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	Engineering and Design TRI-SERVICE SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM (SCAPS)	
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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
CEMP-RT **Washington, DC 20314-1000**

Engineer Technical
Letter 1110-1-171

31 January 1996

Engineering and Design
TRI-SERVICE SITE CHARACTERIZATION AND ANALYSIS PENETROMETER SYSTEM (SCAPS)

1. <u>Purpose</u>. This letter provides information on the capabilities and potential uses of the Tri-Service Site Characterization and Analysis Penetrometer System (SCAPS) direct-push technology for the investigation of hazardous, toxic, and radioactive waste (HTRW) sites.

2. <u>Applicability</u>. This letter applies to all USACE major subordinate commands, districts, laboratories, and field operating activities having HTRW investigation and design responsibility.

3. <u>References</u>.

a. American Society for Testing and Materials (ASTM) D-3441-86 Standard Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil

b. Fugro Mobile Electronic Cone Penetrometer System (Descriptive Bulletin, no date), Leidschendam, the Netherlands

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

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

e. Olsen, R.S. and Malone, P.G., 1988, "Soil Classification and Site Characterization Using the Cone Penetrometer Test", Penetration Testing 1988, ISOPT-1, De Ruiter (ed), Rotterdam, the Netherlands

f. Robertson, P.K. and Campanella, R.G., 1983, "Interpretation of Cone Penetrometer Test. Part I: Sand", Canadian Geotechnical Journal, vol. 20

g. Robertson, P.K. and Campanella, R.G., 1983, "Interpretation of Cone Penetrometer Test. Part II: Clay", Canadian Geotechnical Journal, vol. 20

4. Background.

a. The cone penetrometer has been used extensively to determine subsurface stratigraphy and geotechnical properties in conventional geotechnical investigations. The electronic cone has been in use since 1969. The cone penetrometer is fast, 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, monitoring 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 Army Environmental Center (AEC), formerly the US Army Toxic and Hazardous Materials Agency (USATHAMA), sponsored the US Army Engineer Waterways Experiment Station (WES) to develop SCAPS under a Tri-Service agreement. Development began in 1986; initial sensor development was based on a fluorometric method of detecting hydrocarbons developed in conjunction with the Naval Command, Control and Ocean Surveillance, RDT&E Division (NRaD). The first SCAPS technology demonstration was conducted by WES and AEC 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.

5. Discussion.

a. General System:

(1) The SCAPS is mounted in a 18144 kilogram (kg) truck equipped with two hydraulic rams capable of exerting 17237 kg of force to make a direct push. 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)/sec 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. This arrangement minimizes crew exposure to potential contamination and crew down time for decontamination.

(3) The current SCAPS has three in-situ sensing capabilities: defining soil stratigraphy, detecting polynuclear aromatic hydrocarbon (PAH) contamination with laser induced fluorescence (LIF), and profiling resistivity. The LIF sensor is mounted on 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. Sensors are connected to electronic signal processors through wiring bundled together into an umbilical cord. The umbilical cord also contains a grout tube so push holes can be sealed as the penetrometer is withdrawn. Two optical fibers are contained in the LIF sensor umbilical. An umbilical 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 and displayed in the form of panel plots as they are acquired. The LIF and resistivity sensors are mounted on separate cone penetrometer probes; therefore separate pushes are required for each sensor.

(4) The SCAPS can also be used to collect ground water, small volume soil samples, and to install small diameter wells. Each physical sample obtained or well installed also requires a separate push.

(5) Subsurface conditions and rod diameter affect push depth. Equipment includes two sets of push rods; one set has an O.D. of 44.4 mm and the other set has an O.D. of 36.6 mm. Pushes can be made in geologically suitable materials to approximately 24 meters using 44.4 mm outer diameter (O.D.) rods and 46 meters using the smaller diameter rods.

(6) The truck is 4.1 meters tall, 2.6 meters wide and 10.7 meters long. The SCAPS truck also has a 4.3 meter long, 2.4 meter wide support trailer containing a 1135 liter 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 are based on Olsen (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.

(b) The configuration of the cone and sleeve conforms to ASTM D-3441-86 Standard Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil.

(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 the 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 fluorometer 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). One of the first principles of light is that shorter wavelength light is more energetic than longer wavelength light. Since 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. Hence, the resulting wavelength of fluorescence or emitted light is always longer than the wavelength of the excitation source. Because a population of molecules is being considered and each molecule within the population has its own micro environment, a variety of decay times and wavelength emissions can be observed. The intensity of light produced at a specified wavelength and time is indicative of the number of molecules within the population producing the fluorescence. Fluorometry data can be plotted in two ways: first, the intensity of light produced is graphed against the wavelength of emission. Second, the intensity of light produced is graphed against time after excitation has occurred.

(c) The SCAPS POL sensor uses laser-induced fluorescence (LIF) technology within a cone penetrometer probe. A diagram of the fiber optic LIF probe is shown in Appendix C. The LIF sensor uses a nitrogen (N_2) laser as the ultraviolet excitation source. 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 3 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. A 400 micrometer (μm; 1 micrometer = 10^{-6} meter) diameter silica fiber optic cable transmits light from the exit port of the laser, down through the push rods and to a 6.35 mm diameter sapphire window located in the sensor probe. 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. The return fiber terminates at the on-board optical analyzer. The analyzer is comprised of a diffraction grating, a photo diode array, a multichannel analyzer, and a data processor. The photo diode array consists of 1024 diodes. The system records the light intensity at each diode over the range between 300 and 800 nm; thus the optical analyzer provides approximately 0.5 nm resolved spectra. Wavelength maximum (peak wavelength) and intensity are used to characterize the nature and concentration of the fluorescent material in the soil matrix.

(d) Higher excitation energies (or shorter wavelengths) are required to produce fluorescence in light aromatic hydrocarbons such as benzene. The tunable dye laser (normally operated at 290 nm) developed by the Air Force is capable of detecting light aromatic hydrocarbons of less than 3 rings.

(e) The efficiency of the laser signal can degrade if the sapphire window 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 and the data is corrected by computer-based routines.

(f) The LIF response can be affected by fluorescent dyes, optical brighteners, sunlight in the top of the hole, and naturally occurring fluorescent minerals. Dyes and brighteners can be found in antifreeze and detergents.

(3) Resistivity Measurement:

(a) The resistivity sensor uses four equally-spaced electrodes in a Wenner array to measure soil resistivity. The electrodes consist of stainless steel rings encircling the outer diameter of the probe. They are separated by nonconductive Teflon™ insulators. Resistivity measurements are made by passing a DC current between the two outer electrodes and measuring the voltage drop across the two inner electrodes. The SCAPS computer is used to calculate the nominal resistivity in ohm-meters by using the excitation current, the voltage drop across the inner electrodes, and predetermined geometric factors derived from potential field theory.

(b) The close spacing of electrodes provides for a small test area and limited horizontal extent of investigation (50 mm), but provides well defined differences in measured resistance. Since 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.

c. <u>Physical Sampling Capabilities</u>:

(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. Assuming a soil density of 1.7 grams/cubic cm, sample barrels can contain approximately 175 grams, 900 grams, or 1675 grams of material respectively.

(2) Ground Water Sampling:

(a) SCAPS can use commercially available ground water sample probes such as the HydroPunch II™ (HP II). The body of the HP II is attached to the push rods and samples are collected in one of two ways:

- The manufacturer refers to the first way as the hydrocarbon mode. A 1.5-meter long disposable screen and tip is inserted into the HP-II, the HP-II is pushed to the desired depth and the outer body of the HP-II is retracted. The disposable screen is exposed to the ground water and a 19 mm I.D. bailer is lowered through the rods and into the screened zone for sample collection.

- The manufacturer refers to the second way as the ground water mode. The HP II is fitted with a check valve assembly and pushed. At the desired depth, the body of the HP II is retracted about 0.3 meters. Water enters a 101.6 mm long screen within the body of the HP II. When the HP II is full, the entire sampler is retrieved and the sample is decanted through the check valves.

(b) Other commercially available ground water sample probes such as the Bengt-Arne Torstensson (BAT)(R) sampler, and the Westbay(R) MP may be compatible with SCAPS.

(c) SCAPS can also be used to install ground water sampling points made of 12.7 mm I.D. or 38.1 mm I.D. polyvinyl chloride (PVC) casing and screen. The casing and screen are flush jointed and available in one meter or 1.5 meter lengths. The screen slot size is usually 0.25 mm. The 12.7 mm I.D. PVC can be emplaced two different ways:

- One way is by using the PowerPunch™ system. This commercially-available system has a screen inside a drive casing. This assembly is driven to depth with special 47 mm O.D. rods fitted with o-ring seals. The 12.7 mm I.D. PVC is emplaced through the center of the rods and fitted to the screen. The body of the PowerPunch™ is retracted and separated from the rods. The body forms a seal above the screen.

- The other way is to screw an expendable metal tip into the end of a slotted PVC screen. The 12.7 mm PVC is placed through the center of the 44.4 mm O.D. rods. As the screen is pushed to depth additional screen or casing is added along with direct push pipes. At the desired depth, the push rods are retracted leaving the metal tip, PVC screen and risers in place. The 38.1 mm I.D. PVC is emplaced in a similar way, but the PVC is placed over, rather than inside, the 36.6 mm push rods.

(d) Sampling from well points is more desirable from a production standpoint; if the truck is tied up in ground water sample collection (e.g., with a HydroPunch™), it is not available to collect sensor data at other locations. Depending on the number of analytes and the permeability of the formation, ground water sampling can be very time consuming.

d. Grouting Capabilities: Cone penetrometer push holes are grouted through the tip of the probe as the rods are withdrawn from the push hole. 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 cord. The grout forces a small expendable metal tip from the end of the probe. Holes made to collect physical samples are grouted after the rods are retracted since sampling devices do not have grouting capability.

e. Survey: SCAPS is equipped with either a Sokkia Total Station electronic distance measurement (EDM) survey instrument or Trimble 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 SCAPS program continues to develop new sensors and samplers to expand and enhance system capabilities. Sensors currently being field tested include a sensor for nitrate-based explosives, electrochemical sensing of volatile organic compounds (VOCs), and a spectral gamma sensor for detection and speciation of radioactive contamination. Samplers undergoing field testing include a multi-port soil gas sampler, in-situ sparging device for sampling groundwater, and a thermal desorption soil sampler; all for VOC sampling. Sensors under development include one for heavy metals utilizing laser-induced breakdown spectroscopy, and volatile organics/solvents sensor using fiber optic Raman spectroscopy.

g. Data Collected:

(1) Geotechnical: Tip resistance and sleeve friction 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/sec. 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 displayed in real time on a computer screen panel plot as the push is in progress. Hard copies of the 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.

h. 3-D Visualization: 3-dimensional visualization of data is currently available through WES. SCAPS districts should have this capability in FY96 with either Silicon Graphics™ or Intergraph™ packages.

i. Field Testing Options: Soil and water samples collected with SCAPS can be analyzed in the field to enhance decision-making capability. Immunoassay test kits and field gas chromatographs are available to provide near-real-time contaminant identification. This allows SCAPS to provide a flexible, optimized site characterization program. An Ion Trap Mass Spectrometer will be available in FY96 for field analysis of volatile organic compounds.

j. Data Validation:

(1) Geotechnical Validation: The cone penetrometer probe does not produce samples for direct observation of soil types. This can be overcome by comparing sensor results to existing stratigraphic information. Most HTRW sites have been

investigated to some extent and will have boring information. Military HTRW sites will have construction boring information which can be accessed. Soil classification by cone penetrometer testing (CPT) and factors affecting CPT results have been established empirically and discussed in the literature. Several references are provided in paragraph 3.

(2) Sensor Validation: The LIF sensor responds to polynuclear aromatic hydrocarbons and was designed to detect petroleum/oil/lubricants (POLs). Laboratory and field validation experiments have been performed on a number of samples. Comparisons have been made between the LIF response and conventional analytical methods. 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 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. Preliminary detection limit determinations have indicated response is influenced by soil type and other matrix effects. Additional validation work is in progress and is planned for the future. Reports on this work will be available periodically.

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 prior to using a sensor probe. Although geotechnical data cannot be obtained with this approach, it does allow sensor probe data (e.g., LIF) to be obtained while minimizing the risk of damage to the sensors.

(2) The LIF sensor can be used on sites where petroleum hydrocarbons are expected to be contaminants. 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.

(3) 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 prior to permanent well installation. Field sensor results can be used to optimize well placement or sampling locations.

(4) SCAPS can be used on sites where investigation derived waste is a problem since drill cuttings are not produced. If necessary, decontamination water can be collected as it is generated to facilitate appropriate disposal.

(5) SCAPS can be used to collect samples or sensor data to monitor the effectiveness of on-going remediation.

(6) Typical cost and production data are included as Appendix B.

l. <u>Obtaining SCAPS Services</u>:

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

(2) Districts requesting SCAPS support should provide preliminary information on site geology, standard penetration test (SPT) blow counts if available, nature of contamination, depth to water and specific objectives of investigation. If a determination is made that a site is feasible for direct push, the SCAPS district will supply a cost estimate, SCAPS health and safety plan, and 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 which might be obtained
(e) trash and PPE disposal options
(f) notification to appropriate State & Federal regulators
(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.

6. Action. Recommend district technical staff make a determination regarding SCAPS applicability to all projects scheduled for intrusive activities, before commencement of field activities. If assistance is needed contact a SCAPS Operating District as noted in Appendix A.

FOR THE DIRECTOR OF MILITARY PROGRAMS:

CARY JONES, P.E.
Chief, Environmental Restoration Division

3 Appendices
APP A - SCAPS Areas of Responsibility
APP B - Comparison of Costs for SCAPS Versus Conventional Drilling
APP C Fiber Optic Fluorometric Probe

Appendix A

SCAPS Areas of Responsibility

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. OCONUS locations are not considered feasible for SCAPS application due to high mobilization/demobilization costs. However, SCAPS sensor and sampler technologies may be interfaced with existing OCONUS cone penetrometer vehicles. WES is the POC for OCONUS projects.

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, a map showing areas of responsibility for SCAPS is not practical, and Table A-1 is preferred 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 points of contact are:

U.S. Army Engineer District, Kansas City
ATTN: CEMRK-EP-GG
601 East 12th Street
Kansas City, MO 64106-2896
Phone: (816) 426-3554
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-GS
1645 South 101st East Avenue
Tulsa, OK 74128-4629
Phone: (918) 669-7169 / (918) 832-4122
Fax: (918) 669-7532

U.S. Army Waterways Experiment Station, WES
ATTN: CEWES-EP-J
3903 Halls Ferry Road
Vicksburg, MS 39180-6199
Phone: (601) 634-2446
Fax: (601) 634-2732

TABLE A-1

SCAPS Operating Areas by Division/District

DIVISION/LAB	DISTRICT	SCAPS OPERATING DISTRICT
HNC		SAS
LMVD	LMK	MRK
	LMM	MRK
	LMN	MRK
	LMS	MRK
MRD	MRK	MRK
	MRO	MRK
NAD	NAB	MRK
	NAN	MRK
	NAO	SAS
	NAP	MRK
NCD	NCB	SAS
	NCC	MRK
	NCE	MRK
	NCR	MRK
	NCS	MRK
NED		SAS
NPD*	NPP	SWT
	NPS	SWT
	NPW	SWT
ORD	ORH	SAS
	ORL	SAS
	ORN	SAS
	ORP	SAS
SAD	SAC	SAS
	SAJ	SAS
	SAM	SAS
	SAS	SAS
	SAW	SAS

TABLE A-1
(CONTINUED)
SCAPS Operating Areas by Division/District

DIVISION/LAB	DISTRICT	SCAPS OPERATION DISTRICT
SPD	SPK	SWT
	SPL	SWT
	SPN	SWT
SWD	SWA	SWT
	SWF	SWT
	SWG	SWT
	SWL	SWT
	SWT	SWT
LABS	CERL	SAS
	CRREL	SAS
	HEC	SWT
	TEC	SAS

* NPA is not included in this table due to high mobilization/demobilization costs associated with SCAPS deployment to Alaska.

APPENDIX B

COMPARISON OF COSTS FOR SCAPS VERSUS CONVENTIONAL DRILLING

1. Current experience has shown that daily costs to operate the SCAPS may be higher than operation of a hollow stem auger. The following comparison will show, however, that because of the unique capabilities of the SCAPS, total project costs will probably still be less than if conventional drilling techniques alone are used. The costs used for this illustration are based on CEMRK drill crew and SCAPS average daily rates. Assumptions are the same as those shown on page B-3: working days do not include mob/demob but mob/demob costs are averaged in total cost. Resistivity pushes, prepushes and pushes to obtain soil samples have not been accounted for in this comparison. Twenty-five LIF pushes and eleven wells are installed during an average project.

2. Assumptions are:

a. An average 25 foot deep LIF direct push boring (from table on B-3) is equivalent to a 25 foot deep auger boring made to collect five soil samples for laboratory analysis.

(1) two of these 25-foot-deep borings can be drilled and sampled in a day

(2) includes set up, drilling, sampling, sample preservation, decontamination, and backfilling

(3) 25 borings/2 a day = 12.5 days

b. 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 set up, drill, set well, decon, and develop.

(2) 11 wells x 12 hours = 132 hours/8 hours = 16.5 days

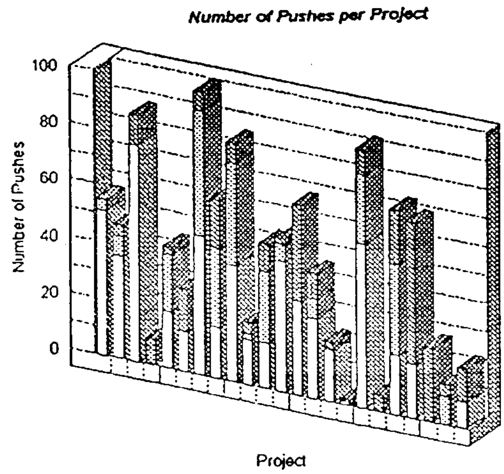
c. The average daily cost for hollow stem auger drilling, at $2,765/day, includes labor, overhead, perdiem, and materials and two days mob/demob.

(1) Soil boring and sampling is estimated to be $34,563.

(2) Well installation is estimated to be $45,622.

3. It is estimated to cost $80,185 and take 29 days to accomplish with conventional drilling equipment essentially the same work that SCAPS can do in 6 days for $24,185.

Typical Cost and Production Data for the Kansas City District SCAPS - FY95



Average Production per Project - FY 1995				
	LIF	Wells	Other	Total
Pushes	25	11	11	47
Feet	675	233	216	1124

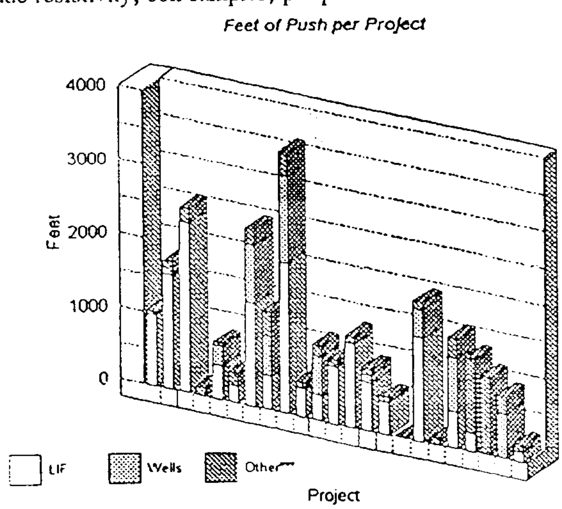
Average Working Days per Project: 6*
Average Project Cost: $24,185**

Notes:

*Average Working days do not include Mobilization and Demobilization time.

** Average Project Cost includes cost of Mobilization and Demobilization, Labor, Per Diem, Material

*** Other pushes include resistivity, soil samples, pre-pushes.



Appendix C
Schematic of SCAPS Probe for POL and Geophysical Sensors