situ sparge inlet for input to a DS-ITMS. In situ soil vapor measurements made with this sensor correlate well with contaminant concentrations of conventional soil samples measured by gas chromatography/mass spectrometry.

3. Explosives Sensing

Site characterization of explosives-contaminated sites is frequently difficult, with physical sampling very costly since the distribution of these contaminants can be extremely heterogeneous. Cone penetrometry offers cost relief and time savings. The SCAPS Explosives Sensor was designed to contain electrochemical sensors for nitroaromatic breakdown products and geophysical sensors for determining soil layering. The increase in current output of the sensor electrode is directly related to the concentration of the explosive in the soil. The design uses an imbedded heating element that is isolated from direct contact with the soil. When the soil is warmed briefly, explosive compounds vaporize and decompose into nitrogen-containing gaseous products. Then the evolved gases are drawn by a pneumatic system through an internal vapor sweep gas stream into the probe, and detected using an NO sensor in concert with a CO sensor. This duo permits discrimination of explosive organic nitrogen compounds from inorganic nitrogen compounds such as fertilizers.

The safety of this probe was evaluated by an independent contractor. GES Allegany Ballistics Laboratory SCAPS Explosives Hazard Analysis report concludes that “SCAPS Explosives probe operation offers occasional marginal or remote marginal probability of risk associated with the evaluation of explosives-contaminated soils.”

4. Metals Sensing

A. Laser Induced Breakdown Spectroscopy (LIBS) Sensors

These sensors are used to detect and identify heavy metal contaminants in the unsaturated and capillary zones. LIBS use a high-power pulsed laser to generate diagnostic plasma from soil. Two LIBS sensor probes have been developed, one by the Navy that is configured with the laser in the SCAPS truck and one by the Army Engineers (See Figure 6) that uses a miniaturized laser in the probe. The output of the laser beam is focused on the surface of the soil. This causes a breakdown of the soil and contaminants that result in the formation of a high temperature plasma spark that emits light for a brief time. A spectrometer breaks this light into its constituent colors, much like the action of a prism. The wavelengths of light in the plasma correspond to specific metal elements and the brightness of the light at a given wavelength indicates how much of that metal is present. LIBS can detect metals in the single ppm range.

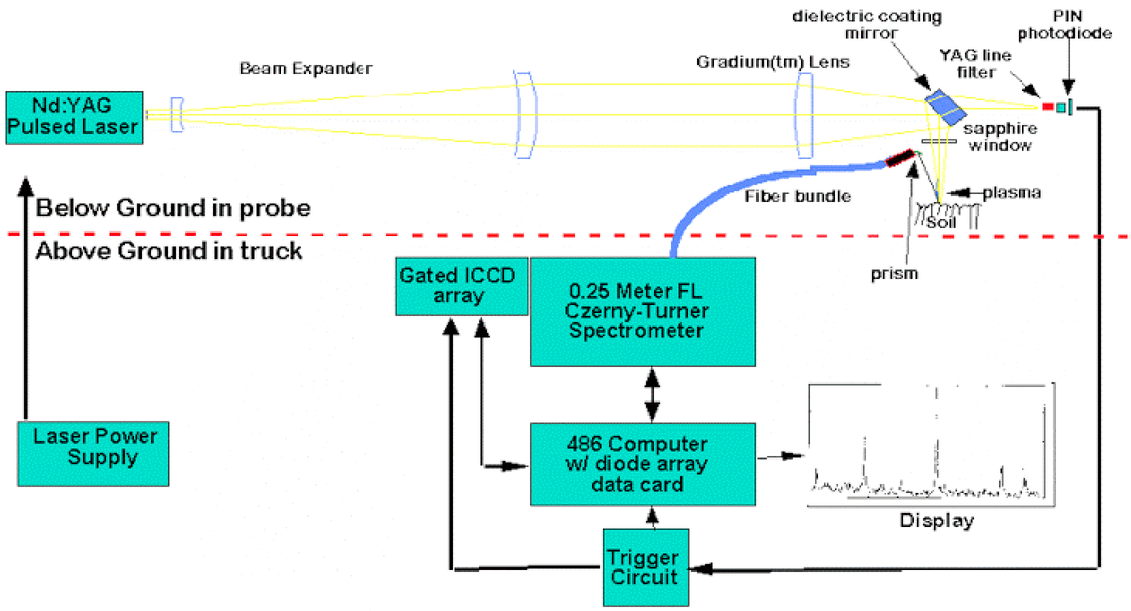


Figure 6. The SCAPS DL-LIBS (Downhole Laser) system.

B. X-Ray Fluorescence (XRF) Sensor

The SCAPS XRF Metals Sensor can detect metal elements at levels below 100 ppm in both the saturated and unsaturated zones. This probe can detect elements higher than atomic number 20, calcium, including radioactive elements. XRF technology is a well-established, non-destructive laboratory and hand-held field screening method for determining elemental concentrations at ppm levels in complex samples The SCAPS XRF Metals Sensor operates by detecting the characteristic x-ray emitted by metal atoms in the soil (See Figure 7). The sensor is advanced to a selected sampling depth at which point an x-ray source in the probe tip bombards the surrounding soil with incident x-rays. Metal atoms present in the soil are excited and emit fluorescent x-rays with energy that is characteristic for specific elements. The emitted x-rays are detected at the probe tip and provide an individual peak for each type of metal present in the soil. These signatures are identified and quantified in real time on board the SCAPS truck.

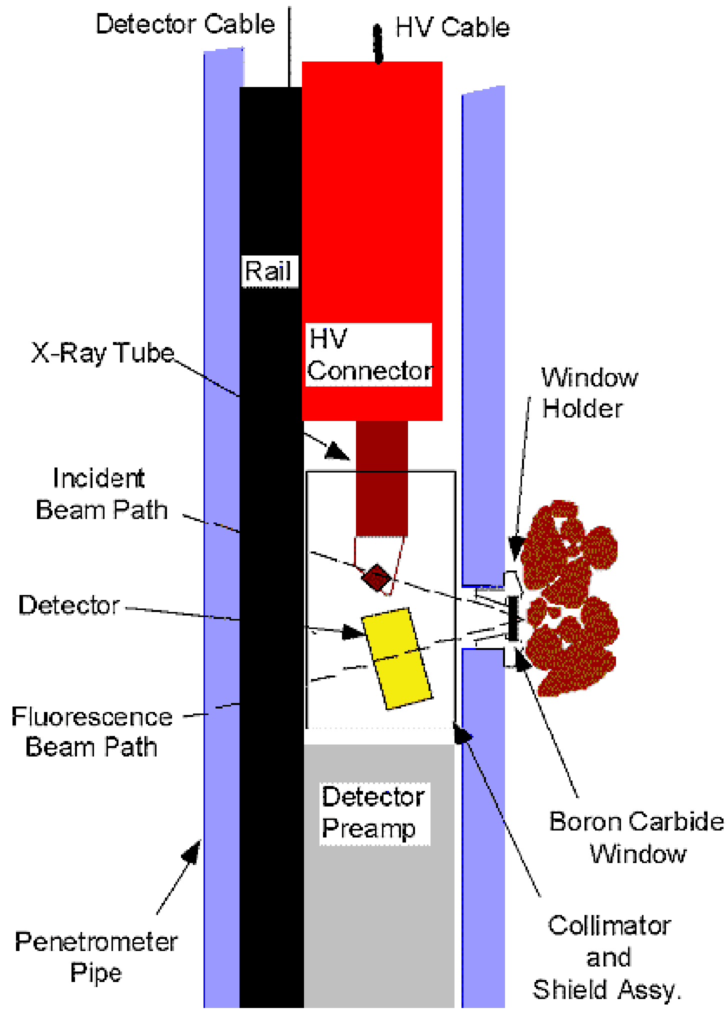


Figure 7. Schematic of the XRF probe optics.

5. Radionuclides

A. Spectral Gamma Probe

The SCAPS spectral gamma probe was developed for rapid, cost-effective site characterization of radionuclide contaminated soils with funding from SERDP and the Department of Energy.

The spectral gamma probe consists of a temperature-monitored sodium iodide (NaI) detector and a custom designed preamplifier installed downhole in the penetrometer tip. Power supplies and state-of-the-art support electronics located in the truck are connected through an umbilical cable to the downhole sensors. This sensor was designed with a view toward sensitivity, ruggedness and low cost in light of the possibility that the probe could become contaminated by radiation and need to be properly disposed. The use of this probe at highly contaminated sites may necessitate the use of specialized radiological-control area equipment in addition to the usual protection provided by SCAPS truck operations. This can be accomplished by using a "tent" inside the push room in the truck and placing a self-contained decontamination unit under the truck for the probe to push through in order to isolate personnel from possible radioactive contamination.

Figure 8. The Spectral Gamma Probe in use at the DOE Savannah River Site.

The probe was first used at the Savannah River Site R-reactor basin area during the summer of 1997 (See Figure 8). The SRS site consists of a filled basin area that was covered with asphalt paving in order to isolate the ~2700 Ci of mixed radioactive waste that was discharged into Basin 1 in the late 1950s. An independent assessment of cost savings realized by using the SCAPS spectral gamma probe at the Savannah River Site was estimated to have saved in excess of $800,000 (equal to 56% of the cost) in these operations.

B. Multisensor Probe

The development of the sensors that allowed this probe to be made was supported by the SERDP, although the construction of this multisensor device was funded by the DOE. The Multisensor probe combines the XRF metals sensor and the spectral gamma sensor in a single probe housing.

In addition to the multiple sensors available, a Soil Video Imaging System (Geo VIS) provides real time video images of the subsurface. Video images provide information on soil type and can be used to directly image non-aqueous phase liquid (NAPL) contaminants in the saturated zone.

Table 1. SCAPS capabilities vs. traditional CPT

FEATURES	SCAPS	CPT
Determine physical characteristics of the soil	YES	YES
Measures electrical resistivity	YES	YES
Samples soil and groundwater	YES	YES
Grouts push hole as rod is removed	YES	NO
Allows easy decontamination	YES	NO
Fiber optic laser probe for detection of petroleum, oil, and lubricant contamination (POL)	YES	NO
POL field screening capability	YES	NO

Finally, the Penetrometer is equipped with strain gauges in the tip to provide information about the physical characteristics of the soil through data on compression and sleeve friction. This allows a classification scheme to identify the types of soils encountered by the probe.[6]

Limitations and Concerns

The following limitations and concerns are directly related to the LIF POL sensor, but many of the remarks have applications across the entire process of SCAPS technology.

Field-screening methods do not eliminate the need for laboratory analyses, but they substantially reduce the number of samples and improve the efficiency of sample collection. The LIF technology has only been validated as a semi-quantitative methodology (detect/non-detect); it does not completely eliminate the need for traditional sampling. As the technology is now applied, random samples are taken to the laboratory to confirm that the results are accurate and to recalibrate the LIF sensor.

Detection limits vary among sites. The range of detection levels is 10-100 parts per millions (ppm) in soil and 0.5-10 ppm in groundwater. Minerals such as calcite, naturally occurring organic matter, and man-made chemicals also can fluoresce, possibly causing interference problems. Extensive experience is required for proper system operation. The maximum depth for this technology is 150 feet, due to signal attenuation in the optical fiber cord. The space above the truck must be free of obstructions such as power lines and the subsurface in the immediate vicinity of a cone penetrometer push must be free of buried objects such as utilities. The cone penetrometer probes will not penetrate boulders, cobbles, rubble, well compacted sediment, or sound bedrock. Cold weather may cause problems by freezing of parts of the cone penetrometer system. These systems may be expensive to use on small-scale projects. They have primarily been used at large sites such as Department of Defense (DoD) and Department of Energy (DOE) facilities. Some

[6] www.spawar.navy.mil/sti/publications/pubs/td/2744rl/

maintenance of the cone penetrometer tools and the LIF sensors is required. Downtime due to the breakage of fiber optic cables and push rods, as well as fogging of the sapphire window, may occur. Work performed at Dover Air Force Base indicated the potential for smearing as well as a memory effect on the sensor.[7]

Additional limitations:

- SCAPS is an on-site characterization tool that can be used to delineate contaminant plumes and provide soil information. However, the sensors are field-screening tools and probably do not eliminate the need for laboratory analyses.
- Some of the sensors and sampling devices may have difficulty detecting small concentrations.
- Verification of the Hydrosparge sample is difficult to obtain, as only a small volume of water is sampled.
- There are concerns that the thermal desorption sensor/sampler will have different efficiencies relative to soil types.
- SCAPS has a limited use as a monitoring tool. A new hole has to be punched every quarter because the holes collapse after the penetrometer is withdrawn.
- Access to the testing location for the SCAPS truck may not allow for testing in all locations.
- The penetrometer is not able to penetrate cemented sands, gravel, cobbles, boulders, bedrock, and concrete.

Application of the Innovation

There are currently seven SCAPS trucks in use (four maintained by the Army Corps of Engineers and three by the Navy). Many of the applications of SCAPS technology along with a brief background of each project can be found in Appendix B. Shown in Figure 9 is an example of the data produced through an investigation with the LIF POL Sensor. The purple lines show the locations of a penetration and from that information a three dimensional graph can be produced to show the limits and extent of the contamination.

Because of the wide variety of sensors available, there is an unlimited amount of data that can be produced with a SCAPS investigation.

[7] http://www.cpeo.org/techtree/ttdescript/lasinfl.htm

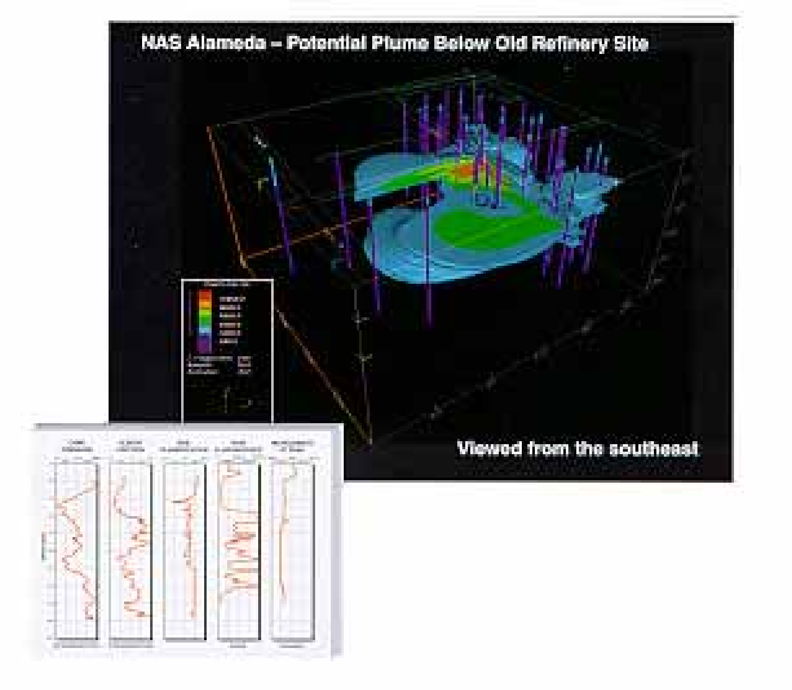


Figure 9. Three Dimensional Graph of Contaminant Plume with LIF POL Sensor.

Answer to Key Points from the Jury

What does it look like and how does it work?

This question is addressed in the body of this report. Basically a truck mounted penetrometer that has a variety of sensor ends that is pushed hydraulically into potentially contaminated soil. Sensors are able to detect different subsurface contaminants and provide real-time data

Do engineers in field believe in it, trust it?

Yes, based on the extensive documentation and trials that have been performed. In many cases, traditional monitoring wells were used in conjunction with SCAPS technology for verification and testing. Endorsements by the EPA, an ASTM standard for the LIF POL sensor, and acceptance by the Department of Energy, the Department of Defense, etc. all indicate that this technology is verifiable.

Can it be used in non-military construction?

Yes, through a cooperative technology transfer program the Navy had a goal of commercialization for SCAPS. Two privately held companies now hold license to the technology. See section on Competing Products.

What does it really change, save, improve?

It changes the way a site subsurface investigation is performed by allowing for real-time data collection and the use of fewer, if any, labor intensive monitoring wells. This results in savings of both time and money. See Appendix B for examples.

Background of the Innovation

SCAPS technology falls under the larger umbrella of Cone Penetrometer Technology (CPT). Originally introduced in the Netherlands in 1934, electrical measurement sensors were not developed until 1948 and not widely used until the 1960s. By the 1980s, the cone penetrometer was available from a dozen or more companies and was used in geotechnical applications. Research initiated in the late 1980s (presumable by the Army Corps) to develop other sensors that could be used to test for the presence of petroleum hydrocarbons, organic compounds, metals, radioactivity, and explosives among others.

Responsibility for the Innovation

Mr. Stafford Cooper, retired US Army Engineer Waterways Experiment Station (WES), now the ERDC, proposed in 1988 the development of cone penetrometer technologies with contaminant and geotechnical sensors for in situ direct push applications to Mr. Paul Lurk of the US Army Toxic and Hazardous Materials Agency (USATHAA), now the US Army Environmental Center (AEC).

Mr. Cooper designed and developed the first SCAPS multisensor penetrometer probe that used laser induced fluorescence (LIF) to detect petroleum, oil, and lubricant (POL) contaminants in real-time via optic fibers that linked a truck mounted laser to an advancing subsurface penetrometer. Mr. Cooper and Dr. Philip Malone were awarded US Patent Number 5,128,992 for this work. Mr. Cooper became team leader for the early design and development of SCAPS contaminant sensor probe technologies. Mr. Bobby Reed of the WES Instrumentation Services Division implemented down-hole sensors in the probes and electronic signal processing systems in the SCAPS truck. Early versions of multisensor real-time processing and display algorithms were developed by Richard Olsen of the WES Geotechnical Laboratory.[8]

Dr. Fleming lists three key individuals as responsible for developing the innovation.

1) Dr. Beth C. Fleming, Director, ERDC Environmental Laboratory, Vicksburg, MS.
2) Dr. James I. Arnold, Jr., AEC Chief, Weapons Acquisition & Technology Division, Aberdeen Proving Ground-EA, MD.
3) Dr. Jeffrey Marqusee, Technical Director, SERDP and Director ESTCP, Arlington, VA.

Also listed are six people who should be recognized for their efforts in the development of SCAPS.

[8] This section is in response to the question "How did the innovation originate as an idea and who were the people responsible?" and "How was the idea implemented as a practical system and who were the people responsible?" Letter from Dr. Beth C. Fleming, dated October 6, 2006.

Competing Products

What are conventional or competing systems that it replaces? SCAPS team member Dr. Beth Fleming responded, “There are no competing systems.”

After searching the internet, I was able to find a private company called Precision Sampling (www.precisionsampling.com) with offices in both Florida and California. This company advertises a Cone Penetrometer Technology (CPT) system in a mobile truck unit for geotechnical characterization of soils, but they also mention additional sensors that are available to complete fast and efficient environmental investigations. Their sampling description and truck setup have a close resemblance to the SCAPS setup. They mention an affiliation with the University of Waterloo in Canada.

Figure 10. Photo of Precision Sampling Truck for Cone Penetrometer Technology

Another company, Fugro Engineering Services Limited (www.fugro.com) with headquarters in the UK, offers a number of geo-environmental cones that can detect the presence of contamination without the need for drilling and laboratory testing. They give a partial list of contaminants detectable with their cones as: landfill leachate, methane, ionic chemicals (acids/alkali), crude oil derivatives e.g. petrol, diesel, jet fuels, oils, coal tar, etc., chlorinated solvents and radiation. According to a SCAPS document, Fugro holds license to the technology calling their service Rapid Optical Screening Tool (ROST) with the Fuel Fluorescence Detector (FFD) sensor being marketed by Vertek Manufacturing. The document states “the commercial investment in this technology reflects the confidence that has been generated and the success achieved by the SCAPS program.[9] It appears that any competition comes

[9] www.sparwar.navy.mil/sti/publications/pubs/td/2744rl/

Investigator's Comments

This is definitely a well-documented innovation. John Ballard, Focus Area Manager, R&D for the ERDC, who was my contact for the innovation research, provided excellent documentation and a CD-ROM with 80 articles dating back to 1988! This was all a bit overwhelming, but with the help of the internet and Dr. Beth Fleming's responses to my list of questions, I feel that I have covered the intricate and important details of this innovation. Indeed SCAPS was developed for military applications, but they recognize a need for this in the private sector. The crossover to the private sector is most likely a difficult and expensive process. Two privately held companies are offering SCAPS services outside of military applications. One company, Fugro is overseas and has offices worldwide. They offer site investigation services through their Rapid Optical Screening Tool (ROST). The other company, Vertek, is manufacturing the Fuel Fluorescence Detector (FFD). I expect this technology will always be concentrated in military and government applications as they are the ones with the primary need.

Not only has SCAPS received regulatory acceptance from the United States EPA and the California EPA, it has also been accepted by a seven state task group consisting of California, Idaho, Louisiana, Nebraska, New Jersey, New Mexico and Utah. This Interstate Technology and Regulatory Cooperation Work Group of the Western Governor's Association have endorsed the use of SCAPS in their respective states.[10] It has been identified as an "Emerging Construction Technology" by Purdue University.[11] In 1998 the American Society of Testing and Materials (ASTM) gave approval to the Laser Induced Fluorescence (LIF) Sensor with designation D6197-97 for the detection of petroleum, oils, and lubricants in subsurface soil and water.

In my opinion, this is one of the most sophisticated innovations to come through the CIF NOVA nomination process and while you may not understand all of it, it is a significant advancement within the industry. Powered by a presumably large research budget and some of the best and brightest people in our field, any engineer can appreciate this innovation. This innovation did not happen overnight. It has taken many years of development and refinement will continue with time. Yet we can definitely quantify the cost and time savings afforded by this technology. It is my recommendation therefore that SCAPS is worthy of the NOVA Award in all regards.

[10] http://www.westgov.org/wga/publicat/scapsweb.htm
[11] www.new-technologies.org/ECT/Other/sensors_scaps.htm

SUPPORTING EXHIBITS

1. **APPENDIX A: Sample Cost Estimate – Traditional Methods vs. SCAPS**
2. **APPENDIX B: Time and Cost Savings**
3. **APPENDIX C: SCAPS Matrix of Sensor and Sampler Tools**

APPENDIX A
Sample Cost Estimate

Introduction: This cost estimate is based on CENWK drill crew and SCAPS average daily rates and the following assumptions.

a. Mobilization/demobilization (mob/demob) days are averaged into daily cost.
b. Work days are 8 hours long.
c. During an average project 25 LIF pushes and 11 wells are installed.
d. An average 25-foot-deep LIF direct push boring is equivalent to a 25-foot-deep auger boring made to collect five soil samples for laboratory analysis.

(1) Two 25-foot-deep auger borings can be drilled and sampled in a day. This includes setup, drilling, sampling, sample preservation, decontamination, waste handling, and backfilling with a mix of spoil and grout.
(2) 25 borings/2 a day = 12.5 days

e. An average 21-foot-deep well point installed in sand by direct push is equivalent to the same depth well installed through hollow stem augers (the most frequently used method of well installation on HTRW sites).

(1) Each well installed through hollow stems will take approximately 12 hours to complete. This includes setup, drilling, setting well, decontamination, development, setting protective pad and posts, and handling investigation derived waste.
(2) 11 wells × 12 hours = 132 hours / 8 hours = 16.5 days
(3) Each well installed with the SCAPS will take approximately 3 hours to complete. This includes setup, pushing to depth, setting well, decontamination, and handling investigation derived waste.
(4) 11 wells × 3 hours = 33 hours / 8 hours ≈ 4 days

	Drilling		SCAPS	
	Quantity	Cost per day	Quantity	Cost per day
Soil borings or LIF pushes /day	2	$2,692	5	$2,887
	Days	Costs	Days	Costs
Total number of days, drilling/sampling	12.5	$33,650	5	$14,435
Total number of days, well installation	16.5	$44,418	4	$11,548
Mob/demob		$3,454		$4,498
Per diem incl. mob/demob	39	$15,600	11	$4,400
Materials, incl. drums		$3,550		$1,100
Total cost with no analytical included		$100,672		$35,981
4 days of field analysis of dissolved VOCs in ground water using DSITMS				$15,400
SCAPS cost with field analysis of volatiles				$51,381
Cost savings realized by using SCAPS				$100,672 – $51,381 = $49,291

APPENDIX A: Continued

Cost Comparison of SCAPS Metal Sensors with Conventional Sampling and Direct-Push Sampling.

SCAPS Metal Sensor *In Situ* Measurement		Conventional Drilling (Hollow Stem Auger, Split Spoon, and Off-Site Analyses)		Direct-Push and Off-Site Analyses	
10 pushes to 30 ft. Metals and geotechnical data	COST	10 borings to 30 ft (60 soil samples for ICP analysis)	COST	10 borings to 30 ft (60 soil samples for ICP analysis)	COST
Two 10-hr field days @ $6,380/day	$12,760	Drilling & sampling @ $50/ft for 300 ft (approx. three 10-hr days)	$15,000	Drilling & sampling for 300 ft (approx. two 10-hr days)	$3,000
1 sample/2 inches for metals = 1,800 total samples	Included in basic cost	ICP laboratory @ $50 per sample x 60 samples	$3,000	ICP laboratory @ $50 per sample x 60 samples	$3,000
1 sample/inch for geotechnical data	Included in basic cost	Geotechnical laboratory analysis @ $100/sample x 5 samples	$500	Geotechnical laboratory analysis @ $100/sample x 5 samples	$500
4 waste drums @ $40/drum	$160	28 waste drums @ $40/drum	$1,120	1 waste drum @ $40/drum	$40
Decon water testing	$1,000	Decon water testing	$1,000	Decon water testing	$1,000
Waste soil testing	$0	Waste soil testing	$3,000	Waste soil testing	$0
Waste soil not produced	$0	Waste soil disposal, 20 drums @ $100/drum	$2,000	Waste soil not produced	$0
Decon water disposal for 4 drums @ $100/ drum	$400	Decon water disposal	$800	Decon water disposal for 1 drum @ $100/ drum	$100
4 man crew	Included in basic cost	Geologist @ $75/hr x 36 hrs	$2,700	Geologist @ $75/hr x 36 hrs	$2,700
		Technician @ $40/hr x 40 hrs	$1,600		
TOTAL	**$14,320**	**TOTAL**	**$30,720**	**TOTAL**	**$10,340**
Per Sample Cost for 1,800 samples	$7.95/sample	Per Sample Cost for 60 samples	$512/sample	Per Sample Cost for 60 samples	$172/sample

Reference: ESTCP – Cost and Performance Report, CU9716. (2003) "Site Characterization and Analysis Penetrometer System (SCAPS) Heavy Metal Sensors."

APPENDIX B
Time and Cost Savings

Camp Pendleton, California - $600,000 SAVED

The Navy was set to spend $620,000 to dewater or move 19,000 CY of soil from a site containing fuel residue. A SCAPS effort to investigate the side in August 1995 produced a more accurate “picture” of the contamination boundaries, showing the plume was smaller than indicated by a prior investigation. The SCAPS results showed dewatering wasn’t necessary and only half the original amount of soil needed excavation and treatment. Total Savings: more than a year of work and $600,000.

Contact: Mr. Rod Soule
(619) 556-9506

FISC Fuel Farm, Point Loma, California - $1 Million SAVED

Contractor investigations turned up more than 9,000 tons of diesel-contaminated soil on an earthen moat site. The Navy’s proposal to excavate and remediate the soil with thermal desorption would have cost approximately $1 Million, however a SCAPS investigation indicated the contamination was mostly near the surface and did not extend to the water table. The data allowed the Navy to seek closure of the site without spending the money for unnecessary remediation – an option accepted by San Diego County regulators.

Contact: Mr. Rod Soule
(619) 556-9506

Former Donaldson Air Force Base, South Carolina - $360,000 SAVED

The Savannah District of the Army Corps of Engineers used SCAPS and PowerPunch mini-well to assess 75 underground storage tanks and associated pipelines, including 20,000 linear feet of distribution systems and a free product line. The system’s quick data-gathering capability allowed more time for interpretation, and made it easier to meet project deadlines. Further, the Savannah District installed 90 mini-wells for about $1,000 each – versus $5,000 each for traditional wells – saving $360,000 and 22 months of work.

Contact: Mr. Cardwell Smith
(912) 652-5674

Savannah River Site, South Carolina - $800,000 SAVED

Using the SCAPS Enhanced Spectral Gamma Sensor, the Department of Energy saved more than $800,000 over conventional sampling technologies during a field investigation and demonstration at the R-Reactor Seepage Basin.

Contact: Mr. John Ballard
(601) 634-2446

Aberdeen Proving Ground, Maryland - $300,000 SAVED

The Army saved more than $300,000 by using the SCAPS Hydrosparge VOC sampler at the proving ground’s Bush River Area. The SCAPS Hyrdrosparge VOC sampler – interfaced to a field-portable Ion Trap Mass Spectrometer – provided near real-time analytical results from 30 mini-well locations in eight days, where it would have taken 155 days to install, sample, and receive analytical laboratory results from 30 conventional monitoring wells.

Contact: Mr. John Ballard
(601) 634-2446

Fort Campbell Army Air Field, Kentucky - $200,000 SAVED

The Army Corp of Engineers Nashville District used SCAPS equipment to determine the extent of benzene, toluene, ethylbenzene and xylene (BTEX) contaminants from a leaking above ground storage tank. The Corps made 40 SCAPS monitoring “punches” in areas of suspected contaminants but detected no BTEX. SCAPS screening results were verified through more rigorous analytical methods that confirmed the absence of BTEX at the site. The three-day effort cost $40,000, approximately $200,000 less than what it would have cost to obtain the same level of confidence using only traditional laboratory data.

Contact: Ms. Kathy Older
(816) 983-3683

Fort Dix, New Jersey - $208,000 SAVED

In one of the first SCAPS field successes, the Army used the system to significantly reduce the number of wells needed to monitor pertroleum hydrocarbon contamination. By eliminating the need to install and develop 57 monitoring wells across 15 sites the Army saved $208,000. Other savings: $114,000 in groundwater sampling and chemical analyses; $8,000 in soil-gas survey costs; and $183,000 in soil boring and sampling.

Contact: Mr. John Ballard
(601) 634-2446

Long Beach Naval Complex, California - $150,000 SAVED

SCAPS data – gathered with the LIF Sensor – helped installation officials convince state regulators that no further action was required on several former underground storage tank sites. At the Los Alimitos Golf Course site, a proposal to use SCAPS with monitoring and phytoremediation would have cost $20,000, a fraction of the $150,000 needed to dig and treat the soil traditionally for an $80,000 bioslurping-bioventing system.

Contact: Mr. Rod Soule
(619) 56-9506

Former Donaldson Air Force Base, South Carolina - $250,000 SAVED

To collect soil and groundwater samples on a cleanup site, the Army Corps of Engineers installed 58 PowerPunch wells and 28 soil borings, collecting 38 soil samples. The Corps also conducted a site survey with a Global Positioning System that included latitude, longitude, and top-of-casing elevations. A traditional drill rig would have taken three months and cost more than $316,000, including more than $20,000 to dispose of waste from the investigation. With no leftover waste, the SCAPS effort took 15 days and cost $61,300.

Contact: Mr. Cardwell Smith
(912) 652-5674

Vance Air Force Base, Oklahoma - $350,000 SAVED

The Army Corps of Engineers Tulsa District performed SCAPS rapid site assessments at three flight line sites in a third of time and cost of conventional investigation techniques. The team found and analyzed solvent contamination using portable and analytical equipment in a mobile chemistry lab. The month-long effort covered 55 acres and only generated two 55-gallon drums of decontamination at a project cost of $143,000. Using conventional drilling and analytical methods the same effort would have taken 81 days, produced 400 drums of waste soil and water at an estimated project cost in excess of $500,000.

Fort Meade, Maryland - $50,000 SAVED

After workers discovered 270 buried drums during a routine construction job at Fort Meade's Covered Storage Facility, the Army used a SCAPS unit to determine the extent of soil and groundwater contamination. Based on the findings of the study, which included probes with a Laser Induced Fluorescence Sensor, and on-site sample analysis with an Ion Trap Mass Spectrometer, the Army removed soils affected by high levels of petroleum hydrocarbons. This field effort saved $50,000 and two months of work.

Contact: Mr. Cardwell Smith
(912) 652-5674

APPENDIX C: SCAPS Matrix

SCAPS Penetrometer Contaminant and Geophysical Sensor and Sampler Tools

Penetrometer Sensor and Sampler Tools	Soil Class	Retraction Grouting	Vadose Zone	Saturated Zone	Speciation	Lower Limit Of Detection In Sandy Soil *	Commercial Availability	ERDC Supported Availability	Semi-Quantitative Vs. Screening
2-inch OD Mini-well Groundwater Sampler (Multiple Vendors)	No	No	No	Yes	NA	NA	Yes	No	S
Soil Sampler (Multiple Vendors)	No	No	Yes	No	NA	NA	Yes	No	S
Multiple Discrete Depth Soil Sampler	No	Yes	Yes	No	NA	NA	No	Yes	S
Soil Classification Sensor (Multiple Vendors)	Yes	Yes	Yes	Yes	No	NA	Yes	Yes **	S
Penetrometer Mounted Video Camera	Yes	No	Yes	Yes	No	NA	Yes	No	S
Soil Electrical Resistivity And/or Soil Moisture Sensors (Multiple Vendors)	Yes	Yes	Yes	Yes	No	NA	Yes	No	SQ
Petroleum, Oil & Lubricant (POL) Laser Induced Fluorescence (LIF) Sensor	Yes	Yes	Yes	Yes	Yes	100 ppm	Yes ***	Yes ****	SQ
Multisensor: Pore Pressure, pH, and Temperature	Yes	Yes	Temp. Yes	Yes	No	NA	Yes	Yes	SQ
Hydrosparge / DSITMS VOC Sensor/Sampler +	No	No	No	Yes	Yes	2 ppb	Yes	Yes	SQ
Thermal Desorption/ DSITMS VOC Sensor / Sampler	No	No	Yes	No	Yes	10 ppb	No	Yes	SQ
Modified Membrane Interface Probe DSITMS VOC Sensor / Sampler	Yes ++	Yes ++	Yes	Yes	Yes	300 ppb	Yes +++	Yes ++	SQ
Laser Induced Breakdown Spec-troscopy (LIBS) Metals Sensor	Yes	No	Yes	No	Yes	100 ppm	No	Yes	SQ
X-Ray Fluorescence (XRF) Metals Sensor	Yes	No	Yes	Yes	Yes	100 ppm	No	Yes	SQ
Spectral Gamma Sensor (High Resolution NaI Detector)	Yes	Yes	Yes	Yes	Yes	5 pCi/gram	Yes	Yes ++++	SQ
Spectral Gamma / XRF Metals Multisensor	Yes	No	Yes	Yes	Yes	5 pCi/gram 100 ppm	No	Yes	SQ

* The lower limit of detection for each sensor is soil matrix dependent.
** Provided with ERDC developed probes.
*** U.S. Army patented technology licensed to Applied Research Associates, Inc., and Fugro Geosciences, Inc.
**** The ERDC POL LIF Sensor Probe incorporates probe "break prevention" sensor technology.
\+ DSITMS – Direct Sampling Ion Trap Mass Spectrometer.
++ Soil Classification and retraction grouting are provided with installation of the ERDC umbilical cable and grout injection / soil classification sensor module.
+++ The Membrane Interface Probe (MIP) is manufactured by Geoprobe Systems, Inc.
++++ The ERDC Spectral Gamma Sensor System provides lower limits of detection than commercially available systems.