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**Engineering and Design
SITE CHARACTERIZATION AND
ANALYSIS PENETROMETER SYSTEM (SCAPS)**

- 1. Purpose.** This pamphlet provides information on the capabilities and potential uses of the Site Characterization and Analysis Penetrometer System (SCAPS) direct-push technology for the investigation of hazardous, toxic, and radioactive waste (HTRW) sites.
- 2. Applicability.** This pamphlet applies to all USACE major subordinate commands, Districts, laboratories, and field operating activities having HTRW investigation and design responsibility.
- 3. Distribution Statement.** Approved for public release, distribution is unlimited.
- 4. References.** Required and related publications are listed in paragraph 4 of this document.

FOR THE COMMANDER:

5 Appendices
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4. References.

a. Required References.

None.

b. Related References.

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Standard Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil. American Society for Testing and Materials.

ASTM D-5778

Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils. American Society for Testing and Materials.

ASTM D-6187

Standard Practice for Cone Penetrometer Technology Characterization of Petroleum Contaminated Sites with Nitrogen Laser-Induced Fluorescence. American Society for Testing and Materials.

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ETC (1990)

Earth Technology Corporation Testing Services Group, June 1990, Application of the Electric Cone Penetration Test to Environmental Groundwater Investigations.

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The Cone Penetrometer Test, Bulletin FHWA-SA-91-043, National Technical Information Service and Federal Highway Administration, U.S. Dept. of Commerce, Feb. 1992.

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5. Background.

a. The cone penetrometer has been used extensively to determine subsurface stratigraphy and geotechnical properties in conventional geotechnical investigations. The electric cone has been in use since 1969. The cone penetrometer is fast and economical, provides a continuous stratigraphic record, and can identify thin subsurface strata. These characteristics make the cone penetrometer a useful investigative tool on HTRW sites.

b. HTRW site investigations, including drilling, monitor well installation, and sampling for laboratory analysis, have been time consuming and costly. An Army, Navy, and Air Force Tri-Service research and development effort focused on the use of the cone penetrometer to decrease the time and money spent on HTRW sites. The use of SCAPS as part of HTRW site investigations may optimize the selection of boring locations and samples for chemical analyses, identify preferential pathways of contaminant migration, reduce or eliminate investigation-derived waste, and reduce or eliminate worker exposure to environmental contaminants.

c. The U.S. Army Environmental Center (AEC), formerly the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), sponsored the Mississippi site of the U.S. Army Engineer Research and Development Center (ERDC), formerly the U.S. Army Engineer Waterways Experiment Station (WES), to develop SCAPS under a Tri-Service development effort that began in 1986. Initially, the sensor was based on a fluorometric method for detecting hydrocarbons, which was developed in conjunction with the U.S. Naval Space and Naval Warfare Systems Center, formerly the U.S. Naval Command, Control and Ocean Surveillance Center. The initial field trial of the SCAPS petroleum, oil, and lubricant (POL) sensor was conducted in 1990 at the Jacksonville Naval Air Station, Florida, waste oil disposal site. The first SCAPS site demonstration was in 1992 at Fort Dix, New Jersey.

d. The Corps of Engineers operates SCAPS vehicles in Kansas City, Savannah, and Tulsa Districts. Refer to Appendix A for a discussion of the areas of responsibility for each of the SCAPS Districts. Appendix B contains the current status of SCAPS District capabilities.

6. Discussion.

a. General System.

(1) The SCAPS is mounted in a 18,144-kilogram (kg) truck, equipped with two hydraulic rams capable of exerting approximately 169 kN (17,237 kg) of force to make a direct push. (Note: The kg is a unit of mass; the Newton [N] is a unit of force where $9.8 \text{ N} = 1 \text{ kg}$. Hence, $17,237 \text{ kg} = 168,923 \text{ N}$ or approximately 169 kN.). The weight of the truck is supported by hydraulic jacks, while the penetrometer is pushed into the ground with hydraulic rams. Pushes are made at the rate of 20 millimeters (mm)/second (s) or about 1.2 meters/minute.

(2) The truck is divided into two compartments, separated by a wall with a viewing window. All walls are stainless steel for ease of decontamination (if necessary). 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 down-time for equipment decontamination. This also minimizes the quantity of decontamination wash water that must be managed.

(3) The current SCAPS has several readily available in situ sensing capabilities: defining soil stratigraphy, detecting polynuclear aromatic hydrocarbon (PAH) contamination with laser-induced fluorescence (LIF), determining soil resistivity, detecting volatile organic compounds (VOC) in soil and groundwater, and measuring gamma-emitting radionuclide activity levels. The LIF sensor is mounted in a cone penetrometer probe so that soil classification data and fluorescence data are collected simultaneously. The resistivity sensor is mounted on a separate cone penetrometer probe so that resistivity and soil classification data are collected simultaneously. The VOC and radionuclide probes are also configured with soil classification sensor technology. Sensors are connected to electronic signal processors through wiring bundled together into an umbilical cable. The umbilical cable also contains a grout tube so push holes can be sealed as the penetrometer is withdrawn. Two optic fibers (transmit and receive) are contained in the LIF sensor umbilical cable. An umbilical cable and sensor probe are supplied as one unit. Data are handled by an on-board computer system and electronic signal processing equipment. Sensor data are collected every 20 mm as a push is made. The data are displayed in real-time in the form of panel plots as they are acquired. Panel plots typically contain data on tip resistance, sleeve resistance, estimated soil type, peak fluorescence intensity, and peak fluorescence wavelength. The VOC hybrid sensor/sampler is normally interfaced via umbilical cable transfer tubes to a surface mounted direct sampling ion trap mass spectrometer (DSITMS). The radionuclide sensor is interfaced via umbilical cable to surface mounted nuclear instrument module (NIM) data acquisition/processing equipment.

(4) Other sensors with compound-specific detection capabilities are available on a limited basis. These sensors include: two technologies for metal detection, either by x-ray fluorescence (XRF) or laser-induced breakdown spectroscopy (LIBS); and one for detection of radioactive material. These sensor probes are similar to the LIF and the resistivity sensor probes in that soil classification data are collected simultaneously. However, grout cannot be emplaced through the tip of the metals and radioactive material sensor probes.

(5) Video imaging probes, which allow the operator to continuously view and record subsurface materials during a push, are also available to use with SCAPS. Video images may allow the operator to view residual non-aqueous phase liquid (NAPL) in situ and estimate grain size and porosity in granular material. Images are typically recorded on VHS videotape.

(6) SCAPS can employ any of several methods to detect volatile organic compounds (VOCs). These methods all rely on use of a field portable analytical device, such as a DSITMS or a gas chromatograph.

(a) The Hydrosparge VOC sensing system consists of a commercially available ground water sampling tool and an in situ direct sampling sparge device interfaced to a field-portable ion trap mass spectrometer. The sparge device, developed by Oak Ridge National Laboratory, uses a helium gas flow to strip VOCs from ground water and transfer them to the analytical device.

(b) The Geoprobe[®] Systems Membrane Interface Probe (MIP) is a commercially available VOC sensor that can be used in the vadose and the phreatic (saturated) zones. The MIP uses heat to volatilize organic compounds in situ. The VOC compounds pass through a membrane and are transferred to the surface via tubing and a carrier gas to an onboard analytical device. The Environmental Security Technology Certification Program (ESTCP) sponsored demonstrations that included comparisons between MIP VOC interrogations and verification samples analyzed at an offsite laboratory. Results for saturated zone interrogations provided better correlations than vadose zone interrogations when compared to the verification samples.

(c) The thermal desorption sampler (TDS) can be used in the vadose zone and is available from the ERDC. This probe collects a small soil sample. The sample is heated and volatiles are released and transferred to the surface, where they are either trapped for later analysis or interfaced to an ion trap mass spectrometer for analysis in near-real-time on the site. ESTCP-sponsored TDS VOC site characterization demonstrations for vadose zone interrogations recorded high correlation with verification sample results. The TDS is not configured for saturated zone interrogations.

(7) The SCAPS can be used to collect ground water samples and small volume soil samples. SCAPS can also be used to install small diameter wells. When using a commercial sampler, each physical sample obtained or well installed requires a separate push. However, the ERDC has developed a soil sampler that has the capability to obtain discrete soil samples from multiple depths during a single push without retracting the outer housing of the sampler.

(8) Subsurface conditions and rod diameter affect push depth. Equipment includes push rods for sensor probes; generally, rods with a 44.4-mm outside diameter (O.D.) are used but other sizes may be available. Rods up to 50.8 mm, the largest diameter that can be accommodated by the current geometry of the chucking system, can be used. Pushes can be made in geologically suitable materials to approximately 50 meters, depending on rod diameter, and the geometry of sensor probes and rod adapter to push rods.

(9) The truck is 4.1 meters tall, 2.6 meters wide, and 10.7 meters long. The SCAPS truck also has a support trailer containing a water tank, a grout pump, and a high pressure hot water cleaner.

b. Description of Sensors and Associated System Capabilities.

(1) Cone Tip and Sleeve Friction.

(a) The cone and sleeve, or penetrometer portion of the probe, profiles subsurface stratigraphy through soil strength measurements. The cone tip and sleeve friction sensors are individual load cells. Computer-based routines use load cell gauge readings, calibration curves, and empirical equations to determine soil classification in the field. The empirical equations used with sensors built by the ERDC are based on Olsen and Malone (1988). The cone tip sensor provides a voltage output proportional to the axial force exerted on the tip of the sensor by the subsurface material. The sleeve friction sensor, directly above the cone tip, provides an output proportional to the frictional force applied to the free floating cylindrical sleeve. Cone tip resistance and sleeve resistance are generally plotted on panel plots in real-time as the data are acquired.

(b) Commercial cone penetrometers with an array of sensors for measuring geotechnical properties are also available. These sensors include piezocones to obtain pore pressures, pressure cells to measure lateral stress, and geophones to measure seismic properties.

(c) The configuration of the cone and sleeve conforms to ASTM D-3441.

(2) Laser-induced Fluorescence.

(a) Chemists have used the fluorescence method for dozens of years as one technique to analyze for chemical compounds. Fluorescence is distinguished from most other analytical methods because of its extremely high sensitivity. Fluorescence is a type of luminescence; in general, luminescence occurs when an electronically excited molecule emits light or electromagnetic radiation. The phenomenon of fluorescence is characterized by the light emission event occurring approximately 50 to 250 nanoseconds (1 nanosecond = 10^{-9} second) after an excitation event.

(b) Fluorometry frequently uses monochromatic light, that is, light at a single wavelength or one color, to excite a defined population of molecules. One type of fluorimeter provides a burst or pulse of monochromatic light to the group of molecules to raise them to an excited state. Once the pulse ends and the outside energy source is gone, the molecules lose that energy by a combination of mechanisms. Some energy is lost by molecular vibration or heat generation. Energy is also lost through the release of electromagnetic radiation, sometimes in the form of visible light. Because some of the energy of an excited molecule is lost to vibration, the energy left for fluorescence is less than that provided by the excitation source. For this reason, the resulting wavelength of fluorescence or emitted light is always longer or less energetic than the wavelength of the excitation source.

(c) The SCAPS POL (petroleum, oil, lubricants) sensor is a laser-induced fluorimeter (LIF) housed within a cone penetrometer probe. A diagram of the fiber optic LIF probe is shown in Appendix C. A laser provides the ultraviolet excitation source. Currently, any of three lasers may be available as the excitation source. These include a nitrogen (N_2) laser, a xenon chloride laser, or a pulsed dye tunable laser. A 400-micrometer (μm ; 1 micrometer = 10^{-6} meter) diameter silica fiber optic cable, located in the umbilical cable, transmits light from the exit port of the laser mounted in the SCAPS truck, down through the umbilical cable within the push rods and to a 6.35-mm-diameter sapphire window located in the side of the sensor probe housing. The window is located 0.6 meter above the cone tip. After the laser light reacts with the soil matrix and fluorescence is produced, the light returns through the window and is collected and transmitted back up the probe by another 400- μm fiber optic cable located in the umbilical cable. The return fiber terminates at the on-board analyzer, which is dependent on the laser type.

(d) The N_2 laser has a wavelength of 337 nanometers (nm; 1 nanometer = 10^{-9} meter) and pulses at a rate of 10 times per second. The N_2 laser has enough energy to excite polynuclear aromatic hydrocarbon (PAH) compounds with three or more rings with a high degree of efficiency. Single-ring aromatic, double-ring aromatic, and aliphatic hydrocarbons will not fluoresce efficiently when excited at 337 nm. Higher excitation energies (or lower wavelengths) are required to produce fluorescence in light aromatic hydrocarbons such as benzene. A tunable dye laser system operated at 290 nm was developed by the Air Force and is capable of detecting light aromatic hydrocarbons of less than three rings. The xenon chloride laser has an emission wavelength of 308 nm and is capable of detecting double-ring aromatics.

(e) A down hole mercury vapor lamp is also available for detection of POL. The lamp, operating at 254 nm, induces fluorescence and an optic fiber transmits the fluorescence signal to an uphole analyzer. The mercury vapor lamp system is capable of detecting single-ring aromatic compounds. The analyzer can be fitted with changeable filters to identify specific fuels.

(f) The efficiency of the laser signal can degrade if the sapphire window has internal impurities, is abraded, or if the optic fiber is misaligned or pitted. Therefore, the energy of the signal is evaluated before and after each push. Degradation of the signal is assumed to be linear between the pre- and post-push evaluations and the data are corrected by computer-based routines.

(g) The LIF response can be affected by fluorescent dyes and optical brighteners, such as those found in antifreeze and detergents. Naturally-occurring fluorescent minerals such as calcite can also produce LIF response. The above materials produce fluorescence that can be interpreted as false positive sensor responses.

(h) The spectral signature of the fluorescing substance may be analyzed to allow speciation of the fluorescing POL or to determine if the fluorescence is from naturally occurring

background material. Peak fluorescence intensity and corresponding peak fluorescence wavelength are typically displayed on panel plots in real-time as the data are acquired.

(3) *Resistivity Measurement.*

(a) The SCAPS electronic array for the resistivity sensor uses four equally spaced electrodes (Wenner array) to measure apparent resistivity. The electrodes consist of metallic rings encircling the outer diameter of the probe. They are separated by a nonconductive Teflon™ insulator. A voltage between the outer rings induces a current in the surrounding material. The voltage difference is measured across the two middle electrodes. The SCAPS computer can calculate the apparent resistivity in ohm-meters.

(b) The close spacing of electrodes gives a small test area and limited horizontal extent of investigation (50 mm), but provides well-defined differences in measured resistance. As electrical resistance is related to both the soil type and the pore fluid constituents, the sensor can be used to determine soil type and ground water table, depending on soil type. The sensor can also determine different relative levels of contaminants in a uniform soil with uniform moisture content.

(c) At least three electrical conductivity or resistivity sensors are commercially available. Although all are slightly different, these sensors can be used with the SCAPS if minor software or hardware modifications are made.

c. *Physical Sampling Capabilities.*

(1) *Soil Sampling.*

(a) SCAPS can use commercially available direct push samplers to obtain soil samples. These samplers are similar in that all have a retractable tip and a removable stainless steel inner barrel. Sampler inner barrels can be split or whole. The sampler is pushed to a depth above the desired sample interval with the tip and barrel in place. The tip is then retracted and locked into the top of the sampler and the sampler is pushed through the sample interval. The sample can be extracted in the field or capped and submitted for laboratory analysis.

(b) The volume of one soil sample retrieved by the SCAPS is usually smaller than that obtained by conventional drilling methods. At least three manufacturers currently offer soil samplers. The dimensions of each sample barrel are 25.4 mm inside diameter (I.D.) by 203.2 mm; 35.6 mm I.D. by 533.4 mm; and 35.6 mm I.D. by 990.6 mm. Using an assumed soil density of 1.7 g/cm³, sample barrels can contain approximately 175 grams, 900 grams, or 1675 grams of material, respectively.

(c) The ERDC-developed Multiple Discrete Depth Soil Sampler (MDDSS) has the capability to collect soil samples in the vadose zone at discrete depths without retracting the outer sampler rods. The MDDSS is also configured with a grout module that injects grout during sampler retraction.

(2) *Ground Water Sampling.*

(a) SCAPS can use commercially available ground water sample probes, such as the PowerPunch™ or the HydroPunch II™ (HP II), to directly obtain ground water samples. Other commercially available ground water sample probes, including the Bengt-Arne Torstensson (BAT)® sampler, and the Westbay® MP, may be compatible with SCAPS.

(b) SCAPS can also be used to install ground water sampling points made of 12.7-mm I.D., 19.0-mm I.D. or 38.1-mm I.D. polyvinyl chloride (PVC) casing and screen. The casing and screen are flush joint and available in 1- or 1.5-meter lengths. The screen slot size is usually 0.25 mm. The smaller diameter well material is usually emplaced by one of two methods.

- The first method uses the PowerPunch™ system. This commercially available system consists of an expendable point, a mechanical sealing body, and 47-mm O.D. rods that are fitted with o-ring seals. The expendable metal tip is fitted into the end of a slotted PVC screen and this screen assembly is fitted onto the sealing body. The whole assembly is then inserted into the lead push rod. After the rods reach the terminal depth, a PVC riser is fed through the rods and threaded onto the screen. The sealing body of the PowerPunch™ is retracted to above the screen, the rods are rotated, and the sealing body is separated from the lead rod. The metal tip, screen, and riser remain in place. The sealing body remains in place to form a seal above the screen. This technique is effective when the rod string can be easily rotated, either at shallow depths or when resistance to rotation can be overcome.

- The second method is similar; however, an expanding annular seal is used instead of a mechanical sealing body and the first several rods have an increased I.D. of 47.5 mm. In this method, a section of PVC riser with an attached expanding foam seal, or an expanding bentonite sleeve, or a combination of the two, is threaded onto the top of the screen section. This assembly is fed through the rods and pushed to the desired depth. At the desired depth, PVC riser is inserted through the push rods and threaded onto the sealing assembly, the push rods are retracted, and the metal point, the screen, the sealing assembly, and the riser are left in place. This technique is effective at any depth and does not depend on physical rotation of the rod string. Pre-packed screens for small particle filtration and expanding seals are also commercially available.

(c) PVC well points of 38.1-mm I.D. are installed by placing the PVC over small-diameter (36.6-mm) push rods. The PVC screen is in contact with all subsurface materials through which

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it passes during the push. The push rods are retracted through the inside of the PVC. This is the least desirable method of installing well points.

(d) If well points or other access points are used, ground water samples for direct analysis of volatiles can be obtained by in situ sparge. After a well screen is open and the rate of ground water rise has been measured, an in situ sparge device is lowered into the well point. The sparge device uses helium to purge volatiles from the ground water and carry them directly to a DSITMS. Ground water samples for mass spectrometer analysis may also be obtained with a small diameter stainless steel bailer or peristaltic pump and then be vial-sparged, by directly connecting 40-mL vials to the mass spectrometer. Small diameter bladder pumps are also commercially available for use in collecting ground water samples from direct-push well points.

d. *Grouting Capabilities.* Army-manufactured LIF, electrical resistivity, modified MIP, and MDDSS probes allow for grouting through the tip of the probe as the rods are withdrawn from the push hole. The spectral gamma probe injects grout from a port directly above the gamma sensor module. A grout consisting of microfine cement or portland cement, water, and bentonite (if desired) is mixed. The grout is pumped to the probe tip via a 9.5-mm diameter Teflon™ tube contained in the umbilical cable. The grout forces a small, expendable metal tip from the end of the probe. Holes made to collect physical samples or holes made by commercially available sensor probes may be grouted as the rods are retracted, or after the rods are retracted, depending on the grouting capability of the specific tool.

e. *Survey.* SCAPS is equipped with either an Electronic Distance Measurement (EDM) survey instrument or a Global Positioning System (GPS) capability. The EDM instrument can provide readings in both vertical and horizontal directions. A three-prism mirror configuration yields a range of 1067 meters. An electronic field notebook is attached for data collection. Data are downloaded into a software program that renders drawings of survey points. GPS equipment provides differential location accuracies of 30 to 50 mm (horizontal and vertical) and automatic annotation of the boring data file with location information.

f. *New Sensors.* The DoD Laboratories and commercial vendors continue to develop new sensors and samplers to improve system capabilities. The status and capabilities of available sensors are continually changing. Appendix D contains a chart describing SCAPS penetrometer contaminant and geophysical sensor and sampler tools.

g. *Data Collected.*

(1) *Geotechnical.* Tip resistance and sleeve friction stresses are recorded versus depth at 20-mm intervals. These data are recorded in ASCII form on the system computers. The push rate is hydraulically controlled; however, dense material may slow down the rate of advance.

(2) *Laser-induced Fluorescence*. Fluorescence data are collected as the cone penetrometer is continuously pushed at a rate of 20 mm/s. One data point represents approximately 40 mm. The rate of data collection is computer-controlled; however, the rate can be adjusted by the operator. Returned light intensity versus wavelength is recorded digitally as binary data for each data point. The maximum intensity and corresponding wavelength versus depth are also graphically displayed in real-time on a computer screen as the push is in progress. Hard copies of the graphical displays or panel plots are produced at the end of a push. Data storage and retrieval are possible by acquiring the data on the hard drive and transferring the data to a removable disk at the convenience of the operator.

(3) *ITMS Analytical Results*. Concentrations of volatile organics in vapor, ground water, or soil, as determined by mass spectroscopy, are available within minutes of testing. Final reports of results, including chromatograms, are usually available within one month of data collection.

h. 3-D Visualization. Data can be visualized in 3-D using Intergraph's Environmental Resource Management Application (ERMA), Intergraph's Voxel Analyst, or the Department of Defense's Ground Water Modeling System (GMS). The ERDC-provided and supported SCIRT (Site Characterization Interactive Research Toolkit) is also available. SCIRT is 3-D visualization software developed at Mississippi State University.

i. Field Analysis Options. Soil and water samples collected with SCAPS can be analyzed in the field to enhance decision-making capability. Mass spectrometers, gas chromatographs, immunoassay test kits, and SCAPS sensors, such as the X-ray fluorescence metals sensor, are available to identify contaminants in near-real-time.

j. Data Validation.

(1) *Geotechnical Validation*. The cone penetrometer probe continuously estimates soil type using empirical equations and cone tip and sleeve resistance. Samples of formation material are not continuously brought to the surface to be inspected and described. This can be overcome by comparing sensor results to existing stratigraphic information or to periodic samples of site-specific material collected by cone penetrometer samplers or other means. Most HTRW sites have been investigated to some extent and will have boring information. Military HTRW sites generally have construction boring information that can be accessed. Soil classification by cone penetrometer test (CPT) and factors affecting CPT results have been established empirically and discussed in the literature. Several references are provided in Paragraph 4.

(2) *Chemical Sensor Validation*.

(a) The LIF sensor responds to polynuclear aromatic hydrocarbons and was designed to detect POLs. The SCAPS LIF sensor system has been extensively validated in both laboratory and field experiments at a number of sites under the sponsorship of the ESTCP. The SCAPS LIF

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POL Sensor System has received regulatory approval. The LIF response and conventional analytical methods have been compared. Available chemical data indicate that the LIF sensor, equipped with the nitrogen laser (excitation wavelength of 337 nm), can detect diesel, heavy weight fuel oils, and coal tar derivatives at relatively low concentrations and gasoline and JP4 at relatively high concentrations or as pure products. The tunable dye laser (excitation wavelength of 290 or 266 nm) is more capable of detecting the lighter or more volatile fuels than the LIF probe equipped with the nitrogen laser, although only limited field tests have been conducted. Detection limit determinations have indicated that response is influenced by soil type and other matrix effects. Several references are provided in Paragraph 4.

(b) Several sensors are available for detecting volatile organics. These sensors depend on an analytical device, generally a DSITMS. See DOE (1998) as a reference for this field method. The SCAPS Hydrosparge VOC Sensor System and the SCAPS Thermal Desorption VOC Sampler may be interfaced with a field-portable DSITMS for onsite near-real-time analysis. The Hydrosparge and Thermal Desorption Sampler systems, interfaced to DSITMS equipment, have also been validated in the field by ESTCP and have received regulatory approval.

k. Field Applications.

(1) SCAPS can be used anywhere static direct push is feasible. A static direct push method is most suited for fine-grained, unconsolidated materials, including sands, silts, and clays, which are typically found in recent flood plains, coastal plains, and lake beds. Unconsolidated Pleistocene and Tertiary deposits corresponding with the environmental settings listed above are also suitable, as is eolian loess. In some areas where hard surficial materials are found, it may be possible to pre-push holes with non-instrumented probes before a sensor probe is used. Any subsequent soil classification sensor data collected through a pre-pushed portion of a hole is of questionable value. However, contaminant sensor data for screening may still be collected and are of value.

(2) The LIF sensor can be used on sites where petroleum hydrocarbon contamination is expected. These sites include fuel storage areas, refueling stations, former manufactured gas plants, air base flight lines, fire training areas, fuel pipelines, fuel spill areas, and vehicle maintenance shops. The use of the LIF sensor to delineate in situ contamination can reduce and focus the amount of physical sampling and laboratory analysis required by regulatory programs, in addition to improving the effectiveness of monitoring well placements. The SCAPS LIF POL Sensor System typically saves 25–40 percent versus conventional drill/sample and offsite analysis techniques.

(3) Numerous sensors or sampling devices are available for the detection of volatile organics. The TDS, interfaced to appropriate analytical instrumentation, is designed for use in the vadose zone and is useful in screening discrete depths for contamination (vertical profiling). The MIP, when interfaced to appropriate analytical instrumentation, can be used for vertical

profiling in both the vadose and the phreatic zones and may be especially useful for delineating suspected source areas. The ERDC interfaced a soil classification sensor module and a MIP. With a soil classification sensor module located below the MIP sensor, specific soil horizons may be identified and sampled during one push. This dual sensing capability can assist in identifying possible zones of preferential contaminant transport in the subsurface. The Hydrosparge sampler, interfaced to appropriate analytical instrumentation, is useful for delineating contaminants dissolved in ground water. Vertical profiling is possible with the Hydrosparge, but only one sample may be taken per push. Relative to the MIP, the Hydrosparge sampler provides more repeatable results at this time and is capable of lower detection limits. Both are considered semi-quantitative screening devices.

(4) SCAPS can be used in different phases of site investigation and remediation. For example, in a phased investigation approach, SCAPS can install well points to determine flow direction or obtain ground water samples for analysis before a permanent well is installed. SCAPS field sensor results can be used to optimize the placement of monitoring wells and the location of future soil or ground water sampling sites. SCAPS sensor data can also be collected to monitor the progress or effectiveness of on-going remediation activities.

(5) SCAPS can be used on sites to minimize investigation-derived waste (IDW) because drill cuttings are not produced. If necessary, decontamination water can be collected as it is generated to facilitate appropriate disposal.

l. Obtaining SCAPS Services.

(1) Information on the availability of SCAPS can be obtained from each SCAPS District. Contacts are contained in Appendix A.

(2) Districts requesting SCAPS should provide preliminary information on site geology, standard penetration test blow counts (if available), nature of contamination, depth to water, and specific objectives of the investigation. If a site is determined to be a candidate for direct push, the SCAPS District will supply a cost estimate and a general SCAPS health and safety plan, and will contribute to the site work plan. Customer Districts should be able to coordinate with site personnel and appropriate regulatory agencies to provide or identify the following.

(a) Water source for decontamination.

(b) Site or installation contact.

(c) Permit issues.

(d) IDW requirements for decontamination water or limited spoil from any soil samples that might be obtained.

- (e) Trash and personal protective equipment disposal options.
- (f) Notification of appropriate State regulator.
- (g) Length of time for utility clearances.
- (h) Accessibility problems.
- (i) Unique safety issues.

(3) SCAPS Districts will provide data in the form of panel plots. Final reports and data interpretation may be a collaborative effort between SCAPS and customer Districts and will depend on project requirements (scope of work), funding, and schedule requirements. Personnel of the ERDC can be utilized for specialized data acquisition, processing, and analysis on an “as needed” reimbursable basis.

- (4) Typical cost and production data are included as Appendix E.

7. Action. Recommend that District technical staff determine if SCAPS is applicable to all projects scheduled for intrusive activities, before field operations begin. If assistance is needed, contact a SCAPS Operating District as noted in Appendix A.

APPENDIX A SCAPS Areas of Responsibility

A-1. General. The Site Characterization and Analysis Penetrometer System is a resource to be used by all Corps Districts and laboratories. The three SCAPS operating Districts serve as a team to meet the needs of requesting offices anywhere within CONUS. SCAPS has been used OCONUS but mobilization logistics make precise job scheduling uncertain and costly.

A-2. SCAPS Districts. This appendix lists the initial point of contact for a District or laboratory requesting information about SCAPS or requesting SCAPS services. The District having project or construction management responsibility should be responsible for arranging for SCAPS services (as opposed to a District that has been “subcontracted” by another to provide site investigation or other support services). Districts with SCAPS units are assigned operating areas based on established customer relationships and geographic proximity to potential site locations. The areas of responsibility are defined in Table A-1. The defined areas are not the only areas in which a particular SCAPS unit may work. The SCAPS District will coordinate requested work to determine who will perform a given project based on crew availability, project locations, and schedule. With the current distribution of civil works and military construction responsibilities within the Corps, some overlap of areas is inevitable (e.g., the civil works boundary of St. Louis District overlaps the military boundary for Louisville District). Therefore, Table A-1 is included for ease of use. Districts requesting SCAPS information or services should contact the SCAPS Coordinator at the appropriate SCAPS Operating District, as shown in Table A-1, regardless of whether a project is civil or military. SCAPS Operating District points of contact are:

U.S. Army Engineer District, Kansas City
ATTN: CENWK-EC-GG
601 East 12th Street
Kansas City, MO 64106-2896
Phone: (816) 983-3683
Fax: (816) 426-5462

U.S. Army Engineer District, Savannah
ATTN: CESAS-EN-GG
P.O. Box 889
Savannah, GA 31402-0889
Phone: (912) 652-5674 / 5676
Fax: (912) 652-5311

U.S. Army Engineer District, Tulsa
ATTN: CESWT-EC-EI
1645 South 101st East Avenue
Tulsa, OK 74128-4629
Phone: (918) 605-9342 (cell phone) / (918) 832-4122
Fax: (918) 669-7532

Table A-1
SCAPS Operating Areas by District and State

Savannah District:	Kansas City District:	Tulsa District:
Illinois (including ERDC/CERL)	Montana	Idaho
Indiana	North Dakota	Washington
Michigan	South Dakota	Oregon
Ohio	Minnesota	California (including HEC)*
Pennsylvania	Wisconsin	Louisiana
Delaware	Wyoming	Nevada*
Maryland	Colorado	Arizona
West Virginia	Nebraska	New Mexico
Kentucky	Kansas	Texas
Virginia (including TEC and TAC/Europe)	Iowa	Oklahoma
North Carolina	Missouri	Arkansas
Tennessee	Maine	Alaska
South Carolina	New Hampshire (including ERDC/CRREL)	Hawaii
Georgia	Vermont	Pacific Ocean and Asia
Alabama (including HNC)	Massachusetts	
Florida	Rhode Island	
	Connecticut	
	New York	
	New Jersey	
	California **	
	Mississippi (including ERDC)	
	Nevada	
	Utah	
	AF installations as requested by AFCEE & AF Research Lab	

* Los Angeles District Boundaries

** Sacramento and San Francisco District Boundaries

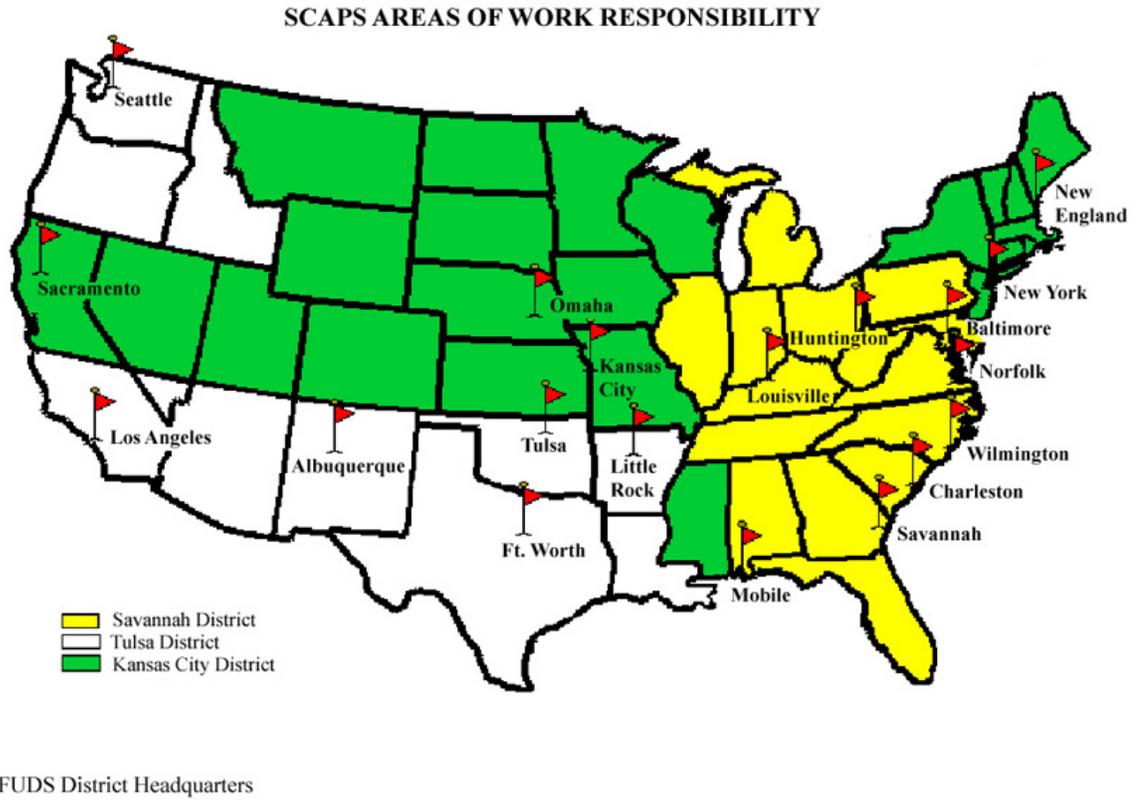


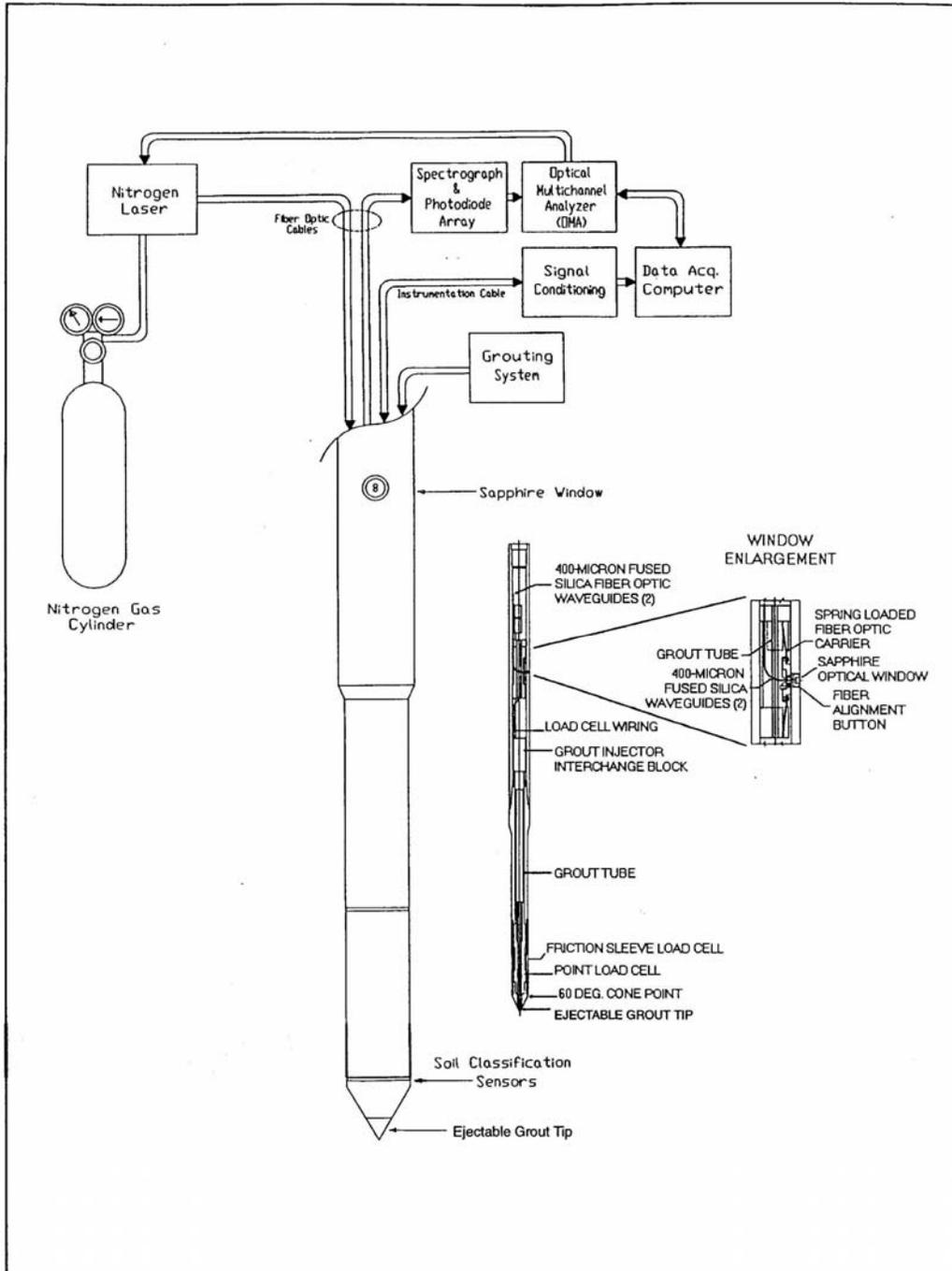
Figure A-1. SCAPS Operating Areas.

APPENDIX B
SCAPS Capability Matrix

CONTACT INFORMATION	SENSORS										SAMPLERS		FIELD SCREENING										OTHER				
	Videocore	Membrane Interface Probe	Laser Induced Fluorescence	Resistivity	Piezocore	Stratigraphy	Rapid Optical Screening Tool	Soil Sampler	Soil Gas	PowerPunch 1" wells	HydroPunch sampler	HydroSparge	Field Portable GC	Field Portable GC/MS	Field Portable Ion Trap MS	Field X-Ray Fluorescence	Total BTEX/PAH Test Kits	High Explosives Test Kits	PCB Test Kit	PCP Test Kit	Iron II & Nitrate	Phosphorus	Global Positioning System	Modeling/3D Visualization	Geophysics (EM-31)	Aquifer Test Equipment	FLUTE Membrane
<p>Kansas City District Kathy Older / John Hoyt 601 East 12th Street Kansas City, MO 64106-2896 (816) 983-3683 phone kathleen.older@nwk02.usace.army.mil scaps_pcc@nwk02.usace.army.mil</p>	■	■	■*	■		■	■		+		#			#		■	■	■	■	■	■	■	■	■	■	▲	
<p>Savannah District Card Smith / Bob O'Kelley P.O. Box 889 Savannah, GA 31402-0889 (912) 652-5674 phone H.Cardwell.Smith@sas02.usace.army.mil</p>	▲	■	■*	■	■	■	■	■	+	■	#	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	▲
<p>Tulsa District Steve Brewer 1645 S. 101 East Ave Tulsa, OK 74128 (918) 605-9342 cell phone Billy.S.Brewer@swt02.swt.usace.army.mil</p>		■	■*	■	■	■	■	■	+	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	▲

- Capability owned by the District
- * Equipped with probe breakage sensor
- + Sampled using 0.5" x 30" bailer (stainless steel or disposable) or peristaltic pump
- # HydroSparge/ITMS units available through Oak Ridge National Laboratory
- ▲ Equipment rented; District has experience performing

APPENDIX C Schematic of the SCAPS POL and Geophysical Sensors Probe



APPENDIX D
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 Spectroscopy (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.

APPENDIX E Sample Cost Estimate

E-1. 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 \times 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 \times 3 hours = 33 hours / 8 hours \approx 4 days

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E-2. Cost Comparison. The following table compares costs for auger drilling and SCAPS direct push:

	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