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December 1993

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Initial Field Trials of the Site Characterization and Analysis Penetrometer System (SCAPS)

Reconnaissance of Jacksonville Naval Air Station Waste Oil and Solvents Disposal Site

by *Stafford S. Cooper, Donald H. Douglas, Michael K. Sharp,*
Richard A. Olsen, Gregory D. Comes, Philip G. Malone
Geotechnical Laboratory

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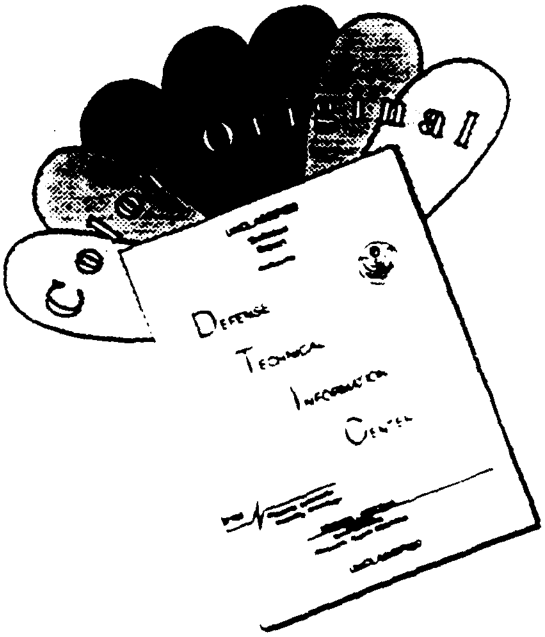
Prepared for Naval Facilities Engineering Command



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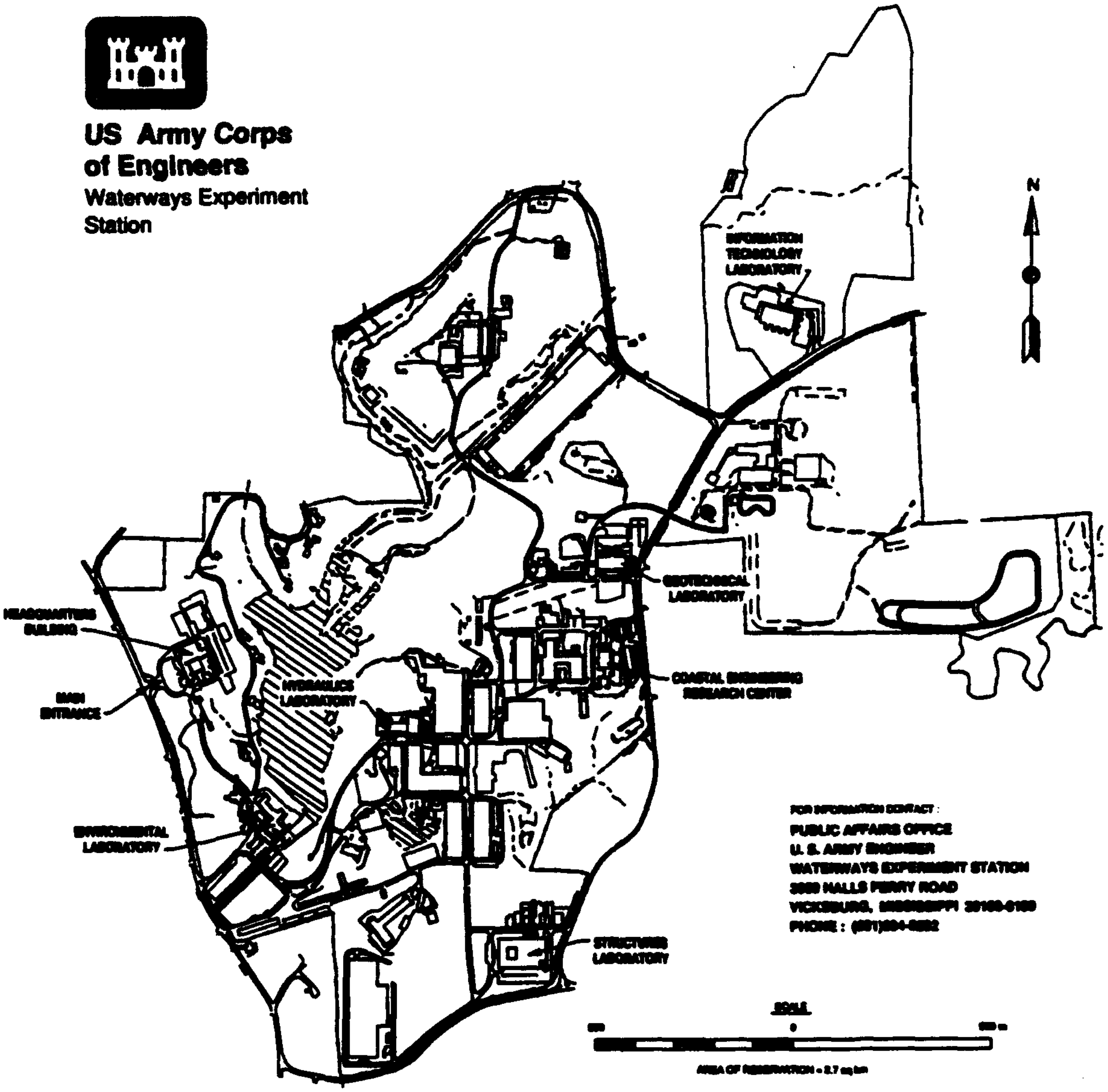

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Preface

The work described herein was undertaken by the Earthquake Engineering and Geophysics Division (EEGD), Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), for the Naval Facilities Engineering Command (NAVFAC), Southern Division, under Navcomp Form 2275, Order No. N6246790MP00907, dated 15 March 1990. This report covers the field work done during the period from 16 July 1990 to 14 August 1990 at the Naval Air Station (NAS), Jacksonville, FL. The Project Officer for NAVFAC was Mr. Joel Murphy. Coordination of the field work was done by Mr. Timothy Curtain, Jacksonville NAS.

The investigation was undertaken in part as a field trial of equipment developed in the Site Characterization and Analysis Cone Penetrometer Tri-Services Project directed by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center. Coordination with USATHAMA was provided by Messrs. Paul W. Lurk, Wayne Sisk, and Robert Bartell. Another objective of the work was to provide some initial site screening results of possibly contaminated sites at the Jacksonville NAS to assist them in formulating remediation plans.

Field work was done by Messrs. Stafford S. Cooper, Donald H. Douglas, Michael K. Sharp, Richard A. Olsen, and Karl F. Konecny, EEGD, and Messrs. Henry L. Blake, Eugene A. Graves, and W. Bryant Peterson, Instrumentation Services Division, and Mr. William H. Dulaney, Logistics Office, WES. Assistance in the field work was provided Dr. Stephen A. Lieberman and Mr. Gregory Theriault, Naval Ocean Systems Center.

Report preparation was done by Messrs. Cooper, Douglas, Sharp, Olsen, Gregory D. Comes, and Dr. Philip G. Malone, EEGD. Assistance was provided by Messrs. Ezell Allen, William Megehee, and Melvin Seid, EEGD. Mr. Cooper now works in the Environmental Laboratory, WES, and Dr. Malone works in the Structures Laboratory, WES.

The project was under the direct supervision of Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch, EEGD, Dr. A. G. Franklin, Chief, EEGD, and Dr. W. F. Marcuson III, Director, GL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Summary

At the request of the Naval Facilities Engineering Command (NAVFAC), Southern Division, Charleston, SC, the U.S. Army Engineer Waterways Experiment Station (WES) conducted the initial field trial of the Site Characterization and Analysis Penetrometer System (SCAPS) at Jacksonville Naval Air Station (NAS), Jacksonville, FL. This work was carried out by a field crew consisting of personnel from WES and the Naval Ocean Systems Center (NOSC) during the period 16 July 1990 to 14 August 1990. Funding was provided under NAVCOMP Form 2275, Order No. N6246790MP00907 dated 15 March 1990. Mr. Joel Murphy, Southern Division, NAVFAC, was the project monitor for this work.

The SCAPS investigation at the Jacksonville NAS had two primary objectives: (a) to provide data that could be useful in formulating remediation plans for the facility and (b) to provide for the initial field trial of the SCAPS currently under development by WES for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center. Since the investigation served both contaminant screening and continuing research and development interests, USATHAMA also provided support for this field investigation effort. Messrs. Paul Lurk and Wayne Sisk were USATHAMA project managers during this phase of the SCAPS program.

The original concept for the SCAPS was to develop an integrated site screening characterization system whose capabilities would include (a) surface mapping, (b) geophysical surveys using magnetic, induced electromagnetic, and radar instruments, (c) measurements of soil strength, soil electrical resistivity, and laser-induced soil fluorometry using screening instrumentation mounted in a soil penetrometer, (d) soil and fluid samplers, and (e) computerized data acquisition, interpretation, and visualization. The goal of the SCAPS program is to provide detailed, rapid, and cost-effective surface and subsurface data for input to site assessment/remediation efforts. Although a few system components had been previously field tested, this was the first field deployment of the full SCAPS with its unique fiber optic fluorescence detection tools.

The test areas selected for this work were located on the southern half of the Jacksonville NAS in a closed oil and solvent disposal pits area (site), approximately 300 m west of Mad Fox Drive (1,000 m west of the St. Johns

River) and bounded on the north by Child Street and on the south by Gannet Road. Oily wastes and used solvents had been disposed in this area in the past by pouring the liquids into open pits in the area and covering the pits over as they were filled. It is estimated that 265,000 to 475,000 ℓ of waste oil have been buried in the northern part of the area near Childs Street (Test Site 1) and over 3,600 ℓ of waste solvents and metal-finishing wastes have been buried in the southern part of the area (Test Site 2).

A geophysical survey was undertaken over the site, and separate measurements were made over the points where penetrometer pushes were planned. The survey systems were used to prevent metallic debris from damaging the instrumentation on the penetrometer. Sweeps were made using a magnetometer and an induced electromagnetic unit. The magnetometer showed primarily metal debris scattered over the area. No distinct pattern that could be related to the location of disposal pits could be found with the magnetometer over either Test Sites 1 or 2. The electromagnetic (E-M) survey (or soil conductivity survey) showed much higher variability over Test Site 1 (90 mhos/m range) than that over Test Site 2 (60 mhos/m range). Local low-conductivity locations were found in Test Site 1 that were approximately in the location of the oil burial pits. Ground-penetrating radar (GPR) was tested over known targets (metal pipe and culvert), but was not routinely employed. After testing with both antenna systems, E-M and magnetometer surveys were judged to be more effective than GPR for this site.

The site investigation was undertaken with a soil penetrometer unit *equipped to measure soil strength characteristics* and either soil fluorescence or soil electrical resistivity. The soil strength measurements (tip resistance and sleeve friction) were used to determine the soil type. Soil fluorescence was used as an indicator of oil contamination. Soil electrical resistivity (DC resistivity) was used to detect any contaminant that can alter the electrical properties of the soil.

In the course of the investigation, two sites were tested with the fiber optic (36 pushes) and resistivity (10 pushes) screening penetrometer tools. Five soil samples were obtained using a commercially available Mostap soil sampler. One fluid sample was obtained with a commercially developed Hydropunch sampler.

Thirty-four pushes were made at the oil disposal site (Test Site 1) using a laser-induced soil fluorometer. Tests with the unit demonstrated that it could detect the presence of oil at or above a concentration of 500 ppm. Determination of the detection limit was done using sand samples that were spiked with weighed amounts of marine diesel fuel. Estimates of the waste oil concentrations present were obtained by measuring the maximum fluorescence intensity within the spectral region of interest (350 to 550 nm) and calculating the corresponding oil concentration based on the calibration standards prepared from marine diesel fuel and clean sand. Fluorescence in petroleum products is dependent on the exact composition of the product, whether the oil is free or absorbed on the soil, and the soil pH and temperature. Because of the number of variables that can change the fluorescence response, the soil fluorometer is considered in this study to be a semiquantitative screening tool. Possible interferences from soil matrices and other fluorescing materials in the soil remain to be determined by further field and laboratory testing.

Data from the fluorometer are taken every 1 sec as the penetrometer rod is being advanced at a rate of 2 cm/second. The data obtained were used to produce a three-dimensional visualization of the shape and size of the mass of the contaminated soil. Visualizations were prepared for soil masses that showed increasingly high concentrations of oil. The positions of the highest concentration can be assumed to be the locations of the formerly used disposal pits.

Two pushes with the soil fluorometer were made at Test Site 2. The results showed no detectable fluorescence; the testing was continued at Site 2 with the electrical resistivity tool. Ten pushes were made with the electrical resistivity tool in the area of suspected solvent contamination (Test Site 2). An area of high resistivity was noted in several pushes at a depth of approximately 13 m (43 to 45 ft). A water sample was collected using the Hydropunch sampler and showed that the high resistivity was probably caused by the uncontaminated (clean) water present at this depth in the lower sandy unit at Test Site 2. The resistivity tool could not detect solvent contamination at the low levels (<5 ppm) reported at Test Site 2.

The following conclusions can be drawn from the field testing at the *Jacksonville NAS:*

a. The geophysical equipment functioned adequately and allowed the testing to be accomplished without damage to the penetrometer equipment.

b. The laser surveying equipment provided the resolution necessary for the location of the penetrometer holes.

c. The fluorometer successfully located the oil contamination at Test Site 1. The limit of detection with the fluorometer (as configured at the Jacksonville NAS) for diesel fuel and related oily waste is approximately 500 ppm.

d. The soil fluorometer did not respond to solvent contamination in the low levels (<5 ppm) present at Test Site 2.

e. The DC resistivity tool did not detect any consistent anomalies that could be attributed to solvent contamination at Test Site 2. The most persistent resistivity anomaly occurred at a depth of 13 m (43 to 45 ft). A water sample collected at the depth of the resistivity increase showed that the sand unit at this depth contained uncontaminated water. The very clean water in a sand unit is the cause for the high resistivity observed at the 13-m depth.

f. The commercially available soil sampler used performed satisfactorily until it was broken when encountering buried objects at depths below the limits of investigation. Conditions at the NAS test sites required that the water sampler be operated at depths exceeding the manufacturer's recommended maximum depth. The water sampler failed on the first push and was not available for the further sampling.

The field investigation conducted at the Jacksonville NAS has led to the following recommendations for future research:

a. The double-fiber fluorometer used at the NAS should become the standard design for future use in detecting hydrocarbons (POL).

b. The resistivity sensor should be specifically used when contrast in electrical properties is a major feature in the contaminated subsurface material. Work on a detection system for solvents should be emphasized in future research programs.

c. Soil strength measurements should be continued as an integral part of the sensor systems.

d. Attempts should be made to obtain more robust water and soil samplers either by modifying the commercial unit or preparing a new design.

e. Future field efforts should include side-by-side comparison of sensor output and sample analyses so that the response of the sensors can be carefully assessed under a variety of field conditions. Future studies should also be used to address adverse soil matrix effects and interference from other fluorescing compounds that may be present in soil. Such effects could prove troublesome, particularly at low concentrations of contamination.

f. A nonhazardous substance should be developed for use in an in situ grouting system that will allow for grouting as the probe is retracted.

1 Introduction

Background

In 1988, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center, tasked the U.S. Army Engineer Waterways Experiment Station (WES) to accelerate development of a rapid and cost-effective penetrometer system for hazardous waste site soils assessments. In 1989, the project was designated as a Tri-Services (Army, Navy, Air Force) program with USATHAMA as the lead agency and WES as principal developer of a Site Characterization and Analysis Penetrometer System (SCAPS). The objective of the SCAPS development program is to provide equipment and methods that can be used to collect soils characterization data and contaminant screening data onsite so that remediation decisions can be expedited. The truck-mounted SCAPS (Figure 1) provides a basis for this work by combining a rapid mapping capability, geophysical equipment for reconnaissance surveys, penetrometer screening tools or sensor systems for soils characterization and contaminant detection, penetrometer-based samplers, computerized data acquisition, and onsite data processing. Data on soil type and soil contamination are interpreted using a three-dimensional (3-D) visualization program (Interactive Volume Model or IVM), which is used offsite after data are acquired. The program takes soil data and measurements of the level of contamination in soil and produces 3-D gridded data that depicts the contaminated zones as a series of shells or interrelated shapes in the gridded space. The interaction of the components of the SCAPS is shown graphically in Figure 2.

At the time the investigation reported here was undertaken, the SCAPS, although not completed, included innovative software and hardware that required evaluation under realistic field conditions. Among the more important developments to be tested was the first fiber optic fluorometric sensor developed for in situ measurements of fluorescence in soils. Using laser excitation, this sensor system has proven capable of detecting the fluorescence of dyes injected into soil, as well as petroleum, oil, and lubricants mixed in soils in the laboratory (Cooper, Malone, and Lieberman 1990). Since the first version of the truck-mounted SCAPS had recently been assembled and two prototype contaminant sensors had been developed (a resistivity-measuring unit and fiber

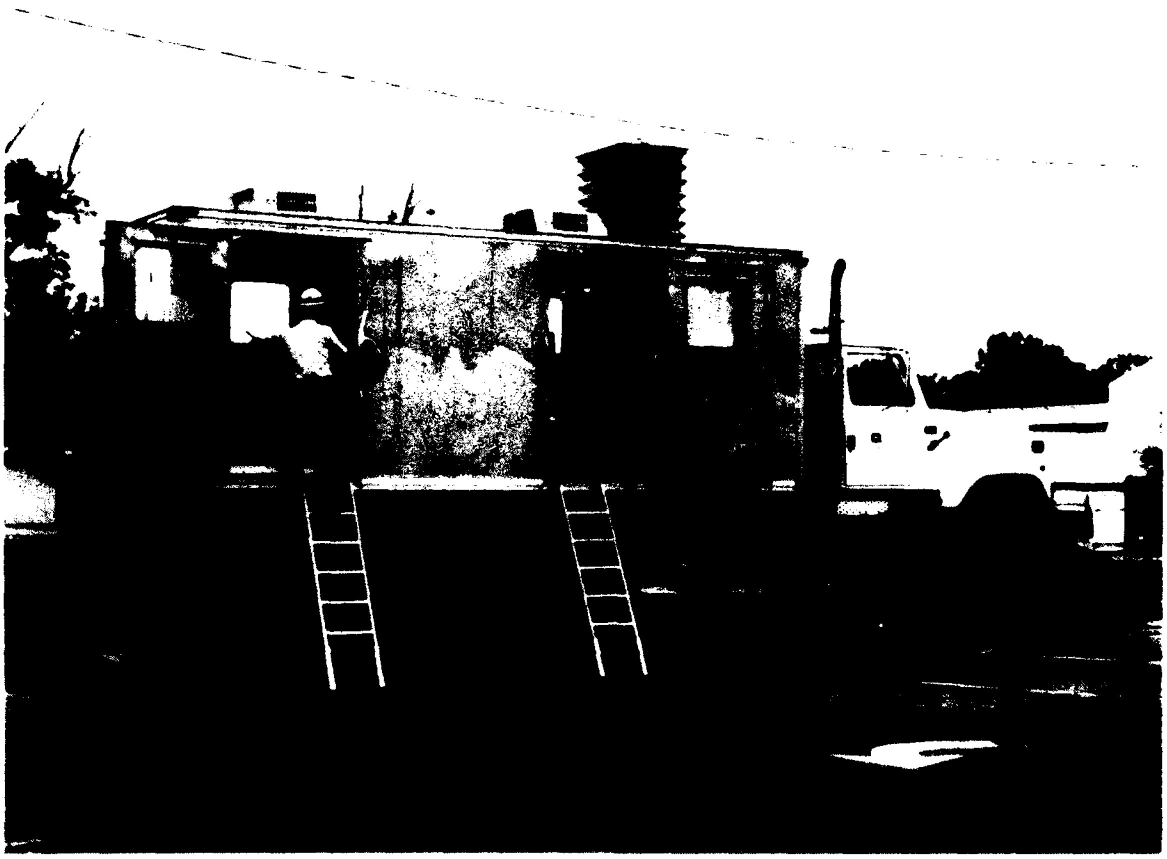


Figure 1. SCAPS penetrometer truck

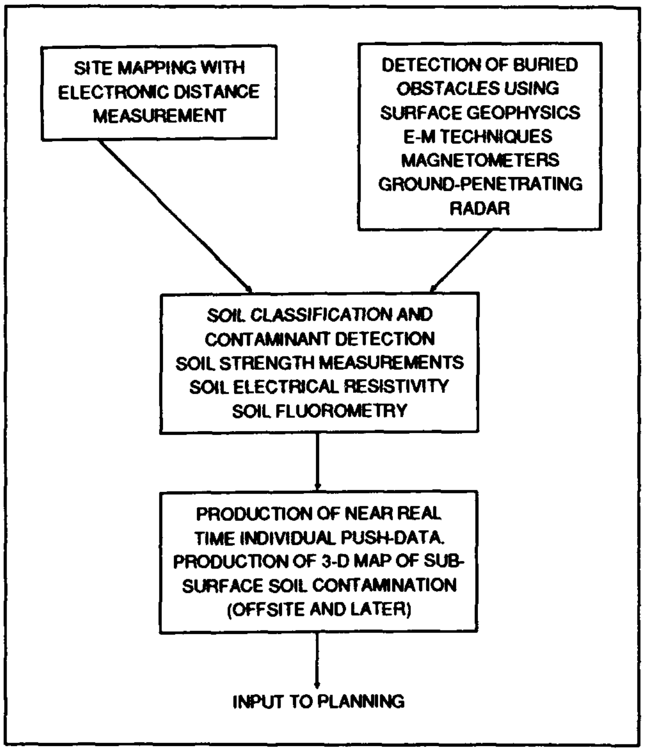


Figure 2. Components of the Site Characterization and Analysis Penetrometer System (SCAPS)

optic soil fluorometer), the decision was made to conduct proof-of-concept field testing of the system.

In discussions with the staff of the Southern Division Naval Facilities Engineering Command, Charleston, SC, Naval Air Station (NAS), Jacksonville, FL, was proposed as a candidate site for the initial field testing of the SCAPS unit. The Jacksonville NAS had several potentially useful test areas including a closed oil disposal site and a closed solvent disposal area.

The closed disposal sites were intensively studied to control the movement of petroleum, oil, and lubricant (POL) wastes. Additional remediation studies are underway. The sites allowed the field evaluation of the SCAPS unit with relatively low exposure risks to the personnel and equipment. Information developed with the SCAPS equipment can be used as input to remediation planning.

Purpose

The purpose of this field exercise was to evaluate all of the components and software developed for the SCAPS system at a documented field site where known contamination was present. The goal of the field exercise was to compare the site screening data available from SCAPS with data obtained from conventional site investigation results. The field exercise was also an opportunity for assembling new configurations of the equipment as difficulties were observed in the existing setup. The field operations consisted of testing, modification, and additional testing to optimize the penetrometer unit and to evaluate the visualization system.

Scope

Geophysical survey techniques (magnetometer, induced electromagnetic measurements, and ground-penetrating radar) were used to scan the area for buried metal objects that would be obstacles for the penetrometer and to look for patterns of disturbed ground that would indicate the location of burial pits. In the process of surveying, the usefulness of each survey technique was evaluated.

The field exercise reported here involved using the soil stratigraphic characterization capabilities of the SCAPS at both an oil disposal site and a solvent disposal site. The resistivity sensor was tested primarily in the solvent disposal area. The soil fluorometer was used to map oil contamination at the oil disposal area.

The data collected on the site were displayed as profiles and partly analyzed onsite. The results from the oil contamination mapping were further analyzed after the field work was complete by using a computer visualization system.

The visualization system contours the concentrations of the contaminant of interest and allows changes in the contouring parameters (interaction of the data points) and addition of extended data sets as they are developed.

The initial field testing of the SCAPS unit was undertaken at a well-documented site where soil contamination investigations are continuing in order to have comparative data on the extent of soil contamination that had been collected prior to this field investigation using conventional approaches such as drilling, sampling, and analysis of samples. The field investigation did not include extensive comparative sampling and testing to develop a sample-by-sample comparison of sensor output and laboratory analyses. Only five soil samples were analyzed to assist in interpreting data from the fluorometric sensor. Two soil samples and one water sample were collected from the area where the resistivity sensor had been used. The sampling effort provided the basis for an evaluation of the penetrometer-based soil and water samplers.

2 Description of Equipment

The SCAPS includes a suite of surface geophysical equipment, survey and mapping equipment, special penetrometers with sensors for contaminant detection, and soil and pore fluid penetrometer samplers. The SCAPS system is mounted in a uniquely engineered truck designed with protected work spaces to allow access to toxic and hazardous sites while minimizing exposure of the work crew. The SCAPS screening penetrometers are equipped with sensors that can determine physical and chemical characteristics of the soil as the penetrometer tip is forced through the soil. The SCAPS includes sensors that can determine the strength, electrical resistivity, and spectral properties—in this case, the fluorescence of soils. All sensors read out in real time, and a computer-based data collection and analysis system permits a display and partial interpretation of data in the instrument compartment on the penetrometer truck. The data analysis system also allows processing of various types of surface geophysical and mapping data collected onsite and integration of data into a unified database. Fluid and soil samples can be collected using devices such as the "Hydropunch" and the Mostap soil sampler that are designed for use with penetrometers. The SCAPS system is also equipped to seal each penetrometer hole with grout as the geotechnical investigation proceeds across a site. However, tremie grouting with a cement-bentonite mixture was used at this site because of concerns about the toxicity of the only two-component polymer grout formulation available at the time. SCAPS is designed to save time and costs and to minimize exposure of the crew while sensor data or samples are collected. The SCAPS unit is built so that surfaces and compartments exposed to waste can be thoroughly and completely decontaminated. No penetrometer units available in the private sector have this combination of capabilities.

Site Mapping Equipment

The location of penetrometer push points and the layout of the geophysical survey stations is done using a Total Station Electronic Distance Measuring (EDM) System. The site mapping work at the Jacksonville NAS was done with a Topcon EDM unit equipped with a Leitz Electronic Notebook. The electronic notebook was read into an HP Vectra computer in the penetrometer truck, and preliminary processing was done in the field. The final site maps were generated at WES using an AutoCad version on an Intergraph Microstation.

Geophysical Survey Equipment

A geophysical site survey was undertaken primarily to determine if there was metallic debris in the area where the penetrometer unit would be operating. A secondary objective was to determine if there was any geophysical evidence of burial pits that had been reported to have been used for oil disposal. Three different geophysical techniques were evaluated on the Jacksonville NAS site. Total magnetic field intensity was measured using an EDA OMNI IV Magnetometer System. Soil conductivity was determined with Geonics EM-31 Terrain Conductivity System run in a configuration that measured the quadrature-phase component—that part of the EM signal that is most sensitive to changes in earth conductivity. A ground-probing radar (GSSI model 4800 GPR) was evaluated at several locations where known targets such as utility pipes or culverts were present.

Penetrometer Screening Equipment

The major component of the SCAPS system is a 20-ton (18,143-lb), all-wheel-drive truck that was designed specifically for operations at hazardous waste sites. The truck carries a hydraulic power unit and controls to operate the push apparatus, a power takeoff-driven 25-kw generator, dual air conditioning units, separated push and data acquisition work spaces, a shock-isolated floor for the electronics package, easily decontaminated stainless steel van body, and numerous other personnel protection features. A specially designed trailer is used to carry the grouting pumps, water tank, and a closed loop steam cleaner to clean the penetrometer rods and tools as they are withdrawn from the soil.

The electronics package includes WES-designed and built signal-conditioning hardware and test equipment capable of providing onsite calibrations of contaminant detectors and load cells used to measure the force required to overcome soil penetration resistance.

Data acquisition and initial data processing are carried out with an HP Vectra 25 Mhz computer, and a matching computer is used for data management and file integration. The second computer affords redundancy in the event of a computer failure. Postprocessing of the data to provide a 3-D visualization of site conditions is presently done with a computer work station that can be used at WES or brought to the installation.

The use of the soil strength measurements (cone tip and sleeve friction) made with the cone penetrometer to determine soil type has been well-documented (Campanella and Roberts 1982; Olsen 1988; Olsen and Farr

1986). The design of the equipment and the interpretation technique used in this study have been described in Cooper et al. (1988).

The soil electrical (DC) resistivity measurements were made using equipment similar to that described in Cooper et al. (1988). Calibration and operation followed standard practices described in detail in this same reference.

The soil fluorometer was adapted from a design developed by Lieberman, Inman, and Theriault (1989) for use in measuring fluorescence in seawater. A schematic of the system is presented in Figure 3. In making a measurement, the exciting radiation is produced by firing a pulsed nitrogen laser (emitting at 337 nm). The laser light is separated with a beam splitter, and a part of the pulse is used to start the timing circuit for the detector. The major part of the pulse is directed into a 250-µm optical fiber by passing it through a 3-mm-diam hole in the backside of a mirror oriented at 45 deg to the path of the beam. The exciting radiation passes down the fiber that runs through the center of the penetrometer rod. The fiber ends at a 6.35-mm sapphire window that passes the light onto the soil surface adjacent to the window. The fluorescence signal is collected by the same fiber and returned to the mirror and optically coupled to the polychromator. The dispersed energy is measured using a linear photodiode array and an optical multichannel analyzer. This system is much faster than the traditional scanning spectro-fluorometers. Readout of an entire emission spectrum requires only 15 msec. The rapidity of the readout makes it practical to "stack" or add successive pulses and increase the sensitivity of the unit.

An improved version of the fiber optic fluorometer became available while the penetrometer unit was at the Jacksonville NAS. The new system involved changing the single-fiber cable to use a newly developed two-fiber cable and eliminating one mirror. The parts were brought into the field and the fluorometer was modified on the spot. The new unit was aligned and calibrated and data collection continued. The two-fiber fluorometer operated in the same way as the single-fiber system described above, but required less attention to alignment and provided greater sensitivity.

The soil fluorometer employing the nitrogen laser excitation source was run with a variety of standards prepared from clay and sand matrices. In this case, the typical limit for the detection of fresh diesel fuel is 500 ppm by weight in soil. Initial work indicates the moisture content of the solid has little effect on the fluorescence response. The response of the fluorometer is directly related to the concentration of aromatic compounds in the hydrocarbon fuel.

The fluorescence data available from the soil probe presents unique problems in data reduction and interpretation. Each fluorescence spectrum consists of intensities measured at 1,024 points for every 2-cm (0.8-in.) layer of soil investigated. A fully operational soil probe (or penetrometer) has the potential to investigate a total of 210 m (700 ft.) of soil in a single day. This amount of data can make interpretation slow. The present data processing system records all spectral intensity measurements and makes corrections for standards and for

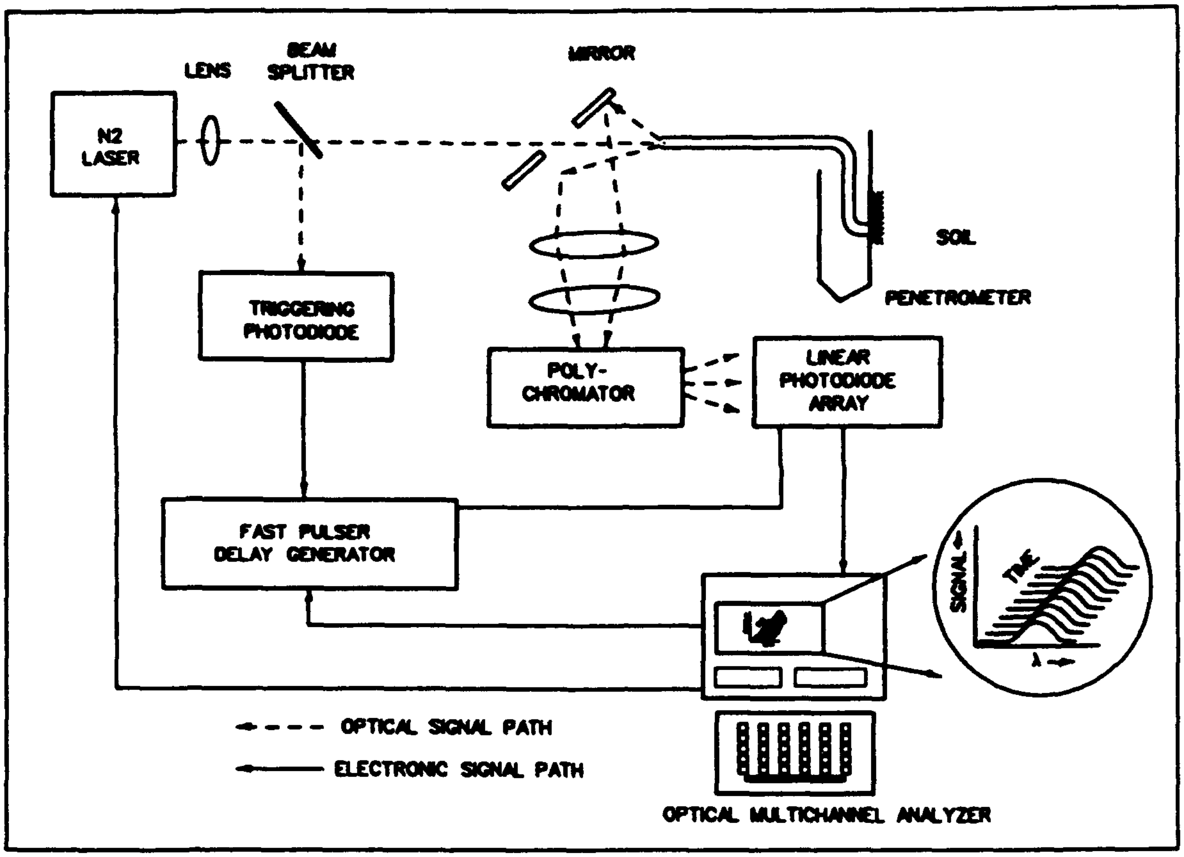


Figure 3. Schematic diagram of the soil fluorometer

instrument drift during measurement. The corrected data are screened to develop the photon counts for the peak of interest and the background. The peak height is then compared with a calibration curve prepared with the contaminant in a soil matrix similar to that found on the site being investigated. A file showing the estimated contaminant concentration, the map coordinates, and the depth below a surveyed datum is prepared from the spectral data. The final data file is transformed into a 3-D gridded file and is plotted using a visualization program.

The soil fluorometer system has wide application in the delineation of contaminated soil produced by leaks or spills of diesel fuel, gasoline, and other POL products. Although most chemical compounds used in industry do not fluoresce, those that do are also relatively common constituents in industrial-grade solvents and degreasers. Optical brighteners that are being commonly incorporated in cleaners and detergents can also provide a fluorescing tracer for wastewater.

The Jacksonville NAS site has relatively high concentrations of heavy-bodied long chain hydrocarbons that were readily detected by the SCAPS laser system as currently configured; however, more field and laboratory testing are needed to assess the effect of soil matrices and possible interference from other fluorescent materials that may be present in soil.

Penetrometer Sampling Equipment

At present, SCAPS is using commercially available samplers for collecting groundwater and soil samples. Groundwater sampling was attempted with a Hydropunch Sampler (QED Inc., Ann Arbor, MI). The Hydropunch sampler mounts on the end of the penetrometer push rod and can be used to obtain a groundwater sample of approximately 200-ml volume. The maximum sample depth is determined by the strength and type of soil through which the sampler is pushed. The maximum load that can be put on the sampler during a sampling push is approximately 67 MPa (700 tsf). The maximum depth proved to be approximately 15 m (45 ft).

The Mostap Sampler (A. P. Van der Berg, Netherlands) used was a "stab-type" sampler designed to collect a soil core that was 35 mm in diameter and up to 1 m (3.03 ft) long. The sampler mounts on the end of the conventional penetrometer push rod. The maximum depth for sampling is estimated by the manufacturer to be approximately 60 m (196 ft). The practical depth of sampling depends on the strength and the type of soil and the presence of buried items in the soil that can damage the samplers. Both units were tested to near or beyond their structural limits, which resulted in structural failures.

Automated Data Acquisition/Processing

The data acquisition system and the postprocessing system each have a separate computer in control. The two computers are linked with a token network so that data can be exchanged during and after the penetration testing.

The data acquisition computer controls all systems and stores all the data on a demountable hard disk during the penetration test. The major block of data is generated by the soil fluorometer system in the optical multichannel analyzer (OMA). The OMA is a separate computer that is controlled by the data acquisition computer through a general purpose interface bus. The data acquisition is also interfaced directly with the amplifier/filter components for the measurement of strain on the cone tip and sleeve, amplifiers for the electrical resistivity measurements, a variable potentiometer that reads out the position of the hydraulic rams (data used to calculate the depth of the penetrometer tip), and the computer token network.

The postprocessing computer can exchange data with the data acquisition computer using the token network during and after a penetration test. The postprocessing computer can be used while the data acquisition computer is acquiring data for file editing, individual penetration test plotting, pollution plume plotting, interfacing with the survey field notebook equipment, site plan plotting, or project documentation.

Computerized Site Characterization/Visualization

The SCAPS unit has the potential to investigate approximately 210 m (700 ft.) of soil per day, although the SCAPS has not met that potential yet. This level of activity can generate a massive amount of data on the variation of point resistance, sleeve friction, soil electrical resistance, and soil fluorescence. Measurements are typically made at 2-cm (0.8-in.) intervals. Currently, penetrometer data are being interpreted using 3-D visualization performed using Interactive Volume Modeler (IVM) software developed by Dynamic Graphics, Inc. (Alameda, CA) on a Silicon Graphics (Mt. View, CA) workstation. The IVM accepts scattered data file in ASCII format and creates a uniform 3-D grid. Smooth extrapolation and interpretation for points is used to create grid values within and near the existing data. A lateral clipping plane is created to clip extrapolated data outside the bounds of the original data. The basic data controls the location of each known value, but the aspect of the final 3-D shapes produced from a data set can be altered by varying the spacing on the 3-D grid derived from the original data. Typically, the spacing values for the derived grid are selected by examining 3-D volume plots and observing which spacing combination produces a plot that most closely agrees with the original data points.

3 Activities at the Jacksonville Naval Air Station Test Site

Site History

Jacksonville NAS is located south of Jacksonville, in Duval County, Florida (Figure 4). This report summarizes an investigation undertaken at a waste and solvent disposal area approximately 1,000 m west of the St. Johns River. There are two documented closed oil pits (Sites No. 1 and 3 in Figure 5) and one solvent disposal pit (Site No. 2 in Figure 5). The general area northeast and southwest of Childs Road has been used as a disposal area for several decades. Wastes dumped in the disposal area included spent lubricating oil, residues from the paint shops, solvents, cold-carbon remover, and other waste liquids and residues (Geraghty and Miller, Inc. 1980). Most of the waste disposal activities for the shops and maintenance areas involved burying the materials in the three disposal areas. Disposal procedures involved digging trenches and pits and pouring the waste directly into the pits. Records indicate drummed wastes were not a major component of the disposed materials.

In a report prepared in 1980, investigators noted that depressions indicating former disposal pits could be found both northeast and southwest of Childs Road (Geraghty and Miller, Inc. 1980). Borings made in the area east and west of Childs Road indicated oil was present floating on the groundwater. Borings that showed floating products also had dissolved oil in water through the entire thickness of the boring (0.6 to 0.8 m). In 33 borings and wells, the oil floating on the water table averaged 4 cm (1.5 in.). In other borings, the oil was an emulsion and no distinct layer was present. The report estimated that the quantity of waste oil on the site was 265,000 to 475,000 ℓ (70,000 to 125,000 gal).

The waste disposal site also received a wide variety of organic solvents. The primary pits for disposal of organic solvents in the test area are labeled as Site 2 in Figure 5. This area received a large volume of used degreasing and paint-stripping solvents. The compounds present in the solvent and strippers were as follows:

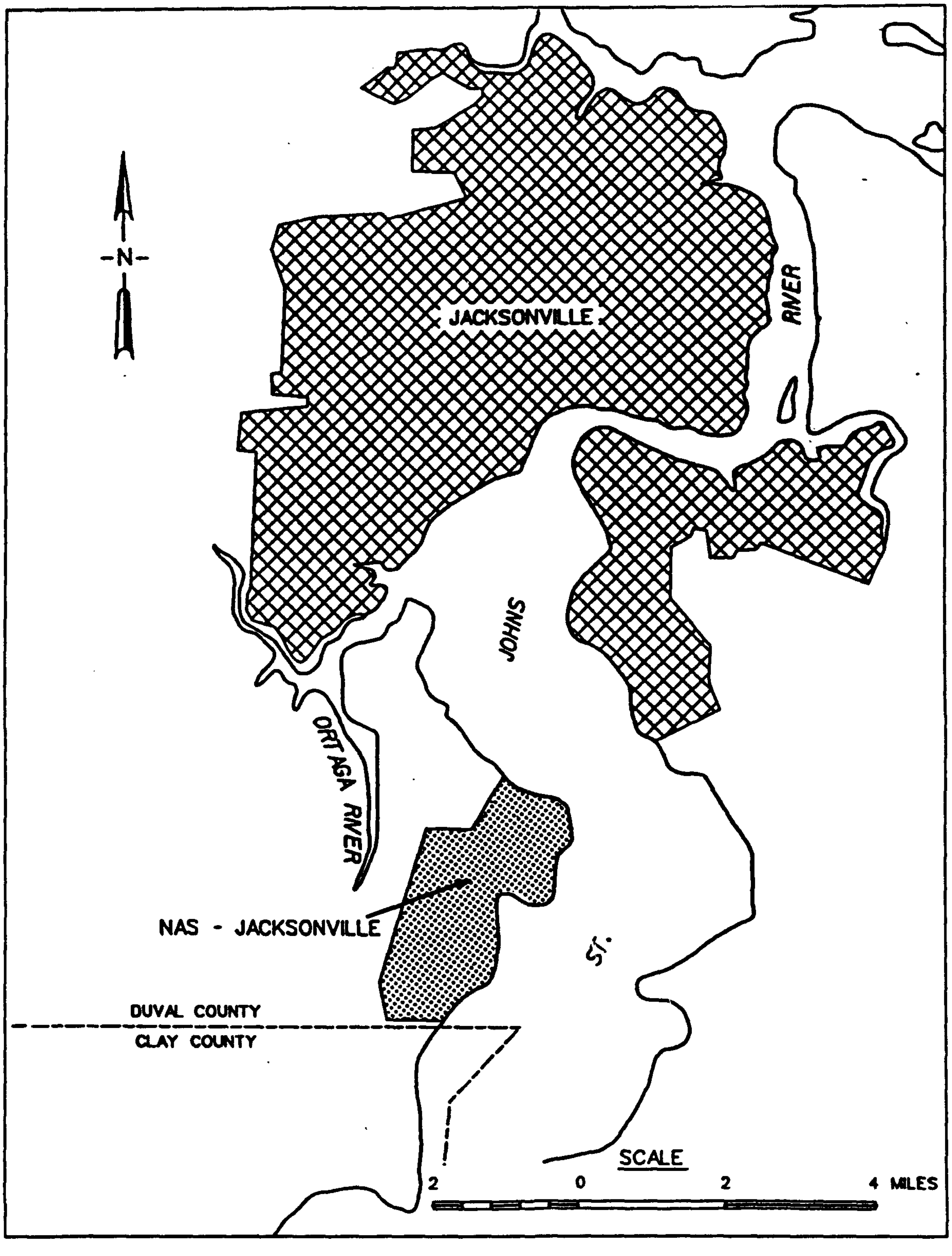


Figure 4. Jacksonville Naval Air Station

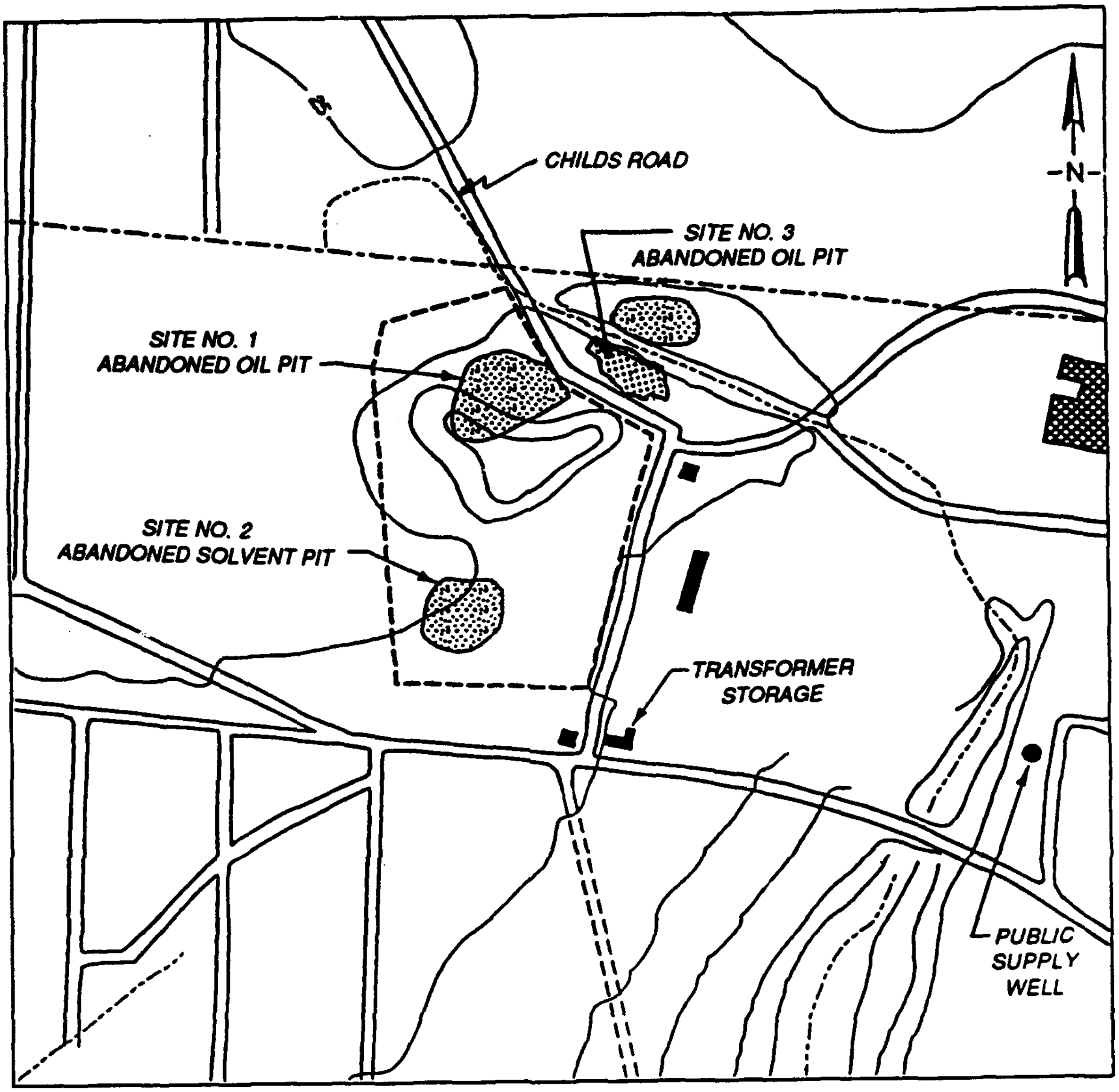


Figure 5. Oil disposal area and solvent disposal area from Gerharty and Miller, Inc. (1980)

methylene chloride
methylethyl ketone
ethyl acetate
trichloroethylene
methyl isobutyl ketone
n-butyl acetate
xylene

The ketones and methylene chloride are ingredients in the paint stripper; trichloroethylene and methylene chloride are major constituents in the degreaser. The acetates and xylene are associated with paint stripper and lacquer solvents. Past activity records indicate that 800 ℓ (200 gal) per week of cold carbon cleaner, 1,200 ℓ (300 gal) of used degreaser, and 2,400 ℓ (600 gal) of paint stripper per week were disposed on the site for several decades.

In the 1980 study, only four compounds suspected of being dumped in the disposal site were found. These were as follows:

methylethyl ketone	(188 ppb)
trichloroethylene	(62 ppb)
methyl isobutyl ketone	(40 ppb)
xylene	(120 ppb)

The disposal of paint-stripping waste also produced the possibility of contamination of the groundwater with heavy metals. Groundwater samples across the area were analyzed for heavy metals. Metal levels above the U.S. Environmental Protection Agency (EPA) Interim Drinking Water Standards were found in wells along the west side of the test site and in the plume areas northeast and southwest of Childs Road. The high levels of metal contaminants in the waste oil dumped at the site may account for the heavy metal contamination noted. The highest concentrations observed were as follows:

cadmium	(67 ppb)
chromium	(588 ppb)
lead	(1,324 ppb)
mercury	(7.2 ppb)

Site Description

The test site can be characterized as an open grassy field with occasional stands of trees, mostly flat, with maximum site relief on the order of 0.3 to 1 m (1 to 3 ft). Access to most test locations on the site was good to excellent, and no trafficability problems (mud, etc.) were encountered, even in wet weather. A map of the site is shown in Figure 6.

Safety Program

The safety plan for operations at the oil and volatile products disposal pits was developed after a review of the past work at the test site and consultation with the NAS. The major hazard at the site consisted of fuel and diluted chlorinated solvents. The crew was equipped to operate with Level C personal protective equipment inside and outside the penetrometer truck. After arrival on the site and after site surveillance, the decision was made to move to Level D personal protection equipment. As a precaution against any exposure problems, Level C equipment, especially respirators and chemical-resistant coveralls, were maintained within easy reach of personnel in the penetrometer

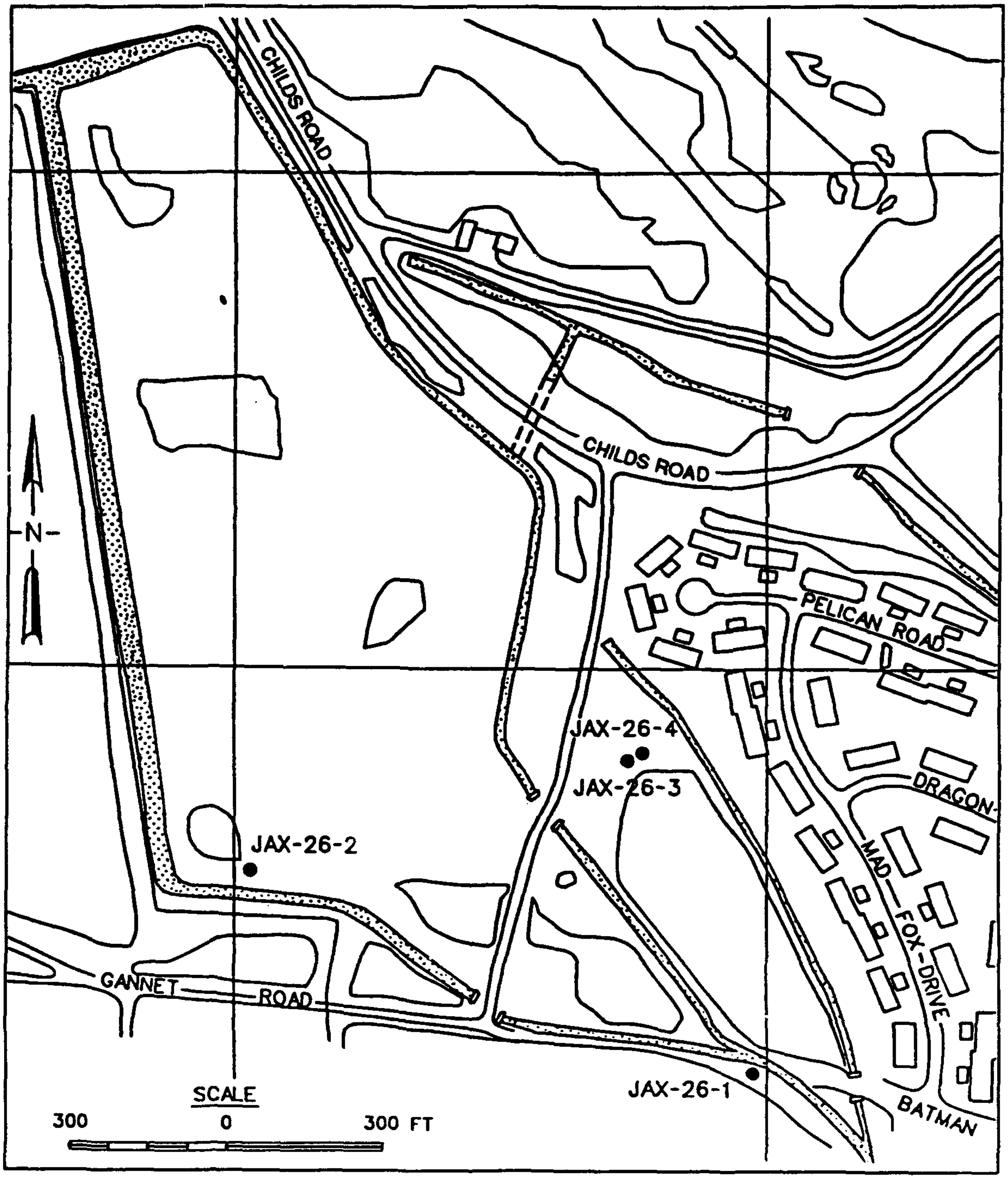


Figure 6. Overall map of test areas

truck. Additionally, chemical-resistant gloves were worn, and escape masks were kept available in the truck.

A separate laser safety plan was developed for use by personnel operating the nitrogen laser used for fluorescence excitation and the helium-neon alignment laser. This plan called for safety goggles and power interlocks on the laser equipment, as well as restricting access to the instrumentation compartment during laser operation.

The atmosphere in the truck was monitored intermittently using a Foxboro Organic Vapor Analyzer (OVA). The OVA was also used to monitor for the presence of volatile organic solvents on the penetrometer rods as they were withdrawn from the soil and any gases issuing from the penetrometer hole.

Geophysical Site Investigation

A grid was established covering the areas where station records indicated the disposal activity had taken place. The layout used is shown in Figure 7. The "north-south" grid lines were laid out on a bearing of 15 deg west if true north to accommodate the irregular shape of the survey area. The stations on the gird were on 14.4-m (50-ft) centers. The geophysical measurement stations were identified with plastic (nonmagnetic) markers. The area in the immediate vicinity of Childs Road and the area east of Childs Road were not included in the survey gird because the utility lines associated with the road right-of-way provided false anomalies and concealed any anomalies caused by waste disposal activities.

Magnetic measurements were taken throughout the grid to locate metal debris on the site. The magnetic survey was made using a "looping procedure" where one point was established as the base, and the base station was reoccupied at approximately 30-min intervals. The repeated measurements at the base station were used to correct for any drift in the earth's magnetic field.

The EM-31 system was used to take conductivity measurements at all survey points. The unit was operated with the transmitter and receiver poles oriented vertically to give the maximum depth of investigation.

The ground-penetrating radar (GPR) unit was tested over known targets (metal pipe and culvert). Both the 300-Hz antenna and the 100-Hz antenna were run on a trial basis. However, neither antenna used produced satisfactory results against these known targets, and the GPR was not used in the general survey of the test site.

Field Testing for Petroleum-Contaminated Soils

The fluorometric sensor presented some unusual problems in calibration in that the fluorescence peak measured in the waste oil/soil samples found at Site 1 occurred in a broad area between 350 and 550 nm. The fluorometry unit was set up to search the area from 350 to 550 nm in 0.2-nm increments and to present the maximum count for any single channel (0.2-nm bandwidth) in that interval. This procedure was necessary because of the wide variety of

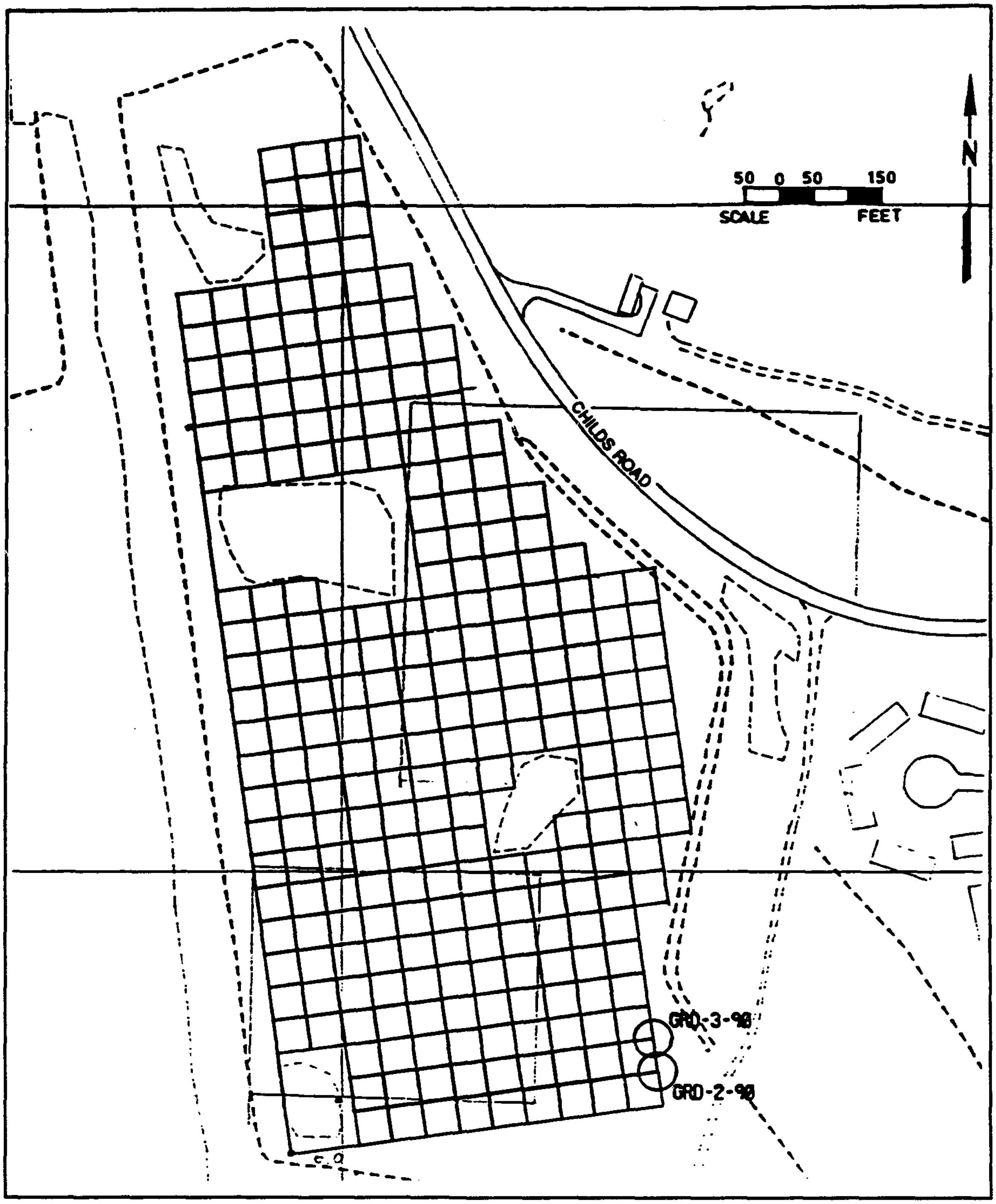


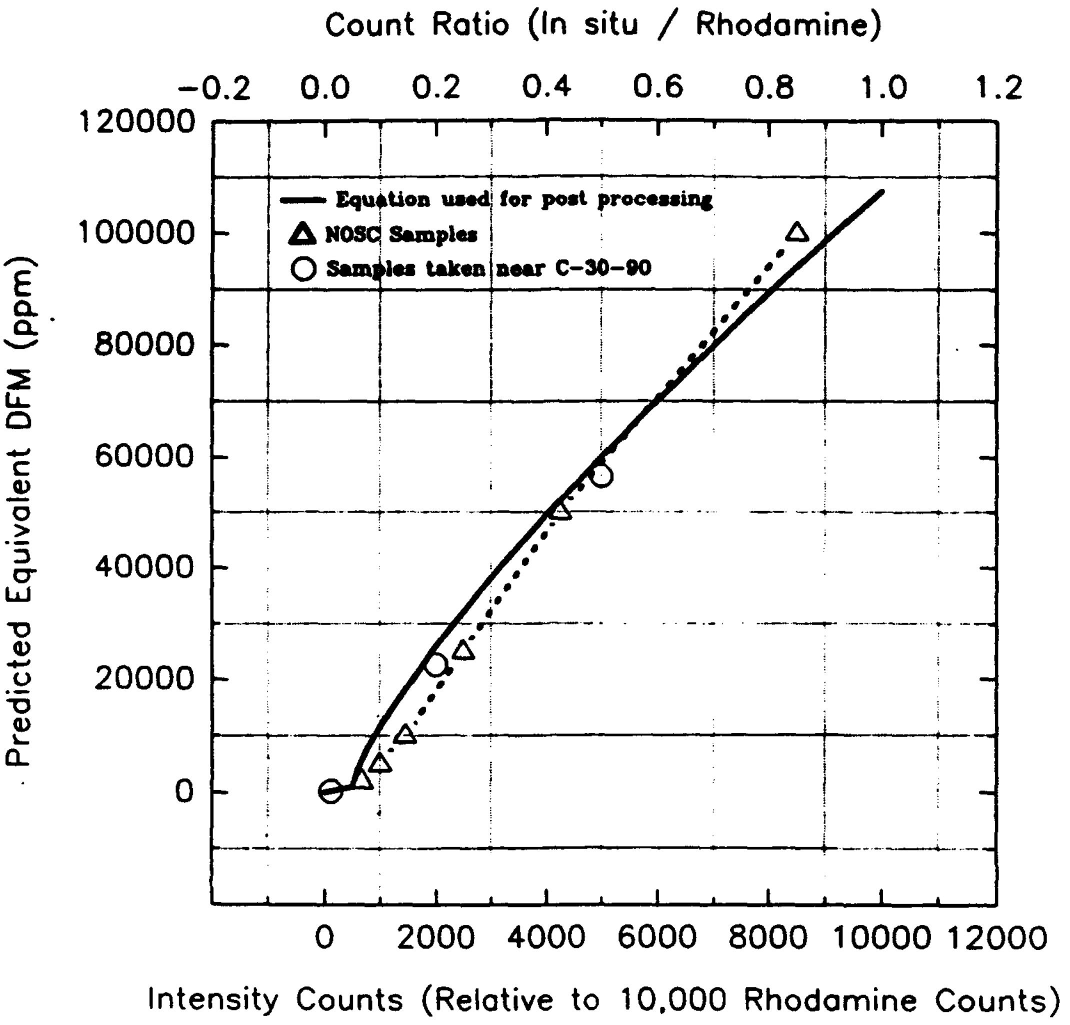
Figure 7. Outline of grid for geophysical survey of overall site

aromatic compounds in the waste oil mixture present in the soil. The different compounds fluoresced at different wavelengths, and not every compound was abundant or even present in every soil sample examined. In order to present the data with some reference to its origin (a petroleum product), standards were made up using weighed amounts of clean diesel fuel in sand. It was recognized early in the development of the SCAPS laser induced fluorescence (LIF) system that some means of intersystem verification would be a necessary requirement. This was due to the inherent variability of optical systems and the need to relate optical system performance to some known and easily verifiable standard. Hence, the need emerged to develop and adapt a 10 micro molar solution of rhodamine dye as a within-system verification standard (Figure 8). In this way, the standard rhodamine solution could be used in a sealed cuvette to monitor the optical system performance over time and to account for the variability of fluorescence counts among tools of varying sensitivity since it was expected that there would be subtle variations in the optical performance of each LIF tool as a result of manufacturing and optical path tolerances. In this way, within-system variations could be compensated for and reasonable variations in sensitivity on a single system output could be related (normalized) to a common standard over time or account for variability in performance among tools (manufactured at different times and to differing specifications). For example, the maximum output of any serially numbered LIF tool could be related to a common calibration standard, and the comparison of maximum calibration counts to a measured count could be used to calculate concentration, even among tools with wide variations in optical performance. Also, this procedure could be used to evaluate system performance changes (for example, to identify a subtle or dramatic change in overall performance of a given tool with time and/or damage incurred during penetration). This approach would provide a powerful diagnostic control in the event of either gradual or catastrophic system degradation and was viewed as an essential step.

Next, it was understood that with a wide variety of possible POL wastes, it was unlikely that any single calibration procedure could prove to be clinically accurate in a comparison of POL concentration based on fluorescence measurements with laboratory analytic procedures based on tests of specific sample. For example, the fluorescence measurements are a relative index of fluorescence over a 1-in. or less depth interval, whereas the laboratory test makes use of a homogenized sample of sufficient volume to satisfy an arbitrary standard. Extreme care must be taken to relate the in situ LIF method to any laboratory test method for oil and grease (O & G), total recoverable petroleum hydrocarbons, or other standard laboratory procedures. However, if the LIF procedure is intended to provide a relative measure of concentration, then it satisfies its primary role as a screening tool. The essence of its worth is that it can indicate areas where further testing (via laboratory accepted regulatory methodology) is required to define the final answer as opposed to testing everything in a 3-D soil matrix in hopes of defining the problem. For more than 50 years, the oil industry has made use of screening methods to identify potential zones of interest for further investigation, rather than using an arbitrarily decided, closely spaced sampling technique as a cost-effective means to provide the needed information. The screening method approach, governed basically by proven results and economics, is advocated here and is the preferred methodology for large-scale investigations in terms of either depth or areal extent or both. In this scenario, concentrating effort where it is needed is preferred over any "scatter" methodology that may be exquisitely accurate but is also inherently haphazard and unsystematic since it does not rely on the detailed knowledge of in situ conditions that the penetrometer routinely provides.

The fluorometric sensor was calibrated prior to use by filling a test cell fitted over the detector window with clean sand thoroughly mixed with a carefully weighed amount of clean diesel fuel (marine). The test cell was designed to provide infinite thickness for the exciting ultraviolet radiation. The diesel fuel/sand samples were prepared in the laboratory at the Naval Ocean Systems Center from cleaned, dried Ottawa sand and fresh marine diesel fuel and brought to the field in sealed containers. Calibration samples were used only once and discarded after use because of the volatility of the fuel. Calibration curves were prepared by measuring the maximum fluorescence (in counts) of the diesel fuel/sand sample and plotting the count against the concentration of the diesel fuel (in ppm by weight). The maximum fluorescence of the diesel fuel occurred consistently at 440 nm. The data are presented as the equivalent concentration of diesel fuel (marine) or DFM that would produce the same intensity of fluorescence.

Field testing began with several resistivity and fiber optic trial pushes in close proximity to the ditch (north center, Test Area 1). The intent of the trial pushes was to see if the equipment could detect the relatively high concentration of POL known to exist at the location from visible oil seepage into the ditch. The trials were successful in that both the resistivity and the fiber optic systems registered strong anomalous responses at depths (3 to 4.5 m) and locations that were consistent with the visible POL seepage into the ditch. Samples dug from the POL seepage zones in the walls of the ditch were also held against the fiber optic sensor port, with the tool at the surface; these samples showed spectral responses that were virtually identical to the anomalies measured during the pushes. Surface samples of clean sand taken from Area 1 and at other locations on the station were similarly tested and showed no spectral anomalies. The good agreement among resistivity and fiber optic observations and the spectral correlation with contaminated samples were indications that the resistivity and fiber optic tools were capable of detecting moderate to high POL concentrations in situ at this site. This was an important determination. The fiber optic sensor had been bench tested in the laboratory only against available fresh petroleum products, whereas the petroleum contaminants at this site had been in the soil for 5 to 20 years at least. In addition, there was no database available to predict fluorescence variation as a function of product aging, mixing of hydrocarbon products, or changes in situ. In view of these uncertainties, the initial results were most encouraging, and the decision was made to continue field testing. The locations of Test Areas 1 and 2 are shown in Figure 9.



If Ratio <= 0.05 then DFM(ppm) = [Ratio * 2] * 10,000
If Ratio > 0.05 then DFM(ppm) = [Ratio * 2 + ((((ratio - 0.05/0.45)^0.75)*5)] * 10,000

Figure 8. Rhodamine calibration counts

Locations of 34 fiber optic and resistivity screening tool test pushes completed in Area 1 (POL-contaminated area) are shown in Figure 10. The investigation in Area 1 was continued as an exploration to delineate the POL plume boundaries to the limit of detection provided by the tools used.

Field Testing for Solvent-Contaminated Soils

Area 2, shown in Figure 11, is a closed solvents dumping area. The major contaminants of interest are trichloroethylene and methylene chloride, which are known to have been extensively used as a solvent in cleaning operations at

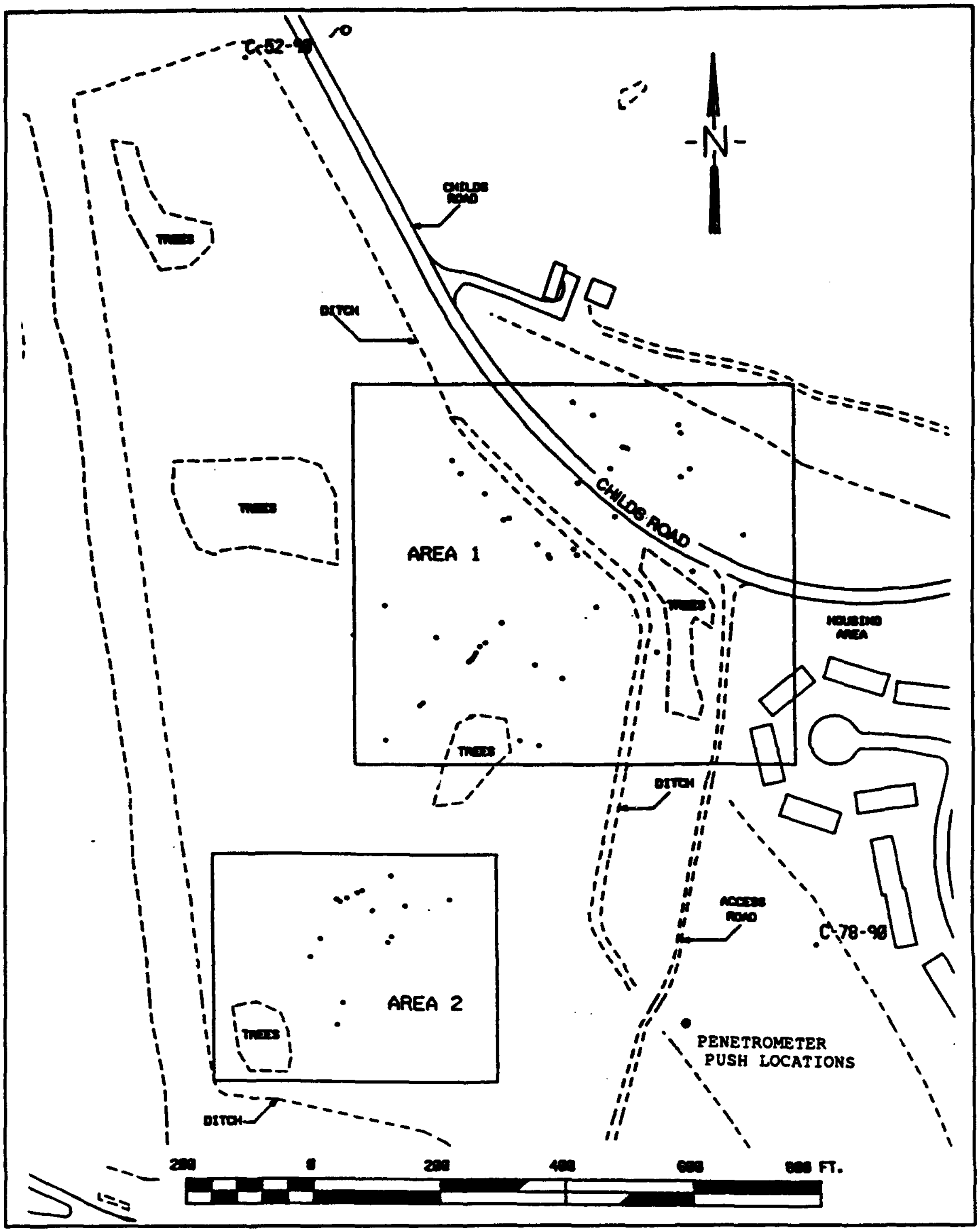


Figure 9. Location of penetrometer pushes in both test areas

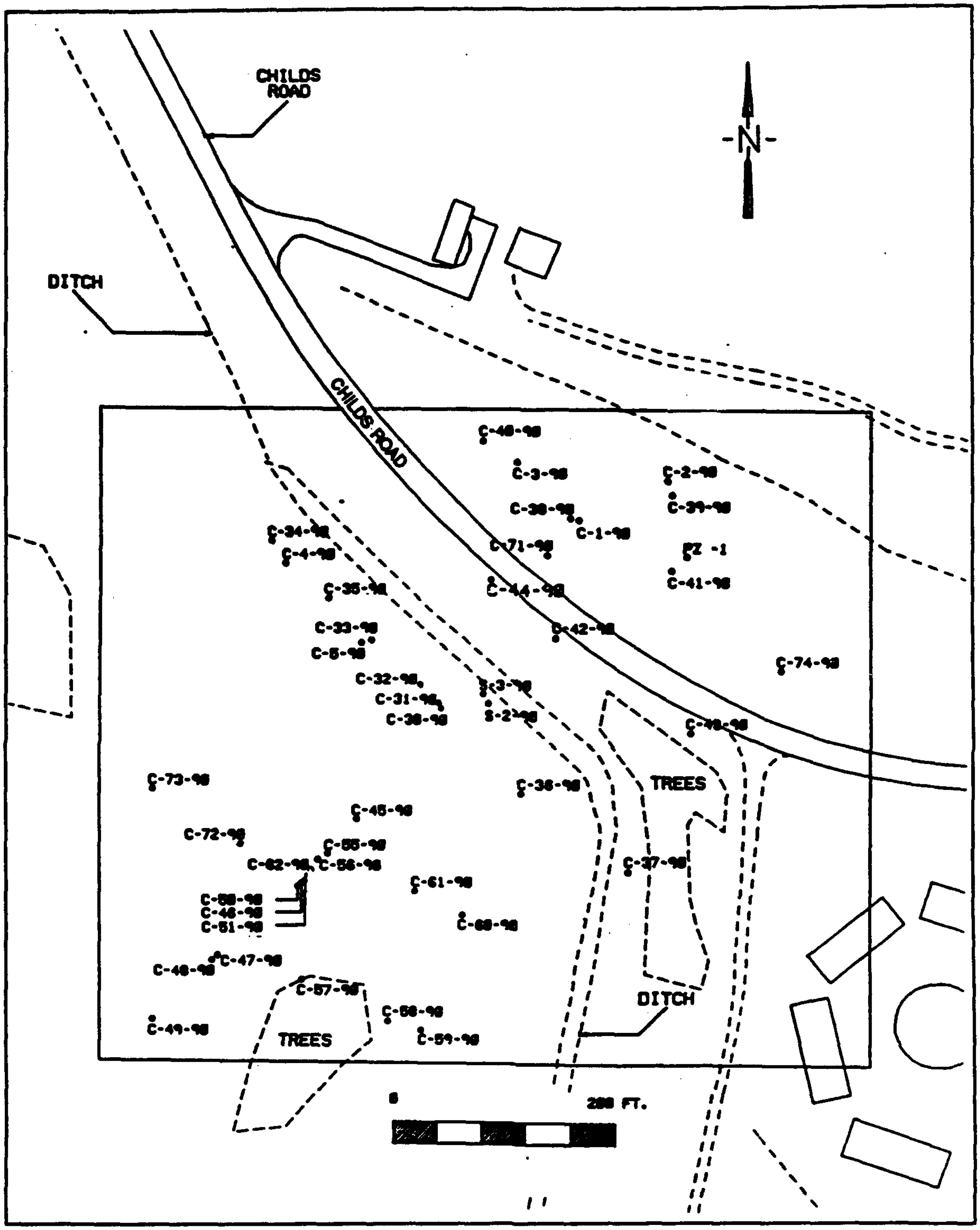


Figure 10. Location of penetrometer pushes in Test Area 1

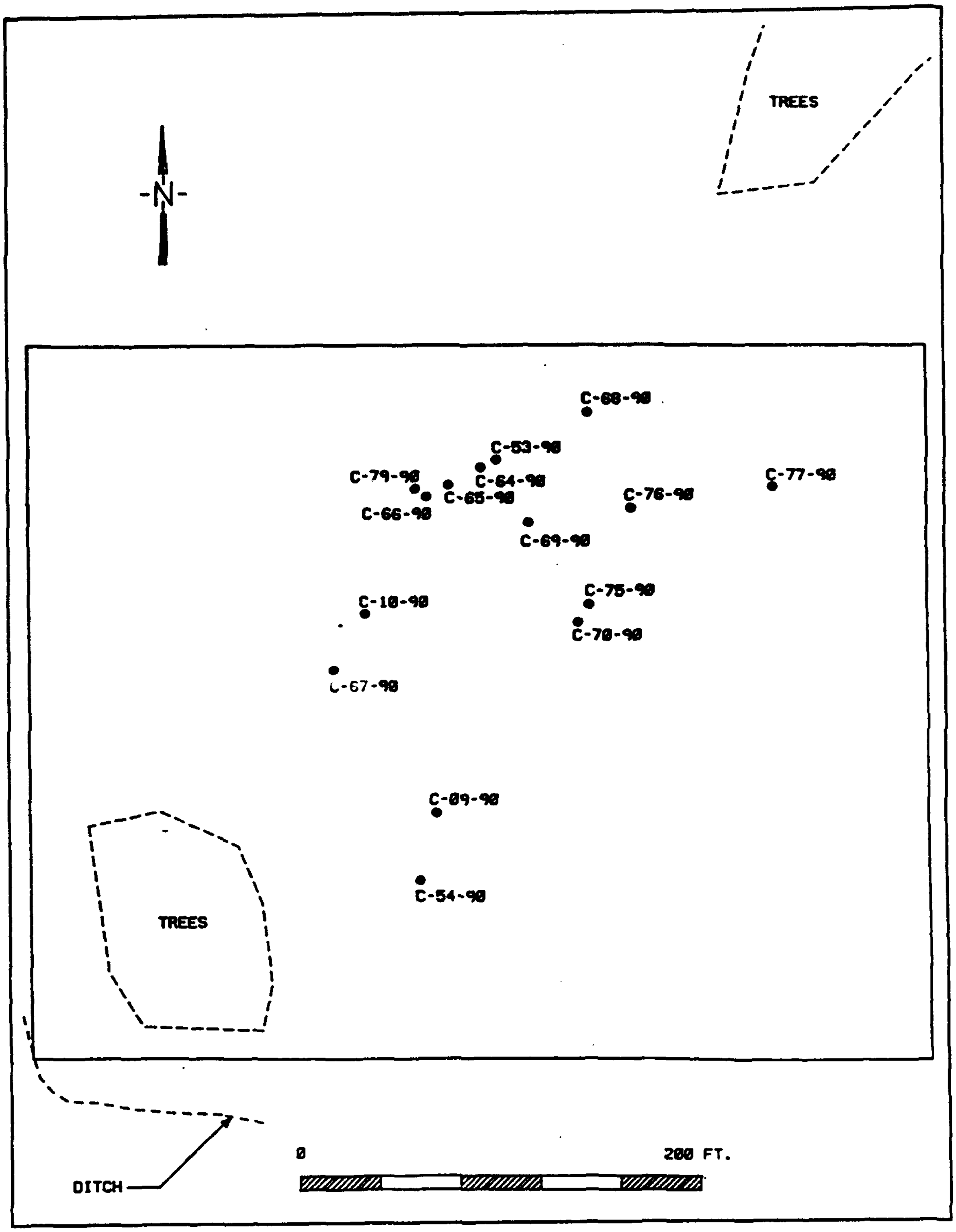


Figure 11. Location of penetrometer pushes in Test Area 2

the Jacksonville NAS. These solvents were not expected to have a significant (easily recognized) fluorescence anomaly that could be detected with the fiber optic tool. Most of the screening pushes in Area 2 were carried out using the resistivity tool. This tool could be expected to show dense chlorinated solvent contamination as a high resistivity anomaly in the soil media if there was sufficient chlorinated solvent to form a separated nonaqueous phase liquid.

The resistivity probe was calibrated by immersing the section carrying the electrodes in a tank of salt solution with known resistivity. The resistivity of the salt solution used in calibration was determined from temperature of the solution and the quantity of salt added and by comparing the measured resistivity (or conductivity) of the salt solution with a standard potassium chloride solution. A field portable conductivity cell was used to verify the resistivity of the salt solution used in the calibration. A detailed account of the procedure is given in Cooper et al. (1988).

Soil/Fluid Sampling

Seven soil samples were collected. Two samples were taken from the sides and bottom of the ditch on the southwest side of Childs Road at a location immediately north of penetrometer hole C-30-90. These samples were obtained by digging obvious flow zone sediment out of the side and bottom of the ditch using hand shovels and trowels. The sample from the side of the ditch was at a depth of 2.4 m (8 ft) and the interval sampled extended approximately 0.46 (1.5 ft). The sample from the bottom of the trench was at a depth of 4.3 m (14 ft). The three other soil samples were collected using the Mostap Soil Sampler and were collected at various depths near penetrometer holes to provide partial confirmation of fluorometer measurements versus depth in penetrometer holes.

All of the soil samples were handled with clean equipment and placed in commercially prepared (precleaned) sample bottles (I-CHEM Research, Hayward, CA). All soil samples were packed in ice and shipped back to the Analytical Laboratory Group, Environmental Laboratory, WES, for analysis. The five samples from Test Area 1 (POL-contaminated area) were analyzed for oil and grease; the two samples from Area 2 (solvent-contaminated area) were extracted, and the extracts were run for volatile hydrocarbons.

A single water sample was collected near penetrometer hole C-76-90 that showed an anomalously high resistivity in soil media of typically low resistivity. This sample was treated with the same care as the soil samples and was submitted for analysis for volatile hydrocarbons.

Laboratory Testing of Samples

Samples were received at the laboratory packed in ice and were maintained in refrigerated storage until the appropriate analyses were performed. The analytical laboratory at WES has full EPA certification. All samples were handled and analyzed using the approved EPA methodologies presented in "Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods," SW-846, September 1986, "Methods for the Chemical Analysis of Water and Wastes," EPA 600/4-79-020, March 1983, and "Procedures for Handling and Chemical Analysis of Sediment and Water Samples," EPA/CE-81-1, May 1981.

In this initial field testing, only eight water and soil samples were taken to evaluate the sampling methodology and sampler performance and to provide a limited verification of the penetrometer screening data by chemical analysis. An extensive sampling effort was not intended and could not have been executed because of time and funding constraints. In the process of collecting the samples both of the commercially available soil and water, samplers were broken. The loss of the equipment is due to encountering buried items at depths below the limits of investigation of the surface geophysical testing.

4 Summary of Results

Geophysical Survey

The results of the magnetic survey are given in Figure 12. The major magnetic anomalies were not in the survey area. The results are presented in parts per thousand deviation from the normal magnetic field. The magnetometer appeared to respond primarily to the local metallic debris scattered over the site. There was no pattern that could be related to the location of the disposal pits in either the northern or southern test areas.

The results of the soil conductivity survey are presented in Figure 13. The area shows a range of over 90 mhos/m in the northern penetrometer test area and a range of 60 mhos/m in the southern penetrometer test area. The local variations in resistivity in the northern test area were far larger than the variations observed over the extreme northern and southern parts of the surveyed area, suggesting local variation may be due to the trenches and the disposed materials buried in this area. Disposed oil should cause lower conductivity if the oil displaces local groundwater. The occurrence of lower conductivities near the northern end of the north area near Childs Road is consistent with the reported locations of the oil disposal pits. The southern test area was used primarily for disposal of degreaser and metal-plating waste, which would have produced less impact on the conductivity.

Stratigraphic Assessment

Previous reports (Geraghty and Miller, Inc. 1980; Hart Associates, Inc. 1983) have presented stratigraphic sections through the area of the oil and solvent disposal site. The major features noted by previous investigators are as follows: (a) an upper layer that consists of 6 to 8 m (18 to 24 ft) of quartz sand with seams or layers of clayey sand; (b) a middle layer of clean quartz sand that is approximately 2 m (6 ft) thick; (c) a lower layer of quartz sand with interbedded clay that is approximately 1 to 2 m (3 to 6 ft) thick; and (d) a marine clay that is over 7 m (21 ft) thick. The upper three major stratigraphic units appear on the block diagram (Figure 14) prepared from the penetrometer data. The penetrometer, however, provides more detail, fine

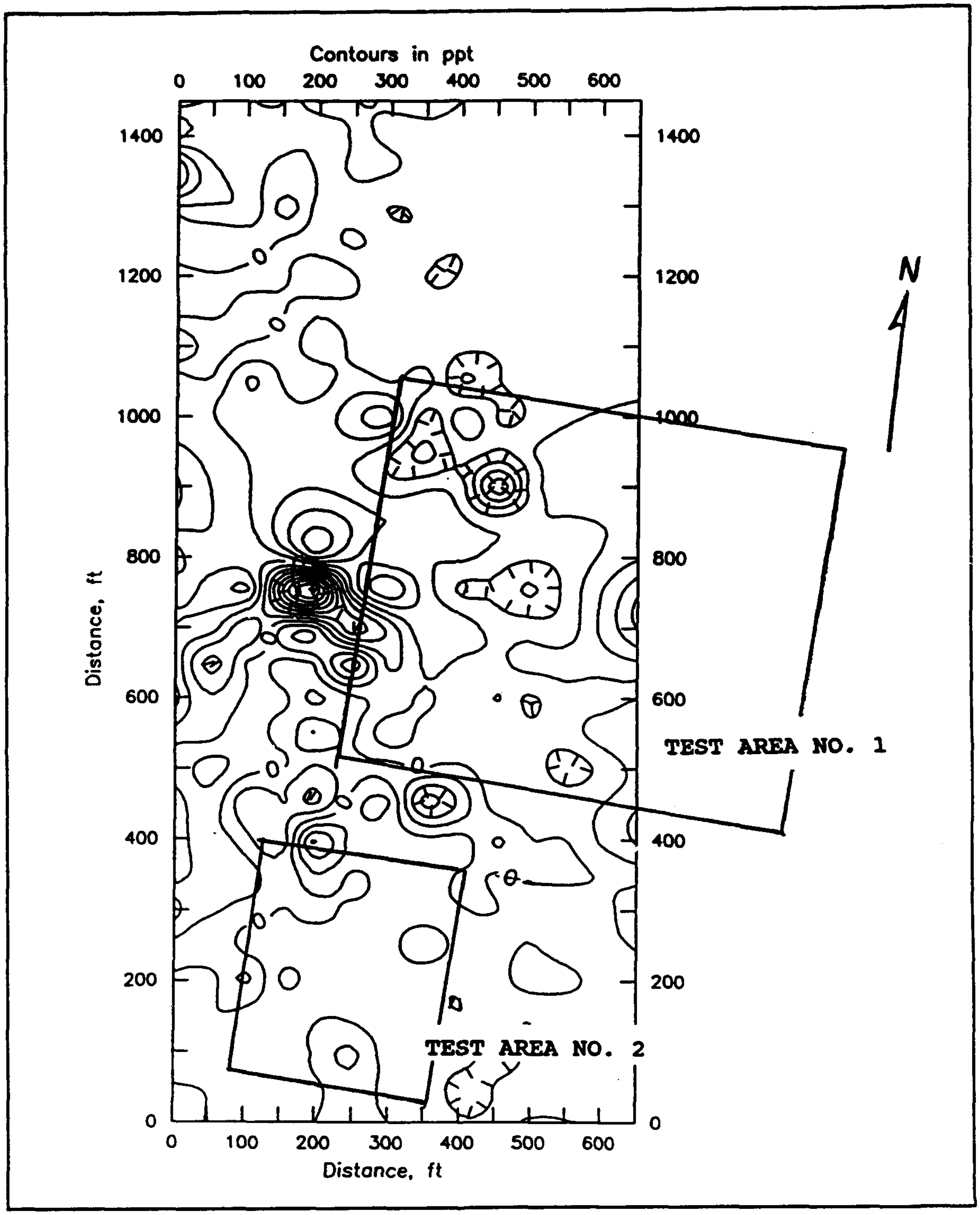


Figure 12. Magnetic survey of test areas

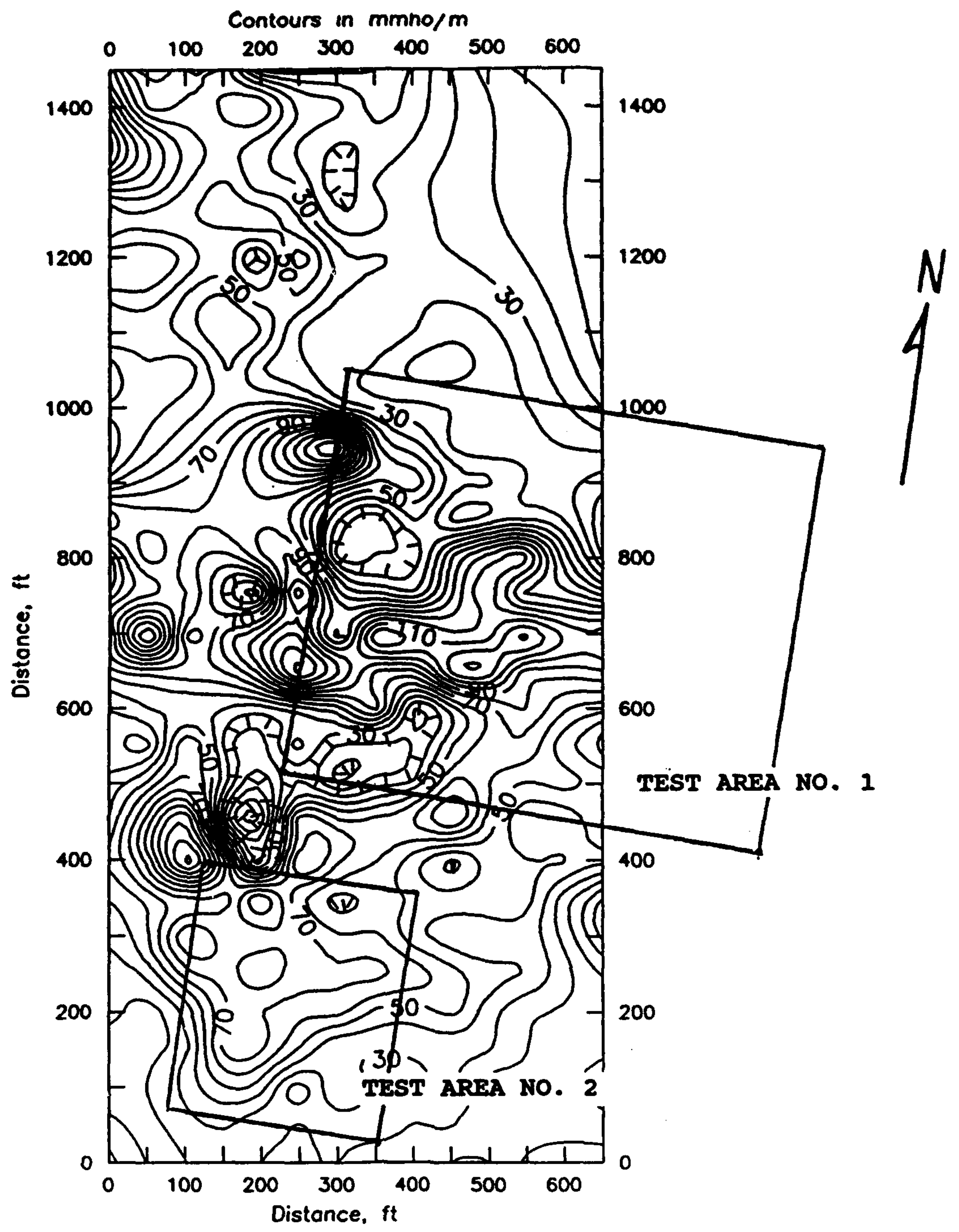


Figure 13. Induced electro-magnetic survey of test areas

resolution, and denser data points than any drilling log. The sand unit (b) shows a thin, continuous layer of near pure (soil classification 4) sand that extends across the diagram at an elevation of 2 to 4 m (6 to 12 ft) above sea level. Examination of the volume model with all penetrometer pushes (for the area included) shows that the sand, while nearly continuous through the block, does turn clayey toward the center of the study area. None of the sandy units shown in Figure 14 could be classed as continuous in three-dimensions.

The supposition from drilling logs that a continuous clean sand is present across Test Area 1 (Geraghty and Miller, Inc. 1980) at an elevation of 3 to 4 m above mean sea level is probably not valid.

The subsurface materials at the test area are best characterized as interbedded, lens-like units of clay, sandy clay, and sand. The penetrometer data indicate that monitoring the movement of contaminants in Area 1 with monitoring wells will be very difficult because of changes in soil characteristics and, therefore, permeability.

Field Testing for Petroleum Contamination

Petroleum contamination was mapped using the fiber optic fluorometric sensor. Thirty-six probe pushes were made with the fluorometric sensor with a maximum depth of 7 m (23 ft). The results are presented in Appendix A. Thirty-four fluorometer pushes in Area 1, the closed oil disposal area, were used to map the occurrence of contaminated soil in detail. The distribution of oil-contaminated soil down to fluorescence levels that are equivalent to the fluorescence of soil contaminated with 1,000 ppm of fresh marine diesel fuel is presented in Figures 15-26. The pattern of oil distribution shown in Figure 27 (from Geraghty and Miller, Inc. 1980) demonstrates that the same area determined by other investigators to be involved in the oil contamination was accurately located in this investigation using the fluorometric sensor. The fringes of the contaminated soil are shown with more detail in the penetrometer-based report because of the greater control and the close placement of sensor holes. As the interactive volume model produces diagrams of higher concentration levels, it is possible to see the source areas for the petroleum contamination that should be the locations of the old disposal pits. This type of map can be far more useful in planning further remedial activity than a simple contour map developed from analysis of well samples from arbitarily placed monitoring wells that sparsely populate an area of interest.

Field Testing for Solvent Contamination

The DC resistivity probe was primarily used in Area 2 to look for resistivity changes that would be related to solvent or paint waste disposal. Ten pushes with the resistivity probe were made in Area 2. The data are presented in Appendix B. Generally, no response that could be related to the occurrence

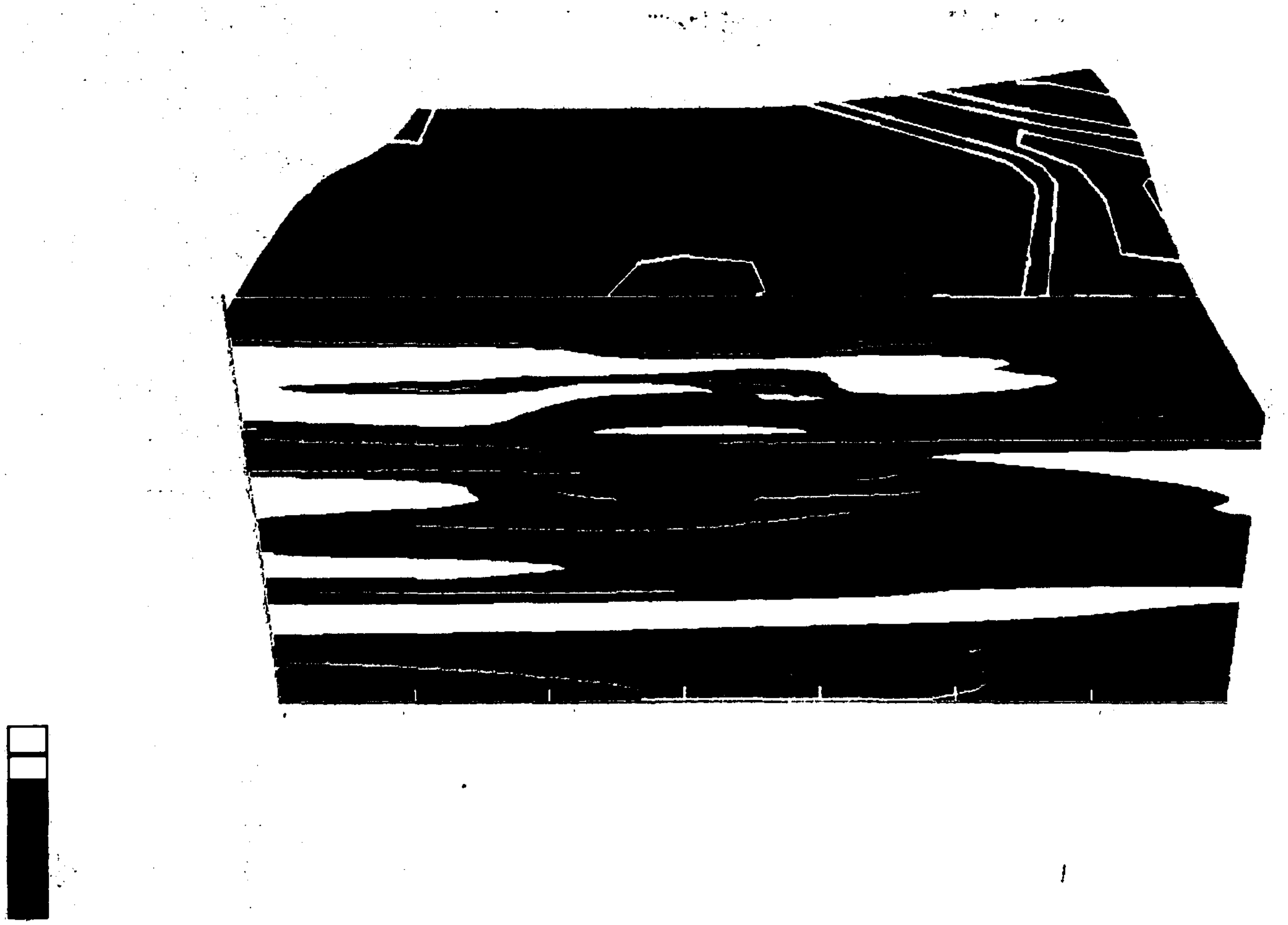


Figure 14. Stratigraphic section for the disposal site. The block diagram shows Test Site 1 with the soil type shown as determined from the penetrometer. A pure sand is Soil Class No. 5 (white) and a pure clay is Soil Class No. 1 (blue). Mixtures are designated by *intermediate numbers in the series*

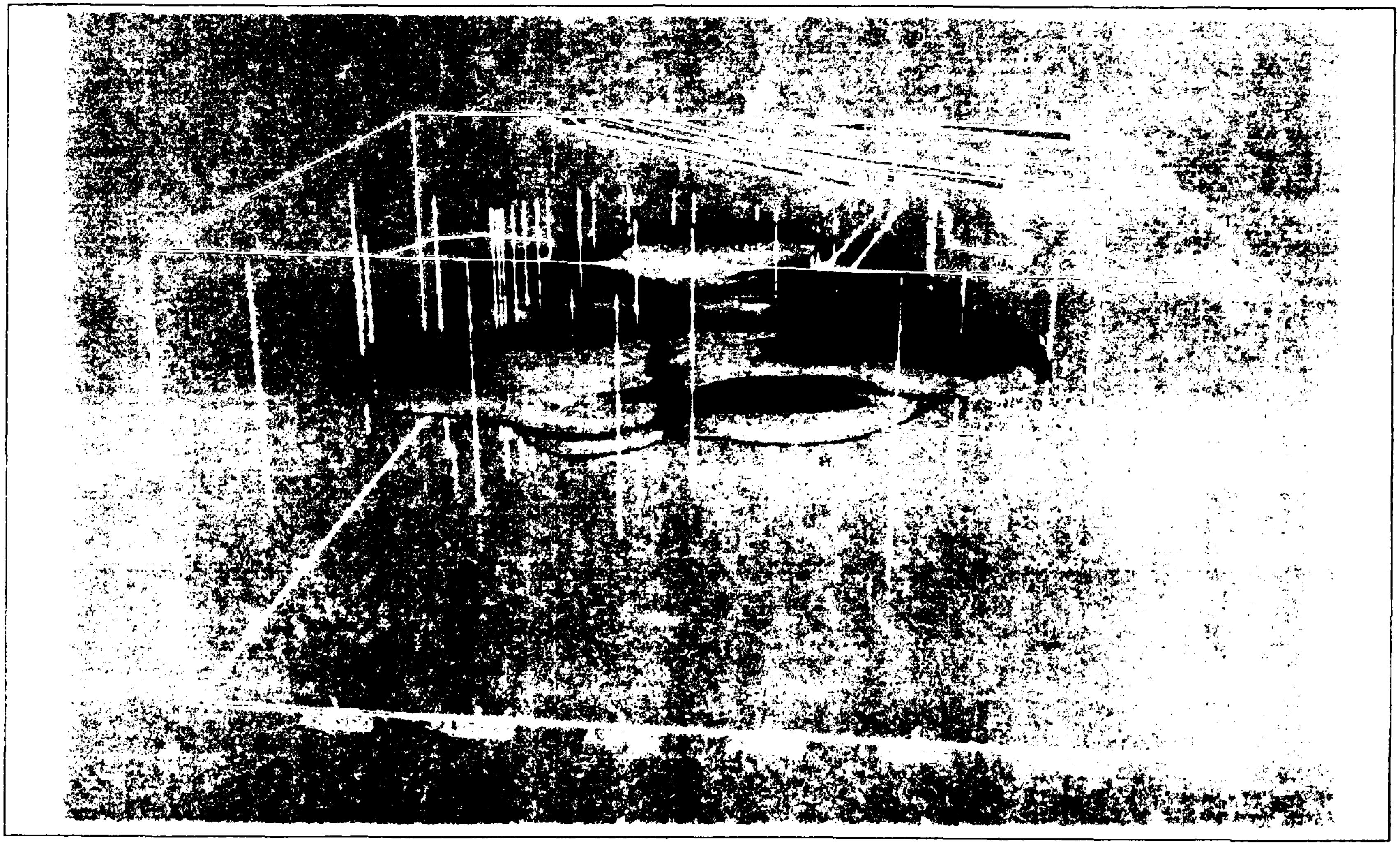


Figure 15. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking north)

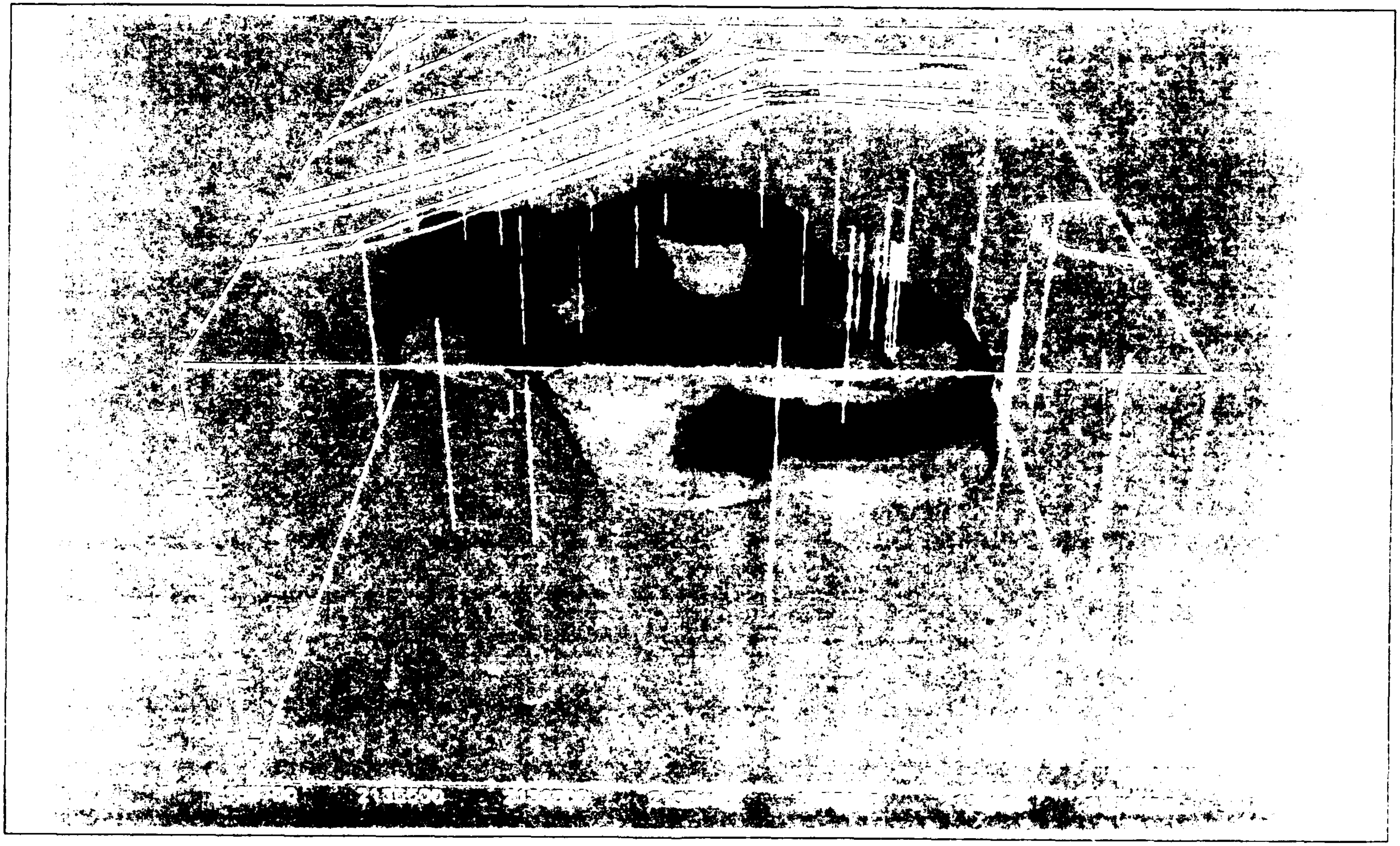


Figure 16. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking east)

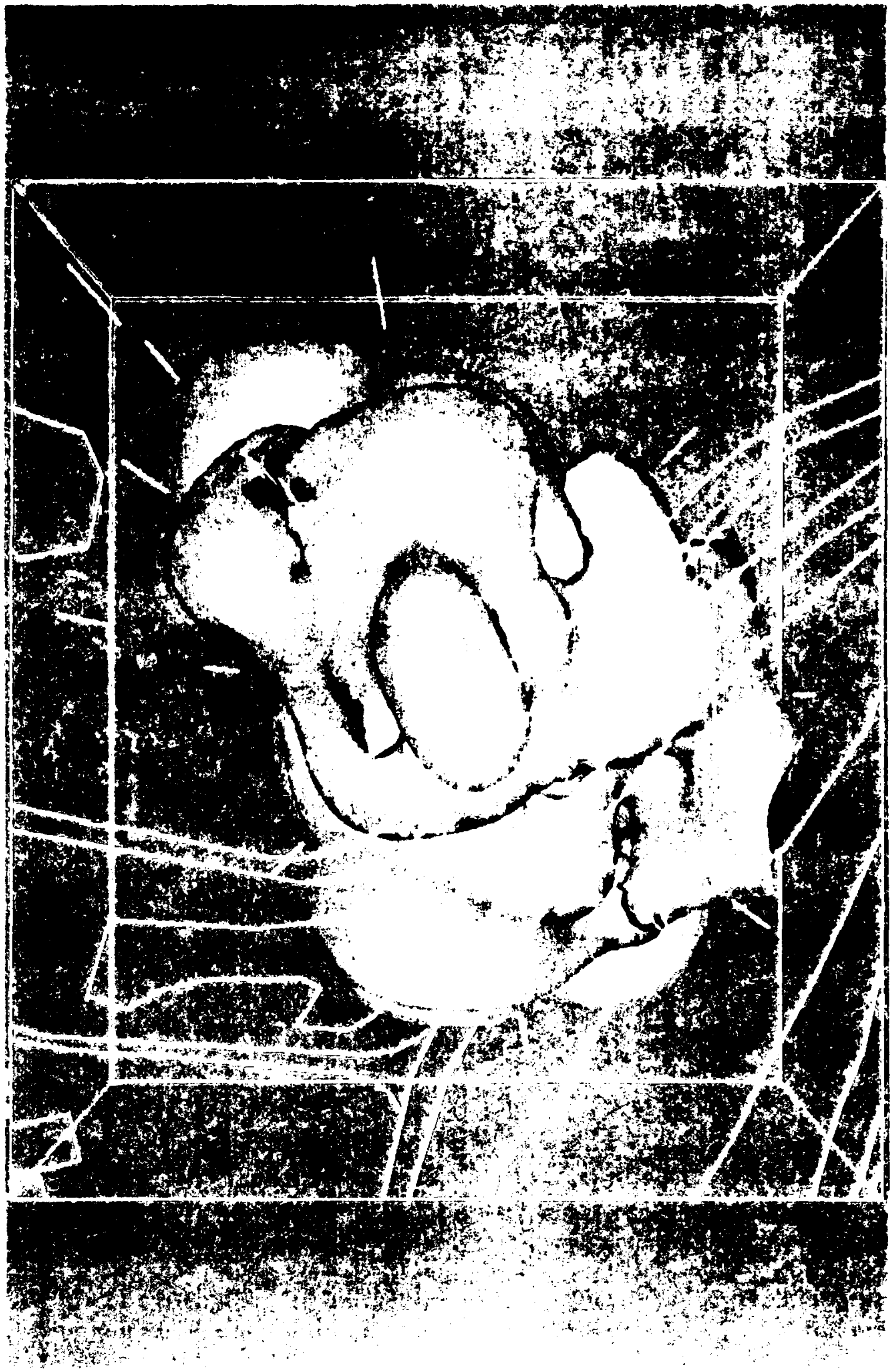


Figure 17. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking down)

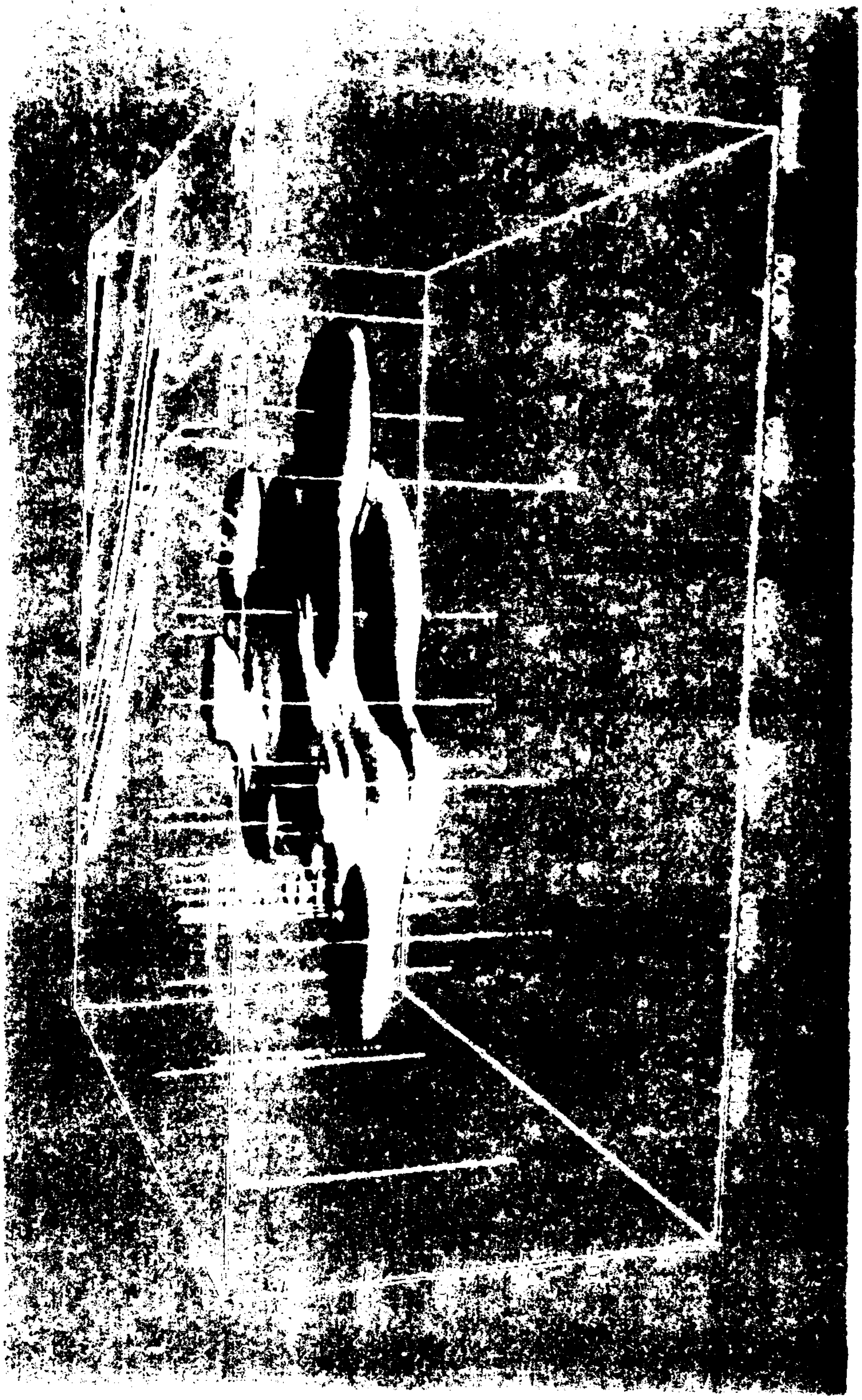


Figure 18. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking north)

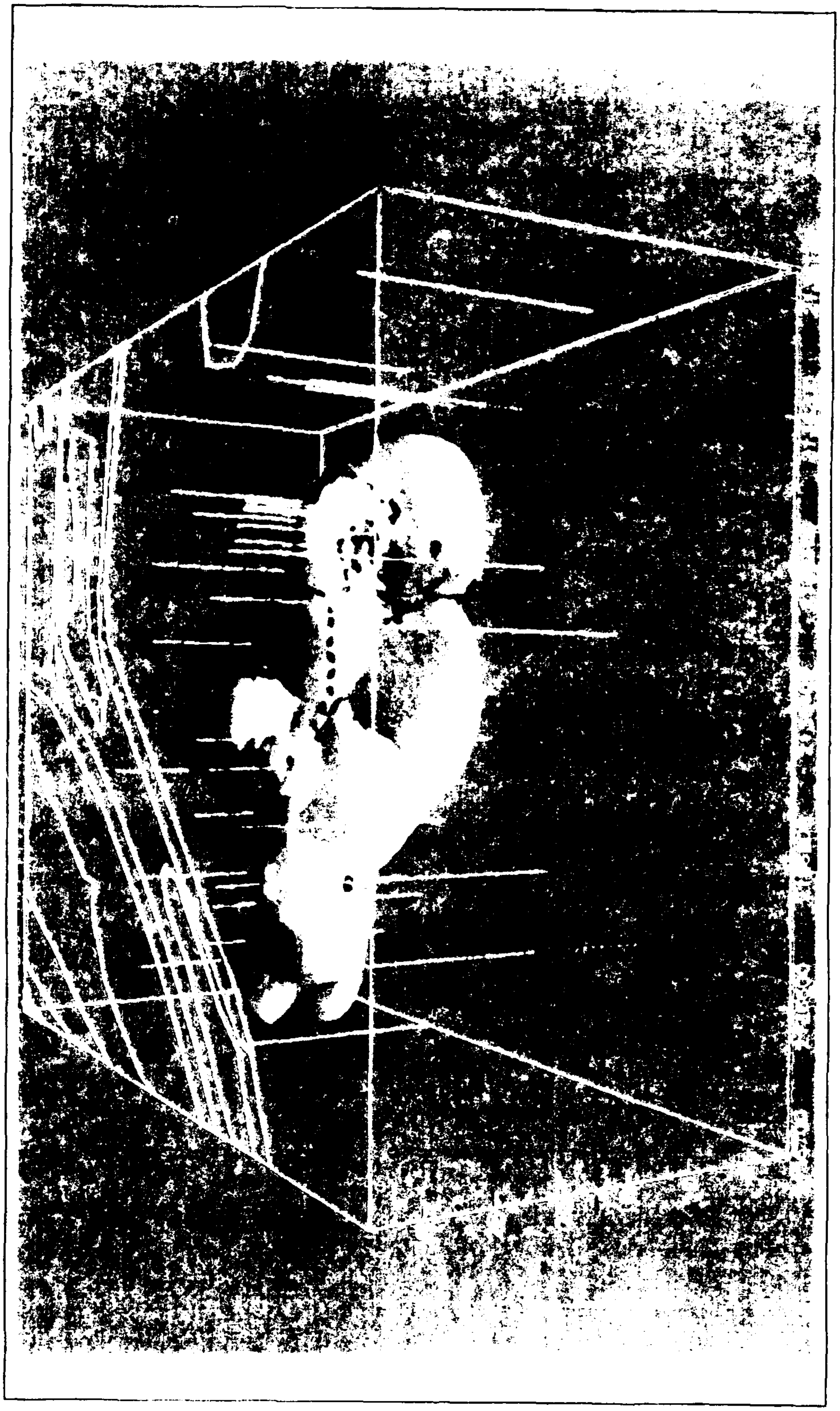


Figure 19. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking east)

Figure 20. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking down)

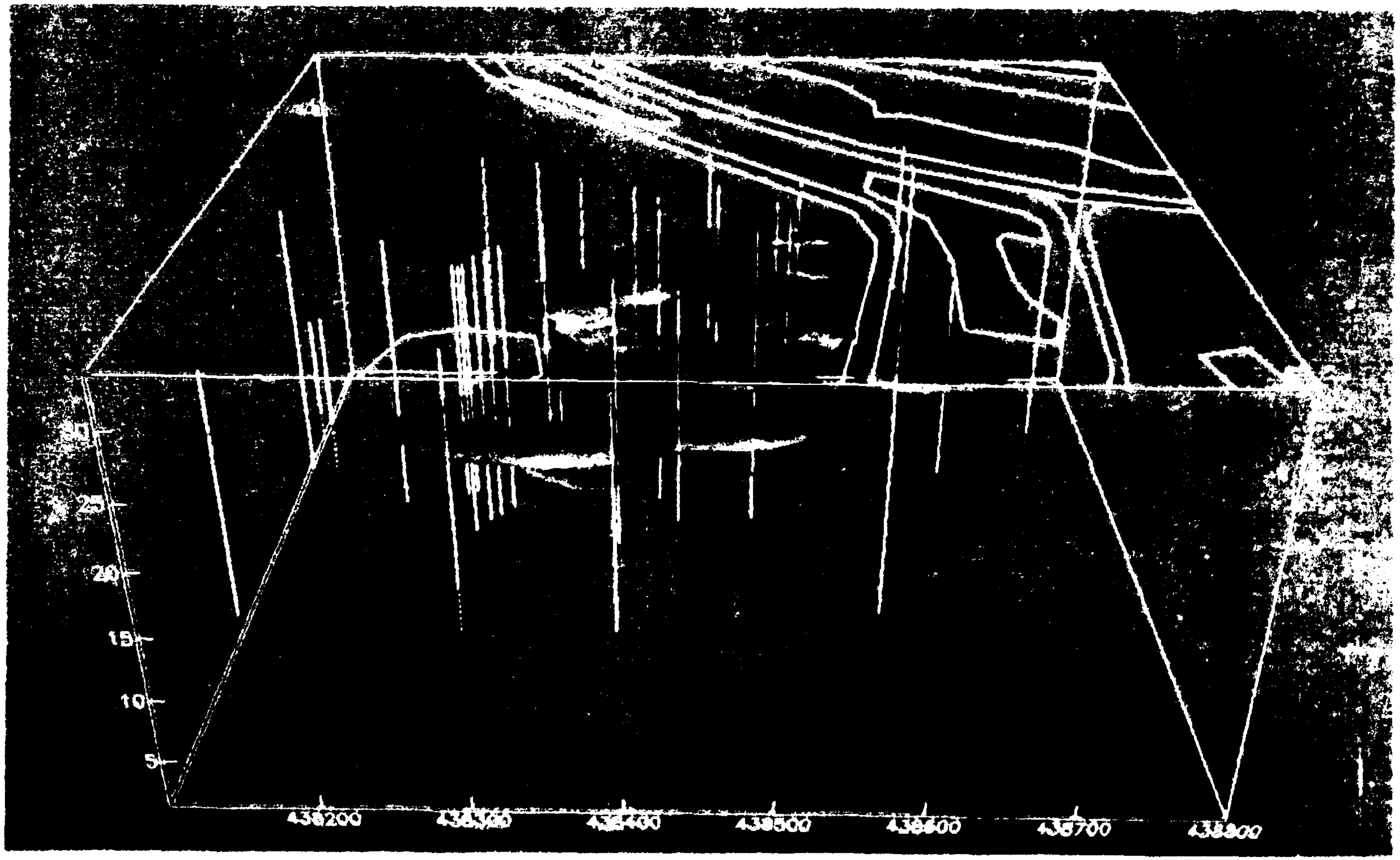


Figure 21. Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking north)

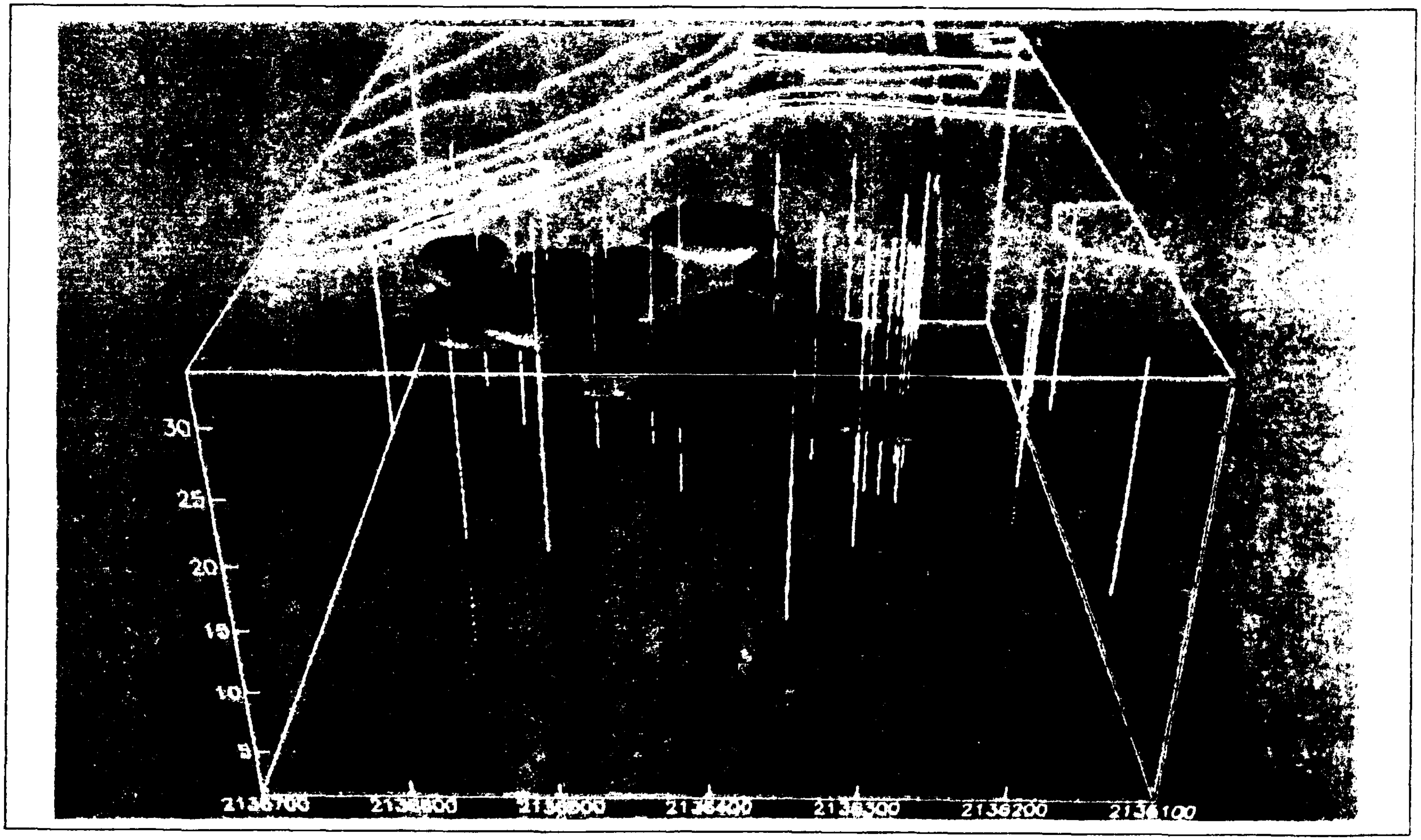


Figure 22. Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking east)

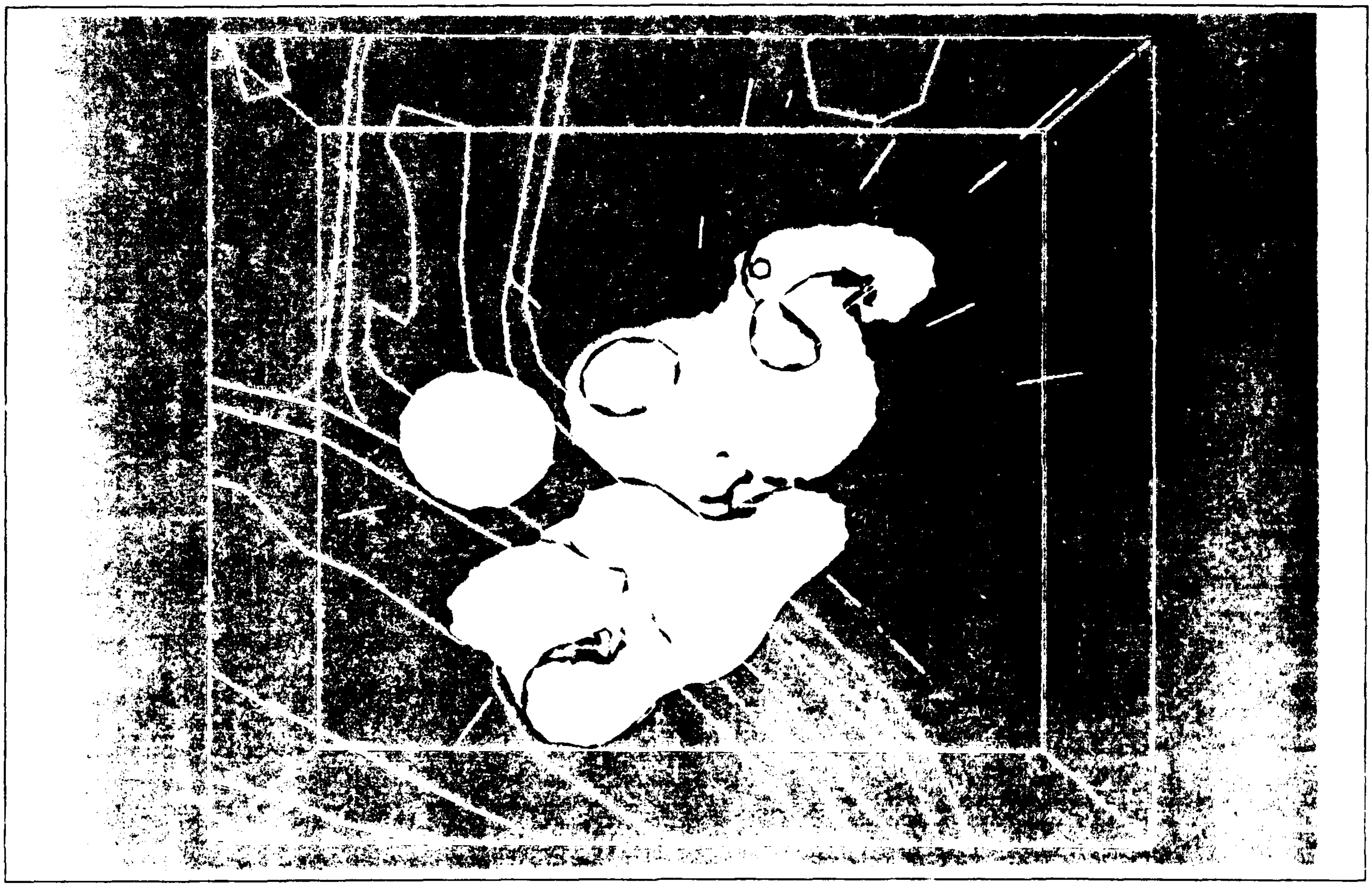


Figure 23. Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking down)

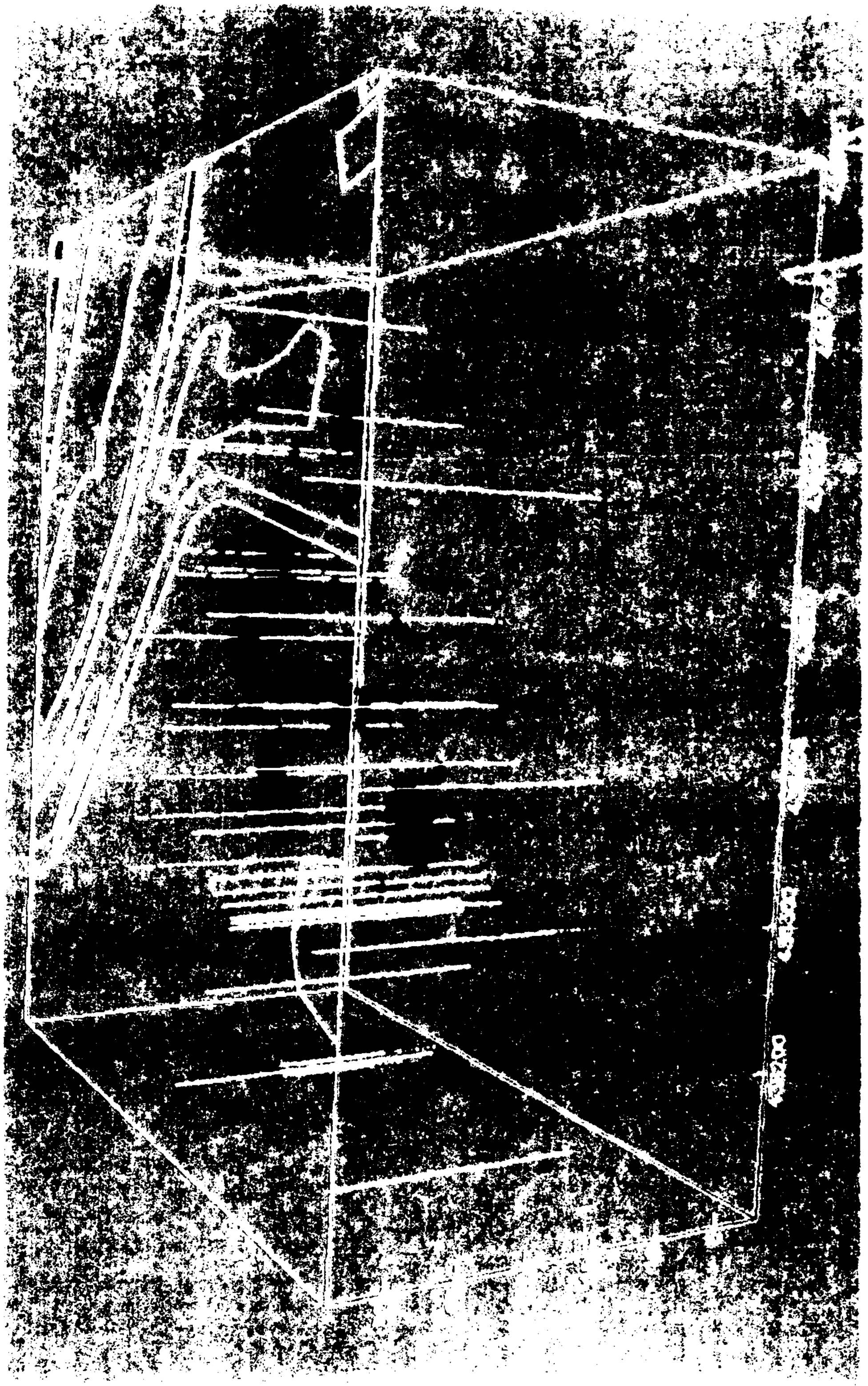


Figure 24. Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking north)

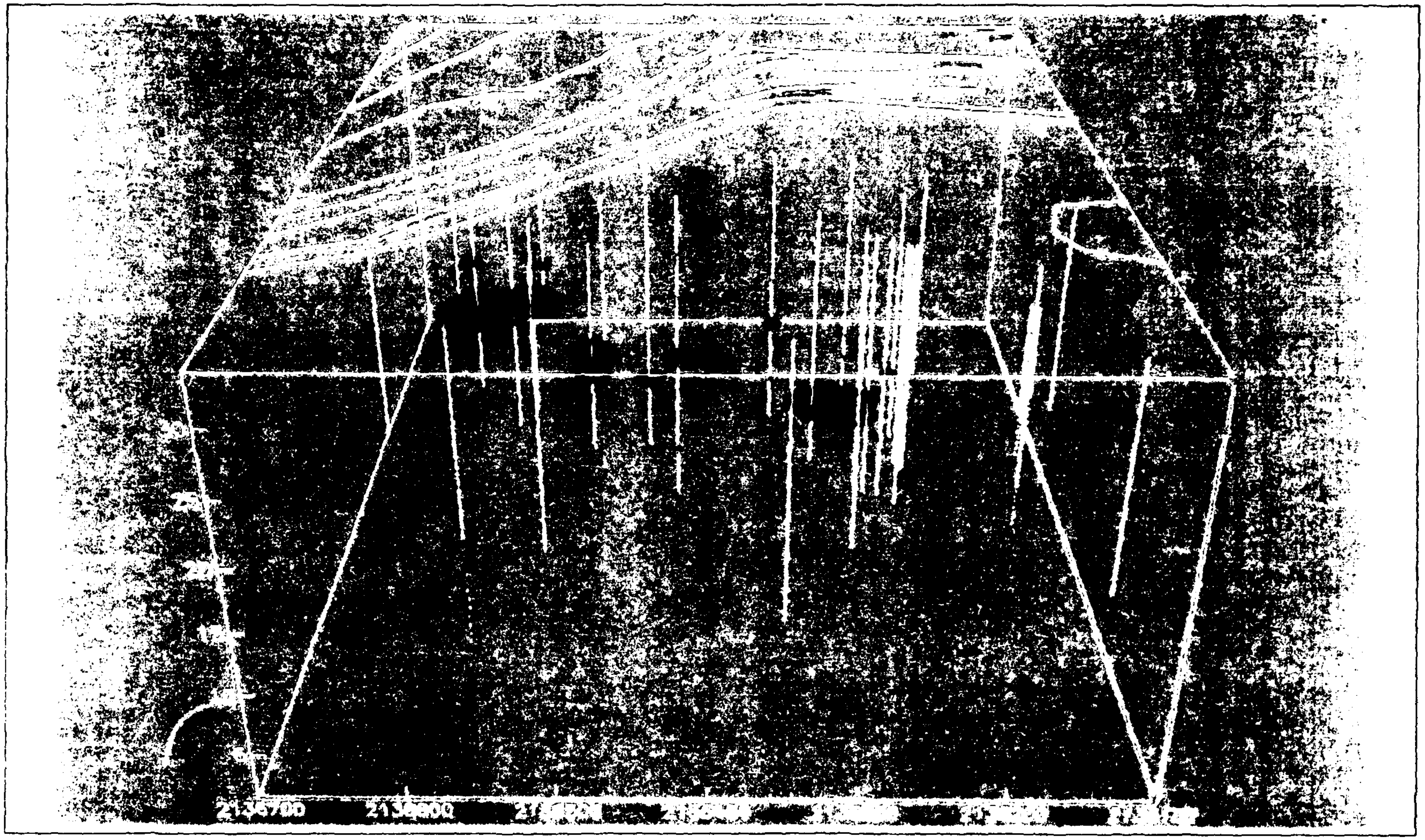


Figure 25. Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking east)

Figure 26. Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking down)

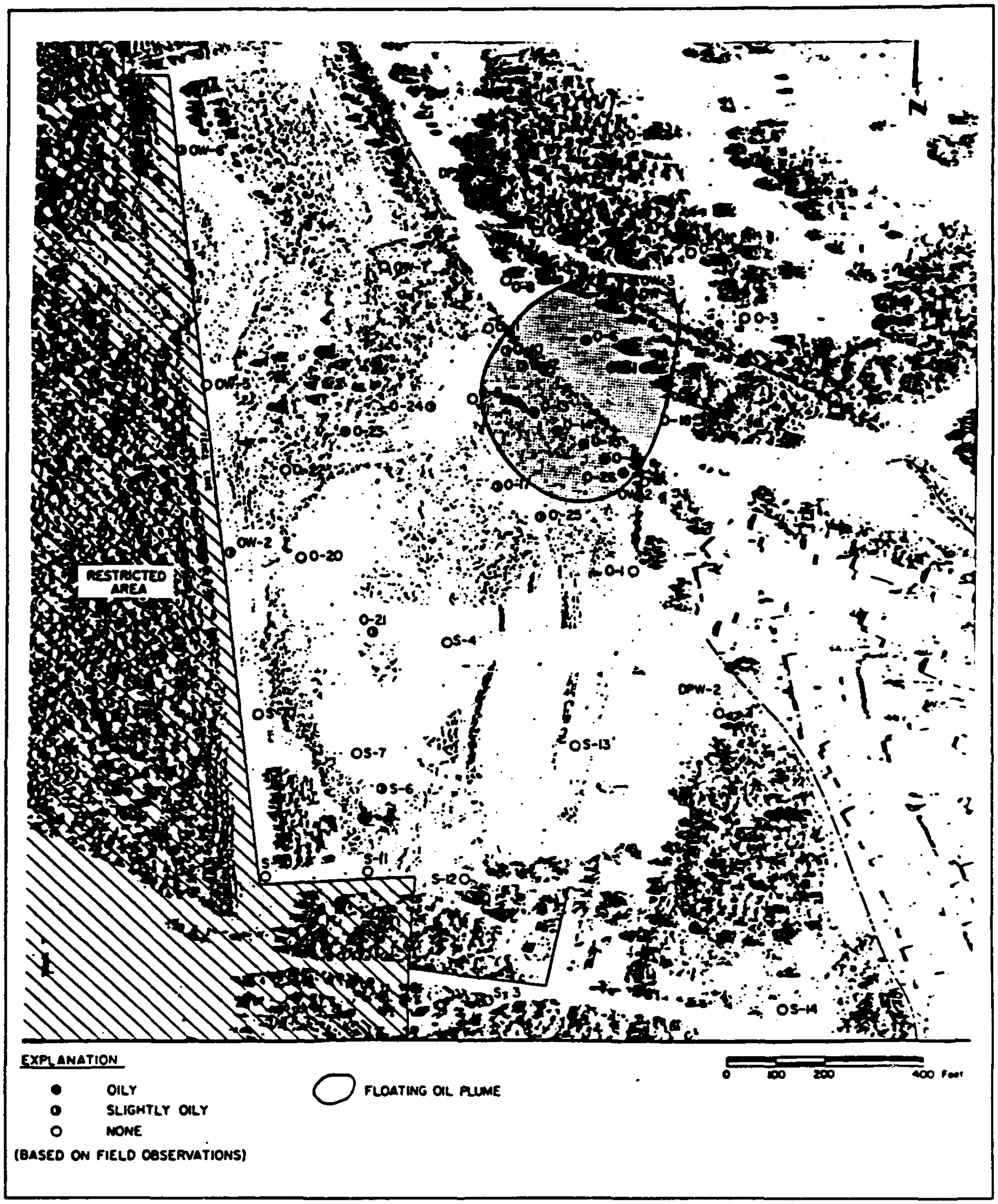


Figure 27. Plume of oil contamination mapped with drilling and sampling from Geraghty and Miller, Inc. (1980)

of solvent or the disposal of metal-rich paint wastes could be found. The major anomaly that was observed below the water table related to high resistivities that occurred at depths below 13 m (42.6 ft) in holes pushed at C-76-90 and C-77-90. A water sample was obtained near these holes, and the results of the analysis for solvents are presented in Appendix C.

Sampling and Sample Analysis

Both water and soil samples were taken with the penetrometer unit. The results obtained from the analysis of the samples are presented in Appendix C. The Hydropunch water sampler was used to collect a water sample in Area 2, but was damaged in a second attempt to collect water in the same area. The water sample collected near C-76-90 showed no detectable contamination.

Five soil samples were collected with the Mostap sampler from Areas 1 and 2. The three samples from Area 1 showed varying levels of hydrocarbon (oil and grease) contamination from 175 ppm to 62,500 ppm. The variation in the concentration of the hydrocarbons in the soil samples were consistent with the variation that has been observed in the record from the fluorometric sensor.

Two soil samples were collected in Area 2. Only the shallow sample from C-77-90 showed any appreciable solvent contamination. Analysis for solvents showed the presence of methylene chloride and 1,1,2,2-tetrachloroethane, along with toluene, P-xylene, chlorobenzene, and ethylbenzene. The deep sample (from 45 ft below C-66-90) showed only a minor amount of methylene chloride. The shallow soil sample demonstrated that there was definite solvent contamination. The electrical resistivity could not be reliably correlated with the concentration of solvent at this depth because of "edge effects" on the resistivity probe at this shallow depth above the water table. The second soil sample was taken at a depth that showed an unusual increase in resistivity. The analytical results indicate that the resistivity change is due to a decrease in the resistivity of the groundwater, not to an accumulation of organic solvents.

Comparison of Fluorescence and Laboratory Test Results from Soil Samples

Sample No.	Nearest Cone Penetrometer Test	Sample Depth ft	Count Ratio	Prediction Based on DFM (ppm) Calibration	Analytical Sample Test Results O & G ppm
07048	C-30-90	11.0	0.012	240	175
07044	C-30-90	9.0	0.200	25,934	22,570
07045	C-30-90	13.5	0.500	60,000	56,600
07046	C-62-90	9.5	0.160	20,582	62,500

Samples 07048, 07044, and 07045 were dug from the wall of a drainage ditch approximately 20 ft from penetrometer push C-30-90. These samples were measured with the fluorometer tool at the surface. Sample 07046 was obtained with a MOSTAP soil sampler approximately 5 ft away from penetrometer push C-62-90; however, the compared fluorescence measurement was made in situ during the push. The variability in contaminant concentration in soil may account for the difference in predicted versus sample test results for this case.

5 Conclusions

The field test at the Jacksonville NAS provided a wide range of information with regard to the application of the SCAPS unit. Major conclusions developed from this exercise include the following:

a. The penetrometer can be successfully used with multiple sensors such as the fluorometric sensors and the tip and sleeve soil strength measuring devices.

b. The fluorometric sensors can be successfully employed to produce a detailed delineation of a hydrocarbon (POL) plume that far exceeded the capability of the usual drill-and-sample site investigation.

c. Neither the fluorometric sensor nor the resistivity sensor in their present configuration could detect chlorinated hydrocarbons in the levels present at the Jacksonville NAS (<5 ppm total chlorinated hydrocarbon).

d. The commercial soil and groundwater samplers successfully functioned in collecting samples, but were not hardened sufficiently to survive in soil with buried obstacles such as found at the Jacksonville NAS.

e. The analyses obtained from soil and water samples were consistent with the estimates of contamination obtained with the sensors.

f. A water sample taken at a depth below 13 m showed no evidence of solvent contamination, indicating that the increased resistivity is due to the presence of clean water with a low conductivity.

g. The interactive volume model is a useful technique for rapidly reducing the large volume of data developed from a sensor-equipped penetrometer survey of a hazardous waste site.

6 Recommendations

The experience with the SCAPS unit at the Jacksonville NAS allows the following recommendations to be made:

a. The double fiber fluorometric sensor should be developed as the standard POL sensor. The system has low maintenance and collects data satisfactorily.

b. The resistivity sensor should be specifically used when contrast in electrical properties is a major feature in the contaminated subsurface materials.

c. The soil strength measurements should be continued as an integral part of the sensor systems.

d. The samplers used with the penetrometer must be designed to withstand impact with obstacles in the subsurface.

e. Future field efforts should include a side-by-side comparison of sensor output and sample analyses so that the response of the sensors can be carefully assessed under a variety of circumstances. Questions regarding possible adverse effects from soil matrices and interference from naturally occurring fluorescent compounds in soil or multiple contaminants of uncertain origin should be a high priority effort.

f. A viable in situ grouting system should be developed that does not introduce hazardous substances, is inert, and can be used during probe retraction.

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Appendix A
Data from the Penetrometer Unit Equipped with a Soil Strength Measuring System and the Fluorometric Sensor

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Explanation of Plot Formats

The figures presenting plots of penetrometer data versus depth are organized in panels. Data obtained with the Site Characterization and Analysis Penetrometer System (SCAPS) resistivity tool are shown in four panels, i.e., point penetration resistance q_c in tons/square feet versus depth in the first (left hand) panel, sleeve function f_s in tons/square feet versus depth in the second panel, soil classification computed from q_c and f_s versus depth in the third panel, and soil resistivity in ohm-feet versus depth in the fourth panel.

Data obtained with the SCAPS fiber-optic fluorescence tool are shown in seven panels. The first three panels show q_c, f_s, and soil classification versus depth as described previously. The fourth panel shows raw fluorescence intensity versus depth; the fifth panel shows predicted equivalent concentration of diesel fuel in parts per million (ppm) versus depth; the sixth panel shows a log-log plot of predicted equivalent concentration of diesel fuel in ppm versus depth; and the seventh panel shows a plot of the wavelength at which the peak fluorescence intensity occurred versus depth.

The first three panels in each figure deal with point penetration resistance q_c, friction sleeve resistance f_s, and the soil classifications derived from them. In the most general sense, cohesive soils (clays) tend to adhere (stick) to the friction sleeve, whereas, noncohesive soils (sands) do not. Hence, the f_s/q_c is typically higher in clays than in sands, and soil admixtures (silty sand, sandy clay, etc.) exhibit intermediate f_s/q_c ratios. This is the (simplistic) basis for calculating soil classification from q_c and f_s measurements made with an electric instrumented cone. For additional information on cone penetrometer strength data and interpretations, the reader is referred to the literature (Olsen 1988).[1]

Soil resistivity measurements are routinely made in surface geophysical surveys, in borehole logging, and less frequently used penetrometers. Resistivity measurements are used typically in conjunction with other measurements to identify soil layering or to sense the presence of moderate to high concentrations of contaminants in these layers. However, when contaminant concentrations are low (a few tens of a part per million) soil resistivity changes will generally be too subtle to detect. Under best case conditions, there will be a significant contrast in resistivity measured in a contaminated zone versus measurements made in an uncontaminated host soil. High concentrations of petroleum, oil, and lubricants (POL) in the predominately sandy soil at Jacksonville Naval Air Station (NAS) should consistently be detected as high resistivity anomalies since hydrocarbons are usually excellent insulators. However, local variations in soil composition and groundwater can also produce appreciable changes in resistivity measured in the same soil layer. Hence, in situ soil resistivity measurements are inherently ambiguous and nonspecific regarding contaminant type; apparent resistivity anomalies should be evaluated by other means, preferably by physical sampling.

As previously discussed, the figures presenting the fluorometric measurements made with the SCAPS fiber-optic tool are arranged in seven panels. The first three panels show soil strength (q_c and f_s) and soil classification versus depth measurements that are common to both the resistivity and fiber-optic tools. The remaining panels of fluorometric data were designed to facilitate comparisons of results at different penetration locations and as an expedient way to summarize a very extensive database. The fourth panel shows a linearly scaled plot of raw fluorescence intensity data versus depth. This panel permits a rapid comparison of the magnitude of fluorescence anomalies encountered across the site. The fifth panel presents a linearly scaled plot of predicted equivalent diesel fuel concentration in ppm versus depth. Comparison of panels four and five should indicate that the general data trend is preserved when the diesel equivalency calculation is made. Panel six presents a log-log plot of predicted equivalent diesel fuel concentration in ppm versus depth. This panel was included to facilitate comparisons of relatively low level predicted POL concentrations. The final panel, panel seven, shows a plot of wavelength at peak fluorescence intensity versus depth.

The wavelength plot provides a means to judge the source of the fluorescence being detected. For example, when the tool is being advanced through clean soil, no fluorescence is detected; the wavelength peak intensity algorithm is reading random system noise (approximately 10 to 20 counts). Consequently, the wavelength determination is inconsistent. However, when a significant fluorescence signal (50 counts) is detected, the wavelength plot can be a useful indicator of the kind of fluorescence source being measured. In the

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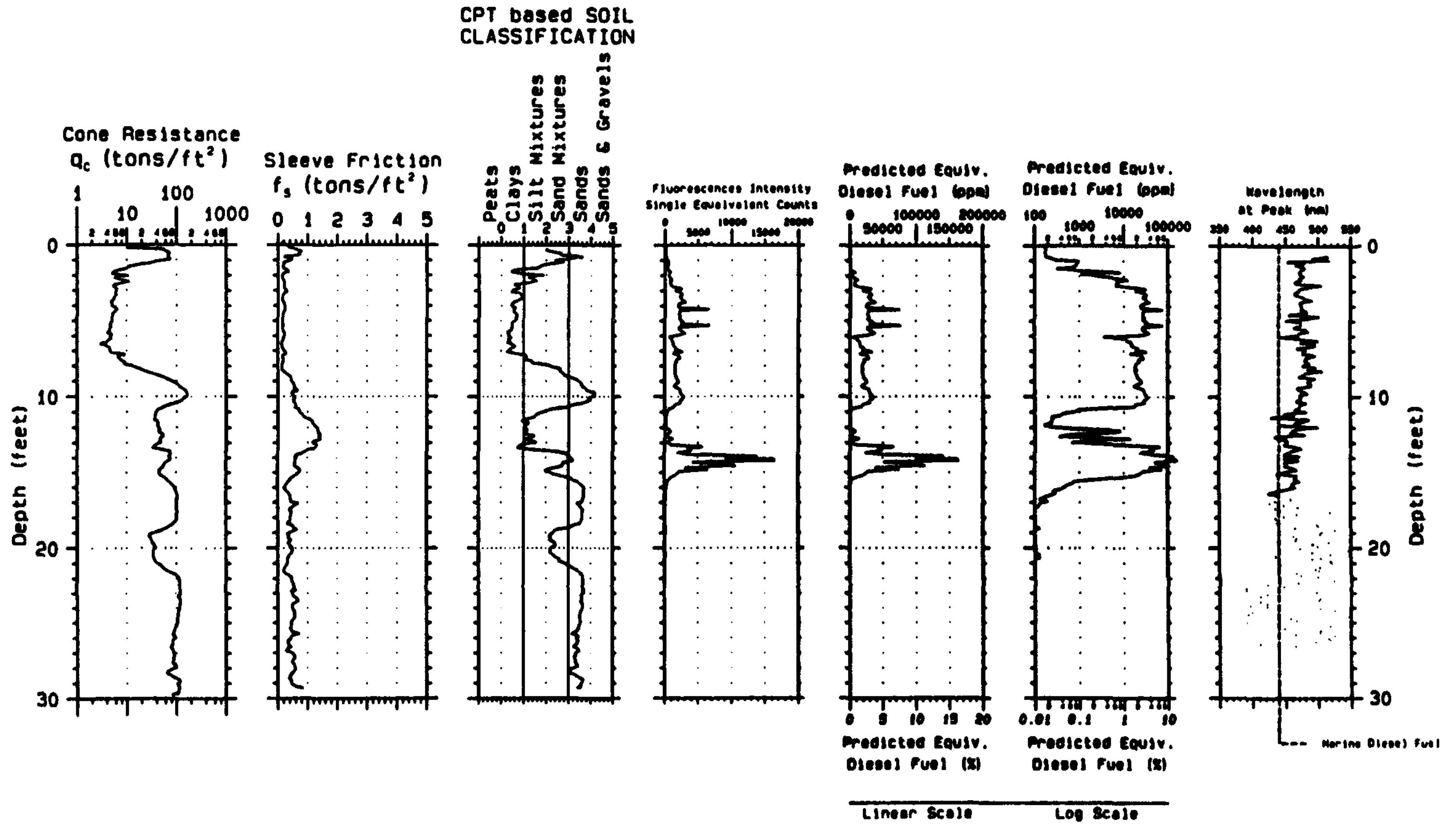
[1] References cited in this appendix are located at the end of the main text.

case of Jacksonville POL contamination, physical samples obtained near surface and from seep zones 10 ft down in the intercept trench were tested with the fluorescence tool and showed peak wavelengths in the range form 430 to 460 nm. Hence, POL anomalies detected *in situ* at Jacksonville NAS with the fluorescence tool should presumably show comparable wavelengths. At this writing, it is known from extensive bench testing that freshly refined petroleum products can usually be differentiated according to their spectral (wavelength) fluorescence. But, little is known about the same products after 20 to 30 years residence in soil. This is the first time that in situ fluorescence measurements have been successfully made with penetrometer equipment, and only with additional testing to enlarge the fluorescence database will more informed judgements be possible at mixed POL waste sites.



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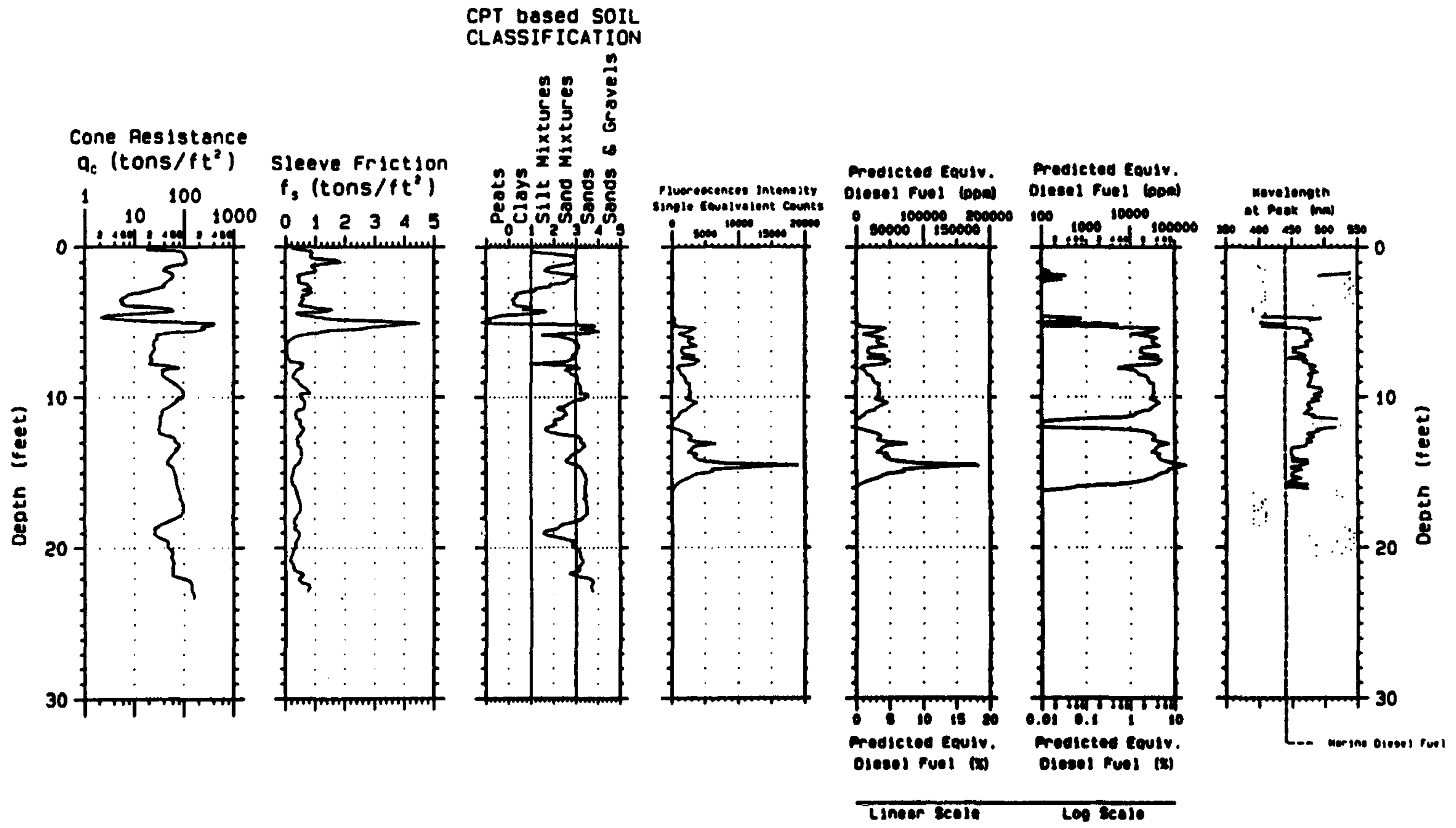

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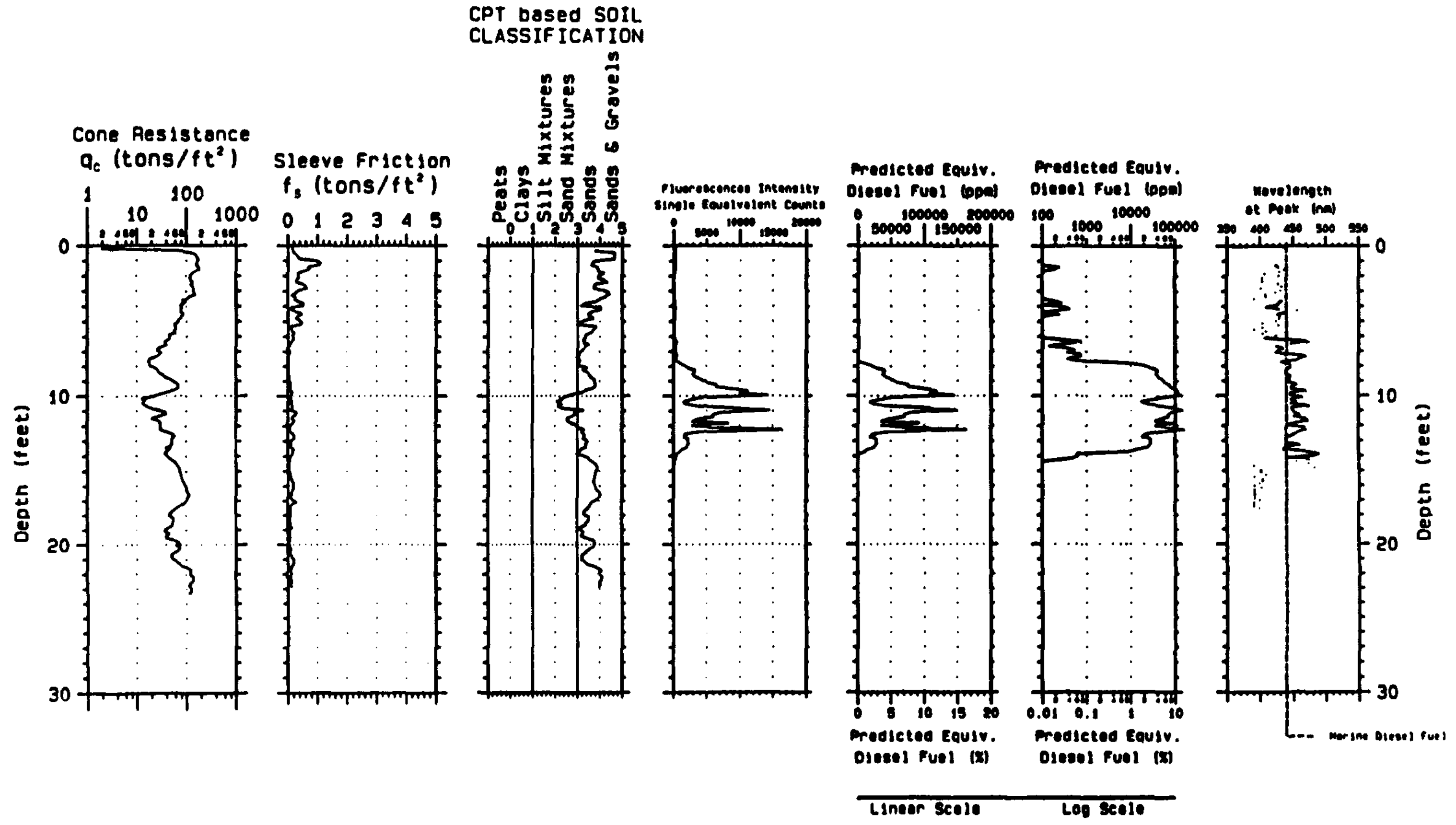

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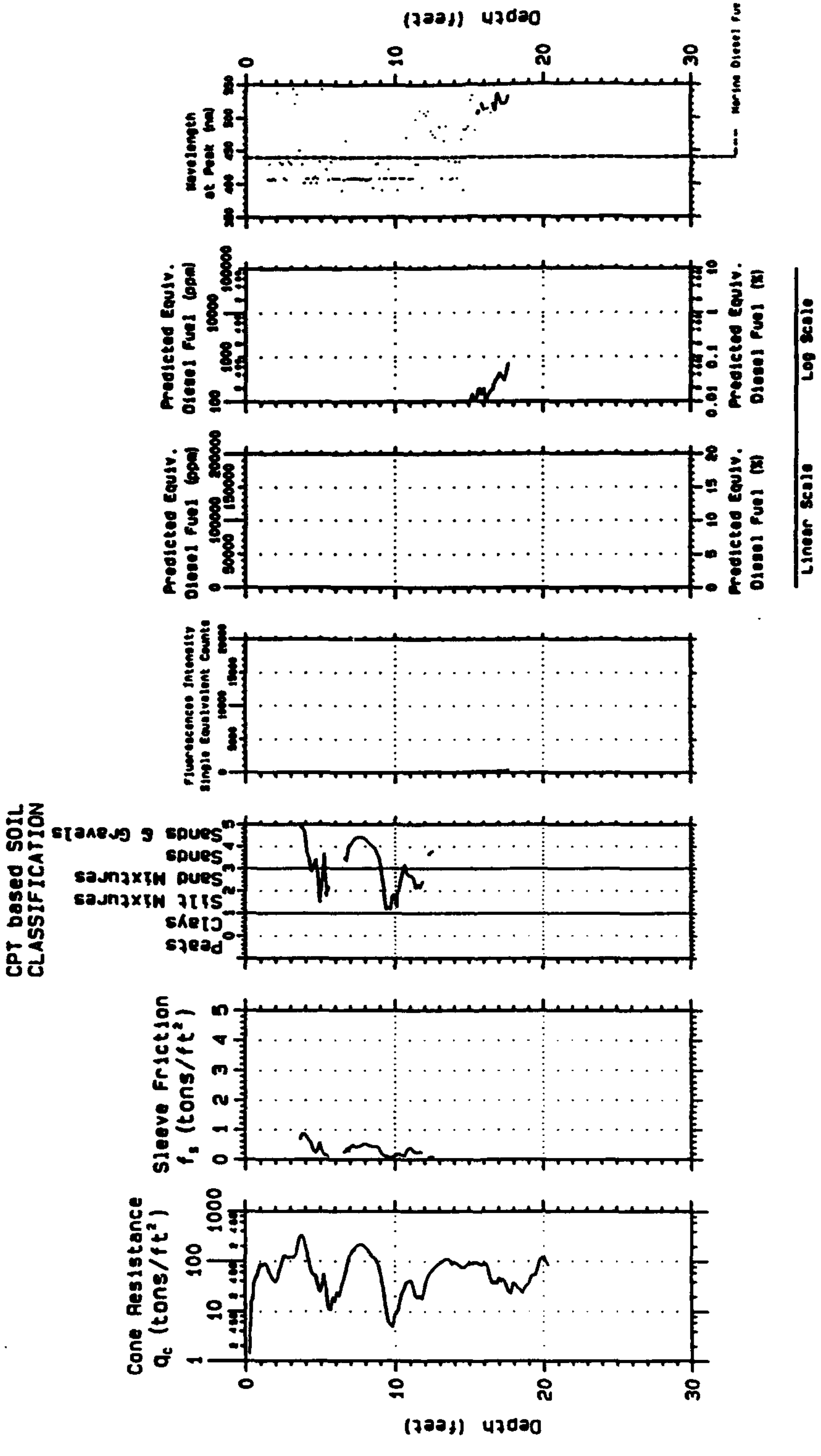

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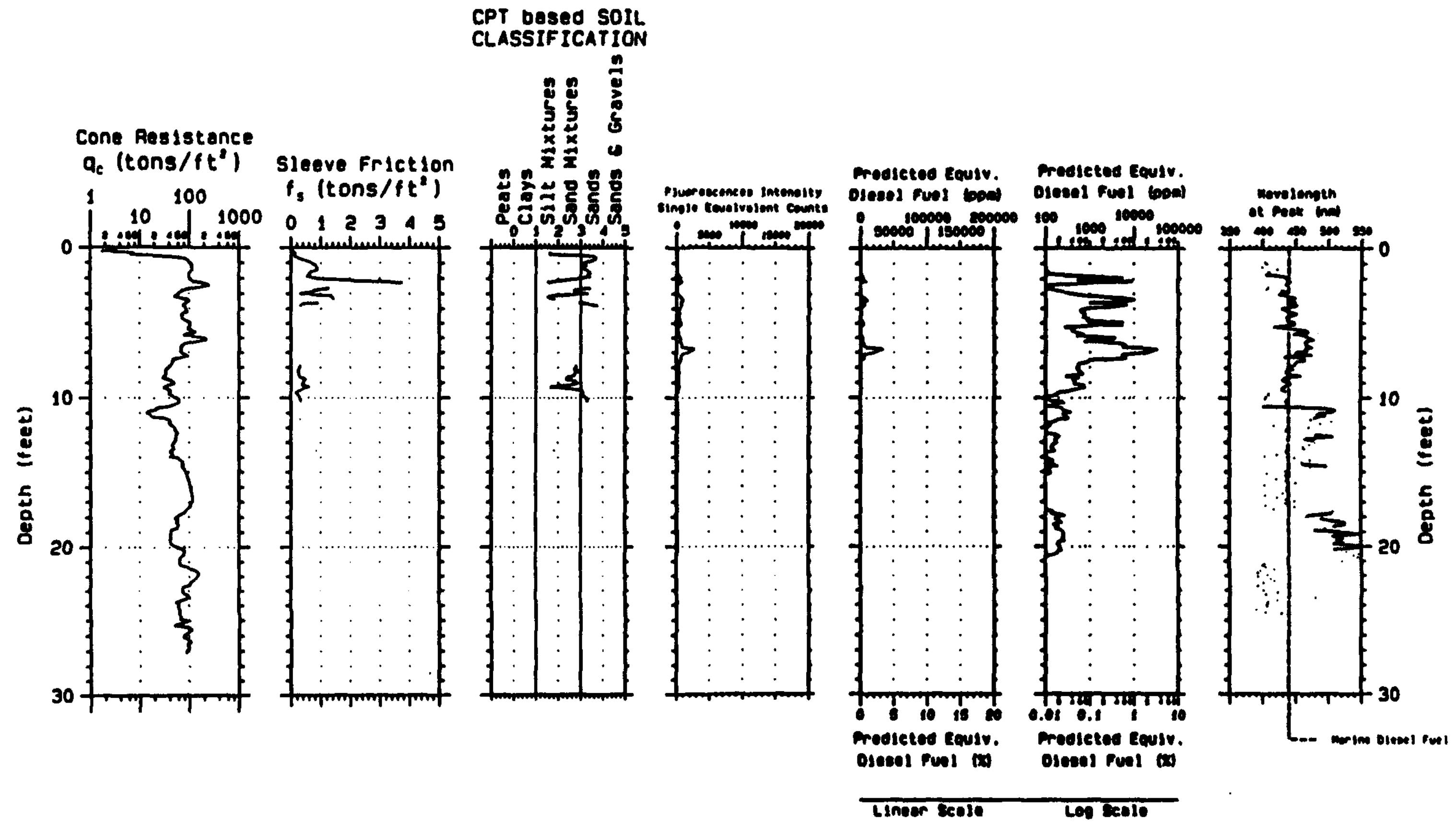

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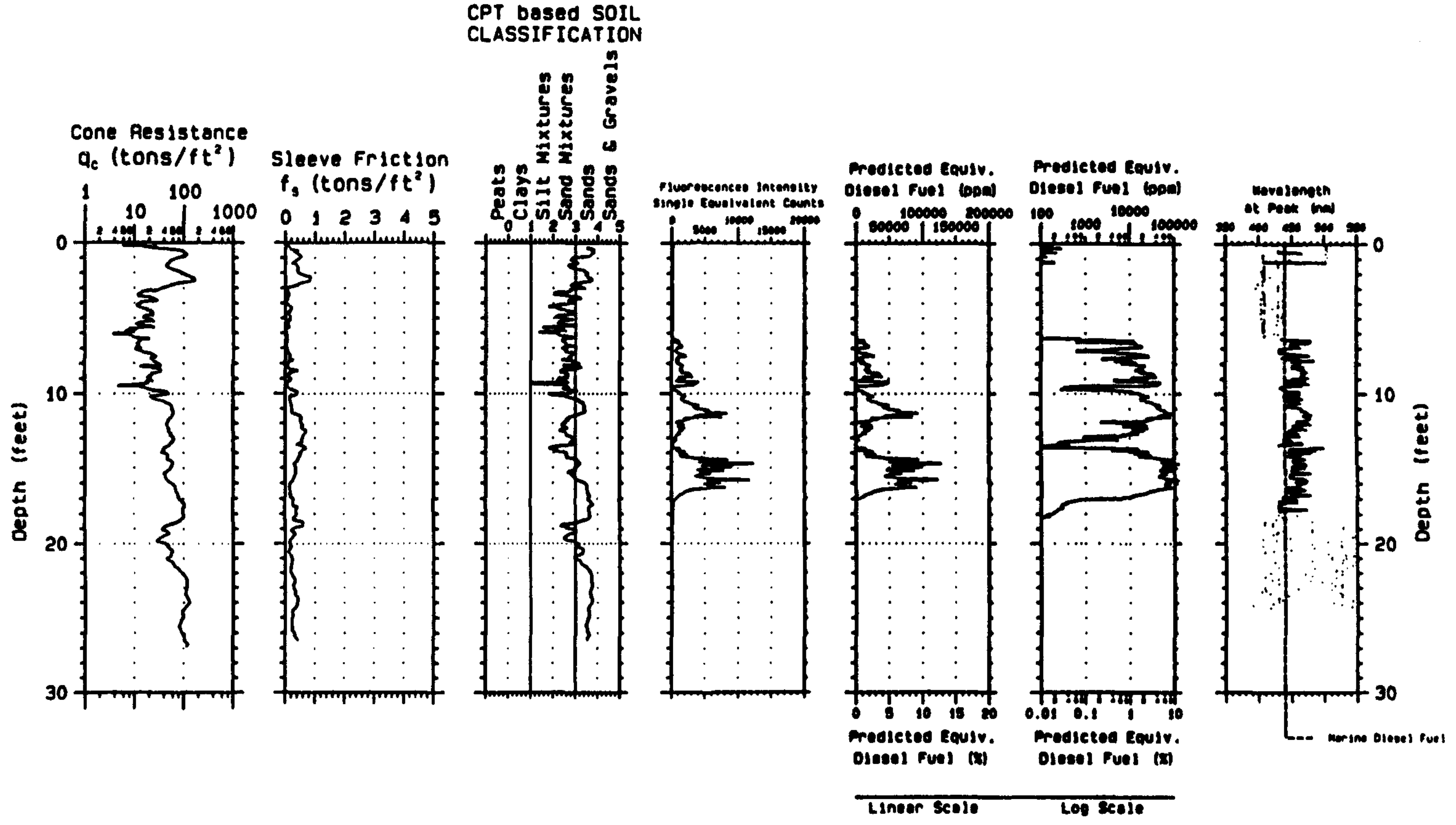

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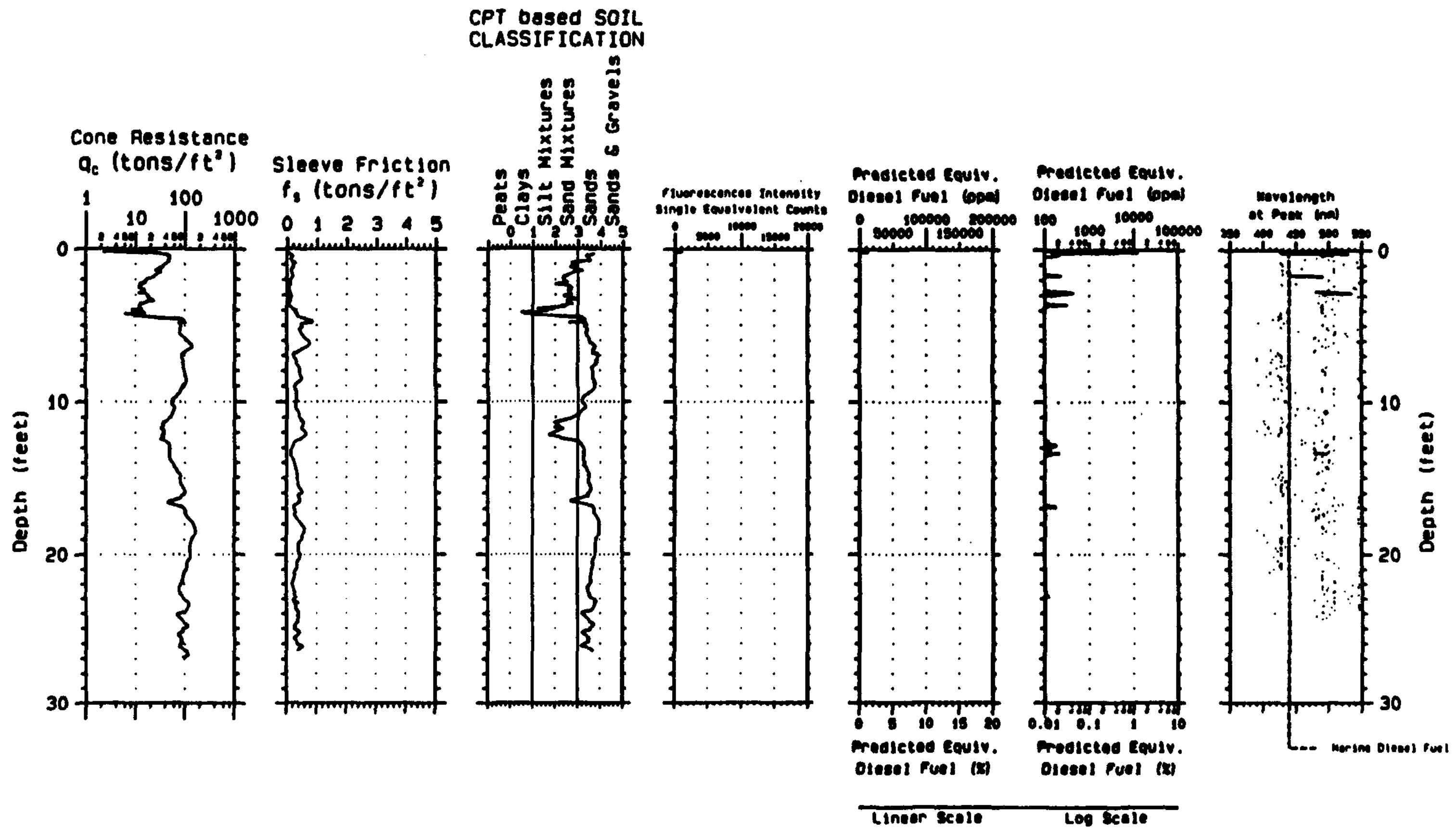

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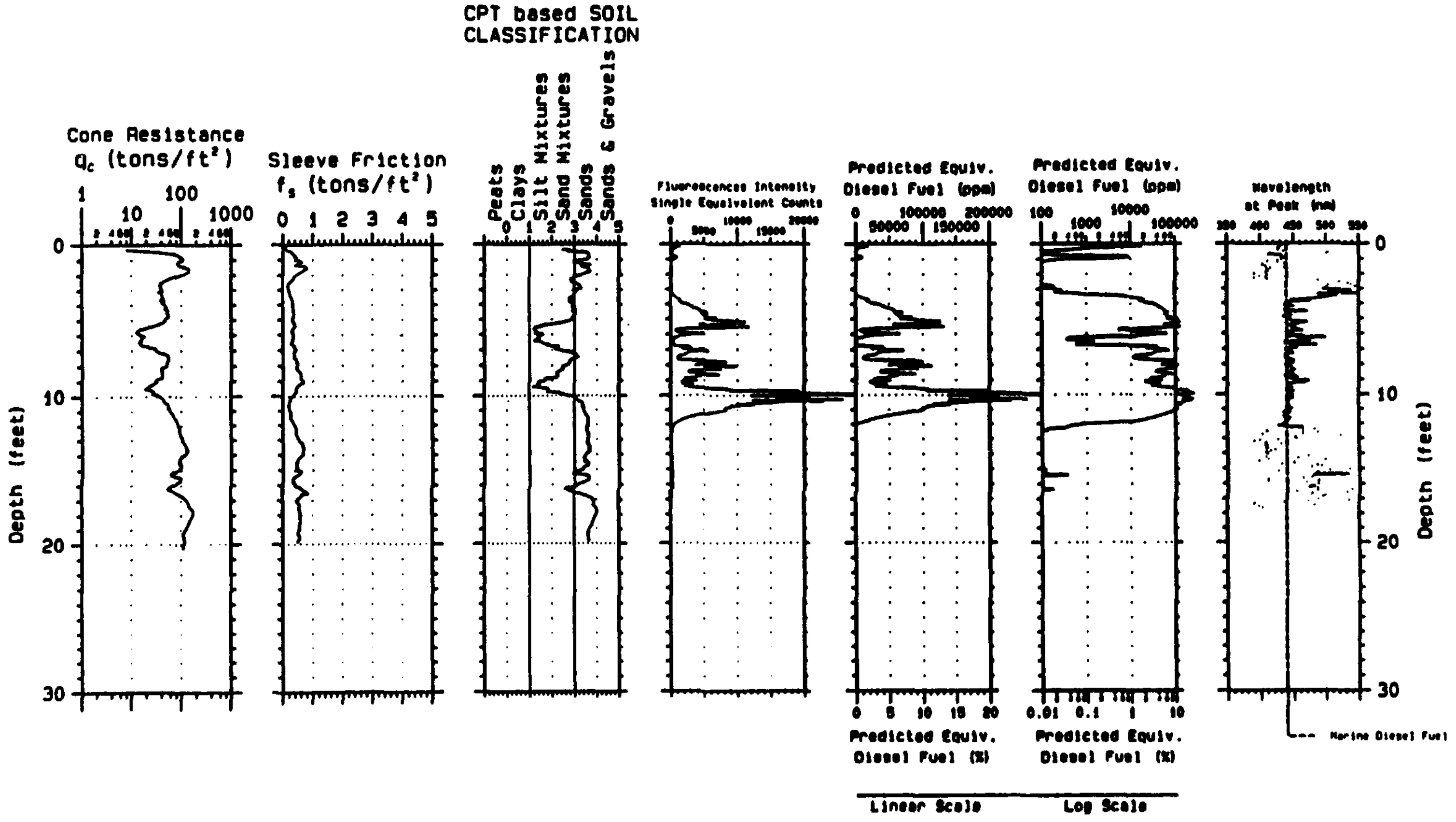

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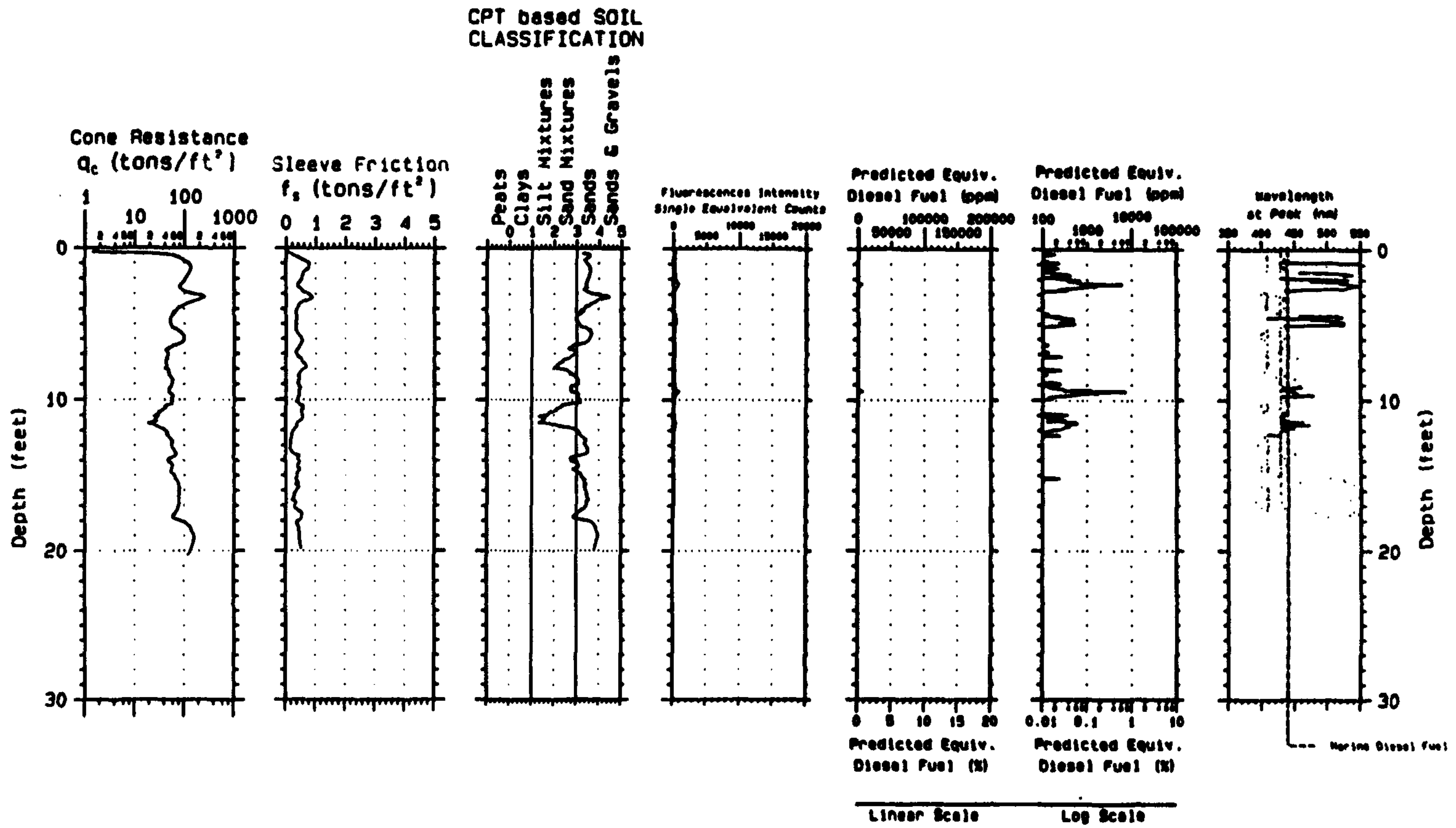

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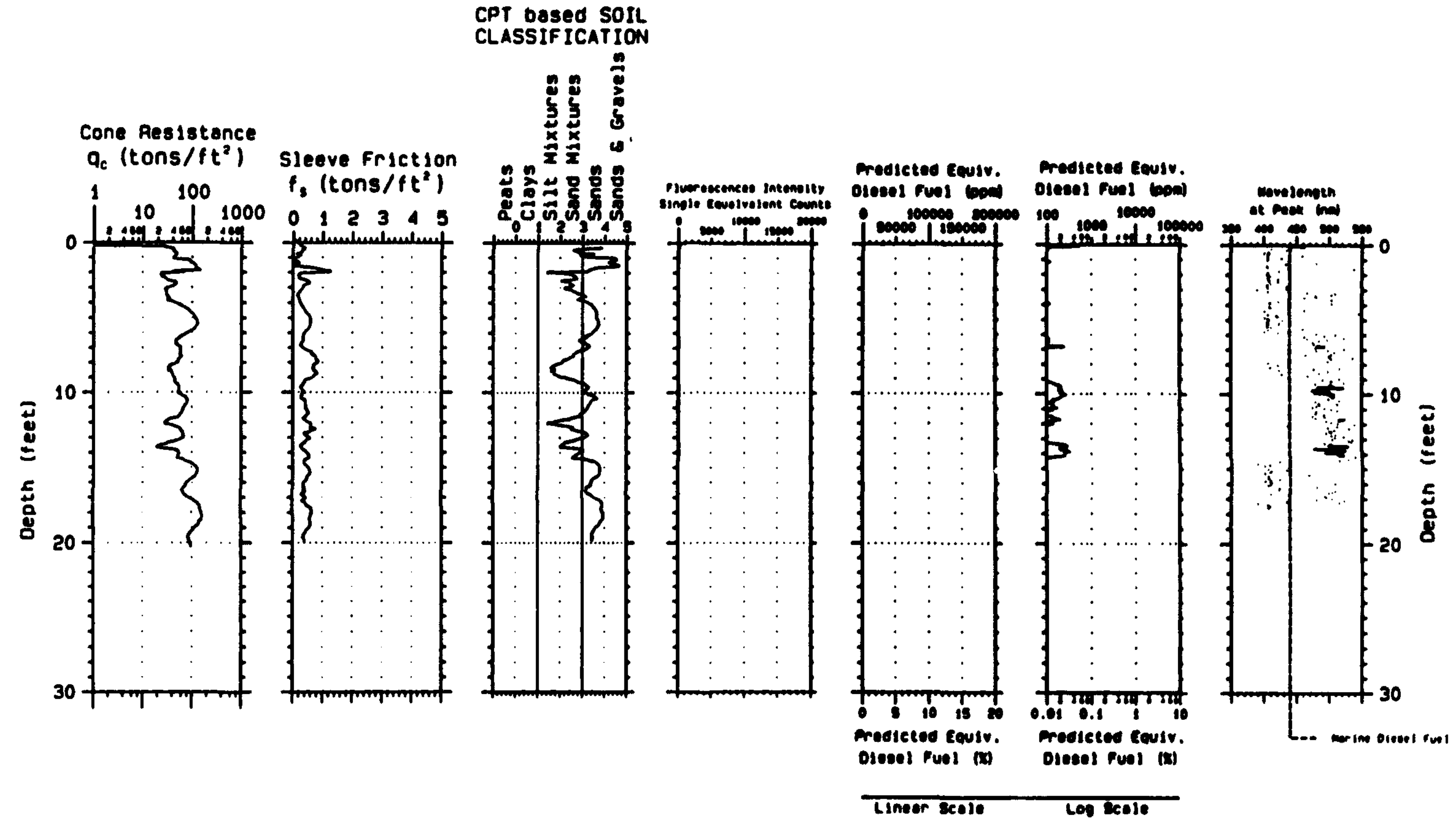

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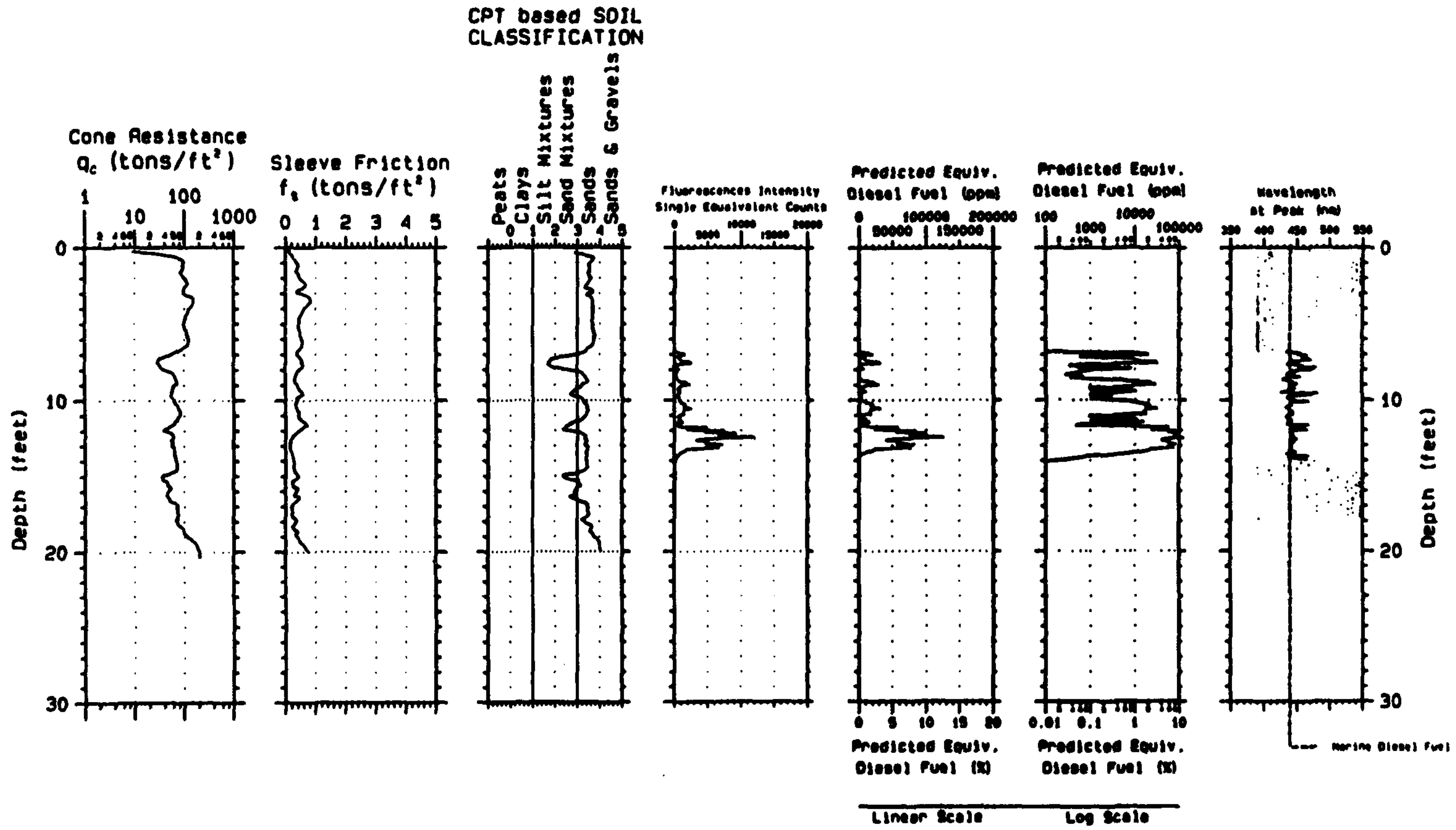

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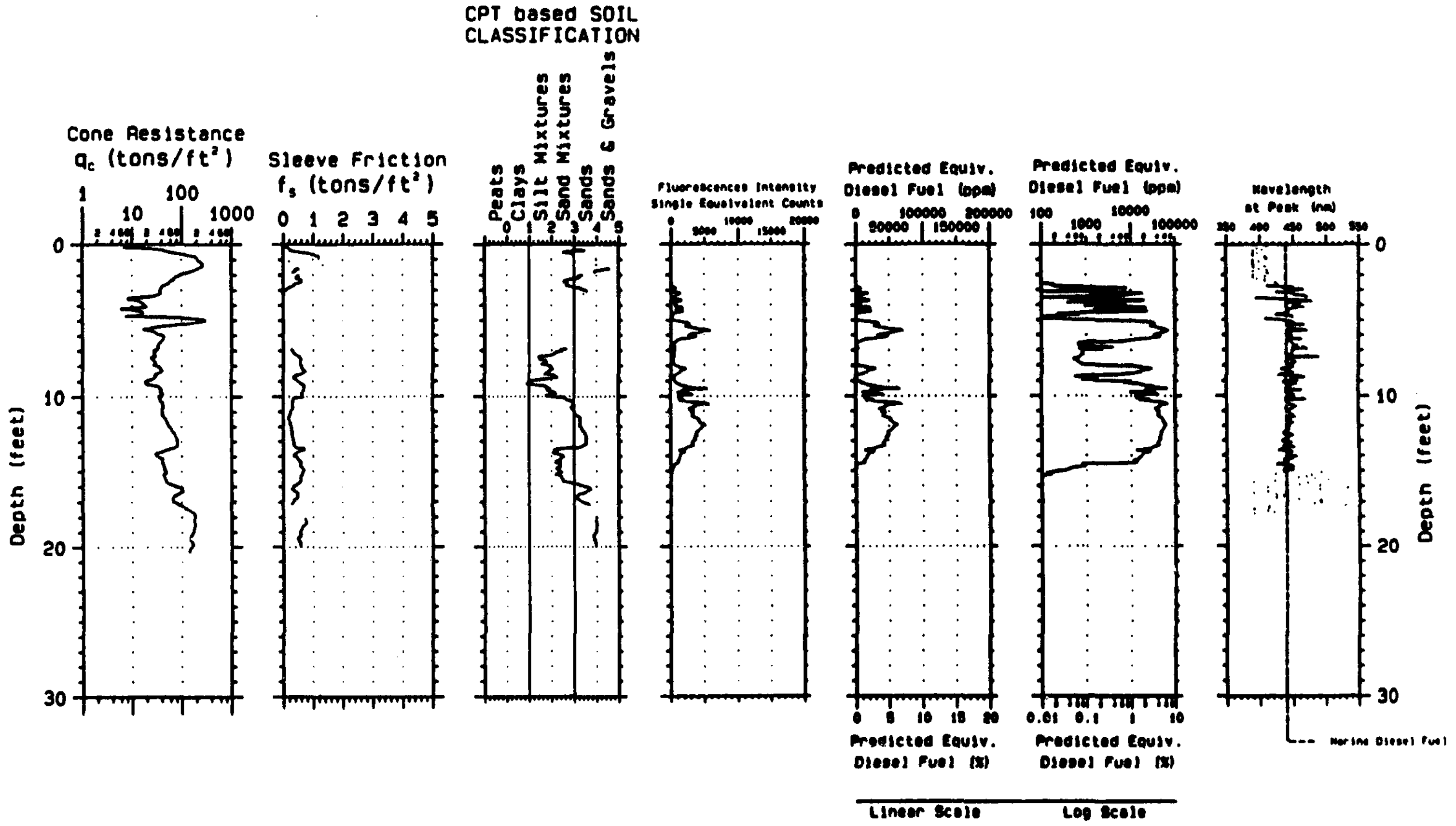

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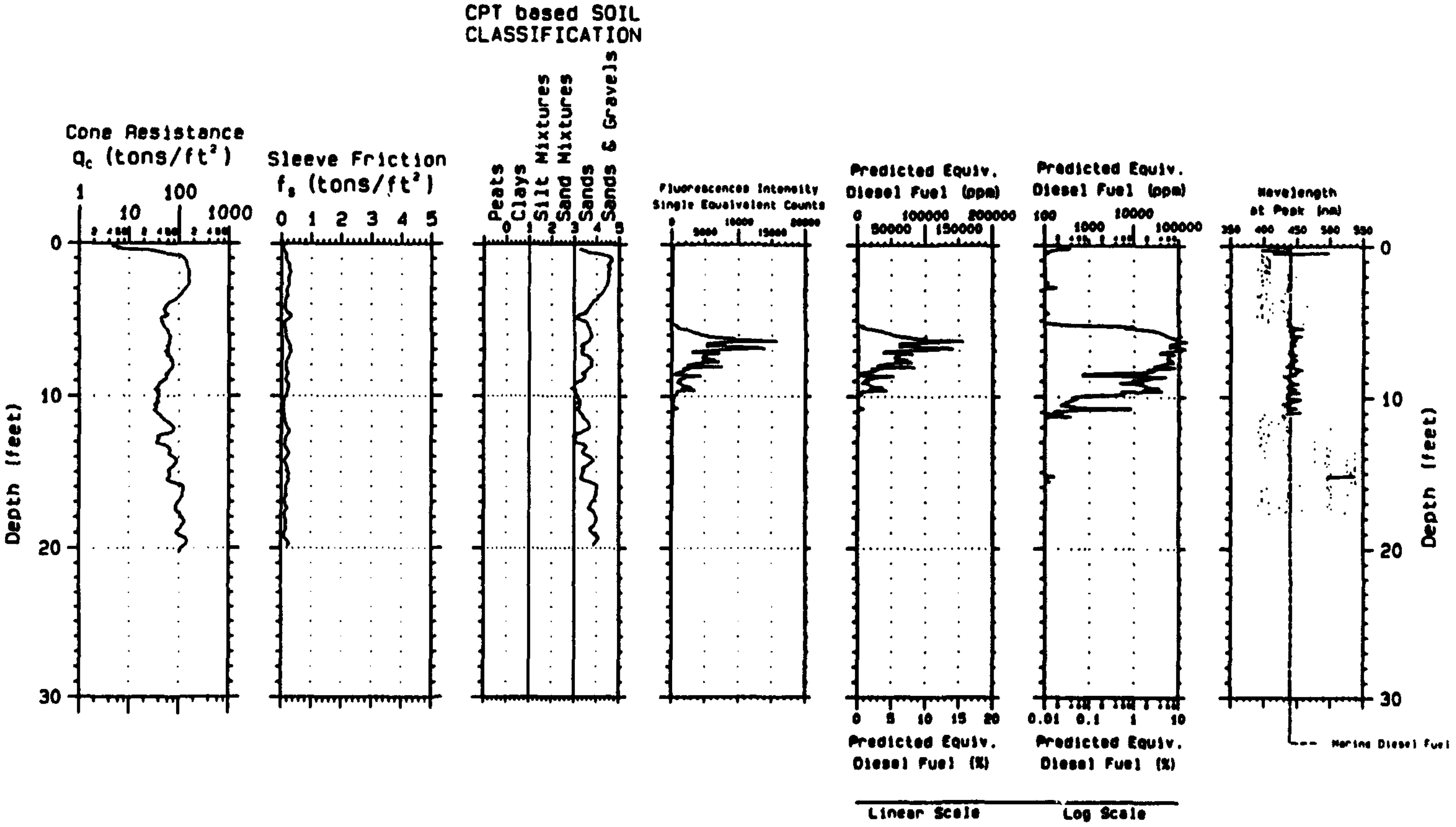

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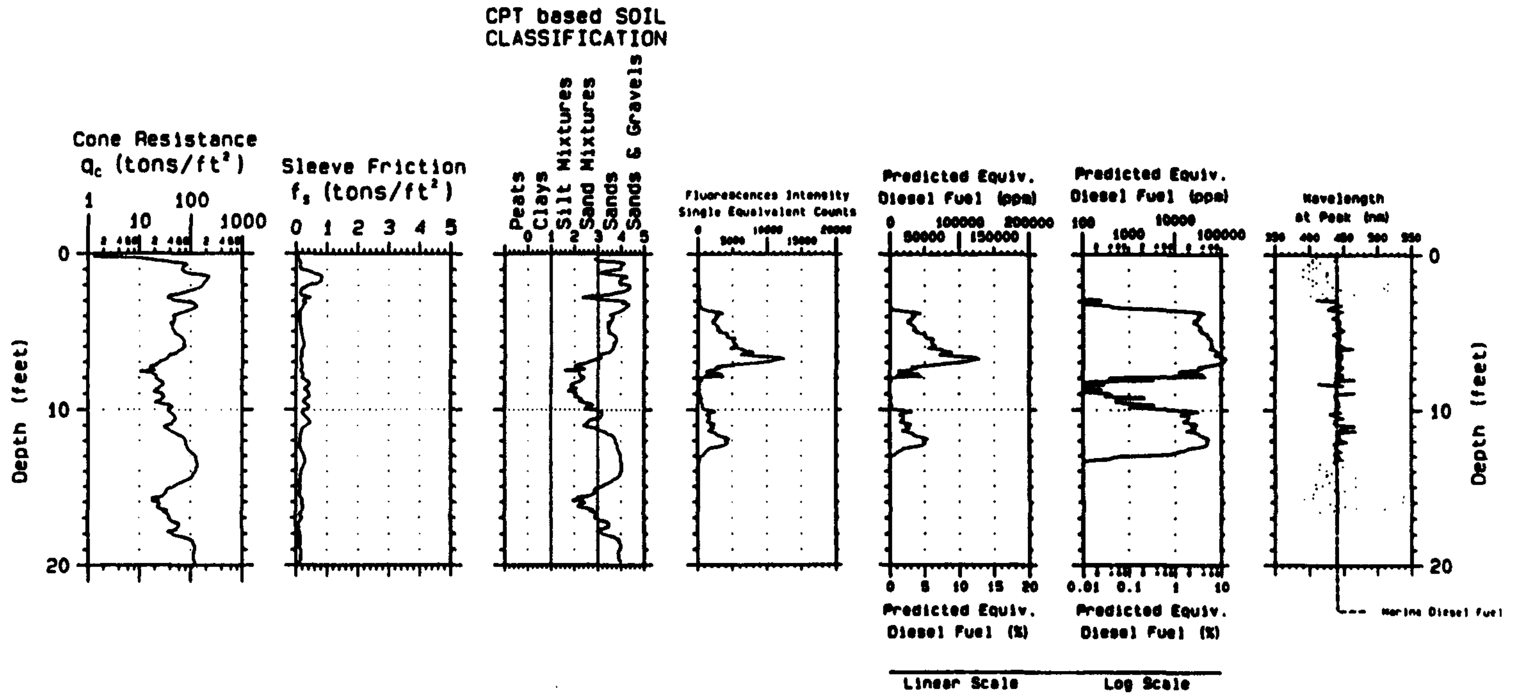

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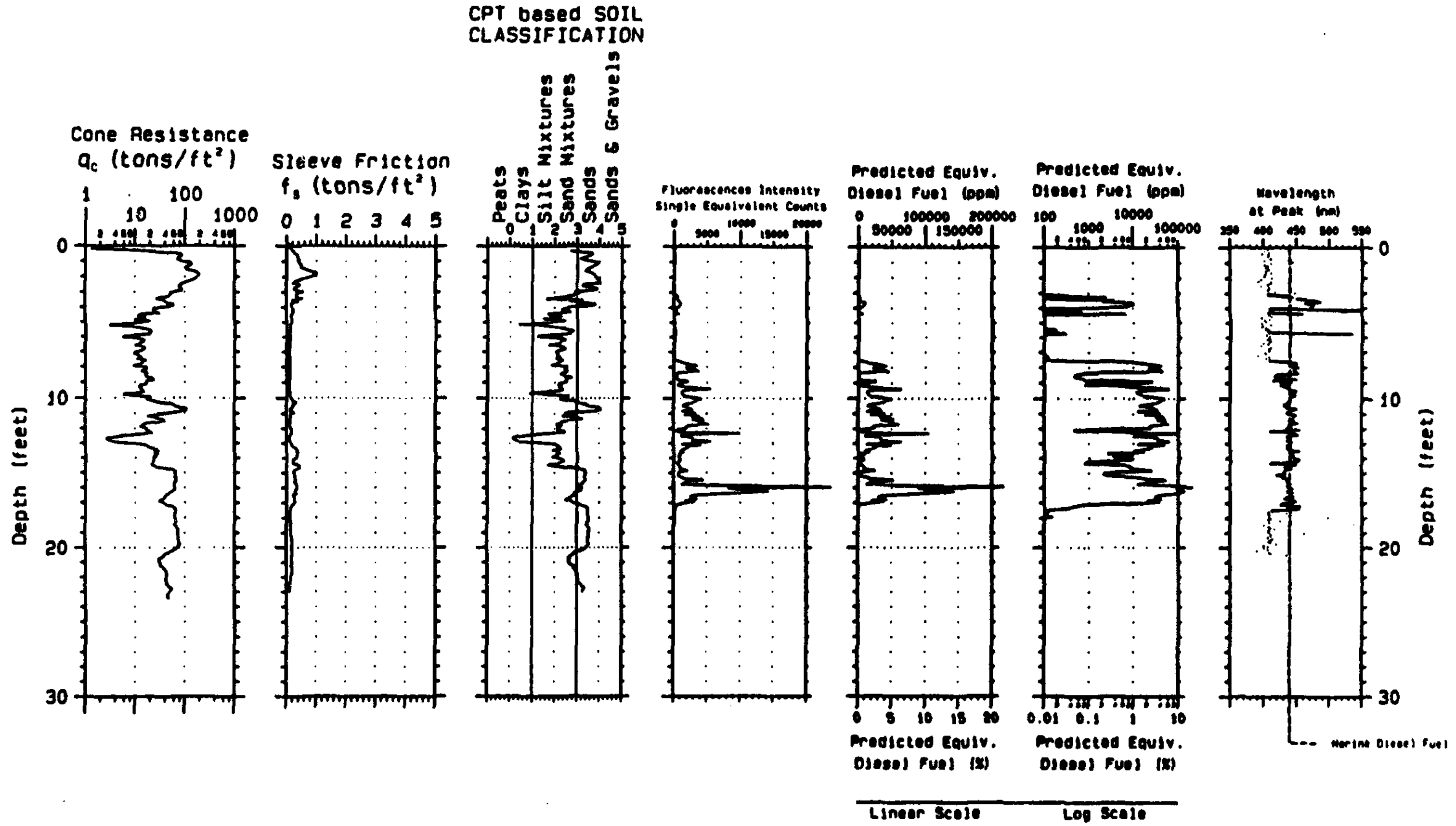

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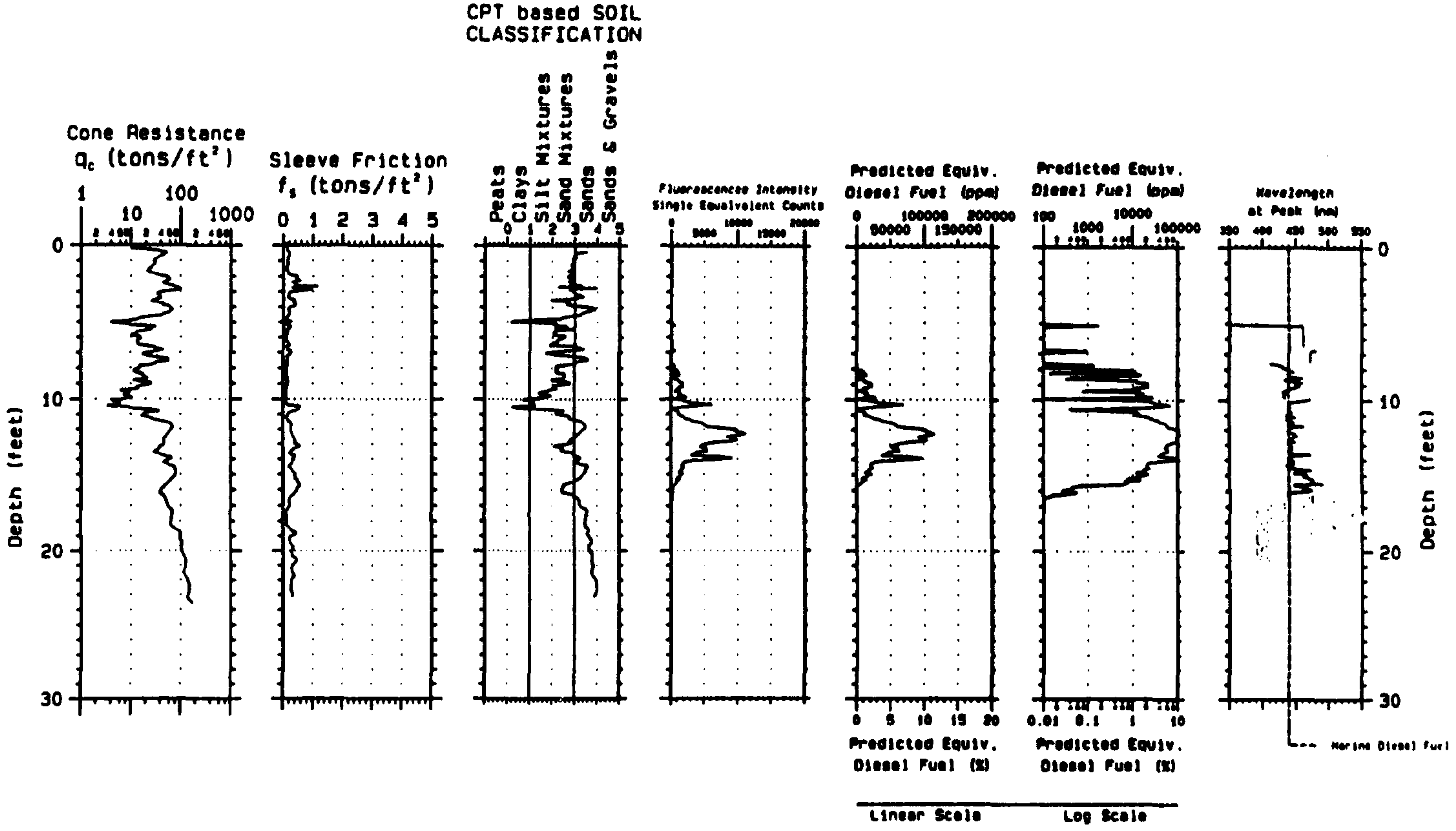

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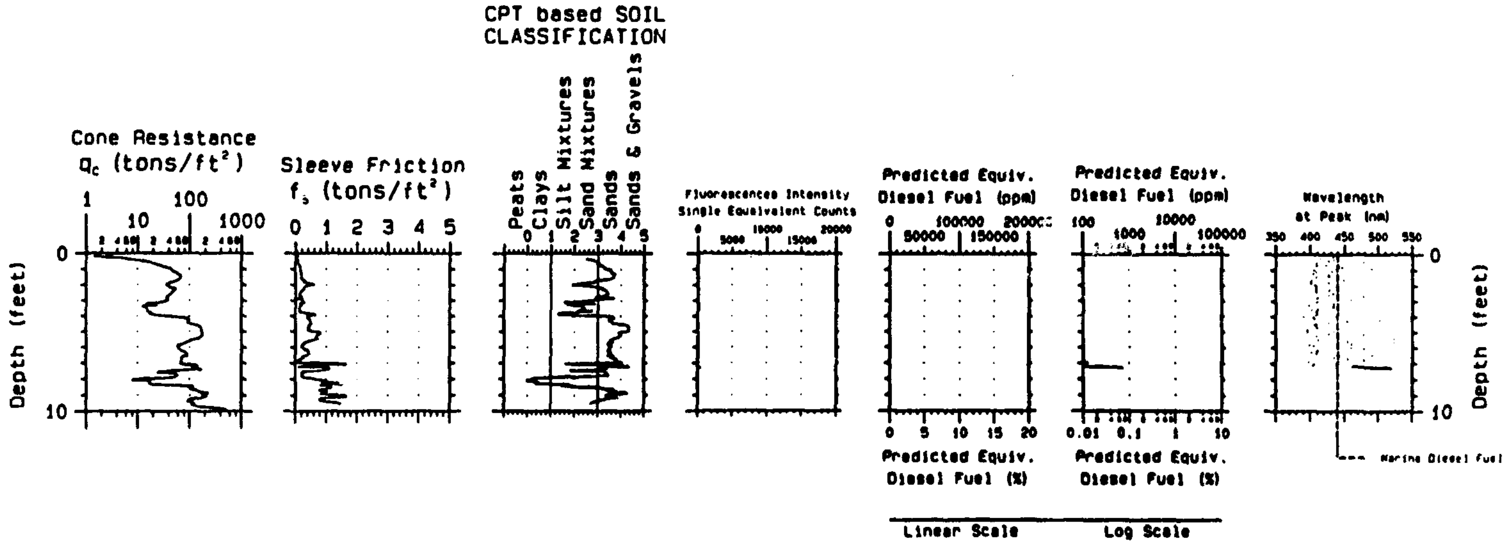

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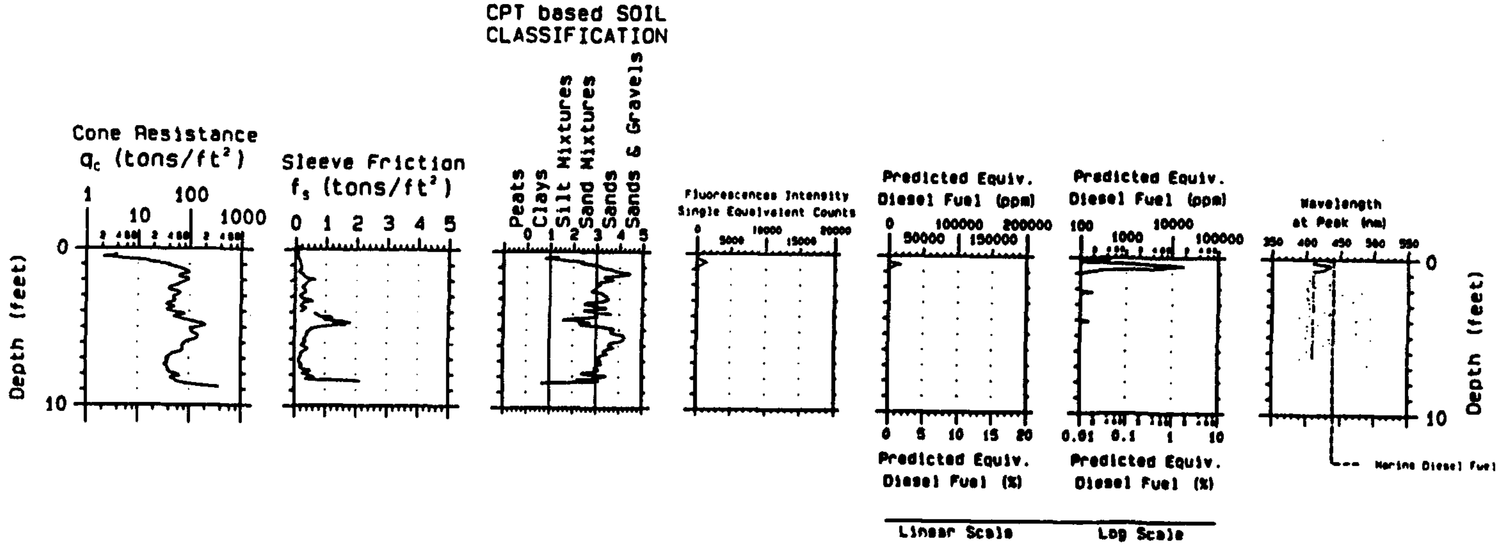

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Disk file name: c:\data\JAX\C-48-90.Q0F

STATE COORDINATES:

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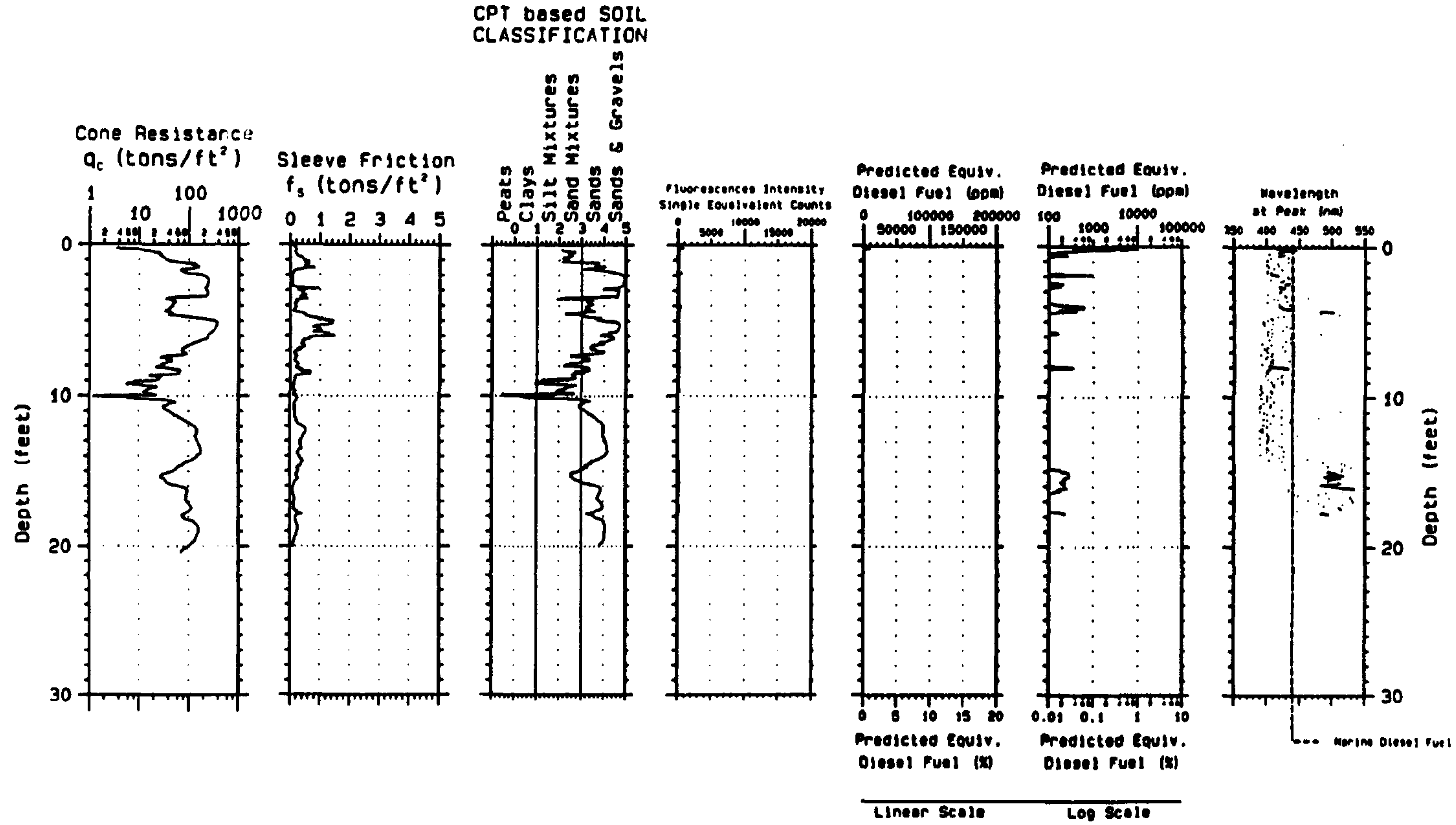

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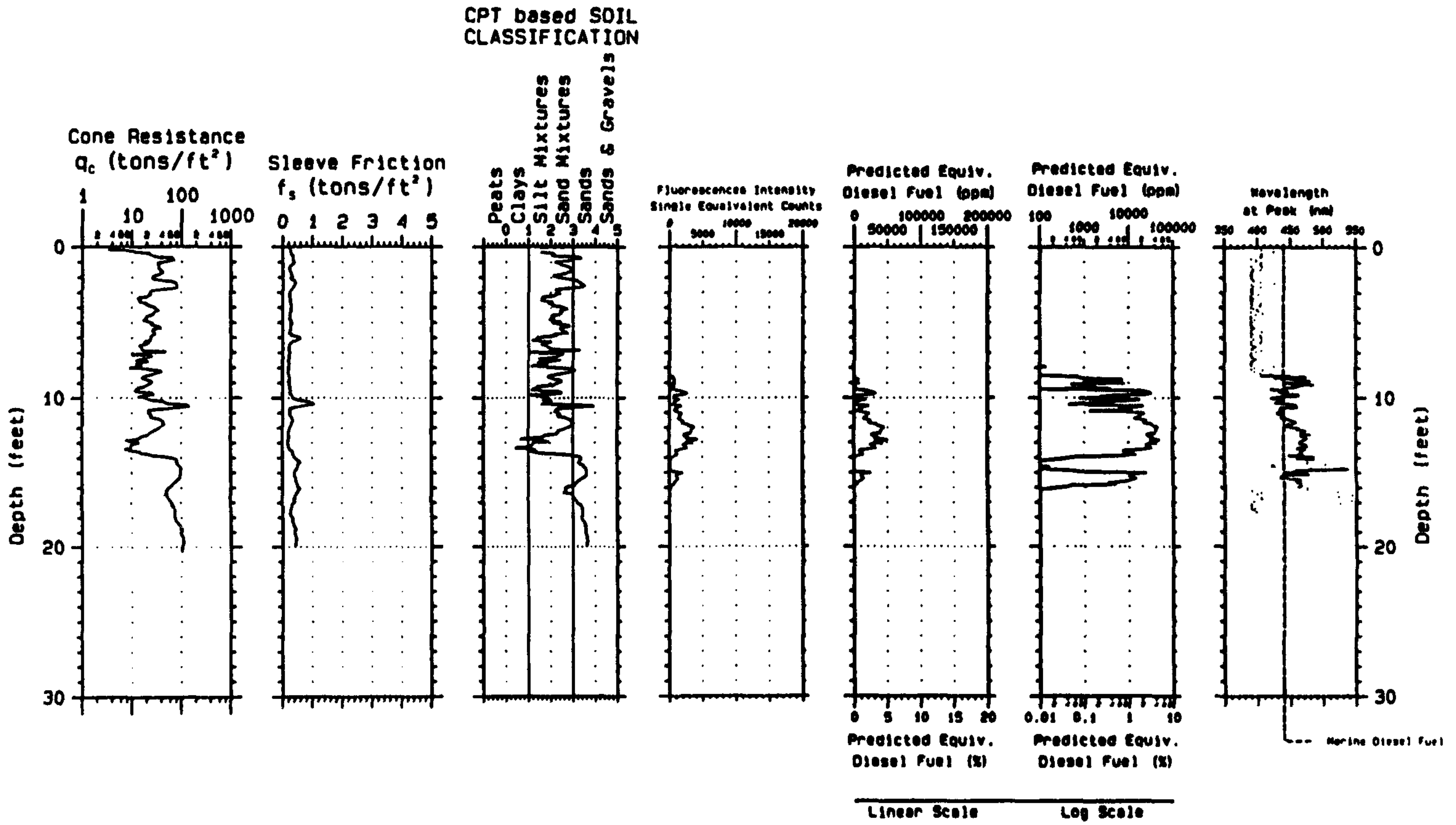

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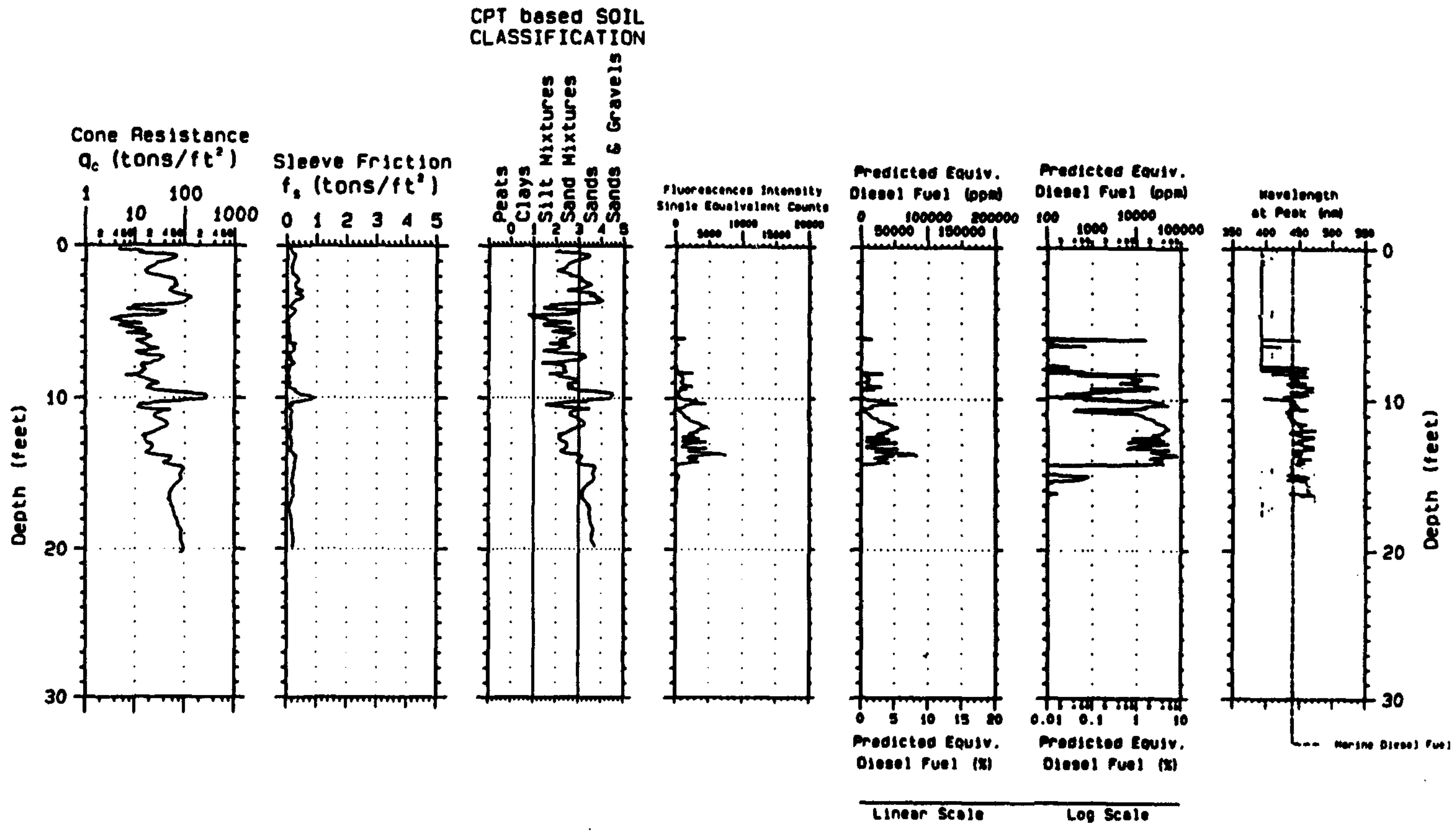

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STATE COORDINATES:

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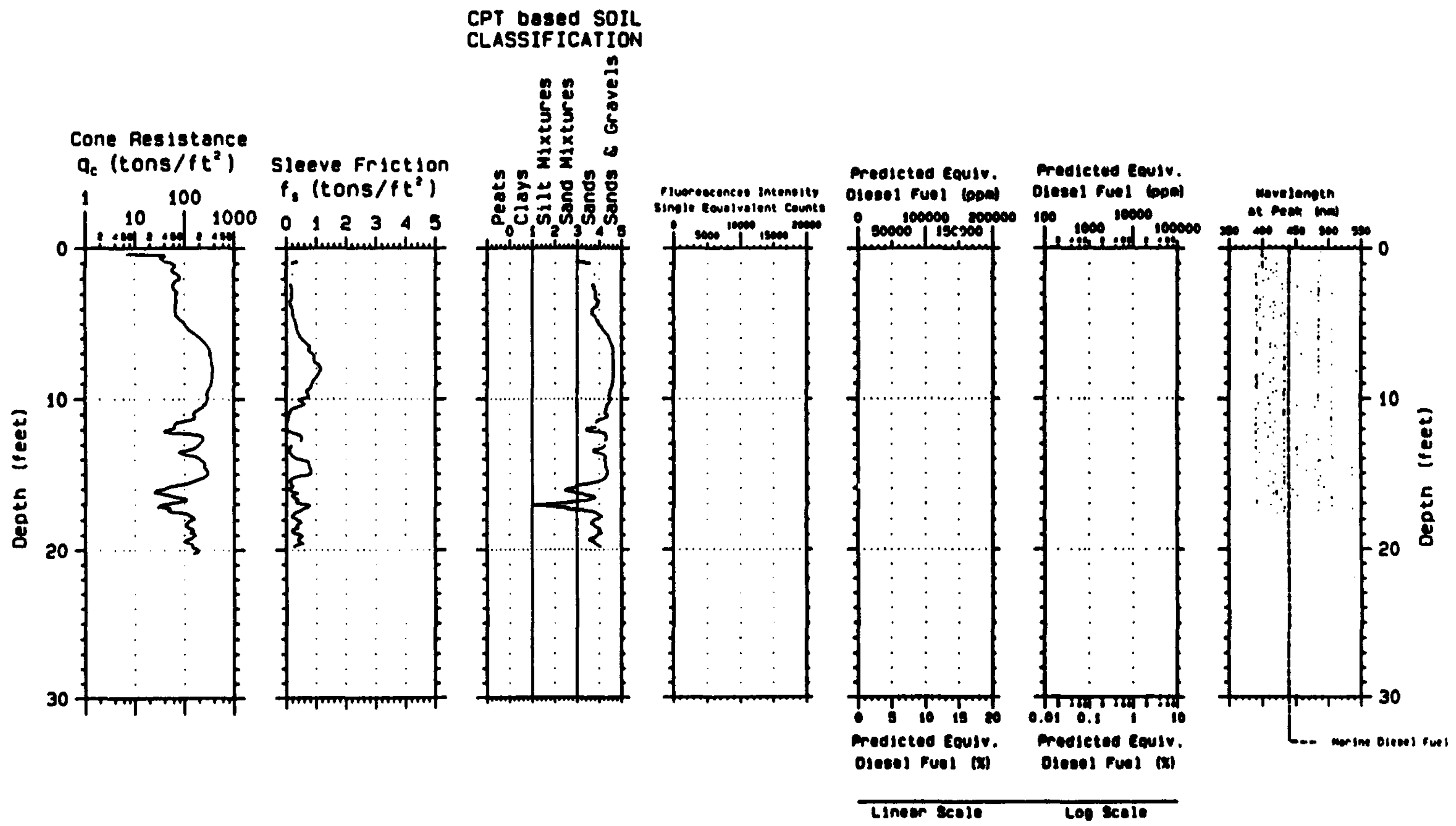

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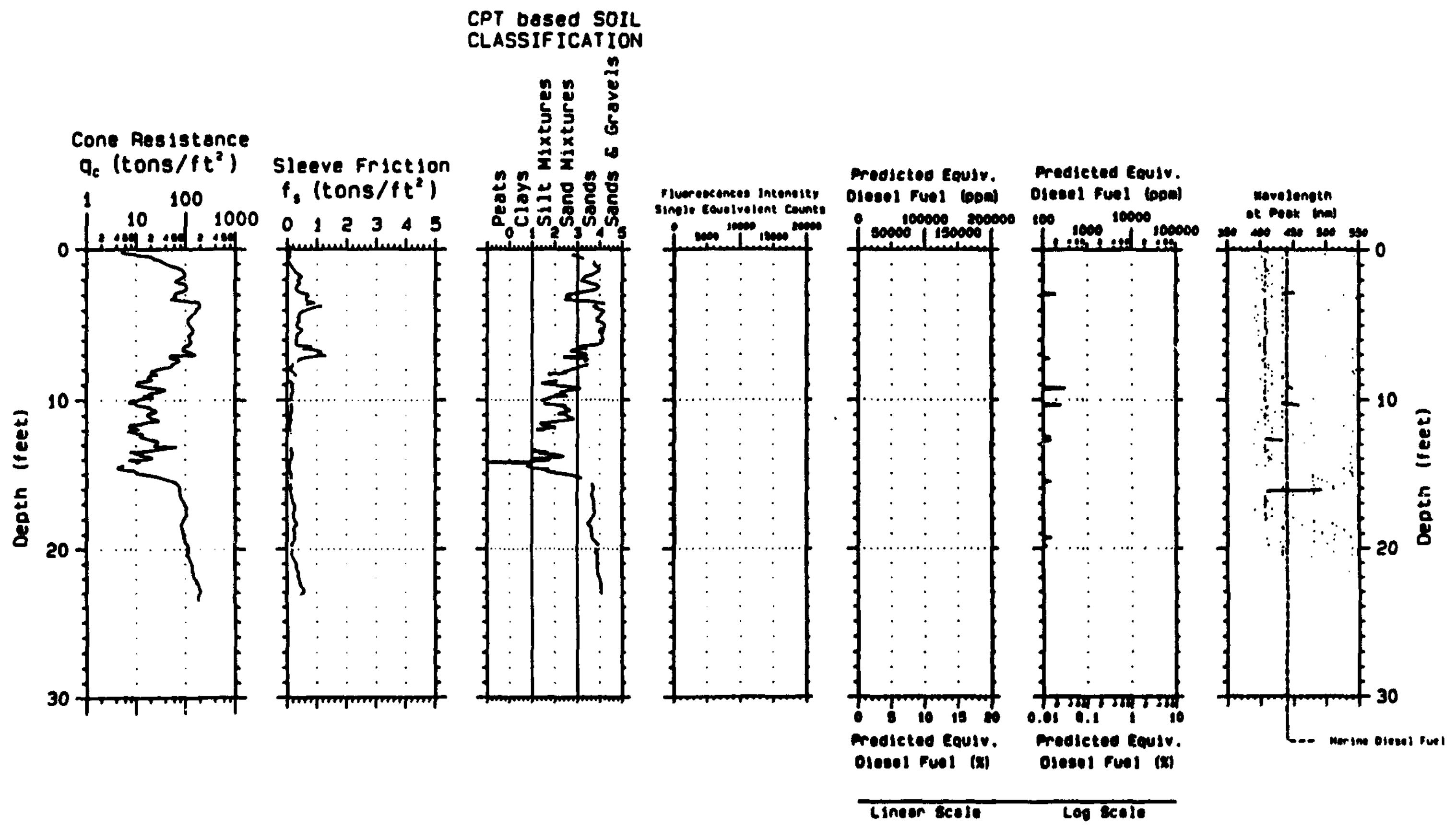

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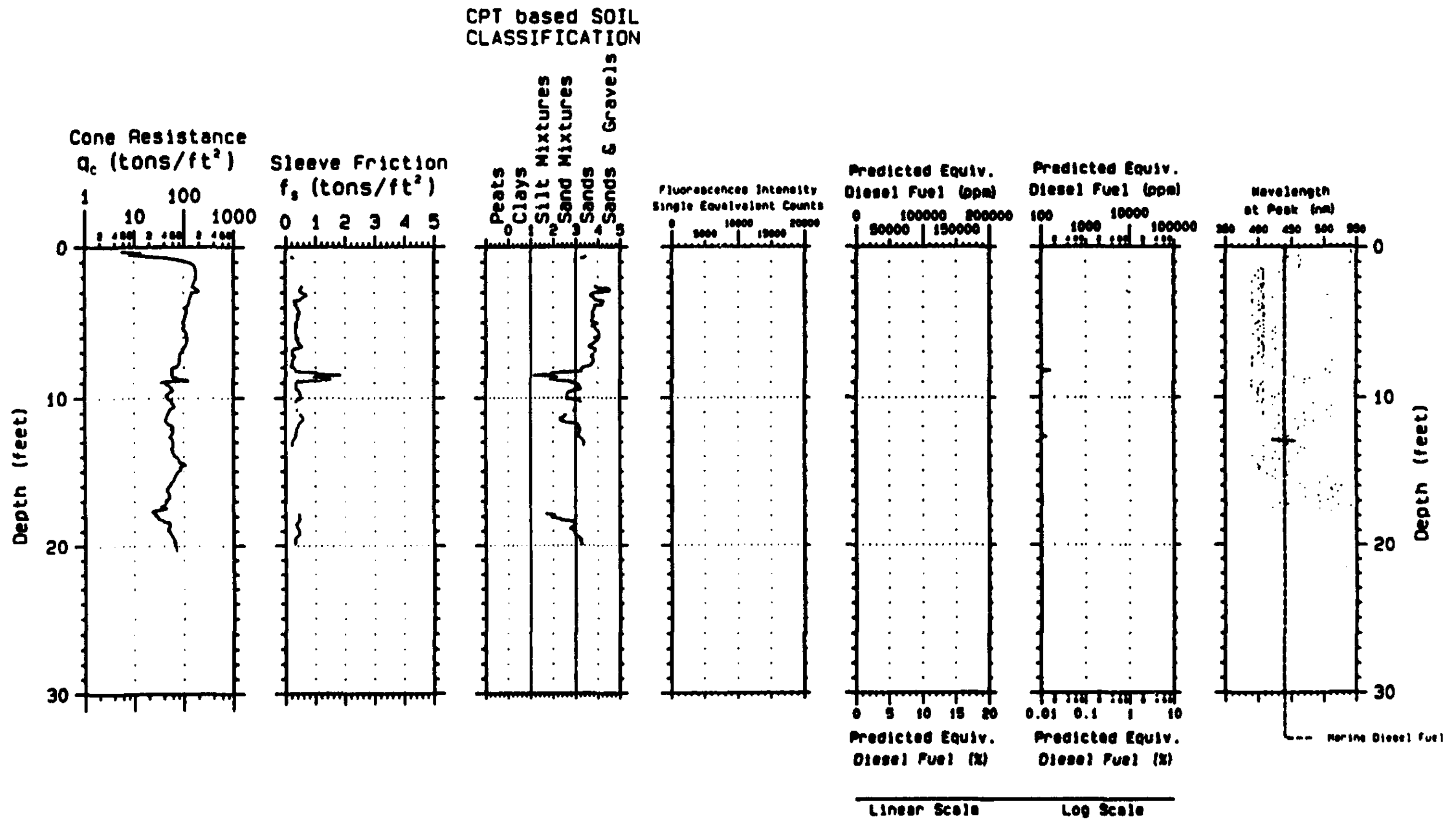

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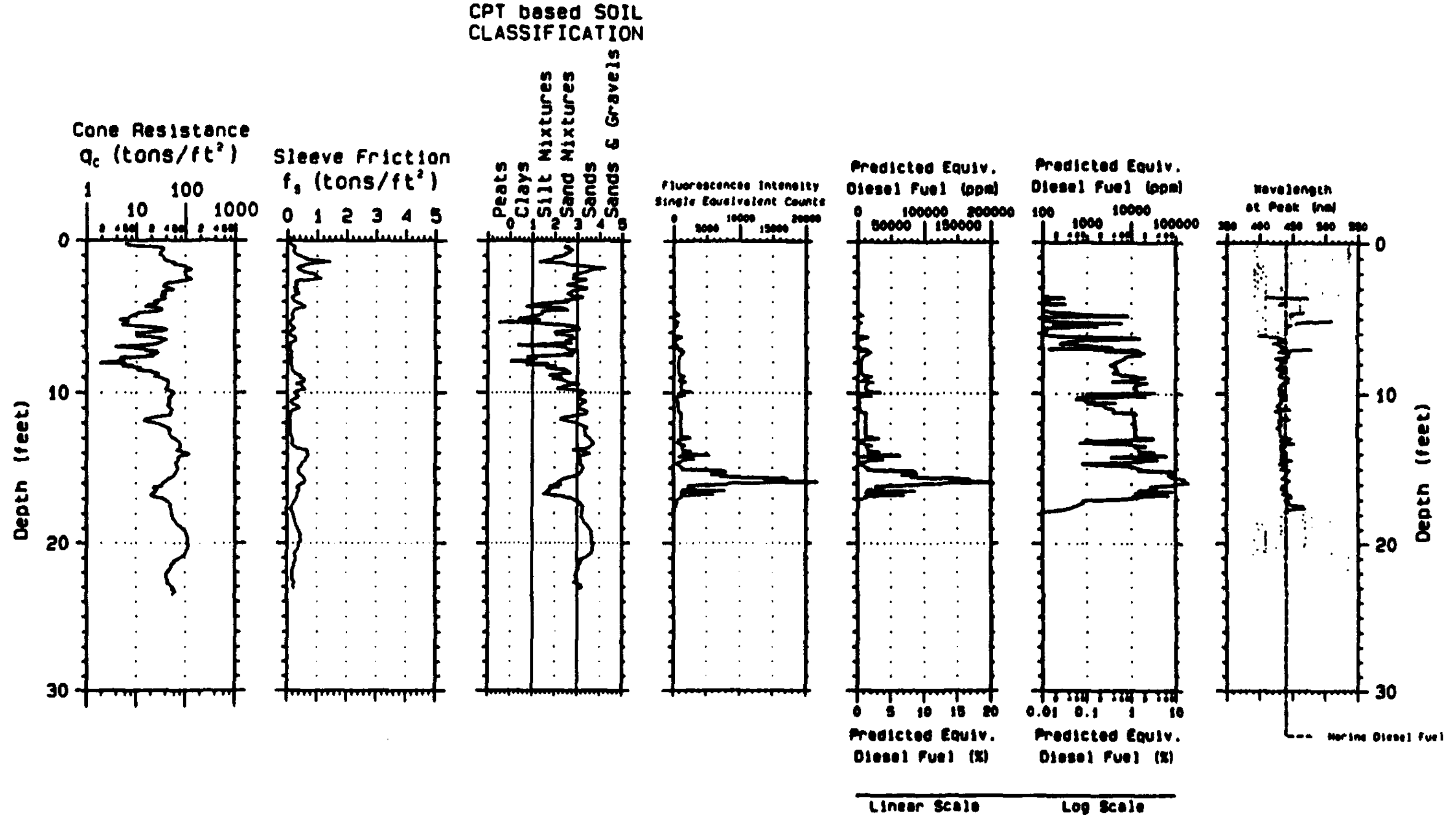

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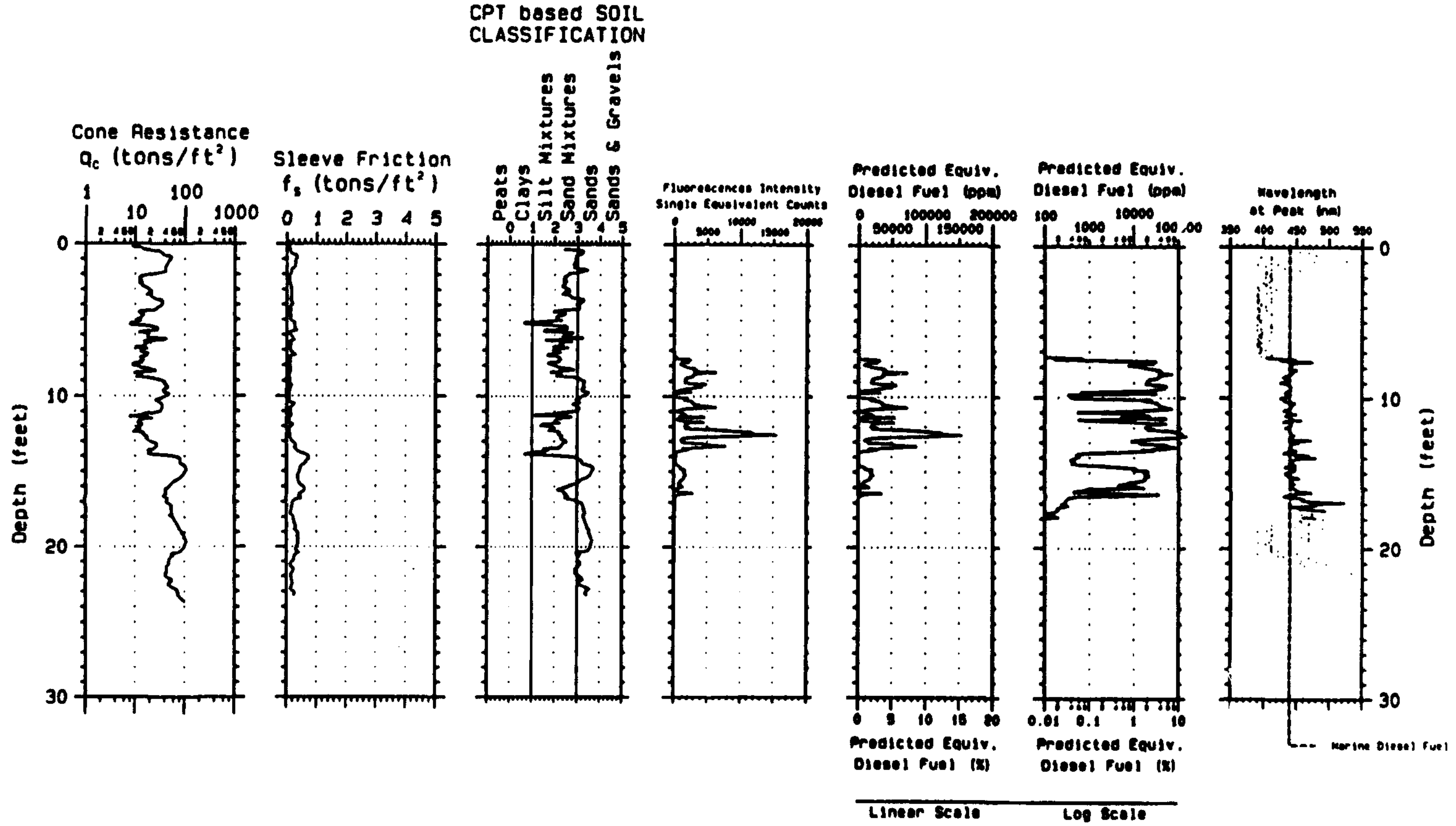

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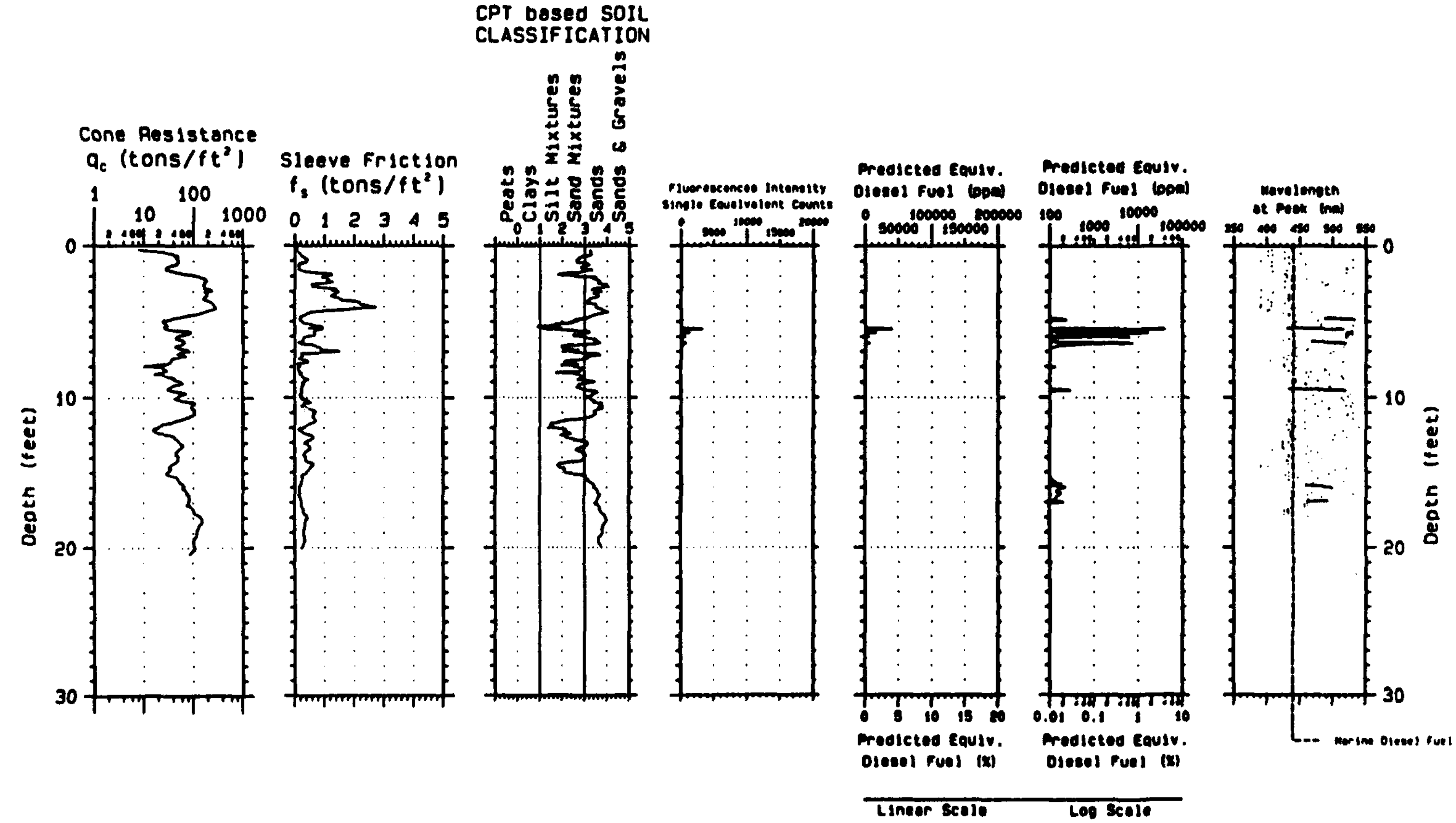

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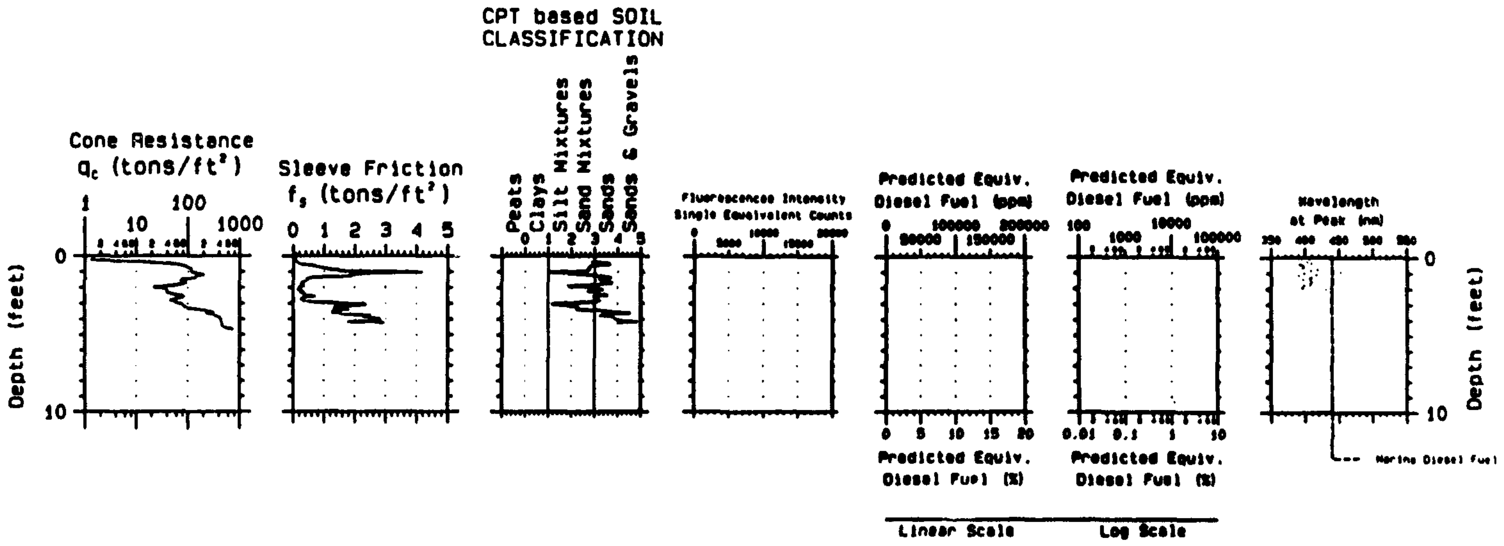
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438288.5	2136172	32.1

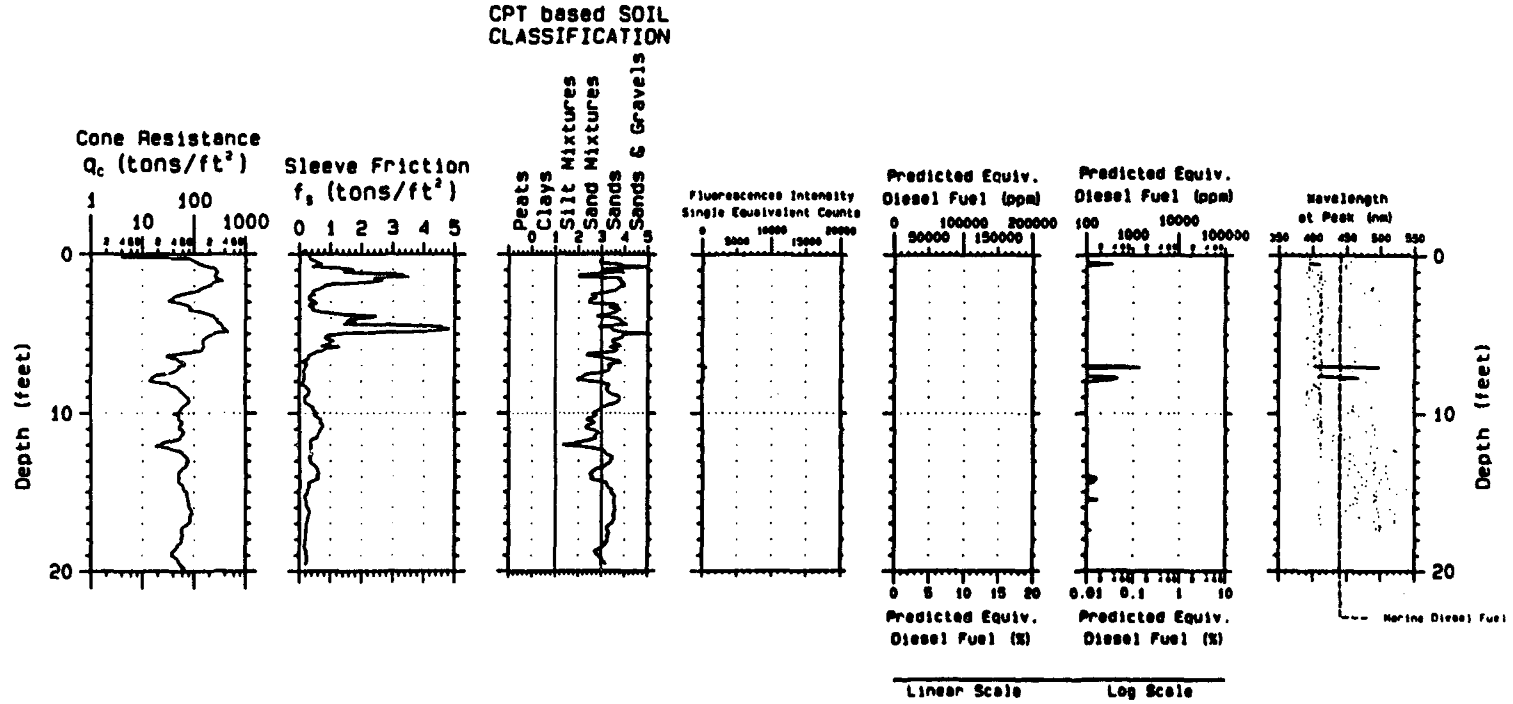


CPT; C-58-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-58-90.00F

STATE COORDINATES: 1 foot = 0.305 m.

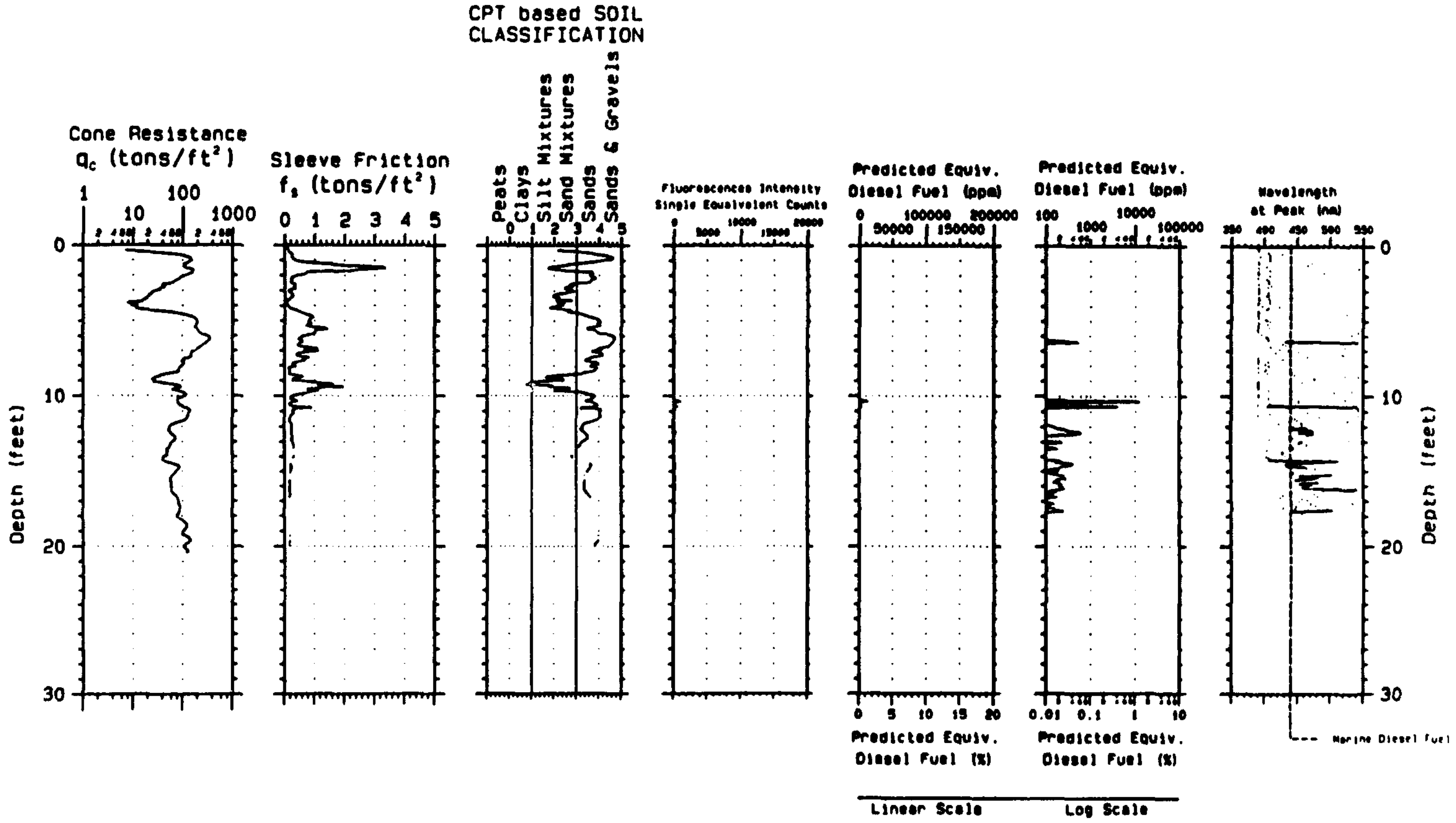
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438366.2	2136134	31.361



CPT; c-59-90 Project; Jacksonville
Disk file name; c:\data\JAX\C-59-90.QOF

1 foot = 0.305 m.

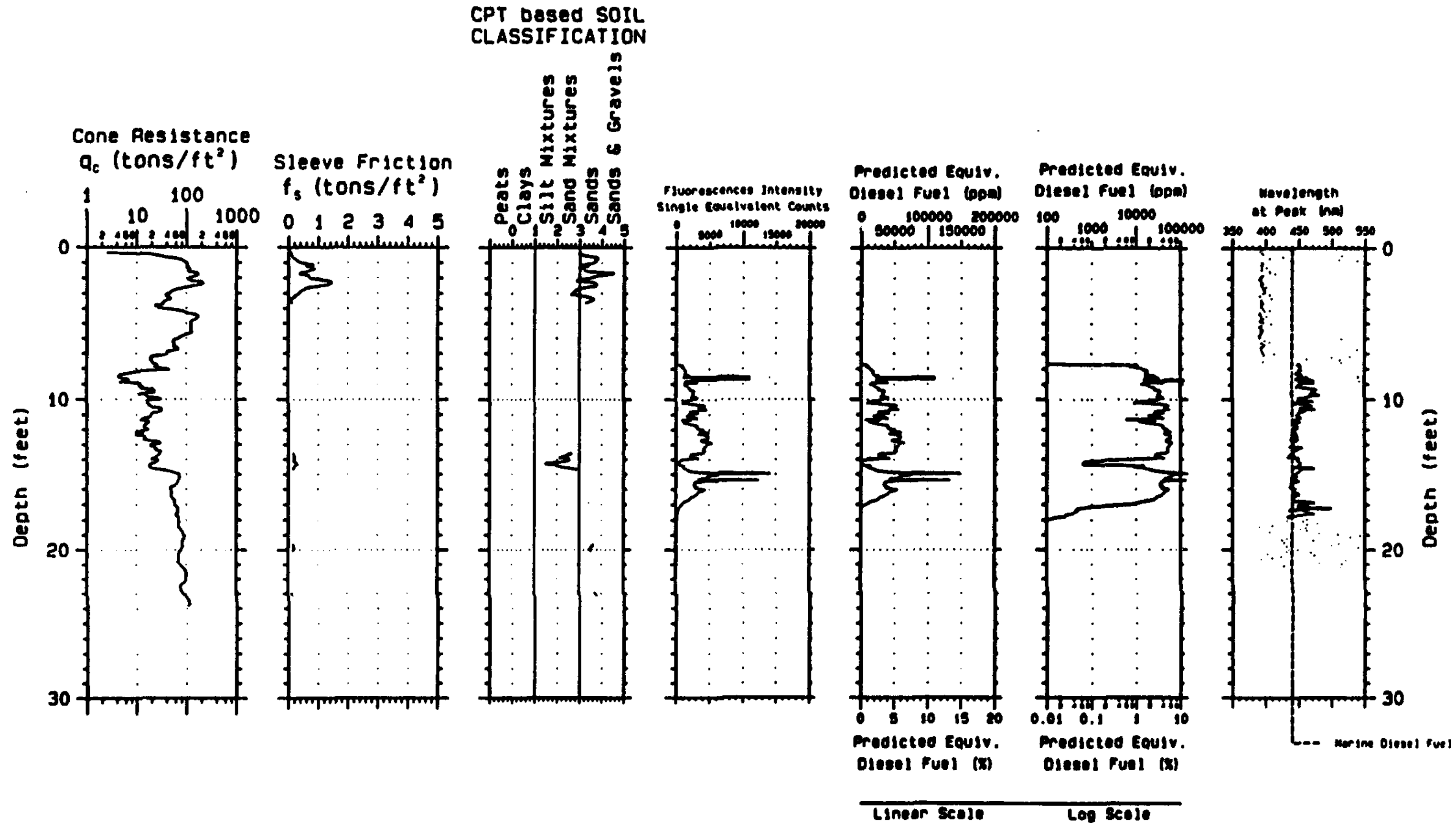
STATE COORDINATES:		
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438396.3	2136126	31.815



CPT; c-60-90　　Project; Jacksonville
Disk file name; c:\data\JAX\C-60-90.QOF

STATE COORDINATES:　　1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438433.9	2136233	33.361



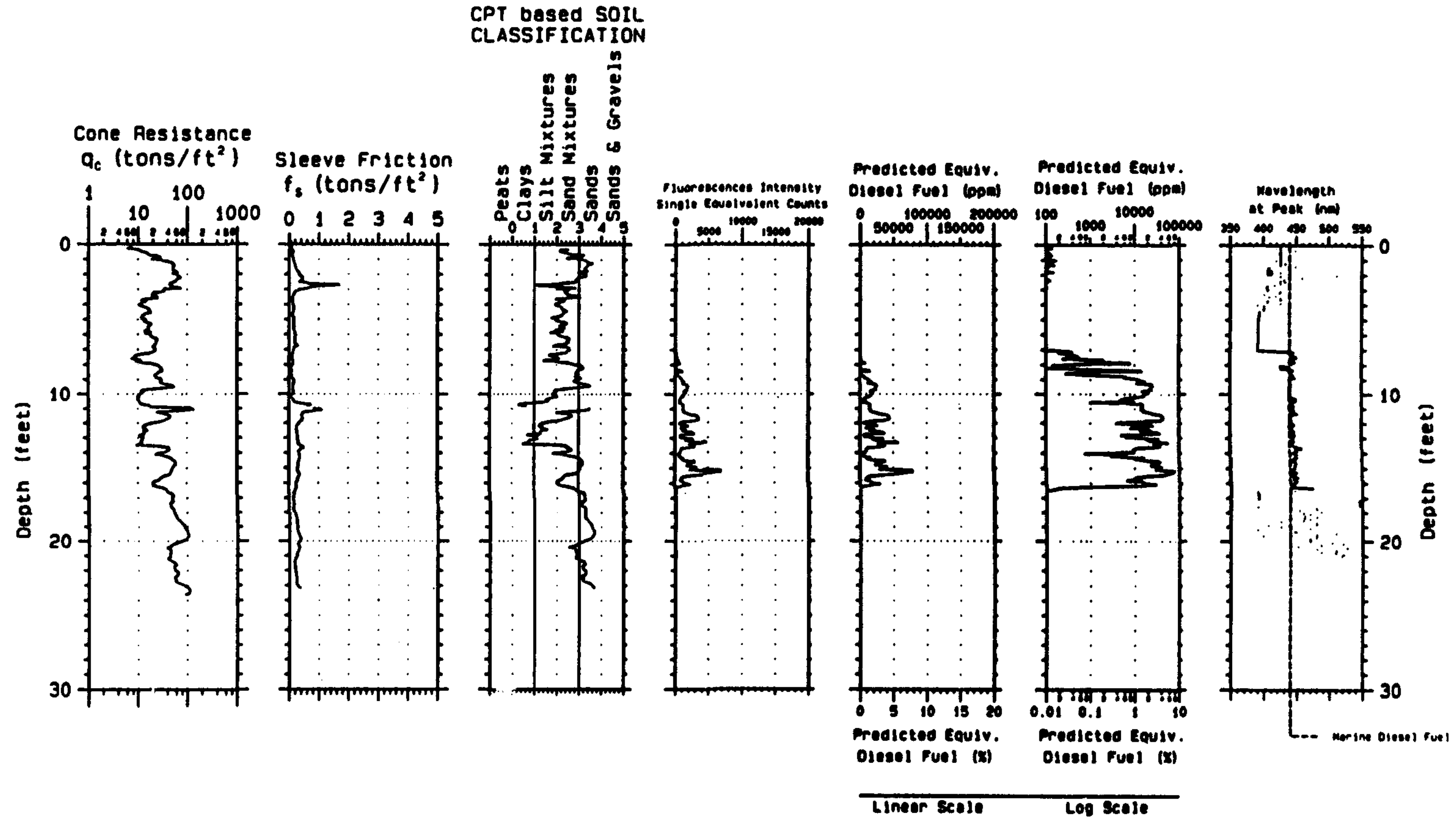
CPT; C-61-90

Project; Jacksonville
Disk file name; c:\data\JAX\C-61-90.QOF

STATE COORDINATES:

1 foot = 0.305 m.

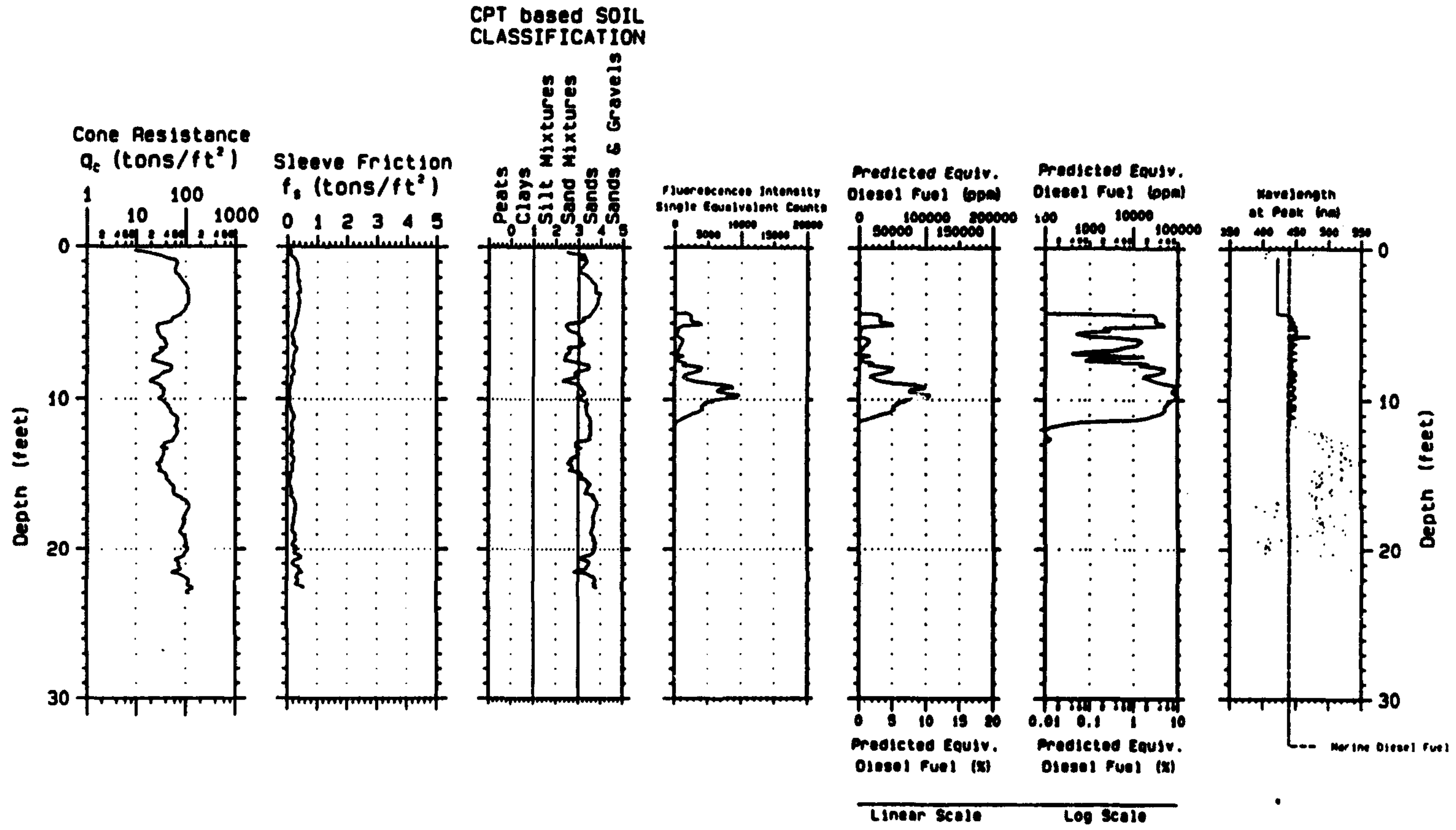
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438390.7	2136255	33.406



CPT; C-62-90 Project; Jacksonville
Disk file name; c:\data\JAX\C-62-90.QOF

1 foot = 0.305 m.

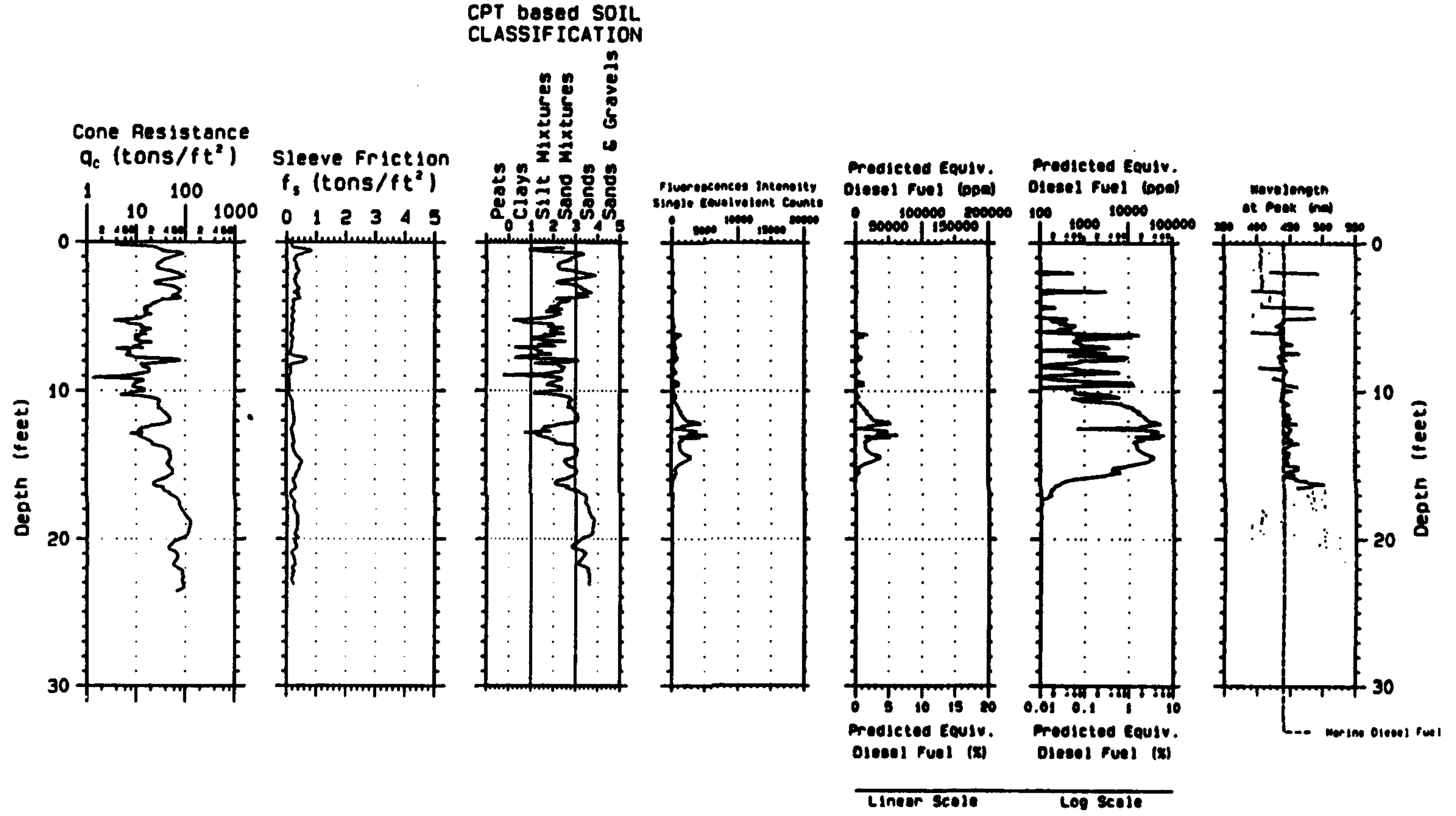
STATE COORDINATES:		
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438296.9	2136274	33.725



CPT; C-71-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-71-90.QOF

STATE COORDINATES:		1 foot = 0.305 m.
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438511	2136568	26.069

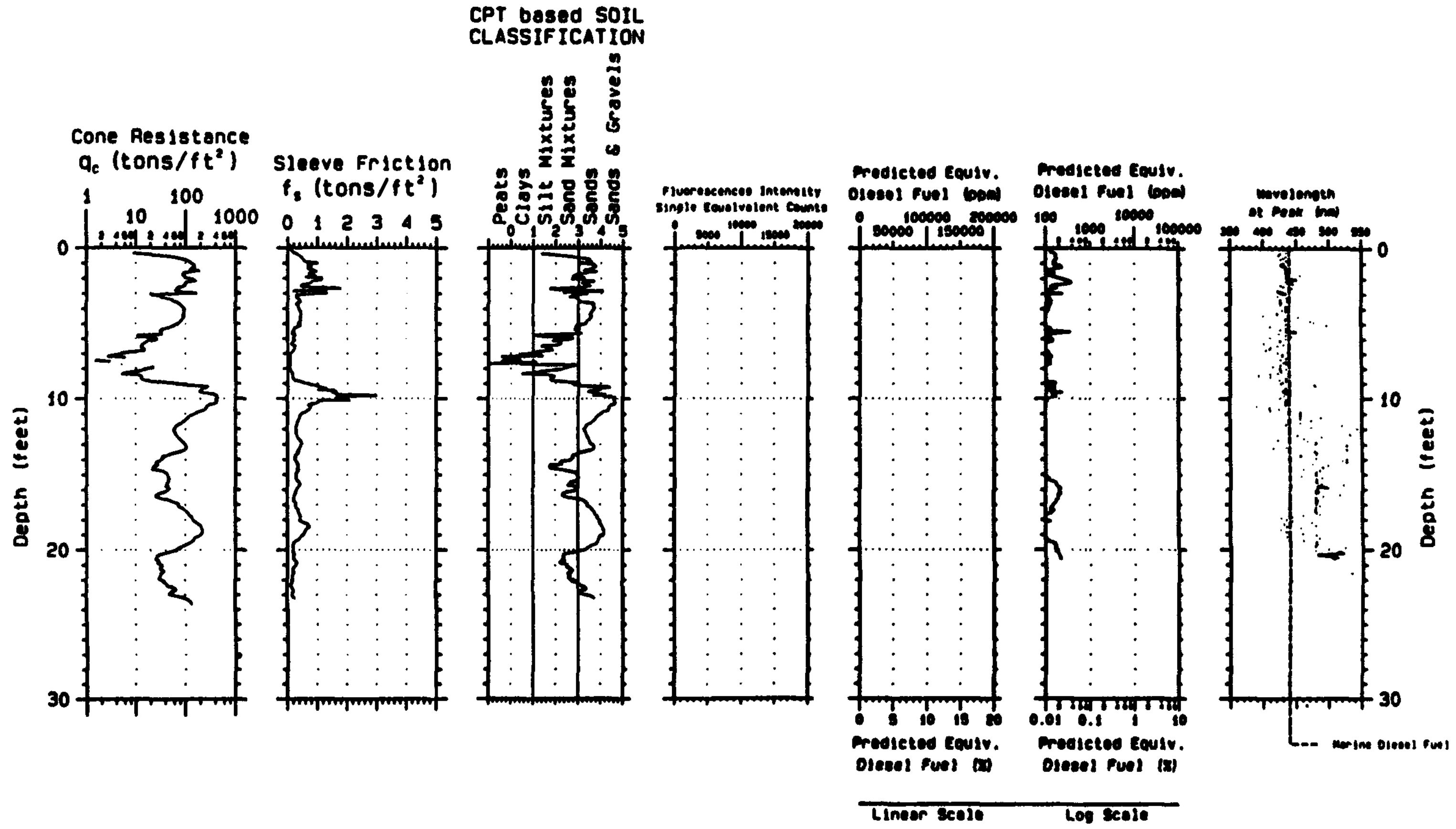


CPT; C-72-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-72-90.QOF

STATE COORDINATES: 1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438232	2136298	33.698



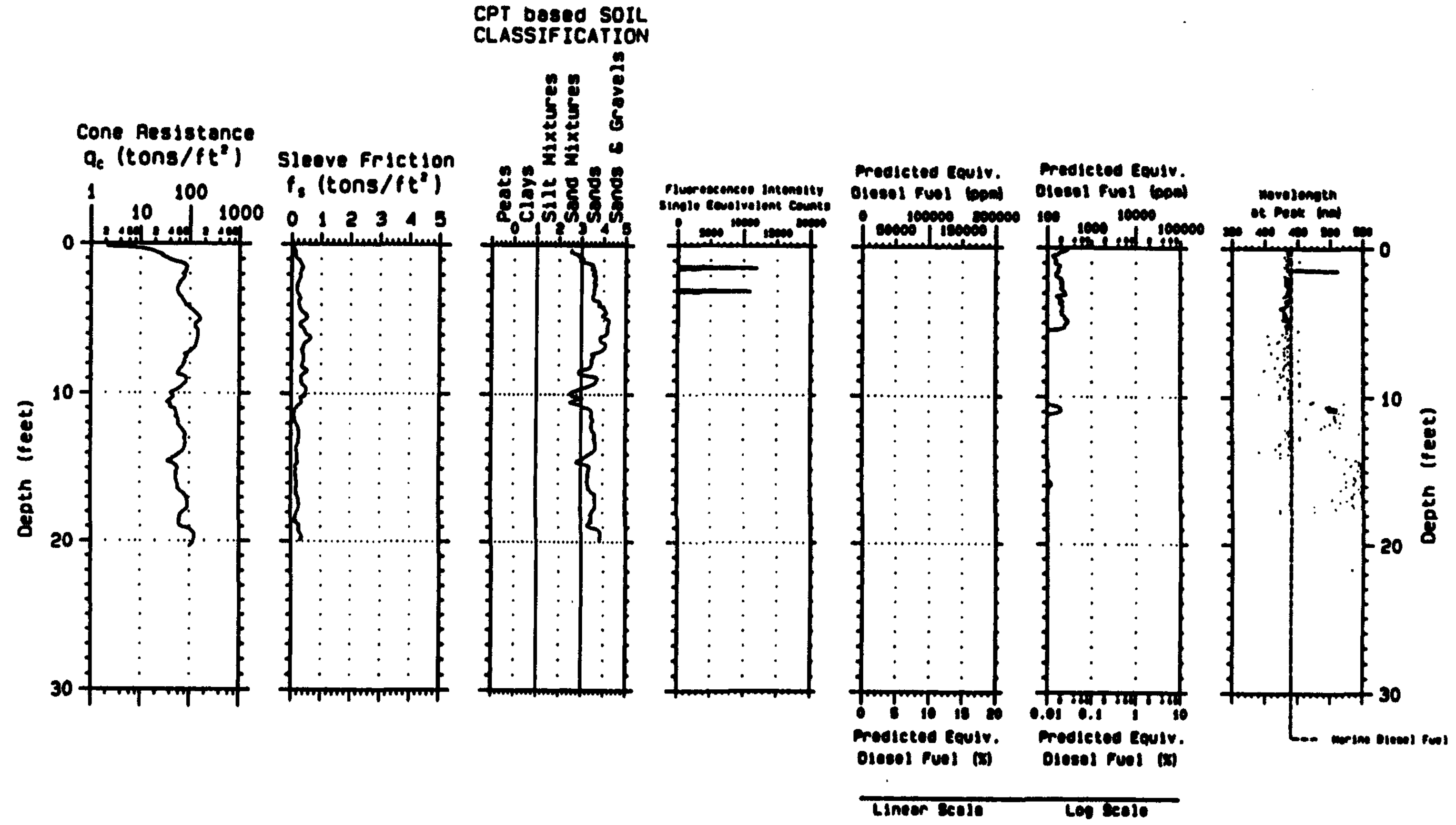
CPT; C-73-90

Project; Jacksonville
Disk file name; c:\data\JAX\C-73-90.QOF

STATE COORDINATES:

1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438151	2136349	33.565



CPT; C-74-90 Project; Jacksonville

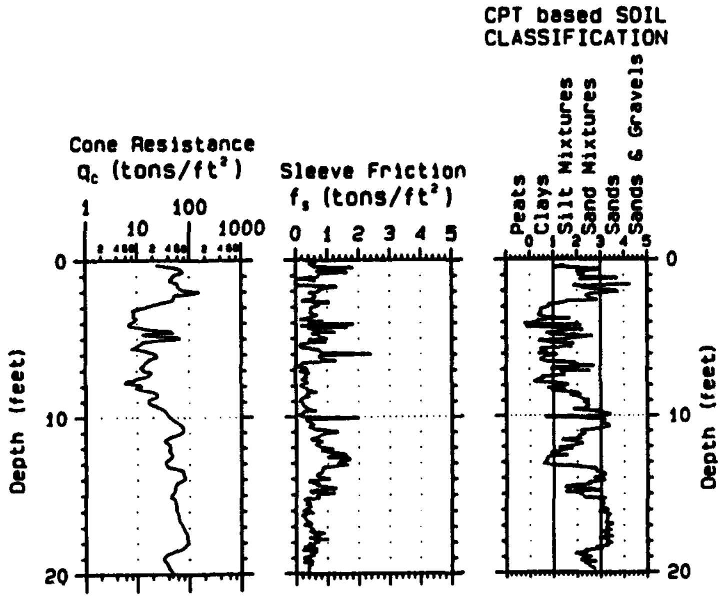
Disk file name; c:\data\JAX\C-74-90.OOF

1 foot = 0.305 m.

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438719.8	2136462	27.384

Appendix B
Data from the Penetrometer Unit Equipped with a Soil Strength Measuring System and the Electrical Resistivity Sensor

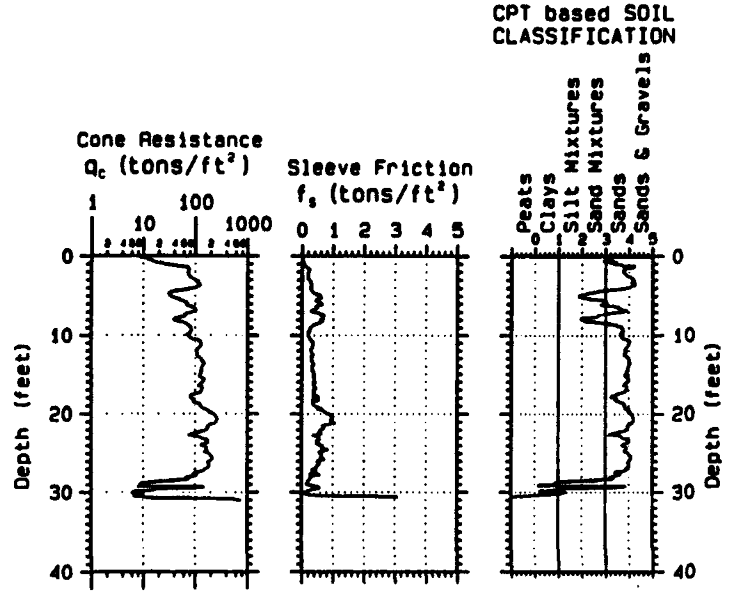


CPT; C-31-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-31-90.QNF

1 foot = 0.305 m.

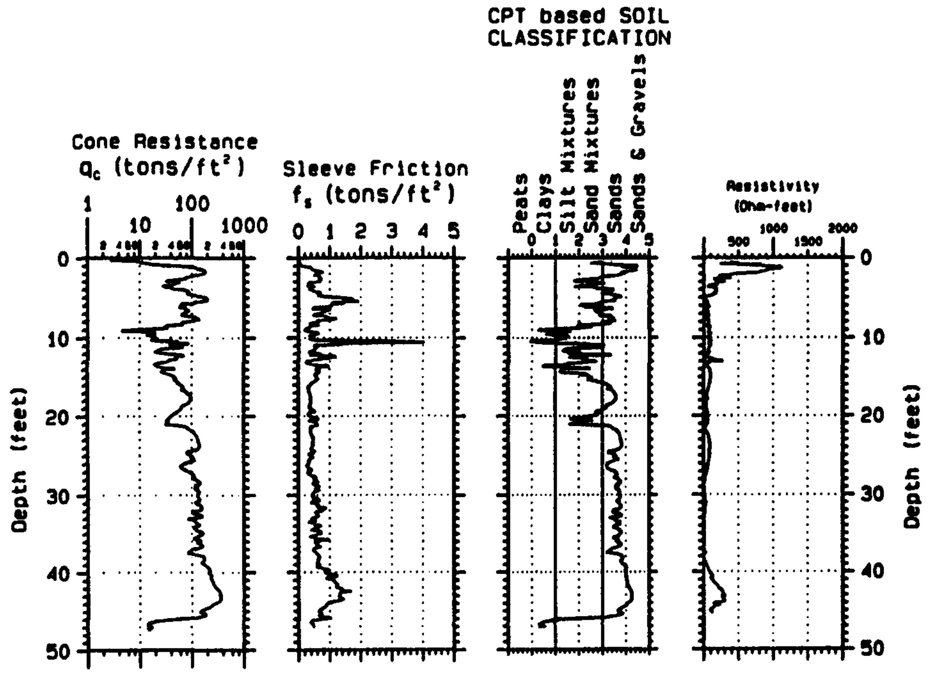
STATE COORDINATES:		
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438412.5	2136430	31.783



CPT; C-78-90 Project; Jacksonville
Disk file name; c:\data\JAX\C-78-90.QRF

STATE COORDINATES: 1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438830.8	2135808	24.543

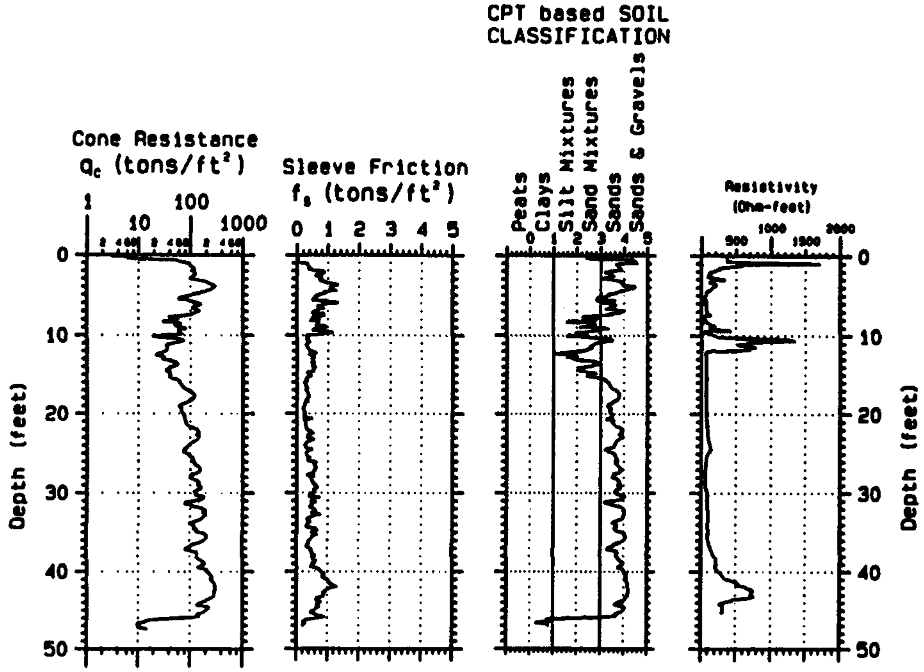


CPT; C-77-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-77-90.QRF

STATE COORDINATES: 1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438251.7	2135880	32.041

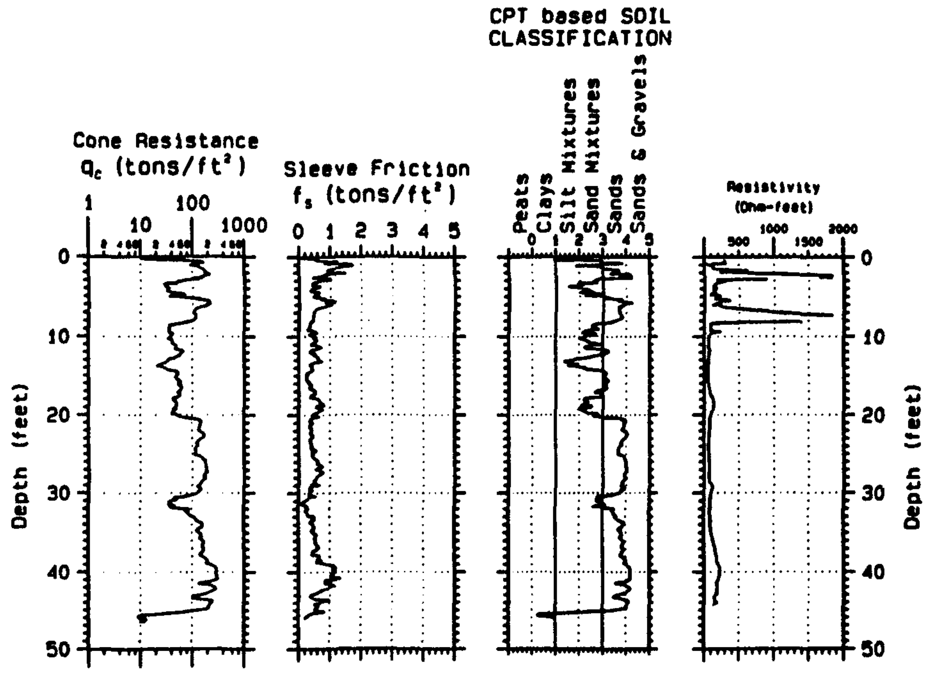


CPT; C-76-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-76-90.QRF

1 foot = 0.305 m.

STATE COORDINATES: EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438181	2135869	32.571

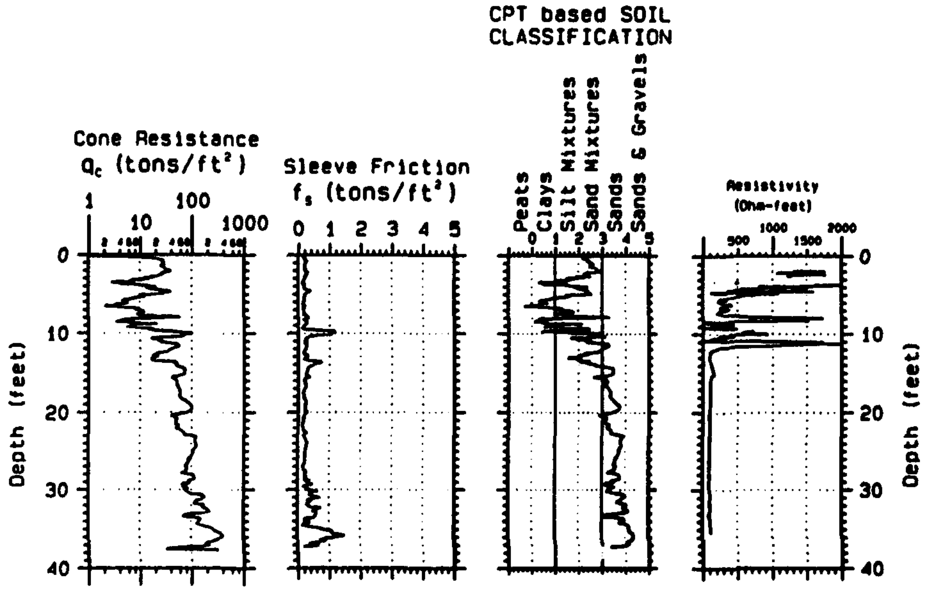


CPT; C-75-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-75-90.ORF

STATE COORDINATES: 1 foot = 0.305 m.

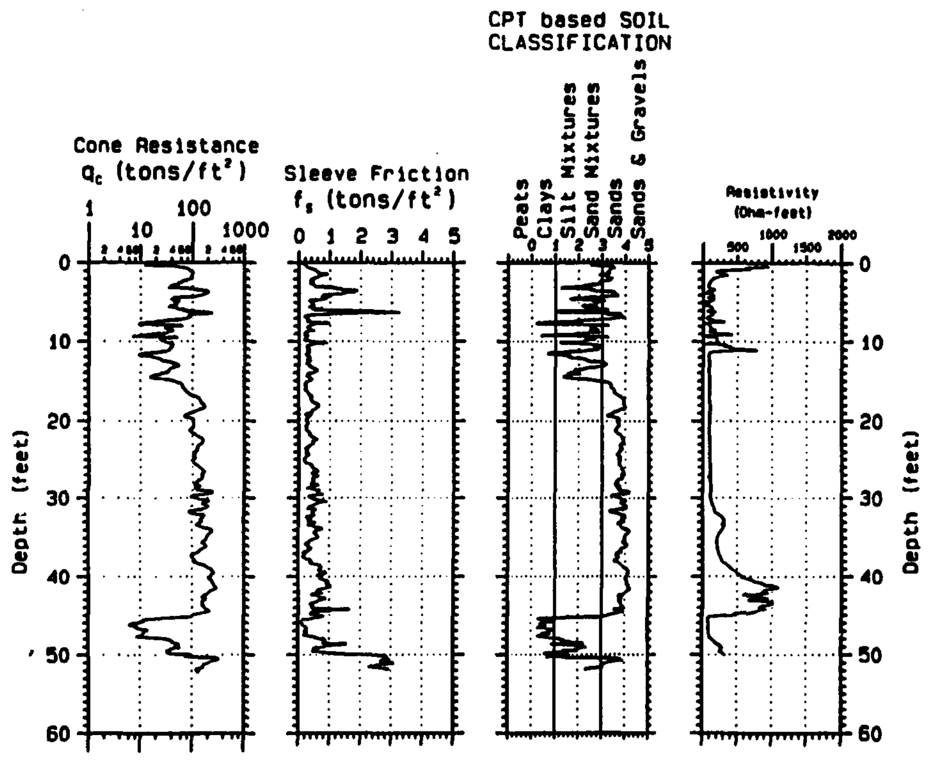
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438160	2135820	31.143



CPT; C-63-90 Project; Jacksonville
Disk file name; c:\data\JAX\C-63-90.QRF

STATE COORDINATES: 1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438293.9	2136269	33.688



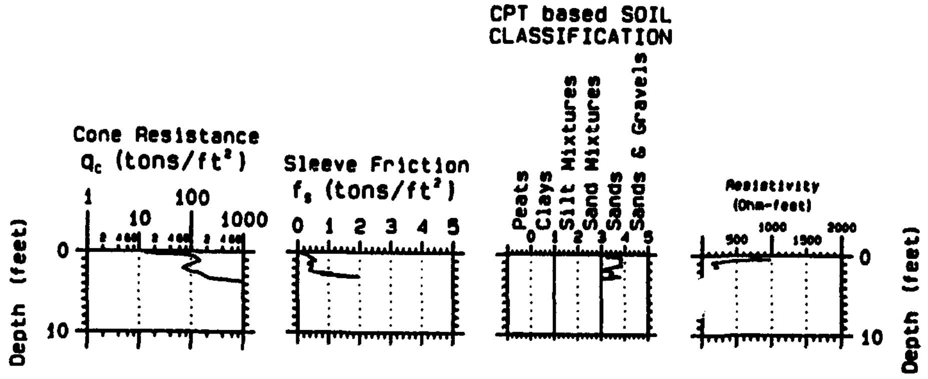
CPT: C-64-90

Project: Jacksonville
Disk file name: c:\data\JAX\C-64-90.QRF

1 foot = 0.305 m.

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438106.1	2135890	32.126



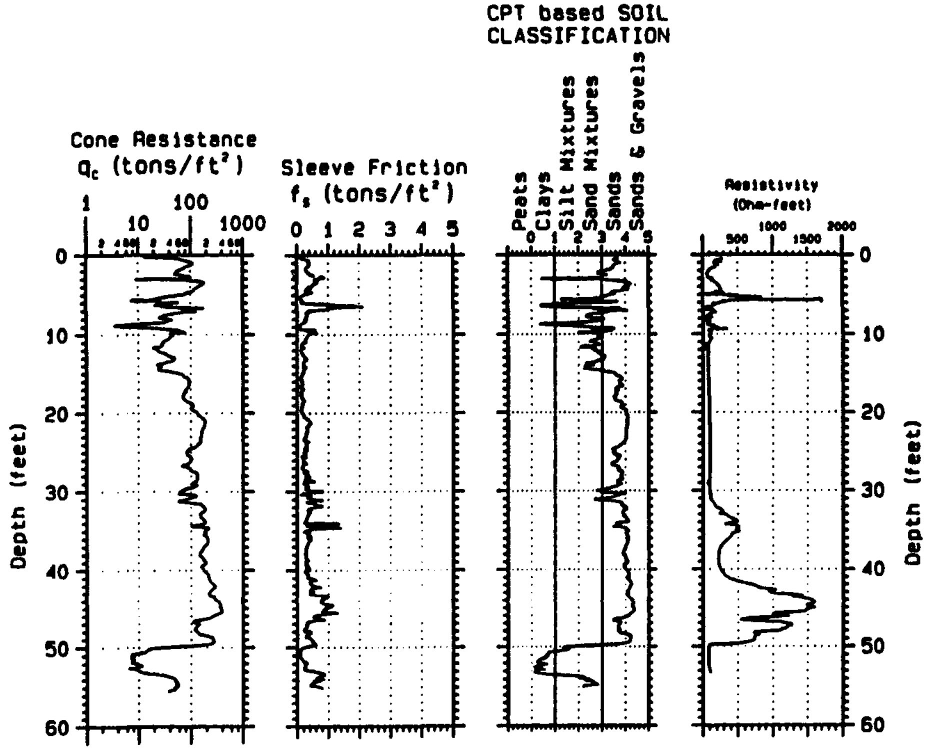
CPT; C-65-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-65-90.QRF

STATE COORDINATES:

1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438089.9	2135881	31.573



CPT; C-66-90

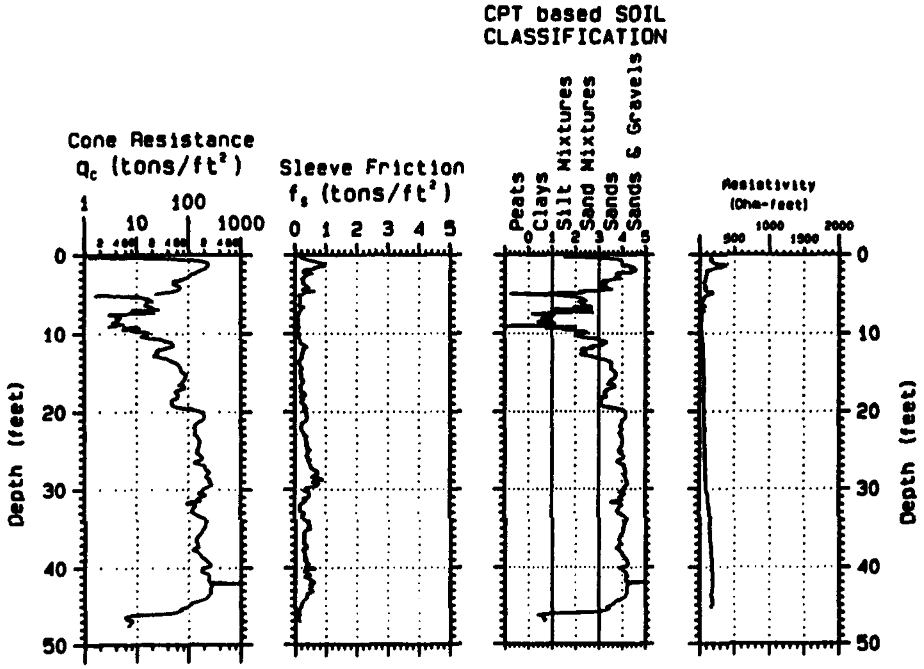
Project; Jacksonville

Disk file name; c:\data\JAX\C-66-90.QRF

1 foot = 0.305 m.

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438079.2	2135875	31.776



CPT; C-67-90

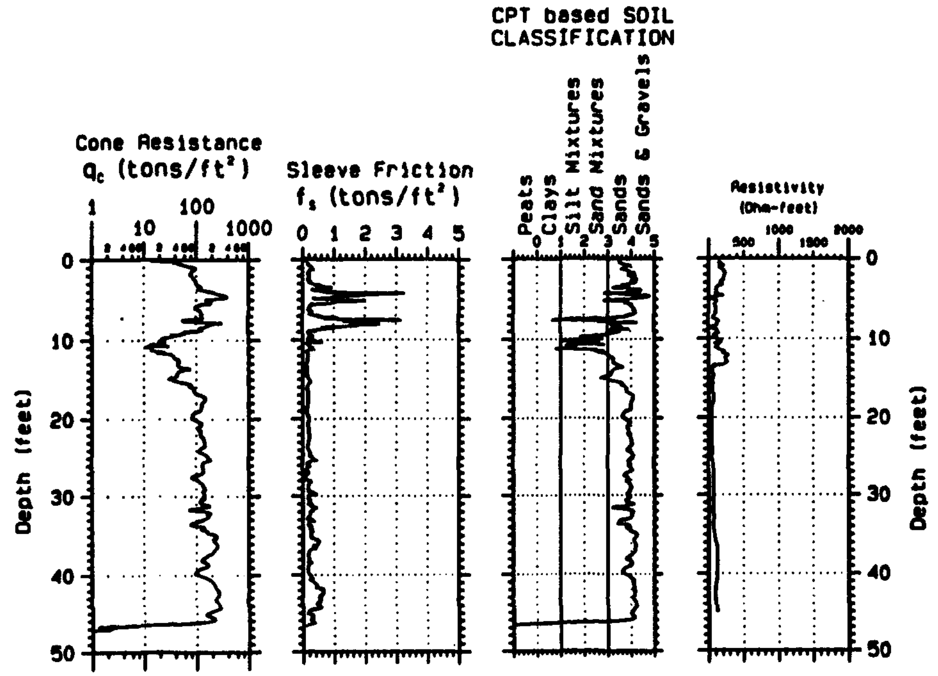
Project; Jacksonville

Disk file name; c:\data\JAX\C-67-90.QRF

STATE COORDINATES:

1 foot = 0.305 m.

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438031.7	2135786	30.262



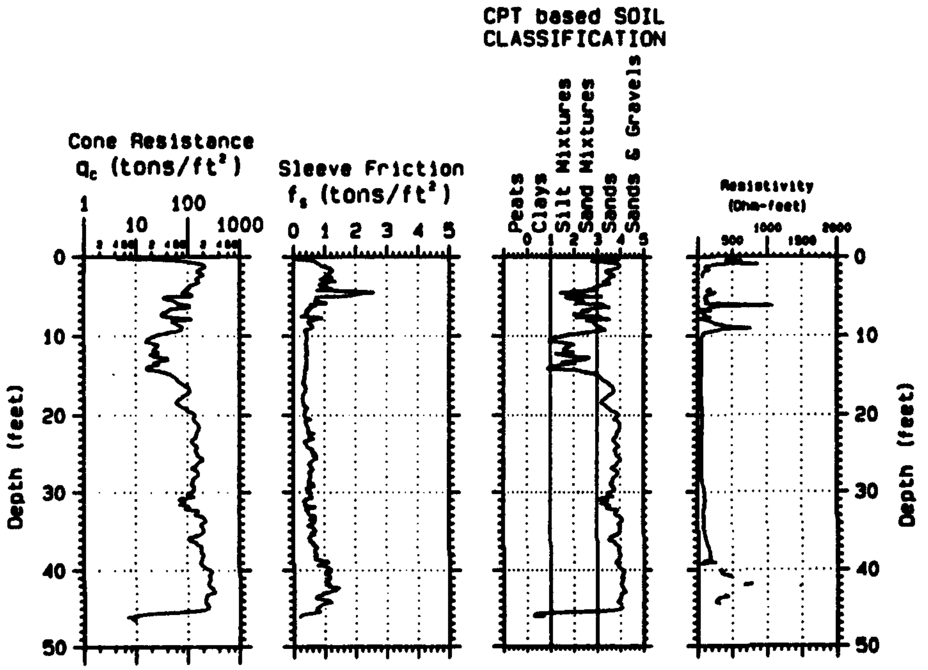
CPT: C-68-90 Project: Jacksonville

Disk file name: c:\data\JAX\C-68-90.QRF

1 foot = 0.305 m.

STATE COORDINATES:

EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438159.7	2135918	32.776

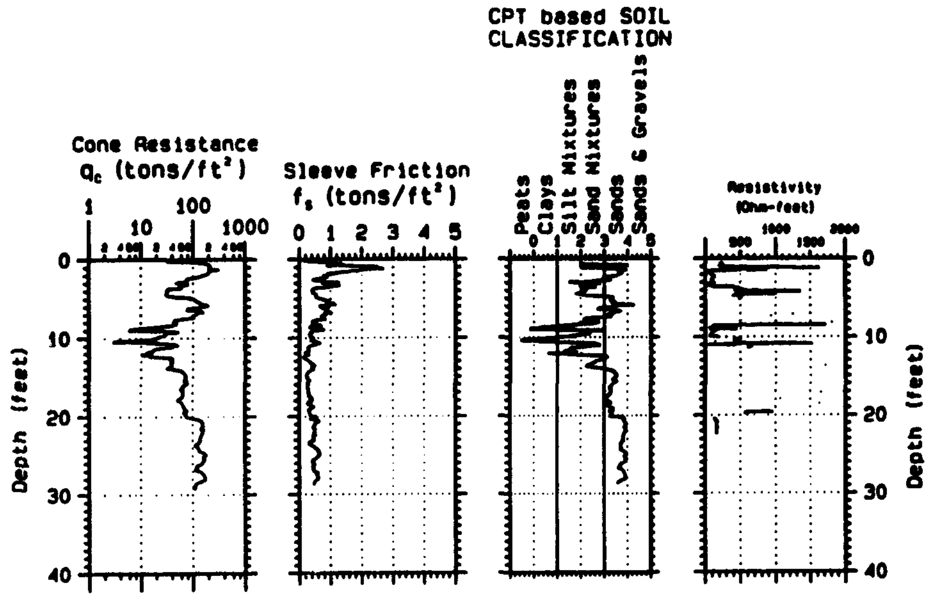


CPT; C-69-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-69-90.QRF

1 foot = 0.305 m.

STATE COORDINATES:		
EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438129.7	2135862	31.592



CPT; C-70-90 Project; Jacksonville

Disk file name; c:\data\JAX\C-70-90.QRF

1 foot = 0.305 m.

STATE COORDINATES: EASTING (ft.)	NORTHING (ft.)	ELEV. ABOVE MSL (ft.)
438154.1	2135811	31.051

Appendix C
Data from the Chemical Analysis of Soil and Water Samples Collected at the Jacksonville Naval Air Station

```
JOB FILE:  07044                                                                                   DATE:  14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  1 OF   1 )**************************


 # DESCRIPTION:  JACKSONVILLE NAS - GL                      JOB NUMBER:  RDOG42501170001         RECEIPT DATE:  16 AUG 90
 HEM. PRESERVATIVE:                               TYPE OF SAMPLE:  SEDIMENT                        EST. COMP. DATE:  14 SEP 90

                 COLUMN.........   1
                 ANALYTE........   100
                 MG/KG..........   O&G

SAMP #   DESCRIPTION                                                                                                      ROW

07044    TAKEN IN DITCH     CONC  22570     |                                                                               1
         SIDE               %REC            |
         near C-30-90       DUPL  20600     |
         8-14-90            OID   05990248  |


07045    TAKEN IN DITCH     CONC  56600     |                                                                               2
         BOTTOM             %REC            |
                            DUPL            |
        near C-30-90        OID   05990248  |
        8-14-90

07046    9.5 DEEP           CONC  62500     |                                                                               3
       near C-62-90         %REC            |
       8-14-90              DUPL            |
       Depth is top of      OID   05990248  |
         18" sample

07047    10.5 DEPTH         CONC  374       |                                                                               4
       near C-76-90         %REC            |
       8-14-90              DUPL            |
       Depth is top of      OID   05990248  |
         18" sample

07048    11 DEPTH           CONC  175       |                                                                               5
       near C-30-90         %REC            |
       8-14-90              DUPL            |
       Depth is top of      OID   05990248  |
         18" sample

BL#01    METHOD BLANK       CONC  <5.0      |                                                                               6
                            %REC  102.6     |
                            DUPL            |
                            OID   05990248  |


O&G      Oil & Grease
```

```
JOB FILE:  07042                                                                                      DATE:  14 JAN 91

************************* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  1 OF   7 )************************

  DESCRIPTION:  JACKSONVILLE NAS - GL                          JOB NUMBER:  RDOG425E1170001       RECEIPT DATE:  16 AUG 90
 EM. PRESERVATIVE:                                 TYPE OF SAMPLE:  SEDIMENT                      EST. COMP. DATE:  31 AUG 90

                  COLUMN.........  1             2             3             4             5             6
                  ANALYTE........  183           184           185           186           187           188
                  MG/KG..........  ClMETH        BrMETH        VNLCL         ClETHA        MECL          11DClETE

SAMP #   DESCRIPTION                                                                                                  ROW

07042    TAKEN AT 1'        CONC  <0.14        | <0.14       | <0.14       | <0.14       | 0.79        | <0.028      |    1
         near C-77-90       %REC               |             |             |             |             |             |
         8-13-90            DUPL               |             |             |             |             |             |
         Depth of top of    OID   08930232     | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |
          . 18" sample

07043    TAKEN AT 45'       CONC  <0.012       | <0.012      | <0.012      | <0.012      | 0.17        | <0.0061     |    2
         DEPTH              %REC               |             |             |             |             |             |
         6" east of         DUPL               |             |             |             |             |             |
         C-66-90            OID   08930232     | 08930232    | 06930232    | 08930232    | 08930232    | 08930232    |
         8-13-90

BL#01    METHOD BLANK       CONC  <0.010       | <0.010      | <0.010      | <0.010      | 0.0036 J  #1| <0.005      |    3
                            %REC               |             |             |             |             |             |
                            DUPL               |             |             |             |             |             |
                            OID   08930232     | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |


ClMETH   Chloromethane                                       BrMETH     Bromomethane
VNLCL    Vinyl Chloride                                      ClETHA     Chloroethane
MECL     Methylene Chloride                                  11DClETE   1,1-Dichloroethene

FOOTNOTES:
 #1 J indicates value below statistical quantitation limits.
```

JOB FILE: 07042 DATE: 14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 2 OF 7)**************************

JOB DESCRIPTION: JACKSONVILLE NAS - GL JOB NUMBER: R00G425E1170001 RECEIPT DATE: 16 AUG 90

CHEM. PRESERVATIVE: TYPE OF SAMPLE: SEDIMENT EST. COMP. DATE: 31 AUG 90

		COLUMN.........	7	8	9	10	11	12	
		ANALYTE........	189	190	191	192	193	194	
		MG/KG..........	11DCLETA	t-DCLETE	c-DCLETE	CHCL3	12DCLETA	111TCA	
SAMP #	DESCRIPTION								ROW
07042	TAKEN AT 1'	CONC	0.0048 J #1	<0.028	<0.028	<0.028	<0.028	<0.028	1
	DEPTH	%REC							
	near C-77-90	DUPL							
	8-13-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	Depth of top of 18" sample								
07043	TAKEN AT 45'	CONC	<0.0061	<0.0061	<0.0061	0.0022 J #1	<0.0061	<0.0061	2
	DEPTH	%REC							
	6" east of	DUPL							
	C-66-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	8-13-90								
BL#01	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	3
		%REC							
		DUPL							
		OID	08930232	08930232	08930232	08930232	08930232	08930232	

11DCLETA	1,1-Dichloroethane	t-DCLETE	Trans-1,2-Dichloroethene
c-DCLETE	cis-1,2-Dichloroethene	CHCL3	Chloroform
12DCLETA	1,2-Dichloroethane	111TCA	1,1,1-Trichloroethane

FOOTNOTES:

#1 J indicates value below statistical quantitation limits.

```
JOB FILE:  07042                                                                                         DATE:  14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  3 OF   7 )************************

 JB DESCRIPTION:  JACKSONVILLE NAS - GL                        JOB NUMBER:  RDOG425E1170001        RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                                      TYPE OF SAMPLE:  SEDIMENT                 EST. COMP. DATE:  31 AUG 90

                 COLUMN.........   13            14            15            16            17            18
                 ANALYTE........   195           196           197           198           199           200
                 MG/KG..........   CCL4          BrOClME       12DClPR       t13ClPRE      TCE           DBrClME

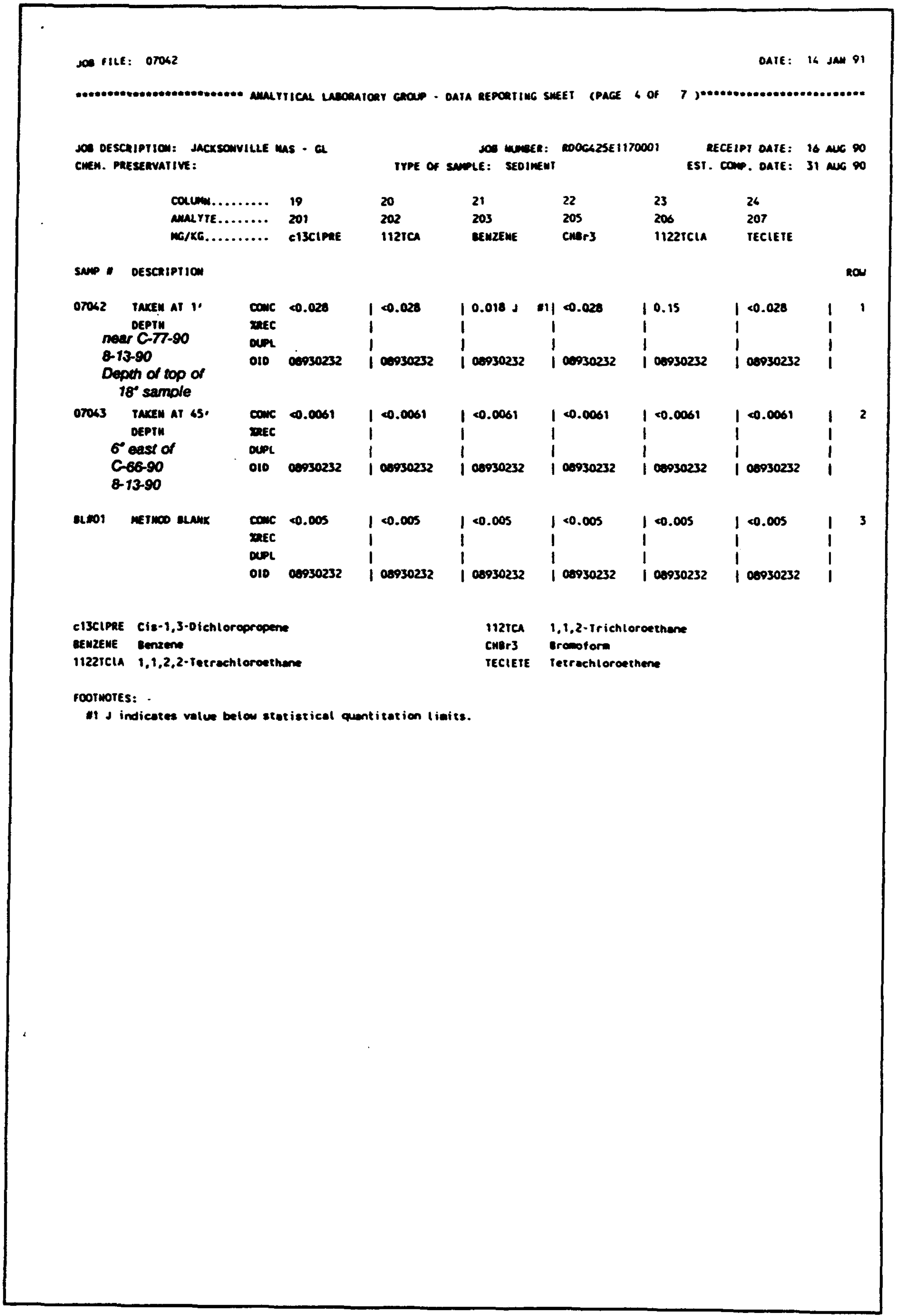
SAMP #   DESCRIPTION                                                                                                   ROW

07042    TAKEN AT 1'      CONC  <0.028      | 0.0046 J  #1| <0.028      | <0.028      | <0.028      | <0.028      |    1
         DEPTH            %REC              |             |             |             |             |             |
   near C-77-90           DUPL              |             |             |             |             |             |
   8-13-90                OID   08930232    | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |
   Depth of top of
     18" sample
07043    TAKEN AT 45'     CONC  <0.0061     | 0.012 J   #1| <0.0061     | <0.0061     | <0.0061     | <0.0061     |    2
         DEPTH            %REC              |             |             |             |             |             |
     6" east of           DUPL              |             |             |             |             |             |
     C-66-90              OID   08930232    | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |
     8-13-90

BL#01    METHOD BLANK     CONC  <0.005      | <0.005      | <0.005      | <0.005      | <0.005      | <0.005      |    3
                          %REC              |             |             |             |             |             |
                          DUPL              |             |             |             |             |             |
                          OID   08930232    | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |

CCL4      Carbon Tetrachloride                                 BrOClME   Bromodichloromethane
12DClPR   1,2-Dichloropropene                                  t13ClPRE  Trans-1,3-Dichloropropene
TCE       Trichloroethene                                      DBrClME   Dibromochloromethane

FOOTNOTES:
 #1 J indicates value below statistical quantitation limits.
```



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JOB FILE:  07042                                                                                        DATE:  14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  4 OF   7 )************************


JOB DESCRIPTION:  JACKSONVILLE NAS - GL                          JOB NUMBER:  R00G425E1170001       RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                                   TYPE OF SAMPLE:  SEDIMENT                    EST. COMP. DATE:  31 AUG 90

                  COLUMN.........   19           20           21           22           23           24
                  ANALYTE........   201          202          203          205          206          207
                  MG/KG..........   c13ClPRE     112TCA       BENZENE      CHBr3        1122TClA     TEClETE

SAMP #   DESCRIPTION                                                                                                     ROW

07042    TAKEN AT 1'     CONC   <0.028     | <0.028     | 0.018 J   #1| <0.028     | 0.15       | <0.028     |    1
         DEPTH           %REC              |            |             |            |            |            |
    near C-77-90         DUPL              |            |             |            |            |            |
    8-13-90              OID    08930232   | 08930232   | 08930232    | 08930232   | 08930232   | 08930232   |
    Depth of top of
      18" sample
07043    TAKEN AT 45'    CONC   <0.0061    | <0.0061    | <0.0061     | <0.0061    | <0.0061    | <0.0061    |    2
         DEPTH           %REC              |            |             |            |            |            |
    6" east of           DUPL              |            |             |            |            |            |
    C-66-90              OID    08930232   | 08930232   | 08930232    | 08930232   | 08930232   | 08930232   |
    8-13-90

BL#01    METHOD BLANK    CONC   <0.005     | <0.005     | <0.005      | <0.005     | <0.005     | <0.005     |    3
                         %REC              |            |             |            |            |            |
                         DUPL              |            |             |            |            |            |
                         OID    08930232   | 08930232   | 08930232    | 08930232   | 08930232   | 08930232   |

c13ClPRE  Cis-1,3-Dichloropropene                        112TCA    1,1,2-Trichloroethane
BENZENE   Benzene                                        CHBr3     Bromoform
1122TClA  1,1,2,2-Tetrachloroethane                      TEClETE   Tetrachloroethene

FOOTNOTES: -
  #1 J indicates value below statistical quantitation limits.
```

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JOB FILE:  07042                                                                                   DATE:  14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  5 OF   7 )**************************

 J DESCRIPTION:  JACKSONVILLE NAS - GL                    JOB NUMBER:  RDOG425E1170001      RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                            TYPE OF SAMPLE:  SEDIMENT                      EST. COMP. DATE:  31 AUG 90

               COLUMN.........  25          26          27          28              29          30
               ANALYTE........  208         209         210         213             214         215
               MG/KG..........  TOLUENE     ClBEN       ETBEN       ACETONE         BUTANO      CS2

SAMP #   DESCRIPTION                                                                                           ROW

07042    TAKEN AT 1'        CONC  0.091      | 3.8        | 0.94       | 0.20 J    #1| <0.56      | <0.028     |    1
         DEPTH              %REC             |            |            |             |            |            |
      near C-77-90          DUPL             |            |            |             |            |            |
      8-13-90               OID   08930232   | 08930232   | 08930232   | 08930232    | 08930232   | 08930232   |
      Depth of top of
        18" sample
07043    TAKEN AT 45'       CONC  <0.0061    | <0.0061    | <0.0061    | 0.027 J   #1| <0.12      | <0.0061    |    2
         DEPTH              %REC             |            |            |             |            |            |
       6" east of           DUPL             |            |            |             |            |            |
       C-66-90              OID   08930232   | 08930232   | 08930232   | 08930232    | 08930232   | 08930232   |
       8-13-90

BL#01    METHOD BLANK       CONC  <0.005     | <0.005     | <0.005     | 0.014 J   #1| <0.10      | <0.005     |    3
                            %REC             |            |            |             |            |            |
                            DUPL             |            |            |             |            |            |
                            OID   08930232   | 08930232   | 08930232   | 08930232    | 08930232   | 08930232   |

TOLUENE   Toluene                                       ClBEN     Chlorobenzene
ETBEN     Ethylbenzene                                  ACETONE   Acetone
BUTANO    2-Butanone                                    CS2       Carbondisulfide

FOOTNOTES:
 #1 J indicates value below statistical quantitation limits.
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JOB FILE:  07042                                                                              DATE:  14 JAN 91

************************* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  6 OF   7 )************************

JOB DESCRIPTION:  JACKSONVILLE NAS - GL                        JOB NUMBER:  RDOG425E1170001        RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                                  TYPE OF SAMPLE:  SEDIMENT                     EST. COMP. DATE:  31 AUG 90

                   COLUMN.........  31          32          33          34          35          36
                   ANALYTE........  216         217         218         219         220         221
                   MG/KG..........  2HEXANO     4MeZPE      STYRENE     VNACETA     T-XYLENE    12DCIE-S

SAMP #   DESCRIPTION                                                                                                   ROW

07042    TAKEN AT 1'        CONC  <0.28      | <0.28      | <0.028     | <0.28      | 1.1        | 115%       |    1
         DEPTH              %REC             |            |            |            |            |            |
   near C-77-90             DUPL             |            |            |            |            |            |
   8-13-90                  OID   08930232   | 08930232   | 08930232   | 08930232   | 08930232   | 08930232   |
   Depth of top of
      18" sample
07043    TAKEN AT 45'       CONC  <0.061     | <0.061     | <0.0061    | <0.061     | <0.0061    | 113%       |    2
         DEPTH              %REC             |            |            |            |            |            |
   6" east of               DUPL             |            |            |            |            |            |
   C-66-90                  OID   08930232   | 08930232   | 08930232   | 08930232   | 08930232   | 08930232   |
   8-13-90

BL#01    METHOD BLANK       CONC  <0.050     | <0.050     | <0.005     | <0.050     | <0.005     | 104%       |    3
                            %REC             |            |            |            |            |            |
                            DUPL             |            |            |            |            |            |
                            OID   08930232   | 08930232   | 08930232   | 08930232   | 08930232   | 08930232   |

2HEXANO    2-Hexanone                                      4MeZPE     4-Methyl-2-Pentanone
STYRENE    Styrene                                         VNACETA    Vinyl Acetate
T-XYLENE   T-Xylene                                        12DCIE-S   1,2-Dichloroethane-d4(Surrogate (70-121))
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JOB FILE: 07042 DATE: 14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 7 OF 7)**************************

JOB DESCRIPTION: JACKSONVILLE NAS - GL JOB NUMBER: RDOG425E1170001 RECEIPT DATE: 16 AUG 90

CHEM. PRESERVATIVE: TYPE OF SAMPLE: SEDIMENT EST. COMP. DATE: 31 AUG 90

	COLUMN.........		37	38	
	ANALYTE........		222	223	
	MG/KG..........		TOL-d8-S	4BrFB-S	
SAMP #	DESCRIPTION				ROW
07042	TAKEN AT 1'	CONC	89.3%	102%	1
	DEPTH	%REC			
	near C-77-90	DUPL			
	8-13-90	OID	08930232	08930232	
	Depth of top of 18" sample				
07043	TAKEN AT 45'	CONC	98.7%	97.0%	2
	DEPTH	%REC			
	6" east of	DUPL			
	C-66-90	OID	08930232	08930232	
	8-13-90				
BL#01	METHOD BLANK	CONC	97.2%	97.0%	3
		%REC			
		DUPL			
		OID	08930232	08930232	

TOL-d8-S Toluene-D8(Surrogate (81-117))

4BrFB-S 4-Bromofluorobenzene(Surrogate (74-121))

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JOB FILE:  07041                                                                                          DATE:  14 JAN 91

************************* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  1 OF   7 )*************************

 @ DESCRIPTION:  JACKSONVILLE NAS - GL                     JOB NUMBER:  RDOG425E1170001        RECEIPT DATE:  16 AUG 90
_HEM. PRESERVATIVE:                              TYPE OF SAMPLE:  Water                          EST. COMP. DATE:  31 AUG 90

                  COLUMN.........   1            2           3            4            5            6
                  ANALYTE........   183          184         185          186          187          188
                  PPM............   ClMETH       BrMETH      VNLCL        ClETHA       MECL         11DClETE

SAMP #   DESCRIPTION                                                                                                  ROW

07041    43.5 DEPTH       CONC  <0.010     | <0.010    | <0.010     | <0.010     | <0.005     | <0.005     |      1
         8/13/90          %REC             |           |            |            |            |            |
near C-76-90              DUPL             |           |            |            |            |            |
Depth is screen of        OID   08930232   | 08930223  | 08930232   | 08930232   | 08930232   | 08930232   |
Hydropunch

BL#01    METHOD BLANK     CONC  <0.010     | <0.010    | <0.010     | <0.010     | 0.0036 J #1| <0.005     |      2
                          %REC             |           |            |            |            |            |
                          DUPL             |           |            |            |            |            |
                          OID   08930232   | 08930232  | 08930232   | 08930232   | 08930232   | 08930232   |


ClMETH   Chloromethane                                   BrMETH     Bromomethane
VNLCL    Vinyl Chloride                                  ClETHA     Chloroethane
MECL     Methylene Chloride                              11DClETE   1,1-Dichloroethene

FOOTNOTES:
  #1 J indicated value below statistical quantitation limits.
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JOB FILE:  07041                                                                                     DATE:  14 JAN 91

************************* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  2 OF   7 )*************************


JOB DESCRIPTION:  JACKSONVILLE NAS - GL                JOB NUMBER:  RDOG425E1170001          RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                          TYPE OF SAMPLE:  Water                          EST. COMP. DATE:  31 AUG 90

               COLUMN.........  7           8           9           10          11          12
               ANALYTE........  189         190         191         192         193         194
               PPM............  11DCLETA    t-DCLETE    c-DCLETE    CHCL3       12DCLETA    111TCA

SAMP #   DESCRIPTION                                                                                               ROW

07041    43.5 DEPTH       CONC  <0.005    | <0.005    | <0.005    | <0.005    | <0.005    | <0.005    |    1
         8/13/90          %REC            |           |           |           |           |           |
                          DUPL            |           |           |           |           |           |
    near C-76-90
    Depth is screen of    OID   08930232  | 08930232  | 08930232  | 08930232  | 08930232  | 08930232  |
    Hydropunch

BL#01    METHOD BLANK     CONC  <0.005    | <0.005    | <0.005    | <0.005    | <0.005    | <0.005    |    2
                          %REC            |           |           |           |           |           |
                          DUPL            |           |           |           |           |           |
                          OID   08930232  | 08930232  | 08930232  | 08930232  | 08930232  | 08930232  |


11DCLETA  1,1-Dichloroethane                             t-DCLETE   Trans-1,2-Dichloroethene
c-DCLETE  cis-1,2-Dichloroethene                         CHCL3      Chloroform
12DCLETA  1,2-Dichloroethane                             111TCA     1,1,1-Trichloroethane
```

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JOB FILE:  07041                                                                                   DATE:  14 JAN 91

************************* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  3 OF   7 )*************************

 J DESCRIPTION:  JACKSONVILLE NAS - GL                          JOB NUMBER:  800G425E1170001       RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                                    TYPE OF SAMPLE:  Water                      EST. COMP. DATE:  31 AUG 90

                  COLUMN.........  13          14          15          16          17          18
                  ANALYTE........  195         196         197         198         199         200
                  PPM............  CCL4        BrDClME     12DClPR     t13ClPRE    TCE         DBrClME

SAMP #   DESCRIPTION                                                                                           ROW

07041    43.5 DEPTH          CONC  <0.005     | <0.005    | <0.005    | <0.005    | <0.005    | <0.005    |     1
         8/13/90             %REC             |           |           |           |           |           |
   near C-76-90              DUPL             |           |           |           |           |           |
   Depth is screen of        OID   08930232   | 08930232  | 08930232  | 08930232  | 08930232  | 08930232  |
   Hydropunch

BL#01    METHOD BLANK        CONC  <0.005     | <0.005    | <0.005    | <0.005    | <0.005    | <0.005    |     2
                             %REC             |           |           |           |           |           |
                             DUPL             |           |           |           |           |           |
                             OID   08930232   | 08930232  | 08930232  | 08930232  | 08930232  | 08930232  |


CCL4       Carbon Tetrachloride                         BrDClME    Bromodichloromethane
12DClPR    1,2-Dichloropropane                          t13ClPRE   Trans-1,3-Dichloropropene
TCE        Trichloroethene                              DBrClME    Dibromochloromethane
```

JOB FILE: 07041 DATE: 14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 4 OF 7)**************************

JOB DESCRIPTION: JACKSONVILLE NAS - GL JOB NUMBER: RDOG425E1170001 RECEIPT DATE: 16 AUG 90
CHEM. PRESERVATIVE: TYPE OF SAMPLE: Water EST. COMP. DATE: 31 AUG 90

SAMP #	DESCRIPTION	COLUMN.........	19	20	21	22	23	24	ROW
		ANALYTE........	201	202	203	205	206	207	
		PPM............	c13ClPRE	112TCA	BENZENE	CHBr3	1122TClA	TEClETE	
07041	43.5 DEPTH	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1
	8/13/90	%REC							
	near C-76-90	DUPL							
	Depth is screen of Hydropunch	OID	08930232	08930232	08930232	08930232	08930232	08930232	
BL#01	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	2
		%REC							
		DUPL							
		OID	08930232	08930232	08930232	08930232	08930232	08930232	

c13ClPRE	Cis-1,3-Dichloropropene
BENZENE	Benzene
1122TClA	1,1,2,2-Tetrachloroethane
112TCA	1,1,2-Trichloroethane
CHBr3	Bromoform
TEClETE	Tetrachloroethene

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JOB FILE:  07041                                                                                DATE:  14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  5 OF   7 )**************************


JOB DESCRIPTION:  JACKSONVILLE NAS - GL                        JOB NUMBER:  RD06425E1170001      RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                                  TYPE OF SAMPLE:  Water                      EST. COMP. DATE:  31 AUG 90

                  COLUMN.........  25            26            27            28            29            30
                  ANALYTE........  208           209           210           213           214           215
                  PPM............  TOLUENE       ClBEN         ETBEN         ACETONE       BUTANO        CS2

SAMP #   DESCRIPTION                                                                                                      ROW

07041    43.5 DEPTH          CONC  <0.005      | 0.0018 J  #1| <0.005      | 0.005 J   #1| <0.10       | <0.005      |      1
         8/13/90             %REC              |             |             |             |             |             |
  near C-76-90               DUPL              |             |             |             |             |             |
  Depth is screen of         OID   08930232    | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |
  Hydropunch

BL#01    METHOD BLANK        CONC  <0.005      | <0.005      | <0.005      | 0.014 J   #1| <0.10       | <0.005      |      2
                             %REC              |             |             |             |             |             |
                             DUPL              |             |             |             |             |             |
                             OID   08930232    | 08930232    | 08930232    | 08930232    | 08930232    | 08930232    |


TOLUENE   Toluene                                          ClBEN     Chlorobenzene
ETBEN     Ethylbenzene                                     ACETONE   Acetone
BUTANO    2-Butanone                                       CS2       Carbondisulfide

 JTNOTES:
 #1 J indicated value below statistical quantitation limits.
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JOB FILE:  07041                                                                                      DATE:  14 JAN 91

************************* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  6 OF   7 )*************************


JOB DESCRIPTION:  JACKSONVILLE NAS - GL                         JOB NUMBER:  BD0G425E1170001       RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                              TYPE OF SAMPLE:  Water                           EST. COMP. DATE:  31 AUG 90

                COLUMN.........   31           32           33           34           35           36
                ANALYTE........   216          217          218          219          220          221
                PPM............   2HEXANO      4Me2PE       STYRENE      VNACETA      T-XYLENE     12DCLE-S

SAMP #   DESCRIPTION                                                                                                 ROW

07041    43.5 DEPTH        CONC  <0.050     | <0.050     | <0.005     | <0.050     | <0.005     | 106%        |      1
         8/13/90           %REC             |            |            |            |            |             |
 near C-76-90              DUPL             |            |            |            |            |             |
 Depth is screen of        OID   08930232   | 08930232   | 08930232   | 08930232   | 08930232   | 08930232    |
 Hydropunch

BL#01    METHOD BLANK      CONC  <0.050     | <0.050     | <0.005     | <0.050     | <0.005     | 104%        |      2
                           %REC             |            |            |            |            |             |
                           DUPL             |            |            |            |            |             |
                           OID   08930232   | 08930232   | 08930232   | 08930232   | 08930232   | 08930232    |


2HEXANO   2-Hexanone                                            4Me2PE    4-Methyl-2-Pentanone
STYRENE   Styrene                                               VNACETA   Vinyl Acetate
T-XYLENE  T-Xylene                                              12DCLE-S  1,2-Dichloroethane-d4(Surrogate (76-114))
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JOB FILE:  07041                                                                                         DATE:  14 JAN 91

************************** ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET  (PAGE  7 OF   7 )************************


JOB DESCRIPTION:  JACKSONVILLE NAS - GL                           JOB NUMBER:  RDOG425E1170001      RECEIPT DATE:  16 AUG 90
CHEM. PRESERVATIVE:                                    TYPE OF SAMPLE:  Water                     EST. COMP. DATE:  31 AUG 90

                  COLUMN.........  37          38
                  ANALYTE........  222         223
                  PPM............  TOL-d8-S    4BrFB-S

SAMP #   DESCRIPTION                                                                                                  ROW

07041    43.5 DEPTH         CONC  95.8%      | 94.6%       |                                                           1
         8/13/90            %REC             |             |
 near C-76-90               DUPL             |             |
 Depth is screen of         OID   08930232   | 08930232    |
 Hydropunch

BL#01    METHOD BLANK       CONC  100%       | 97.0%       |                                                           2
                            %REC             |             |
                            DUPL             |             |
                            OID   08930232   | 08930232    |

TOL-d8-S  Toluene-D8(Surrogate (88-110))                    4BrFB-S   4-Bromofluorobenzene(Surrogate (86-115))
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13. ABSTRACT *(Maximum 200 words)*

At the request of the Naval Facilities Engineering Command (NAVFAC), Southern Division, Charleston, SC, the U.S. Army Engineer Waterways Experiment Station (WES) conducted the initial field trial of the Site Characterization and Analysis Penetrometer System (SCAPS) at Jacksonville Naval Air Station (NAS), Jacksonville FL. This work was carried out by a field crew consisting of personnel from WES and the Naval Ocean Systems Center during the period of 16 July 1990 to 14 August 1990.

The SCAPS investigation at the Jacksonville NAS has two primary objectives: (a) to provide data that could be useful in formulating remediation plans for the facility and (b) to provide for the initial field trial of the SCAPS currently under development by WES for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center.

The original concepts for the SCAPS was to develop an integrated site screening characterization system whose capabilities would include (a) surface mapping, (b) geophysical surveys using magnetic, induced electromagnetic, and radar instruments, (c) measurements of soil strength, soil electrical resistivity, and laser-induced soil fluorometry

(Continued)

14. SUBJECT TERMS
Cone penetrometer
Laser induced fluorescence (LIF)
POL contamination
Site characterization and analysis penetrometer system (SCAPS)

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143

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
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using screening instrumentation mounted in a soil penetrometer, (d) soil and fluid samplers, and (e) computerized data acquisition, interpretation, and visualization. The goal of the SCAPS program is to provide detailed, rapid, and cost-effective surface and subsurface data for input to site assessment/remediation efforts. Although a few system components had been previously field tested, this was the first field deployment of the full SCAPS with its unique fiber optic fluorescence detection tools.