Remedial Investigation Report

Volume 1 of 3

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

June 30, 1997

Project No. 21-02

MICHAEL PISANI & ASSOCIATES, INC.
Environmental Management and Engineering Services

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Executive Summary

Overview

This report presents the findings of a Remedial Investigation (RI) of the former Gulf States Creosoting site (the site) in Hattiesburg, Mississippi. RI field activities were conducted between February 24 and April 30, 1997. The investigation was performed in accordance with a work plan approved by the Mississippi Department of Environmental Quality (MDEQ).

The RI resulted in the following findings regarding the site:

- Wood treating residuals exist at two distinct and separate locations. The first location is an approximate 2.5-acre former process area located in the northeastern corner of the site (the Process Area). The second location is an obvious fill area located between Gordon's Creek and West Pine Street, within and adjacent to the former Gordon's Creek channel (the Fill Area). The Gordon's Creek channel was moved west to its current location in the early 1960s to allow for the extension of West Pine Street and the redevelopment of this area.
- The Process Area is separated from the Fill Area by both surface topographic and underground geologic barriers.
- Historical aerial photographs reveal that the Fill Area was created after the closure of the wood treating facility and in conjunction with redevelopment of the site. This correlates well with physical examination of these materials, which appear to be placed, not native.
- Creosote-impacted soils in the Process Area are currently covered with asphalt paving or concrete slabs; there is no surface exposure to these creosote-impacted soils.
- Creosote-impacted soils and ground water at the site are effectively isolated from regional drinking water supplies by a massive (120 to 200 feet thick) clay of the Hattiesburg formation.
- The Rapid Optical Screening Tool Laser-Induced Fluorescence (ROST LIF) system was demonstrated to be an accurate, quick, and cost-effective method for identifying creosote contamination in subsurface soils. ROST LIF results were used to define the lateral and vertical extent of creosote-impacted soils within the site boundaries.
- The lateral extent of affected shallow ground water at the site has not been fully defined.

Project Background

Kerr-McGee Chemical Corporation (KMCC) entered into an agreement with the Mississippi Department of Environmental Quality (MDEQ) and the Mississippi Commission on Environmental Quality (Commission) pursuant to the Uncontrolled Site Voluntary Evaluation Program for the investigation of the site. The agreement calls for the investigation of the site under the direction and review of the MDEQ Office of Pollution Control, Uncontrolled Sites Section. MDEQ guidance for the program states that investigations will include all activities necessary to characterize the environmental setting and to define the degree and extent of affected site media. The MDEQ guidance refers to this investigative process as a Remedial Investigation (RI).

After meeting with MDEQ to discuss investigation requirements and proposed activities, KMCC prepared a Site Investigation Work Plan for the former Gulf States Creosoting site. The plan was submitted to MDEQ for review on January 8, 1997. In a letter dated February 21, 1997, MDEQ approved the Site Investigation Work Plan for implementation. This report presents the findings of the site investigation (hereafter referred to as the Remedial Investigation).

Remedial Investigation Field Activities

Remedial Investigation field activities were conducted between February 24 and April 30, 1997. These activities included the following:

- Advanced 64 cone penetrometer testing (CPT) pushes to depths up to 75 feet to define site stratigraphy
- Advanced six hollow-stem auger soil borings for the installation of monitoring wells and to correlate CPT findings
- Collected seven subsurface soil samples for geotechnical laboratory testing
- Utilized the ROST LIF system at 56 CPT pushes to determine the presence/absence and relative concentrations of aromatic hydrocarbons in soils [illegible]
- Collected 18 subsurface soil samples for laboratory chemical analysis to correlate ROST findings and to generate constituent-specific data
- Conducted ground water investigations to determine ground water quality, ground water flow direction and gradient, and aquifer characteristics
- Collected 18 surface soil samples to determine the presence and concentration of creosote constituents in near surface soils
- Mapped site surface water runoff
- Performed surveying to establish vertical and lateral control
- Performed a database search for water wells within one mile of the site

Site Description and Operations

The former Gulf States Creosoting site is a former wood treating facility located near the intersections of U.S. Highways 49 and 11 in Hattiesburg, Mississippi. The former site property is currently bounded by Scooba Street on the northeast, Gordon's Creek and Corinne Street on the west and northwest, U.S. Highway 49 on the southwest, and the Southern Railroad on the southeast. The wood treating facility operated between the early 1900s and approximately 1960. The site was redeveloped for commercial and light industrial use beginning in approximately 1962; there are no residential or institutional (e.g., schools) uses of the site.

Operations at the Gulf States Creosoting facility were of a relatively small scale consisting of the use of creosote in a single pressure cylinder. Creosoting and the associated storage and handling of chemicals were confined to an approximately 2.5-acre process area at the northeastern corner of the site. This area of the site is referred to as the Process Area and is now occupied by Courtesy Ford Motors; specifically the parking areas and body shop east of the main Courtesy Ford building. Subsequent to closure of the facility and concurrent with the redevelopment of the site, placement of demolition debris such as broken concrete and asphalt and other waste materials occurred at the southwestern site boundary near

Gordon's Creek. This area of the site is referred to as the Gordon's Creek Fill Area or the Fill Area and remains undeveloped.

Remedial Investigation Findings

A review of current (1996) and historical (1957-1960) topographic surveys indicates that the site is located within two distinct drainage areas separated by a topographic and drainage divide. The area northeast of this divide, including the former Process Area, is drained to the east by a ditch and culvert system. The area southwest of the divide, including the Fill Area, is drained to the west by Gordon's Creek and its tributary ditches.

Results of subsurface investigations show the geology of the Process Area and Fill Area to be significantly different, with the exception of an underlying clay aquitard common to both areas. The Process Area geology is characterized by the presence of an upper clay unit, a sand channel, and the underlying clay aquitard. The sand channel, which is the uppermost water-bearing zone beneath the Process Area, does not extend westward to Gordon's Creek or beneath the Fill Area. The Fill Area geology is characterized by shallow interbedded sands and clays underlain by the clay aquitard. The interbedded sand deposits beneath the Fill Area do not extend northeastward to the Process Area. The clay aquitard underlying the entire site at elevations of 150 to 170 feet above mean sea level (msl) is believed to be the massive clay of the Hattiesburg formation. Published reports and area well logs indicate that this clay layer ranges in thickness from 120 to 200 feet.

During RI activities, four new ground water monitoring wells were installed to verify site ground water flow direction and to determine site-wide ground water quality. Ground water elevation data obtained during the RI indicate that ground water flow within the Process Area sand channel is to the east, or in the opposite direction asserted in reports of previous investigations by others (this due to errors in a previous elevation survey). The ground water gradient in the sand channel is approximately 0.01 feet per foot to the east. The estimated ground water flow velocity is on the order of 0.2 to 0.04 feet per day.

A search of a U.S. Geological Survey (U.S.G.S.) water well database reported the presence of six wells within a one-mile radius of the Process Area and Fill Area; four additional wells were identified by MDEQ as possibly within one mile of the site. Three of the ten wells identified are screened at depths of less than 300 feet (i.e., above the massive Hattiesburg clay). The current status and use of these wells are unknown.

The ROST system was used in conjunction with laboratory analytical data to delineate the extent of creosote-impacted soil within the Process Area and Fill Area. The ROST system was demonstrated to be an effective tool for determining the presence or absence of creosote constituents and, where present, their relative concentrations. Samples collected from intervals exhibiting no ROST response contained virtually no creosote constituents; samples from intervals showing moderate ROST responses contained up to 600 milligrams per kilogram (mg/kg) total polycyclic aromatic hydrocarbons (PAHs); and samples from intervals showing relatively high ROST responses contained up to 3,700 mg/kg total PAHs.

Creosote-impacted soils within the Process Area are confined to areas beneath and/or immediately adjacent to former wood treating operational features. Mapping of the lateral extent of creosote-impacted soils above the water table indicates approximately 3.4 acres of soil in and around the Process Area have been impacted by former wood treating operations. The vertical extent of creosote-impacted soils above the water table throughout the Process Area ranges from a few feet below land surface (bls) to the top of the water table (20 to 25 feet bls). The saturated upper sand channel in portions of the Process Area is also impacted. All areas of identified impacted soils within the Process Area are covered with asphalt paving or concrete slabs; there are no current surface exposures to the creosote-impacted materials.

Creosote-impacted soils within the Fill Area are presently within and adjacent to areas where filling occurred in conjunction with redevelopment of the property beginning in approximately 1962. Mapping of the lateral extent of creosote-impacted soils indicates approximately 2.1 acres of soil in and around the Fill Area have been impacted. The upper 3 to 4 feet of soil in the Fill Area is generally not affected. Evidence of creosote impact extends into the upper saturated sand beneath the Fill Area. The thickness of creosote-impacted soil varies by location and ranges from several feet to as much as 15 feet.

Results of the RI indicate a lack of a historical or present transport mechanism for creosote or other constituents to migrate from the Process Area to the Fill Area: the surface drainage is not connected and flows to separate basins; the ground water flow beneath the Process Area is away from the Fill Area and is confined to a sand which does not extend to the Fill Area; and the dip of the underlying clay in the Process Area slopes away from the Fill Area. These findings, coupled with evaluation of historical aerial photographs and topographic surveys, indicate that creosote-impacted media in the Fill Area are not a result of creosote wood treating operations but resulted from the placement of creosote-impacted soils and debris (combined with other waste material) in the Fill Area during redevelopment of the site in the early 1960s.

Samples were collected from existing ground water monitoring wells in the Process Area and from new wells near site boundaries during the RI. The results of ground water monitoring indicate that affected ground water is present within the uppermost water-bearing zone (i.e., the sand channel) beneath the Process Area. Affected ground water does not extend to the west of the Process Area; the extent of affected ground water to the north and east of the Process Area has not been defined. Analytical results from other on-site monitoring wells, including one well located between the Process Area and Fill Area, indicate no ground water contamination. Ground water flow direction and quality beneath the Fill Area have not been characterized; the direction of flow in the shallow interbedded sands is anticipated to be toward or downstream along Gordon's Creek.

The results of surface soil sampling performed in exposed (i.e., unpaved or uncovered) areas throughout the site indicate the presence of very low concentrations of wood treating constituents in the upper 12 inches of soil below land surface. The highest sum total of all PAHs in any surface soil sample was less than 30 mg/kg.

The results of investigations performed at the site indicate that affected subsurface media are confined to two separate and distinct areas: the Process Area and the Fill Area. These areas comprise approximately 5.5 acres of the original site property. No additional on-site work is warranted outside of these two areas. Additional investigation activities will be necessary to fully determine the extent of affected ground water in the Process Area and Fill Area.

1.0 Introduction

1.1 Purpose of Report

In January 1997, KMCC submitted to the Mississippi Department of Environmental Quality (MDEQ) a work plan for a Remedial Investigation (RI) at the former Gulf States Creosoting site in Hattiesburg, Mississippi (the site). The objective of the investigation was to define site stratigraphy, ground water conditions, and other physical site characteristics and to determine the nature and extent of chemical constituents in site media. The work plan was approved for implementation by the MDEQ Office of Pollution Control (OPC), Uncontrolled Sites Section, in a letter dated February 21, 1997.

RI field activities were conducted between February 24, 1997 and April 30, 1997. Work was performed according to procedures specified in the MDEQ-approved work plan. This RI Report documents data collection activities and presents the results of the remedial investigation. The report was prepared in general conformance with the following documents:

- *Guidance for Remediation of Uncontrolled Hazardous Substance Sites in Mississippi*, Superfund Branch, Hazardous Waste Division, Office of Pollution Control, Department of Environmental Quality, State of Mississippi, September 1990; and
- *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, U.S. EPA, October 1988.

1.2 Report Organization

The RI report is organized as follows:

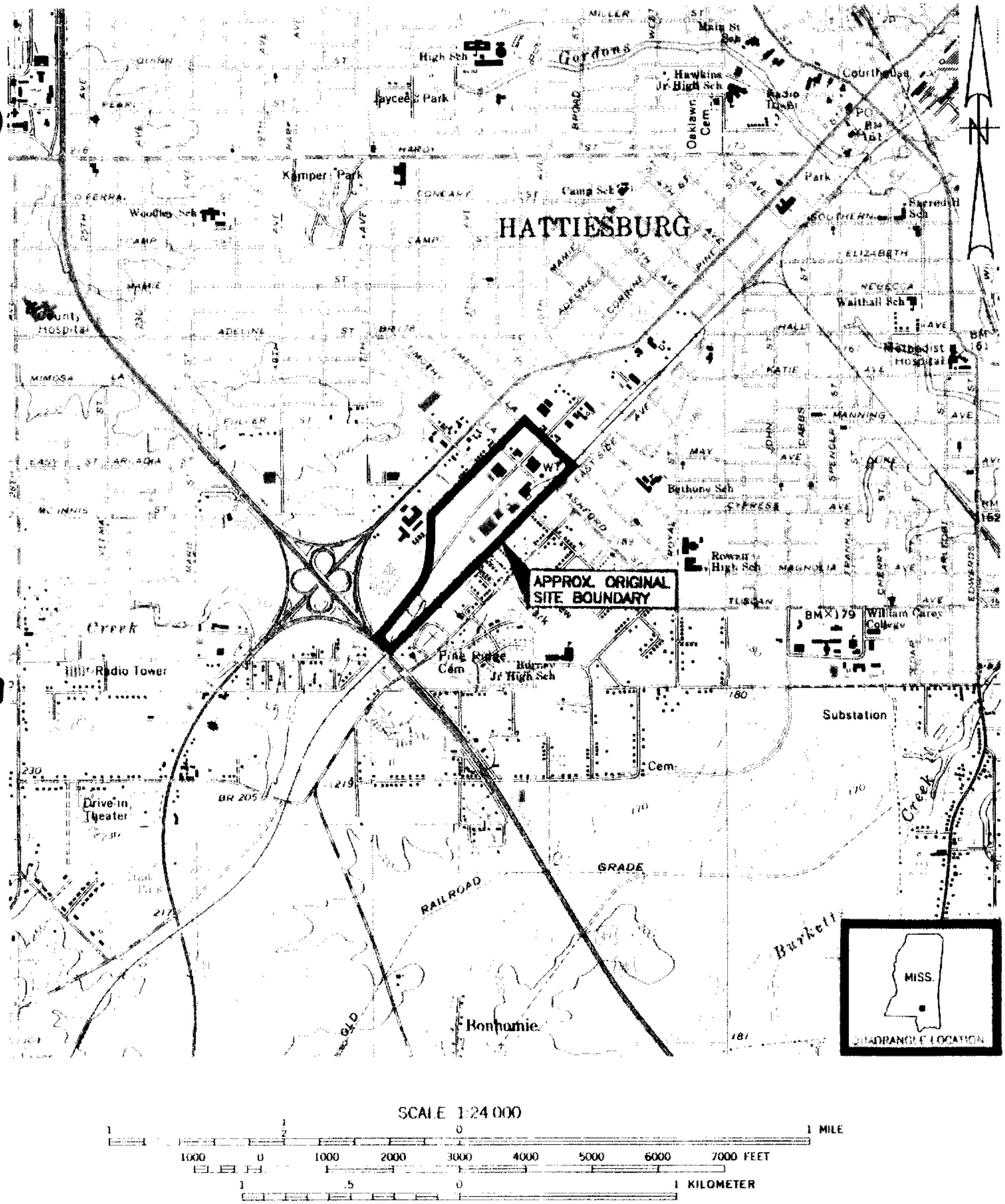
- Section 1 presents site background information.
- Section 2 presents details of study area investigation activities undertaken during the RI, including sampling procedures and the number and types of samples.
- Section 3 presents information on the environmental setting (physical characteristics) of the study area.
- Section 4 presents information on the nature and extent of chemical constituents in site media.
- Section 5 presents conclusions of RI activities.

1.3 Site Background

1.3.1 Site Description

The former Gulf States Creosoting site is located in Hattiesburg, Mississippi near the intersection of U.S. Highways 49 and 11. The site is situated entirely within Section 16 of Township 4 North, Range 13 West, in Forrest County, Mississippi. The site is bounded by Scooba Street on the northeast, Gordon's Creek and Corinne Street on the northwest, U.S. Highway 49 on the southwest, and the N.O. & N.E. Railroad (also known as the Southern Railroad) on the southeast. The location and approximate boundary of the original plant area are shown on Figure 1-1.

Aerial photographs depicting the site area were identified, obtained, and interpreted by Aero-Data Corp. of Baton Rouge, Louisiana. A listing of identified aerial photographic



SOURCE: USGS MAP OF HATTIESBURG, MISSISSIPPI, 7.5' QUADRANGLE, 1964 PHOTOREVISED 1982

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana — Houston, Texas

SCALE:
DWG. NO.: 21-01/07A

FIGURE 1-1
SITE LOCATION

FORMER GULF STATES CREOSOTING SITE
HATTIESBURG, MISSISSIPPI

coverage of the site is provided in Table 1-1. The aerial photographs were used to develop the description of site operations provided in the following paragraphs.

The property comprising the former Gulf States Creosoting site is an irregularly-shaped, elongated southwest/northeast property located within the City of Hattiesburg, Mississippi. Creosoting and the associated storage and handling of bulk chemicals used in the creosoting process were confined to a Process Area located at the northeastern corner of the site. This Process Area encompassed approximately 2.5 acres and was located in the area currently bounded by Timothy Lane, Scooba Street, West Pine Street, and the N.O. & N.E. Railroad. The portion of the site currently southwest of Timothy Lane between West Pine Street and the Southern Railroad was historically used for the storage of either treated or untreated wood. Subsequent to closure of the facility in approximately 1960, the Gordon's Creek channel was moved 200 to 300 feet to the northwest to allow for the development of land along the extension of West Pine Street and an area at the western edge of the property near Gordon's Creek was cleared of trees. The shallow subsurface in this area currently contains fill consisting of demolition rubble and waste materials, the exact source of which is unknown. This area is referred to as the Gordon's Creek Fill Area, or simply the Fill Area, in this report.

The property was developed commercially beginning in approximately 1962. The original plant area is currently occupied by several automobile dealerships, auto parts stores, a beverage dealership, a convenience store, and other commercial operations. The Process Area and wood storage areas have been regraded, covered with asphalt, and are no longer evident (Weston, May 1990). Figure 1-2 is a map depicting the current site features.

1.3.2 Site History and Operations

Creosoting operations are believed to have been conducted at the site between the early 1900s and approximately 1960 (Roy F. Weston 1990). Interviews with former employees indicate that during the life of the facility, operations consisted of treating primarily cross-ties in a single pressure cylinder. In an August 1994 deposition, a former plant supervisor indicated that to his knowledge, the only preservative ever used at the site was creosote (Deposition of Paul Davis Mabry, August 30, 1994). The major components of creosote are listed in Table 1-2 (US EPA 1990).

Historical aerial photographs and Sanborn maps have been used to establish the former locations of the various wood treating components. The following are among the components identified within the Process Area: a settling basin (or U-basin), boiler house, treating room(s), a dry kiln, preservative storage and working tanks, wood storage areas, and an office. Locations of operational features are shown on a 1960 photograph provided as Figure 1-3. Figure 1-4 shows current site features relative to 1960 site operational features.

1.3.3 Previous Investigations

Previous investigations performed at the site, with corresponding reports cited, include the following:

- January and March 1990 investigations by Roy F Weston for U.S. EPA (*Soil Gas and Soil Sampling*, Roy F. Weston, Inc., May 1990);
- An October 1991 investigation by MDEQ (*Site Inspection, Phase II Report*, MDEQ, January 7, 1992);

Table 1-1
Identified Aerial Photographic Coverage

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Date	Scale	Source (a)
9/3/37	1: 18,000	TOBIN
3/6/42	1: 20,000	NARA
3/7/43	1: 20,000	NARA
4/27/52	1: 20,000	NARA
2/29/56	1: 11,670	NARA
3/2/58	1: 20,000	ASCS
3/21/60	1: 18,000	USGS
4/5/60	1: 18,000	USGS
8/8/62	1: 40,000	NOS
11/8/63	1: 24,000	USGS
10/17/64	1: 20,000	ASCS
10/3/66	1: 24,000	GCAM
1/26/82	1: 40,000	ASCS
2/22/96	1: 31,680	ADC

(a) Abbreviations stand for the following organizations and agencies:

TOBIN: Tobin Research
NARA: National Archives and Records Administration
ASCS: Agricultural Stabilization Conservation Service
USGS: United States Geologic Survey
NOS National Oceanic Service
GCAM: Gulf Coast Aerial Mapping
ADC: Aero-Data Corporation

Table 1-2
Major Chemical Components of Creosote

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Component	Composition
Naphthalene	17.0
2-Methylnaphthalene	6.5
1-Methylnaphthalene	3.5
Biphenyl	1.9
Acenaphthylene	0.5
Acenaphthene	7.8
Dibenzofuran	5.2
Fluorene	6.0
Phenanthrene	19.4
Anthracene	2.5
Carbozole	5.1
Fluoranthene	11.8
Pyrene	8.4
1,2-Benzanthracene/Chrysene	4.2
Total	**99.8**

(1) - US EPA 1990

Figure 1-4
FORMER GULF STATES CREOSOTING SITE
Aerial Photography Analysis
Hattiesburg, Mississippi

Legend

- ● Tanks
- Buildings
- Rail Road
- Unpaved Roads
- Water Channel
- Ditch
- Flow Vectors
- Lagoon
- ▨ Treated Wood
- Untreated Wood

Scale
200' 0 200' 400'

Figure 1-3
FORMER GULF STATES CREOSOTING SITE
Aerial Photography Analysis
Hattiesburg, Mississippi

- A May 1994 investigation by Environmental Protection Systems (EPS) (*Phase II Site Investigation of the Former Gulf States Creosote Company Process Area*, EPS, July 1994);
- A June 1994 investigation by Bonner Analytical Testing Company (BATCO) (Letter to Mrs. John D. Thomas re former Gibson's Shopping Center property, BATCO, July 7, 1994);
- An October/November 1994 investigation by BATCO (*A Preliminary Subsurface Investigation, Ryan Motors/RSCO Realty*, BATCO, October 31 through November 3, 1994);
- Two late-1995 three-dimensional resistivity surveys by American Remediation Technology (*Three-Dimensional Resistivity Survey, Courtesy Ford Facility*, American Remediation Technology, December 19, 1995 and *Three-Dimensional Resistivity Survey, West Pine Street Drainage Ditch Area*, American Remediation Technology, December 22, 1995);
- A May 1996 investigation by McLaren/Hart (*Report of Investigative Activities*, McLaren/Hart, June 16, 1996 and *Report of Investigative Activities, Supplemental Information*, McLaren/Hart, June 25, 1996); and
- A June 1996 investigation by KMCC (no report issued; laboratory reports and boring logs available).

Information from the investigations listed above was summarized in Section 2.3 of the MDEQ-approved work plan. The summary included a map depicting sampling locations, if available, and tabulated analytical data from previous investigations. Subsequent to the preparation of the summary provided in the work plan, the following additional information was received:

- A map of boring locations from the October/November 1994 BATCO investigation of Ryan Motors/RSCO Realty property; and
- A report from a June/July 1995 investigation by BATCO (Letter to Mrs. John D. Thomas re former Gibson's Shopping Center property, BATCO, September 14, 1995).

A copy of Section 2.3 from the work plan, updated to include additional information from previous investigations, is provided as Appendix A.

2.0 Study Area Investigations

RI field activities were comprised of four specific tasks:

1. Stratigraphic Definition and Determination of Soil Properties
2. Delineation of Creosote-Impacted Subsurface Soils
3. Ground Water Investigations
4. Surface Soil Investigation

Procedures used to complete each of the above specific tasks are summarized in the following sections of this report. Unless stated otherwise, field procedures were performed as specified in the MDEQ-approved work plan. Analytical results and other findings of the RI field activities are presented in Sections 3 and 4 of this report.

2.1 Stratigraphic Definition and Determination of Soil Properties

The purpose of this task was to more thoroughly characterize the site-wide stratigraphy and to collect soil data necessary to assist in the evaluation of contaminant migration potential and/or control. The task was accomplished by implementing a cone penetrometer testing (CPT) program in conjunction with a conventional soil boring program. Additionally, subsurface soil samples were collected and tested by an independent laboratory to determine the geotechnical and contaminant transport properties of various soil horizons beneath the site.

Three technologies were selectively used to physically probe the subsurface and allow determination of subsurface soil characteristics: cone penetrometer testing, Geoprobe sampling, and conventional hollow-stem auger drilling. These three technologies are briefly described in the following paragraphs.

Cone penetrometer testing (CPT) consists of measuring the in-place subsurface soil properties of resistance to penetration (tip resistance), sleeve or frictional resistance, and pore pressure. These physical parameters, plus the ratio of frictional resistance to tip resistance, can be used to characterize subsurface soil types on a continuous basis. For example, relatively high tip resistance (hard materials) and relatively low frictional resistance (unconsolidated materials) are characteristic of sands and gravels. Alternatively, relatively low tip resistance (soft materials) and relatively high frictional resistance (consolidated materials) are characteristic of clays. Sands also exhibit relatively low pore pressures, whereas clays have high pore pressures. Actual numerical correlations are generally site-specific and are established by physically sampling and logging a representative subset of the CPT push locations.

The equipment used in CPT consists of a truck containing the electronics, recording equipment, and hydraulic push device; the hollow-stem rods; and the measuring cone. The cone is a cylindrical steel device with a precision-machined cone-shaped head (thus the name cone penetrometer). Strain gauges are mounted on the tip and sleeve of the cone for measuring resistance in units of tons per square foot. The pore pressure is measured via a porous ceramic filter and pressure transducer. The measured parameters are transmitted to the truck via electrical signals carried by cables strung through the push rods. The push rods are advanced at a continuous rate of 20 millimeters per second by a hydraulic press located within the truck.

The Geoprobe is a direct push soil sampling device. The soil sampling barrel is closed and sealed as it is advanced to the target sampling depth with hollow steel push rods and a percussion hammer. At the target sampling depth, the sample barrel is opened and advanced further to allow the collection of a discrete soil sample. The sample barrel typically has a nominal diameter of one inch. The collected soil sample and push rods are retrieved using a hydraulic jack.

Conventional environmental drilling consists of advancing hollow-stem augers to drill a borehole. Samples are collected in advance of the augers by pushing samplers through the hollow-stem using solid rods. This methodology is capable of producing larger diameter boreholes and obtaining larger samples but also produces more wastes and surface disturbance than Geoprobe sampling.

2.1.1 CPT Program and Correlation Soil Borings

CPT and Geoprobe work was performed by Fugro Geosciences, Inc. of Houston, Texas; hollow-stem auger drilling was performed by Technical Drilling Services, Inc. (TDS) of Knoxville, Alabama. The following work was performed as part of the CPT/soil boring program:

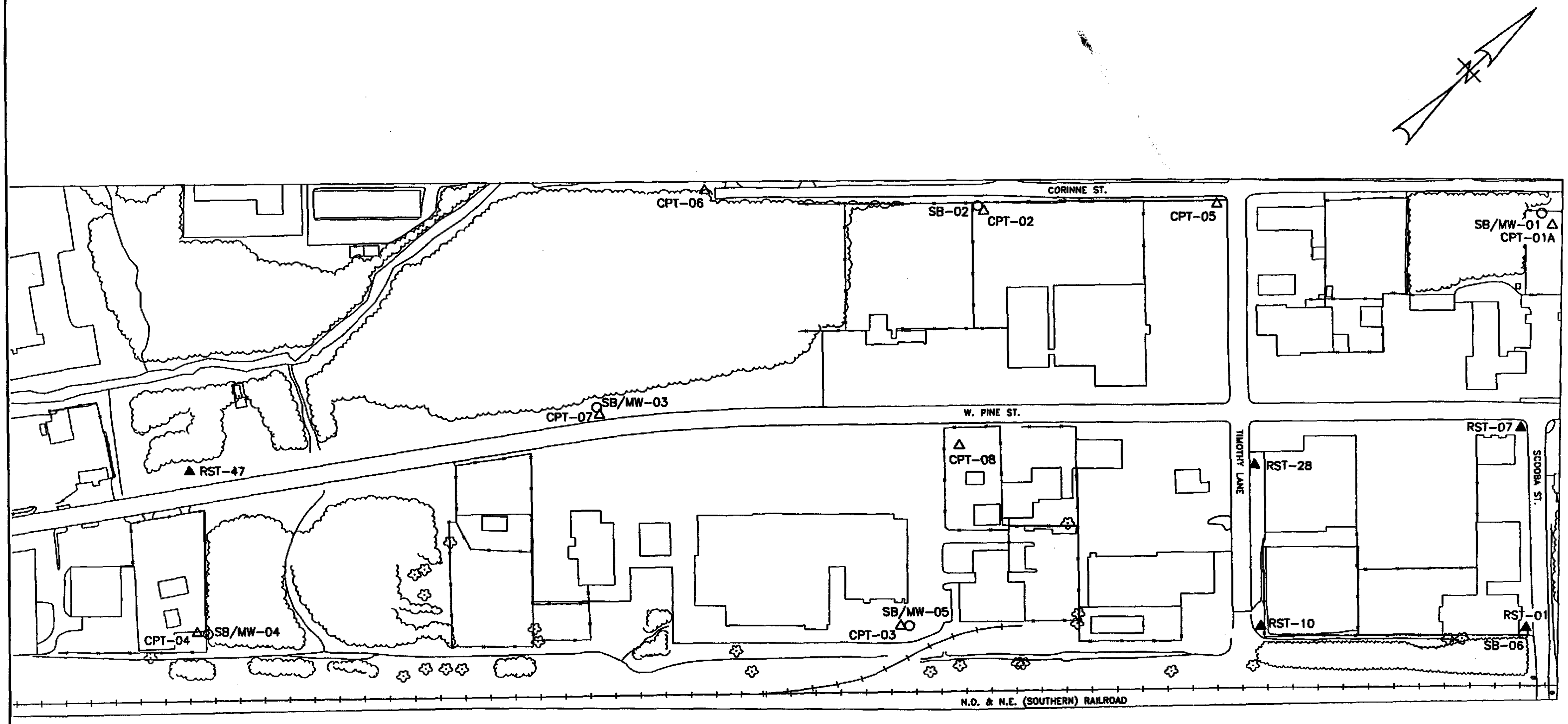
- 13 CPT pushes were advanced at locations shown on Figure 2-1 to define site stratigraphy. A piezocone penetrometer was utilized to determine pore pressure development as well as subsurface stratigraphy during penetration testing. Stratigraphic pushes were advanced to depths of 60 feet or greater except for RST-10, where dense sands resulted in refusal at a depth of approximately 38 feet below land surface (bls).
- Standard penetration and piezocone data were obtained at all Rapid Optical Screening Tool (ROST) pushes advanced within the Process Area and Fill Area. Locations of ROST pushes are shown on Figure 2-2.
- Six hollow-stem auger soil borings were advanced to depths ranging from 29 to 54 feet at locations shown on Figure 2-1 for the purpose of installing ground water monitoring wells. Soil borings were advanced adjacent to CPT pushes so that boring logs could be used to correlate CPT findings.
- Seven Geoprobe borings were advanced in the Fill Area for the collection of soil samples to correlate ROST findings. Logs of borings were generated for comparison with CPT results.

Additional information on CPT methodology is provided in Appendix B. CPT logs and soil boring logs are provided as Appendices C and D, respectively. The results of the CPT/soil boring program are presented in Section 3.3.2 of this report.

2.1.2 Geotechnical Testing

Seven subsurface soil samples were collected for laboratory geotechnical testing. The samples were collected from soil borings SB-01, SB-02, and SB-04 from three major soil horizons identified within the uppermost 75 feet beneath the site. Laboratory testing was performed by Eustis Engineering Company, Inc. of Metairie, Louisiana. All geotechnical soil samples were tested to determine the following properties:

- Unified Soil Classification System (USCS) classification (ASTM method D 2487-93);
- initial moisture content (ASTM method D 2216-92);
- dry and wet density (ASTM method D 698-91);
- initial void ratio (ASTM method D 698-91);
- initial percent saturation (ASTM method D 698-91);
- specific gravity (ASTM method D 854-92);



0 100 200 300 400

SCALE FEET

LEGEND

- △ CPT PUSH
- ▲ ROST PUSH
- ○ SOIL BORING/MONITORING WELL

BASE MAP FROM ATLANTIC TECHNOLOGIES, LTD.,
HUNTSVILLE, ALABAMA, APRIL 1, 1996

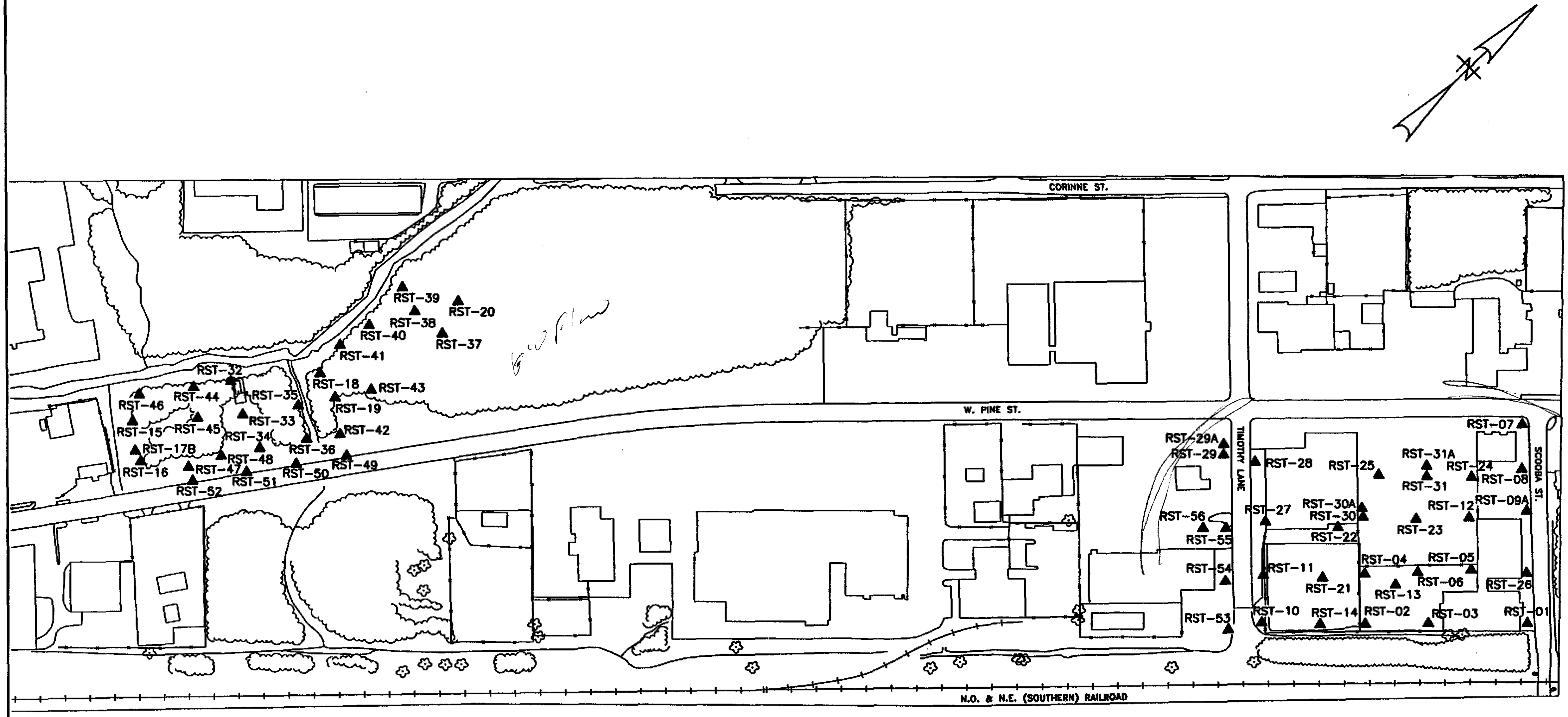
MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

TITLE: FIGURE 2-1
STRATIGRAPHIC CPT LOCATIONS AND
CORRELATION SOIL BORINGS

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: 1"=200' DWG. NO.: 21-02/05B



LEGEND

▲ ROST PUSH

0 100 200 300 400

SCALE FEET

BASE MAP FROM ATLANTIC TECHNOLOGIES, LTD.,
HUNTSVILLE, ALABAMA, APRIL 1, 1996

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

TITLE: FIGURE 2-2
ROST LOCATIONS

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: 1"=200' DWG. NO.: 21-02/06B

- grain size (ASTM method D 422-63);
- organic content percentage (ASTM method D 2974-87); and
- initial porosity (ASTM method D 698-91).

In addition, all cohesive samples were tested for coefficient of permeability (ASTM method 5084-90) and Atterberg limits (ASTM method 4318-93). Laboratory geotechnical reports are provided in Appendix E. The results of geotechnical testing are presented in Section 3.4 of this report.

2.2 Delineation of Creosote-Impacted Soils

The purpose of this task was to delineate the vertical and lateral extent of creosote-impacted soils within the Process Area and Fill Area. The task was accomplished by utilizing the ROST system as a subsurface screening tool and collecting and analyzing subsurface soil samples to correlate ROST results and obtain constituent-specific data.

2.2.1 ROST Program

The Rapid Optical Screening Tool (ROST) technology is designed to provide rapid sampling and real-time analysis of the chemical characteristics (primarily aromatic hydrocarbons, including creosote) of subsurface soils on a continuous sampling basis. The ROST system employs a wavelength-tunable, high energy pulsed ultraviolet laser combined with a sapphire window and fiber optic transmission/receiving cables to sense the absence or presence and relative concentration of aromatic hydrocarbons in the soil. The system works on the principle that aromatic organic substances contain compounds which fluoresce when excited by ultraviolet light, and that the fluorescence intensity is proportional to the contaminant concentration. The instrument output is relative to a synthetic standard and is expressed as a percentage of full-scale response to the standard. Relative insitu soil concentrations of site contaminants are determined by comparing the ROST response outputs to actual measured soil concentrations. The ROST system has been proven and is well-established for determining the presence or absence of creosote and also the relative total concentration of contaminants of concern (i.e., low, medium, or high).

Within the Process Area, ROST pushes were advanced at 29 locations on an approximate 100-foot grid pattern, exclusive of buildings and other structures (see Figure 2-2). The work plan specified that ROST pushes within the Process Area would be advanced to depths of 25 feet based on the depth to ground water, estimated to be between 17 and 21 feet bls. Once in the field however, a decision was made to advance pushes to the top of the competent clay layer underlying the first water-bearing zone to allow mapping of the clay unit; to determine the presence/absence of creosote on top of the clay layer; and to define the vertical extent of creosote, where present, in the clay. Within the Process Area, the top of the clay was encountered at depths ranging from 30 to 45 feet bls.

A total of 27 ROST pushes were advanced within the Gordon's Creek Fill Area at locations depicted on Figure 2-2. Due to site access limitations, a true grid pattern was not practical; however, good overall coverage of the Fill Area was achieved. Once again, although the work plan specified that most pushes would be advanced to depths of 25 feet with a limited number advanced to 45 feet, nearly all pushes were advanced to depths of 45 feet or more to determine/document the presence of a continuous, competent, underlying clay layer.

ROST logs are provided as Appendix F. A discussion of the ROST results is provided in Sections 4.1.1 and 4.2 of this report.

2.2.2 Correlation Soil Sampling

Subsurface soil samples were collected for laboratory chemical analysis. Results of this sampling were used to correlate ROST system responses to actual chemical concentrations in soil. The MDEQ-approved work plan required the collection of correlation samples at a minimum of 20% of ROST locations.

A total of 10 correlation soil samples were collected at seven ROST locations within the Process Area (24% of all locations). Samples from within the Process Area were collected using a CPT piston-type soil sampler. A total of eight samples were collected at seven ROST locations within the Fill Area (26% of all locations). Due to limited accessibility, samples from within the Fill Area were collected using an ATV-mounted Geoprobe. The locations of correlation soil samples are depicted on Figure 2-3.

All correlation soil samples were analyzed for US EPA's Target Compound List (TCL) volatile and semivolatile constituents. Due to the nature of the Fill Area (i.e., fill of unknown origin), a single sample from the Fill Area was also analyzed for pesticides and PCBs. A discussion on the comparison of ROST and laboratory results is provided in Sections 4.1.1 and 4.2 of this report.

2.3 Ground Water Investigations

The purpose of this task was to develop a basic understanding of shallow ground water flow direction and velocity, to determine the presence of site-related constituents in ground water, and to evaluate the potential for migration of any identified constituents. The task was accomplished by implementing a ground water investigation to determine ground water quality, ground water flow direction and gradient, and aquifer characteristics.

2.3.1 Monitoring Well Installation and Development

The work plan called for the installation of five to six new ground water monitoring wells as part of the ground water investigation. Proposed well locations were selected to provide site-wide coverage and to allow for the evaluation of ground water quality near the site boundary. Four new monitoring wells (MW-01, MW-03, MW-04, and MW-05) were installed during the RI at locations depicted on Figure 2-4.

Wells were not installed at the two remaining proposed locations due to unanticipated field conditions. Boring SB-02 was advanced at the western corner of Ryan Chevrolet's rear parking lot (see Figure 2-1). The boring was drilled and continuously sampled to a depth of 54 feet bls. No sand layers or other saturated permeable zones were encountered during drilling and logging activities. Upon removal of the entire hollow-stem auger string from the borehole, no water entered the borehole. CPT push CPT-02, advanced to a depth of 60 feet adjacent to boring SB-02, confirmed that no sand was present within the soil column at this location. Because no saturated permeable materials (i.e., water-bearing zones) were present, a well could not be installed.

Boring SB-06 was advanced at the eastern corner of the Courtesy Ford Body Shop (see Figure 2-1). Soils within the upper 19 feet bls exhibited brown-black staining and a creosote odor and contained pockets of brown oily material. Because the presence of soils impacted to this degree was not anticipated at proposed well locations, the drillers were not equipped to install surface casings (i.e., they did not have appropriately-sized augers or surface casing on site). Because no means were available to seal off the affected portion of the soil column, no well was installed at this location. In addition, this proposed well location was described as "optional" in the work plan because of the existence of four nearby wells.

Wells were constructed as specified in the work plan. Screen lengths for the new wells range from 5 to 20 feet, depending on the thickness of the first water-bearing zone. Due to their locations in high traffic areas (i.e., in parking lots or along roadways), wells were *completed at grade with water-tight, flush-mount manhole covers. Well completion* information is summarized in Table 2-1. Well construction diagrams are provided in Appendix G.

Upon completion, wells were developed to remove sediment and to facilitate the collection of samples which were representative of ground water within the screened material. Wells were developed by pumping until ground water was visually sediment-free. Approximately 55 gallons of water (one full drum) were removed from each of wells MW-01, MW-04, and MW-05. Well MW-03 was pumped dry several times; approximately 30 gallons of water were removed from the well.

2.3.2 Water Level Measurements

Prior to ground water sampling, well caps were removed from all monitoring wells to allow water levels in wells to equilibrate to atmospheric pressure. Water levels in wells were then measured using an electronic water level indicator. The four existing wells within the Process Area were checked for the presence of dense non-aqueous phase liquid using cotton string and a brass weight. [At wood treating sites, creosote is often present as a separate phase oily liquid. Because most creosote constituents are more dense than water, this separate phase liquid sinks and sometimes collects at the base of a well or aquifer. This liquid is therefore commonly known as dense non-aqueous phase liquid, or DNAPL.]

2.3.3 Ground Water Purging and Sampling

Prior to sampling, wells were purged to remove stagnant water. Purging was performed with disposable bailers. During purging, the volume of water removed was recorded and the temperature, pH, and specific conductance of the water were monitored. Well purging was considered complete when these parameters had stabilized and a minimum of three *well volumes had been removed.*

Ground water samples were collected from all four new wells and two of four existing wells. Samples of the DNAPL in wells MW-1 and MW-2 were collected in lieu of water samples. Samples were poured directly from bailers into clean, laboratory-supplied sample containers. The order of collection was volatiles, semivolatiles, cyanide, and metals. Ground water samples were analyzed for TCL volatile and semivolatile constituents and Target Analyte List (TAL) inorganics; DNAPL samples were analyzed for TCL volatile and semivolatile constituents. Ground water sampling records are provided as Appendix H.

2.3.4 Slug Tests

Slug tests were performed at the four new and two existing wells (all wells not containing DNAPL) to estimate a range of hydraulic conductivities for the first water-bearing zone. Initially, the water level in a well was measured to determine the static water level. An In-Situ TROLL 4000 datalogger/probe was lowered to the base of the well, then raised approximately three feet. Once the well equilibrated, a rising head ("slug out") test and/or a falling head ("slug-in") test were performed at each of the six wells tested.

Table 2-1
Summary of Monitoring Well Completion Information

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Well	Date Installed	Borehole Diameter (inches)	Well Diameter (inches)	Construction Material	Well Depth (ft. bls)	Top of Casing Elevation (ft. msl)	Screened Interval (ft. bls)	Screened Interval Elevation (ft. msl)
MW-1	May 1994	10.25	4	PVC	30	188.98	20-30	158.98-168.98
MW-2	May 1994	10.25	4	PVC	30	189.71	20-30	159.71-169.71
MW-3	May 1994	10.25	4	PVC	30	188.19	20-30	158.19-168.19
MW-4	May 1994	10.25	4	PVC	34	191.42	24-34	157.42-167.42
MW-01	February 1997	8.25	2	PVC	35	186.14	17-32	154.14-169.14
MW-03	February 1997	8.25	2	PVC	37	189.24	29-34	155.24-160.24
MW-04	February 1997	8.25	2	PVC	40	191.28	27-37	154.28-164.28
MW-05	February 1997	8.25	2	PVC	42	191.59	19-39	152.59-172.59

Note:
All elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88) and are reported with respect to mean sea level.
bls - below land surface

In a falling head test, a solid PVC "slug" of a known volume was lowered beneath the water's surface, causing an instantaneous increase in the water level, and the slug test was begun. In a rising head test, the process is reversed (i.e., the test is performed while the well is recovering from the removal of a slug from the well). During the tests, the datalogger recorded water levels with respect to time until the well had recovered to static or near static level.

2.4 Surface Soil Investigation

The purpose of this task was to collect soil samples for laboratory analysis from unpaved areas to determine the presence/absence of creosote constituents in near surface soils. The task was accomplished by collecting and analyzing soil samples within the upper 12 inches bls in exposed (i.e., unpaved or uncovered) areas.

A total of 18 surface soil samples were collected on a grid pattern at a frequency of approximately one per each 40,000 square feet of exposed area. Samples were collected from the 0- to 12-inch depth interval using a stainless steel hand auger and were analyzed for TCL semivolatile compounds. Surface sample locations are depicted on Figure 2-5.

3.0 Environmental Setting of Study Area

3.1 Climate

The climate of Forrest County is humid and semitropical, and is characterized by long, hot summers and cool, fairly short winters. Precipitation is moderately heavy throughout the year, with average annual rainfall in the County approximately 58 inches. In winter the average temperature is 51 degrees F, and the average daily minimum is 39 degrees. In summer the average temperature is 81 degrees, and the average daily maximum is 92 degrees. Prevailing winds are from the south (U.S. Department of Agriculture, April 1979).

3.2 Topography and Drainage

3.2.1 Regional Topography and Drainage

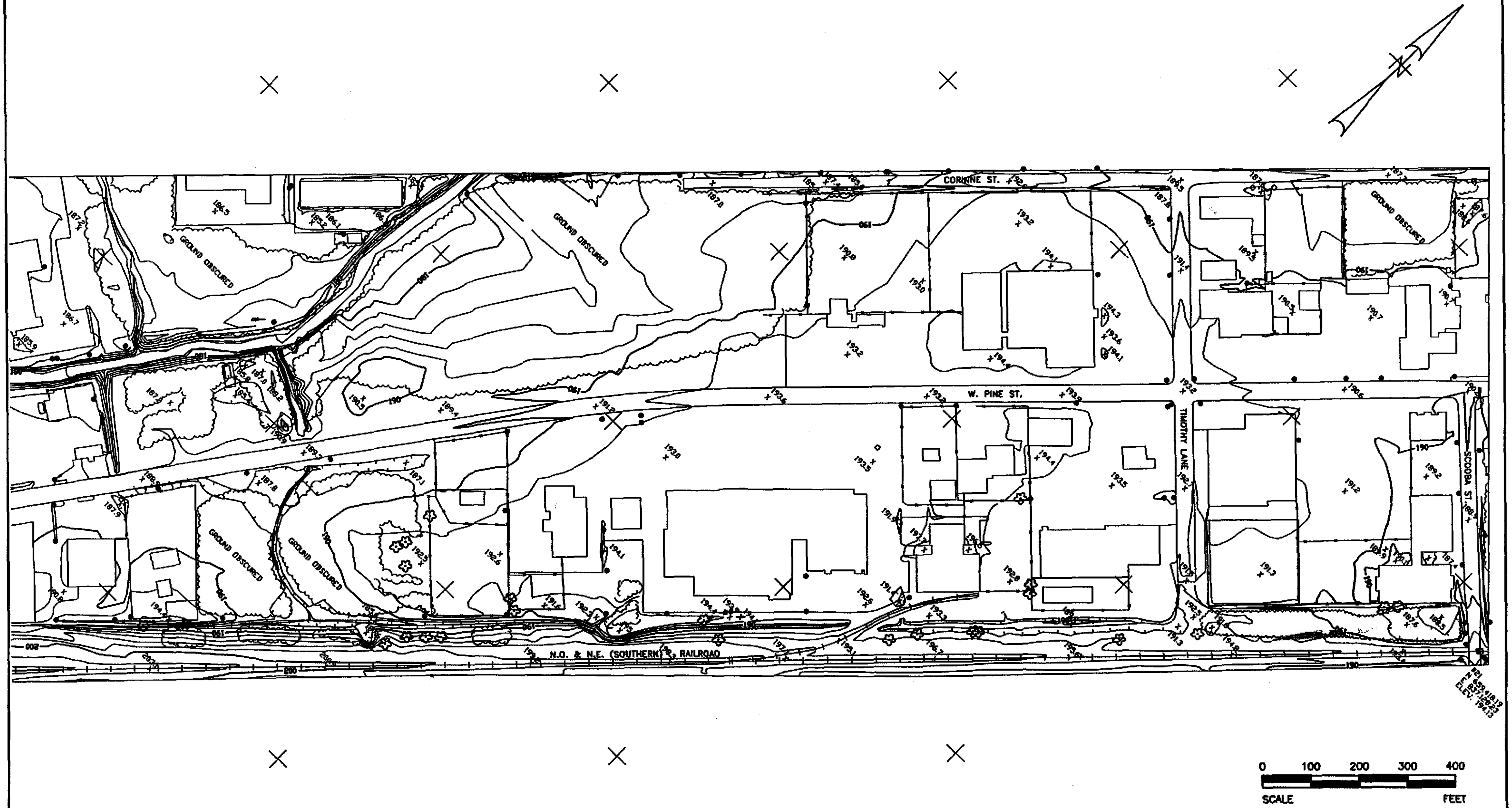
All of Forrest County lies within the Pine Hills physiographic region. The topography of the area is that of a gently southeastward-sloping plain dissected by a series of parallel, southeastward-flowing rivers or streams. These rivers or streams have eroded broad terraced valleys which are separated by ridges known as cuestas. These ridges, or series of hills, typically exhibit steep northeasterly and gentle southwesterly slopes.

The City of Hattiesburg is located on the northeastern slope of a ridge formed by the Bouie and Leaf Rivers on the northeast and Black Creek on the southwest. This northeastward-facing slope is relatively steep, although somewhat modified by the terraces of the Bouie and Leaf Rivers (Foster 1941). Elevations in the Hattiesburg area range from greater than 350 feet msl at the crest of the divide between the Bouie/Leaf Rivers and Black Creek to approximately 130 feet immediately adjacent to the Leaf River. The City of Hattiesburg, including the site, is built upon the lowermost of the high terraces of the Leaf River, which has an elevation of approximately 175 feet msl (Foster 1941).

Hattiesburg is situated at the convergence of the Bouie and Leaf River valleys, which average about two and four miles in width, respectively. The confluence of the Bouie and Leaf Rivers occurs at the northeastern corner of the city; the Leaf River then continues flowing in a southeasterly direction some 70 miles to its mouth, the confluence with the Chickasawhay River. The two rivers combine to form the Pascagoula River, which flows south and eventually empties into the Gulf of Mexico.

3.2.2 Site Topography and Drainage

Figure 3-1 is a topographic map of the site prepared from a 1996 aerial survey by Atlantic Technologies of Huntsville, Alabama. The map indicates that present site elevations range from approximately 194 feet msl along a topographic ridge or divide in the north central portion of the site to 176 feet msl within the Gordon's Creek channel at the western edge of the site. The topographic divide for the site is located approximately 300 to 400 feet southwest of Timothy Lane and runs parallel to Timothy Lane. The ground surface southwest of this topographic divide slopes gradually from east to west, toward Gordon's Creek. Northeast of the divide, the ground surface slopes northeastward toward Scooba Street.



BASE MAP FROM ATLANTIC TECHNOLOGIES, LTD.,
HUNTSVILLE, ALABAMA, APRIL 1, 1996

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana **Houston, Texas**

TITLE: FIGURE 3–1
1996 SITE TOPOGRAPHIC SURVEY

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: DWG. NO.: 21-02/29B

Figure 3-2 is a topographic map re-created from a 1957 survey (revised 1960) by R.L. Morrison Construction Engineers of Hattiesburg, Mississippi. The map shows that the topographic divide in the north central portion of the site existed prior to closure of the plant, and that the general site topography today is much as it was 40 years ago. The following three features have changed noticeably since the 1957/1960 map was prepared:

- Gordon's Creek was re-channelized on the southern portion of the site. This has been confirmed by a review of historical aerial photographs;
- a mounded area indicative of filling activities is present between Gordon's Creek and West Pine Street just north of the drainage ditch leading to the creek; and
- a general elevation increase occurred in the area between Gordon's Creek and West Pine Street.

Surface drainage from the site flows to two separate and distinct drainage basins. The first is a drainage basin created by a system of ditches and culverts, including the Southern Railroad ditch immediately adjacent to Courtesy Ford, which flow eastward toward the Leaf River. The second is a drainage basin created by Gordon's Creek which flows northward from the site and eventually turns east toward the Leaf River. Drainage from the block occupied by Courtesy Ford and physically defined by the centerlines of West Pine Street and Timothy Lane drains to the east toward the Leaf River via the ditch and culvert system; the remainder of the site drains westward to Gordon's Creek. Current site drainage is depicted on Figure 3-3. Examination of the 1957/1960 topographic survey indicates this same drainage pathway existed during site operation with the exception that the drainage basin created by the easterly flowing ditch and culvert system may have extended several hundred feet further southwest beyond Timothy Lane.

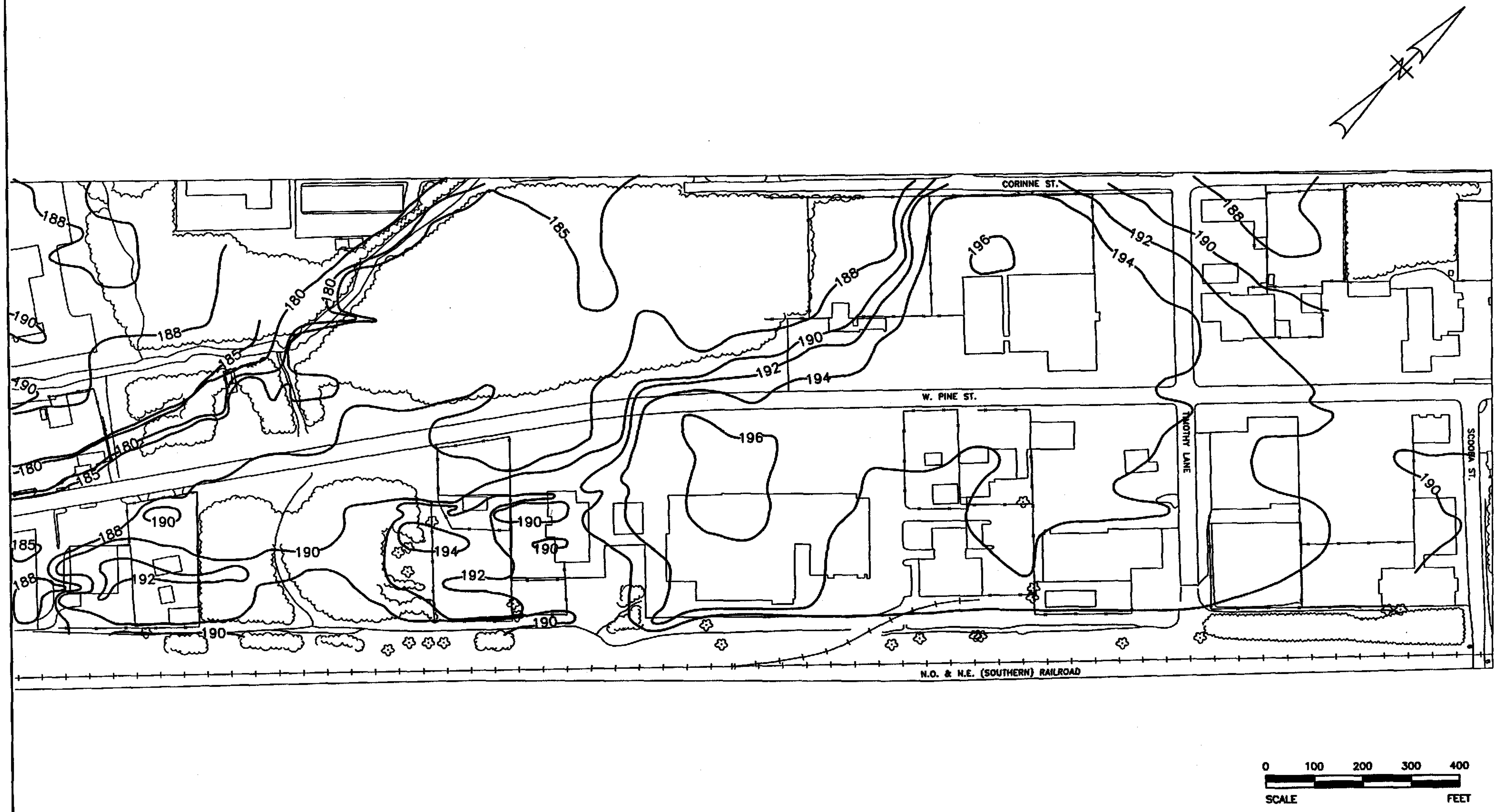
Two significant discoveries were made during the topographic survey review. First, topographic surveys provide evidence of suspected filling adjacent to Gordon's Creek during redevelopment of the site in the early 1960s. Secondly, although the Fill Area is at a lower elevation than the Process Area, there is historical evidence of a topographic and surface drainage divide between the two areas; affected materials in the shallow subsurface adjacent to Gordon's Creek could therefore not have been deposited by surface drainage from the Process Area.

3.3 Geology

3.3.1 Regional Geology

Forrest County is underlain by a great thickness of massive clay, silt, and clayey fine-grained sand of Miocene age (10 to 25 million years old), and gravelly sand probably of Pliocene age (1 to 10 million years old). Pleistocene (less than 1 million years old) high terrace deposits and Recent low terraces/alluvium are present within and adjacent to the major stream beds. In descending order, the formations typically encountered within the upper 1,000 feet beneath Forrest County are:

Formation	Age
Low terraces/alluvium	Recent
High terraces	Pleistocene
Citronelle	Pliocene
Pascagoula	Miocene
Hattiesburg	Miocene
Catahoula	Miocene



TOPOGRAPHIC CONTOURS FROM R.L. MORRISON CONSULTING ENGINEERS, HATTIESBURG, MISSISSIPPI, CREATED 5-25-57, LAST REVISION 9-16-60

CURRENT SITE FEATURES FROM ATLANTIC TECHNOLOGIES, LTD. HUNTSVILLE, ALABAMA, APRIL 1, 1996

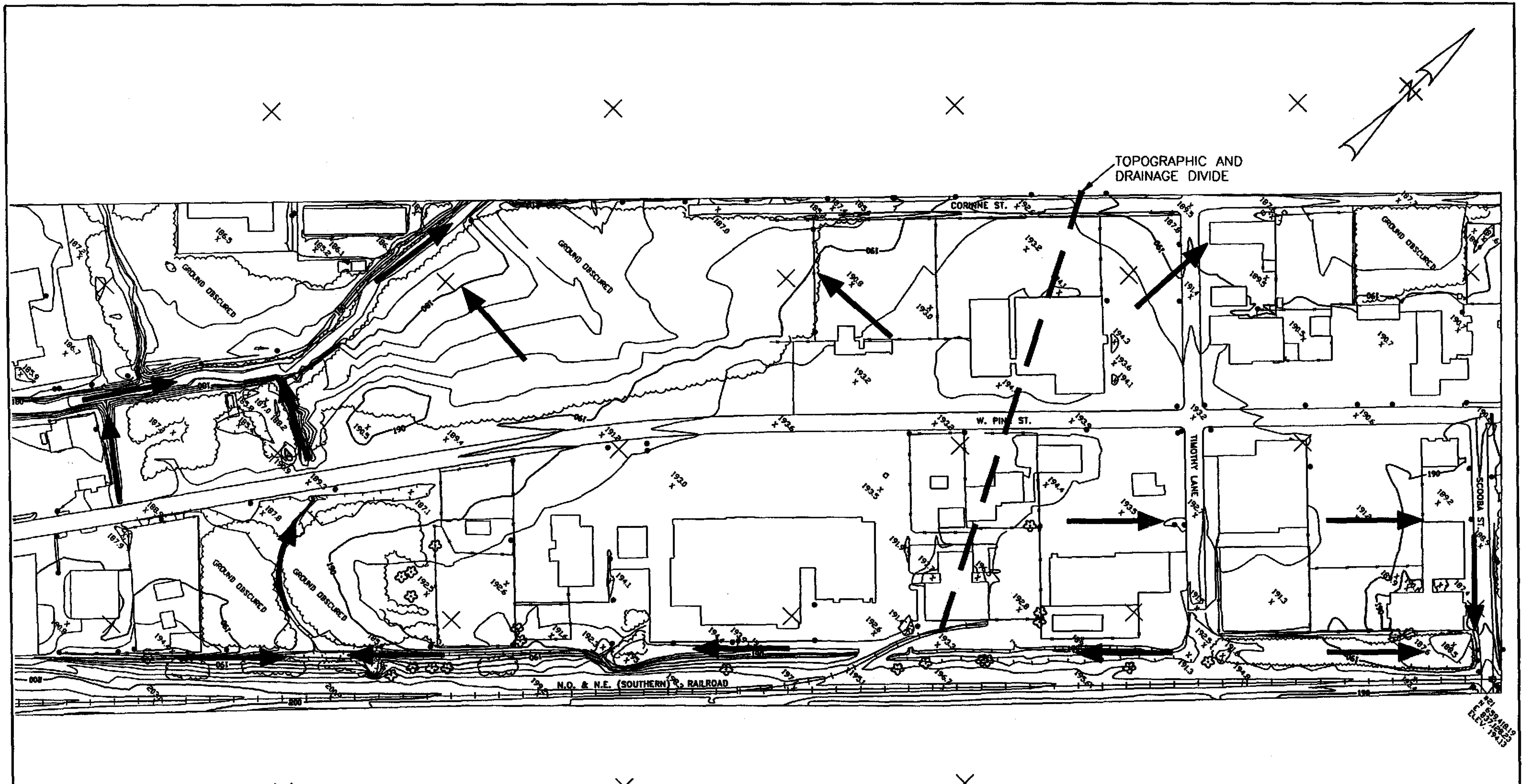
MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

TITLE: FIGURE 3-2
1960 SITE TOPOGRAPHIC SURVEY

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: 1"=200' DWG. NO.: 21-02/308



0 100 200 300 400

SCALE FEET

LEGEND

▬▶ GENERAL DIRECTION OF SURFACE DRAINAGE

BASE MAP FROM ATLANTIC TECHNOLOGIES, LTD.,
HUNTSVILLE, ALABAMA, APRIL 1, 1996

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

TITLE: FIGURE 3-3
SITE DRAINAGE

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: 1"=200' DWG. NO.: 21-02/32B

Due to the complex depositional and erosional history of the area, the younger formations (late Miocene through Recent) are absent in many locations.

The Catahoula formation does not outcrop in Forrest County, but has been reached by numerous wells at depths of 170 to 250 feet in Hattiesburg. The formation consists of beds of sand and/or gravel separated by clay layers (Shows 1970). The sands are typically white to gray in color and fine to medium grained, and are frequently semi-consolidated to consolidated.

Outcrops of the Hattiesburg formation in the Leaf and Bouie River bluffs consist of a massive clay between 150 and 200 feet thick (Foster 1941). Numerous geological logs of borings in the Hattiesburg area indicate a clay layer 120 to 200 feet thick in the interval between the elevations of approximately 150 feet above and 50 feet below msl. The massive Hattiesburg clay is described as blue-gray at or near the surface and light chocolate brown in deeper test holes. The Pascagoula formation overlies the Hattiesburg formation and has many of the same characteristics, making it difficult to distinguish between the two formations.

The Citronelle formation is only present in the uplands of Forrest County as blanket deposits at or near the peaks of cuestas. These deposits are considered by some to be high terrace deposits (Foster 1941). The sands, gravels, and clays of this formation are usually brightly colored due to intense weathering.

Pleistocene high terrace deposits were formed by the erosion, reworking, and deposition of Citronelle deposits on stream-cut terraces at a time when stream levels were 75 to 150 feet above their present channels. These deposits are comprised of interbedded sands, gravels, and clays, and are extremely discontinuous. Subsequent to the deposition of high terrace deposits but also during the Pleistocene epoch, streams cut far beneath their current flood plains in many valleys. Low terrace and alluvial deposits formed by the filling of these channels with sand and gravel (Brown 1944).

3.3.2 Site Geology

Although numerous borings were advanced at the site prior to RI activities, the large majority of these borings were terminated at depths of 20 feet or less. Because of the limited number of deeper borings, the thickness and lateral continuity of water-bearing zones and confining layers beneath the site were not determined through previous investigations. The purpose of the CPT and soil boring program implemented during the RI was to more thoroughly characterize the site-wide stratigraphy, particularly the presence and geometry of shallow sand bodies and confining clay layers.

The results of subsurface RI activities were evaluated in conjunction with subsurface information obtained through previous studies. Results indicate that the sediments encountered within the upper 75 feet bls are most likely comprised of high terrace deposits and the upper portion of the massive Hattiesburg clay. The presence of high terrace deposits at the surface is consistent with published reports (Foster 1941). The top of a hard clay was encountered in all borings or CPT pushes at elevations ranging from 145 to 165 feet msl. Published reports and geologic boring logs from wells in the Hattiesburg area indicate that this is roughly equivalent in elevation to the top of the massive Hattiesburg clay. Up to 37 feet of competent clay was penetrated (in CPT push CPT-01A); no borings or CPT pushes fully penetrated the clay layer, which is reported to be between 120 and 200 feet thick in the Hattiesburg area (Brown 1944).

Figure 3-4 depicts the locations of cross-sections generated using site subsurface data. Cross-sections A-A', B-B', and C-C', constructed through the Process Area and former wood storage area, are included on Figure 3-5; cross-sections D-D' and E-E', constructed through the Fill Area, are included on Figure 3-6. These cross-sections show the geology of the Process Area and the Fill Area to be significantly different. The geology of the two areas is described in detail in the following sections.

Process Area Geology

The Process Area is underlain by three major units. These units are, in descending order:

1. an upper silty clay, 20 to 25 feet thick;
2. the first water-bearing zone, a sand channel with a maximum thickness of 20 feet; and
3. an underlying clay aquitard at least 15 to 20 feet thick.

The upper unit is a light gray and tan silty clay which is moist, stiff to very stiff, and exhibits abundant orange and red mineral staining. Within the former Process Area (i.e., the area currently bounded by Timothy Street, West Pine Street, Scooba Street, and the Southern Railroad ditch), the unit ranges in thickness from 20 to 25 feet. CPT logs show the upper clay to be continuous throughout the Process Area, with only thin, discontinuous zones of sandy clay (indicated by slightly higher CPT tip resistance) interrupting the unit.

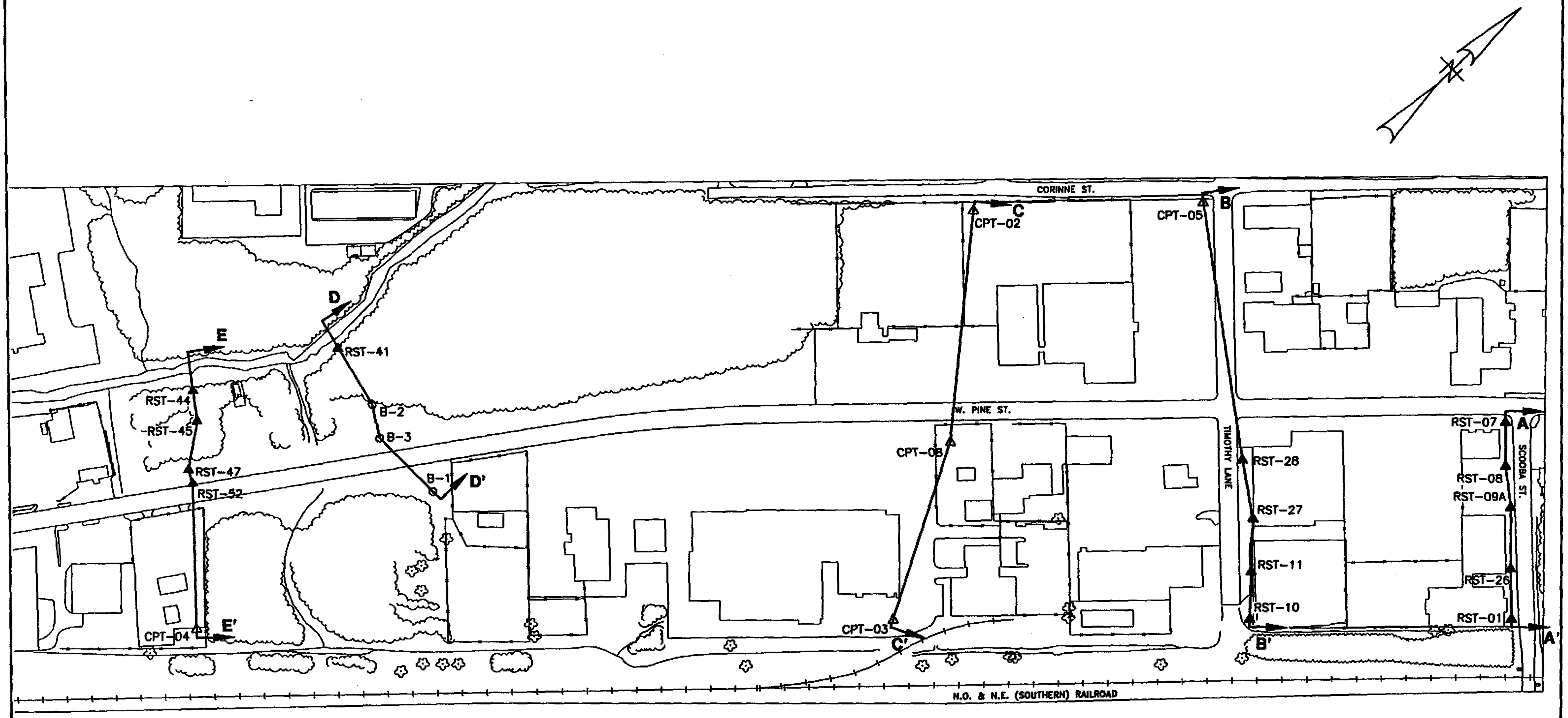
The first water-bearing unit beneath the Process Area consists of white to light gray sand which is saturated, fine to medium grained, and dense. A thin gravelly zone (sand with pea-size or smaller gravel) is typically present at the base of the sand body. The unit exhibits a geometry (i.e., shape) typical of channel deposits and ranges in thickness from 6 feet to just over 21 feet beneath the Process Area (see section B-B' on Figure 3-5). Its upper surface is relatively flat, while its lower surface becomes concave upward as the unit pinches out to the west. Figure 3-7 is a contour map on the bottom of the sand/top of the underlying clay, with a cross-section depicting the channel-type characteristics of the sand.

The Figure 3-7 contour map and the three Figure 3-5 cross-sections show the Process Area sand channel to trend southwest to northeast, parallel to the long axis of the site. The channel pinches out in a westerly direction; no sand was present in CPT pushes CPT-02, CPT-05, or CPT-06 at elevations correlative to the channel in the Process Area. Figure 3-6 cross-sections show that the Process Area sand does not extend beneath the Fill Area. The extent and geometry of the sand body to the east (toward the Southern Railroad) and north (across Scooba Street) are not known.

The underlying clay is a gray to brown silty clay which is dry and hard. The characteristics of this clay unit correspond with published descriptions of the massive Hattiesburg clay. The upper surface of the clay beneath the thickest portion of the sand channel is penetrated at an elevation of approximately 150 feet msl; the clay is encountered at progressively higher elevations as the overlying sand channel pinches out.

Fill Area Geology

The upper 20 to 25 feet beneath the Fill Area consists of interbedded sands and clays, making the geology of the area more difficult to define than that of the Process Area. As shown on the two Figure 3-5 cross-sections, the sandiest section of the Fill Area deposits is located immediately adjacent to Gordon's Creek. Beneath the creek's eastern bank, a clay layer separates two shallow sandy zones. The upper sand and the top of the intervening clay can be observed in outcrop on the cut bank of Gordon's Creek. Both sand units pinch out to the east of the Fill Area. At the eastern edge of the site (i.e., along the



0 100 200 300 400

SCALE FEET

LEGEND

△ CPT PUSH

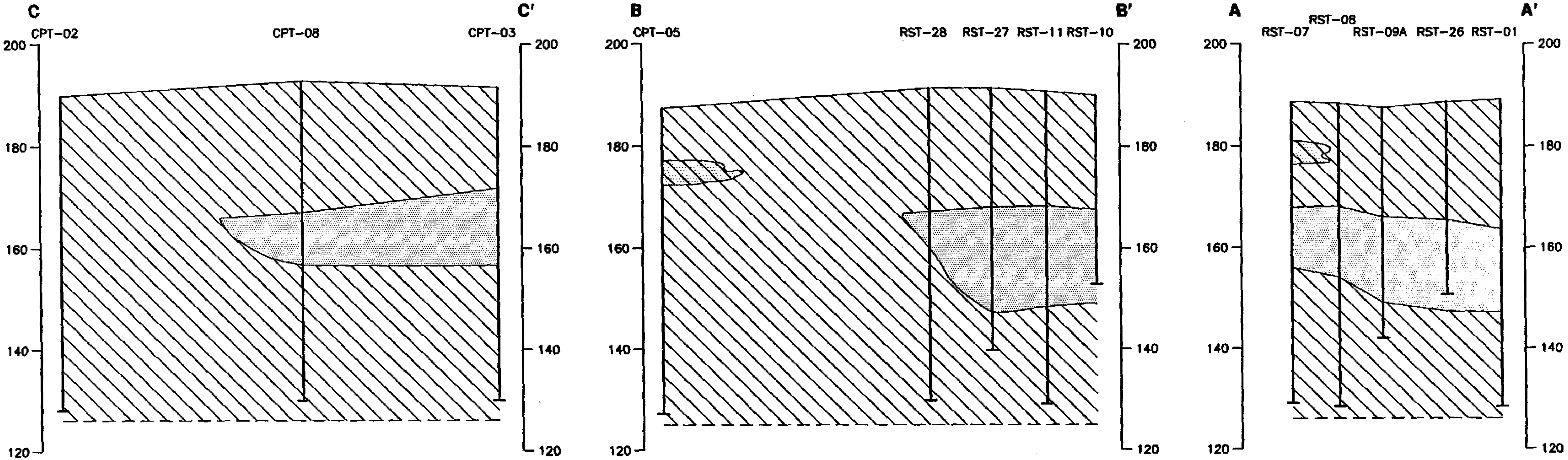
▲ ROST PUSH

○ SOIL BORING

BASE MAP FROM ATLANTIC TECHNOLOGIES, LTD., HUNTSVILLE, ALABAMA, APRIL 1, 1996

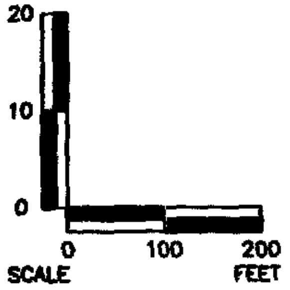
MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

TITLE: FIGURE 3-4 CROSS-SECTION LOCATION MAP	
PROJECT: FORMER GULF STATES CREOSOTING SITE	
LOCATION: HATTIESBURG, MISSISSIPPI	
SCALE: 1"=200'	DWG. NO.: 21-02/248



LEGEND

- ▨ ANCESTRAL CHANNEL SAND
- ▨ GORDON'S CREEK SAND DEPOSITS
- ▨ SANDY CLAY/CLAYEY SAND
- ▨ CLAY



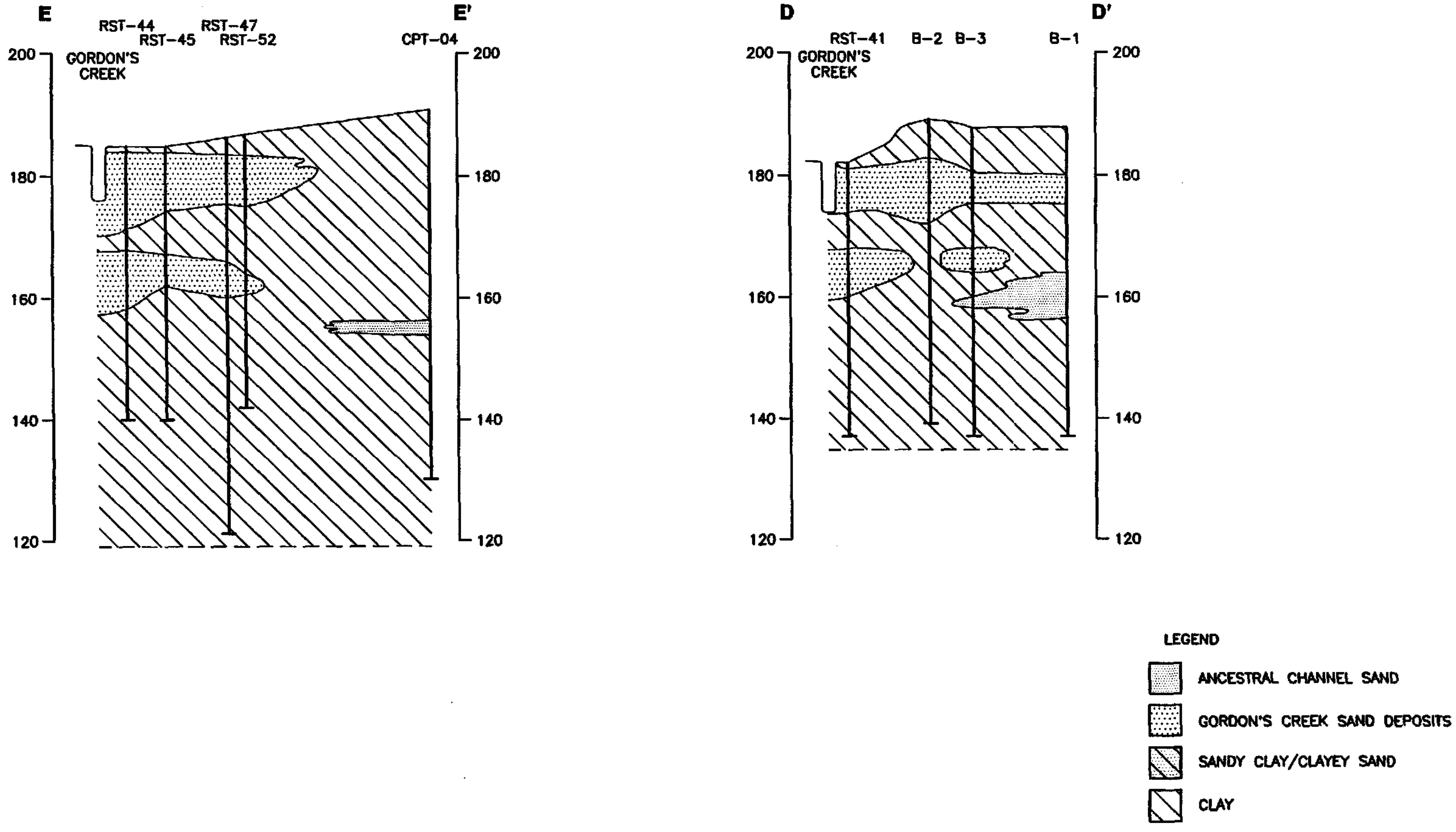
MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana **Houston, Texas**

TITLE:
FIGURE 3–5
PROCESS AREA CROSS-SECTIONS

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: 1"=200'/1"=20' | DWG. NO.: 21-02/27B



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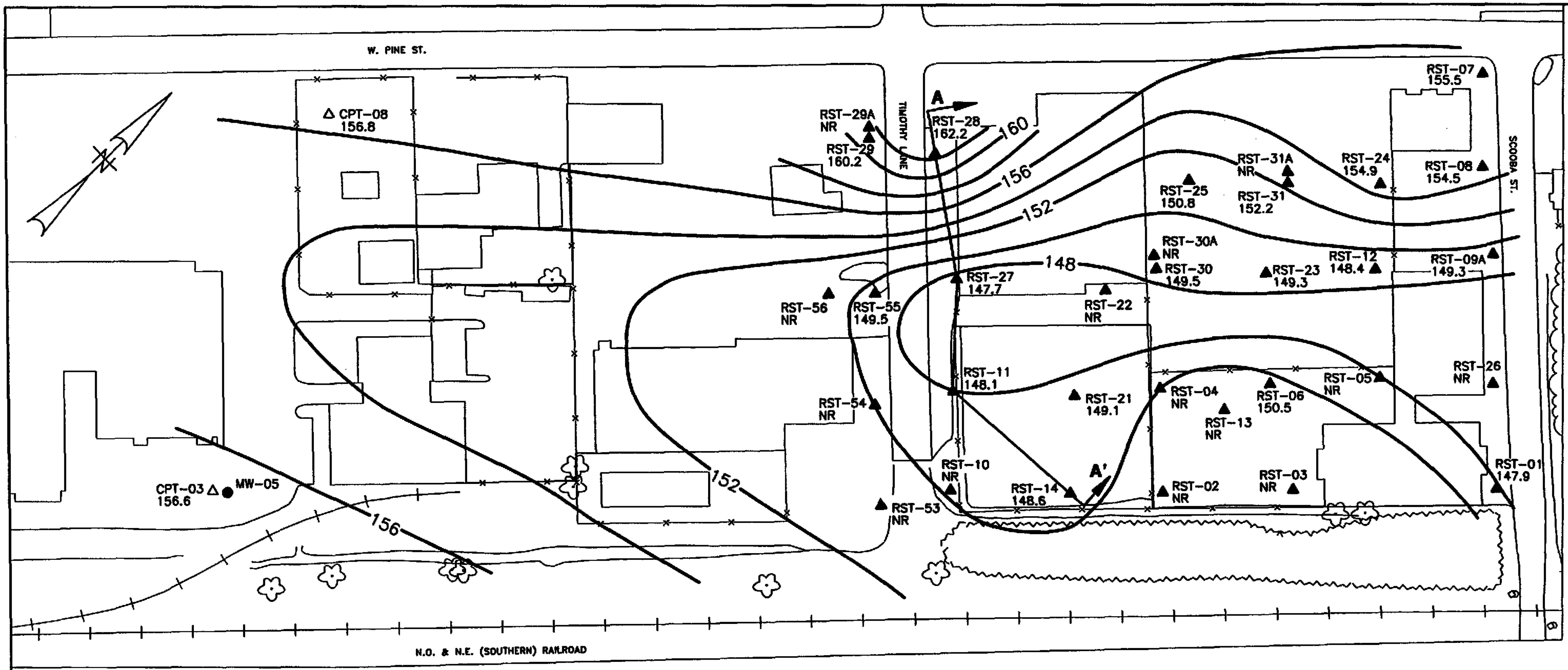
New Orleans, Louisiana Houston, Texas

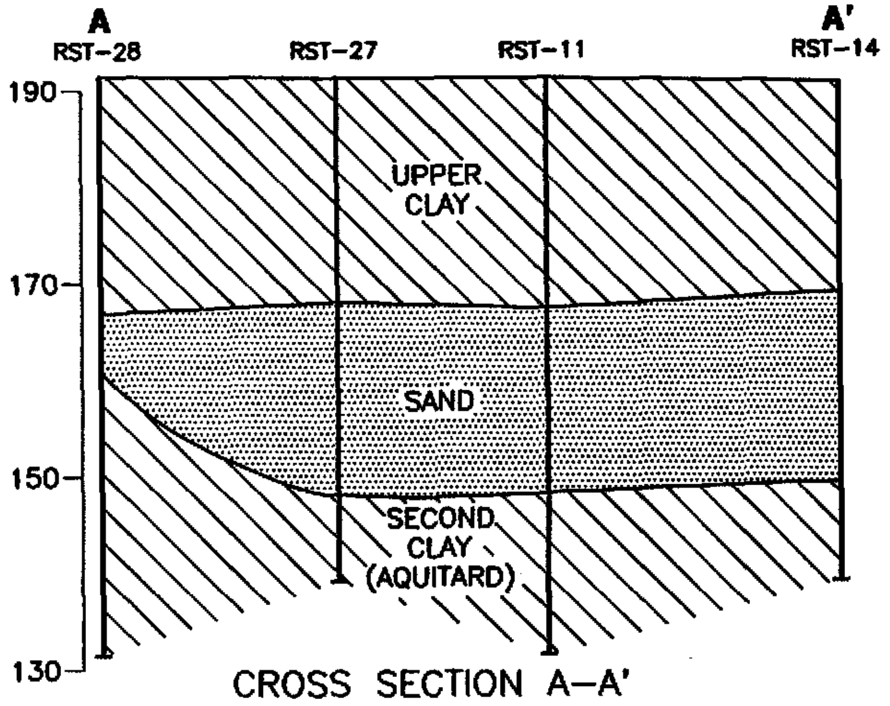
TITLE: FIGURE 3-6
FILL AREA CROSS-SECTIONS

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: 1"=200'/1"=20' DWG. NO.: 21-02/28B





CROSS SECTION A-A'

LEGEND

- ● MONITORING WELL
- △ CPT PUSH
- ▲ ROST PUSH
- NR – TOP OF AQUITARD NOT REACHED
- —152— ELEVATION OF TOP OF CLAY: MSL

BASE MAP FROM ATLANTIC TECHNOLOGIES, LTD.,
HUNTSVILLE, ALABAMA, APRIL 1, 1996

0 50 100 150 200
SCALE FEET

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

TITLE: FIGURE 3-7
CONTOUR MAP ON TOP OF AQUITARD

PROJECT: FORMER GULF STATES CREOSOTING SITE

LOCATION: HATTIESBURG, MISSISSIPPI

SCALE: DWG. NO.: 21-02/09B

Southern Railroad right-of-way), the only sand present within the uppermost 60 feet bls is the channel sand which extends northward to the Process Area.

A stiff clay layer is encountered beneath the second sandy zone in the Fill Area. This clay is encountered at approximately the same elevation (155 to 165 feet msl) and exhibits the same characteristics as the underlying clay in the Process Area, and is believed to represent the top of the massive Hattiesburg clay. This clay unit is continuous beneath the entire area formerly occupied by the Gulf States Creosoting plant.

3.4 Soils

As described in Section 2.1.2, seven subsurface soil samples were collected and submitted for laboratory geotechnical testing during the RI. Samples were collected from the three major and distinct soil horizons from borings advanced at the north end (SB-01), south end (SB-04) and central portion (SB-03) of the site. Results were evaluated to compare the properties of each zone tested and to determine if soil properties varied spatially within the same zone. The results of geotechnical testing are summarized in Table 3-1.

Test results indicate that the properties of soil samples collected from the same zones at different locations were very comparable. Samples collected from the upper and lower clays were similar except that reported densities were slightly higher in the upper clay, and the organic content percentage in lower clay samples was roughly twice that reported for upper clay samples. Vertical permeabilties of samples collected from both clay zones ranged from 2.5 x 10^{-8} to 3.7 x 10^{-7} centimeters per second (cm/sec), indicating that both zones are relatively impermeable. The sand sample collected from SB-03, located at the edge of the sand channel was not nearly as well sorted as the sand sample from SB-01.

3.5 Hydrogeology

3.5.1 Regional Hydrogeology

Southern Mississippi is underlain by several thick Miocene-age aquifers, namely the Catahoula, Hattiesburg, and Pascagoula aquifers. These aquifers consist of thick beds of sand or gravel separated by clay layers. Due to difficulties separating the Hattiesburg from the underlying Catahoula or the overlying Pascagoula, these units are frequently referred to as "Miocene aquifers" and not designated by individual formation. The Miocene aquifers are capable of yielding large volumes of water to wells (Shows 1970).

In the southern portion of Forrest County near Camp Shelby, water supply wells are primarily screened within two sands of the Hattiesburg formation. These sands pinch out updip and in the direction of Hattiesburg; at Hattiesburg, the Hattiesburg formation is comprised of a massive clay layer containing some thin, discontinuous sandy zones. The underlying Catahoula sandstone, comprised of interbedded clay, sand, sandstone, and gravel, is the principal source of ground water within the Hattiesburg area.

Other aquifers in Forrest County include sand and gravel deposits of the Citronelle formation, high and low terrace deposits, and alluvium. The lower portions of the Citronelle and high terrace deposits are typically saturated and capable of yielding water to shallow wells and springs. However, due to their limited areal extent and seasonally low water tables, these formations are not capable of yielding large perennial supplies. The Leaf River alluvium is hydrologically connected with area streams, and is reported to contain a large, undeveloped source of ground water (Brown 1944).

Table 3-1
Summary of Geotechnical Testing Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Identification	Zone	USCS Classification	Initial Moisture Content, %	Density, lb/ft^3		Coefficient of Permeability at 20°C, cm/sec	Initial Void Ratio	Initial Saturation, %
				Dry	Wet			
SB-04/14-16	Upper Clay	Silty Clay (CL)	20.5	106.3	128.1	3.7×10^{-7}	0.553	97.9
SB-03/14-16	Upper Clay	Silty Clay (CL)	20.6	107.2	129.2	2.5×10^{-8}	0.556	98.9
SB-01/24-26	Channel Sand	Fine to Medium Sand (SP)	15.5	98.5	113.8	----	0.669	60.9
SB-03/30-32	Channel Sand	Fine to Coarse Sand with Silt and Gravel (SP-SM)	11.8	115.4	129.1	----	0.425	73.4
SB-01/34-36	Lower Clay	Silty Clay (CL)	27.5	95.6	121.9	4.2×10^{-8}	0.762	97.3
SB-03/34-36	Lower Clay	Silty Clay (CL)	27.3	94.9	120.7	7.7×10^{-8}	0.792	93.7
SB-04/39-41	Lower Clay	Silty Clay (CL)	25.3	99.2	124.3	3.9×10^{-8}	0.679	99.3

Table 3-1
Summary of Geotechnical Testing Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Identification	Zone	USCS Classification	Specific Gravity	Atterberg Limits			Percent Passing #200 Sieve	Organic Content, %	Initial Porosity, %
				LL	PL	PI			
SB-04/14-16	Upper Clay	Silty Clay (CL)	2.646	43	19	24	97.9	3.64	35.6
SB-03/14-16	Upper Clay	Silty Clay (CL)	2.673	38	18	20	91.5	2.46	35.7
SB-01/24-26	Channel Sand	Fine to Medium Sand (SP)	2.635	----	----	----	0.0	0.04	40.1
SB-03/30-32	Channel Sand	Fine to Coarse Sand with Silt and Gravel (SP-SM)	2.635	----	----	----	8.4	0.58	29.8
SB-01/34-36	Lower Clay	Silty Clay (CL)	2.700	48	18	26	99.8	5.47	43.3
SB-03/34-36	Lower Clay	Silty Clay (CL)	2.725	49	21	28	99.9	5.20	44.2
SB-04/39-41	Lower Clay	Silty Clay (CL)	2.670	47	20	27	99.4	5.85	40.4

3.5.2 Site Hydrogeology

Two distinct shallow aquifer systems are present within the upper 75 feet beneath the site. The first consists of the Process Area channel sand, whose physical characteristics were discussed in detail in Section 3.3.2. The second is comprised of the sandy zones beneath the Gordon's Creek Fill Area. As the sandy zones beneath the two areas are separated from one another by zones comprised of clay, ground water occurrence and conditions are addressed separately in the following sections.

Process Area Ground Water

During the RI, as well as during previous investigations, the Process Area sand channel has been observed to be saturated from its top to base. Due to insufficient ground water monitoring data, it is not known how water levels in the sand channel are affected by seasonal fluctuations in precipitation. The source of ground water recharge to the sand channel is not known, but recharge is suspected to be via infiltration of precipitation through the upper clay in unpaved or uncovered areas located southwest of the site.

The July 1994 Phase II Site Investigation Report by EPS stated that top-of-casing elevations at four Process Area monitoring wells (MW-1 through MW-4) were established by a level survey conducted by EPS personnel on May 27, 1994. Elevations were established relative to an assumed site benchmark datum of 100 feet. The depth to ground water in the wells ranged from 16.70 feet to 19.72 feet below top of casing. Based on the ground water elevation data calculated by EPS, the general ground water flow was depicted as being to the southwest (toward Gordon's Creek) at a gradient of 0.01 feet per foot.

Subsequent to the installation of four new monitoring wells during the RI, top-of-casing elevations were established at the four new wells and re-established at the four existing wells. Surveying was performed by Shows, Dearman, and Waits (SD&W), licensed professional land surveyors in the State of Mississippi. Elevations were established relative to the North American Vertical Datum of 1988 (NAVD 88) with respect to mean sea level.

A comparison of elevation data from the two surveys is presented in Table 3-2. The survey data indicate significant discrepancies in the relative elevations from the two surveys. Because of these discrepancies, SD&W personnel were directed to re-survey top-of-casing elevations at the four Process Area wells. The results of the second SD&W survey were consistent (i.e., within 0.03 feet) with those from the original SD&W survey.

Figure 3-8 is a potentiometric surface map constructed using water level data obtained on March 11, 1997. The map shows that ground water within the channel flows to the east, or in the opposite direction asserted in the July 1994 EPS report. Ground water elevations in the channel ranged from 177.93 feet msl at the southern end of the site in MW-04 to 171.86 feet msl in the Process Area in MW-1 (see Table 3-3). The ground water gradient in the channel, except within the Process Area where it is slightly flatter, is approximately 0.01 feet per foot.

The depiction of ground water flow within the sand channel as being to the east instead of west is consistent with the geometry of the sand channel for the following reasons:

1. As shown on Figure 3-7, the base of the sand channel dips to the east-northeast. Flow within a sand body typically follows the dip of the top of the underlying aquitard; and
2. The sand channel pinches out to the west, making the flow of ground water within the channel to the west physically impossible.

Table 3-2
Comparison of Surveyed Top of Casing Elevations
Process Area Wells

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Well	1994 EPS Top of Casing Elevation (ft) (a)	1997 SD&W Top of Casing Elevation (ft.) (b)	Elevation Difference	Relative Elevation Difference (c)
MW-1	99.20	188.98	89.78	0.00
MW-2	97.64	189.71	92.07	-2.29
MW-3	99.33	188.19	88.86	0.92
MW-4	98.62	191.42	92.80	-3.02

(a) Referenced to an arbitrary on-site benchmark assumed to be 100.00 feet
(b) Referenced to the North American Vertical Datum of 1988 (NAVD 88) and reported with respect to mean sea level.
(c) Assumes identical elevations for top of casing at MW-1

Table 3-3
Summary of Ground Water Elevation Data

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

20'

Well	Top of Casing Elevation (ft.)	3/11/97 Water Level (a)	3/11/97 Ground Water Elevation (ft.)
MW-1	188.98	17.12	171.86
MW-2	189.71	17.55	172.16
MW-3	188.19	16.11	172.08
MW-4	191.42	19.10	172.32
MW-01	186.14	12.43	173.71
MW-03	189.24	13.54	175.70
MW-04	191.28	13.35	177.93
MW-05	191.59	19.47	172.12

17.12
3

14

16'

Notes:
Elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88) and are reported with respect to mean sea level.
(a) Feet below top of well casing

This new finding regarding the direction of site ground water flow significantly changes the conceptual site model, resulting in the need for additional data collection. Additional data needs are addressed in Section 5.2 of this report.

Slug test data from the four new wells were analyzed using the Cooper, Bredehoeft, Papadopulous method for fully penetrating wells in confined aquifers. The results of slug test analyses are summarized in Table 3-4; slug test data are provided in Appendix I. Data from slug tests performed at Process Area wells MW-3 and MW-4 were not analyzed due to uncertainty regarding borehole geology and well construction; slug test data from these wells, however, are provided in Appendix I.

Hydraulic conductivities estimated via slug test analyses ranged from 3.8 x 10^{-4} cm/sec to 2.1 x 10^{-3} cm/sec (1.1 ft/day to 5.9 ft/day). These values are consistent with published values for sandy aquifers. Using this range of hydraulic conductivity values, an assumed effective porosity of 30%, and a gradient of 0.01 feet per foot, calculated linear ground water flow velocities in the sand channel range from 0.04 to 0.2 feet per day.

Fill Area Ground Water

Two separate shallow water-bearing zones were identified beneath the Fill Area during the RI. As stated in Section 3.3.2, both sandy zones pinch out to the east of the Fill Area. The upper two to four feet of the upper sandy zone were dry to slightly moist, while the lower portion of the upper sand above the intervening clay layer was saturated. In boring GEO/SB-05, which was advanced adjacent to RST-41, the upper portion of the second sand was sampled and logged and was observed to be saturated.

Prior to the RI, the shallow geology beneath the Fill Area had not been characterized adequately to plan for the installation of ground water monitoring wells. Because no wells are present in the Fill Area, neither ground water elevation data nor aquifer testing data are currently available for this area. Additional data collection is addressed in Section 5.2 of this report

3.5.3 Ground Water Use

Section 2.B.IV of the document *Guidance for the Remediation of Uncontrolled Hazardous Substance Sites in Mississippi* (MDEQ 1990) states that ground water use within one mile of impacted areas must be determined. As part of the RI, searches of the two known Mississippi water well databases were performed to evaluate ground water usage in the vicinity of the site.

The U.S. Geological Survey (U.S.G.S.) and the MDEQ Division of Land and Water maintain computerized databases of ground water wells in the State of Mississippi. Both databases provide information on wells such as owner, date drilled, use, depth, and screened interval. Searches of the U.S.G.S. and MDEQ listings were conducted in May and June 1997, respectively, to obtain information on the presence, locations, depths, and usage of water wells in the vicinity of the site. Copies of the printouts from the two searches are provided as Appendix J.

The search of the U.S.G.S. database reported the presence of six wells within a one-mile radius of the Process Area and Fill Area. These wells are listed in Table 3-5; their locations are shown on Figure 3-9. Four of these wells are categorized for domestic use, one for stock, and one for industrial use. Only one well, a domestic well screened from 115 to 120 feet below grade and located approximately 3,000 feet southwest of the Fill Area, is screened at a depth of less than 300 feet (i.e., above the massive Hattiesburg clay). The

Table 3-4
Summary of Slug Test Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Well	Aquifer Thickness (feet)	Hydraulic Conductivity (cm/sec)		Transmissivity (ft^2/day)	
		Low	High	Low	High
MW-01	9.8	6.4×10^{-4}	1.8×10^{-3}	17.7	49.7
MW-03	3.8	3.8×10^{-4}	7.8×10^{-4}	4.1	8.4
MW-04	1.8	7.5×10^{-4}	8.6×10^{-4}	3.8	4.4
MW-05	15.5	1.1×10^{-3}	2.1×10^{-3}	47.9	9.4

Note: Data from slug tests performed at Process Area wells MW-3 and MW-4 were not analyzed due to uncertainty regarding borehole geology and well construction.

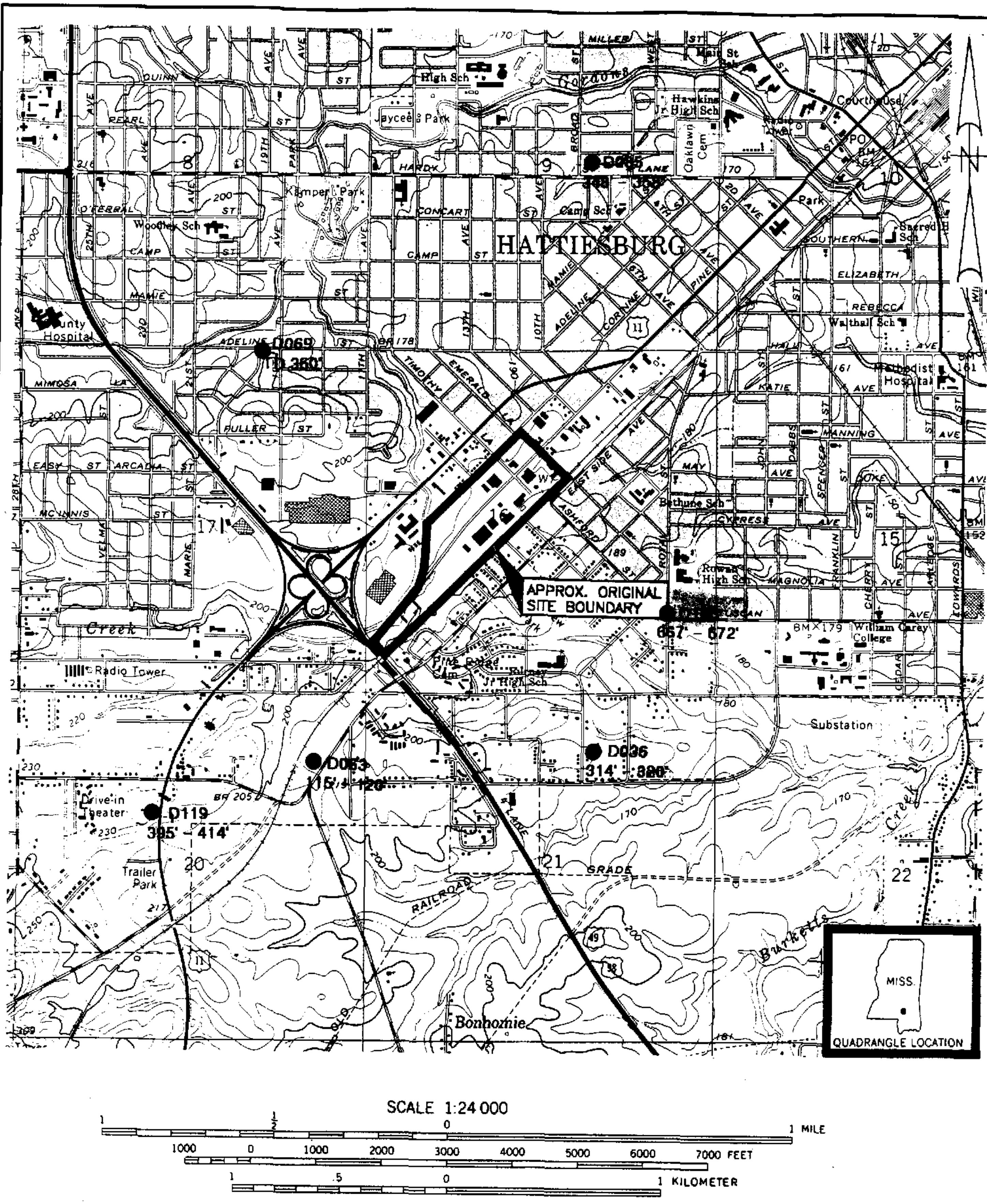
Table 3-5
Wells Within A One Mile Radius of Site

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Local Well Number	Owner	Database	Land Net Location	Latitude (degrees)	Longitude (degrees)	Use	Depth, feet	Top of Open Interval, feet	Bottom of Open Interval, feet	Discharge, GPM	Aquifer	Altitude of Land Surface, feet
D036	Rev Berry Bell	USGS	NENWS21T04NR13W	31° 18' 02"	89° 18' 13"	Domestic	320	314	NA	NA	Catahoula	183
D063	Geo Varnado	USGS	----S23T04NR13W	31° 18' 00"	89° 19' 00"	Domestic	120	115	NA	NA	Hattiesburg	NA
D069	J D Lewis	USGS	SESES08T04NR13W	31° 19' 01"	89° 19' 10"	Stock	360	NA	NA	NA	Catahoula	NA
D085	M Brewer	USGS	----S10T04NR13W	31° 19' 30"	89° 18' 12"	Domestic	358	348	NA	14	Catahoula	NA
D106	Civil Defense	USGS	NENWS15T04NR13W	31° 18' 23"	89° 17' 58"	Domestic	672	667	672	10	Catahoula	155
D119	Nordan Smith	USGS	S20T04NR13W	31° 17' 51"	89° 19' 28"	Industrial	415	395	415	85	Catahoula	230
D2000	W. E. Ward	MDEQ	S20T04NR---	NA	NA	Home	32	NA	NA	NA	NA	NA
D2015 (a)	Danny Bryant	MDEQ	S20T04NR13W	NA	NA	Home	60	NA	NA	NA	NA	NA
D2020 (a)	Essco Heating & Air	MDEQ	S19T04NR13W	NA	NA	Commercial	200	NA	NA	NA	NA	NA
D2023 (a)	Breazeale	MDEQ	S08T04NR13W	NA	NA	Irrigation	340	NA	NA	NA	NA	NA

(a) Precise location unknown; well may or may not be within one mile of site.

NA - Not available



CONTOUR INTERVAL 10 FEET

SOURCE: USGS MAP OF HATTIESBURG, MISSISSIPPI, 7.5' QUADRANGLE, 1964 PHOTOREVISED 1982

MICHAEL PISANI & ASSOCIATES Environmental Management and Engineering Services New Orleans, Louisiana Houston, Texas		FIGURE 3-9 MAP OF WATER WELLS WITHIN ONE MILE OF SITE FORMER GULF STATES CREOSOTING SITE HATTIESBURG, MISSISSIPPI
SCALE:	DWG. NO.: 21-02/25A	

current status and use of this well are unknown; the well is, however, located hydraulically upgradient of the site.

Unlike the U.S.G.S. database, which provides well locations by latitude and longitude, the MDEQ database provides only the Section, Township, and Range in which a well is located. It is therefore impossible to know which, if any, wells listed in the MDEQ database are located within a one-mile radius of the site. The search of the MDEQ listing identified four wells which, based on their Section, Township, and Range, could possibly be within one mile of the site; these wells are listed in Table 3-5. Two of the wells are reported to be screened above the top of the Hattiesburg clay, with total well depths of 32 and 60 feet; the use of these wells is designated as "Home". The locations and current status/use of these wells are unknown.

4.0 Nature and Extent of Affected Media

4.1 Process Area

Data from site characterization activities conducted to determine the nature and extent of affected media within the Process Area include ROST data, subsurface soil data, and ground water data.

4.1.1 Subsurface Soils

ROST and subsurface soil analytical data indicate that creosote-impacted soils within the Process Area are confined to areas beneath and/or immediately adjacent to former wood treating operational features. These features, as identified from historical Sanborn maps and aerial photographs, include a settling basin, storage tanks, treating and creosote blending areas, and an oily sump. Former wood treating operational features were limited to an area currently bounded by Timothy Street on the southwest, the Southern Railroad ditch on the southeast, Scooba Street on the northeast, and a line roughly parallel to and approximately 200 feet east of West Pine Street on the northwest.

Figure 4-1 presents four ROST cross-sections through the Process Area. Cross-section F-F' is situated approximately 100 feet west of the area which once contained wood treating operational features. Logs of ROST pushes along section F-F' show essentially no fluorescence from the land surface to total depth. This lack of response is indicative of "clean" soils, i.e., soils not containing aromatic hydrocarbons. Cross-section G-G' runs immediately along the western boundary of the former operations area. Logs from some of the pushes along this section (RST-56, -27, -30A, and -12) indicate clean soils, while others (RST-55, -23, and -09A) are indicative of marginally affected soils. Note that push RST-22 met refusal at a depth of approximately 12 feet, indicating the presence of a subsurface obstruction in the vicinity of the former treating room.

Cross-section H-H' runs through the center of the former operations area. The entire log for RST-54 and the log for RST-11 above the saturated zone are indicative of clean soils, while logs for the remainder of the pushes in the section indicate the presence of creosote-impacted soils. This section shows that the southern boundary of affected soils is located between pushes RST-11 and RST-21, and that soils are becoming less affected near the northern edge of the former operations area near Scooba Street. Cross-section I-I' runs along the eastern boundary of the former operations area. RST-53 establishes the presence of clean soils to the south, while logs of other pushes indicate the presence of soils ranging from marginally affected (RST-14 and -30) to affected (RST-01 and -10).

Ten subsurface soil samples were collected at locations adjacent to seven ROST pushes in the Process Area. Sample locations and depths were selected to determine constituent concentrations in soils falling into one of three ROST categories: 1) unaffected; 2) marginally affected; and 3) affected. Subsurface soil samples were analyzed for TCL volatile and semivolatile constituents.

Subsurface soil analytical data are summarized in Table 4-1. Laboratory reports are provided as Appendix K. No target constituents were reported above laboratory limits of quantitation in samples collected from CPT/SB-01, -03, or -06, collected adjacent to RST-12, -53, and -29/29A, respectively. Target constituents reported in the remaining samples consisted primarily of PAHs, with naphthalene and phenanthrene detected at the highest concentrations. Several phenolic compounds were reported, as were extremely low concentrations of benzene, toluene, ethylbenzene, xylenes (BTEX), and styrene. BTEX and styrene are not typical components of creosote.

Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	CPT/SB-01/8-10 2679073 3/15/97		CPT/SB-01/44-46 2679074 3/15/97			CPT/SB-02/9-11 2679075 3/15/97			CPT/SB-03/20-22 2679076 3/15/97		CPT/SB-04/20-22 2679077 3/15/97		
Parameter	CAS Number	Standard MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Volatiles															
1,1-Dichloroethene	75-35-4	0.002	ND			ND			ND		ND		0.01	ND	
Trichloroethene	79-01-6	0.001	ND			ND			ND		ND		0.005	ND	
Benzene	71-43-2	0.001	ND			ND			ND		ND		0.005	0.021	J
Toluene	108-88-3	0.001	ND			ND			0.013		ND		0.005	0.34	
Chlorobenzene	108-90-7	0.001	ND			ND			ND		ND		0.005	ND	
Xylene (total)	1330-20-7	0.001	ND			ND			0.28		ND		0.005	1.3	
Chloromethane	74-87-3	0.002	ND			ND			ND		ND		0.01	ND	
Bromomethane	74-83-9	0.003	ND			ND			ND		ND		0.015	ND	
Vinyl Chloride	75-01-4	0.002	ND			ND			ND		ND		0.01	ND	
Chloroethane	75-00-3	0.003	ND			ND			ND		ND		0.015	ND	
Methylene Chloride	75-09-2	0.002	ND			ND			ND		ND		0.01	ND	
1,1-Dichloroethane	75-34-3	0.001	ND			ND			ND		ND		0.005	ND	
Chloroform	67-66-3	0.001	ND			ND			ND		ND		0.005	ND	
1,2-Dichloroethane	107-06-2	0.002	ND			ND			ND		ND		0.01	ND	
1,1,1-Trichloroethane	71-55-6	0.001	ND			ND			ND		ND		0.005	ND	
Carbon Tetrachloride	56-23-5	0.001	ND			ND			ND		ND		0.005	ND	
Bromodichloromethane	75-27-4	0.002	ND			ND			ND		ND		0.01	ND	
1,1,2,2-Tetrachloroethane	79-34-5	0.001	ND			ND			ND		ND		0.005	ND	
1,2-Dichloropropane	78-87-5	0.003	ND			ND			ND		ND		0.015	ND	
trans-1,3-Dichloropropene	10061-02-6	0.001	ND			ND			ND		ND		0.005	ND	
Dibromochloromethane	124-48-1	0.001	ND			ND			ND		ND		0.005	ND	
1,1,2-Trichloroethane	79-00-5	0.002	ND			ND			ND		ND		0.01	ND	
cis-1,3-Dichloropropene	10061-01-5	0.001	ND			ND			ND		ND		0.005	ND	
Bromoform	75-25-2	0.001	ND			ND			ND		ND		0.005	ND	
Tetrachloroethene	127-18-4	0.001	ND			ND			ND		ND		0.005	ND	
Ethylbenzene	100-41-4	0.001	ND			ND			0.046		ND		0.005	0.25	
Acetone	67-64-1	0.007	0.059	J	0.035	0.730	J		0.009	J	ND	J	0.035	0.099	J
Carbon Disulfide	75-15-0	0.003	ND			ND			ND		ND		0.015	ND	
2-Butanone	78-93-3	0.007	ND			ND			ND		ND		0.035	ND	
Vinyl Acetate	108-05-4	0.003	ND			ND			ND		ND		0.015	ND	
2-Hexanone	591-78-6	0.003	ND			ND			ND		ND		0.015	ND	
4-Methyl-2-pentanone	108-10-1	0.003	ND			ND			ND		ND		0.015	ND	
Styrene	100-42-5	0.001	ND			ND			ND		ND		0.005	0.24	
trans-1,2-Dichloroethene	156-60-5	0.002	ND			ND			ND		ND		0.01	ND	
cis-1,2-Dichloroethene	156-59-2	0.002	ND			ND			ND		ND		0.01	ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample
GEO/SB-05/409.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

	MP&A Sample ID Lab Sample Number Date Collected		CPT/SB-01/8-10 2679073 3/15/97		CPT/SB-01/44-46 2679074 3/15/97			CPT/SB-02/9-11 2679075 3/15/97			CPT/SB-03/20-22 2679076 3/15/97		CPT/SB-04/20-22 2679077 3/15/97		
Parameter	CAS Number	Standard MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Semivolatiles															
phenol	108-95-2	0.033	ND			ND		0.17	ND		ND		1.7	53	4,8+4
2-chlorophenol	95-57-8	0.033	ND			ND		0.17	ND		ND		0.17	ND	
1,4-dichlorobenzene	106-46-7	0.033	ND			ND		0.17	ND		ND		0.17	ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	ND			ND		0.33	ND		ND		0.33	ND	
1,2,4-trichlorobenzene	120-82-1	0.033	ND			ND		0.17	ND		ND		0.17	ND	
4-chloro-3-methylphenol	59-50-7	0.067	ND			ND		0.33	ND		ND		0.33	ND	
acenaphthene	83-32-9	0.033	ND			ND		0.17	26		ND		1.7	73	—4.4+3
4-nitrophenol	100-02-7	0.17	ND			ND		0.83	ND		ND		0.83	ND	
2,4-dinitrotoluene	121-14-2	0.067	ND			ND		0.33	ND		ND		0.33	ND	
pentachlorophenol	87-86-5	0.17	ND			ND		0.83	ND		ND		0.83	ND	
pyrene	129-00-0	0.067	ND			ND		0.33	24		ND		3.3	62	2 4+3
2-nitrophenol	88-75-5	0.067	ND			ND		0.33	ND		ND		0.33	ND	
2,4-dimethylphenol	105-67-9	0.067	ND			ND		0.33	ND		ND		0.33	20	1.6+3
2,4-dichlorophenol	120-83-2	0.033	ND			ND		0.17	ND		ND		0.17	ND	
2,4,6-trichlorophenol	88-06-2	0.067	ND			ND		0.33	ND		ND		0.33	ND	
2,4-dinitrophenol	51-28-5	0.17	ND			ND		0.83	ND		ND		0.83	ND	
bis (2-chloroethyl) ether	111-44-4	0.067	ND			ND		0.33	ND		ND		0.33	ND	
1,3-dichlorobenzene	541-73-1	0.033	ND			ND		0.17	ND		ND		0.17	ND	
1,2-dichlorobenzene	95-50-1	0.033	ND			ND		0.17	ND		ND		0.17	ND	
hexachloroethane	67-72-1	0.067	ND			ND		0.33	ND		ND		0.33	ND	
nitrobenzene	98-95-3	0.033	ND			ND		0.17	ND		ND		0.17	ND	
isophorone	78-59-1	0.067	ND			ND		0.33	ND		ND		0.33	ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	ND			ND		0.17	ND		ND		0.17	ND	
naphthalene	91-20-3	0.033	ND			ND		1.7	180		ND		3.3	340	-
hexachlorobutadiene	87-68-3	0.067	ND			ND		0.33	ND		ND		0.33	ND	
hexachlorocyclopentadiene	77-47-4	0.17	ND			ND		0.83	ND		ND		0.83	ND	
2-chloronaphthalene	91-58-7	0.033	ND			ND		0.17	ND		ND		0.17	ND	
acenaphthylene	208-96-8	0.033	ND			ND		0.17	0.84	J	ND		0.17	3.7	-
dimethyl phthalate	131-11-3	0.033	ND			ND		0.17	ND		ND		0.17	ND	
fluorene	86-73-7	0.033	ND			ND		1.7	47		ND		1.7	90	3.2+3
4-chlorophenyl phenyl ether	7005-72-3	0.067	ND			ND		0.33	ND		ND		0.33	ND	
diethyl phthalate	84-66-2	0.067	ND			ND		0.33	ND		ND		0.33	ND	
N-nitrosodiphenylamine	86-30-6	0.067	ND			ND		0.33	ND		ND		0.33	ND	
4-bromophenyl phenyl ether	101-55-3	0.1	ND			ND		0.5	ND		ND		0.5	ND	
hexachlorobenzene	118-74-1	0.1	ND			ND		0.5	ND		ND		0.5	ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample
GEO/SB-05/409.
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID Lab Sample Number Date Collected			CPT/SB-01/8-10 2679073 3/15/97		CPT/SB-01/44-46 2679074 3/15/97			CPT/SB-02/9-11 2679075 3/15/97			CPT/SB-03/20-22 2679076 3/15/97		CPT/SB-04/20-22 2679077 3/15/97		
Parameter	CAS Number	Standard MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes
phenanthrene	85-01-8	0.033	ND			ND		1.7	110		ND		1.7	190	
anthracene	120-12-7	0.033	ND			ND		0.17	18		ND		0.17	26	7.4+4
di-n-butyl phthalate	84-74-2	0.033	ND			ND		0.17	ND		ND		0.17	ND	
fluoranthene	206-44-0	0.033	ND			ND		1.7	56		ND		1.7	98	7.2+3
butyl benzyl phthalate	85-68-7	0.067	ND			ND		0.33	ND		ND		0.33	ND	
benzo (a) anthracene	56-55-3	0.033	ND			ND		0.17	9.5		ND		0.17	15	.56
chrysene	218-01-9	0.033	ND			ND		0.17	8.5		ND		0.17	14	.96
3,3'-dichlorobenzidine	91-94-1	0.13	ND			ND		0.67	ND		ND		0.67	ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.067	ND			ND		0.33	ND		ND		0.33	ND	
di-n-octyl phthalate	117-84-0	0.067	ND			ND		0.33	ND		ND		0.33	ND	
benzo (b) fluoranthene	205-99-2	0.067	ND			ND		0.33	5.1		ND		0.33	8.9	.96
benzo (k) fluoranthene	207-08-9	0.13	ND			ND		0.67	1.9		ND		0.67	3.6	.96
benzo (a) pyrene	50-32-8	0.067	ND			ND		0.33	3.5		ND		0.33	6.6	.096
indeno (1,2,3-cd) pyrene	193-39-5	0.067	ND			ND		0.33	1.2	J	ND		0.33	2.7	.96
dibenz (a,h) anthracene	53-70-3	0.067	ND			ND		0.33	ND		ND		0.33	0.79	J .096
benzo (ghi) perylene	191-24-2	0.067	ND			ND		0.33	0.99	J	ND		0.33	2.1	
2-methylphenol	95-48-7	0.067	ND			ND		0.33	ND		ND		0.33	20	4.+3
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	ND			ND		0.5	ND		ND		0.5	ND	
4-methylphenol	106-44-5	0.1	ND			ND		0.5	ND		ND		5	76	
4-chloroaniline	106-47-8	0.1	ND			ND		0.5	ND		ND		0.5	ND	
2-methylnaphthalene	91-57-6	0.033	ND			ND		1.7	79		ND		3.3	110	
2,4,5-trichlorophenol	95-95-4	0.067	ND			ND		0.33	ND		ND		0.33	ND	
2-nitroaniline	88-74-4	0.067	ND			ND		0.33	ND		ND		0.33	ND	
3-nitroaniline	99-09-2	0.067	ND			ND		0.33	ND		ND		0.33	ND	
dibenzofuran	132-64-9	0.033	ND			ND		0.17	26		ND		1.7	68	
2,6-dinitrotoluene	606-20-2	0.067	ND			ND		0.33	ND		ND		0.33	ND	
4-nitroaniline	100-01-6	0.1	ND			ND		0.5	ND		ND		0.5	ND	
4,6-dinitro-2-methylphenol	534-52-1	0.17	ND			ND		0.83	ND		ND		0.83	ND	
carbazole	86-74-8	0.033	ND			ND		0.17	11		ND		0.17	15	

Notes

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SW-846 8270B for semivolatiles.
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	CPT/SB-04/29-31 2679078 3/15/97			CPT/SB-05/10.5-12.5 2679079 3/15/97			CPT/SB-06/6-10 2679080 3/17/97		CPT/SB-06/36-38 2679084 3/17/97			CPT/SB-07/14-16 2679083 3/17/97		
Parameter	CAS Number	Standard MDL	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Volatiles																
1,1-Dichloroethene	75-35-4	0.002	0.01	ND		0.01	ND		ND			ND			ND	
Trichloroethene	79-01-6	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Benzene	71-43-2	0.001	0.005	0.006	J	0.005	0.007	J	ND			ND			0.005	J
Toluene	108-88-3	0.001	0.005	0.063		0.005	0.14		ND			ND			0.015	
Chlorobenzene	108-90-7	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Xylene (total)	1330-20-7	0.001	0.005	0.35		0.005	0.78		ND			ND			0.075	
Chloromethane	74-87-3	0.002	0.01	ND		0.01	ND		ND			ND			ND	
Bromomethane	74-83-9	0.003	0.015	ND		0.015	ND		ND			ND			ND	
Vinyl Chloride	75-01-4	0.002	0.01	ND		0.01	ND		ND			ND			ND	
Chloroethane	75-00-3	0.003	0.015	ND		0.015	ND		ND			ND			ND	
Methylene Chloride	75-09-2	0.002	0.01	ND		0.01	ND		ND			ND			ND	
1,1-Dichloroethane	75-34-3	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Chloroform	67-66-3	0.001	0.005	ND		0.005	ND		ND			ND			ND	
1,2-Dichloroethane	107-06-2	0.002	0.01	ND		0.01	ND		ND			ND			ND	
1,1,1-Trichloroethane	71-55-6	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Carbon Tetrachloride	56-23-5	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Bromodichloromethane	75-27-4	0.002	0.01	ND		0.01	ND		ND			ND			ND	
1,1,2,2-Tetrachloroethane	79-34-5	0.001	0.005	ND		0.005	ND		ND			ND			ND	
1,2-Dichloropropane	78-87-5	0.003	0.015	ND		0.015	ND		ND			ND			ND	
trans-1,3-Dichloropropene	10061-02-6	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Dibromochloromethane	124-48-1	0.001	0.005	ND		0.005	ND		ND			ND			ND	
1,1,2-Trichloroethane	79-00-5	0.002	0.01	ND		0.01	ND		ND			ND			ND	
cis-1,3-Dichloropropene	10061-01-5	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Bromoform	75-25-2	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Tetrachloroethene	127-18-4	0.001	0.005	ND		0.005	ND		ND			ND			ND	
Ethylbenzene	100-41-4	0.001	0.005	0.06		0.005	0.12		ND			ND			0.024	
Acetone	67-64-1	0.007	0.035	0.068	J	0.035	0.1	J	0.01	J	0.035	1.5	J		0.042	J
Carbon Disulfide	75-15-0	0.003	0.015	ND		0.015	ND		ND			ND			ND	
2-Butanone	78-93-3	0.007	0.035	ND		0.035	ND		ND			ND			ND	
Vinyl Acetate	108-05-4	0.003	0.015	ND		0.015	ND		ND			ND			ND	
2-Hexanone	591-78-6	0.003	0.015	ND		0.015	ND		ND			ND			ND	
4-Methyl-2-pentanone	108-10-1	0.003	0.015	ND		0.015	ND		ND			ND			ND	
Styrene	*100-42-5*	*0.001*	*0.005*	*0.071*		*0.005*	*0.1*		*ND*			*ND*			*ND*	
trans-1,2-Dichloroethene	156-60-5	0.002	0.01	ND		0.01	ND		ND			ND			ND	
cis-1,2-Dichloroethene	156-59-2	0.002	0.01	ND		0.01	ND		ND			ND			ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID			CPT/SB-04/29-31			CPT/SB-05/10.5-12.5			CPT/SB-06/6-10		CPT/SB-06/36-38			CPT/SB-07/14-16		
Lab Sample Number			2679078			2679079			2679080		2679084			2679083		
Date Collected			3/15/97			3/15/97			3/17/97		3/17/97			3/17/97		
Parameter	CAS Number	Standard MDL	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Semivolatiles																
phenol	108-95-2	0.033	1.7	46		0.67	ND		ND			ND			ND	
2-chlorophenol	95-57-8	0.033	0.17	ND		0.67	ND		ND			ND			ND	
1,4-dichlorobenzene	106-46-7	0.033	0.17	ND		0.67	ND		ND			ND			ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	0.33	ND		1.3	ND		ND			ND			ND	
1,2,4-trichlorobenzene	120-82-1	0.033	0.17	ND		0.67	ND		ND			ND			ND	
4-chloro-3-methylphenol	59-50-7	0.067	0.33	ND		1.3	ND		ND			ND			ND	
acenaphthene	83-32-9	0.033	1.7	51		6.7	290		ND			0.042	J	0.17	9.6	
4-nitrophenol	100-02-7	0.17	0.83	ND		3.3	ND		ND			ND			ND	
2,4-dinitrotoluene	121-14-2	0.067	0.33	ND		1.3	ND		ND			ND			ND	
pentachlorophenol	87-86-5	0.17	0.83	ND		3.3	ND		ND			ND			ND	
pyrene	129-00-0	0.067	0.33	26		13	250		ND			ND			3.9	
2-nitrophenol	88-75-5	0.067	0.33	ND		1.3	ND		ND			ND			ND	
2,4-dimethylphenol	105-67-9	0.067	0.33	17		1.3	ND		ND			ND			ND	
2,4-dichlorophenol	120-83-2	0.033	0.17	ND		0.67	ND		ND			ND			ND	
2,4,6-trichlorophenol	88-06-2	0.067	0.33	ND		1.3	ND		ND			ND			ND	
2,4-dinitrophenol	51-28-5	0.17	0.83	ND		3.3	ND		ND			ND			ND	
bis (2-chloroethyl) ether	111-44-4	0.067	0.33	ND		1.3	ND		ND			ND			ND	
1,3-dichlorobenzene	541-73-1	0.033	0.17	ND		0.67	ND		ND			ND			ND	
1,2-dichlorobenzene	95-50-1	0.033	0.17	ND		0.67	ND		ND			ND			ND	
hexachloroethane	67-72-1	0.067	0.33	ND		1.3	ND		ND			ND			ND	
nitrobenzene	98-95-3	0.033	0.17	ND		0.67	ND		ND			ND			ND	
isophorone	78-59-1	0.067	0.33	ND		1.3	ND		ND			ND			ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	0.17	ND		0.67	ND		ND			ND			ND	
naphthalene	91-20-3	0.033	1.7	200		6.7	910		ND			0.05	J	0.33	36	
hexachlorobutadiene	87-68-3	0.067	0.33	ND		1.3	ND		ND			ND			ND	
hexachlorocyclopentadiene	77-47-4	0.17	0.83	ND		3.3	ND		ND			ND			ND	
2-chloronaphthalene	91-58-7	0.033	0.17	ND		0.67	ND		ND			ND			ND	
acenaphthylene	208-96-8	0.033	0.17	2.7		0.67	10		ND			ND			0.31	J
dimethyl phthalate	131-11-3	0.033	0.17	ND		0.67	ND		ND			ND			ND	
fluorene	86-73-7	0.033	1.7	64		6.7	330		ND			0.049	J	0.17	8.5	
4-chlorophenyl phenyl ether	7005-72-3	0.067	0.33	ND		1.3	ND		ND			ND			ND	
diethyl phthalate	84-66-2	0.067	0.33	ND		1.3	ND		ND			ND			ND	
N-nitrosodiphenylamine	86-30-6	0.067	0.33	ND		1.3	ND		ND			ND			ND	
4-bromophenyl phenyl ether	101-55-3	0.1	0.5	ND		2	ND		ND			ND			ND	
hexachlorobenzene	118-74-1	0.1	0.5	ND		2	ND		ND			ND			ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	CPT/SB-04/29-31 2679078 3/15/97			CPT/SB-05/10.5-12.5 2679079 3/15/97			CPT/SB-06/6-10 2679080 3/17/97		CPT/SB-06/36-38 2679084 3/17/97			CPT/SB-07/14-16 2679083 3/17/97		
Parameter	CAS Number	Standard MDL	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes
phenanthrene	85-01-8	0.033	1.7	130		6.7	710		ND			0.16	J	0.17	20	
anthracene	120-12-7	0.033	0.17	20		0.67	98		ND			ND			4.8	
di-n-butyl phthalate	84-74-2	0.033	0.17	ND		0.67	ND		ND			ND			ND	
fluoranthene	206-44-0	0.033	1.7	71		6.7	430		ND			0.094	J	0.17	8.2	
butyl benzyl phthalate	85-68-7	0.067	0.33	ND		1.3	ND		ND			ND			ND	
benzo (a) anthracene	56-55-3	0.033	0.17	12		0.67	69		ND			ND			1.3	
chrysene	218-01-9	0.033	0.17	10		0.67	62		ND			ND			1.3	
3,3'-dichlorobenzidine	91-94-1	0.13	0.67	ND		2.7	ND		ND			ND			ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.067	0.33	ND		1.3	ND		ND			ND			ND	
di-n-octyl phthalate	117-84-0	0.067	0.33	ND		1.3	ND		ND			ND			ND	
benzo (b) fluoranthene	205-99-2	0.067	0.33	6.6		1.3	38		ND			ND			0.89	
benzo (k) fluoranthene	207-08-9	0.13	0.67	2.6		2.7	13		ND			ND			0.33	J
benzo (a) pyrene	50-32-8	0.067	0.33	4.9		1.3	26		ND			ND			0.69	.096
indeno (1,2,3-cd) pyrene	193-39-5	0.067	0.33	2		1.3	8.5		ND			ND			0.38	.96
dibenz (a,h) anthracene	53-70-3	0.067	0.33	0.58	J	1.3	2.5	J	ND			ND			0.09	J , .016
benzo (ghi) perylene	191-24-2	0.067	0.33	1.5	J	1.3	6.5	J	ND			ND			0.28	J
2-methylphenol	95-48-7	0.067	0.33	17		1.3	ND		ND			ND			ND	
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	0.5	ND		2	ND		ND			ND			ND	
4-methylphenol	106-44-5	0.1	5	71		2	ND		ND			ND			ND	
4-chloroaniline	106-47-8	0.1	0.5	ND		2	ND		ND			ND			ND	
2-methylnaphthalene	91-57-6	0.033	1.7	77		6.7	440		ND			ND		0.17	15	
2,4,5-trichlorophenol	95-95-4	0.067	0.33	ND		1.3	ND		ND			ND			ND	
2-nitroaniline	88-74-4	0.067	0.33	ND		1.3	ND		ND			ND			ND	
3-nitroaniline	99-09-2	0.067	0.33	ND		1.3	ND		ND			ND			ND	
dibenzofuran	132-64-9	0.033	1.7	48		6.7	270		ND			0.037	J	0.17	9.7	
2,6-dinitrotoluene	606-20-2	0.067	0.33	ND		1.3	ND		ND			ND			ND	
4-nitroaniline	100-01-6	0.1	0.5	ND		2	ND		ND			ND			ND	
4,6-dinitro-2-methylphenol	534-52-1	0.17	0.83	ND		3.3	ND		ND			ND			ND	
carbazole	86-74-8	0.033	0.17	11		0.67	69		ND			ND			0.97	

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Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	GEO/SB-01/10-12		GEO/SB-02/10-12		GEO/SB-03/8-9.3		GEO/SB-04/10-12			GEO/SB-05/4-9	
		Lab Sample Number	2680801		2680802		2680803		2680804			2680805	
		Date Collected	3/18/97		3/18/97		3/18/97		3/18/97			3/18/97	
Parameter	CAS Number	Standard MDL	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Volatiles													
1,1-Dichloroethene	75-35-4	0.002	ND		ND		ND		ND		0.01	ND	
Trichloroethene	79-01-6	0.001	ND		ND		ND		ND		0.005	ND	
Benzene	71-43-2	0.001	ND		ND		ND		ND		0.005	ND	
Toluene	108-88-3	0.001	ND		ND		ND		ND		0.005	0.05	
Chlorobenzene	108-90-7	0.001	ND		ND		ND		ND		0.005	ND	
Xylene (total)	1330-20-7	0.001	ND		ND		ND		ND		0.005	1.2	
Chloromethane	74-87-3	0.002	ND		ND		ND		ND		0.01	ND	
Bromomethane	74-83-9	0.003	ND		ND		ND		ND		0.015	ND	
Vinyl Chloride	75-01-4	0.002	ND		ND		ND		ND		0.01	ND	
Chloroethane	75-00-3	0.003	ND		ND		ND		ND		0.015	ND	
Methylene Chloride	75-09-2	0.002	ND		ND		ND		ND		0.01	ND	
1,1-Dichloroethane	75-34-3	0.001	ND		ND		ND		ND		0.005	ND	
Chloroform	67-66-3	0.001	ND		ND		ND		ND		0.005	ND	
1,2-Dichloroethane	107-06-2	0.002	ND		ND		ND		ND		0.01	ND	
1,1,1-Trichloroethane	71-55-6	0.001	ND		ND		ND		ND		0.005	ND	
Carbon Tetrachloride	56-23-5	0.001	ND		ND		ND		ND		0.005	ND	
Bromodichloromethane	75-27-4	0.002	ND		ND		ND		ND		0.01	ND	
1,1,2,2-Tetrachloroethane	79-34-5	0.001	ND		ND		ND		ND		0.005	ND	
1,2-Dichloropropane	78-87-5	0.003	ND		ND		ND		ND		0.015	ND	
trans-1,3-Dichloropropene	10061-02-6	0.001	ND		ND		ND		ND		0.005	ND	
Dibromochloromethane	124-48-1	0.001	ND		ND		ND		ND		0.005	ND	
1,1,2-Trichloroethane	79-00-5	0.002	ND		ND		ND		ND		0.01	ND	
cis-1,3-Dichloropropene	10061-01-5	0.001	ND		ND		ND		ND		0.005	ND	
Bromoform	75-25-2	0.001	ND		ND		ND		ND		0.005	ND	
Tetrachloroethene	127-18-4	0.001	ND		ND		ND		ND		0.005	ND	
Ethylbenzene	100-41-4	0.001	ND		ND		ND		ND		0.005	0.23	
Acetone	67-64-1	0.007	ND		ND		ND		ND		0.035	0.073	J
Carbon Disulfide	75-15-0	0.003	ND		ND		ND		ND		0.015	ND	
2-Butanone	78-93-3	0.007	ND		ND		ND		ND		0.035	ND	
Vinyl Acetate	108-05-4	0.003	ND		ND		ND		ND		0.015	ND	
2-Hexanone	591-78-6	0.003	ND		ND		ND		ND		0.015	ND	
4-Methyl-2-pentanone	108-10-1	0.003	ND		ND		ND		ND		0.015	ND	
Styrene	100-42-5	0.001	ND		ND		ND		ND		0.005	ND	
trans-1,2-Dichloroethene	156-60-5	0.002	ND		ND		ND		ND		0.01	ND	
cis-1,2-Dichloroethene	156-59-2	0.002	ND		ND		ND		ND		0.01	ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample
GEO/SB-05/409.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	GEO/SB-01/10-12		GEO/SB-02/10-12		GEO/SB-03/8-9.3		GEO/SB-04/10-12		GEO/SB-05/4-9		
		Lab Sample Number	2680801		2680802		2680803		2680804		2680805		
		Date Collected	3/18/97		3/18/97		3/18/97		3/18/97		3/18/97		
Parameter	CAS Number	Standard MDL	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Semivolatiles													
phenol	108-95-2	0.033	ND		ND		ND		ND		0.33	ND	
2-chlorophenol	95-57-8	0.033	ND		ND		ND		ND		0.33	ND	
1,4-dichlorobenzene	106-46-7	0.033	ND		ND		ND		ND		0.33	ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	ND		ND		ND		ND		0.67	ND	
1,2,4-trichlorobenzene	120-82-1	0.033	ND		ND		ND		ND		0.33	ND	
4-chloro-3-methylphenol	59-50-7	0.067	ND		ND		ND		ND		0.67	ND	
acenaphthene	83-32-9	0.033	ND		ND		ND		ND		3.3	63	
4-nitrophenol	100-02-7	0.17	ND		ND		ND		ND		1.7	ND	
2,4-dinitrotoluene	121-14-2	0.067	ND		ND		ND		ND		0.67	ND	
pentachlorophenol	87-86-5	0.17	ND		ND		ND		ND		1.7	ND	
pyrene	129-00-0	0.067	ND		ND		ND		ND		6.7	180	
2-nitrophenol	88-75-5	0.067	ND		ND		ND		ND		0.67	ND	
2,4-dimethylphenol	105-67-9	0.067	ND		ND		ND		ND		0.67	1.2	J
2,4-dichlorophenol	120-83-2	0.033	ND		ND		ND		ND		0.33	ND	
2,4,6-trichlorophenol	88-06-2	0.067	ND		ND		ND		ND		0.67	ND	
2,4-dinitrophenol	51-28-5	0.17	ND		ND		ND		ND		1.7	ND	
bis (2-chloroethyl) ether	111-44-4	0.067	ND		ND		ND		ND		0.67	ND	
1,3-dichlorobenzene	541-73-1	0.033	ND		ND		ND		ND		0.33	ND	
1,2-dichlorobenzene	95-50-1	0.033	ND		ND		ND		ND		0.33	ND	
hexachloroethane	67-72-1	0.067	ND		ND		ND		ND		0.67	ND	
nitrobenzene	98-95-3	0.033	ND		ND		ND		ND		0.33	ND	
isophorone	78-59-1	0.067	ND		ND		ND		ND		0.67	ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	ND		ND		ND		ND		0.33	ND	
naphthalene	91-20-3	0.033	0.098	J	ND		0.2	J	ND		3.3	400	
hexachlorobutadiene	87-68-3	0.067	ND		ND		ND		ND		0.67	ND	
hexachlorocyclopentadiene	77-47-4	0.17	ND		ND		ND		ND		1.7	ND	
2-chloronaphthalene	91-58-7	0.033	ND		ND		ND		ND		0.33	ND	
acenaphthylene	208-96-8	0.033	ND		ND		ND		ND		0.33	8.3	
dimethyl phthalate	131-11-3	0.033	ND		ND		ND		ND		0.33	ND	
fluorene	86-73-7	0.033	ND		ND		ND		ND		3.3	130	
4-chlorophenyl phenyl ether	7005-72-3	0.067	ND		ND		ND		ND		0.67	ND	
diethyl phthalate	84-66-2	0.067	ND		ND		ND		ND		0.67	ND	
N-nitrosodiphenylamine	86-30-6	0.067	ND		ND		ND		ND		0.67	ND	
4-bromophenyl phenyl ether	101-55-3	0.1	ND		ND		ND		ND		1	ND	
hexachlorobenzene	118-74-1	0.1	ND		ND		ND		ND		1	ND	

Notes

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SW-846 8270B for semivolatiles.
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Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample GEO/SB-05/409.
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID Lab Sample Number Date Collected			GEO/SB-01/10-12 2680801 3/18/97		GEO/SB-02/10-12 2680802 3/18/97		GEO/SB-03/8-9.3 2680803 3/18/97		GEO/SB-04/10-12 2680804 3/18/97		GEO/SB-05/4-9 2680805 3/18/97		
Parameter	CAS Number	Standard MDL	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes
phenanthrene	85-01-8	0.033	ND		ND		ND		ND		3.3	360	
anthracene	120-12-7	0.033	ND		ND		ND		ND		3.3	98	
di-n-butyl phthalate	84-74-2	0.033	ND		ND		ND		ND		0.33	ND	
fluoranthene	206-44-0	0.033	ND		ND		ND		ND		3.3	220	
butyl benzyl phthalate	85-68-7	0.067	ND		ND		ND		ND		0.67	ND	
benzo (a) anthracene	56-55-3	0.033	ND		ND		ND		ND		0.33	52	
chrysene	218-01-9	0.033	ND		ND		ND		ND		0.33	48	
3,3'-dichlorobenzidine	91-94-1	0.13	ND		ND		ND		ND		1.3	ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.067	ND		ND		ND		ND		0.67	ND	
di-n-octyl phthalate	117-84-0	0.067	ND		ND		ND		ND		0.67	ND	
benzo (b) fluoranthene	205-99-2	0.067	ND		ND		ND		ND		0.67	36	
benzo (k) fluoranthene	207-08-9	0.13	ND		ND		ND		ND		1.3	14	
benzo (a) pyrene	50-32-8	0.067	ND		ND		ND		ND		0.67	24	
indeno (1,2,3-cd) pyrene	193-39-5	0.067	ND		ND		ND		ND		0.67	9.6	
dibenz (a,h) anthracene	53-70-3	0.067	ND		ND		ND		ND		0.67	2.7	J
benzo (ghi) perylene	191-24-2	0.067	ND		ND		ND		ND		0.67	6.4	
2-methylphenol	95-48-7	0.067	ND		ND		ND		ND		0.67	ND	
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	ND		ND		ND		ND		1	ND	
4-methylphenol	106-44-5	0.1	ND		ND		ND		ND		1	ND	
4-chloroaniline	106-47-8	0.1	ND		ND		ND		ND		1	ND	
2-methylnaphthalene	91-57-6	0.033	ND		ND		ND		ND		3.3	220	
2,4,5-trichlorophenol	95-95-4	0.067	ND		ND		ND		ND		0.67	ND	
2-nitroaniline	88-74-4	0.067	ND		ND		ND		ND		0.67	ND	
3-nitroaniline	99-09-2	0.067	ND		ND		ND		ND		0.67	ND	
dibenzofuran	132-64-9	0.033	ND		ND		ND		ND		3.3	130	
2,6-dinitrotoluene	606-20-2	0.067	ND		ND		ND		ND		0.67	ND	
4-nitroaniline	100-01-6	0.1	ND		ND		ND		ND		1	ND	
4,6-dinitro-2-methylphenol	534-52-1	0.17	ND		ND		ND		ND		1.7	ND	
carbazole	86-74-8	0.033	ND		ND		ND		ND		3.3	52	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID Lab Sample Number Date Collected			GEO/SB-29/6-8 (a) 2680808 3/18/97			GEO/SB-05A/17-19 2680806 3/18/97		GEO/SB-06/10-12 2680809 3/19/97			GEO/SB-07/5-7 2680810 3/19/97		
Parameter	CAS Number	Standard MDL	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Volatiles													
1,1-Dichloroethene	75-35-4	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
Trichloroethene	79-01-6	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Benzene	71-43-2	0.001	0.005	ND		0.002	J	0.005	0.008	J	0.005	ND	
Toluene	108-88-3	0.001	0.005	0.045		ND		0.005	0.095		0.005	0.014	J
Chlorobenzene	108-90-7	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Xylene (total)	1330-20-7	0.001	0.005	1.2		0.001	J	0.005	1.7		0.005	0.49	
Chloromethane	74-87-3	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
Bromomethane	74-83-9	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
Vinyl Chloride	75-01-4	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
Chloroethane	75-00-3	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
Methylene Chloride	75-09-2	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
1,1-Dichloroethane	75-34-3	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Chloroform	67-66-3	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
1,2-Dichloroethane	107-06-2	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
1,1,1-Trichloroethane	71-55-6	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Carbon Tetrachloride	56-23-5	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Bromodichloromethane	75-27-4	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
1,1,2,2-Tetrachloroethane	79-34-5	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
1,2-Dichloropropane	78-87-5	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
trans-1,3-Dichloropropene	10061-02-6	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Dibromochloromethane	124-48-1	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
1,1,2-Trichloroethane	79-00-5	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
cis-1,3-Dichloropropene	10061-01-5	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Bromoform	75-25-2	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Tetrachloroethene	127-18-4	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
Ethylbenzene	100-41-4	0.001	0.005	0.21		ND		0.005	0.48		0.005	0.068	
Acetone	67-64-1	0.007	0.035	0.053	J	ND		0.035	0.044	J	0.035	ND	
Carbon Disulfide	75-15-0	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
2-Butanone	78-93-3	0.007	0.035	ND		ND		0.035	ND		0.035	ND	
Vinyl Acetate	108-05-4	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
2-Hexanone	591-78-6	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
4-Methyl-2-pentanone	108-10-1	0.003	0.015	ND		ND		0.015	ND		0.015	ND	
Styrene	100-42-5	0.001	0.005	ND		ND		0.005	ND		0.005	ND	
trans-1,2-Dichloroethene	156-60-5	0.002	0.01	ND		ND		0.01	ND		0.01	ND	
cis-1,2-Dichloroethene	156-59-2	0.002	0.01	ND		ND		0.01	ND		0.01	ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample
GEO/SB-05/409.
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Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	GEO/SB-29/6-8 (a) 2680808 3/18/97			GEO/SB-05A/17-19 2680806 3/18/97		GEO/SB-06/10-12 2680809 3/19/97			GEO/SB-07/5-7 2680810 3/19/97		
Parameter	CAS Number	Standard MDL	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes
TCL Semivolatiles													
phenol	108-95-2	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
2-chlorophenol	95-57-8	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
1,4-dichlorobenzene	106-46-7	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
1,2,4-trichlorobenzene	120-82-1	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
4-chloro-3-methylphenol	59-50-7	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
acenaphthene	83-32-9	0.033	1.7	130		ND		1.7	150		4.2	200	
4-nitrophenol	100-02-7	0.17	0.83	ND		ND		0.83	ND		0.83	ND	
2,4-dinitrotoluene	121-14-2	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
pentachlorophenol	87-86-5	0.17	0.83	ND		ND		0.83	ND		0.83	ND	
pyrene	129-00-0	0.067	3.3	140		0.12	J	3.3	120		8.3	230	
2-nitrophenol	88-75-5	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
2,4-dimethylphenol	105-67-9	0.067	0.33	1	J	ND		0.33	1.3	J	0.33	ND	
2,4-dichlorophenol	120-83-2	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
2,4,6-trichlorophenol	88-06-2	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
2,4-dinitrophenol	51-28-5	0.17	0.83	ND		ND		0.83	ND		0.83	ND	
bis (2-chloroethyl) ether	111-44-4	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
1,3-dichlorobenzene	541-73-1	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
1,2-dichlorobenzene	95-50-1	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
hexachloroethane	67-72-1	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
nitrobenzene	98-95-3	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
isophorone	78-59-1	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
naphthalene	91-20-3	0.033	3.3	380		ND		3.3	420		4.2	210	
hexachlorobutadiene	87-68-3	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
hexachlorocyclopentadiene	77-47-4	0.17	0.83	ND		ND		0.83	ND		0.83	ND	
2-chloronaphthalene	91-58-7	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
acenaphthylene	208-96-8	0.033	0.17	5.5		ND		0.17	5.2		0.17	7.7	
dimethyl phthalate	131-11-3	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
fluorene	86-73-7	0.033	1.7	140		ND		1.7	160		4.2	250	
4-chlorophenyl phenyl ether	7005-72-3	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
diethyl phthalate	84-66-2	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
N-nitrosodiphenylamine	86-30-6	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
4-bromophenyl phenyl ether	101-55-3	0.1	0.5	ND		ND		0.5	ND		0.5	ND	
hexachlorobenzene	118-74-1	0.1	0.5	ND		ND		0.5	ND		0.5	ND	

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample
GEO/SB-05/409.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-1
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID			GEO/SB-29/6-8 (a)			GEO/SB-05A/17-19		GEO/SB-06/10-12			GEO/SB-07/5-7		
Lab Sample Number			2680808			2680806		2680809			2680810		
Date Collected			3/18/97			3/18/97		3/19/97			3/19/97		
Parameter	CAS Number	Standard MDL	Sample-Specific MDL	Result	Notes	Result	Notes	Sample-Specific MDL	Result	Notes	Sample-Specific MDL	Result	Notes
phenanthrene	85-01-8	0.033	3.3	350		0.21	J	3.3	370		4.2	510	
anthracene	120-12-7	0.033	1.7	78		0.13	J	1.7	55		4.2	120	
di-n-butyl phthalate	84-74-2	0.033	0.17	ND		ND		0.17	ND		0.17	ND	
fluoranthene	206-44-0	0.033	1.7	180		0.16	J	1.7	170		4.2	250	
butyl benzyl phthalate	85-68-7	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
benzo (a) anthracene	56-55-3	0.033	1.7	44		0.043	J	1.7	40		4.2	61	
chrysene	218-01-9	0.033	1.7	41		ND		1.7	33		4.2	52	
3,3'-dichlorobenzidine	91-94-1	0.13	0.67	ND		ND		0.67	ND		0.67	ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
di-n-octyl phthalate	117-84-0	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
benzo (b) fluoranthene	205-99-2	0.067	0.33	25		ND		0.33	18		8.3	33	J
benzo (k) fluoranthene	207-08-9	0.13	0.67	8.7		ND		0.67	6.7		0.67	11	
benzo (a) pyrene	50-32-8	0.067	0.33	17		ND		0.33	13		0.33	.22	
indeno (1,2,3-cd) pyrene	193-39-5	0.067	0.33	6.3		ND		0.33	4.1		0.33	8.7	
dibenz (a,h) anthracene	53-70-3	0.067	0.33	1.8		ND		0.33	1.4	J	0.33	3.4	
benzo (ghi) perylene	191-24-2	0.067	0.33	4.8		ND		0.33	2.4		0.33	6.4	
2-methylphenol	95-48-7	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	0.5	ND		ND		0.5	ND		0.5	ND	
4-methylphenol	106-44-5	0.1	0.5	ND		ND		0.5	ND		0.5	ND	
4-chloroaniline	106-47-8	0.1	0.5	ND		ND		0.5	ND		0.5	ND	
2-methylnaphthalene	91-57-6	0.033	1.7	180		ND		1.7	190		4.2	230	
2,4,5-trichlorophenol	95-95-4	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
2-nitroaniline	88-74-4	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
3-nitroaniline	99-09-2	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
dibenzofuran	132-64-9	0.033	1.7	120		ND		1.7	130		4.2	180	
2,6-dinitrotoluene	606-20-2	0.067	0.33	ND		ND		0.33	ND		0.33	ND	
4-nitroaniline	100-01-6	0.1	0.5	ND		ND		0.5	ND		0.5	ND	
4,6-dinitro-2-methylphenol	534-52-1	0.17	0.83	ND		ND		0.83	ND		0.83	ND	
carbazole	86-74-8	0.033	1.7	48		0.056	J	1.7	38		4.2	27	J

Notes

Analytical methods: SW-846 8240B for volatiles;
SW-846 8270B for semivolatiles.
All results are reported on an "as received" basis in mg/kg.
Last two numbers of MP&A Sample ID indicate sample depth intervel.
(a) Sample GEO/SB-29/6-8 is a blind duplicate of sample
GEO/SB-05/409.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-1A
Summary of Subsurface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

	MP&A Sample ID	GEO/SB-05/4-9		
	Lab Sample Number	2680805		
	Date Collected	3/18/97		
Parameter	CAS Number	Sample-Specific MDL	Result	Notes
Pesticides/PCBs				
Gamma BHC - Lindane	58-89-9	0.0006	ND	
Heptachlor	76-44-8	0.001	0.01	
Aldrin	309-00-2	0.001	ND	
DDT	50-29-3	0.003	ND	
Dieldrin	60-57-1	0.002	ND	
Endrin	72-20-8	0.002	ND	
Methoxychlor	72-43-5	0.008	ND	
Alpha BHC	319-84-6	0.0004	ND	
Beta BHC	319-85-7	0.001	ND	
Delta BHC	319-86-8	0.0006	ND	
Heptachlor Epoxide	1024-57-3	0.0006	ND	
DDE	72-55-9	0.003	ND	
DDD	72-54-8	0.001	ND	
Toxaphene	8001-35-2	0.1	ND	
Endosulfan I	959-98-8	0.001	0.004	J
Endosulfan II	33213-65-9	0.004	ND	
Endosulfan Sulfate	1031-07-8	0.003	ND	
Endrin Aldehyde	7421-93-4	0.006	ND	
PCB-1016	12674-11-2	0.03	ND	
PCB-1221	11104-28-2	0.05	ND	
PCB-1232	11141-16-5	0.03	ND	
PCB-1242	53469-21-9	0.01	ND	
PCB-1248	12672-29-6	0.04	ND	
PCB-1254	11097-69-1	0.1	ND	
PCB-1260	11096-82-5	0.2	ND	
Endrin Ketone	53494-70-5	0.005	ND	
Alpha Chlordane	5103-71-9	0.001	ND	
Gamma Chlordane	5103-74-2	0.0002	ND	

Where other data

Notes
Analytical methods: SW-846 8081.
All results are reported on an "as received" basis in mg/kg.
J - Estimated value.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected		MW-3 2677537 3/12/97			MW-23 (b) 2677538 3/12/97		MW-4 2677539 3/12/97	
Parameter	CAS Number	Method Detection Limit	Sample Specific MDL	Result	Notes	Sample Specific MDL	Result	Notes	Result	Notes
Volatiles										
2-Butanone	78-93-3	0.003	0.06	ND		0.06	ND		ND	
Bromomethane	74-83-9	0.003	0.06	ND		0.06	ND		ND	
Chloromethane	74-87-3	0.003	0.06	ND		0.06	ND		ND	
Vinyl Chloride	75-01-4	0.002	0.04	ND		0.04	ND		ND	
Chloroethane	75-00-3	0.003	0.06	ND		0.06	ND		ND	
Methylene Chloride	75-09-2	0.002	0.04	ND		0.04	ND		ND	
Acetone	67-64-1	0.006	0.12	ND		0.12	ND		ND	
Carbon Disulfide	75-15-0	0.003	0.06	ND		0.06	ND		ND	
1,1-Dichloroethene	75-35-4	0.001	0.02	ND		0.02	ND		ND	
1,1-Dichloroethane	75-34-3	0.002	0.04	ND		0.04	ND		ND	
Chloroform	67-66-3	0.001	0.02	ND		0.02	ND		ND	
1,2-Dichloroethane	107-06-2	0.002	0.04	ND		0.04	ND		ND	
1,1,1-Trichloroethane	71-55-6	0.001	0.02	ND		0.02	ND		ND	
Carbon Tetrachloride	56-23-5	0.001	0.02	ND		0.02	ND		ND	
Vinyl Acetate	108-05-4	0.002	0.04	ND	R	0.04	ND	R	ND	R
Bromodichloromethane	75-27-4	0.001	0.02	ND		0.02	ND		ND	
1,2-Dichloropropane	78-87-5	0.001	0.02	ND		0.02	ND		ND	
trans-1,3-Dichloropropene	10061-02-6	0.001	0.02	ND		0.02	ND		ND	
Trichloroethene	79-01-6	0.001	0.02	ND		0.02	ND		ND	
Dibromochloromethane	124-48-1	0.002	0.04	ND		0.04	ND		ND	
1,1,2-Trichloroethane	79-00-5	0.002	0.04	ND	8ug	0.04	ND		ND	
Benzene	71-43-2	0.001	0.02	0.81 ✓	.005	0.02	0.79 ✓		ND	
cis-1,3-Dichloropropene	*10061-01-5*	*0.001*	*0.02*	*ND*		0.02	*ND*		*ND*	
Bromoform	75-25-2	0.001	0.02	ND		0.02	ND		ND	
2-Hexanone	591-78-6	0.007	0.14	ND		0.14	ND		ND	
4-Methyl-2-pentanone	108-10-1	0.005	0.1	ND		0.1	ND		ND	
Tetrachloroethene	127-18-4	0.001	0.02	ND		0.02	ND		ND	
1,1,2,2-Tetrachloroethane	79-34-5	0.002	0.04	ND		0.04	ND		ND	
Toluene	108-88-3	0.002	0.04	0.44	.1 ppm	0.04	0.43		ND ✓	
Chlorobenzene	108-90-7	0.001	0.02	ND		0.02	ND		ND	

Notes
Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Parameter	CAS Number	Method Detection Limit	Sample Specific MDL	MW-3 2677537 3/12/97 Result	Notes	Sample Specific MDL	MW-23 (b) 2677538 3/12/97 Result	Notes	MW-4 2677539 3/12/97 Result	Notes
MP&A Sample ID / Lab Sample Number / Date Collected										
Ethylbenzene	100-41-4	0.002	0.04	0.062	J .7	0.04	0.06	J	ND	
Styrene	100-42-5	0.001	0.02	0.085	J .1	0.02	0.077	J	ND	
Xylene (total)	1330-20-7	0.001	0.02	0.38		0.02	0.37		ND	
trans-1,2-Dichloroethene	156-60-5	0.002	0.04	ND		0.04	ND		ND	
cis-1,2-Dichloroethene	156-59-2	0.002	0.04	ND		0.04	ND		ND	
Metals										
Aluminum	7429-90-5	0.057		7.32	J		14.8	J	1.77	
Antimony	7440-36-0	0.015		ND	R		ND	R	ND	R
Barium	7440-39-3	0.0022		0.11	J		0.16	J	0.0917	J
Beryllium	7440-41-7	0.0013		0.0037	J		0.0026	J	ND	
Cadmium	7440-43-9	0.0027		ND			ND		ND	
Calcium	7440-70-2	0.03		2.84	J		3.67	J	5.85	J
Chromium	7440-47-3	0.0043		0.0197	J		0.038	J	ND	
Cobalt	7440-48-4	0.0055		ND			0.0086	J	ND	
Copper	7440-50-8	0.0038		ND	J		ND	J	ND	
Iron	7439-89-6	0.0059		9.84	J		15.3	J	2.3	J
Magnesium	7439-95-4	0.024		1.8	J		2.39	J	1.93	
Manganese	7439-96-5	0.0029		0.061	J		0.088	J	0.128	J
Nickel	7440-02-0	0.0054		0.0068	J		0.0112	J	ND	
Potassium	7440-09-7	0.15		1.15	J		1.59	J	1.73	J
Silver	7440-22-4	0.0036		ND			ND		ND	
Sodium	7440-23-5	0.2		13.7	J		14.2		7.18	
Vanadium	7440-62-2	0.007		0.035	J		0.063	J	ND	
Zinc	7440-66-6	0.012		ND			0.093	J	ND	
Thallium TR	7440-28-0	0.0045		ND			ND		0.011	J
Arsenic TR	7440-38-2	0.0027		0.068 ✓ .05			0.07		0.025	
Selenium TR	7782-49-2	0.0027		ND			ND		ND	
Lead TR	7439-92-1	0.002		ND			0.0225 ✓	J	ND	J .015
Mercury	7439-97-6	0.000043		ND	J		0.00026	J	ND	J

Notes
Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

	MP&A Sample ID Lab Sample Number Date Collected		MW-3 2677537 3/12/97			MW-23 (b) 2677538 3/12/97			MW-4 2677539 3/12/97	
Parameter	CAS Number	Method Detection Limit	Sample Specific MDL	Result	Notes	Sample Specific MDL	Result	Notes	Result	Notes
Pesticides/PCBs										
Endrin Ketone	53494-70-5	0.000004	0.000005	ND	J		ND	J	ND	
Alpha Chlordane	5103-71-9	0.000001		ND	J		ND	J	ND	
Gamma Chlordane	5103-74-2	0.000001	0.000002	ND	J		ND	J	ND	
Alpha BHC	319-84-6	0.000001	0.00003	ND	J		ND	J	ND	
Beta BHC	319-85-7	0.000001		ND	J		ND	J	ND	
Gamma BHC - Lindane	58-89-9	0.000001		ND	J		ND	J	ND	
Delta BHC	319-86-8	0.000003	0.000004	ND	J		ND	J	ND	
Heptachlor	76-44-8	0.000002		ND	J		ND	J	ND	
Aldrin	309-00-2	0.000006	0.000008	ND	J		ND	J	ND	
Heptachlor Epoxide	1024-57-3	0.000001		ND	J		ND	J	ND	
DDE	72-55-9	0.000001	0.000003	ND	J		0.00002	J	ND	.000003
DDD	72-54-8	0.000005	0.000006	ND	J		ND	J	ND	
DDT	50-29-3	0.000009	0.00001	ND	J		0.00001	J	ND	.00003
Dieldrin	60-57-1	0.000001		ND	J	0.00002	ND	J	ND	
Endrin	72-20-8	0.000007	0.00009	0.00004	J		ND	J	ND	.0002 ppm
Toxaphene	8001-35-2	0.0004	0.0003	ND	J		ND	J	ND	
Endosulfan II	33213-65-9	0.000005	0.000006	ND	J		0.000009	J	ND	
Endosulfan I	959-98-8	0.000002	0.000003	ND	J		ND	J	ND	
Endosulfan Sulfate	1031-07-8	0.000003	0.000004	ND	J		0.000024	J	ND	
Endrin Aldehyde	7421-93-4	0.000005	0.000006	ND	J		0.000024	J	ND	
PCB-1016	12674-11-2	0.00004	0.00005	ND	J		ND	J	ND	
PCB-1221	11104-28-2	0.0001	0.0008	ND	J	0.0006	ND	J	ND	
PCB-1232	11141-16-5	0.00005	0.00006	ND	J		ND	J	ND	
PCB-1242	53469-21-9	0.0001		ND	J		ND	J	ND	
PCB-1248	12672-29-6	0.00004	0.00005	ND	J		ND	J	ND	
PCB-1254	11097-69-1	0.0001	0.0002	ND	J		ND	J	ND	
PCB-1260	11096-82-5	0.00004	0.00005	ND	J		ND	J	ND	
Methoxychlor	72-43-5	0.00002		ND	J		ND	J	ND	

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Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected		MW-3 2677537 3/12/97			MW-23 (b) 2677538 3/12/97		MW-4 2677539 3/12/97	
Parameter	CAS Number	Method Detection Limit	Sample Specific MDL	Result	Notes	Sample Specific MDL	Result	Notes	Result	Notes
Semivolatiles										
acenaphthene	83-32-9	0.001		0.3	J		0.31		ND	J.1
acenaphthylene	208-96-8	0.001		0.019			0.02		ND	
anthracene	120-12-7	0.001		0.02			0.017		ND	10.5
benzo (a) anthracene	56-55-3	0.001		0.007	J .2		0.004	2 J	ND	
benzo (b) fluoranthene	205-99-2	0.002		0.005	J .2		0.003	J	ND	
benzo (k) fluoranthene	207-08-9	0.002		ND			ND		ND	
benzo (ghi) perylene	191-24-2	0.002		ND			ND		ND	
benzo (a) pyrene	50-32-8	0.002		0.003	J .2		ND		ND	
bis (2-chloroethoxy) methane	111-91-1	0.001		ND	J		ND		ND	
bis (2-chloroethyl) ether	111-44-4	0.001		ND			ND		ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.002		0.007	J		0.0004	J	0.019	
4-bromophenyl phenyl ether	101-55-3	0.002		ND			ND		ND	
butyl benzyl phthalate	85-68-7	0.002		ND			ND		ND	
4-chloroaniline	106-47-8	0.002		ND	J		ND	J	ND	
4-chloro-3-methylphenol	59-50-7	0.002		ND	J		ND		ND	
2-chloronaphthalene	91-58-7	0.001		ND			ND		ND	
2-chlorophenol	95-57-8	0.001		ND			ND		ND	
4-chlorophenyl phenyl ether	7005-72-3	0.002		ND			ND		ND	
chrysene	218-01-9	0.001		0.007	J .2		0.004	J	ND	
dibenzofuran	132-64-9	0.001		0.15			0.15		0.004	J
di-n-butyl phthalate	84-74-2	0.001		ND			ND		ND	
dibenz (a,h) anthracene	53-70-3	0.002		ND			ND		ND	
1,2-dichlorobenzene	95-50-1	0.001		ND			ND		ND	
1,3-dichlorobenzene	541-73-1	0.001		ND			ND		ND	
1,4-dichlorobenzene	106-46-7	0.001		ND			ND		ND	
3,3'-dichlorobenzidine	91-94-1	0.002		ND			ND		ND	
2,4-dichlorophenol	120-83-2	0.002		ND	J		ND		ND	
diethyl phthalate	84-66-2	0.002		ND			ND		ND	
2,4-dimethylphenol	105-67-9	0.001		4.5	J		5.2		ND	.7
dimethyl phthalate	131-11-3	0.003		ND			ND		ND	
2,4-dinitrophenol	51-28-5	0.005		ND			ND		ND	
2,4-dinitrotoluene	121-14-2	0.002		ND			ND		ND	
2,6-dinitrotoluene	606-20-2	0.001		ND			ND		ND	

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03. MW-3
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected		MW-3 2677537 3/12/97			MW-23 (b) 2677538 3/12/97		MW-4 2677539 3/12/97	
Parameter	CAS Number	Method Detection Limit	Sample Specific MDL	Result	Notes	Sample Specific MDL	Result	Notes	Result	Notes
di-n-octyl phthalate	117-84-0	0.002		ND			ND		ND	
fluoranthene	206-44-0	0.001		0.034			0.02		ND	1.4 ok
fluorene	86-73-7	0.001		0.14			0.14		ND	1.4 ok
hexachlorobenzene	118-74-1	0.001		ND			ND		ND	
hexachlorobutadiene	87-68-3	0.001		ND	J		ND		ND	
hexachlorocyclopentadiene	77-47-4	0.003		ND			ND		ND	
hexachloroethane	67-72-1	0.002		ND			ND		ND	
indeno (1,2,3-cd) pyrene	193-39-5	0.002		ND			ND		ND	
isophorone	78-59-1	0.001		ND	J		ND		ND	
2-methylnaphthalene	91-57-6	0.001		1.1	J		0.99		ND	
naphthalene	91-20-3	0.001		5.8	J		11		0.018	
2-nitroaniline	88-74-4	0.001		ND			ND		ND	
3-nitroaniline	99-09-2	0.001		ND			ND		ND	
4-nitroaniline	100-01-6	0.002		ND			ND		ND	
nitrobenzene	98-95-3	0.001		ND	J		ND		ND	
2-nitrophenol	88-75-5	0.002		ND	J		ND		ND	
4-nitrophenol	100-02-7	0.005		ND			ND		ND	
N-nitrosodiphenylamine	86-30-6	0.002		ND			ND		ND	
N-nitrosodi-n-propylamine	621-64-7	0.002		ND			ND		ND	
pentachlorophenol	87-86-5	0.001		ND			ND		ND	
phenanthrene	85-01-8	0.001		0.13			0.12		ND	
phenol	108-95-2	0.001		0.32	J		0.36		ND	21 ok
pyrene	129-00-0	0.001		0.023			0.014		ND	1.5 ok
1,2,4-trichlorobenzene	120-82-1	0.001		ND	J		ND		ND	
2,4,5-trichlorophenol	95-95-4	0.001		ND			ND		ND	
2,4,6-trichlorophenol	88-06-2	0.001		ND			ND		ND	
2-methylphenol	95-48-7	0.002		1.3			1.2		ND	1.7 ok
2,2'oxybis (1-chloropropane)	108-60-1	0.002		ND			ND		ND	
4-methylphenol	106-44-5	0.002		1.8			2		ND	
4,6-dinitro-2-methylphenol	534-52-1	0.005		ND	R		ND	R	ND	R
carbazole	86-74-8	0.001		0.38	J		0.39		ND	
Total cyanide	57-12-5	0.000004		ND			ND		ND	

Notes
Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-2 presents a comparison of ROST data and laboratory analytical data for subsurface soil samples collected during the RI. The data indicate correlation between ROST total fluorescence intensity (TFI) and total PAH concentrations. Analyses of samples collected adjacent to unaffected ROST pushes were essentially non-detect; samples collected adjacent to marginally-affected ROST intervals contained concentrations of total PAH compounds ranging from 111 to 571 milligrams per kilogram (mg/kg); and samples collected in affected ROST intervals contained total PAH concentrations ranging from 680 mg/kg to 3689 mg/kg. Figure 4-2 is a graph depicting average TFIs versus total PAH concentrations for subsurface soil samples. This figure is provided to graphically depict the relationship between ROST response and laboratory data, and should not be used to estimate constituent concentrations based on ROST responses.

The approximate extent of affected soil within the Process Area, based on the ROST data and subsurface soil results, is depicted by the shaded area on Figure 4-1. It appears that lateral migration of constituents (away from the Process Area) was limited by the highly adsorptive nature of the constituents, the adsorbing capacity of the upper clay, and the low permeability of the upper clay. The approximate surface area underlain by affected soils is 3.4 acres. The depth of impacted soil in this area varies by location but ranges from approximately 5 feet bls to the top of ground water (20 to 25 feet bls).

4.1.2 DNAPL

Four ground water monitoring wells were installed within the Process Area during the Phase II Site Investigation conducted by EPS in 1994. These four wells (MW-1, MW-2, MW-3, and MW-4), as well as four new wells installed to monitor ground water on a site-wide basis, were sampled as part of RI activities. Ground water samples were collected from wells MW-3 and MW-4; samples of DNAPL were collected from wells MW-1 and MW-2. The presence of DNAPL in these two wells is not believed to be indicative of a measurable layer of DNAPL at the base of the Process Area sand channel. During the RI, numerous ROST pushes were advanced to the top of the underlying clay within the Process Area and no highly elevated TFIs were recorded at the base of the sand channel.

A review of the boring logs and well construction diagrams for wells MW-1 and MW-2 provides a possible explanation for the presence of DNAPL in the two wells. Results of this review indicate that while the majority of the screen for the two wells is set within the uppermost portion of the Process Area sand channel, the screen and filter pack extend upward into the creosote-impacted upper clay unit. This construction would furnish a preferential migration pathway for creosote entrained in the upper clay, i.e., into the filter pack, through the well screen, and into the well. The base of the well would then act as a sump for the accumulation of DNAPL. This explanation is consistent with scenarios known to exist at other wood treating sites.

DNAPL data are reported in Table 4-3. DNAPL samples were analyzed for TCL volatiles and semivolatiles. The major DNAPL constituents were PAHs. Lower concentrations of several phenolic compounds, BTEX compounds, and styrene were also reported in the DNAPL samples. The constituents detected and their relative concentrations were almost identical in the two samples, suggesting that the source of DNAPL in the two wells is the same.

Table 4-2
Comparison of ROST Data and Subsurface Soil Analytical Data

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Subsurface Soil Sample	Corresponding ROST Push	Soil Sample Depth, feet	Sample Interval Average TFI (a)	Total Semivolatile Compounds	Total Non-Carcinogenic PAHs	Total Carcinogenic PAHs	Total PAH Compounds	Naphthalene
CPT/SB-01/8-10	RST-12	8 - 10	0.11	0.22	0	0	0	ND
CPT/SB-01/44-46	RST-12	44 - 46	0.11	0	0	0	0	ND
CPT/SB-02/9-11	RST-02	9 - 11	1.27	609	541	29.7	571	180
CPT/SB-03/20-22	RST-53	20 - 22	0.22	0.12	0	0	0	ND
CPT/SB-04/20-22	RST-10	20 - 22	2.12	1300	993	51.6	1044	340
CPT/SB-04/29-31	RST-10	29 - 31	5.66	892	642	38.7	680	200
CPT/SB-05/10.5-12.5	RST-01	10.5 - 12.5	1.72	4030	3470	219	3689	910
CPT/SB-06/6-10	RST-29A	6 - 10	0.35	0	0	0	0	ND
CPT/SB-06/36-38	RST-29A	36 - 38	NA (b)	0.43	0.395	0	0	0.05 J
CPT/SB-07/14-16	RST-09A	14 - 16	0.76	122	106	4.98	111	36
GEO/SB-01/10-12	RST-38	10 - 12	0.29	0.098	0.098	0	0	0.098 J
GEO/SB-02/10-12	RST-49	10 - 12	0.23	0	0	0	0	ND
GEO/SB-03/8-9.3	RST-46	8 - 9.3	0.28	0.2	0.2	0	0	0.2 J
GEO/SB-04/10-12	RST-51	10 - 12	0.32	0	0	0	0	ND
GEO/SB-05/4-9	RST-41	4 - 9	2.37	2060	1680	186	1866	400
GEO/SB-05A/17-19	RST-41	17 - 19	1.56	0.719	0.62	0.043	1	ND
GEO/SB-06/10-12	RST-47	10 - 12	1.96	1930.0	1640	116	1756	420
GEO/SB-07/5-7	RST-35	5 - 7	2.83	2410	2010	191	2201	210

Notes:
All values are reported on an as received basis in mg/kg except average TFI, which is reported as a percent response to ROST standard.
(a) TFI = Total Fluorescence Intensity
(b) Not available; RST-29A, a re-push of RST-29, was terminated at 20 feet below grade.

Table 4-2
Chemical Constituents Included in Semivolatile and PAH Totals

Former Gulf States Cresoting Site
Hattiesburg, Mississippi

Semivolatile Compounds

- phenol
- 2-chlorophenol
- 1,4-dichlorobenzene
- N-nitrosodi-n-propylamine
- 1,2,4-trichlorobenzene
- 4-chloro-3-methylphenol
- acenaphthene
- 4-nitrophenol
- 2,4-dinitrotoluene
- pentachlorophenol
- pyrene
- 2-nitrophenol
- 2,4-dimethylphenol
- 2,4-dichlorophenol
- 2,4,6-trichlorophenol
- 2,4-dinitrophenol
- bis (2-chloroethyl) ether
- 1,3-dichlorobenzene
- 1,2-dichlorobenzene
- hexachloroethane
- nitrobenzene
- isophorone
- bis (2-chloroethoxy) methane
- naphthalene
- hexachlorobutadiene
- hexachlorocyclopentadiene
- 2-chloronaphthalene
- acenaphthylene
- dimethyl phthalate
- fluorene
- 4-chlorophenyl phenyl ether
- diethyl phthalate
- N-nitrosodiphenylamine
- 4-bromophenyl phenyl ether
- hexachlorobenzene
- phenanthrene
- anthracene
- di-n-butyl phthalate
- fluoranthene
- butyl benzyl phthalate
- benzo (a) anthracene
- chrysene
- 3,3'-dichlorobenzidine
- bis (2-ethylhexyl) phthalate
- di-n-octyl phthalate
- benzo (b) fluoranthene
- benzo (k) fluoranthene
- benzo (a) pyrene
- indeno (1,2,3-cd) pyrene
- dibenz (a,h) anthracene
- benzo (ghi) perylene
- 2-methylphenol
- 2,2'-oxybis (1-chloropropane)
- 4-methylphenol
- 4-chloroaniline
- 2-methylnaphthalene
- 2,4,5-trichlorophenol
- 2-nitroaniline
- 3-nitroaniline
- dibenzofuran
- 2,6-dinitrotoluene
- 4-nitroaniline
- 4,6-dinitro-2-methylphenol
- carbazole

Total PAHs

Carcinogenic

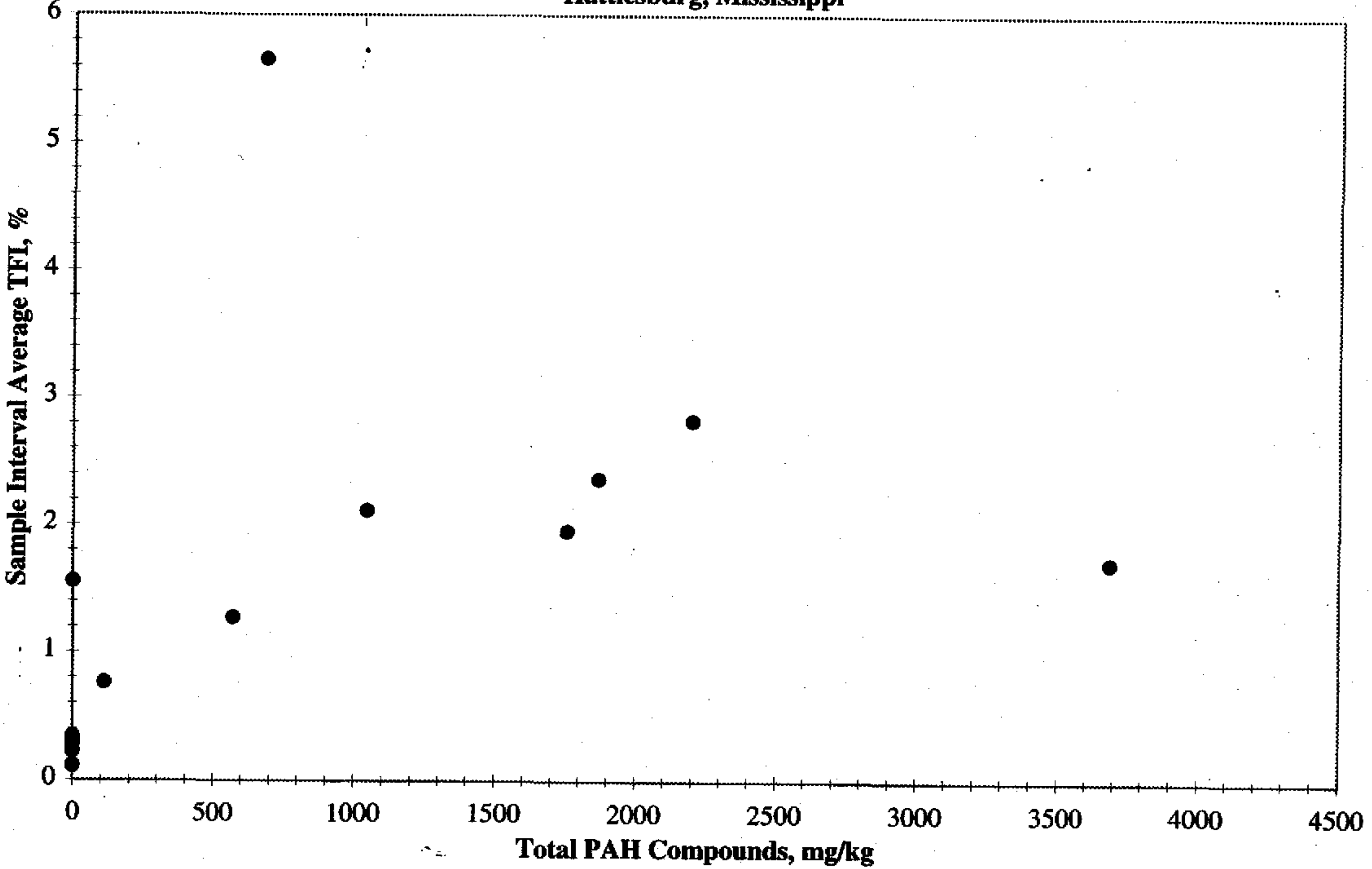
- benzo (a) anthracene
- chrysene
- benzo (b) fluoranthene
- benzo (k) fluoranthene
- benzo (a) pyrene
- indeno (1,2,3-cd) pyrene
- dibenz (a,h) anthracene

Noncarcinogenic

- acenaphthene
- pyrene
- naphthalene
- acenaphthylene
- fluorene
- phenanthrene
- anthracene
- fluoranthene
- benzo (ghi) perylene
- 2-methylnaphthalene

Figure 4-2
Average ROST TFI vs. PAH Concentrations
In Subsurface Soil Samples

Former Gulf States Creosoting Site
Hattiesburg, Mississippi



MPA21-02/TFIv.TCLSV

Table 4-3
Summary of DNAPL Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID Lab Sample Number Date Collected		MW-1 2677693 3/13/97			MW-2 2677694 3/13/97		
Parameter	CAS Number	Method Detection Limit	Result	Notes	Method Detection Limit	Result	Notes
TCL Volatiles							
1,1-Dichloroethene	75-35-4	13	ND	J	13	ND	J
Trichloroethene	79-01-6	6.3	ND	J	6.3	ND	J
Benzene	71-43-2	6.3	36	J	6.3	92	J
Toluene	108-88-3	6.3	190	J	6.3	350	J
Chlorobenzene	108-90-7	6.3	ND	J	6.3	ND	J
Xylene (total)	1330-20-7	6.3	1000	J	6.3	1100	J
Chloromethane	74-87-3	13	ND	J	13	ND	J
Bromomethane	74-83-9	19	ND	J	19	ND	J
Vinyl Chloride	75-01-4	13	ND	J	13	ND	J
Chloroethane	75-00-3	19	ND	J	19	ND	J
Methylene Chloride	75-09-2	13	ND	J	13	ND	J
1,1-Dichloroethane	75-34-3	6.3	ND	J	6.3	ND	J
Chloroform	67-66-3	6.3	ND	J	6.3	ND	J
1,2-Dichloroethane	107-06-2	13	ND	J	13	ND	J
1,1,1-Trichloroethane	71-55-6	6.3	ND	J	6.3	ND	J
Carbon Tetrachloride	56-23-5	6.3	ND	J	6.3	ND	J
Bromodichloromethane	75-27-4	13	ND	J	13	ND	J
1,1,2,2-Tetrachloroethane	79-34-5	6.3	ND	J	6.3	ND	J
1,2-Dichloropropane	78-87-5	19	ND	J	19	ND	J
trans-1,3-Dichloropropene	10061-02-6	6.3	ND	J	6.3	ND	J
Dibromochloromethane	124-48-1	6.3	ND	J	6.3	ND	J
1,1,2-Trichloroethane	79-00-5	13	ND	J	13	ND	J
cis-1,3-Dichloropropene	10061-01-5	6.3	ND	J	6.3	ND	J
Bromoform	75-25-2	6.3	ND	J	6.3	ND	J
Tetrachloroethene	127-18-4	6.3	ND	J	6.3	ND	J
Ethylbenzene	100-41-4	6.3	180	J	6.3	230	J
Acetone	67-64-1	44	ND	J	44	ND	J
Carbon Disulfide	75-15-0	19	ND	J	19	ND	J
2-Butanone	78-93-3	44	ND	J	44	ND	J
Vinyl Acetate	108-05-4	19	ND	J	19	ND	J
2-Hexanone	591-78-6	19	ND	J	19	ND	J
4-Methyl-2-pentanone	108-10-1	19	ND	J	19	ND	J
Styrene	100-42-5	6.3	120	J	6.3	240	J
trans-1,2-Dichloroethene	156-60-5	13	ND	J	13	ND	J
cis-1,2-Dichloroethene	156-59-2	13	ND	J	13	ND	J

.7

.1

1005 mg/k

1 mg/k

10

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B.

All results are reported on an "as received" basis in mg/l except moisture content, which is expressed as a percentage.

J - Estimated value; in cases of ND, indicates MDL is estimated.

R - Unusable result; analyte may or may not be present in the sample.

Table 4-3
Summary of DNAPL Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

	MP&A Sample ID	MW-1			MW-2			
	Lab Sample Number	2677693			2677694			
	Date Collected	3/13/97			3/13/97			
Parameter	CAS Number	Method Detection Limit	Result	Notes	Method Detection Limit	Result	Notes	
TCL Semivolatiles								
phenol	108-95-2	5	ND	J	10	130	J	
2-chlorophenol	95-57-8	5	ND	J	5	ND	J	
1,4-dichlorobenzene	106-46-7	5	ND	J	5	ND	J	
N-nitrosodi-n-propylamine	621-64-7	10	ND	J	10	ND	J	
1,2,4-trichlorobenzene	120-82-1	5	ND	J	5	ND	J	
4-chloro-3-methylphenol	59-50-7	10	ND	J	10	ND	J	
acenaphthene	83-32-9	400	18000	J	800	17000	J	2.1
4-nitrophenol	100-02-7	25	ND	J	25	ND	J	
2,4-dinitrotoluene	121-14-2	10	ND	J	10	ND	J	
pentachlorophenol	87-86-5	25	ND	J	25	ND	J	
pyrene	129-00-0	800	15000	J	1600	14000	J	1.05
2-nitrophenol	88-75-5	10	ND	J	10	ND	J	
2,4-dimethylphenol	105-67-9	20	140	J	20	2900	J	.7
2,4-dichlorophenol	120-83-2	5	ND	J	5	ND	J	
2,4,6-trichlorophenol	88-06-2	10	ND	J	10	ND	J	
2,4-dinitrophenol	51-28-5	25	ND	J	25	ND	J	
bis (2-chloroethyl) ether	111-44-4	10	ND	J	10	ND	J	
1,3-dichlorobenzene	541-73-1	5	ND	J	5	ND	J	
1,2-dichlorobenzene	95-50-1	5	ND	J	5	ND	J	
hexachloroethane	67-72-1	10	ND	J	10	ND	J	
nitrobenzene	98-95-3	5	ND	J	5	ND	J	
isophorone	78-59-1	10	ND	J	10	ND	J	
bis (2-chloroethoxy) methane	111-91-1	5	ND	J	5	ND	J	
naphthalene	91-20-3	400	62000	J	800	96000	J	1.4
hexachlorobutadiene	87-68-3	10	ND	J	10	ND	J	
hexachlorocyclopentadiene	77-47-4	25	ND	J	25	ND	J	
2-chloronaphthalene	91-58-7	5	ND	J	5	ND	J	
acenaphthylene	208-96-8	10	720	J	10	1100	J	—
dimethyl phthalate	131-11-3	5	ND	J	5	ND	J	
fluorene	86-73-7	400	18000	J	800	18000	J	1.4
4-chlorophenyl phenyl ether	7005-72-3	10	ND	J	10	ND	J	
diethyl phthalate	84-66-2	10	ND	J	10	ND	J	
N-nitrosodiphenylamine	86-30-6	10	ND	J	10	ND	J	
4-bromophenyl phenyl ether	101-55-3	15	ND	J	15	ND	J	
hexachlorobenzene	118-74-1	15	ND	J	15	ND	J	

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B.

All results are reported on an "as received" basis in mg/l except moisture content, which is expressed as a percentage.

J - Estimated value; in cases of ND, indicates MDL is estimated.

R - Unusable result; analyte may or may not be present in the sample.

Table 4-3
Summary of DNAPL Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MP&A Sample ID		[redacted]			[redacted]		
Lab Sample Number		[redacted]			2677694		
Date Collected		3/13/97			3/13/97		

Parameter	CAS Number	Method Detection Limit	Result	Notes	Method Detection Limit	Result	Notes
phenanthrene	85-01-8	400	41000	J	800	47000	J
anthracene	120-12-7	400	4600	J	800	6500	J 10.5
di-n-butyl phthalate	84-74-2	5	ND	J	5	ND	J
fluoranthene	206-44-0	400	21000	J	800	19000	J 1.4
butyl benzyl phthalate	85-68-7	10	ND	J	10	ND	J
benzo (a) anthracene	56-55-3	400	4600	J	800	3900	J .2ppb
chrysene	218-01-9	400	3900	J	800	3100	J .2ppb
3,3'-dichlorobenzidine	91-94-1	20	ND	J	20	ND	J
bis (2-ethylhexyl) phthalate	117-81-7	10	ND	J	10	ND	J
di-n-octyl phthalate	117-84-0	10	ND	J	10	ND	J
benzo (b) fluoranthene	205-99-2	800	2100	J	1600	1800	J .2
benzo (k) fluoranthene	207-08-9	40	1000	J	40	850	J .2
benzo (a) pyrene	50-32-8	800	1500	J	20	1800	J .2
indeno (1,2,3-cd) pyrene	193-39-5	20	700	J	20	740	J .2
dibenz (a,h) anthracene	53-70-3	20	180	J	20	210	J .2
benzo (ghi) perylene	191-24-2	20	490	J	20	530	J
2-methylphenol	95-48-7	10	ND	J	20	400	J 1.75
2,2'-oxybis (1-chloropropane)	108-60-1	15	ND	J	15	ND	J
4-methylphenol	106-44-5	15	ND	J	30	810	J
4-chloroaniline	106-47-8	15	ND	J	15	ND	J
2-methylnaphthalene	91-57-6	400	28000	J	800	27000	J
2,4,5-trichlorophenol	95-95-4	10	ND	J	10	ND	J
2-nitroaniline	88-74-4	10	ND	J	10	ND	J
3-nitroaniline	99-09-2	10	ND	J	10	ND	J
dibenzofuran	132-64-9	400	15000	J	800	15000	J
2,6-dinitrotoluene	606-20-2	10	ND	J	10	ND	J
4-nitroaniline	100-01-6	15	ND	J	15	ND	J
4,6-dinitro-2-methylphenol	534-52-1	25	ND	R	25	ND	R
carbazole	86-74-8	400	2300	J	800	3000	J
Moisture Content		0.08	48.8		0.08	45.7	

PPM

MCL

MCL

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B.

All results are reported on an "as received" basis in mg/l except moisture content, which is expressed as a percentage.

J - Estimated value; in cases of ND, indicates MDL is estimated.

R - Unusable result; analyte may or may not be present in the sample.

4.1.3 Ground Water

Ground water data are summarized in Table 4-4. Ground water samples were analyzed for TCL volatiles, semivolatiles, pesticides and PCBs, and TAL inorganics. With the exception of naphthalene (0.018 mg/l) and bis (2-ethylhexyl) phthalate (0.019 mg/l), no organic target compounds were reported above laboratory limits of quantitation in the sample collected from MW-4. Naphthalene is the most prominent constituent in DNAPL and soil samples collected within the Process Area; phthalates are common laboratory artifacts. Metals were reported in the MW-4 samples at concentrations which, based on site-wide ground water quality (see Section 4.3.2), appear to be ubiquitous. These results indicate that ground water within the western (i.e., updip) portion of the Process Area sand channel remains essentially unaffected. The potentiometric surface map (Figure 3-7) and MW-4 analytical data support the revised conceptual site model, that is that Process Area constituents are not migrating to the west via the ground water pathway.

The sample from MW-3 contained many of the same constituents reported in DNAPL samples (i.e., PAHs with minor concentrations of BTEX and phenolics), albeit at much lower concentrations. These results are consistent with the well's location within the former operations area. During the drilling of SB-06 (advanced adjacent to RST-01), black staining and creosote odors were observed at the top of the Process Area sand channel, indicating that affected ground water extends to the eastern corner of the Process Area near Scooba Street.

Due to the pre-RI conceptual site model indicating Process Area ground water flow to the southwest, the presence of affected ground water at the eastern corner of the Process Area was not anticipated. The extent of affected ground water to the north and east of the Process Area was not determined during the RI. Additional data collection is addressed in Section 5.2.

4.2 Fill Area

Data from site characterization activities conducted to determine the nature and extent of affected media within the Fill Area include ROST data and subsurface soil data.

ROST and subsurface soil analytical data indicate that creosote-impacted soils are present in an area adjacent to Gordon's Creek. Surface features which indicate that filling has occurred include: 1) a visible mounded area between Gordon's Creek and West Pine Street just north of the drainage ditch leading to the creek; and 2) fill debris (concrete, etc.) within an apparent former channel cut along both banks of the drainage ditch. The location of the fill debris coincides with the trace of the former Gordon's Creek channel shown on Figure 3-2.

Figure 4-3 presents four ROST cross-sections through the Fill Area. Cross-section J-J' runs along the eastern bank of Gordon's Creek through the sandiest portion of the Fill Area. Pushes along this section are believed to be situated between potential areas of filling (i.e., the mound and former creek channel) and the present-day Gordon's Creek channel. Logs of ROST pushes RST-39 and RST-46 show essentially no fluorescence from the land surface to total depth, establishing the presence of clean soil at each end of the section. ROST responses within the impacted area range from marginal (RST-40) to affected (RST-41).

Cross-sections K-K' and L-L' run through the central portion of the area containing affected subsurface materials. RST-43 and RST-15/RST 16 indicate the presence of

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	MW-03		MW-04		MW-04 dup (a)		MW-05		MW-01	
		Lab Sample Number	2677529		2677530		2677531		2677535		2677536	
		Date Collected	3/12/97		3/12/97		3/12/97		3/12/97		3/12/97	
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
Volatiles												
2-Butanone	78-93-3	0.003	ND		ND		NA		ND		ND	
Bromomethane	74-83-9	0.003	ND		ND		NA		ND		ND	
Chloromethane	74-87-3	0.003	ND		ND		NA		ND		ND	
Vinyl Chloride	75-01-4	0.002	ND		ND		NA		ND		ND	
Chloroethane	75-00-3	0.003	ND		ND		NA		ND		ND	
Methylene Chloride	75-09-2	0.002	ND		ND		NA		ND		ND	
Acetone	67-64-1	0.006	ND		ND		NA		ND		ND	
Carbon Disulfide	75-15-0	0.003	0.023		0.027		NA		ND		0.057	
1,1-Dichloroethene	75-35-4	0.001	ND		ND		NA		ND		ND	
1,1-Dichloroethane	75-34-3	0.002	ND		ND		NA		ND		ND	
Chloroform	67-66-3	0.001	ND		ND		NA		0.002	J	0.006	
1,2-Dichloroethane	107-06-2	0.002	ND		ND		NA		ND		ND	
1,1,1-Trichloroethane	71-55-6	0.001	ND		ND		NA		ND		ND	
Carbon Tetrachloride	56-23-5	0.001	ND		ND		NA		ND		ND	
Vinyl Acetate	108-05-4	0.002	ND	R	ND	R	NA		ND	R	ND	R
Bromodichloromethane	75-27-4	0.001	ND		ND		NA		ND		ND	
1,2-Dichloropropane	78-87-5	0.001	ND		ND		NA		ND		ND	
trans-1,3-Dichloropropene	10061-02-6	0.001	ND		ND		NA		ND		ND	
Trichloroethene	79-01-6	0.001	ND		ND		NA		ND		ND	
Dibromochloromethane	124-48-1	0.002	ND		ND		NA		ND		ND	
1,1,2-Trichloroethane	79-00-5	0.002	ND		ND		NA		ND		ND	
Benzene	71-43-2	0.001	ND		ND		NA		ND		ND	
cis-1,3-Dichloropropene	10061-01-5	0.001	ND		ND		NA		ND		ND	
Bromoform	75-25-2	0.001	ND		ND		NA		ND		ND	
2-Hexanone	591-78-6	0.007	ND		ND	J	NA		ND		ND	
4-Methyl-2-pentanone	108-10-1	0.005	ND		ND		NA		ND		ND	
Tetrachloroethene	127-18-4	0.001	ND		ND		NA		ND		ND	
1,1,2,2-Tetrachloroethane	79-34-5	0.002	ND		ND		NA		ND		ND	
Toluene	108-88-3	0.002	ND		ND		NA		ND		ND	
Chlorobenzene	108-90-7	0.001	ND		ND		NA		ND		ND	

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	MW-03 2677529 3/12/97		MW-04 2677530 3/12/97		MW-04 dup (a) 2677531 3/12/97		MW-05 2677535 3/12/97		MW-01 2677536 3/12/97		
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	
Ethylbenzene	100-41-4	0.002	ND		ND		NA		ND		ND		
Styrene	100-42-5	0.001	ND		ND		NA		ND		ND		
Xylene (total)	1330-20-7	0.001	ND		ND		NA		ND		ND		
trans-1,2-Dichloroethene	156-60-5	0.002	ND		ND		NA		ND		ND		
cis-1,2-Dichloroethene	156-59-2	0.002	ND		ND		NA		ND		ND		
Metals													
Aluminum	7429-90-5	0.057	11.1		16.6		19.8		47.8		9.03		
Antimony	7440-36-0	0.015	ND	R	ND	R	ND		ND	R	ND	R	.004
Barium	7440-39-3	0.0022	0.25		0.49		0.51		0.61		0.27		
Beryllium	7440-41-7	0.0013	0.0043 ✓	J	0.0042 ✓	J	0.0022	J	0.0071 ✓	J	0.0017	J	
Cadmium	7440-43-9	0.0027	ND		ND		ND		ND		ND		
Calcium	7440-70-2	0.03	17.7	J	42.6	J	42.9		19.2	J	12.7	J	
Chromium	7440-47-3	0.0043	0.028	J	0.0185	J	0.0217	J	0.071		0.042		.1
Cobalt	7440-48-4	0.0055	0.0132	J	0.0156	J	0.0177	J	0.0403	J	0.0121	J	
Copper	7440-50-8	0.0038	ND		ND		0.0217	J	0.047		ND		
Iron	7439-89-6	0.0059	26.3	J	21.9	J	27.1		79.3	J	13.2	J	
Magnesium	7439-95-4	0.024	4.67		20.6		21.5		10.3		4.18		
Manganese	7439-96-5	0.0029	0.5	J	1.22 ✓	J	1.26 ✓		1.09	J	0.343	J	.175
Nickel	7440-02-0	0.0054	0.0163	J	0.0305	J	0.035	J	0.0407	J	0.0124	J	
Potassium	7440-09-7	0.15	2.92	J	5.67		6.1		5.64		2.21		
Silver	7440-22-4	0.0036 .175	ND		ND		ND		ND		ND		
Sodium	7440-23-5	0.2	19.5		53.4		59.4		19.6		15.5		
Vanadium	7440-62-2	0.007	0.047		0.048		0.054		0.109		0.051		
Zinc	7440-66-6	0.012	ND		0.085		0.089		0.135		0.075		
Thallium TR	7440-28-0	0.0045	ND		ND		ND		ND		ND		
Arsenic TR	7440-38-2	0.0027	0.067 ✓	.05	0.012		0.014		0.057 ✓		0.047		
Selenium TR	7782-49-2	0.0027	ND		ND		ND		ND		0.0044	J	
Lead TR	7439-92-1	0.002	0.0207 ✓		0.0262 ✓		0.0301 ✓		0.0669 ✓		ND		.015
Mercury	7439-97-6	0.000043	ND		ND		0.000093	J	ND		0.00023		

.002

Notes

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Inorganics by appropriate SW-846 methods

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(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.

(b) Sample MW-23 is a blind duplicate of sample MW-03.

J - Estimated value; in cases of ND, indicates MDL is estimated.

R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	MW-03 2677529 3/12/97		MW-04 2677530 3/12/97		MW-04 dup (a) 2677531 3/12/97		MW-05 2677535 3/12/97		MW-01 2677536 3/12/97		
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	
Pesticides/PCBs													
Endrin Ketone	53494-70-5	0.000004	ND	J	ND	J	NA		ND	J	ND	J	
Alpha Chlordane	5103-71-9	0.000001	ND	J	ND	J	NA		ND	J	ND	J	
Gamma Chlordane	5103-74-2	0.000001	ND	J	ND	J	NA		ND	J	ND	J	
Alpha BHC	319-84-6	0.000001	ND	J	ND	J	NA		ND	J	ND	J	
Beta BHC	319-85-7	0.000001	ND	J	ND	J	NA		ND	J	ND	J	
Gamma BHC - Lindane	58-89-9	0.000001	ND	J	ND	J	NA		0.000002	J	0.000002	J	.0002 mg/l
Delta BHC	319-86-8	0.000003	ND	J	ND	J	NA		ND	J	ND	J	
Heptachlor	76-44-8	0.000002	ND	J	ND	J	NA		ND	J	ND	J	
Aldrin	309-00-2	0.000006	ND	J	ND	J	NA		ND	J	ND	J	
Heptachlor Epoxide	1024-57-3	0.000001	ND	J	ND	J	NA		0.000002	J	ND	J	
DDE	72-55-9	0.000001	ND	J	ND	J	NA		ND	J	0.000002	J	TEC .0002 m
DDD	72-54-8	0.000005	ND	J	ND	J	NA		ND	J	ND	J	
DDT	50-29-3	0.000009	ND	J	ND	J	NA		ND	J	ND	J	
Dieldrin	60-57-1	0.000001	ND	J	ND	J	NA		ND	J	ND	J	
Endrin	72-20-8	0.000007	ND	J	ND	J	NA		ND	J	ND	J	
Toxaphene	8001-35-2	0.0004	ND	J	ND	J	NA		ND	J	ND	J	
Endosulfan II	33213-65-9	0.000005	ND	J	ND	J	NA		ND	J	ND	J	
Endosulfan I	959-98-8	0.000002	ND	J	ND	J	NA		ND	J	ND	J	
Endosulfan Sulfate	1031-07-8	0.000003	ND	J	ND	J	NA		ND	J	ND	J	
Endrin Aldehyde	7421-93-4	0.000005	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1016	12674-11-2	0.00004	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1221	11104-28-2	0.0001	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1232	11141-16-5	0.00005	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1242	53469-21-9	0.0001	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1248	12672-29-6	0.00004	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1254	11097-69-1	0.0001	ND	J	ND	J	NA		ND	J	ND	J	
PCB-1260	11096-82-5	0.00004	ND	J	ND	J	NA		ND	J	ND	J	
Methoxychlor	72-43-5	0.00002	ND	J	ND	J	NA		ND	J	ND	J	

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods

All results are reported in mg/l.

(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.

(b) Sample MW-23 is a blind duplicate of sample MW-03.

J - Estimated value; in cases of ND, indicates MDL is estimated.

R - Unusable result; analyte may or may not be present in the sample.

Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
		MP&A Sample ID	MW-03		MW-04		MW-04 dup (a)		MW-05		MW-01	
		Lab Sample Number	2677529		2677530		2677531		2677535		2677536	
		Date Collected	3/12/97		3/12/97		3/12/97		3/12/97		3/12/97	
Semivolatiles												
acenaphthene	83-32-9	0.001	ND		ND		NA		ND		ND	
acenaphthylene	208-96-8	0.001	ND		ND		NA		ND		ND	
anthracene	120-12-7	0.001	ND		ND		NA		ND		ND	
benzo (a) anthracene	56-55-3	0.001	ND		ND		NA		ND		ND	
benzo (b) fluoranthene	205-99-2	0.002	ND		ND		NA		ND		ND	
benzo (k) fluoranthene	207-08-9	0.002	ND		ND		NA		ND		ND	
benzo (ghi) perylene	191-24-2	0.002	ND		ND		NA		ND		ND	
benzo (a) pyrene	50-32-8	0.002	ND		ND		NA		ND		ND	
bis (2-chloroethoxy) methane	111-91-1	0.001	ND		ND		NA		ND		ND	
bis (2-chloroethyl) ether	111-44-4	0.001	ND		ND		NA		ND		ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.002	ND		ND		NA		ND		ND	
4-bromophenyl phenyl ether	101-55-3	0.002	ND		ND		NA		ND		ND	
butyl benzyl phthalate	85-68-7	0.002	ND		ND		NA		ND		ND	
4-chloroaniline	106-47-8	0.002	ND	J	ND		NA		ND		ND	
4-chloro-3-methylphenol	59-50-7	0.002	ND		ND		NA		ND	J	ND	J
2-chloronaphthalene	91-58-7	0.001	ND		ND		NA		ND		ND	
2-chlorophenol	95-57-8	0.001	ND		ND		NA		ND		ND	
4-chlorophenyl phenyl ether	7005-72-3	0.002	ND		ND		NA		ND		ND	
chrysene	218-01-9	0.001	ND		ND		NA		ND		ND	
dibenzofuran	132-64-9	0.001	ND		ND		NA		ND		ND	
di-n-butyl phthalate	84-74-2	0.001	ND		ND		NA		ND		0.001	J
dibenz (a,h) anthracene	53-70-3	0.002	ND		ND		NA		ND		ND	
1,2-dichlorobenzene	95-50-1	0.001	ND		ND		NA		ND		ND	
1,3-dichlorobenzene	541-73-1	0.001	ND		ND		NA		ND		ND	
1,4-dichlorobenzene	106-46-7	0.001	ND		ND		NA		ND		ND	
3,3'-dichlorobenzidine	91-94-1	0.002	ND		ND		NA		ND		ND	
2,4-dichlorophenol	120-83-2	0.002	ND		ND		NA		ND		ND	
diethyl phthalate	84-66-2	0.002	ND		ND		NA		ND		ND	
2,4-dimethylphenol	105-67-9	0.001	ND		ND		NA		ND		ND	
dimethyl phthalate	131-11-3	0.003	ND		ND		NA		ND		ND	
2,4-dinitrophenol	51-28-5	0.005	ND		ND		NA		ND		ND	
2,4-dinitrotoluene	121-14-2	0.002	ND		ND		NA		ND		ND	
2,6-dinitrotoluene	606-20-2	0.001	ND		ND		NA		ND		ND	

Notes

Analytical methods: Volatiles by SW-846 8240B;
Semivolatiles by SW-846 8270B; Pesticides PCBs by SW-846 8081;
Inorganics by appropriate SW-846 methods
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(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
(b) Sample MW-23 is a blind duplicate of sample MW-03.
J - Estimated value; in cases of ND, indicates MDL is estimated.
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Table 4-4
Summary of Ground Water Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	MW-03		MW-04		MW-04 dup (a)		MW-05		MW-01	
		Lab Sample Number	2677529		2677530		2677531		2677535		2677536	
		Date Collected	3/12/97		3/12/97		3/12/97		3/12/97		3/12/97	
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
di-n-octyl phthalate	117-84-0	0.002	ND		ND		NA		ND		ND	
fluoranthene	206-44-0	0.001	ND		ND		NA		ND		ND	
fluorene	86-73-7	0.001	ND		ND		NA		ND		ND	
hexachlorobenzene	118-74-1	0.001	ND		ND		NA		ND		ND	
hexachlorobutadiene	87-68-3	0.001	ND		ND		NA		ND		ND	
hexachlorocyclopentadiene	77-47-4	0.003	ND		ND		NA		ND		ND	
hexachloroethane	67-72-1	0.002	ND		ND		NA		ND		ND	
indeno (1,2,3-cd) pyrene	193-39-5	0.002	ND		ND		NA		ND		ND	
isophorone	78-59-1	0.001	ND		ND		NA		ND		ND	
2-methylnaphthalene	91-57-6	0.001	ND		ND		NA		ND		ND	
naphthalene	91-20-3	0.001	ND		ND		NA		ND		ND	
2-nitroaniline	88-74-4	0.001	ND		ND		NA		ND		ND	
3-nitroaniline	99-09-2	0.001	ND		ND		NA		ND		ND	
4-nitroaniline	100-01-6	0.002	ND		ND		NA		ND		ND	
nitrobenzene	98-95-3	0.001	ND		ND		NA		ND		ND	
2-nitrophenol	88-75-5	0.002	ND		ND		NA		ND		ND	
4-nitrophenol	100-02-7	0.005	ND		ND		NA		ND		ND	
N-nitrosodiphenylamine	86-30-6	0.002	ND		ND		NA		ND		ND	
N-nitrosodi-n-propylamine	621-64-7	0.002	ND		ND		NA		ND		ND	
pentachlorophenol	87-86-5	0.001	ND		ND		NA		ND		ND	
phenanthrene	85-01-8	0.001	0.002	J	ND		NA		ND		ND	
phenol	108-95-2	0.001	ND		ND		NA		ND		ND	
pyrene	129-00-0	0.001	ND		ND		NA		ND		ND	
1,2,4-trichlorobenzene	120-82-1	0.001	ND		ND		NA		ND		0.003	.07
2,4,5-trichlorophenol	95-95-4	0.001	ND		ND		NA		ND		ND	
2,4,6-trichlorophenol	88-06-2	0.001	ND		ND		NA		ND		ND	
2-methylphenol	95-48-7	0.002	ND		ND		NA		ND		ND	
2,2'oxybis (1-chloropropane)	108-60-1	0.002	ND		ND		NA		ND		ND	
4-methylphenol	106-44-5	0.002	ND		ND		NA		ND		ND	
4,6-dinitro-2-methylphenol	534-52-1	0.005	ND	R	ND	R	NA		ND	R	ND	R
carbazole	86-74-8	0.001	ND		ND		NA		ND		ND	
Total cyanide	57-12-5	0.000004	ND		ND		ND		ND		ND	

Notes

Analytical methods: Volatiles by SW-846 8240B;
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Inorganics by appropriate SW-846 methods
All results are reported in mg/l.
(a) Sample MW-04 dup is a laboratory duplicate of sample MW-04 and was analyzed for metals only.
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unaffected soils at the north and south ends, respectively, of the Fill Area. RST-33, -35, -47, and -48 are believed to be located within or immediately adjacent to the former creek channel; RST-19 is located immediately southeast of the mounded area. The remainder of the marginally-affected pushes along these sections are believed to be located near, but not within, potential areas of filling.

Cross-section M-M' runs along West Pine Street and establishes the eastern extent of the Fill Area. With the exception of RST-52, which shows the residual effect of fills within the former creek channel, logs of pushes along this section show no fluorescence from land surface to total depth.

Eight subsurface soil samples were collected at locations adjacent to seven ROST pushes in the Fill Area. Sample locations and depths were selected to determine constituent concentrations in soils characterized by ROST logs as either unaffected or affected. All subsurface soil samples were analyzed for TCL volatile and semivolatile constituents. Due to the unknown nature of the fill, a single sample was analyzed for TCL pesticides and PCBs.

Subsurface soil analytical data are summarized in Table 4-1. No target constituents were reported above laboratory limits of quantitation in samples collected from GEO/SB-01, -02, 03, or 04, collected adjacent to RST-38, -49, -46, and -51, respectively. Target constituents reported in the remaining samples consisted primarily of polycyclic aromatic hydrocarbons (PAHs), with naphthalene and phenanthrene detected at the highest concentrations. Extremely low concentrations of BTEX compounds were also reported. the pesticide heptachlor was reported in sample GEO/SB-05/4-9 at 0.01 mg/kg.

Table 4-2 presents a comparison of ROST data and laboratory analytical data for subsurface soil samples collected during the RI. As in the Process Area, the data indicate correlation between TFIs and total PAH concentrations. Analyses of samples collected adjacent to unaffected ROST pushes were essentially non-detect. Samples collected in affected ROST intervals contained total PAH concentrations near 2,000 mg/kg with one exception: a sample collected from the second sandy zone contained only 1 mg/kg total PAH compounds. Figure 4-2 is a graph depicting the correlation between average TFI and total PAH concentrations for subsurface soil samples. As stated previously, this graph is provided for data comparison purposes only.

The approximate extent of affected soil within the Fill Area, based on the ROST data and subsurface soil results, is depicted by the shaded area on Figure 4-3. The vertical and lateral extent of affected soil within the Fill Area appear to be dictated by the placement of fill materials and by sand and clay layers beneath the area. The approximate surface area underlain by affected soils is 2.1 acres. The upper 3 to 4 feet of soil in the Fill Area is generally not affected. Evidence of creosote impact extends into the upper saturated sand beneath the Fill Area. The thickness of creosote-impacted soil varies by location and ranges from several feet to as much as 15 feet.

4.3 Site-Wide Media

As a result of the activities described in Section 2, information available to characterize the nature and extent of affected media on a site-wide basis include surface soil data and ground water data.

4.3.1 Surface Soils

Surface soil analytical data are summarized in Table 4-5. Low concentrations of PAHs were reported in all but two (SS- 6 and SS-7) of the 18 surface soil samples collected during the RI. Concentrations of total PAHs ranged from non-detect in SS-6 and SS-7 to 28.56 mg/kg in SS-10.

4.3.2 Ground Water

The nature and extent of affected Process Area ground water was discussed in Section 4.1.2. Prior to the RI, ground water quality had not been characterized on a site-wide basis. Well locations for the RI were selected to provide site-wide coverage and allow for the evaluation of ground water quality near the site boundary.

Ground water analytical data are summarized in Table 4-4. Results from wells outside of the Process Area indicate that with the exception of extremely low concentrations of carbon disulfide in samples from wells MW-01, -03, and -04, and 0.006 mg/l chloroform in MW-01, no organic target constituents were reported in the four new wells at concentrations above laboratory limits of quantitation. These constituents are not normally associated with creosote and probably have an origin other than former creosoting operations. Concentrations of metals in ground water were fairly consistent throughout the site; therefore, these low concentrations of metals in site ground water are not believed to have resulted from former wood treating operations. Results of site-wide ground water monitoring indicate that although Process Area ground water is known to be affected, ground water at the northwestern end (MW-01), eastern end south of the Process Area (MW-05), southeastern end (MW-04), and in the area between the Process Area and Fill Area (MW-03) remains unaffected.

Table 4-5
Summary of Surface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	SS-11		SS-6		SS-8		SS-9		SS-4		SS-10		SS-7	
		Lab Sample Number	2677435		2677436		2677439		2677440		2677441		2677442		2677443	
		Date Collected	3/13/97		3/13/97		3/13/97		3/13/97		3/13/97		3/13/97		3/13/97	
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
TCL Semivolatiles																
phenol	108-95-2	0.033	ND		ND		ND		ND		ND		ND		ND	
2-chlorophenol	95-57-8	0.033	ND		ND		ND		ND		ND		ND		ND	
1,4-dichlorobenzene	106-46-7	0.033	ND		ND		ND		ND		ND		ND		ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	ND		ND		ND		ND		ND		ND		ND	
1,2,4-trichlorobenzene	120-82-1	0.033	ND		ND		ND		ND		ND		ND		ND	
4-chloro-3-methylphenol	59-50-7	0.067	ND		ND		ND		ND		ND		ND		ND	
acenaphthene	83-32-9	0.033	ND		ND		ND		ND		ND		ND		ND	
4-nitrophenol	100-02-7	0.17	ND		ND		ND		ND		ND		ND		ND	
2,4-dinitrotoluene	121-14-2	0.067	ND		ND		ND		ND		ND		ND		ND	
pentachlorophenol	87-86-5	0.17	ND		ND		ND		ND		ND		ND		ND	
pyrene	129-00-0	0.067	0.16	J	ND		1.1		0.4		0.54		3.5		ND	
2-nitrophenol	88-75-5	0.067	ND		ND		ND		ND		ND		ND		ND	
2,4-dimethylphenol	105-67-9	0.067	ND		ND		ND		ND		ND		ND		ND	
2,4-dichlorophenol	120-83-2	0.033	ND		ND		ND		ND		ND		ND		ND	
2,4,6-trichlorophenol	88-06-2	0.067	ND		ND		ND		ND		ND		ND		ND	
2,4-dinitrophenol	51-28-5	0.17	ND	J	ND	J	ND	J	ND	J	ND		ND		ND	
bis (2-chloroethyl) ether	111-44-4	0.067	ND		ND		ND		ND		ND		ND		ND	
1,3-dichlorobenzene	541-73-1	0.033	ND		ND		ND		ND		ND		ND		ND	
1,2-dichlorobenzene	95-50-1	0.033	ND		ND		ND		ND		ND		ND		ND	
hexachloroethane	67-72-1	0.067	ND		ND		ND		ND		ND		ND		ND	
nitrobenzene	98-95-3	0.033	ND		ND		ND		ND		ND		ND		ND	
isophorone	78-59-1	0.067	ND		ND		ND		ND		ND		ND		ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	ND		ND		ND		ND		ND		ND		ND	
naphthalene	91-20-3	0.033	ND		ND		ND		ND		ND		0.17	J	ND	
hexachlorobutadiene	87-68-3	0.067	ND		ND		ND		ND		ND		ND		ND	
hexachlorocyclopentadiene	77-47-4	0.17	ND		ND		ND		ND		ND		ND		ND	
2-chloronaphthalene	91-58-7	0.033	ND		ND		ND		ND		ND		ND		ND	
acenaphthylene	208-96-8	0.033	ND		ND		0.14	J	0.045	J	ND		0.49		ND	
dimethyl phthalate	131-11-3	0.033	ND		ND		ND		ND		ND		ND		ND	
fluorene	86-73-7	0.033	ND		ND		ND		ND		ND		0.045	J	ND	
4-chlorophenyl phenyl ether	7005-72-3	0.067	ND		ND		ND		ND		ND		ND		ND	
diethyl phthalate	84-66-2	0.067	ND		ND		ND		ND		ND		ND		ND	
N-nitrosodiphenylamine	86-30-6	0.067	ND		ND		ND		ND		ND		ND		ND	
4-bromophenyl phenyl ether	101-55-3	0.1	ND		ND		ND		ND		ND		ND		ND	
hexachlorobenzene	118-74-1	0.1	ND		ND		ND		ND		ND		ND		ND	
phenanthrene	85-01-8	0.033	ND		ND		0.063	J	ND		0.068	J	0.43		ND	
anthracene	120-12-7	0.033	ND		ND		0.11	J	0.06	J	ND		0.53		ND	

Notes
Analytical method: SW-846 8270B
All results are reported on an "as received" basis in mg/kg.
All samples were collected from 0 - 12" depth interval.
(a) Sample SS-27 is a blind duplicate of sample SS-7.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-5
Summary of Surface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	SS-11		SS-6		SS-8		SS-9		SS-4		SS-10		SS-7	
		Lab Sample Number	2677435		2677436		2677439		2677440		2677441		2677442		2677443	
		Date Collected	3/13/97		3/13/97		3/13/97		3/13/97		3/13/97		3/13/97		3/13/97	
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
di-n-butyl phthalate	84-74-2	0.033	ND		ND		ND		ND		0.049	J	0.11	J	0.046	J
fluoranthene	206-44-0	0.033	0.12	J	ND		0.95		0.26	J	0.3	J	3.1		ND	
butyl benzyl phthalate	85-68-7	0.067	ND		ND		ND		ND		ND		ND		ND	
benzo (a) anthracene	56-55-3	0.033	0.067	J	ND		0.64		0.22	J	0.27	J	2.3		ND	
chrysene	218-01-9	0.033	0.11	J	ND		0.85		0.21	J	0.36		3.4		ND	
3,3'-dichlorobenzidine	91-94-1	0.13	ND		ND		ND		ND		ND		ND		ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.067	ND		ND		ND		ND		ND		ND		ND	
di-n-octyl phthalate	117-84-0	0.067	ND		ND		ND		ND		ND		ND		ND	
benzo (b) fluoranthene	205-99-2	0.067	0.18	J	ND		1.4 ✓		0.7		0.93		5.2 ✓		ND	.96
benzo (k) fluoranthene	207-08-9	0.13	ND		ND		0.53		0.25	J	0.34		2.3 ✓		ND	96
benzo (a) pyrene	50-32-8	0.067	0.084	J	ND		0.65 ✓		0.33	J	0.21	J	2.4 ✓		ND	096
indeno (1,2,3-cd) pyrene	193-39-5	0.067	ND		ND		0.54		0.23	J	0.3	J	2.1 ✓		ND	96
dibenz (a,h) anthracene	53-70-3	0.067	ND		ND		0.15	J	ND		0.072	J	0.64 ✓		ND	096
benzo (ghi) perylene	191-24-2	0.067	ND		ND		0.42		0.17	J	0.2	J	1.8		ND	
2-methylphenol	95-48-7	0.067	ND		ND		ND		ND		ND		ND		ND	
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	ND		ND		ND		ND		ND		ND		ND	
4-methylphenol	106-44-5	0.1	ND		ND		ND		ND		ND		ND		ND	
4-chloroaniline	106-47-8	0.1	ND		ND		ND		ND		ND		ND		ND	
2-methylnaphthalene	91-57-6	0.033	ND		ND		ND		ND		ND		0.16	J	ND	
2,4,5-trichlorophenol	95-95-4	0.067	ND		ND		ND		ND		ND		ND		ND	
2-nitroaniline	88-74-4	0.067	ND		ND		ND		ND		ND		ND		ND	
3-nitroaniline	99-09-2	0.067	ND		ND		ND		ND		ND		ND		ND	
dibenzofuran	132-64-9	0.033	ND		ND		ND		ND		ND		ND		ND	
2,6-dinitrotoluene	606-20-2	0.067	ND		ND		ND		ND		ND		0.098	J	ND	
4-nitroaniline	100-01-6	0.1	ND		ND		ND		ND		ND		ND		ND	
4,6-dinitro-2-methylphenol	534-52-1	0.17	ND	R	ND	R	ND	R	ND	R	ND		ND		ND	
carbazole	86-74-8	0.033	ND		ND		0.043	J	ND		ND		0.26	J	ND	

Notes
Analytical method: SW-846 8270B
All results are reported on an "as received" basis in mg/kg.
All samples were collected from 0 - 12" depth interval.
(a) Sample SS-27 is a blind duplicate of sample SS-7.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-5
Summary of Surface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	SS-27 (a)		SS-5		SS-12		SS-3		SS-1		SS-15		SS-14	
		Lab Sample Number	2677446		2677444		2677445		2677447		2678197		2678198		2678199	
		Date Collected	3/13/97		3/13/97		3/13/97		3/13/97		3/14/97		3/14/97		3/14/97	
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
TCL Semivolatiles																
phenol	108-95-2	0.033	ND		ND		ND		ND		ND		ND		ND	
2-chlorophenol	95-57-8	0.033	ND		ND		ND		ND		ND		ND		ND	
1,4-dichlorobenzene	106-46-7	0.033	ND		ND		ND		ND		ND		ND		ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	ND		ND		ND		ND		ND		ND		ND	
1,2,4-trichlorobenzene	120-82-1	0.033	ND		ND		ND		ND		ND		ND		ND	
4-chloro-3-methylphenol	59-50-7	0.067	ND		ND		ND		ND		ND		ND		ND	
acenaphthene	83-32-9	0.033	ND		ND		ND		ND		ND		ND		ND	
4-nitrophenol	100-02-7	0.17	ND		ND		ND		ND		ND		ND		ND	
2,4-dinitrotoluene	121-14-2	0.067	ND		ND		ND		ND		ND		ND		ND	
pentachlorophenol	87-86-5	0.17	ND		ND		ND		ND		ND		ND		ND	
pyrene	129-00-0	0.067	ND		0.098	J	0.48		0.64		0.83		0.12	J	ND	
2-nitrophenol	88-75-5	0.067	ND		ND		ND		ND		ND		ND		ND	
2,4-dimethylphenol	105-67-9	0.067	ND		ND		ND		ND		ND		ND		ND	
2,4-dichlorophenol	120-83-2	0.033	ND		ND		ND		ND		ND		ND		ND	
2,4,6-trichlorophenol	88-06-2	0.067	ND		ND		ND		ND		ND		ND		ND	
2,4-dinitrophenol	51-28-5	0.17	ND		ND		ND		ND		ND		ND		ND	
bis (2-chloroethyl) ether	111-44-4	0.067	ND		ND		ND		ND		ND		ND		ND	
1,3-dichlorobenzene	541-73-1	0.033	ND		ND		ND		ND		ND		ND		ND	
1,2-dichlorobenzene	95-50-1	0.033	ND		ND		ND		ND		ND		ND		ND	
hexachloroethane	67-72-1	0.067	ND		ND		ND		ND		ND		ND		ND	
nitrobenzene	98-95-3	0.033	ND		ND		ND		ND		ND		ND		ND	
isophorone	78-59-1	0.067	ND		ND		ND		ND		ND		ND		ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	ND		ND		ND		ND		ND		ND		ND	
naphthalene	91-20-3	0.033	ND		ND		ND		ND		ND		ND		ND	
hexachlorobutadiene	87-68-3	0.067	ND		ND		ND		ND		ND		ND		ND	
hexachlorocyclopentadiene	77-47-4	0.17	ND		ND		ND		ND		ND		ND		ND	
2-chloronaphthalene	91-58-7	0.033	ND		ND		ND		ND		ND		ND		ND	
acenaphthylene	208-96-8	0.033	ND		ND		ND		0.037	J	ND		ND		ND	
dimethyl phthalate	131-11-3	0.033	ND		ND		ND		ND		ND		ND		ND	
fluorene	86-73-7	0.033	ND		ND		ND		ND		ND		ND		ND	
4-chlorophenyl phenyl ether	7005-72-3	0.067	ND		ND		ND		ND		ND		ND		ND	
diethyl phthalate	84-66-2	0.067	ND		ND		ND		ND		ND		ND		ND	
N-nitrosodiphenylamine	86-30-6	0.067	ND		ND		ND		ND		ND		ND		ND	
4-bromophenyl phenyl ether	101-55-3	0.1	ND		ND		ND		ND		ND		ND		ND	
hexachlorobenzene	118-74-1	0.1	ND		ND		ND		ND		ND		ND		ND	
phenanthrene	85-01-8	0.033	ND		ND		0.087	J	0.091	J	ND		ND		ND	
anthracene	120-12-7	0.033	ND		ND		ND		0.041	J	0.067	J	ND		ND	

Notes
Analytical method: SW-846 8270B
All results are reported on an "as received" basis in mg/kg.
All samples were collected from 0 - 12" depth interval.
(a) Sample SS-27 is a blind duplicate of sample SS-7.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-5
Summary of Surface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Parameter	CAS Number	MP&A Sample ID Lab Sample Number Date Collected Method Detection Limit	SS-27 (a) 2677446 3/13/97 Result	 Notes	SS-5 2677444 3/13/97 Result	 Notes	SS-12 2677445 3/13/97 Result	 Notes	SS-3 2677447 3/13/97 Result	 Notes	SS-1 2678197 3/14/97 Result	 Notes	SS-15 2678198 3/14/97 Result	 Notes	SS-14 2678199 3/14/97 Result	 Notes
di-n-butyl phthalate	84-74-2	0.033	0.044	J	0.055	J	0.057	J	0.051	J	0.038	J	0.04	J	0.042	J
fluoranthene	206-44-0	0.033	ND		0.072	J	0.39		0.42		0.48		0.12	J	ND	
butyl benzyl phthalate	85-68-7	0.067	ND		ND		ND		ND		ND		ND		ND	
benzo (a) anthracene	56-55-3	0.033	ND		0.044	J	0.22	J	0.4		0.54		0.056	J	ND	
chrysene	218-01-9	0.033	ND		0.078	J	0.32	J	0.62		0.93		0.11	J	ND	
3,3'-dichlorobenzidine	91-94-1	0.13	ND		ND		ND		ND		ND		ND		ND	
bis (2-ethylhexyl) phthalate	117-81-7	0.067	ND		ND		ND		ND		ND		ND		0.23	J
di-n-octyl phthalate	117-84-0	0.067	ND		ND		ND		ND		ND		ND		ND	
benzo (b) fluoranthene	205-99-2	0.067	ND		0.13	J	0.54		1.2		2.2		0.19	J	ND	.46
benzo (k) fluoranthene	207-08-9	0.13	ND		ND		0.19	J	0.43		0.65		ND		ND	.66
benzo (a) pyrene	50-32-8	0.067	ND		ND		0.21	J	0.42		0.41		ND		ND	.076
indeno (1,2,3-cd) pyrene	193-39-5	0.067	ND		ND		0.25	J	0.47		0.46		0.086	J	ND	.96
dibenz (a,h) anthracene	53-70-3	0.067	ND		ND		ND		0.14	J	0.16	J	ND		ND	.076
benzo (ghi) perylene	191-24-2	0.067	ND		ND		0.2	J	0.34		0.24	J	0.08	J	ND	
2-methylphenol	95-48-7	0.067	ND		ND		ND		ND		ND		ND		ND	
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	ND		ND		ND		ND		ND		ND		ND	
4-methylphenol	106-44-5	0.1	ND		ND		ND		ND		ND		ND		ND	
4-chloroaniline	106-47-8	0.1	ND		ND		ND		ND		ND		ND		ND	
2-methylnaphthalene	91-57-6	0.033	ND		ND		ND		ND		ND		ND		ND	
2,4,5-trichlorophenol	95-95-4	0.067	ND		ND		ND		ND		ND		ND		ND	
2-nitroaniline	88-74-4	0.067	ND		ND		ND		ND		ND		ND		ND	
3-nitroaniline	99-09-2	0.067	ND		ND		ND		ND		ND		ND		ND	
dibenzofuran	132-64-9	0.033	ND		ND		ND		ND		ND		ND		ND	
2,6-dinitrotoluene	606-20-2	0.067	ND		ND		ND		ND		ND		ND		ND	
4-nitroaniline	100-01-6	0.1	ND		ND		ND		ND		ND		ND		ND	
4,6-dinitro-2-methylphenol	534-52-1	0.17	ND		ND		ND		ND		ND		ND		ND	
carbazole	86-74-8	0.033	ND		ND		ND		ND		ND		ND		ND	

Notes
Analytical method: SW-846 8270B
All results are reported on an "as received" basis in mg/kg.
All samples were collected from 0 - 12" depth interval.
(a) Sample SS-27 is a blind duplicate of sample SS-7.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-5
Summary of Surface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID	SS-13		SS-18		SS-2		SS-17		SS-16	
		Lab Sample Number	2678200		2678201		2678202		2678203		2678204	
		Date Collected	3/14/97		3/14/97		3/14/97		3/14/97		3/14/97	
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes
TCL Semivolatiles												
phenol	108-95-2	0.033	ND		ND		ND		ND		ND	
2-chlorophenol	95-57-8	0.033	ND		ND		ND		ND		ND	
1,4-dichlorobenzene	106-46-7	0.033	ND		ND		ND		ND		ND	
N-nitrosodi-n-propylamine	621-64-7	0.067	ND		ND		ND		ND		ND	
1,2,4-trichlorobenzene	120-82-1	0.033	ND		ND		ND		ND		ND	
4-chloro-3-methylphenol	59-50-7	0.067	ND		ND		ND		ND		ND	
acenaphthene	83-32-9	0.033	ND		0.047	J	ND		ND		ND	
4-nitrophenol	100-02-7	0.17	ND		ND		ND		ND		ND	
2,4-dinitrotoluene	121-14-2	0.067	ND		ND		ND		ND		ND	
pentachlorophenol	87-86-5	0.17	ND		ND		ND		ND		ND	
pyrene	129-00-0	0.067	1.8		2.4		0.2	J	1		0.95	
2-nitrophenol	88-75-5	0.067	ND		ND		ND		ND		ND	
2,4-dimethylphenol	105-67-9	0.067	ND		ND		ND		ND		ND	
2,4-dichlorophenol	120-83-2	0.033	ND		ND		ND		ND		ND	
2,4,6-trichlorophenol	88-06-2	0.067	ND		ND		ND		ND		ND	
2,4-dinitrophenol	51-28-5	0.17	ND		ND		ND		ND		ND	
bis (2-chloroethyl) ether	111-44-4	0.067	ND		ND		ND		ND		ND	
1,3-dichlorobenzene	541-73-1	0.033	ND		ND		ND		ND		ND	
1,2-dichlorobenzene	95-50-1	0.033	ND		ND		ND		ND		ND	
hexachloroethane	67-72-1	0.067	ND		ND		ND		ND		ND	
nitrobenzene	98-95-3	0.033	ND		ND		ND		ND		ND	
isophorone	78-59-1	0.067	ND		ND		ND		ND		ND	
bis (2-chloroethoxy) methane	111-91-1	0.033	ND		ND		ND		ND		ND	
naphthalene	91-20-3	0.033	ND		0.047	J	ND		ND		0.16	J
hexachlorobutadiene	87-68-3	0.067	ND		ND		ND		ND		ND	
hexachlorocyclopentadiene	77-47-4	0.17	ND		ND		ND		ND		ND	
2-chloronaphthalene	91-58-7	0.033	ND		ND		ND		ND		ND	
acenaphthylene	208-96-8	0.033	0.088	J	0.23	J	ND		0.12	J	0.17	J
dimethyl phthalate	131-11-3	0.033	ND		ND		ND		ND		ND	
fluorene	86-73-7	0.033	ND		0.088	J	ND		ND		ND	
4-chlorophenyl phenyl ether	7005-72-3	0.067	ND		ND		ND		ND		ND	
diethyl phthalate	84-66-2	0.067	ND		ND		ND		ND		ND	
N-nitrosodiphenylamine	86-30-6	0.067	ND		0.082	J	ND		ND		ND	
4-bromophenyl phenyl ether	101-55-3	0.1	ND		ND		ND		ND		ND	
hexachlorobenzene	118-74-1	0.1	ND		ND		ND		ND		ND	
phenanthrene	85-01-8	0.033	0.17	J	1.3		0.037	J	0.13	J	0.25	J
anthracene	120-12-7	0.033	0.12	J	0.22	J	ND		0.12	J	0.17	J

Notes
Analytical method: SW-846 8270B
All results are reported on an "as received" basis in mg/kg.
All samples were collected from 0 - 12" depth interval.
(a) Sample SS-27 is a blind duplicate of sample SS-7.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

Table 4-5
Summary of Surface Soil Analytical Results

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

		MP&A Sample ID Lab Sample Number Date Collected	SS-13 2678200 3/14/97		SS-18 2678201 3/14/97		SS-2 2678202 3/14/97		SS-17 2678203 3/14/97		SS-16 2678204 3/14/97		
Parameter	CAS Number	Method Detection Limit	Result	Notes	Result	Notes	Result	Notes	Result	Notes	Result	Notes	
di-n-butyl phthalate	84-74-2	0.033	0.036	J	0.1	J	0.059	J	0.099	J	0.11	J	
fluoranthene	206-44-0	0.033	1.4		3.2		0.066	J	0.68		0.78		
butyl benzyl phthalate	85-68-7	0.067	ND		ND		ND		ND		ND		
benzo (a) anthracene	56-55-3	0.033	1.1		1.1		0.041	J	0.54		0.49		
chrysene	218-01-9	0.033	1.7		1.7		0.062	J	0.8		0.87		
3,3'-dichlorobenzidine	91-94-1	0.13	ND		ND		ND		ND		ND		
bis (2-ethylhexyl) phthalate	117-81-7	0.067	ND		0.078	J	ND		ND		ND		
di-n-octyl phthalate	117-84-0	0.067	ND		ND		ND		ND		ND		
benzo (b) fluoranthene	205-99-2	0.067	3.9		2.1		0.11	J	1.2		1.4		.2
benzo (k) fluoranthene	207-08-9	0.13	1.2		0.8		ND		0.47		0.49		.9
benzo (a) pyrene	50-32-8	0.067	1.4		0.99		0.22	J	0.56		0.71		1.07
indeno (1,2,3-cd) pyrene	193-39-5	0.067	0.95		0.7		0.096	J	0.47		0.6		.95
dibenz (a,h) anthracene	53-70-3	0.067	0.28	J	0.21	J	ND		0.14	J	0.16	J	.092
benzo (ghi) perylene	191-24-2	0.067	0.7		0.75		0.74		0.68		1.2		
2-methylphenol	95-48-7	0.067	ND		ND		ND		ND		ND		
2,2'-oxybis (1-chloropropane)	108-60-1	0.1	ND		ND		ND		ND		ND		
4-methylphenol	106-44-5	0.1	ND		ND		ND		ND		ND		
4-chloroaniline	106-47-8	0.1	ND		ND		ND		ND		ND		
2-methylnaphthalene	91-57-6	0.033	ND		0.05	J	ND		ND		0.23	J	
2,4,5-trichlorophenol	95-95-4	0.067	ND		ND		ND		ND		ND		
2-nitroaniline	88-74-4	0.067	ND		ND		ND		ND		ND		
3-nitroaniline	99-09-2	0.067	ND		ND		ND		ND		ND		
dibenzofuran	132-64-9	0.033	ND		0.075	J	ND		0.036	J	0.093	J	
2,6-dinitrotoluene	606-20-2	0.067	ND		ND		ND		ND		ND		
4-nitroaniline	100-01-6	0.1	ND		ND		ND		ND		ND		
4,6-dinitro-2-methylphenol	534-52-1	0.17	ND		ND		ND		ND		ND		
carbazole	86-74-8	0.033	0.061	J	0.28	J	ND		0.046	J	0.11	J	

Notes
Analytical method: SW-846 8270B
All results are reported on an "as received" basis in mg/kg.
All samples were collected from 0 - 12" depth interval.
(a) Sample SS-27 is a blind duplicate of sample SS-7.
J - Estimated value; in cases of ND, indicates MDL is estimated.
R - Unusable result; analyte may or may not be present in the sample.

5.0 Conclusions

5.1 Conclusions

The following is a summary of major conclusions based on the results of RI activities:

1. The former Gulf States Creosoting site property is currently bounded by Scooba Street on the northeast, Gordon's Creek and Corinne Street on the west and northwest, U.S. Highway 49 on the southwest, and the Southern Railroad on the southeast. The approximate area of the entire property is 80 acres.

2. The Gulf States Creosoting facility operated between the early 1900s and approximately 1960. Operations at the facility were of a relatively small scale, consisting of the use of creosote only in a single pressure cylinder.

3. Creosoting and the associated storage and handling of chemicals were confined to an approximately 2.5-acre Process Area at the northeastern corner of the site. This area, which is now occupied by Courtesy Ford Motors, is currently bounded by Scooba Street, Timothy Lane, the Southern Railroad ditch, and an imaginary line connecting the northwestern side of the Ryan Auto Parts building and the southeastern side of the main Courtesy Ford building. During the operation of the wood treating facility, the area to the southwest of the Process Area was utilized for the storage of treated and untreated wood.

4. The site was redeveloped for commercial and light industrial use beginning in approximately 1962. There are no residential or institutional (e.g., schools) uses of the site.

5. Subsequent to closure of the facility and in conjunction with the redevelopment of the site, grading and filling with demolition debris and other waste materials occurred at the southwestern site boundary near Gordon's Creek. Gordon's Creek was also rechannelized (i.e., moved 200 to 300 feet to the northwest) to allow for the development of land along the extension of West Pine Street.

6. The former site property is currently occupied by several automobile dealerships, auto parts stores, a beverage dealership, a convenience store, and other commercial operations. The Process Area and wood storage areas have been regraded, covered with asphalt, and are no longer evident. The Fill Area remains undeveloped.

7. Dating back to at least 1957, the Process Area and Fill Area have been located within two distinct drainage basins separated by a topographic and drainage divide. The northeastern portion of the site, including the Process Area, is drained to the east by a system of ditches and culverts. The remainder of the site, including the Fill Area, is drained to the west by Gordon's Creek and its tributary ditches.

8. The geology of the Process Area and Fill Area are significantly different, with the exception of an underlying clay aquitard common to both areas. The clay aquitard underlies the uppermost water-bearing units in both areas and represents the top of a massive (120 to 200 feet thick) regional clay of the upper Hattiesburg formation.

9. The Process Area geology and hydrogeology are characterized by three major units: an upper silty clay, 20 to 25 feet thick; a fine- to medium-grained sand channel with a maximum thickness of 20 feet (the upper water-bearing unit); and the underlying clay aquitard. The Process Area sand channel does not extend westward to the Fill Area.

10. The Fill Area geology and hydrogeology are characterized by 20 to 25 feet of interbedded sands and clays (the sandy zones comprising the upper water-bearing unit) and the underlying clay aquitard. The discontinuous sandy zones near Gordon's Creek do not extend northeastward to the Process Area.

11. Ground water flow within the Process Area sand channel is to the east at a gradient of approximately 0.01 feet per foot (in the opposite direction as portrayed by others in previous reports). Estimates of the sand channel's hydraulic conductivity range from 3.8×10^{-4} cm/sec to 2.1×10^{-3} cm/sec. The estimated ground water flow velocity within the sand channel ranges from 0.04 to 0.2 feet per day. The direction of ground water flow within the discontinuous Fill Area sands is unknown, but is anticipated to be toward or downstream along Gordon's Creek.

12. A search of water well databases identified the presence of up to three wells screened at depths of less than 300 feet (i.e., above the massive regional clay) within one mile of the site. The current status and use of these wells are unknown.

13. The ROST system was demonstrated to be an effective screening tool for the delineation of the vertical and lateral extent of creosote-impacted soils within the Process Area and Fill Area. ROST results correlated with laboratory analytical data to allow for the determination of the presence/absence and relative concentrations of creosote.

14. Creosote-impacted soils within the Process Area are confined to areas beneath or immediately adjacent to former wood treating operational features. The surface area underlain by creosote-impacted soils is approximately 3.4 acres in the Process Area.

15. Creosote-impacted soils within the Fill Area are present within and adjacent to areas where filling occurred in conjunction with the redevelopment of the property beginning in approximately 1962. The surface area underlain by creosote-impacted soils is approximately 2.1 acres in the Fill Area.

16. Ground water in the uppermost water-bearing zone beneath the Process Area has been impacted by former wood treating operations. Affected ground water does not extend west of the Process Area; the extent of affected ground water to the north and east of the Process Area has not been defined.

17. ROST pushes through the uppermost water-bearing zone in the Process Area do not indicate the presence of a free-phase creosote plume at the base of the zone.

18. Affected ground water in the Process Area is vertically confined by the underlying massive clay of the Hattiesburg formation. This clay layer affords protection to the drinking water resources of the Hattiesburg area. ROST pushes into this clay indicate the absence of any creosote migration into this layer.

19. Ground water quality beneath the Fill Area has not been characterized, although ROST pushes through the uppermost water-bearing zone indicate the presence of some creosote-impacted sand.

20. Extremely low concentrations of wood treating constituents are present within near-surface soils (i.e., the upper 12 inches) in unpaved and uncovered areas of the site.

21. RI results indicate the lack of a transport mechanism, either currently or historically, for the migration of creosote or other constituents from the Process Area to the Fill Area.

- Available site information indicates that the presence of creosote-impacted soils within the Fill Area is not a result of creosote wood treating operations, but resulted from the placement of creosote-impacted soils and other waste material in the Fill Area during the early 1960s.

22. The results of the RI indicate that affected subsurface media are confined to two separate and distinct areas: the Process Area and the Fill Area. The two areas can be considered independently during the development of possible response scenarios.

5.2 Additional Data Needs

Based upon a review of information obtained during the RI, additional investigative activities will be necessary to determine the extent of affected site media and evaluate potential site remedies. The following sections present additional data needs for the Process Area and Fill Area.

5.2.1 Process Area

RI activities delineated the vertical and lateral extent of creosote-impacted soils within the limits of the site, defined the geometry of the sand channel beneath the Process Area, determined the direction and gradient of ground water flow in the sand channel, and characterized ground water quality in the sand channel beneath the Process Area. The following are additional data needs identified for the Process Area:

1. Determination of the western extent of the Process Area sand channel (i.e., exactly where the channel pinches out);
2. Determination of the geometry of the sand channel to the north and east of the Process Area;
3. Determination of lateral extent of creosote-impacted ground water within the sand channel to the north and east of the Process Area; and
4. Determination of contaminant transport and natural attenuation parameters for the sand channel.

5.2.2 Fill Area

RI activities determined the extent of creosote-impacted soils within the Fill Area and better defined the Fill Area geology. The following are additional data needs identified for the Fill Area:

1. Determination of ground water flow direction within the Fill Area sands;
2. Determination of the hydraulic connection between discontinuous Fill Area sands and Gordon's Creek;
3. Determination of ground water quality within the Fill Area sands.

5.2.3 Other Site Areas

Results of the RI indicate that no additional study is warranted beyond the limits of the Process Area and Fill Area.

Appendix A

Summary of Data from Previous Investigations

Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

2.3 Previous Investigations

Previous investigations performed at the site, with corresponding reports cited, include the following:

- January and March 1990 investigations by Roy F Weston for U.S. EPA (*Soil Gas and Soil Sampling*, Roy F. Weston, Inc., May 1990);
- An October 1991 investigation by MDEQ (*Site Inspection, Phase II Report*, MDEQ, January 7, 1992);
- A May 1994 investigation by Environmental Protection Systems (EPS) (*Phase II Site Investigation of the Former Gulf States Creosote Company Process Area*, EPS, July 1994);
- A June 1994 investigation by Bonner Analytical Testing Company (BATCO) (Letter to Mrs. John D. Thomas re former Gibson's Shopping Center property, BATCO, July 7, 1994);
- An October/November 1994 investigation by BATCO (*A Preliminary Subsurface Investigation, Ryan Motors/RSCO Realty*, BATCO, October 31 through November 3, 1994);
- A report from a June/July 1995 investigation by BATCO (Letter to Mrs. John D. Thomas re former Gibson's Shopping Center property, BATCO, September 14, 1995).
- Two late-1995 three-dimensional resistivity surveys by American Remediation Technology (*Three-Dimensional Resistivity Survey, Courtesy Ford Facility*, American Remediation Technology, December 19, 1995 and *Three-Dimensional Resistivity Survey, West Pine Street Drainage Ditch Area*, American Remediation Technology, December 22, 1995);
- A May 1996 investigation by McLaren/Hart (*Report of Investigative Activities*, McLaren/Hart, June 16, 1996 and *Report of Investigative Activities, Supplemental Information*, McLaren/Hart, June 25, 1996); and
- A June 1996 investigation by Kerr-McGee Chemical (no report issued; laboratory reports and boring logs available).

A map depicting sampling locations from previous investigations is provided as Figure 2-2. Summaries including the number and types of samples collected and analytical results areprovided in the following sections. Inclusion of these summaries is for informational purposes only and does not represent an endorsement or validation of this work.

2.3.1 1990 Roy F. Weston Investigations

Roy F. Weston conducted site investigation activities in January and March 1990. The following activities were completed during the Roy F. Weston investigations:

- Advanced 17 soil borings to depths ranging from 3 to 14 feet;
- Analyzed 19 subsurface soil samples for polynuclear aromatic hydrocarbons (PAHs);
- Sampled or monitored 65 soil gas sampling stations; and
- Analyzed three air samples for PAHs.

Subsurface soil analytical results from the January and March Roy F. Weston investigations are summarized in Tables 2-1 and 2-2, respectively. Of the 19 subsurface soil samples collected, 12 contained detectable concentrations of PAHs. Samples collected

Table 2-1
Summary of Soil Analytical Data
January 1990 Roy F. Weston Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	**B0 2.5**	**D00**	**D00**	**D01**	**D01**	**E20**
Sample Depth	**0-12 in.**	**5 ft.**	**8 ft.**	**5 ft.**	**8 ft.**	**4 ft.**
Constituent						
Naphthalene	ND	178	354	280	148	4.1J
2-Methylnaphthalene	ND	99	197	460	82	3.6J
1-Methylnaphthalene	ND	72	104	340	45	ND
Biphenyl	ND	22J	55	9J	24	ND
2,6-Dimethylnaphthalene	ND	72	65	53	28	ND
Acenaphthylene	ND	4.4J	4.2J	2.3J	ND	ND
Acenaphthene	ND	259	156	225	81	14J
Dibenzofuran	ND	158	125	114	78	4.7J
Fluorene	ND	245	140	219	90	9.4J
Phenanthrene	6.5J	718	325	715	229	26
Anthracene	ND	465	210	521	114	69
Carbazole	ND	173	96	157	38	15J
Fluoranthene	3J	844	215	763	188	138
Pyrene	1.1J	181	64	266	65	98
Benzo(a)anthracene	1.6J	181	54	259	62	104
Chrysene	2.9J	230	61	318	73	160
Benzo(b)fluoranthene	3.8J	ND	78	143	127	248
Benzo(k)fluoranthene	ND	231	74	135	121	236
Benzo(c)pyrene	2.5J	83	25	97	52	83
Benzo(a)pyrene	2.5J	125	35	133	55	116
Indeno(1,2,3-cd)pyrene	1.8J	51	15J	54	26	53
Dibenzo(a,h)anthracene	.5J	23	5J	19J	12J	17J
Benzo(g,h,i)perylene	1.5J	41	11J	42	22	42

Notes: Only those samples containing detectable PAHs are included in this table.
All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-2
Summary of Soil Analytical Data
March 1990 Roy F. Weston Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	D03A	D03A	E19	E24	E25	E27
Sample Depth	10 ft. Top of Auger	Bottom of Auger	11 ft.	8 ft.	8 ft.	8 ft.
Constituent						
Naphthalene	.5J	7.3	2.5	544	48	753
2-Methylnaphthalene	ND	.1J	0.9	224	26	293
1-Methylnaphthalene	ND	.06J	0.6	107	26	193
Biphenyl	ND	.02J	.3J	55	3.5J	140
2,6-Dimethylnaphthalene	ND	ND	.4J	71	13	160
Acenaphthylene	ND	ND	.04J	7.3J	2.4J	20
Acenaphthene	ND	.1J	1.5	264	86	213
Dibenzofuran	ND	.05J	0.7	159	37	125
Fluorene	ND	.05J	0.9	194	66	129
Phenanthrene	ND	.04J	2.7	420	136	425
Anthracene	ND	ND	1.7	87	41	126
Carbazole	ND	0.07	0.3	48	5.5J	59
Fluoranthene	.1J	.03J	2.9	224	144	288
Pyrene	.2J	.04J	3.4	180	126	296
Benzo(a)anthracene	.07J	ND	1.1	52	34	100
Chrysene	.08J	ND	1.2	42	37	86
Benzo(b)fluoranthene	ND	ND	1	ND	ND	86
Benzo(k)fluoranthene	ND	ND	0.4	27J	30	ND
Benzo(c)pyrene	ND	ND	0.5	ND	9.7J	31
Benzo(a)pyrene	ND	ND	0.6	ND	11	42
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND

Notes: Only those samples containing detectable PAHs are included in this table.
All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

from the Gordon's Creek fill area between West Pine Street and Gordon's Creek exhibited the highest concentrations of PAHs.

Results of the soil gas survey indicated that there was no apparent relationship between field screening results using hand-held photoionization and flame ionization detectors (PIDs and FIDs) and soil gas analytical results. Results of air sampling performed prior to initiation of the investigations indicated that ambient air quality had not been affected by site residuals.

2.3.2 October 1991 MDEQ Investigation

MDEQ conducted site investigation activities in October 1991. The following activities were completed during the MDEQ investigation:

- Advanced two soil borings to unknown depths;
- Analyzed two subsurface soil samples for semivolatile constituents;
- Analyzed three ground water samples (two from temporary wells, one from a City of Hattiesburg municipal well) for semivolatile constituents; and
- Analyzed two sediment samples for semivolatile constituents.

Analytical results from the MDEQ investigation are summarized in Table 2-3. The subsurface soil sample collected as a background sample (GS-SB-01) contained no semivolatile constituents, while the sample collected from the Gordon's Creek fill area (GS-SB-02) contained 3,500 and 4,200 mg/kg phenanthrene and anthracene, respectively, as well as other semivolatile constituents. The sediment sample collected upstream of the two drainage pathways (GS-SD-01) contained low concentrations (less than one mg/kg) phenanthrene, fluoranthene, and pyrene; the downstream sediment sample (GS-SD-02) contained 18,000 mg/kg phenanthrene plus other semivolatile constituents. None of the three ground water sample (GS-TW-01, GS-TW-02, or GS-PW-01) contained detectable concentrations of semivolatile constituents.

2.3.3 May 1994 Environmental Protection Systems Investigation

Environmental Protection Systems (EPS) conducted site investigation activities in May 1994. The following activities were completed during the EPS investigation:

- Advanced 16 soil borings to depths ranging from 1.5 to 36 feet in the former process area;
- Analyzed 36 subsurface soil samples for PAHs;
- Installed four ground water monitoring wells; and
- Analyzed four ground water samples for PAHs.

Soil analytical results from the EPS investigation are summarized in Table 2-4. PAHs in subsurface "soil" samples from the former process area were reported at concentrations indicating that either tank bottom materials or other creosote-saturated materials were sampled. Typically, samples collected from borings which met refusal, indicating the presence of subsurface process area debris, contained a higher range of PAHs.

Ground water analytical results from the EPS investigation are summarized in Table 2-5. PAHs were reported in ground water samples collected from three of the monitoring wells completed in the process area.

Table 2-3
Summary of Analytical Data
1991 MDEQ Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Location	Upgradient Well	Downgradient Well	Upstream Sediment	Downstream Sediment	Background Soil	Soil - Source Area
Sample Name	GS-TW-01	GS-TW-02	GS-SD-01	GS-SD-02	GS-SB-01	GB-SB-02
Constituent						
Naphthalene	ND	ND	ND	240	ND	1,900
2-Methylnaphthalene	ND	ND	ND	240	ND	1,400
Acenaphthylene	ND	ND	ND	Trace	ND	Trace
Acenaphthene	ND	ND	ND	370	ND	970
Dibenzofuran	ND	ND	ND	400	ND	1,000
Fluorene	ND	ND	ND	550	ND	1,500
Phenanthrene	ND	ND	0.47	18,000	ND	3,500
Anthracene	ND	ND	ND	220	ND	4,200
Fluoranthene	ND	ND	0.7	770	ND	1,600
Pyrene	ND	ND	0.47	490	ND	770
Benzo(a)anthracene	ND	ND	Trace	170	ND	270
Chrysene	ND	ND	Trace	160	ND	280
Benzo(b)fluoranthene	ND	ND	ND	58	ND	113
Benzo(k)fluoranthene	ND	ND	ND	72	ND	100
Benzo(a)pyrene	ND	ND	ND	60	ND	85
Indeno(1,2,3-cd)pyrene	ND	ND	ND	Trace	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	Trace	ND	ND

Notes: All concentrations are reported in mg/kg or mg/l (ppm).
ND - Constituent not detected at or above laboratory detection limit.

Table 2-4
Summary of Soil Analytical Data
1994 EPS Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Date Sampled	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94	5/24/94	5/25/94	5/25/94	5/25/94	5/24/94
Sample Location	SB1/001	SB2/002	SB2/003	SB2/004	SB3/001	SB3/002	SB4-1/001	SB4-3/002	SB4-3/003	SB4-3/004	SB5/001
Sample Depth	3-5 feet	8-10 feet	13 - 15 feet	18 - 20 feet	3 - 5 feet	8 - 10 feet	3 - 5 feet	8 - 10 feet	13 - 15 feet	18 - 20 feet	3 - 5 feet
Constituent											
Methylnaphthalene	41.5	52.77	18.12	449	818	ND	21,778	1,475	ND	ND	ND
Acenaphthene	1.63	51.52	49.19	ND	357	ND	4,396	2,541	1,725	48.88	27.84
Acenaphthylene	ND	ND	106	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	7,685	19,261	3,339	3,486	13,115	ND	284,781	327,549	10,261	2,346	196,894
Chrysene	ND	ND	ND	ND	23.79	ND	ND	4,344	ND	ND	ND
Dibenzofuran	136	42.72	36.89	66.6	247	ND	ND	2,459	1,315	ND	ND
Fluoranthene	942	668	210	241	1,555	ND	33,566	97,625	6,326	311	368
Fluorene	290	119	91.91	82.46	404	ND	4,529	8,524	2,494	62.21	47.49
Naphthalene	29	28.9	22.65	ND	23,857	1,390	250,882	195,742	4,615	2,675	ND
Phenanthrene	189	37.7	ND	ND	504	31.12	1,998	ND	ND	ND	ND
Pyrene	521	168	62.78	66.1	409	ND	ND	105,084	4,466	71.1	ND
Benzo(b)fluoranthene	ND	ND	10.35	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	1,066	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	573	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	6,042	ND	ND
Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	46.62	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	119	124	ND

Notes: Only those samples containing detectable PAHs are included in this table.
Only those parameters detected in one or more samples are included in this table.
All concentrations are reported in mg/kg (ppm) using detection limits for ground water.
ND - Constituent not detected at or above laboratory detection limit.
Table includes only those parameters detected in one or more samples.

Table 2-4
Summary of Soil Analytical Data
1994 EPS Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Date Sampled	5/24/94	5/25/94	5/25/94	5/25/94	5/25/94	5/25/94	5/25/94	5/26/94	5/26/94	5/26/94
Sample Location	SB5/002	SB7/001	SB8/001	SB9/001	SB10/001	SB10/002	SB10/004	SB11/001	SB12/001	SB13/001
Sample Depth	8 -10 feet	3 - 5 feet	2 feet	1.5 feet	3 - 5 feet	8 - 10 feet	18 - 20 feet	2 feet	3 feet	3 - 5 feet
Constituent										
Methylnaphthalene	20.45	ND	ND	ND	ND	ND	2,506	ND	1,055	ND
Acenaphthene	18.94	18.55	ND	15,136	962	ND	857	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	478,712	10,499	ND	40,722	47,362	86,752	888
Chrysene	ND	ND	ND	ND	ND	ND	76.34	939	ND	ND
Dibenzofuran	165	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	28.2	13.32	ND	167,509	5,034	ND	9,139	5,331	2,133	197
Fluorene	17.8	ND	ND	13,420	772	ND	674	ND	ND	ND
Naphthalene	66.66	146	ND	ND	4,607	ND	10,830	ND	12,573	ND
Phenanthrene	ND	12.84	17,819	ND	ND	ND	818	ND	ND	ND
Pyrene	ND	47.1	17,659	53,986	2,752	ND	3,751	2,261	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	43.48	ND	ND	ND	ND
Methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: Only those samples containing detectable PAHs are included in this table.
Only those parameters detected in one or more samples are included in this table.
All concentrations are reported in mg/kg (ppm) usimg detection limits for ground water.
ND - Constituent not detected at or above laboratory detection limit.
Table includes only those parameters detected in one or more samples.

Table 2-5
Summary of Ground Water Analytical Data
1994 EPS Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Date Sampled	5/27/94	5/27/94	5/27/94
Well Number	MW1	MW2	MW3
Constituent	ND	ND	ND
Naphthalene	123	216	443
Phenol	ND	2.87	ND
2,4-Dimethylphenol	ND	ND	63.36

Notes: Only those samples containing detectable PAHs are included in this table.
Only those parameters detected in one or more samples are included in this ta
All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
Table includes only those parameters detected in one or more samples.
Method detection limit (MDL) = 0.01 ppm

2.3.4 June 1994 BATCO Investigation

BATCO conducted a Phase II investigation at Gibson's Shopping Center in June 1994. The following activities were completed during the BATCO investigation:

- Advanced 12 soil borings to depths of up to 20 feet
- Analyzed 36 subsurface soil samples for PAHs; and
- Analyzed three ground water samples for PAHs.

Analytical results from the BATCO investigation at Gibson's Shopping Center are summarized in Table 2-6. PAHs were reported in only two of 36 soil samples. PAHs were not reported in any of the three ground water samples collected. No boring logs were provided with the report.

2.3.5 October/November 1994 BATCO Investigation

BATCO conducted a Phase II investigation at Ryan Motors in October and November 1994. The following activities were completed during the BATCO investigation:

- Advanced nine soil borings to depths of up to 20 feet
- Analyzed 18 subsurface soil samples for PAHs; and
- Analyzed seven ground water samples for PAHs.

Analytical results from the BATCO investigation at Ryan Motors are summarized in Table 2-7. PAHs were reported in 12 of 18 soil samples and in five of seven ground water samples collected. No survey data or boring logs were provided with the report.

2.3.6 June/July 1995 BATCO Investigation

BATCO conducted additional soil investigations at Gibson's Shopping Center in June and July 1995. The following activities were completed during the BATCO investigation:

- Advanced 14 soil borings to depths of up to 30 feet; and
- Analyzed 35 subsurface soil samples for PAHs.

Analytical results from the BATCO investigation at Gibson's Shopping Center are summarized in Table 2-7b. PAHs were reported in 14 of 35 soil samples collected. No survey data or boring logs were provided with the report; the map provided in the report was inadequate to plot sample locations..

2.3.7 1995 American Remediation Technology 3-D Resistivity Surveys

In late 1995, American Remediation Technology performed three-dimensional resistivity (3DR) surveys in both the process area and the Gordon's Creek fill area.

2.3.8 May 1996 McLaren/Hart Investigation

McLaren/Hart conducted site investigation activities in May 1996. The following activities were completed during the McLaren/Hart investigation:

- Advanced nine soil borings to depths ranging from 20 to 50 feet; and

Table 2-6
Summary of Soil Analytical Data
June 1994 Bonner Phase II Investigation
Gibson's Shopping Center

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #1	Hole #1	Hole #1	Hole #2	Hole #2	Hole #2	Hole #3	Hole #3	Hole #3	Hole #4
Sample Depth	3' - 5'	10'	15'	1'	5'	Composite	0 - 1'	5'	Composite	0 - 1'
Sample Type	Soil	Soil	Water	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Constituent										
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-6
Summary of Soil Analytical Data
June 1994 Bonner Phase II Investigation
Gibson's Shopping Center

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #4	Hole #4	Hole #5	Hole #5	Hole #5	Hole #6	Hole #6	Hole #6	Hole #7	Hole #7
Sample Depth	5'	Composite	0 - 1'	5'	Composite	0 - 1'	5'	Composite	0 - 1'	5'
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Constituent										
Naphthalene	ND	ND	ND	ND	ND	0.0068 J	ND	ND	0.730 J	ND
Acenaphthylene	ND	ND	ND	ND	ND	0.0505 J	ND	ND	4.615 J	ND
Acenaphthene	ND	ND	ND	ND	ND	0.0107 J	ND	ND	2.470 J	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	4.719 J	ND
Phenanthrene	ND	ND	ND	ND	ND	0.0903 J	ND	ND	8.562 J	ND
Anthracene	ND	ND	ND	ND	ND	0.0883 J	ND	ND	8.374 J	ND
Fluoranthene	ND	ND	ND	ND	ND	0.596	ND	ND	78.960	ND
Pyrene	ND	ND	ND	ND	ND	0.698	ND	ND	75.011	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	0.7	ND	ND	42.449	ND
Chrysene	ND	ND	ND	ND	ND	0.727	ND	ND	44.074	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	0.788	ND	ND	43.681	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	0.807	ND	ND	44.746	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	0.501	ND	ND	30.450	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	0.467	ND	ND	22.322	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	0.115 J	ND	ND	5.871 J	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	0.261 J	ND	ND	13.008 J	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-6
Summary of Soil Analytical Data
June 1994 Bonner Phase II Investigation
Gibson's Shopping Center

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	**Hole #7**	**Hole #7**	**Hole #7**	**Hole #7**	**Hole #8**	**Hole #8**	**Hole #8**	**Hole #9**	**Hole #9**	**Hole #9**
Sample Depth	**10'**	**10' Dup**	**15'**	**20'**	**0 - 1'**	**5'**	**Composite**	**0 - 1'**	**5'**	**Composite**
Sample Type	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**
Constituent										
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-6
Summary of Soil Analytical Data
June 1994 Bonner Phase II Investigation
Gibson's Shopping Center

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	**Hole #10**	**Hole #10**	**Hole #10**	**Hole #11**	**Hole #11**	**Hole #11**	**Hole #12**	**Hole #12**	**Hole #12**
Sample Depth	**0 - 1'**	**5'**	**Composite**	**0 - 1'**	**5'**	**Composite**	**0 - 1'**	**5'**	**6'**
Sample Type	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Soil**	**Water**
Constituent									
Naphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-7
Summary of Soil Analytical Data
October/November 1994 Bonner Phase II Investigation
[redacted]

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #2	Hole #5	Hole #5	Hole #5	Hole #5	Hole #5	Hole #2	Hole #2	Hole #2	Hole #11	Hole #1	Hole #3
Sample Depth	0 - 2'	0 - 2'	5'	7'	10'	10'	5'	10'	10'	[illegible]		
Sample Type	Soil	Soil	Soil	Soil	Soil	Water	Soil	Soil	Water	Soil	Water	Water
Constituent												
Naphthalene	ND	ND	16.741 J	90.839	13.967 J	2.377	ND	40.143 J	2.766	40.242 J	ND	ND
Acenaphthylene	ND	1.845 J	ND	1.841 J	ND	0.0205	ND	ND	0.0275	ND	ND	ND
Acenaphthene	ND	ND	3.249 J	28.693 J	2.937 J	0.217	ND	8.537 J	0.178	17.203 J	ND	ND
Fluorene	0.304	ND	4.117 J	46.014 J	3.945 J	0.138	ND	9.547 J	0.193	27.034 J	ND	ND
Phenanthrene	0.538	1.818 J	9.979 J	101.277	9.067 J	0.109	ND	24.684 J	0.275	67.280 J	ND	ND
Anthracene	3.385	2.603 J	9.954 J	136.074	9.465 J	0.0216	ND	4.951 J	0.0453	67.418 J	ND	ND
Fluoranthene	1.326	16.812 J	6.289 J	43.544 J	5.098 J	0.0154	ND	10.105 J	0.0334	29.179 J	ND	ND
Pyrene	1.716	49.564	9.439 J	44.532 J	9.312 J	0.0155	0.339	8.197 J	0.0227	24.495 J	ND	ND
Benzo(a)anthracene	0.503	12.046 J	2.820 J	11.830 J	2.142 J	ND	ND	2.196 J	ND	6.501 J	ND	ND
Chrysene	0.776	17.181 J	3.516 J	12.577 J	2.768 J	ND	0.162 J	2.108 J	ND	6.069 J	ND	ND
Benzo(b)fluoranthene	0.335	21.119	2.530 J	6.763 J	3.785 J	ND	0.289	1.038 J	ND	3.370 J	ND	ND
Benzo(k)fluoranthene	0.307	22.590	2.240 J	6.408 J	4.376 J	ND	0.239	ND	ND	ND	ND	ND
Benzo(a)pyrene	0.232	15.849 J	2.186 J	6.050 J	1.876 J	ND	0.189 J	ND	ND	3.068 J	ND	ND
Indeno(1,2,3-cd)pyrene	ND	7.382 J	ND	1.213 J	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	1.102 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	6.002 J	ND	1.123 J	ND	ND	ND	ND	ND	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-7
Summary of Soil Analytical Data
October/November 1994 Bonner Phase II Investigation
[redacted]

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #4	Hole #6	Hole #9	Hole #3	Hole #4	Hole #8	Hole # 8	Hole #8	Hole #8	Hole #8	Hole #8	Hole #9	Hole #10
Sample Depth				Composite	*Composite*	Composite	20 '	15'	10'	5'	0 - 2'	Composite	Composite
Sample Type	Water	Water	Water	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Constituent													
Naphthalene	1.079	3.742	4.606	ND	ND	ND	ND	ND	ND	0.00366 J	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	1.424	1.396	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	2.097	2.619	ND	ND	0.00604 J	ND	ND	ND	0.0519 J	ND	ND	ND
Phenanthrene	ND	3.195	8.138	ND	ND	0.0262 J	ND	ND	ND	0.254	ND	ND	ND
Anthracene	ND	ND	8.163	ND	ND	0.00695 J	ND	ND	ND	0.0508 J	ND	ND	ND
Fluoranthene	ND	ND	1.927	ND	ND	0.0125 J	ND	ND	ND	0.0723 J	ND	ND	ND
Pyrene	ND	ND	1.554	ND	ND	0.0110 J	ND	ND	ND	0.0727 J	ND	ND	0.00764 J
Benzo(a)anthracene	ND	ND	ND	ND	ND	0.00276 J	ND	ND	ND	0.0175 J	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	0.00281 J	ND	ND	ND	0.0170 J	ND	ND	0.00282 J
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00899 J	ND	ND	0.00462 J
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0129 J	1.069	ND	0.00534 J
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00675 J	ND	ND	0.00296 J
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the *concentration is* given as an approximate value.

Table 2-7B
Summary of Soil Analytical Data
June and July 1995 Bonner Investigation
Sunflower Building

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #1	Hole #1	Hole #1	Hole #2	Hole #2	Hole #2	Hole #2	Hole #3	Hole #3	Hole #4	Hole #4	Hole #4
Sample Depth	0 - 2'	5'	7'	6" - 12"	2' - 2.5'	4' - 4.5'	6' - 7'	12" - 18"	6' - 7'	12" - 18"	4' - 4.5'	6' - 7'
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Constituent												
Naphthalene	0.63	ND	ND	3.42	0.18 J	0.06 J	ND	1.52	ND	0.41	ND	ND
Acenaphthylene	1.78	ND	ND	7.62	0.03 J	ND	ND	2.72	ND	2.01	ND	ND
Acenaphthene	0.33	ND	ND	3.06	0.17 J	ND	ND	6.07	ND	13.74	ND	ND
Fluorene	0.40	ND	ND	4.03	0.20 J	0.03 J	ND	11.12	ND	19.60	ND	ND
Phenanthrene	5.49	ND	ND	24.78	1.65	ND	ND	48.31	ND	78.10	ND	ND
Anthracene	1.66	ND	ND	17.84	0.20 J	ND	ND	16.21	ND	31.25	ND	ND
Fluoranthene	11.52	ND	ND	86.25	0.83 J	0.03 J	ND	52.47	ND	75.00	ND	ND
Pyrene	16.24	ND	ND	206.95	0.44 J	0.02 J	ND	74.37	ND	76.36	ND	ND
Benzo(a)anthracene	12.10	ND	ND	98.66	0.21 J	0.02 J	ND	31.98	ND	11.92	ND	ND
Chrysene	12.33	ND	ND	83.73	0.23 J	ND	ND	29.93	ND	40.96	ND	ND
Benzo(b)fluoranthene	17.68	ND	ND	100.18	0.25 J	ND	ND	30.45	ND	36.84	ND	ND
Benzo(k)fluoranthene	8.05	ND	ND	36.61	0.06J	ND	ND	12.61	ND	9.45	ND	ND
Benzo(a)pyrene	10.09	ND	ND	58.48	0.12 J	ND	ND	19.64	ND	30.63	ND	ND
Indeno(1,2,3-cd)pyrene	7.76	ND	ND	28.11	0.05 J	ND	ND	12.60	ND	ND	ND	ND
Dibenzo(a,h)anthracene	2.95	ND	ND	12.52	ND	ND	ND	4.94	ND	ND	ND	ND
Benzo(g,h,i)perylene	6.82	ND	ND	21.12	0.03 J	ND	ND	8.19	ND	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 330.0 ug/kg, but greater than zero and the concentration is given as an approximate value.

Table 2-7B
Summary of Soil Analytical Data
June and July 1995 Bonner Investigation
Sunflower Building

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #5	Hole #5	Hole #5	Hole #6	Hole #6	Hole #6	Hole #7	Hole #7	Hole #8	Hole #8	Hole #9	Hole #9
Sample Depth	12" - 18"	4' - 4.5'	6' - 7'	12" - 18"	4' - 4.5'	6' - 7'	0 - 1'	3.5' - 5'	0 - 1'	3.5' - 5'	0 - 1'	3.5' - 5'
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Constituent												
Naphthalene	0.14 J	ND	ND	0.04 J	ND	ND	0.25 J	ND	0.16 J	ND	ND	ND
Acenaphthylene	0.52	ND	ND	0.49	ND	ND	0.84	ND	1.53	ND	ND	ND
Acenaphthene	0.35	ND	ND	0.03 J	ND	ND	0.23 J	ND	0.08 J	ND	ND	ND
Fluorene	0.71	ND	ND	0.11 J	ND	ND	0.27 J	ND	0.26 J	ND	ND	ND
Phenanthrene	5.26	ND	ND	1.06	ND	ND	1.49	ND	2.68	ND	ND	ND
Anthracene	3.78	ND	ND	0.56	ND	ND	0.71	ND	1.29	ND	ND	ND
Fluoranthene	13.04	ND	ND	6.30	ND	ND	5.95	ND	13.53	ND	0.086 J	ND
Pyrene	14.36	ND	ND	8.09	ND	ND	8.22	ND	25.16	ND	0.18 J	ND
Benzo(a)anthracene	7.76	ND	ND	3.13	ND	ND	3.88	ND	8.62	ND	0.05 J	ND
Chrysene	9.78	ND	ND	5.41	ND	ND	7.18	ND	13.99	ND	0.14 J	ND
Benzo(b)fluoranthene	9.91	ND	ND	4.96	ND	ND	8.88	ND	19.27	ND	0.29 J	ND
Benzo(k)fluoranthene	9.63	ND	ND	5.21	ND	ND	10.18	ND	10.15	ND	0.03 J	ND
Benzo(a)pyrene	8.20	ND	ND	3.99	ND	ND	8.23	ND	9.24	ND	0.10 J	ND
Indeno(1,2,3-cd)pyrene	2.94	ND	ND	2.50	ND	ND	5.88	ND	8.39	ND	0.02 J	ND
Dibenzo(a,h)anthracene	1.92	ND	ND	1.09	ND	ND	2.55	ND	0.97	ND	ND	ND
Benzo(g,h,i)perylene	2.52	ND	ND	1.80	ND	ND	3.13	ND	5.75	ND	ND	ND

Notes: All concentrations are reported in mg/kg (ppm).

ND - Constituent not detected at or above laboratory detection limit.

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

Table 2-7B
Summary of Soil Analytical Data
June and July 1995 Bonner Investigation
Sunflower Building

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample Location	Hole #10	Hole #10	Hole #11	Hole #11	Hole #11	Hole #12	Hole #12	Hole #13	Hole #13	Hole #14	Hole #14
Sample Depth	0 - 1'	3.5' - 5'	0 - 1'	2'	3.5' - 5'	0 - 18"	4'	12 - 18"	24 - 30'	6 - 18"	24 - 30'
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Constituent											
Naphthalene	ND	ND	0.36	0.03 J	ND	0.52	ND	0.04 J	ND	0.27 J	ND
Acenaphthylene	ND	ND	0.88	0.22 J	ND	1.26	ND	0.12 J	ND	0.44	ND
Acenaphthene	ND	ND	0.30 J	0.01 J	ND	0.75	ND	0.08 J	ND	0.02 J	ND
Fluorene	ND	ND	0.70 J	0.02 J	ND	1.53	ND	0.14 J	ND	ND	ND
Phenanthrene	ND	ND	6.41	0.14 J	ND	10.36	ND	1.95	ND	0.61	ND
Anthracene	ND	ND	1.54	0.12 J	ND	2.54	ND	0.62	ND	0.35	ND
Fluoranthene	ND	ND	19.48	0.63	ND	26.28	ND	2.93	ND	2.00	ND
Pyrene	ND	ND	28.58	0.80	ND	24.27	ND	2.44	ND	1.74	ND
Benzo(a)anthracene	ND	ND	12.12	0.54	ND	16.68	ND	1.17	ND	1.07	ND
Chrysene	ND	ND	13.61	0.86	ND	18.92	ND	1.71	ND	1.73	ND
Benzo(b)fluoranthene	ND	ND	13.79	1.24	ND	19.44	ND	1.58	ND	2.31	ND
Benzo(k)fluoranthene	ND	ND	5.83	1.26	ND	9.32	ND	1.43	ND	1.98	ND
Benzo(a)pyrene	ND	ND	7.24	1.11	ND	12.43	ND	1.18	ND	1.79	ND
Indeno(1,2,3-cd)pyrene	ND	ND	4.66	0.81	ND	6.63	ND	0.68	ND	1.40	ND
Dibenzo(a,h)anthracene	ND	ND	1.24	0.14	ND	1.10	ND	0.12	ND	0.26 J	ND
Benzo(g,h,i)perylene	ND	ND	3.26	0.72	ND	5.71	ND	0.52	ND	1.18	ND

Notes: All concentrations are reported in mg/kg (ppm).
ND - Constituent not detected at or above laboratory detection limit.
J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the lowest linear detection limit of 10.0 ug/ml, but greater than zero and the concentration is given as an approximate value.

- Analyzed 18 subsurface soil samples for phenols.

Soil analytical results from the McLaren/Hart investigation are summarized in Table 2-8. Phenols were detected in 13 of the 18 subsurface soil samples analyzed. However, only samples from borings SB-1 at a depth of 8 to 10 feet below land surface and SB-2 at a depth of 13 to 15 feet below land surface contained phenols concentrations greater than 6.7 mg/kg (56.8 and 48.4 mg/kg, respectively).

No maps depicting boring locations or survey data were provided with the McLaren/Hart reports. Boring locations depicted on Figure 2-2 are approximate based on a sketch provided in the September 17, 1996 deposition of Joseph W. Abshire.

2.3.8 June 1996 TDS Investigation

TDS conducted site investigation activities in June 1996. The following activities were completed during the TDS investigation:

- Advanced six soil borings in and adjacent to the Gordon's Creek fill area to depths ranging from 16 to 51 feet; and
- Analyzed 12 subsurface soil samples for compounds associated with creosote wood treating operations and total petroleum hydrocarbons (TPH) as diesel and oil.

Soil analytical results from the TDS investigation are summarized in Table 2-9. Only one sample, collected from boring B6 at a depth of 13.5 to 14.0 feet below land surface, contained detectable concentrations of compounds associated with creosote wood treating operations. TPH as diesel and oil were not reported in any samples above laboratory detection limits.

Table 2-8
Summary of Soil Analytical Data
May 1996 McLaren/Hart Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Sample ID	Date Sampled	Sample Depth (feet)	Phenols Concentration
SB-1/8-10	5/30/96	8-10	56.8
SB-1/48-50	5/30/96	48-50	1.1
SB-2/13-15	5/31/96	13-15	48.4
SB-2/23-25	5/31/96	23-25	0.8
SB-2/33-35	5/31/96	33-35	6.7
GP-1/3	5/30/96	3	1.3
GP-1/20	5/30/96	20	ND(0.6)
GP-2/0.5	5/30/96	0.5	0.9
GP-2/20	5/30/96	20	1.8
GP-3/1	5/30/96	1	ND(0.6)
GP-3/20	5/30/96	20	1.9
GP-4/1	5/30/96	1	ND(0.6)
GP-5/9	5/31/96	9	ND(0.6)
GP-5/20	5/31/96	20	ND(0.6)
GP-6/15	5/31/96	15	3.2
GP-6/20	5/31/96	20	2.8
GP-7/8	5/31/96	8	1.5
GP-7/20	5/31/96	20	0.6

Notes: All concentrations are reported in mg/kg (ppm).
ND(#) - Constituent not detected at or above laboratory detection limit shown in parentheses.

Table 2-9
Summary of Soil Analytical Data
June 1996 TDS Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Date Sampled	6/13/96	6/11/96	6/11/96	6/11/96	6/11/96	6/11/96
Sample Location	**B1 10.5 - 11**	**B1 49 - 51**	**B3 12 - 12.5**	**B2 49 - 51**	**B2 17.5 - 18**	**B3 49 - 51**
Sample Depth	**10.5 - 11 feet**	**49 - 51 feet**	**12 - 12.5 feet**	**49 - 51 feet**	**17.5 - 18 feet**	**49 - 51 feet**
Constituent						
Phenol	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
2-Chlorophenol	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
2,4-Dimethylphenol	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
2,4-Dinitrophenol	ND(2.0)	ND(2.0)	ND(1.9)	ND(2.0)	ND(2.0)	ND(2.3)
p-chloro-m-cresol	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Acenaphthylene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Pentachlorophenol	ND(2.0)	ND(2.0)	ND(1.9)	ND(2.0)	ND(2.0)	ND(2.3)
Fluorene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Naphthalene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Acenaphthene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Fluoranthene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Phenanthrene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Anthracene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Indeno(1,2,3-cd)pyrene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Benzo(b)fluoranthene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Benzo(a)anthracene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Benzo(a)pyrene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Benzo(k)fluoranthene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Dibenzo(a,h)anthracene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Benzo(g,h,i)perylene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Pyrene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Chrysene	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
2,3,4,5-tetrachlorophenol	ND(0.780)	ND(0.800)	ND(0.760)	ND(0.800)	ND(0.780)	ND(0.920)
2,3,4,6-tetrachlorophenol	ND(0.780)	ND(0.800)	ND(0.760)	ND(0.800)	ND(0.780)	ND(0.920)
2,4,5-trichlorophenol	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
2,4,6-trichlorophenol	ND(0.390)	ND(0.400)	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.460)
Hydrocarbons as heavy oils	ND(39)	ND(39)	ND(38)	ND(39)	ND(39)	ND(46)
Hydrocarbons as diesel fuel	ND(39)	ND(39)	ND(38)	ND(39)	ND(39)	ND(46)
Percent solids	84	83	86	83	83	70

Notes: All concentrations are reported in mg/kg (ppm).
ND(#) - Constituent not detected at or above laboratory detection limit shown in parentheses.

Table 2-9
Summary of Soil Analytical Data
June 1996 TDS Investigation

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Date Sampled	6/12/96	6/12/96	6/12/96	6/12/96	6/13/96	6/13/96
Sample Location	B4 14.5 - 15	B4 50 - 51	B5 10 - 11	B5 49.5 - 50.5	B6 13.5 - 14	B6 15 - 16
Sample Depth	14.5 - 15 feet	50 - 51 feet	10 - 11 feet	49.5 - 50.5 feet	13.5 - 14 feet	15 - 16 feet
Constituent						
Phenol	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
2-Chlorophenol	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
2,4-Dimethylphenol	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
2,4-Dinitrophenol	ND(1.9)	ND(2.0)	ND(2.0)	ND(2.0)	ND(600)	ND(1.9)
p-chloro-m-cresol	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
Acenaphthylene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
Pentachlorophenol	ND(1.9)	ND(2.0)	ND(2.0)	ND(2.0)	ND(600)	ND(1.9)
Fluorene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	810	ND(0.380)
Naphthalene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	1000	ND(0.380)
Acenaphthene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	640	ND(0.380)
Fluoranthene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	1200	ND(0.380)
Phenanthrene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	1700	ND(0.380)
Anthracene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	1200	ND(0.380)
Indeno(1,2,3-cd)pyrene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
Benzo(b)fluoranthene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	140	ND(0.380)
Benzo(a)anthracene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	260	ND(0.380)
Benzo(a)pyrene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	120	ND(0.380)
Benzo(k)fluoranthene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	150	ND(0.380)
Dibenzo(a,h)anthracene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
Benzo(g,h,i)perylene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
Pyrene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	550	ND(0.380)
Chrysene	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	320	ND(0.380)
2,3,4,5-tetrachlorophenol	ND(0.760)	ND(0.800)	ND(0.780)	ND(0.800)	ND(240)	ND(0.760)
2,3,4,6-tetrachlorophenol	ND(0.760)	ND(0.800)	ND(0.780)	ND(0.800)	ND(240)	ND(0.760)
2,4,5-trichlorophenol	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
2,4,6-trichlorophenol	ND(0.380)	ND(0.400)	ND(0.390)	ND(0.400)	ND(120)	ND(0.380)
Hydrocarbons as heavy oils	ND(38)	ND(40)	ND(38)	ND(40)	ND(12,000)	ND(38)
Hydrocarbons as diesel fuel	ND(38)	ND(40)	ND(38)	ND(40)	ND(12,000)	ND(38)
Percent solids	85	83	85	83	75	86

Notes: All concentrations are reported in mg/kg (ppm).
ND(#) - Constituent not detected at or above laboratory detection limit shown in parentheses.

Appendix B

Information on CPT and ROST Technologies

Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Designation: D 5778 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils[1]

This standard is issued under the fixed designation D 5778; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the procedure for determining the resistance to penetration of a conical pointed penetrometer as it is advanced into subsurface soils at a slow, steady rate.

1.2 This test method is also used to determine the frictional resistance of a cylindrical sleeve located behind the conical point as it is advanced through subsurface soils at a slow, steady rate.

1.3 This test method applies to friction-cone penetrometers of the electronic type.

1.4 This test method can be used to determine pore pressure development during push of a piezocone penetrometer. Pore pressure dissipation, after a push, can also be monitored for correlation to soil compressibility and permeability.

1.5 Other sensors such as inclinometer, seismic, and temperature sensors may be included in the penetrometer to provide useful information. The use of an inclinometer is highly recommended since it will provide information on potentially damaging situations during the sounding process.

1.6 Cone penetration test data can be used to interpret subsurface stratigraphy, and through use of site specific correlations it can provide data on engineering properties of soils intended for use in design and construction of earthworks and foundations for structures.

1.7 The values stated in SI units are to be regarded as standard. Within Section 13 on Calculations, SI metric units are considered the standard. Other commonly used units such as the inch-pound system are shown in brackets. The various data reported should be displayed in mutually compatible units as agreed to by the client or user. Cone tip projected area is commonly referred to in centimetres for convenience. The values stated in each system are not equivalents; therefore, each system must be used independently of the other.

NOTE 1—This test method does not include hydraulic or pneumatic penetrometers. However, many of the procedural requirements herein could apply to those penetrometers.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
E 4 Practice for Force Verification of Testing Machines[3]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are in accordance with Terminology D 653.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *apparent load transfer*—apparent resistance measured on either the cone or friction sleeve of an electronic cone penetrometer while that element is in a no-load condition but the other element is loaded. Apparent load transfer is the sum of cross talk, subtraction error, and mechanical load transfer.

3.2.2 *baseline*—a set of zero load readings, expressed in terms of apparent resistance, that are used as reference values during performance of testing and calibration.

3.2.3 *cone*—the conical point of a cone penetrometer on which the end bearing component of penetration resistance is developed. The cone has a 60° apex angle, a projected (horizontal plane) surface area or cone base area of 10 or 15 cm^2, and a cylindrical extension behind the cone base.

3.2.4 *cone penetration test*—a series of penetration readings performed at one location over the entire depth when using a cone penetrometer. Also referred to as cone sounding.

3.2.5 *cone penetrometer*—a penetrometer in which the leading end of the penetrometer tip is a conical point designed for penetrating soil and for measuring the end-bearing component of penetration resistance.

3.2.6 *cone resistance, q_c*—the end-bearing component of penetration resistance. The resistance to penetration developed on the cone is equal to the vertical force applied to the cone divided by the cone base area.

3.2.7 *corrected total cone resistance, q_t*—tip resistance corrected for water pressure acting behind the tip (see 13.2.1). Correction for water pressure requires measuring water pressures with a piezocone element behind the tip at location u_2. The correction results in estimated total tip resistance.

3.2.8 *cross talk*—an apparent load transfer between the cone and the friction sleeve caused by interference between the separate signal channels.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Evaluations.

Current edition approved Sept. 10, 1995. Published January 1996.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

3.2.9 *electronic cone penetrometer*—a friction cone penetrometer that uses force transducers, such as strain gage load cells, built into a non-telescoping penetrometer tip for measuring, within the penetrometer tip, the components of penetration resistance.

3.2.10 *electronic piezocone penetrometer*—an electronic cone penetrometer equipped with a low volume fluid chamber, porous element, and pressure transducer for determination of pore pressure at the porous element soil interface.

3.2.11 *end bearing resistance*—same as cone resistance or tip resistance, q_c.

3.2.12 *equilibrium pore water pressure,* u_0—at rest water pressure at depth of interest. Same as hydrostatic pressure (see Terminology D 653).

3.2.13 *excess pore water pressure,* Δu—the difference between pore pressure measured as the penetration occurs, u, and estimated equilibrium pore water pressure ($u_0 - u$). Excess pore pressure can either be positive or negative.

3.2.14 *friction cone penetrometer*—a cone penetrometer with the capability of measuring the friction component of penetration resistance.

3.2.15 *friction ratio,* R_f—the ratio of friction sleeve resistance, f_s, to cone resistance, q_c, measured at where the middle of the friction sleeve and cone point are at the same depth, expressed as a percentage.

3.2.16 *friction reducer*—a narrow local protuberance on the outside of the push rod surface, placed at a certain distance above the penetrometer tip, that is provided to reduce the total side friction on the push rods and allow for greater penetration depths for a given push capacity.

3.2.17 *friction sleeve*—an isolated cylindrical sleeve section on a penetrometer tip upon which the friction component of penetration resistance develops. The friction sleeve has a surface area of either 150 for 10 cm² cone tip.

3.2.18 *friction sleeve resistance,* f_s—the friction component of penetration resistance developed on a friction sleeve, equal to the shear force applied to the friction sleeve divided by its surface area.

3.2.19 *FSO*—abbreviation for full-scale output. The output of an electronic force transducer when loaded to 100 % rated capacity.

3.2.20 *local side friction*—same as friction sleeve resistance.

3.2.21 *penetration resistance measuring system*—a measuring system that provides the means for transmitting information from the penetrometer tip and displaying the data at the surface where it can be seen or recorded.

3.2.22 *penetrometer*—an apparatus consisting of a series of cylindrical push rods with a terminal body (end section), called the penetrometer tip, and measuring devices for determination of the components of penetration resistance.

3.2.23 *penetrometer tip*—the terminal body (end section) of the penetrometer which contains the active elements that sense the components of penetration resistance. The penetrometer tip may include additional electronic instrumentation for signal conditioning and amplification.

3.2.24 *piezocone*—same as *electronic piezocone penetrometer* (see 3.2.10).

3.2.25 *piezocone pore pressure,* u—fluid pressure measured using the piezocone penetration test.

3.2.26 *piezocone pore pressure measurement locations,* u_1, u_2, u_3—fluid pressure measured by the piezocone penetrometer at specific locations on the penetrometer as follows: u_1—pore pressure filter location on the face or tip of the cone, u_2—pore pressure filter location immediately behind the cone tip (standard location) and, u_3—pore pressure filter location behind the friction sleeve.

3.2.27 *pore pressure ratio*—the ratio of excess pore pressure, Δu, to cone resistance, q_c, expressed as a percentage (see 13.5.3).

3.2.28 *pore pressure ratio parameter,* B_q—the ratio of excess pore pressure at measurement location Δu_2, to corrected total cone resistance q_t, minus the total vertical stress, σ_v (see 13.5.4.1).

3.2.29 *push rods*—the thick-walled tubes or rods used to advance the penetrometer tip.

3.2.30 *sleeve friction, sleeve, and friction resistance*—same as friction sleeve resistance.

3.2.31 *subtraction error*—an apparent load transfer from the cone to the friction sleeve of a subtraction type electronic cone penetrometer caused by minor voltage differences in response to load between the two strain element cells.

3.3 *Abbreviations:*

3.3.1 *CPT*—abbreviation for the cone penetration test.

3.3.2 *CPTu*—abbreviation for the piezocone penetration test.

4. Summary of Test Method

4.1 A penetrometer tip with a conical point having a 60° apex angle and a cone base area of 10 or 15 cm² is advanced through the soil at a constant rate of 20 mm/s. The force on the conical point (cone) required to penetrate the soil is measured by electrical methods, at a minimum of every 50 mm of penetration. Stress is calculated by dividing the measured force (total cone force) by the cone base area to obtain cone resistance, q_c.

4.2 A friction sleeve is present on the penetrometer immediately behind the cone tip, and the force exerted on the friction sleeve is measured by electrical methods at a minimum of every 50 mm of penetration. Stress is calculated by dividing the measured force by the surface area of the friction sleeve to determine friction sleeve resistance, f_s.

4.3 Many penetrometers are capable of registering pore water pressure induced during advancement of the penetrometer tip using an electronic pressure transducer. These penetrometers are called "piezocones." The piezocone is advanced at a rate of 20 mm/s, and readings are taken at a minimum of every 50 mm of penetration. The dissipation of either positive or negative excess pore water pressure can be monitored by stopping penetration, unloading the push rod, and recording pore pressure as a function of time. When pore pressure becomes constant it is measuring the equilibrium value or piezometric level at that depth.

5. Significance and Use

5.1 Tests performed using this test method provide a detailed record of cone resistance which is useful for evaluation of site stratigraphy, homogeneity and depth to firm layers, voids or cavities, and other discontinuities. The use of a friction sleeve and pore pressure element can provide an estimate of soil classification, and correlations with engineering properties of soils. When properly performed at suitable sites, the test provides a rapid means for determining subsurface conditions.

5.2 This test method provides data used for estimating engineering properties of soil intended to help with the design and construction of earthworks, the foundations for structures, and the behavior of soils under static and dynamic loads.

5.3 This test method tests the soil in situ and soil samples are not obtained. The interpretation of the results from this test method provides estimates of the types of soil penetrated. Engineers may obtain soil samples from parallel borings for correlation purposes but prior information or experience may preclude the need for borings.

6. Interferences

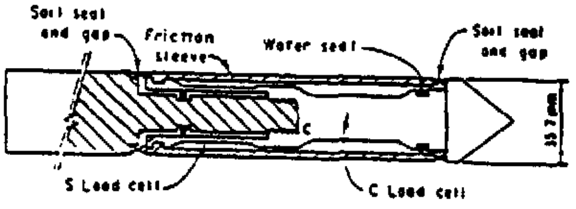
6.1 Refusal, deflection, or damage to the penetrometer may occur in coarse grained soil deposits with maximum particle sizes that approach or exceed the diameter of the cone.

6.2 Partially lithified and lithified deposits may cause refusal, deflection, or damage to the penetrometer.

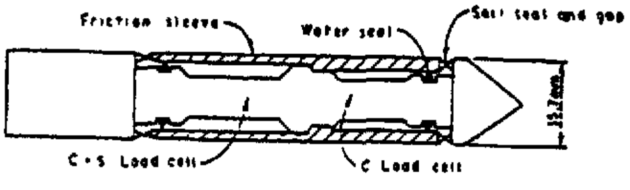
6.3 Standard push rods can be damaged or broken under extreme loadings. The amount of force that push rods are able to sustain is a function of the unrestrained length of the rods and the weak links in the push rod-penetrometer tip string such as push rod joints and push rod-penetrometer tip connections. The force at which rods may break is a function of the equipment configuration and ground conditions during penetration. Excessive rod deflection is the most common cause for rod breakage.

7. Apparatus

7.1 *Friction Cone Penetrometer*—The penetrometer tip should meet requirements as given below and in 10.1. In a typical friction cone penetrometer tip (as shown on Fig. 1 (1)),[4] the forces produced by friction sleeve resistance and cone resistance during penetration are measured by two load cells within the electronic friction cone penetrometer. Either independent or subtraction-type electronic friction cone penetrometer tips are acceptable for use.



(a) Independent tension-type electric friction — cone penetrometer.



(b) Subtraction-type electric friction — cone penetrometer.

FIG. 1 Typical Electric Friction—Cone Penetrometer Tip Configurations (1)

7.1.1 In the subtraction-type friction cone penetrometer, the cone and sleeve both produce compressive forces on the load cells. The load cells are joined together in such a manner that the cell nearest the cone (the "C" cell on Fig. 1(*b*)) measures the compressive force on the cone while the second cell (the "C+S" cell on Fig. 1(*b*)) measures the sum of the compressive forces on both the cone and friction sleeve. The compressive force from just the friction sleeve is computed then by subtraction. This cone design finds the most common use in industry. It is preferred because of its rugged design. This design forms the basis for minimum performance requirements for electronic penetrometers.

7.1.1.1 In the independent tension-type cone penetrometer tip, the cone produces a compression force on the cone load cell (the "C" cell on Fig. 1(*a*)) while the friction sleeve produces a tensile force on the independent friction sleeve load cell (the "S" cell on Fig. 1(*a*)). Designs are also available where the independent sleeve element is placed in compression. This penetrometer tip design results in a higher degree of accuracy in friction sleeve measurement, but, depending on the design, it is more susceptible to damage under extreme loading conditions.

7.1.1.2 Typical general purpose cone penetrometers are manufactured to full scale outputs equivalent to net loads of 10 to 20 tons. Often, weak soils are the most critical in an investigation program and in some cases very accurate friction sleeve data may be required. To gain better resolution, the FSO can be lowered or independent type penetrometers can be selected. A low FSO subtraction cone may provide more accurate data than a standard FSO independent type cone depending on such factors as system design and thermal compensation. If the FSO is lowered, this may place electrical components at risk if overloaded in stronger soils. Expensive preboring efforts may be required to avoid damage in these cases. The selection of penetrometer type and resolution should consider such factors as practicality, availability, calibration requirements, cost, risk of damage, and preboring requirements.

7.1.1.3 The user or client should select the cone design requirements by consulting with experienced users or manufacturers. The need for a specific cone design depends on the design data needs outlined in the exploration program.

7.1.1.4 Regardless of penetrometer type, the friction sleeve load cell system must operate in such a way that the system is sensitive to only shear stresses applied to the friction sleeve and not to normal stresses.

7.1.2 *Cone*—Nominal dimensions, with manufacturing and operating tolerances, for the cone are shown on Fig. 2. The cone has a projected base area, A_c = 1000 mm^2, +2 %–5 % with an apex angle of 60°. A cylindrical extension, h_e, of 5 mm should be located behind the base of the cone to protect the outer edges of the cone base from

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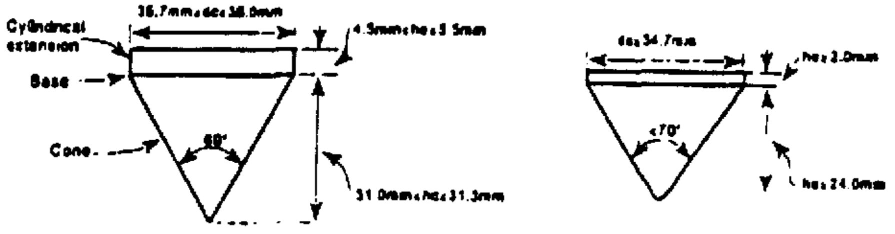
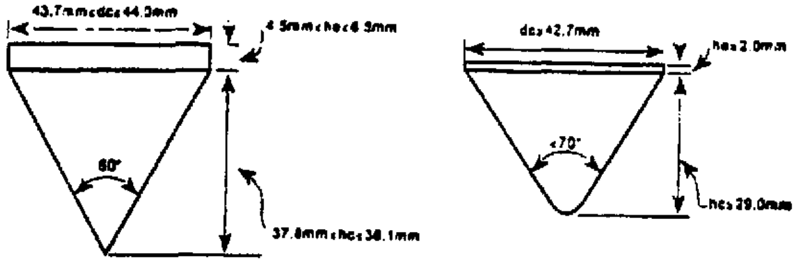
[4] The boldface numbers given in parentheses refer to a list of references at the end of the text.



(a) Manufacturing tolerances of 10 cm² cones.

(b) Operating tolerances of 10 cm² cones.



(c) Manufacturing tolerances of 15 cm² cones.

(d) Operating tolerances of 15 cm² cones.

CONE BASE AREA	NOMINAL			TOLERANCE MANUFACTURED (OPERATIONS)		
	BASE DIAMETER	CONE HEIGHT	EXTENSION			
cm²	dc mm	hc mm	he mm	dc mm	hc mm	he mm
10	35.7	31.0	5.0	+0.3 - 0.0 (≥34.7)	+0.3 - 0.0 (≥24.0)	+0.0 - 0.5 (≥2.0)
15	43.7	37.8	5.0 - 6.0	+0.3 - 0.0 (≥42.7)	+0.3 - 0.0 (≥29.0)	+0.0 - 0.5 (≥2.0)

FIG. 2 Manufacturing and Operating Tolerances of Cones (2)

excessive wear. The 10 cm² cone is considered the reference standard for which results of other penetrometers with proportionally scaled dimensions can be compared.

7.1.2.1 In certain cases, it may be desirable to increase the cone diameter in order to add room for sensors or increase ruggedness of the penetrometer. The standard increase is to a base diameter which provides a projected cone base area of 15 cm² while maintaining a 60° apex angle. Nominal dimensions, with manufacturing and operating tolerances for the 15 cm² cone, are shown on Fig. 2.

7.1.2.2 The cone is made of high strength steel of a type and hardness suitable to resist wear due to abrasion by soil. Cone tips which have worn to the operating tolerance shown on Fig. 2(*b*) and (*d*) should be replaced. Piezocone tips should be replaced when the height of cylindrical extension has worn to approximately 1.5 mm.

NOTE 2—In some applications it may be desirable to scale the cone diameter down to a smaller projected area. Cone penetrometers with 5 cm² projected area find use in the field applications and even smaller sizes are used in the laboratory for research purposes. These cones should be designed with dimensions scaled in direct proportion to 10 cm² penetrometers. In thinly layered soils, the diameter affects how accurately the layers may be sensed. Smaller diameter cones may sense thinner layers more accurately than larger cones. If there are questions as to the effect of scaling the penetrometer to either larger or smaller size, results can be compared in the field to the 10 cm² penetrometer for soils under consideration. This is because the 10 cm² cone is considered the reference penetrometer for field testing.

7.1.3 *Friction Sleeve*—The outside diameter of the manufactured friction sleeve and the operating diameter are equal to the diameter of the base of the cone with a tolerance of + 0.35 mm and −0.0 mm. The friction sleeve is made from high strength steel of a type and hardness to resist wear due to abrasion by soil. Chrome plated steel is not recommended due to differing frictional behavior. The surface area of the friction sleeve is 1.5×10^4 mm² ± 2 %, for a 10 cm² cone. If the cone base area is increased to 15 cm², as provided for in 7.1.2.1, the surface area of the friction sleeve should be adjusted proportionally, with the same length to diameter ratio as the 10 cm² cone. With the 15 cm² tip, sleeve areas of 2.0 to 3.0×10^4 mm² have been used successfully in practice. This indicates that acceptable sleeve length to tip diameter ranges from three to five.

7.1.3.1 The top diameter of the sleeve must not be smaller than the bottom diameter or significantly lower sleeve resistance will occur. During testing, the top and bottom of the sleeve should be periodically checked for wear with a micrometer. Normally the top of the sleeve will wear faster than the bottom.

7.1.3.2 Friction sleeves must be designed with equal end areas which are exposed to water pressures. This will remove the tendency for unbalanced end forces to act on the sleeve. Sleeve design must be checked in accordance with A1.7 to ensure proper response.

7.1.4 *Gap*—Figs. 3(*a*) and (*b*) illustrate penetrometer requirements immediately above the cone tip for the friction cone penetrometer. The gap (annular space) between the cylindrical extension of the cone base and the other elements of the penetrometer tip should be kept to the minimum necessary for operation of the sensing devices and should be designed and constructed in such a way to prevent the entry of soil particles. Gap requirements apply to the gaps at either end of the friction sleeve and to other elements of the penetrometer tip.

7.1.4.1 The gap between the cylindrical extension of the cone base and other elements of the penetrometer tip, e_o, must not be larger than 5 mm for the friction cone penetrometer.

7.1.4.2 If a seal is placed in the gap, it should be properly designed and manufactured to prevent entry of soil particles into the penetrometer tip. It must have a deformability at least two orders of magnitude greater than the material comprising the load transferring components of the sensing devices in order to prevent load transfer from the tip to the sleeve.

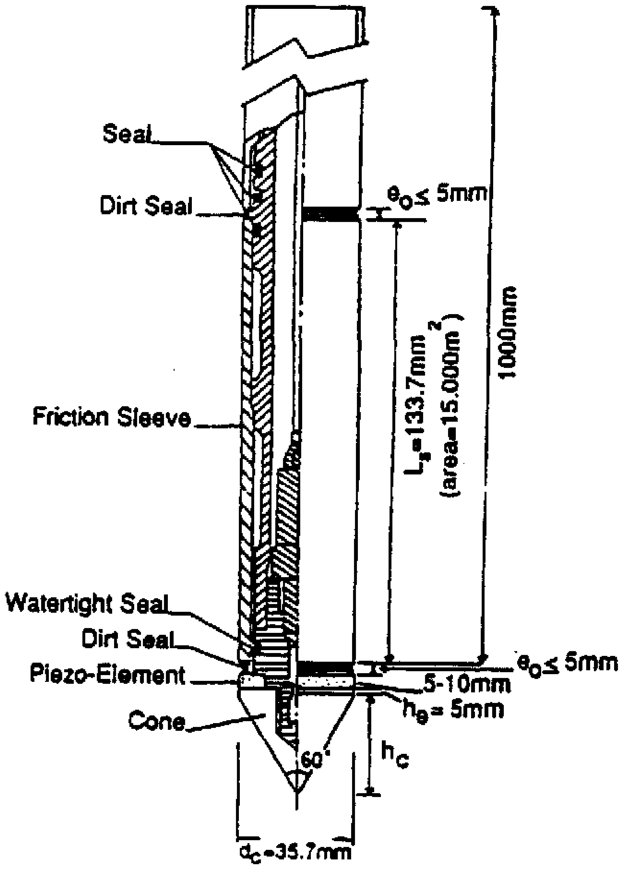


FIG. 3 Example of a Reference Penetrometer With a Fixed Cone and With Friction Sleeve

7.1.4.3 *Filter Element in the Gap*—If a filter element for a piezocone is placed in the gap between cone and sleeve the sum of the height of cylindrical extension, h_e, plus element thickness filling the gap, e_o, can range from 8 to 20 mm (see 7.1.8 for explanation).

7.1.5 *Diameter Requirements*—The penetrometer tip is the terminal body housing all sensors to be monitored during testing (see 3.2.25). The penetrometer tip includes the cone tip, friction sleeve, and other sensors normally located just above the friction sleeve. The friction sleeve should be located within 5 to 15 mm behind the base of the cone. The friction sleeve diameter tolerance is given in 7.1.3. The annular spaces and seals between the friction sleeve and other portions of the penetrometer tip must conform to the same specifications as described in 7.1.4. Changes in the diameter of the penetrometer body above the friction sleeve should be such that tip or sleeve measurements are not influenced by increases in diameter. International reference test procedures require that the penetrometer body has the same diameter as the cone for the complete length of the penetrometer body (2).

7.1.5.1 For some penetrometer designs, it may be desirable to increase the diameter of the penetrometer body to house additional sensors or reduce friction along push rods. These diameter changes are acceptable if they do not have significant influence on tip and sleeve data. If there is question regarding a specific design with diameter increases, comparison studies can be made to a penetrometer with constant diameter. Information on diameters of the complete penetrometer body should be reported.

NOTE 3—The effects diameter changes of the penetrometer on tip and sleeve resistance are dependent on the magnitude of diameter increase and location on the penetrometer body. Most practioners feel that diameter increases equivalent to addition of a friction reducer with area increases of 15 to 20 % should be restricted to a location at least eight to ten cone diameters behind the friction sleeve.

7.1.6 The axis of the cone, the friction sleeve (if included), and the body of the penetrometer tip must be coincident.

7.1.7 *Force Sensing Devices*—The typical force sensing device is a strain gage load cell that contains temperature compensated bonded strain gages. The configuration and location of strain gages should be such that measurements are not influenced by possible eccentricity of loading.

7.1.8 *Electronic Piezocone Penetrometer*—A piezocone penetrometers can contain porous element(s), pressure transducer(s), and fluid filled ports connecting the elements to the transducer to measure pore water pressure. Numerous design and configuration aspects can affect the measurement of dynamic water pressures. Variables such as the element location, design and volume of ports, and the type and degree of saturation of the fluids, cavitation of the element fluid system and resaturation lag time, depth and saturation of soil during testing all affect the dynamic pore pressure measured during testing and dissipation tests of dynamic pressures (3). It is beyond the scope of the procedure to address all of these variables. As a minimum, complete information should be reported as to the design, configuration, and the preparation of the piezocone system.

7.1.8.1 Measurement of hydrostatic water pressures during pauses in testing are more straightforward. The presence of air entrained in the system only affects dynamic response. In high permeability soils hydrostatic pressures will equalize within minutes. In low permeability materials such as high plasticity clays, equalization can take many hours. If the goal of the exploration program is only to acquire hydrostatic pressures in sands, some of the preparation procedures for dynamic pressure measuring can be relaxed, such as deairing fluids.

7.1.8.2 The pore pressure measurement locations of the porous element are limited to the face or tip of the cone, u_1, directly behind the cylindrical extension of the base of the cone, u_2, or behind the sleeve, u_3. Some penetrometers used for research purposes may have multiple measurement locations.

7.1.8.3 There are several advantages to locating the porous element immediately behind the tip of the cone in location u_2. The element is less subject to damage and abrasion, there are less compressibility effects, and the data can be used for corrected total tip pressure, q_t (3). Elements located in the u_2 location may be subject to cavitation at shallow depths in sands because the zone behind the height of cylindrical extension is a zone of dilation in drained soils. In some cases, the corrected total cone resistance, q_t, can be estimated with pore pressures measured in the u_1 position through empirical correlation with soil type. Some piezometer elements are housed within the height of cylindrical extension of the cone tip itself. Pore pressure measurements obtained in the u_1 location are more effective for compressibility determinations and layer detection but are more subject to wear (3). In the u_2 location a minimum 2.5-mm cylindrical extension of the cone tip, h_e, should be maintained for protection of the cone. Typical element thickness in all locations in the horizontal plane ranges from 5 to 10 mm.

7.1.8.4 The miniature diaphragm type electronic pressure transducer is normally [illegible] used near the tip of the cone. For dynamic pressure measurements, the filter and ports are filled with deaired fluid to measure dynamic pore pressure response. The volume of connecting ports to the transducer should be minimized to facilitate dynamic pressure response. These electronic transducers are normally very reliable, accurate, and linear in response. The transducer shall have a precision of at least ±14 kPa. The pore pressure transducer must meet requirements given in 10.2.

7.1.8.5 *Element*—The element is a fine porous filter made from plastic, sintered steel or bronze, or ceramic. Typical pore size is 200 µm or smaller. Different materials have different advantages. Smearing of the element openings by hard soil grains may reduce dynamic response of the system. Problems have been experienced with smearing of sintered metal elements. Ceramic elements are very brittle and often crack when loaded. Polypropylene plastic elements are most commonly used in practice. Typically, the filter element is wedged in the tip, U_1 location, or located in the gap immediately above the cone extension, U_2 location. In these locations it is important to design the penetrometer such that compression of the filter elements is minimized.

7.1.8.6 *Fluids for Saturation*—Silicon oil or glycerin is most often used for deairing elements for dynamic response. The stiff, viscous oils have less tendency to cavitate, although cavitation may be controlled by the effective pore size of the element mounting surfaces. Water can be used for the fluid if dynamic response is not important. The fluids are deaired using procedures described in 11.2.

7.2 *Measuring System*—The signals from the penetrometer transducers are to be displayed at the surface during testing as a continuously updated plot against depth. The data are also to be recorded electronically for subsequent processing. Electronic recording shall be digital and use at least twelve bit (one part in 4096) resolution in the analogue to digital conversion. Either magnetic (disk or tape) or optical (disk) non-volatile storage may be used. The temperature stability and accuracy of the analogue to digital converter shall be such that the overall cone/transmission/recording system complies with calibration requirements set forth in the annex.

7.2.1 Use of analog systems is acceptable but the system resolution may be lower than requirements in the annex and Section 10. Use of an analog recorder as a supplement to digital system is advantageous because it can provide system backup.

NOTE 4—Present practice is to use ASCII formatted data on magnetic floppy disks readable by MS-DOS compatible computers. The data files should include project, location, operator, and data format information so that the data can be understood when reading the file with a text editor.

7.3 *Push Rods*—Steel rods are required having a cross sectional area adequate to sustain, without buckling, the thrust required to advance the penetrometer tip. For penetrometers using electrical cables the cable is prestrung through the rods prior to testing. Push rods are supplied in 1-meter lengths. The push rods must be secured together to bear against each other at the joints and form a rigid-jointed string of push rods. The deviation of push rod alignment from a straight axis should be held to a minimum, especially in the push rods near the penetrometer tip, to avoid excessive directional penetrometer drift. Generally, when a 1-m long push rod is subjected to a permanent circular bending resulting in 1 to 2 mm of center axis rod shortening, the push rod should be discarded. This corresponds to a horizontal deflection of 2 to 3 mm at the center of bending. The locations of push rods in the string should be varied periodically to avoid permanent curvature.

7.3.1 For the 10 cm² penetrometer, standard 20-metric ton high tensile strength steel push rods are 36-mm outside diameter, 16-mm inside diameter, and have a mass per unit length of 6.65 kg/m. 15 cm² penetrometers may be pushed with 44.5 mm outside diameter rods or with standard rods used for the 10 cm² penetrometer.

7.4 *Friction Reducer*—Friction reducers are normally used on the push rods to reduce rod friction. If a friction reducer is used, it should be located on the push rods no closer than 0.5 m behind the base of the cone. Friction reducers, that increase push rod outside diameter by approximately 25 %, are typically used for 10 cm² cones. If a 15 cm² penetrometer is advanced with 36 mm push rods there may be no need for friction reducers. The type, size, amount, and location of friction reducer(s) used during testing must be reported.

7.5 *Thrust Machine and Reaction*—The thrust machine will provide a continuous stroke, preferably over a distance greater than 1 m. The thrust machine should be capable of adjusting push direction through the use of a leveling system such that push initiates in a vertical orientation. The machine must advance the penetrometer tip and push rods at a smooth, constant rate (see 12.1.2) while the magnitude of thrust can fluctuate. The thrust machine must be anchored or ballasted, or both, so that it provides the necessary reaction for the penetrometer and does not move relative to the soil surface during thrust.

NOTE 5—Cone penetration soundings usually require thrust capabilities ranging from 98 to 196 kN (10 to 20 metric tons). High mass ballasted vehicles can cause soil surface deformations which may affect penetrometer resistance(s) measured in near surface layers. Anchored or ballasted vehicles, or both, may induce changes in ground surface reference level. If these conditions are evident, they should be noted in reports.

7.6 *Other Sensing Devices*—Other sensing devices can be included in the penetrometer body to provide additional information during the sounding. These instruments are normally read at the same rate as tip, sleeve and pore pressure sensors or during pauses of push. Typical sensors are inclinometer, temperature, or seismic sensors. These sensors should be calibrated if their use is critical to the investigation program. The use of an inclinometer is highly recommended since it will provide information on potentially damaging situations during the sounding process. An inclinometer can provide a useful depth reliability check because it provides information on verticality. The configuration and methods of operating such sensors should be reported.

8. Reagents and Materials

8.1 *O-Ring Compound*—A petroleum or silicon compound for facilitating seals with O-rings. Use of silicon compounds may impede repair of strain gages if the strain gage surface is exposed to the compound.

8.2 *Glycerin* $CHOH(CH_2OH)_2$, for use in pore pressure measurement system. 95 % pure glycerin can be procured from most drug stores.

8.3 *Silicon Oil*, for use in pore pressure measurement system. This material is available in varying viscosities ranging from 400 to 10 000 CP. More viscous versions may provide better response.

9. Hazards

9.1 *Technical Precautions—General:*

9.1.1 Use of penetrometer components that do not meet required tolerances or show visible signs of non-symmetric wear can result in erroneous penetration resistance data.

9.1.2 The application of thrust in excess of rated capacity of the equipment can result in damage to equipment (see Section 6).

9.1.3 A cone sounding must not be performed any closer than 25 borehole diameters from any existing unbackfilled or uncased bore hole.

9.1.4 When performing cone penetration testing in prebored holes, an estimate of the depth below the prebored depth which is disturbed by drilling, should be made and penetration resistance data obtained in this zone should be noted. Usually, this depth of disturbance is assumed to be equal to at least three borehole diameters.

9.1.5 Significant bending or buckling of the push rods can influence penetration resistance data. The use of a tubular rod guide is recommended at the base of the thrust machine and also in prebored holes to help prevent push rod bending.

9.1.6 Push rods not meeting requirements of 7.3 may result in excessive directional penetrometer drift and possibly unreliable penetration resistance values.

9.1.7 Passing through or alongside obstructions may deflect the penetrometer and induce directional drift. Note any indications of encountering such obstructions, and be alert for possible subsequent improper penetrometer tip operation.

9.1.8 If the proper rate of advance of the penetrometer is not maintained for the entire stroke through the measurement interval, penetration resistance data will be erroneous.

9.2 *Technical Precautions—Electronic Friction Cone Penetrometer:*

9.2.1 Failure of O-ring seals can result in damage to or inaccurate readings from electronic transducers. The O-ring seals should be inspected regularly, after each sounding, for overall condition and watertightness.

9.2.2 Soil ingress between different elements of a penetrometer tip can result in unreliable data. Specifically, soil ingress will detrimentally affect sleeve resistance data. Seals should be inspected after each sounding, maintained regularly, and replaced when necessary. If very accurate sleeve resistance data is required, it is recommended to clean all seals after each sounding.

9.2.3 Electronic cone penetrometer tips should be temperature compensated. If extreme temperatures outside of the range established in A1.3.3 are to be encountered, the penetrometer should be checked for the required temperature range to establish they can meet the calibration requirements.

9.2.4 If the shift in baseline reading after extracting the penetrometer tip from the soil is so large that the conditions of accuracy as defined in 10.1.2.1 are no longer met, penetration resistance data should be noted as unreliable. If baseline readings do not conform to allowable limits established by accuracy requirements in 10.1.2.2, the penetrometer tip must be repaired, and recalibrated or replaced.

9.2.5 Electronic friction cone penetrometer tips having an unequal friction sleeve end area ratios will yield friction sleeve resistance data that are erroneous because of unequal dynamic pore pressures encountered along the length of the sleeve during penetrometer tip advancement. Friction sleeve design should be checked in accordance with A1.7 to ensure balanced response. The response is also dependent on location of water seals. If O-ring water seals are damaged during testing, and sleeve data appear affected, the sounding data should be noted as unreliable and the seals should be repaired.

9.3 *Piezocone Penetrometer*—The electronic piezocone penetrometer tip measures pore water pressures on the exterior of the penetrometer tip by transferring the pressure through a de-aired fluid system to a pressure transducer in the interior of the tip. For proper dynamic response, the measurement system (consisting of fluid ports and porous element) must be completely saturated prior to testing. Entrained air must be removed from the fluid-filled system or pore pressure fluctuation during penetrometer tip advancement will be incorrect due to response lag from compression of air bubbles (see 11.2, 12.3.1, and 12.3.2). For soundings where dynamic response is important, the prepared filter elements should be replaced after every sounding.

10. Calibration and Standardization

10.1 *Electronic Friction Cone Penetrometers:*

10.1.1 The requirements for newly manufactured or repaired cone penetrometers are of importance. Newly manufactured or repaired electronic cone penetrometers are to be checked to meet the minimum calibration requirements described in the annex. These calibrations include load tests, thermal tests, and mechanical tests for effects of imbalanced hydrostatic forces. Calibration procedures and requirements given in the annex are for subtraction-type cone penetrometers. Calibration requirements for independent-type cone penetrometers should equal or exceed those requirements. The calibration records must be certified as correct by a registered professional engineer or other responsible engineer with knowledge and experience in materials testing for quality assurance. Applied forces or masses must be traceable to calibration standard forces or masses retained by the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards. For description of calibration terms and methods for calibrating, refer to the annex.

10.1.2 Field calibration of electronic cone penetrometers is required. Field calibration requires use of a loading device, calibrated to traceable calibration standards, that can independently apply forces up to 50 % of rated capacity on the cone and friction sleeve load cells.

10.1.2.1 *Baseline Readings*—Baseline or zero-load readings for both cone and friction sleeve load cells must be taken before and after each sounding. The baseline reading is a reliable indicator of output stability, temperature-induced apparent load, soil ingress, internal friction threshold sensitivity, and unknown loading during zeroing. Take the initial baseline reading after warming electrical circuits according to the manufacturer's instructions, generally for 15 to 30 min, and in a temperature environment as close as possible to that of the material to be sounded. If temperature is of concern, immerse the penetrometer tip in a bucket of fresh tap water, or insert the penetrometer tip in the ground while electrically warming circuits to stabilize its temperature and then extracted for rapid determination of initial baseline. After a sounding is completed, take a final baseline. The change in initial and final baseline values should not exceed 1 % FSO for the cone and 2 % FSO for the sleeve.

10.1.2.2 Maintain a continuous record of initial and final baselines during production testing. After each sounding, compare the final baseline to the initial baseline for agreement within the tolerances noted above. In some cases during heavy production testing where the cone is not disassembled and cleaned after each sounding, the initial baseline for the next sounding can serve as the final baseline to the previous sounding as long as agreement is within allowable limits.

10.1.2.3 If the post sounding baseline shift exceeds above criteria, inspect the cone for damage by inspecting the tip and checking to see that the sleeve can be rotated by hand. If there is apparent damage replace parts as required. Clean the cone and allow temperatures to equalize to presounding conditions, and obtain a new baseline. If this value agrees with the initial baseline within the above criteria, a load range calibration check is not required. If the pre and post baselines are still not within the above criteria then it is likely that the shift was caused by an obstacle or obstruction and linearity should be checked with a load range calibration.

10.1.2.4 If the baseline shift still exceeds the above criteria, perform a load range calibration as described in 10.1.2.1. If the cone load cell baseline shift exceeds 2 % FSO, the cone is likely damaged and will not meet load range criteria in 10.1.2.3. Sleeve load cell baseline shifts for subtraction-type penetrometers usually can exceed 2 % FSO and still meet load range criteria.

10.1.2.5 Report data for the sounding where unacceptable baseline shift occurs as unreliable. In some cases it may be obvious where the damage occurred and data prior to that point may be considered reliable. The location where obvious damage occurred should be clearly noted in reports.

10.1.3 *Load Range Calibrations*—For penetrometers used in production, it is recommended to have a plan for performing linearity checks at regular periodic intervals or when baseline information may indicate damage. Load range calibrations can be performed either in the field or in the laboratory. Conditions where load range checks should be performed are listed in 10.1.3.1, 10.1.3.2, and 10.1.3.4. Perform calibrations with all O-rings and seals in place. Working load range calibrations are to consist of a minimum of 6 points at 0, 2, 5, 10, 25, and 50 % of full-scale loading for cone and friction sleeve load cells independently. Field load range calibrations may be performed with maximum load increments less than 50 % FSO if safety is a concern. During load range calibrations, the amount of apparent load transfer during cone or friction sleeve loading must also be monitored. Penetrometers that do not meet the requirements given below or in 10.1.2.1 must be discarded, recalibrated, or sent to the manufacturer for repair.

Calibration Parameter		Element Requirement
Zero load shift	Cone	≤ ± 0.5 % FSO
Zero load shift	Sleeve	≤ ± 1 % FSO
Linearity	Cone	≤ ± 1 % FSO
Linearity	Sleeve	≤ ± 2 % FSO
Apparent load transfer	Cone	Maximum sleeve value ≤ ± 2.0 % FSO
Apparent load transfer	Sleeve	Maximum cone value ≤ ± 0.5 % FSO
Calibration error	Cone	≤ ± 2 % of Measured output at loads greater than 20 % of FSO
Calibration error	Sleeve	≤ ± 3 % of Measured output at loads greater than 20 % of FSO

10.1.3.1 For penetrometers used regularly during production, regular periodic load range checks should be performed. The period can be based on production footage such as once every 1500 m. If field load range equipment is not available, the penetrometer may be checked in the laboratory at the end of a project.

10.1.3.2 For penetrometers that are infrequently used a periodic check may be based on time period, such as once every year. If a penetrometer has not been used for a long period of time, checking it before use is advisable.

10.1.3.3 For projects requiring a high level of quality assurance, it may be required to do load range checks before and after the project.

10.1.3.4 Load range calibrations are required if the initial and final baselines for a sounding do not meet requirements given in 10.1.2.1.

10.1.3.5 Records documenting the history of an individual penetrometer should be maintained for evaluation of performance.

10.2 *Pore Pressure Transducer*—Calibrate newly manufactured or repaired transducers in accordance with requirements in the annex. During production, the transducer should be calibrated at regularly scheduled intervals (as in 10.1.3.1) and whenever linear performance is suspect. A load range calibration to 50 % of FSO with a minimum of five equally spaced points should result in pressure readings within ± 14 kPa of reference gage values. The reference gage can be a bourden tube pressure gage, or electronic pressure transducer that is calibrated annually to NIST traceable loading device (dead weight testing apparatus).

10.2.1 Prior to testing, baseline values or initial zeroing of the transducer is performed on the pore pressure transducer at ambient air pressures at the surface. Maintain records as to the baseline values for the transducer in similar fashion to those for tip and sleeve resistance. If significant changes in baseline values occur, normally 1 to 2 % FSO, perform load range tests to check for possible damage and nonlinear response.

10.3 *Calibrations of Other Sensing Devices*—Calibration data for other sensors in the penetrometer body may require calibrations using procedures similar to those given in the annex for load cells and pressure transducers. The need for calibration depends on the requirements of the individual investigation program. For minimum important programs, the occurrence of reasonable readings may be sufficient. In critical programs, it may be necessary to load the sensor through the range of interest with reference standards to ensure accurate readings.

11. Conditioning

11.1 Power electronic cone penetrometer and data acquisition systems for a minimum time period to stabilize electric circuits before performing soundings. Power the system to manufacturer's recommendations prior to obtaining reference baselines. For most electronic systems this time period is 15 to 30 min.

11.2 Electronic piezocone penetrometer soundings require special preparation of the transmitting fluid and porous elements such that entrained air is removed from the system. For soundings where dynamic response is important, replace the prepared filter elements and the ports flushed after every sounding. Some of the techniques discussed below have been successful for preparation of elements. Regardless of the techniques used, report the equipment and methods.

11.2.1 Field or laboratory tests can be performed to evaluate assembled system response. Place the cone tip and element in a pressurized chamber and subject to rapid pressure change. Compare the response of the system to the applied pressure changes and if responses match, the system is properly prepared. These tests are not routinely performed in practice as long as proven preparation methods such as those listed below are followed.

11.2.2 Place elements in a pure glycerin or silicon oil bath under a vacuum of almost one atmosphere. Maintain vacuum until air bubble generation is reduced to a minimum. Application of ultrasonic vibration and low heat, <50°C, will assist in removal of air. Generally with use of combined vacuum, ultrasonic vibration, and low heat, elements can be deaired in 3 to 4 h.

11.2.3 Elements can be prepared in water by boiling the elements while submerged in water for 4 to 5 h.

11.2.4 *Other Suitable Means*—Report other techniques.

11.2.5 *Storage*—Store prepared elements submerged in the prepared fluid until ready for use. Fill the containers and evacuate during storage. Allowable storage length depends on the fluid. If elements are prepared in water they must be deaired again one day after containers are opened and exposed to air. Elements stored in glycerin or silicon may be stored for longer periods, up to one month, after storage containers have been exposed to air.

12. Procedure

12.1 *General Requirements:*

12.1.1 Prior to beginning a sounding, perform site surveys to ensure hazards such as underground utilities will not be encountered. Position the thrust machine over the location of the sounding, and lower leveling jacks to raise the machine mass off the suspension system. Set the hydraulic rams of the penetrometer thrust system to as near vertical as possible. The axis of the push rods must coincide with the thrust direction.

12.1.2 Set the hydraulic ram feed rate to advance the penetrometer at a rate of 20 ± 5 mm/s for all electronic cone penetrometers. This rate must be maintained during the entire stroke during downward advance of the rods while taking readings.

12.1.3 Check push rods for straightness as required in 7.3. Push rods are assembled and tightened by hand, but care must be taken and threads may need cleaning to ensure that the shoulders are tightly butted to prevent damage to the push rods. For electronic cone penetrometers using cables, the cable is prestrung through the push rods. Add friction reducer to the string of push rods as required, usually the first push rod behind the penetrometer tip and other rods as required.

12.1.4 Inspect penetrometer tips before and after soundings for damage, soil ingress, and wear. In very soft and sensitive soils where accurate sleeve data is required, dismantle electronic cone penetrometer tips after each sounding to clean and lubricate as required. If damage is found after a sounding, note and record this information on the sounding data record or report.

12.2 *Friction Cone Penetrometers:*

12.2.1 Power up the penetrometer tip and data acquisition system according to the manufacturer's recommendations, typically 15 to 30 min, prior to use.

12.2.2 Obtain an initial baseline reading for the penetrometer in an unloaded condition at a temperature as close as possible to ground conditions. Obtain baseline readings with the penetrometer tip hanging freely in air or in water, out of direct sunlight. Compare baseline readings with the previous baseline reading for the requirements given in 10.1.2.1. If thermal stability needs to be assured, immerse the penetrometer tip in a bucket of water at temperature close to ground; or perform an initial short penetration test hole, stop penetration and allow the penetrometer tip to reach soil temperature, and withdraw the penetrometer.

12.2.3 Measure the depth at which readings were taken with an accuracy of at least ±100 mm from the ground surface.

12.2.4 Determine the cone resistance and friction sleeve resistance, continuously with depth, and record the data at intervals of depth not exceeding 50 mm.

12.2.5 During the progress of sounding, monitor tip and sleeve forces continuously for signs of proper operations. It is helpful to monitor other indicators such as ram pressure or inclination to ensure that damage may not occur if highly resistant layers or obstructions are encountered. Inclination is a particularly useful indicator of imminent danger to the system (see 12.4).

12.2.6 At the end of a sounding, extract the penetrometer tip, obtain a final set of baseline readings with the penetrometer tip hanging freely in air or in water, and check them against the initial baseline. Record initial and final baselines on all documents related to the sounding.

12.3 *Electronic Piezocone Penetrometers:*

12.3.1 Assemble the piezo elements with all fluid chambers submerged in the de-aired medium used to prepare the elements. Flush all confined areas with fluid to remove air bubbles. Tighten the cone tip to effectively seal the flat surfaces. For water fluid systems, protect the assembled system from evaporation by enclosing the porous element inside a fluid-filled plastic bag or cap sealed to the penetrometer tip.

12.3.2 If unsaturated soil is first penetrated and it is desired to obtain accurate dynamic pore pressure response once below the ground water, it may be necessary to prebore or sound a pilot hole to the water table. In many cases the piezocone, fluid system may be cavitated during penetration through unsaturated soil or in dilating sand layers below the water table which can adversely affect dynamic response. As the cone is advanced deeper, the saturation levels may recover as air bubbles are driven back into solution according to Boyles Law. Evaluation of proper interpretation of dynamic response requires experience (3).

12.3.3 Record baseline readings with the penetrometer tip hanging freely in air, or in water, out of direct sunlight. Compare baseline readings with reference baseline readings for requirements given in 10.1.2.1 and 10.2. A baselines for the pore pressure transducer is obtained for immediately after assembly to avoid evaporation effects. If evaporation is a problem, temporarily immerse the penetrometer in a bucket of water until ready for baseline. Do not obtain transducer baselines with protective caps or covers in place as these may induce pressure in the system. Note the pressure from the pressure transducer to see if it is a reasonable value for the equipment and assembly technique used.

12.3.4 Follow procedures in 12.2.4 through 12.2.6 with the addition of recording pore pressure.

12.3.5 *Dissipation Tests*—If dissipation tests are to be conducted during progress of the sounding, penetration is temporarily stopped at the location of interest. If pore pressures are measured at the u_2 or u_3 locations it is common practice to release the force on the push rods. If pore pressures are measured at location u_1, maintain the force on the push rods. Record pore pressure versus time during conduct of the dissipation test. Monitor pressures until equilibrium pore pressure is reached or 50 % of the initial pore pressure has dissipated. In fine grained soils of very low conductivity, very long times may be required to reach the 50 % dissipation. Depending on the requirements of the program, and any concern of friction buildup on the push rods, dissipation testing may be terminated prior to reaching the 50 % level. Report dissipation test data as a record of pressure versus time.

12.4 *Penetrometer Operation and Data Interpretation-Guidelines:*

12.4.1 *Directional Drift of Penetrometer:*

12.4.1.1 The penetrometer may drift directionally from vertical alignment. Large deviations in inclination can create nonuniform loading and result in unreliable penetration resistance data. Reduce drift by accurately setting thrust alignment and using push rods which meet tolerances given in 7.3.

12.4.1.2 Passing through or alongside obstructions such as boulders, cobbles, coarse gravel, soil concretions, thin rock layers, or inclined dense layers will deflect the penetrometer tip and induce drifting. Note and record any indication of encountering such obstructions, and be alert for possible subsequent improper penetrometer tip operations as a sign of serious directional drift.

12.4.1.3 Penetrometer inclination is typically monitored in cone penetrometers. Impose limitations on inclination in the system to prevent damage to push rods and non-symmetric loading of the penetrometer tip. Generally, a 5° change in inclination over 1 m of penetration can impose detrimental push rod bending. Total drift of over 12° in 10 m of penetration imposes non-symetric loading and possible unreliable penetration resistance data.

12.4.2 *Push Rod Addition Interruptions*—Short duration interruptions in the penetration rate during addition of each new push rod can affect initial cone and friction sleeve readings at the beginning of the next push. If necessary, note and record the depths at which push rods are added and where long pauses may have affected initial startup resistances.

12.4.3 *Piezocone Pore Pressure Dissipation Interruptions*—Pore pressure dissipation studies, for which soundings are stopped and rod load is released for varying time durations, can affect the initial cone, friction sleeve, and dynamic pore pressure readings at resumptions of cone penetration. If dissipation tests are performed, be aware of possible rebound effects on initial excess pore pressures. Note and record the depth and duration for which dissipation values are taken.

12.4.4 *Interruptions Due to Obstructions*—If obstructions are encountered and normal advance of the sounding is stopped to bore through the obstructions, obtain further penetration resistance data only after the penetrometer tip has passed through the estimated zone of disturbance due to drilling. As an alternative, readings may be continued without first making the additional penetration and the disturbed zone evaluated from these data. Note and record the depth and thickness of obstructions and disturbed zones in areas where obstructions are drilled through.

12.4.5 *Excessive Thrust Capacity*—If excessive thrust pressure begins to impede the progress of the sounding, it may be necessary to withdraw and change friction reducers. Alternately, sometimes friction may be reduced by withdrawing the penetrometer and rods up to one third to one half of the penetration depth and then repushing to depth at which the friction caused stopping. Continue collection of sounding data from the point of stopping. Note and record the delay time and depths to which the penetrometer was moved. Long delays and pauses may cause buildup of friction on the rods. Hold delays to the minimum required to perform dissipation tests or equipment repairs.

12.4.5.1 If a high resistance layer is encountered, and the truck is physically moved during penetration, terminate the sounding. Another indicator of reaching thrust capacity is the rebound of rods after they are released. The magnitude of rebound depends on the flexibility of the thrust machine and the push rods. An operator must become familiar with the safe deflection of the system and decide when excessive deflections are being reached.

12.4.6 *Unusual Occurrences*—As data are recorded, it is important to note unusual occurrences in testing. When penetrating gravels, it is important to note "crunching" sounds that may occur when particle size and percentage of coarse particles begin to influence penetration. Note and report all occurrences of coarse gravels.

12.5 *Withdrawal:*

12.5.1 Withdraw the push rods and penetrometer tip as soon as possible after attaining complete sounding depth.

12.5.2 Upon complete withdrawal of the penetrometer, inspect the penetrometer tip for proper operation. The friction sleeve should be able to be rotated through 360° by hand without detectable binding.

12.5.3 Record baseline readings with the penetrometer tip hanging freely in air, or in water, out of direct sunlight. Compare baseline readings with initial baseline reading for requirements given in 10.1.2.1.

13. Calculation

13.1 *Friction Cone Penetrometers*—Most electronic cone penetrometers in use at the present time measure a change in voltage across a strain gage element to determine change in length of the strain element. Using known constitutive relationships between stress and strain for the strain element, the applied force may be determined for the cone or friction sleeve. The applied force may then be converted to stresses using the basic equations given in 13.2 and 13.3. Since there are a wide variety of additional, optional measurements currently being obtained with electronic cone penetrometers and new ones being continually developed, it is beyond the scope of this procedure to detail the makeup, adjustments, and calculations for these optional measurements.

13.2 *Cone Resistance, q_c—Required:*

$$q_c = Q_c/A_c$$

where:

q_c = cone resistance MPa (ton/ft^2, kg$_f$/cm^2, or bar),
Q_c = force on cone kN (ton, or kg$_f$), and
A_c = cone base area, typically 10 cm^2, or 15 cm^2.

13.2.1 *Corrected Total Cone Resistance (Optional)*—Calculation of corrected total cone resistance requires measurement of dynamic pore pressures measured cone tip. This correction is most readily performed with water pressure measured in the u_2 position. Empirical adjustment factors based on soil types have been developed for some pressure elements in the u_1 position.

$$q_t = q_c + u_2(1 - a)$$

where:

q_t = corrected total cone resistance, MPa (ton/ft^2, kg$_f$/cm^2, or bar),
u_2 = pore pressure generated immediately behind the cone tip, kPa (lb$_f$/in.^{2}, kg$_f$/cm^2, bar), and
a = net area ratio (see A1.7).

13.3 *Friction Sleeve Resistance, f_s—Required:*

$$f_s = Q_s/A_s$$

where:

f_s = friction sleeve resistance kPa (ton/ft^2, kg$_f$/cm^2, or bar),
Q_s = force on friction sleeve kN (ton, kg$_f$), and
A_s = area of friction sleeve, typically 150 cm^2, or 225 cm^2.

13.4 *Friction Ratio, R_f—Required:*

$$R_f = (f_s/q_c) \cdot 100$$

where:

R_f = friction ratio, %,
f_s = friction sleeve resistance kPa (ton/ft^2, kg$_f$/cm^2, or bar),
q_c = cone resistance kPa (ton/ft^2, kg$_f$/cm^2, or bar), and
100 = conversion from decimal to percent.

13.4.1 Determination of the friction ratio requires obtaining a cone resistance and friction sleeve resistance at the same point in the soil mass. The point of the cone is taken as the reference depth. Typically, a previous cone resistance reading at friction sleeve midpoint depth is used for the calculations. For the 10 cm^2 cone the standard offset is 30 mm. If an offset other than midheight is used it must be reported.

NOTE 6—In some cases, if readings are compared at the same point in a soil mass which has alternating layers of soft and hard materials erratic friction ratio data will be generated. This is because cone resistance is sensed, to varying degrees, ahead of the cone. The erratic data may not be representative of soils actually present.

NOTE 7—The friction sleeve resistance and friction ratio obtained from the mechanical friction cone penetrometers will differ considerably from values obtained from electronic friction cone penetrometers. When using soil classification charts that use R_f and q_c, it is important to use charts based on correlations for the type of penetrometer being used.

13.5 *Pore Pressure Data:*

13.5.1 SI metric units for reporting pore pressure data are kPa.

13.5.2 *Conversion of Measured Pore Pressures to Equivalent Height of Water—Optional*—If it is desired to display pore pressure in equivalent height of water, convert the dynamic or static water pressures to height by dividing pressure by the unit weight of water—9.8 kN/m^3 (62.4 lb$_f$/ft^3).

13.5.3 *Pore Pressure Ratio—Optional*—Some reports may require a plot of pore pressure ratio. This is ratio of excess pore pressure, Δu, to cone resistance, q_c, expressed as a percentage. Excess pore pressure can only be calculated by knowing equilibrium pore water pressure, u_o (see 3.2.14). The equilibrium water pressure can be measured by dissipation test or estimated by calculation as follows (see Terminology D 653):

$$u_o = \text{estimated equilibrium water pressure} = h_i \cdot \gamma_w$$

where:

h_t = height of water, m, estimated from site conditions, and

γ_w = unit weight of water = 9.8 kN/m^3.

In layered soils with multiple perched aquifers the assumption of a single height of water may be in error.

13.5.4 *Normalized Pore Pressure Parameters—Optional*—Several researchers have proposed normalized penetration resistance parameters to more accurately predict soil properties such as overconsolidation ratio (3, 4). Some of the parameters listed below may be calculated depending on requirements of the investigation program.

13.5.4.1 *Pore Pressure Parameter Ratio,* B_q—This parameter is normally calculated with the pore pressure measurement location immediately behind the cone tip, u_2.

$$B_q = \Delta u_2/(q_t - \sigma_{vo})$$

where:

Δu = excess pore water pressure ($u - u_o$) (see 3.2.15),

u_o = estimated equilibrium water pressure (see 13.5.3), and

σ_{vo} = total vertical overburden stress =

$$\Sigma\, h_i \cdot \gamma_i$$

where:

h_i = layer thickness, and

γ_i = total unit weight of soil for layer thickness, estimated from penetration data or site conditions.

13.5.4.2 *Revised Friction Ratio—F*—This parameter is normally calculated with the pore pressure measurement location immediately behind the cone tip, u_2. This parameter is calculated as:

$$F = f_s/(q_t - \sigma_v)$$

Where f_s, q_t, and σ_v are defined above.

14. Report

14.1 Report the following information:

14.1.1 General—Each sounding log should provide as a minimum:

14.1.1.1 Operator name,

14.1.1.2 Project information,

14.1.1.3 Feature notes,

14.1.1.4 Water surface elevation (if available),

14.1.1.5 Sounding location,

14.1.1.6 Sounding number, and

14.1.1.7 Sounding date.

14.1.2 Reports should contain information concerning:

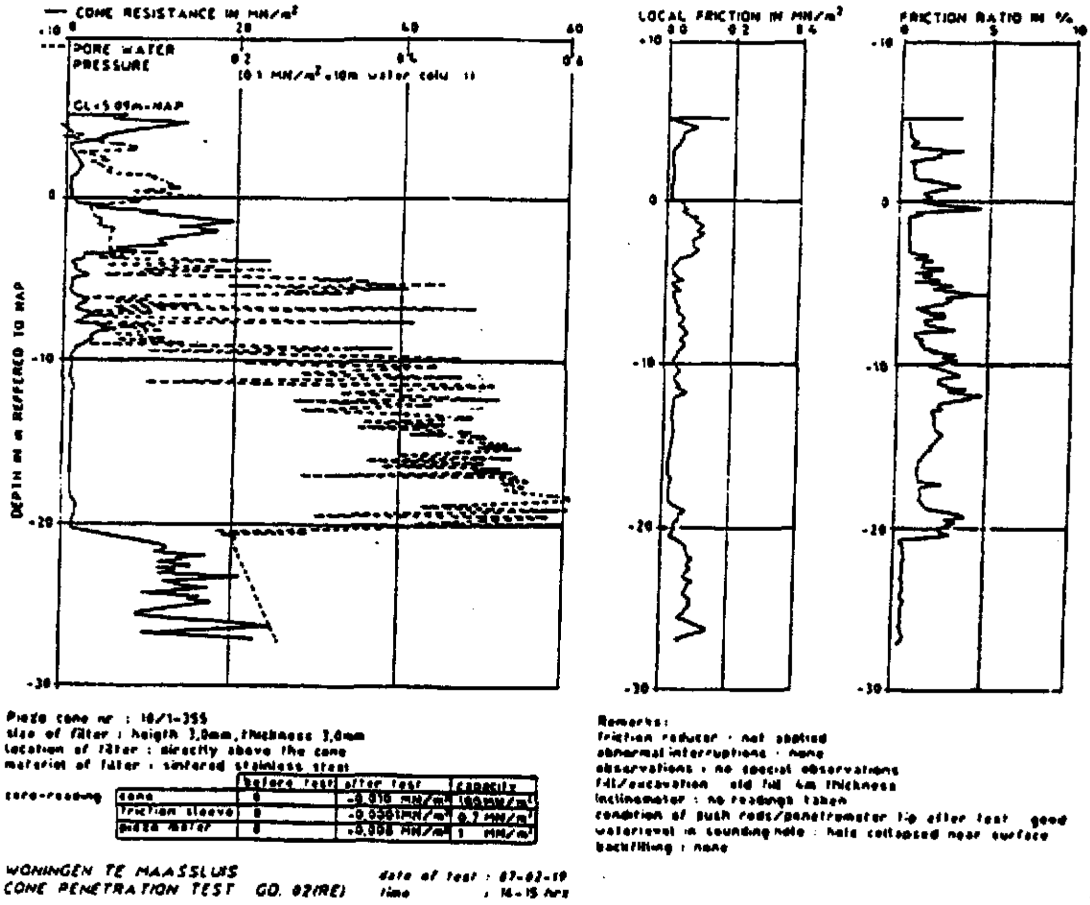
14.1.2.1 *Equipment Used*—Design drawings and data on all sensors,

14.1.2.2 Graphical data,

14.1.2.3 Tabular data (optional),

14.1.2.4 Procedures followed, and

14.1.2.5 *Calibration Information*—For all sensors, information required in Section 10.



	before test	after test	capacity
cone	0	-0.010 MN/m²	100 MN/m²
friction sleeve	0	-0.0001 MN/m²	0.7 MN/m²
piezo meter	0	+0.005 MN/m²	1 MN/m²

FIG. 4 Example of the Presentation of the Test Results on a Graph

14.1.3 The report should contain a text that discusses items required in 14.2 and 14.3. Each sounding should be documented with:

14.1.3.1 Sounding plot.

14.1.3.2 *Accompanying Tabular Output*—Tabular output is considered optional due to its bulk. It is optional as long as computer data files are preserved and archived for later use.

14.1.3.3 *Computer Data Files*—Preferably in ASCII format. Computer data files must contain header as required in 14.1, sounding log information. Certain interpretation programs require data to be in a particular format. It is the responsibility of the user to determine acceptable formats.

14.1.3.4 The comments should contain notes on equipment and procedures, particular to the individual sounding.

14.2 *Equipment*—The report should include notes concerning:

14.2.1 Penetrometer manufacturer,

14.2.2 Types of penetrometer tips used,

14.2.3 Penetrometer details such as friction sleeve end areas, location and types of sensors, location and type of friction reducers,

14.2.4 Offset between tip and sleeve resistance used for friction ratio determination,

14.2.5 Serial numbers of penetrometer tips,

14.2.6 Type of thrust machine,

14.2.7 Method used to provide reaction force—with notes as to possible surface deformations,

14.2.8 Location and type of friction reduction system (if any),

14.2.9 Method of recording data,

14.2.10 Condition of push rods and penetrometer tip after withdrawal,

14.2.11 Any special difficulties or other observations concerning performance of the equipment,

14.2.12 Details on piezocone design, filter elements, and fluid conditioning procedures, and

14.2.13 Information on other sensing devices used during the sounding.

14.3 *Calibration Certifications*—For each project the report should include the load range calibrations of the cones used that were performed in accordance with Section 10. The report should include the initial and final baseline readings for each sounding. Calibration records for the pore pressure transducers are required as given in 10.2. If the project requires calibrations of other sensors they should also be submitted in final reports.

14.4 *Graphs*—Every report of friction cone penetration sounding is to include a cone resistance plot, q_c, MPa (ton/ft^2, kg$_f$/cm^2, or bar) with depth below ground surface m (ft), friction sleeve resistance, f_s, kPa (ton/ft^2, kg$_f$/cm^2, or bar), and friction ratio, Rf(%), on the same plot. (See Figs. 4 and 5 for example plots.) As a minimum, the plot should provide general information as outlined in 14.1. Electronic piezocone penetrometer soundings should provide an additional plot of pore pressure kPa (lb$_f$/in.^{2}, kg$_f$/cm^2, or bar) versus depth m (ft). Pore pressures can be plotted or the pressure may be converted to equivalent heights of water.

14.4.1 Symbols q_c and f_s for tip and sleeve resistance are

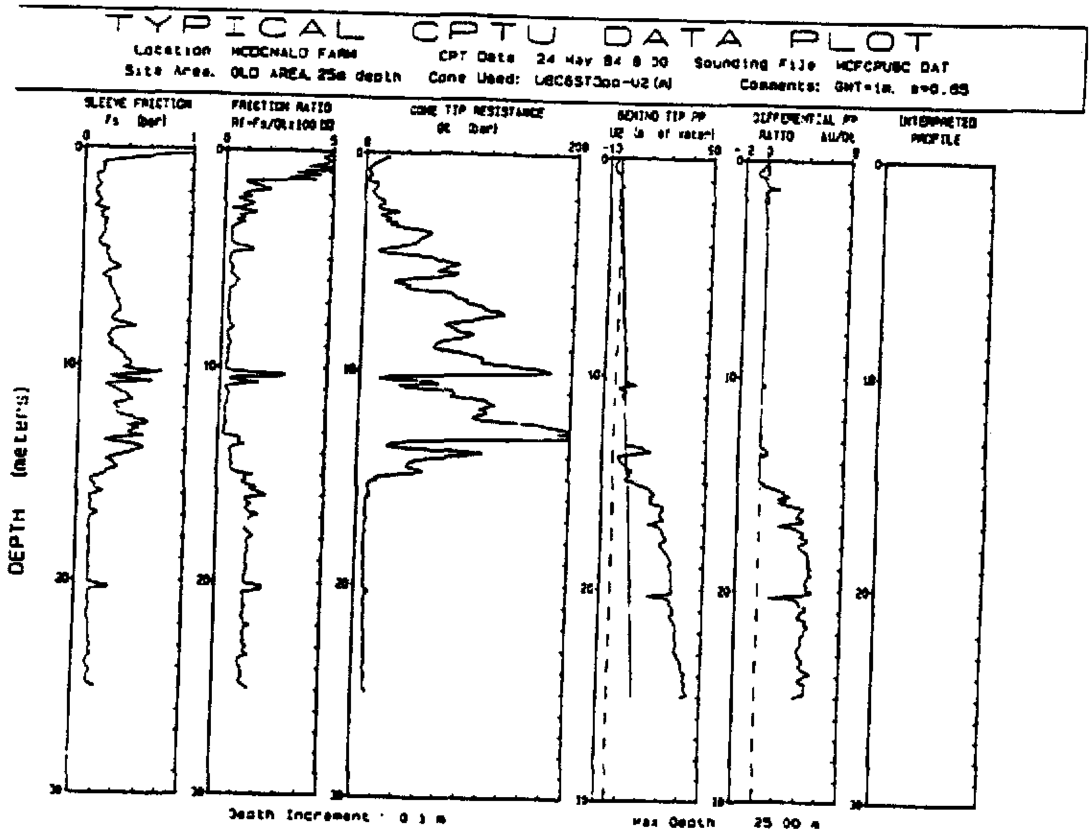


FIG. 5 Example Piezocone Graph

accepted by the International Society for Soil Mechanics and Foundation Engineering (2). Some plotters are not capable of plotting subscript symbols. In these cases it would be acceptable to have plots displayed in terms of q_c and f_r.

14.4.2 For uniform presentation of data, the vertical axis (ordinate) should display depth and the horizontal axis (abscissa) should display the test values. There are many preferences in plotting such that uniform plotting scales and presentation will not be required.

15. Precision and Bias

15.1 *Precision*—There is little direct data on the precision of this test method, in particular because of the natural variability of the ground. Committee D-18 is actively seeking comparative studies. Judging from observed repeatability in approximate uniform deposits, persons familiar with this test estimate its precision as follows:

15.1.1 *Cone Resistance*—Provided that compensation is made for unequal area effects as described in 13.2.1, a standard deviation of approximately 2 % FSO (that is, comparable to the basic electromechanical combined accuracy, nonlinearity, and hysteresis).

15.1.2 *Sleeve Friction—Subtraction Cones*—Standard deviation of 15 % FSO.

15.1.3 *Sleeve Friction—Independent Cones*—Standard deviation of 5 % FSO.

15.1.4 *Dynamic Pore Water Pressure*—Strongly dependent upon operational procedures and adequacy of saturation as described in 11.2. When carefully carried out a standard deviation of 2 % FSO can be obtained.

15.2 *Bias*—This test method has no bias because the values determined can be defined only in terms of this test method.

NOTE 8—Jefferies and Davies (5) report q_c repeatability of the two different soundings in compact clean sand using two different cones by the same manufacturer. Approximately 50 % of the data lay within 8 % of the average of the two tests, and 90 % of the data lay within 15 % of the average. In this trial the transducers (that conformed to the requirements in A1.5) were loaded to between one tenth and one fifth of their rated FSO, so confirming a standard deviation of better than 2 % FSO.

16. Keywords

16.1 cone penetration test; cone penetrometer; explorations; penetration tests; piezocone; soil investigations

ANNEX

(Mandatory Information)

A1. CALIBRATION REQUIREMENTS ON NEWLY MANUFACTURED OR REPAIRED ELECTRONIC FRICTION CONE AND PIEZOCONE PENETROMETERS

A1.1 *Introduction:*

A1.1.1 This annex describes procedures and requirements for calibrating electronic cone penetrometers. The evaluation of cone penetrometer calibration as described in this annex is a quality assurance standard for newly manufactured and repaired penetrometer tips. Many of the standards may be impractical to evaluate under field operating condition. Therefore, determination of these calibration errors for any individual penetrometer tip should be performed in a laboratory environment under ideal conditions by the manufacturer or other qualified personnel with necessary knowledge, experience, and facilities.

A1.1.2 The electronic cone penetrometer is a delicate instrument subjected to severe field conditions. Proper use of such an instrument requires detailed calibration after manufacture and continuous field calibrations. Years of cone penetrometer design and performance experience have resulted in refined cone designs and calibration procedures which make the electronic cone penetrometer a highly reliable instrument. Reports of these experiences form the basis for requirements in this annex (1, 6).

A1.1.3 The required calibration tolerances developed in this annex are based on subtraction type electronic cone penetrometers. These penetrometers are more robust than electronic cone penetrometers with independent tip and sleeve load cells and are the most widely used design. The subtraction type penetrometer, however, has less precision due to the subtraction process (1, 6). As a result, calibration tolerances given here are considered maximum values and requirements for more sensitive cone penetrometers imply smaller tolerances having greater precision. The calibration process consists of loading the penetrometer tip with reference forces and pressures and then comparing measured output to the reference.

A1.1.4 Calibrations in the laboratory environment should be performed with the complete penetrometer system to be used in the field. The same make and model computer, cable, signal conditioning system, and penetrometer to be used in the field shall be calibrated in the laboratory. Depending on the components of the system some components may be substituted with acceptable replacements. Each individual penetrometer must be tested over a range of loads to assure adequate performance.

A1.2 *Terms Related to Force Transducer Calibrations:*

A1.2.1 Figure A1.1 is a graphical depiction of terms related to transducer calibrations as set forth by the Instrument Society of America (1). The example calibration that follows deals with zero-load error, nonlinearity, hysteresis, and calibration error.

A1.2.2 To evaluate several of these values, the FSO (full scale output) of the penetrometer tip is needed. The manufacturer shall provide full scale output information for the system. Cone penetrometer tips usually are available in nominal capacities of 5, 10, and 15 metric tons. Typical full-scale outputs for these penetrometer tips follow:

Nominal Capacity, metric tons	Full-Scale Output of Cone, q_c		Full-Scale Output of Friction Sleeve, f_s	
	ton/ft²	MPa	ton/ft²	kPa
5	500	50	5	500
10	1000	100	10	1000
15	1000	100	10	1000

A1.2.3 It is important to check with the manufacturer on the full scale output of electronic cone penetrometer tips to

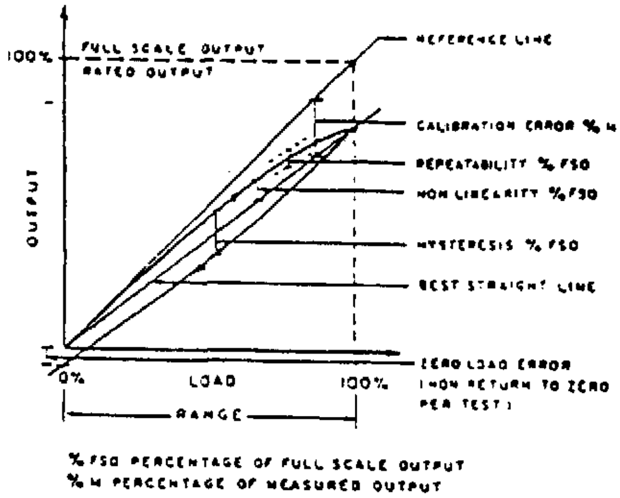


FIG. A1.1 Definition of Terms Related to Calibration (1)

avoid overloading and damaging penetrometer tips.

A1.3 *Zero Load Baseline Values:*

A1.3.1 Zero-load output variation of the cone penetrometer during testing and calibration is a reliable indicator of output stability, internal O-ring friction, and temperature-induced apparent load. The variation in zero load output is affected by temperature fluctuation because temperature compensated strain gages do not compensate for material effects and system component effects (1, 6).

A1.3.2 Systems with microprocessors provide "reference baseline" values for the transducers that are not equal to zero but are measured positive or negative values depending on the electronics of the system. For the particular penetrometer and penetrometer system used, the baseline values should remain relatively constant through the life of the penetrometer. As testing is performed in the field, the baseline resistances are monitored for changes. If large changes are noted the penetrometer should be loaded to check for linearity and possible damage. Evaluate the zero-load error during load range calibration by taking the difference between initial and final baseline values.

A1.3.3 *Thermal Stability*—For ensurance of thermal stability, evaluate a particular design of a newly manufactured cone under a range of temperature conditions. Newly manufactured penetrometer tips are first cycled to a minimum of 80 % of FSO five times at room temperature, to remove any residual nonlinearity. After cycling, establish an initial reference baseline value at room temperature after the cone has been electrically powered for about 30 min. To evaluate thermal stability, stabilize the penetrometer tip at temperatures of 10 and 30°C and new baseline values are obtained. The change in baseline values must be ≤ 1.0 % FSO of either cone or friction sleeve resistances.

A1.4 *Load Range Calibration:*

A1.4.1 Calibrate newly manufactured or repaired cone penetrometers over a range of loads after production or repair. Load test the cone penetrometer system in a universal testing machine or specially designed cone penetrometer calibration device capable of independently loading the cone and friction sleeve. If a universal testing machine is used, a calibration certificate (current within the last year) in accordance with Practice E 4 must be available. If a cone calibration apparatus is used, it should also have a calibration document current within the last year. The calibration document shows that applied forces or masses are traceable to standard forces or masses retained by the National Institute of Standards and Technology (National Bureau of Standards). The universal testing machine or cone calibration devices must be capable of loading the penetrometer tip to 100 % FSO.

A1.4.2 Example calibrations of an electronic cone penetrometer are shown in Tables A1.1 and A1.2. The calibrations were performed on a 10-ton subtraction-type electronic cone penetrometer. The measured output was a readout of cone and friction sleeve resistance obtained through a microprocessor based data acquisition system. An initial baseline was taken and then subtracted to obtain zero resistance at zero load. Selection of loading steps and maximum loading varies depending on need and application. Select the load steps and maximum load to cover the range of interest and not necessarily the maximum capacity of the cone. Some calibrations stress more frequent load steps at lower loads to evaluate weaker materials. Selection of more frequent lower load steps may result in higher levels of calibration error since the best fit line is more influenced by the low range data.

A1.4.3 As shown in Table A1.1, the cone tip is first loaded. Perform this loading after the cone is subjected to five cycles of compressive loading and reference baselines, or internal zeroing, have been obtained at room temperature. The cone is loaded in a minimum of six increments at forces equivalent to 0, 2, 5, 10, 25, 50, and 75 % FSO for the cone. At each increment of force, record both cone and sleeve resistance. Compute the actual cone resistance by dividing the applied force by the cone base area. Determine the "best fit straight line" by linear regression of applied force and measured output. The linearity is the difference between measured cone resistance and best-straight line cone resistance divided by the cone FSO. Evaluate hysteresis by comparing the difference between cone resistance at the same level of applied force in loading and unloading and dividing by cone FSO. Calculate calibration error by taking the difference between the best-fit-straight line cone resistance and actual cone resistance and dividing by the actual cone resistance. Calibration error can become larger with smaller measured outputs and, therefore, it is not evaluated at loadings equivalent to less than 20 % of cone FSO.

A1.4.3.1 When calibrating the cone, monitor the friction sleeve resistance to evaluate apparent load transfer. With a subtraction-type electronic cone penetrometer tip, the apparent friction sleeve resistance is caused by electrical subtraction error, crosstalk, and any load transferred mechanically to the sleeve. With a cone, that provides for independent cone and sleeve measurements, apparent friction sleeve resistances are caused by electrical crosstalk and mechanical load transfer. Apparent load transfer must be less than 1.5 % of FSO of the friction sleeve (1000 kPa).

A1.4.3.2 As shown in Table A1.1, maximum nonlinearity is 0.2 %, maximum calibration error is 0.5 %, and maximum apparent load transfer is 1.2 %. For this calibration, the zero load error was zero. Hysteresis was not evaluated in this

TABLE A1.1 Calibration of Cone Penetrometer—Cone Tip Calibration

DATE:
PROJECT:
FEATURE:
CLIENT:

CALIBRATED BY:		
CONE #:	361	
FSO TIP:	100 MPA	
FSO SLEEVE:	1000 KPA	
TIP AREA:	10 CM^2	
SLEEVE ARE	150 CM^2	

	m	b
CALIBRATOR DATA:	0.04971	-0.07311
CALIBRATOR SETTING	100KN	

TARGET GAUGE READING	ACTUAL GAUGE REACING	APPLIED FORCE X kN	FULL SCALE OUTPUT FSO - %	MEASURED CONE RESISTANCE Y qc - mPA	MEASURED SLEEVE RESISTANCE fs - kN/M^2	ACTUAL CONE RESISTANCE qca mPa	BEST STRAIGHT LINE* Y'=mX+b mPA	LINEARITY Y-Y'/FSO % FSO	CALIBRATION ERROR qca-Y'/qca % MO
0.000 BASELINE				-0.2	-10.3				
0	0	-0.079	-0.1	-0.0	-0.2	-0.1	0.034	0.04	
40	40	1.909	1.9	2.1	-0.2	1.9	2.053	0.00	
100	100	4.892	4.9	5.1	0.2	4.9	5.081	0.04	
200	200	9.862	9.9	10.2	0.3	9.9	10.128	0.03	
500	507	25.122	25.1	25.5	1.2	25.1	25.523	0.08	
1000	1001	49.578	49.7	50.6	0.6	49.7	50.556	0.08	1.99
500	499	24.725	24.7	25.2	0.3	24.7	25.219	0.02	1.77
200	198	9.763	9.8	10.0	0.3	9.8	10.027	0.01	
100	100	4.892	4.9	5.1	0.4	4.9	5.081	0.01	
40	40	1.909	1.9	2.1	0.4	1.9	2.053	0.03	
0	0	-0.079	-0.1	0.0	0.0	-0.1	0.034	0.08	
0.000 BASELINE				-0.3	-9.8			0.03	

		RESULT	UNIT	ALLOWABLE	APPROVAL
*BEST FIT STRAIGHT LINE (Y=mX+b	m=	1.015			
	b=	0.114			
MAXIMUM LOAD TRANSFER -SLEEVE		0.1	%FSO	2.000	YES
MAXIMUM LINEARITY ERROR		0.1	%FSO	1.0	YES
MAXIMUM CALIBRATION ERROR		1.99	%MO	2.0%MO>20%FSO	NO
MAXIMUM ZERO LOAD ERROR -CONE		0.0	%FSO	0.5	YES
MAXIMUM ZERO LOAD ERROR - SLEEVE		0.1	%FSO	1.0	YES

COMMENTS:

example because the testing machine was incapable of producing the exact same force on the loading and unloading steps.

A1.4.4 Table A1.2 shows the calibration of the friction sleeve element, independent of cone loading. This is accomplished by removing the cone and loading the bottom edge of the friction sleeve. Again, apply the forces in seven increments at 0, 2, 5, 10, 25, 50, and 75 % of FSO, that is, approximately 1000 kPa. Nonlinearity, hysteresis, and calibration error are evaluated in the same manner as calibrations for the cone. During friction sleeve calibration, monitor cone resistance to evaluate apparent load transfer that was not apparent in this calibration.

A1.5 *Force Transducer Calibration Requirements:*

A1.5.1 Calibration requirements developed for electronic cone penetrometers are based on past experience with subtraction-type electronic cone penetrometers and, as a result of this experience, represent the minimum precision requirement of electronic cone penetrometers. In cases where a higher level of precision is required, stricter calibration requirements would be required. Newly manufactured or repaired electronic cone penetrometers are required to meet the following requirements:

Calibration Parameter	Element	Requirement
Zero-load error	Cone and sleeve	≤ ± 0.5 % FSO
Zero-load thermal stability	Cone and sleeve	≤ ± 1.0 % FSO
Nonlinearity	Cone	≤ ± 0.5 % FSO
	Sleeve	≤ ± 1.0 % FSO
Hysteresis	Cone and sleeve	≤ ± 1.0 % FSO
Calibration error	Cone	≤ ± 1.5 % MO at >20 % FSO
	Sleeve	≤ ± 1.0 % MO at >20 % FSO
Apparent load	While loading cone	≤ ± 1.5 % FSO of sleeve transfer
	While loading sleeve	≤ ± 0.5 % FSO of cone

A1.6 *Pressure Transducer Calibrations:*

A1.6.1 Newly manufactured or repaired pressure transducers shall be supplied with a load range calibration provided by the manufacturer. The load range calibration shall consist of a minimum of six points of loading to at least 75 % of FSO. The applied pressures shall be traceable to reference forces maintained by NIST. The calibration shall meet the manufacturer's stated tolerances. Minimum requirements are linearity better than 1 % of FSO and zero load error less than ± 1.0 lb/in.^{2} (±7 kPa).

A1.6.2 The transducer shall be subjected to regular periodic inspection meeting requirements in A1.6.1.

A1.7 *Determination of Cone Area Ratio and Sleeve End Area Imbalance:*

A1.7.1 Figure A1.2 illustrates the areas where water pressures can act on the cone tip and sleeve elements. Water pressure that acts behind the cone tip will reduce measured cone resistance, q_c, by the magnitude of water pressure multiplied by the net area ratio, a. Water pressure may also act on both ends of the sleeve, resulting in an imbalance of forces if the sleeve is not designed with equal effective end areas. The water pressure acting on the ends of the sleeve are not just a function of geometry; they are a function of the location of water seals. Water pressures during penetration are not often measured at both ends of the sleeve so a correction based on measurements is not possible.

A1.7.2 Equal end area friction sleeves are required for use and should be designed by the manufacturer. The best method for evaluating sleeve imbalance is to seal the

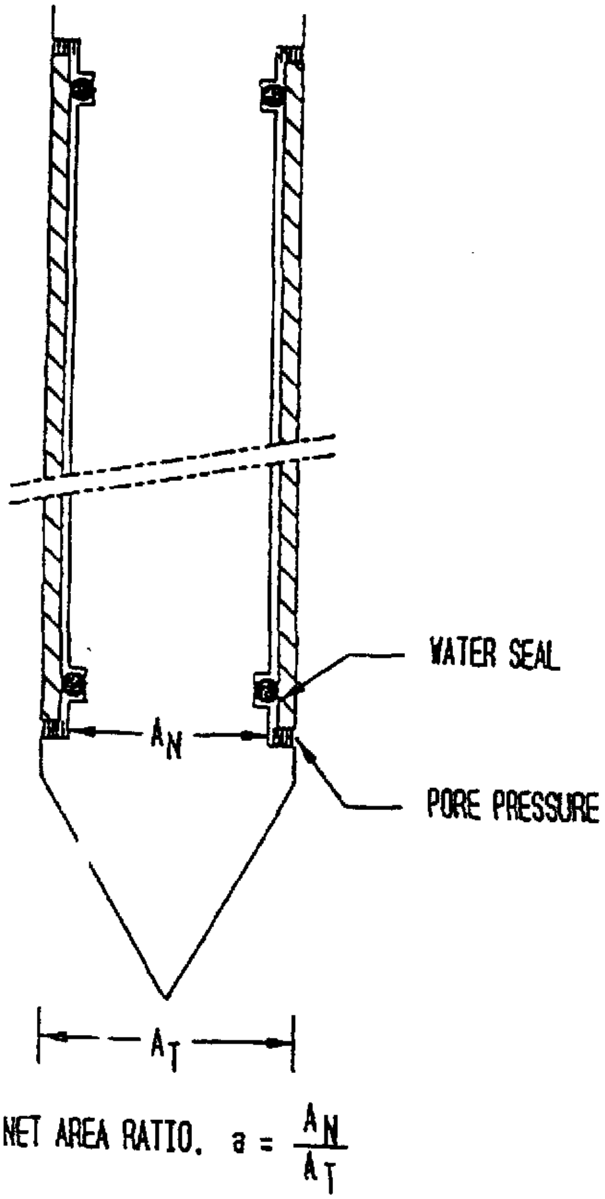


FIG. A1.2 Net Area Ratio, *a*

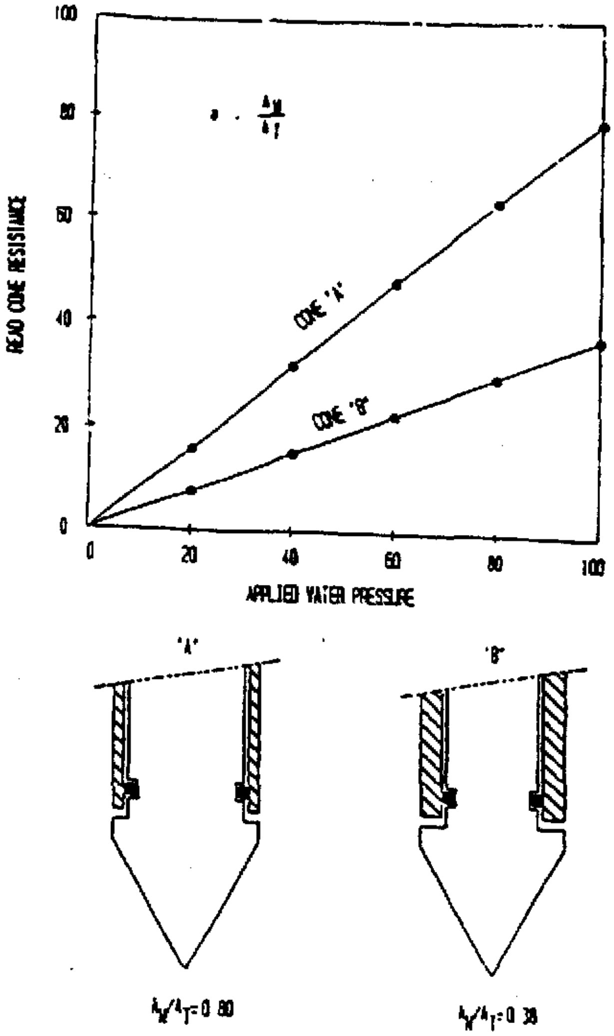


FIG. A1.3 Determination of Unequal End Area Correction

penetrometer in a pressure chamber and apply forces to measure the sleeve resistance after zeroing the system. Manufacturer's should perform this check for a particular design to assure minimal imbalance.

A1.7.3 If it is necessary to calculate the corrected total cone resistance, q_t, as shown in 13.2.1, it will be necessary to determine the area ratio of the cone. The penetrometer can be enclosed in a sealed pressure vessel and pressures should be applied as shown in the example in Fig. A1.3. The net area ratio is then used in computing the corrected total tip resistance.

A1.8 *Other Calibrations*—Other sensors such as inclination, temperature, etc. may require calibration depending on the requirements of the investigation. Perform such calibrations using similar techniques given in this annex or by other reference procedures. Report such calibrations when required.

A1.9 *Documentation of Calibrations:*

A1.9.1 Laboratory calibration documents consisting of a short report on the equipment and methods of testing, along with tables and figures similar to those in this annex, are required for the following occurrences:

A1.9.1.1 When new penetrometer tips are received,

A1.9.1.2 When damaged penetrometer tips are repaired, and

A1.9.1.3 In instances when qualifications or proposals are required for contract negotiations.

A1.9.2 The report must be certified by a registered professional engineer or other responsible engineer with knowledge and experience in materials testing for quality assurance. Calibration documents are retained on file by the offices responsible for performing soundings and should be updated at required intervals. For contract soundings, calibration documents should be obtained prior to contract acceptance and after testing on unaltered equipment.

A1.9.3 If the electronic cone penetrometer meets the field

TABLE A1.2 Calibration of Cone Penetrometer—Sleeve Calibration

DATE:	CALIBRAT BY:		CALIBRATOR DATA:	m 0.00992	b -0.012888
PROJECT:	CONE #:	381	CALIBRATOR SETTING:	20kN	
FEATURE:	FSO TIP:	100 MPA			
CLIENT:	FSO SLEEVE:	1000 KPA			
	TIP AREA:	10 CM^2			
	SLEEVE AREA:	150 CM^2			

TARGET GAUGE READING	ACTUAL GAUGE READING	APPLIED FORCE X kN	FULL SCALE OUTPUT FSO - %	MEASURED SLEEVE RESISTANCE Y fs - kPa	MEASURED CONE RESISTANCE qc - mPa	ACTUAL SLEEVE RESISTANCE fsa kPa	BEST STRAIGHT LINE* Y'=mX+b kPa	LINEARITY Y-Y'/FSO % FSO	CALIBRATION ERROR fsa-Y'/fsa % MO
0.000	BASELINE			-9.8	-0.3				
0	0	-0.013	-0.1	0.0	0.0	-0.8	3.113	0.31	
30	30	0.285	1.9	20.3	0.0	19.0	22.970	0.27	
75	75	0.731	4.9	51.2	0.0	48.7	52.757	0.16	
150	149	1.465	9.8	101.2	0.0	97.6	101.738	0.05	
375	378	3.735	24.9	249.1	0.0	249.0	253.320	0.42	1.73
750	749	7.414	49.4	495.3	0.0	494.2	498.893	0.36	0.94
375	375	3.705	24.7	260.2	0.1	247.0	251.334	0.89	
150	153	1.504	10.0	110.7	0.0	100.3	104.387	0.63	
75	77	0.751	5.0	57.7	0.0	50.1	54.081	0.36	
30	32	0.305	2.0	24.1	0.0	20.3	24.294	0.02	
0	0	-0.013	-0.1	0.2	0.0	-0.8	3.113	0.29	
0.000	BASELINE			-9.8	-0.3				

		RESULT	UNIT	ALLOWABLE	APPROVAL
*BEST FIT LINE (Y=mX+b)	m=	66.760			
	b=	3.958			
MAXIMUM LOAD TRANSFER -CONE		0.1	%FSO	0.5	YES
MAXIMUM LINEARITY ERROR		0.9	%FSO	2.0	YES
MAXIMUM CALIBRATION ERROR		1.73	%MO	3.0%MO>20%FSO	YES
MAXIMUM ZERO LOAD ERROR -CONE		0.0	%FSO	0.5	YES
MAXIMUM ZERO LOAD ERROR - SLEEVE		0.0	%FSO	1.0	YES

COMMENTS.

calibration requirements given in 10.1.3, it is only necessary to adjust the penetrometer tip to the laboratory requirements on a yearly basis. Cone penetrometers should be calibrated usin_ laboratory procedures prior to use on each new project, but they do not need to meet calibration tolerances as required for newly manufactured cones.

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Agency Washington DC 20460 [illegible]

EPA

The Rapid Optical Screening Tool (ROST™) Laser-Induced Fluorescence (LIF) System for Screening of Petroleum Hydrocarbons in Subsurface Soils

259ASD98

Notice

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List of Abbreviations and Acronyms

AEC	Army Environmental Center
ASTM	American Society for Testing and Materials
ATI	Analytical Technologies, Inc.
bbl	Barrel (Equivalent to 42 U.S. Gallons)
bgs	Below Ground Surface
Cal EPA-DTSC	State of California Environmental Protection Agency, Department of Toxic Substances Control
CAS	Chemical Abstracts Service
cm	Centimeter
CPT	Cone Penetrometer Testing
CSC	Computer Sciences Corporation
CSCT	Consortium for Site Characterization Technology
DFM	Diesel Fuel Marine
DHS	Department of Health Services (State of California)
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DQO	Data Quality Objective
EMMC	Environmental Monitoring Management Council
EPA	U.S. Environmental Protection Agency
ETI	Environmental Technology Initiative
ETV	Environmental Technology Verification
ft	Feet
FVD	Fluorescence Versus Depth
GC/FID	Gas Chromatograph/Flame Ionization Detector
HNTS	Hydrocarbon National Test Site
HSA	Hollow Stem Auger
Hz	Hertz
IDW	Investigation Derived Waste
IR	Infrared
IRP	Installation Restoration Program
ITER	Innovative Technology Evaluation Report
LIF	Laser-Induced Fluorescence
LOD	Limit of Detection
m	Meter
µm	Micrometer
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
m/min	Meters per Minute

Acknowledgments

We wish to acknowledge the support of all those who helped plan and conduct the demonstrations, interpret data, and prepare this report. In particular, for demonstration site access and relevant background information, Stephan McCarel and Ernest Lory (Naval Facilities Engineering Service Center), and David Miller (SNL); for implementation of the demonstration plan and data evaluation, Grace Bujewski, Brian Rutherford, Robert Knowlton, Robert Helgesen, and Peter Stang (PRC); for logistical and health and safety support, Michael Skelly (Roy F. Weston, Inc.) and Michael Strosinsky (SNL); for editorial and publication support, Merlyn Liberty (Tech Reps, Inc.); for peer and technical reviews, Jerry Peace (SNL); Bruce LaBelle (State of California Environmental Protection Agency, Department of Toxic Substances Control); and for U.S. EPA project management, Stephen Billets and Bob Lien (U.S. EPA). In addition, we gratefully acknowledge the participation of the ROST™ technology developers, Greg Gillispie and Randy St. Germain, Dakota Technologies, Inc. (701-237-4908); Mr. Andy Taer, Fugro Geosciences (713) 778-5580; and Mr. George Robitaille, Tri-Services SCAPS Program of the U.S. Army Environmental Center (410-612-6865).

The ROST™ uses a wavelength tunable ultraviolet laser source coupled with an optical detector to measure fluorescence via optical fibers. The measurement is made through a sapphire window on a probe that is pushed into the ground with a truck-mounted CPT. The optical fibers are integrated with the geotechnical probe and umbilical of a standard truck-mounted CPT system. CPT and standard penetrometer testing (SPT) have been widely used in the geotechnical industry for determining soil strength and soil type from measurements of tip resistance and sleeve friction on an instrumented probe.

The ROST™ LIF method provides data on the *in situ* distribution of petroleum hydrocarbons from the fluorescence response induced in the polycyclic aromatic hydrocarbon (PAH) compounds that are components of the petroleum hydrocarbon. The methods detect PAHs in the bulk soil matrix throughout the vadose, capillary fringe, and saturated zones. The methods provide a screening of the relative petroleum hydrocarbon concentrations present. However, for the purposes of this demonstration, only the detect/nondetect capability of ROST™ was evaluated.

Demonstration Objectives and Approach

The primary objectives of the field demonstrations were to evaluate the ROST™ LIF technology in the following areas: (1) its performance compared to conventional sampling and analytical methods; (2) the logistical resources necessary to operate the technology; (3) the quality of the LIF data; (4) the applications of the technology as determined by its performance in the CSCT demonstrations; and (5) its performance relative to developer claims. Performance of the ROST™ LIF sensor was evaluated to determine the agreement between LIF "detect/nondetect" data and laboratory analyses for both total recoverable petroleum hydrocarbons by EPA Method 418.1 and total petroleum hydrocarbons by California Department of Health Services Method 8015-modified. A secondary objective for this demonstration was to evaluate the LIF technology for cost, range of usefulness, and ease of operation.

In the approved demonstration plan, the developers presented several performance claims against which they were evaluated. These claims included the ability to collect measurements up to 150 feet below the surface when the sensor is used with an industry-standard 20-ton CPT rig; the ability to integrate the sensor subassembly with the rig in the field within a few hours, a standard data collection rate of one sample every 1.2 seconds, providing a spatial resolution of less than 0.2 feet for a standard push rate of 1 meter per minute; the ability of the system to acquire multidimensional data representations such as wavelength time matrices (WTMs) to identify fuel or waste type (*e.g.*, creosote); and the ability of the crew to utilize WTM information to eliminate false positives from nonhydrocarbon fluorophores.

The demonstration was designed to evaluate the ROST™ technology as a field screening method by comparing the LIF data to data produced by conventional sampling and analytical methods. For both demonstrations, conventional sampling and analysis consisted of boring with a hollow stem auger, collecting split spoon samples as closely as possible to the push cavity, and analyzing discrete samples at an off-site commercial laboratory for petroleum hydrocarbons by EPA Method 418.1 and California Department of Health Services Method 8015-modified. The demonstrations were conducted at two geologically and climatologically different sites: (1) the Hydrocarbon National Test Site located at Naval Construction Batallion Center (NCBC), Port Hueneme, California, in May 1995, and (2) the Steam Plant Tank Farm at Sandia National Laboratories (SNL), Albuquerque, New Mexico, in November 1995.

Section 2

Introduction

The Site Characterization Technology Challenge

Rapid, reliable and cost effective field screening technologies are needed to assist in the complex task of characterizing and monitoring of hazardous and chemical waste sites. However, some environmental regulators and remediation site managers may be reluctant to use new site characterization technologies that have not been validated in an EPA-sanctioned testing program, since data from them may not be admissible in potential legal proceedings associated with a site or its cleanup. Until characterization technology claims can be verified through an unbiased evaluation, the user community will remain skeptical of innovative technologies, despite their promise of better, less expensive and faster environmental analyses.

The Consortium for Site Characterization Technology was established as a component of the Environmental Technology Innovation, Commercialization and Enhancement Program as outlined in 1993 in President Clinton's Environmental Technology Initiative to specifically address these concerns. The CSCT is a partnership between the EPA, the Department of Energy, and the Department of Defense. As a partnership, the CSCT offers valuable expertise to support the demonstration of new and emerging technologies. Through its organizational structure, it provides a formal mechanism for independent third-party assessment, evaluation, and verification of emerging site characterization technologies.

The mission of the CSCT is to identify, demonstrate, assess, and disseminate information about innovative and alternative environmental monitoring, measurement, and characterization technologies to developers, remediation site managers, and regulators. The Consortium is intended to be a principal source of information and support with respect to the availability, maturity, and performance of innovative environmental monitoring, measurement, and characterization technologies.

Technology Demonstration Process

The CSCT provides technology developers a clearly defined performance assessment, evaluation and verification pathway. The pathway is outlined in the following four components:

- technology selection;
- technology demonstration;
- technology performance assessment, evaluation, and verification, and
- information distribution.

These are discussed in more detail in the following paragraphs.

Technology Selection

The first step in the overall demonstration process is one of technology selection. The selection process comprises two components. Beyond the initial identification of potential technologies, a critical aspect of technology selection is an assessment of its *field deployment readiness*. Only pre-production and production instrumentation with a history of successful laboratory or field the Level 3 technologies since these are considered market-ready. As part of the demonstration objectives, the CSCT evaluates the developer claims regarding the capabilities of the Level 3 technology and prepares a technology evaluation report containing an assessment of the technology's performance.

Information Distribution

Evaluation reports for Level 2 technologies are distributed to the technology developers, CSCT partners, and the general public. In addition, for Level 3 technologies performance verification statements are distributed to the developers for subsequent use in seeking additional developmental funding or marketing.

Technology reports for Level 1 technologies are distributed as EPA project reports. There is no technology evaluation contained in these documents. Results are compiled and reference data is provided so that the developer and reader can formulate an opinion regarding technology performance.

The CPT-LIF Sensor Demonstrations

The developer of the ROST™ LIF technology was Loral Corporation and Dakota Technologies, Inc. (DTI). PRC Environmental Management, Inc. (PRC), a contractor to the NCCOSC RDT&E Division (the developer of the SCAPS LIF technology), prepared the demonstration plan for both developers and conducted the predemonstration and demonstration field efforts, coordinated the analyses of the soil samples, and provided the raw data to Sandia National Laboratories-New Mexico (SNL), a DOE-owned laboratory operated by Lockheed Martin Corporation. SNL, as the EPA's verification entity, reviewed and approved the demonstration plan and amendments and reduced and analyzed the data generated during the two field demonstrations.

The ROST™ LIF is a CSCT Level 3 technology. For these demonstrations, the CSCT and the developers selected the demonstration sites, participated in the demonstration planning process, and jointly and separately evaluated the data generated during both demonstrations.

This report describes how the demonstration participants collected and analyzed samples, provides the results of the demonstration, and describes how the performance of the ROST™ LIF technology was verified. Section 5 discusses the experimental design for the demonstration. Section 4 presents the reference laboratory results and evaluation. Section 3 describes the ROST™ LIF technology. Section 6 presents the ROST™ LIF demonstration results and evaluation. Section 7 is an assessment of recommended applications of the technology. Section 8 is a forum wherein the developer has the opportunity to discuss the technology results and comment on the evaluation and future technology developments. Section 9 is a table summarizing selected ROST™ commercial projects. In addition, there are appendices containing the reference laboratory data, ROST™ LIF data, and proposed ROST™ LIF method.

Laser Source

The ROST™ LIF primary laser uses a neodymium-doped yttrium aluminum garnet pump (Nd:YAG) laser. It produces 532-nm light at 50 Hertz (Hz) with a pulse energy of 50 mJ. The light from the primary laser pumps a rhodamine 6G dye laser whose output is then frequency-doubled to produce ultraviolet (UV) light. The laser system used in the ROST™ is capable of generating wavelengths of light ranging from about 280 nm to about 300 nm, depending on the dye being used. The wavelength of light produced by the ROST™ LIF laser is tunable within this range. The ROST™ laser system is coupled to a silica clad silica ultraviolet/visible light transmitting optical fiber. This fiber and the collection fiber are integrated with the geotechnical probe and umbilical of a standard truck-mounted CPT system.

System Components

The Rapid Optical Screening Tool consists of the spectrometer rack and the control rack (Figure-3-1). The spectrometer rack holds all the spectroscopic instrumentation, including the Nd:YAG pump laser, tunable dye laser, emission monochromator, photomultiplier tube, and associated power supplies and motion controllers. The control rack contains the control computer and a digital oscilloscope signal processor. In operation the racks can be positioned independently and separated from each other by up to 25 feet. The racks themselves are standard industrial models with a 20-inch by 25-inch footprint and stand 25 inches high. The Nd:YAG pump laser and dye laser are arranged on an optical breadboard affixed to the top of the spectrometer rack. When the opaque plastic dye laser cover is in place, the total height of the spectrometer rack is 34 inches. The computer monitor can be conveniently placed on top of either the control rack or the dye laser cover.

Spectrometer Rack Components

The spectrometer rack holds modules for generation of pulsed ultraviolet light and detection of the return fluorescence signal. The fiberoptic cables leading to and from the cone penetrometer probe are interfaced at the back of the spectrometer rack through ST connectors. The generation of exitation light in the ROST is based on a two-stage dye laser pumped by the 532 nm harmonic of a compact pulsed Nd:YAG laser. The Nd:YAG laser head, Rhodamine 6G dye laser, and all related optics are arranged on a 19-in. by 23-in. aluminum breadboard, which is affixed to the top of the spectrometer rack. Light in the 280-300 nm wavelength range is generated via frequency doubling of the dye laser output. A 266-nm exictation wavelength capability is employed for direct detection of benzene, toluene, ethylbenzene, and xylenes (BTEX) and other single-ring aromatic hydrocarbons. In this case, the 532-nm Nd:YAG beam is diverted around the dye laser to the frequency doubling crystal for fourth harmonic generation (266 nm) To change between the tunable and 266-nm configurations requires insertion (or removal) of two mirrors on kinematic mounts.

All other mechanical operations are controlled through software. During normal operation, the only time the cover need be removed is to change between the 266-nm and 280-300-nm configurations. The frequency doubling crystal has been incorporated into a housing whose temperature is held at 40° C for isolation from any temperature drift in the truck. Pyroelectric power meters are built in for monitoring the 532-nm output of the Nd:YAG laser and the ultraviolet light emerging from the doubling crystal. If the ultraviolet output relative to the 532-nm pump input falls below specifications, an automated routine is initiated by the operator to re-optimize the frequency doubling crystal position.

The pulsed electrical signal from the PMT is fed to a digital storage oscilloscope, which digitizes, averages, and displays the fluorescence intensity versus time waveform. The user may select the number of waveforms to be averaged in the digital storage oscilloscope. After completion of the specified number of acquisitions, the waveform is downloaded to the computer for permanent storage and post-processing of the data. The digital storage oscilloscope and computer communicate via a GPIB bus.

Dynamic Range

The linear dynamic range of the ROST™ LIF detector depends on the specific hydrocarbon analyte as well as the particular matrix. Generally, for *in situ* measurements, it has been found that the linear portion of the response curves extends well beyond three orders of magnitude. Nonlinearity tends to occur at concentrations greater than 10,000 mg/kg. In sandy soils, the nonlinearity occurs at lower concentrations than in clay rich soils, possibly due to self absorption or saturation. The linear dynamic range of the LIF sensor also depends on operator-controlled instrumental parameters. The linear dynamic range may be extended to higher concentrations by adjusting the slit width of the detector, but this results in decreased sensitivity at lower concentrations.

Sensitivity, Noise, and Background

Three quantities are needed to determine the fluorescence LOD and concentration LOD limit: noise, background, and sensitivity. Sensitivity is determined using the calibration samples prepared, in most cases, immediately prior to the site visit using soil from the site and standard analytical techniques. The noise is computed after the pushes have been performed and is generally computed on a push by push basis.

The fluorescence intensity for each calibration sample is measured in triplicate each day prior to the start of operations. The three measurements are averaged to provide a single measured intensity for each concentration. The fluorescence data are regressed using the known concentration values to establish a slope and intercept. The intercept is an estimate of the intensity of the unspiked calibration standard (0 mg/kg). The slope is an estimate of the "sensitivity" of the fluorescence measurement to changes in hydrocarbon contamination.:

intercept: b = intensity measured on 0 mg/kg calibration sample

slope :

$$m = \frac{\Sigma(y_i - b)\, x_i}{\Sigma x_i^2}$$

where the sums are taken over the range of calibration samples. For these calibration soils, *x* is given by the concentration of the target fuel, while *y* is the measured fluorescence intensity adjusted to be a percentage of the M-1 standard.

Following each push, a histogram is provided for the LIF responses showing a percentage of the M-1 standard. A subjective decision is made based on the belief that background counts (again expressed as a percentage of M-1 standard) should be somewhat normally distributed. This decision results in an estimate of background noise and an estimate of the mean background fluorescence level, expressed as a percentage of M-1 standard and the background noise, the

Technology Applications

Fugro Geosciences' ROST™ LIF system was developed in response to the need for real-time *in situ* measurements of subsurface contamination at hazardous waste sites. The ROST™ LIF system performs rapid field screening to determine either the presence or absence or relative concentration of petroleum hydrocarbon contaminants within the subsurface of the site. The site can be further characterized with limited numbers of carefully placed borings or wells. In addition, remediation efforts can be directed on an expedited basis as a result of the immediate availability of the LIF and soil matrix data.

Advantages of the Technology

The LIF sensing technology is an *in situ* field screening technique for characterizing the subsurface distribution of petroleum hydrocarbon contamination before installing groundwater monitoring wells or soil borings. The method is not intended to be a complete replacement for traditional soil borings and monitoring wells, but is a means of more accurately placing a reduced number of borings and monitoring wells in order to achieve site characterization.

The LIF technology using a CPT platform provides real-time field screening of the physical characteristics of soil and chemical characteristics of petroleum hydrocarbons at hazardous waste sites. The current configuration is designed to quickly and cost-effectively distinguish petroleum hydrocarbon-contaminated areas from uncontaminated areas. This capability allows further investigation and remediation decisions to be made more efficiently and reduces the number of samples that must be submitted to laboratories for costly analysis. By achieving site characterization while expending a minimum amount of resources, remaining resources can be directed at studying the actual risks posed by the hazardous waste site and for remediation if warranted.

Table 3-1 compares the important attributes of the ROST™ technology with those of traditional laboratory methods. The major advantage of ROST™ is that it provides real-time data in the field without the need for sample manipulation and the accompanying risk of sample degradation. ROST™ also provides a qualitative fingerprinting capability in a fraction of the time required by gas chromatography. Under normal conditions, an average of 300 feet of pushes can be reasonably advanced in one day.

Table 3-1. Total petroleum hydrocarbon analysis methods.

Criterion	DHS Method 8015	EPA Method 418.1	ROST™
Basis of method	Gas chromatography	IR absorbance in C-H	Fluorescence
Applicability	Volatile organic compounds	Compounds with C-H bonds	Aromatic hydrocarbons (single, double, and multi-ring)
Possible interferences	Any volatile compound	Any species with C-H bonds	Fluorescent minerals
Sample preparation	Extract, filter	Extract, filter	None
Analysis time	5-30 minutes	Seconds	Seconds
Fingerprint capability	Yes	No	Yes
Real-time/*In situ*	No	No	Yes

proportional to the available surface area of the soil substrate. Sandy soils tend to have a much lower total available surface area than clay soils. Hydrocarbon compounds in sandy soils generally yield a correspondingly higher fluorescence response than they do in clay rich soils. In one study, soil samples were prepared as a series of sand/clay (illite) mixtures with progressively increasing clay content. The relative LIF response to DFM in each soil is essentially identical once the response curves were normalized to the available surface area of each of the soils. The moisture content of the soil matrix is another influencing factor. The LIF sensitivity to petroleum hydrocarbons generally increases with greater soil moisture content, although in some natural soils the effect appears to be small. LIF response curves representing the results of fluorescence measurements on a soil with varying water content have also been generated. These results suggest that the response is fairly insensitive to changes in moisture content. In another study it was demonstrated that increasing the amount of water in a soil tends to narrow the sensitivity difference between sandy and clay soils. It is thought that water physically displaces the hydrocarbons from within the pore spaces of the matrix, effectively reducing the surface area available to contaminants. The effects of soil grain size have also been examined in laboratory studies. LIF sensitivity generally increases with increased grain size. The measured fluorescence was shown to be substantially greater in the coarser mesh sizes.

Spectral Interferences

The ROST™ LIF sensor is sensitive to any material that fluoresces when excited by ultraviolet wavelengths. Although intended to specifically target petroleum hydrocarbons, the excitation energy produced by the LIF system's laser may cause other naturally occurring substances to fluoresce as well. At some investigation sites, it is possible that LIF sensors could respond to fluorescence originating from nonhydrocarbon sources. Many common fluorescent minerals can produce a measurable LIF signal. Other non-hydrocarbon fluorescent material introduced through human activity may be found in the subsurface environment. Deicing agents, antifreeze additives, and many detergent products are all known to fluoresce very strongly. The potential presence of fluorescence emission from nontarget (non-hydrocarbon) analytes within the soil matrix must be considered when assessing LIF field screening data. In some instances, the inability to discriminate between hydrocarbon fluorescence and nonhydrocarbon fluorescence can lead to false positives for the presence of hydrocarbons. Nonhydrocarbon fluorescence can mask the presence of hydrocarbon fluorescence, leading to reduced sensitivity or erroneous estimation of the relative amount of hydrocarbon present. In the worst case, spectral interference can lead to a false positive or false negative report of findings. However, because the LIF sensor collects full spectral information, it is almost always possible to discriminate between hydrocarbon and nonhydrocarbon fluorescence by analyzing the spectral features associated with the data.

Truck-Mounted Cone Penetrometer Access Limits

The CPT support platform used to deploy the ROST™ LIF is typically a 20-ton all-wheel drive diesel powered truck. The dimensions of the truck require a minimum access width of 10 feet and a height clearance of 15 feet. Some sites, or certain areas of sites, might not be accessible to a vehicle of this size. The access limits for a typical CPT truck are similar to those for conventional drill rigs and heavy excavation equipment.

Section 4

Reference Laboratory Results and Evaluation

The purpose of this section is to address issues related to the reference laboratory used for these demonstrations. Section 4 is divided into four subsections. The first subsection provides details concerning the selection of ATI as the reference laboratory and the reference methods performed on the soil samples at ATI for the purpose of comparison with results from the LIF technology. The second subsection provides an assessment of data quality for the laboratory and gives a description of the quality control procedures for TRPH (total recoverable petroleum hydrocarbons by IR spectrophotometry) by EPA Method 418.1 and California DHS Method 8015-modified for TPH (total petroleum hydrocarbons by GC-FID). These methods will be referred to as TRPH and TPH throughout the remainder of this report. In the third subsection, the methods used to estimate accuracy, precision, and completeness are discussed and results provided. The final subsection provides a summary of the laboratory data quality evaluation and a brief discussion of how the laboratory results will be used for comparison with the results of the LIF technology.

Selection of Reference Laboratory and Methods

To assess the performance of the LIF technology as a field screening tool for petroleum hydrocarbons in the subsurface, the data generated using the LIF technology was compared to data obtained using conventional sample collection and analytical methods. The analytical laboratory selected to provide reference analytical services, ATI, is certified in the state of California. The laboratory is located in San Diego, California.

ATI was selected because of its experience with QA procedures, analytical result reporting requirements, data quality parameters, and previous involvement with the Navy SCAPS program. ATI is not affiliated with the U.S. Navy, Loral Corporation, DTI, or any of the demonstration team members. ATI provided copies of the analytical results directly to SNL in order to maintain independence of the data. Copies of all QA and analytical procedures were provided to SNL for review prior to the demonstration and were included in the approved demonstration plan.

After discussion between representatives of State of California EPA, SNL, and the U.S. EPA, EPA Method 418.1 for TRPH and California DHS Method 8015-Modified for TPH were selected as the reference methods for the LIF technologies. The TRPH and TPH methods were chosen because of their widespread and generally accepted use in delineating the extent of petroleum hydrocarbon contamination. The TRPH and TPH methods are currently used as indicators of petroleum contamination in leaking underground and aboveground fuel tank investigations; as such they are the most comparable analytical methods corresponding to the objective of demonstrating rapid field screening using LIF.

EPA Method 418.1 for total recoverable petroleum hydrocarbons (TRPH) is used for the measurement of Freon-113-extractable petroleum hydrocarbons from surface and saline waters, soil, and industrial and domestic wastes. The sample is acidified to a low pH (<2) and serially extracted with Freon-113 in a separatory funnel. Interferences from polar animal oils and greases

Sample Analysis

TRPH was determined by EPA Method 418.1 by calculating the linear regression of absorbance versus concentration. The concentration thus derived tells only the concentration of oils in the Freon-113 extract. This was then related back to the original sample. TPH was quantified by DHS Method 8015-modified by sample peak area using the mean response factor of the curve. The concentration was calculated using the response factor and the mean calibration factor obtained from prepared diesel fuel standards and adjusting for volume and dilution factors. FID was used for compound detection.

Detection Limits

The ATI method detection limit for TRPH is 1.0 mg/kg for soil. The method detection limit for TPH is 5.0 mg/kg for soil.

Quality Control Procedures

For TPH, quality control procedures included preparation of a calibration curve for instrument calibration using NIST-traceable standards. A reagent blank is extracted each time a batch of no more than 20 samples is extracted. An additional reagent blank is extracted for each batch of 20 samples in any given day. A blank spike is extracted with each batch of no more than 20 samples. Surrogates are run with each soil sample and quality control sample. Matrix spikes and matrix spike duplicates are also prepared and associated to no more than 20 samples of a similar matrix to check for precision and accuracy. Spiking is done directly into the sample prior to extraction. Spiking levels for fuel hydrocarbons are 100 mg/kg for soils.

For TRPH, a reagent blank, blank spike, matrix spike, and matrix spike duplicate were analyzed for each batch of 10 samples. Spiking level for petroleum hydrocarbons is 130 mg/kg for soils. A laboratory control sample was analyzed to verify the working curve, and a midrange check standard was run every tenth scan. The working calibration curve was prepared once per day.

Calibration standards were run at least every 10 samples to verify the calibration curve. In addition, a laboratory control sample (a midrange reference standard) was run at least once during each instrument run to verify the calibration curves. ATI did not report the actual results to the developers or SNL, but did report that all calibration and control standards were within acceptance limits.

Accuracy, Precision, and Completeness

This section discusses the accuracy, precision, and completeness of the reference method data. Tables 4-1 and 4-2 display the results of the quality control samples used to estimate accuracy and precision of the methods. The data from the reference laboratory were internally reviewed by ATI QC personnel before the data were delivered to SNL and NCCOSC RDT&E Division. SNL reviewed the raw data and quality control sample results and verified all calculations.

Accuracy

Accuracy and matrix bias of the reference methods were assessed using laboratory spiked samples and, in the case of DHS Method 8015-modified, surrogate additions. Results of past PE audits of ATI were also reviewed to verify laboratory performance for accuracy and precision.

Field duplicate samples were analyzed by both reference methods. After the soil samples were homogenized, nine of the samples from the Port Hueneme site and one of the samples (SNLDB11-40) from the SNL site were analyzed in duplicate (see Table A-1). This subset was selected randomly by the SNL verification entity in the field during the Port Hueneme demonstration, based on a visual assessment of the contamination of the sample; only the samples containing visually detectable hydrocarbon contamination were analyzed in duplicate. The sample for the SNL demonstration was selected after the demonstration based on inspection of the LIF results. The mean precision estimate (RPD) for the 10 total field duplicates was 10.7% for TPH and 16.4% for TRPH. Overall, these data show good agreement between the samples and their respective field duplicates, indicating a high degree of precision by the reference laboratory.

The precision for the laboratory duplicates (Table 4-1, 4-2) was estimated by comparing the results of 14 pairs of matrix spike/matrix spike duplicates for TPH and 23 pairs of matrix spike/matrix spike duplicates for TRPH. Overall, those data shows good agreement between the laboratory matrix spikes and their duplicates for both methods.

Completeness

Percent completeness is defined as follows for all measurements:

$$\%C = 100\% \times \left(\frac{V}{T}\right)$$

where

V = number of sample measurements judged to be valid
T = total number of discrete sample measurements

Results were obtained for all of the soil samples. A total of 130 analytical soil sample results plus nine field duplicate results using both TPH and TRPH methods were available from Port Hueneme. A total of 92 soil sample results for both TPH and TRPH plus one field duplicate sample result were available from the SNL Tank Farm demonstration data set. As mentioned earlier, two samples from SNL that were left unrefrigerated for 5 days at the laboratory were included in the data set because their suitability for comparison to the LIF measurements did not appear to be compromised. Based on these results, the completeness of the data set was 100 percent.

Use of Qualified Data for Statistical Analysis

As noted above, 100 percent of the reference laboratory results from Port Hueneme and SNL samples were reported and validated. The data review indicated that all data were acceptable for meeting the demonstration objectives. The results of these analyses are presented in tabular form in Appendix A, Tables A-1 and A-2, and graphically in Section 6.

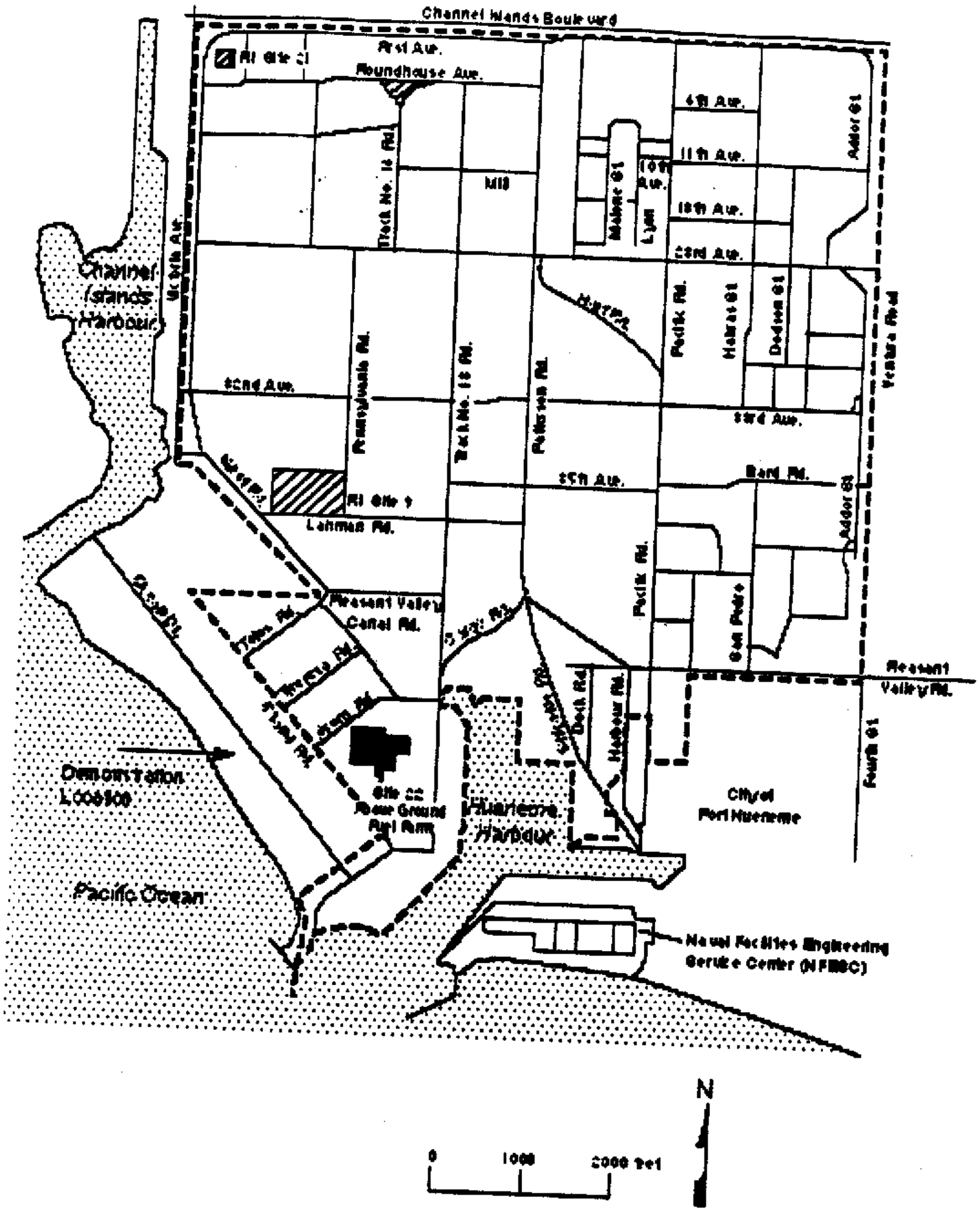

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Figure 5-1. Site vicinity map, Port Hueneme; NCBC Port Hueneme area is delineated by the dashed perimeter.

confirmatory analyses. Representatives of Cal EPA-DTSC collected duplicates for analysis at the State of California Hazardous Materials Laboratory for verification of contaminants.

In addition to the soil samples submitted to ATI and the State of California Hazardous Materials Laboratory for chemical analysis, one to two soil samples per boring were submitted to the Law/Crandall geotechnical laboratory in San Diego, California. These samples were subjected to mechanical soil analysis for grain size estimation using ASTM Method 422 and for moisture and density analysis using ASTM Method 2937.

The results of the predemonstration sampling and analysis were used by the developers to assess matrix effects or interferences, revise operating procedures where necessary, and finalize their performance claims. The developers and representatives of Cal EPA-DTSC, SNL, and U.S. EPA determined that the site and the contaminant type and distribution were acceptable for the purposes of this demonstration.

Demonstration Sampling Operations, Port Hueneme

The objective of the sampling design at Port Hueneme was to collect *in situ* LIF and conventional laboratory analytical data concurrently to demonstrate the ROST™ LIF sensor's capability to delineate the boundary (field screening) of a petroleum hydrocarbon plume. To accomplish this, a series of eight iterative pushes and comparison borings were advanced between Tank 5114 and the expected plume boundary. After each push, a boring was drilled adjacent to the push hole and sampled. The push and boring locations are depicted in Figure 5-2.

According to the demonstration plan, the SCAPS CPT platform alternatively pushed the SCAPS LIF probe and ROST™ LIF probe, producing a pair of pushes located approximately 8 inches apart, prior to the advancement of the comparison boring between the two push holes.

The SCAPS CPT platform was used to push the ROST™ LIF probe and acquire fluorescence data to a total depth of 16 to 20 feet bgs. Following the pair of pushes, the rig was moved completely away from the location and a hollow stem auger (HSA) drill rig was positioned with its stem center approximately 4 inches from the push hole. A hole was drilled using an 8-inch diameter hollow stem auger such that the internal diameter of the auger was parallel to, and approximately 2 inches offset from, the LIF probe cavity. Operating within this drilling geometry, the advancing auger flights destroyed the LIF probe's push hole while allowing for the collection of split spoon soil samples within approximately 3 inches (horizontally) of the push cavity. Soil samples were collected with a split spoon sampler lined with 6-inch long, 2.5-inch diameter stainless steel tubes. The sampler was driven in advance of the lead auger using a 140-pound slide hammer falling over a 30-inch distance, in accordance with the ASTM 1586 Standard Penetration Test.

Soil samples were collected from every 1 to 1.5 feet of boring starting at a depth of approximately 2 feet below ground surface. The sampler was overdrilled approximately 6 inches prior to retrieval to reduce the amount of slough soils typically in the bottom of the borehole. Only tubes containing sample soils that appeared relatively undisturbed were used.

Method 2937. Those samples determined by grain size analysis to contain a substantial portion (>25 percent) of fine-grained material (defined as that passing through a #200 sieve) were subjected to hydrometer testing by ASTM Method 422. Although not part of the verification process, Law/Crandall, Inc., performed the geotechnical laboratory analyses on selected soil samples to confirm the visual logging of the borings in the field.

- Rinsate samples of the split spoon sampler were collected to check for cross-contamination after decontamination of the sampler. The rinsate samples were submitted to ATI for analysis.

Port Hueneme Sampling Locations

The sampling locations were in a line running west to east located south of Tank 5114 (Figure 5-2). The first ROST™ push was located in what was estimated to be an area within the plume and identified as PHDR21, at 6 feet east of the 0-foot location (Table 5-1). The first boring was advanced and sampled immediately after the probe was retrieved and the CPT rig was moved away. A second push, designated as PHDR22, was then advanced in an area estimated to be outside of the plume boundary. The second boring was advanced and sampled immediately after the probe was retrieved and the CPT rig was moved away. The strategy was to advance the first two pushes in locations that would bound the edge of the plume and then locate subsequent pushes, PHDR23-PHDR28, in an effort to close in on the horizontal extent of the plume. The distance between each successive push decreased until the edge of the subsurface hydrocarbon plume had been defined within 9 feet, for a total of 8 borings. The number of sampling locations was based on past use of the CPT and LIF technology to define hydrocarbon plume boundaries at other sites and on demonstration budget constraints.

Table 5-1. Port Hueneme boring and push summary table.

Push or Boring Identification	Date	Comments
PHDR21 PHDB21	5-17-95	R21 located 6 feet 8 inches east of zero point; B21 located 4 inches west of R21. Total of 15 samples collected; max depth 19 feet.
PHDR22 PHDB22	5-17-95	R22 located 200 feet east of zero point; B22 located 4 inches east of R22. Total of 17 samples collected; max depth 19.5 feet.
PHDR23 PHDB23	5-18-95	R23 located 53 feet 8 inches east of zero point; B23 located 4 inches west of R23. Total of 16 samples collected; max depth 19 feet.
PHDR24 PHDB24	5-18-95	R24 located 162 feet east of zero point; B24 located 4 inches east of R24. Total of 21 samples collected; max depth 19.5 feet.
PHDR25 PHDB25	5-19-95	R25 located 81 feet 8 inches east of zero point; B25 located 4 inches west of R25. Total of 16 samples collected; max depth 20 feet.
PHDR26 PHDB26	5-19-95	R26 located 142 feet east of zero point; B26 located 4 inches west of R26. Total of 17 samples collected; max depth 20 feet.
PHDR27A PHDB27	5-22-95	R27A advanced through 6 feet pilot hole of approximately 6 feet bgs. R27A located 156 feet 4 inches east of zero point. B27 located 4 inches east of R27A. Note that push R27 was refused in upper 5 feet due to gravel and cobble. Total of 19 samples collected; max depth 19.5 feet.
PHDR28 PHDB28	5-22-95	R28 advanced through 6-ft pilot hole 148 feet east of zero point. B28 located 4 inches east of R28. Total of 17 samples collected; max depth 18.5 feet.

Note: PHDR represents the ROST™ push at the Port Hueneme site. PHDB represents the hollow stem auger boring.

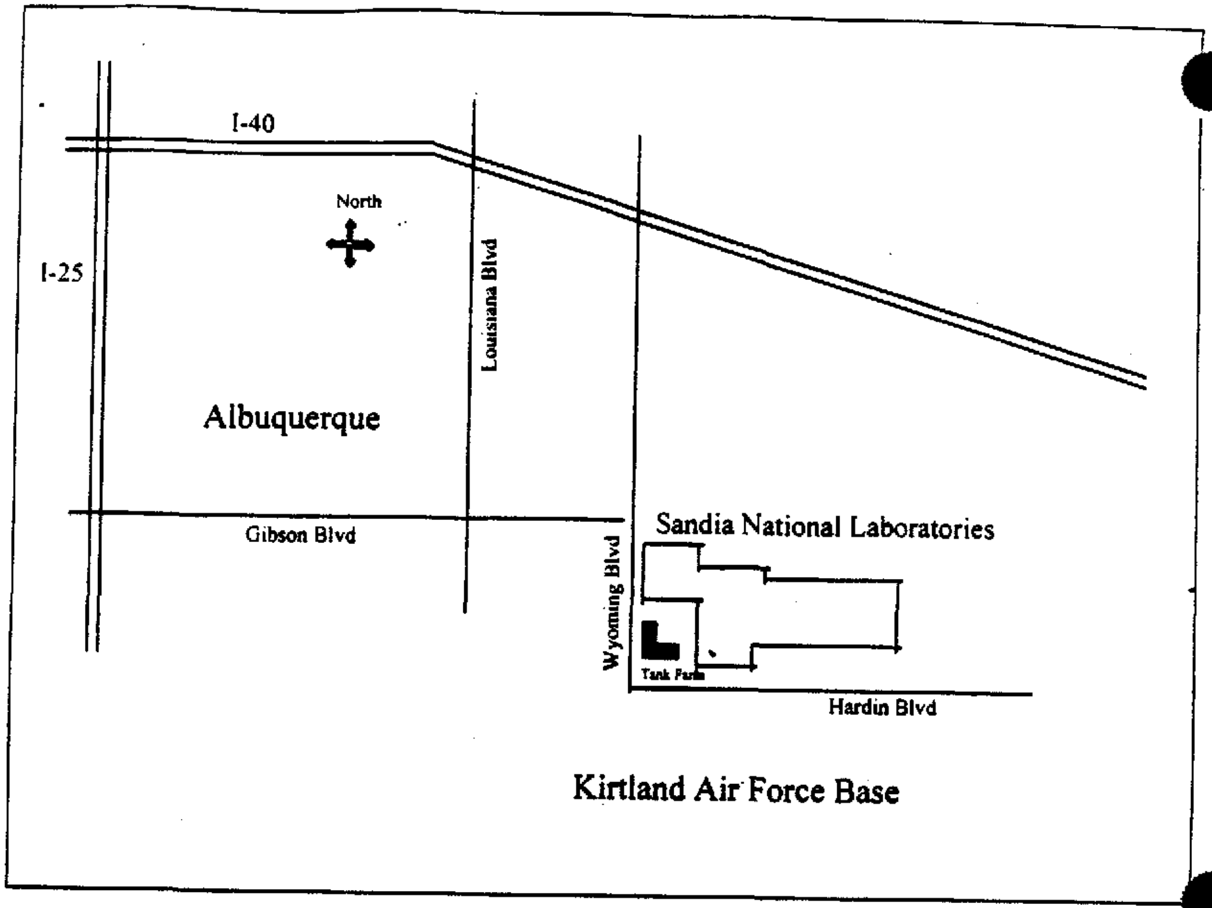

Figure 5-3. Site vicinity map, SNL Tank Farm

on the surface are composed of alluvial fan deposits shed from the eastern uplifts that interfinger with valley alluvium and consist of clayey to silty sands, with lesser amounts of silt, clay, and sand. Surficial deposits are underlain by a thick sequence (greater than 5,000 feet) of basin-fill deposits of interbedded gravels, sands, silts, and clays. Depth to groundwater is approximately 500 feet, with the potential for perched water at shallower depths. During the exploratory and informal predemonstration investigations, the SCAPS CPT consistently met with refusal at a depth of 52-57 feet, due to a consolidated gravel/caliche layer at this depth.

SNL Tank Farm Site Contaminants and Distribution

The SNL Geoprobe® investigations and the preliminary investigations using the SCAPS LIF sensor indicated diesel contamination greater than 1000 mg/kg in the vadose zone down to 56 feet. The area that was excavated down to approximately 15 feet and subsequently backfilled with the contaminated soil contains a somewhat homogenized mixture of diesel contaminated soil and uncontaminated soil. A high concentration of subsuface fluorescing minerals, most likely calcium carbonate, was identified prior to the demonstration. Calcium carbonate is present to some degree throughout the vadose zone in this area; it is more concentrated near the surface.

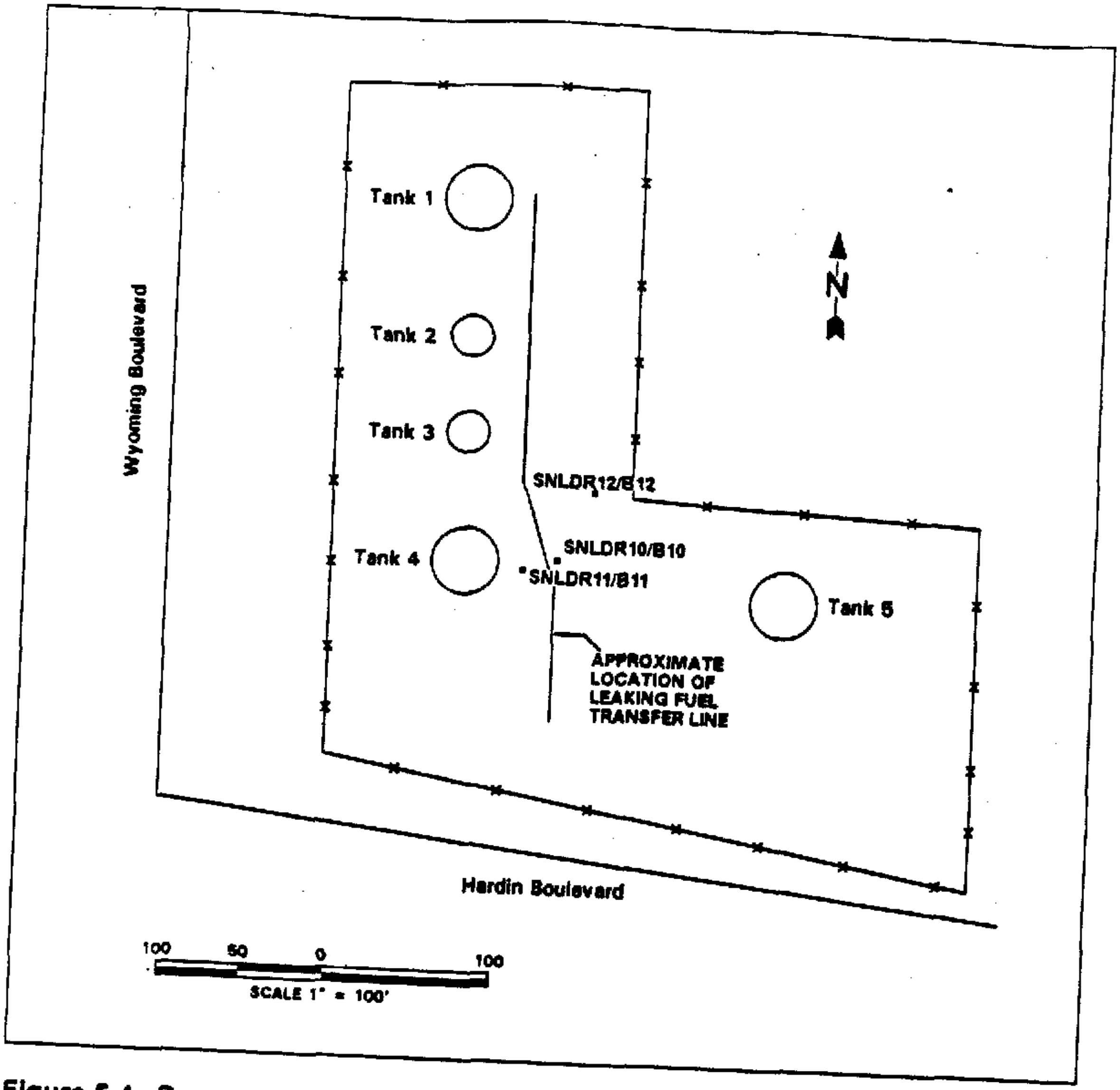

Figure 5-4. Demonstration site and sampling locations, SNL Tank Farm

SNL Tank Farm Predemonstration Sampling

A formal predemonstration event was not conducted at the SNL Tank Farm site. The site was evaluated for its suitability as a demonstration site during a site exploratory tour by the NCCOSC RDT&E Division in August 1995. Two other arid locations were evaluated at this time and determined to be unsuitable for this demonstration. Immediately prior to the field demonstration in November, NCCOSC RDT&E Division personnel performed informal sampling to determine sampling locations for the demonstration. Earthen berms had been removed to allow access to contaminated areas. Following select pushes, stab samples (discrete soil samples collected using the cone penetrometer soil sampling apparatus) were collected and shipped to ATI for overnight confirmatory TPH and TRPH analysis. Laboratory analysis of the stab samples indicated TRPH of 3380 mg/kg and TPH of 3300 mg/kg (as diesel) at a depth of 25 feet. Carbonate was observed in all the discrete soil samples in varying concentrations by the professional geologist

Table 5-2. SNL Tank Farm boring and push summary table.

Push or Boring Identification	Date	Comments
SNLDR10 SNLDB10	11-6-95	R10 located 2 feet 8 inches north and east of fuel transfer line. B10 located 4 inches offset from R10. Total of 53 samples collected; max depth 56.25 feet.
SNLDR11 SNLDB11	11-7-95	R11 located 9 feet 8 inches south and west of fuel transfer line. B11 located 4 inches offset from R11. Total of 28 samples collected; max depth 55.25 feet.
SNLDR12 SNLDB12	11-8-95	R12 located 50 feet north and east of R10. B12 located 4 inches offset from R12. Total of 20 samples collected; max depth 49.5 feet.

Note: SNLDR represents the ROST™ push at the SNL Tank Farm Demonstration. SNLDB represents the hollow stem auger boring.

Calibration Procedures, Quality Control Checks, and Corrective Action

Calibration procedures, method-specific QC requirements, and corrective action associated with nonconformance QC for the LIF technology are described in the following paragraphs.

ROST™ LIF Initial Calibration Procedures

The time window (typically 250 ns wide) on the digital oscilloscope is adjusted to compensate for the light transmit time through the optical fiber. For a 50-meter long push, the fluorescence signal is received at the detector about 500 ns after the laser has actually fired. Once set, the time delay needs to be adjusted only if the length of the fiber in the probe umbilical is changed. The position of the ROST™ time window can be determined automatically with routines built into the scope's software. The procedure was carried out prior to the demonstration.

A wavelength calibration for the emission monochromator was performed at the start of the demonstration and thereafter during troubleshooting procedures. The 532 nm Nd:YAG second harmonic light was used as a primary reference to verify the wavelength accuracy of the monochromator. A small amount of 532 nm light was directed into the monochromator at a narrow slitwidth, and the wavelength was scanned to verify that the signal maximizes at 532±0.2 nm. The monochromator can then be used as a secondary reference to calibrate the dye laser wavelength.

The concentration calibration was performed using a set of calibration standards (DFM-spiked site-specific soil samples) prepared by the serial addition method. The calibration standards were run in triplicate at the beginning of each day and again when equipment was changed. These samples were sequentially presented to the sapphire window for measurement. After measurement, the average and standard deviation was computed for each sample. If the standard deviation exceeded 20 percent for replicate analyses of any single sample, that sample was rerun. If deviation remained excessive, the system check standard was measured. If the check standard was out of compliance, system checkout and debugging was required. A calibration curve was generated by regressing fluorescence peak intensity expressed as a percentage of a reference solution versus the concentration of fuel product added to the calibration soil sample.

ROST™ LIF Continuing Calibration Procedures

A fluorescence reference measurement was performed before and after each push for normalization purposes and to check system performance. The reference material, referred to as M-1 submitted to ATI for analysis of TRPH and TPH using the reference analysis methods previously described.

Data Reporting, Reduction, and Verification Steps

To maintain good data quality, specific procedures were followed by the developer and the SNL verification entity during data reduction, validation, and reporting. These procedures are detailed below.

Data Reporting

The following data were reported to SNL:

1. Data logs from all pushes, including ROST™ fluorescence as a percentage of M-1 fluorescence with respect to depth. Also provided were wavelength time matrices for select positions along each push.
2. System check and calibration sample concentrations; tabulated raw system check and calibration sample fluorescence data; average system check intensity and system check ratio for each push; background, noise, and sensitivity calculated from calibration data.
3. Borehole logs indicating soil sample collection information, including sample numbers, depth of samples, location of water table, and other relevant information concerning the collection of the soil samples, and chain-of-custody documentation associated with soil samples.
4. Laboratory results for TPH and TRPH measurements of soil samples, including the reference method analytical results and quality control data.

Data Reduction and Verification Steps for the ROST™ LIF Data

The LIF system records the fluorescence as a percentage of the M-1 standard as a function of depth as the probe is pushed into the ground. This raw data is calibrated using the system check standard measured before and after each push, and the series of calibration samples measured on a daily basis during the site operations. The raw data and daily calibration procedures were used to make decisions in the field. Following the conclusion of site operations, the raw fluorescence measurements were adjusted by a normalization factor, and a site-wide regression slope was computed to the detection limits. This procedure is detailed below.

1. Each day, calibration curves were established using the DFM-spiked samples prepared prior to the demonstration. The resulting sensitivity (the slope of the line estimated using all calibration data) was used to determine the limit of detection (LOD) in mg/kg.
2. Each fluorescence versus depth (FVD) log was analyzed to determine if depth data from the depth encoder were correct.
3. Each FVD was analyzed to determine the background signal for each push. Background signals are assumed to generate a bell-shaped curve at the low end of the histogram centered around the mean of the background generated signal. The calculated mean of the bell shaped curve is then used to represent the background for that push. The background is subtracted from each percent fluorescence measurement to produce a background-corrected data set. The standard deviation is used as an estimate of noise. The LOD is calculated as 2.58 standard deviations (the 99th percentile) added to the background.

calibration standards prepared prior to the demonstration showed a strong fluorescence signal, it was agreed by all parties that a revised set of calibration standards would be prepared using soil more representative of the subsurface environment. This soil was collected at a depth of 36 feet bgs using the split spoon sampler during advancement of boring SNLDB12, the nonimpacted location. The developer reported that the background signal produced using the newly prepared calibration standards did not appreciably affect their data set, and elected not to use the new calibration standards.

reference laboratory data. The indicators evaluated for the ROST™ LIF technology were precision and completeness. The accuracy of the data was assessed upon comparison to the laboratory results.

Precision

Precision refers to the reproducibility of measurements of the same characteristic, usually under a given set of conditions. Unfortunately, the conditions can vary in environmental data to an extent that leaves the term ambiguous. Differences from site to site, sample to sample within a site, and differences in results from repeated measurements from a single sample provide examples. Because the ROST™ LIF sensor's primary utility is for *in situ* sensing as the probe is pushed into the ground, it was not possible to obtain precision data for the sensor under conditions that exactly duplicated the manner in which *in situ* measurements are made in the subsurface.

During the Port Hueneme demonstration, an estimate of the instrumental precision was obtained by placing a standard cuvette containing M-1 reference standard in front of the sapphire window and measuring the sample 20 times (50 laser shots for each analysis). This is the same as the system check procedure used before and after each push. Because the system check standard is a liquid, it was considered to be homogenous. This procedure provided an estimate of the precision of the instrument. The standard deviation of the 20 measurements was 2.2% of the mean count.

Completeness

Completeness refers to the amount of data collected from a measurement process compared to the amount that could be obtained under ideal conditions. For this demonstration, completeness refers to the proportion of valid, acceptable data generated using each method. It was anticipated that less than 100 percent completeness of both the LIF data and discrete sample analysis results would occur. For LIF data collection, a push that was refused due to contact with cobbles or other obstructions was disqualified. A substitute push was advanced in these cases, within 8 inches horizontally of the disqualified push. This occurred on ROST™ push 27 at Port Hueneme. At this site, the refusals occurred near the surface, so the subsequent push (PHDR27A) allowed for LIF data to be collected near the same location. As long as the substitute push was located within 8 inches, the disqualified push was not counted against the completeness goal. Therefore, the completeness was 100 percent for Port Hueneme. At SNL, preliminary pushes had indicated an impenetrable gravel/caliche layer at approximately 50-58 feet bgs. While this was able to be penetrated by the HSA rig, the cone penetrometer was not advanced past this depth. The pushes were considered to be complete at the point of refusal. Therefore, the LIF data set was considered 100 percent complete for the SNL site.

Accuracy

Accuracy refers to the degree of agreement of a measurement to the true value. For an *in situ* field screening measurement technique such as LIF, determining the accuracy of the technique presents a particular challenge. This is because it is not a simple matter to confidently assign a "true" value to a subsurface contaminant distribution. When compared to conventional laboratory-based measurements, the accuracy of the method is a function of both the sampling errors and errors associated with the measurement method.

Port Hueneme Site Data Presentation and Results

The data presented in this section are used to assess of the ability of the ROST™ LIF to provide field screening and mapping of subsurface contaminants in a shallow, coastal site with contamination in the vadose zone, capillary fringe, and saturated zone. The percentage agreement with the laboratory results of soil samples from the Port Hueneme demonstration site is reported in this section.

Port Hueneme Detection Limit

As described in Section 5, the LOD was determined on a push-by-push basis in the field during the demonstration, and a composite site sensitivity was calculated for determination of agreement with the laboratory results. For the Port Hueneme site, the ROST™ site LOD was 5 mg/kg. Because the soil samples were 6 inches long, the fluorescence for the 6-inch interval associated with each sample was averaged and compared to the LOD. The reference method data were considered to show a detect when the value exceeded the Port Hueneme LIF site detection limit of 5 mg/kg. When the average *in situ* fluorescence result exceeded the fluorescence LOD, this was designated a "detect." The actual results for the Port Hueneme demonstration are presented in Table 6-1. The results indicate that the LIF data correlate better with the TPH results, which may be due to the humic interferences common to TPRH analysis. The instances where matches or misses occurred are listed in Appendix A, Table A-1.

Table 6-1. Summary of comparison of Port Hueneme LIF data with laboratory data.

Category LIF/Lab	Compared to TRPH result	Compared to TPH result
Nondetect/Nondetect Match	91	97
Detect/Detect Match	23	19
Nondetect/Detect Miss ("FN")	13	7
Detect/Nondetect Miss ("FP")	3	7
Total Samples	130	130
Percent ND/ND of Total	70%	74.6%
Percent D/D of Total	17.7%	14.6%
Percent Matches of Total	87.7%	89.2%
Percent ND/D Misses ("FN") of Total	10%	5.4%
Percent D/ND Misses ("FP") of Total	2.3%	5.4%

Downhole Results for Port Hueneme

The LIF results obtained during five contaminated pushes at Port Hueneme have been plotted in Figure 6-1. These five plots indicate the pushes and associated borings along the transect near Tank 5114. The corresponding soil sample collection locations and results are also indicated. The square symbols indicate the locations and results of the single point tests. As discussed in Section 5, during the predemonstration event there was a depth discrepancy observed with the hollow stem auger and split spoon sampling operation, believed to be due to sloughing of sands in the saturated zone. This was also observed during the demonstration. The reference laboratory provided splits of the homogenized samples from the demonstration to NCCOSC

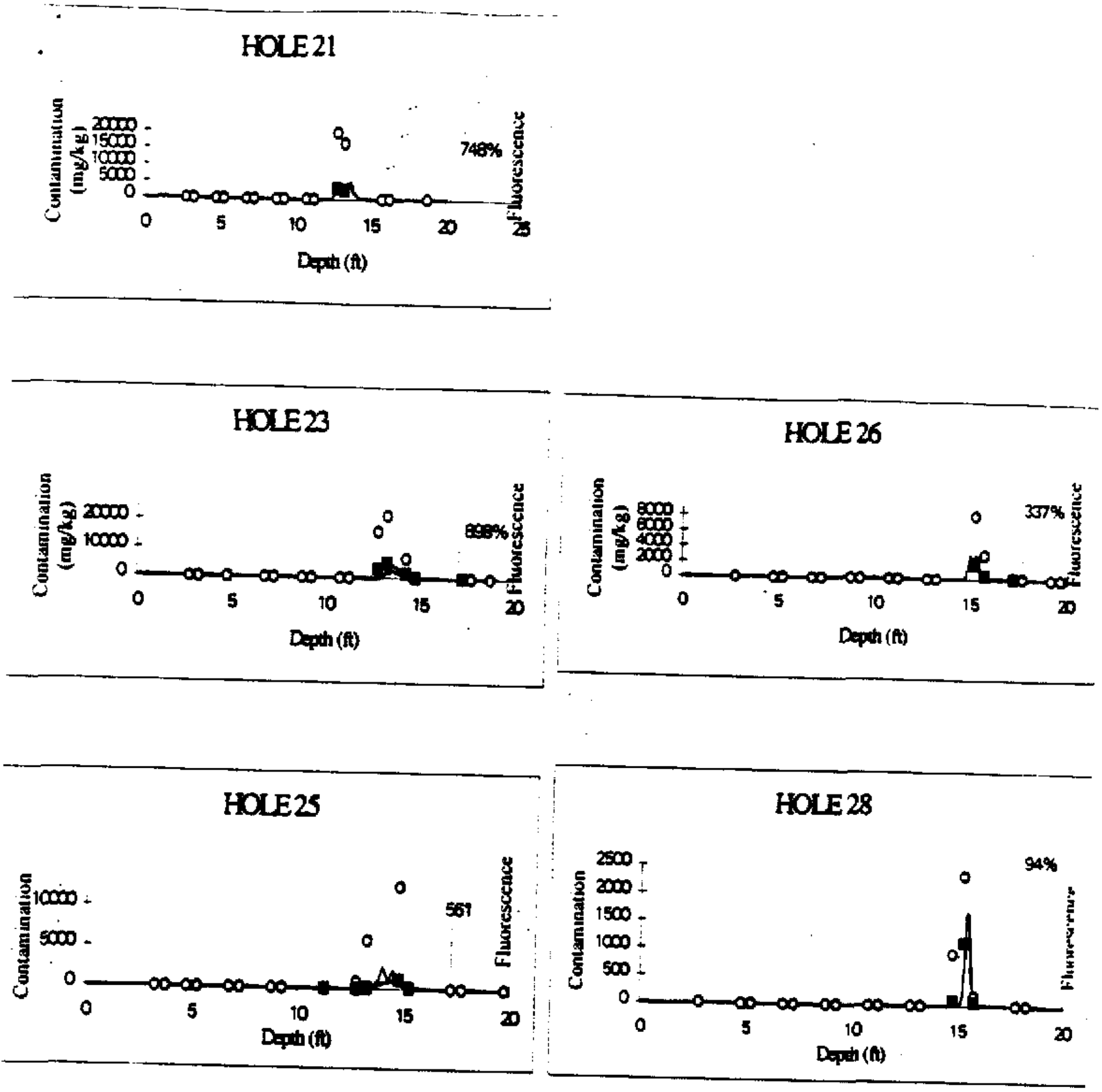

Figure 6-1. Downhole results for Port Hueneme. Results from the five drilling locations where single-point tests were evaluated are illustrated above. The laboratory measurements are indicated by the circles, the single point test measurements are indicated with the square symbols, and the LIF results are indicated by the continuous solid line. The horizontal axis is indexed by both concentration in mg/kg as measured by the average of the analytical methods and in % fluorescence measured by the ROST™ LIF technology. Note: It is inappropriate to compare the relative magnitude of the laboratory concentration to the LIF peaks as the LIF results are not linear at higher concentrations.

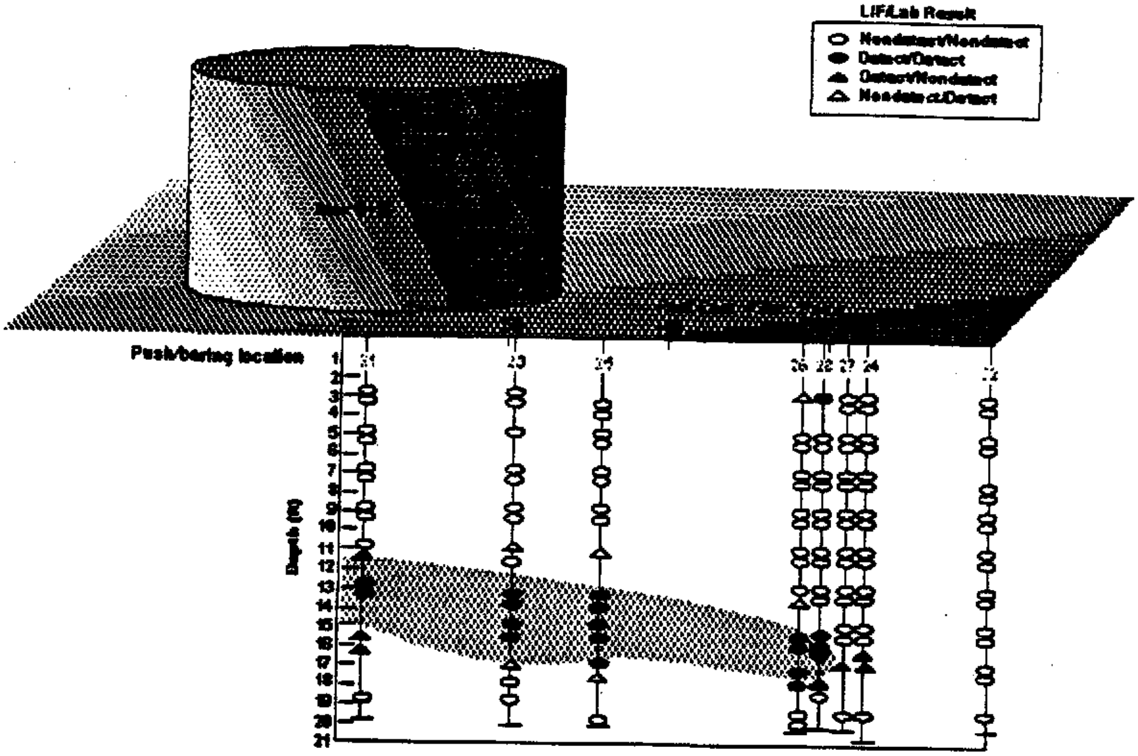

Figure 6-3. Cross-sectional map of transect near Tank 5114 at Port Hueneme. A contour view of the results shown in Table 6-1, comparing the TPH results to those of the ROST™.

SNL Tank Farm Site Data Presentation and Results

As described in the addendum to the demonstration plan, the purpose of the SNL Tank Farm demonstration was to demonstrate the capabilities of the LIF technology at an arid site with a deeper hydrocarbon plume in the vadose zone. Again, the percentage agreement of the LIF technology data set with the laboratory analytical results of soil samples from the SNL Tank farm site provides the basis for evaluation.

SNL Tank Farm Detection Limit

For the SNL Tank Farm site, a detection limit was determined on a push-by-push basis in the field during the demonstration. For the SNL Tank Farm site, the LODs for the three pushes were 102.4 mg/kg (PHDR10), 77.8 mg/kg (PHDR11), and 41.0 mg/kg (PHDR12). The TRPH and TPH measurements for each push were considered to show a detect when their values exceeded these limits.

During the demonstration, it was realized that the site-specific background soil to be used for preparation of calibration soils had been collected from the area that had been previously excavated. This soil had a high concentration of fluorescent minerals and a high background difference in results. After independent analysis, the verification entity agreed with the Loral results. This improved the matching percentage to 96.5% and reduced the false positives to 1.1% when compared to either TPH and TRPH. WTMs and FVDs for all pushes are presented in Appendix B.

Downhole Results for SNL Tank Farm

Figure 6-4 shows the downhole fluorescence measurements for pushes 10, 11, and 12. Again, the developers determined that the area near the surface in SNLDR12 exhibited nonhydrocarbon fluorescence, and the on-site geologist confirmed this by examining the soil samples collected with the HSA after the push was completed.

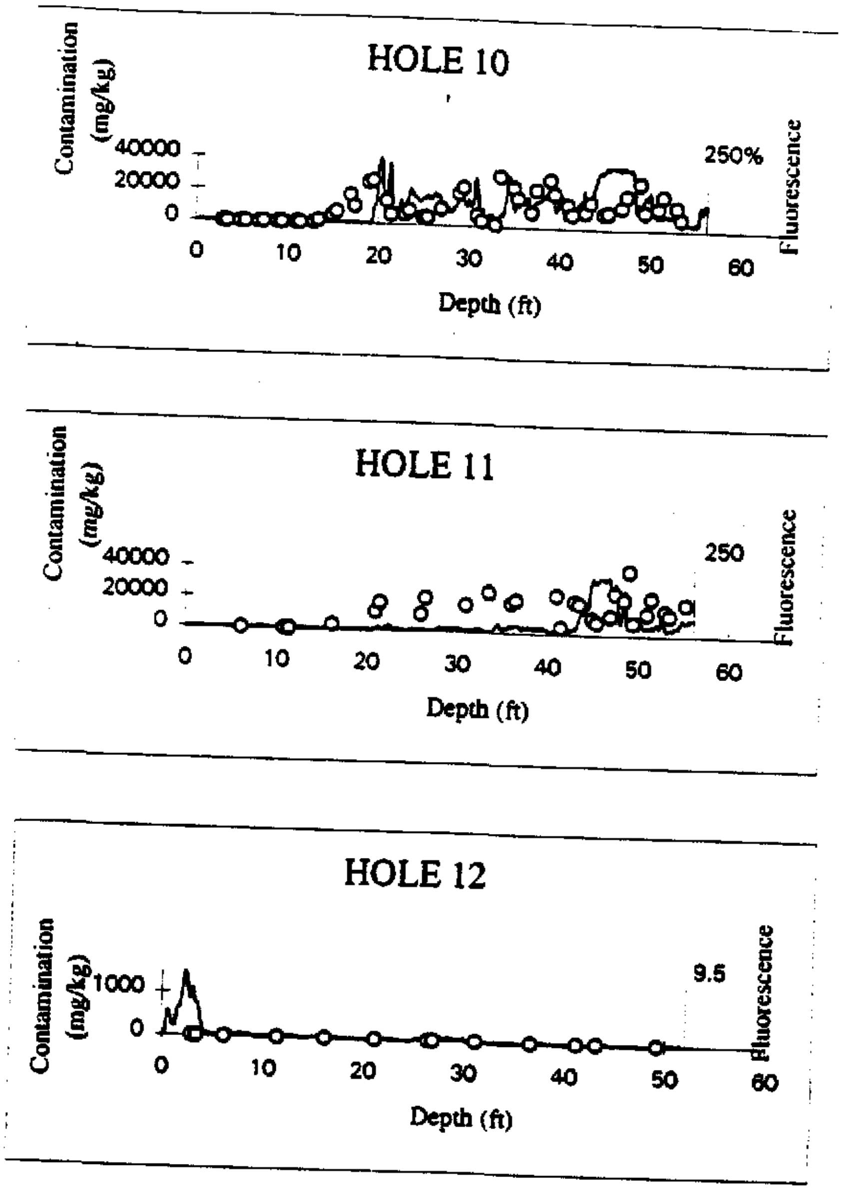

Figure 6-4. Downhole results for SNL Tank Farm.

Cost Evaluation

Table 6-3 provides a comparison of deployment costs for 1) the ROST™ LIF system, 2) conventional drilling and sampling with a hollow stem auger drilling rig outfitted with a split spoon sampler, and 3) a Geoprobe® for a typical POL investigation.

Table 6-3. Cost comparison.

Scenario: Define the lateral and horizontal extent of free-phase volatile organic petroleum hydrocarbons and residual hydrocarbons. Depth to groundwater is 30 feet bgs. Soils will be continuously sampled from the surface to 35 feet bgs. The soil samples will be logged for soil classification and screened for petroleum hydrocarbon contamination in the field. The two soil samples from each boring that exhibit the greatest response to the field screening will be submitted for laboratory analysis.		
Hollow Stem Auger		
Assumptions: 10 borings to 35 feet bgs Production rate with continuous sampling, logging, and grouting is 70 feet per day		
Drilling	5 days @ $1500/day	$7500
Consultant Geologist	50 hrs @ $65/hr	3250
Organic Vapor Meter	5 days @ $75/day	375
Truck Rental	5 days @ $50/day	250
Disposal of Cuttings	8 drums @ $100/drum	800
Analytical Testing	20 samples @ $60/sample	1200
Total		$13,375
Geoprobe®		
Assumptions: 10 borings to 35 feet bgs Production rate with continuous sampling, logging, and grouting is 100 feet per day		
Geoprobing	3.5 days @ $1200/day	$4200
Consultant Geologist	35 hrs @ $65/hr	2275
Organic Vapor Meter	4 days @ $75/day	300
Truck Rental	4 days @ $50/day	200
Analytical Testing	20 samples @ $60/sample	1200
Total		$8,175
ROST™/CPT		
Assumptions: 10 pushes to 35 feet bgs Production rate is ten locations per day (10 hr day) Includes basic data report		
ROST™/CPT	1 day @ $5300/day	$5300
Per Diem/3 crew members	1 day @ $225/day	225
Per Diem/Consultant Geologist	15 hrs @ $65/hr	975
Sampling (CPT)	0.5 day @ $2500/day	1250
Analytical Testing (confirmatory samples from impacted zone)	5 samples @ $60/sample	300
Total		$8,050

Section 7

Applications Assessment

The ROST™ LIF technology is emerging as a supplement to and possible replacement for conventional drilling and sampling methods. As demonstrated, the ROST™ LIF technology has advantages and limitations. These advantages and limitations are described in the following sections.

Advantages of the Technology

Real-Time Analysis

Through the use of a cone penetrometer system, the ROST™ LIF provides real-time analysis of site conditions. This approach is faster than any competitive technology, and therefore quite useful for real-time decision making in the field. This is especially important in guiding soil sampling activities. For conventional field characterization, soil samples are collected using a standard drill rig and sent to a commercial laboratory for analysis. It can take weeks, and sometimes months, to get results. When the results are reviewed, a return trip to the field for further drilling and sampling may be indicated. Real-time sampling and data analysis often eliminates the expense and time delays of laboratory analysis and return trips to the field.

Continuous LIF Data Output

The ROST™ LIF has an advantage over conventional drilling and sampling methods in its ability to provide nearly continuous spatial data. It is common practice in environmental investigations to select a sampling interval (*e.g.*, every 5 feet) to collect samples for analysis at a commercial laboratory. Characterization of the contaminant zone may be severely impaired when the data density is sparse as it commonly is with conventional drilling and sampling approaches due to budget constraints. Areas of contamination may go wholly unnoticed in extreme cases. ROST™ allows a continuous record of possible contaminant locations and a more complete delineation of the area of contamination. In addition, some drilling and sampling operations can be hindered by an inability to produce core samples, due to flowing sands or limited cohesiveness of the soils to be sampled, whereas an *in situ* method such as ROST™ could potentially retrieve readings from these horizons.

Continuous Lithological Logging

The cone penetrometer affords continuous logging of the subsurface lithology with on-board geotechnical sensors used in conjunction with the LIF sensor. This allows a user to target stratigraphy of interest, which may influence contaminant flow and transport or have potential interfering influences on the LIF readings. A conventional drilling and sampling program would require continuous core collection and a dedicated geologist to get the same level of detail. The geologist may be able to define finer scale attributes of the media, but only through a much more labor-intensive effort. Compared to the conventional approach of sampling at regular intervals (*e.g.*, every 5 feet), the CPT offers much greater resolution. Although the CPT was not the focus

Table 7-1. Performance statistics.

Demonstration Site	Percent Agreement Claim (≥80%)	Percent False Positive (implicit claim <20%)	Percent False Negative (claim <5%)
Port Hueneme	87.7% (TRPH) 89.2% (TPH)	2.3% (TRPH) 5.4% (TPH)	10% (TRPH) 5.4% (TPH)
SNL	93.4% (TRPH and TPH)	3.3% (TRPH and TPH)	3.3% (TRPH and TPH)

The ROST™ LIF system should meet the expectations of regulators or site owners interested in compliance with EPA sampling guidance (U.S. EPA, 1989b). In designing sampling strategies, the EPA has acknowledged the concepts of uncertainty and potential errors in analysis. They have incorporated these expectations in their guidance on allowable false positive and negative rates when comparing confirmatory sampling data to screening data. The EPA guidance on statistical sampling typically accepts a 5 to 10 percent false negative rate, which is within the range of the ROST™ LIF based on the results of these demonstrations. In addition, they allow a higher percentage of false positives, typically up to 20 percent. The ROST™ LIF system appears to be capable of meeting EPA's guidance of performance criteria for comparison of laboratory versus screening data.

Limitations of the Technology

Applicability

The ROST™ LIF system is applicable only to fuels and wastes containing nonchlorinated multi-ring aromatic hydrocarbon molecules. The detection capabilities for ROST™ include, but are not limited to, jet fuel, gasoline, diesel, lubricating oils, coal tar, and creosote. Other common compounds such as chlorinated hydrocarbons would require separate sensors.

ROST™ has been used to detect two-ring aromatic compounds (naphthalenes) on commercial projects involving jet fuel. In addition, ROST™ can readily detect mixtures of fuels and other materials; however, the technology may not distinguish them in the presence of the other. These capabilities were not evaluated as part of the CSCT demonstrations.

Quantitation and Speciation

The ROST™ LIF does not allow for the direct quantitation of specific constituents in the petroleum contaminant. The regulatory requirements for determining cleanup requirements for RCRA or CERCLA sites are established on the basis of individual constituent concentrations (*e.g.*, naphthalene concentrations) through comparisons with background, or established through the use of risk assessment techniques.

ROST™ has been calibrated to TPH in soil, which is appropriate for underground storage tank investigations. For RCRA or CERCLA investigations, it is best used as screening measure to pinpoint optimal locations for conventional sampling and analysis. The RCRA and CERCLA requirements are based on constituent-specific concentration thresholds and not aggregate measures of a total class of products such as TPH. TPH is affected by many interferants and is not readily correlated to individual constituents. For leaking underground fuel tank applications,

Section 8

Developer Forum

The following information was provided by Fugro Geosciences.

Fugro Geosciences acquired the technology from Loral (now Lockheed Martin) in May 1996. Since ROST™'s introduction in 1994, Fugro has worked closely with Loral, providing CPT services on the majority of Loral's ROST™ projects. Fugro now provides ROST™ worldwide directly to consultants and site owners as an integrated service with our extensive direct push capabilities.

Overall, Fugro Geosciences is pleased with the design and conclusions of the EPA CSCT evaluation of ROST™. However, some significant features of ROST™ were not fully evaluated by CSCT, due to ROST™,s deployment from the Navy's SCAPS CPT truck, the presence of only a single contaminant in test site soils, and the detect/nondetect evaluation criteria. Specifically, the features not evaluated are the high mobility and productivity rate of Fugro's CPT/ROST™, ROST™'s contaminant applicability and product identification capability, and ROST™,s delineation capabilities. Each of these important features are detailed in the following sections.

High Mobility and Productivity Rate of Fugro CPT/ROST™

Deployment of ROST™ from Fugro Geosciences' truck or all-terrain vehicle-mounted CPT rigs would have allowed demonstration of our high site mobility and productivity rate. Fugro's production rate on ROST™/CPT projects typically exceeds 300 linear feet per day for pushes averaging 30 feet or greater in depth. Typically, 10 to 12 ROST™/CPT pushes per day can be completed for projects involving shallower push depths.

Contaminant Applicability and Product Identification Capability

ROST™'s application to a wide range of petroleum contaminants and the technology's product differentiation capability make it a powerful site characterization tool. However, these capabilities were not demonstrated, since diesel fuel was the only contaminant present at both evaluation sites. ROST™ has been used successfully on commercial projects to delineate and differentiate materials including jet fuel/kerosene, gasoline, diesel fuel, lubricating oil, crude oil, bunker oil, coal tar, and creosote. The ability to differentiate between these materials in real-time using ROST™'s WTM function allows multiple sources to be recognized and delineated.

ROST™'s Delineation Capabilities

The demonstration only evaluated the detect/nondetect agreement between ROST™ and the reference method. However, ROST™ provides significantly more value than simply a detect/nondetect field screening tool. Since fluorescence intensity is generally proportional to *in*

Section 9
Previous Commercial Projects

The following information was provided by Fugro. The investigations included industrial plants, oil production facilities, refineries, railyards, and military bases in both the United States and Europe. Further information on these deployments may be obtained from Fugro Geosciences.

Table 9-1. Summary of Selected CPT/ROST™ Commercial Projects.

Facility Type	Site Location	Contaminant of Concern	CPT/ROST Soundings Completed	Total Linear Footage of Testing
Refinery Landfarm	Texas City, TX	Petroleum Hydrocarbons	23	485
Industrial Plant	Everett, MA	Naphthalene	72	640
Industrial Plant	Tennessee	Petroleum Hydrocarbons	29	1100
Oil Production Field	Guadalupe, CA	Kerosene, Diesel, Crude Oil	319	7,458
Oil Production Field	Lost Hills, CA	Compressor Lubricants	10	430
Natural Gas Production Plant	Refugio, TX	Natural Gas Condensate	17	625
Refinery	Beaumont, TX	Polyaromatic Hydrocarbons	21	845
Petrochemical Plant	Seadrift, TX	Petroleum Hydrocarbons	19	549
Manufactured Gas Plant	England, Wales, and Scotland	Coal Tar	54	623
Degasification Plant	Paris, France	Petroleum Hydrocarbons	13	115
Refinery Stormwater Impoundment	Beaumont, TX	Petroleum Hydrocarbons	56	635
Air Force Base	San Bernadino, CA	Gasoline, Diesel, Jet Fuel	105	1,610
Refinery	Westville, NJ	Petroleum Hydrocarbons	30	1,075
Industrial Plant	Vernon, CA	Petroleum Hydrocarbons	41	2,101
Industrial Plant	Indianapolis, IN	Diesel, Fuel Oil, Lubricants, Naphtha, Gasoline, Kerosene	47	1,372
Paint Manufacturing Plant	Anaheim, CA	Petroleum Hydrocarbons	11	624
Wood Preserving Plant	Green Spring, WV	Creosote	40	653
Retail Service Station	Valencia, CA	Gasoline	6	188
Wood Preserving Plant	Visalia, CA	Creosote	30	3433
Railroad Yard	California	Diesel, Bunker Oil	41	858

Section 10

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PRC. 1995d. LIF/CPT Technology Predemonstration and Demonstration Summary Report, Arid Demonstration Site, Sandia National Laboratories Above Ground Fuel Farm, Contract N66001-94-D0141, Delivery Order 0006. December 20, 1995.

Table A-1 (continued)
Reference Laboratory Results of Soil Samples
NCBC Port Hueneme

Sample Number	Depth	Date	TRPH Concentration mg/kg	TPH mg/kg	LIF/TRPH Result	LIF/TPH Result
PHDB23-14	17.0-17.5'	5/18/95	224	89	ND/D	ND/D
PHDB23-15	17.5-18.0'	5/18/95	2	<5.0	ND/ND	ND/ND
PHDB23-16	18.5-19.0'	5/18/95	5	<5.0	ND/ND	ND/ND
PHDB24-1	2.5-3.0'	5/18/95	81	77	ND/D	ND/D
PHDB24-2	3.0-3.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-4	4.5-5.0'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-5	5.0-5.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-7	6.5-7.0'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-8	7.0-7.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-9	8.5-9.0'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-10	9.0-9.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-12	10.5-11.0'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-13	11.0-11.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-14	12.5-13.0'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-15	13.0-13.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-17	14.5-15.0'	5/18/95	17	<5.0	ND/D	ND/ND
PHDB24-18	15.0-15.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB24-19	16.0-16.5'	5/18/95	<1	<5.0	D/ND	D/ND
PHDB24-20	16.5-17.0'	5/18/95	11	<5.0	D/D	D/ND
PHDB24-21	19.0-19.5'	5/18/95	<1	<5.0	ND/ND	ND/ND
PHDB25-1	3.0-3.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-2	3.5-4.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-3	4.5-5.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-4	5.0-5.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-5	6.5-7.01	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-6	7.0-7.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-7	8.5-9.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-8	9.0-9.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB25-9	11.0-11.5'	5/19/95	25	51	ND/D	ND/D
PHDB25-10	12.5-13.0'	5/19/95	748	1100	D/D	D/D
PHDB25-11	13.0-13.5'	5/19/95	5620	6400	D/D	D/D
PHDB25-12	14.5-15.0'	5/19/95	9340 (Dup 13600)	16000 (Dup 15000)	D/D	D/D
PHDB25-13	15.0-15.5'	5/19/95	172 (Dup 264)	150 (Dup 190)	D/D	D/D
PHDB25-14	17.0-17.5'	5/19/95	28	16	D/D	D/D
PHDB25-15	17.5-18.0'	5/19/95	1	11	ND/ND	ND/D
PHDB25-16	19.5-20.0'	5/19/95	9	<5.0	ND/D	ND/ND
PHDB26-1	2.5-3.0'	5/19/95	31	11	ND/D	ND/D
PHDB26-2	4.5-5.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-3	5.0-5.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-4	6.5-7.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-5	7.0-7.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-6	8.5-9.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-7	9.0-9.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-8	10.5-11.0'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-9	11.0-11.5'	5/19/95	<1	<5.0	ND/ND	ND/ND
PHDB26-10	12.5-13.0'	5/19/95	<1	<5.0	ND/ND	ND/ND

Table A-2
Reference Laboratory Results of Soil Samples
SNL Tank Farm

Sample Number	Depth	Date	TRPH Concentration mg/kg	TPH Concentration mg/kg	LIF/TRPH Result	LIF/TPH Result
SNLDB10-1	2.75-3.0'	11/6/95	60	23	ND/ND	ND/ND
SNLDB10-2	3.25-3.5'	11/6/95	25	<5	ND/ND	ND/ND
SNLDB10-3	4.75-5.0'	11/6/95	89	99	ND/ND	ND/ND
SNLDB10-4	5.25-5.5'	11/6/95	42	54	ND/ND	ND/ND
SNLDB10-5	6.75-7.0'	11/6/95	71	70	D/ND	D/ND
SNLDB10-6	7.25-7.5'	11/6/95	162	150	ND/D	ND/D
SNLDB10-7	8.75-9.0'	11/6/95	17	<5	ND/ND	ND/ND
SNLDB10-8	9.25-9.5'	11/6/95	11	14	ND/ND	ND/ND
SNLDB10-9	10.75-11.0'	11/6/95	27	24	ND/ND	ND/ND
SNLDB10-10	11.25-11.5'	11/6/95	22	27	ND/ND	ND/ND
SNLDB10-11	12.75-13.0'	11/6/95	206	270	D/D	D/D
SNLDB10-12	13.25-13.5'	11/6/95	1470	1500	ND/D	ND/D
SNLDB10-13	14.75-15.0'	11/6/95	4870	5000	D/D	D/D
SNLDB10-14	15.25-15.5'	11/6/95	7600	6600	D/D	D/D
SNLDB10-15	16.75-17.0'	11/6/95	14300	21000	D/D	D/D
SNLDB10-16	17.25-17.5'	11/6/95	8500	13000	D/D	D/D
SNLDB10-17	18.75-19.0'	11/6/95	25600	26000	D/D	D/D
SNLDB10-18	19.25-19.5'	11/6/95	25800	28000	D/D	D/D
SNLDB10-19	20.75-21.0'	11/6/95	14700	14000	D/D	D/D
SNLDB10-20	21.25-21.5'	11/6/95	5790	6300	D/D	D/D
SNLDB10-21	22.75-23.0'	11/6/95	6530	6900	D/D	D/D
SNLDB10-22	23.25-23.5'	11/6/95	8560	9100	D/D	D/D
SNLDB10-23	24.75-25.0'	11/6/95	5100	4200	D/D	D/D
SNLDB10-24	25.25-25.5'	11/6/95	5400	4500	D/D	D/D
SNLDB10-25	26.75-27.0'	11/6/95	11200	9800	D/D	D/D
SNLDB10-26	28.75-29.0'	11/6/95	20400	20000	D/D	D/D
SNLDB10-27	29.25-29.5'	11/6/95	24900	23000	D/D	D/D
SNLDB10-28	30.75-31.0'	11/6/95	7330	6600	D/D	D/D
SNLDB10-29	31.25-31.5'	11/6/95	3520	3100	D/D	D/D
SNLDB10-30	32.75-33.0'	11/6/95	1340	1400	D/D	D/D
SNLDB10-31	33.25-33.5'	11/6/95	28400	35000	D/D	D/D
SNLDB10-32	34.75-35.0'	11/6/95		24000	D/D	D/D
SNLDB10-33	35.25-35.5'	11/6/95	18200	18000	D/D	D/D
SNLDB10-34	36.75-37.0'	11/6/95	9620	10000	D/D	D/D
SNLDB10-35	37.25-37.5'	11/6/95	26200	21000	D/D	D/D
SNLDB10-36	38.75-39.0'	11/6/95	32200	28000	D/D	D/D
SNLDB10-37	39.25-39.5'	11/6/95	21700	21000	D/D	D/D

Table A-2 (continued)
Reference Laboratory Results of Soil Samples
SNL Tank Farm

Sample Number	Depth	Date	TRPH Concentration mg/kg	TPH Concentration mg/kg	LIF/TRPH Result	LIF/TPH Result
SNLDB12-1	2.75-3.0'	11/8/95	3	<5	D/ND	D/ND**
SNLDB12-2	3.25-3.5'	11/8/95	2	<5	D/ND	D/ND**
SNLDB12-3	6.0-6.25	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-5	11.25-11.5'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-7	16.0-16.25'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-9	21.0-21.25'	11/8/95	2	<5	ND/ND	ND/ND
SNLDB12-11	26.25-26.5'	11/8/95	2	<5	ND/ND	ND/ND
SNLDB12-12	26.75-27.0'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-13	31.0-31.25'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-15	36.5-36.75'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-17	41.0-41.25'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-19	43.0-43.25'	11/8/95	<1	<5	ND/ND	ND/ND
SNLDB12-20	49.0-49.5'	11/8/95	<1	<5	ND/ND	ND/ND

1. TRPH indicates total recoverable petroleum hydrocarbons, analyzed by EPA method 418.1.
2. TPH indicates total petroleum hydrocarbons, analyzed by the Calif. DHS Method 8015-modified.
3. mg/kg = milligrams per kilogram.
4. ** indicates where WTM review indicated a nonhydrocarbon fluorophore.

3.0 Definitions

3.1 LIF: laser induced fluorescence.

3.2 Penetrometer: an instrument in the form of a conically-tipped cylindrical rod that is hydraulically advanced into soil to acquire subsurface measurements of penetration resistance. Used for cone penetrometer testing (CPT). Also called cone penetrometer, friction-cone penetrometer.

3.3 POL: petroleum, oil, lubricant. Used in reference to any petroleum product or derivative.

3.4 Push rods: cylindrical rods with threaded tips that are joined to advance the penetrometer probe into the ground.

3.5 UV: ultraviolet

3.6 PMT: photomultiplier tube

3.7 DSO: digital storage oscilloscope

4.0 INTERFERENCES

4.1 In addition to the aromatic hydrocarbon constituents of the specifically targeted petroleum hydrocarbons, other substances may fluoresce when excited by the laser light source and interfere with the POL determination. Possible interfering species include fluorescent minerals, naturally occurring organic material, de-icing agents, antifreeze additives, and detergent products.

4.2 The possibility of fluorescence emission from nontarget (non-POL) analytes, leading to false positive assignment of POL contamination, must be considered. The fluorescence of the POL species of interest can be distinguished from non-POL fluorescence on the basis of spectral and temporal (fluorescence decay) information acquired at selected (or all) depths during the push. Past experience indicates that POL species have characteristic fluorescence patterns (wavelength-time matrices) that allow them to be identified and distinguished from potential interferents.

4.3 There are several background sources caused by the laser light separate from the petroleum or soil matrix fluorescence. Their signal amplitudes occur on the same time scale as the petroleum fluorescence and can therefore contribute to the total intensity. The possibilities include window fluorescence, cladding/buffer fluorescence, Raman signals generated within fiber, stray light in monochromator. These can be distinguished from the true fluorescence signals by appropriate control experiments.

5.0 SAFETY

5.1 The ROST LIF sensor involves high-power pulsed laser beams that represent a potential eye hazard. Eye protection precaution similar to those which apply to the use of pulsed lasers in laboratory situations must be observed.

5.2 Components of the ROST system are at sufficiently high voltage to present a shock hazard. However, these components are not accessible during normal operation.

8.2 The CPT truck is positioned over the push location and then elevated and leveled on hydraulic jacks. Following a short series of measurements to establish ROST quality control, the sensor is pushed into the ground at a rate of 1 meter/minute. The push rods are 1 meter in length, and rods are added approximately once a minute as the sensor is advanced. A 30-meter push will typically require about 40 minutes to reach full depth. Approximately 300 linear feet of push data can be accomplished in a routine day's operation.

8.3 The ROST sensor measures fluorescence signal as a function of depth as the penetrometer is pushed into the ground, thereby providing a fluorescence vs. depth (FVD) log. The ordinate of the FVD is presented relative to the check reference intensity.

8.4 As the next push rod is being added, a wavelength-time matrix can be acquired for contaminant identification purposes. Alternatively, the ROST operator can signal to the hydraulics operator to temporarily interrupt the push for WTM measurement.

9.0 QUALITY CONTROL AND SYSTEM CHECKOUT

9.1 The fluorescence intensity value is typically reported relative to the fluorescence intensity of a reference solution, which is measured just prior to the initiation of each push. The M-1 reference solution, a selected fluid hydrocarbon mixture, is contained in a standard 1-cm pathlength cuvette, which can be strapped onto the sapphire window. The procedure provides an end-to-end system check and normalizes the data for any variation in the power of the laser light used to excite the contaminant, length of cable carrying the excitation and emission light, background noise, and other instrument settings such as monochromator slitwidth.

9.2 If the reference check intensity varies by more than 25 percent from the average of the previous values, the probe window and sample cuvette should be cleaned and the measurement repeated. If compliance cannot be achieved, the system operator should begin troubleshooting procedures as per the system's maintenance manual.

9.3 The time window (typically 250 ns wide) on the digital oscilloscope is adjusted to compensate for the light transit time through the optical fiber; for a 50 meter long fluorescence signal is received at the detector about 500 ns after the laser has actually fired. Once set, the time delay need by adjusted only if the length of fiber in the probe umbilical is changed. The position of the ROST time window can be determined automatically with routines built into the scope's software.

9.4 A wavelength calibration for the emission monochromator is performed at the start of the job and thereafter during troubleshooting procedures. The 532 nm Nd:YAG 2nd harmonic light is used as a primary reference to verify the wavelength accuracy of the monochromator. A small amount of 532 nm light is directed into the monochromator at a narrow slitwidth and the wavelength is scanned to verify that the signal maximizes at 532 ± 0.2 nm. The monochromator can then be used as a secondary reference to calibrate the dye laser wavelength.

10.0 CALIBRATION OF CONTAMINANT CONCENTRATION

10.1 At present, there is no standard procedure for calibrating the LIF sensor. Depending on data objectives, fluorescence intensity alone may be reported as a relative indicator of POL presence. The reference fluorescence intensity data format is well-suited for field screening applications, in which the goal is to delineate contaminant plume boundaries and to define the relative distribution of contamination over the site. The fluorescence intensity is proportional to POL concentration over a wide range of concentration. The reliability of LIF-CPT for screening sites in this fashion, *i.e.*, without any formal calibration procedure, has been demonstrated on many occasions.

center of the Gaussian falls at the true background amplitude and the width corresponds to the noise level (uncertainty). We generate a histogram of the intensities measured during the course of a push.

13.0 METHOD PERFORMANCE

13.1 The detection limit, accuracy, and precision obtained through use of the method are dependent on the soil matrix, target analyte, and choice of laser wavelength, as well as instrumental conditions such as fiber length and monochromator slitwidth. They must be established on a case-by-case basis.

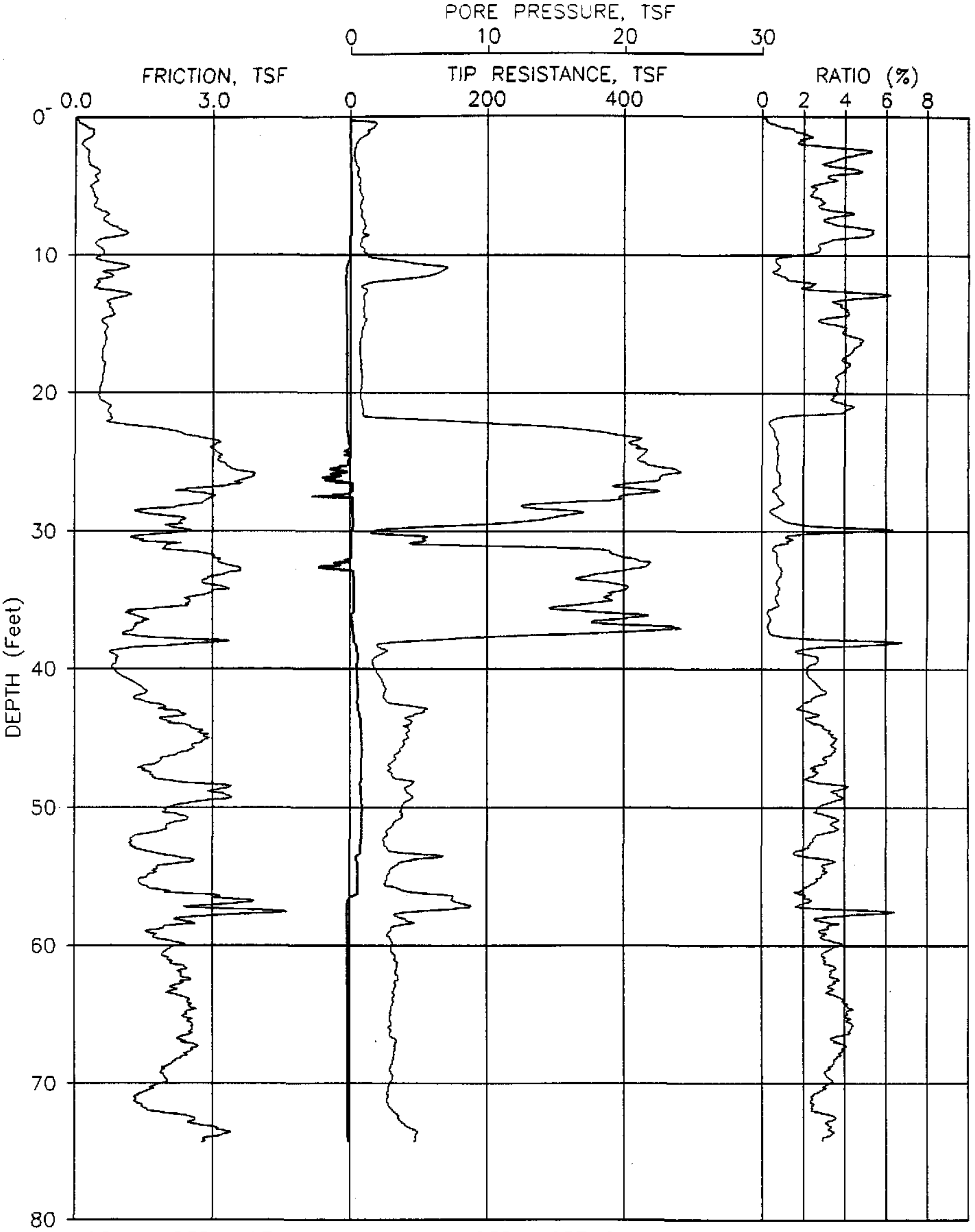
14.0 REFERENCES

References are to be provided by Loral.

Appendix C

CPT Logs

Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi



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CONE NUMBER: F7.5CKEW806

DATE: 03-03-1997
PLATE: 1 OF 1

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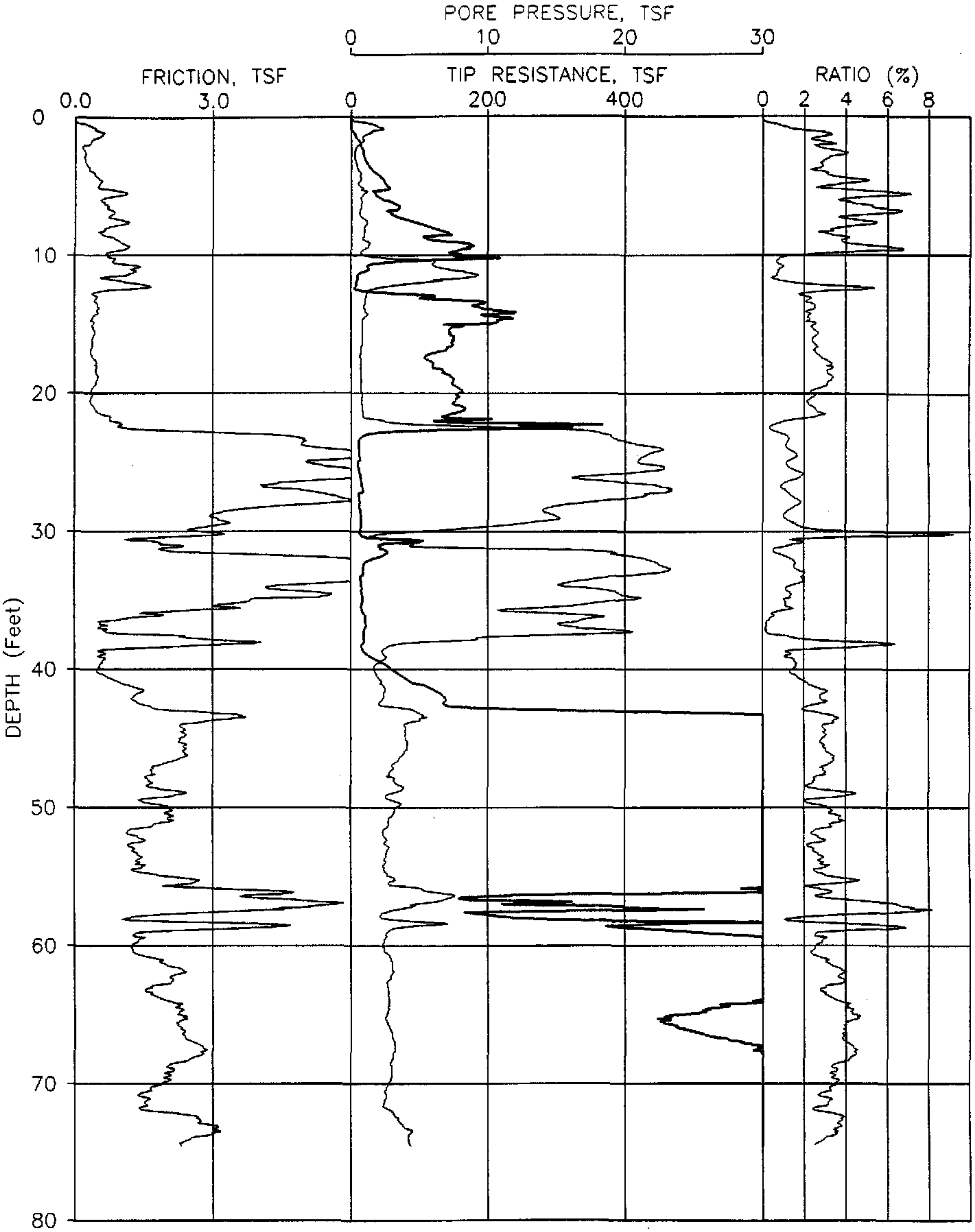

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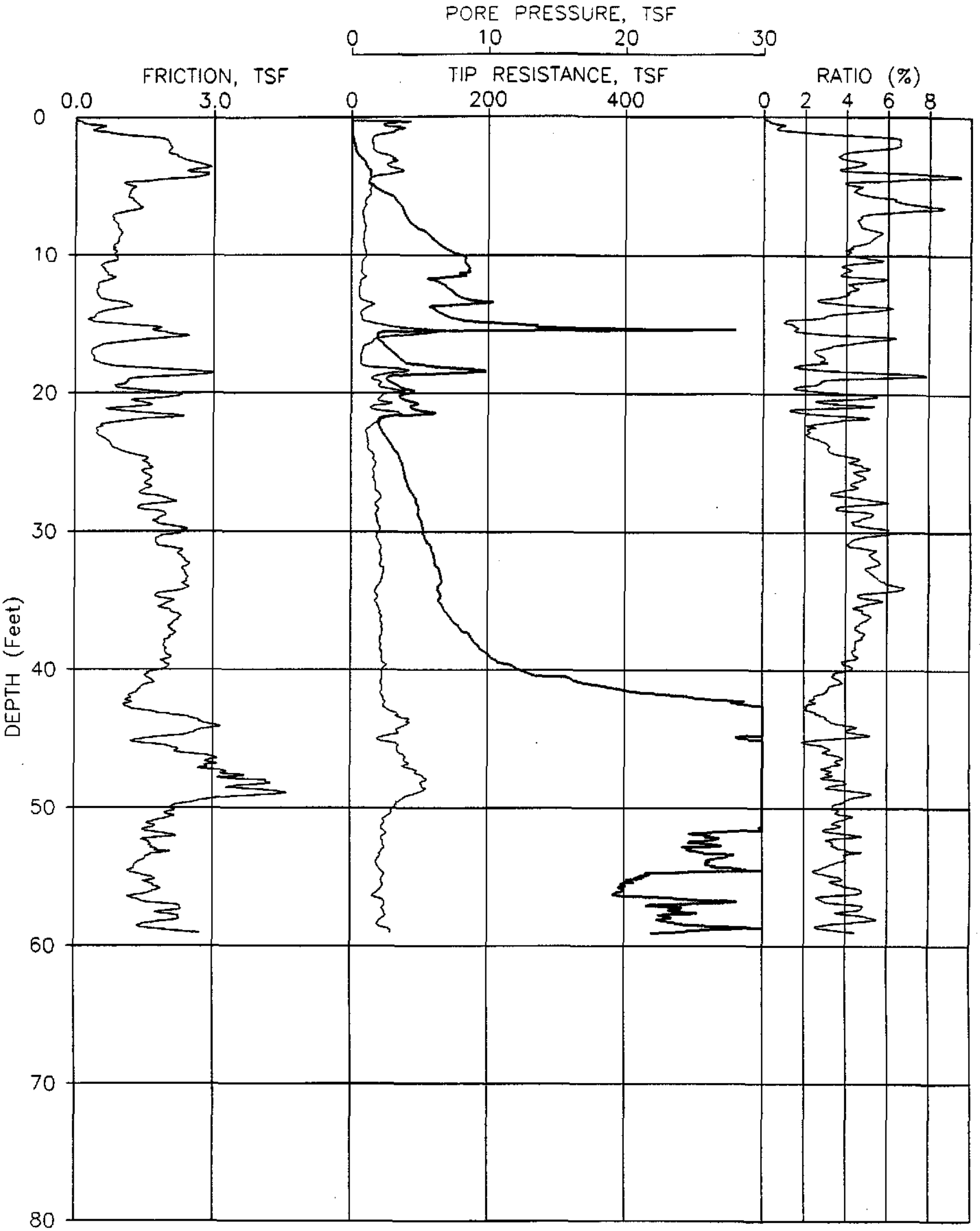

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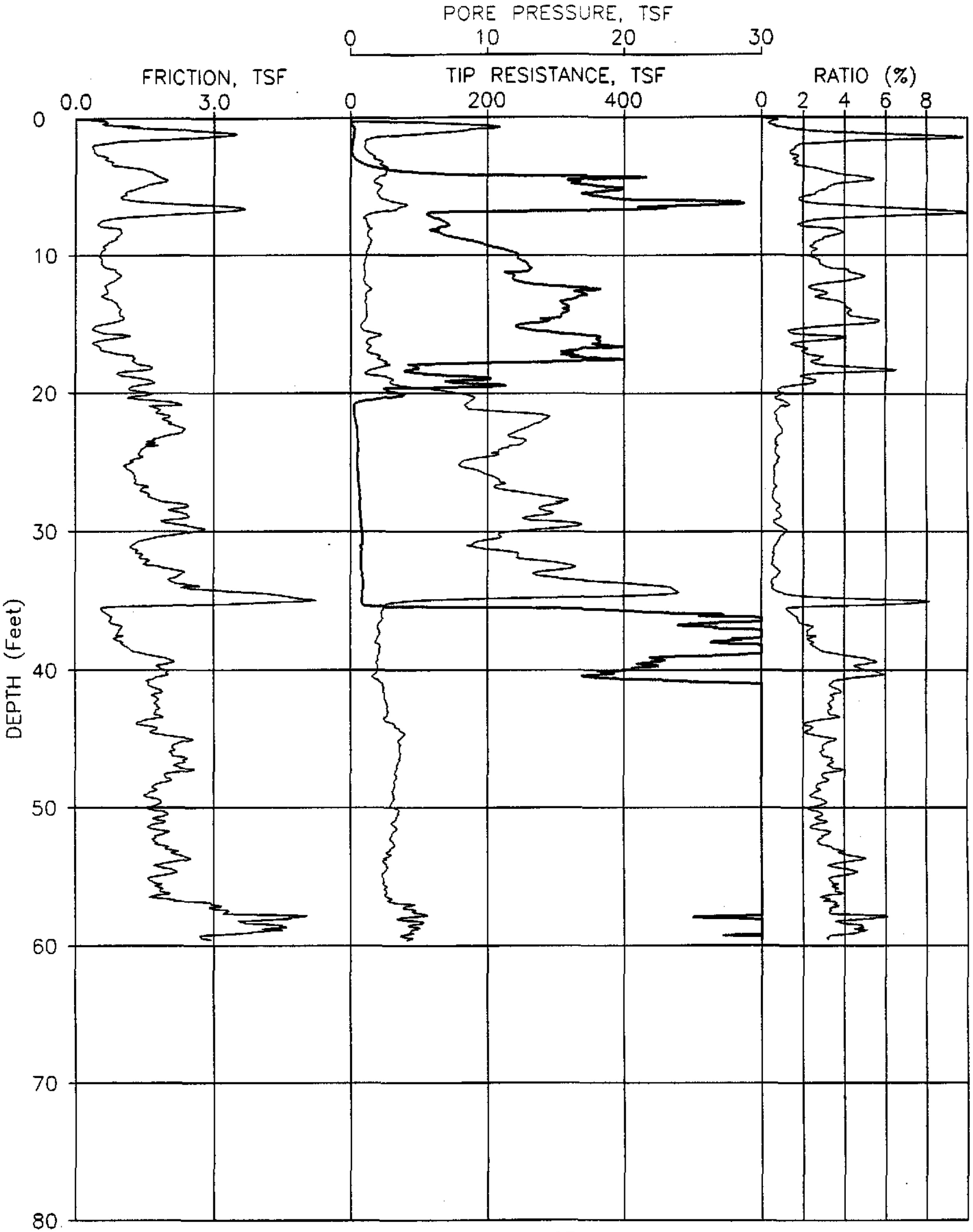

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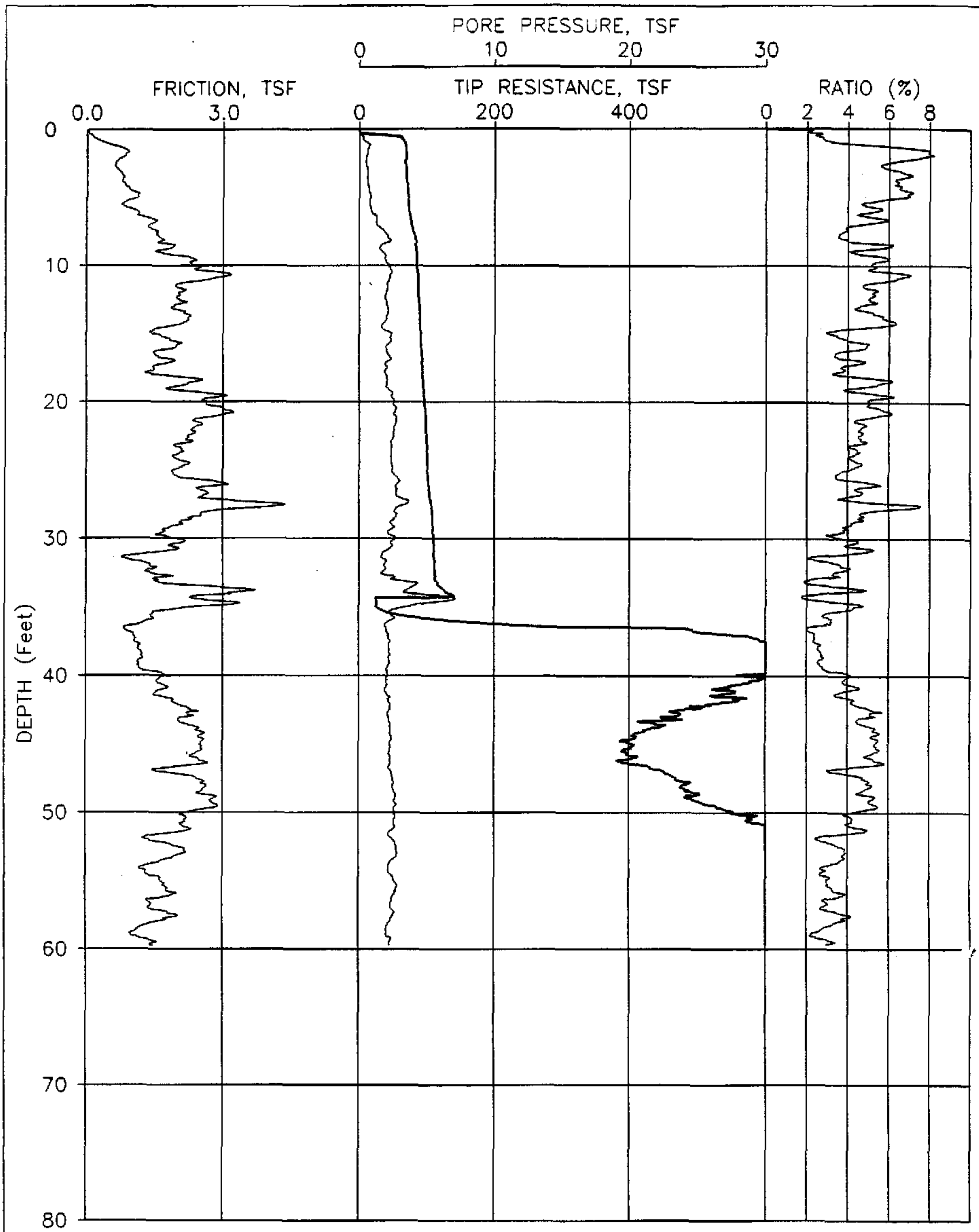

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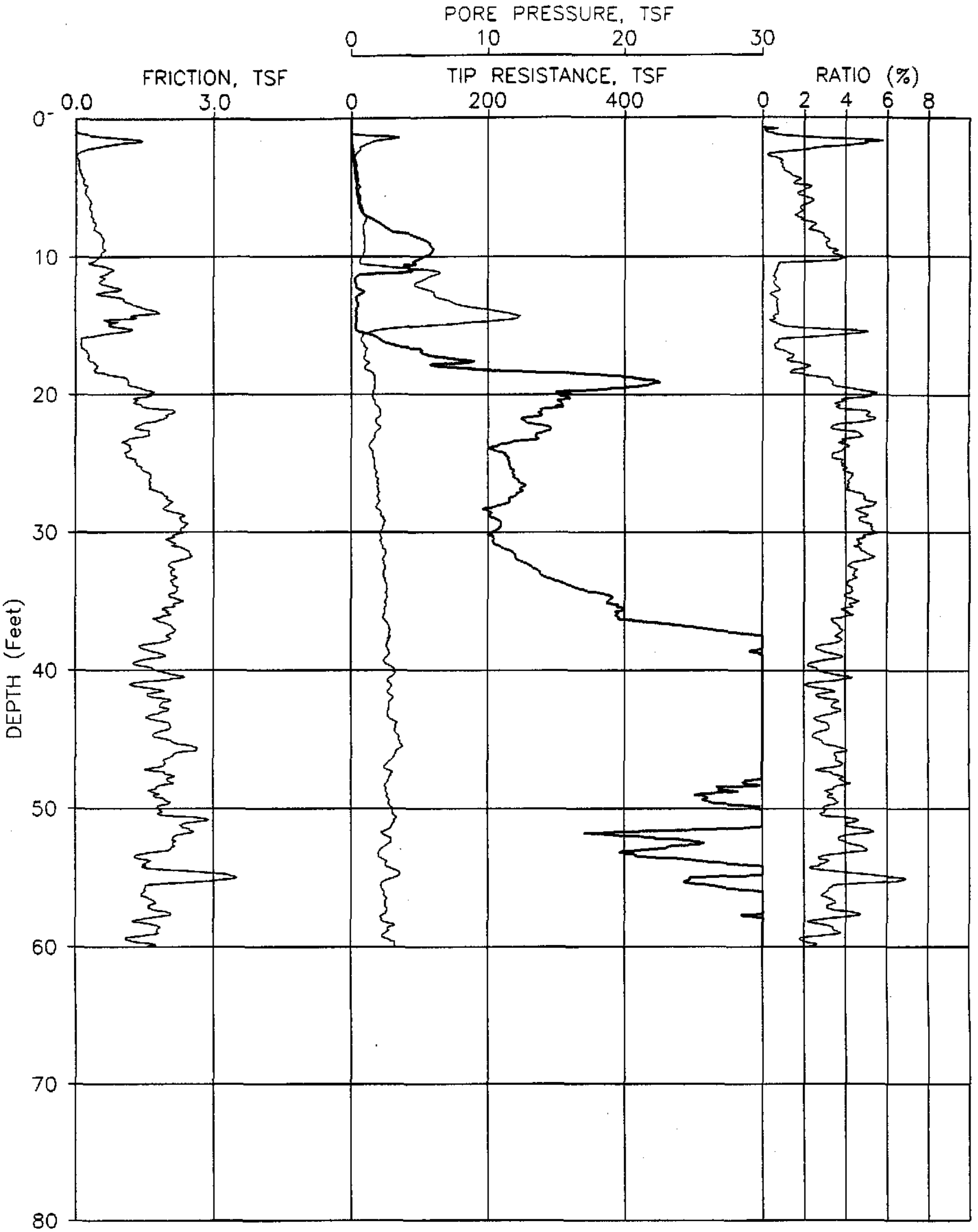

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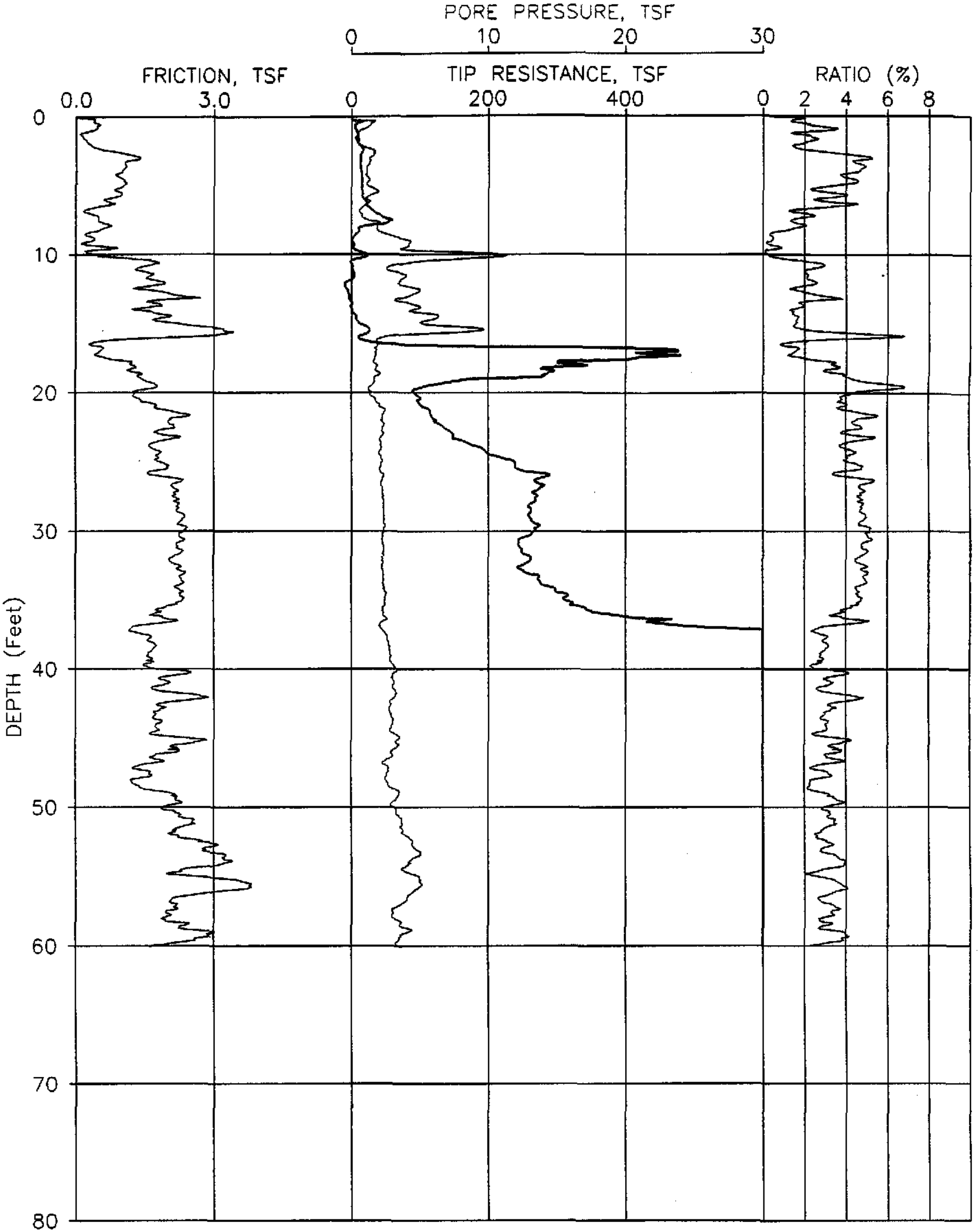

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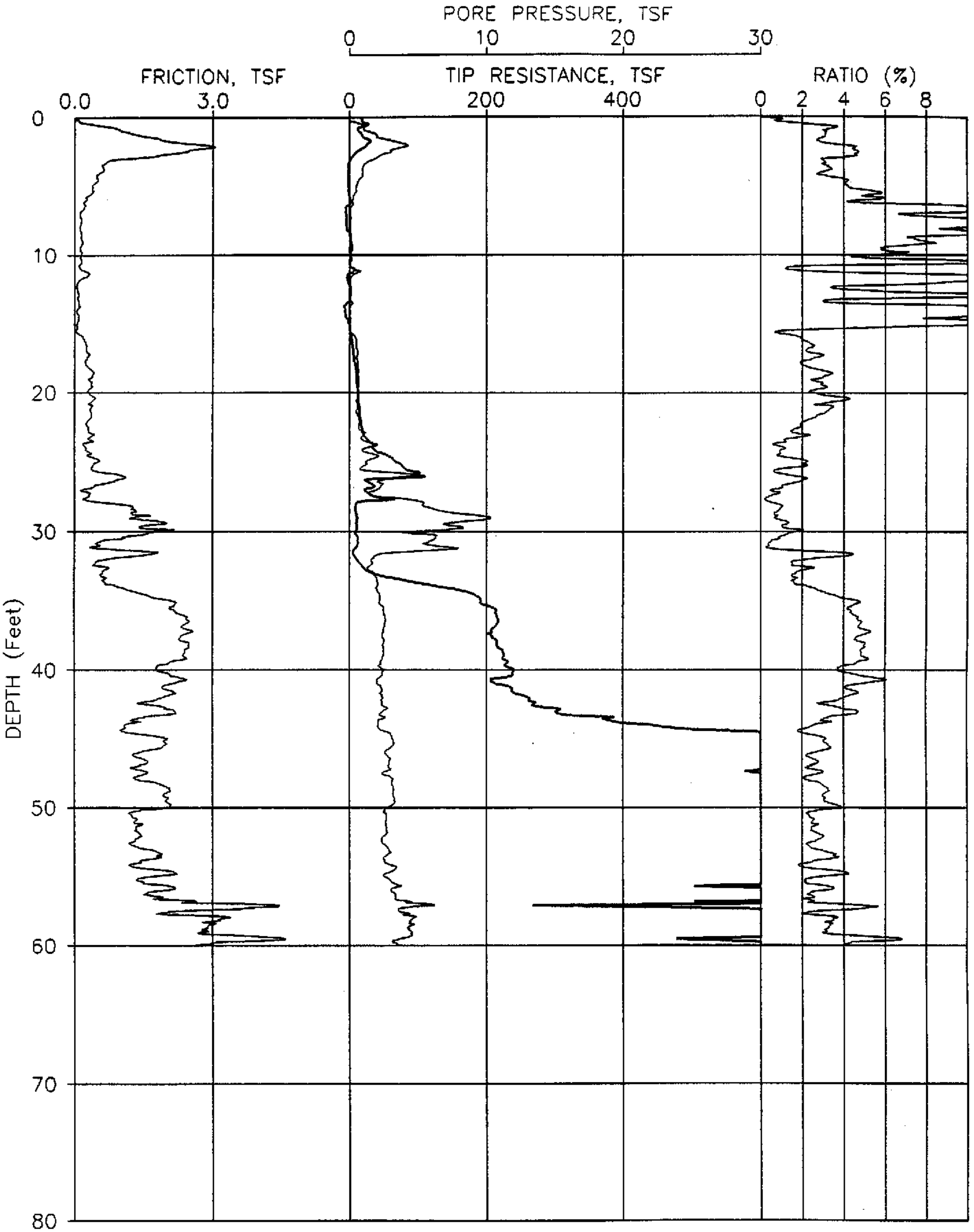

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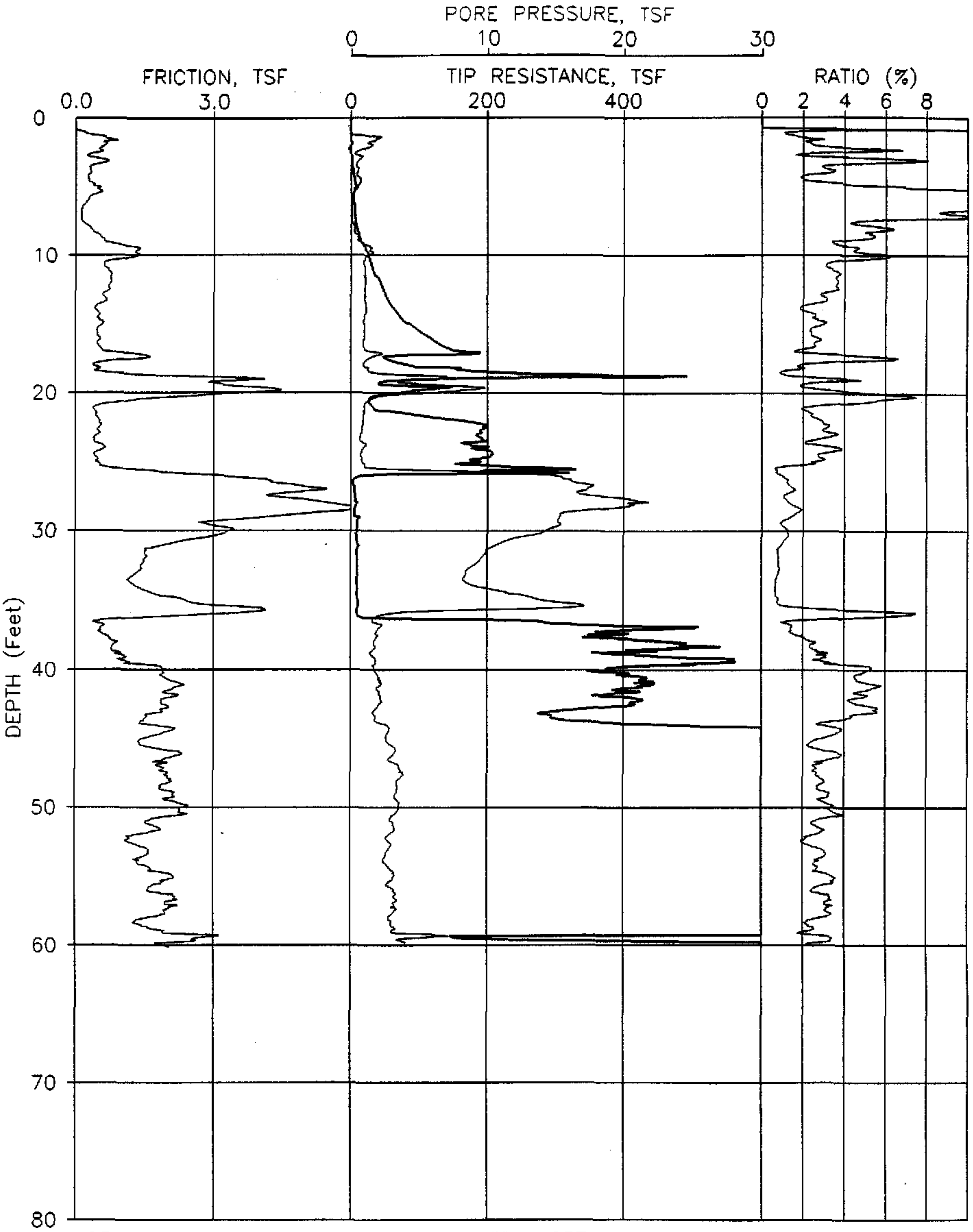

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CONE NUMBER: F7.5CKEW230

DATE: 03-04-1997

PLATE: 1 OF 1

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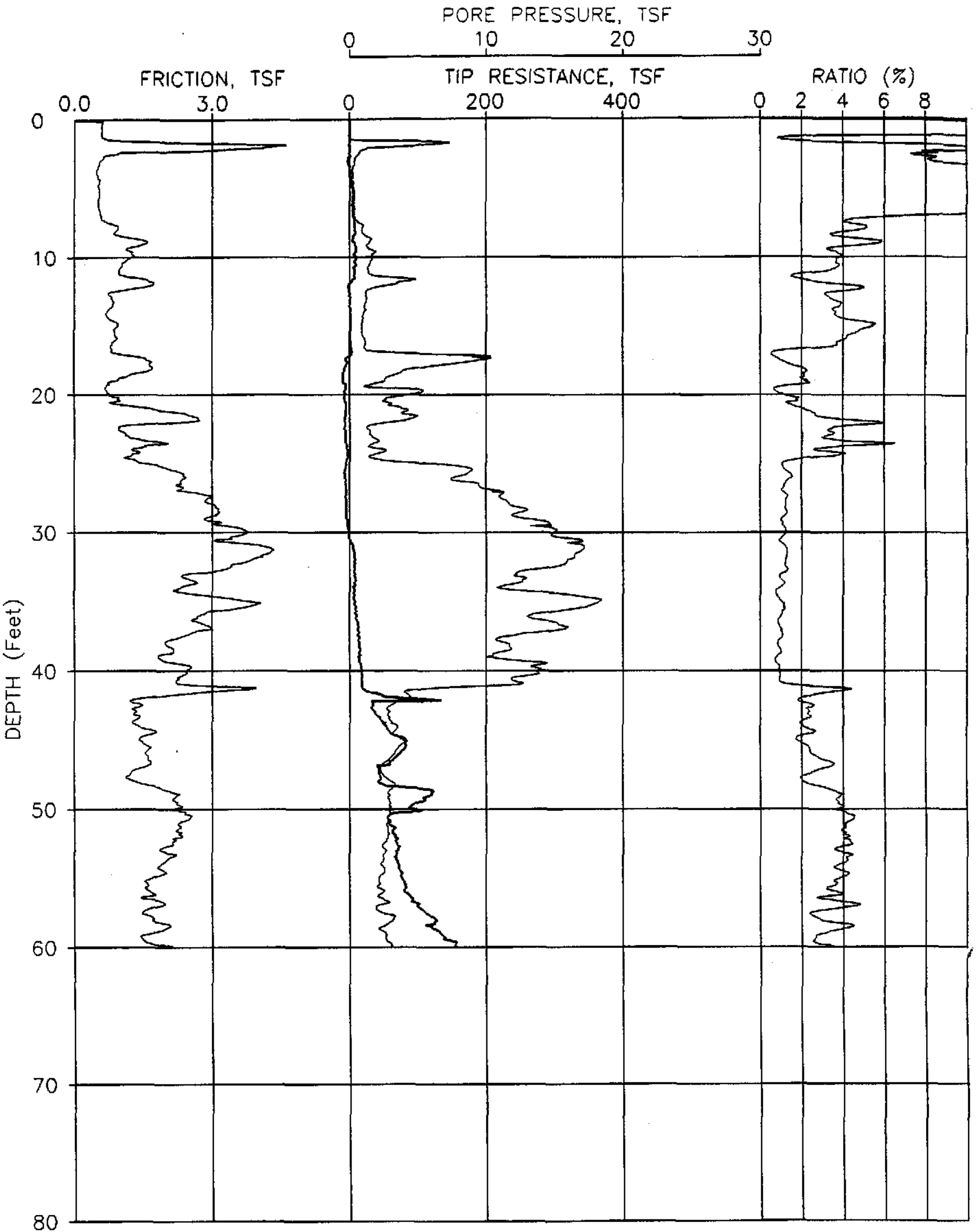

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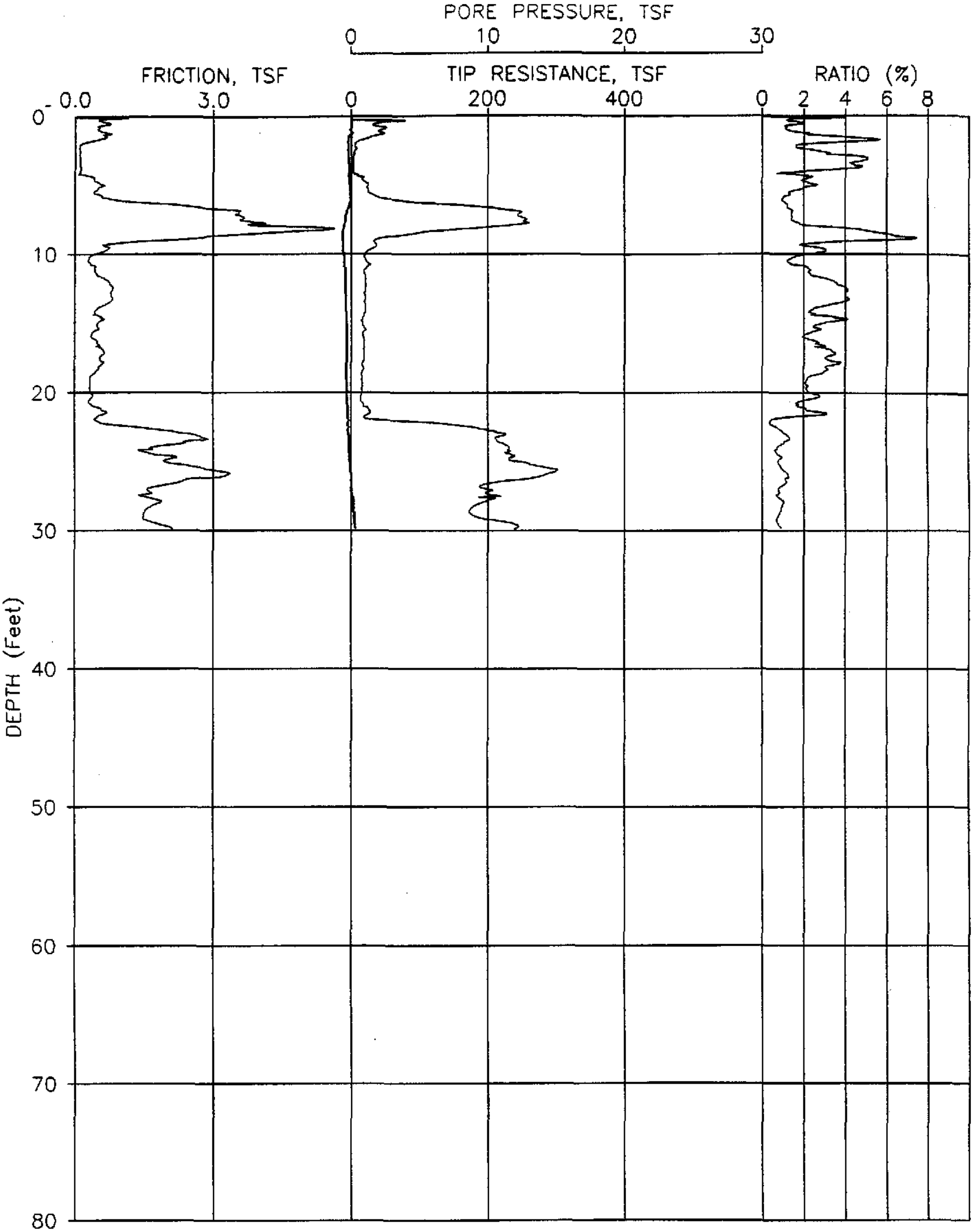

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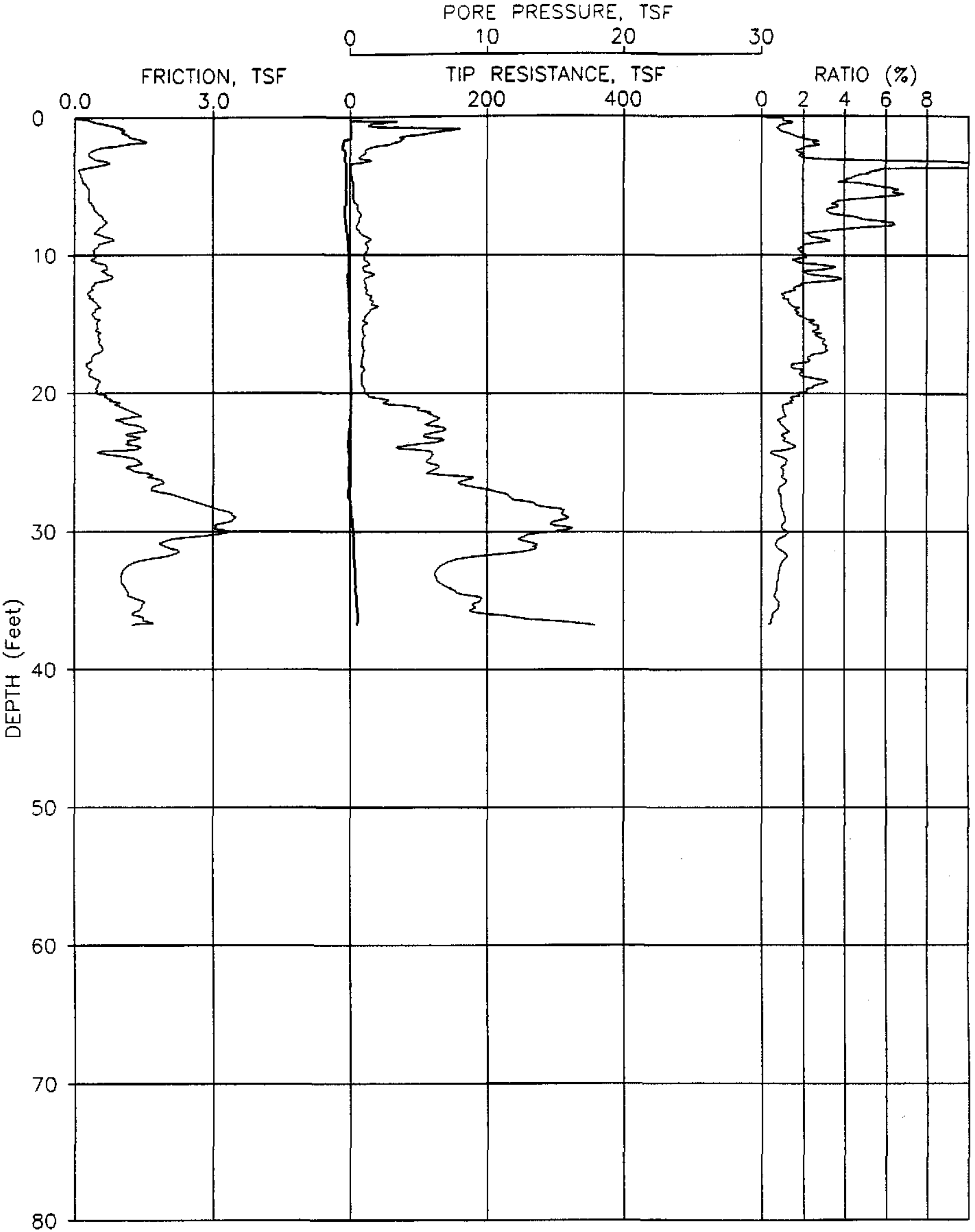

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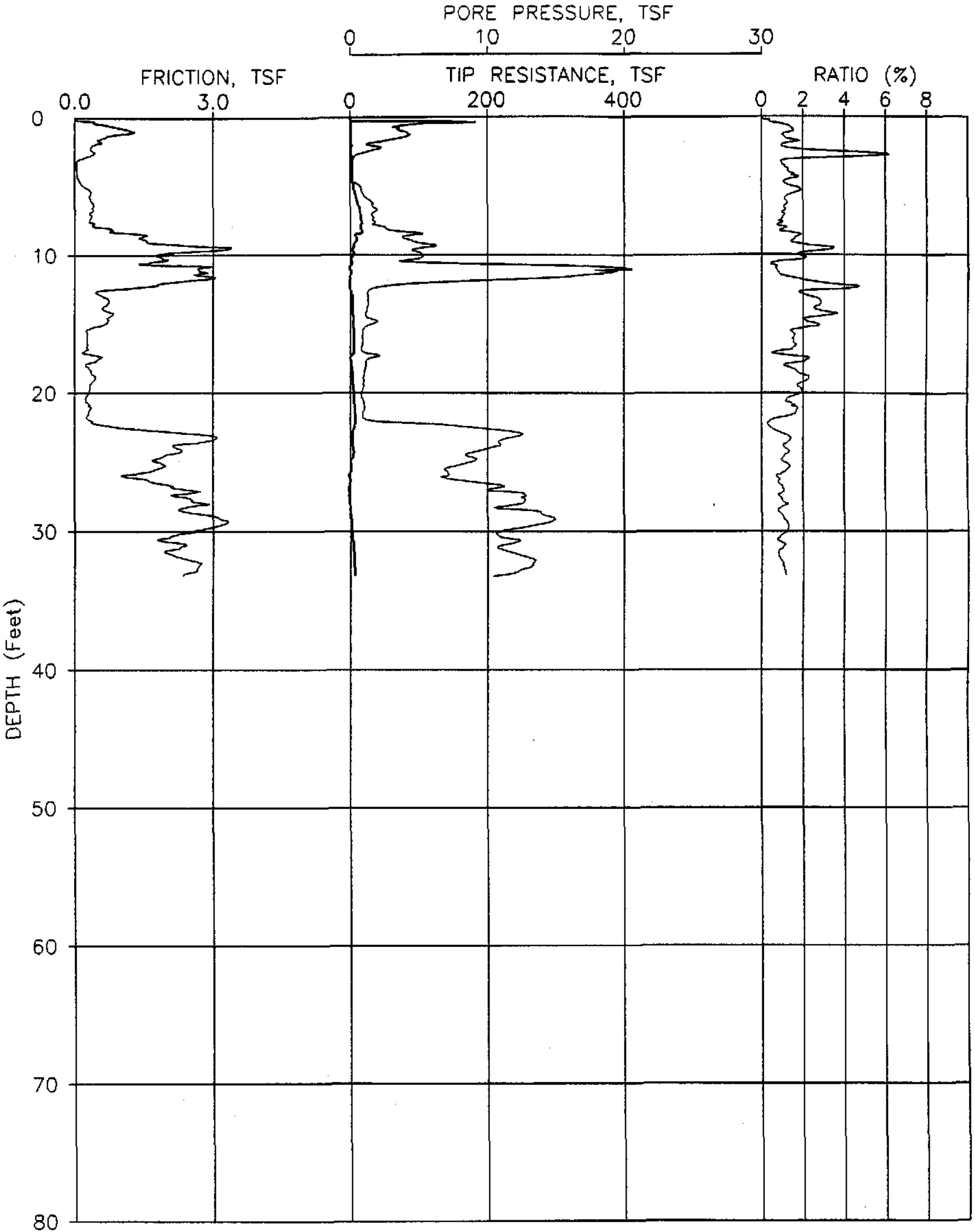

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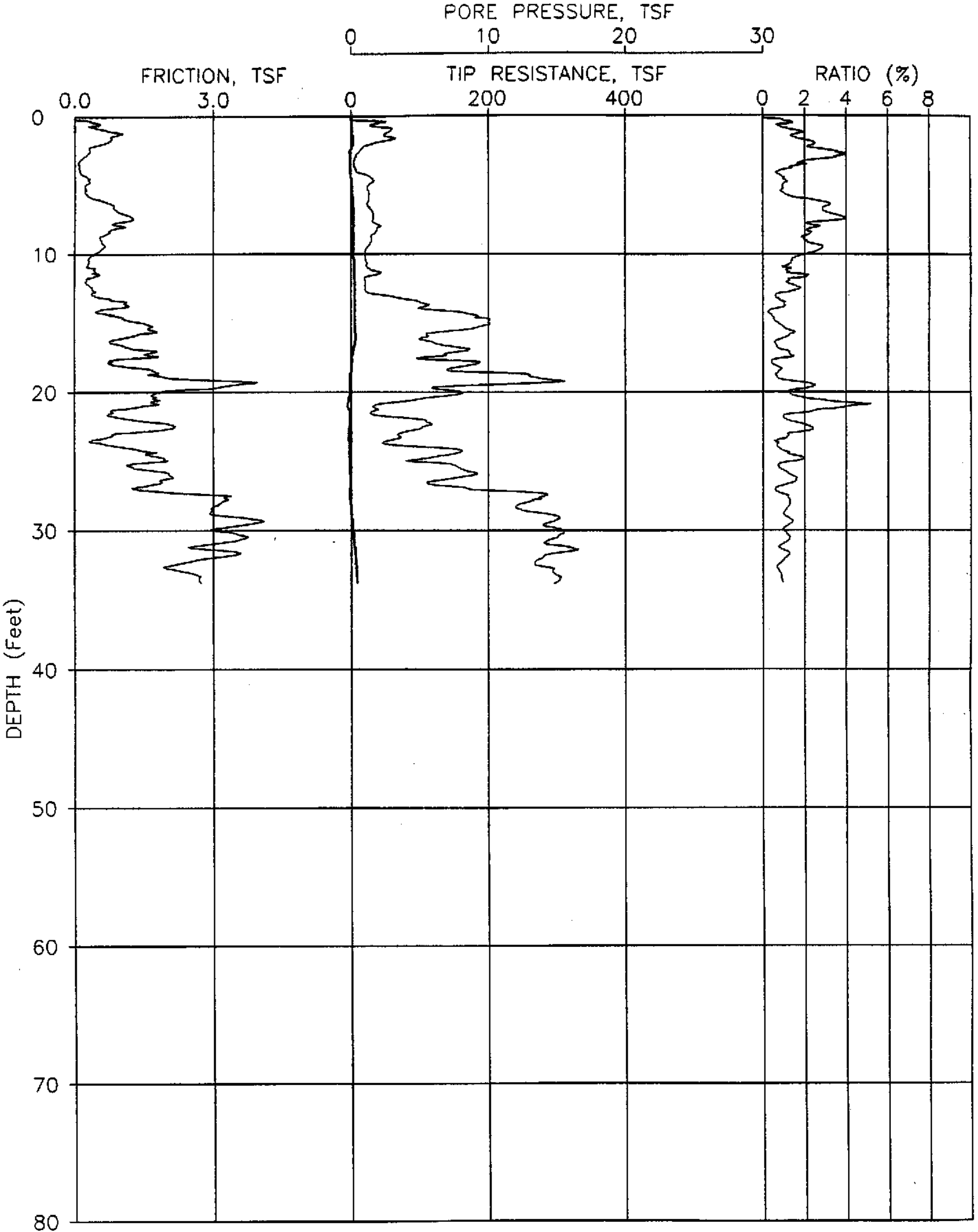

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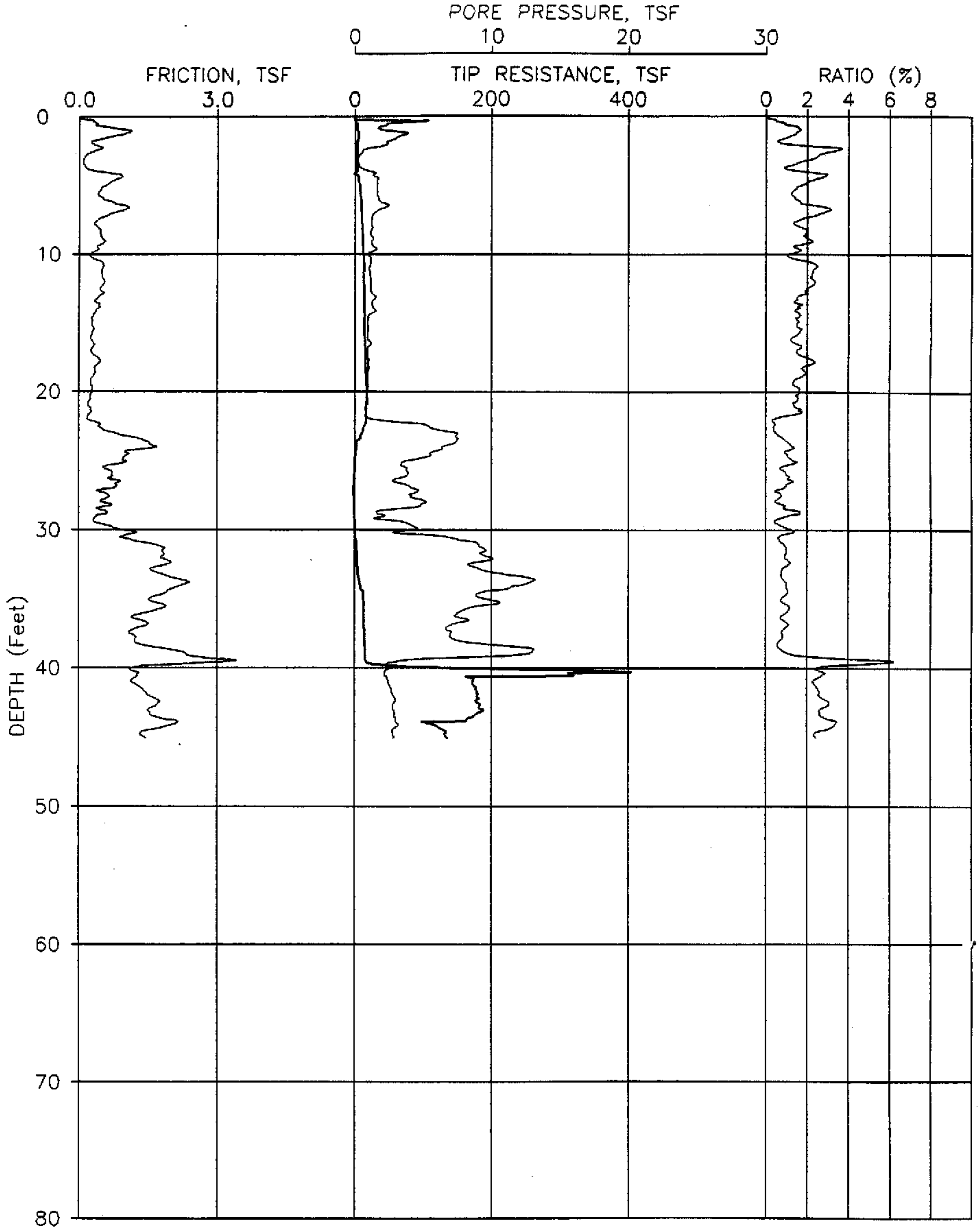

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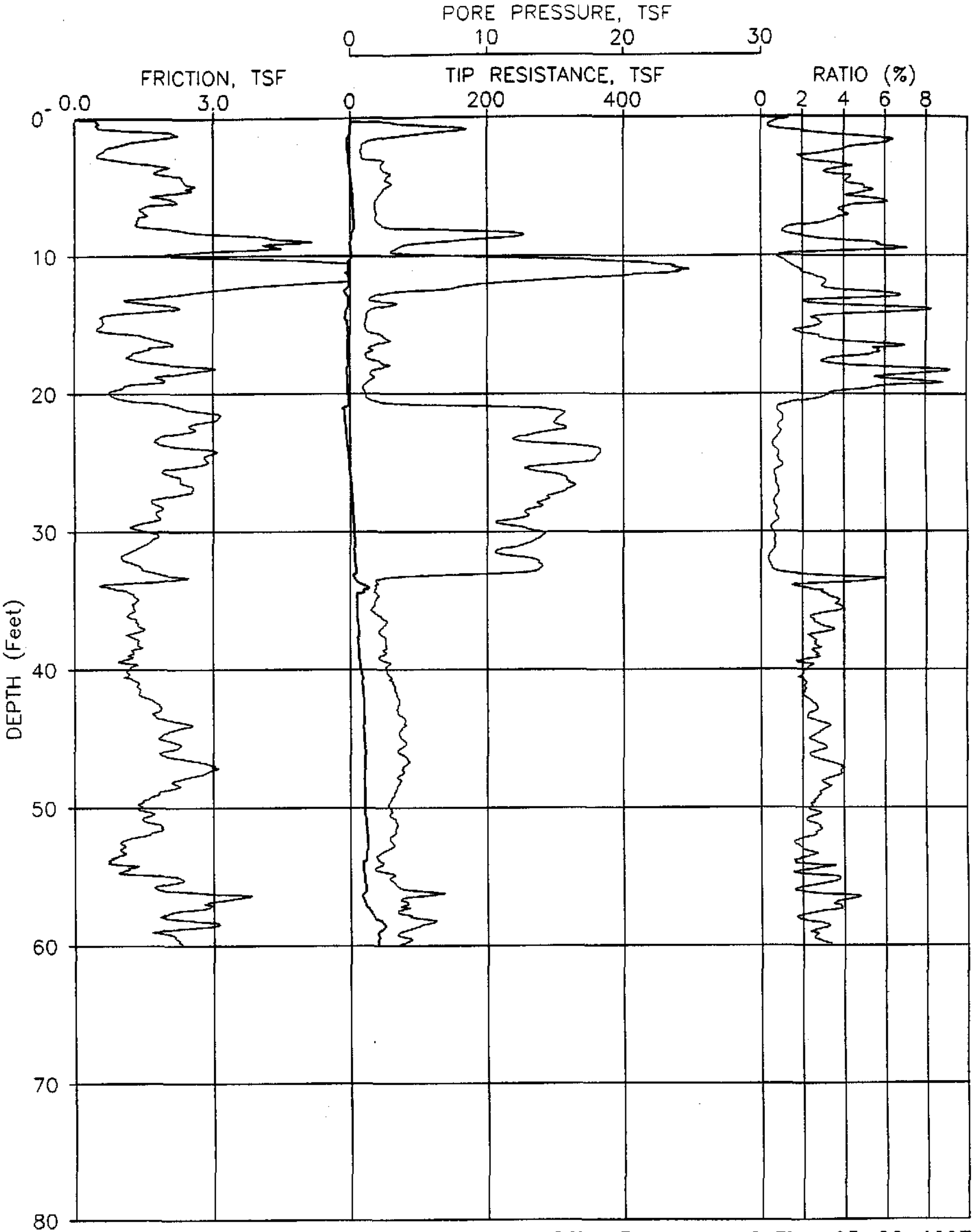

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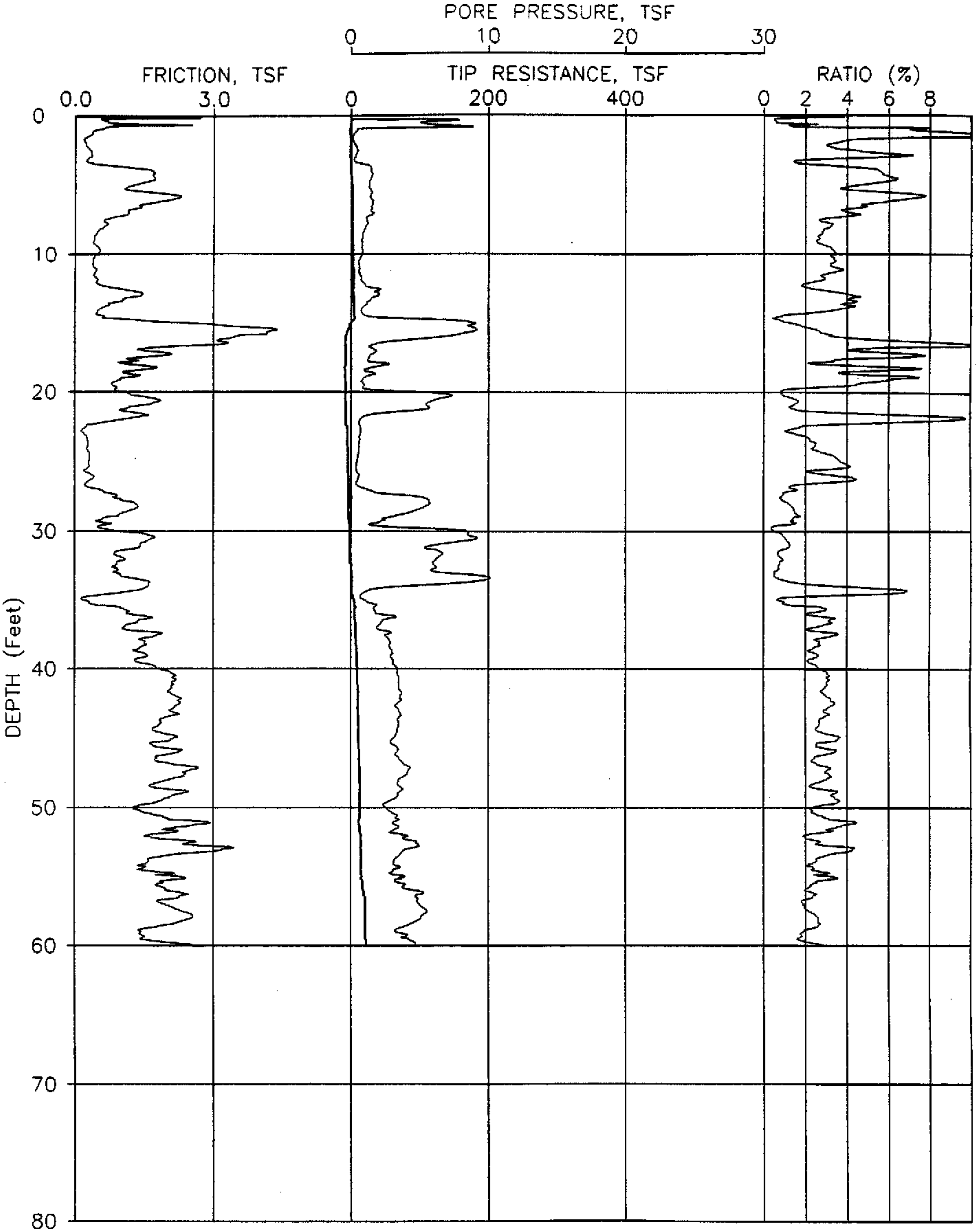

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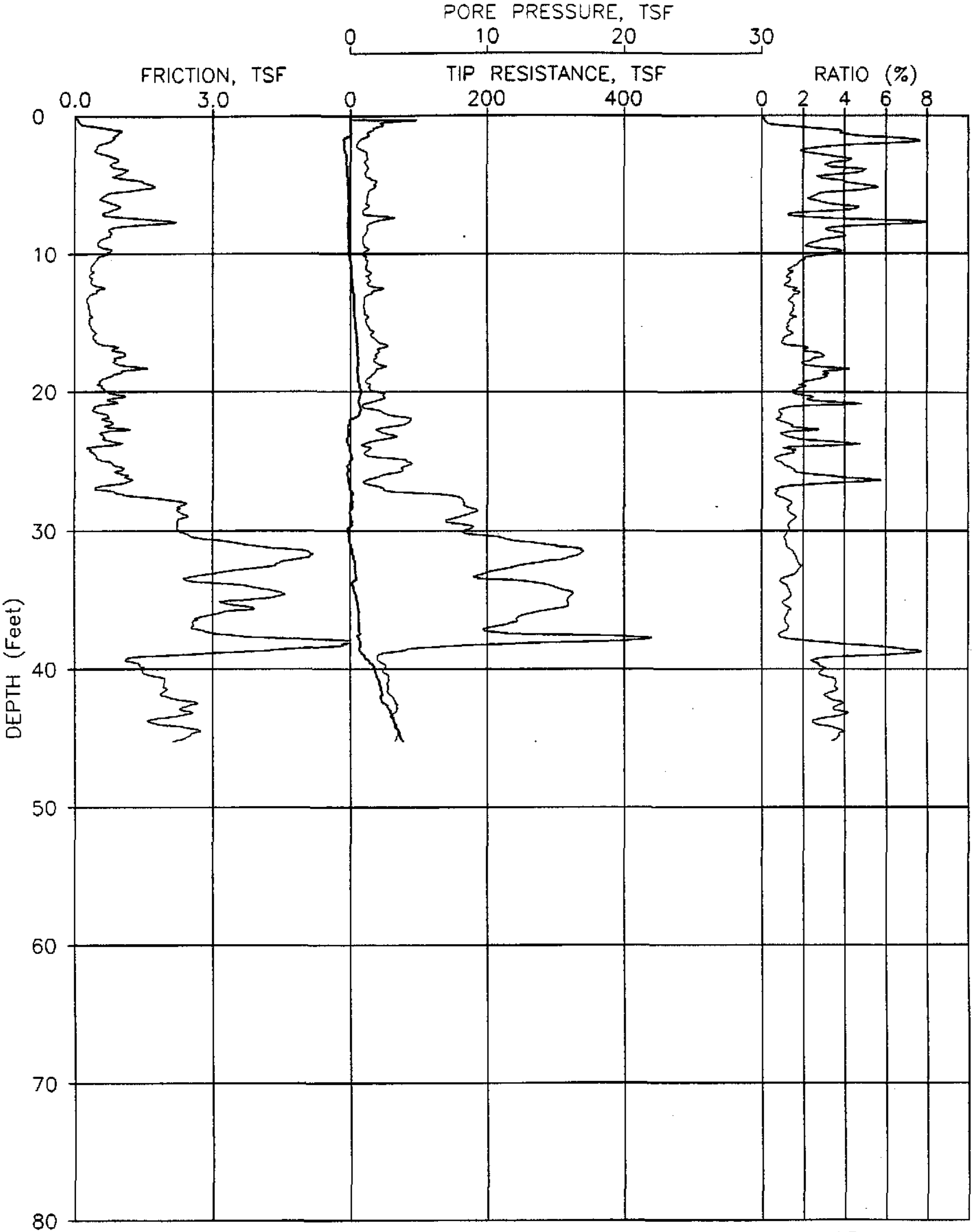

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DATE: 03-10-1997
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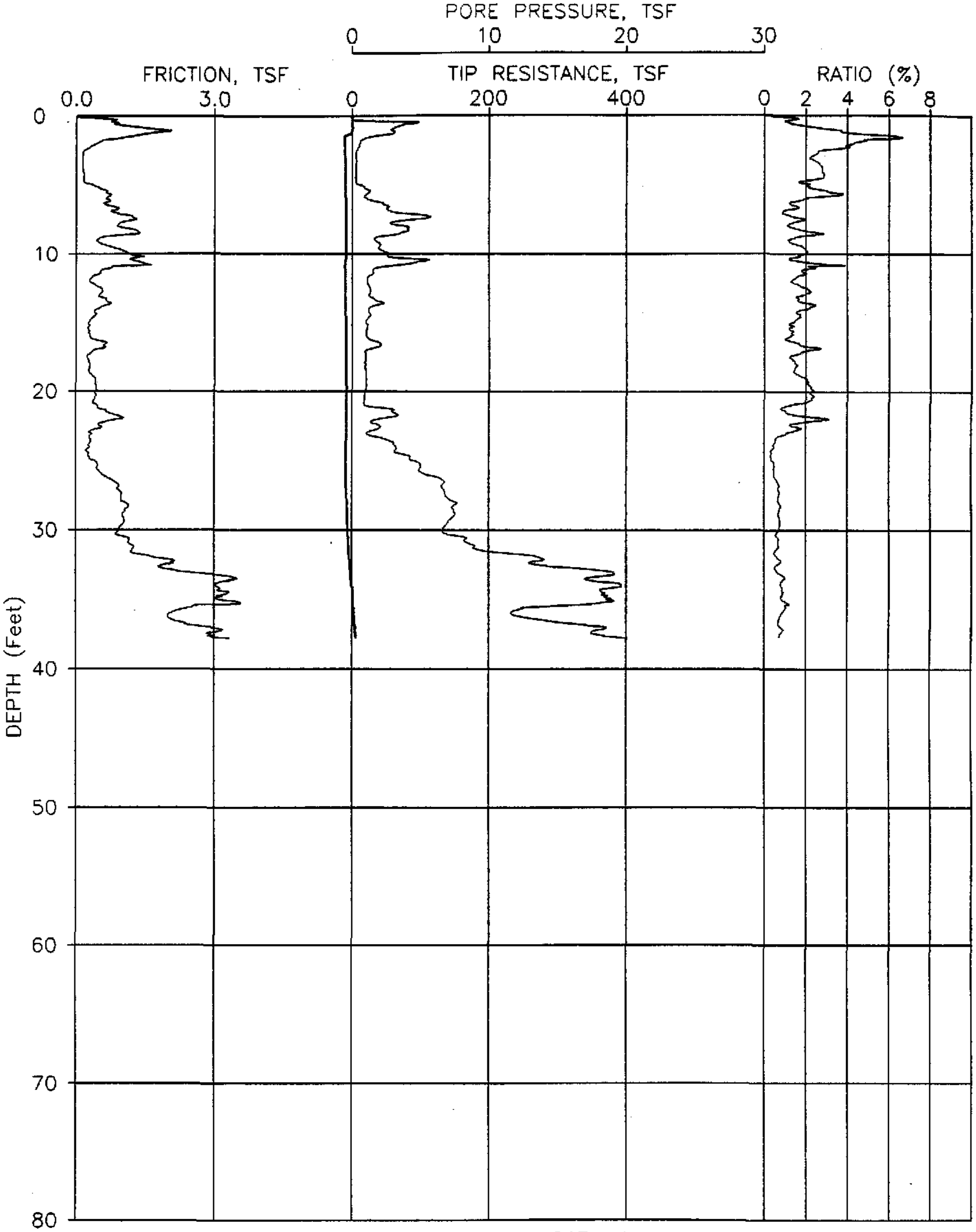

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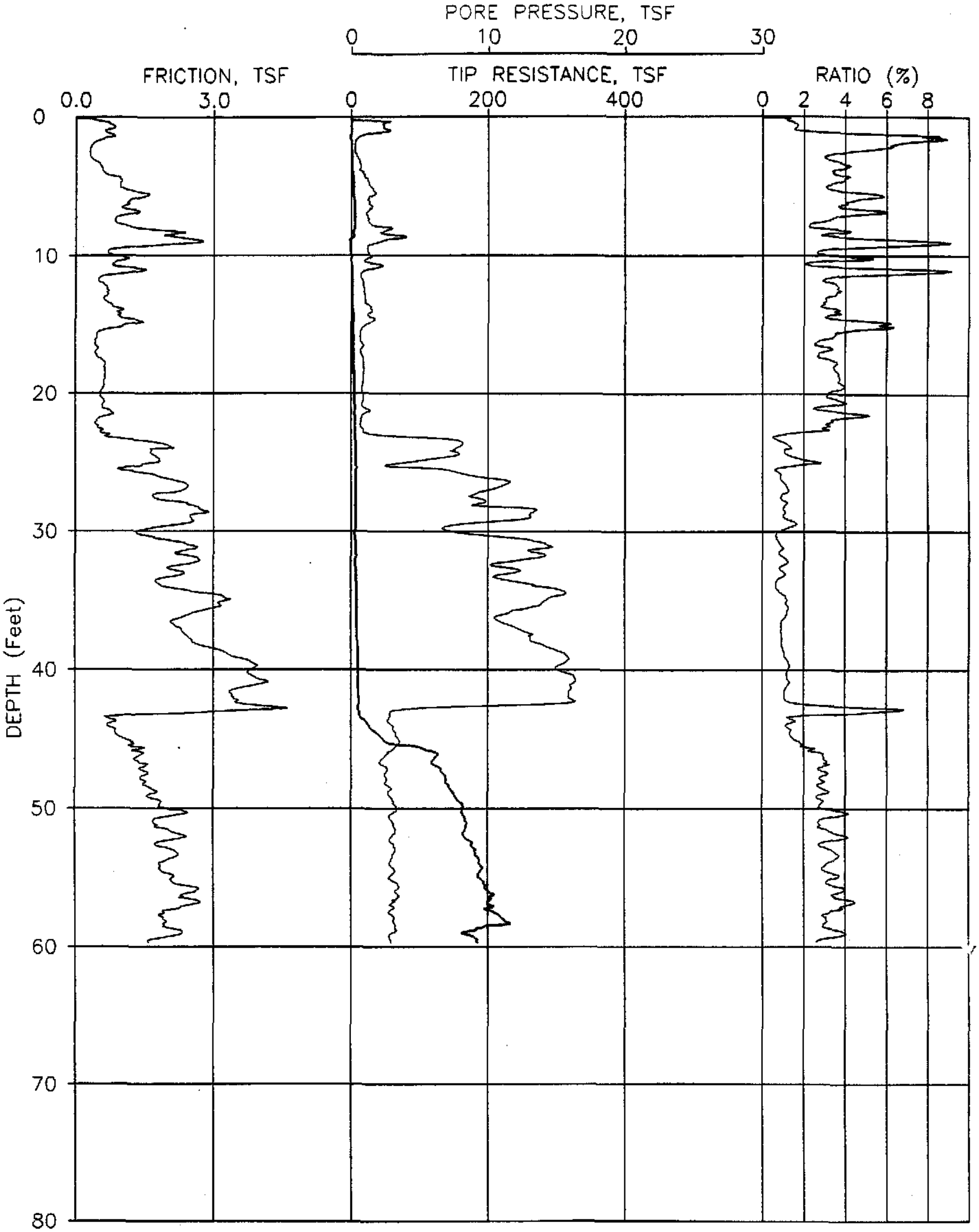

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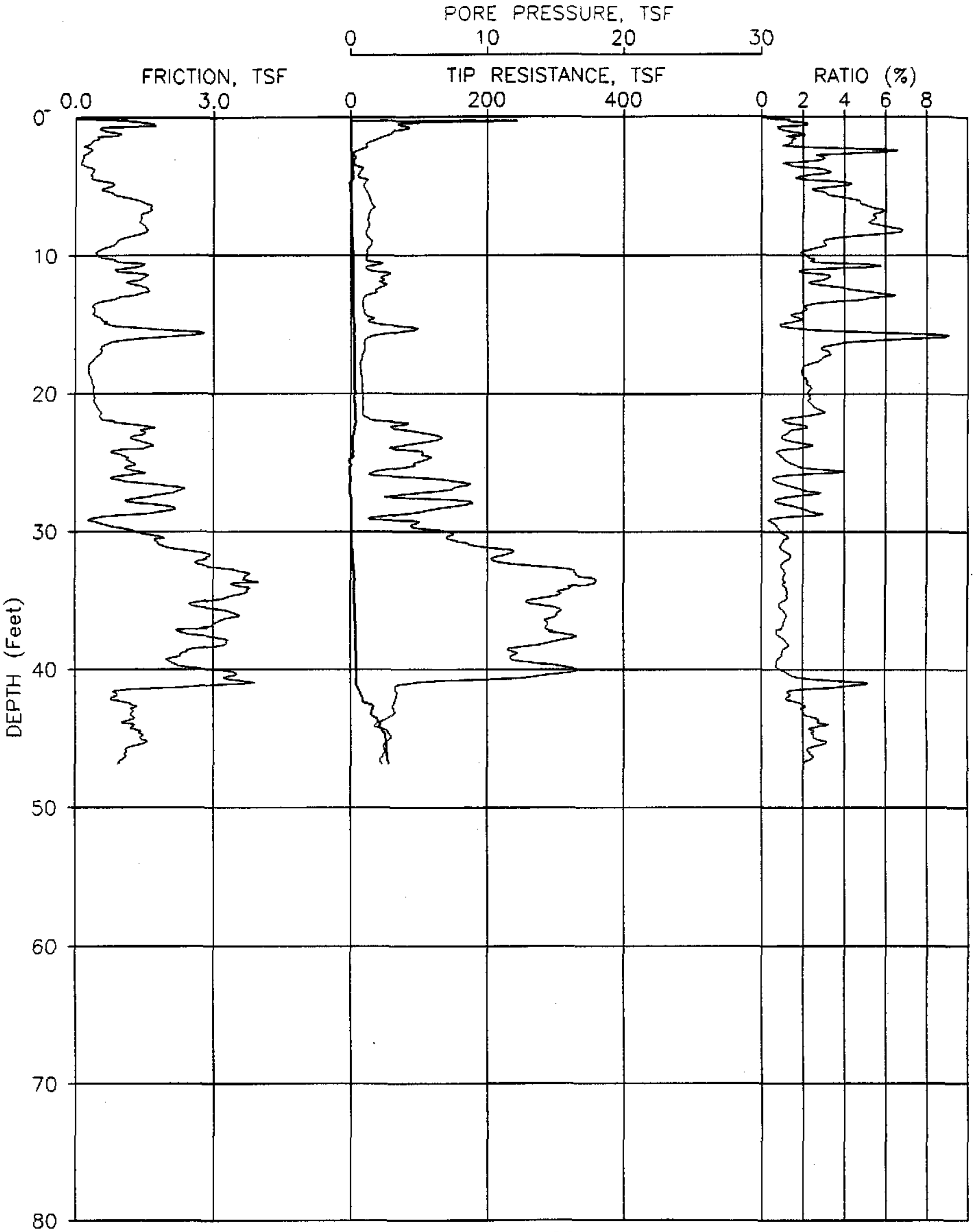

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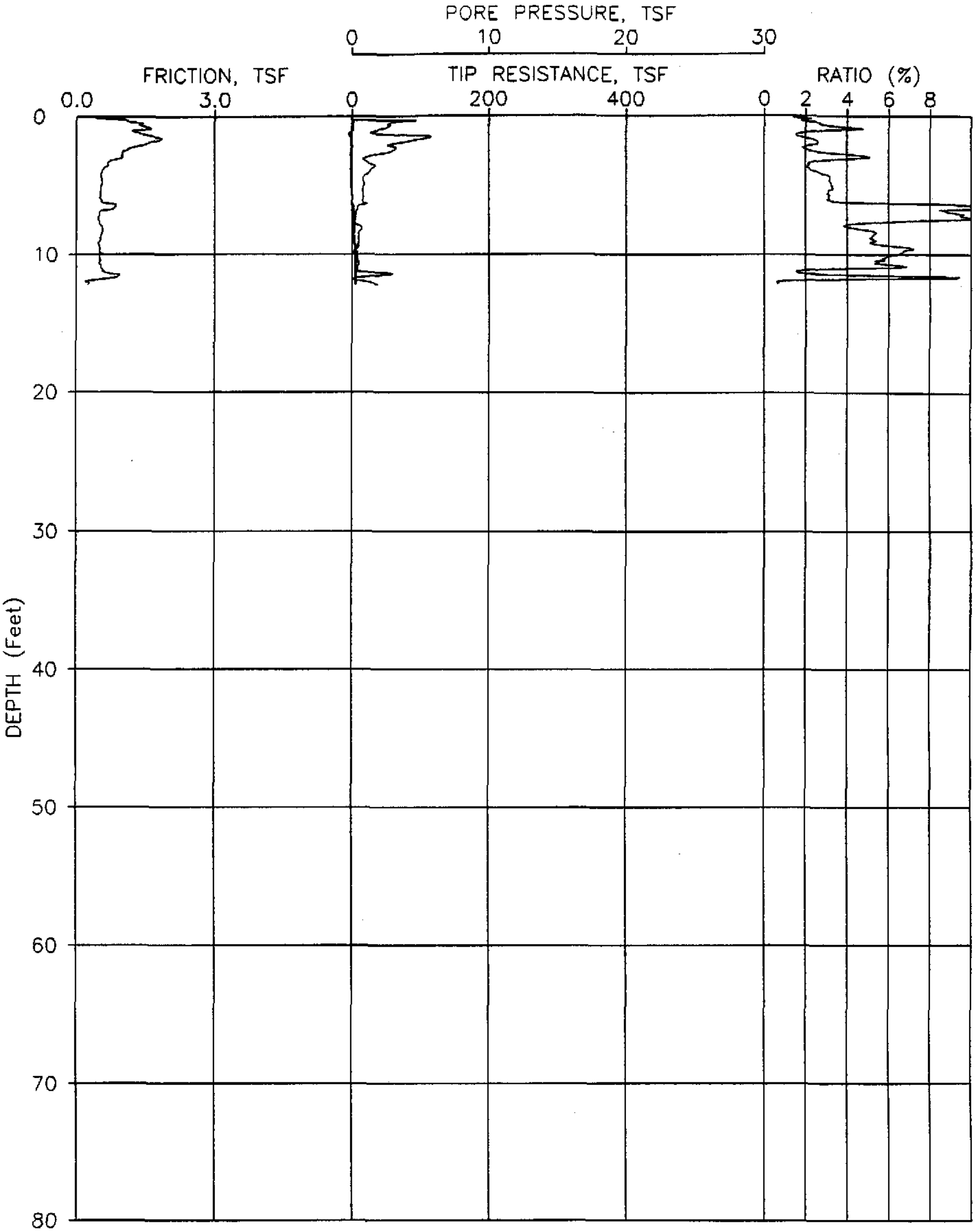

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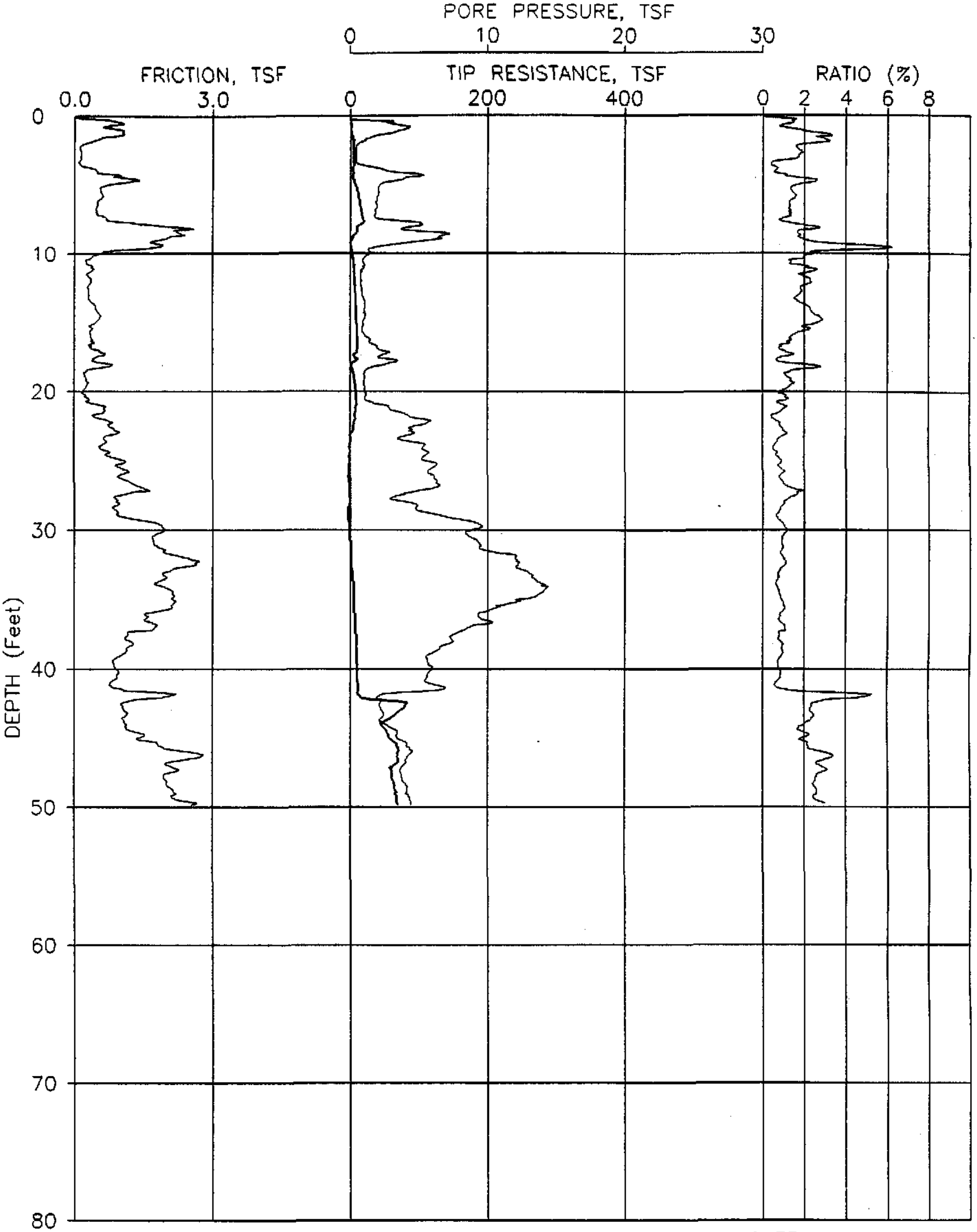

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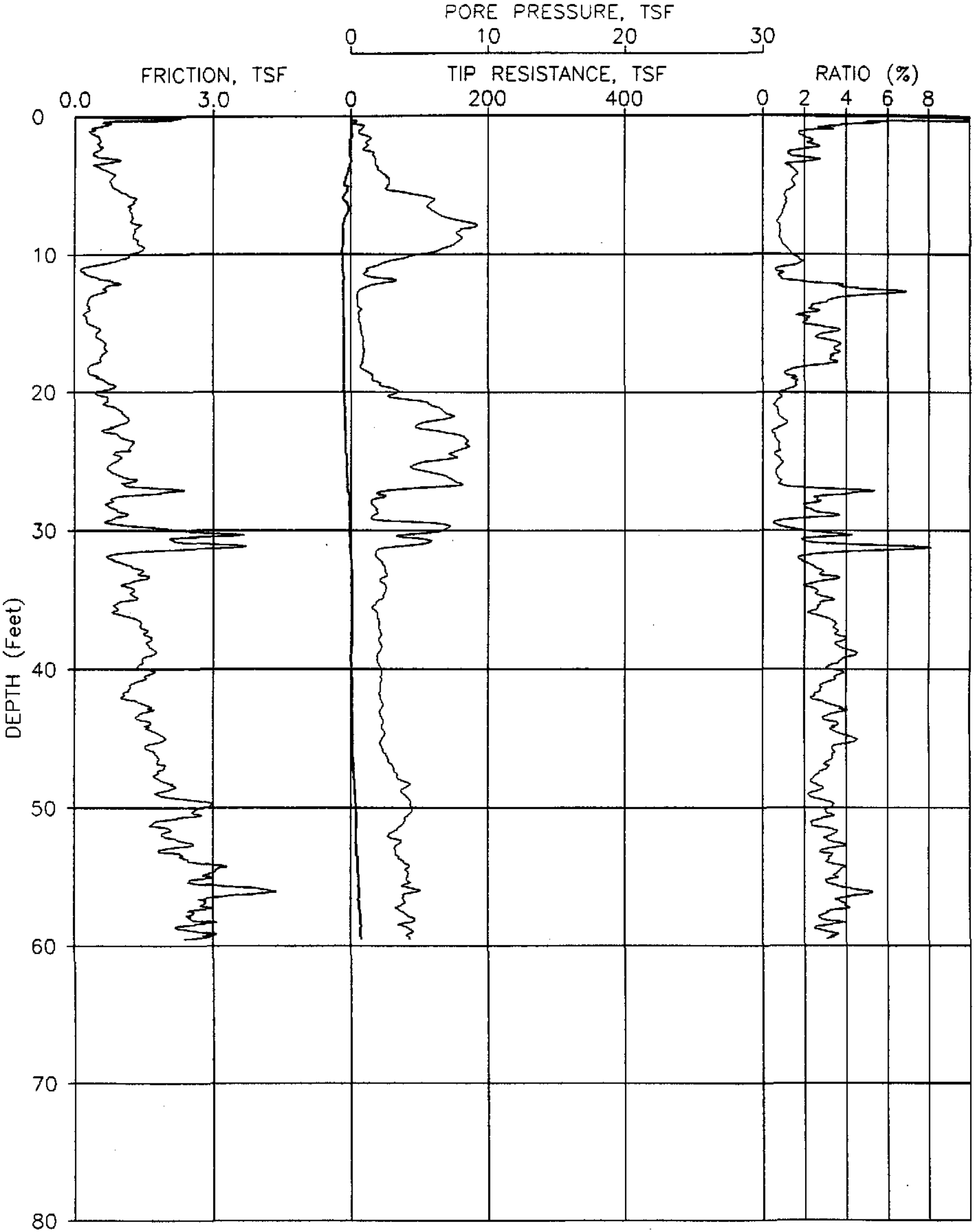

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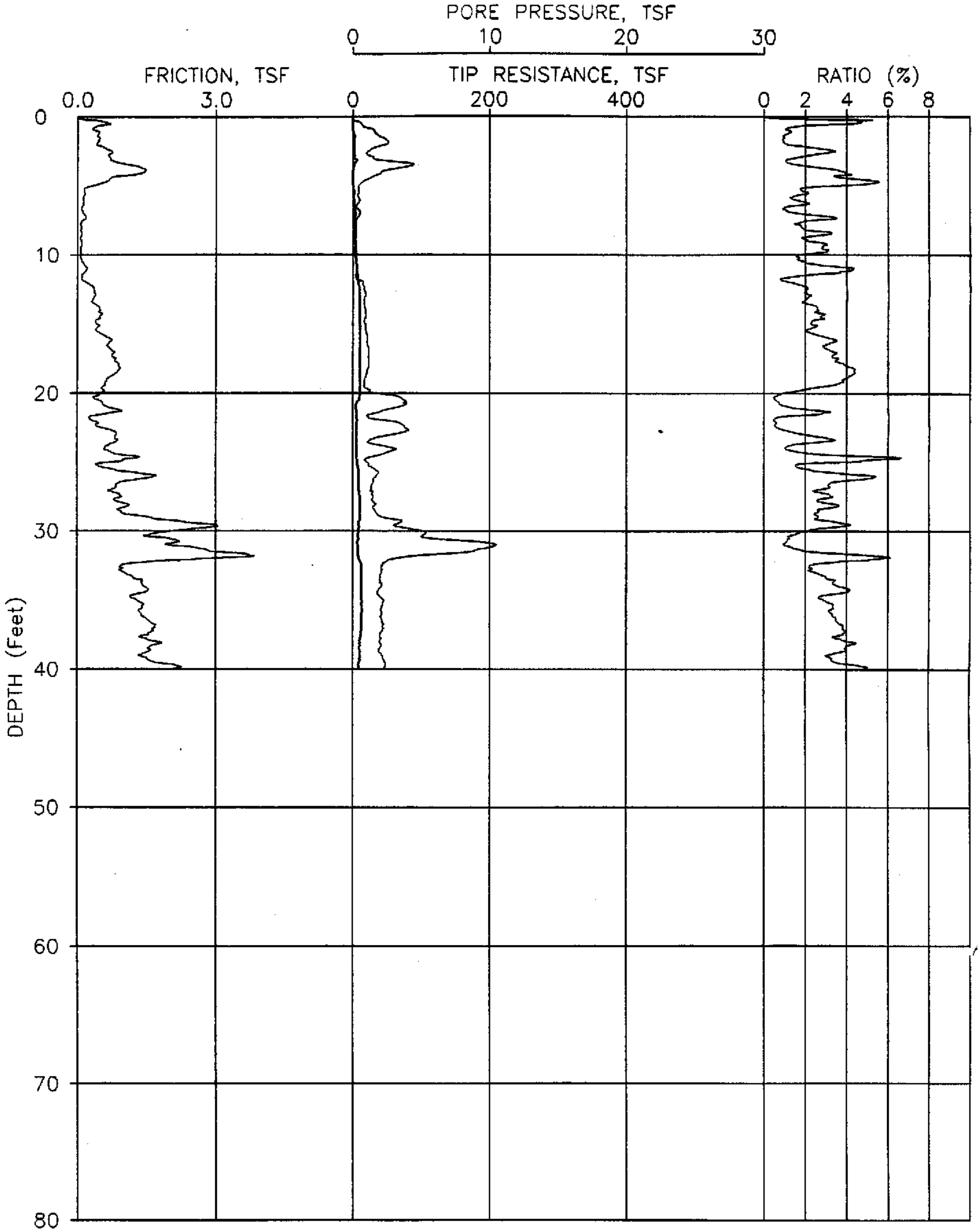

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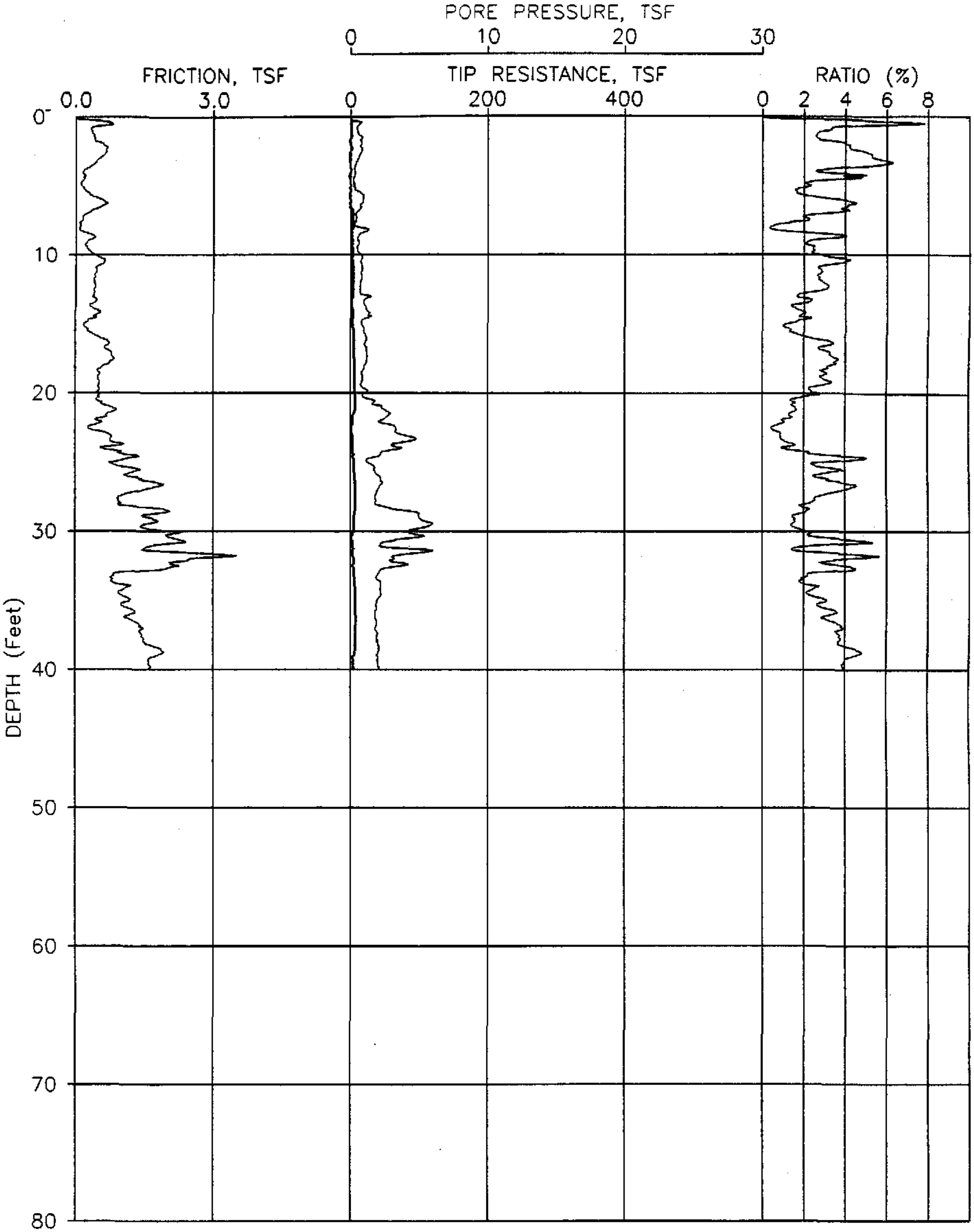

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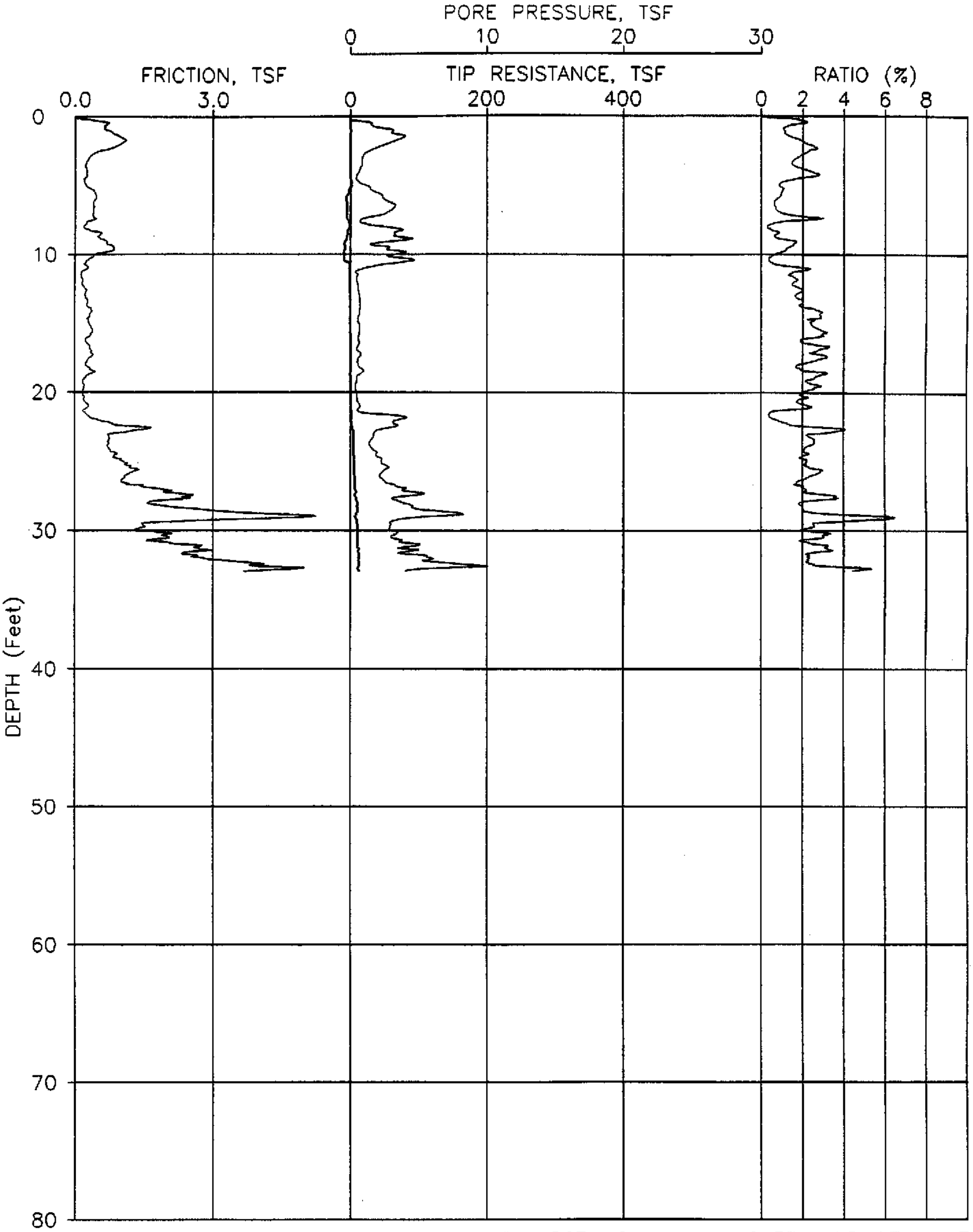

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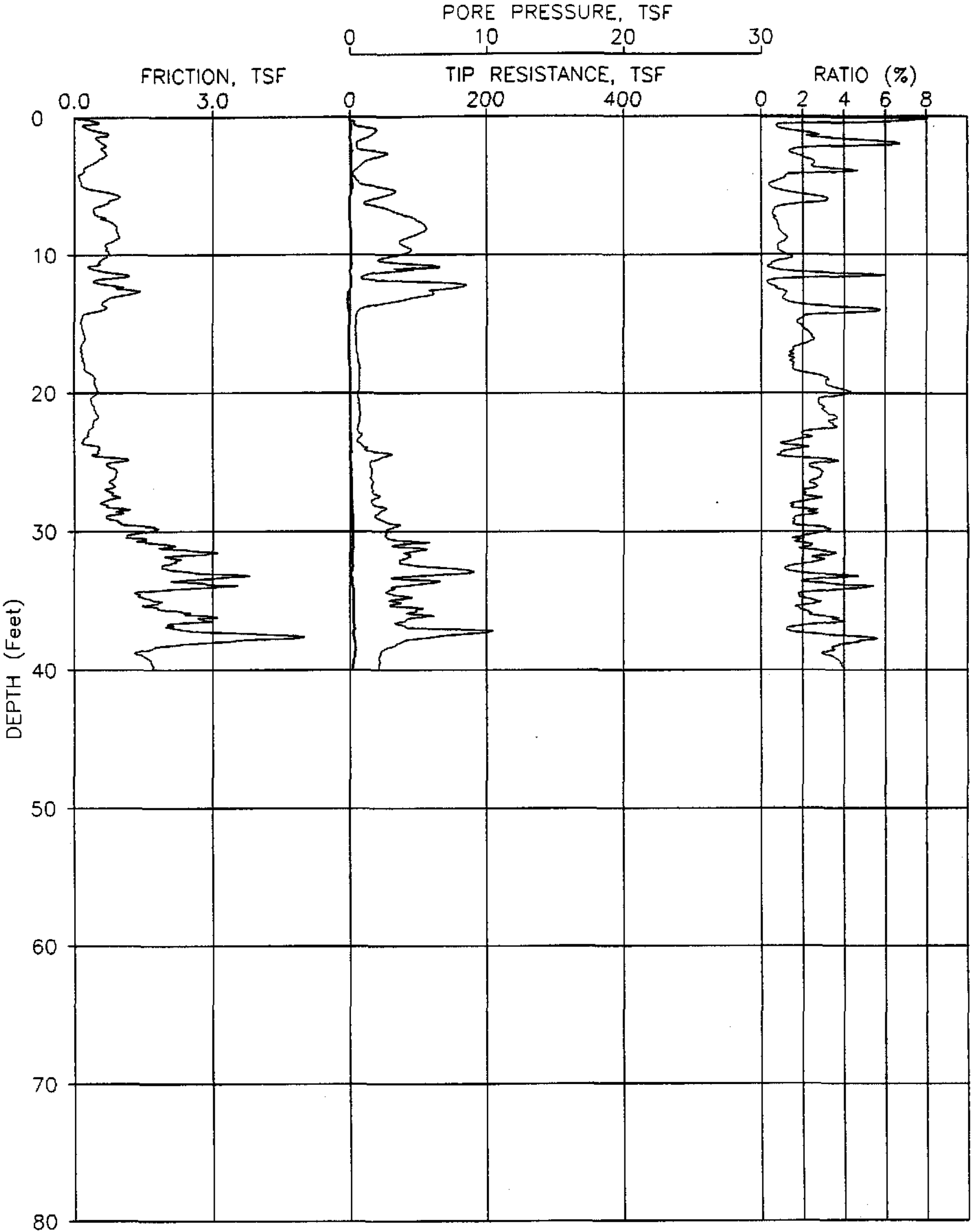

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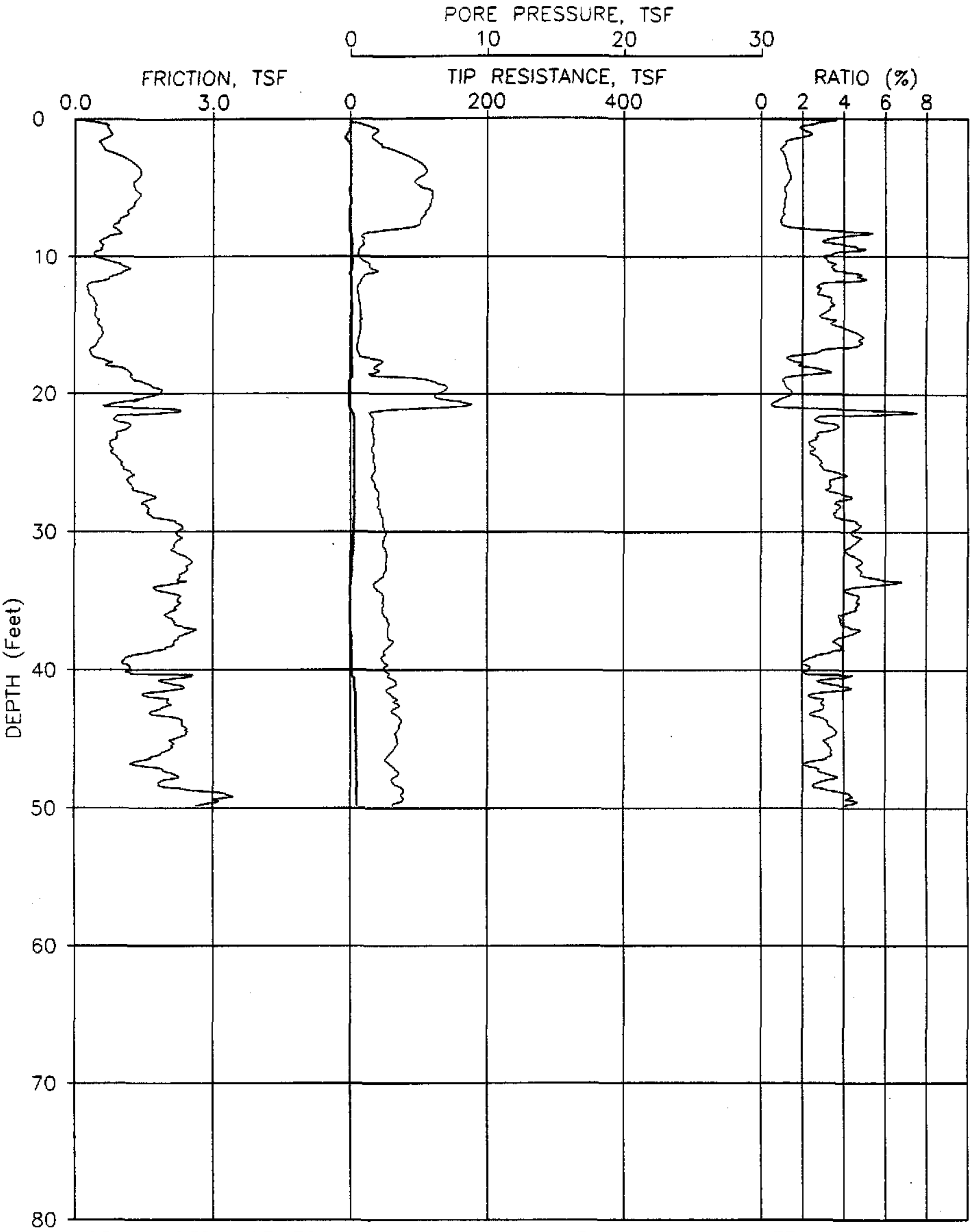

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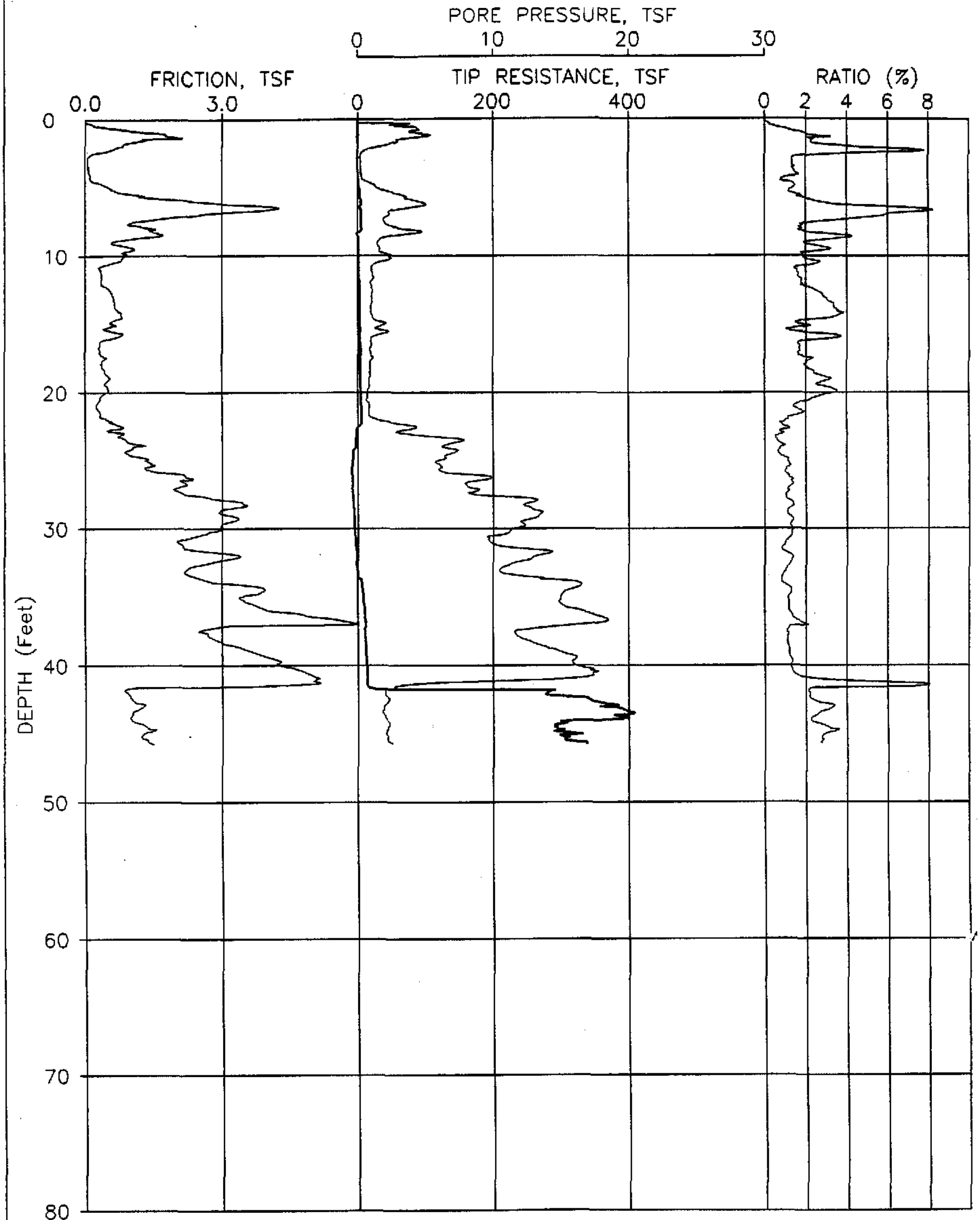

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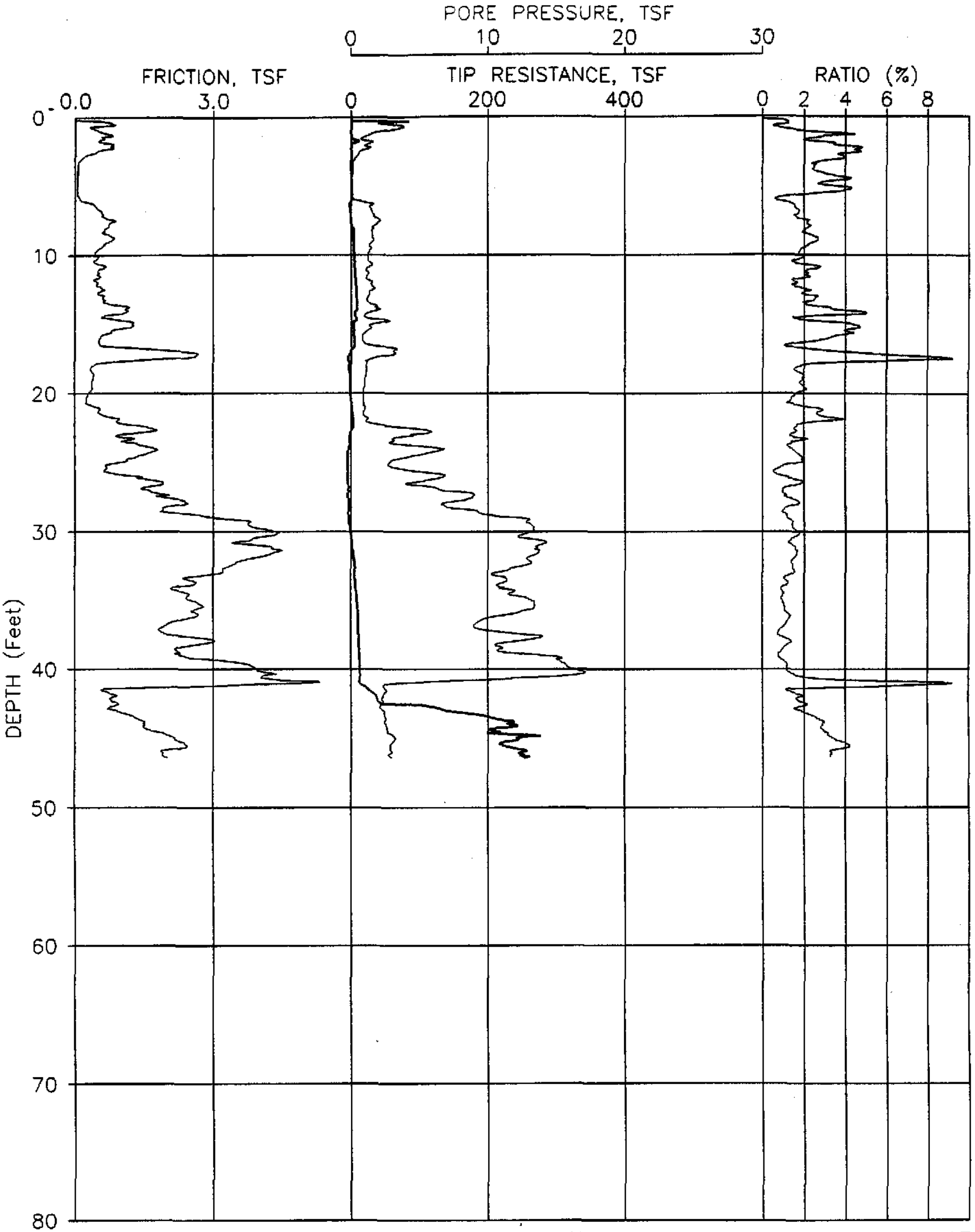

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DATE: 03-10-1997
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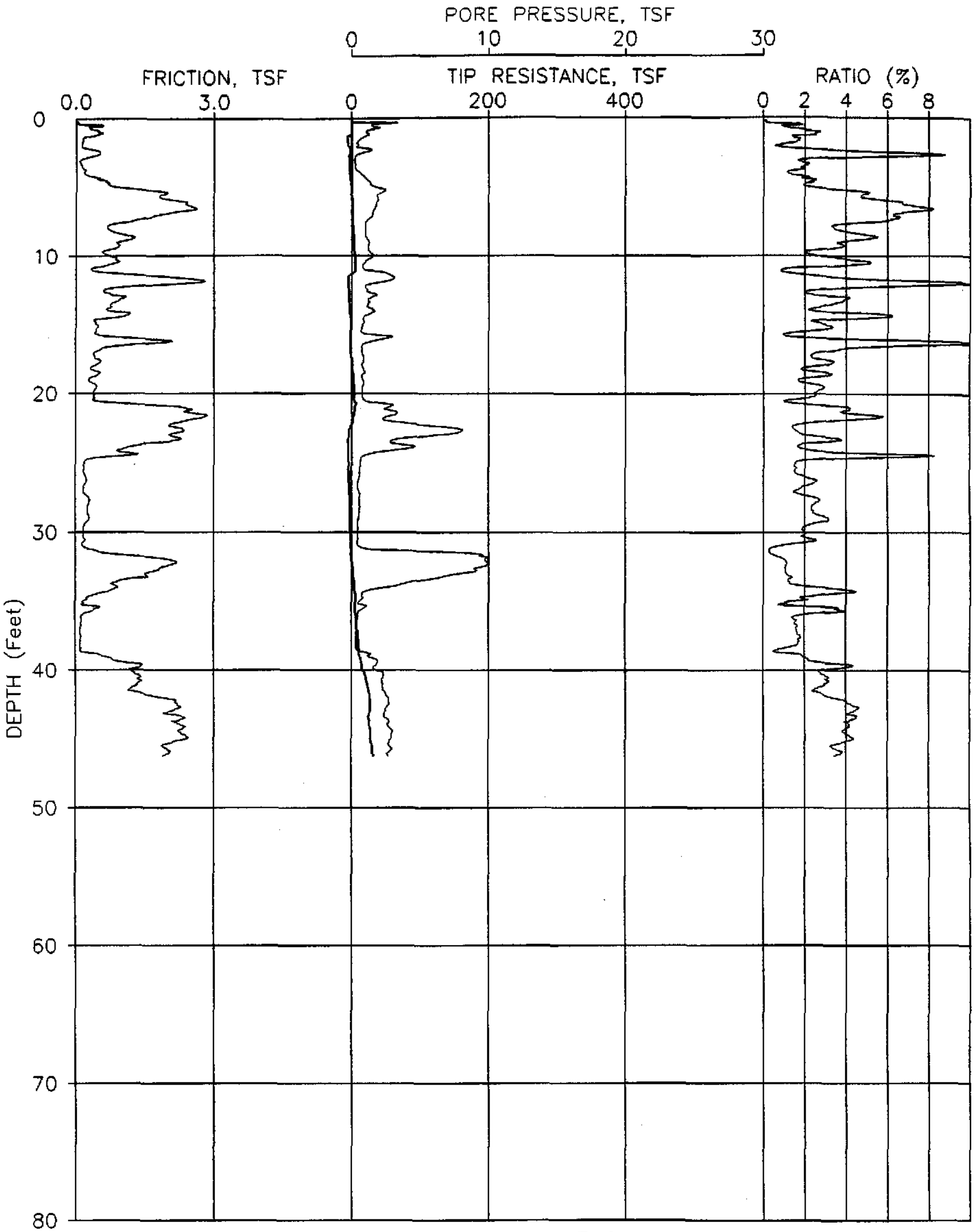

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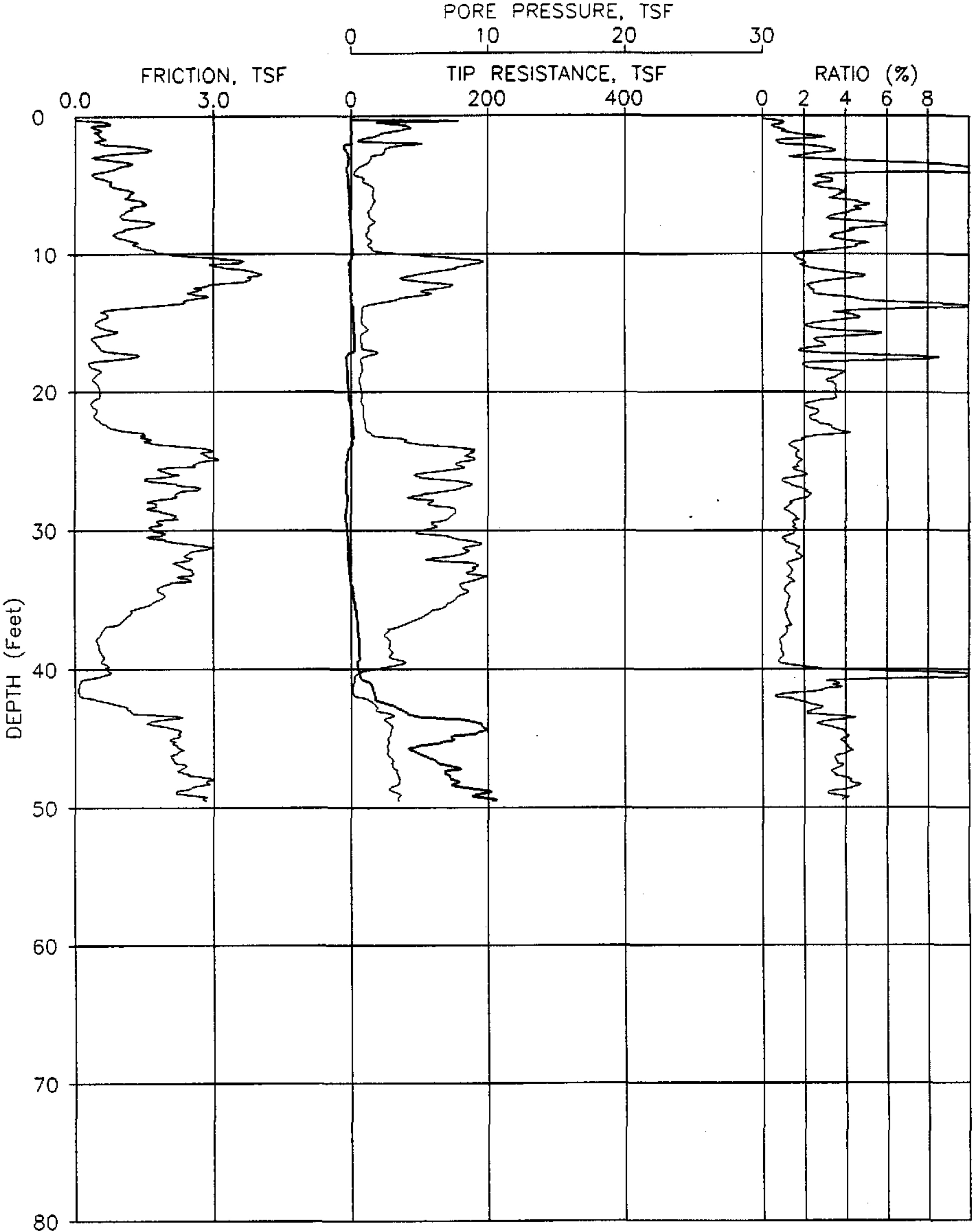

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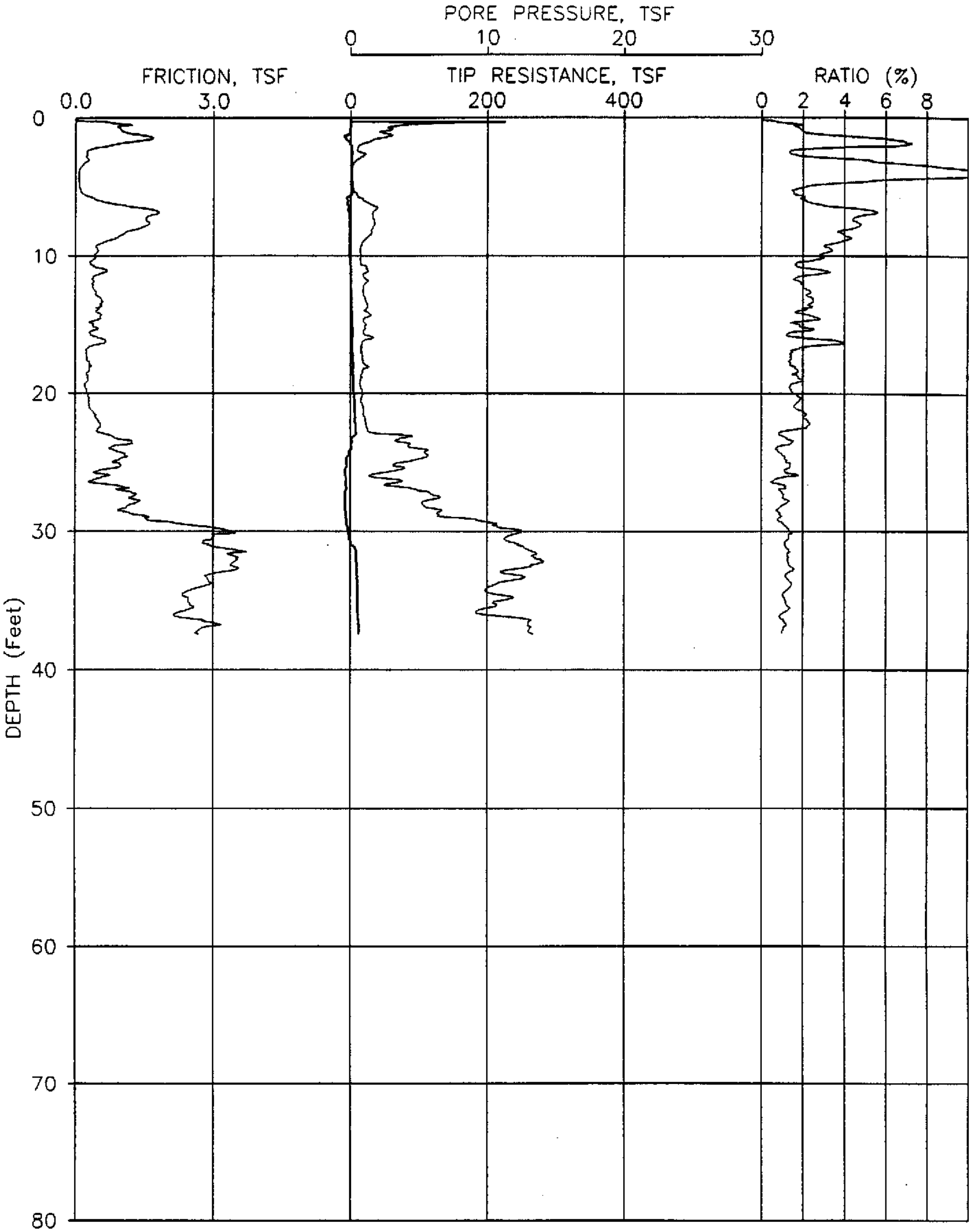

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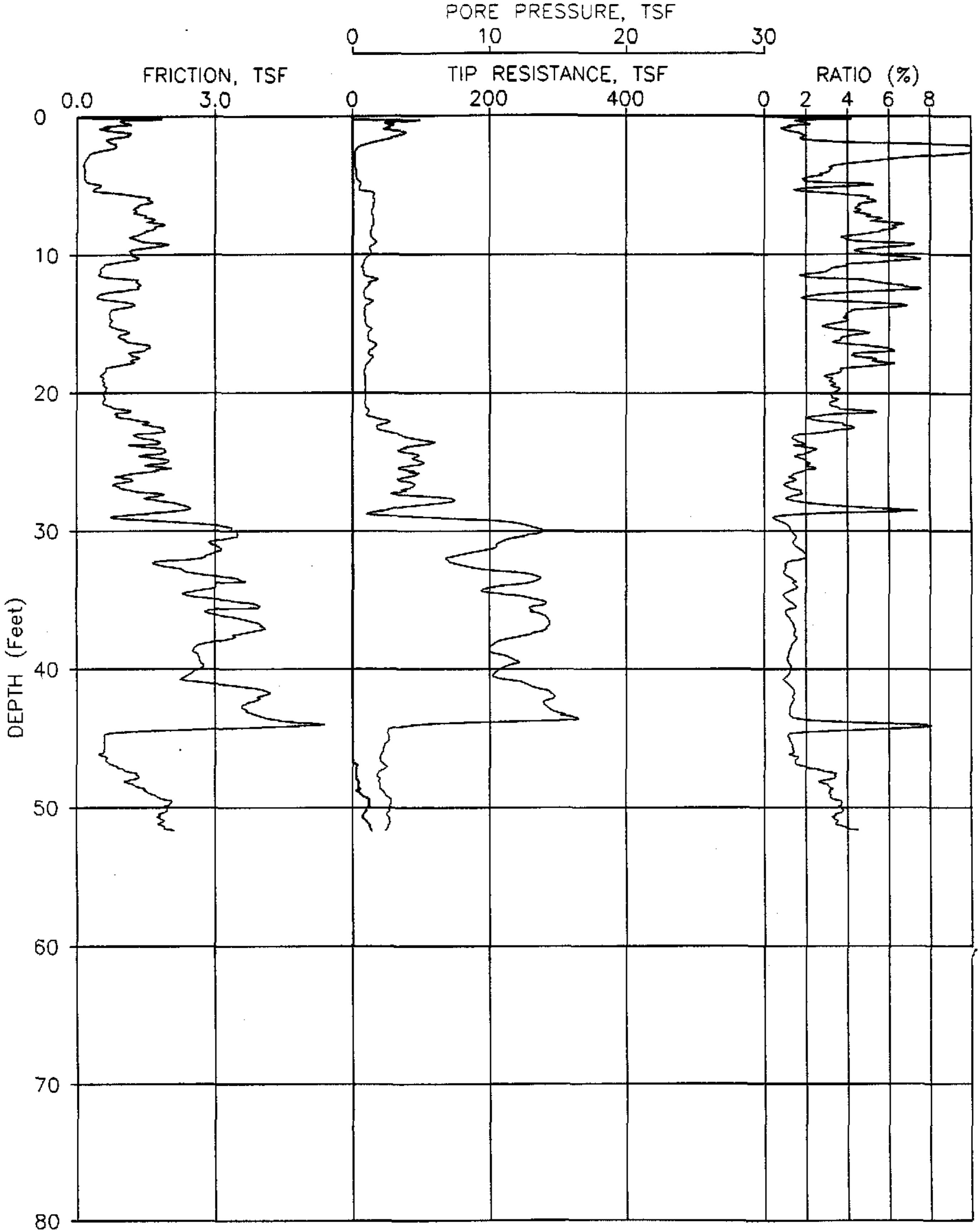

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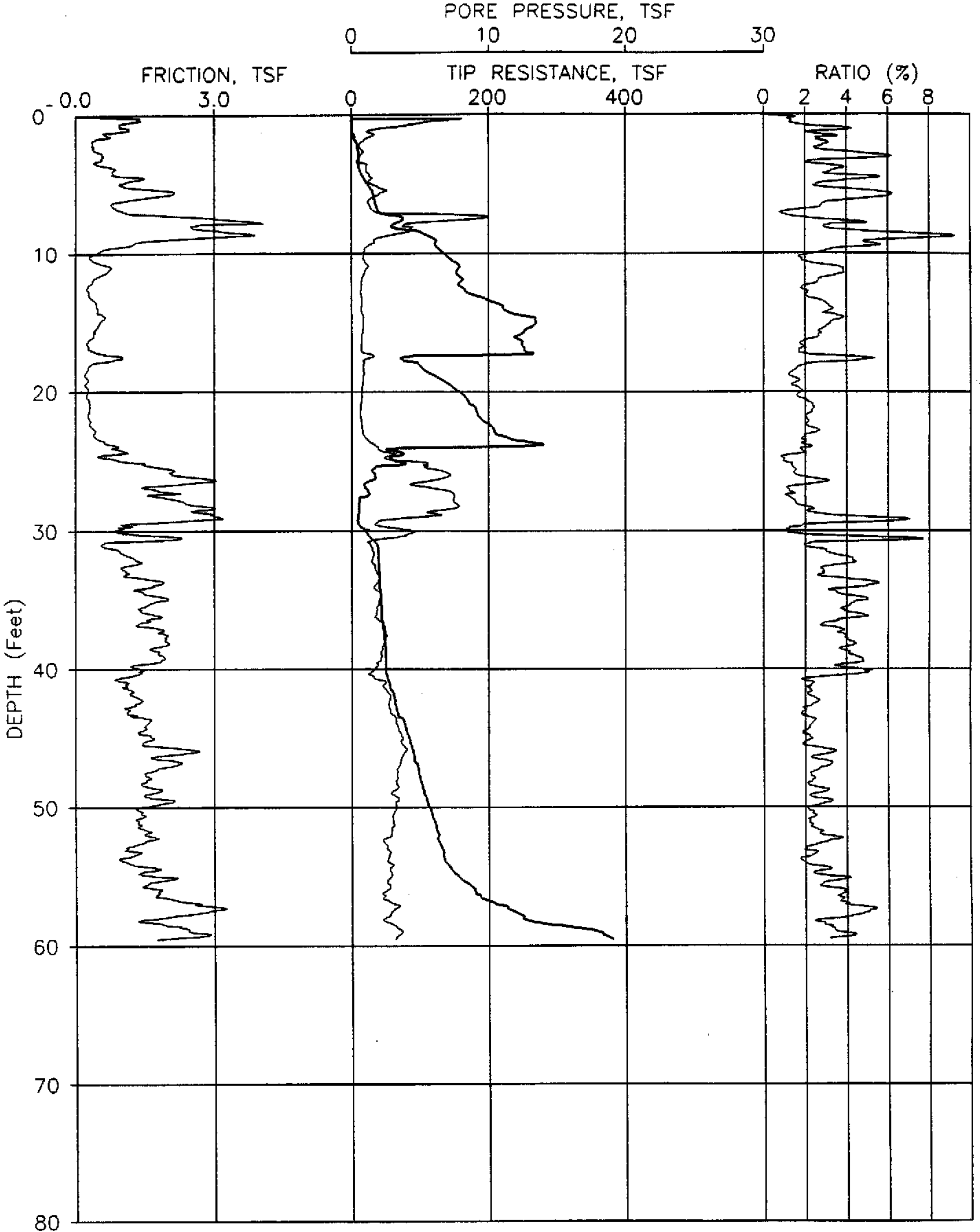

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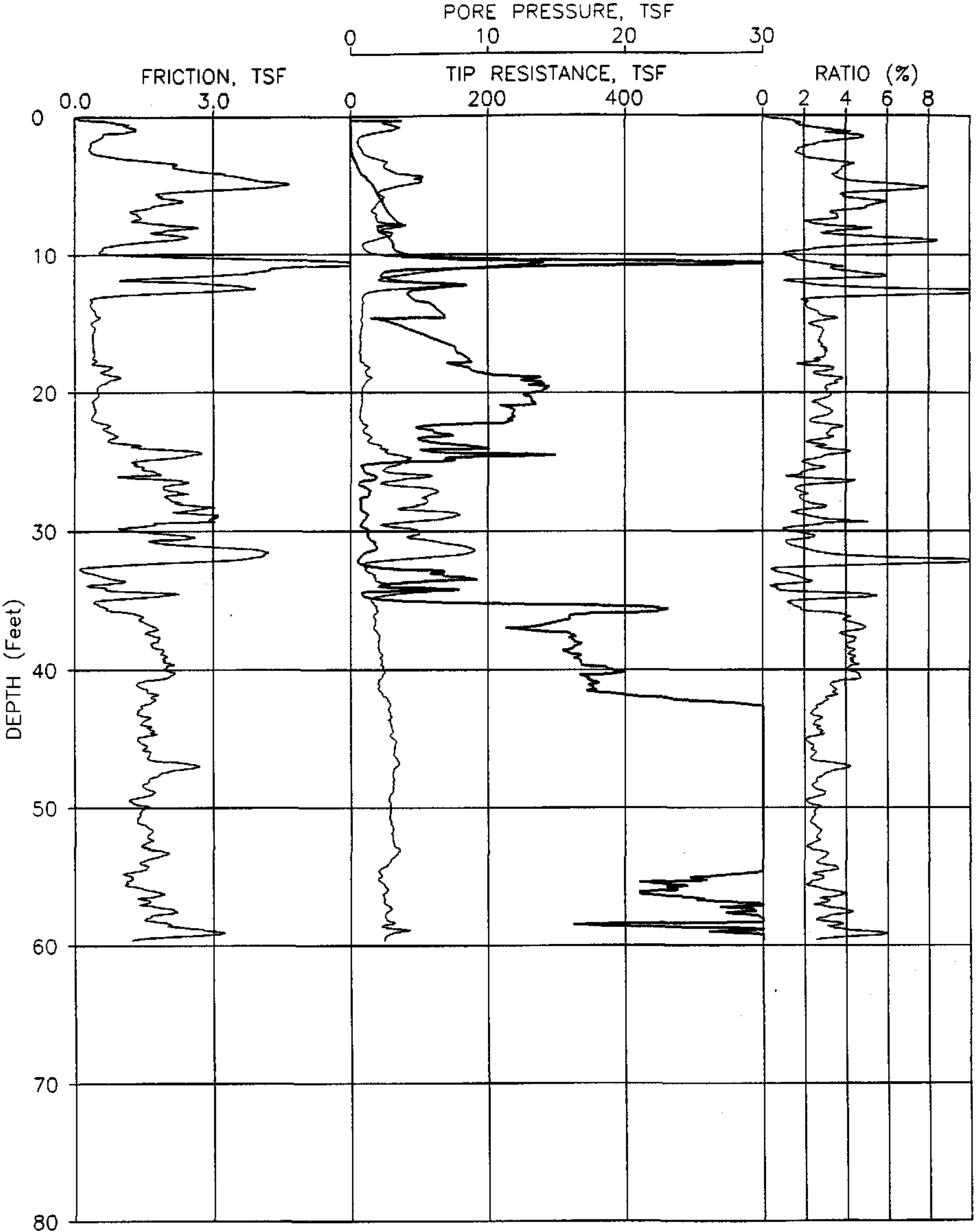

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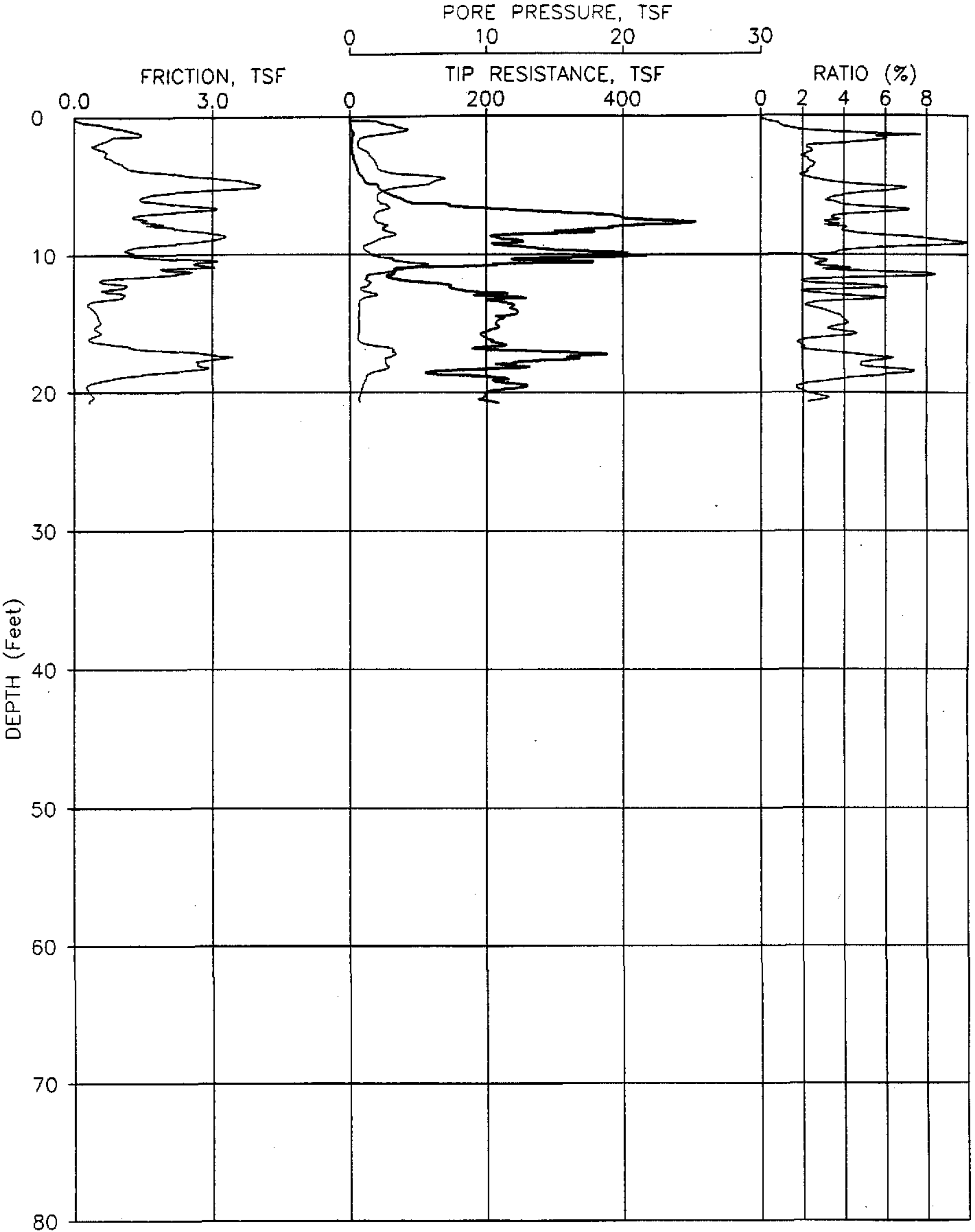

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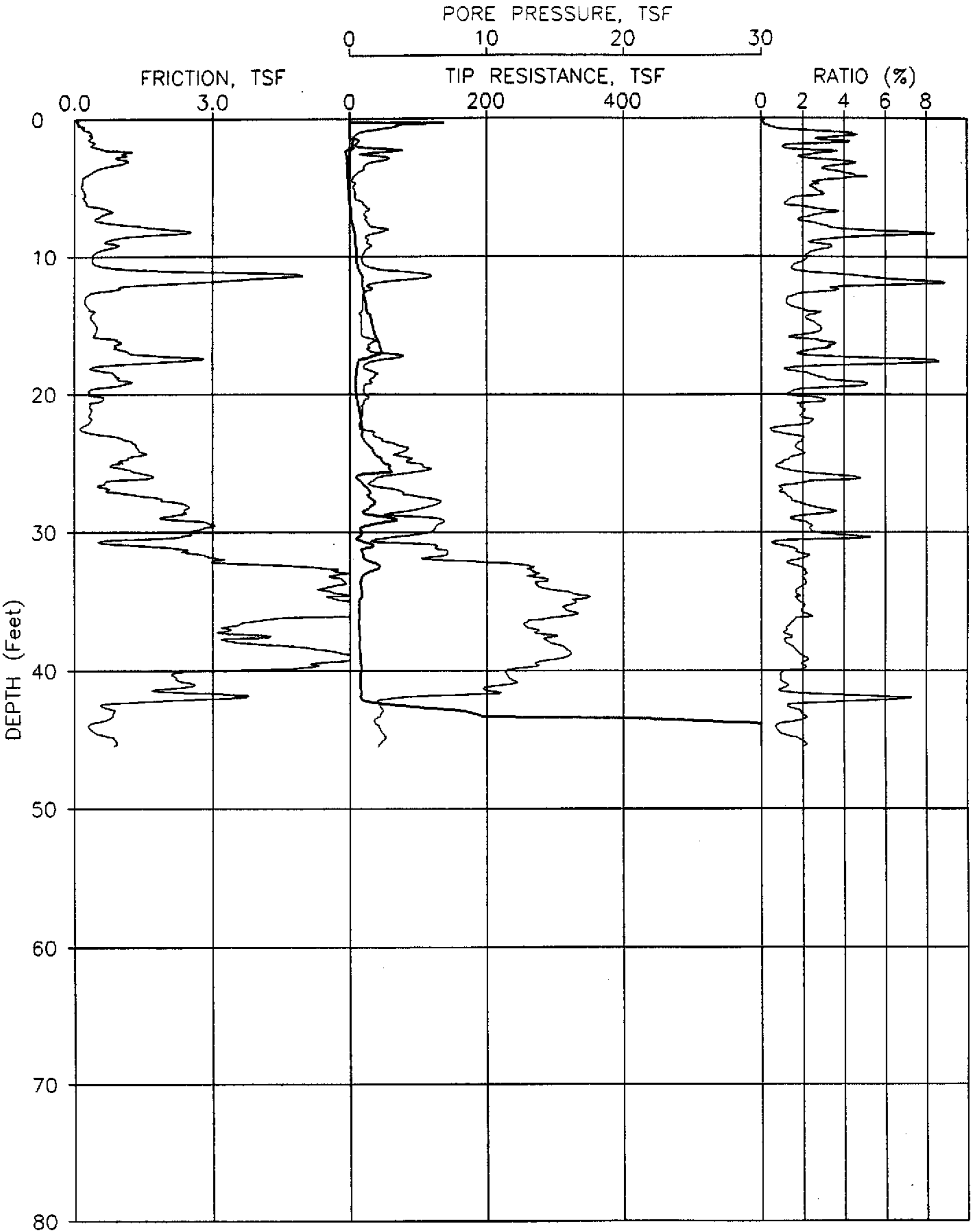
ELEVATION: 0.00

CPT NUMBER: RST-29A
CONE NUMBER: F7.5CKEW230

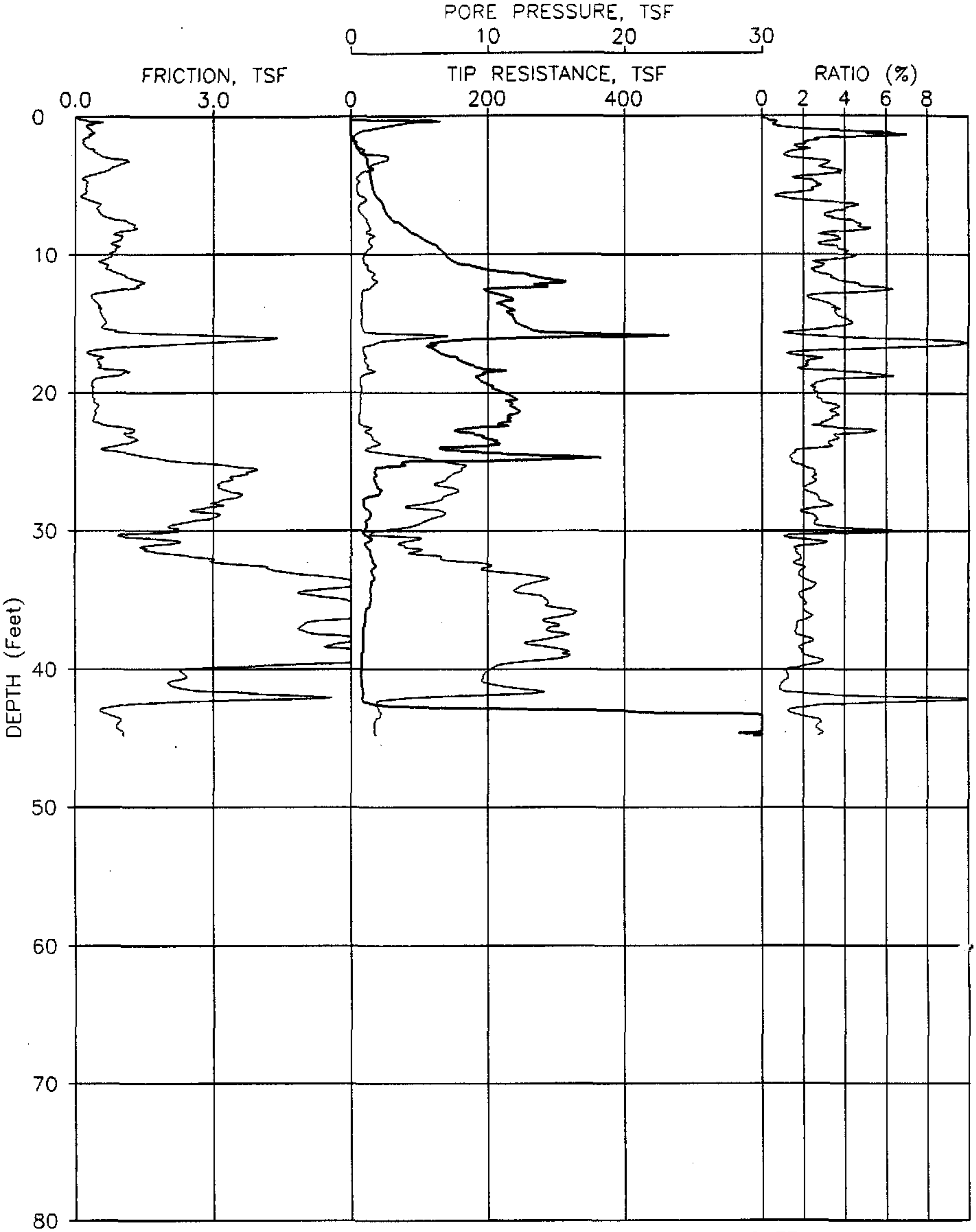
DATE: 03-11-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



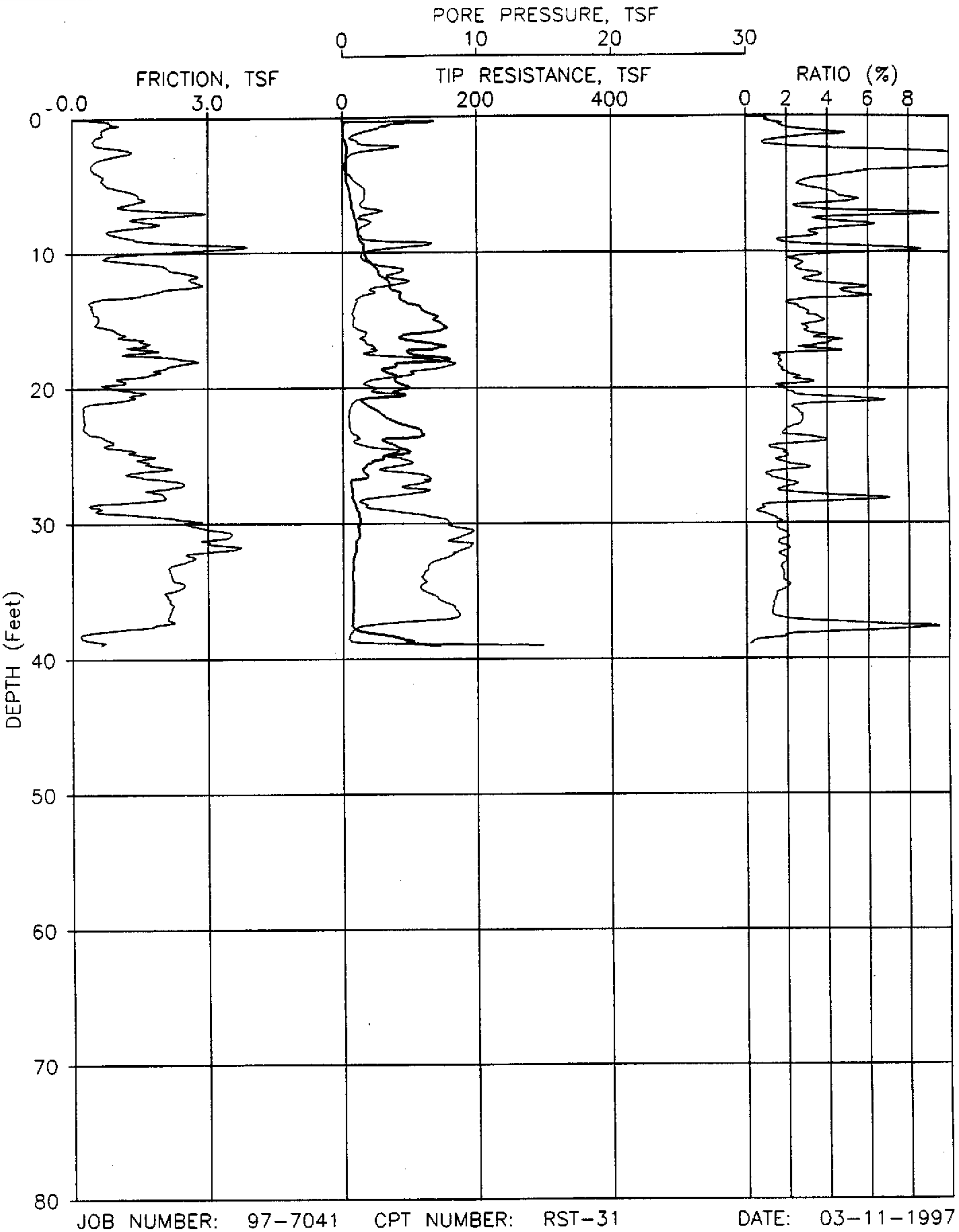
JOB NUMBER:	97–7041	CPT NUMBER:	RST–30	DATE:	03–11–1997
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEW230	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041 CPT NUMBER: RST-30A DATE: 03-14-1997
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

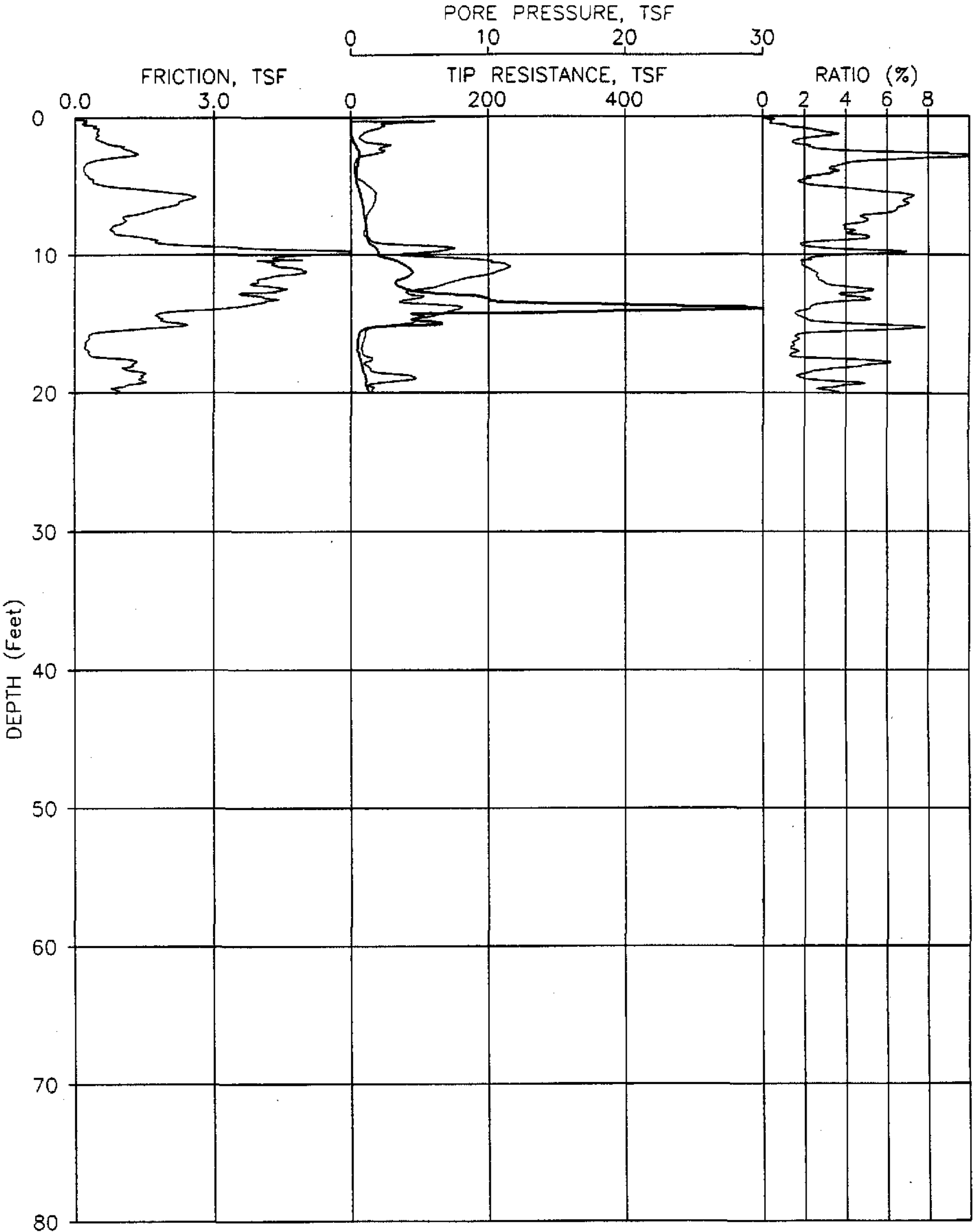


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-31
CONE NUMBER: F7.5CKEW230

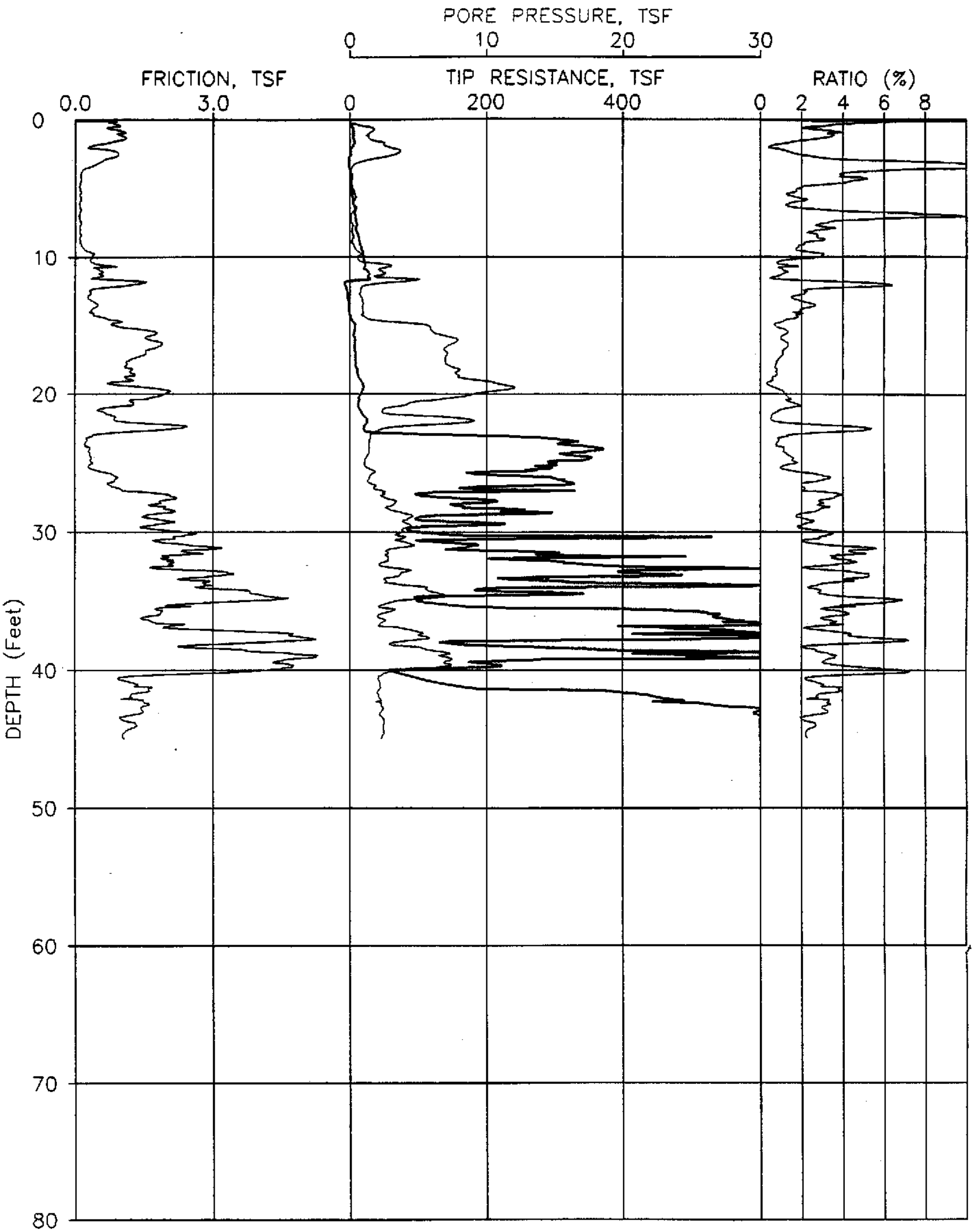
DATE: 03-11-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



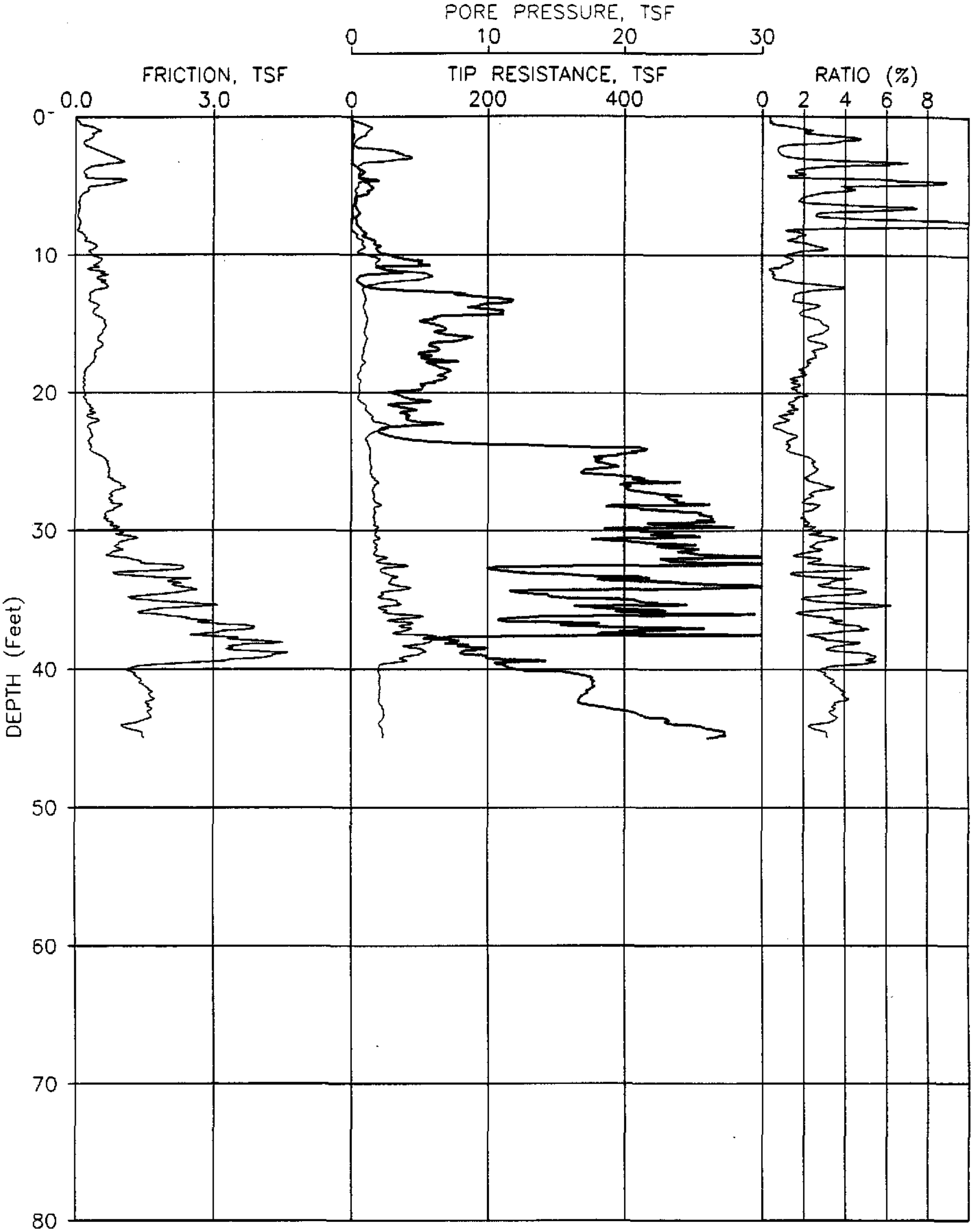
JOB NUMBER: 97-7041
ELEVATION: 0.00
CPT NUMBER: RST-31A
CONE NUMBER: F7.5CKEW230
DATE: 03-14-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER:	97-7041	CPT NUMBER:	RST-32	DATE:	03-12-1997
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEW230	PLATE:	1 OF 1

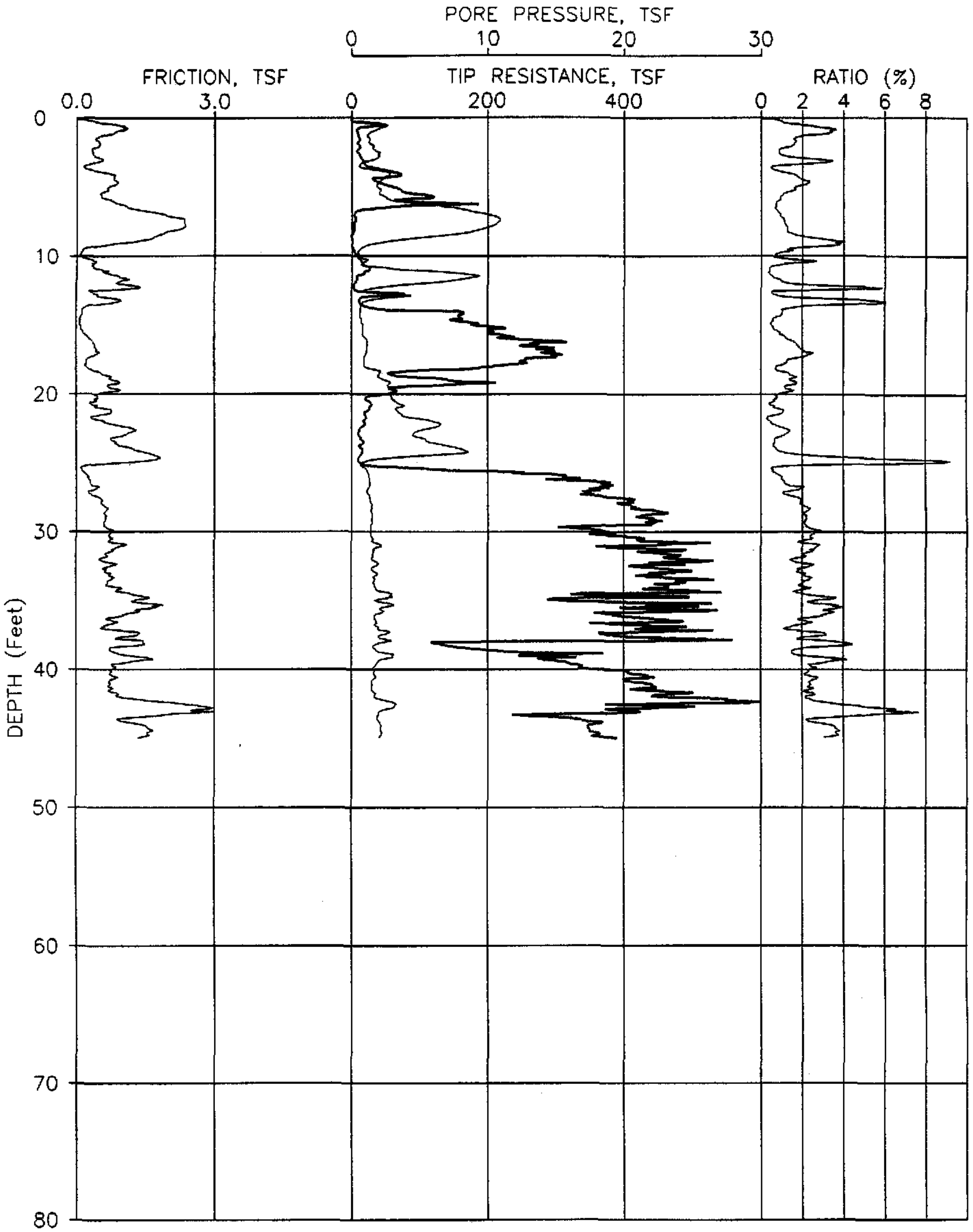
FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041 CPT NUMBER: RST-33 DATE: 03-12-1997

ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

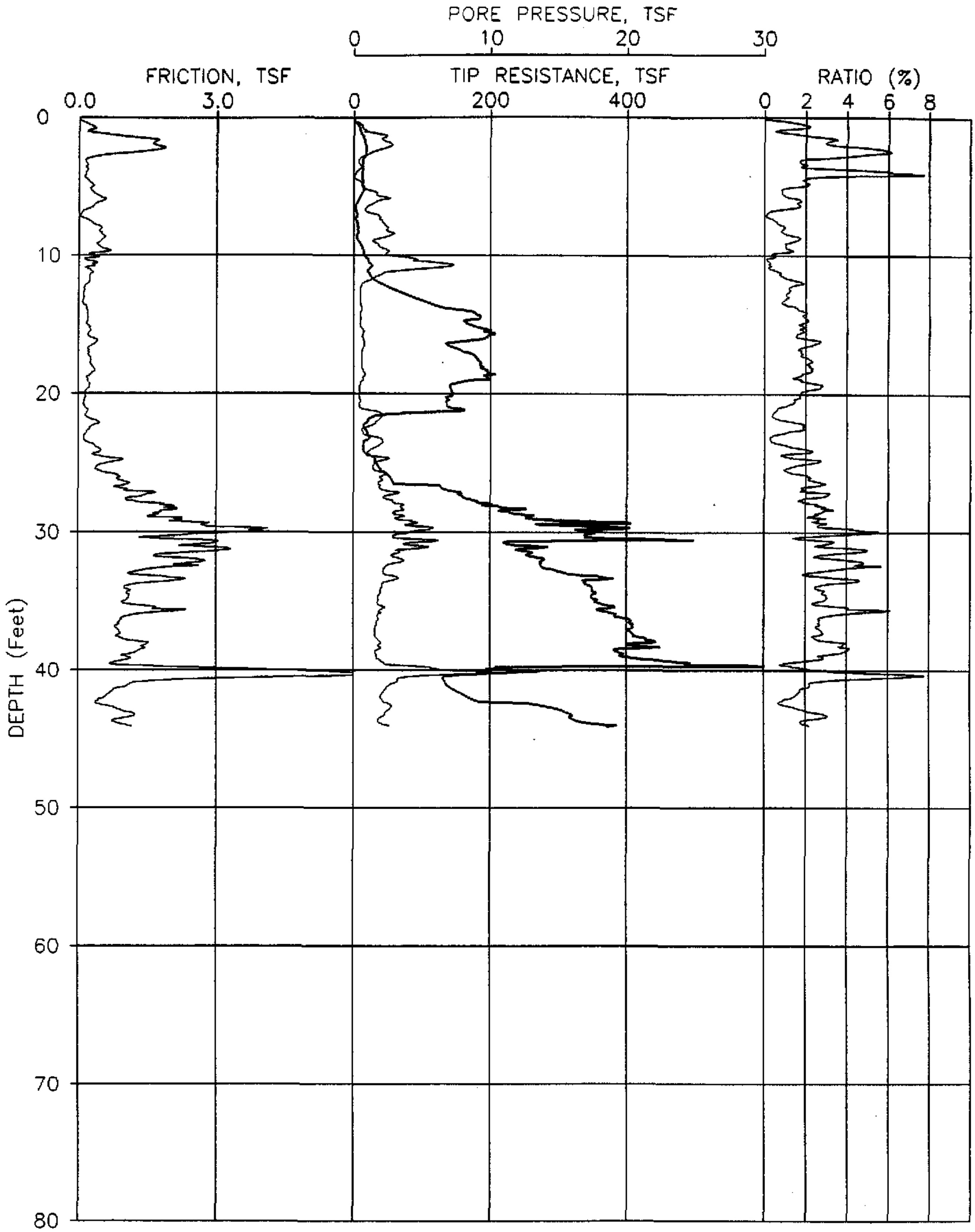
FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-34
CONE NUMBER: F7.5CKEW230

DATE: 03-12-1997
PLATE: 1 OF 1

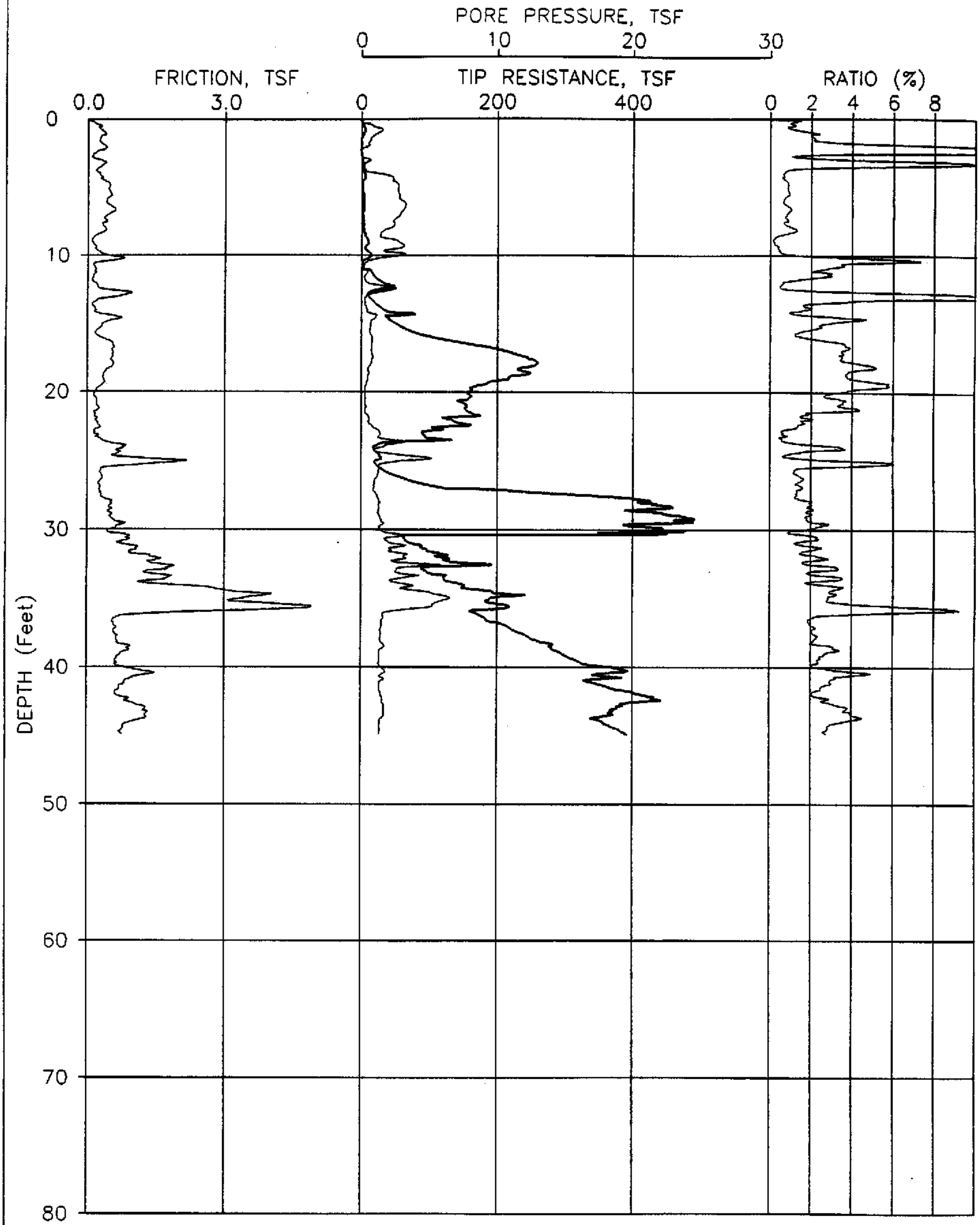


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-35
CONE NUMBER: F7.5CKEW230

DATE: 03-12-1997
PLATE: 1 OF 1

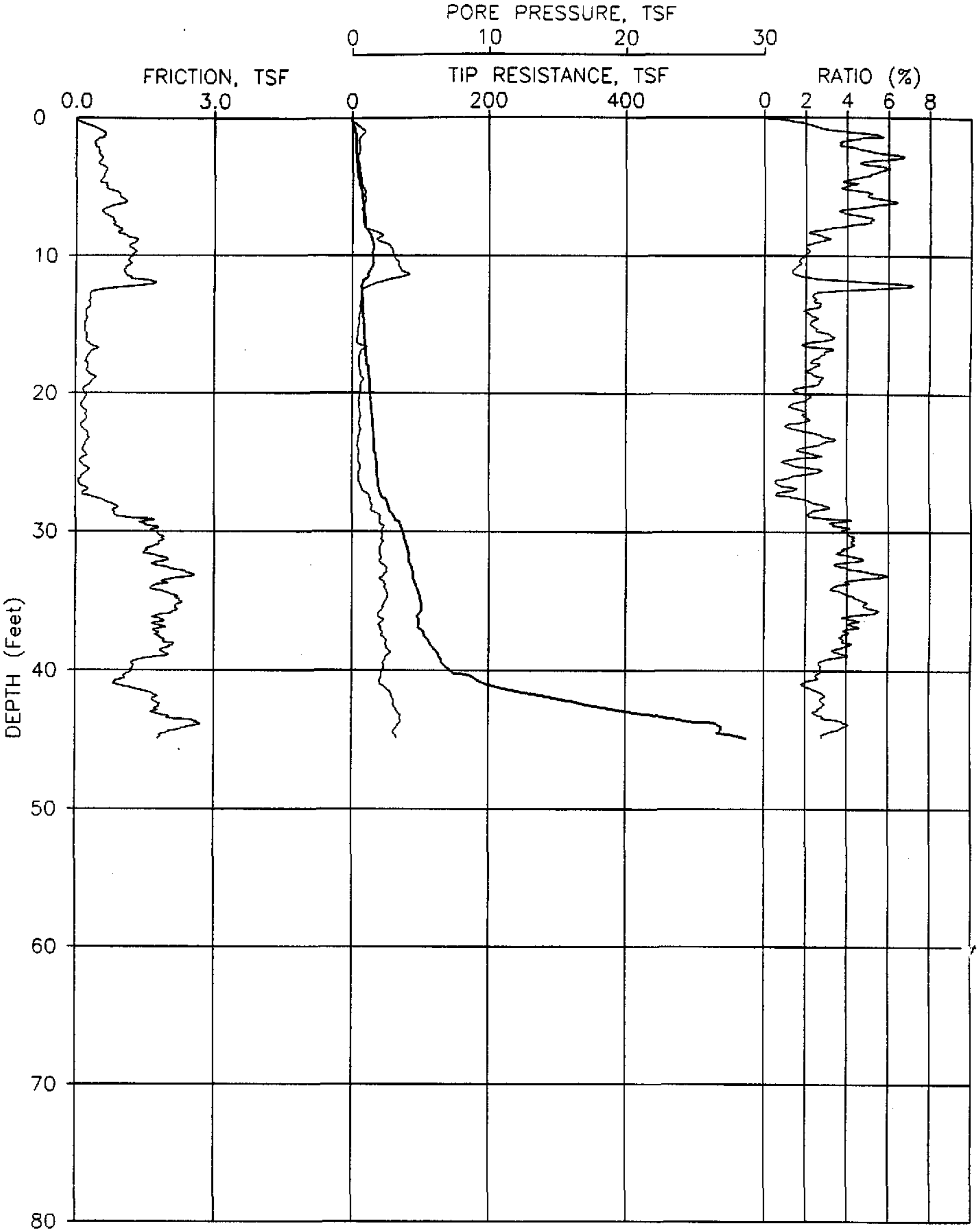
FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041 CPT NUMBER: RST-36 DATE: 03-12-1997

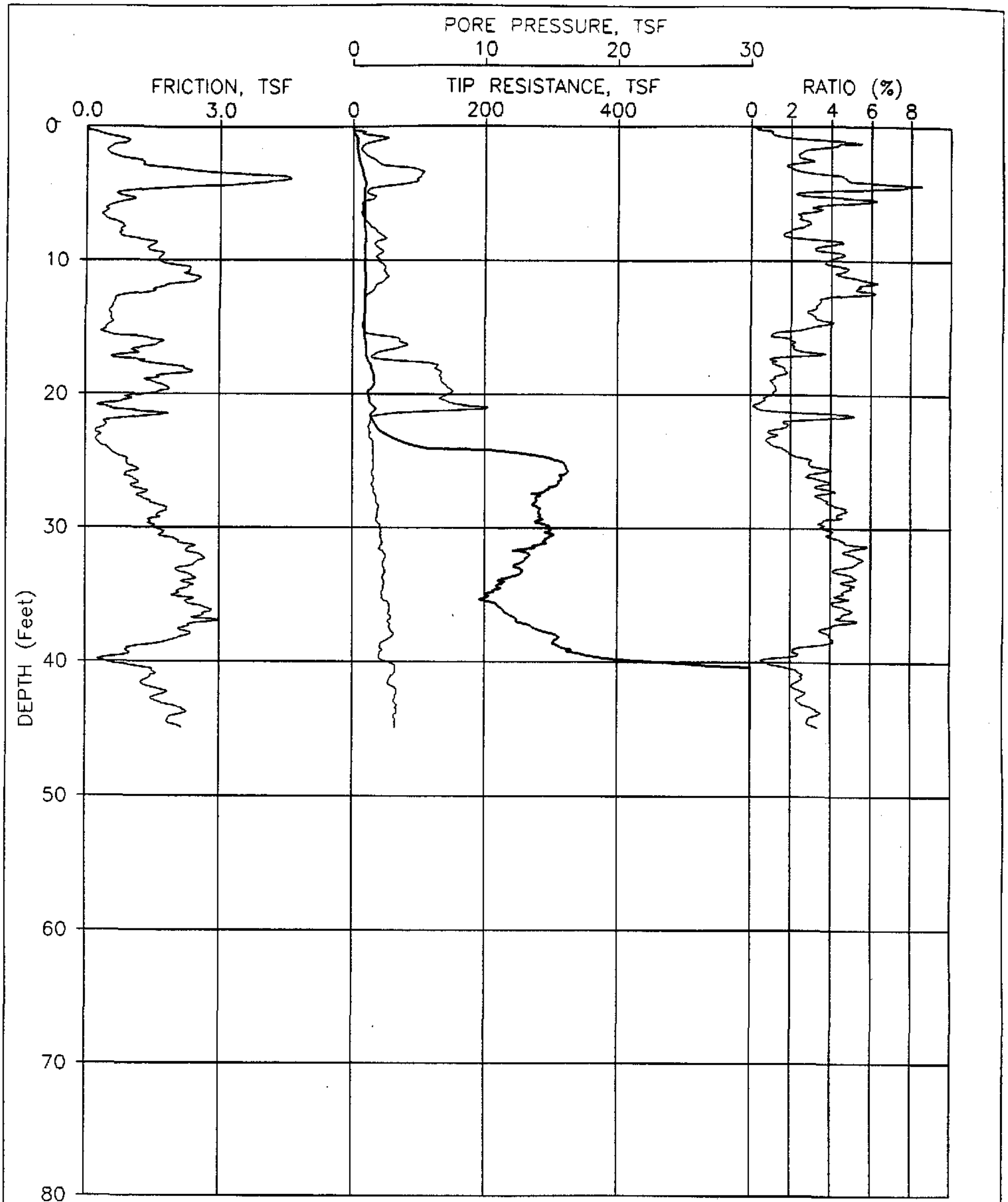
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



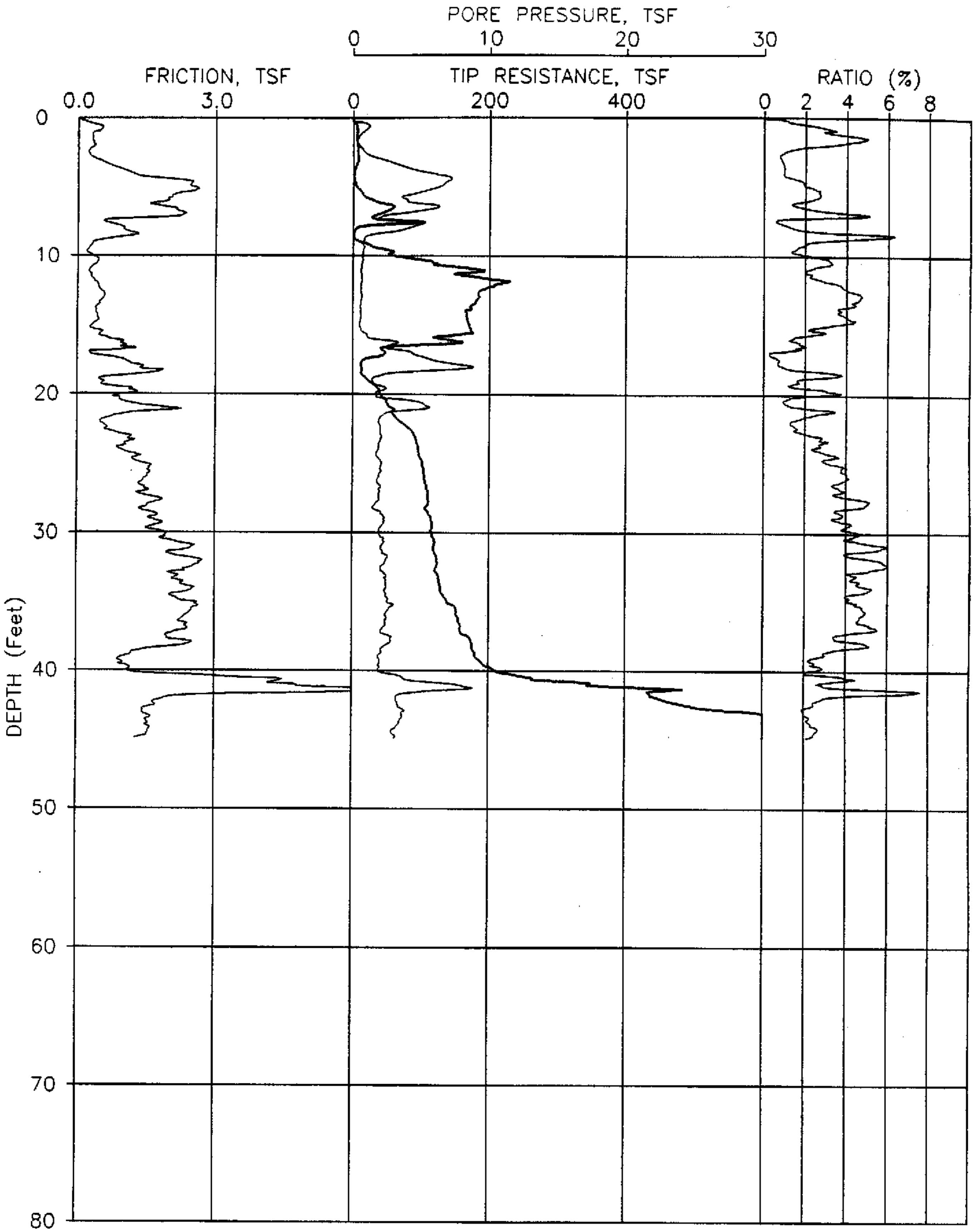
JOB NUMBER: 97-7041 CPT NUMBER: RST-37 DATE: 03-12-1997
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER:	97-7041	CPT NUMBER:	RST-38	DATE:	03-12-1997
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEW230	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC

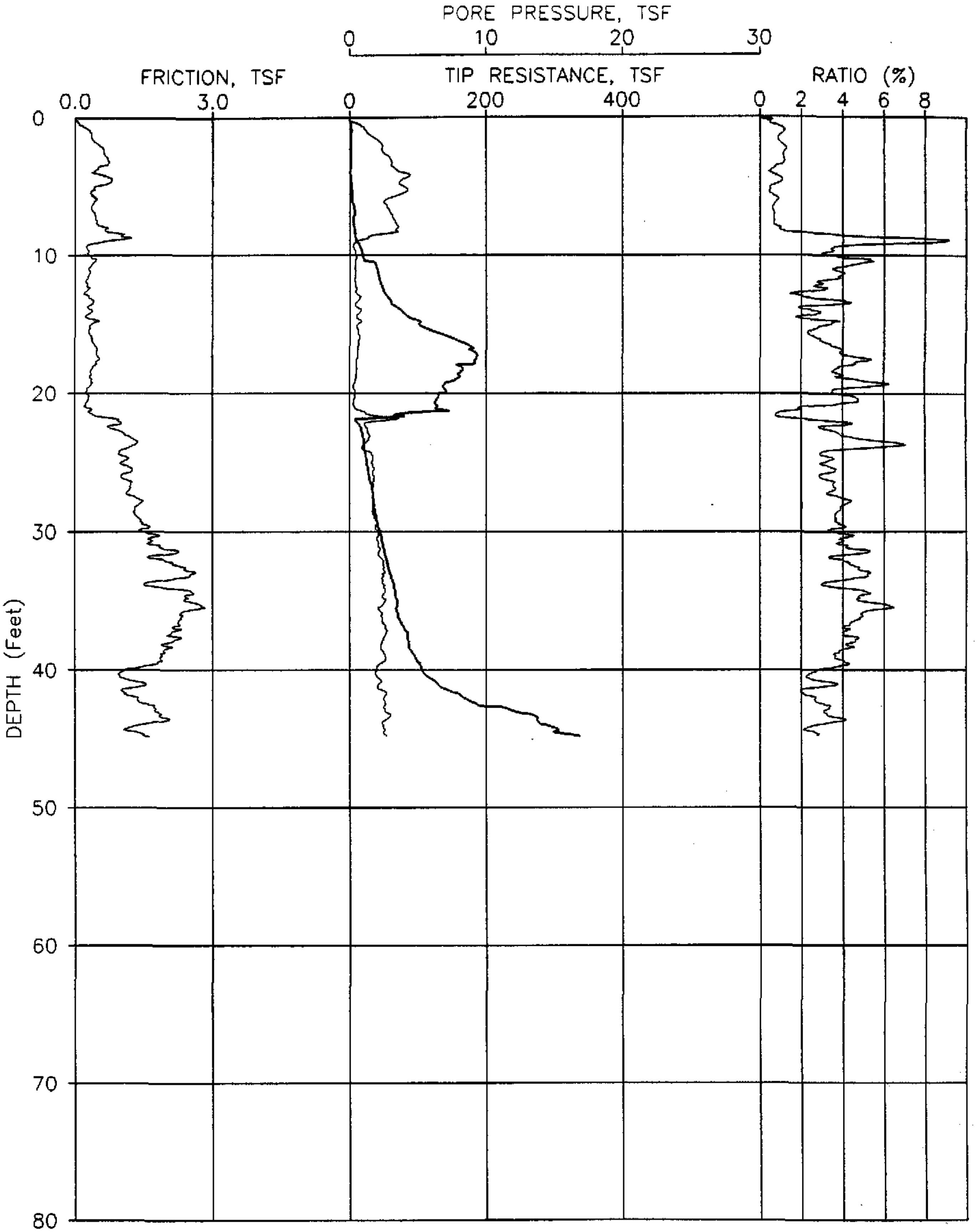


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-39
CONE NUMBER: F7.5CKEW230

DATE: 03-12-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

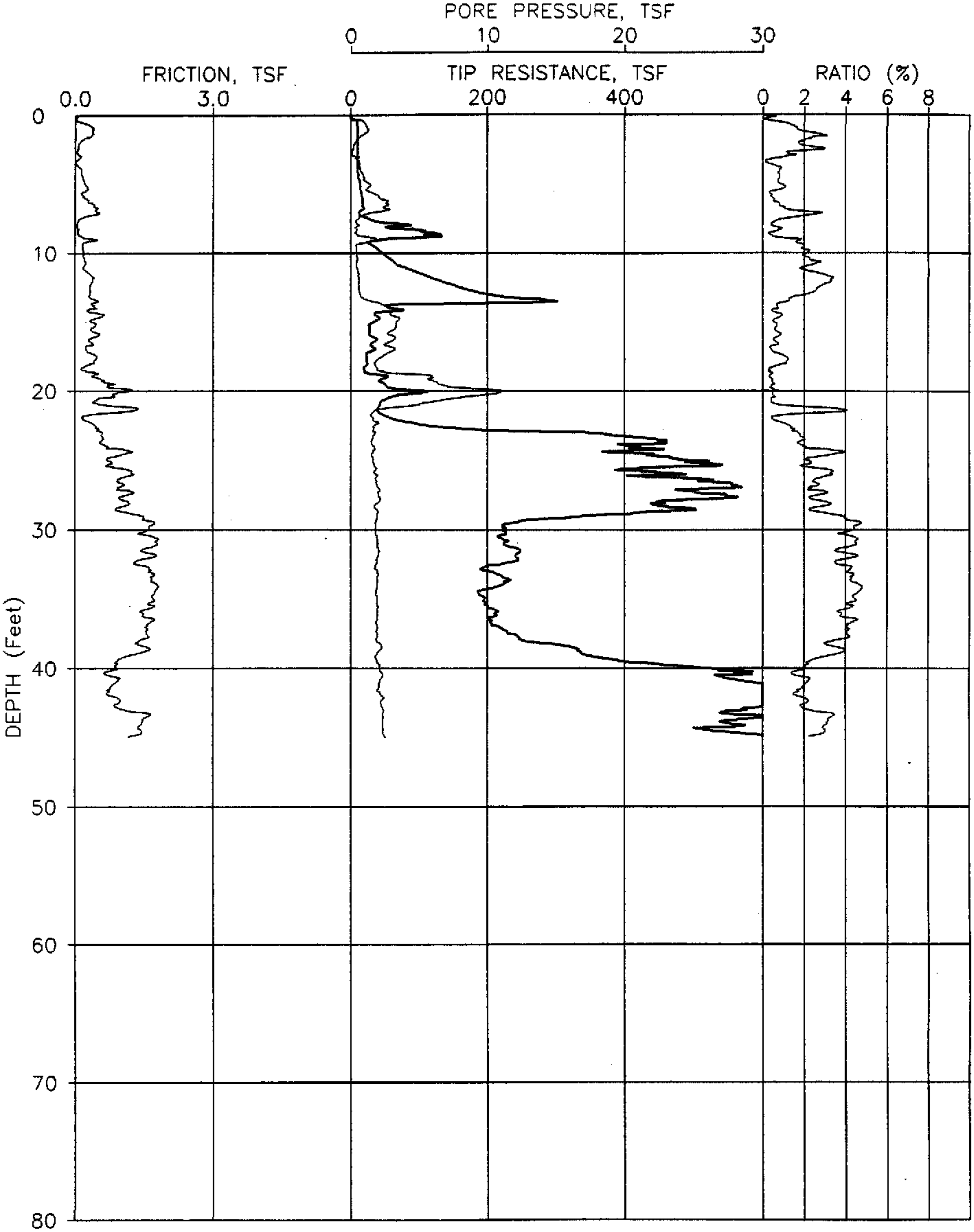


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-40
CONE NUMBER: F7.5CKEW230

DATE: 03-12-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

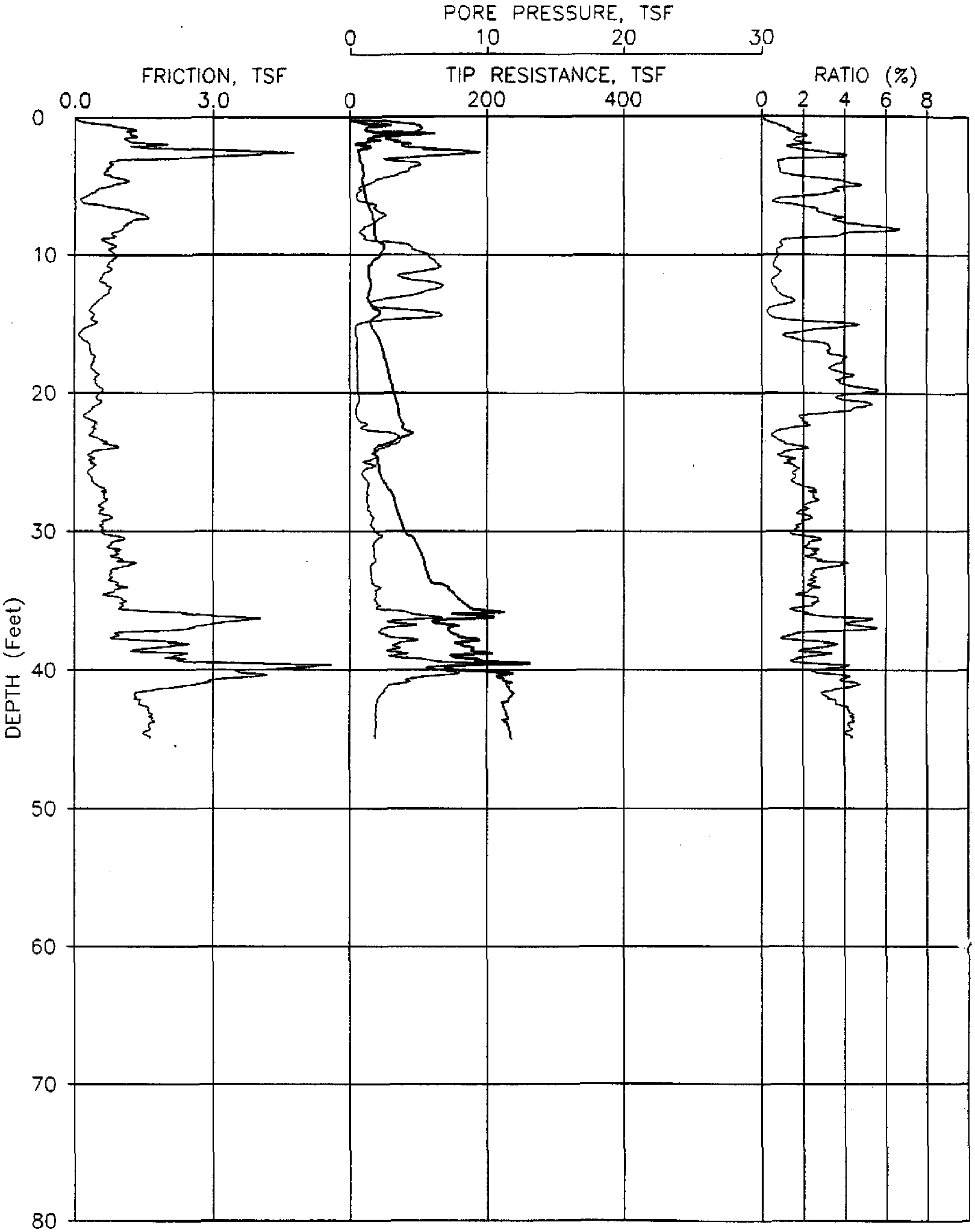


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-41
CONE NUMBER: F7.5CKEW230

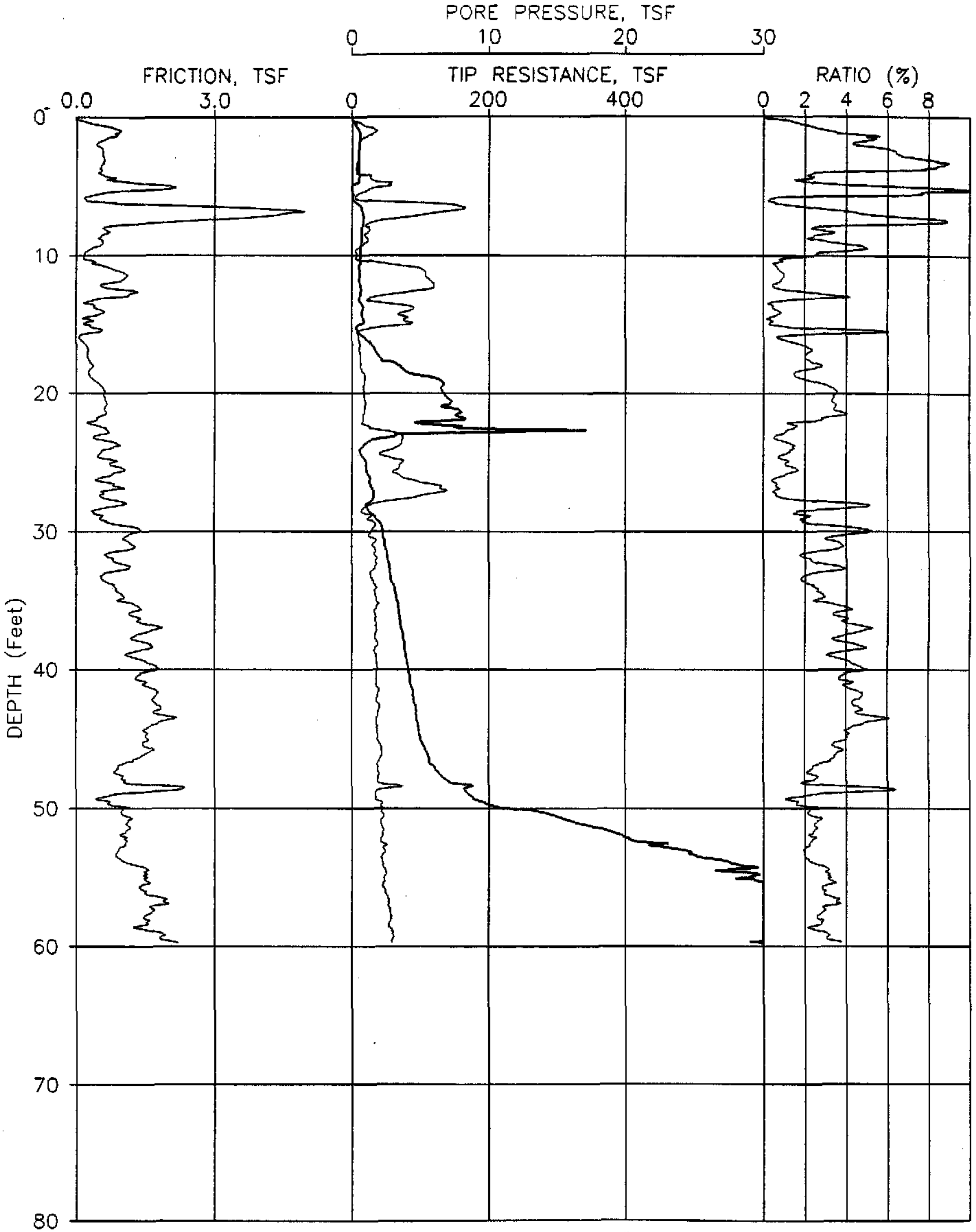
DATE: 03-12-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



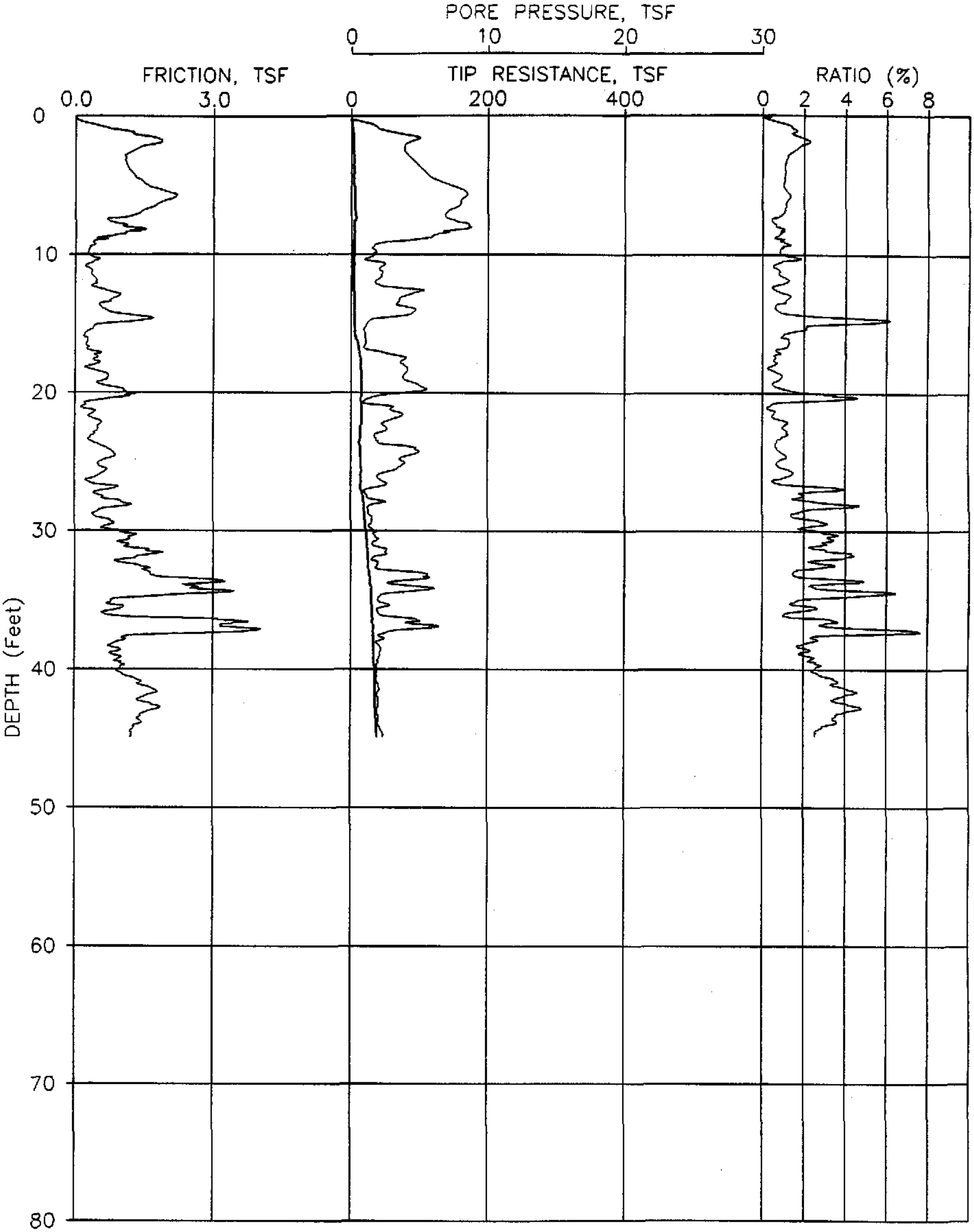
JOB NUMBER: 97-7041
CPT NUMBER: RST-42
DATE: 03-12-1997
ELEVATION: 0.00
CONE NUMBER: F7.5CKEW230
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041 CPT NUMBER: RST-43 DATE: 03-12-1997
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

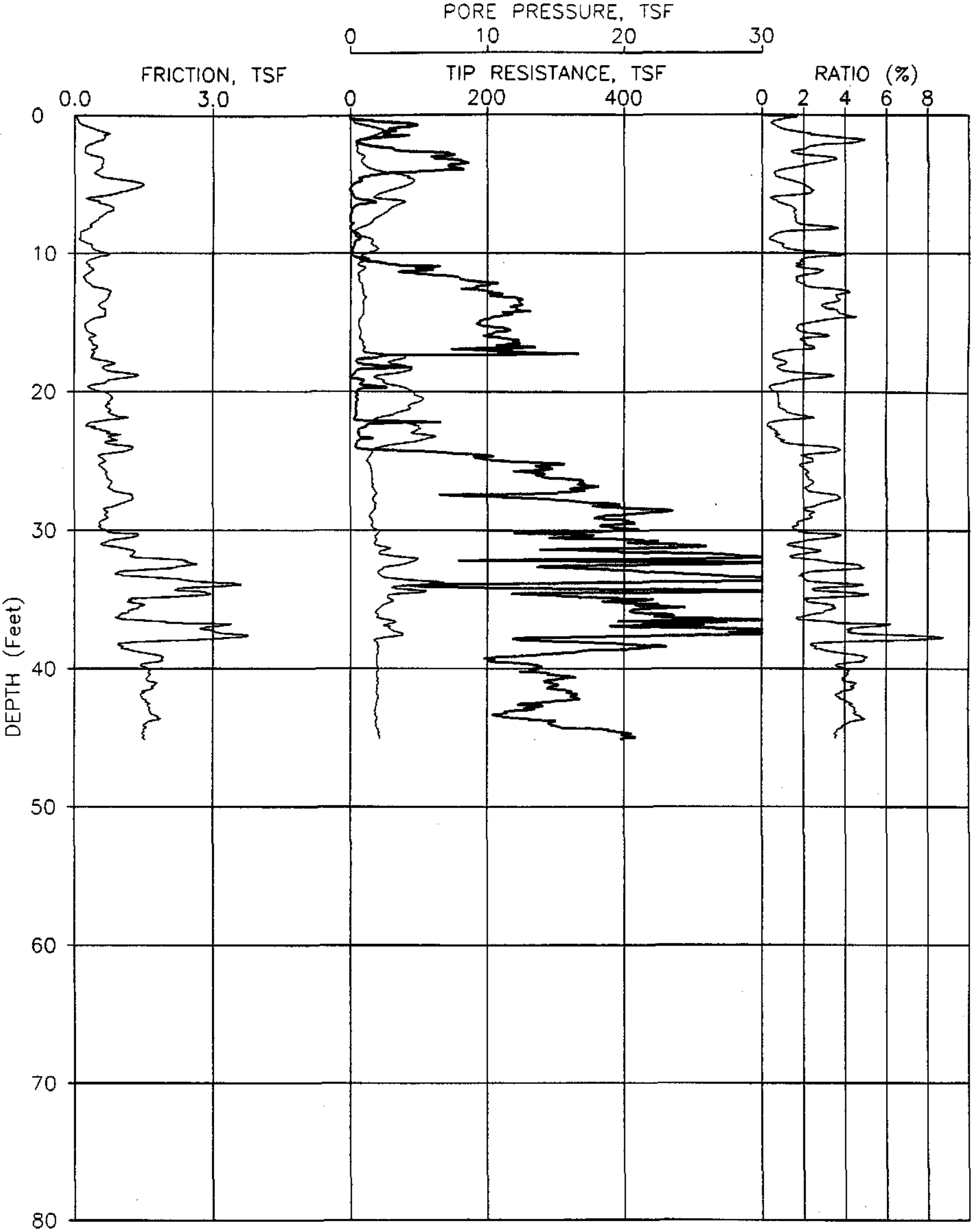


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-44
CONE NUMBER: F7.5CKEW230

DATE: 03-13-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

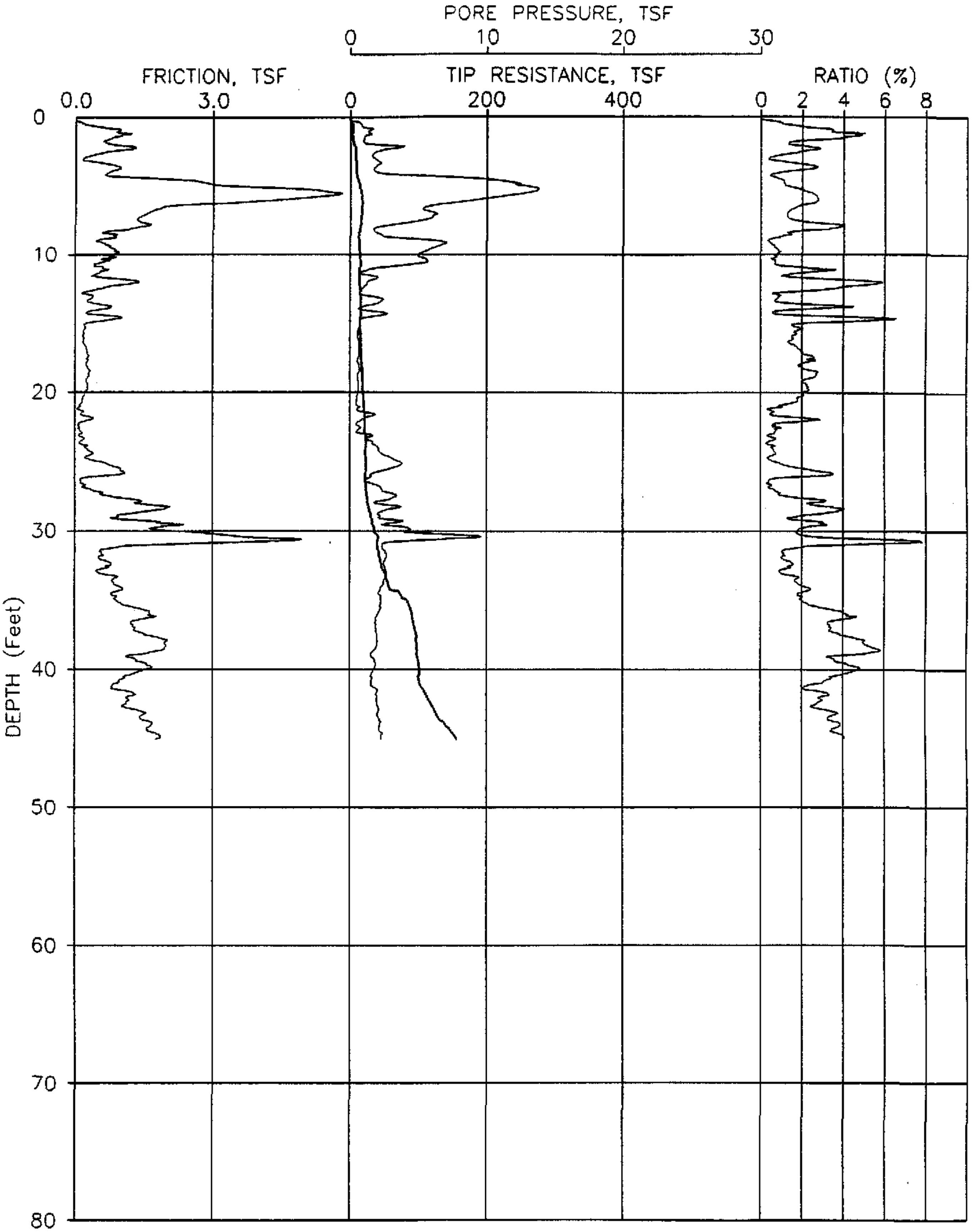


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-45
CONE NUMBER: F7.5CKEW230

DATE: 03-13-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

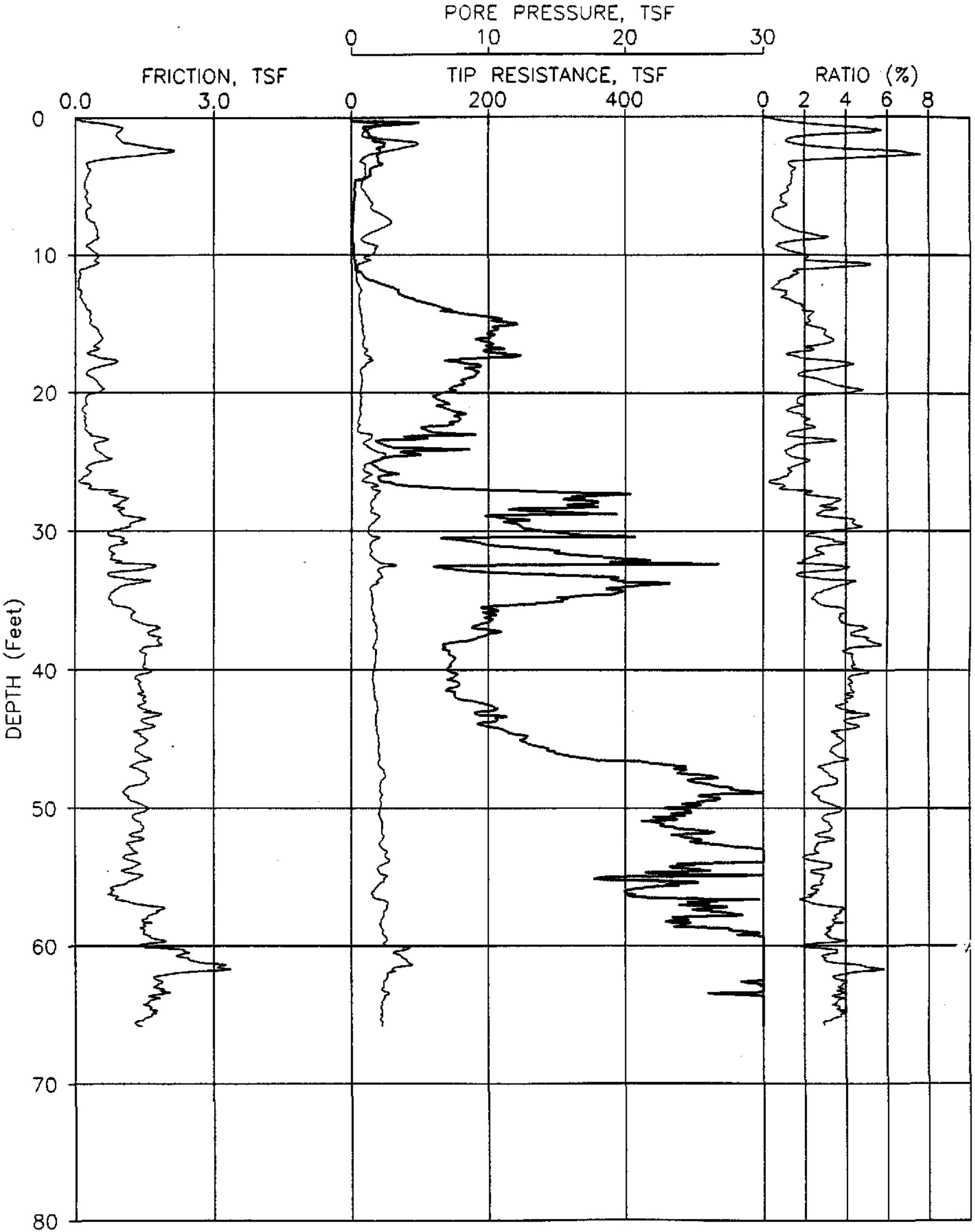


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-46
CONE NUMBER: F7.5CKEW230

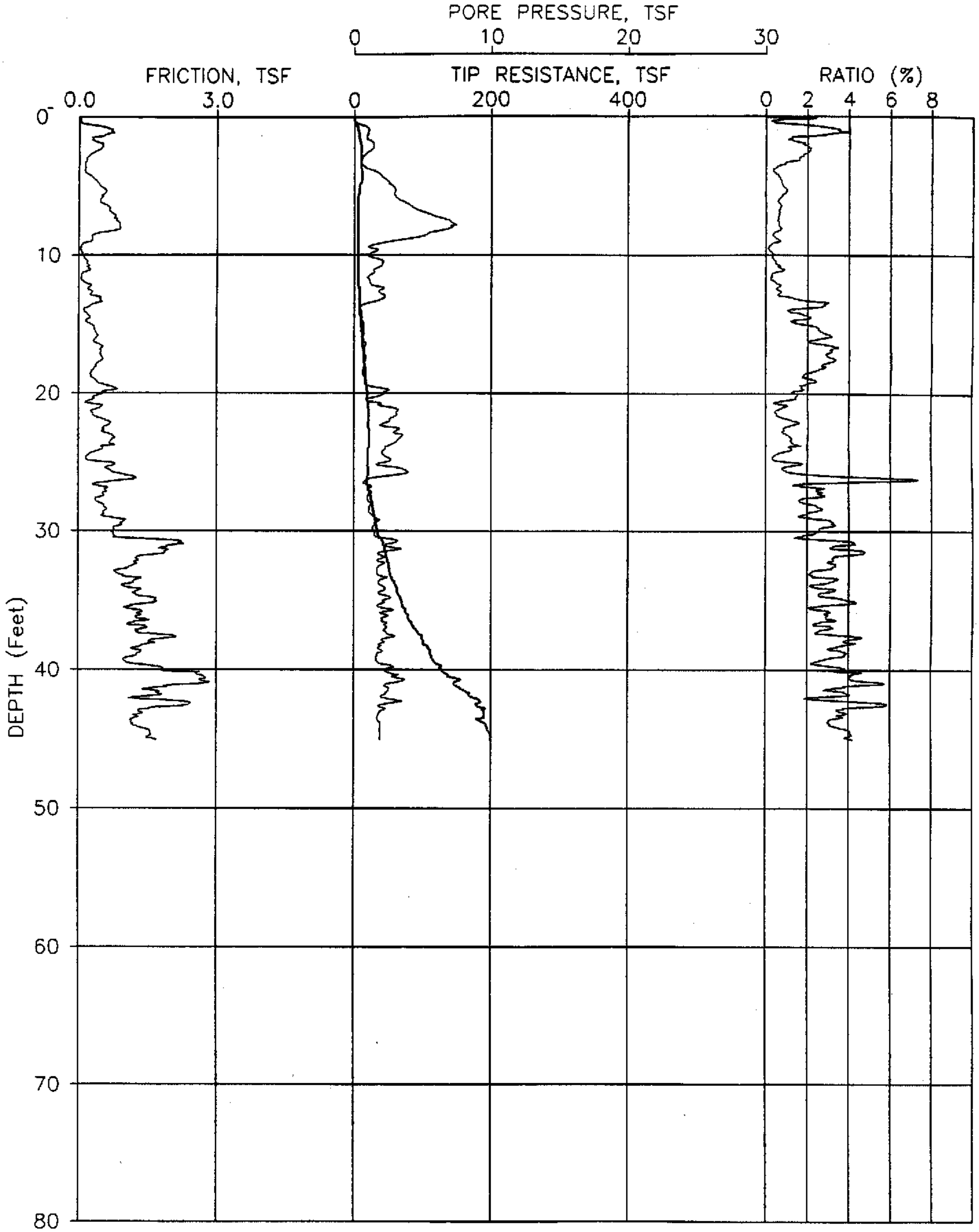
DATE: 03-13-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER:	97-7041	CPT NUMBER:	RST-47	DATE:	03-13-1997
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEW230	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC

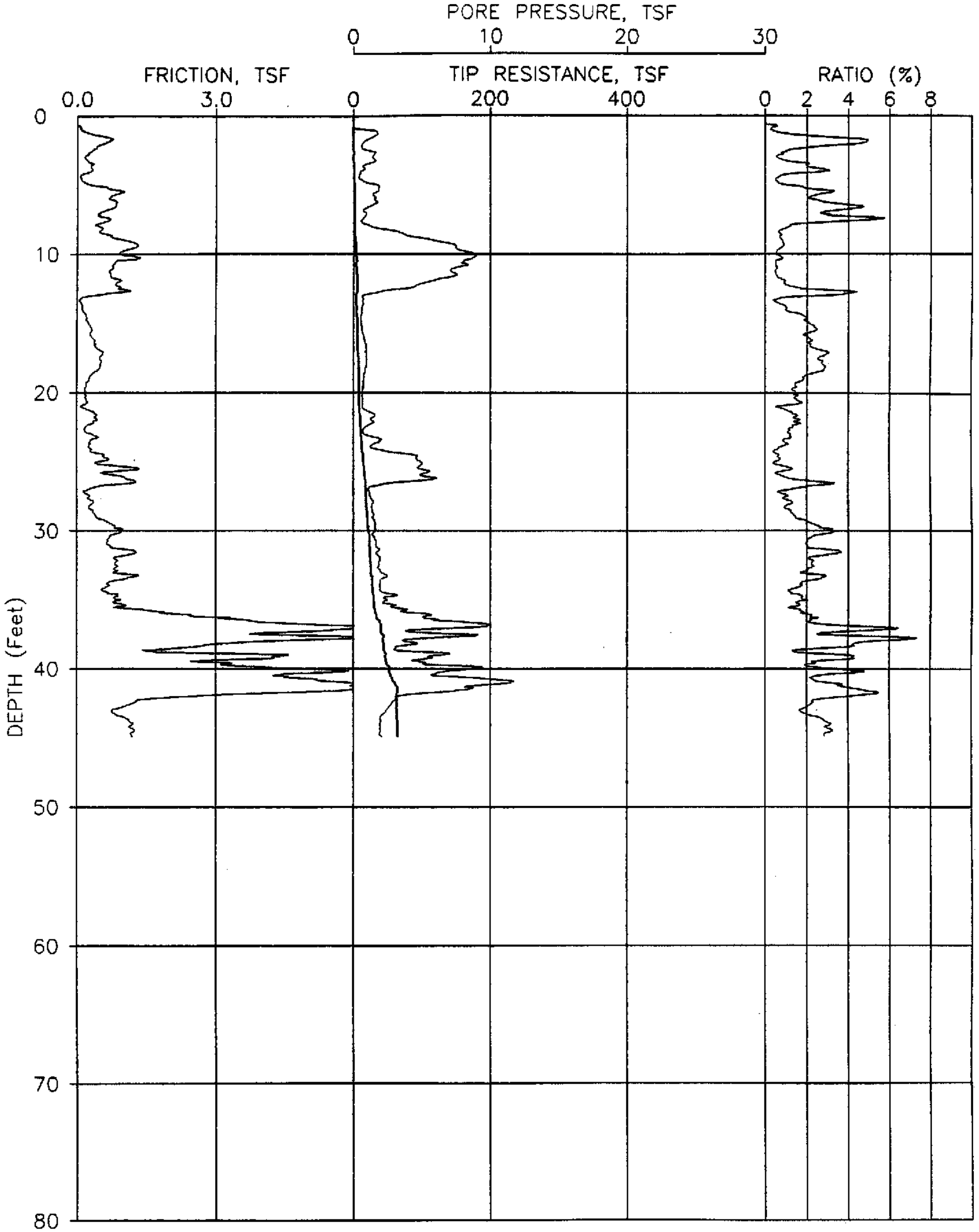


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-48
CONE NUMBER: F7.5CKEW230

DATE: 03-13-1997
PLATE: 1 OF 1

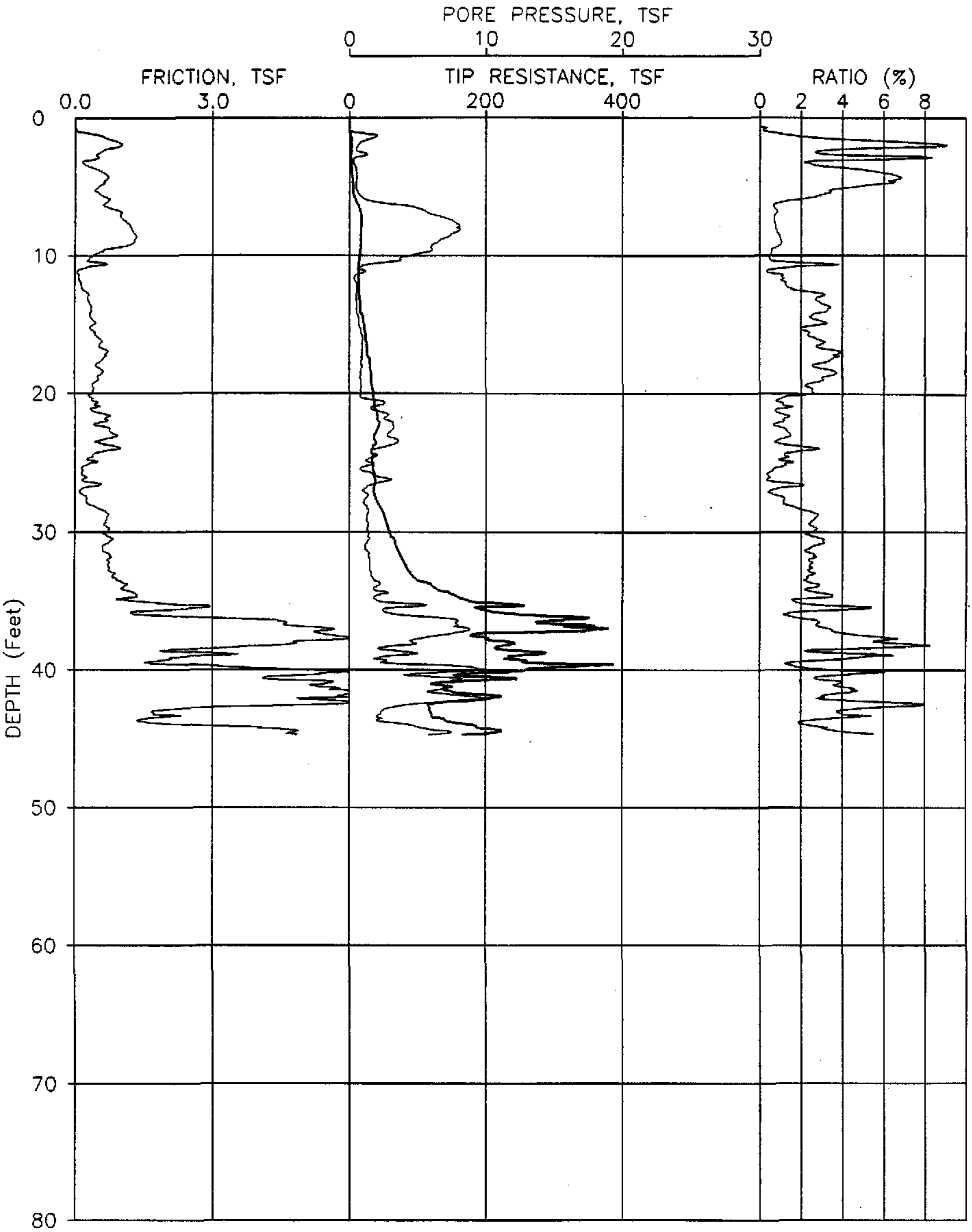
FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041 CPT NUMBER: RST-49 DATE: 03-14-1997

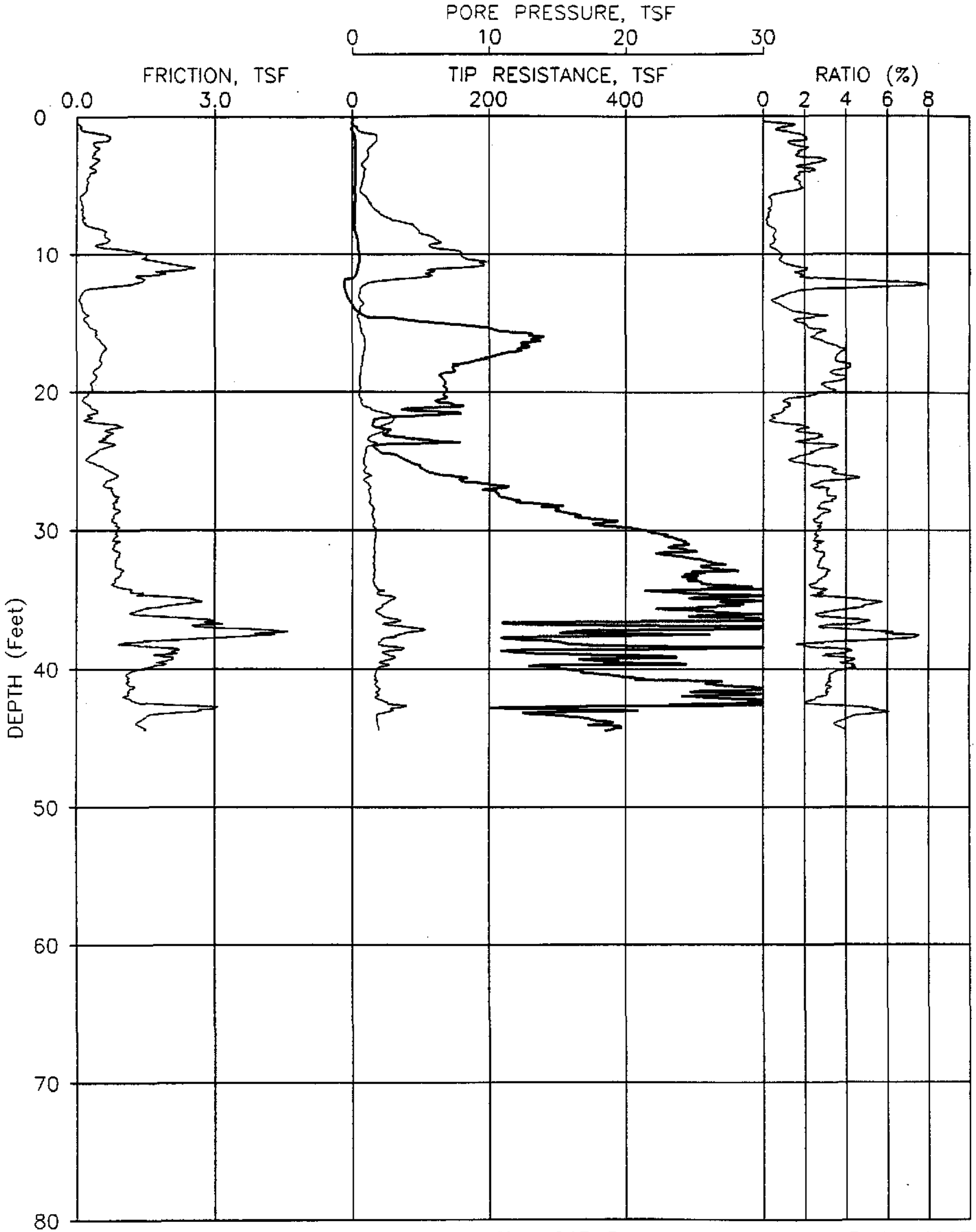
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



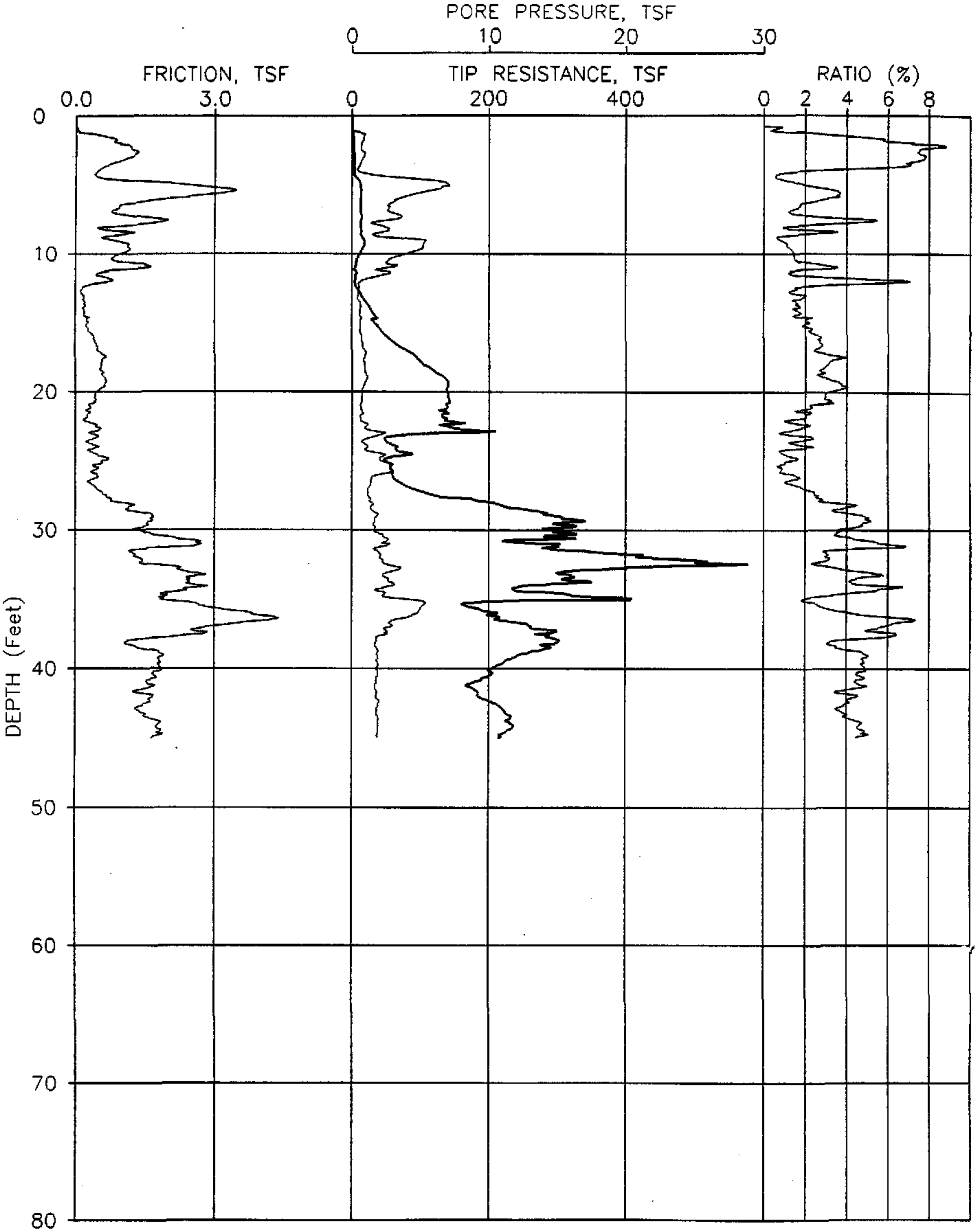
JOB NUMBER:	97-7041	CPT NUMBER:	RST-50	DATE:	03-14-1997
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEW230	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC



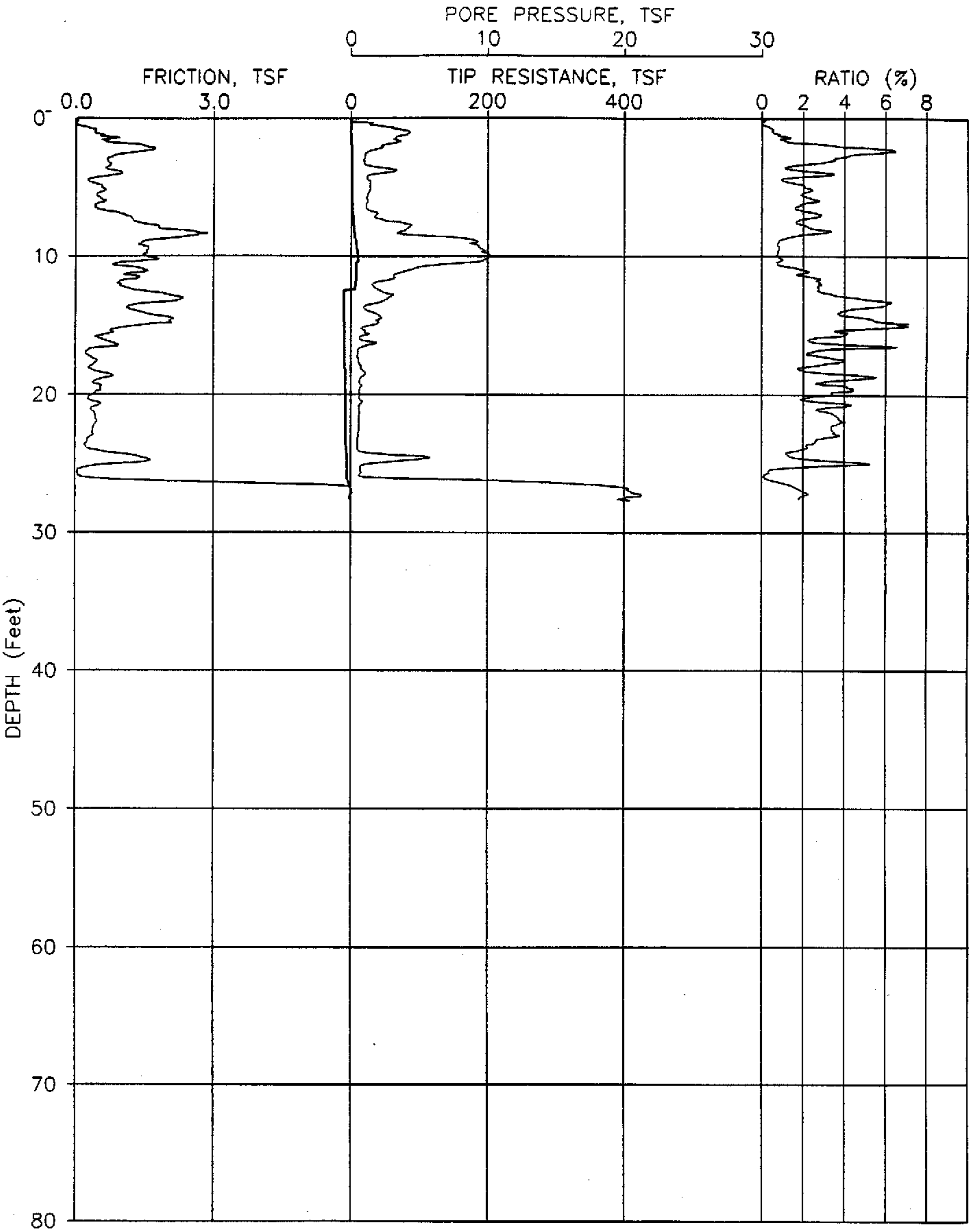
JOB NUMBER: 97-7041 CPT NUMBER: RST-51 DATE: 03-14-1997
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041
ELEVATION: 0.00
CPT NUMBER: RST-52
CONE NUMBER: F7.5CKEW230
DATE: 03-14-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

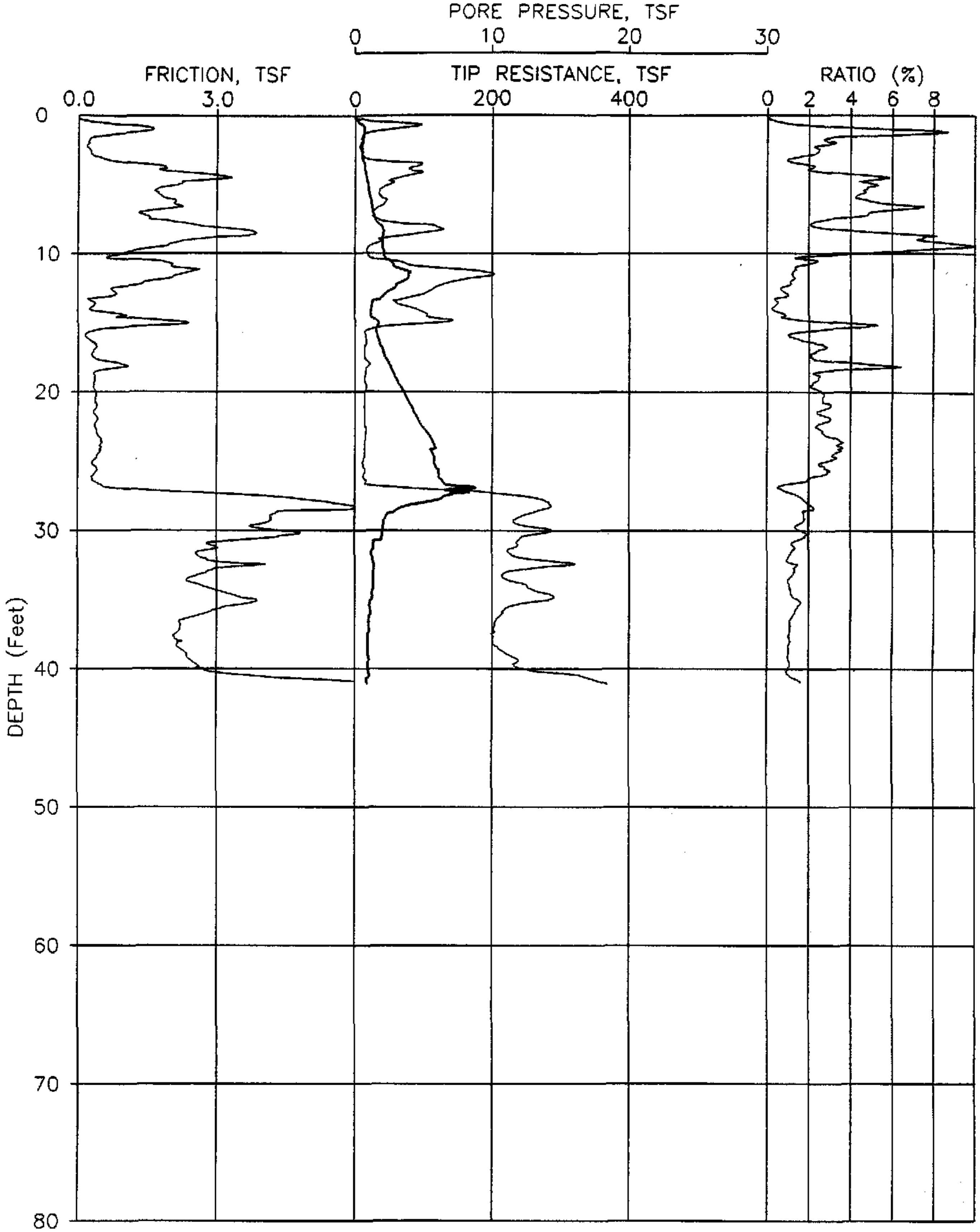


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-53
CONE NUMBER: F7.5CKEW230

DATE: 03-14-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

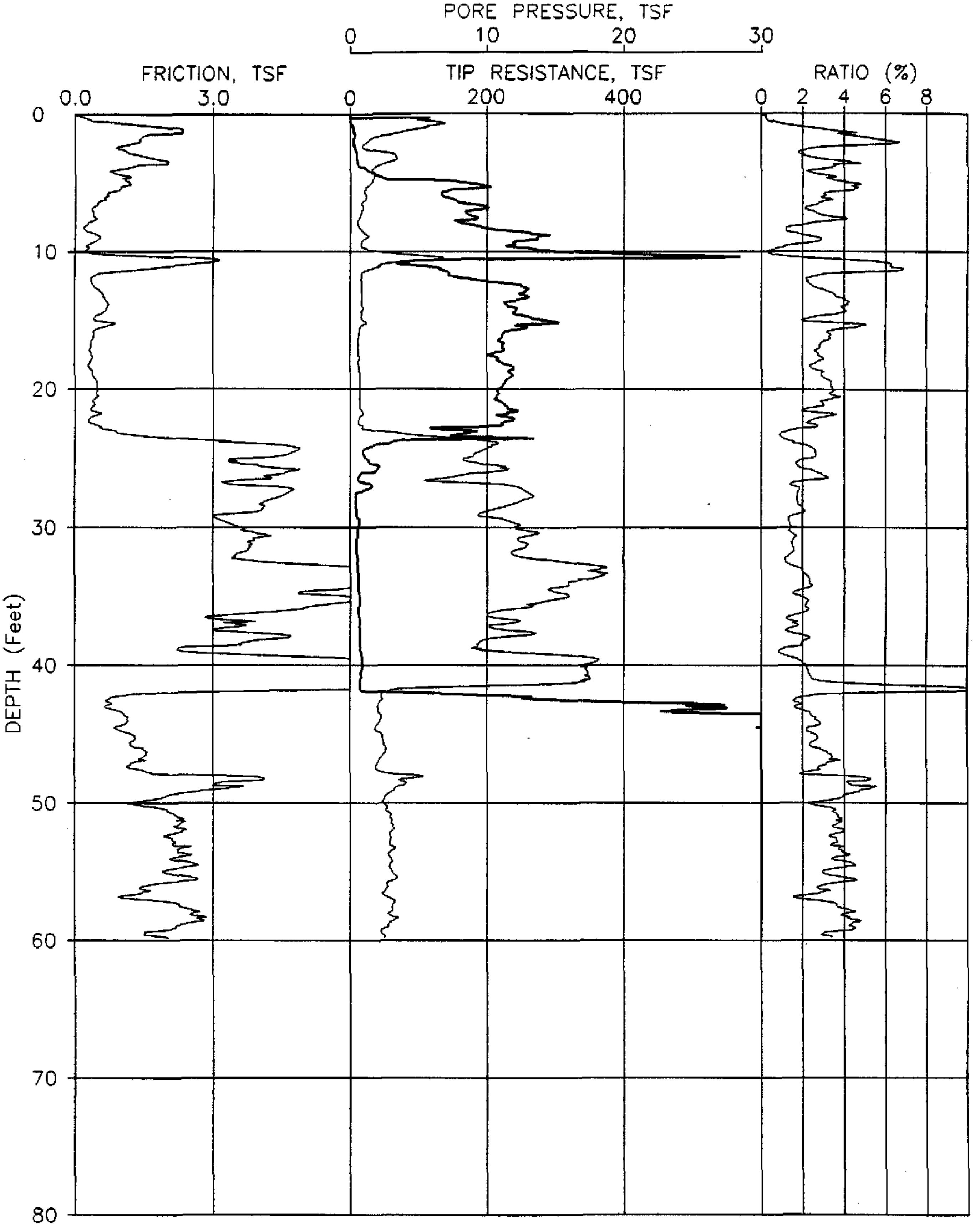


JOB NUMBER: 97-7041
ELEVATION: 0.00

CPT NUMBER: RST-54
CONE NUMBER: F7.5CKEW230

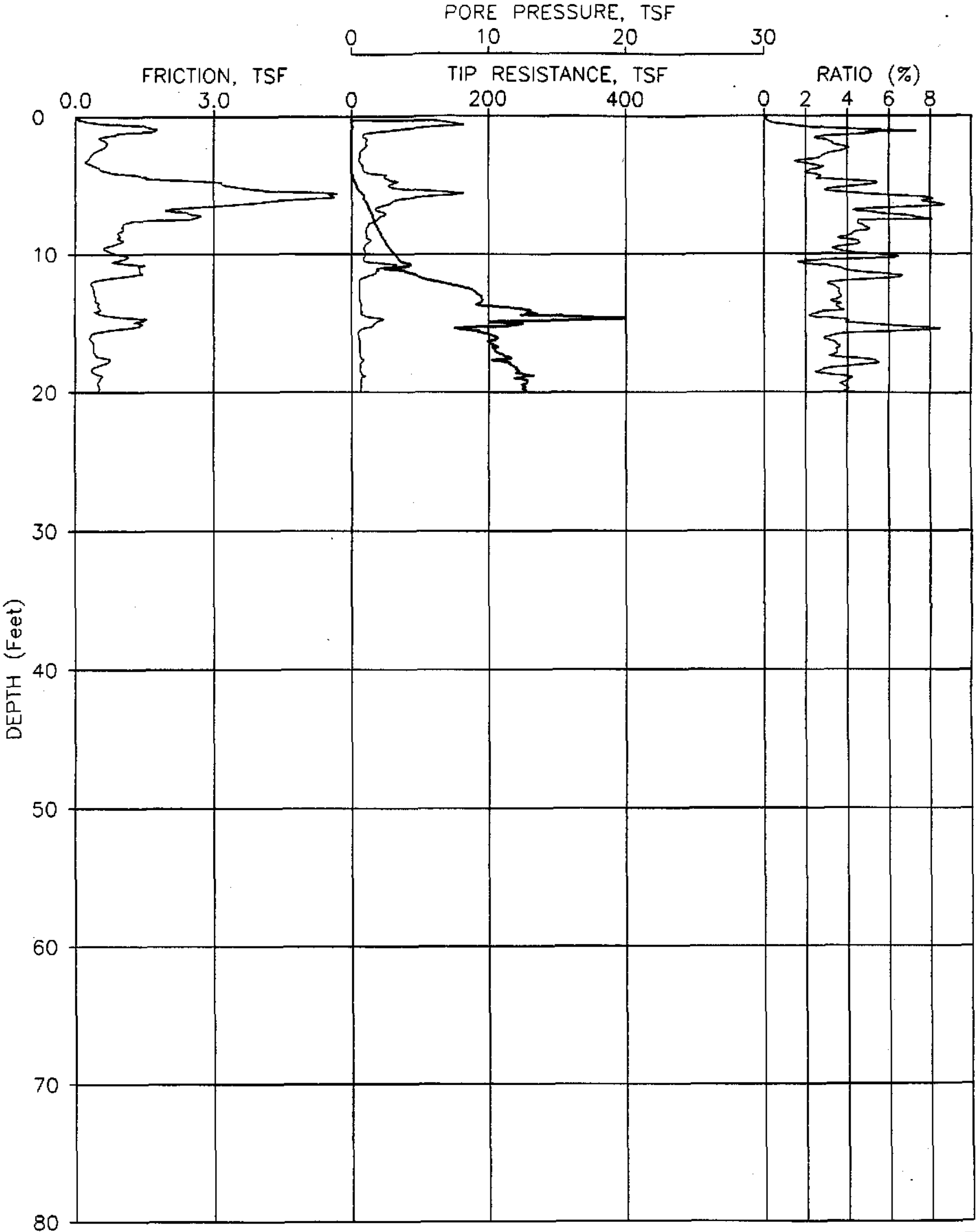
DATE: 03-14-1997
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER:	97-7041	CPT NUMBER:	RST-55	DATE:	03-14-1997
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEW230	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER: 97-7041 CPT NUMBER: RST-56 DATE: 03-14-1997
ELEVATION: 0.00 CONE NUMBER: F7.5CKEW230 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

Appendix D

Soil Boring Logs

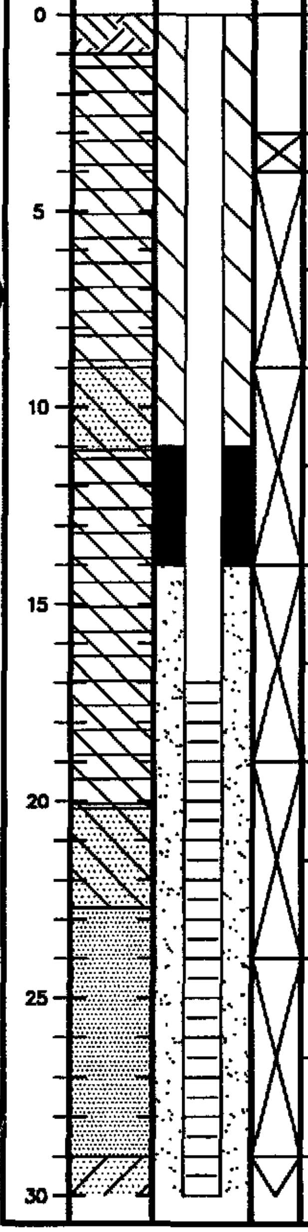
Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-01

Project: FORMER GULF STATES CREOSOTING SITE Project No.: 21-02
Location: GULF DEVELOPMENT PROPERTY
Surface Elev.: 186.35 Boring T.D.: 36 ft. Boring Dia.: 8.25 in.
Date Started: 2-25-97 Date Completed: 2-25-97
Drilling Company: TECHNICAL DRILLING SERVICES Driller: CURTIS LEE
Drilling Method: HOLLOW STEM AUGER Grouting Method: PURE BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE



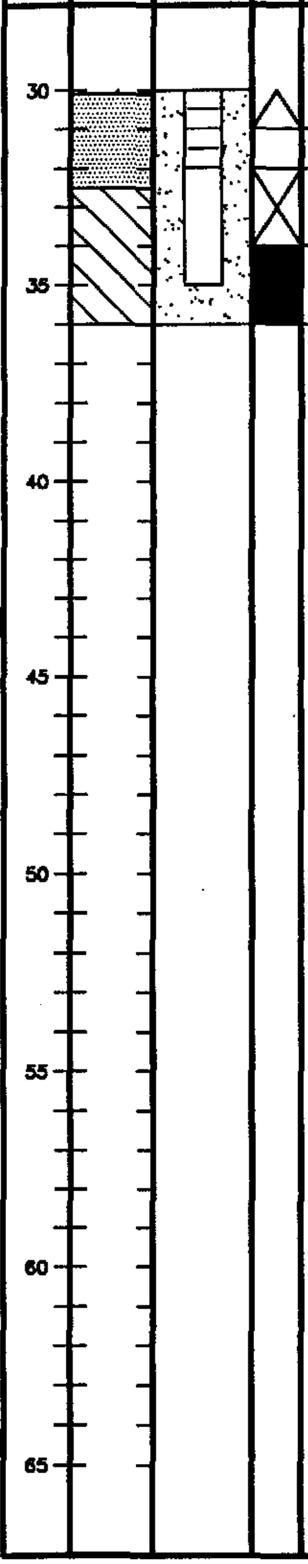
DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				0		0-3	POST-HOLE DIG TO 3': 1.0' FILL: SAND & GRAVEL, TAN, MOIST, THEN 2.0' SILTY CLAY: TAN (10YR6/6) & LIGHT GRAY, VERY MOIST, SOFT, ROOTLETS, SOME ORANGE MINERAL STAINING
				0	1.0/1	3-4	AS ABOVE
5				0 0	4.3/5	4-9	SILTY CLAY: LIGHT GRAY (2.5Y7/1), MOIST, STIFF TO VERY STIFF (STIFFNESS INCREASING WITH DEPTH), SOME ORANGE MINERAL STAINING, BECOMING SANDY AT BASE
10				0 0	5.0/5	9-14	2.1' SANDY CLAY: LIGHT GRAY (2.5Y7/1), VERY MOIST, STIFF, THEN 2.9' SILTY CLAY: LIGHT TO MEDIUM GRAY (2.5Y7&6/1), DRY TO SLIGHTLY MOIST, HARD, ABUNDANT ORANGE MINERAL STAINING
15				0 0	4.7/5	14-19	SILTY CLAY: GRAYISH BROWN (2.5Y5/2), SLIGHTLY MOIST, HARD, ORANGE MINERAL STAINING
20				0 0	3.9/5	19-24	1.2' AS ABOVE WITH SAND, THEN 2.5' SANDY CLAY: GRAYISH BROWN (2.5Y5/2), MOIST, FRIABLE, ORANGE MINERAL STAINING AT BASE, THEN 0.2' SAND: TAN (2.5Y5/2), SATURATED, MEDIUM GRAINED, ORANGE MINERAL STAINING
25				0 0	1.8/5	24-29	SAND: TAN TO LIGHT GRAY (2.5Y7/2), SATURATED, MEDIUM GRAINED
30							

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-01

Project No.: 21-02 Date Drilled: 2-25-97



DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
				0	1.9/2	29-31	1.2' CLAYEY SAND: GRAYISH BROWN (2.5Y5/2), SATURATED, MEDIUM GRAINED, ORANGE MINERAL STAINING, THEN 0.7' SAND: ORANGE, SATURATED, MEDIUM TO COARSE GRAINED WITH PEA GRAVEL
				0	1.5/2	32-34	0.5' SAND: TAN TO LIGHT GRAY (2.5Y7/2), SATURATED, MEDIUM GRAINED, THEN 1.0' CLAY: GRAY (2.5Y6/1), MOIST, STIFF
							AS ABOVE (FROM BASE OF SHELBY TUBE) DRILL TO 34', SAMPLE TO 36'

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB-02

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: RYAN MOTORS
Surface Elev.: 189.70
Boring T.D.: 54 ft.
Boring Dia.: 8.25 in.
Date Started: 2-26-97
Date Completed: 2-26-97
Drilling Company: TECHNICAL DRILLING SERVICES
Driller: CURTIS LEE
Drilling Method: HOLLOW STEM AUGER
Grouting Method: PURE BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0	▨			0		0–3	POST-HOLE DIG TO 3': 0.1' ASPHALT, THEN FILL: 0.3' FILL SAND AND GRAVEL, THEN SANDY CLAY FILL WITH GRAVEL, GRAY AND ORANGE, SLIGHTLY MOIST, FRIABLE
	▨		☒	0	1.0/1	3–4	AS ABOVE
5	▨		☒	0 0	5.0/5	4–9	SILTY CLAY: GRAY (2.5Y6/1), MOIST, STIFF TO VERY STIFF, ORANGE AND REDDISH PURPLE MINERAL STAINING, SOME SANDY ZONES FROM 4–6'
10	▨		☒	0 0	4.9/5	9–14	SILTY CLAY: GRAY (2.5Y6/1), DRY, VERY STIFF TO HARD, ORANGE MINERAL STAINING THROUGHOUT
15	▨		☒	0 0	4.8/5	14–19	2.5' AS ABOVE, THEN 2.3' SANDY CLAY: GRAYISH BROWN (2.5Y5/2), VERY MOIST, SOME GRAVEL 18–19'
20	▨		☒	0 0	4.2/5	19–24	SILTY CLAY: PALE OLIVE (5Y6/3), DRY, HARD, ORANGE, DARK BROWN AND BLACK MINERAL STAINING, NO ODOR
25	▨		☒	0 0	4.0/5	24–29	SILTY CLAY: MOSTLY BROWN (10Y4/4) WITH SOME PALE OLIVE, DRY, HARD
30	▨		☒				

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB-02

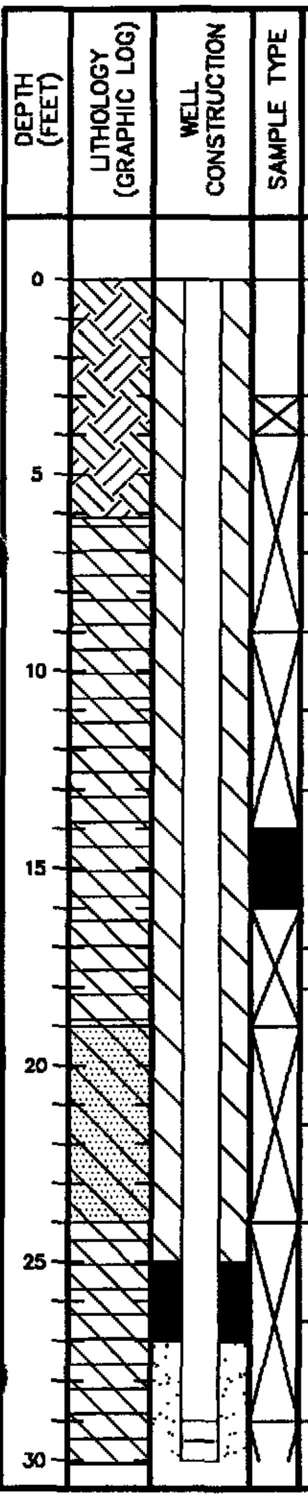
Project No.: 21-02 Date Drilled: 2-26-97

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
30	▨		☒	0 0	3.5/5	29–34	AS ABOVE
35	▨		☒	0 0	3.6/5	34–39	AS ABOVE, LESS PALE OLIVE
40	▨		☒	0 0	4.4/5	39–44	SILTY CLAY: 3.1' BROWN (10YR4/4), DRY, HARD, THEN SILTY CLAY: LIGHT GRAY (10Y7/1), DRY, HARD
45	▨		☒	0 0	5.0/5	44–49	AS ABOVE WITH BRIGHT GREEN (COLOR NOT ON MUNSELL CHART) INTERSPERSED
50	▨		☒	0 0	4.0/5	49–54	SILTY CLAY: LIGHT GRAY (10Y7/1), DRY, HARD
55							TD @ 54': REMOVED AUGERS FROM HOLE, BOREHOLE DRY TO TD
60							
65							

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-03

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: RSCO PROPERTY ADJACENT TO W. PINE ST.
Surface Elev.: 169.47
Boring T.D.: 37 ft.
Boring Dia.: 8.25 in.
Date Started: 2-26-97
Date Completed: 2-26-97
Drilling Company: TECHNICAL DRILLING SERVICES
Driller: CURTIS LEE
Drilling Method: HOLLOW STEM AUGER
Grouting Method: PURE BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE



PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0		0–3	POST-HOLE DIG TO 3': FILL: CLAY, BROWN AND BLACK WITH WOOD FRAGMENTS, ROCKS, ASPHALT ODOR
0	1.0/1	3–4	AS ABOVE
0 124	2.7/5	4–9	2.1' FILL: CLAY, WOOD, BRICK, AND BLACK ASPHALT-LIKE MATERIAL (NO ODOR), THEN 0.6' SILTY CLAY: GRAY (2.5Y6/1) WITH SOME TAN (2.5Y6/4), MOIST, STIFF, PINE ROOTS, STRONG AROMATIC PINE SCENT
106 15	4.0/5	9–14	AS ABOVE, STIFFER, WITH ORANGE MINERAL STAINING AT BASE
9	2.5/3	16–19	SILTY CLAY: GRAY (2.5Y6/1), VERY MOIST, STIFF TO VERY STIFF, SOME SOFT, SANDY, SATURATED ZONES FROM 16–17', ORANGE MINERAL STAINING AT BASE
0 0	5.0/5	19–24	SANDY CLAY: GRAY (2.5Y6/1), VERY MOIST, STIFF, ORANGE MINERAL STAINING, WITH SATURATED CLAYEY SAND ZONE FROM 20.3' TO 22.6'
0 0	4.8/5	24–29	SILTY CLAY: GRAY (2.5Y6/1), VERY MOIST, STIFF TO VERY STIFF, SOME SAND, SATURATED ZONE FROM 25–26'

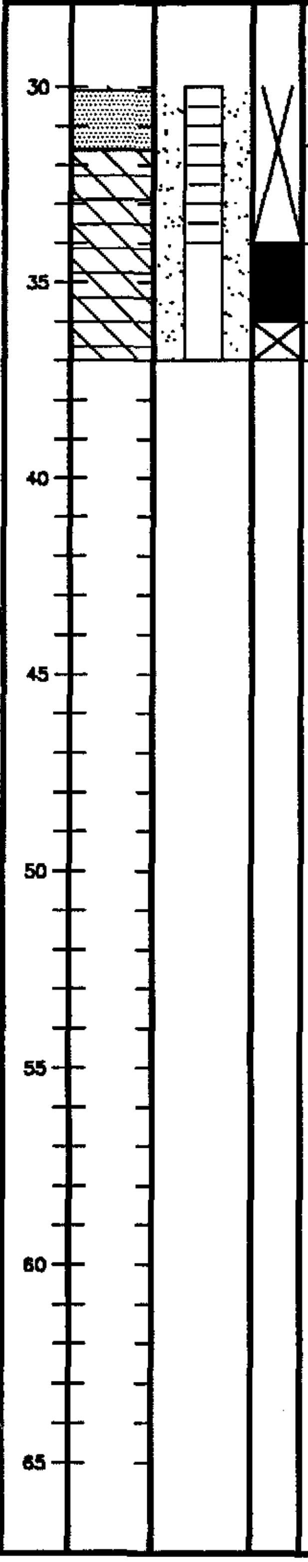
2102A14

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-03

Project No.: 21-02 Date Drilled: 2-26-97



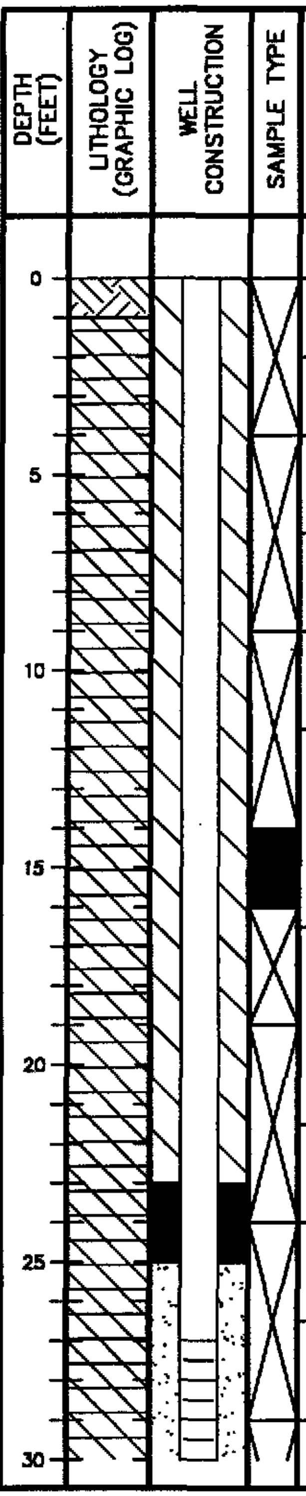
DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
				0 0	3.5/5	29-34	1.1' AS ABOVE THEN 1.5' SAND: LIGHT GRAY (2.5Y7/2), SATURATED, MEDIUM TO COARSE GRAINED WITH PEA GRAVEL, ORANGE MINERAL STAINING AT BASE, THEN 0.9' SILTY CLAY: GRAY (2.5Y6/1), BECOMING BROWN (10YR4/4), DRY, HARD
				0	1.0/1	36-37	AS ABOVE
							TD AT 37'

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-04

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: HENSON AUTO SALES PROPERTY
Surface Elev.: 191.27
Boring T.D.: 41 ft.
Boring Dia.: 8.25 in.
Date Started: 2-27-97
Date Completed: 2-27-97
Drilling Company: TECHNICAL DRILLING SERVICES
Driller: CURTIS LEE
Drilling Method: HOLLOW STEM AUGER
Grouting Method: PURE BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE



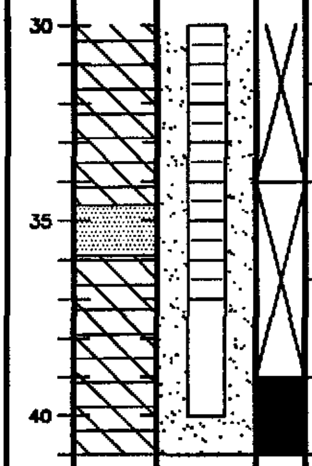
PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0 0	3.7/4	0-4	1.0' FILL: CLAY, TAN AND LIGHT GRAY WITH WOOD FRAGMENTS THEN SILTY CLAY: LIGHT GRAY (2.5Y7/1), MOIST, STIFF, RED AND ORANGE MINERAL STAINING, ROOTLETS
0 0	4.8/5	4-9	3.9' SILTY CLAY: LIGHT GRAY (2.5Y7/1), DRY TO SLIGHTLY MOIST, VERY STIFF, LESS MINERAL STAINING THAN ABOVE, THEN 0.9' AS ABOVE WITH SAND, DRY, FRIABLE
0 0	4.2/5	9-14	2.3' SILTY CLAY: MOSTLY BROWN (10YR6/3) WITH SOME GRAY, DRY, FRIABLE, BLACK MINERAL STAINING, THEN 1.9' SILTY CLAY: COLOR AS ABOVE, DRY, VERY STIFF TO HARD, BLACK MINERAL STAINING (AS NODULES AND IN CRACKS AND FISSURES)
0			
0	2.7/3	16-19	SILTY CLAY: GREENISH GRAY (10Y7/1), DRY, VERY STIFF, FRIABLE, ORANGE AND BLACK MINERAL STAINING, GREEN-COLORED ZONES FROM 18-19'
0	3.7/5	19-24	2.5' AS ABOVE, THEN SILTY CLAY: GREENISH GRAY (10Y7/1), DRY, HARD, RUST-BROWN MINERAL STAINING
0 0	4.1/5	24-29	AS ABOVE

2102A16

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-04

Project No.: 21-02 Date Drilled: 2-27-97



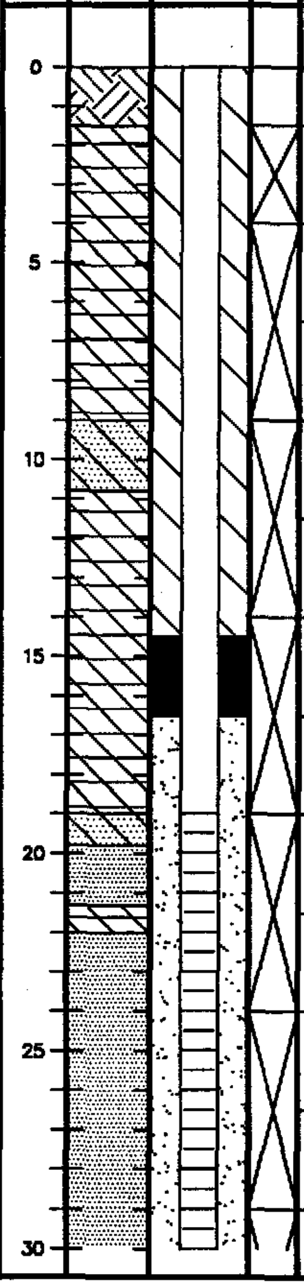
DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
30				0 0	4.0/5	29-34	AS ABOVE WITH SOME SAND AT BASE
35				0 0	3.2/5	34-39	0.6' AS ABOVE, THEN 1.3' SAND: LIGHT GRAY (2.5Y7/2), SATURATED, MEDIUM GRAINED, THEN 1.3' SILTY CLAY: GREENISH GRAY (10Y7/1), WITH BROWN (10YR4/4), DRY, HARD
40							
							DRILL TO 39', SAMPLE TO 41'

2102A17

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-05

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: OMT PROPERTIES
Surface Elev.: 191.78
Boring T.D.: 42 ft.
Boring Dia.: 8.25 in.
Date Started: 2-28-97
Date Completed: 2-28-97
Drilling Company: TECHNICAL DRILLING SERVICES
Driller: CURTIS LEE
Drilling Method: HOLLOW STEM AUGER
Grouting Method: PURE BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE



DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
				0		0–1.5	POST-HOLE DIG TO 1.5': FILL: 0.2' ASPHALT, 0.4' RED FILL SAND, 0.8' ASPHALT, THEN SILTY CLAY
				0	2.3/2.5	1.5–4	SILTY CLAY: GRAY (5Y6/1) AND TAN (10YR5/6), VERY MOIST, MEDIUM STIFF TO STIFF, BROWN AND BLACK MINERAL NODULES, WOOD FRAGMENTS IN UPPER 0.4'
				0 0	5.6/5	4–9	0.6' AS ABOVE, THEN SILTY CLAY: LIGHT GRAY (2.5Y7/1) AND TAN (10YR6/8), DRY, VERY STIFF TO HARD, ORANGE AND RED MINERAL STAINING
				0 0	4.6/5	9–14	1.8' SANDY CLAY/CLAYEY SAND: LIGHT GRAY (2.5Y7/1), MOIST, FRIABLE, WITH ORANGE MINERAL STAINING, THEN 2.8' SILTY CLAY: COLOR AS ABOVE, DRY TO SLIGHTLY MOIST, VERY STIFF TO HARD, ORANGE MINERAL STAINING
				0 0	5.0/5	14–19	SILTY CLAY: GRAY (2.5Y6/1), DRY, VERY STIFF TO HARD, ABUNDANT ORANGE MINERAL STAINING
				0 0	3.5/5	19–24	0.8' SANDY CLAY: COLOR AS ABOVE, DRY, FRIABLE, THEN 1.5' SAND: GRAY (2.5Y6/1), VERY MOIST, MEDIUM GRAINED, ORANGE MINERAL STAINING, THEN 0.7' SILTY CLAY: GRAY VERY MOIST, VERY STIFF, THEN 0.8' SAND: LIGHT GRAY (2.5Y7/1), SATURATED, MEDIUM GRAINED, ORANGE MINERAL STAINING
				0 0	3.0/5	24–29	SAND: LIGHT GRAY BECOMING TAN (2.5Y6/4), SATURATED, MEDIUM GRAINED, PURPLE AND ORANGE MINERAL STAINING

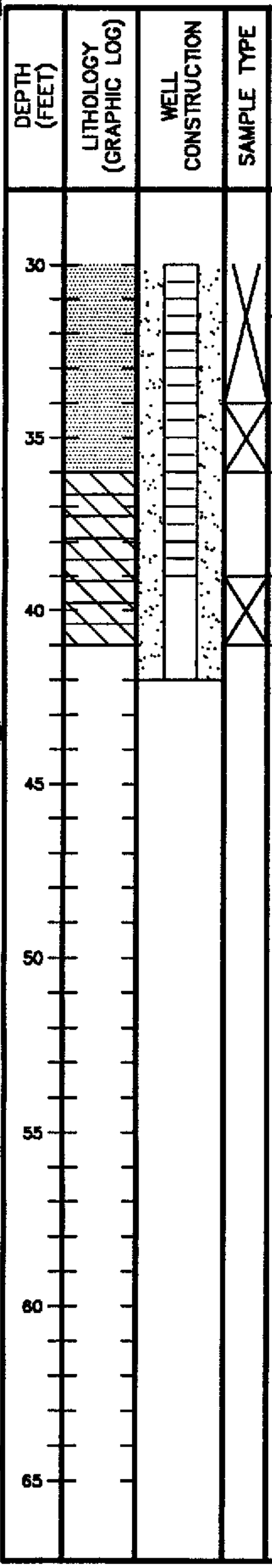
MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services

New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB/MW-05

Project No.: 21-02 Date Drilled: 2-28-97

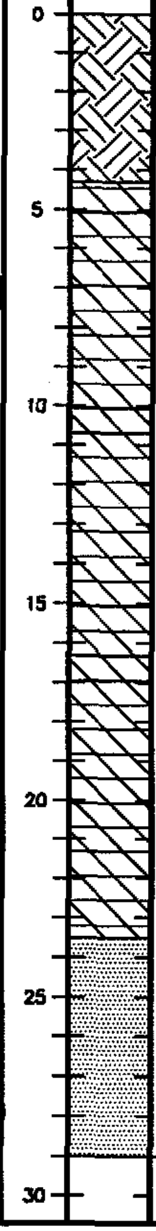


PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0 0	2.8/5	29-34	SAND: LIGHT GRAY TO WHITE, SATURATED, MEDIUM TO COARSE GRAINED WITH PEA GRAVEL
0	1.0/2	34-36	AS ABOVE WITH GRAVEL UP TO 1/2"
0	1.1/2	39-41	CLAY: BROWN (10YR4/4) AND OLIVE GRAY, DRY, HARD, MINOR BLACK MINERAL STAINING
			TD AT 42'

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: SB-06

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: COURTESY FORD BODY SHOP
Surface Elev.: 189.18
Boring T.D.: 29 ft.
Boring Dia.: 8.25 in.
Date Started: 2-28-97
Date Completed: 2-28-97
Drilling Company: TECHNICAL DRILLING SERVICES
Driller: CURTIS LEE
Drilling Method: HOLLOW STEM AUGER
Grouting Method: PURE BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				0		0-3	POST-HOLE DIG TO 3': FILL: 0.2' ASPHALT, THEN 2.8' CLAY, BROWN AND BLACK, WET, WITH GRAVEL, ASPHALT
				1	0.7/1	3-4	FILL: CLAY, GRAVEL AND WOOD, BLACK, SATURATED, CREOSOTE ODOR
5			☒	39 1.5	3.2/5	4-9	0.3' FILL, AS ABOVE, THEN 1.2' SILTY CLAY: BROWN AND BLACK, SATURATED, SOFT, BLACK LIQUID AND SHEEN, CREOSOTE ODOR, THEN 1.7' SILTY CLAY: GRAY, DRY TO SLIGHTLY MOIST, VERY STIFF, ORANGE AND RED MINERAL STAINING, BLACK STAINING IN POCKETS, CREOSOTE ODOR
10			☒	35 37	5.0/5	9-14	SILTY CLAY: LIGHT GRAY, DRY TO SLIGHTLY MOIST, HARD, ORANGE MINERAL STAINING, POCKETS OF BROWN-BLACK STAINING, CREOSOTE ODOR
15			☒	33 28	4.7/5	14-19	2.2' AS ABOVE BECOMING MOSTLY TAN, THEN 2.5' SILTY CLAY: GRAY, MOIST, HARD, SOME SAND, PINK AND RED MINERAL STAINING, POCKETS OF BROWN-BLACK STAINING (ALSO IN CRACKS, FISSURES), CREOSOTE ODOR
20			☒	9 28	5.1/5	19-24	1.3' AS ABOVE, NO BROWN-BLACK STAINING BUT CREOSOTE ODOR PERSISTS, THEN 1.4' SILTY CLAY: GRAY, MOIST, HARD, ABUNDANT ORANGE MINERAL STAINING, CREOSOTE ODOR BUT NO BROWN-BLACK STAINING, THEN 1.9' AS ABOVE WITH NO MINERAL STAINING, THEN 0.5' SAND: LIGHT GRAY, SATURATED, MEDIUM GRAINED, BLACK STAINING AT CLAY/SAND INTERFACE, CREOSOTE ODOR
25			☒	8	2.2/5	24-29	AS ABOVE , NO BLACK STAINING
30							TD AT 29'

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-01

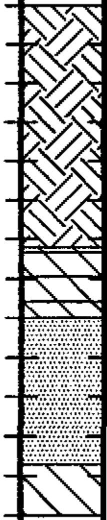
Project:	FORMER GULF STATES CREOSOTING SITE	Project No.:	21-02
Location:	ADJACENT TO RST-38		
Surface Elev.:	183.57	Boring T.D.:	12 ft.
Boring Dia.:	2 in.		
Date Started:	3-18-97	Date Completed:	3-18-97
Drilling Company:	FUGRO GEOSCIENCES	Driller:	ROBERT LEGETT
Drilling Method:	GEOPROBE	Grouting Method:	CEMENT BENTONITE GROUT VIA TREMIE
Logged by:	DAVID UPTHEGROVE		

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0	▨			0 0	3.8/4	0-4	1.2' SILTY CLAY: TOP 0.3' DARK BROWN, MOIST, ROOTS, THEN LIGHT BROWN, FRIABLE, BROWN-BLACK MINERAL STAINING AND NODULES, THEN SANDY CLAY: LIGHT GRAY, DRY, FRIABLE, MINERAL STAINING AND NODULES
5	▨			0 0	3.7/4	4-8	SILTY AND SANDY CLAY: LIGHT GRAY, MOIST, STIFF, ORANGE AND RUST-COLORED MINERAL STAINING, GRAVEL FROM 5-8', INCREASING AMOUNT AND SIZE WITH DEPTH (UP TO 1" IN DIAMETER)
10	▨			0 0	3.5/4	8-12	AS ABOVE, HARD, NO GRAVEL, ABUNDANT ORANGE MINERAL STAINING
15 20 25 30							TD @ 12'

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-02

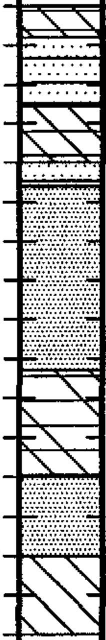
Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: ADJACENT TO RST-49
Surface Elev.: 187.95
Boring T.D.: 13 ft.
Boring Dia.: 2 in.
Date Started: 3-18-97
Date Completed: 3-18-97
Drilling Company: FUGRO GEOSCIENCES
Driller: ROBERT LEGETT
Drilling Method: GEOPROBE
Grouting Method: CEMENT BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				0 0	3.3/4	0-4	FILL: 0.9' TOPSOIL, BROWN, SANDY, WITH ROOTS, THEN 1.0' FILL SAND WITH GRAVEL, RED AND TAN, FINE-GRAINED, MOIST, THEN 1.4' SILTY AND SANDY FILL MATERIAL, MOIST, FRIABLE, WITH GRAVEL, BRICK FRAGMENTS AND ASPHALT
5				0 0	2.8/4	4-8	2.2' OF CLAYEY AND SANDY FILL MATERIAL WITH GRAVEL AND ASPHALT, THEN 0.6' SILTY CLAY: LIGHT GRAY, MOIST, VERY STIFF, WITH BLACK AND ORANGE MINERAL STAINING
10							TOP OF SAND AT ±8' (FROM CPT LOG)
				0	1.8/2	11-13	0.7' SAND: LIGHT BROWN, SATURATED, MEDIUM GRAINED, WITH GRAVEL, ORANGE MINERAL STAINING AT BASE, THEN 1.1' CLAY: LIGHT GRAY, MOIST, VERY STIFF, SOME MINERAL STAINING
15 20 25 30							TD @ 13'

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-03

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: ADJACENT TO RST-46
Surface Elev.: 186.37
Boring T.D.: 16 ft.
Boring Dia.: 2 in.
Date Started: 3-18-97
Date Completed: 3-18-97
Drilling Company: FUGRO GEOSCIENCES
Driller: ROBERT LEGETT
Drilling Method: GEOPROBE
Grouting Method: CEMENT BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE



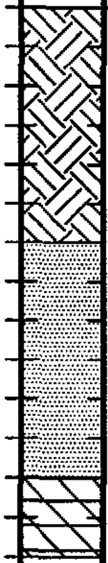
DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				0 0	3.4/4	0-4	0.8' SILTY CLAY: TAN, MOIST, FIRM, ROOTS, THEN 1.7' SILTY SAND: BROWN, MOIST, FINE-GRAINED, THEN 0.9' SILTY CLAY: LIGHT GRAY, MOIST, VERY STIFF, ORANGE MINERAL STAINING
5				0 0	3.6/4	4-8	0.6' SILTY SAND: BROWN AND TAN, MOIST, FINE-GRAINED, THEN SAND: TAN, MOIST (SATURATED AT 7'), FINE-GRAINED
10				0 0	3.1/4	8-12	1.3' SAND: TAN, SATURATED, MEDIUM-GRAINED WITH GRAVEL AND ORANGE MINERAL STAINING, THEN 1.8' SILTY CLAY: GREEN-GRAY, VERY MOIST TO SATURATED, STIFF, SANDY AT BASE
				0	0.5/2	12-14	SAND: GRAY, SATURATED, MEDIUM-GRAINED
15				0	1.7/2	14-16	CLAY: GRAY, MOIST, VERY STIFF TO HARD, ORANGE MINERAL STAINING
20 25 30							TD @ 16'

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-04

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: ADJACENT TO RST-51
Surface Elev.: 187.50
Boring T.D.: 14 ft.
Boring Dia.: 2 in.
Date Started: 3-18-97
Date Completed: 3-18-97
Drilling Company: FUGRO GEOSCIENCES
Driller: ROBERT LEGETT
Drilling Method: GEOPROBE
Grouting Method: CEMENT BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				0 0	3.5/4	0-4	FILL: SANDY SILT WITH SOME CLAY, BROWN, MOIST, FRIABLE, WITH GRAVEL, ROOTS, AND WOOD FRAGMENTS
5				0 0	3.3/4	4-8	FILL: 0.2' SANDY, THEN 0.8' SILTY CLAY, GRAY, MOIST, STIFF, THEN 0.7' FILL SAND AND GRAVEL, THEN 0.3' SILTY CLAY, THEN SAND: TAN, VERY MOIST, (SATURATED AT BASE), FINE TO MEDIUM-GRAINED, SOME SMALL GRAVEL
10				0 0	3.5/4	8-12	SAND: 1.4' TAN, SATURATED, MEDIUM-GRAINED WITH SOME GRAVEL, THE < 0.1' CLAY, THEN SAND: GRAY, SATURATED, MEDIUM-GRAINED
				0	1.5/2	12-14	SILTY CLAY: GRAY, VERY MOIST, DRYING WITH DEPTH, STIFF
15							TD @ 14'
20							
25							
30							

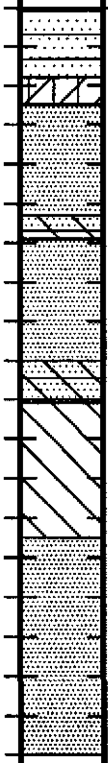
2102A24

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-05

Project:	FORMER GULF STATES CREOSOTING SITE			Project No.:	21-02
Location:	ADJACENT TO RST-41				
Surface Elev.:	182.14	Boring T.D.:	19 ft.	Boring Dia.:	2 in.
Date Started:	3-18-97	Date Completed:	3-18-97		
Drilling Company:	FUGRO GEOSCIENCES	Driller:	ROBERT LEGETT		
Drilling Method:	GEOPROBE	Grouting Method:	CEMENT BENTONITE GROUT VIA TREMIE		
Logged by:	DAVID UPTHEGROVE				



DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				0 0	3.6/4	0–4	1.8' SILTY SAND: BROWN, MOIST, LOOSE, VERY FINE-GRAINED, THEN 0.7' CLAY SILT: TAN AND GRAY, VERY MOIST, THEN 1.1' SAND: DARK BROWN, VERY MOIST, ABUNDANT ORGANIC MATERIAL, ODOR AT BASE
5				53 51	2.9/4	4–8	1.3' SAND: BROWN, SATURATED, MEDIUM-GRAINED, WITH WOOD FRAGMENTS, SMALL GRAVEL, AND BROWN OILY LIQUID AND SHEEN, THEN 0.6' SILTY AND SANDY CLAY: GRAY, SATURATED, STIFF, WITH ODOR, WOOD, BROWN OILY LIQUID, THEN SAND: BROWN, SATURATED, MEDIUM-GRAINED WITH ODOR, BROWN OILY LIQUID AND SHEEN
10				69 32	3.5/4	8–12	1.0' AS ABOVE, THEN 1.0' SILTY AND SANDY CLAY: GRAY, SATURATED, ODOR AND STAINING, THEN 0.1' GRAVEL: WITH BROWN OILY LIQUID, THEN 1.4' CLAY: GRAY-GREEN, MOIST, STIFF, ODOR, NO STAINING
15				3 1	3.4/4	12–16	1.5' AS ABOVE, THEN SAND: GRAY-GREEN, SATURATED, MEDIUM-GRAINED, ODOR, ISOLATED THIN CLAY LAYERS
				0	1.7/2	17–19	SAND: WHITE TO GRAY, SATURATED, MEDIUM TO COARSE-GRAINED, ODOR, GRAVEL AT BASE
20							TD @ 19'
25							
30							

MICHAEL PISANI & ASSOCIATES

Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-06

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: ADJACENT TO RST-47
Surface Elev.: 186.27
Boring T.D.: 12 ft.
Boring Dia.: 2 in.
Date Started: 3-19-97
Date Completed: 3-19-97

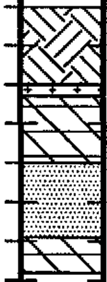
Drilling Company: FUGRO GEOSCIENCES
Driller: ROBERT LEGETT
Drilling Method: GEOPROBE
Grouting Method: CEMENT BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0	▨			0	3.5/4	0-4	FILL: 1.6' SILTY CLAY, BROWN, SLIGHTLY MOIST, GRAVEL, BRICK, AND ROOTS, THEN 1.5' SILTY CLAY, DARK BROWN, MOIST, STIFF, WITH BLACK COAL-LIKE MATERIAL AT BASE, THEN 0.4' SAND: DARK BROWN, VERY MOIST, VERY FINE-GRAINED
	▨ ░			0			
5	░			2	2.8/4	4-8	SAND: GRAY-BROWN, TOP 2.2' VERY MOIST, BOTTOM 0.6' SATURATED, VERY FINE TO FINE-GRAINED, ODOR IN BOTTOM 0.6'
	░			2			
	░			3	3.6/4	8-12	1.5' SAND: GRAY, SATURATED, MEDIUM TO COARSE-GRAINED, ODOR, THEN SAND: GRAY, SATURATED, FINE-GRAINED, WITH SOME CLAY, WOOD, ODOR, AND BROWN OILY LIQUID
10	░			72			
							TD @ 12'
15							
20							
25							
30							

MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

Boring/Well No.: GEO/SB-07

Project: FORMER GULF STATES CREOSOTING SITE
Project No.: 21-02
Location: ADJACENT TO RST-35
Surface Elev.: 183.93
Boring T.D.: 8 ft.
Boring Dia.: 2 in.
Date Started: 3-19-97
Date Completed: 3-19-97
Drilling Company: FUGRO GEOSCIENCES
Driller: ROBERT LEGETT
Drilling Method: GEOPROBE
Grouting Method: CEMENT BENTONITE GROUT VIA TREMIE
Logged by: DAVID UPTHEGROVE

DEPTH (FEET)	LITHOLOGY (GRAPHIC LOG)	WELL CONSTRUCTION	SAMPLE TYPE	PID (PPM)	SAMPLE RECOVERY (FEET/FEET)	DESCRIPTION INTERVAL (FEET)	SOIL DESCRIPTION
0				4	3.5/4	0-4	2.0' FILL: 1.0' CLAYEY SILT, 1.0' SAND, MOIST, SOME GRAVEL, ROOTS, THEN 0.3' ORGANICS (LEAVES AND ROOTS), THEN 1.2' SILTY CLAY: GRAY-BROWN, VERY MOIST, WOOD FRAGMENTS, ODOR, SHEEN
				7			
5				6	2.8/4	4-8	1.9' SAND: TAN, SATURATED, MEDIUM-GRAINED, ODOR, BROWN STAINING, THEN 0.9 SILTY CLAY: GRAY, VERY MOIST, SOFT TO MEDIUM STIFF, ODOR, BROWN LIQUID AT INTERFACE WITH OVERLYING SAND
				30			
							TD @ 8'
10							
15							
20							
25							
30							

LEGEND

■	THIN-WALLED TUBE
☒	SPLIT-BARREL SAMPLER
▩	FILL
▒	SAND
▥	SILT
▧	CLAY
▧	SANDY CLAY
▧	SILTY CLAY
▥	SANDY SILT
▤	SILTY SAND
▧	SANDY SILTY CLAY
▨	CLAYEY SAND

BORLEGND

Appendix E

Geotechnical Laboratory Reports

Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

EUSTIS ENGINEERING COMPANY, INC.
GEOTECHNICAL ENGINEERS
CONSTRUCTION QUALITY CONTROL & MATERIALS TESTING
3011 28th Street • Metairie, Louisiana 70002 • 504-834-0157 / Fax 504-834-0354

18 April 1997

Michael Pisani & Associates, Inc.
1100 Poydras Street
1430 Energy Center
New Orleans, LA 70163

Attention Mr. Michael Pisani, P.E.

Gentlemen:

Laboratory Testing
Project No. GSCS/21-02

In accordance with your request, we have performed laboratory tests on submitted soil samples. The results of these tests are shown on the enclosures. Also enclosed are copies of the ASTM specifications applicable to the testing procedures used for this project.

If we can be of further assistance, please do not hesitate to contact us.

Yours very truly,

EUSTIS ENGINEERING COMPANY, INC.

Martin L Dawson

MARTIN L. DAWSON

MLD:aln/mcp

Enclosures

EE 14662

MICHAEL PISANI & ASSOCIATES, INC.
PROJECT NO. GSCS/21-02

RESULTS OF SOIL MECHANICS LABORATORY TESTS

SAMPLE IDENTIFICATION	CLASSIFICATION (USCS)	INITIAL MOISTURE CONTENT	DENSITY PCF		COEFFICIENT OF PERMEABILITY AT 20°C CM / SEC.	INITIAL VOID RATIO	INITIAL PERCENT SATURATION
			DRY	WET			
SB-04/39-41 (Note 1)	Very stiff reddish-brown & gray silty clay, fissured (CL)	25.3	99.2	124.3	3.9×10^{-8} (Note 3)	0.679	99.3
SB-01/34-36 (Note 1)	Very stiff greenish-gray silty clay, fissured (CL)	27.5	95.6	121.9	4.2×10^{-8}	0.762	97.3
SB-04/14-16 (Note 1)	Very stiff light gray & tan silty clay, with trace organic matter, fissured (CL)	20.5	106.3	128.1	3.7×10^{-7} (Note 3)	0.553	97.9
SB-03/14-16 (Note 1)	Stiff gray & tan silty clay (CL)	20.6	107.2	129.2	2.5×10^{-8}	0.556	98.9
SB-03/34-36 (Note 1)	Very stiff brownish-red silty clay, fissured (CL)	27.3	94.9	120.7	7.7×10^{-8} (Note 3)	0.792	93.7
SB-03/30-32 (Note 2, 4)	Yellow-brown & light gray fine to coarse sand with silt and gravel (SP-SM)	11.8	115.4	129.1	--	0.425	73.4
SB-01/24-26 (Note 2, 4)	Light tan fine to medium sand (SP)	15.5	98.5	113.8	--	0.669	60.9

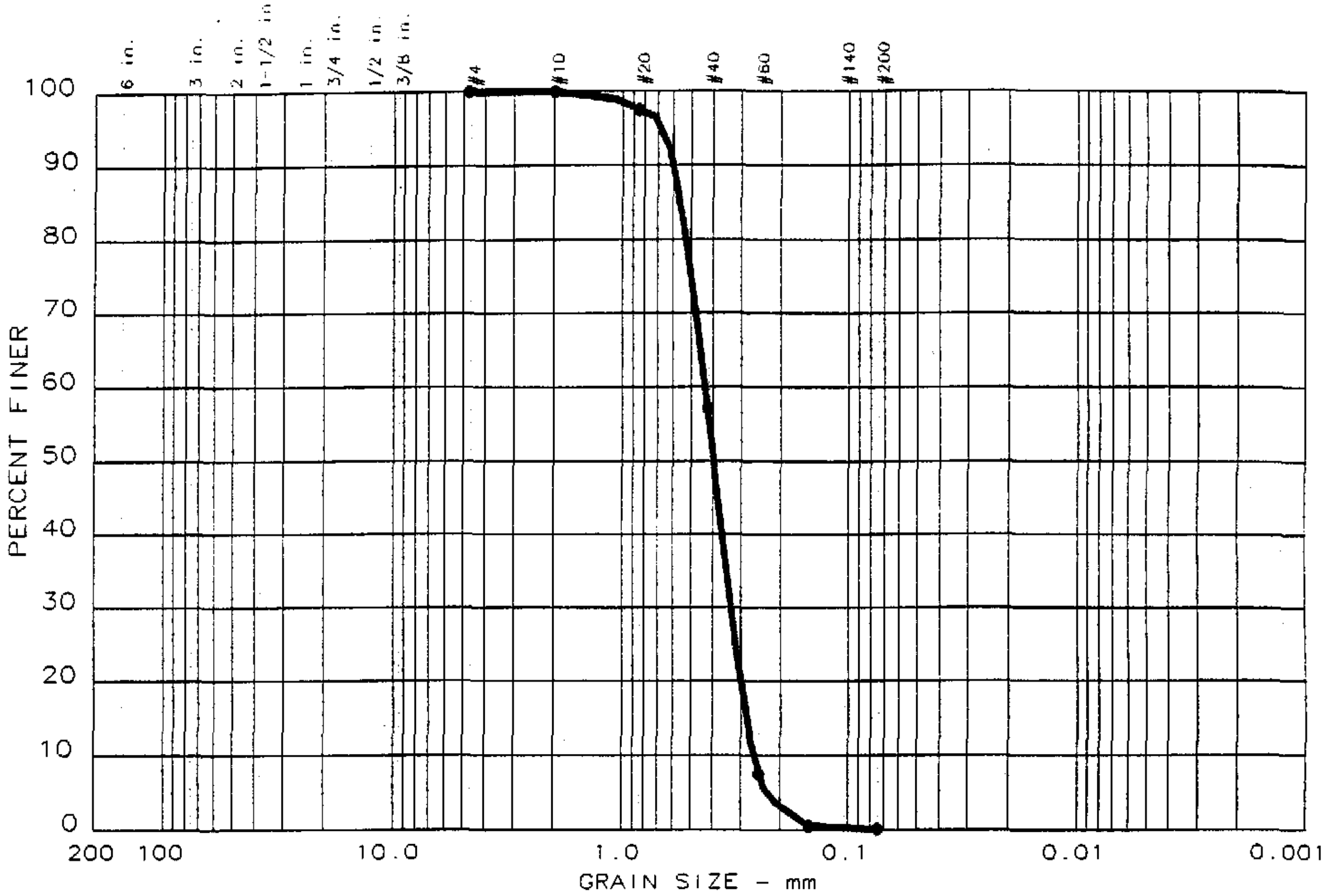
Notes:
1) Shelby tube sample.
2) Bag sample.
3) Sample consolidated using approximate overburden pressure before running flexible wall permeability, ASTM D5084.
4) Sample molded at "as received" moisture, using standard *compactive effort, ASTM D698*.

RESULTS OF SOIL MECHANICS LABORATORY TESTS

SAMPLE IDENTIFICATION	CLASSIFICATION (USCS)	SPECIFIC GRAVITY	ATTERBERG LIMITS			PERCENT PASSING #200 SIEVE	ORGANIC CONTENT PERCENT	INITIAL POROSITY PERCENT
			LL	PL	PI			
SB-04/39-41 (Note 1)	Very stiff reddish-brown & gray silty clay, fissured (CL)	2.670	47	20	27	99.4	5.85	40.4
SB-01/34-36 (Note 1)	Very stiff greenish-gray silty clay, fissured (CL)	2.700	48	18	26	99.8	5.47	43.3
SB-04/14-16 (Note 1)	Very stiff light gray & tan silty clay w/trace organic matter, fissured (CL)	2.646	43	19	24	97.9	3.64	35.6
SB-03/14-16 (Note 1)	Stiff gray & tan silty clay (CL)	2.673	38	18	20	91.5	2.46	35.7
SB-03/34-36 (Note 1)	Very stiff brownish-red silty clay, fissured (CL)	2.725	49	21	28	99.9	5.20	44.2
SB-03/30-32 (Note 2, 4)	Yellow-brown & light gray fine to coarse sand, w/silt & gravel (SP-SM)	2.635	--	--	--	8.4	0.58	29.8
SB-01/24-26 (Note 2, 4)	Light tan fine to medium sand (SP)	2.635	--	--	--	0.0	0.04	40.1

Notes:
1) Shelby tube sample.
2) Bag sample.
3) Sample consolidated using approximate overburden pressure before running flexible wall permeability, ASTM D5084.
4) Sample molded at "as received" moisture, using standard compactive effort, ASTM D698.

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	100.0	0.0		SP		

SIEVE inches size	PERCENT FINER ●		
	GRAIN SIZE		
D_{60}	0.44		
D_{30}	0.33		
D_{10}	0.26		
	COEFFICIENTS		
C_c	0.97		
C_u	1.7		

SIEVE number size	PERCENT FINER ●		
4	100.0		
10	99.9		
20	97.5		
40	57.1		
60	7.5		
100	0.5		
200	0.0		

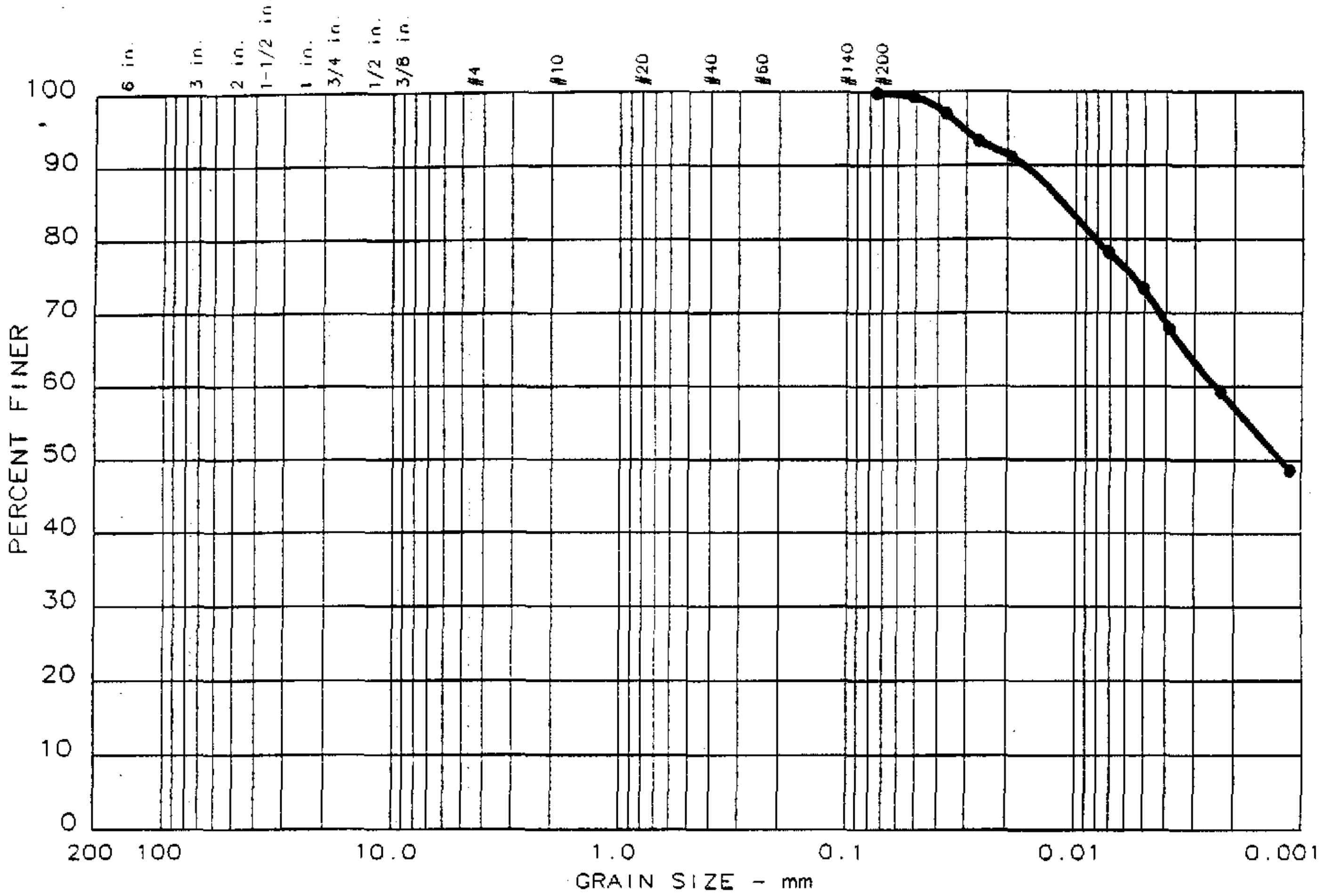
Sample information:
● SB-01 / 24'-26'
Light Tan FINE - MEDIUM SAND

Remarks:
Bag Sample
Sampled 2-25-97

Eustis Engineering Company, Inc.

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97 Data Sheet No. ——

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	0.2	26.7	73.1	CL	48	26

SIEVE inches size	PERCENT FINER ●		

	GRAIN SIZE		
D_{60} D_{30} D_{10}	0.00		

	COEFFICIENTS		
C_c C_u			

SIEVE number size	PERCENT FINER ●		
200	99.8		

Sample information:

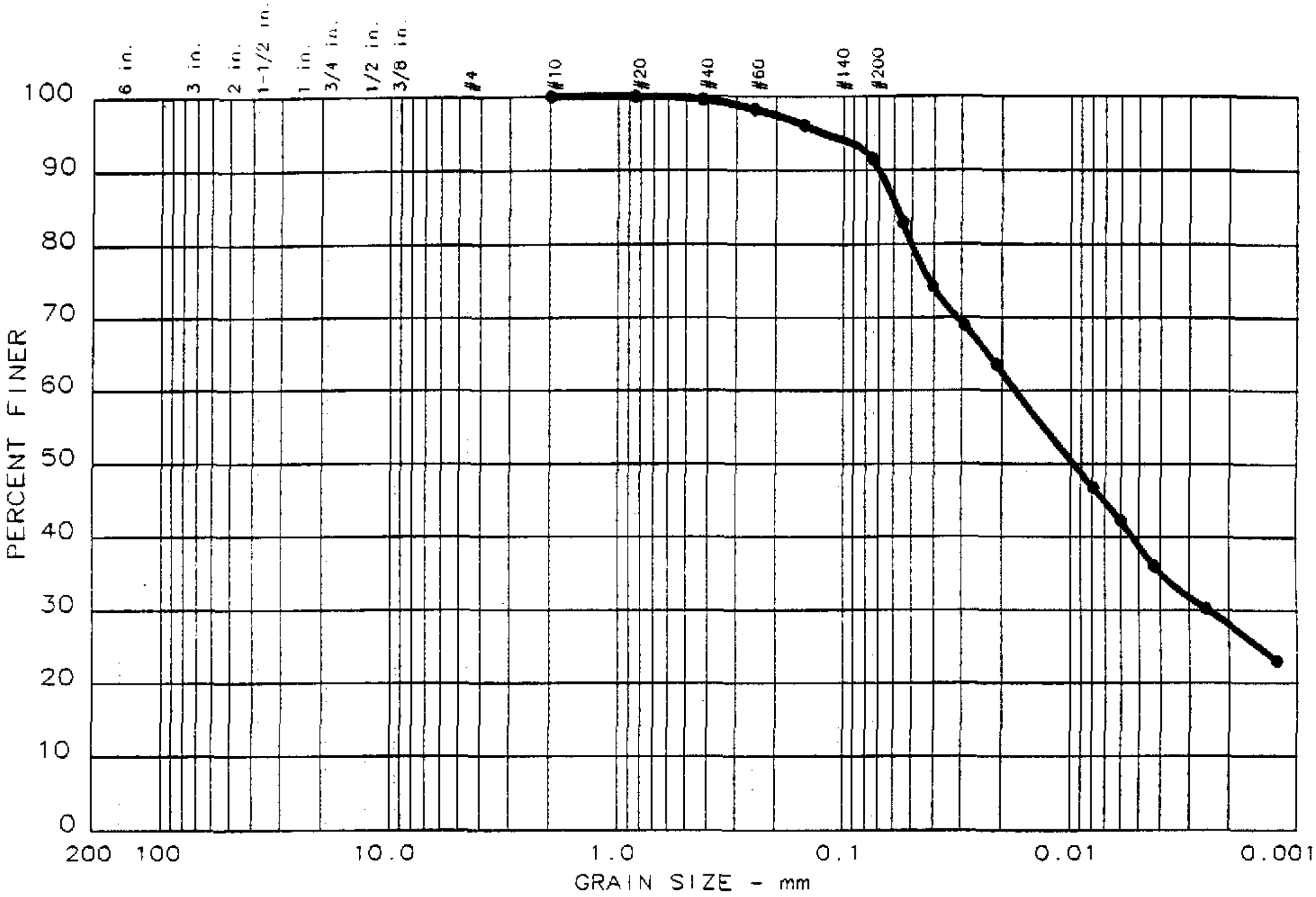
● SB-01 / 34'-36'
VStiff greenish - gray
SILTY CLAY

Remarks:
Shelby tube Sample
Sampled 2-25-97

Eustis Engineering Company, Inc.

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97
Data Sheet No. ——

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	8.5	52.7	38.8	CL	38	20

SIEVE inches size	PERCENT FINER ●		

	GRAIN SIZE		
D_{60}	0.02		
D_{30}	0.002		
D_{10}			

	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ●		
10	100.0		
20	99.9		
40	99.5		
60	98.2		
100	96.1		
200	91.5		

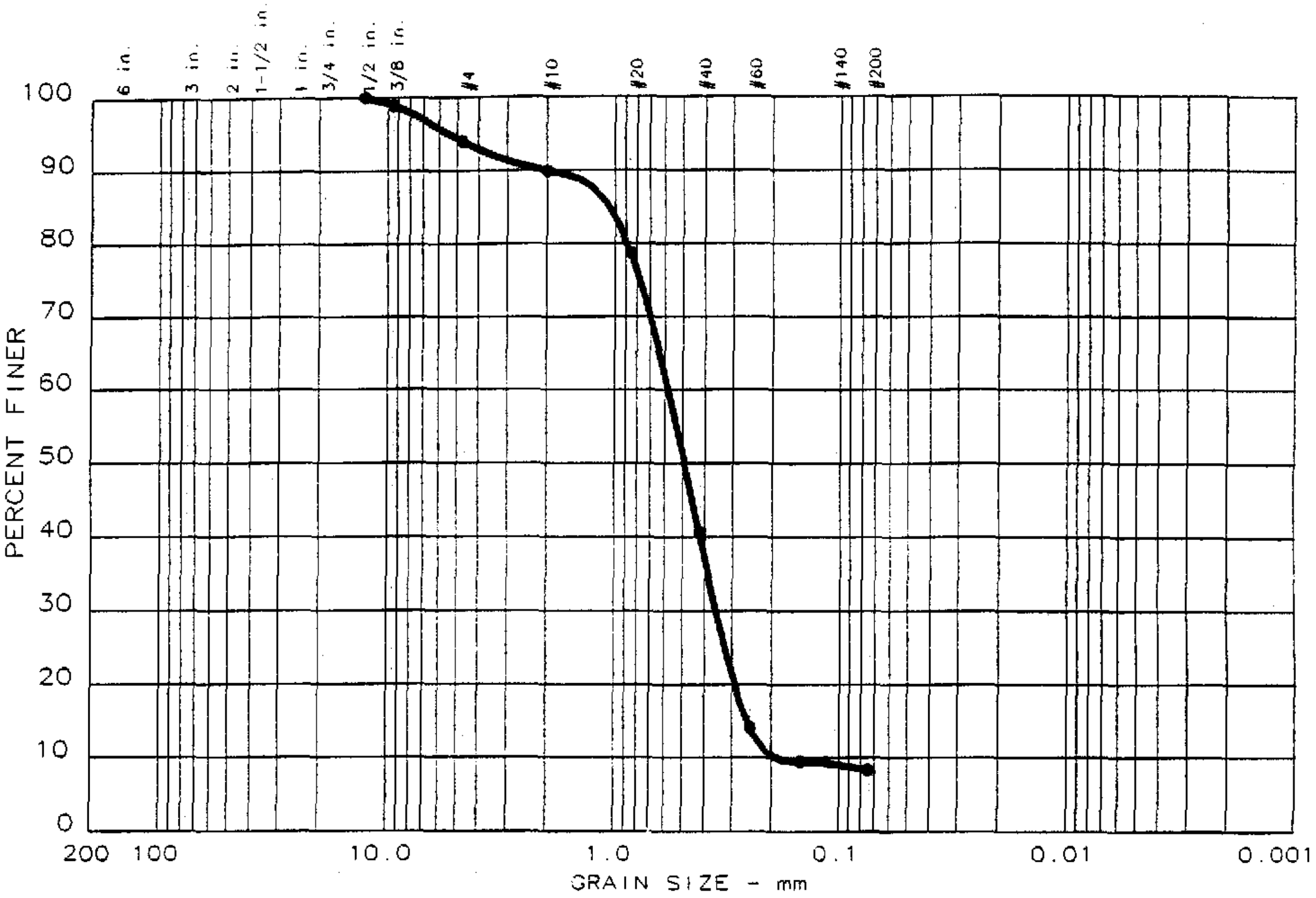
Sample information:
● SB-03 / 14'-16'
Stiff gray & tan SILTY CLAY

Remarks:
Shelby tube Sample
Sampled 2-26-97

Eustis Engineering Company, Inc.

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97
Data Sheet No. ——

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	6.0	85.6	8.4		SP-SM		

SIEVE inches size	PERCENT FINER ●		
0.5	100.0		
0.375	98.9		

	GRAIN SIZE		
D_{60}	0.58		
D_{30}	0.36		
D_{10}	0.19		

	COEFFICIENTS		
C_c	1.13		
C_u	3.0		

SIEVE number size	PERCENT FINER ●		
4	94.0		
10	89.9		
20	78.7		
40	40.6		
60	14.1		
100	9.5		
200	8.4		

Sample information:

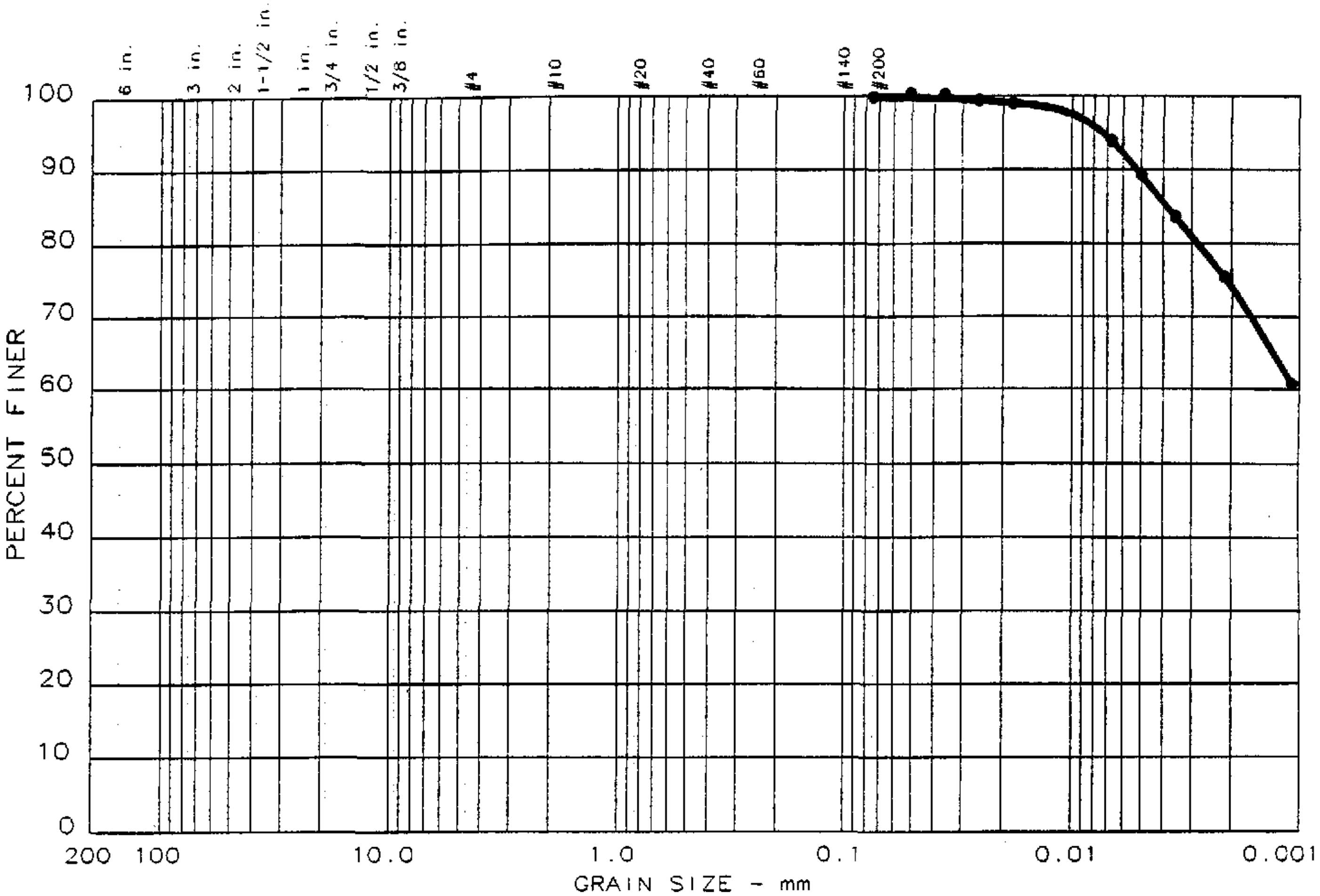
● SB-03 / 30'-32'
Y - brn & lt g FINE - COARSE SAND w/si & grav

Remarks:
Bag Sample
Sampled 2-26-97

Eustis Engineering Company, Inc.

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97
Data Sheet No. ____

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	0.1	10.6	89.3	CL	49	28

SIEVE inches size	PERCENT FINER ●		
GRAIN SIZE			
D_{60} D_{30} D_{10}			
COEFFICIENTS			
C_c C_u			

SIEVE number size	PERCENT FINER ●		
200	99.9		

Sample information:

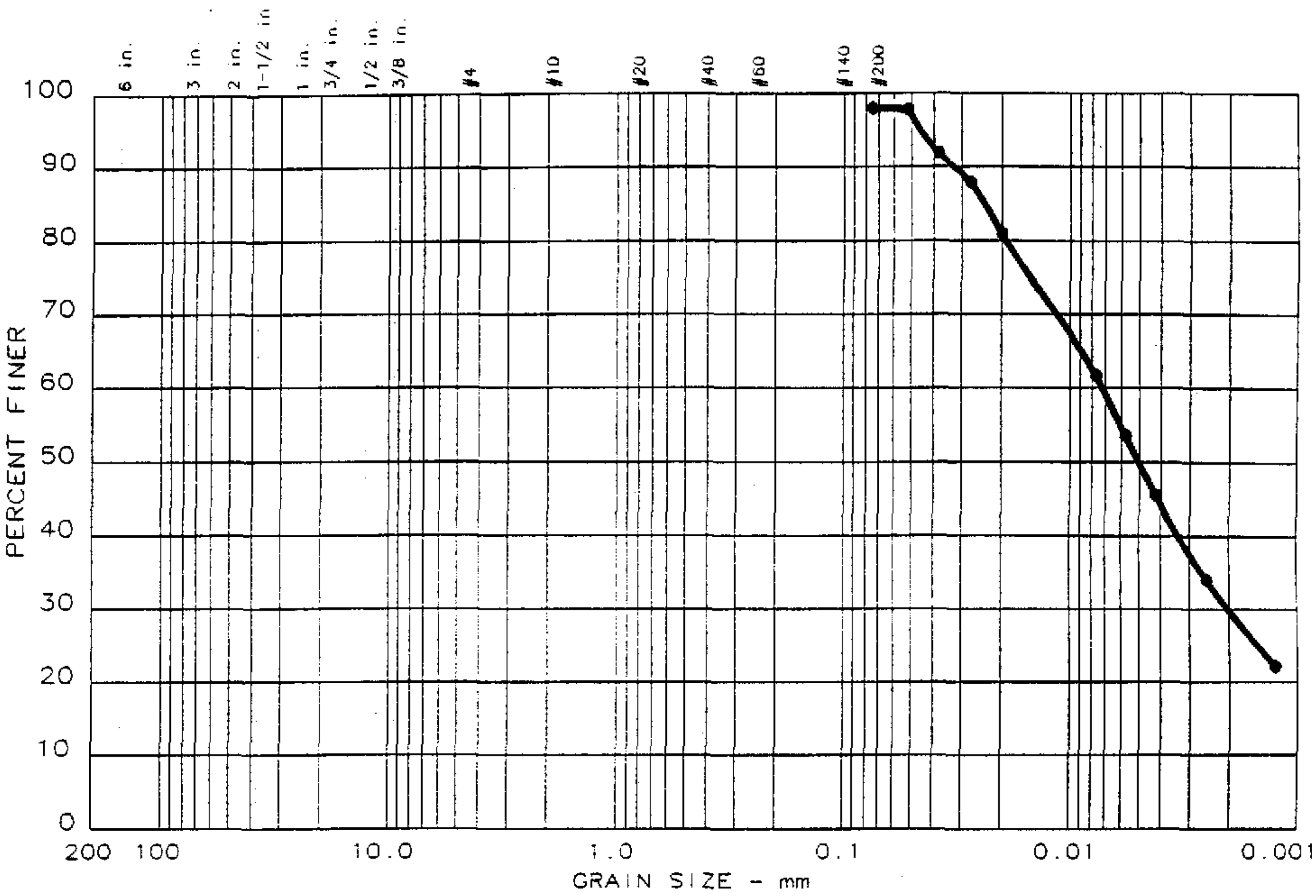
● SB-03 / 34'-36'
Very Stiff brownish-red
SILTY CLAY

Remarks:
Shelby tube Sample
Sampled 2-26-97

Eustis Engineering Company, Inc.

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97 Data Sheet No. ———

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	2.1	48.2	49.7	CL	43	24

SIEVE inches size	PERCENT FINER		
	●		

	GRAIN SIZE		
D_{60}	0.01		
D_{30}	0.002		
D_{10}			

	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER		
	●		
200	97.9		

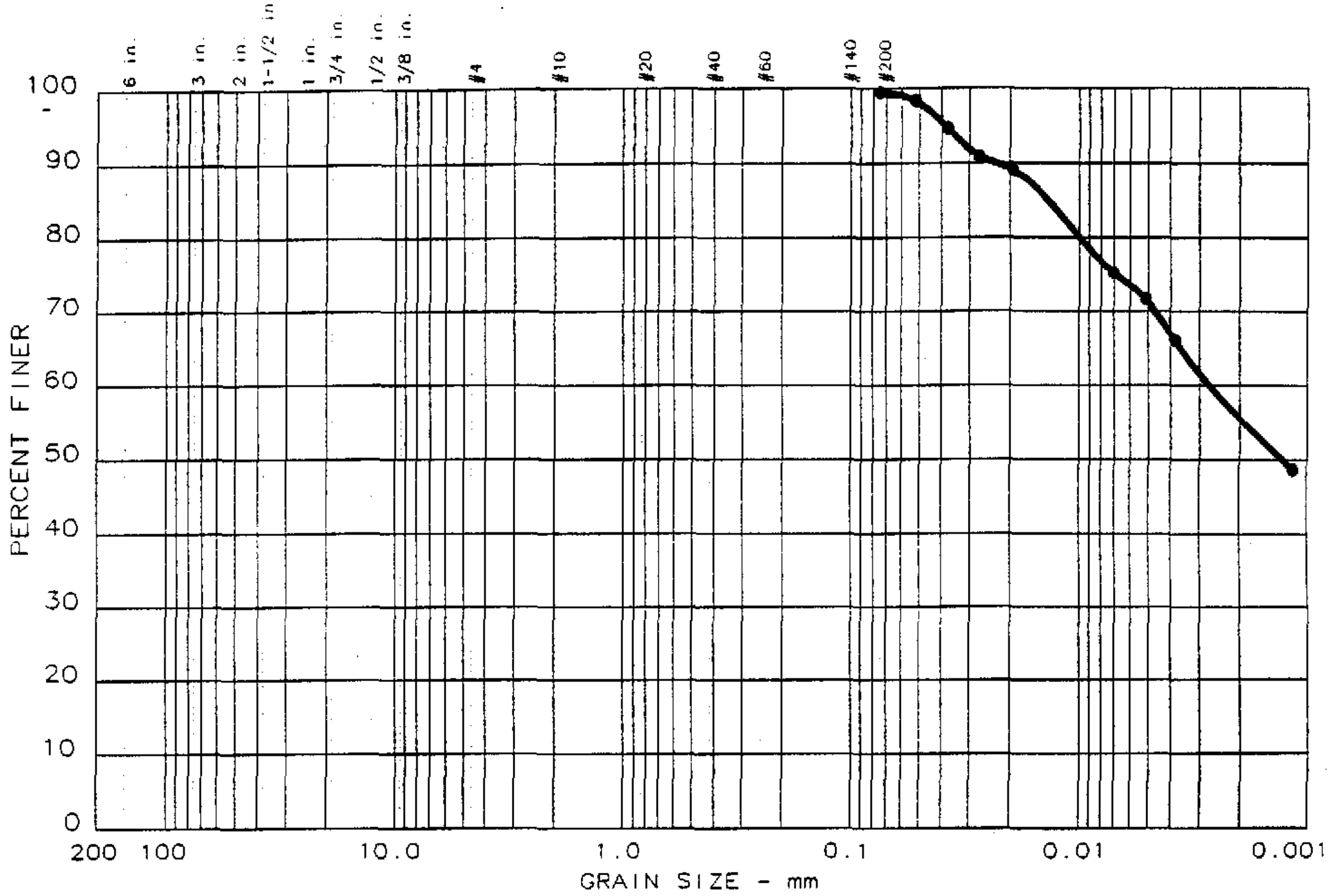
Sample information:
● SB-04 / 14'-16'
VStiff lt gray & tan
SILTY CLAY w/ tr om

Remarks:
Shelby tube Sample
Sampled 2-27-97

Eustis
Engineering
Company, Inc.

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97
Data Sheet No.

PARTICLE SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	0.6	28.2	71.2	CL	47	27

SIEVE inches size	PERCENT FINER		
	●		
	GRAIN SIZE		
D_{60} D_{30} D_{10}	0.00		
	COEFFICIENTS		
C_c C_u			

SIEVE number size	PERCENT FINER		
	●		
200	99.4		

Sample information:

● SB-04 / 39'-41'
VStiff reddish - brown
& gray SILTY CLAY

Remarks:
Shelby tube Sample
Sampled 2-27-97

**Eustis
Engineering
Company, Inc.**

Project No.: 14662
Project: Michael Pisani & Associates, Inc.
Date: 4-15-97 Data Sheet No. ____

Designation: D 422 - 63 (Reapproved 1990)$^{\epsilon 1}$

Standard Test Method for Particle-Size Analysis of Soils[1]

This standard is issued under the fixed designation D 422; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ Note—Section 19 was added editorially in September 1990.

1. Scope

1.1 This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 µm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 µm is determined by a sedimentation process, using a hydrometer to secure the necessary data (Notes 1 and 2).

Note 1—Separation may be made on the No. 4 (4.75-mm), No. 40 (425-µm), or No. 200 (75-µm) sieve instead of the No. 10. For whatever sieve used, the size shall be indicated in the report.

Note 2—Two types of dispersion devices are provided: (*1*) a high-speed mechanical stirrer, and (*2*) air dispersion. Extensive investigations indicate that air-dispersion devices produce a more positive dispersion of plastic soils below the 20-µm size and appreciably less degradation on all sizes when used with sandy soils. Because of the definite advantages favoring air dispersion, its use is recommended. The results from the two types of devices differ in magnitude, depending upon soil type, leading to marked differences in particle size distribution, especially for sizes finer than 20 µm.

2. Referenced Documents

2.1 *ASTM Standards:*

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

E 100 Specification for ASTM Hydrometers[4]

3. Apparatus

3.1 *Balances*—A balance sensitive to 0.01 g for weighing the material passing a No. 10 (2.00-mm) sieve, and a balance sensitive to 0.1 % of the mass of the sample to be weighed for weighing the material retained on a No. 10 sieve.

3.2 *Stirring Apparatus*—Either apparatus A or B may be used.

3.2.1 Apparatus A shall consist of a mechanically operated stirring device in which a suitably mounted electric motor turns a vertical shaft at a speed of not less than 10 000 rpm without load. The shaft shall be equipped with a replaceable stirring paddle made of metal, plastic, or hard rubber, as shown in Fig. 1. The shaft shall be of such length that the stirring paddle will operate not less than ¾ in. (19.0 mm) nor more than 1½ in. (38.1 mm) above the bottom of the dispersion cup. A special dispersion cup conforming to either of the designs shown in Fig. 2 shall be provided to hold the sample while it is being dispersed.

3.2.2 Apparatus B shall consist of an air-jet dispersion cup[5] (Note 3) conforming to the general details shown in Fig. 3 (Notes 4 and 5).

Note 3—The amount of air required by an air-jet dispersion cup is of the order of 2 ft^3/min; some small air compressors are not capable of supplying sufficient air to operate a cup.

Note 4—Another air-type dispersion device, known as a dispersion tube, developed by Chu and Davidson at Iowa State College, has been shown to give results equivalent to those secured by the air-jet dispersion cups. When it is used, soaking of the sample can be done in the sedimentation cylinder, thus eliminating the need for transferring the slurry. When the air-dispersion tube is used, it shall be so indicated in the report.

Note 5—Water may condense in air lines when not in use. This water must be removed, either by using a water trap on the air line, or by blowing the water out of the line before using any of the air for dispersion purposes.

3.3 *Hydrometer*—An ASTM hydrometer, graduated to read in either specific gravity of the suspension or grams per litre of suspension, and conforming to the requirements for hydrometers 151H or 152H in Specifications E 100. Dimensions of both hydrometers are the same, the scale being the only item of difference.

3.4 *Sedimentation Cylinder*—A glass cylinder essentially 18 in. (457 mm) in height and 2½ in. (63.5 mm) in diameter, and marked for a volume of 1000 mL. The inside diameter shall be such that the 1000-mL mark is 36 ± 2 cm from the bottom on the inside.

3.5 *Thermometer*—A thermometer accurate to 1°F (0.5°C).

3.6 *Sieves*—A series of sieves, of square-mesh woven-wire cloth, conforming to the requirements of Specification E 11. A full set of sieves includes the following (Note 6):

---

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

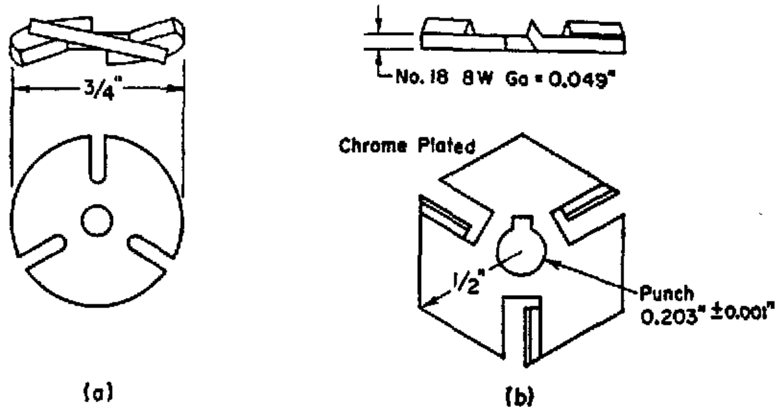
Current edition approved Nov. 21, 1963. Originally published 1935. Replaces D 422 - 62.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] Detailed working drawings for this cup are available at a nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. Order Adjunct No. 12-404220-00.



Metric Equivalents

in.	0.001	0.049	0.203	½	¾
mm	0.03	1.24	5.16	12.7	19.0

FIG. 1 Detail of Stirring Paddles

3-in. (75-mm)
2-in. (50-mm)
1½-in. (37.5-mm)
1-in. (25.0-mm)
¾-in. (19.0-mm)
⅜-in. (9.5-mm)
No. 4 (4.75-mm)
No. 10 (2.00-mm)
No. 20 (850-µm)
No. 40 (425-µm)
No. 60 (250-µm)
No. 140 (106-µm)
No. 200 (75-µm)

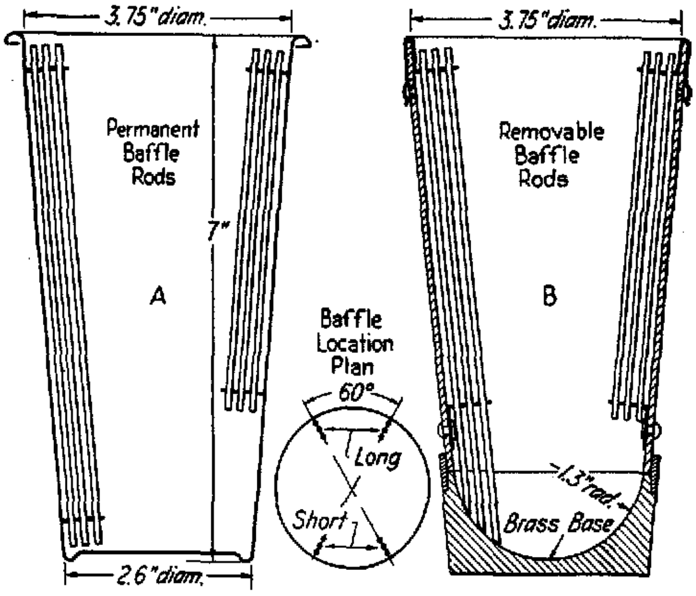
NOTE 6—A set of sieves giving uniform spacing of points for the graph, as required in Section 17, may be used if desired. This set consists of the following sieves:

3-in. (75-mm)
1½-in. (37.5-mm)
¾-in. (19.0-mm)
⅜-in. (9.5-mm)
No. 4 (4.75-mm)
No. 8 (2.36-mm)
No. 16 (1.18-mm)
No. 30 (600-µm)
No. 50 (300-µm)
No. 100 (150-µm)
No. 200 (75-µm)

3.7 *Water Bath or Constant-Temperature Room*—A water bath or constant-temperature room for maintaining the soil suspension at a constant temperature during the hydrometer analysis. A satisfactory water tank is an insulated tank that maintains the temperature of the suspension at a convenient constant temperature at or near 68°F (20°C). Such a device is illustrated in Fig. 4. In cases where the work is performed in a room at an automatically controlled constant temperature, the water bath is not necessary.

3.8 *Beaker*—A beaker of 250-mL capacity.

3.9 *Timing Device*—A watch or clock with a second hand.



Metric Equivalents

in.	1.3	2.6	3.75
mm	33	66	95.2

FIG. 2 Dispersion Cups of Apparatus

4. Dispersing Agent

4.1 A solution of sodium hexametaphosphate (sometimes called sodium metaphosphate) shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution (Note 7).

NOTE 7—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action. Solutions should be prepared frequently (at least once a month) or adjusted to pH of 8 or 9 by means of sodium carbonate. Bottles containing solutions should have the date of preparation marked on them.

4.2 All water used shall be either distilled or demineralized water. The water for a hydrometer test shall be brought to the temperature that is expected to prevail during the hydrometer test. For example, if the sedimentation cylinder is to be placed in the water bath, the distilled or demineralized water to be used shall be brought to the temperature of the controlled water bath; or, if the sedimentation cylinder is used in a room with controlled temperature, the water for the test shall be at the temperature of the room. The basic temperature for the hydrometer test is 68°F (20°C). Small variations of temperature do not introduce differences that are of practical significance and do not prevent the use of corrections derived as prescribed.

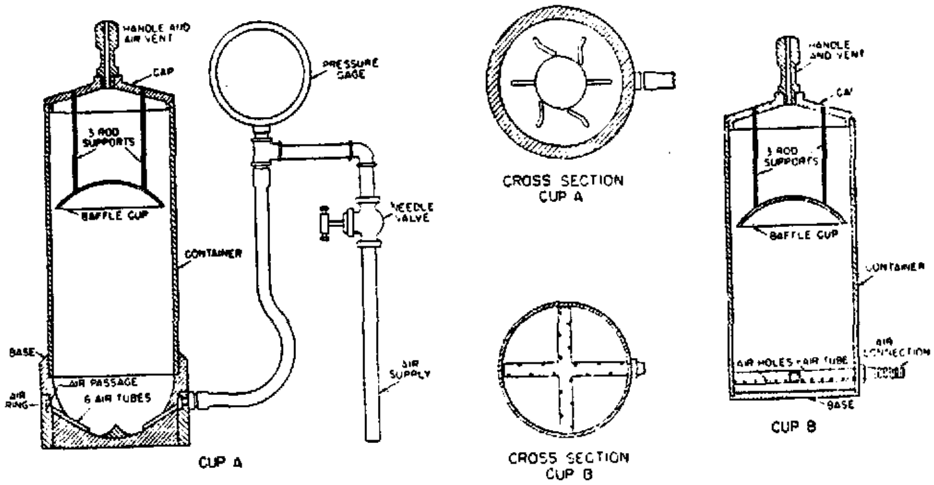


FIG. 3 Air-Jet Dispersion Cups of Apparatus B

5. Test Sample

5.1 Prepare the test sample for mechanical analysis as outlined in Practice D 421. During the preparation procedure the sample is divided into two portions. One portion contains only particles retained on the No. 10 (2.00-mm) sieve while the other portion contains only particles passing the No. 10 sieve. The mass of air-dried soil selected for purpose of tests, as prescribed in Practice D 421, shall be sufficient to yield quantities for mechanical analysis as follows:

5.1.1 The size of the portion retained on the No. 10 sieve shall depend on the maximum size of particle, according to the following schedule:

Nominal Diameter of Largest Particles, in. (mm)	Approximate Minimum Mass of Portion, g
⅜ (9.5)	500
¾ (19.0)	1000
1 (25.4)	2000
1½ (38.1)	3000
2 (50.8)	4000
3 (76.2)	5000

5.1.2 The size of the portion passing the No. 10 sieve shall be approximately 115 g for sandy soils and approximately 65 g for silt and clay soils.

5.2 Provision is made in *Section 5 of Practice D 421* for weighing of the air-dry soil selected for purpose of tests, the separation of the soil on the No. 10 sieve by dry-sieving and washing, and the weighing of the washed and dried fraction retained on the No. 10 sieve. From these two masses the percentages retained and passing the No. 10 sieve can be calculated in accordance with 12.1.

NOTE 8—A check on the mass values and the thoroughness of pulverization of the clods may be secured by weighing the portion passing the No. 10 sieve and adding this value to the mass of the washed and oven-dried portion retained on the No. 10 sieve.

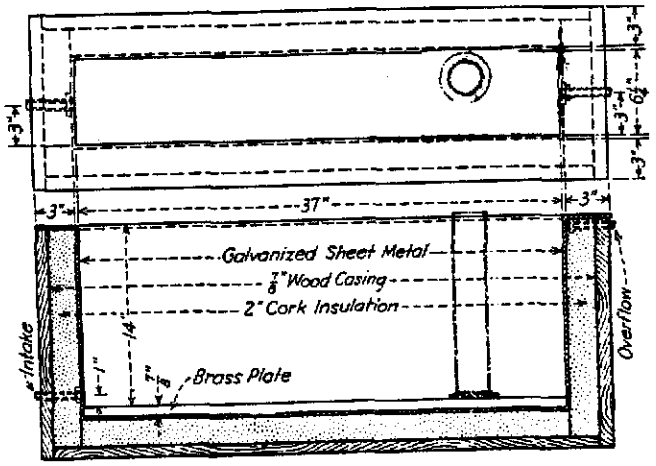
SIEVE ANALYSIS OF PORTION RETAINED ON NO. 10 (2.00-mm) SIEVE

6. Procedure

6.1 Separate the portion retained on the No. 10 (2.00-mm) sieve into a series of fractions using the 3-in. (75-mm), 2-in. (50-mm), 1½-in. (37.5-mm), 1-in. (25.0-mm), ¾-in. (19.0-mm), ⅜-in. (9.5-mm), No. 4 (4.75-mm), and No. 10 sieves, or as many as may be needed depending on the sample, or upon the specifications for the material under test.

6.2 Conduct the sieving operation by means of a lateral and vertical motion of the sieve, accompanied by a jarring action in order to keep the sample moving continuously over the surface of the sieve. In no case turn or manipulate fragments in the sample through the sieve by hand. Continue sieving until not more than 1 mass % of the residue on a sieve passes that sieve during 1 min of sieving. When mechanical sieving is used, test the thoroughness of sieving by using the hand method of sieving as described above.

6.3 Determine the mass of each fraction on a balance conforming to the requirements of 3.1. At the end of weighing, the sum of the masses retained on all the sieves used should equal closely the original mass of the quantity sieved.



Metric Equivalents

in.	⅞	1	3	6¼	14	37
mm	22.2	25.4	76.2	158.2	356	940

FIG. 4 Insulated Water Bath

HYDROMETER AND SIEVE ANALYSIS OF PORTION PASSING THE NO. 10 (2.00-mm) SIEVE

7. Determination of Composite Correction for Hydrometer Reading

7.1 Equations for percentages of soil remaining in suspension, as given in 14.3, are based on the use of distilled or demineralized water. A dispersing agent is used in the water, however, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

7.1.1 Both soil hydrometers are calibrated at 68°F (20°C), and variations in temperature from this standard temperature produce inaccuracies in the actual hydrometer readings. The amount of the inaccuracy increases as the variation from the standard temperature increases.

7.1.2 Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to secure readings of soil suspensions at the bottom of the meniscus, readings must be taken at the top and a correction applied.

7.1.3 The net amount of the corrections for the three items enumerated is designated as the composite correction, and may be determined experimentally.

7.2 For convenience, a graph or table of composite corrections for a series of 1° temperature differences for the range of expected test temperatures may be prepared and used as needed. Measurement of the composite corrections may be made at two temperatures spanning the range of expected test temperatures, and corrections for the intermediate temperatures calculated assuming a straight-line relationship between the two observed values.

7.3 Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportion as will prevail in the sedimentation (hydrometer) test. Place the liquid in a sedimentation cyclinder and the cylinder in the constant-temperature water bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and, after a short interval to permit the hydrometer to come to the temperature of the liquid, read the hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one; for hydrometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and secure the composite correction as before.

8. Hygroscopic Moisture

8.1 When the sample is weighed for the hydrometer test, weigh out an auxiliary portion of from 10 to 15 g in a small metal or glass container, dry the sample to a constant mass in an oven at 230 ± 9°F (110 ± 5°C), and weigh again. Record the masses.

9. Dispersion of Soil Sample

9.1 When the soil is mostly of the clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

9.2 Place the sample in the 250-mL beaker and cover with 125 mL of sodium hexametaphosphate solution (40 g/L). Stir until the soil is thoroughly wetted. Allow to soak for at least 16 h.

9.3 At the end of the soaking period, disperse the sample further, using either stirring apparatus A or B. If stirring apparatus A is used, transfer the soil - water slurry from the beaker into the special dispersion cup shown in Fig. 2, washing any residue from the beaker into the cup with distilled or demineralized water (Note 9). Add distilled or demineralized water, if necessary, so that the cup is more than half full. Stir for a period of 1 min.

NOTE 9—A large size syringe is a convenient device for handling the water in the washing operation. Other devices include the wash-water bottle and a hose with nozzle connected to a pressurized distilled water tank.

9.4 If stirring apparatus B (Fig. 3) is used, remove the cover cap and connect the cup to a compressed air supply by means of a rubber hose. A air gage must be on the line between the cup and the control valve. Open the control valve so that the gage indicates 1 psi (7 kPa) pressure (Note 10). Transfer the soil - water slurry from the beaker to the air-jet dispersion cup by washing with distilled or demineralized water. Add distilled or demineralized water, if necessary, so that the total volume in the cup is 250 mL, but no more.

NOTE 10—The initial air pressure of 1 psi is required to prevent the soil - water mixture from entering the air-jet chamber when the mixture is transferred to the dispersion cup.

9.5 Place the cover cap on the cup and open the air control valve until the gage pressure is 20 psi (140 kPa). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, min
Under 5	5
6 to 20	10
Over 20	15

Soils containing large percentages of mica need be dispersed for only 1 min. After the dispersion period, reduce the gage pressure to 1 psi preparatory to transfer of soil - water slurry to the sedimentation cylinder.

10. Hydrometer Test

10.1 Immediately after dispersion, transfer the soil - water slurry to the glass sedimentation cylinder, and add distilled or demineralized water until the total volume is 1000 mL.

10.2 Using the palm of the hand over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min to complete the agitation of the slurry (Note 11). At the end of 1 min set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE 11—The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns.

Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

10.3 When it is desired to take a hydrometer reading, carefully insert the hydrometer about 20 to 25 s before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

NOTE 12—It is important to remove the hydrometer immediately after each reading. Readings shall be taken at the top of the meniscus formed by the suspension around the stem, since it is not possible to secure readings at the bottom of the meniscus.

10.4 After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

11. Sieve Analysis

11.1 After taking the final hydrometer reading, transfer the suspension to a No. 200 (75-µm) sieve and wash with tap water until the wash water is clear. Transfer the material on the No. 200 sieve to a suitable container, dry in an oven at 230 ± 9°F (110 ± 5°C) and make a sieve analysis of the portion retained, using as many sieves as desired, or required for the material, or upon the specification of the material under test.

CALCULATIONS AND REPORT

12. Sieve Analysis Values for the Portion Coarser than the No. 10 (2.00-mm) Sieve

12.1 Calculate the percentage passing the No. 10 sieve by dividing the mass passing the No. 10 sieve by the mass of soil originally split on the No. 10 sieve, and multiplying the result by 100. To obtain the mass passing the No. 10 sieve, subtract the mass retained on the No. 10 sieve from the original mass.

12.2 To secure the total mass of soil passing the No. 4 (4.75-mm) sieve, add to the mass of the material passing the No. 10 sieve the mass of the fraction passing the No. 4 sieve and retained on the No. 10 sieve. To secure the total mass of soil passing the ⅜-in. (9.5-mm) sieve, add to the total mass of soil passing the No. 4 sieve, the mass of the fraction passing the ⅜-in. sieve and retained on the No. 4 sieve. For the remaining sieves, continue the calculations in the same manner.

12.3 To determine the total percentage passing for each sieve, divide the total mass passing (see 12.2) by the total mass of sample and multiply the result by 100.

13. Hygroscopic Moisture Correction Factor

13.1 The hydroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

14. Percentages of Soil in Suspension

14.1 Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

14.2 Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the No. 10 (2.00-mm) sieve, and multiplying the result by 100. This value is the weight W in the equation for percentage remaining in suspension.

TABLE 1 Values of Correction Factor, α, for Different Specific Gravities of Soil Particles[A]

Specific Gravity	Correction Factor[A]
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

[A] For use in equation for percentage of soil remaining in suspension when using Hydrometer 152H.

14.3 The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows (Note 13): For hydrometer 151H:

$$P = [(100\,000/W) \times G/(G - G_1)](R - G_1)$$

NOTE 13—The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) \times 100$$

where:

a = correction faction to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

P = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

R = hydrometer reading with composite correction applied (Section 7),

W = oven-dry mass of soil in a total test sample represented by mass of soil dispersed (see 14.2), g,

G = specific gravity of the soil particles, and

G_1 = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation. In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for R is based on a value of one for G_1.

15. Diameter of Soil Particles

15.1 The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law (Note 14), on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. According to Stokes' law:

$$D = \sqrt{[30n/980(G - G_1)] \times L/T}$$

where:

D = diameter of particle, mm,

n = coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),

L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth (Table 2)),

T = interval of time from beginning of sedimentation to the taking of the reading, min,

G = specific gravity of soil particles, and

G_l = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE 14—Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

15.2 For convenience in calculations the above equation may be written as follows:

$$D = K\sqrt{L/T}$$

where:

K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 3. The value of K does not change for a series of readings constituting a test, while values of L and T do vary.

15.3 Values of D may be computed with sufficient accuracy, using an ordinary 10-in. slide rule.

NOTE 15—The value of L is divided by T using the *A*- and *B*-scales, the square root being indicated on the *D*-scale. Without ascertaining the value of the square root it may be multiplied by K, using either the *C*- or *CI*-scale.

16. Sieve Analysis Values for Portion Finer than No. 10 (2.00-mm) Sieve

16.1 Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the No. 10 sieve had it not been removed. This mass is equal to the total percentage retained on the No. 10 sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in 14.2), and the result divided by 100.

16.2 Calculate next the total mass passing the No. 200 sieve. Add together the fractional masses retained on all the sieves, including the No. 10 sieve, and subtract this sum from the mass of the total sample (as calculated in 14.2).

16.3 Calculate next the total masses passing each of the other sieves, in a manner similar to that given in 12.2.

16.4 Calculate last the total percentages passing by dividing the total mass passing (as calculated in 16.3) by the total mass of sample (as calculated in 14.2), and multiply the result by 100.

17. Graph

17.1 When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an

TABLE 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes[A]

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.8	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

[A] Values of effective depth are calculated from the equation:

$$L = L_1 + \tfrac{1}{2}\left[L_2 - (V_B/A)\right]$$

where:

L = effective depth, cm,

L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm,

L_2 = overall length of the hydrometer bulb, cm,

V_B = volume of hydrometer bulb, cm^3, and

A = cross-sectional area of sedimentation cylinder, cm^2

Values used in calculating the values in Table 2 are as follows:

For both hydrometers, 151H and 152H:

L_2 = 14.0 cm

V_B = 67.0 cm^3

A = 27.8 cm^2

For hydrometer 151H:

L_1 = 10.5 cm for a reading of 1.000
= 2.3 cm for a reading of 1.031

For hydrometer 152H:

L_1 = 10.5 cm for a reading of 0 g/litre
= 2.3 cm for a reading of 50 g/litre

TABLE 3 Values of K for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature, °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.1323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

arithmetic scale as the ordinate. When the hydrometer analysis is not made on a portion of the soil, the preparation of the graph is optional, since values may be secured directly from tabulated data.

18. Report

18.1 The report shall include the following:

18.1.1 Maximum size of particles,

18.1.2 Percentage passing (or retained on) each sieve, which may be tabulated or presented by plotting on a graph (Note 16),

18.1.3 Description of sand and gravel particles:

18.1.3.1 Shape—rounded or angular,

18.1.3.2 Hardness—hard and durable, soft, or weathered and friable,

18.1.4 Specific gravity, if unusually high or low,

18.1.5 Any difficulty in dispersing the fraction passing the No. 10 (2.00-mm) sieve, indicating any change in type and amount of dispersing agent, and

18.1.6 The dispersion device used and the length of the dispersion period.

NOTE 16—This tabulation of graph represents the gradation of the sample tested. If particles larger than those contained in the sample were removed before testing, the report shall so state giving the amount and maximum size.

18.2 For materials tested for compliance with definite specifications, the fractions called for in such specifications shall be reported. The fractions smaller than the No. 10 sieve shall be read from the graph.

18.3 For materials for which compliance with definite specifications is not indicated and when the soil is composed almost entirely of particles passing the No. 4 (4.75-mm) sieve, the results read from the graph may be reported as follows:

(*1*) Gravel, passing 3-in. and retained on No. 4 sieve .... %
(*2*) Sand, passing No. 4 sieve and retained on No. 200 sieve .... %
  (*a*) Coarse sand, passing No. 4 sieve and retained on No. 10 sieve .... %
  (*b*) Medium sand, passing No. 10 sieve and retained on No. 40 sieve .... %
  (*c*) Fine sand, passing No. 40 sieve and retained on No. 200 sieve .... %
(*3*) Silt size, 0.074 to 0.005 mm .... %
(*4*) Clay size, smaller than 0.005 mm .... %
  Colloids, smaller than 0.001 mm .... %

18.4 For materials for which compliance with definite specifications is not indicated and when the soil contains material retained on the No. 4 sieve sufficient to require a sieve analysis on that portion, the results may be reported as follows (Note 17):

SIEVE ANALYSIS

Sieve Size	Percentage Passing
3-in.	....
2-in.	....
1½-in.	....
1-in.	....
¾-in.	....
⅜-in.	....
No. 4 (4.75-mm)	....
No. 10 (2.00-mm)	....
No. 40 (425-µm)	....
No. 200 (75-µm)	....

HYDROMETER ANALYSIS

0.074 mm	....
0.005 mm	....
0.001 mm	....

NOTE 17—No. 8 (2.36-mm) and No. 50 (300-µm) sieves may be substituted for No. 10 and No. 40 sieves.

19. Keywords

19.1 grain-size; hydrometer analysis; hygroscopic moisture; particle-size; sieve analysis

Designation: D 698 - 91

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Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))[1]

This standard is issued under the fixed designation D 698; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers laboratory compaction procedures used to determine the relationship between water content and dry unit weight of soils (compaction curve) compacted in a 4 or 6-in. (101.6 or 152.4-mm) diameter mold with a 5.5-lbf (24.4-N) rammer dropped from a height of 12 in. (305 mm) producing a compactive effort of 12,400 ft-lbf/ft^3 (600 kN-m/m^3).

NOTE 1—The equipment and procedures are similar as those proposed by R. R. Proctor (*Engineering News Record*—September 7, 1933) with this one major exception: his rammer blows were applied as "12 inch firm strokes" instead of free fall, producing variable compactive effort depending on the operator, but probably in the range 15,000 to 25,000 ft-lbf/ft^3 (700 to 1,200 kN-m/m^3). The standard effort test (see 3.2.2) is sometimes referred to as the Proctor Test.

NOTE 2—Soils and soil-aggregate mixtures should be regarded as natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

1.2 This test method applies only to soils that have 30 % or less by weight of particles retained on the ¾-inch (19.0-mm) sieve.

NOTE 3—For relationships between unit weights and water contents of soils with 30 % or less by weight of material retained on the ¾-in. (19.0-mm) sieve to unit weights and water contents of the fraction passing ¾-in. (19.0-mm) sieve, see Practice D 4718.

1.3 Three alternative procedures are provided. The procedure used shall be as indicated in the specification for the material being tested. If no procedure is specified, the choice should be based on the material gradation.

1.3.1 *Procedure A:*

1.3.1.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.1.2 *Material*—Passing No. 4 (4.75-mm) sieve.

1.3.1.3 *Layers*—Three.

1.3.1.4 *Blows per layer*—25.

1.3.1.5 *Use*—May be used if 20 % or less by weight of the material is retained on the No. 4 (4.75-mm) sieve.

1.3.1.6 *Other Use*—If this procedure is not specified, materials that meet these gradation requirements may be tested using Procedures B or C.

1.3.2 *Procedure B:*

1.3.2.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.2.2 *Material*—Passing ⅜-in. (9.5-mm) sieve.

1.3.2.3 *Layers*—Three.

1.3.2.4 *Blows per layer*—25.

1.3.2.5 *Use*—Shall be used if more than 20 % by weight of the material is retained on the No. 4 (4.75-mm) sieve and 20 % or less by weight of the material is retained on the ⅜-in. (9.5-mm) sieve.

1.3.2.6 *Other Use*—If this procedure is not specified, materials that meet these gradation requirements may be tested using Procedure C.

1.3.3 *Procedure C:*

1.3.3.1 *Mold*—6-in. (152.4-mm) diameter.

1.3.3.2 *Material*—Passing ¾-inch (19.0-mm) sieve.

1.3.3.3 *Layers*—Three.

1.3.3.4 *Blows per layer*—56.

1.3.3.5 *Use*—Shall be used if more than 20 % by weight of the material is retained on the ⅜-in. (9.5-mm) sieve and less than 30 % by weight of the material is retained on the ¾-in. (19.0-mm) sieve.

1.3.4 The 6-in. (152.4-mm) diameter mold shall not be used with Procedure A or B.

NOTE 4—Results have been found to vary slightly when a material is tested at the same compactive effort in different size molds.

1.4 If the test specimen contains more than 5 % by weight oversize fraction (coarse fraction) and the material will not be included in the test, corrections must be made to the unit weight and water content of the specimen or to the appropriate field in place density test specimen using Practice D 4718.

1.5 This test method will generally produce a well defined maximum dry unit weight for non-free draining soils. If this test method is used for free draining soils the maximum unit weight may not be well defined, and can be less than obtained using Test Methods D 4253.

1.6 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are provided for information only.

1.6.1 In the engineering profession it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations ($F = Ma$) are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is scientifically undesirable to combine the use of two separate systems within a single standard. This test method has been written using inch-pound units (gravimetric system) where the pound (lbf) represents a unit of force. The use of mass (lbm) is for convenience of units and is not intended to convey the use is scientifically correct. Conversions are given in the SI system in accordance with Practice E 380. The use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as nonconformance with this standard.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee *D18.03 on Texture, Plasticity and Density Characteristics of Soils.*

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1.7 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]

C 136 Method for Sieve Analysis of Fine and Coarse Aggregate[2]

D 422 Test Method for Particle Size Analysis of Soils[3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 854 Test Method for Specific Gravity of Soils[3]

D 1557 Test Methods for Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 10-lb (4.54-kg.) Rammer and 18-in. (457 mm) Drop[3]

D 2168 Test Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock and Soil-Aggregate Mixtures[3]

D 2487 Test Method for Classification of Soils for Engineering Purposes[3]

D 2488 Practice for Description of Soils (Visual-Manual Procedure)[3]

D 4220 Practices for Preserving and Transporting Soil Samples[3]

D 4253 Test Methods for Maximum Index Density of Soils Using a Vibratory Table[3]

D 4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles[3]

D 4753 Specification for Evaluating, Selecting and Specifying Balances and Scales For Use in Soil and Rock Testing[3]

E 1 Specification for ASTM Thermometers[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[5]

E 319 Practice for the Evaluation of Single-Pan Mechanical Balances[5]

E 380 Practice for Use of the International System of Units (SI) (the Modernized Metric System)[5]

3. Terminology

3.1 *Definitions*—See Terminology D 653 for general definitions.

3.2 *Description of Terms Specific to This Standard:*

3.2.1 *oversize fraction (coarse fraction), P_c* in %—the portion of total sample not used in performing the compaction test; it may be the portion of total sample retained on the No. 4 (4.75-mm), 3/8-in. (9.5-mm), or 3/4-in. (19.0-mm) sieve.

3.2.2 *standard effort*—the term for the 12,400 ft-lbf/ft^3 (600 kN-m/m^3) compactive effort applied by the equipment and procedures of this test.

3.2.3 *standard maximum dry unit weight, γ_{dmax}* in lbf/ft^3 (kN/m^3)—the maximum value defined by the compaction curve for a compaction test using standard effort.

3.2.4 *standard optimum water content, w_o* in %—the water content at which a soil can be compacted to the maximum dry unit weight using standard compactive effort.

3.2.5 *test fraction (finer fraction), P_F* in %—the portion of the total sample used in performing the compaction test; it is the fraction passing the No. 4 (4.75-mm) sieve in Procedure A, minus 3/8-in. (9.5-mm) sieve in Procedure B, or minus 3/4-in. (19.0-mm) sieve in Procedure C.

4. Summary of Test Method

4.1 A soil at a selected water content is placed in three layers into a mold of given dimensions, with each layer compacted by 25 or 56 blows of a 5.5-lbf (24.4-N) rammer dropped from a distance of 12-in. (305-mm), subjecting the soil to a total compactive effort of about 12,400 ft-lbf/ft^3 (600 kN-m/m^3). The resulting dry unit weight is determined. The procedure is repeated for a sufficient number of water contents to establish a relationship between the dry unit weight and the water content for the soil. This data, when plotted, represents a curvilinear relationship known as the compaction curve. The values of optimum water content and standard maximum dry unit weight are determined from the compaction curve.

5. Significance and Use

5.1 Soil placed as engineering fill (embankments, foundation pads, road bases) is compacted to a dense state to obtain satisfactory engineering properties such as, shear strength, compressibility, or permeability. Also, foundation soils are often compacted to improve their engineering properties. Laboratory compaction tests provide the basis for determining the percent compaction and water content needed t achieve the required engineering properties, and for controlling construction to assure that the required compaction an water contents are achieved.

5.2 During design of an engineered fill, shear, consolidation, permeability, or other tests require preparation of tes specimens by compacting at some water content to som unit weight. It is common practice to first determine th optimum water content (w_o) and maximum dry unit weigh (γ_{dmax}) by means of a compaction test. Test specimens ar compacted at a selected water content (w), either wet or dr of optimum (w_o) or at optimum (w_o), and at a selected dr unit weight related to a percentage of maximum dry uni weight (γ_{dmax}). The selection of water content (w), either we or dry of optimum (w_o) or at optimum (w_o) and the dry uni weight (γ_{dmax}) may be based on past experience, or a range o values may be investigated to determine the necessar percent of compaction.

6. Apparatus

6.1 *Mold Assembly*—The molds shall be cylindrical i shape, made of rigid metal and be within the capacity an dimensions indicated in 6.1.1 or 6.1.2 and Figs. 1 and 2. Th walls of the mold may be solid, split, or tapered. The "split type may consist of two half-round sections, or a section o

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

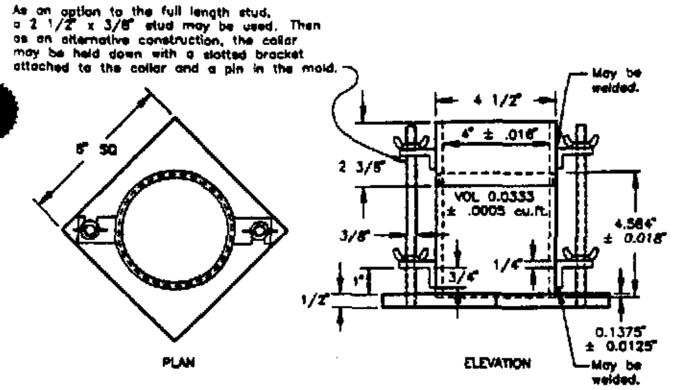

FIG. 1 4.0-in. Cylindrical Mold

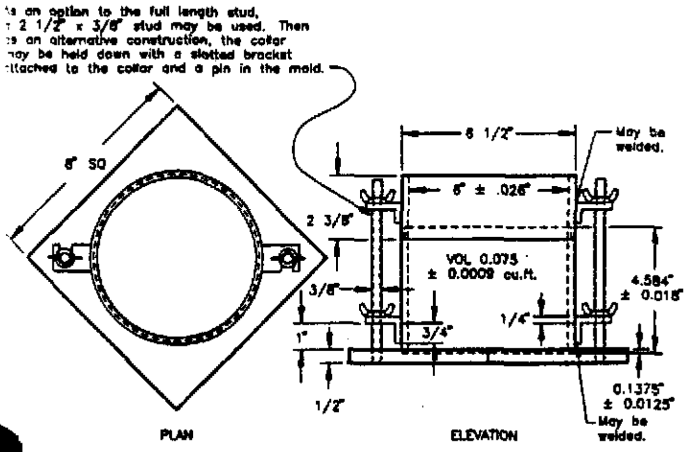

FIG. 2 6.0-in. Cylindrical Mold

pipe split along one element, which can be securely locked together to form a cylinder meeting the requirements of this section. The "tapered" type shall an internal diameter taper that is uniform and not more than 0.200 in./ft (16.7- mm/m) of mold height. Each mold shall have a base plate and an extension collar assembly, both made of rigid metal and constructed so they can be securely attached and easily detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2.0 in. (50.8-mm) which may include an upper section that flares out to form a funnel provided there is at least a 0.75 in. (19.0-mm) straight cylindrical section beneath it. The extension collar shall align with the inside of the mold. The bottom of the base plate and bottom of the centrally recessed area that accepts the cylindrical mold shall be planar.

6.1.1 *Mold, 4 in.*—A mold having a 4.000 ± 0.016-in. (101.6 ± 0.4-mm) average inside diameter, a height of 4.584 ± 0.018-in. (116.4 ± 0.5-mm) and a volume of 0.0333 ± 0.0005 ft^3 (944 ± 14 cm^3). A mold assembly having the minimum required features is shown in Fig. 1.

6.1.2 *Mold, 6 in.*—A mold having a 6.000 ± 0.026-in. (152.4 ± 0.7-mm) average inside diameter, a height of 4.584 ± 0.018-in. (116.4 ± 0.5-mm), and a volume of 0.075 ± 0.0009 ft^3 (2124 ± 25 cm^3). A mold assembly having the minimum required features is shown in Fig. 2.

6.2 *Rammer*—A rammer, either manually operated as described further in 6.2.1 or mechanically operated as described in 6.2.2. The rammer shall fall freely through a distance of 12 ± 0.05-in. (304.8 ± 1.3-mm) from the surface of the specimen. The mass of the rammer shall be 5.5 ± 0.02-lbm (2.5 ± 0.01-kg), except that the mass of the mechanical rammers may be adjusted as described in Test Methods D 2168, see Note 5. The striking face of the rammer shall be planar and circular, except as noted in 6.2.2.3, with a diameter when new of 2.000 ± 0.005-in. (50.80 ± 0.13-mm). The rammer shall be replaced if the striking face becomes worn or bellied to the extent that the diameter exceeds 2.000 ± 0.01-in. (50.80 ± 0.25-mm).

NOTE 5—It is a common and acceptable practice in the inch-pound system to assume that the mass of the rammer is equal to its mass determined using either a kilogram or pound balance and 1 lbf is equal to 1 lbm or 0.4536 kg. or 1 N is equal to 0.2248 lbm or 0.1020 kg.

6.2.1 *Manual Rammer*—The rammer shall be equipped with a guide sleeve that has sufficient clearance that the free fall of the rammer shaft and head is not restricted. The guide sleeve shall have at least four vent holes at each end (eight holes total) located with centers ¾ ± 1/16-in. (19.0 ± 1.6-mm) from each end and spaced 90 degrees apart. The minimum diameter of the vent holes shall be ⅜-in. (9.5-mm). Additional holes or slots may be incorporated in the guide sleeve.

6.2.2 *Mechanical Rammer-Circular Face*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03-in. (2.5 ± 0.8-mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. The mechanical rammer shall meet the calibration requirements of Test Methods D 2168. The mechanical rammer shall be equipped with a positive mechanical means to support the rammer when not in operation.

6.2.2.3 *Mechanical Rammer-Sector Face*—When used with the 6-in. (152.4-mm) mold, a sector face rammer may be used in place of the circular face rammer. The specimen contact face shall have the shape of a sector of a circle of radius equal to 2.90 ± 0.02-in. (73.7 ± 0.5-mm). The rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen.

6.3 *Sample Extruder (optional)*—A jack, frame or other device adapted for the purpose of extruding compacted specimens from the mold.

6.4 *Balance*—A class GP5 balance meeting the requirements of Specification D 4753 for a balance of 1-g readability.

6.5 *Drying Oven*—Thermostatically controlled, preferably of a forced-draft type and capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C) throughout the drying chamber.

6.6 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10-in. (254-mm). The total length of the straightedge shall be machined straight to a tolerance of ±0.005-in. (±0.1-mm). The scraping edge shall be beveled if it is thicker than ⅛-in. (3-mm).

6.7 *Sieves*—¾-in. (19.0-mm), ⅜-in. (9.5-mm), and No. 4 (4.75-mm), conforming to the requirements of Specification E 11.

6.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

7. Calibration

7.1 Perform calibrations before initial use, after repairs or other occurrences that might affect the test results, at intervals not exceeding 1,000 test specimens, or annually, whichever occurs first, for the following apparatus:

7.1.2 *Balance*—Evaluate in accordance with Specification D 4753.

7.1.3 *Molds*—Determine the volume as described in Annex 1.

7.1.4 *Manual Rammer*—Verify the free fall distance, rammer mass, and rammer face in accordance with Section 6.2. Verify the guide sleeve requirements in accordance with Section 6.2.1.

7.1.5 *Mechanical Rammer*—Calibrate and adjust the mechanical rammer in accordance with Test Methods D 2168. In addition, the clearance between the rammer and the inside surface of the mold shall be verified in accordance with 6.2.2.

8. Test Sample

8.1 The required sample mass for Procedures A and B is approximately 35-lbm (16-kg), and for Procedure C is approximately 65-lbm (29-kg) of dry soil. Therefore, the field sample should have a moist mass of at least 50-lbm (23-kg) and 100-lbm (45-kg), respectively.

8.2 Determine the percentage of material retained on the No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm) sieve as appropriate for choosing Procedure A, B, or C. Make this determination by separating out a representative portion from the total sample and determining the percentages passing the sieves of interest by Test Methods D 422 or Method C 136. It is only necessary to calculate percentages for the sieve or sieves for which information is desired.

9. Preparation of Apparatus

9.1 Select the proper compaction mold in accordance with the procedure (A, B, or C) being used. Determine and record its mass to the nearest gram. Assemble the mold, base and extension collar. Check the alignment of the inner wall of the mold and mold extension collar. Adjust if necessary.

9.2 Check that the rammer assembly is in good working condition and that parts are not loose or worn. Make any necessary adjustments or repairs. If adjustments or repairs are made, the rammer must be recalibrated.

10. Procedure

10.1 *Soils:*

10.1.1 Do not reuse soil that has been previously laboratory compacted.

10.1.2 When using this test method for soils containing hydrated halloysite, or where past experience with a particular soil indicates that results will be altered by air drying, use the moist preparation method (see 10.2).

10.1.3 Prepare the soil specimens for testing in accordance with 10.2 (preferred) or with 10.3.

10.2 *Moist Preparation Method (preferred)*—Without previously drying the sample, pass it through a No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm) sieve, depending on the procedure (A, B, or C) being used. Determine the water content of the processed soil.

10.2.1 Prepare at least four (preferably five) specimens having water contents such that they bracket the estimated optimum water content. A specimen having a water content close to optimum should be prepared first by trial additions of water and mixing (see Note 6). Select water contents for the rest of the specimens to provide at least two specimens wet and two specimens dry of optimum, and water contents varying by about 2 %. At least two water contents are necessary on the wet and dry side of optimum to accurately define the dry unit weight compaction curve (see 10.5). Some soils with very high optimum water content or a relatively flat compaction curve may require larger water content increments to obtain a well defined maximum dry unit weight. Water content increments should not exceed 4 %.

NOTE 6—With practice it is usually possible to visually judge a point near optimum water content. Typically, soil at optimum water content can be squeezed into a lump that sticks together when hand pressure is released, but will break cleanly into two sections when "bent". At water contents dry of optimum soils tend to crumble; wet of optimum soils tend to stick together in a sticky cohesive mass. Optimum water content is typically slightly less than the plastic limit.

10.2.2 Use approximately 5-lbm (2.3-kg) of the sieved soil for each specimen to be compacted using Procedure A or B, or 13-lbm (5.9-kg) using Procedure C. To obtain the specimen water contents selected in 10.2.1, add or remove the required amounts of water as follows: to add water, spray it into the soil during mixing; to remove water, allow the soil to dry in air at ambient temperature or in a drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Mix the soil frequently during drying to maintain an even water content distribution. Thoroughly mix each specimen to ensure even distribution of water throughout and then place in a separate covered container and allow to stand in accordance with Table 1 prior to compaction. For the purpose of selecting a standing time, the soil may be classified using Test Method D 2487, Practice D 2488 or data on other samples from the same material source. For referee testing, classification shall be by Test Method D 2487.

10.3 *Dry Preparation Method*—If the sample is too damp to be friable, reduce the water content by air drying until the material is friable. Drying may be in air or by the use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). Thoroughly break up the aggregations in such a manner as to avoid breaking individual particles. Pass the material through the appropriate sieve: No. 4 (4.75-mm), ⅜-in. (9.5-mm), or ¾-in. (19.0-mm). When preparing the material by passing over the ¾-in. sieve for compaction in the 6-in. mold, break up aggregations sufficiently to at least pass the ⅜-in. sieve in order to facilitate the distribution of water throughout the soil in later mixing.

10.3.1 Prepare at least four (preferably five) specimens in accordance with 10.2.1.

10.3.2 Use approximately 5-lbm (2.3-kg) of the sieved soil for each specimen to be compacted using Procedure A or B,

TABLE 1 Required Standing Times of Moisturized Specimens

Classification	Minimum Standing Time, h
GW, GP, SW, SP	No Requirement
GM, SM	3
All other soils	16

TABLE 2 Metric Equivalents for Figs. 1 and 2

in.	mm
0.016	0.41
0.026	0.66
0.032	0.81
0.028	0.71
$\frac{1}{2}$	12.70
$2\frac{1}{2}$	63.50
$2\frac{5}{8}$	66.70
4	101.60
$4\frac{1}{2}$	114.30
4.584	116.43
$4\frac{3}{4}$	120.60
6	152.40
$6\frac{1}{2}$	165.10
$6\frac{5}{8}$	168.30
$6\frac{3}{4}$	171.40
$8\frac{1}{4}$	209.60
ft^3	cm^3
$\frac{1}{30}$ (0.0333)	943
0.0005	14
$\frac{1}{13.333}$ (0.0750)	2,124
0.0011	31

or 13-lbm (5.9-kg) using Procedure C. Add the required amounts of water to bring the water contents of the specimens to the values selected in 10.3.1. Follow the specimen preparation procedure specified in 10.2.2 for drying the soil or adding water into the soil and curing each test specimen.

10.4 *Compaction*—After curing, if required, each specimen shall be compacted as follows:

10.4.1 Determine and record the mass of the mold or mold and base plate.

10.4.2 Assemble and secure the mold and collar to the base plate. The mold shall rest on a uniform rigid foundation, such as provided by a cylinder or cube of concrete with a mass of not less than 200-lbm (91-kg). Secure the base plate to the rigid foundation. The method of attachment to the rigid foundation shall allow easy removal of the assembled mold, collar and base plate after compaction is completed.

10.4.3 Compact the specimen in three layers. After compaction, each layer should be approximately equal in thickness. Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a fluffy or loose state, using either the manual compaction rammer or a 2-in. (5-mm) diameter cylinder. Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed. The trimmed soil may be included with the additional soil for the next layer. A knife or other suitable device may be used. The total amount of soil used shall be such that the third compacted layer slighly extends into the collar, but does not exceed $\frac{1}{4}$-in. (6-mm) above the top of the mold. If the third layer does extend above the top of the mold by more than $\frac{1}{4}$-in. (6-mm), the specimen shall be discarded. The specimen shall be discarded when the last blow on the rammer for the third layer results in the bottom of the rammer extending below the top of the compaction mold.

10.4.4 Compact each layer with 25 blows for the 4-in. (101.6-mm) mold or with 56 blows for the 6-in. (152.4-mm) mold.

NOTE 7—When compacting specimens wetter than optimum water content, uneven compacted surfaces can occur and operator judgement is required as to the average height of the specimen.

10.4.5 In operating the manual rammer, take care to avoid lifting the guide sleeve during the rammer upstroke. Hold the guide sleeve steady and within 5° of vertical. Apply the blows at a uniform rate of approximately 25 blows/min and in such a manner as to provide complete, uniform coverage of the specimen surface.

10.4.6 Following compaction of the last layer, remove the collar and base plate from the mold, except as noted in 10.4.7. A knife may be used to trim the soil adjacent to the collar to loosen the soil from the collar before removal to avoid disrupting the soil below the top of the mold.

10.4.7 Carefully trim the compacted specimen even with the top of the mold by means of the straightedge scraped across the top of the mold to form a plane surface even with the top of the mold. Initial trimming of the specimen above the top of the mold with a knife may prevent the soil from tearing below the top of the mold. Fill any holes in the top surface with unused or trimmed soil from the specimen, press in with the fingers, and again scrape the straightedge across the top of the mold. Repeat the appropriate preceding operations on the bottom of the specimen when the mold volume was determined without the base plate. For very wet or dry soils, soil or water may be lost if the base plate is removed. For these situations, leave the base plate attached to the mold. When the base plate is left attached, the volume of the mold must be calibrated with the base plate attached to the mold rather than a plastic or glass plate as noted in Annex 1, A1.4.

10.4.8 Determine and record the mass of the specimen and mold to the nearest gram. When the base plate is left attached, determine and record the mass of the specimen, mold and base plate to the nearest gram.

10.4.9 Remove the material from the mold. Obtain a specimen for water content by using either the whole specimen (preferred method) or a representative portion. When the entire specimen is used, break it up to facilitate drying. Otherwise, obtain a portion by slicing the compacted specimen axially through the center and removing about 500-g of material from the cut faces. Obtain the water content in accordance with Test Method D 2216.

10.5 Following compaction of the last specimen, compare the wet unit weights to ensure that a desired pattern of obtaining data on each side of the optimum water content will be attained for the dry unit weight compaction curve. Plotting the wet unit weight and water content of each compacted specimen can be an aid in making the above evaluation. If the desired pattern is not obtained, additional compacted specimens will be required. Generally, one water content value wet of the water content defining the maximum wet unit weight is sufficient to ensure data on the wet side of optimum water content for the maximum dry unit weight.

11. Calculation

11.1 Calculate the dry unit weight and water content of each compacted specimen as explained in 11.3 and 11.4. Plot the values and draw the compaction curve as a smooth curve through the points (see example, Fig. 3). Plot dry unit weight

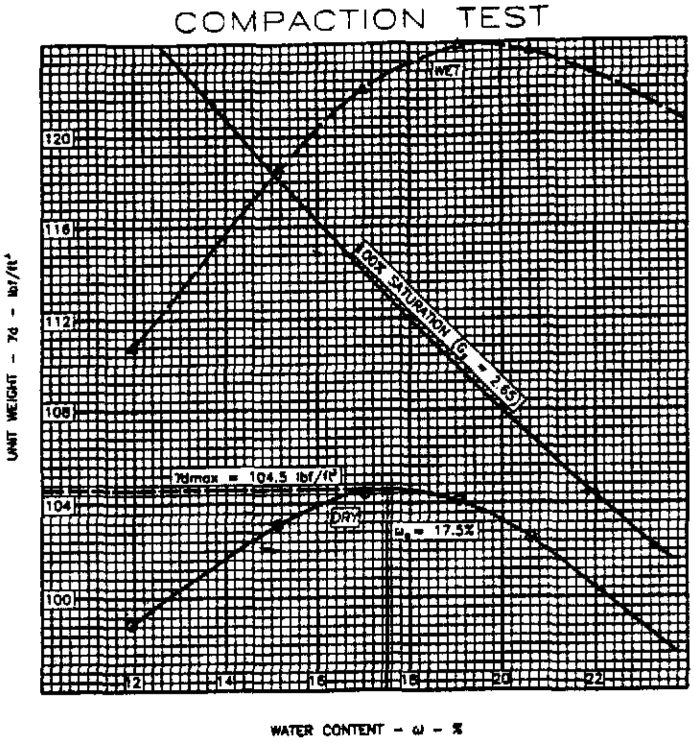

FIG. 3 Example Compaction Curve Plotting

to the nearest 0.1 lbf/ft³ (0.2 kN/m³) and water content to the nearest 0.1 %. From the compaction curve, determine the optimum water content and maximum dry unit weight. If more than 5 % by weight of oversize material was removed from the sample, calculate the corrected optimum water content and maximum dry unit weight of the total material using Practice D 4718. This correction may be made to the appropriate field in place density test specimen rather than to the laboratory test specimen.

11.2 Plot the 100 % saturation curve. Values of water content for the condition of 100 % saturation can be calculated as explained in 11.5 (see example. Fig. 3).

NOTE 8—The 100 % saturation curve is an aid in drawing the compaction curve. For soils containing more than approximately 10 % fines at water contents well above optimum. the two curves generally become roughly parallel with the wet side of the compaction curve between 92 % to 95 % saturation. Theoretically, the compaction curve cannot plot to the right of the 100 % saturation curve. If it does. there is an error in specific gravity, in measurements, in calculations, in test procedures, or in plotting.

NOTE 9—The 100 % saturation curve is sometimes referred to as the zero air voids curve or the complete saturation curve.

11.3 *Water Content*, *w*—Calculate in accordance with Test Method D 2216.

11.4 *Dry Unit Weights*—Calculate the moist density (Eq. 1), the dry density (Eq. 2), and then the dry unit weight (Eq. 3) as follows:

$$\rho_m = 1000(M_t - M_{md})/V \qquad (1)$$

where:

ρ_m = moist density of compacted specimen, Mg/m³.
M_t = mass of moist specimen and mold, kg,
M_{md} = mass of compaction mold, kg, and
V = volume of compaction mold, m³ (see Annex 1)

$$\rho_d = \rho_m/(1 + w/100) \qquad (2)$$

where:

ρ_d = dry density of compacted specimen, Mg/m³, and
w = water content, %.

$$\gamma_d = 62.43\ \rho_d \text{ in lbf/ft}^3 \qquad (3)$$

or

$$\gamma_d = 9.807\ \rho_d \text{ in kN/m}^3$$

where:

γ_d = dry unit weight of compacted specimen.

11.5 To calculate points for plotting the 100 % saturation curve or zero air voids curve select values of dry unit weight, calculate corresponding values of water content corresponding to the condition of 100 % saturation as follows:

$$w_{sat}\ \frac{(\gamma_w)(G_s) - \gamma_d}{(\gamma_d)(G_s)} \times 100 \qquad (4)$$

where:

w_{sat} = water content for complete saturation, %,
γ_w = unit weight of water, 62.43 lbf/ft³ (9.807 kn/m³),
γ_d = dry unit weight of soil, and
G_s = specific gravity of soil.

NOTE 10—Specific gravity may be estimated for the test specimen on the basis of test data from other samples of the same soil classification and source. Otherwise, a specific gravity test (Test Method C 127, Test Method D 854, or both) is necessary.

12. Report

12.1 The report shall contain the following information:

12.1.1 Procedure used (A, B, or C).

12.1.2 Preparation method used (moist or dry).

12.1.3 As received water content if determined.

12.1.4 Standard optimum water content, to the nearest 0.5 %.

12.1.5 Standard maximum dry unit weight, to the nearest 0.5 lbf/ft³.

12.1.6 Description of rammer (manual or mechanical).

12.1.7 Soil sieve data when applicable for determination of procedure (A, B, or C) used.

12.1.8 Description of material used in test, by Practice D 2488, or classification by Test Method D 2487.

12.1.9 Specific gravity and method of determination.

12.1.10 Origin of material used in test, for example. project, location, depth, and the like.

12.1.11 Compaction curve plot showing compaction points used to establish compaction curve, and 100 % saturation curve, point of maximum dry unit weight and optimum water content.

12.1.12 Oversize correction data if used, including the oversize fraction (coarse fraction), P_c in %.

13. Precision and Bias

13.1 *Precision*—Data are being evaluated to determine the precision of this test method. In addition, pertinent data is being solicited from users of the test method.

13.2 *Bias*—It is not possible to obtain information on bias because there is no other method of determining the values of standard maximum dry unit weight and optimum water content.

14. Keywords

14.1 NT—impact compaction using standard effort; RT—density; RT—moisture-density curves; RT—proctor test; UF—compaction characteristics; UF—soil compaction; USE—laboratory tests

ANNEX

(Mandatory Information)

A1. VOLUME OF COMPACTION MOLD

A1.1 Scope

A1.1.1 This annex describes the procedure for determining the volume of a compaction mold.

A1.1.2 The volume is determined by a water-filled method and checked by a linear-measurement method.

A1.2 Apparatus

A1.2.1 In addition to the apparatus listed in Section 6 the following items are required:

A1.2.1.1 *Vernier or Dial Caliper*—having a measuring range of at least 0 to 6 in. (0 to 150 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.2 *Inside Micrometer*—having a measuring range of at least 2 to 12 in. (50 to 300 mm) and readable to at least 0.001 in. (0.02 mm).

A1.2.1.3 *Plastic or Glass Plates*—Two plastic or glass plates approximately 8 in. square by ¼ in. thick (200 by 200 mm by 6 mm).

A1.2.1.4 *Thermometer*—0 to 50°C range, 0.5°C graduations, conforming to the requirements of Specification E 1.

A1.2.1.5 *Stopcock grease* or similar sealant.

A1.2.1.6 *Miscellaneous equipment*—Bulb syringe, towels, etc.

A1.3 Precautions

A1.3.1 Perform this procedure in an area isolated from drafts or extreme temperature fluctuations.

A1.4 Procedure

A1.4.1 *Water-Filling Method:*

A1.4.1.1 Lightly grease the bottom of the compaction mold and place it on one of the plastic or glass plates. Lightly grease the top of the mold. Be careful not to get grease on the inside of the mold. If it is necessary to use the base plate, as noted in 10.4.7, place the greased mold onto the base plate and secure with the locking studs.

A1.4.1.2 Determine the mass of the greased mold and both plastic or glass plates to the nearest 0.01-lbm (1-g) and record. When the base plate is being used in lieu of the bottom plastic or glass plate determine the mass of the mold, base plate and a single plastic or glass plate to be used on top of the mold to the nearest 0.01-lbm (1-g) and record.

A1.4.1.3 Place the mold and the bottom plastic or glass plate on a firm, level surface and fill the mold with water to slightly above its rim.

A1.4.1.4 Slide the second plate over the top surface of the mold so that the mold remains completely filled with water and air bubbles are not entrapped. Add or remove water as necessary with a bulb syringe.

A1.4.1.5 Completely dry any excess water from the outside of the mold and plates.

A1.4.1.6 Determine the mass of the mold, plates and water and record to the nearest 0.01-lbm (1-g).

A1.4.1.7 Determine the temperature of the water in the mold to the nearest 1°C and record. Determine and record the absolute density of water from Table A1.1.

A1.4.1.8 Calculate the mass of water in the mold by subtracting the mass determined in A1.4.1.2 from the mass determined in A1.4.1.6.

A1.4.1.9 Calculate the volume of water by dividing the mass of water by the density of water and record to the nearest 0.0001 ft^3 (1 cm^3).

A1.4.1.10 When the base plate is used for the calibration of the mold volume repeat A1.4.1.3 through A1.4.1.9.

A1.4.2 *Linear Measurement Method:*

A1.4.2.1 Using either the vernier caliper or the inside micrometer, measure the diameter of the mold 6 times at the top of the mold and 6 times at the bottom of the mold, spacing each of the six top and bottom measurements equally around the circumference of the mold. Record the values to the nearest 0.001-in. (0.02-mm).

A1.4.2.2 Using the vernier caliper, measure the inside height of the mold by making three measurements equally spaced around the circumference of the mold. Record values to the nearest 0.001-in. (0.02-mm).

A1.4.2.3 Calculate the average top diameter, average bottom diameter and average height.

A1.4.2.4 Calculate the volume of the mold and record to the nearest 0.0001 ft^3 (1 cm^3) as follows:

$$V = \frac{(\pi)(h)(d_t + d_b)^2}{(16)(1728)} \text{ (inch-pound)}$$

$$V = \frac{(\pi)(h)(d_t + d_b)^2}{(16)(10^3)} \text{ (SI)}$$

TABLE A1 Density of Water[A]

Temperature, °C (°F)	Density of Water, g/ml
18 (64.4)	0.99862
19 (66.2)	0.99843
20 (68.0)	0.99823
21 (69.8)	0.99802
22 (71.6)	0.99779
23 (73.4)	0.99756
24 (75.2)	0.99733
25 (77.0)	0.99707
26 (78.8)	0.99681

[A] Values other than shown may be obtained by referring to the Handbook of Chemistry and Physics, Chemical Rubber Publishing Co., Cleveland, Ohio.

where:

V = volume of mold, ft^3 (cm^3),
h = average height, in. (mm),
d_t = average top diameter, in. (mm),
d_b = average bottom diameter, in. (mm),
$1/1728$ = constant to convert in^3 to ft^3, and
$1/10^3$ = constant to convert mm^3 to cm^3.

A1.5 Comparison of Results

A1.5.1 The volume obtained by either method should be within the volume tolerance requirements of 6.1.1 and 6.1.2.

A1.5.2 The difference between the two methods should not exceed 0.5 % of the nominal volume of the mold.

A1.5.3 Repeat the determination of volume if these criteria are not met.

A1.5.4 Failure to obtain satisfactory agreement between the two methods, even after several trials, is an indication that the mold is badly deformed and should be replaced.

A1.5.5 Use the volume of the mold determined using the water-filling method as the assigned volume value for calculating the moist and dry density (see 11.4).

Designation: D 854 – 92$^{\epsilon 1}$

Standard Test Method for Specific Gravity of Soils[1]

This standard is issued under the fixed designation D 854: the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ NOTE—Editorial changes were made throughout in September 1993.

1. Scope

1.1 This test method covers the determination of the specific gravity of soils that pass the 4.75-mm (No. 4) sieve, by means of a pycnometer. When the soil contains particles larger than the 4.75-mm sieve, Test Method C 127 shall be used for the material retained on the 4.75-mm sieve and this test method shall be used for the material passing the 4.75-mm sieve.

1.1.1 Two procedures for performing the specific gravity are provided as follows:

1.1.1.1 *Method A*—Procedure for Oven-Dry Specimens, described in 9.1.

1.1.1.2 *Method B*—Procedure for Moist Specimens, described in 9.2. The procedure to be used shall be specified by the requesting authority. For specimens of organic soils and highly plastic, fine-grained soils, Procedure B shall be the preferred method.

1.2 When the specific gravity value is to be used in calculations in connection with the hydrometer portion of Test Method D 422, it is intended that the specific gravity test be made on that portion of the sample which passes the 2.00-mm (No. 10) sieve.

1.3 The values stated in acceptable metric units are to be regarded as standard.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]
D 422 Test Method for Particle-Size Analysis of Soils[3]
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]
D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)[3]
D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing[3]
E 1 Specification for ASTM Thermometers[4]
E 11 Specification for Wire-Cloth Sieves for Testing Purposes[5]
E 12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases[6]

2.2 *AASHTO Standards:*[7]

AASHTO Test Method T100

3. Terminology

3.1 All definitions are in accordance with Terminology D 653 and E 12.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *specific gravity*—the ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

4. Significance and Use

4.1 The specific gravity of a soil is used in calculating the phase relationships of soils (that is, the relative volumes of solids to water and air in a given volume of soil).

4.2 The term solid particles is typically assumed to mean naturally occurring mineral particles that are not readily soluble in water. Therefore, the specific gravity of materials containing extraneous matter (such as cement, lime, and the like), water-soluble matter (such as sodium chloride), and soils containing matter with a specific gravity less than one, typically require special treatment or a qualified definition of their specific gravity.

5. Apparatus

5.1 *Pycnometer*—The pycnometer shall be one of the following:

5.1.1 *Volumetric Flask*, having a capacity of at least 100 mL.

5.1.2 *Stoppered Bottle*, having a capacity of at least 50 mL. The stopper shall be of the same material, and shall permit the emission of air and surplus water when it is put in place.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 15.05.

[7] Available from American Association of State Highway and Transportation Officials, 444 N Capital St., NW, Washington, DC 20001.

NOTE 1—Flask sizes of larger than the specified minimum capacity are recommended. Larger flasks are capable of holding larger specimens and tend to produce better statistical results.

5.2 *Balance*—Meeting the requirements of Specification D-4753 and readable, without estimation, to at least 0.1 % of the specimen mass.

5.3 *Drying Oven*—Thermostatically-controlled oven, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F) throughout the drying chamber.

5.4 *Thermometer*, capable of measuring the temperature range within which the test is being performed, graduated in a 0.5°C (1.0°F) division scale and meeting the requirements of Specification E 1.

5.5 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulfate.[8]

NOTE 2—It is preferable to use a desiccant that changes color to indicate when it needs reconstitution.

5.6 *Entrapped Air Removal Apparatus*—To remove entrapped air, use one of the following:

5.6.1 *Hot Plate or Bunsen Burner*, capable of maintaining a temperature adequate to boil water.

5.6.2 *Vacuum System*, a vacuum pump or water aspirator, capable of producing a partial vacuum of 100 min or less absolute pressure.

NOTE 3—A partial vacuum of 100 mm Hg absolute pressure is approximately equivalent to a 660 mm (26 in.) Hg reading on vacuum gauge at sea level.

5.7 *Miscellaneous Equipment*, specimen dishes and insulated gloves.

6. Reagents and Materials

6.1 *Purity of Water*—Where distilled water is referred to in this test method, either distilled or demineralized water may be used.

7. Test Specimen

7.1 The test specimen may be oven-dried or moist soil and shall be representative of the total sample. In either case the specimen shall be large enough that its minimum mass in the oven-dried state is in accordance with the following:

Maximum Particle Size (100 % passing)	Standard Sieve Size	Minimum Mass of Test Specimen, g
2 mm	No. 10	20
4.75 mm	No. 4	100

8. Calibration of Pycnometer

8.1 Determine and record the mass of a clean, dry pycnometer, M_f.

8.2 Fill the pycnometer with distilled water to the calibration mark. Visually inspect the pycnometer and its contents to ensure that there are no air bubbles in the distilled water. Determine and record the mass of the pycnometer and water, M_a.

8.3 Insert a thermometer in the water, and determine and record its temperature, T_a, to the nearest 0.5°C (1.0°F).

8.4 From the mass, M_a, determined at the observed temperature, T_a, prepare a table of values of mass, M_a, for a series of temperatures that are likely to prevail when the mass of the pycnometer, soil, and water, M_b, is determined later. These values of M_a can be determined experimentally or may be calculated as follows:

$$M_a \text{ (at } T_x) = [(\text{density of water at } T_x/\text{density of water at } T_a) \times (M_a \text{ (at } T_a) - M_f)] + M_f$$

where:

M_a = mass of pycnometer and water, g,
M_f = mass of pycnometer, g,
T_a = observed temperature of water, °C, and
T_x = any other desired temperature, °C.

NOTE 4—This test method provides a procedure that is more convenient for laboratories making many determinations with the same pycnometer. It is equally applicable to a single determination. Bringing the pycnometer and contents to some designated temperature when masses M_a and M_b are taken, requires considerable time. It is important that masses M_a and M_b be based on water at the same temperature. Values for the density of water at temperatures from 16.0 to 30.0°C are given in Table 1.

9. Procedure

9.1 *Test Method A—Procedure For Oven-Dried Specimens:*

9.1.1 Dry the specimen to a constant mass in an oven maintained at 110 ± 5°C (230 ± 9°F) (See Note 5) and cool it in a desiccator.

NOTE 5—Drying of certain soils at 110°C (230°F) may bring about loss of water of composition or hydration, and in such cases drying may be done in reduced air pressure or at a lower temperature.

9.1.2 Determine and record the mass of a clean, dry, calibrated pycnometer, M_f. Select a pycnometer of sufficient capacity that the volume filled to the mark will be at least 50

TABLE 1 Density of Water and Correction Factor *K* for Various Temperatures

Temperature, °C	Density of Water (g/mL)	Correction Factor *K*
16.0	0.99897	1.0007
16.5	0.99889	1.0007
17.0	0.99880	1.0006
17.5	0.99871	1.0005
18.0	0.99862	1.0004
18.5	0.99853	1.0003
19.0	0.99843	1.0002
19.5	0.99833	1.0001
20.0	0.99823	1.0000
20.5	0.99812	0.9999
21.0	0.99802	0.9998
21.5	0.99791	0.9997
22.0	0.99780	0.9996
22.5	0.99768	0.9995
23.0	0.99757	0.9993
23.5	0.99745 .00013	0.9992
24.0	0.99732	0.9991
24.5	0.99720 .00012	0.9990
25.0	0.99707	0.9988
25.5	0.99694	0.9987
26.0	0.99681	0.9986
26.5	0.99668	0.9984
27.0	0.99654	0.9983
27.5	0.99640	0.9982
28.0	0.99626	0.9980
28.5	0.99612	0.9979
29.0	0.99597	0.9977
29.5	0.99582	0.9976
30.0	0.99567	0.9974

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[8] Anhydrous calcium sulfate is sold under the trade name Drierite.

percent greater than the space required to accommodate the test specimen. Place the specimen in the pycnometer. Determine the mass of the specimen and pycnometer, and subtract the mass of the pycnometer, M_f, from this value to determine the mass of the oven-dry specimen, M_o.

9.1.3 Fill the pycnometer with distilled water to a level slightly above that required to cover the soil and soak the specimen for at least 12 h.

NOTE 6—For some soils containing a significant fraction of organic matter, kerosine is a better wetting agent than water and may be used in place of distilled water for oven-dried specimens. If kerosine is used, the entrapped air should only be removed by use of an aspirator. Kerosine is a flammable liquid that must be used with extreme caution.

NOTE 7—Adding distilled water to just cover the soil makes it easier to control boil-over during removal of entrapped air.

9.1.4 Remove the entrapped air by one of the following methods:

9.1.4.1 Boil the specimen gently for at least 10 min while agitating the pycnometer occasionally to assist in the removal of air. Then cool the heated specimen to room temperature.

9.1.4.2 Subject the contents to a vacuum (air pressure not exceeding 100 mm Hg) for at least 30 min (Note 8) either by connecting the pycnometer directly to an aspirator or vacuum pump or by use of a bell jar. While the vacuum is being applied, gently agitate the pycnometer periodically to assist in the removal of air. Some soils boil violently when subjected to reduced air pressure. It will be necessary in those cases to reduce the air pressure at a slower rate or to use a larger flask.

NOTE 8—Specimens with a high plasticity at the natural water content may require 6 to 8 h to remove entrapped air. Specimens with a low plasticity at the natural water content may require 4 to 6 h to remove entrapped air. Oven-dried specimens may require 2 to 4 h to remove entrapped air.

9.1.5 Fill the pycnometer to just below the calibration mark with distilled water at room temperature. Add the distilled water slowly and carefully to avoid the entrapment of air bubbles in the specimen (Note 9). Allow the pycnometer to obtain a uniform water temperature (Note 10).

NOTE 9—To avoid the entrapment of air bubbles, the distilled water can be introduced through a piece of small-diameter flexible tubing with its outlet end kept just below the surface of the distilled water in the pycnometer.

NOTE 10—To obtain a uniform water temperature the pycnometer may be allowed to sit overnight or be placed in a constant temperature bath.

9.1.6 Fill the pycnometer with distilled water at the same temperature to the mark, clean the outside, and dry with a clean, dry cloth. Determine and record the mass of the pycnometer filled with soil and water, M_b.

9.1.7 Insert a thermometer into the water, and determine and record its temperature, T_b, to the nearest 0.5°C (1.0°F).

9.2 *Test Method B—Procedure For Moist Specimens:*

9.2.1 Place the specimen in a calibrated pycnometer.

9.2.1.1 Disperse specimens of clay soils in distilled water before they are placed in the pycnometer, by use of the dispersing equipment specified in Test Method D 422. The minimum volume of slurry that can be prepared by this dispersing equipment is such that a 500-mL (or larger) flask is needed as a pycnometer.

9.2.2 Proceed as described in Sections 9.1.4 and 9.1.7.

9.2.3 Remove the specimen from the pycnometer. Dry the specimen to a constant mass in a suitable container in an oven maintained at 110 ± 5°C (230 ± 9°F) (See Note 5). Cool the specimen in a desiccator.

9.2.4 Determine and record the mass of the oven-dried soil, M_o.

10. Calculation

10.1 Calculate the specific gravity of the soil, G, to the nearest 0.01, based on water at a temperature (T_b) as follows:

$$G \text{ at } T_b = M_o/[M_o + (M_a - M_b]$$

where:

M_o = mass of sample of oven-dry soil, g,

M_a = mass of pycnometer filled with water at temperature T_b (Note 11), g,

M_b = mass of pycnometer filled with water and soil at temperature T_b, g,

T_b = temperature of the contents of the pycnometer when mass M_b was determined, °C.

NOTE 11—This value can be obtained from the table of values of M_a, prepared in accordance with 8.4, for the temperatures prevailing when mass M_b was determined, °C.

NOTE 12—The equation shown in 10.1 is for computing the specific gravity of the soil tested in water. When kerosine is used, the Eq must be adjusted by multiplying the result by the specific gravity of kerosine at T_b and dividing it by the density of water at T_b.

10.2 Calculate the weighted average specific gravity for soils containing particles both larger and smaller than the 4.75-mm sieve using the following equation:

$$G_{avg} = \frac{1}{\dfrac{R_1}{100G_1} + \dfrac{P_1}{100G_2}}$$

where:

G_{avg} = weighted average specific gravity of soils composed of particles larger and smaller than the 4.75-mm sieve,

R_1 = percent of soil particles retained on 4.75-mm sieve,

P_1 = percent of soil particles passing the 4.75-mm sieve,

G_1 = apparent specific gravity of soil particles retained on the 4.75-mm sieve as determined by Test Method C 127, and

G_2 = specific gravity of soil particles passing the 4.75-mm sieve as determined by this test method.

10.3 Unless otherwise required, specific gravity (G) values reported shall be based on water at 20°C. Calculate the value based on water at 20°C from the value based on water at the observed temperature T_b, as follows:

$$G \text{ at } 20^\circ\text{C} = K \times (G \text{ at } T_b)$$

where:

K = a number found by dividing the density of water at temperature T_b by the density of water at 20°C. Values for the range of temperatures are given in Table 1.

10.4 In some cases, it is desired to report the specific gravity value based on water at a different temperature. In these cases, the specific gravity value, based on any temperature T_x, may be calculated as follows:

$$G \text{ at } T_x = \frac{G \text{ at } 20^\circ\text{C}}{K}$$

11. Report

11.1 The report (data sheet) shall include the following:

11.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, etc.

11.1.2 Specific gravity at 20°C to the nearest 0.01. Test procedure used (A or B).

11.1.3 Maximum particle size of the test specimen.

11.1.4 Specific gravity to the nearest 0.01 at a specified temperature other than 20°C, if applicable.

11.1.5 Type of fluid used, if other than distilled water.

11.1.6 When any portion of the original sample of soil is eliminated in the preparation of the test specimen, the portion on which the test has been made shall be reported.

12. Precision and Bias

12.1 *Precision*—Criteria for judging the acceptability of specific gravity test results obtained by this test method on material passing the 4.75-mm sieve are given as follows:

12.2 *Statement of Precision*—Criteria for judging the acceptability of specific gravity test results obtained by this test method on material passing the 4.75 (No. 4) or 2.00 mm (No. 10) sieve are given in Table 2. The estimates of precision for material passing the 2.00 mm sieve are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, of testing conducted on material passing the 2.00 (No. 10) sieve by this test method and AASHTO Test Method T100.

TABLE 2 Table of Precision Estimates[A]

Material and Type Index	Standard Deviation[B]		Acceptable Range of Two Results[C]	
	Passing 4.75 mm (No. 4)	Passing 2.00 mm (No. 10)	Passing 4.75 mm (No. 4)	Passing 2.00 mm (No. 10)
Single-operator precision:				
Cohesive soils	0.021	0.019	0.06	0.06
Noncohesive soils	[D]	[D]	[D]	[D]
Multilaboratory precision:				
Cohesive soils	0.056	0.041	0.16	0.12
Noncohesive soils	[D]	[D]	[D]	[D]

[A] The figures given in Columns 2 and 3 are the standard deviations that have been found to be appropriate for the materials described in Column 1. The figures given in Columns 4 and 5 are the limits that should not be exceeded by the difference between the two properly conducted tests.

[B] These numbers represent, respectively, the (1S) limits as described in Practice C 670.

[C] These numbers represent the d2s limits as described in Practice C 670.

[D] *Criteria for assigning standard deviation values for noncohesive soils are not available at the present time.*

12.3 *Bias*—There is no acceptable reference value for this test method; therefore, bias cannot be determined.

13. Keywords

13.1 soil; specific gravity

Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[1]

1. Scope

1.1 This test method covers the laboratory determination of the water (moisture) content of soil, rock, and similar materials by mass. For simplicity, the word "material" hereinafter also refers to either soil or rock, whichever is most applicable.

1.2 The water content of a material is defined by this standard as the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material.

1.3 The term "solid particles" as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, and the like) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method (110°C). Materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water) may present a special problem as this material slowly dehydrates at the standard drying temperature (110°C) and at very low relative humidities, forming a compound (calcium sulfate hemihydrate) which is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum, or to reduce decomposition in highly organic soils, it may be desirable to dry these materials at 60°C or in a desiccator at room temperature. Thus, when a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from standard water content determined at the standard drying temperature.

NOTE 1—Test Methods D 2974 provides an alternate procedure for determining water content of peat materials.

1.4 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments) when tested by this method will give a mass of solids which includes the previously soluble solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must be used.

1.5 This test method requires several hours for proper drying of the water content specimen. Test Method D 4643 provides for drying of the test specimen in a microwave oven which is a shorter process.

1.6 This standard requires the drying of material in an oven at high temperatures. If the material being dried is contaminated with certain chemicals, health and safety hazards can exist. Therefore, this standard should not be used in determining the water content of contaminated soils unless adequate health and safety precautions are taken.

1.7 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils[2]

D 4220 Practice for Preserving and Transporting Soil Samples[2]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

D 4643 Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method[2]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing[2]

E 145 Specification for Gravity-Convection And Forced-Ventilation Ovens[3]

3. Terminology

3.1 Refer to Terminology D 653 for standard definitions of terms.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *water content* (of a material)—the ratio of the mass of water contained in the pore spaces of soil or rock material to the solid mass of particles in that material, expressed as a percentage.

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

4. Summary of Test Method

4.1 A test specimen is dried in an oven to a constant mass. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen.

5. Significance and Use

5.1 For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its properties.

5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.

5.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D 4318, is used to express its relative consistency or liquidity index.

6. Apparatus

6.1 *Drying Oven*, thermostatically-controlled, preferably of the forced-draft type, meeting the requirements of Specification E 145 and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

6.2 *Balances*—All balances must meet the requirements of Specification D 4753 and this Section. A Class GP1 balance of 0.01g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1g readability is required for specimens having a mass over 200 g.

6.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g; while for specimens having a mass greater than about 200 g, containers without lids may be used. One container is needed for each water content determination.

NOTE 2—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.

6.4 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium phosphate. It is preferable to use a desiccant which changes color to indicate it needs reconstitution. See Section 10.5.

NOTE 3—Anhydrous calcium sulfate is sold under the trade name Drierite.

6.5 *Container Handling Apparatus*, gloves, tongs, or suitable holder for moving and handling hot containers after drying.

6.6 *Miscellaneous*, knives, spatulas, scoops, quartering cloth, sample splitters, etc, as required.

7. Samples

7.1 Samples shall be preserved and transported in accordance with Practice 4220 Groups B, C, or D soils. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct contact with sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to prevent or minimize moisture condensation on the insides of the containers.

7.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corrodible containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values given before shall apply.

8.2 The minimum mass of moist material selected to be representative of the total sample, if the total sample is not tested by this method, shall be in accordance with the following:

Maximum particle size (100 % passing)	Standard Sieve Size	Recommended minimum mass of moist test specimen for water content reported to ±0.1 %	Recommended minimum mass of moist test specimen for water content reported to ±1 %
2 mm or less	No. 10	20 g	20 g*
4.75 mm	No. 4	100 g	20 g*
9.5 mm	⅜-in.	500 g	50 g
19.0 mm	¾-in.	2.5 kg	250 g
37.5 mm	1½ in.	10 kg	1 kg
75.0 mm	3-in.	50 kg	5 kg

NOTE—*To be representative not less than 20 g shall be used.

8.2.1 If the total sample is used it does not have to meet the minimum mass requirements provided in the table above. The report shall indicate that the entire sample was used.

8.3 Using a test specimen smaller than the minimum indicated in 8.2 requires discretion, though it may be adequate for the purposes of the test. Any specimen used not meeting these requirements shall be noted in the report of results.

8.4 When working with a small (less than 200g) specimen containing a relatively large gravel particle, it is appropriate not to include this particle in the test specimen. However, any discarded material shall be described and noted in the report of the results.

8.5 For those samples consisting entirely of intact rock, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles, depending on the sample's size, the container and balance being used and to facilitate drying to constant mass, see Section 10.4.

9. Test Specimen Selection

9.1 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, and the likes.)

9.2 For disturbed samples such as trimmings, bag samples, and the like, obtain the test specimen by one of the following methods (listed in order of preference):

9.2.1 If the material is such that it can be manipulated and handled without significant moisture loss, the material should be mixed and then reduced to the required size by quartering or splitting.

9.2.2 If the material is such that it cannot be thoroughly mixed and/or split, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.

9.2.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as possible at random locations that will best represent the moisture condition. Combine all the portions for the test specimen.

9.3 Intact samples such as block, tube, split barrel, and the like, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample.

9.3.1 Carefully trim at least 3 mm of material from the outer surface of the sample to see if material is layered and to remove material that is drier or wetter than the main portion of the sample. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the entire exposed surface or from the interval being tested.

9.3.2 Slice the sample in half. If material is layered see Section 9.3.3. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the exposed surface of one half, or from the interval being tested. Avoid any material on the edges that may be wetter or drier than the main portion of the sample.

NOTE 4—Migration of moisture in some cohesionless soils may require that the full section be sampled.

9.3.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on data sheets.

10. Procedure

10.1 Determine and record the mass of the clean and dry specimen container (and its lid, if used).

10.2 Select representative test specimens in accordance with Section 9.

10.3 Place the moist test specimen in the container and, if used, set the lid securely in position. Determine the mass of the container and moist material using a balance (See 6.2) selected on the basis of the specimen mass. Record this value.

NOTE 5—To prevent mixing of specimens and yielding of incorrect results, all containers, and lids if used, should be numbered and the container numbers shall be recorded on the laboratory data sheets. The lid numbers should match the container numbers to eliminate confusion.

NOTE 6—To assist in the oven-drying of large test specimens, they should be placed in containers having a large surface area (such as pans) and the material broken up into smaller aggregations.

10.4 Remove the lid (if used) and place the container with moist material in the drying oven. Dry the material to a constant mass. Maintain the drying oven at 110 ± 5°C unless otherwise specified (see 1.3). The time required to obtain constant mass will vary depending on the type of material, size of specimen, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment, and experience with the materials being tested and the apparatus being used.

NOTE 7—In most cases, drying a test specimen overnight (about 12 to 16 h) is sufficient. In cases where there is doubt concerning the adequacy of drying, drying should be continued until the change in mass after two successive periods (greater than 1 h) of drying is an insignificant amount (less than about 0.1 %). Specimens of sand may often be dried to constant mass in a period of about 4 h, when a forced-draft oven is used.

NOTE 8—Since some dry materials may absorb moisture from moist specimens, dried specimens should be removed before placing moist specimens in the same oven. However, this would not be applicable if the previously dried specimens will remain in the drying oven for an additional time period of about 16 h.

10.5 After the material has dried to constant mass remove the container from the oven (and replace the lid if used). Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands and the operation of the balance will not be affected by convection currents and/or its being heated. Determine the mass of the container and oven-dried material using the same balance as used in 10.3. Record this value. Tight fitting lids shall be used if it appears that the specimen is absorbing moisture from the air prior to determination of its dry mass.

NOTE 9—Cooling in a desiccator is acceptable in place of tight fitting lids since it greatly reduces absorption of moisture from the atmosphere during cooling especially for containers without tight fitting lids.

11. Calculation

11.1 Calculate the water content of the material as follows:

$$w = [(M_{cws} - M_{cs})/(M_{cs} - M_c)] \times 100 = \frac{M_w}{M_s} \times 100$$

where:

w = water content, %,
M_{cws} = mass of container and wet specimen, g,
M_{cs} = mass of container and oven dry specimen, g,
M_c = mass of container, g,
M_w = mass of water ($M_w = M_{cws} - M_{cds}$), g, and
M_s = mass of solid particles ($M_s = M_{cds} - M_c$), g.

12. Report

12.1 The report (data sheet) shall include the following:

12.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, container number etc.

12.1.2 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum sample used. If this method is used in concert with another method, the water content of the specimen should be reported to the value required by the test method for which the water content is being determined.

12.1.3 Indicate if test specimen had a mass less than the minimum indicated in 8.2.

12.1.4 Indicate if test specimen contained more than one material type (layered, etc.).

12.1.5 Indicate the method of drying if different from oven-drying at 110 ± 5°C.

12.1.6 Indicate if any material (size and amount) was excluded from the test specimen.

13. Precision and Bias

13.1 *Statement on Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

13.2 *Statements on Precision:*

13.2.1 *Single-Operator Precision*—The single-operator coefficient of variation has been found to be 2.7 percent. Therefore, results of two properly conducted tests by the same operator with the same equipment should not be considered suspect unless they differ by more than 7.8 percent of their mean.

13.2.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 5.0 percent. Therefore, results of two properly conducted tests by different operators using different equipment should not be considered suspect unless they differ by more than 14.0 percent of their mean.

14. Keywords

14.1 consistency; index property; laboratory; moisture analysis; moisture content; soil aggregate; water content

Designation: D 2487 - 93

Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)[1]

This standard is issued under the fixed designation D 2487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This standard describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this sytem is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this standard is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This standard is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 This standard is the ASTM version of the Unified Soil Classification System. The basis for the classification scheme is the Airfield Classification System developed by A. Casagrande in the early 1940's.[2] It became known as the Unified Soil Classification System when several U.S. Government Agencies adopted a modified version of the Airfield System in 1952.

1.6 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 117 Test Method for Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing[3]

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates[3]

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size[3]

D 420 Guide for Investigating and Sampling Soil and Rock[4]

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[4]

D 422 Test Method for Particle-Size Analysis of Soils[4]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75-μm) Sieve[4]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[4]

D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[4]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[4]

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)[4]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[4]

D 4427 Classification of Peat Samples by Laboratory Testing[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D 653.

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[1] This standard is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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[2] Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and

Boulders—particles of rock that will not pass a 12in. (300-mm) square opening

3.1.1 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

Coarse—passes 3-in. (75-mm) sieve and retained on ¾-in. (19-mm) sieve, and

Fine—passes ¾-in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.2 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) U.S. standard sieve with the following subdivisions:

Coarse—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve,

Medium—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425-µm) sieve, and

Fine—passes No. 40 (425-µm) sieve and retained on No. 200 (75-µm) sieve.

3.1.3 *clay*—soil passing a No. 200 (75-µm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line.

3.1.4 *silt*—soil passing a No. 200 (75-µm) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the "A" line.

3.1.5 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.6 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.7 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *coefficient of curvature*, Cc—the ratio $(D_{30})^2/(D_{10} \times D_{60})$, where D_{60}, D_{30}, and D_{10} are the particle diameters corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity*, Cu—the ratio D_{60}/D_{10}, where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

4. Summary

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions are further subdivided into a total of 15 basic soil groups.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 2 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

5. Significance and Use

5.1 This standard classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

5.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This standard provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

5.4 This standard may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This standard may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 3, and a cumulative particle-size distribution curve, similar to Fig. 4, are required.

NOTE 5—The "U" line shown on Fig. 3 has been empirically determined to be the approximate "upper limit" for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Recommended Guide D 420 or by other accepted procedures.

7.2 For accurate identification, the minimum amount of test sample required for this test method will depend on which of the laboratory tests need to be performed. Where only the particle-size analysis of the sample is required, specimens having the following minimum dry weights are required:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (⅜ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

Whenever possible, the field samples should have weights two to four times larger than shown.

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests^{A}				Soil Classification	
				Group Symbol	Group Name^{B}
COARSE-GRAINED SOILS More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines^{C}	$Cu \geq 4$ and $1 \leq Cc \leq 3^{E}$	GW	Well-graded gravel^{F}
			$Cu < 4$ and/or $1 > Cc > 3^{E}$	GP	Poorly graded gravel^{F}
		Gravels with Fines More than 12 % fines^{C}	Fines classify as ML or MH	GM	Silty gravel^{F,G,H}
			Fines classify as CL or CH	GC	Clayey gravel^{F,G,H}
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines^{D}	$Cu \geq 6$ and $1 \leq Cc \leq 3^{E}$	SW	Well-graded sand^{I}
			$Cu < 6$ and/or $1 > Cc > 3^{E}$	SP	Poorly graded sand^{I}
		Sands with Fines More than 12 % fines^{D}	Fines classify as ML or MH	SM	Silty sand^{G,H,I}
			Fines classify as CL or CH	SC	Clayey sand^{G,H,I}
FINE-GRAINED SOILS 50 % or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	$PI > 7$ and plots on or above "A" line^{J}	CL	Lean clay^{K,L,M}
			$PI < 4$ or plots below "A" line^{J}	ML	Silt^{K,L,M}
		organic	$\frac{\text{Liquid limit − oven dried}}{\text{Liquid limit − not dried}} < 0.75$	OL	Organic clay^{K,L,M,N} Organic silt^{K,L,M,O}
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay^{K,L,M}
			PI plots below "A" line	MH	Elastic silt^{K,L,M}
		organic	$\frac{\text{Liquid limit − oven dried}}{\text{Liquid limit − not dried}} < 0.75$	OH	Organic clay^{K,L,M,P} Organic silt^{K,L,M,Q}
HIGHLY ORGANIC SOILS		Primarily organic matter, dark in color, and organic odor		PT	Peat

[A] *Based on the material passing the 3-in. (75-mm) sieve.*

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12 % fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

[D] Sands with 5 to 12 % fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15 % sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15 % gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.

[M] *If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.*

[N] $PI \geq 4$ and plots on or above "A" line.

[O] $PI < 4$ or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

7.3 When the liquid and plastic limit tests must also be performed, additional material will be required sufficient to provide 150 g to 200 g of soil finer than the No. 40 (425-µm) sieve.

7.4 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

8. Classification of Peat

8.1 A sample composed primarily of vegetable tissue in various stages of decomposition and has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor should be designated as a highly organic soil and shall be classified as peat, PT, and not subjected to the classification procedures described hereafter.

8.2 If desired, classification of type of peat can be performed *in accordance with Classification D 4427.*

9. Preparation for Classification

9.1 Before a soil can be classified according to this standard, generally the particle-size distribution of the minus 3-in. (75-mm) material and the plasticity characteristics of the minus No. 40 (425-µm) sieve material must be determined. See 9.8 for the specific required tests.

9.2 The preparation of the soil specimen(s) and the testing for particle-size distribution and liquid limit and plasticity index shall be in accordance with accepted standard procedures. Two procedures for preparation of the soil specimens for testing for soil classification purposes are given in Appendixes X3 and X4. Appendix X3 describes the wet preparation method and is the preferred method for cohesive soils that have never dried out and for organic soils.

9.3 When reporting soil classifications determined by this standard, the preparation and test procedures used shall be reported or referenced.

9.4 Although the test procedure used in determining the particle-size distribution or other considerations may require a hydrometer analysis of the material, a hydrometer analysis is not necessary for soil classification.

9.5 The percentage (by dry weight) of any plus 3-in. (75-mm) material must be determined and reported as auxiliary information.

9.6 The maximum particle size shall be determined (measured or estimated) and reported as auxiliary information.

9.7 When the cumulative particle-size distribution is required, a set of sieves shall be used which include the

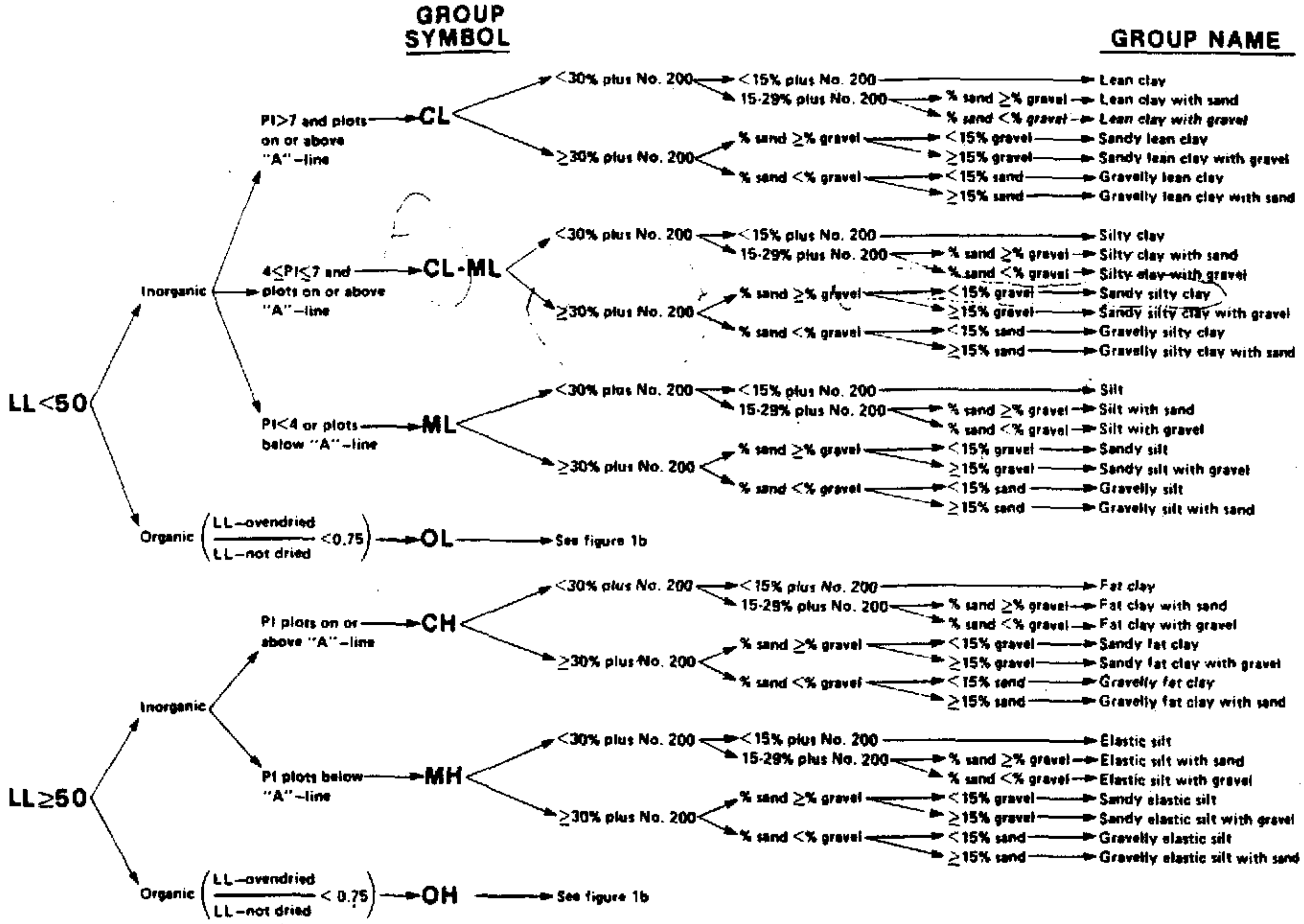


FIG. 1a Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

following sizes (with the largest size commensurate with the maximum particle size) with other sieve sizes as needed or required to define the particle-size distribution:

3-in. (75-mm)
¾-in.(19.0-mm)
No. 4 (4.75-mm)
No. 10 (2.00-mm)
No. 40 (425-μm)
No. 200 (75-μm)

9.8 The tests required to be performed in preparation for classification are as follows:

9.8.1 For soils estimated to contain less than 5 % fines, a plot of the cumulative particle-size distribution curve of the fraction coarser than the No. 200 (75-μm) sieve is required. The cumulative particle-size distribution curve may be plotted on a graph similar to that shown in Fig. 4.

9.8.2 For soils estimated to contain 5 to 15 % fines, a cumulative particle-size distribution curve, as described in 9.8.1, is required, and the liquid limit and plasticity index are required.

9.8.2.1 If sufficient material is not available to determine the liquid limit and plasticity index, the fines should be estimated to be either silty or clayey using the procedures described in Practice D 2488 and so noted in the report.

9.8.3 For soils estimated to contain 15 % or more fines, a determination of the percent fines, percent sand, and percent gravel is required, and the liquid limit and plasticity index are required. For soils estimated to contain 90 % fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in Practice D 2488 and so noted in the report.

10. Preliminary Classification Procedure

10.1 Class the soil as fine-grained if 50 % or more by dry weight of the test specimen passes the No. 200 (75-μm) sieve and follow Section 11.

10.2 Class the soil as coarse-grained if more than 50 % by dry weight of the test specimen is retained on the No. 200 (75-μm) sieve and follow Section 12.

11. Procedure for Classification of Fine-Grained Soils (50 % or more by dry weight passing the No. 200 (75-μm sieve)

11.1 The soil is an inorganic clay if the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line, the plasticity index is greater than 4, and the presence of organic matter does not influence the liquid limit as determined in 11.3.2.

NOTE 6—The plasticity index and liquid limit are determined on the minus No. 40 (425 μm) sieve material.

11.1.1 Classify the soil as a *lean clay*, CL, if the liquid limit is less than 50. See area identified as CL on Fig. 3.

11.1.2 Classify the soil as a *fat clay*, CH, if the liquid limit

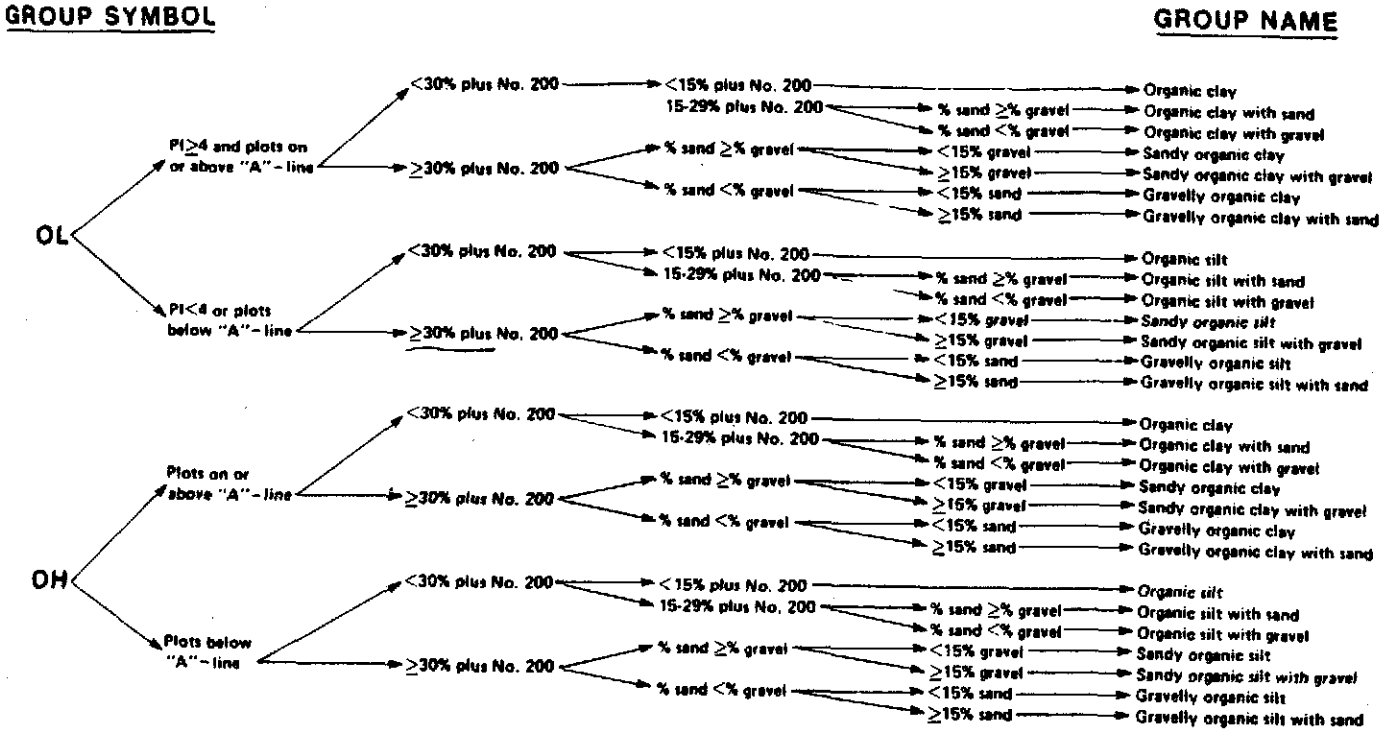


FIG. 1b Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

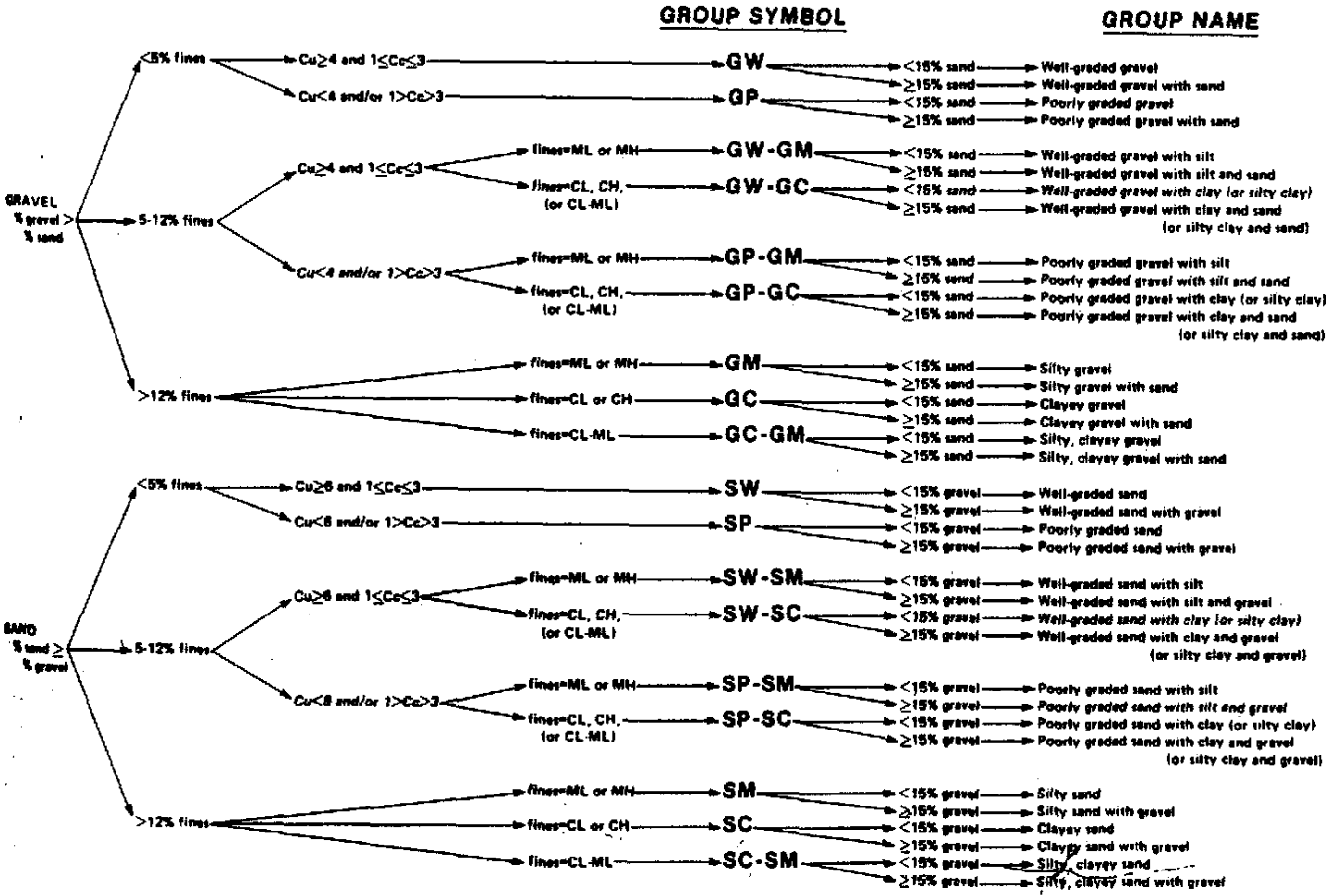


FIG. 2 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

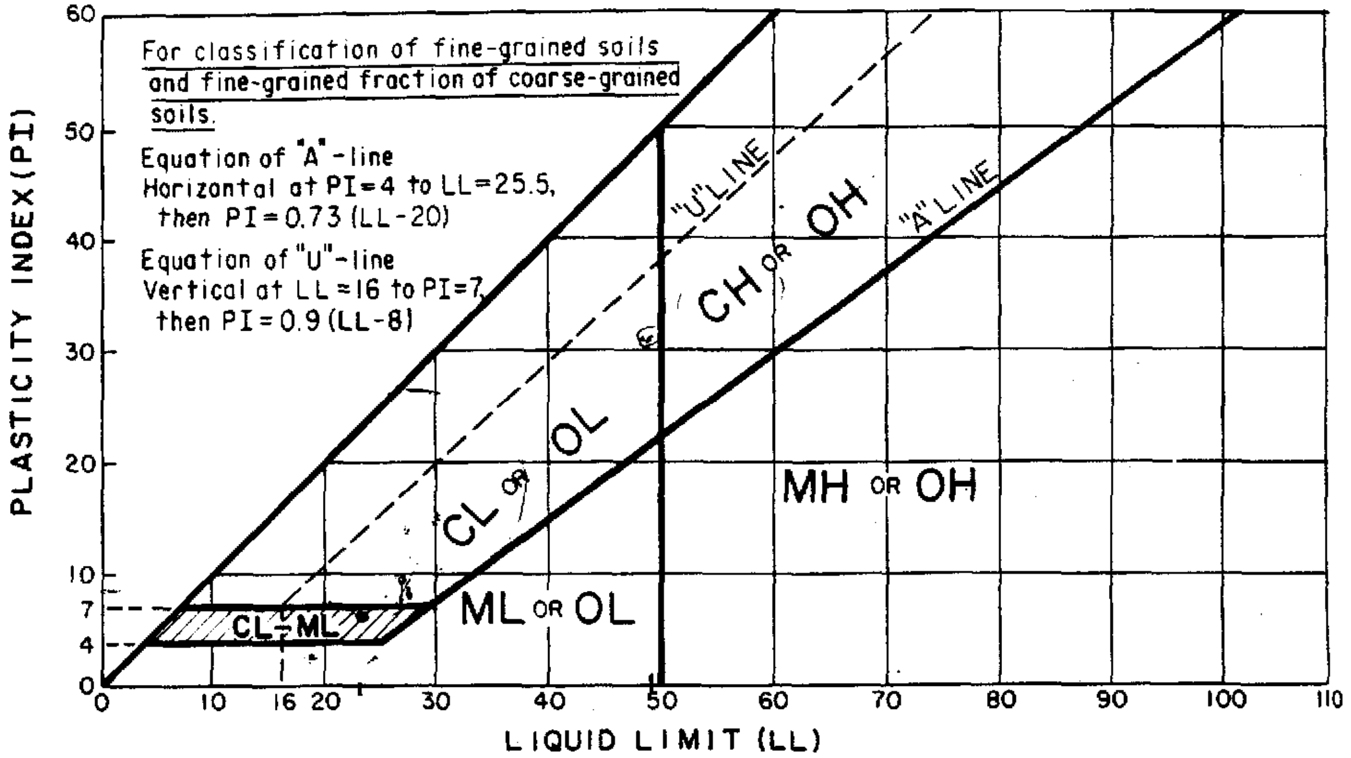


FIG. 3 Plasticity Chart

is 50 or greater. See area identified as CH on Fig. 3.

NOTE 7—In cases where the liquid limit exceeds 110 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.

11.1.3 Classify the soil as a *silty clay*, CL-ML, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line and the plasticity index is in the range of 4 to 7. See area identified as CL-ML on Fig. 3.

11.2 The soil is an inorganic silt if the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4, and presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.2.1 Classify the soil as a *silt*, ML, if the liquid limit is less than 50. See area identified as ML on Fig. 3.

11.2.2 Classify the soil as an *elastic silt*, MH, if the liquid limit is 50 or greater. See area identified as MH on Fig. 3.

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the liquid limit as determined in 11.3.2.

11.3.1 If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test shall be performed on a test specimen which has been oven dried at 110 ± 5°C to a constant weight, typically over night.

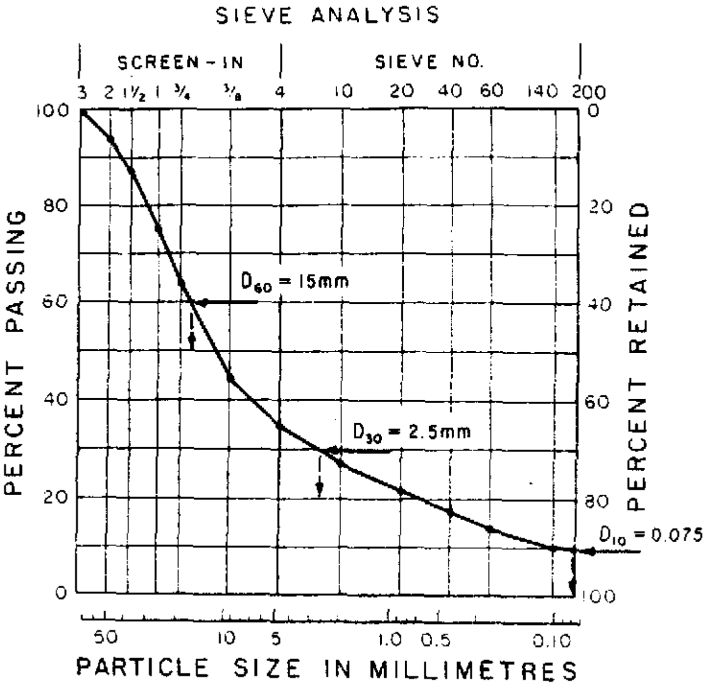
11.3.2 The soil is an organic silt or organic clay if the liquid limit after oven drying is less than 75 % of the liquid limit of the original specimen determined before oven drying (see Procedure B of Practice D 2217).

11.3.3 Classify the soil as an *organic silt* or *organic clay*, OL, if the liquid limit (not oven dried) is less than 50 %. Classify the soil as an *organic silt*, OL, if the plasticity index is less than 4, or the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OL, if the plasticity index is 4 or greater and the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OL (or CL-ML) on Fig. 3.

11.3.4 Classify the soil as an *organic clay* or *organic silt*, OH, if the liquid limit (not oven dried) is 50 or greater. Classify the soil as an *organic silt*, OH, if the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OH, if the position of the plasticity index versus liquid-limit plot falls on or above the "A" line. See area identified as OH on Fig. 3.

11.4 If less than 30 % but 15 % or more of the test specimen is retained on the No. 200 (75-µm) sieve, the words "with sand" or "with gravel" (whichever is predominant) shall be added to the group name. For example, lean clay with sand, CL; silt with gravel, ML. If the percent of sand is equal to the percent of gravel, use "with sand."

11.5 If 30 % or more of the test specimen is retained on the No. 200 (75-µm) sieve, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if 30 % or more of the test specimen is retained on the No. 200 (75-µm) sieve and the coarse-grained portion is predominantly sand. Add the word "gravelly" if 30 % or more of the test specimen is retained on the No. 200 (75-µm) sieve and the coarse-grained portion is predominantly gravel. For example, sandy lean clay, CL; gravelly fat clay, CH; sandy silt, ML. If the percent of sand is equal to the percent of gravel, use "sandy."



$$Cu = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \qquad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 4 Cumulative Particle-Size Plot

12. Procedure for Classification of Coarse-Grained Soils (more than 50 % retained on the No. 200 (75-μm) sieve)

12.1 Class the soil as gravel if more than 50 % of the coarse fraction [plus No. 200 (75-μm) sieve] is retained on the No. 4 (4.75-mm) sieve.

12.2 Class the soil as sand if 50 % or more of the coarse fraction [plus No. 200 (75-μm) sieve] passes the No. 4 (4.75-mm) sieve.

12.3 If 12 % or less of the test specimen passes the No. 200 (75-μm) sieve, plot the cumulative particle-size distribution, Fig. 4, and compute the coefficient of uniformity, Cu, and coefficient of curvature, Cc, as given in Eqs 1 and 2.

$$Cu = D_{60}/D_{10} \tag{1}$$

$$Cc = (D_{30})^2/(D_{10} \times D_{60}) \tag{2}$$

where:

D_{10}, D_{30}, and D_{60} = the particle-size diameters corresponding to 10, 30, and 60 %, respectively, passing on the cumulative particle-size distribution curve, Fig. 4.

NOTE 8—It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

12.3.1 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as a *well-graded gravel*, GW, or *well-graded sand*, SW, if Cu is greater than 4.0 for gravel or greater than 6.0 for sand, and Cc is at least 1.0 but not more than 3.0.

12.3.2 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as *poorly graded gravel*, GP, or *poorly graded sand*, SP, if either the Cu or the Cc criteria for well-graded soils are not satisfied.

12.4 If more than 12 % of the test specimen passes the No. 200 (75-μm) sieve, the soil shall be considered a coarse-grained soil with fines. The fines are determined to be either clayey or silty based on the plasticity index versus liquid limit plot on Fig. 3. (See 9.8.2.1 if insufficient material available for testing). (See NOTE 6)

12.4.1 Classify the soil as a *clayey gravel*, GC, or *clayey sand*, SC, if the fines are clayey, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line and the plasticity index is greater than 7.

12.4.2 Classify the soil as a *silty gravel*, GM, or *silty sand*, SM, if the fines are silty, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4.

12.4.3 If the fines plot as a silty clay, CL-ML, classify the soil as a *silty, clayey gravel*, GC-GM, if it is a gravel or a *silty, clayey sand*, SC-SM, if it is a sand.

12.5 If 5 to 12 % of the test specimen passes the No. 200 (75-μm) sieve, give the soil a dual classification using two group symbols.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 % fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 % fines (GC, GM, SC, SM).

12.5.2 The group name shall correspond to the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example, well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM (See 9.8.2.1 if insufficient material available for testing).

NOTE 9—If the fines plot as a *silty clay*, CL-ML, the second group symbol should be either GC or SC. For example, a poorly graded sand with 10 % fines, a liquid limit of 20, and a plasticity index of 6 would be classified as a poorly graded sand with silty clay, SP-SC.

12.6 If the specimen is predominantly sand or gravel but contains 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example, poorly graded gravel with sand, clayey sand with gravel.

12.7 If the field sample contained any cobbles or boulders or both, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name. For example, silty gravel with cobbles, GM.

13. Report

13.1 The report should include the group name, group symbol, and the results of the laboratory tests. The particle-size distribution shall be given in terms of percent of gravel, sand, and fines. The plot of the cumulative particle-size distribution curve shall be reported if used in classifying the soil. Report appropriate descriptive information according to the procedures in Practice D 2488. A local or commercial name or geologic interpretation for the material may be added at the end of the descriptive information if identified as such. The test procedures used shall be referenced.

NOTE 10—*Example: Clayey Gravel with Sand and Cobbles* (GC)—46 % fine to coarse, hard, subrounded gravel; 30 % fine to coarse, hard, subrounded sand; 24 % clayey fines, LL = 38, PI = 19; weak reaction with HCl; original field sample had 4 % hard, subrounded cobbles; maximum dimension 150 mm.

In-Place Conditions—firm, homogeneous, dry, brown,
Geologic Interpretation—alluvial fan.

NOTE 11—Other examples of soil descriptions are given in Appendix X1.

14. Keywords

14.1 Atterberg limits; classification; clay; gradation; gravel; laboratory classification; organic soils; sand; silt; soil classification; soil tests

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

X1.1 The following examples show how the information required in 13.1 can be reported. The appropriate descriptive information from Practice D 2488 is included for illustrative purposes. The additional descriptive terms that would accompany the soil classification should be based on the intended use of the classification and the individual circumstances.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—73 % fine to coarse, hard, subangular gravel; 23 % fine to coarse, hard, subangular sand; 4 % fines; Cc = 2.7, Cu = 12.4.

X1.1.2 *Silty Sand with Gravel (SM)*—61 % predominantly fine sand; 23 % silty fines, LL = 33, PI = 6; 16 % fine, hard, subrounded gravel; no reaction with HCl; (field sample smaller than recommended). *In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. thick, moist, brown to gray; in-place density = 106 lb/ft^3 and in-place moisture = 9 %.

X1.1.3 *Organic Clay (OL)*—100 % fines, LL (not dried) = 32, LL (oven dried) = 21, PI (not dried) = 10; wet, dark brown, organic odor, weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—74 % fine to coarse, hard, subangular reddish sand; 26 % organic and silty dark-brown fines, LL (not dried) = 37, LL (oven dried) = 26, PI (not dried) = 6, wet, weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—78 % fine to coarse, hard, subrounded to subangular gravel; 16 % fine to coarse, hard, subrounded to subangular sand; 6 % silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had 7 % hard, subrounded cobbles and 2 % hard, subrounded boulders with a maximum dimension of 18 in.

X2. USING SOIL CLASSIFICATION AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The group names and symbols used in this standard may be used as a descriptive system applied to materials that exist in situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, etc.).

X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the procedures used in this standard for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, a classification in accordance with this standard may be assigned to aid in describing the material.

X2.3 If a classification is used, the group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how soil classifications could be incorporated into a description system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. pieces of shale from power auger hole, dry, brown, no reaction with HCl. After laboratory processing by slaking in water for 24 h, material classified as "Sandy Lean Clay (CL)"—61 % clayey fines, LL = 37, PI = 16; 33 % fine to medium sand; 6 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"—91 % fine to medium sand; 9 % silty (estimated) fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—62 % gravel-size broken shells

31 % sand and sand-size shell pieces; 7 % fines; would be classified as "Poorly Graded Gravel with Sand (GP)".

X2.4.4 *Crushed Rock*—Processed gravel and cobbles from Pit No. 7; "Poorly Graded Gravel (GP)"—89 % fine, hard, angular gravel-size particles; 11 % coarse, hard, angular sand-size particles, dry, tan; no reaction with HCl; Cc = 2.4, Cu = 0.9.

X3. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE WET METHOD

X3.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification using a wet-preparation procedure.

X3.2 Samples prepared in accordance with this procedure should contain as much of their natural water content as possible and every effort should be made during obtaining, preparing, and transportating the samples to maintain the natural moisture.

X3.3 The procedures to be followed in this standard assume that the field sample contains fines, sand, gravel, and plus 3-in. (75-mm) particles and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see 9.8). Some of the following steps may be omitted when they are not applicable to the soil being tested.

X3.4 If the soil contains plus No. 200 (75-µm) particles that would degrade during dry sieving, use a test procedure for determining the particle-size characteristics that prevents this degradation.

X3.5 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X3.6 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X3.6.1 Separate the field sample into two fractions on a 3-in. (75-mm) sieve, being careful to maintain the natural water content in the minus 3-in. (75-mm) fraction. Any particles adhering to the plus 3-in. (75-mm) particles shall be brushed or wiped off and placed in the fraction passing the 3-in. (75-mm) sieve.

X3.6.2 Determine the air-dry or oven-dry weight of the fraction retained on the 3-in. (75-mm) sieve. Determine the total (wet) weight of the fraction passing the 3-in. (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve. Determine the water content, in accordance with Test Method D 2216, of a representative specimen with a minimum dry weight as required in 7.2. Save the water-content specimen for determination of the particle-size analysis in accordance with X3.8.

X3.6.4 Compute the dry weight of the fraction passing the 3-in. (75-mm) sieve based on the water content and total (wet) weight. Compute the total dry weight of the sample and calculate the percentage of material retained on the 3-in. (75-mm) sieve.

X3.7 Determine the liquid limit and plasticity index as follows:

X3.7.1 If the soil disaggregates readily, mix on a clean, hard surface and select a representative sample by quartering in accordance with Practice C 702.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, take extreme care in obtaining a representative portion of the No. 40 (425-µm) fraction. Typically, a larger portion than normal has to be selected, such as the minimum weights required in 7.2.

X3.7.1.2 To obtain a representative specimen of a basically cohesive soil, it may be advantageous to pass the soil through a ¾-in. (19-mm) sieve or other convenient size so the material can be more easily mixed and then quartered or split to obtain the representative specimen.

X3.7.2 Process the representative specimen in accordance with Procedure B of Practice D 2217.

X3.7.3 Perform the liquid-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test.

X3.7.4 Perform the plastic-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test, and calculate the plasticity index.

X3.8 Determine the particle-size distribution as follows:

X3.8.1 If the water content of the fraction passing the 3-in. (75-mm) sieve was required (X3.6.3), use the water-content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with Practice C 702 with a minimum dry weight as required in 7.2.

X3.8.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 422. See 9.7 for the set of required sieves.

X3.8.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Method C 136. See 9.7 for the set of required sieves. The specimen should be soaked until all clayey aggregations have softened and then washed in accordance with Test Method C 117 prior to performing the particle-size distribution.

X3.8.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-µm) sieve.

X3.8.5 Calculate the percent fines, percent sand, and percent gravel in the minus 3-in. (75-mm) fraction for classification purposes.

X4. AIR-DRIED METHOD OF PREPARATION OF SOILS FOR TESTING FOR CLASSIFICATION PURPOSES

X4.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification when air-drying the soil before testing is specified or desired or when the natural moisture content is near that of an air-dried state.

X4.2 If the soil contains organic matter or mineral colloids that are irreversibly affected by air drying, the wet-preparation method as described in Appendix X3 should be used.

X4.3 *Since this classification system is limited to the* portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X4.4 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X4.4.1 Air dry and weigh the field sample.

X4.4.2 Separate the field sample into two fractions on a 3-in. (75-mm) sieve.

X4.4.3 Weigh the two fractions and compute the percentage of the plus 3-in. (75-mm) material in the field sample.

X4.5 Determine the particle-size distribution and liquid limit and plasticity index as follows (see 9.8 for when these tests are required):

X4.5.1 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve.

X4.5.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 422. See 9.7 for the set of sieves that is required.

X4.5.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 1140 followed by Method C 136. See 9.7 for the set of sieves that is required.

X4.5.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method D 1140 followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-µm) sieve.

X4.5.5 If required, determine the liquid limit and the plasticity index of the test specimen in accordance with Test Method D 4318.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate *lower case letter prefixes and suffixes as:*

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = cobbles
	b = boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-Sm, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

X6. RATIONALE

X6.1 Changes in this version from the previous D 2488 – 92 include the addition of X5 on Abbreviated Soil Classification Symbols.

Designation: D 2974 – 87

Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils[1]

This standard is issued under the fixed designation D 2974; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover the measurement of moisture content, ash content, and organic matter in peats and other organic soils, such as organic clays, silts, and mucks.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Methods

2.1 *Method A*—Moisture is determined by drying a peat or organic soil sample at 105°C. The moisture content is

tion of moisture in air at room temperature (air-drying), and (2) the subsequent oven drying of the air-dried sample at 105°C. This method provides a more stable sample, the air-dried sample, when tests for nitrogen, pH, cation exchange, and the like are to be made.

2.3 *Methods C and D*—Ash content of a peat or organic soil sample is determined by igniting the oven-dried sample from the moisture content determination in a muffle furnace at 440°C (Method C) or 750°C (Method D). The substance remaining after ignition is the ash. The ash content is expressed as a percentage of the mass of the oven-dried sample.

2.4 Organic matter is determined by subtracting percent ash content from one hundred.

3. Apparatus

3.1 *Oven*, capable of being regulated to a constant temperature of 105 ± 5°C.

NOTE—The temperature of 105°C is quite critical for organic soils. *The oven should be checked for "hot spots" to avoid possible ignition of the specimen.*

3.2 *Muffle Furnace*, capable of producing constant temperatures of 440°C and 750°C.

3.3 *Evaporating Dishes*, of high silica or porcelain of not less than 100-mL capacity.

3.4 *Blender*, high-speed.

3.5 *Aluminum Foil*, heavy-duty.

3.6 *Porcelain Pan, Spoons*, and equipment of the like.

3.7 *Desiccator.*

4. Preparation of Sample

4.1 Place a representative field sample on a square rubber sheet, oil cloth, or equivalent material. Reduce the sample to the quantity required by quartering and place in a moisture-proof container. Work rapidly to prevent moisture loss or perform the operation in a room with a high humidity.

MOISTURE CONTENT

minum foil cover. The dish shall have a capacity of not less than 100 mL.

5.2 Mix thoroughly the representative sample and place a test specimen of at least 50 g in the container described in 5.1. Crush soft lumps with a spoon or spatula. The thickness of peat in the container should not exceed 3 cm.

5.3 Cover immediately with the aluminum foil cover and record the mass to the nearest 0.01 g.

5.4 Dry uncovered for at least 16 h at 105°C or until there is no change in mass of the sample after further drying periods in excess of 1 h. Remove from the oven, cover tightly, cool in a desiccator, and record the mass.

6. Method A Calculation

6.1 Calculate the moisture content as follows:

$$\text{Moisture Content, \%} = [(A - B) \times 100]/A$$

where:

A = mass of the as-received test specimen, g, and
B = mass of the oven-dried specimen, g.

6.1.1 This calculation is used primarily for agriculture, forestry, energy, and horticultural purposes and the result should be referred to as the moisture content as a percentage of as-received or total mass.

6.2 An alternative calculation is as follows:

$$\text{Moisture Content, \%} = [(A - B) \times 100]/B$$

where:

A = as-received test specimen, g, and
B = mass of the oven-dried specimen, g.

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[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.18 on Peats and Related Materials.

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6.2.1 This calculation is used primarily for geotechnical purposes and the result should be referred to as the moisture content as a percentage of oven-dried mass.

6.3 Take care to indicate the calculation method used.

7. Method B

7.1 This method should be used if pH, nitrogen content, cation exchange capacity, and the like are to be tested.

7.2 Mix the sample thoroughly and select a 100 to 300 g representative sample. Determine the mass of this sample and spread evenly on a large flat pan. Crush soft lumps with a spoon or spatula and let the sample come to moisture equilibrium with room air. This will require at least 24 h. Stir occasionally to maintain maximum air exposure of the entire sample. When the mass of the sample reaches a constant value, calculate the moisture removed during air drying as a percentage of the as-received mass.

7.3 Grind a representative portion of the air-dried sample for 1 to 2 min in a high-speed blender. Use the ground portion for moisture, ash, nitrogen, cation exchange capacity tests, and the like.

7.4 Thoroughly mix the air-dried, ground sample. Weigh to the nearest 0.01 g the equivalent of 50 g of test specimen on an as-received basis. Determine the amount, in grams, of air-dried sample *equivalent to 50 g of as-received sample*, as follows:

$$\text{Equivalent Sample Mass, g} = 50.0 - [(50 \times M)/100]$$

where:

M = moisture removed in air drying, %.

7.5 Place the sample in a container as described in 5.1 and proceed as in Method A.

8. Method B Calculation

8.1 Calculate the moisture content as follows:

$$\text{Moisture Content, \%} = (50 - B) \times 2$$

where:

B = oven-dried sample, g.

8.1.1 This calculation gives moisture content as a percentage of as-received mass.

8.2 An alternative calculation is as follows:

$$\text{Moisture Content, \%} = [(50 - B) \times 100]/B$$

8.2.1 This calculation gives moisture content as a percentage of oven-dried mass.

ASH CONTENT

9. Method C

9.1 Determine the mass of a covered high-silica or porcelain dish.

9.2 Place a part of or all of the oven-dried test specimen from a moisture determination in the dish and determine the mass of the dish and specimen.

9.3 Remove the cover and place the dish in a muffle furnace. Gradually bring the temperature in the furnace to 440°C and hold until the specimen is completely ashed (no change of mass occurs after a further period of heating).

9.4 Cover with the retained aluminum foil cover, cool in a desiccator, and determine the mass.

9.5 This method should be used for all geotechnical and general classification purposes.

10. Method D

10.1 Determine the mass of a covered high-silica or porcelain dish.

10.2 Place a part of or all of the oven-dried test specimen from a moisture determination in the dish and determine the mass of the dish and specimen.

10.3 Remove the cover and place the dish in a muffle furnace. Gradually bring the temperature in the furnace to 750°C and hold until the specimen is completely ashed (no change of mass occurs after a further period of heating).

10.4 Cover with the retained aluminum foil cover, cool in a desiccator, and determine the mass.

10.5 This method should be used when peats are being evaluated for use as a fuel.

11. Calculation for Methods C and D

11.1 Calculate the ash content as follows:

$$\text{Ash Content, \%} = (C \times 100)/B$$

where:

C = ash, g, and

B = oven-dried test specimen, g.

ORGANIC MATTER

12. Calculation

12.1 Determine the amount of organic matter by difference, as follows:

$$\text{Organic matter, \%} = 100.0 - D$$

where:

D = ash content, %.

13. Report

13.1 Report the following information:

13.1.1 Results for organic matter and ash content, to the nearest 0.1 %.

13.1.2 Furnace temperature used for ash content determinations.

13.1.3 Whether moisture contents are by proportion of as-received mass or oven-dried mass.

13.1.3.1 Express results for moisture content as a percentage of as-received mass to the nearest 0.1 %.

13.1.3.2 Express results for moisture content as a percentage of oven-dried mass as follows:

(*a*) Below 100 % to the nearest 1 %.

(*b*) Between 100 % and 500 % to the nearest 5 %.

(*c*) Between 500 % and 1000 % to the nearest 10 %.

(*d*) Above 1000 % to the nearest 20 %.

14. Precision and Bias

14.1 The precision and bias of these test methods have not been determined. Data are being sought for use in developing a precision and bias statement.

Designation: D 4318 – 93

Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[1]

This standard is issued under the fixed designation D 4318; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the liquid limit, plastic limit, and the plasticity index of soils as defined in Section 3.

1.1.1 Two procedures for preparing test specimens are provided as follows: *Wet preparation procedure*, as described in 10.1. *Dry preparation procedure*, as described in 10.2. The procedure to be used shall be specified by the requesting authority. If no procedure is specified, use the wet preparation procedure.

1.1.2 Two methods for determining the liquid limit are provided as follows: *Method A*, Multipoint test as described in Sections 11 and 12. *Method B*, One-point test as described in Sections 14 and 15. The method to be used shall be specified by the requesting authority. If no method is specified, use Method A.

1.1.3 The plastic limit test procedure is described in Sections 16, 17, and 18. The plastic limit test is performed on material prepared for the liquid limit test.

1.1.4 The procedure for calculating the plasticity index is given in Section 19.

1.2 The liquid limit and plastic limit of soils (along with the shrinkage limit) are often collectively referred to as the Atterberg limits. These limits distinguished the boundaries of the several consistency states of plastic soils.

1.3 The multipoint liquid limit method is generally more precise than the one-point method. It is recommended that the multipoint method be used in cases where results may be subject to dispute, or where greater precision is required.

1.4 Because the one-point method requires the operator to judge when the test specimen is approximately at its liquid limit, it is particularly not recommended for use by inexperienced operators.

1.5 The correlations on which the calculations of the one-point method are based may not be valid for certain soils, such as organic soils or soils from a marine environment. It is strongly recommended that the liquid limit of these soils be determined by the multipoint method.

1.6 The liquid and plastic limits of many soils that have been allowed to dry before testing may be considerably different from values obtained on undried samples. If the liquid and plastic limits of soils are used to correlate or estimate the engineering behavior of soils in their natural moist state, samples should not be permitted to dry before testing unless data on dried samples are specifically desired.

1.7 The composition and concentration of soluble salts in a soil affect the values of the liquid and plastic limits as well as the water content values of soils (see Method D 2216). Special consideration should therefore be given to soils from a marine environment or other sources where high soluble salt concentrations may be present. The degree to which the salts present in these soils are diluted or concentrated must be given careful consideration.

1.8 Since the tests described herein are performed only on that portion of a soil which passes the 425-μm (No. 40) sieve, the relative contribution of this portion of the soil to the properties of the sample as a whole must be considered when using these tests to evaluate properties of a soil.

1.9 The values stated in acceptable metric units are to be regarded as the standard. The values given in parentheses are for information only.

1.10 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

C 702 Methods for Reducing Field Samples of Aggregate to Testing Size[3]

D 75 Practice for Sampling Aggregates[2]

D 420 Practice for Investigating and Sampling Soil and Rock for Engineering Purposes[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 1241 Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses[2]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[2]

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes[3]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing[3]

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved Nov. 15, 1993. Published January 1994. Originally published as D 4318 – 83. Last previous edition D 4318 – 83$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[2]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions of terms in this test method are in accordance with Terminology D 653.

3.2 *Description of Terms Specific to This Standard:*

3.2.1 *Atterberg limits*—Originally, six "limits of consistency" of fine-grained soils were defined by Albert Atterberg: the upper limit of viscous flow, the liquid limit, the sticky limit, the cohesion limit, the plastic limit, and the shrinkage limit. In current engineering usage, the term usually refers only to the liquid limit, plastic limit, and in some references, the shrinkage limit.

3.2.2 *consistency*—the relative ease with which a soil can be deformed.

3.2.3 *liquid limit (LL)*—the water content, in percent, of a soil at the arbitrarily defined boundary between the liquid and plastic states. This water content is defined as the water content at which a pat of soil placed in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (½ in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of 2 shocks per second.

3.2.3.1 *Discussion*—The undrained shear strength of soil at the liquid limit is considered to be approximately 2 kPa (0.28 psi).

3.2.4 *plastic limit (PL)*—the water content, in percent, of a soil at the boundary between the plastic and brittle states. The water content at this boundary is the water content at which a soil can no longer be deformed by rolling into 3.2 mm (⅛ in.) in diameter threads without crumbling.

3.2.5 *plastic soil*—a soil which has a range of water content over which it exhibits plasticity and which will retain its shape on drying.

3.2.6 *plasticity index (PI)*—the range of water content over which a soil behaves plastically. Numerically, it is the difference between the liquid limit and the plastic limit.

3.2.7 *liquidity index*—the ratio, expressed as a percentage of (1) the natural water content of a soil minus its plastic limit, to (2) its plasticity index.

3.2.8 *activity number (A)*—the ratio of (1) the plasticity index of a soil to (2) the percent by weight of particles having an equivalent diameter smaller than 0.002 mm.

4. Summary of Test Method

4.1 The sample is processed to remove any material retained on a 425-μm (No. 40) sieve. The liquid limit is determined by performing trials in which a portion of the sample is spread in a brass cup, divided in two by a grooving tool, and then allowed to flow together from the shocks caused by repeatedly dropping the cup in a standard mechanical device. The multipoint liquid limit, Method A, requires three or more trials over a range of water contents to be performed and the data from the trials plotted or calculated to make a relationship from which the liquid limit is determined. The one-point liquid limit, Method B, uses the data from two trials at one water content multiplied by a correction factor to determine the liquid limit.

4.2 The plastic limit is determined by alternately pressing together and rolling into a 3.2-mm (⅛-in.) diameter thread a small portion of plastic soil until its water content is reduced to a point at which the thread crumbles and can no longer be pressed together and rerolled. The water content of the soil at this point is reported as the plastic limit.

4.3 The plasticity index is calculated as the difference between the liquid limit and the plastic limit.

5. Significance and Use

5.1 This test method is used as an integral part of several engineering classification systems to characterize the fine-grained fractions of soils (see Test Method D 2487 and Practice D 3282) and to specify the fine-grained fraction of construction materials (see Specification D 1241). The liquid limit, plastic limit, and plasticity index of soils are also used extensively, either individually or together, with other soil properties to correlate with engineering behavior such as compressibility, permeability, compactibility, shrink-swell, and shear strength.

5.2 The liquid and plastic limits of a soil can be used with the natural water content of the soil to express its relative consistency or liquidity index and can be used with the percentage finer than 2-μm size to determine its activity number.

5.3 These methods are sometimes used to evaluate the weathering characteristics of clay-shale materials. When subjected to repeated wetting and drying cycles, the liquid limits of these materials tend to increase. The amount of increase is considered to be a measure of a shale's susceptibility to weathering.

5.4 The liquid limit of a soil containing substantial amounts of organic matter decreases dramatically when the soil is oven-dried before testing. Comparison of the liquid limit of a sample before and after oven-drying can therefore be used as a qualitative measure of organic matter content of a soil.

6. Apparatus

6.1 *Liquid Limit Device*—A mechanical device consisting of a brass cup suspended from a carriage designed to control its drop onto a hard rubber base. Figure 1 shows the essential features and critical dimensions of the device. The device may be operated by either a hand crank or electric motor.

6.1.1 *Base*—A hard rubber base having a D Durometer hardness of 80 to 90, and a resilience such that an 8-mm (5⁄16-in.) diameter polished steel ball, when dropped from a height of 25 cm (9.84 in.) will have an average rebound of at least 80 % but no more than 90 %. Conduct resilience tests on the finished base with the feet attached. Details for measuring the resilience of the base are given in Appendix A.

6.1.2 *Rubber Feet*, supporting the base, designed to provide isolation of the base from the work surface, and having an A Durometer hardness no greater than 60 as measured on the finished feet attached to the base.

6.1.3 *Cup*, brass, with a weight, including cup hanger, of 185 to 215 g.

6.1.4 *Cam*—designed to raise the cup smoothly and continuously to its maximum height, over a distance of at least 180° of cam rotation, without developing an upward or downward velocity of the cup when the cam follower leaves

DIMENSIONS

LETTER	A^Δ	B^Δ	C^Δ	E^Δ	F	G	H	J^Δ	K^Δ	L^Δ	M^Δ
MM	54 ± 0.5	2 ± 0.1	27 ± 0.5	56 ± 2.0	32	10	16	60 ± 1.0	50 ± 2.0	150 ± 2.0	125 ± 2.0

LETTER	N	P	R	T	U^Δ	V	W	Z
MM	24	28	24	45	47 ± 1.0	3.8	13	6.5

Δ ESSENTIAL DIMENSIONS

CAM ANGLE DEGREES	CAM RADIUS
0	0.742
30	0.753
60	0.764
90	0.773
120	0.784
150	0.796
180	0.81
210	0.854
240	0.90
270	0.945
300	0.974
330	0.99
360	1.00

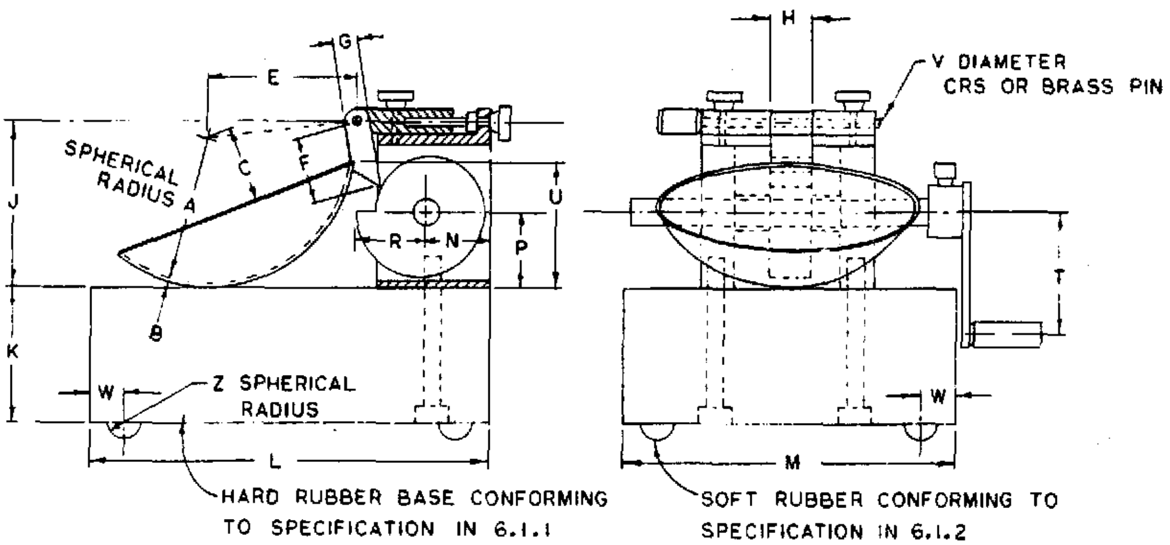


FIG. 1 Hand-Operated Liquid Limit Device

the cam. (The preferred cam motion is a uniformly accelerated lift curve.)

NOTE 1—The cam and follower design in Fig. 1 is for uniformly accelerated (parabolic) motion after contact and assures that the cup has no velocity at drop off. Other cam designs also provide this feature and may be used. However, if the cam-follower lift pattern is not known, zero velocity at drop off can be assured by carefully filing or machining the cam and follower so that the cup height remains constant over the last 20 to 45° of cam rotation.

6.1.5 *Carriage*, constructed in a way that allows convenient but secure adjustment of the height of drop of the cup to 10 mm (0.394 in.), and designed such that the cup and cup hanger assembly is only attached to the carriage by means of a removable pin.

6.1.6 *Motor Drive (Optional)*—As an alternative to the hand crank shown in Fig. 1, the device may be equipped with a motor to turn the cam. Such a motor must turn the cam at 2 ± 0.1 revolutions per second and must be isolated from the rest of the device by rubber mounts or in some other way that prevents vibration from the motor being transmitted to the rest of the apparatus. It must be equipped with an ON-OFF switch and a means of conveniently positioning the cam for height of drop adjustments. The results obtained using a motor-driven device must not differ from those obtained using a manually operated device.

6.2 *Flat Grooving Tool*—A tool made of plastic or noncorroding-metal having the dimensions shown in Fig. 2. The design of the tool may vary as long as the essential dimensions are maintained. The tool may, but need not, incorporate the gage for adjusting the height of drop of liquid limit device.

NOTE 2—Prior to the adoption of this test method, a curved groo tool was specified as part of the apparatus for performing the liquid li test. The curved tool is not considered to be as accurate as the flat described in 6.2 since it does not control the depth of the soil in liquid limit cup. However, there are some data which indicate typically the liquid limit is slightly increased when the flat tool is instead of the curved tool.

6.3 *Gage*—A metal gage block for adjusting the height drop of the cup, having the dimensions shown in Fig. 3. Th design of the tool may vary provided the gage will securely on the base without being susceptible to *rocking* and the edge which contacts the cup during adjustment straight, at least 10 mm (⅜ in.) wide, and without bevel radius.

6.4 *Containers*—Small corrosion-resistant containers snug-fitting lids for water content specimens. Aluminum stainless steel cans 2.5 cm (1 in.) high by 5 cm (2 in.) diameter are appropriate.

6.5 *Balance*, conforming to Specification D 4753, Cl GP1.

6.6 *Storage Container*—A container in which to store prepared soil specimen that will not contaminate the imen in any way, and will prevent moisture loss. A porcelain glass, or plastic dish about 11.4 cm (4½ in.) in diameter a plastic bag large enough to enclose the dish and be fold over is adequate.

6.7 *Ground Glass Plate*—A ground glass plate at least

DIMENSIONS

LETTER	A$^{\Delta}$	B$^{\Delta}$	C$^{\Delta}$	D$^{\Delta}$	E$^{\Delta}$	F$^{\Delta}$
MM	2 ± 0.1	11 ± 0.2	40 ± 0.5	8 ± 0.1	50 ± 0.5	2 ± 0.1
LETTER	G	H	J	K$^{\Delta}$	L$^{\Delta}$	N
MM	10 MINIMUM	13	60	10 ±0.05	60 DEG ± 1 DEG	20

$^{\Delta}$ ESSENTIAL DIMENSIONS

$^{\circ}$ BACK AT LEAST 15 MM FROM TIP

NOTE: DIMENSION A SHOULD BE 1.9–2.0 AND DIMENSION D SHOULD BE 8.0–8.1 WHEN NEW TO ALLOW FOR ADEQUATE SERVICE LIFE

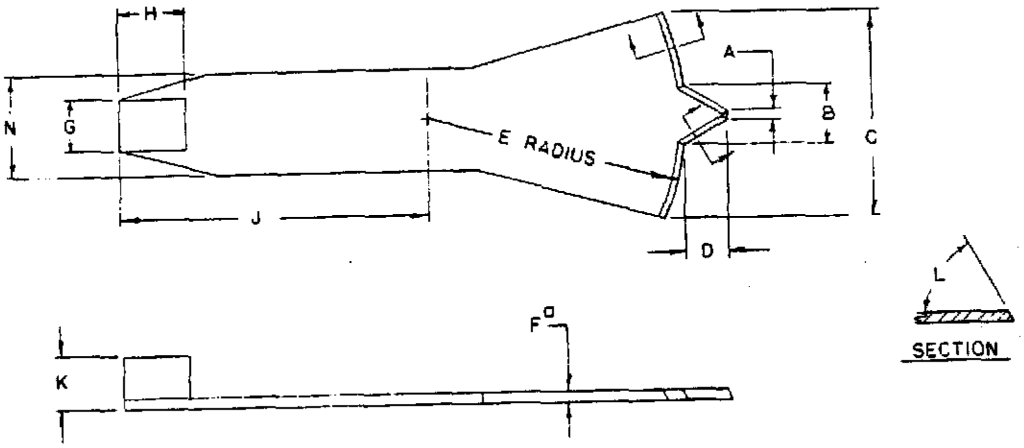
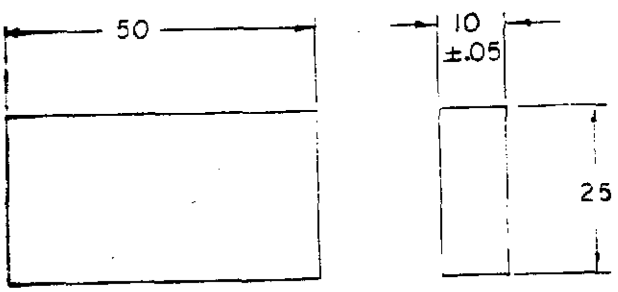


FIG. 2 Grooving Tool (Optional Height-of-Drop Gage Attached)



DIMENSIONS IN MILLIMETRES

FIG. 3 Height of Drop Gage

cm (12 in.) square by 1 cm (3/8 in.) thick for rolling plastic limit threads.

6.8 *Spatula*—A spatula or pill knife having a blade about 2 cm (3/4 in.) wide, and about 10 to 13 cm (3 to 4 in.) long.

6.9 *Sieve*—A 20.3-cm (8-in.) diameter, 425-μm (No. 40) sieve conforming to the requirements of Specification E 11 and having a rim at least 5 cm (2 in.) above the mesh. A 2-mm (No. 10) sieve meeting the same requirements may also be needed.

6.10 *Wash Bottle*, or similar container for adding controlled amounts of water to soil and washing fines from coarse particles.

6.11 *Drying Oven*, thermostatically controlled, preferably of the forced-draft type, capable of continuously maintaining a temperature of 110 ± 5°C (230 ± 9°F) throughout the drying chamber.

6.12 *Washing Pan*, round, flat-bottomed, at least 7.6 cm (3 in.) deep, and slightly larger at the bottom than a 20.3-cm (8-in.) diameter sieve.

7. Reagents and Materials

7.1 *Purity of Water*—Where distilled water is referred to in this test method, either distilled or demineralized water may be used.

8. Sampling

8.1 Samples may be taken from any location that satisfies testing needs. However, Methods C 702, Practice D 75, and Practice D 420 should be used as guides for selecting and preserving samples from various types of sampling operations. Samples which will be prepared using the wet preparation procedure (10.1) must be kept at their natural water content prior to preparation.

8.2 Where sampling operations have preserved the natural stratification of a sample, the various strata must be kept separated and tests performed on the particular stratum of interest with as little contamination as possible from other strata. Where a mixture of materials will be used in construction, combine the various components in such proportions that the resultant sample represents the actual construction case.

8.3 Where data from this test method are to be used for correlation with other laboratory or field test data, use the same material as used for these tests where possible.

8.4 Obtain a representative portion from the total sample sufficient to provide 150 to 200 g of material passing the 425-µm (No. 40) sieve. Free flowing samples may be reduced by the methods of quartering or splitting. Cohesive samples shall be mixed thoroughly in a pan with a spatula, or scoop and a representative portion scooped from the total mass by making one or more sweeps with a scoop through the mixed mass.

9. Calibration of Apparatus

9.1 *Inspection of Wear:*

9.1.1 *Liquid Limit Device*—Determine that the liquid limit device is clean and in good working order. Check the following specific points.

9.1.1.1 *Wear of Base*—The spot on the base where the cup makes contact should be worn no greater than 10 mm (3/8 in.) in diameter. If the wear spot is greater than this, the base can be machined to remove the worn spot provided the resurfacing does not make the base thinner than specified in 6.1 and the other dimensional relationships are maintained.

9.1.1.2 *Wear of Cup*—Replace the cup when the grooving tool has worn a depression in the cup 0.1 mm (0.004 in.) deep or when the rim of the cup has been reduced to half its original thickness. Verify that the cup is firmly attached to the cup hanger.

9.1.1.3 *Wear of Cup Hanger*—Verify that the cup hanger pivot does not bind and is not worn to an extent that allows more than 3 mm (1/8 in.) side-to-side movement of the lowest point on the rim.

9.1.1.4 *Wear of Cam*—The cam shall not be worn to an extent that the cup drops before the cup hanger (cam follower) loses contact with the cam.

9.1.2 *Grooving Tools*—Inspect grooving tools for wear on a frequent and regular basis. The rapidity of wear depends on the material from which the tool is made and the types of soils being tested. Soils containing a large proportion of sand particles may cause rapid wear of grooving tools; therefore, when testing these materials, tools should be inspected more frequently than for other soils.

NOTE 3—*The width of the tip of grooving* tools is conveni checked using a pocket-sized measuring magnifier equipped with millimetre scale. Magnifiers of this type are available from laboratory supply companies. The depth of the tip of grooving tools be checked using the depth measuring feature of vernier calipers.

9.2 *Adjustment of Height of Drop*—Adjust the height drop of the cup so that the point on the cup that comes contact with the base rises to a height of 10 ± 0.2 mm. S Fig. 4 for proper location of the gage relative to the c during adjustment.

NOTE 4—A convenient procedure for adjusting the height of drop as follows: place a piece of masking tape across the outside bottom of cup parallel with the axis of the cup hanger pivot. The edge of the away from the cup hanger should bisect the spot on the cup that co the base. For new cups, placing a piece of carbon paper on the base allowing the cup to drop several times will mark the contact spot. A the cup to the device and turn the crank until the cup is raised to maximum height. Slide the height gage under the cup from the fr and observe whether the gage contacts the cup or the tape. (See Fig. If the tape and cup are both contacted, the height of drop is appro mately correct. If not, adjust the cup until simultaneous contact is ma Check adjustment by turning the crank at 2 revolutions per second holding the gage in position against the tape and cup. If a faint ringing clicking sound is heard without the cup rising from the gage, adjustment is correct. If no ringing is heard or if the cup rises from gage, readjust the height of drop. If the cup rocks on the gage during checking operation, the cam follower pivot is excessively worn and worn parts should be replaced. Always remove tape after completion adjustment operation.

10. Preparation of Test Specimens

10.1 *Wet Preparation*—Except where the dry method specimen preparation is specified (10.2), prepare specim for test as described in the following sections.

10.1.1 *Samples Passing the 425-µm (No. 40) Sieve:*

10.1.1.1 When by visual and manual procedures i determined that the sample has little or no material reta on a 425-µm (No. 40) sieve, prepare a specimen of 150 200 g by mixing thoroughly with distilled or demineral water on the glass plate using the spatula. If desired, soak soil in a storage dish with a small amount of water to so the soil before the start of mixing. Adjust the water cont of the soil to bring it to a consistency that would require to 35 blows of the liquid limit device to close the groo (Note 5).

10.1.1.2 If, during mixing, a small percentage of mat is encountered that would be retained on a 425-µm (No.

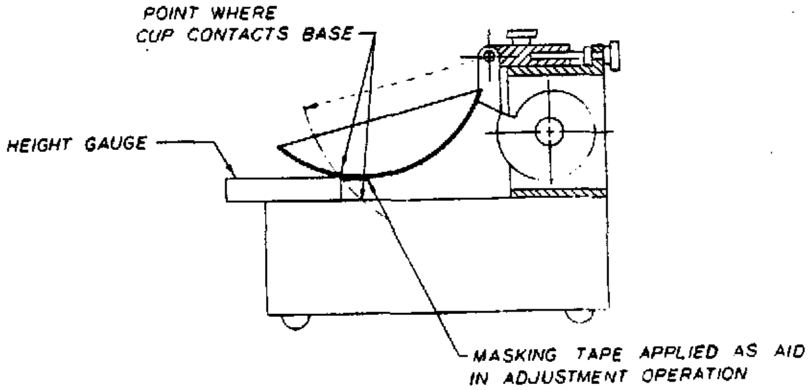


FIG. 4 Calibration for Height of Drop

remove these particles by hand (if possible). If it is tical to remove the coarser material by hand, remove rcentages (less than about 15 %) of coarser material ing the specimen through a 425-μm sieve using a f rubber sheeting, rubber stopper, or other convenient provided the operation does not distort the sieve or e material that would be retained if the washing d described in 10.1.2 were used. If larger percentages rse material are encountered during mixing, or it is ered impractical to remove the coarser material by the ds just described, wash the sample as described in When the coarse particles found during mixing are tions, shells, or other fragile particles, do not crush particles to make them pass a 425-μm sieve, but e by hand or by washing.

1.1.3 Place the mixed soil in the storage dish, cover to nt loss of moisture, and allow to stand for at least 16 h ght). After the standing period and immediately starting the test, thoroughly remix the soil.

t 5—The time taken to adequately mix a soil will vary greatly, ding on the plasticity and initial water content. Initial mixing f more than 30 min may be needed for stiff, fat clays.

1.2 *Samples Containing Material Retained on a 425- No. 40) Sieve:*

1.2.1 Select a sufficient quantity of soil at natural water nt to provide 150 to 200 g of material passing the 425- No. 40) sieve. Place in a pan or dish and add sufficient r to cover the soil. Allow to soak until all lumps have ked and the fines no longer adhere to the surfaces of the e particles (Note 6).

6—In some cases, the cations of salts present in tap water will ge with the natural cations in the soil and significantly alter the sults if tap water is used in the soaking and washing operations. s it is known that such cations are not present in the tap water, led or demineralized water should be used. As a general rule. water ning more than 100 mg/L of dissolved solids should not be used ashing operations.

1.2.2 When the sample contains a large percentage of rial retained on the 425-μm (No. 40) sieve, perform the wing washing operation in increments, washing no more n 0.5 kg (1 lb) of material at one time. Place the 425-μm e in the bottom of the clean pan. Pour the soil-water ture onto the sieve. If gravel or coarse sand particles are ent, rinse as many of these as possible with small ntities of water from a wash bottle, and discard. Alternaly, pour the soil water mixture over a 2.00-mm (No. 10) e nested atop the 425-μm sieve, rinse the fine material ugh and remove the 2.00-mm sieve. After washing and oving as much of the coarser material as possible, add cient water to the pan to bring the level to about 13 mm in.) above the surface of the 425- μm sieve. Agitate the ry by stirring with the fingers while raising and lowering sieve in the pan and swirling the suspension so that fine erial is washed from the coarser particles. Disaggregate e soil lumps that have not slaked by gently rubbing them er the sieve with the fingertips. Complete the washing ration by raising the sieve above the water surface and sing the material retained with a small amount of clean . Discard material retained on the 425-μm sieve.

1.2.3 Reduce the water content of the material passing e 425 μm (No. 40) sieve until it approaches the liquid limit. Reduction of water content may be accomplished by one or a combination of the following methods: (*a*) exposing to air currents at room temperature, (*b*) exposing to warm air currents from a source such as an electric hair dryer, or (*c*) decanting clear water from surface of the suspension. During evaporation and cooling, stir the sample often enough to prevent overdrying of the fringes and soil pinnacles on the surface of the mixture. For soil samples containing soluble salts, use a method of water reduction (*a* or *b*) that will not eliminate the soluble salts from the test specimen.

10.1.2.4 Thoroughly mix the material passing the 425-μm sieve on the glass plate using the spatula. Adjust the water content of the mixture, if necessary, by adding small increments of distilled or demineralized water or by allowing the mixture to dry at room temperature while mixing on the glass plate. The soil should be at a water content that will result in closure of the groove in 25 to 35 blows. Put the mixed soil in the storage dish, cover to prevent loss of moisture, and allow to stand for at least 16 h. After the standing period and immediately before starting the test, thoroughly remix the soil.

10.2 *Dry Preparation:*

10.2.1 Select sufficient soil to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve after processing. Dry the sample at room temperature or in an oven at a temperature not exceeding 60°C until the soil clods will pulverize readily. Disaggregation is expedited if the sample is not allowed to completely dry. However, the soil should have a dry appearance when pulverized.

10.2.2 Pulverize the sample in a mortar with a rubber-tipped pestle or in some other way that does not cause breakdown of individual grains. When the coarse particles found during pulverization are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm (No. 40) sieve, but remove by hand or other suitable means, such as washing.

10.2.3 Separate the sample on a 425-μm (No. 40) sieve, shaking the sieve by hand to assure thorough separation of the finer fraction. Return the material retained on the 425-μm sieve to the pulverizing apparatus and repeat the pulverizing and sieving operations as many times as necessary to assure that all fine material has been disaggregated and material retained on the 425-μm sieve consists only of individual sand or gravel grains.

10.2.4 Place material remaining on the 425-μm (No. 40) sieve after the final pulverizing operations in a dish and soak in a small amount of water. Stir the soil water mixture and pour over a 425-μm sieve, catching the water and any suspended fines in the washing pan. Pour this suspension into a dish containing the dry soil previously sieved through the 425-μm sieve. Discard material retained on the 425-μm sieve.

10.2.5 Proceed as described in 10.1.2.3 and 10.1.2.4.

MULTIPOINT LIQUID LIMIT—METHOD A

11. Procedure

11.1 Place a portion of the prepared soil in the cup of the liquid limit device at the point where the cup rests on the base, squeeze it down, and spread it into the cup to a depth of about 10 mm at its deepest point, tapering to form an approximately horizontal surface. Take care to eliminate air bubbles from the soil pat, but form the pat with as few strokes as possible. Keep the unused soil in the storage dish. Cover the storage dish with a wet towel (or use other means) to retain the moisture in the sample.

11.2 Form a groove in the soil pat by drawing the tool, beveled edge forward, through the soil on a line joining the highest point to the lowest point on the rim of the cup. When cutting the groove, hold the grooving tool against the surface of the cup and draw in an arc, maintaining the tool perpendicular to the surface of the cup throughout its movement. See Fig. 5. In soils where a groove cannot be made in one stroke without tearing the soil, cut the groove with several strokes of the grooving tool. Alternatively, cut the groove to slightly less than required dimensions with a spatula and use the grooving tool to bring the groove to final dimensions. Exercise extreme care to prevent sliding the soil pat relative to the surface of the cup.

11.3 Verify that no crumbs of soil are present on the base or the underside of the cup. Lift and drop the cup by turning the crank at a rate of 1.9 to 2.1 drops per second until the two halves of the soil pat come in contact at the bottom of the groove along a distance of 13 mm (½ in.). See Fig. 6.

NOTE 7—Use of a scale is recommended to verify that the groove has closed 13 mm (½ in.)

11.4 Verify that an air bubble has not caused premature closing of the groove by observing that both sides of the groove have flowed together with approximately the same shape. If a bubble has caused premature closing of the groove, reform the soil in the cup, adding a small amount of soil to make up for that lost in the grooving operation and repeat 11.1 to 11.3. If the soil slides on the surface of the cup, repeat 11.1 through 11.3 at a higher water content. If, after several trials at successively higher water contents, the soil pat continues to slide in the cup or if the number of blows required to close the groove is always less than 25, record that the liquid limit could not be determined, and report the soil as nonplastic without performing the plastic limit test.

11.5 Record the number of drops, N, required to close the groove. Remove a slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, place in a weighed container, and cover.

11.6 Return the soil remaining in the cup to the storage dish. Wash and dry the cup and grooving tool and reattach the cup to the carriage in preparation for the next trial.

11.7 Remix the entire soil specimen in the storage dish adding distilled water to increase the water content of the soil and decrease the number of blows required to close the groove. Repeat 11.1 through 11.6 for at least two additional trials producing successively lower numbers of blows to close the groove. One of the trials shall be for a closure requiring 25 to 35 blows, one for closure between 20 and 30 blows, and one trial for a closure requiring 15 to 25 blows.

11.8 Determine the water content, W^n, of the soil specimen from each trial in accordance with Test Method D 2216. Initial weighings should be performed immediately after completion of the test. If the test is to be interrupted for more than about 15 minutes, the specimens already obtained should be weighed at the time of the interruption.

12. Calculation

12.1 Plot the relationship between the water content, W^n, and the corresponding number of drops, N, of the cup on a semilogarithmic graph with the water content as ordinates on the arithmetical scale, and the number of drops as abscissas

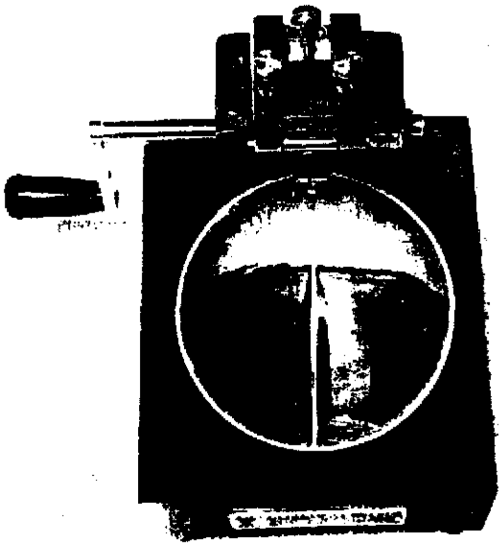


FIG. 5 Grooved Soil Pat in Liquid Limit Device

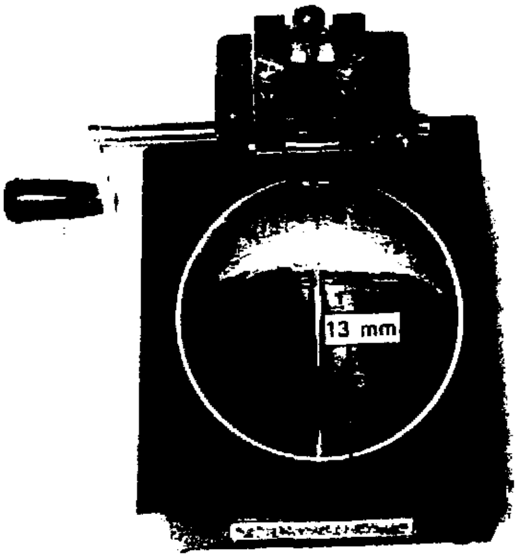


FIG. 6 Soil Pat After Groove Has Closed

on a logarithmic scale. Draw the best straight line through the three or more plotted points.

12.2 Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit of the soil. Computational methods may be substituted for the graphical method for fitting a straight line to the data and determining the liquid limit.

ONE-POINT LIQUID LIMIT—METHOD B

13. Preparation of Test Specimens

13.1 Prepare the specimen in the same manner in accordance with Section 10, except that at mixing, adjust the water content to a consistency requiring 20 to 30 drops of the liquid limit cup to close the groove.

14. Procedure

14.1 Proceed as described in 11.1 through 11.5 except that the number of blows required to close the groove shall be 20 to 30. If less than 20 or more than 30 blows are required, adjust the water content of the soil and repeat the procedure.

TABLE 1 Factors for Obtaining Liquid Limit from Water Content and Number of Drops Causing Closure of Groove

N (Number of Drops)	k (Factor for Liquid Limit)
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

14.2 Immediately after removing a water content specimen as described in 11.5, reform the soil in the cup, adding a small amount of soil to make up for that lost in the grooving and water content sampling orientations. Repeat 11.2 through 11.5, and, if the second closing of the groove requires the same number of drops or no more than two drops difference, secure another water content specimen. Otherwise, remix the entire specimen and repeat.

NOTE 8—Excessive drying or inadequate mixing will cause the number of blows to vary.

14.3 Determine water contents of specimens in accordance with 11.8.

15. Calculation

15.1 Determine the liquid limit for each water content specimen using one of the following equations:

$$LL = W^n \left(\frac{N}{25}\right)^{0.121}$$

or

$$LL = kW^n$$

where:

N = number of blows causing closure of the groove at water content,

W^n = water content, and

k = factor given in Table 1.

The liquid limit is the average of the two trial liquid limit values.

15.2 If the difference between the two trial liquid limit values is greater than one percentage point, repeat the test.

PLASTIC LIMIT

16. Preparation of Test Specimen

16.1 Select a 20-g portion of soil from the material prepared for the liquid limit test, either after the second mixing before the test, or from the soil remaining after completion of the test. Reduce the water content of the soil to a consistency at which it can be rolled without sticking to the hands by spreading or mixing continuously on the glass plate or in the storage dish. The drying process may be accelerated by exposing the soil to the air current from an electric fan, or by blotting with paper that does not add any fiber to the soil, such as hard surface paper toweling or high wet-strength filter paper.

17. Procedure

17.1 From the 20-g mass, select a portion of 1.5 to 2.0 g. Form the test specimen into an ellipsoidal mass. Roll this mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length (Note 9). The thread shall be further deformed on each stroke so that its diameter reaches 3.2 mm (1/8 in.), taking no more than 2 min (Note 10). The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

NOTE 9—A normal rate of rolling for most soils should be 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position. This rate of rolling may have to be decreased for very fragile soils.

NOTE 10—A 3.2-mm (1/8-in.) diameter rod or tube is useful for frequent comparison with the soil thread to ascertain when the thread has reached the proper diameter.

17.1.1 When the diameter of the thread becomes 3.2 mm, break the thread into several pieces. Squeeze the pieces together, knead between the thumb and first finger of each hand, reform into an ellipsoidal mass, and reroll. Continue this alternate rolling to a thread 3.2 mm in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a 3.2-mm diameter thread (see Fig. 7). It has no significance if the thread breaks into threads of shorter length. Roll each of these shorter threads to 3.2 mm in diameter. The only requirement for continuing the test is that they are able to be reformed into an ellipsoidal mass and rolled out again. The operator shall at no time attempt to produce failure at exactly 3.2 mm diameter by allowing the thread to reach 3.2 mm, then reducing the rate of rolling or the hand pressure, or both, while continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal mass nearer to the required 3.2-mm final diameter. If crumbling occurs when the thread has a diameter greater than 3.2 mm, this shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3.2 mm in diameter. Crumbling of the thread will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles, others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. Fat clay soils require much pressure to deform the thread, particularly as they approach the plastic limit. With these soils, the thread breaks into a series of barrel-shaped segments about 3.2 to 9.5 mm (1/8 to 3/8 in.) in length.

17.2 Gather the portions of the crumbled thread together and place in a weighed container. Immediately cover the container.

17.3 Select another 1.5 to 2.0-g portion of soil from the

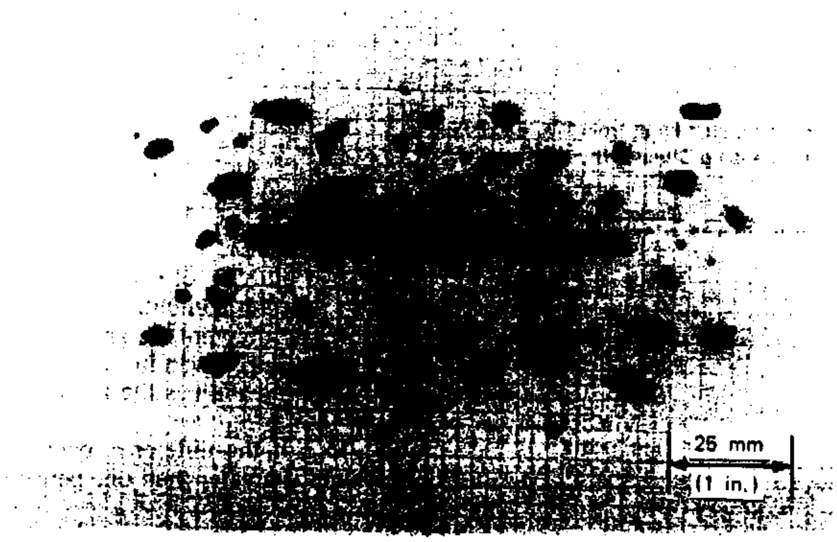


FIG. 7 Lean Clay Soil at the Plastic Limit

TABLE 2 Table of Precision Estimates[A]

Material and Type Index	Standard Deviation[B]	Acceptable Range of Two Results[B]
Single-operator precision:		
Liquid Limit	0.8	2.4
Plastic Limit	0.9	2.6
Multilaboratory precision:		
Liquid Limit	3.5	9.9
Plastic Limit	3.7	10.6

[A] The figures given in Column 2 are the standard deviations that have been found to be appropriate for the test results described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the two properly conducted tests.

[B] These numbers represent, respectively, the (1S) and (D2S) limits as described in Practice C 670.

original 20-g specimen and repeat the operations described in 17.1 and 17.2 until the container has at least 6 g of soil.

17.4 Repeat 17.1 through 17.3 to make another container holding at least 6 g of soil. Determine the water content of the soil contained in the containers in accordance with Test Method D 2216.

18. Calculation

18.1 Compute the average of the two water contents. Repeat the test if the difference between the two water contents is greater than the acceptable range for two results listed in Table 2 for single-operator precision. The plastic limit is the average of the two water contents.

PLASTICITY INDEX

19. Calculation

19.1 Calculate the plasticity index as follows:

$$PI = LL - PL$$

where:

LL = liquid limit,

PL = plastic limit.

19.1.1 Both LL and PL are whole numbers. If either the liquid limit or plastic limit could not be determined, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP.

20. Report

20.1 Report the following information:

20.1.1 Sample identifying information,

20.1.2 Any special specimen selection process used, such as removal of sand lenses from undisturbed sample,

20.1.3 Report sample as air-dried if the sample was air-dried before or during preparation,

20.1.4 Liquid limit, plastic limit, and plasticity index to the nearest whole number, omitting the percent designation. If the liquid limit or plastic limit tests could not be performed, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP,

20.1.5 Estimate of the percentage of sample retained on the 425-μm (No. 40) sieve, and

20.1.6 Procedure by which liquid limit was performed, if it differs from the multipoint method.

21. Precision and Bias

21.1 *Precision*—Criteria for judging the acceptability of liquid limit and plastic limit test results obtained by this test method on material are given in Table 2. The estimates of precision are based on the results of an interlaboratory study that included eleven laboratories performing the multipoint test (Method A) on three replicate samples of soil having a liquid limit of 64 and a plastic limit of 22.

21.2 *Bias*—There is no acceptable reference value for this test method; therefore, bias cannot be determined.

22. Keywords

22.1 activity; Atterberg limits; liquid limit; plasticity index; plastic limit

APPENDIX

(Nonmandatory Information)

X1.1 A device for measuring the resilience of liquid limit device bases is shown in Fig. X1.1. The device consists of a clear acrylic plastic tube and cap, a 5/16-in. diameter steel ball, and a small bar magnet. The cylinder may be cemented to the cap or threaded as shown. The small bar magnet is held in the recess of the cap and the steel ball is fixed into the recess in the underside of the cap with the bar magnet. The cylinder is then turned upright and placed on the top surface of the base to be tested. Holding the tube lightly against the liquid limit device base with one hand, release the ball by pulling the magnet out of the cap. Use the scale markings on the outside of the cylinder to determine the highest point reached by the bottom of the ball. Repeat the drop at least three times, placing the tester in a different location for each drop. Tests should be conducted at room temperature.

CLEAR PLASTIC (SUCH AS ACRYLIC)
CAP AND TUBE

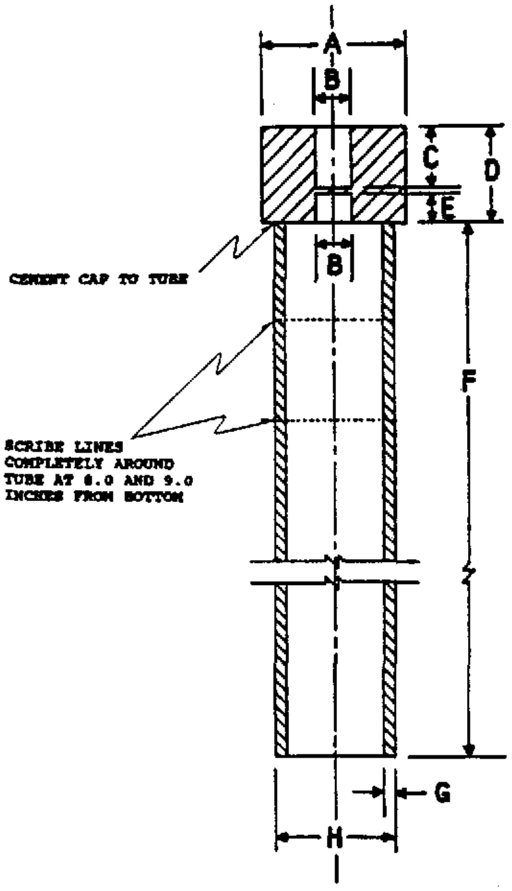


TABLE OF MEASUREMENTS

DIMENSION	DESCRIPTION	ENGLISH, in.	METRIC, [illegible]
A	DIAM. OF CAP	1 1/2	38.10
B	DIAM. OF HOLE	3/8	9.52
C	DEPTH OF HOLE	10/16	15.88
D	HEIGHT OF CAP	1	25.40
E	DEPTH OF HOLE	5/16	7.94
F	LENGTH OF TUBE	10	254.00
G	WALL THICKNESS	1/8	3.18
H	O.D. OF TUBE	1 1/4	31.75

FIG. X1.1 Resilience Tester

Designation: D 5084 - 90

Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter[1]

This standard is issued under the fixed designation D 5084; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers laboratory measurement of the hydraulic conductivity (also referred to as *coefficient of permeability*) of water-saturated porous materials with a flexible wall permeameter.

1.2 This test method may be utilized with undisturbed or compacted specimens that have a hydraulic conductivity less than or equal to 1×10^{-5} m/s (1×10^{-3} cm/s).

1.3 The hydraulic conductivity of materials with hydraulic conductivities greater than 1×10^{-5} m/s may be determined by Test Method D 2434.

1.4 The values stated in SI units are to be regarded as the standard, unless other units are specifically given. By tradition in U.S. practice, hydraulic conductivity is reported in centimetres per second, although the common SI units for hydraulic conductivity are metres per second.

1.5 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[2]

D 1557 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop[2]

D 1587 Practice of Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content in Soil, Rock, and Soil-Aggregate Mixtures[2]

D 2434 Test Method for Permeability of Granular Soils (Constant Head)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

D 4753 Specification for Evaluating, Selecting and Specifying Balances and Scales for Use in Soil and Rock Testing[2]

D 4767 Test Method for Consolidated-Undrained Triaxial Compression[2]

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *hydraulic conductivity, k*—the rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient and standard temperature conditions (20°C).

Discussion—The term *coefficient of permeability* is often used instead of *hydraulic conductivity*, but *hydraulic conductivity* is used exclusively in this test method. A more complete discussion of the terminology associated with Darcy's law is given in the literature.[4]

3.1.2 *pore volume of flow*—the cumulative quantity of flow into a test specimen divided by the volume of voids in the specimen.

3.1.3 For definitions of other terms used in this test method, see Terminology D 653.

4. Significance and Use

4.1 This test method applies to one-dimensional, laminar flow of water within porous materials such as soil and rock.

4.2 The hydraulic conductivity of porous materials generally decreases with an increasing amount of air in the pores of the material. This test method applies to water-saturated porous materials containing virtually no air.

4.3 This test method applies to permeation of porous materials with water. Permeation with other liquids, such as chemical wastes, can be accomplished using procedures similar to those described in this test method. However, this test method is only intended to be used when water is the permeant liquid.

4.4 It is assumed that Darcy's law is valid and that the hydraulic conductivity is essentially unaffected by hydraulic gradient. The validity of Darcy's law may be evaluated by measuring the hydraulic conductivity of the specimen at three hydraulic gradients; if all measured values are similar (within about 25 %), then Darcy's law may be taken as valid. However, when the hydraulic gradient acting on a test

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.04 on Hydrologic Properties of Soil and Rocks.

Current edition approved June 29, 1990. Published October 1990.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] Olson, R. E., and Daniel, D. E., "Measurement of the Hydraulic Conductivity of Fine-Grained Soils," *Symposium on Permeability and Groundwater Contaminant Transport*, *ASTM STP 746*, ASTM, 1981, pp. 18–64.

specimen is changed, the state of stress will also change, and, if the specimen is compressible, the volume of the specimen will change. Thus, some change in hydraulic conductivity may occur when the hydraulic gradient is altered, even in cases where Darcy's law is valid.

4.5 This test method provides a means for determining hydraulic conductivity at a controlled level of effective stress. Hydraulic conductivity varies with varying void ratio, which in turn changes when the effective stress changes. If the void ratio is changed, the hydraulic conductivity of the test specimen will likely change. To determine the relationship between hydraulic conductivity and void ratio, the hydraulic conductivity test would have to be repeated at different effective stresses.

4.6 The correlation between results obtained with this test method and the hydraulic conductivities of in-place field materials has not been fully investigated. Experience has sometimes shown that flow patterns in small test specimens do not necessarily follow the same patterns on large field scales and that hydraulic conductivities measured on small test specimens are not necessarily the same as larger-scale values. Therefore, the results should be applied to field situations with caution and by qualified personnel.

5. Apparatus

5.1 *Hydraulic System*—Constant head (Method A), falling head (Methods B and C), or constant rate of flow (Method D) systems may be utilized provided they meet the criteria outlined as follows:

5.1.1 *Constant Head*—The system must be capable of maintaining constant hydraulic pressures to within ±5 % and shall include means to measure the hydraulic pressures to within the prescribed tolerance. In addition, the head loss across the test specimen must be held constant to within ±5 % and shall be measured with the same accuracy or better. Pressures shall be measured by a pressure gage, electronic pressure transducer, or any other device of suitable accuracy.

5.1.2 *Falling Head*—The system shall allow for measurement of the applied head loss, thus hydraulic gradient, to within 5 % or better at any time. In addition, the ratio of initial head loss divided by final head loss over an interval of time shall be measured such that this computed ratio is accurate to within ±5 %. The head loss shall be measured with a pressure gage, electronic pressure transducer, engineer's scale, graduated pipette, or any other device of suitable accuracy. Falling head tests may be performed with either a constant tailwater elevation (Method B) or a rising tailwater elevation (Method C).

5.1.3 *Constant Rate of Flow*—The system must be capable of maintaining a constant rate of flow through the specimen to within 5 % or better. Flow measurement shall be by calibrated syringe, graduated pipette, or other device of suitable accuracy. The head loss across the specimen shall be measured to an accuracy of 5 % or better using an electronic pressure transducer or other device of suitable accuracy. More information on testing with a constant rate of flow is given in the literature.[5]

5.1.4 *System De-airing*—The hydraulic system shall be designed to facilitate rapid and complete removal of free air bubbles from flow lines.

5.1.5 *Back Pressure System*—The hydraulic system shall have the capability to apply back pressure to the specimen to facilitate saturation. The system shall be capable of maintaining the applied back pressure throughout the duration of hydraulic conductivity measurements. The back pressure system shall be capable of applying, controlling, and measuring the back pressure to 5 % or better of the applied pressure. The back pressure may be provided by a compressed gas supply, a deadweight acting on a piston, or any other method capable of applying and controlling the back pressure to the tolerance prescribed in this paragraph.

NOTE 1—Application of gas pressure directly to a fluid will dissolve gas in the fluid. A variety of techniques are available to minimize dissolution of gas in the back pressure fluid, including separation of gas and liquid phases with a bladder and frequent replacement of the liquid with de-aired water.

5.2 *Flow Measurement System*—Both inflow and outflow volumes shall be measured unless the lack of leakage, continuity of flow, and cessation of consolidation or swelling can be verified by other means. Flow volumes shall be measured by a graduated accumulator, graduated pipette, vertical standpipe in conjunction with an electronic pressure transducer, or other volume-measuring device of suitable accuracy.

5.2.1 *Flow Accuracy*—Required accuracy for the quantity of flow measured over an interval of time is 5 % or better.

5.2.2 *De-airing and Compliance of the System*—The flow-measurement system shall contain a minimum of dead space and be capable of complete and rapid de-airing. Compliance of the system in response to changes in pressure shall be minimized by using a stiff flow measurement system. Rigid tubing, such as metallic or rigid thermoplastic tubing, shall be used.

5.2.3 *Head Losses*—Head losses in the tubes, valves, porous end pieces, and filter paper may lead to error. To guard against such errors, the permeameter shall be assembled with no specimen inside and then the hydraulic system filled. If a constant or falling head test is to be used, the hydraulic pressures or heads that will be used in testing a specimen shall be applied, and the rate of flow measured with an accuracy of 5 % or better. This rate of flow shall be at least ten times greater than the rate of flow that is measured when a specimen is placed inside the permeameter and the same hydraulic pressures or heads are applied. If a constant rate of flow test is to be used, the rate of flow to be used in testing a specimen shall be supplied to the permeameter and the head loss measured. The head loss without a specimen shall be less than 0.1 times the head loss when a specimen is present.

5.3 *Permeameter Cell Pressure System*—The system for pressurizing the permeameter cell shall be capable of applying and controlling the cell pressure to within 5 % of the applied pressure. However, the effective stress on the test specimen (which is the difference between the cell pressure and the pore water pressure) shall be maintained to the desired value with an accuracy of 10 % or better. The device for pressurizing the cell may consist of a reservoir connected to the permeameter cell and partially filled with de-aired

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[5] Olson, H. W., Morin, R. H., and Nichols, R. W., "Flow Pump Applications in Triaxial Testing," *Symposium on Advanced Triaxial Testing of Soil and Rock, ASTM STP 977*, ASTM, 1988, pp. 68–81.

water, with the upper part of the reservoir connected to a compressed gas supply or other source of pressure (see Note 2). The gas pressure shall be controlled by a pressure regulator and measured by a pressure gage, electronic pressure transducer, or any other device capable of measuring to the prescribed tolerance. A hydraulic system pressurized by deadweight acting on a piston or any other pressure device capable of applying and controlling the permeameter cell pressure to the tolerance prescribed in this paragraph may be used.

NOTE 2—De-aired water is commonly used for the cell fluid to minimize potential for diffusion of air through the membrane into the specimen. Other fluids, such as oils, which have low gas solubilities are also acceptable, provided they do not react with components of the permeameter. Also, use of a long (approximately 5 to 7 m) tube connecting the pressurized cell liquid to the cell helps to delay the appearance of air in the cell fluid and to reduce the flux of dissolved air into the cell.

5.4 *Permeameter Cell*—An apparatus shall be provided in which the specimen and porous end pieces, enclosed by a membrane sealed to the cap and base, are subjected to controlled fluid pressures. A schematic diagram of a typical cell is shown in Fig. 1.

5.4.1 The permeameter cell may allow for observation of changes in height of the specimen, either by observation through the cell wall using a cathetometer or other instrument, or by monitoring of either a loading piston or an extensometer extending through the top plate of the cell bearing on the top cap and attached to a dial indicator or other measuring device. The piston or extensometer should pass through a bushing and seal incorporated into the top plate and shall be loaded with sufficient force to compensate for the cell pressure acting over the cross-sectional area of the piston where it passes through the seal. If deformations are measured, the deformation indicator shall be a dial indicator or cathetometer graduated to 0.3 mm (0.01 in.) or better and having an adequate travel range. Any other measuring device meeting these requirements is acceptable.

5.4.2 In order to facilitate gas removal, and thus saturation of the hydraulic system, four drainage lines leading to the specimen, two each to the base and top cap, are recommended. The drainage lines shall be controlled by no-volume-change valves, such as ball valves, and shall be designed to minimize dead space in the lines.

5.5 *Top Cap and Base*—An impermeable, rigid top cap and base shall be used to support the specimen and provide for transmission of permeant liquid to and from the specimen. The diameter or width of the top cap and base shall be equal to the diameter or width of the specimen ±5 %. The base shall prevent leakage, lateral motion, or tilting, and the top cap shall be designed to receive the piston or extensometer, if used, such that the piston-to-top cap contact area is concentric with the cap. The surface of the base and top cap that contacts the membrane to form a seal shall be smooth and free of scratches.

5.6 *Flexible Membranes*—The flexible membrane used to encase the specimen shall provide reliable protection against leakage. The membrane shall be carefully inspected prior to use and if any flaws or pinholes are evident, the membrane shall be discarded. To minimize restrain to the specimen, the diameter or width of the unstretched membrane shall be between 90 and 95 % of that of the specimen. The membrane shall be sealed to the specimen base and cap with rubber O-rings for which the unstressed, inside diameter or width is less than 90 % of the diameter or width of the base and cap, or by any other method that will produce an adequate seal.

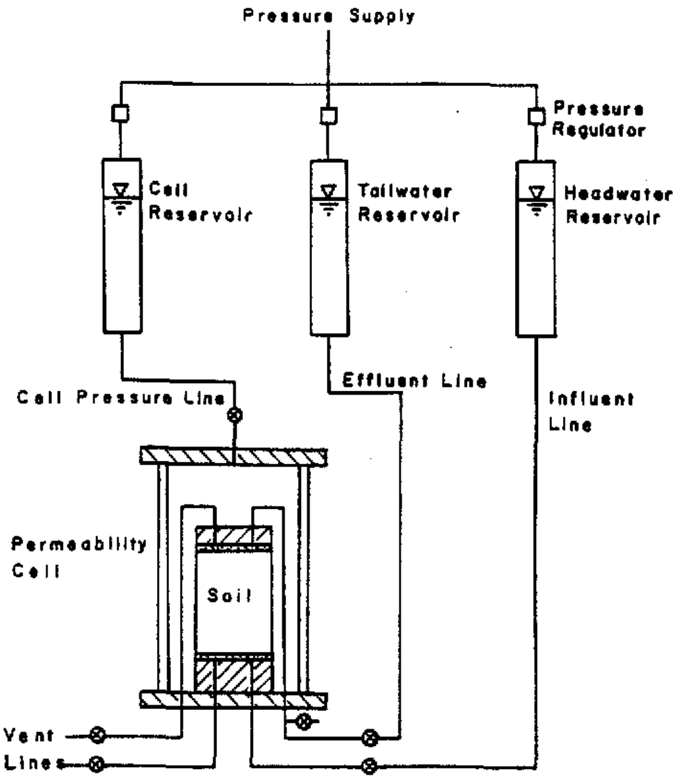

FIG. 1 Permeameter Cell

NOTE 3—Membranes may be tested for flaws by placing them around a form sealed at both ends with rubber O-rings, subjecting them to a small air pressure on the inside, and then dipping them into water. If air bubbles come up from any point on the membrane, or if any visible flaws are observed, the membrane shall be discarded.

5.7 *Porous End Pieces*—The porous end pieces shall be of silicon carbide, aluminum oxide, or other material that is not attacked by the specimen or permeant liquid. The end pieces shall have plane and smooth surfaces and be free of cracks, chips, and nonuniformities. They shall be checked regularly to ensure that they are not clogged.

5.7.1 The porous end pieces shall be the same diameter or width (±5 %) as the specimen, and the thickness shall be sufficient to prevent breaking.

5.7.2 The hydraulic conductivity of the porous end pieces shall be significantly greater than that of the specimen to be tested. The requirements outlined in 5.2.3 ensure this.

5.8 *Filter Paper*—If necessary to prevent intrusion of material into the pores of the porous end pieces, one or more sheets of filter paper shall be placed between the top and bottom porous end pieces and the specimen. The paper shall have a negligibly small hydraulic impedance. The requirements outlined in 5.2.3 ensure that the impedance is small.

5.9 *Equipment for Compacting a Specimen*—Equipment (including compactor and mold) suitable for the method of compaction specified by the requester shall be used.

5.10 *Sample Extruder*—When the material being tested is a soil core, the soil core shall usually be removed from the sampler with an extruder. The sample extruder shall be capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube and with minimum disturbance of the sample. If the soil core is not extruded vertically, care should be taken to avoid bending stresses on the core due to gravity. Conditions at the time of sample extrusion may dictate the direction of removal, but the principal concern is to keep the degree of disturbance minimal.

5.11 *Trimming Equipment*—Specific equipment for trimming the specimen to the desired dimensions will vary depending on quality and characteristics of the sample; however, the following items listed may be used: lathe, wire saw with a wire about 0.3 mm (0.01 in.) in diameter, spatulas, knives, steel rasp for very hard clay specimens, cradle or split mold for trimming specimen ends, and steel straight edge for final trimming of specimen ends.

5.12 *Devices for Measuring the Dimensions of the Specimen*—Devices used to measure the dimensions of the specimen shall be capable of measuring to the nearest 0.3 mm (0.01 in.) or better and shall be constructed such that their use will not disturb the specimen.

5.13 *Balances*—The balance shall be suitable for determining the mass of the specimen and shall be selected as discussed in Specification D 4753. The mass of specimens less than 100 g shall be determined to the nearest 0.01 g. The mass of specimens 100 g or larger shall be determined to the nearest 0.1 g. The mass of specimens >1000 g shall be determined to the nearest 1.0 g.

5.14 *Equipment for Mounting the Specimen*—Equipment for mounting the specimen in the permeameter cell shall include a membrane stretcher or cylinder, and ring for expanding and placing O-rings on the base and top cap to seal the membrane.

5.15 *Vacuum Pump*—To assist with de-airing of permeameter system and saturation of specimens.

5.16 *Temperature Maintaining Device*—The temperature of the permeameter, test specimen, and reservoir of permeant liquid shall not vary more than ±3°C (±5.7°F). Normally, this is accomplished by performing the test in a room with a relatively constant temperature. If such a room is not available, the apparatus shall be placed in a water bath, insulated chamber, or other device that maintains a temperature within the tolerance specified in 5.16. The temperature shall be periodically measured and recorded.

5.17 *Water Content Containers*—The containers shall be in accordance with Method D 2216.

5.18 *Drying Oven*—The oven shall be in accordance with Specification E 145.

6. Reagents

6.1 *Permeant Water:*

6.1.1 The permeant water is the liquid used to permeate the test specimen and is also the liquid used in backpressuring the specimen.

6.1.2 The type of permeant water should be specified by the requestor. If no specification is made, tap water shall be used for the permeant liquid. The type of water utilized shall be indicated in the report.

NOTE 4—Chemical interactions between a permeant liquid and the porous material may lead to variations in hydraulic conductivity. Distilled water can significantly lower the hydraulic conductivity of clayey soils (see the literature).[4] For this reason, distilled water is not usually recommended as a permeant liquid. A permeant liquid used by some is 0.005 N $CaSO_4$, which can be obtained for example, by dissolving 6.8 g of nonhydrated, reagent-grade $CaSO_4$ in 10 L of de-aired, distilled water. This $CaSO_4$ solution is thought to neither increase nor decrease significantly the hydraulic conductivity of clayey soils. In areas with extremely brackish tap water, the $CaSO_4$ solution is recommended.

6.1.3 *Deaired Water*—To aid in removing as much air from the test specimen as possible, deaired water shall be used. The water is usually deaired by boiling, by spraying a fine mist of water into an evacuated vessel attached to a vacuum source, or by forceful agitation of water in a container attached to a vacuum source. If boiling is used, care shall be taken not to evaporate an excessive amount of water, which can lead to a larger salt concentration in the permeant water than desired. To prevent dissolution of air back into the water, deaired water shall not be exposed to air for prolonged periods.

7. Test Specimens

7.1 *Size*—Specimens shall have a minimum diameter of 25 mm (1.0 in.) and a minimum height of 25 mm. The height and diameter of the specimen shall be measured to the nearest 0.3 mm (0.01 in.) or better. The length and diameter shall vary by no more than ±5 %. The surface of the test specimen may be uneven, but indentations must not be so deep that the length or diameter vary by more than ±5 %. The diameter and height of the specimen shall each be at least 6 times greater than the largest particle size within the specimen. If, after completion of a test, it is found based on visual observation that oversized particles are present, that information shall be indicated on the report.

NOTE 5—Most hydraulic conductivity tests are performed on cylindrical test specimens. It is possible to utilize special equipment for testing prismatic test specimens, in which case reference to "diameter" in 7.1 applies to the least width of the prismatic test specimen.

7.2 *Undisturbed Specimens*—Undisturbed test specimens shall be prepared from a representative portion of undisturbed samples secured in accordance with Practice D 1587 or Practice D 2113, and preserved and transported in accordance with requirements for Group C materials in Practice D 4220. Specimens obtained by tube sampling or coring may be tested without trimming except for cutting the end surfaces plane and perpendicular to the longitudinal axis of the specimen, provided soil characteristics are such that no significant disturbance results from sampling. Where the sampling operation has caused disturbance of the soil, the disturbed material shall be trimmed. Where removal of pebbles or crumbling resulting from trimming causes voids on the surface of the specimen that cause the length or diameter to vary by more than ±5 %, the voids shall be filled with remolded material obtained from the trimmings. The ends of the test specimen shall be cut and not troweled (troweling can seal off cracks, slickensides, or other secondary features that might conduct water flow). Specimens shall be trimmed, whenever possible, in an environment where changes in moisture content are minimized. A controlled high-humidity room is usually used for this purpose. The mass and dimensions of the test specimen shall be determined to the tolerances given in 5.12 and 5.13. The test specimen shall be mounted immediately in the permeameter. The water content of the trimmings shall be determined in accordance with Method D 2216.

7.3 *Laboratory-Compacted Specimens*—The material to be tested shall be prepared and compacted inside a mold in a manner specified by the requestor. If the specimen is placed and compacted in layers, the surface of each previously-compacted layer shall be lightly scarified (roughened) with a fork, ice pick, or other suitable object, unless the requester specifically states that scarification is not to be performed. Test Methods D 698 and D 1557 describe two methods of compaction, but any other method specified by the requestor may be used as long as the method is described in the report. Large clods of material should not be broken down prior to compaction unless it is known that they will be broken in field construction, as well, or the requestor specifically requests that the clod size be reduced. Neither hard clods nor individual particles of the material shall exceed 1/6 of either the height or diameter of the specimen. After compaction, the test specimen shall be removed from the mold, the ends scarified, and the dimensions and weight determined within the tolerances given in 5.12 and 5.13. After the dimensions and mass are determined, the test specimen shall be immediately mounted in the permeameter. The water content of the trimmings shall be determined in accordance with Method D 2216.

7.4 *Other Preparation Methods*—Other methods of preparation of a test specimen are permitted if specifically requested. The method of specimen preparation shall be identified in the report.

7.5 After the height, diameter, mass, and water content of the test specimen have been determined, the dry unit weight shall be calculated. Also, the initial degree of saturation shall be estimated (this information may be used later in the backpressure stage).

8. Procedure

8.1 *Specimen Setup:*

8.1.1 Cut two filter paper sheets to approximately the same shape as the cross section of the test specimen. Soak the two porous end pieces and filter paper sheets, if used, in a container of permeant water.

8.1.2 Place the membrane on the membrane expander. Apply a thin coat of silicon high-vacuum grease to the sides of the end caps. Place one porous end piece on the base and place one filter paper sheet, if used, on the porous end piece, followed by the test specimen. Place the second filter paper sheet, if used, on top of the specimen followed by the second porous end piece and the top cap. Place the membrane around the specimen, and using the membrane expander or other suitable O-ring expander, place one or more O-rings to seal the membrane to the base and one or more additional O-rings to seal the membrane to the top cap.

8.1.3 Attach flow tubing to the top cap, if not already attached, assemble the permeameter cell, and fill it with de-aired water or other cell fluid. Attach the cell pressure reservoir to the permeameter cell line and the hydraulic system to the influent and effluent lines. Fill the cell pressure reservoir with deaired water, or other suitable liquid, and the hydraulic system with deaired permeant water. Apply a small confining pressure of 7 to 35 kPa (1 to 5 psi) to the cell and apply a pressure less than the confining pressure to both the influent and effluent systems, and flush permeant water through the flow system. After all visible air has been removed from the flow lines, close the control valves. At no time during saturation of the system and specimen or hydraulic conductivity measurements shall the maximum applied effective stress be allowed to exceed that to which the specimen is to be consolidated.

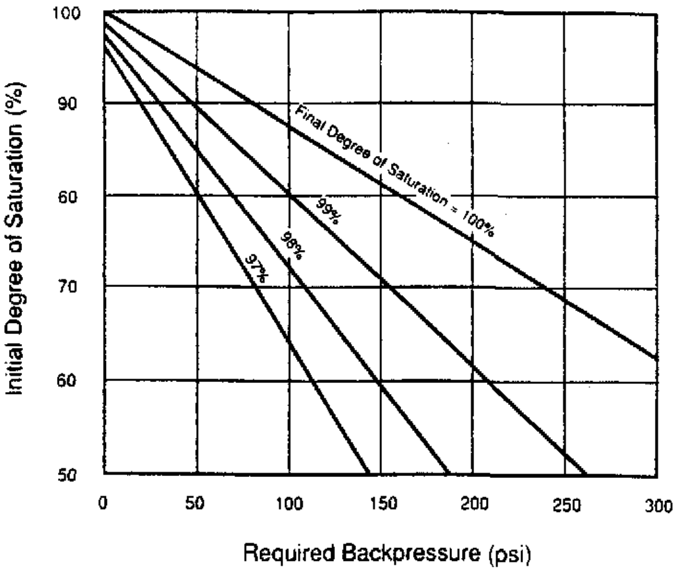

FIG. 2 Back Pressure to Attain Various Degrees of Saturation[6]

8.2 *Specimen Soaking (Optional)*—To aid in saturation, specimens may be soaked under partial vacuum applied to the top of the specimen. Atmospheric pressure shall be applied to the specimen base through the influent lines, and the magnitude of the vacuum set to generate a hydraulic gradient across the sample less than that which will be used during hydraulic conductivity measurements.

NOTE 6—Soaking under vacuum is applicable when there are continuous air voids in the specimen. Soaking under vacuum is only recommended for test specimens with initial degrees of saturation below 70 %. The specimen may swell when exposed to water; the effective stress will tend to counteract the swelling. However, for materials that tend to swell, unless the applied effective stress is greater than or equal to the swell pressure, the specimen will swell.

8.3 *Backpressure Saturation*—To saturate the specimen, backpressuring is usually necessary. Figure 2 provides guidance on back pressure required to attain saturation.

NOTE 7—Figure 2 assumes that the water used for back pressure is deaired and that the only source for air to dissolve into the water is air from the test specimen. If air pressure is used to control the back pressure, pressurized air will dissolve into the water, thus reducing the capacity of the water used for back pressure to dissolve air located in the pores of the test specimen. The problem is minimized by using a long (>5 m) tube that is impermeable to air between the air-water interface and test specimen, by separating the back-pressure water from the air by a material or fluid that is relatively impermeable to air, by periodically replacing the back-pressure water with deaired water, or by other means.

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[6] Lowe, J., and Johnson, T. C., "Use of Back Pressure to Increase Degree of Saturation of Triaxial Test Specimens," *Proceedings, ASCE Research Conference on Shear Strength of Cohesive Soils*, Boulder, CO, 1960.

8.3.1 Open the flow line valves and flush out of the system any free air bubbles using the procedure outlined in 8.1.3. If an electronic pressure transducer or other measuring device is to be used during the test to measure pore pressures or applied hydraulic gradient, it should be bled of any trapped air. Take and record an initial reading of specimen height, if being monitored.

8.3.2 Adjust the applied confining pressure to the value to be used during saturation of the sample. Apply backpressure by simultaneously increasing the cell pressure and the influent and effluent pressures in increments. The maximum value of an increment in backpressure shall be sufficiently low so that no point in the specimen is exposed to an effective stress in excess of that to which the specimen will be subsequently consolidated. At no time shall a head be applied so that the effective confining stress is <7 kPa (1 psi) because of the danger of separation of the membrane from the test specimen. Maintain each increment of pressure for a period of a few minutes to a few hours, depending upon the characteristics of the specimen. To assist in removal of trapped air, a small hydraulic gradient may be applied across the specimen to induce flow.

8.3.3 Saturation shall be verified with one of the three following techniques:

8.3.3.1 Saturation may be verified by measuring the *B* coefficient as described in Test Method D 4767 (see Note 8). The test specimen shall be considered to be adequately saturated if (*1*) the *B* value is ≥0.95, or (*2*) for relatively incompressible materials, for example, rock, if the *B* value remains unchanged with application of larger values of back pressure. The *B* value may be measured prior to or after completion of the consolidation phase (see 8.4). Accurate *B*-value determination can only be made if no gradient is acting on the specimen and all pore pressure induced by consolidation has dissipated.

NOTE 8—The *B* coefficient is defined for this type of test as the change in pore water pressure in the porous material divided by the change in confining pressure. Compressible materials that are fully saturated with water will have a *B* value of 1.0. Relatively incompressible, saturated materials have *B* values which are somewhat less than 1.0.

8.3.3.2 Saturation of the test specimen may be confirmed at the completion of the test by calculation of the final degree of saturation. The final degree of saturation shall be 100 ± 5 %. However, measurement of the *B* coefficient as described in 8.3.3.1 or use of some other technique (8.3.3.3) is strongly recommended because it is much better to confirm saturation prior to permeation than to wait until after the test to determine if the test was valid.

8.3.3.3 Other means for verifying saturation, such as measurement of the volume change of the specimen when the pore water pressure has been changed, can be used for verifying saturation provided data are available for similar materials to establish that the procedure used confirms saturation as required in 8.3.3.1 or 8.3.3.2.

8.4 *Consolidation*—The specimen shall be consolidated to the effective stress specified by the requestor. Consolidation may be accomplished in stages, if desired.

NOTE 9—The test specimen may be consolidated prior to application of backpressure. Also, the backpressure and consolidation phases may be completed concurrently if backpressures are applied sufficiently slowly to minimize potential for overconsolidation of the specimen.

8.4.1 Record the specimen height, if being monitored, prior to application of consolidation pressure and periodically during consolidation.

8.4.2 Increase the cell pressure to the level necessary to develop the desired effective stress, and begin consolidation. Drainage may be allowed from the base or top of the specimen, or simultaneously from both ends.

8.4.3 (Optional) Record outflow volumes to confirm that primary consolidation has been completed prior to initiation of the hydraulic conductivity test. Alternatively, measurements of the change in height of the test specimen can be used to confirm completion of consolidation.

NOTE 10—The procedure in 8.4.3 is optional because the requirements of 8.5 ensure that the test specimen is adequately consolidated during permeation because if it is not, inflow and outflow volumes will differ significantly. However, for accurate *B*-value determination, completion of consolidation should be confirmed (see 8.3.3.1). It is recommended that outflow volumes or height changes be recorded as a means for verifying the completion of consolidation prior to initialization of permeation. Also, measurements in the change in height of the test specimen, coupled with knowledge of the initial height, provide a means for checking the final height of the specimen.

8.5 *Permeation:*

8.5.1 *Hydraulic Gradient*—When possible, the hydraulic gradient used for hydraulic conductivity measurements should be similar to that expected to occur in the field. In general, hydraulic gradients from <1 to 5 cover most field conditions. However, the use of small hydraulic gradients can lead to very long testing times for materials having low hydraulic conductivity (less than about 1×10^{-6} cm/s). Somewhat larger hydraulic gradients are usually used in the laboratory to accelerate testing, but excessive gradients must be avoided because high seepage pressures may consolidate the material, material may be washed from the specimen, or fine particles may be washed downstream and plug the effluent end of the test specimen. These effects could increase or decrease hydraulic conductivity. If no gradient is specified by the requestor, the following guidelines may be followed:

Hydraulic Conductivity, cm/s	Recommended Maximum Hydraulic Gradient
1×10^{-3} to 1×10^{-4}	2
1×10^{-4} to 1×10^{-5}	5
1×10^{-5} to 1×10^{-6}	10
1×10^{-6} to 1×10^{-7}	20
less than 1×10^{-7}	30

NOTE 11—Seepage pressures associated with large hydraulic gradients can consolidate soft, compressible specimens and reduce their hydraulic conductivity. It may be necessary to use smaller hydraulic gradients (<10) for such specimens.

8.5.2 *Initialization*—Initiate permeation of the specimen by increasing the influent pressure (see 8.3.2). The effluent pressure shall not be decreased because air bubbles that were dissolved by the specimen water during backpressuring may come out of solution if the pressure is decreased. The back pressure shall be maintained throughout the permeation phase.

8.5.3 *Constant Head Test (Method A)*—Measure and record the required head loss across the test specimen to the tolerances stated in 5.1.1 and 5.2.3. The head loss across the specimen shall be kept constant ±5 %. Measure and record periodically the quantity of inflow as well as the quantity of outflow. Also measure and record any changes in height of the test specimen, if being monitored (see Note 11). Continue permeation until at least four values of hydraulic conductivity are obtained over an interval of time in which: (*1*) the ratio of outflow to inflow rate is between 0.75 and 1.25, and (*2*) the hydraulic conductivity is steady. The hydraulic conductivity shall be considered steady if four or more consecutive hydraulic conductivity determinations fall within ±25 % of the mean value for $k \geq 1 \times 10^{-10}$ m/s or within ±50 % for $k < 1 \times 10^{-10}$ m/s, and a plot of the hydraulic conductivity versus time shows no significant upward or downward trend.

8.5.4 *Falling-Head Tests (Methods B and C)*—Measure and record the required head loss across the test specimen to the tolerances stated in 5.1.2. For falling-head tests, at no time shall the applied head loss across the specimen be less than 75 % of the initial (maximum) head loss during each individual hydraulic conductivity determination (see Note 12). Periodically measure and record any changes in the height of the specimen, if being monitored. Continue permeation until at least four values of hydraulic conductivity are obtained over an interval of time in which: (*1*) the ratio of outflow to inflow rate is between 0.75 and 1.25, and (*2*) the hydraulic conductivity is steady (see 8.5.3).

NOTE 12—When the water pressure in a test specimen changes and the applied total stress is constant, the effective stress in the test specimen changes, which can cause volume changes that can invalidate the test results. The requirement that the head loss not decrease very much is intended to keep the effective stress from changing too much. For extremely soft, compressible test specimens, even more restrictive criteria might be needed. Also, when the initial and final head losses across the test specimen do not differ by much, great accuracy is needed to comply with the requirement of 5.1.2 that the ratio of initial to final head loss be determined with an accuracy of ±5 % or better. When the initial and final head loss over an interval of time do not differ very much, it may be possible to comply with the requirements for a constant head test (8.5.3) in which the head loss must not differ by more than ±5 % and to treat the test as a constant head test.

8.5.4.1 *Test with Constant Tailwater Level (Method B)*—If the water pressure at the downstream (tailwater) end of the test specimen is kept constant, periodically measure and record either the quantity of inflow or the level of water in the influent standpipe; measure and record the quantity of outflow from the test specimen.

8.5.4.2 *Test with Increasing Tailwater Level (Method C)*—If the water pressure at the downstream end of the test specimen rises during an interval of time, periodically measure and record either the quantity or inflow and outflow or the changes in water levels in the influent and effluent standpipes.

8.5.5 *Constant Rate of Flow Tests (Method D)*—Initiate permeation of the specimen by imposing a constant flow rate. Choose the flow rate so the hydraulic gradient does not exceed the value specified, or if none is specified, the value recommended in 8.5.1. Periodically measure the rate of inflow, the rate of outflow, and head loss across the test specimen to the tolerances given in 5.1.3. Also, measure and record any changes in specimen height, if being monitored. Continue permeation until at least four values of hydraulic conductivity are obtained over an interval of time in which (*1*) the ratio of inflow to outflow rates is between 0.75 and 1.25, and (*2*) hydraulic conductivity is steady (see 8.5.3).

8.6 *Final Dimensions of the Specimen*—After completion of permeation, reduce the applied confining, influent, and effluent pressures in a manner that does not generate significant volume change of the test specimen. Then carefully disassemble the permeater cell and remove the specimen. Measure and record the final height, diameter, and total mass of the specimen. Then determine the final water content of the specimen by the procedure of Method D 2216. Dimensions and mass of the test specimen shall be measured to the tolerances specified in 5.13 and 7.1.

NOTE 13—The specimen may swell after removal of back pressure as a result of air coming out of solution. A correction may be made for this effect, provided that changes in the length of the specimen are monitored during the test. The strain caused by dismantling the cell is computed from the length of the specimen before and after dismantling the cell. The same strain is assumed to have occurred in the diameter. The corrected diameter and actual length before the back pressure was removed are used to compute the volume of the test specimen prior to dismantling the cell. The volume prior to dismantling the cell is used to determine the final dry density and degree of saturation.

9. Calculation

9.1 *Constant Head and Constant Rate of Flow Tests (Methods A and D)*—Calculate the hydraulic conductivity, *k*, as follows:

$$k = QL/Ath \tag{1}$$

where:
k = hydraulic conductivity, m/s,
Q = quantity of flow, taken as the average of inflow and outflow, m^3,
L = length of specimen along path of flow, m,
A = cross-sectional area of specimen, m^2,
t = interval of time, s, over which the flow Q occurs, and
h = difference in hydraulic head across the specimen, m of water.

9.2 *Falling-Head Tests:*

9.2.1 *Constant Tailwater Pressure (Method B)*—Calculate the hydraulic conductivity, *k*, as follows:

$$k = \frac{aL}{At} \ln \left(\frac{h_1}{h_2}\right) \tag{2}$$

where:
a = cross-sectional area of the reservoir containing the influent liquid, m^2,
L = length of the specimen, m,
A = cross-sectional area of the specimen, m^2,
t = elapsed time between determination of h_1 and h_2, s,
h_1 = head loss across the specimen at time t_1, m, and
h_2 = head loss across the specimen at time t_2, m.

9.2.2 *Increasing Tailwater Pressure (Method C)*—Calculate the hydraulic conductivity, *k*, as follows:

$$k = \frac{a_{in}\, a_{out}\, L}{A\, t\, (a_{in} + a_{out})} \ln(h_1/h_2) \tag{3}$$

where:
a_{in} = cross-sectional area of the reservoir containing the influent liquid, m^2,
a_{out} = cross-sectional area of the reservoir containing the effluent liquid, m^2,
L = length of the specimen, m,
A = cross-sectional area of the specimen, m^2,
t = elapsed time between determination of h_1 and h_2, s,
h_1 = head loss across the specimen at time t, m, and
h_2 = head loss across the specimen at time t_2, m.

NOTE 14—For the case in which $a_{out} = a_{in} = a$, the equation for calculating k for a falling head test with a rising tailwater level is:

$$k = \frac{a\ L}{-2\ A\ t} \ln \left(\frac{h_1}{h_2}\right) \tag{4}$$

9.3 Correct the hydraulic conductivity to that for 20°C (68°F), k_{20}, by multiplying k by the ratio of the viscosity of water at test temperature to the viscosity of water at 20°C (68°F), R_T, from Table 1, as follows:

$$k_{20} = R_T k \tag{5}$$

10. Report

10.1 Report the following information:

10.1.1 Sample identifying information,

10.1.2 Any special selection and preparation process, such as removal of stones or other materials, or indication of their presence, if undisturbed specimen,

10.1.3 Descriptive information on method of compaction,

10.1.4 Initial dimensions of the specimen,

10.1.5 Initial water content and dry unit weight of the specimen,

10.1.6 Type of permeant liquid used,

10.1.7 Magnitude of total back pressure,

10.1.8 Maximum and minimum effective consolidation stress,

NOTE 15—The maximum effective stress exists at the effluent end of the test specimen and the minimum stress at the influent end.

10.1.9 Height of specimen after completion of consolidation, if monitored,

10.1.10 Range of hydraulic gradient used,

10.1.11 Final length, diameter, water content, dry unit weight, and degree of saturation of the test specimen,

10.1.12 Average hydraulic conductivity for the last four determinations of hydraulic conductivity (obtained as described in 8.5.3 to 8.5.5), reported with two significant figures, for example, 7.1×10^{-10} m/s, and reported in units of m/s (plus additional units, if requested or customary),

10.1.13 Graph or table of hydraulic conductivity versus time or pore volumes of flow is recommended.

TABLE 1 Correction Factor R_T for Viscosity of Water at Variou Temperatures[A]

Temperature, °C	R_T	Temperature, °C	R_T
0	1.783	25	0.889
1	1.723	26	0.869
2	1.664	27	0.850
3	1.611	28	0.832
4	1.560	29	0.814
5	1.511	30	0.797
6	1.465	31	0.780
7	1.421	32	0.764
8	1.379	33	0.749
9	1.339	34	0.733
10	1.301	35	0.719
11	1.265	36	0.705
12	1.230	37	0.692
13	1.197	38	0.678
14	1.165	39	0.665
15	1.135	40	0.653
16	1.106	41	0.641
17	1.077	42	0.629
18	1.051	43	0.618
19	1.025	44	0.607
20	1.000	45	0.598
21	0.976	46	0.585
22	0.953	47	0.575
23	0.931	48	0.565
24	0.910	49	0.556

[A] $R_T = (-0.02452\ T + 1.495)$ where T is the degrees celsius.

11. Precision and Bias

11.1 *Precision*—Data are being evaluated to determin the precision of this test method. In addition, Subcommitt D18.04 on Hydrologic Properties of Soil and Rocks, seeking pertinent data from users of this test method.

11.2 *Bias*—There is no accepted reference value for th test method, therefore, bias cannot be determined.

12. Keywords

12.1 coefficient of permeability; hydraulic barriers; h draulic conductivity; liner; permeameter

Appendix F

ROST Logs

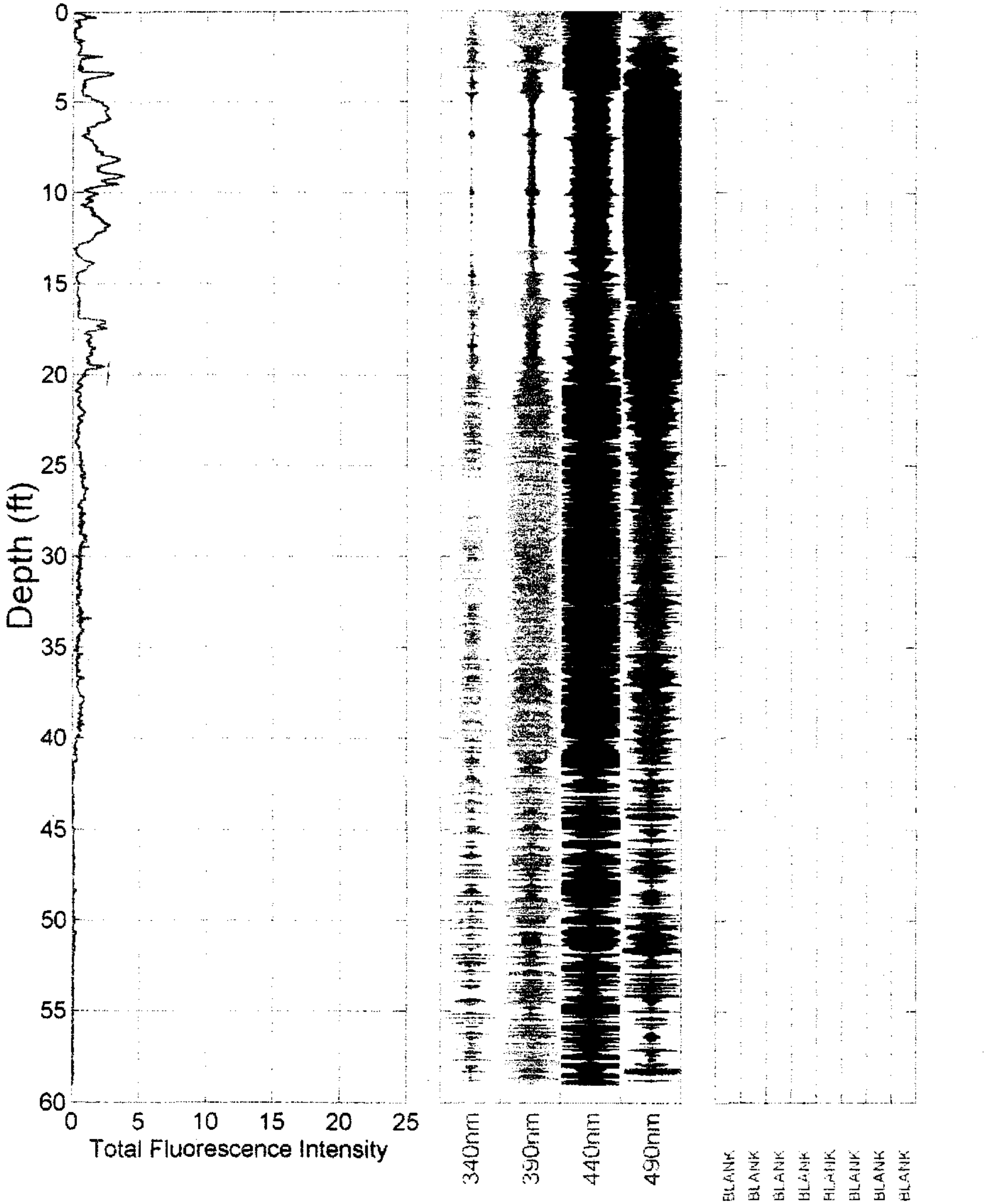
Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

Measured LIF End Depth
59.01 ft
Measured Peak Fluorescence
3.881%

Job#: 0301-7042

Acquisition Date: 03-05-1997

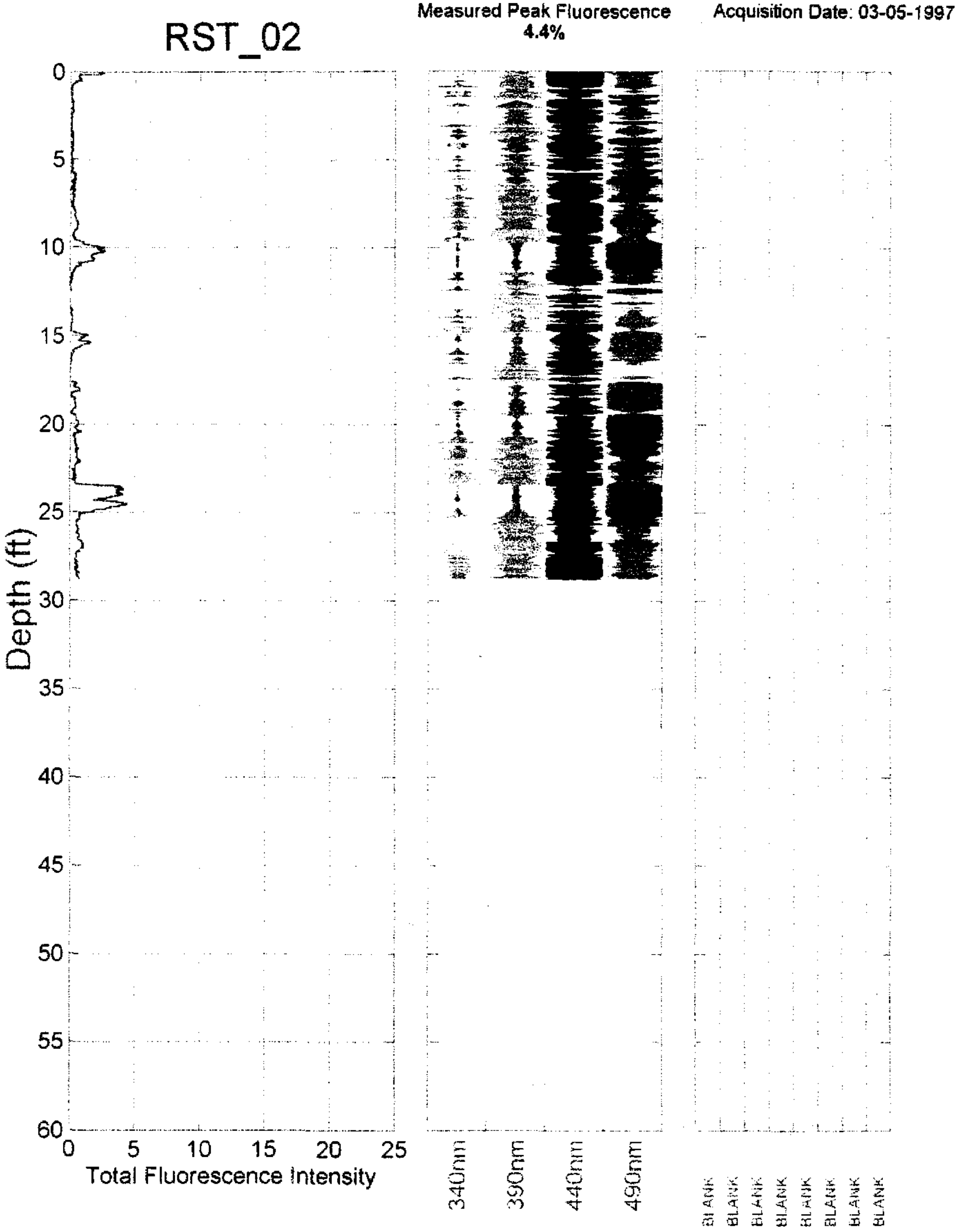
RST_01



Measured LIF End Depth
28.76 ft
Measured Peak Fluorescence
4.4%

Job#: 0301-7042

Acquisition Date: 03-05-1997

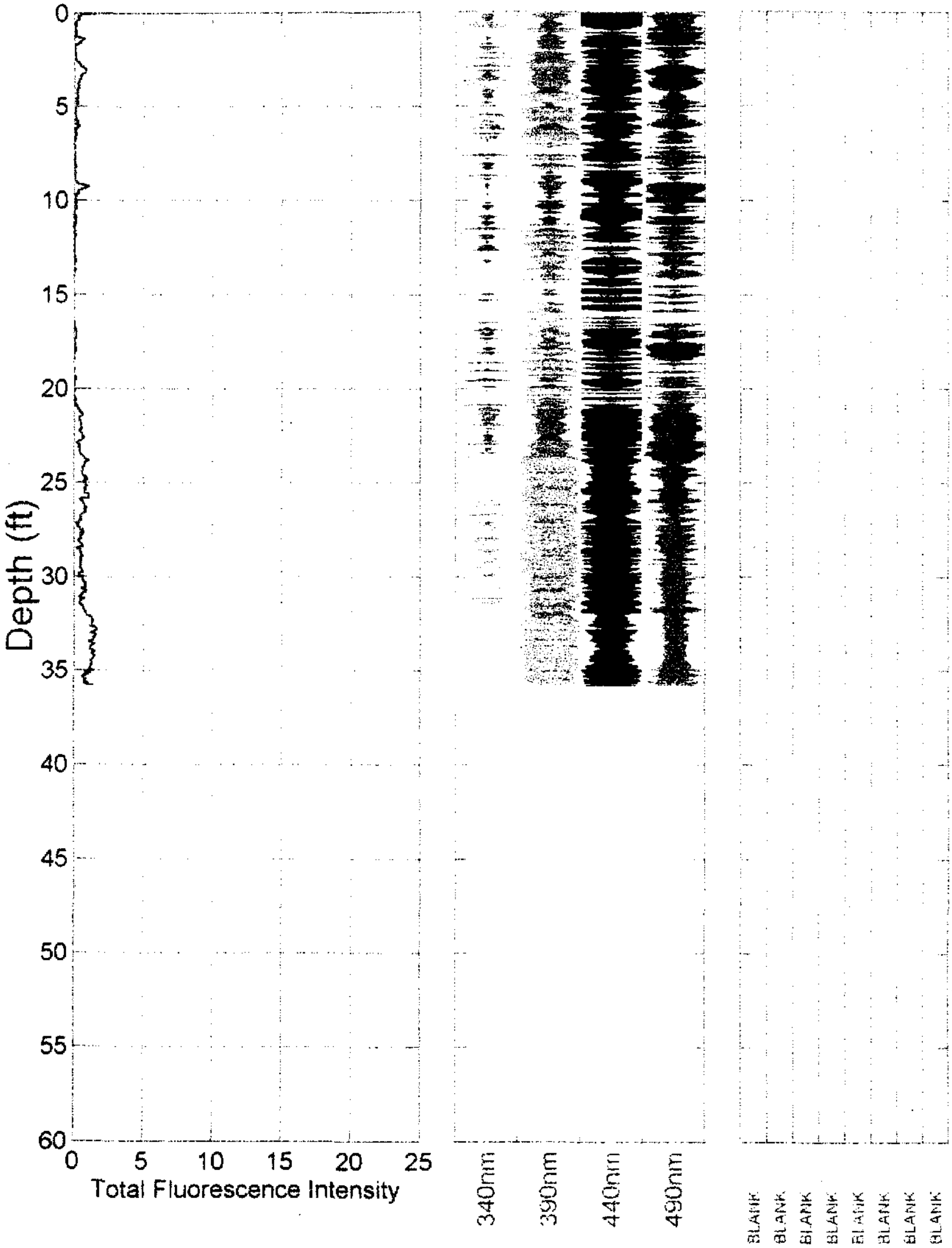


Measured LIF End Depth
35.78 ft
Measured Peak Fluorescence
1.675%

Job#: 0301-7042

Acquisition Date: 03-05-1997

RST_03

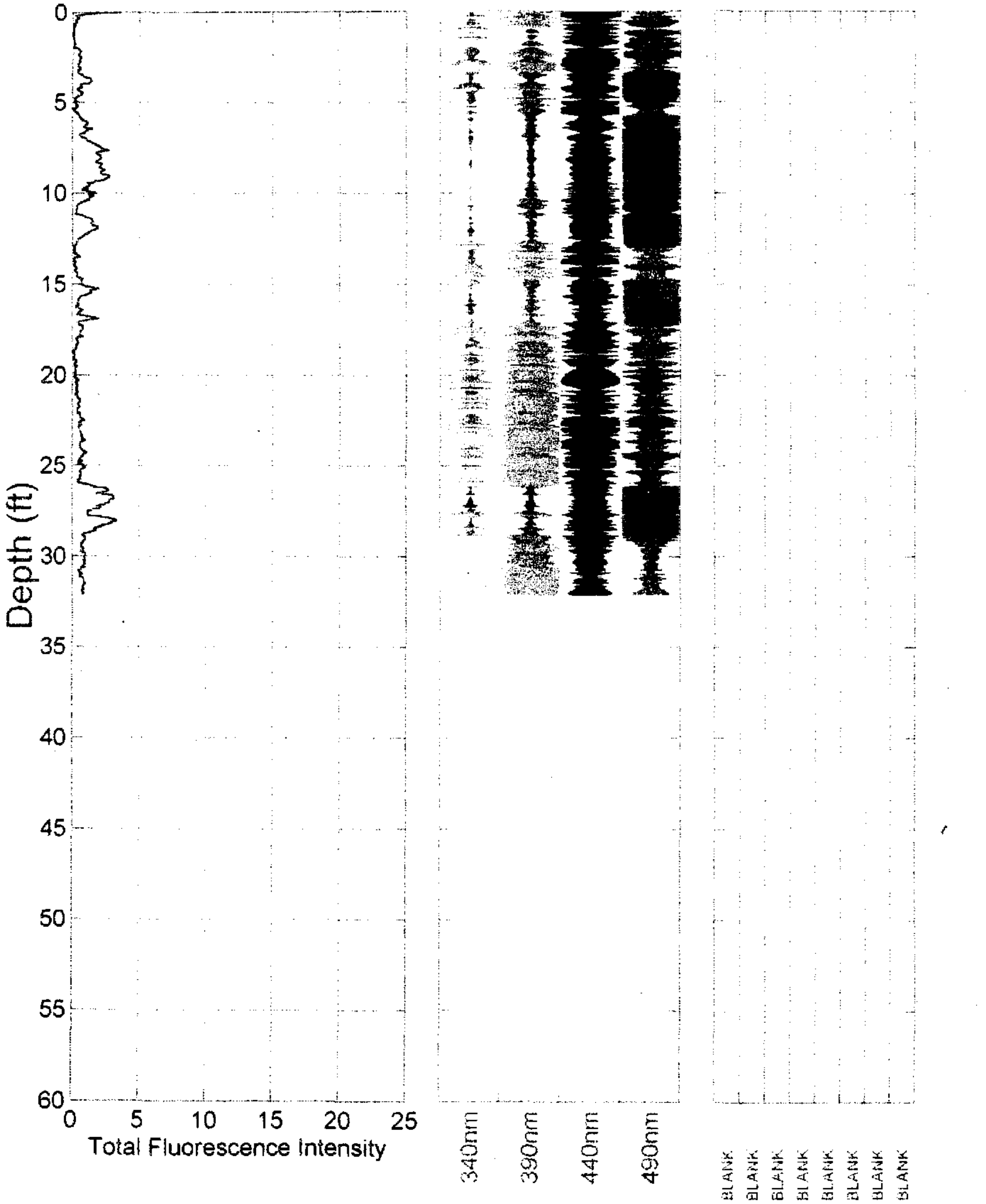


Measured LIF End Depth
32.11 ft
Measured Peak Fluorescence
3.334%

Job#: 0301-7042

Acquisition Date: 03-05-1997

RST_04

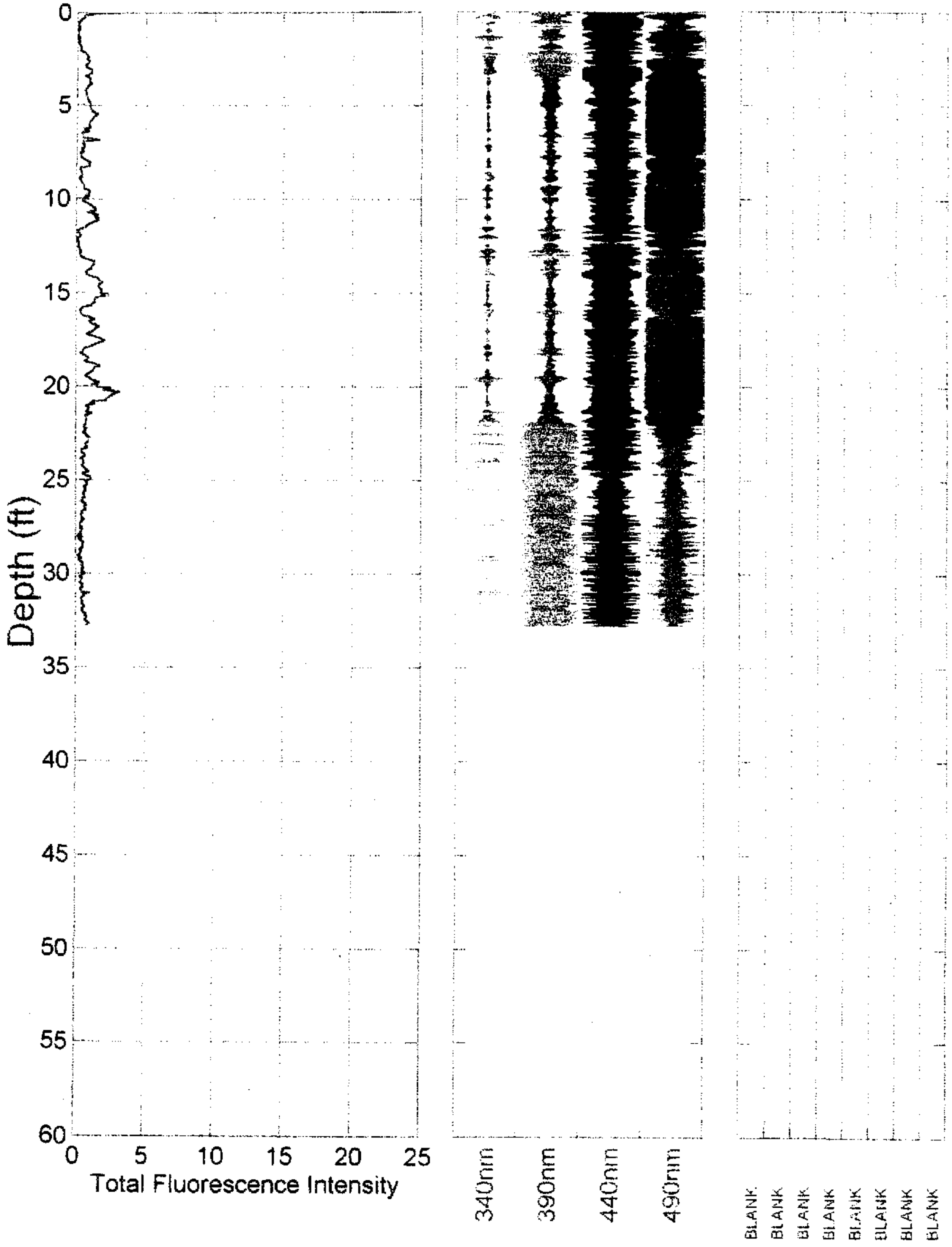


Measured LIF End Depth
32.76 ft
Measured Peak Fluorescence
3.189%

Job#: 0301-7042

Acquisition Date: 03-05-1997

RST_05

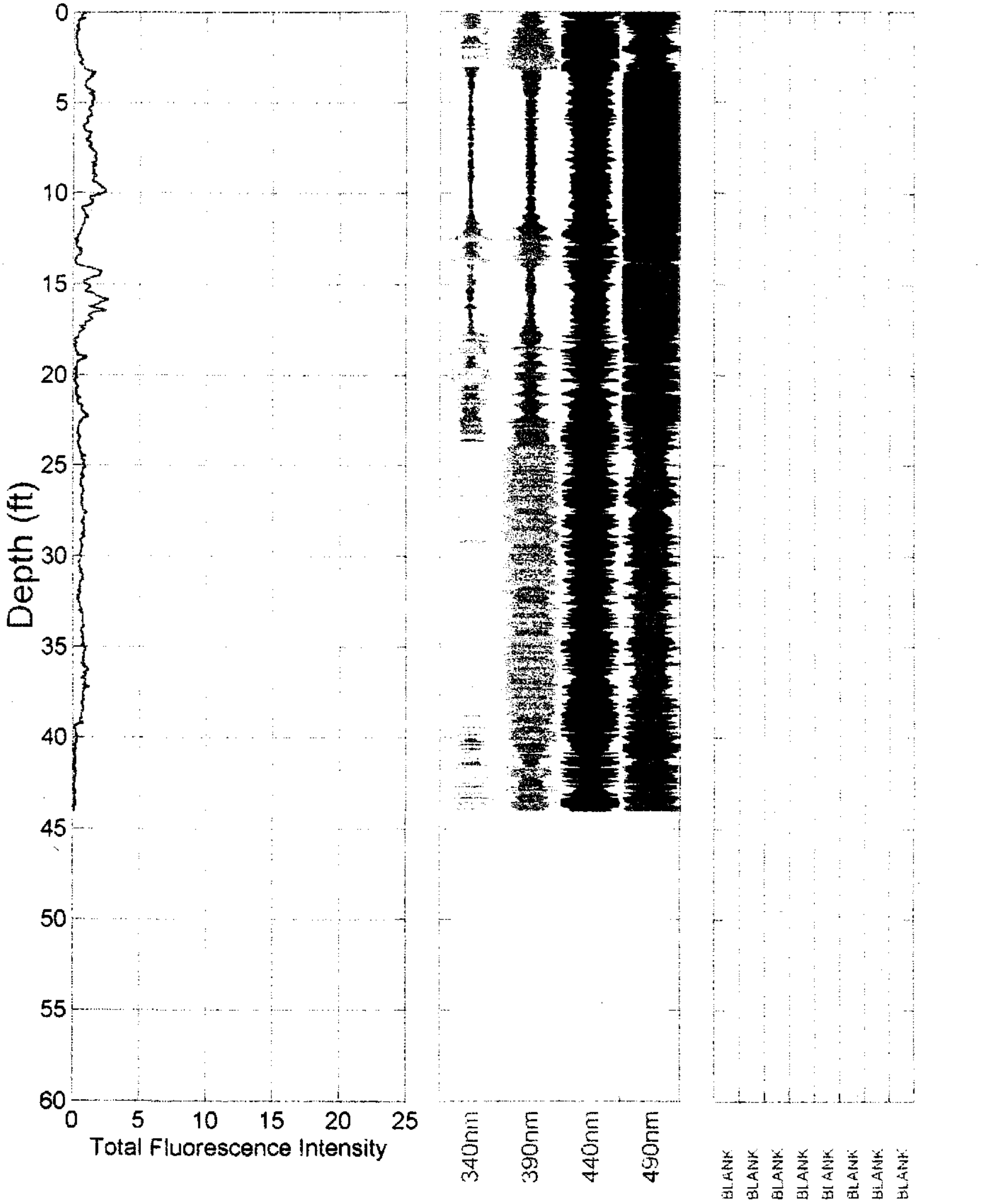


Measured LIF End Depth
44.05 ft
Measured Peak Fluorescence
2.653%

Job#: 0301-7042

Acquisition Date: 03-05-1997

RST_06

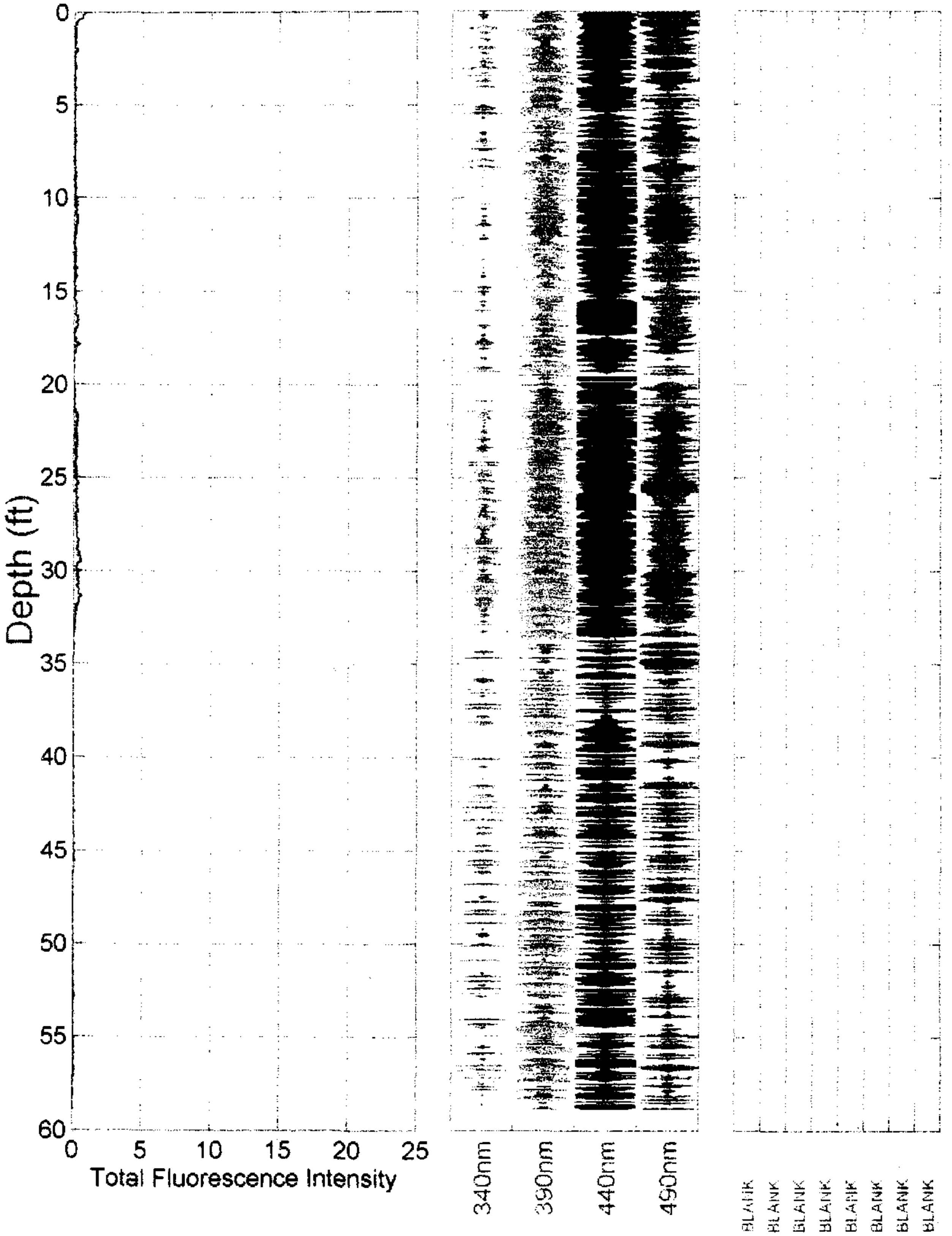


Measured LIF End Depth
58.88 ft
Measured Peak Fluorescence
0.7602%

Job#: 0301-7042

Acquisition Date: 03-06-1997

RST_07

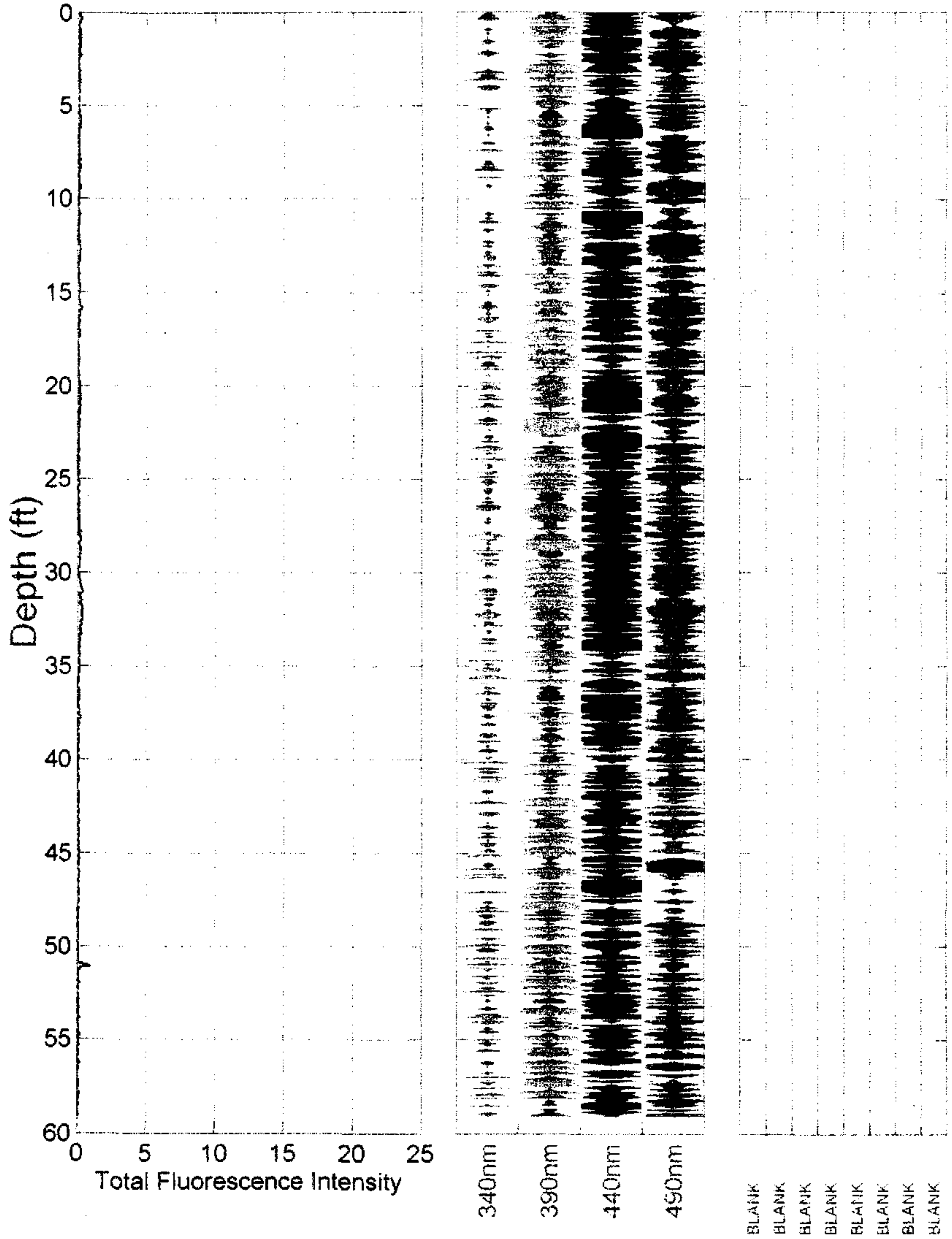


Measured LIF End Depth
59.08 ft
Measured Peak Fluorescence
0.9341%

Job#: 0301-7042

Acquisition Date: 03-06-1997

RST_08

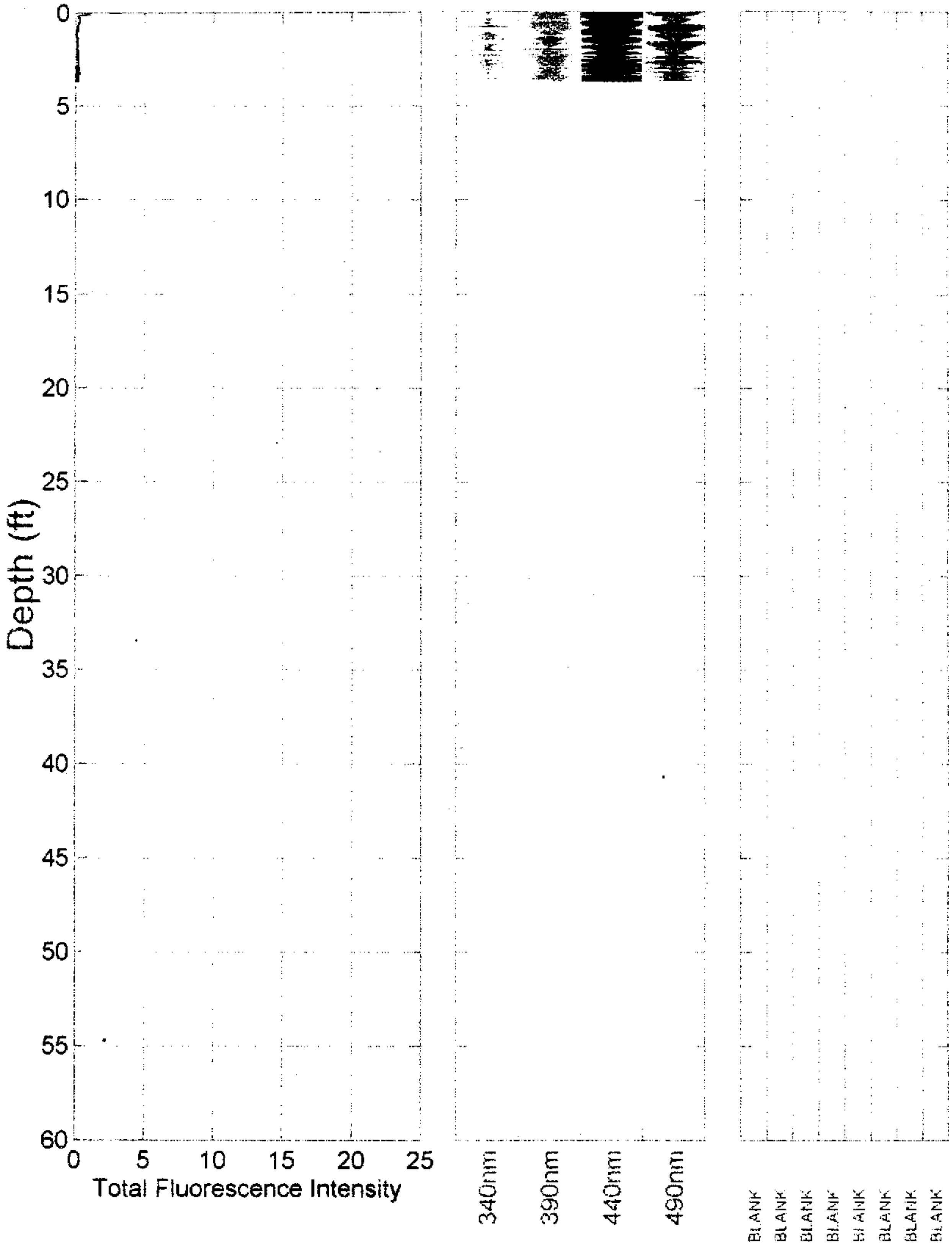


Measured LIF End Depth
3.694 ft
Measured Peak Fluorescence
1.011%

Job#: 0301-7042

Acquisition Date: 03-06-1997

RST_09

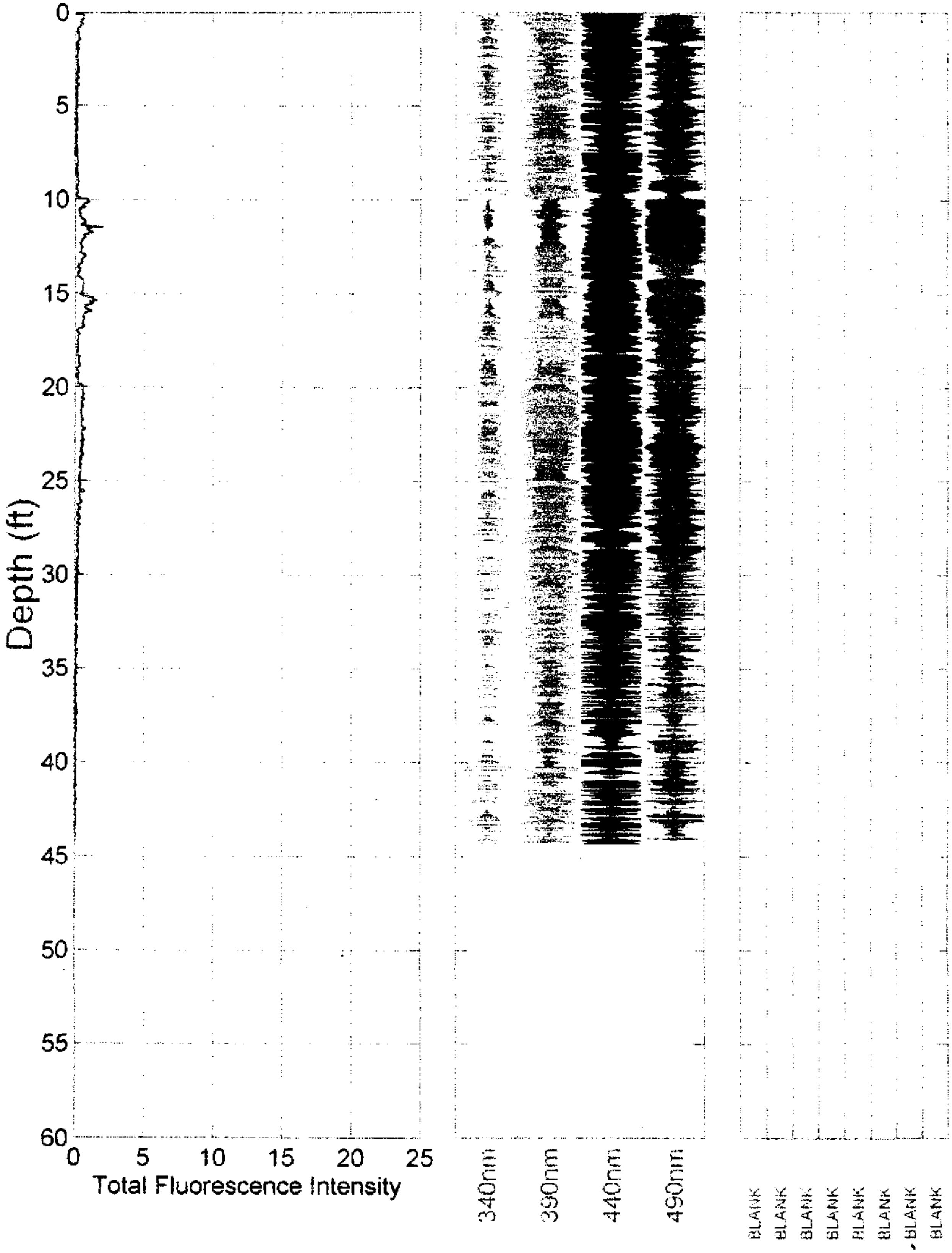


Measured LIF End Depth
44.34 ft
Measured Peak Fluorescence
1.994%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_9A

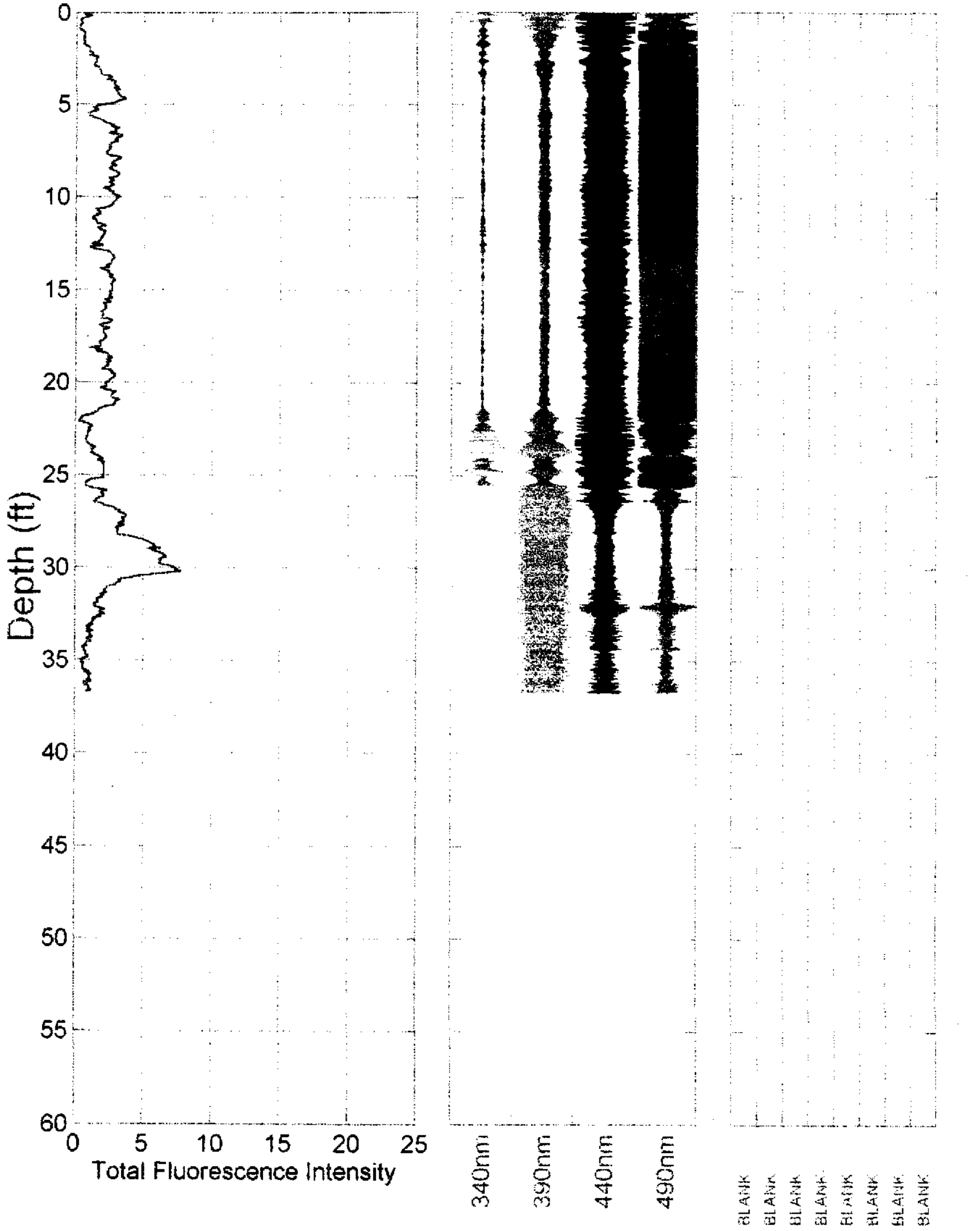


Measured LIF End Depth
36.73 ft
Measured Peak Fluorescence
7.777%

Job#: 0301-7042

Acquisition Date: 03-06-1997

RST_10

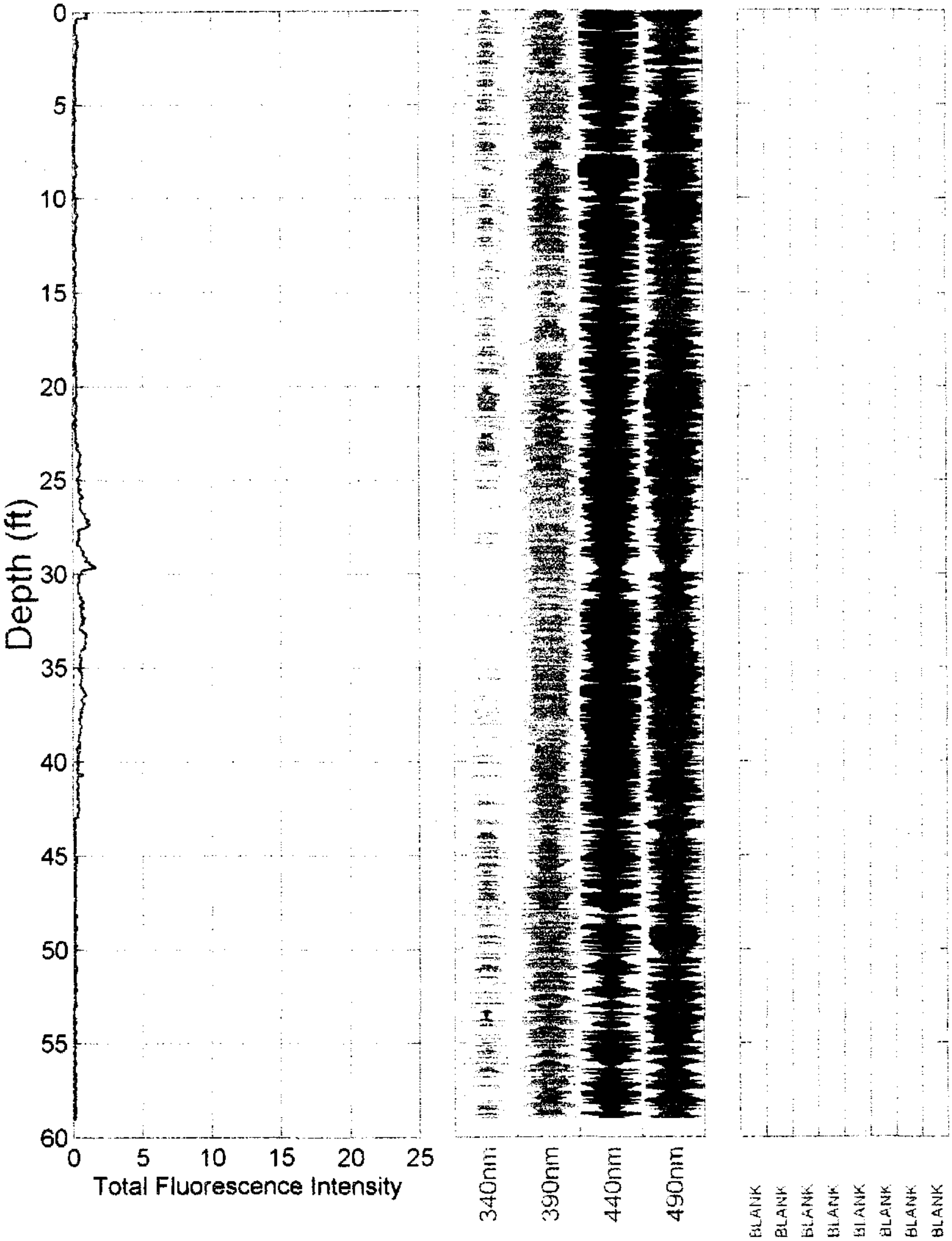


Measured LIF End Depth
59.04 ft
Measured Peak Fluorescence
1.624%

Job#: 0301-7042

Acquisition Date: 03-06-1997

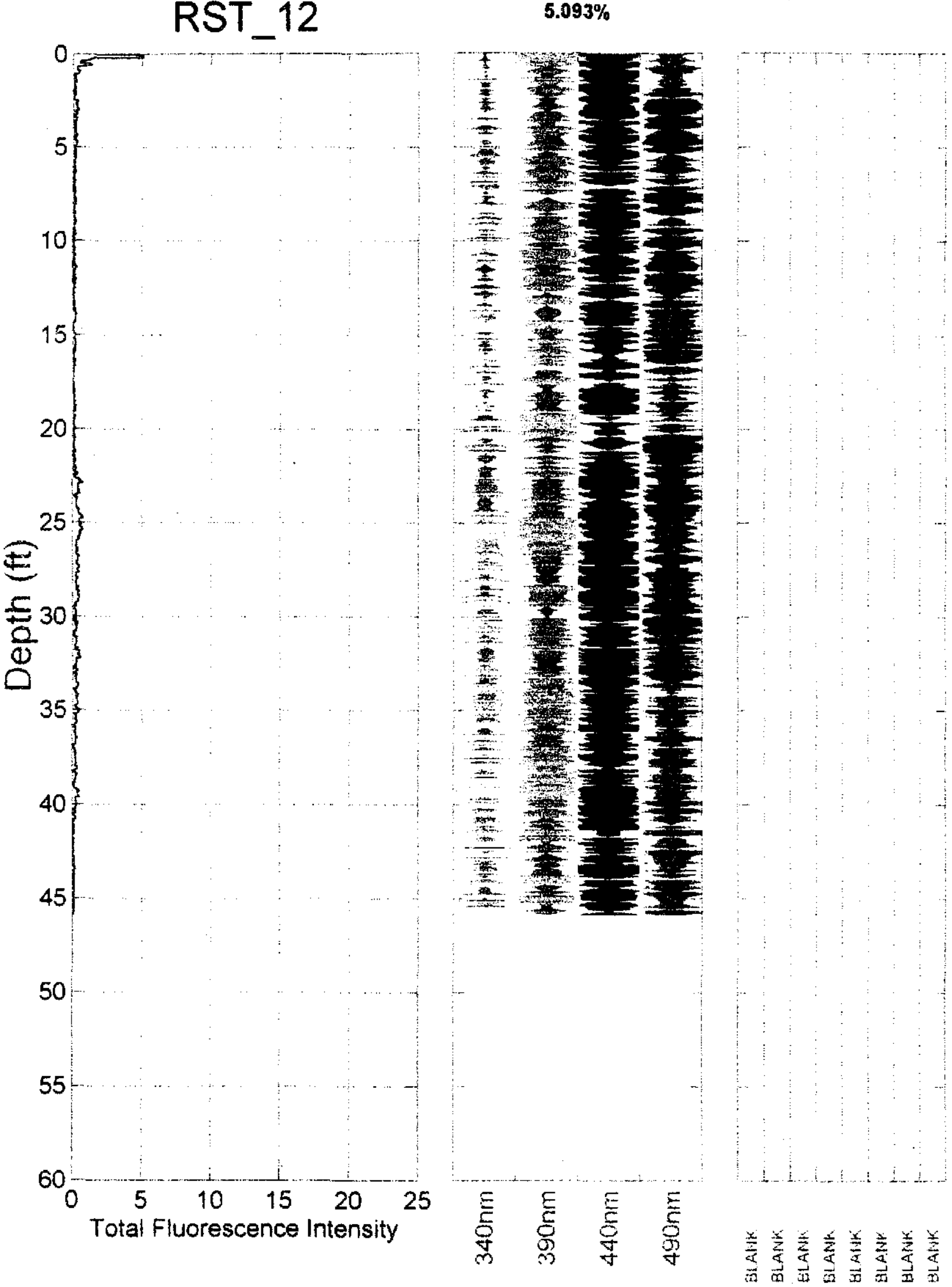
RST_11



Measured LIF End Depth
45.89 ft
Measured Peak Fluorescence
5.093%

Job#: 0301-7042

Acquisition Date: 03-06-1997

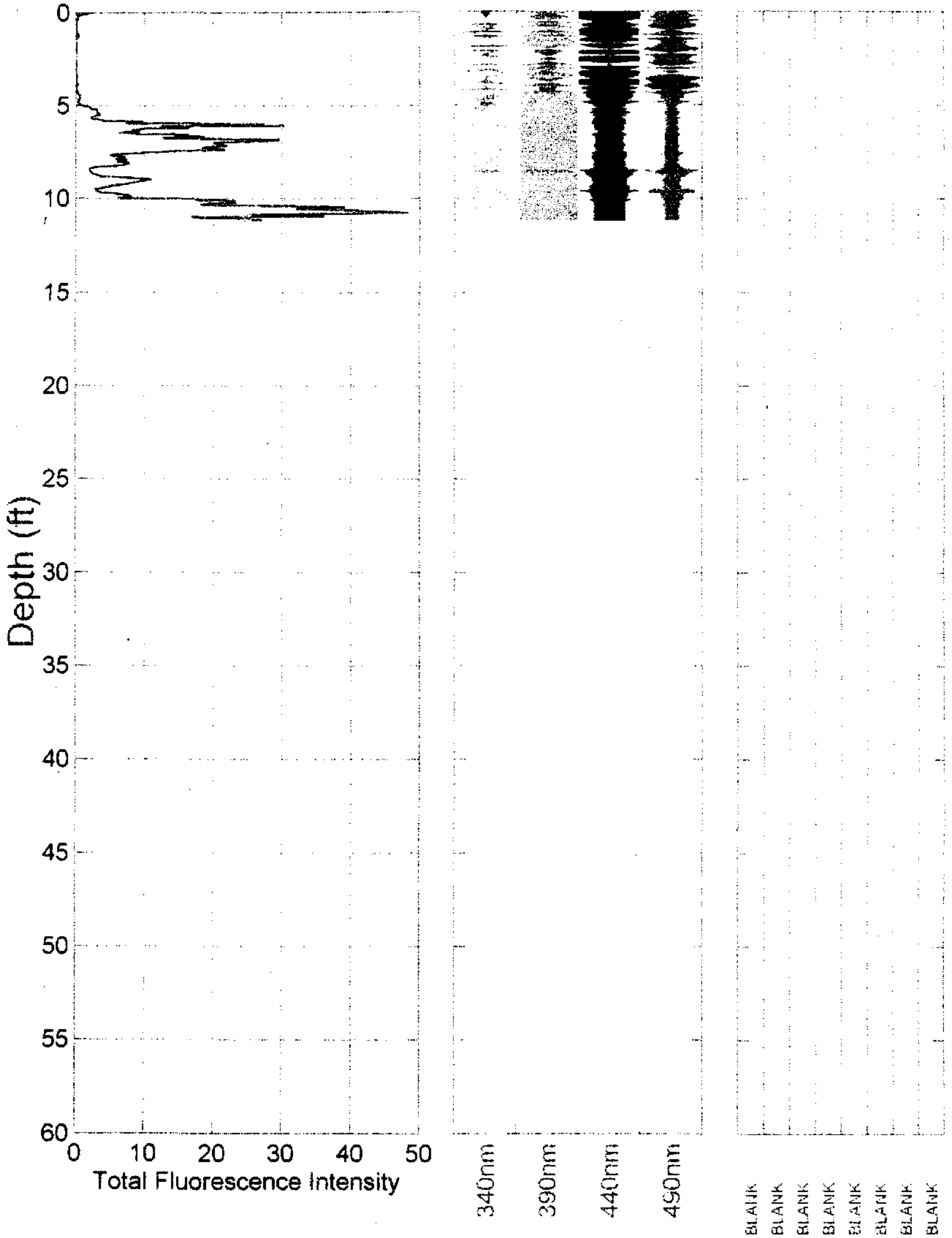


Measured LIF End Depth
11.18 ft
Measured Peak Fluorescence
48.28%

Job#: 0301-7042

Acquisition Date: 03-06-1997

RST_13

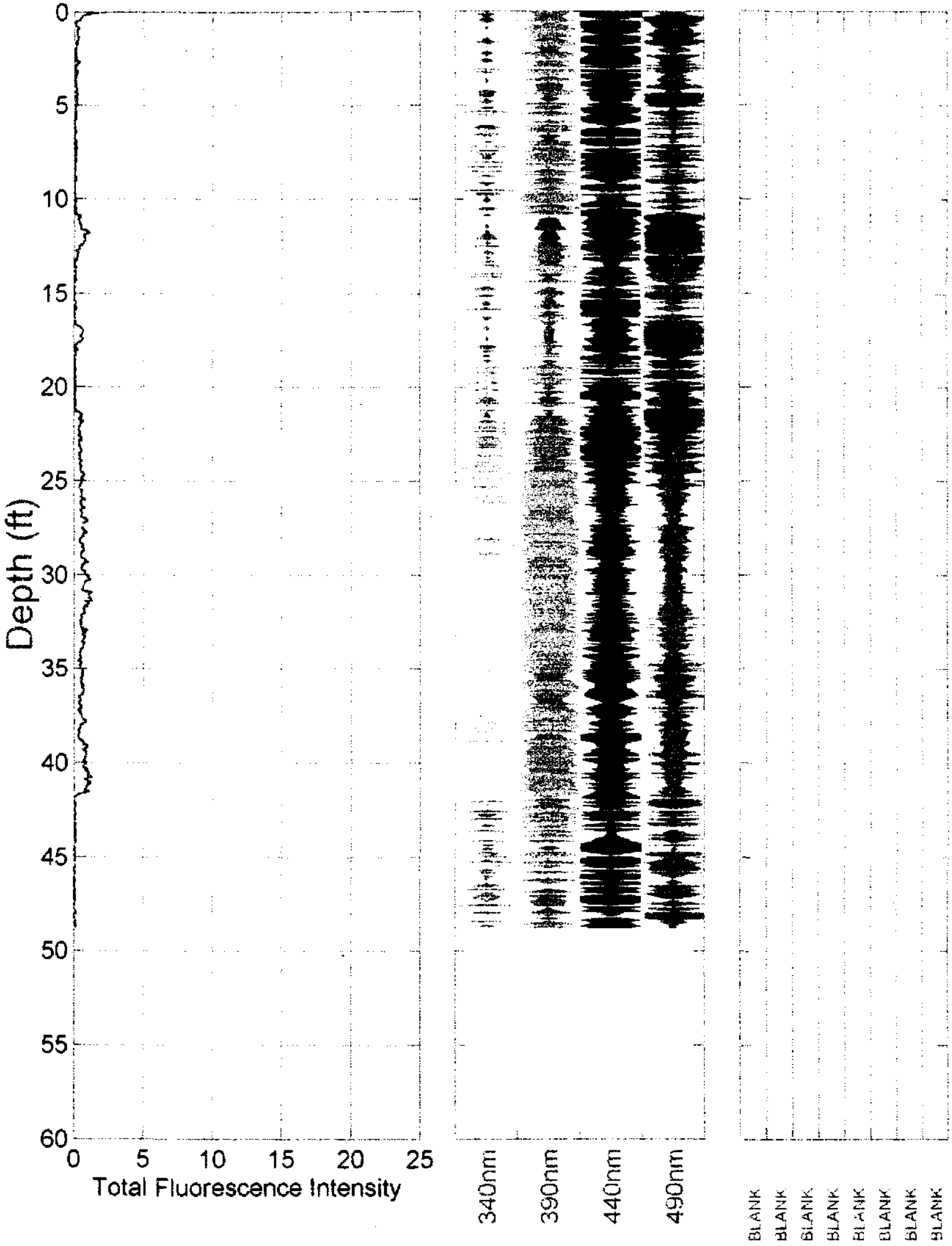


Measured LIF End Depth
48.77 ft
Measured Peak Fluorescence
1.353%

Job#: 0301-7042

Acquisition Date: 03-06-1997

RST_14

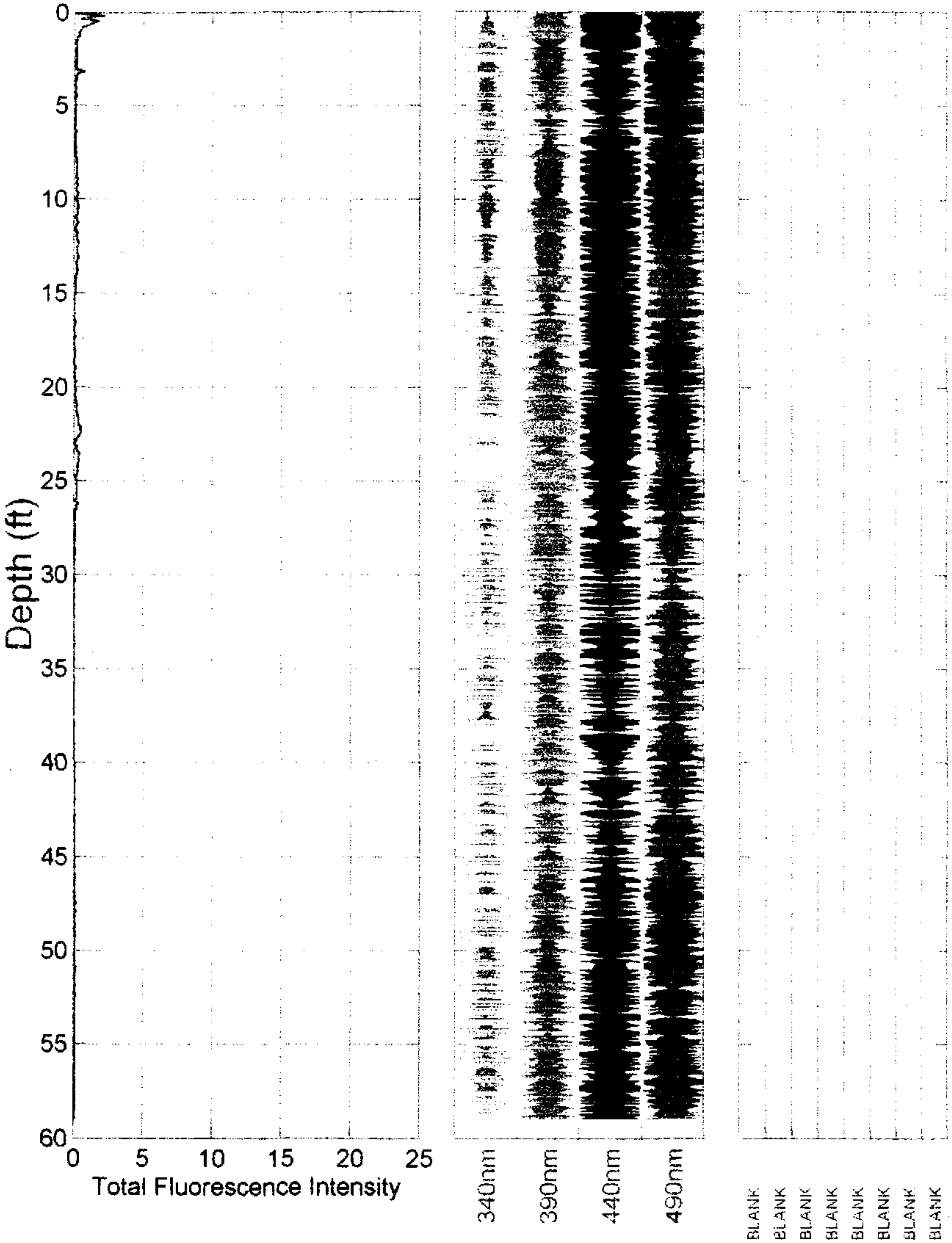


Measured LIF End Depth
58.98 ft
Measured Peak Fluorescence
2.148%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_15

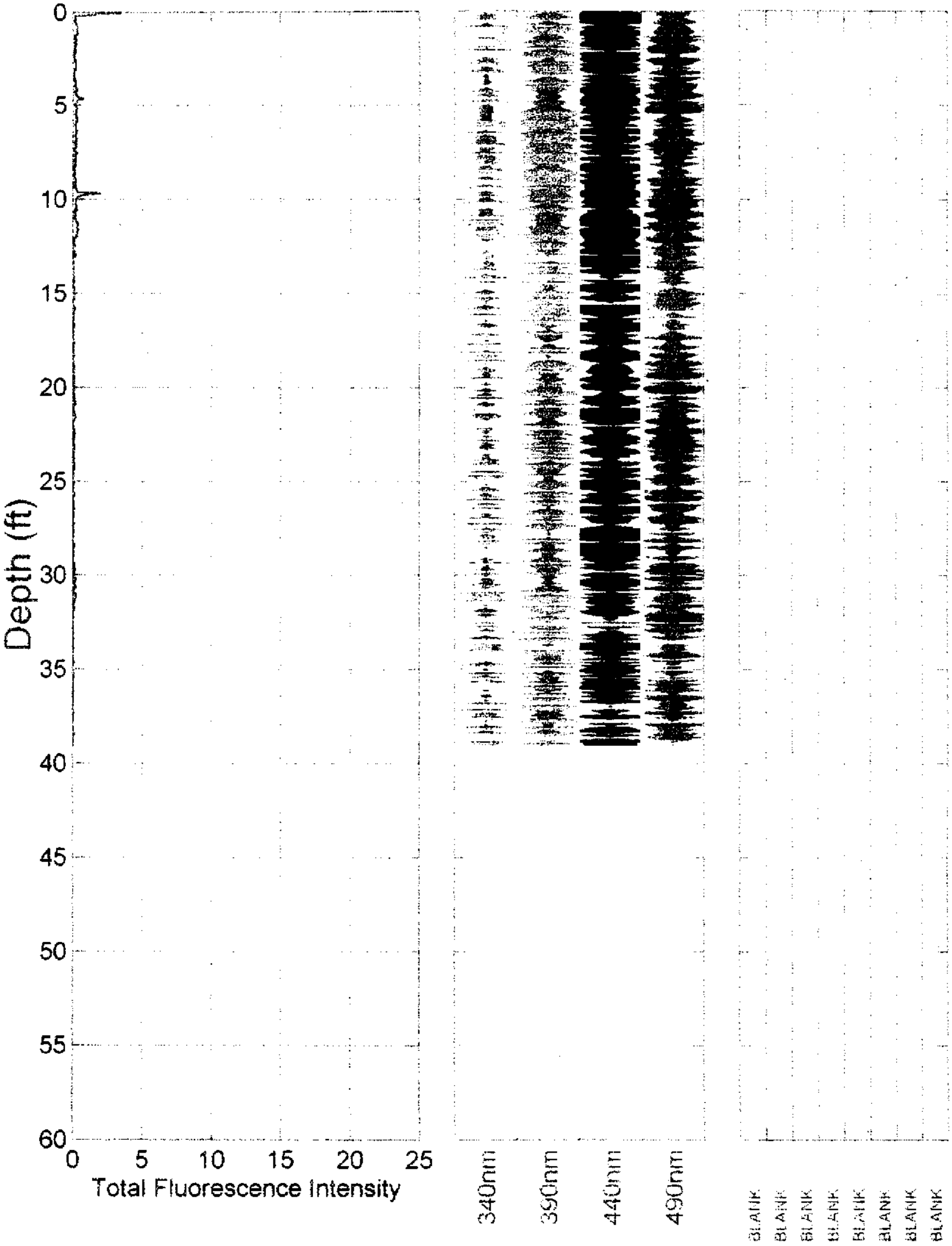


Measured LIF End Depth
39.06 ft
Measured Peak Fluorescence
3.422%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_16

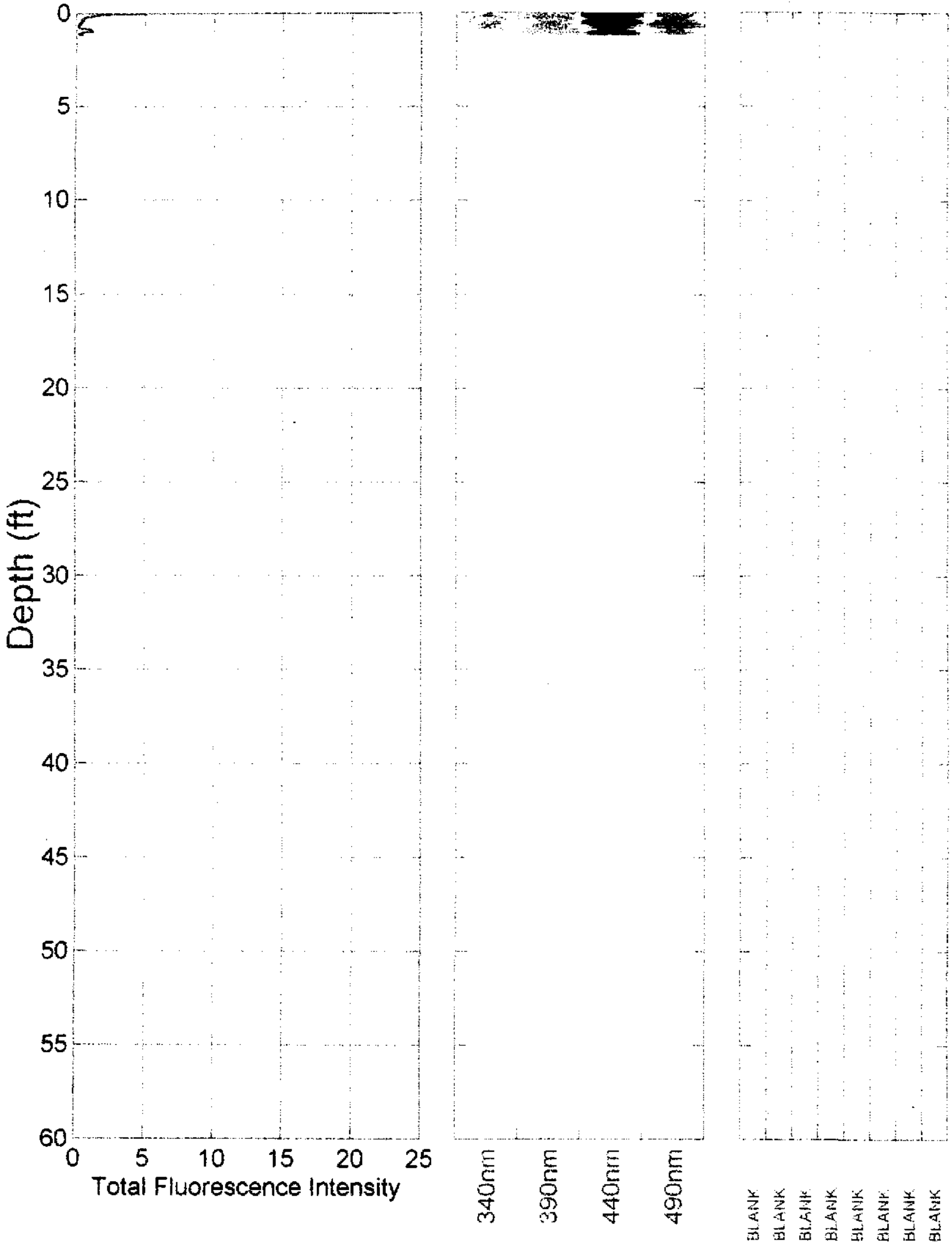


Measured LiF End Depth
1.168 ft
Measured Peak Fluorescence
1.943%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_17

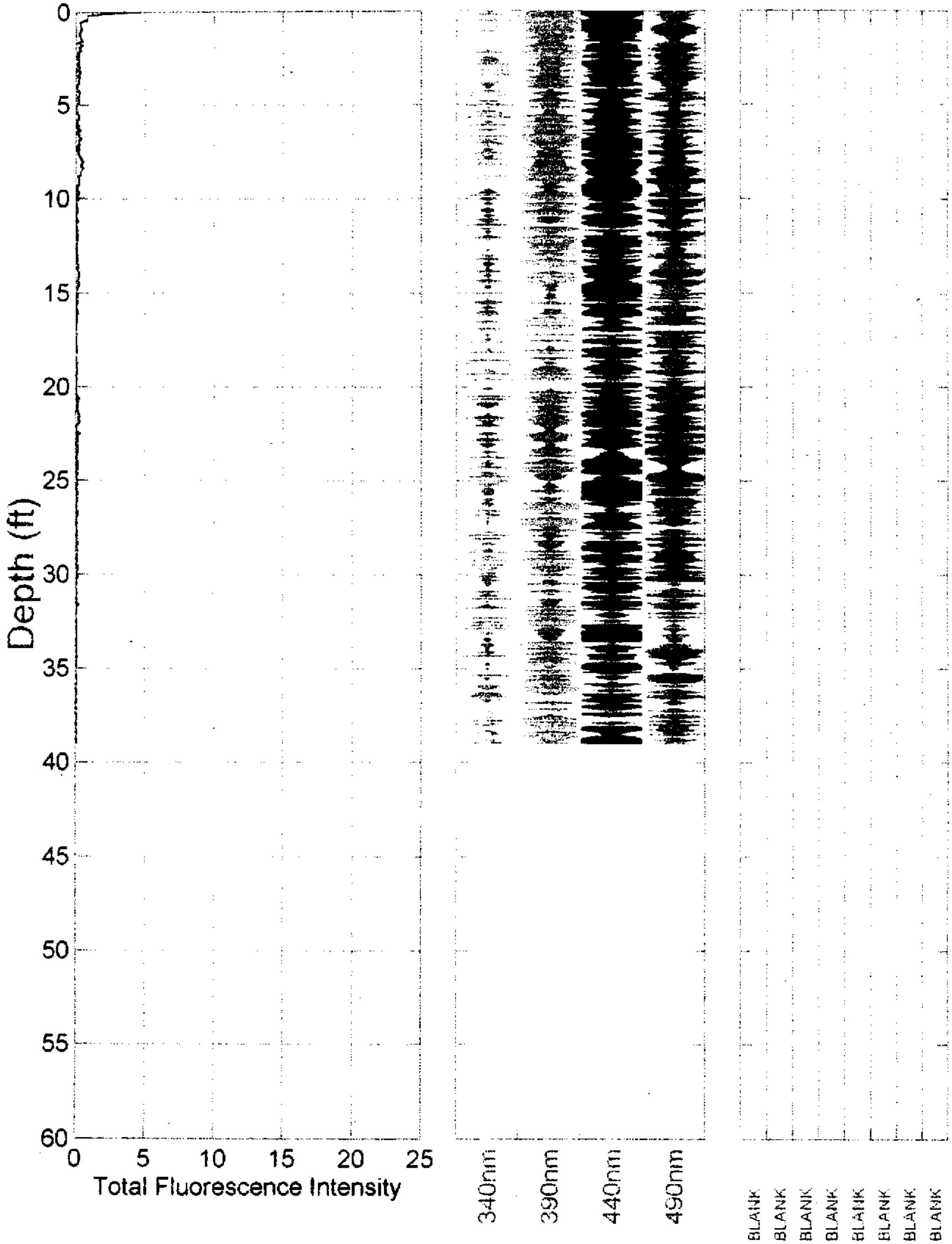


Measured LIF End Depth
39 ft
Measured Peak Fluorescence
1.544%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_17B

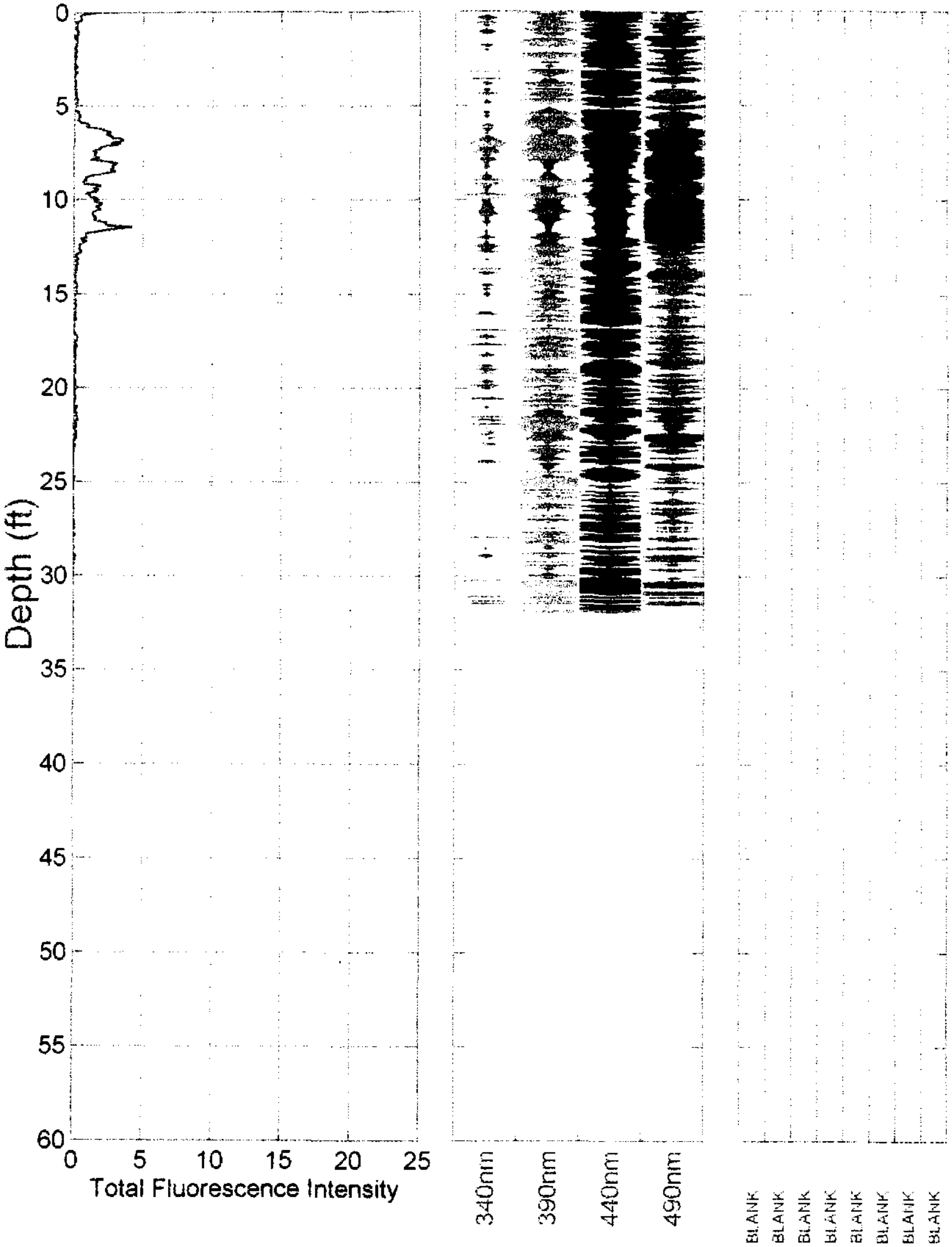


Measured LIF End Depth
31.98 ft
Measured Peak Fluorescence
4.216%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_18

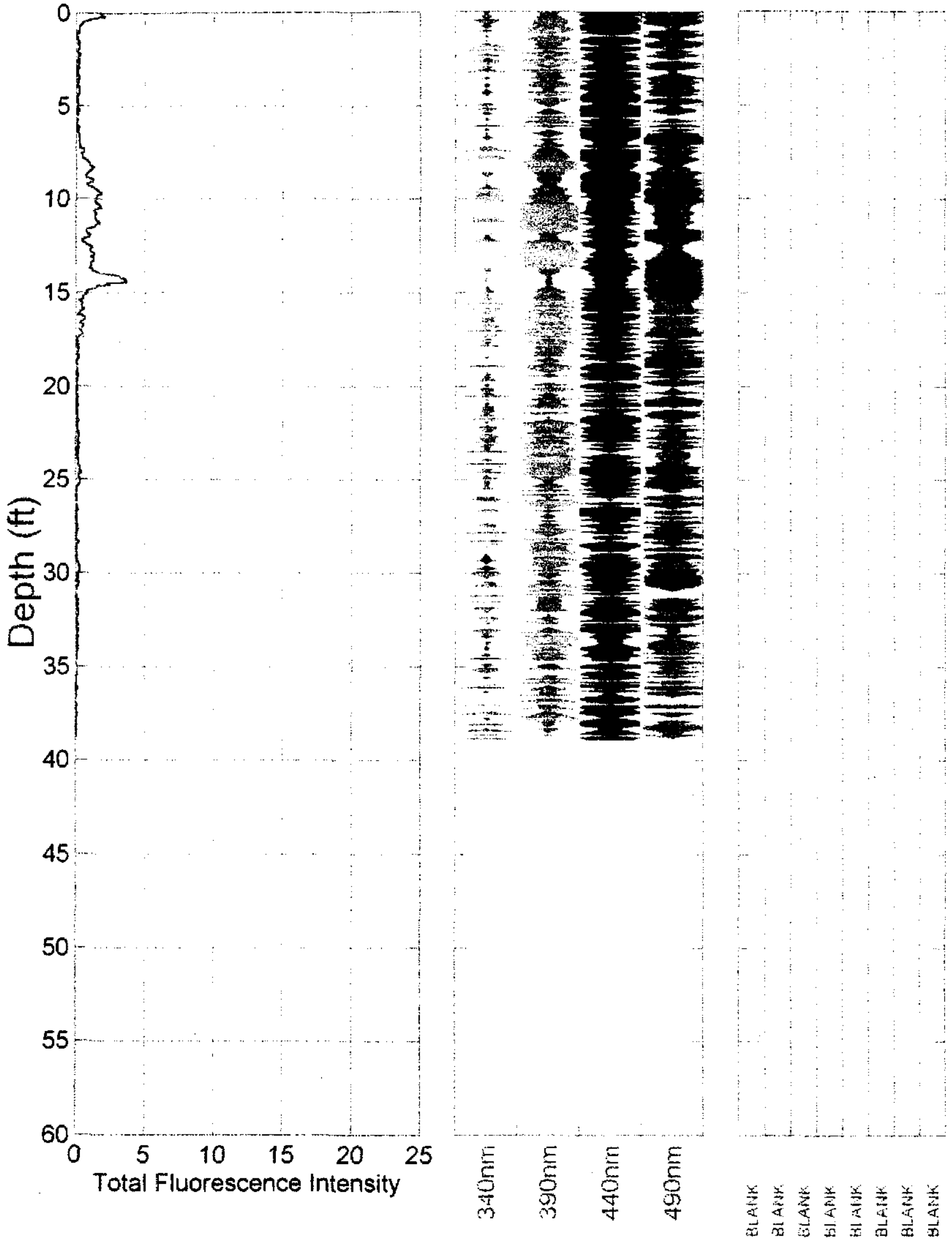


Measured LIF End Depth
38.9 ft
Measured Peak Fluorescence
3.69%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_19

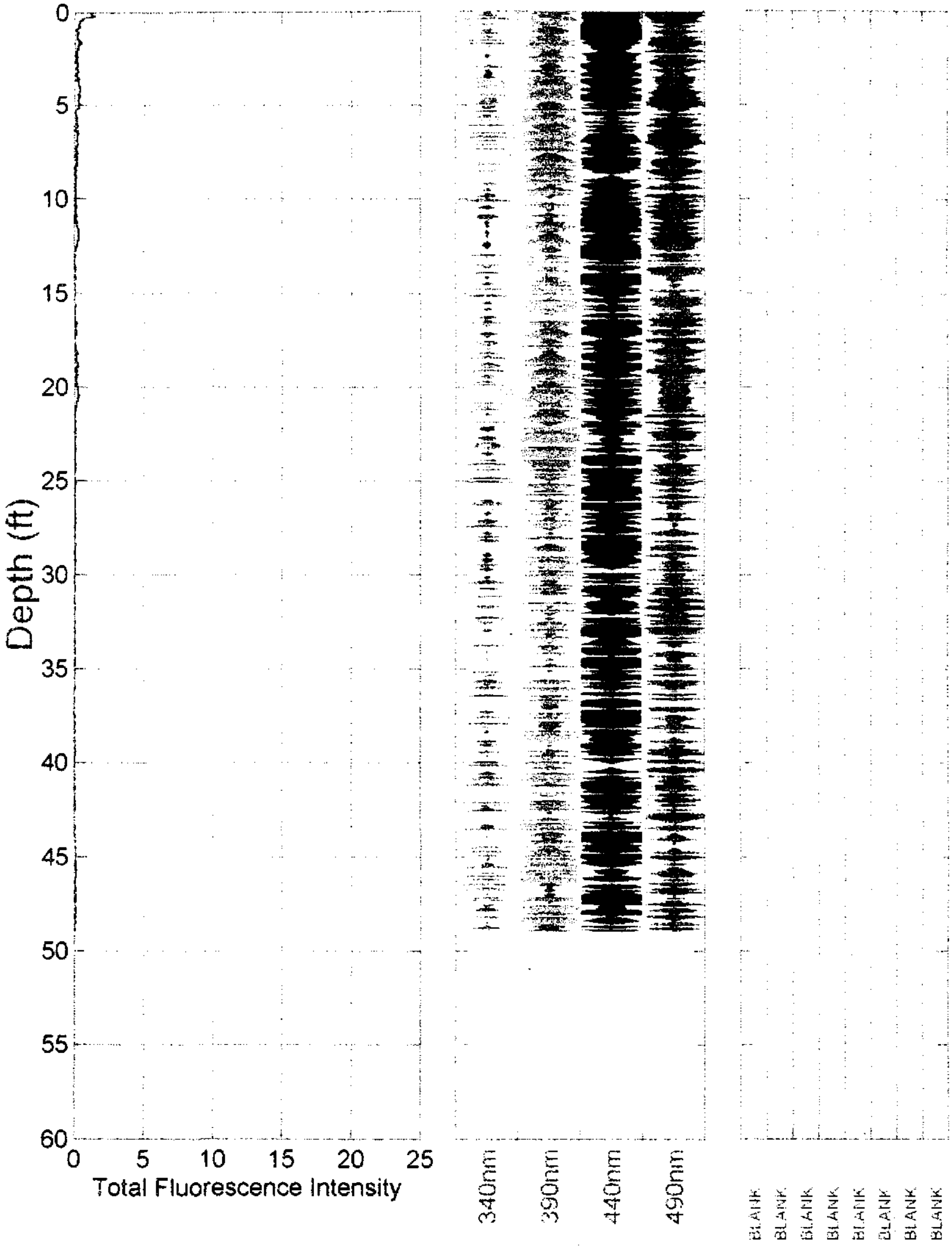


Measured LIF End Depth
48.97 ft
Measured Peak Fluorescence
1.436%

Job#: 0301-7042

Acquisition Date: 03-07-1997

RST_20

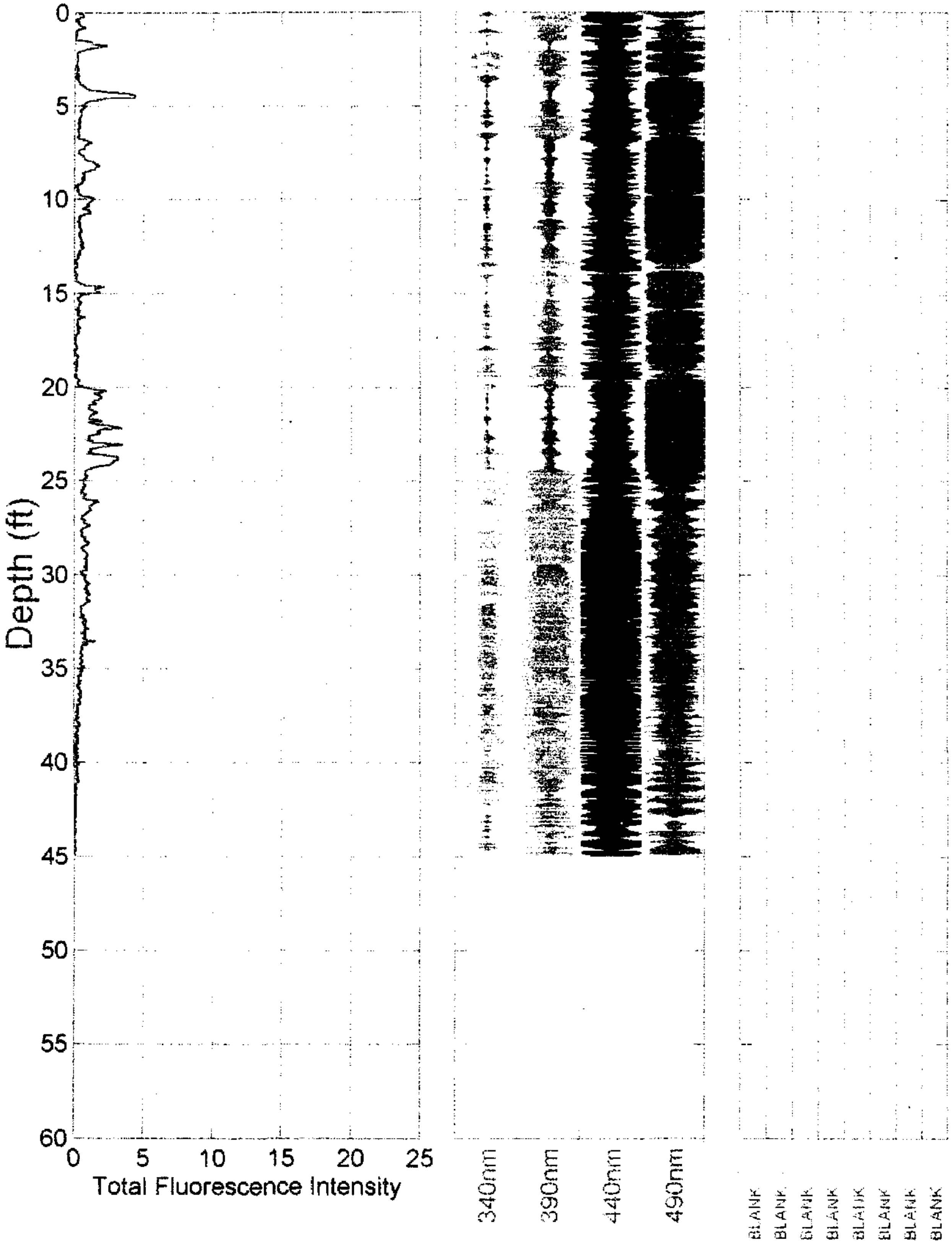


Measured LIF End Depth
44.97 ft
Measured Peak Fluorescence
4.398%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_21

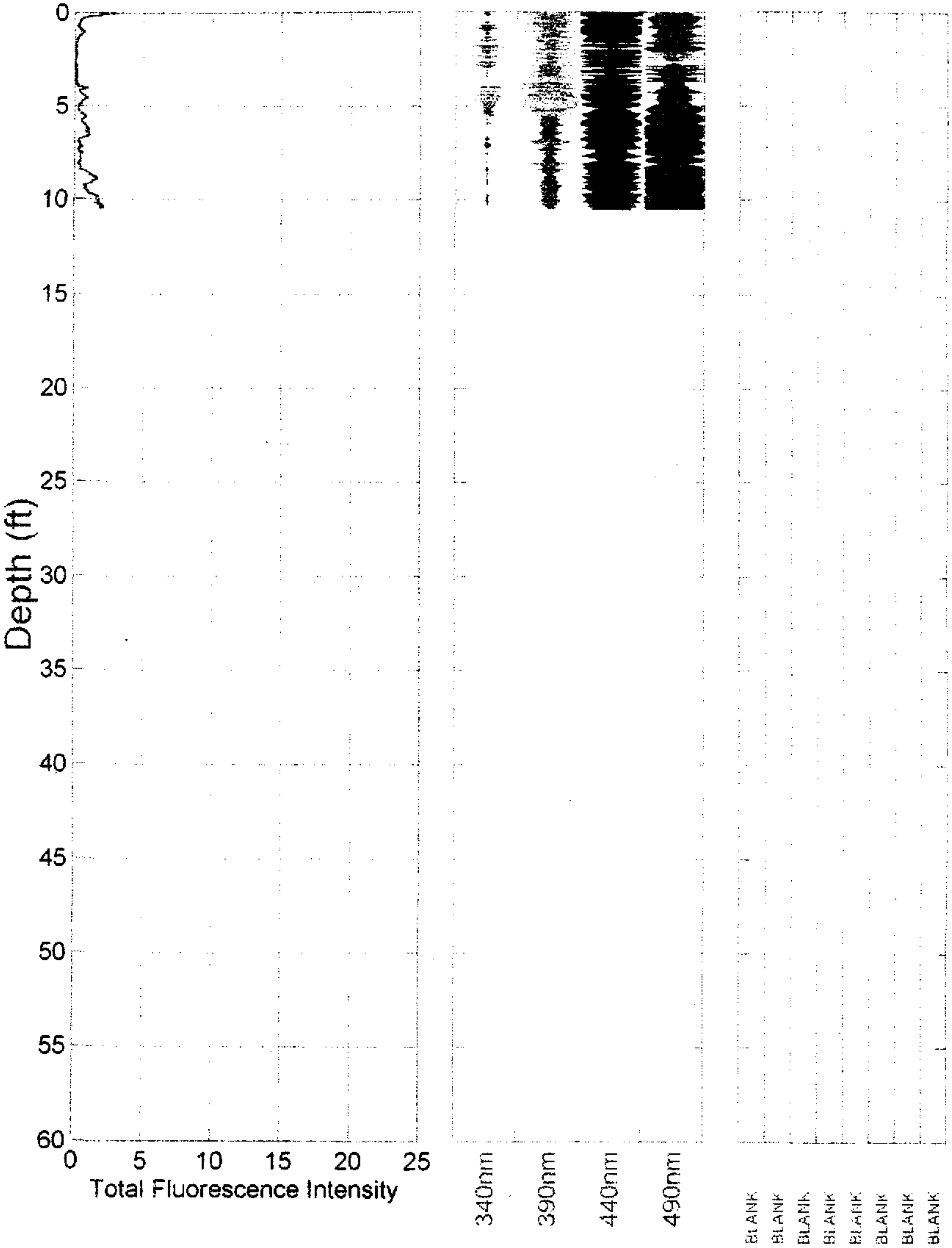


Measured LIF End Depth
10.49 ft
Measured Peak Fluorescence
2.912%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_22

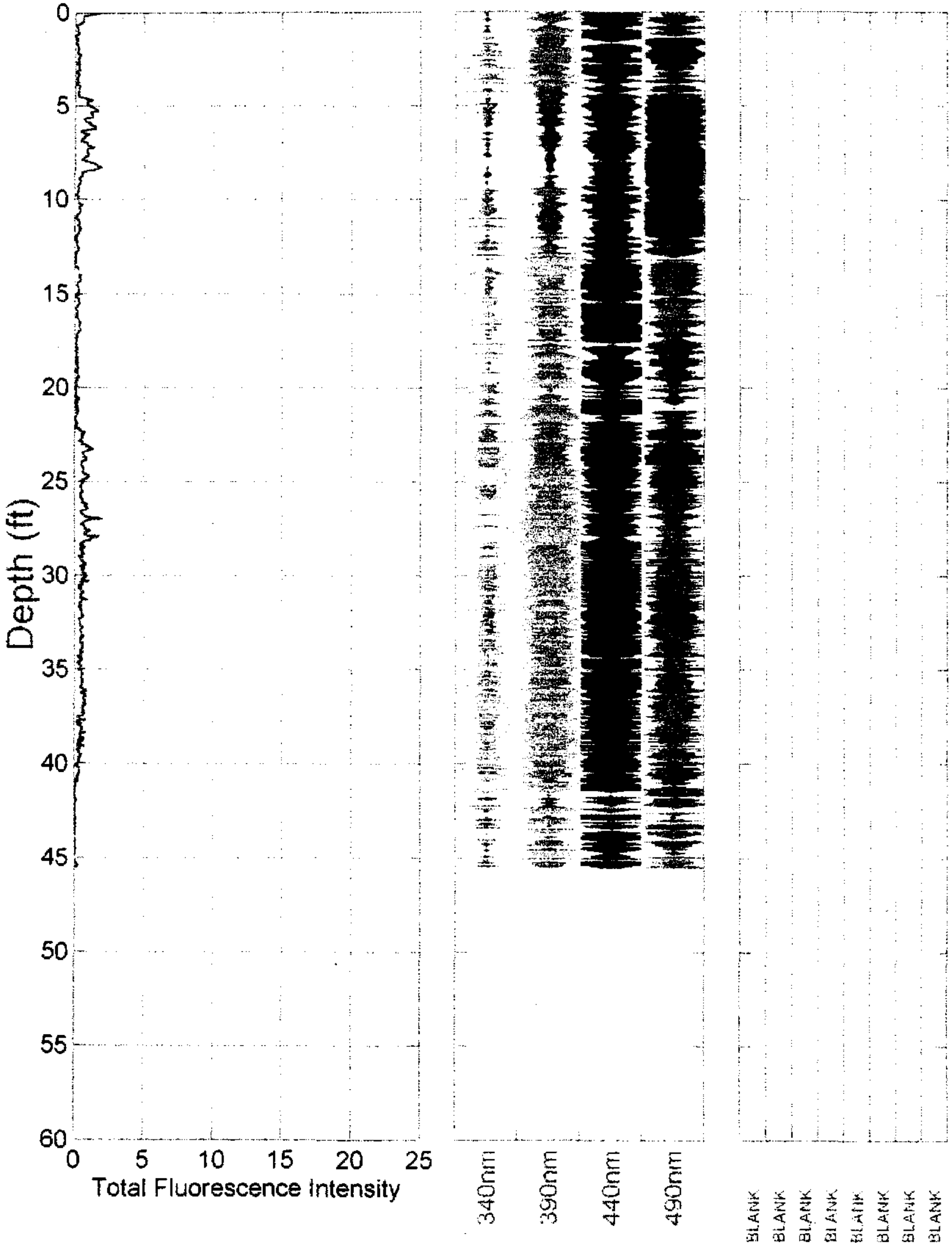


Measured LIF End Depth
45.52 ft
Measured Peak Fluorescence
1.973%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_23

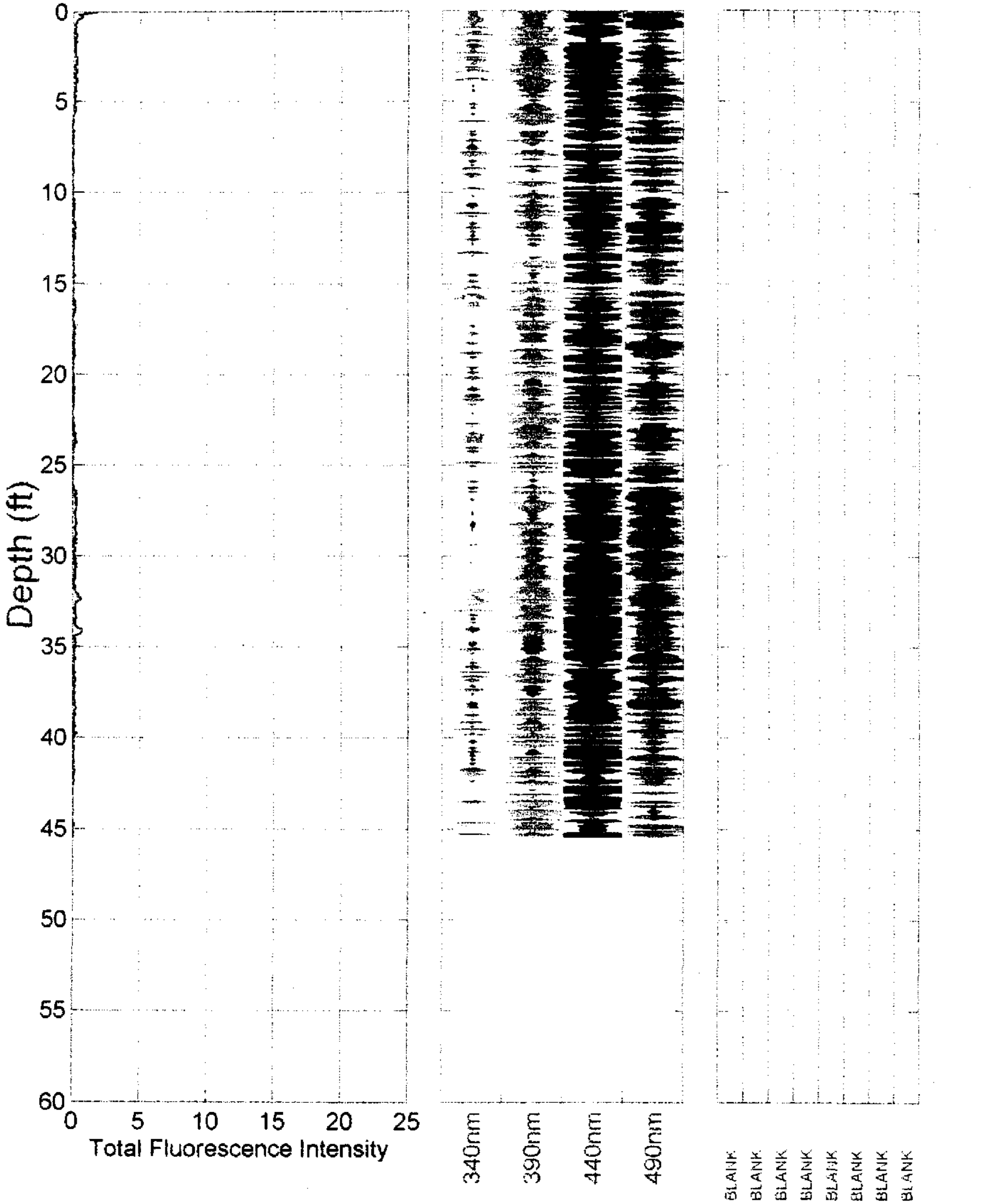


Measured LIF End Depth
45.46 ft
Measured Peak Fluorescence
1.678%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_24

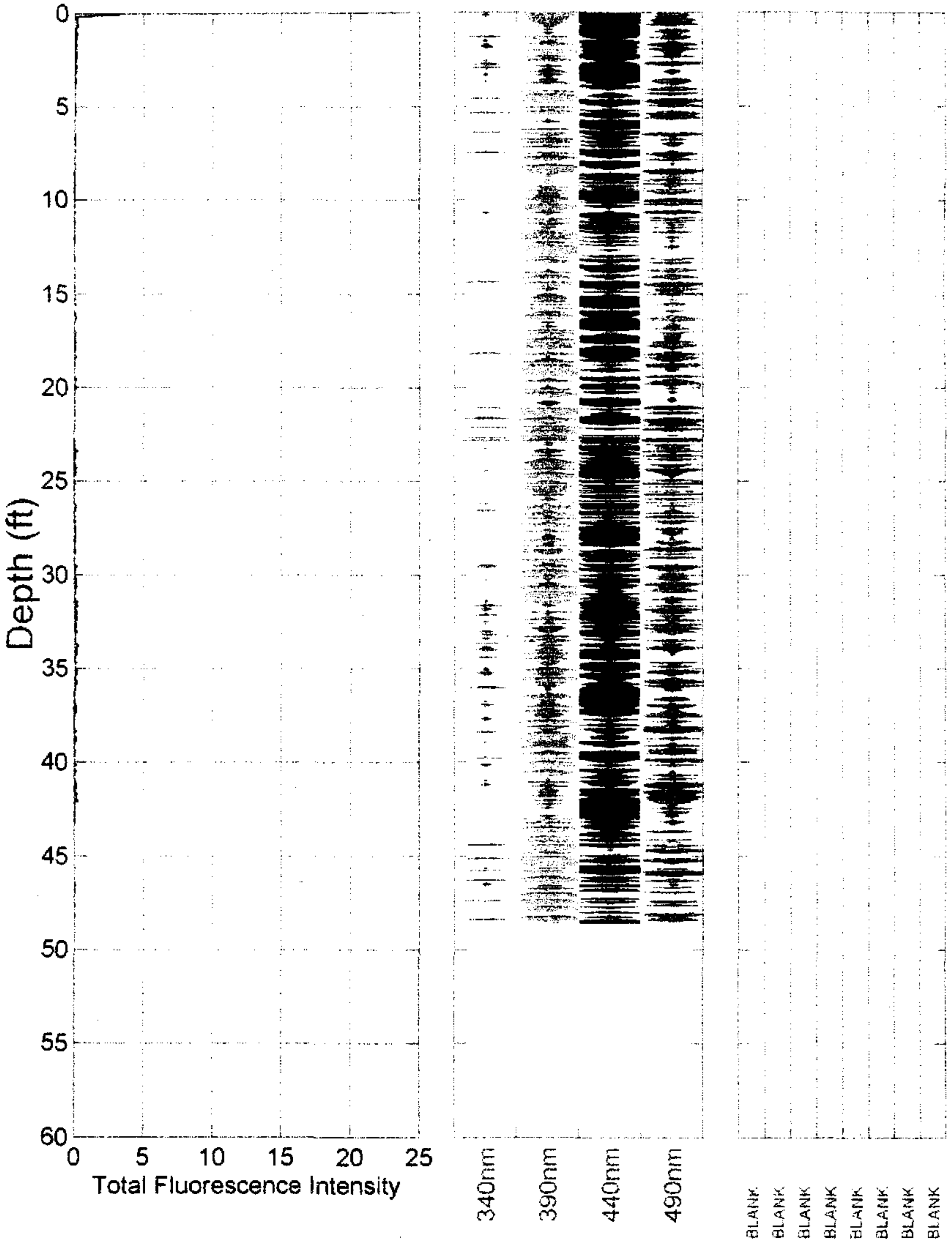


Measured LIF End Depth
48.58 ft
Measured Peak Fluorescence
3.133%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_25

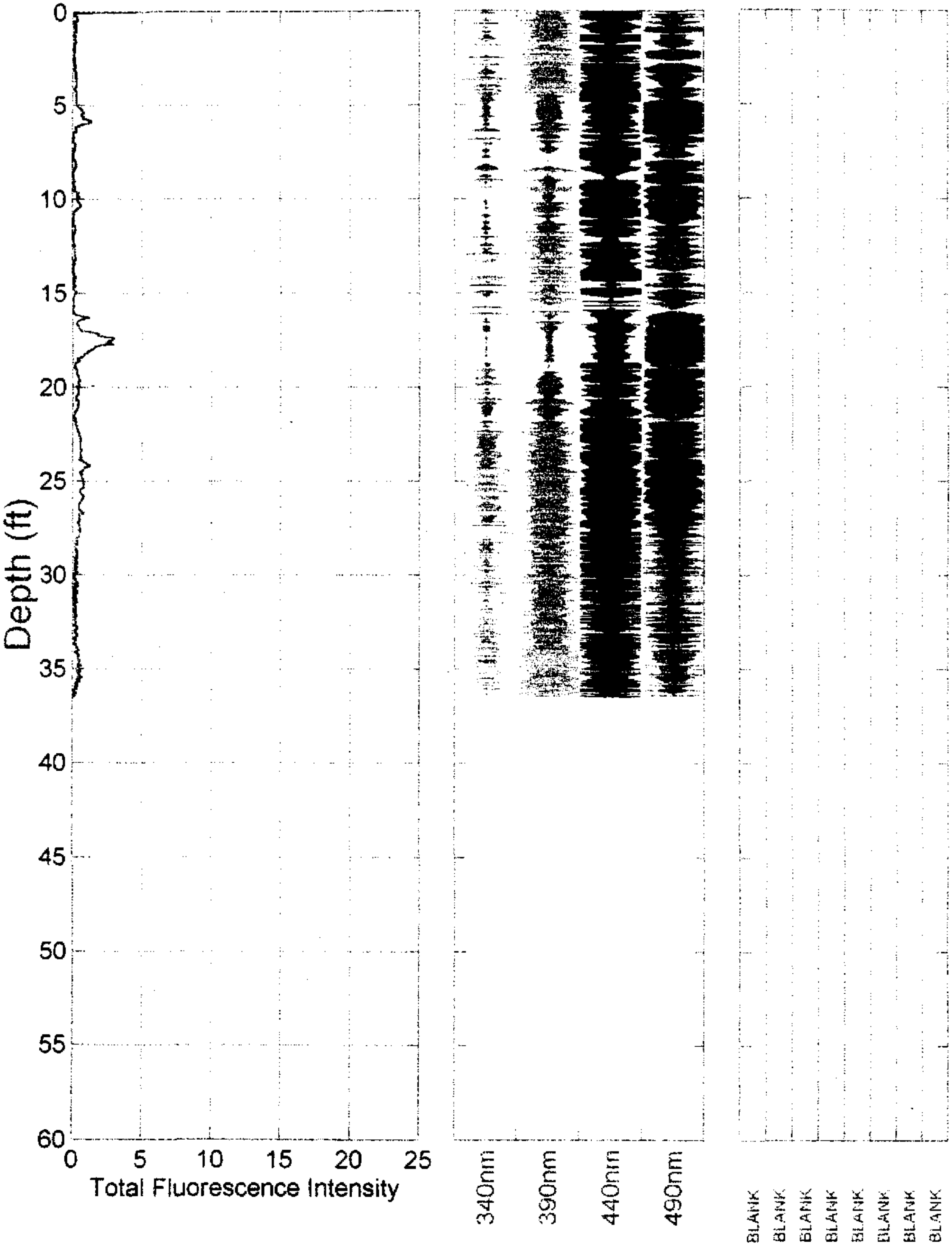


Measured LIF End Depth
36.47 ft
Measured Peak Fluorescence
2.969%

Job#: 0301-7042

Acquisition Date: 03-10-1997

RST_26

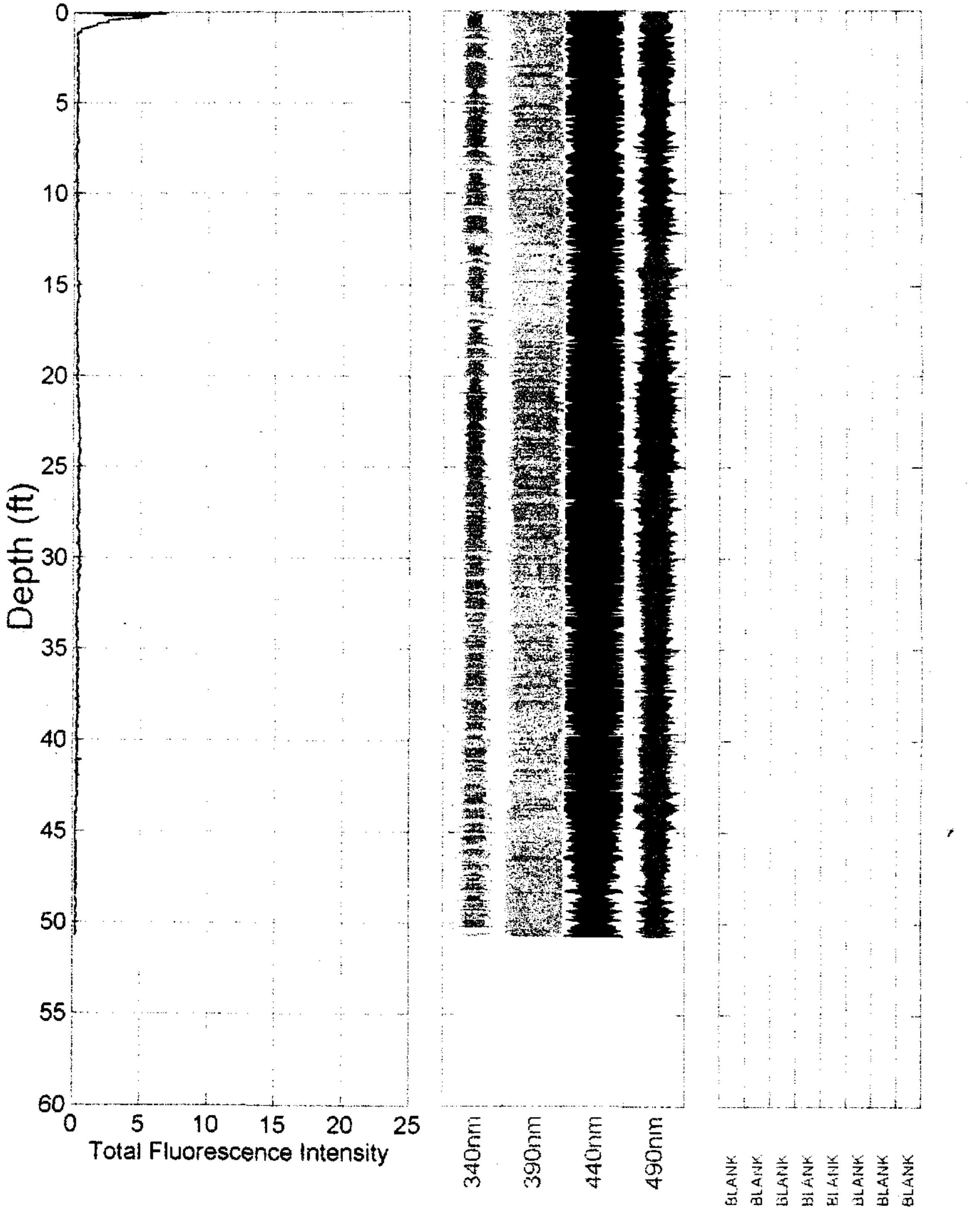


Measured LIF End Depth
50.74 ft
Measured Peak Fluorescence
6.87%

Job#: 0301-7042

Acquisition Date: 03-11-1997

RST_27

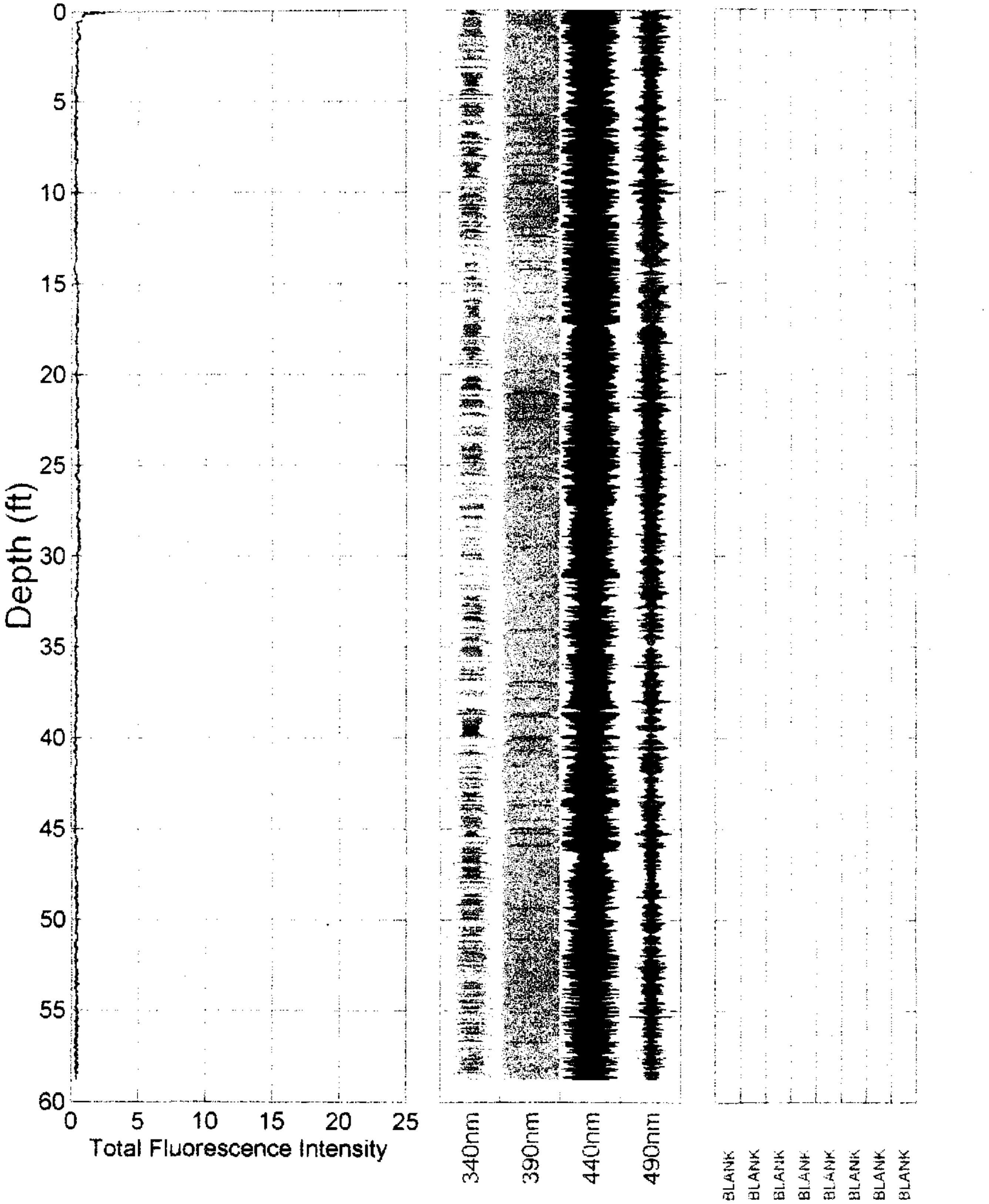


Measured LIF End Depth
58.78 ft
Measured Peak Fluorescence
2.438%

Job#: 0301-7042

Acquisition Date: 03-11-1997

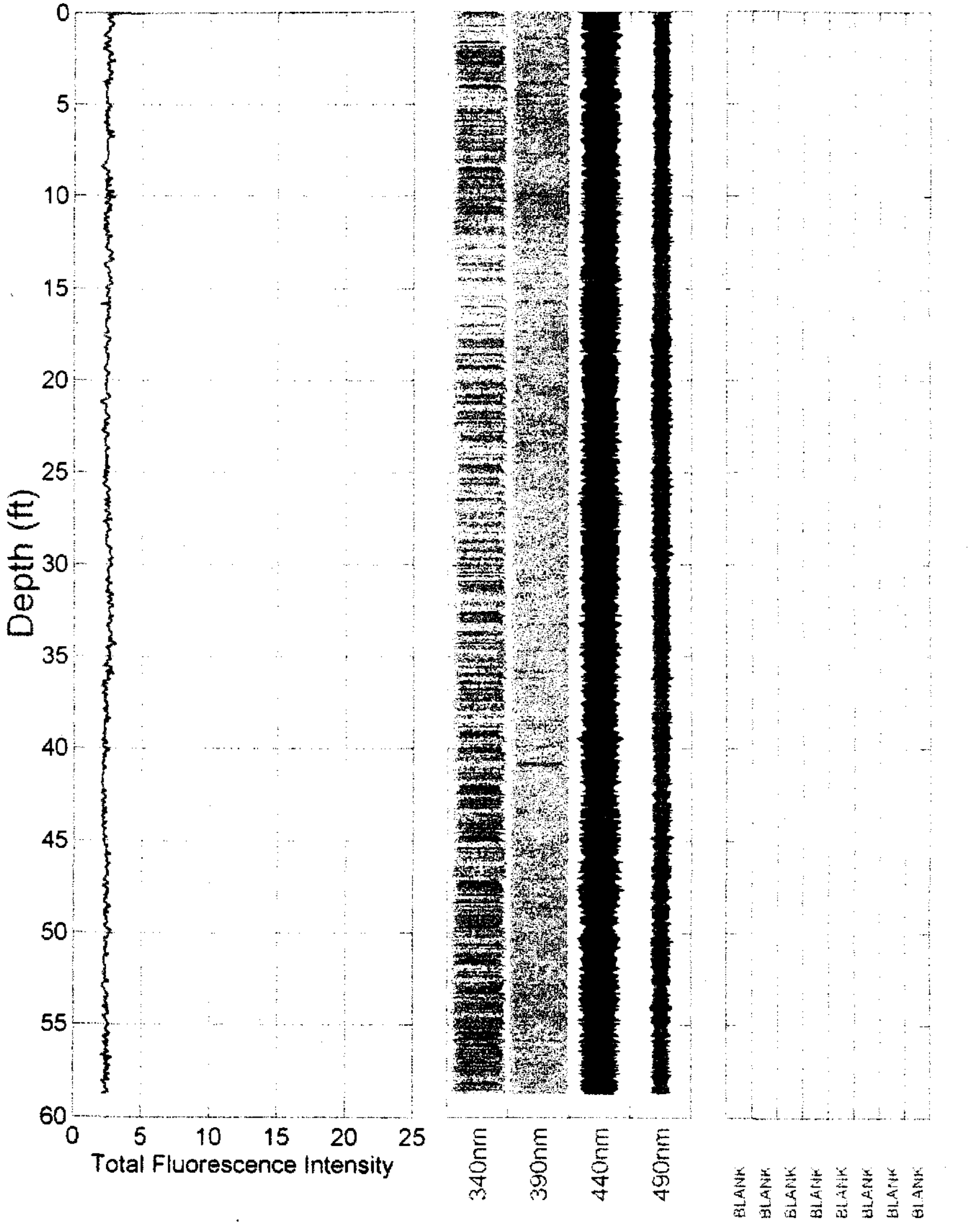
RST_28



Measured LIF End Depth
58.75 ft
Measured Peak Fluorescence
3.815%

Job#: 0301-7042
Acquisition Date: 03-11-1997

RST_29

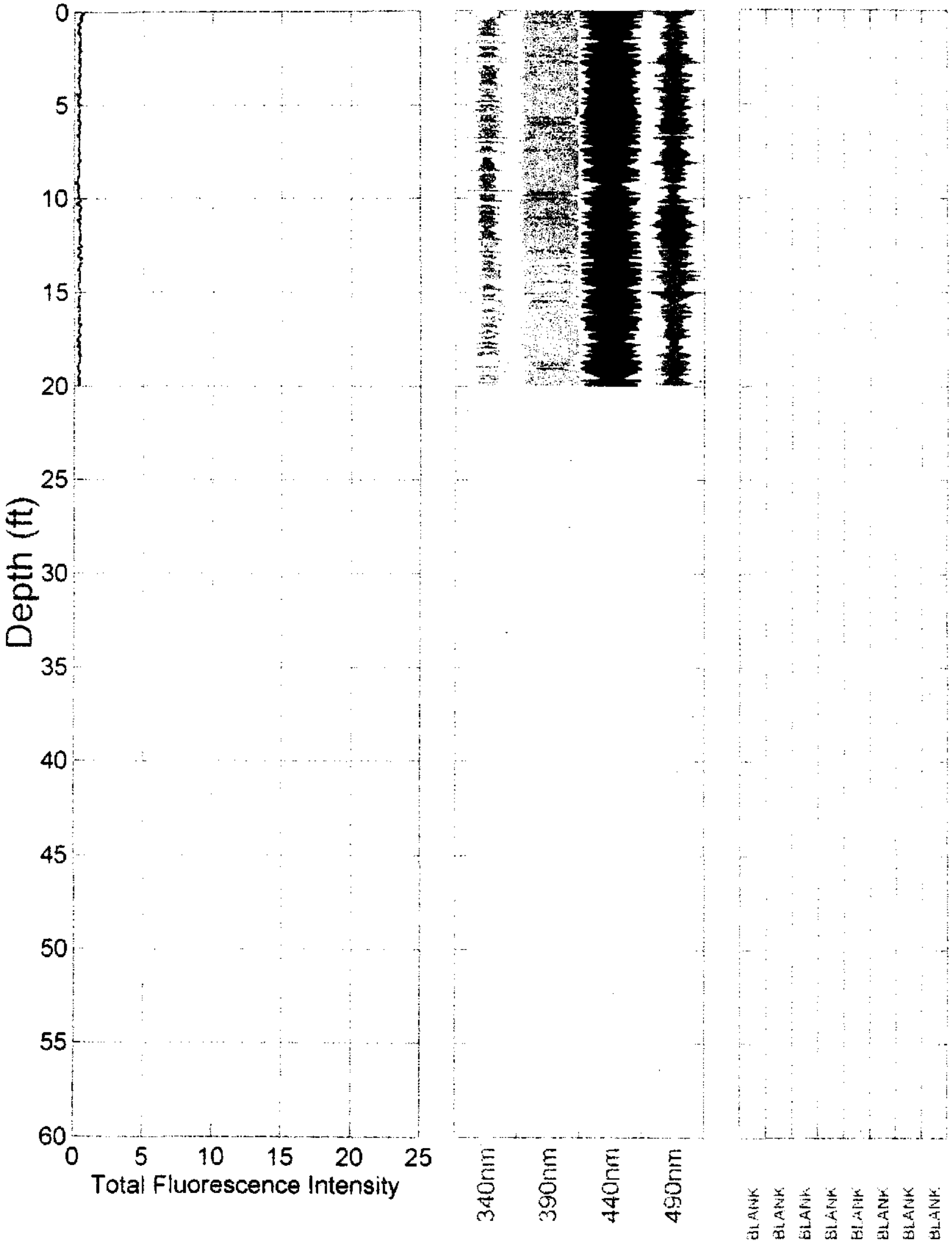


Measured LIF End Depth
19.97 ft
Measured Peak Fluorescence
0.6885%

Job#: 0301-7042

Acquisition Date: 03-11-1997

RST_29A

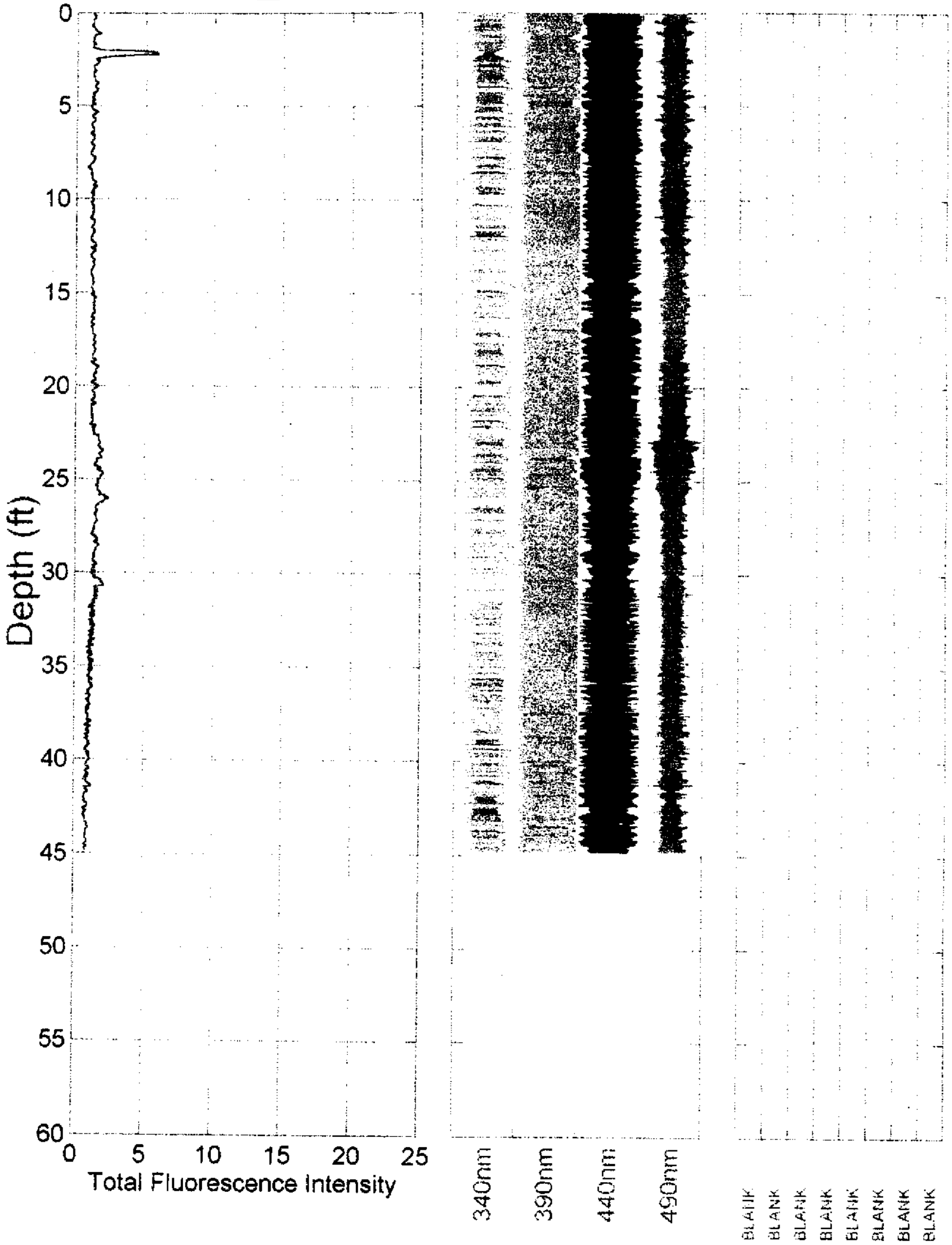


Measured LIF End Depth
44.84 ft
Measured Peak Fluorescence
5.856%

Job#: 0301-7042

Acquisition Date: 03-11-1997

RST_30

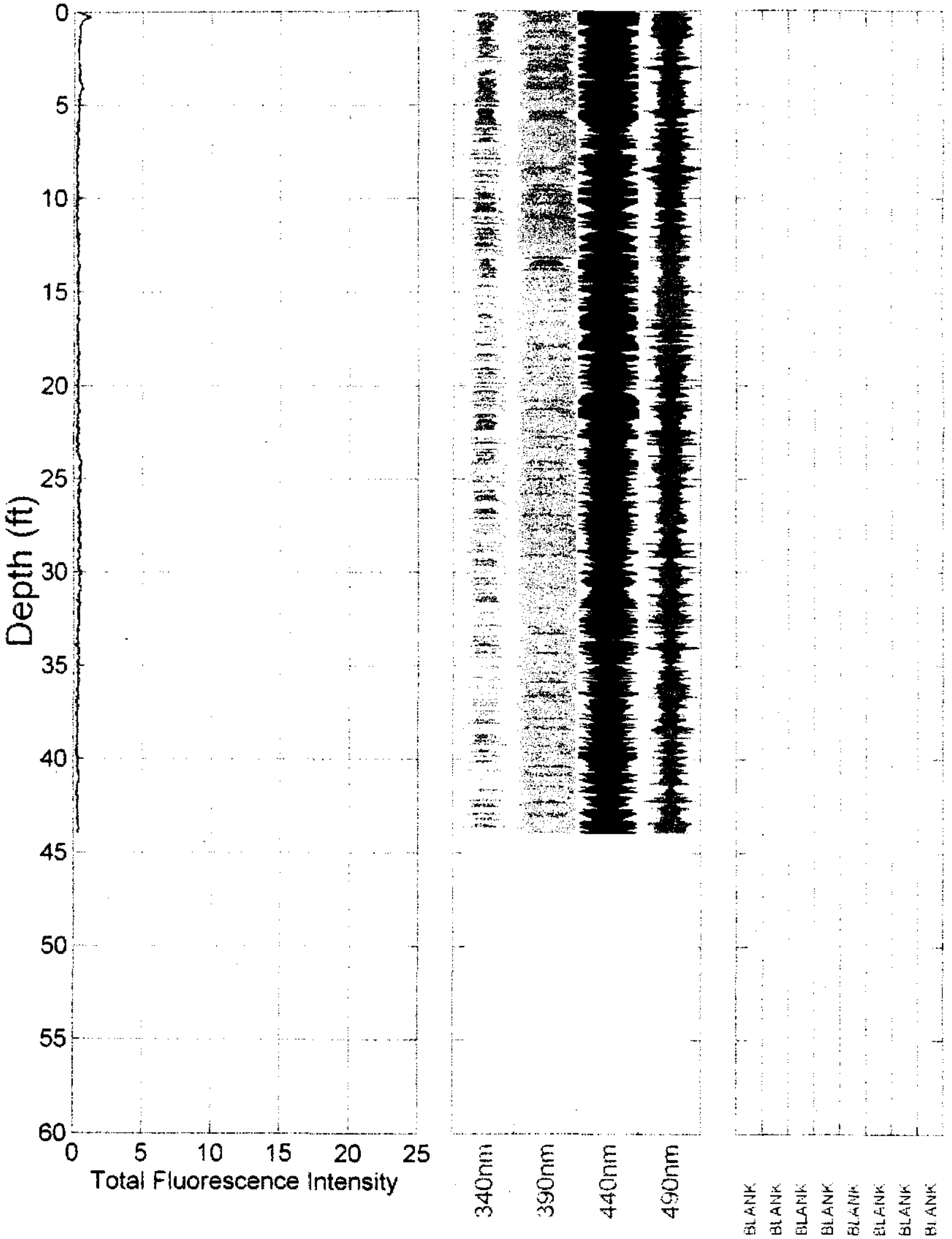


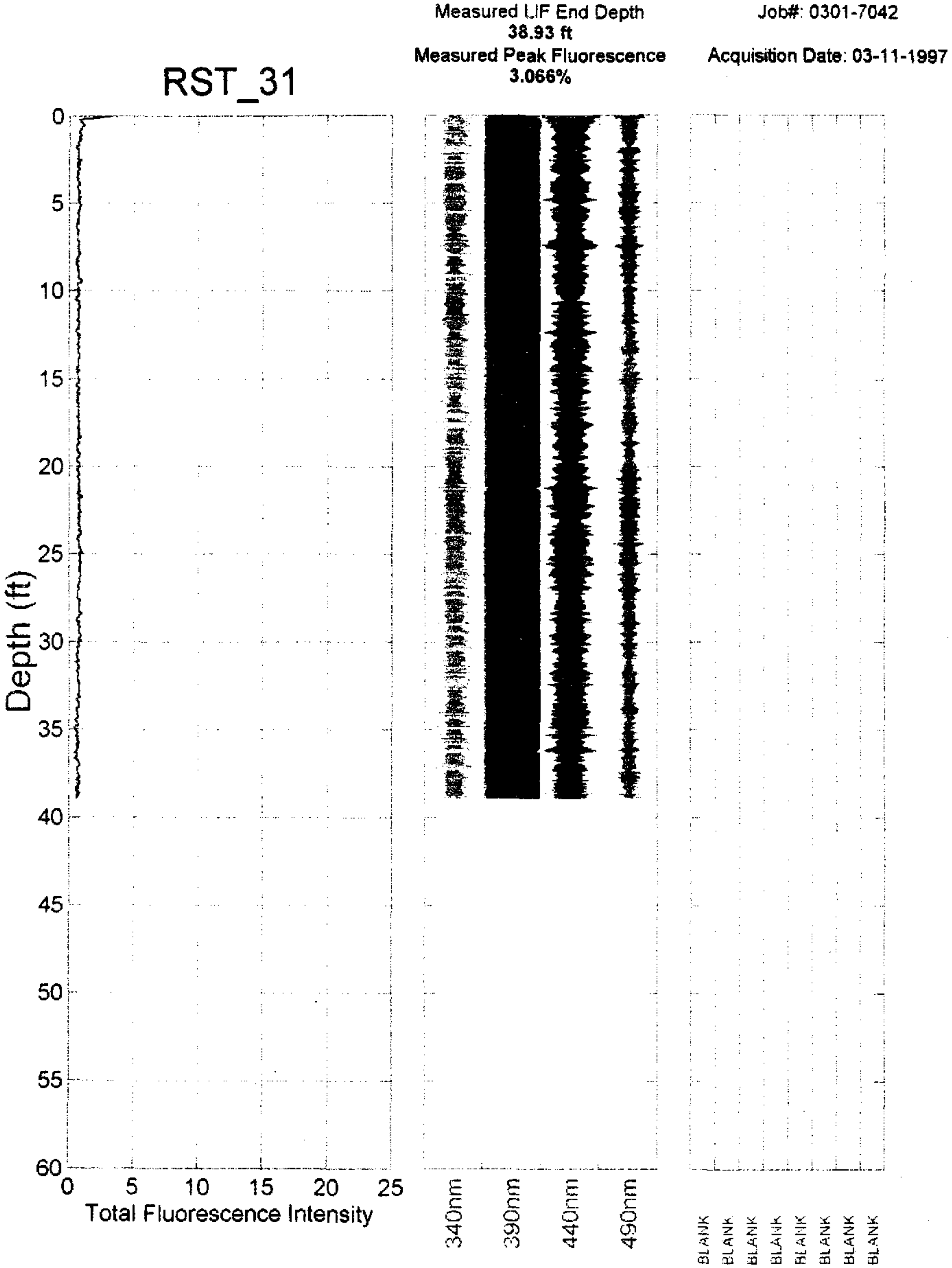
Measured LIF End Depth
43.95 ft
Measured Peak Fluorescence
1.169%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_30A



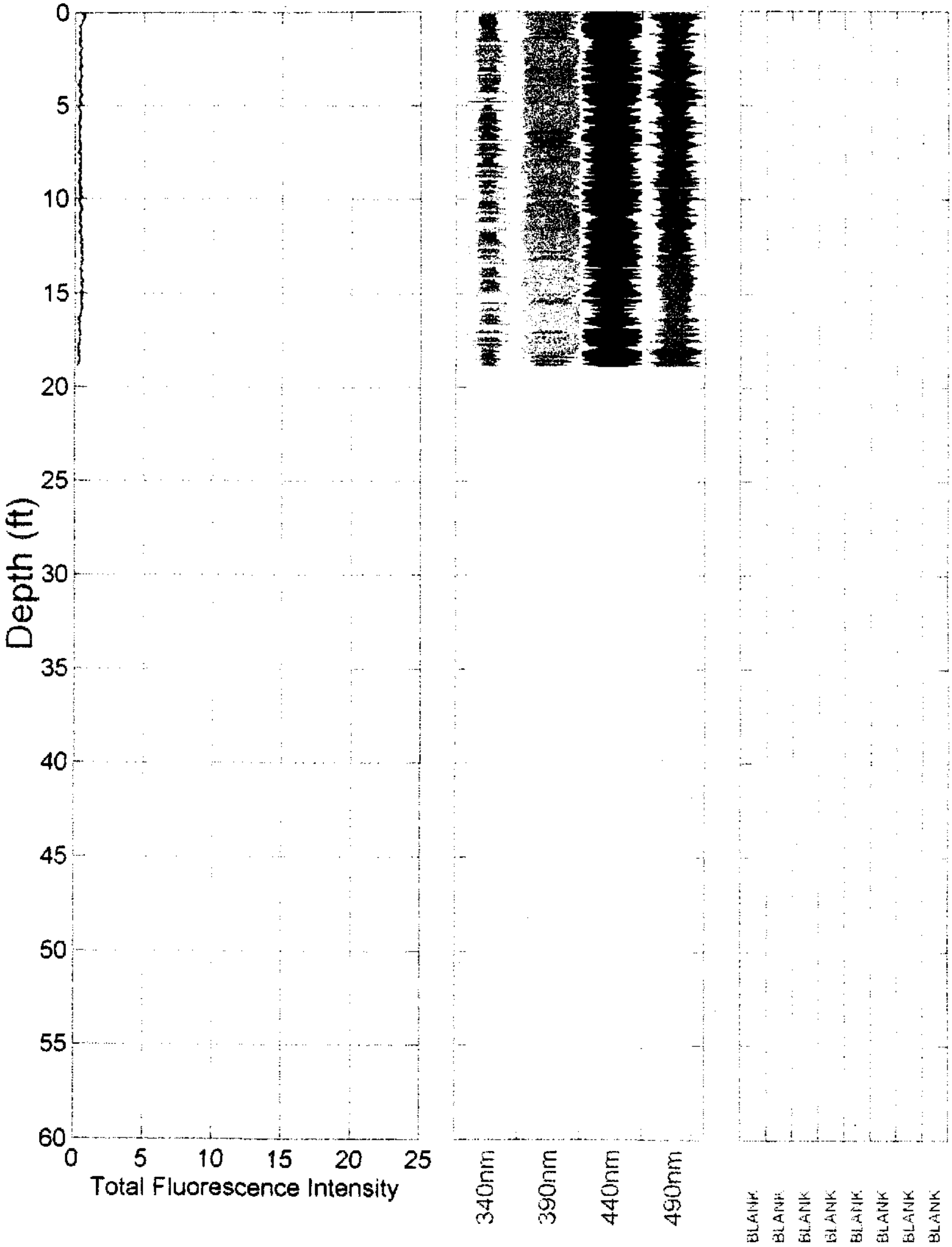


Measured LIF End Depth
18.85 ft
Measured Peak Fluorescence
0.7087%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_31A

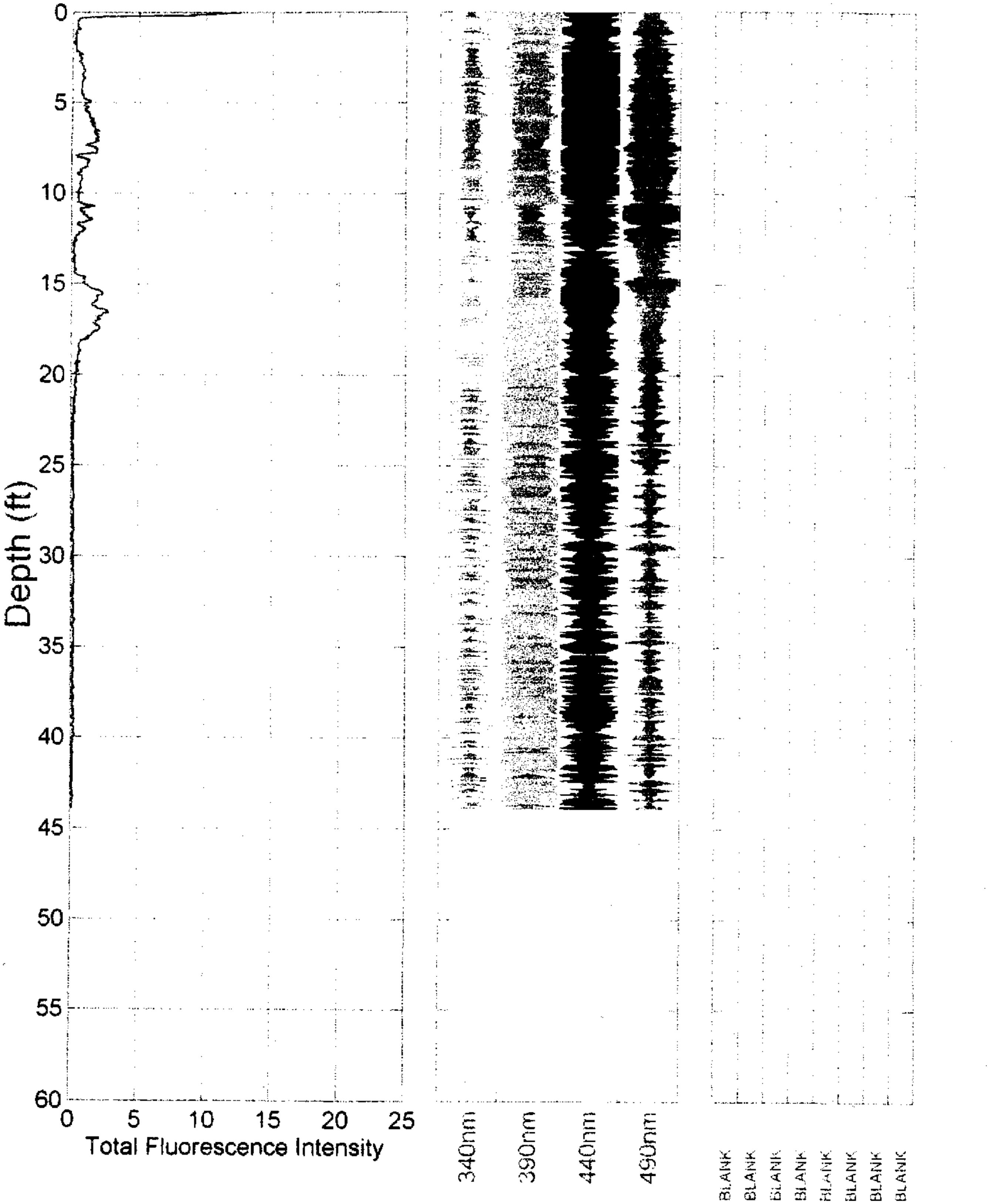


Measured LIF End Depth
43.92 ft
Measured Peak Fluorescence
12.57%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_32

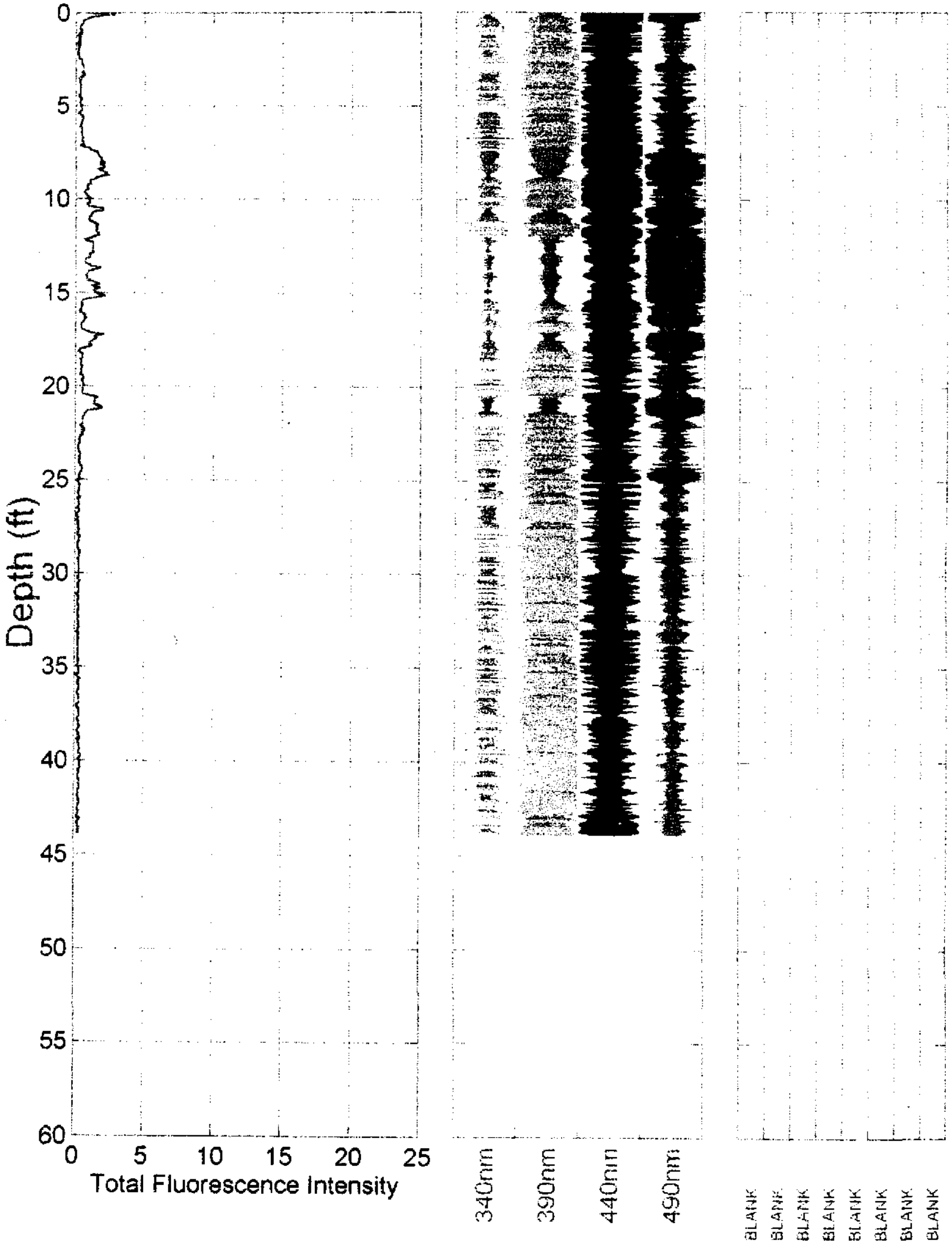


Measured LIF End Depth
43.92 ft
Measured Peak Fluorescence
2.774%

Job#: 0301-7042

Acquisition Date: 03-12-1997

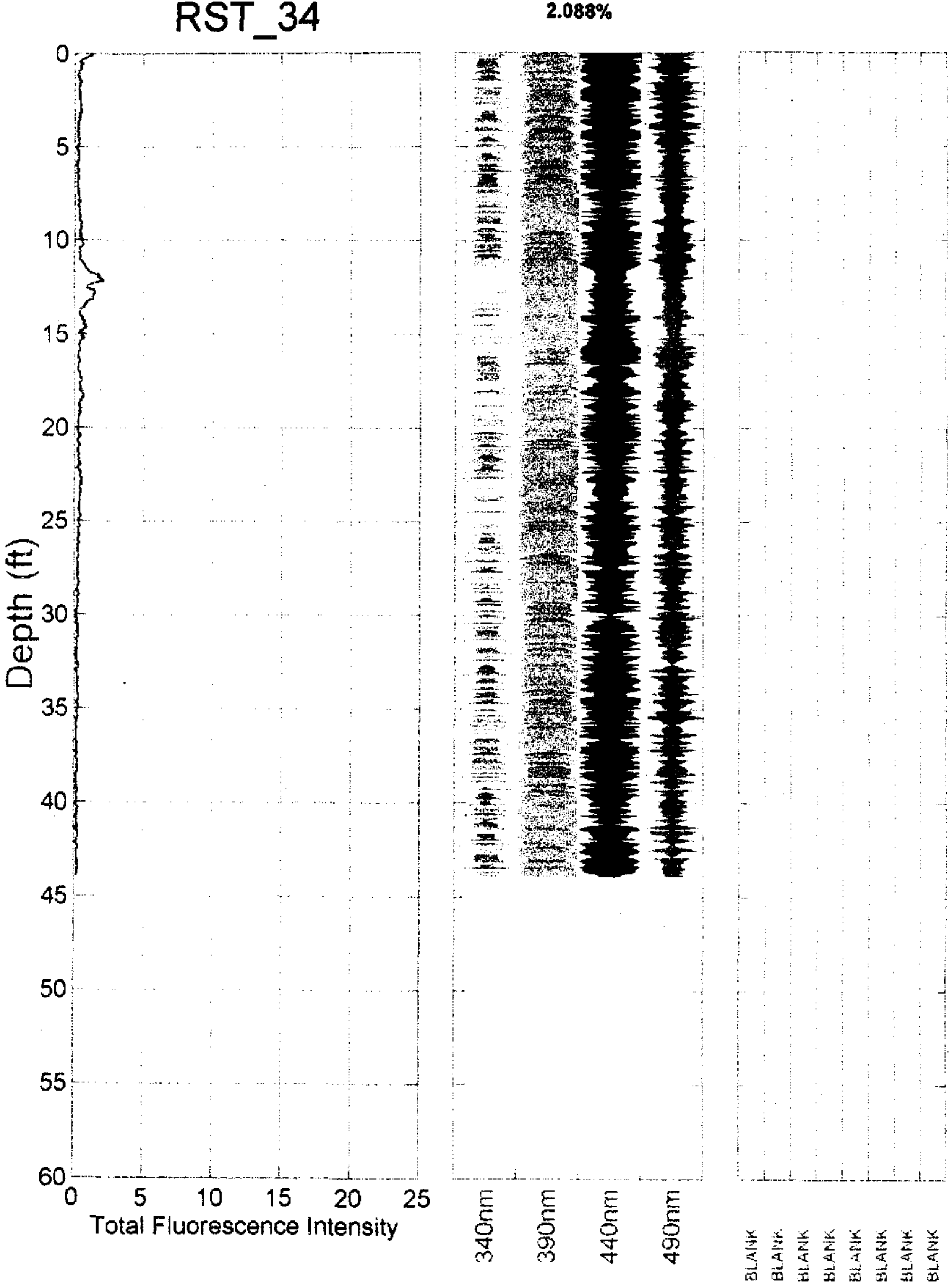
RST_33



Measured LIF End Depth
43.92 ft
Measured Peak Fluorescence
2.088%

Job#: 0301-7042

Acquisition Date: 03-12-1997

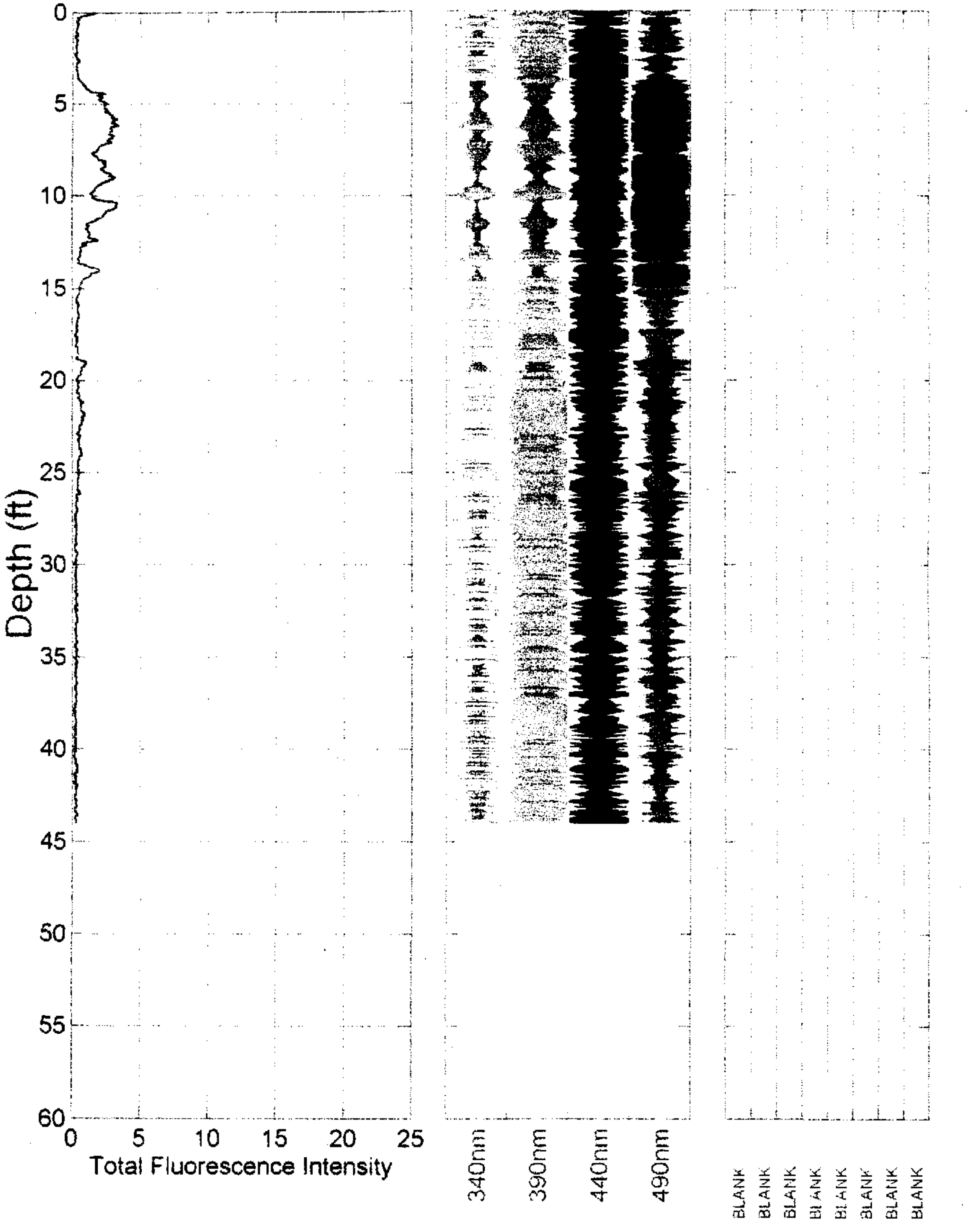


Measured LIF End Depth
44.02 ft
Measured Peak Fluorescence
3.361%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_35

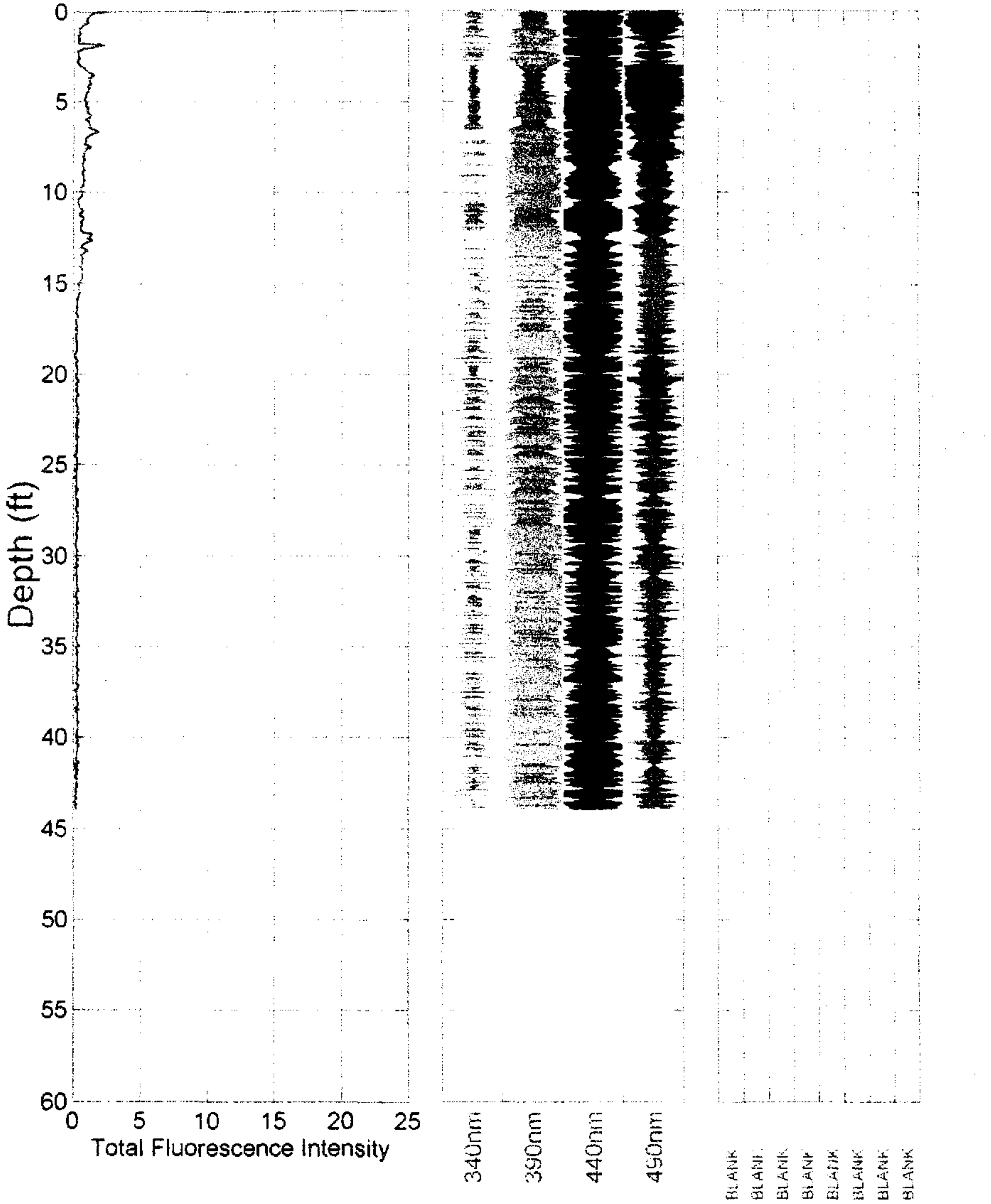


Measured LIF End Depth
43.95 ft
Measured Peak Fluorescence
2.248%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_36

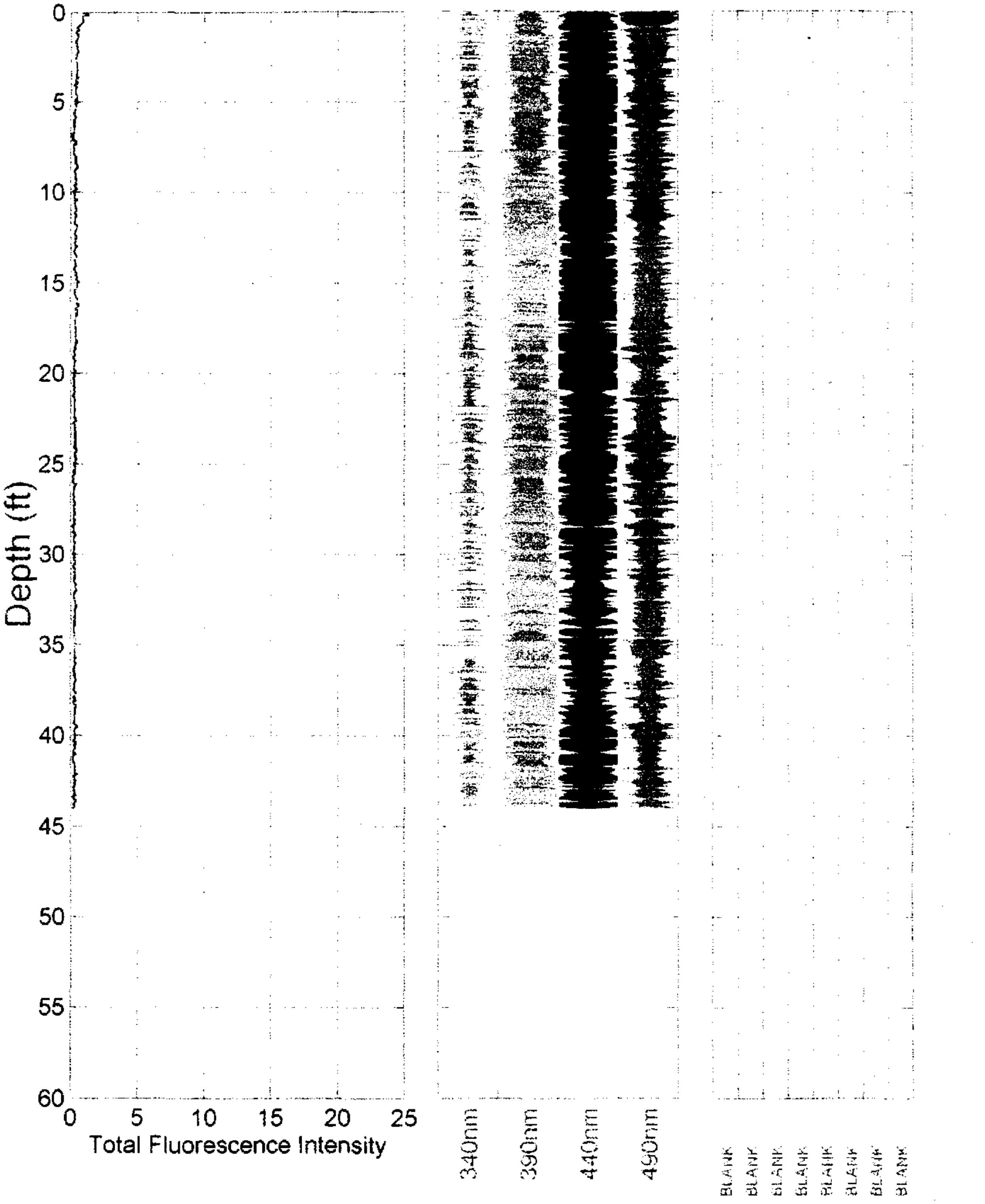


Measured LIF End Depth
44.02 ft
Measured Peak Fluorescence
1.292%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_37

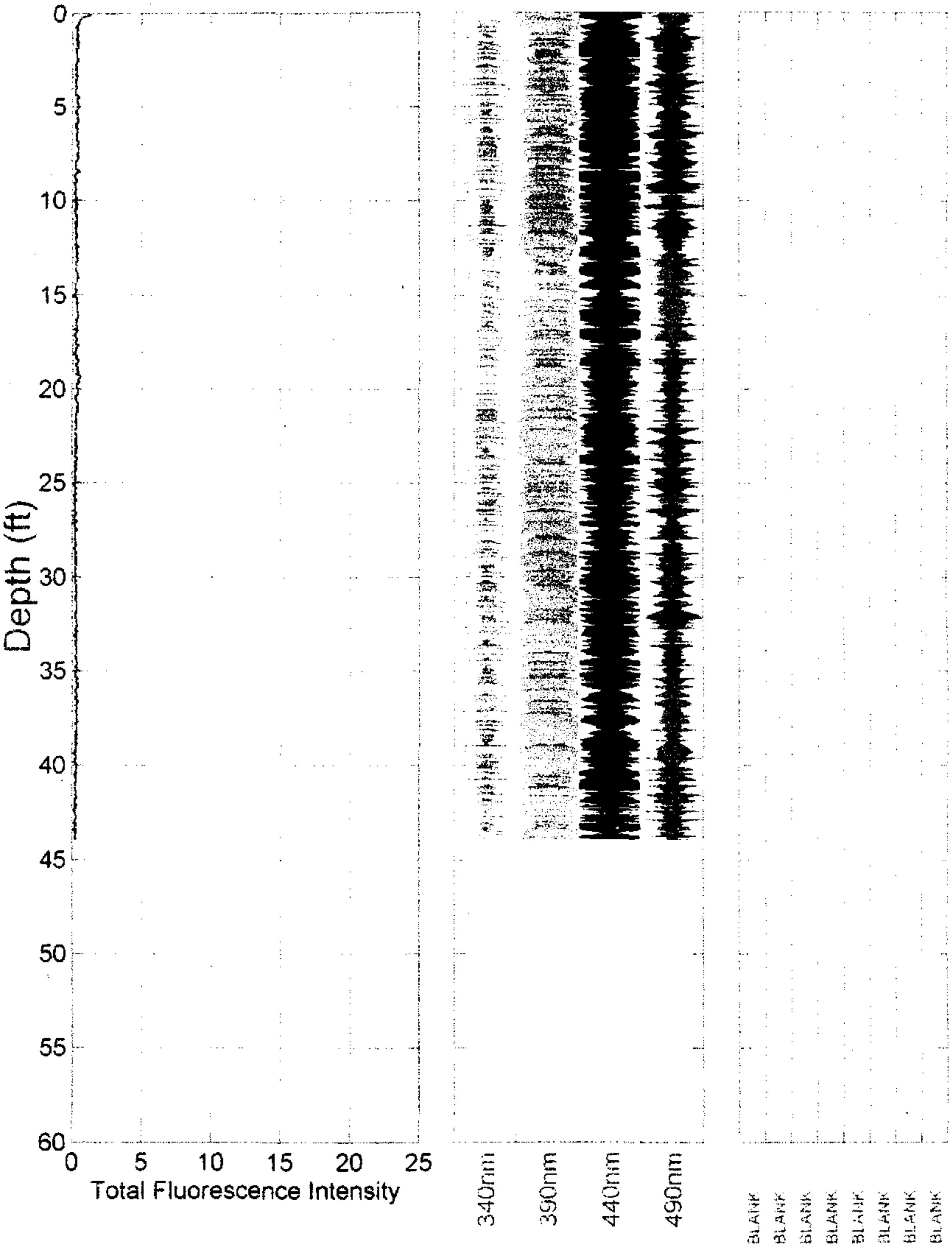


Measured LIF End Depth
43.95 ft
Measured Peak Fluorescence
1.304%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_38

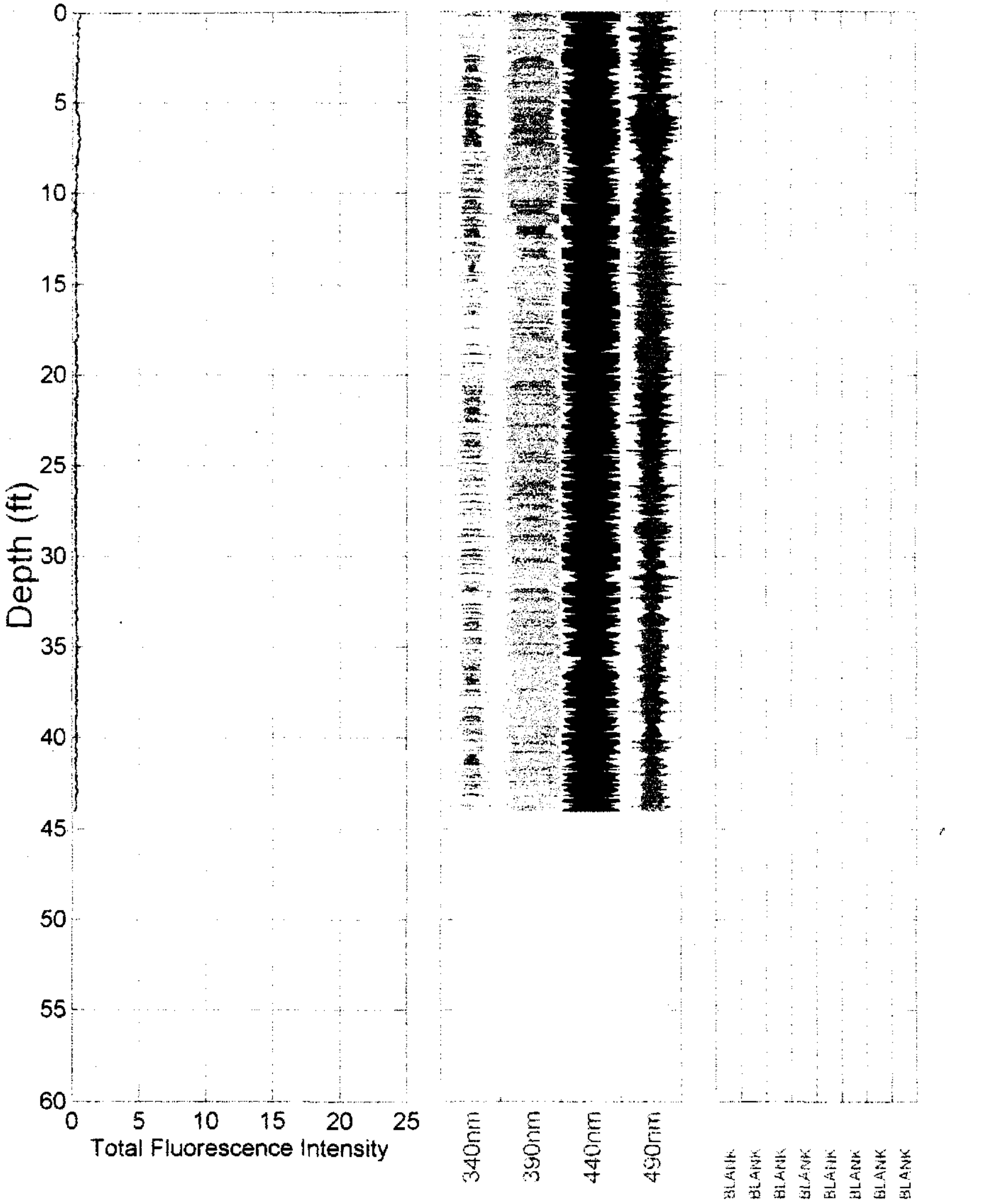


Measured LIF End Depth
44.05 ft
Measured Peak Fluorescence
0.5979%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_39

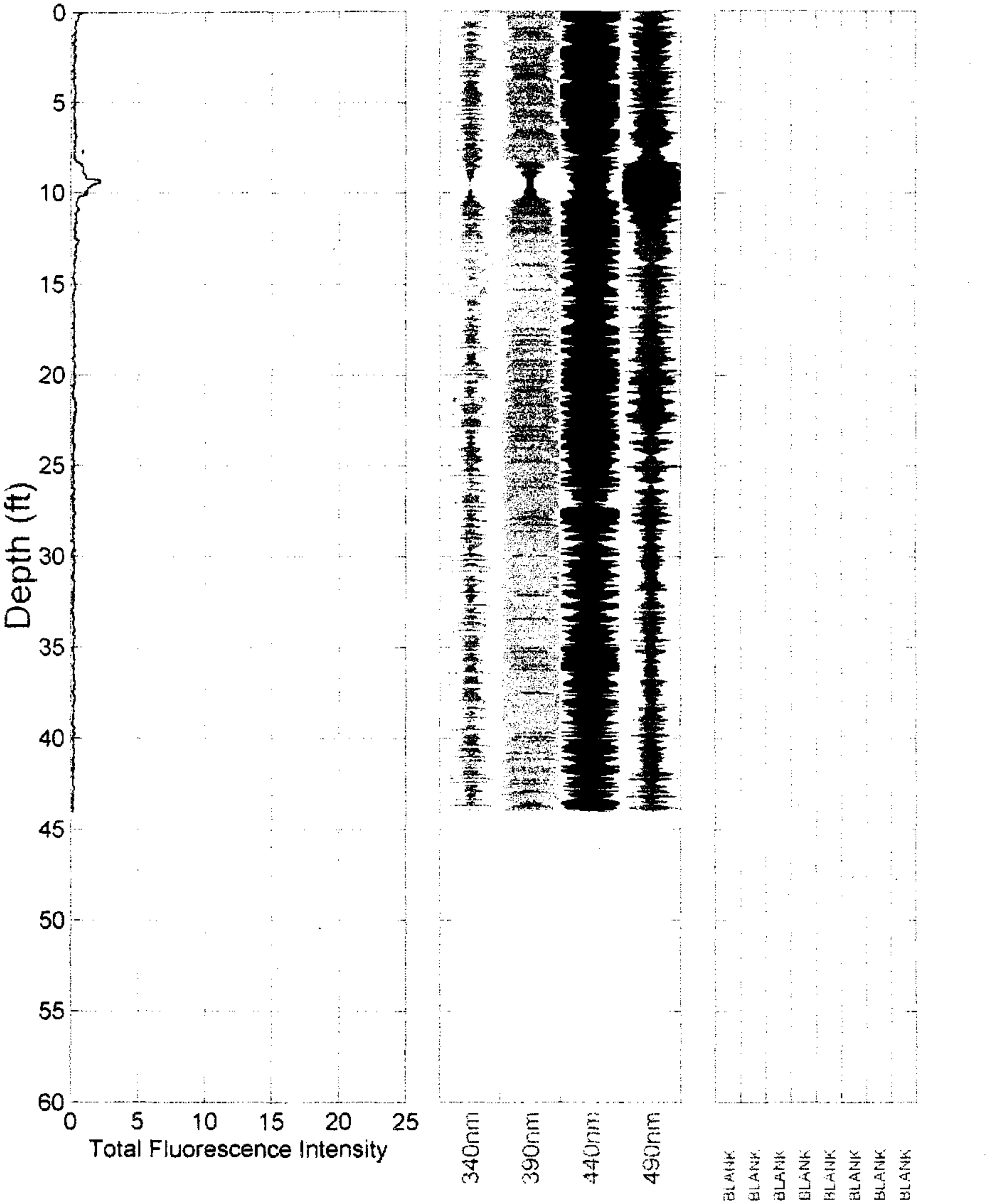


Measured LIF End Depth
44.02 ft
Measured Peak Fluorescence
2.221%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_40

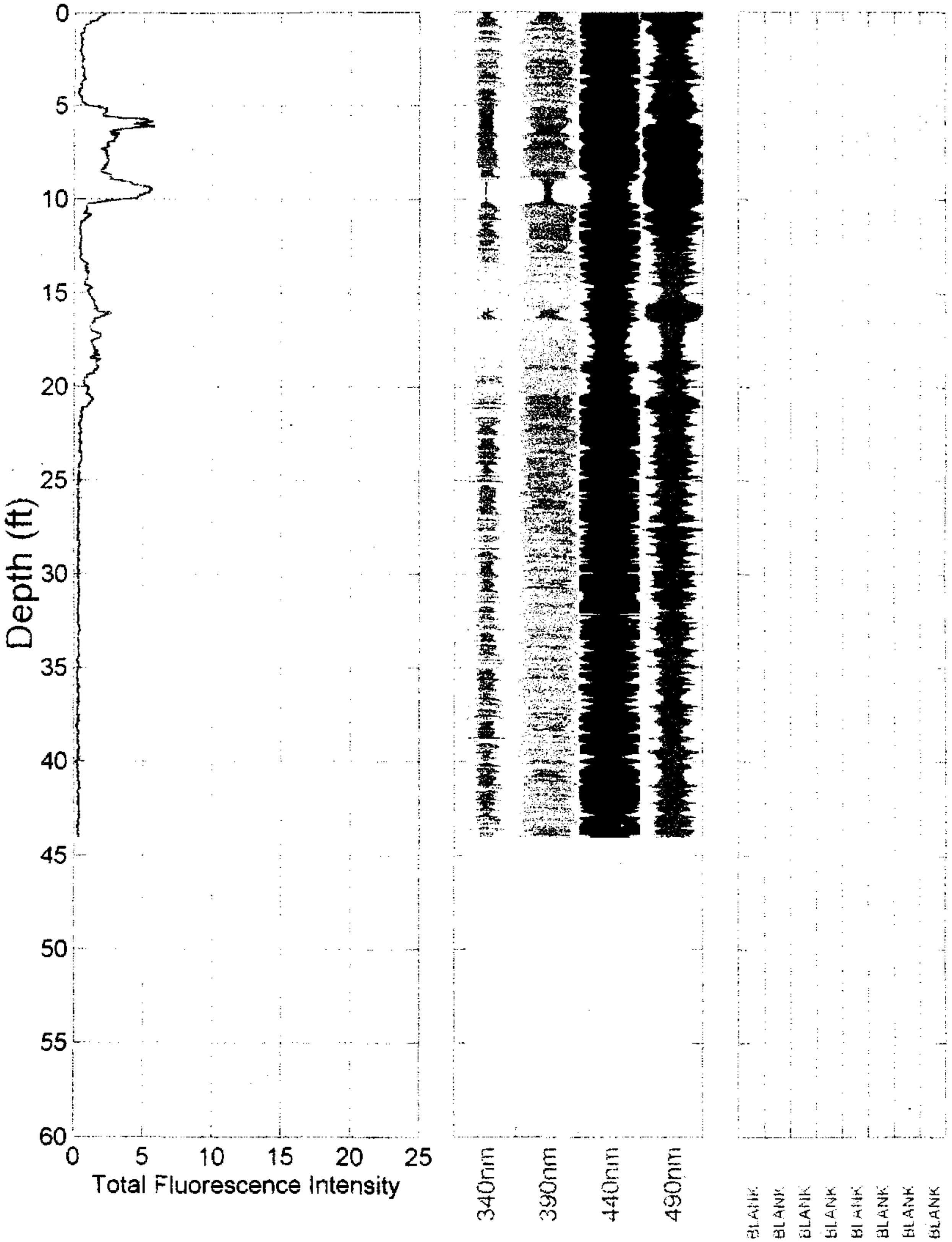


Measured LIF End Depth
44.05 ft
Measured Peak Fluorescence
5.802%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_41

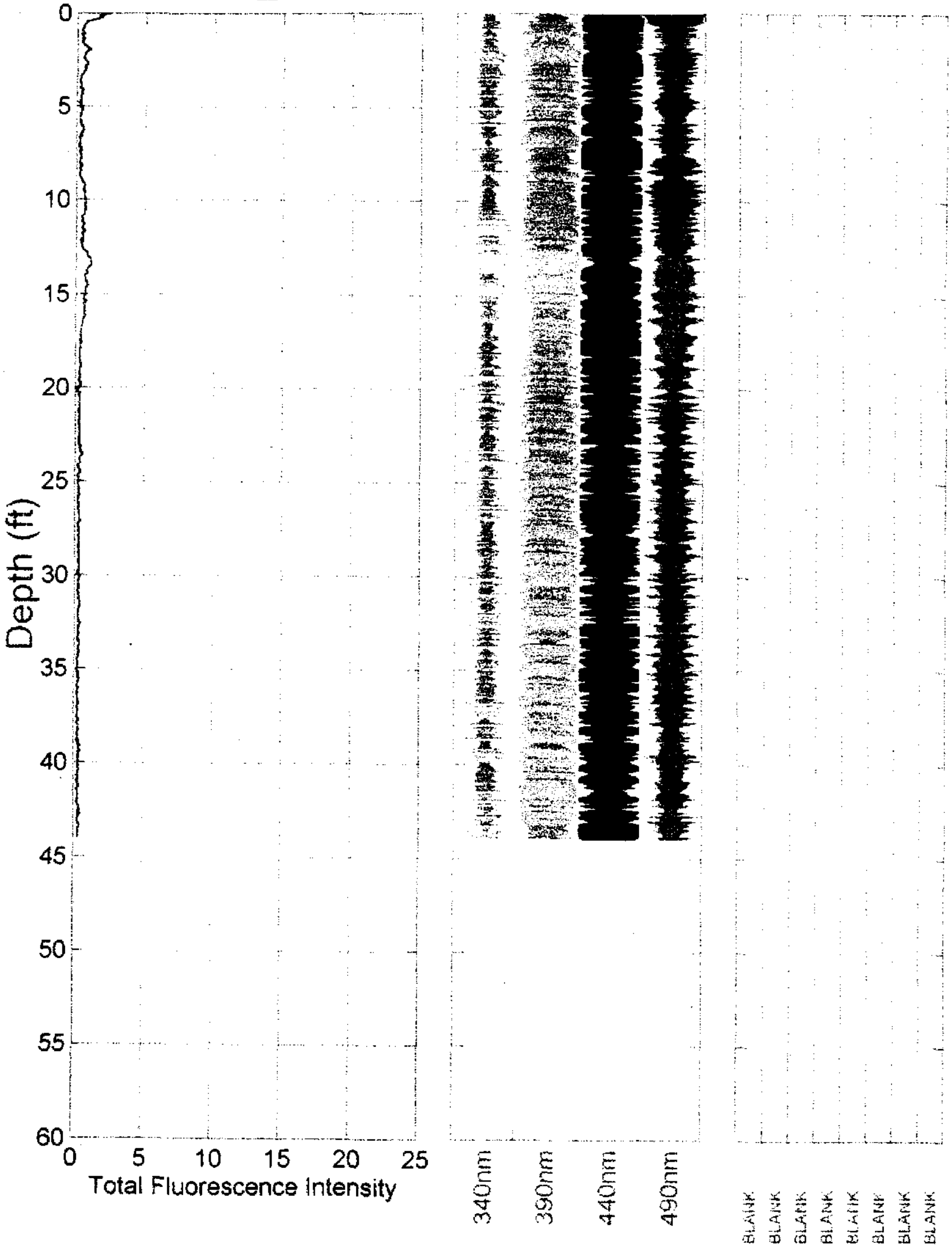


Measured LIF End Depth
43.98 ft
Measured Peak Fluorescence
2.391%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_42

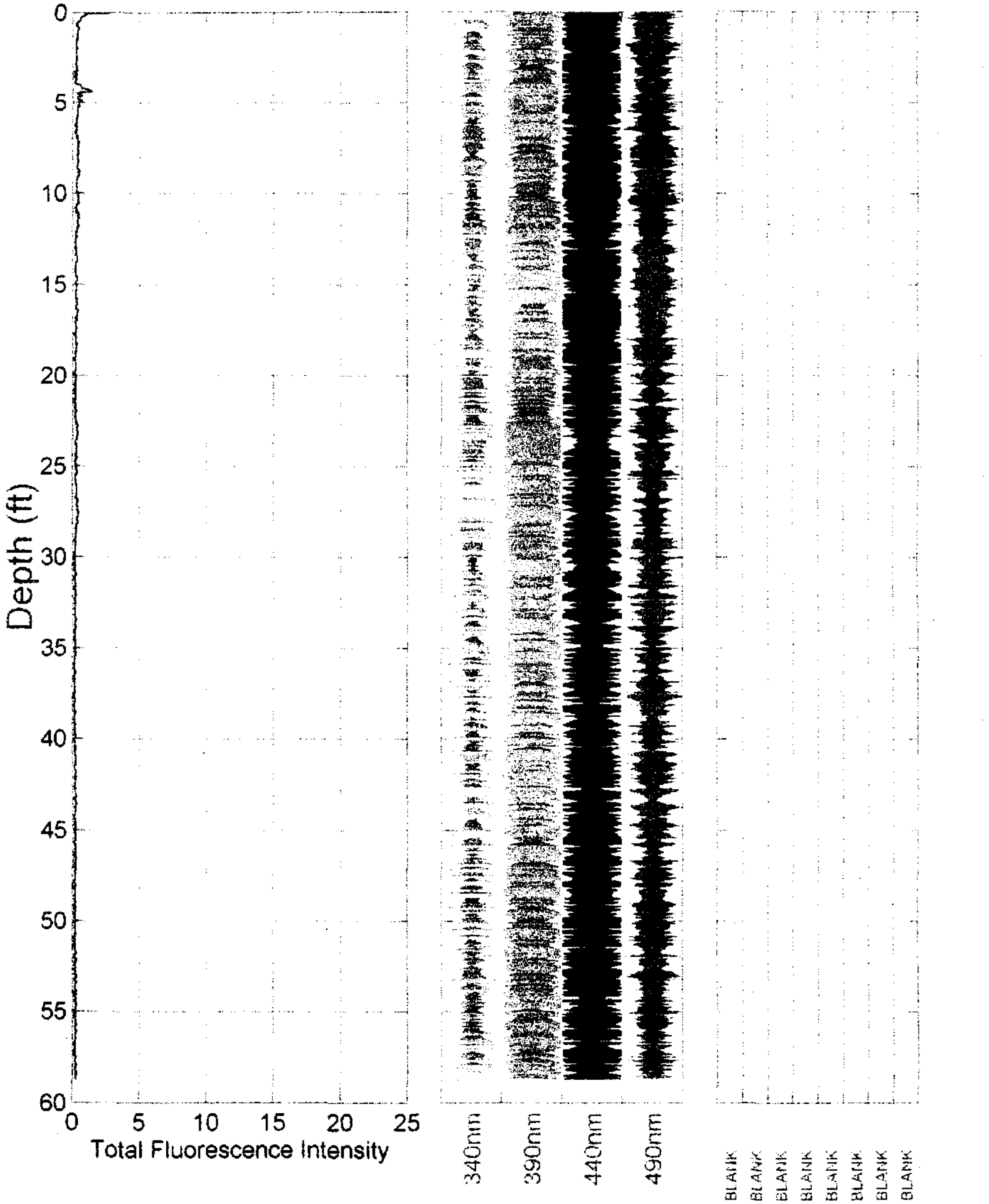


Measured LIF End Depth
58.71 ft
Measured Peak Fluorescence
2.693%

Job#: 0301-7042

Acquisition Date: 03-12-1997

RST_43

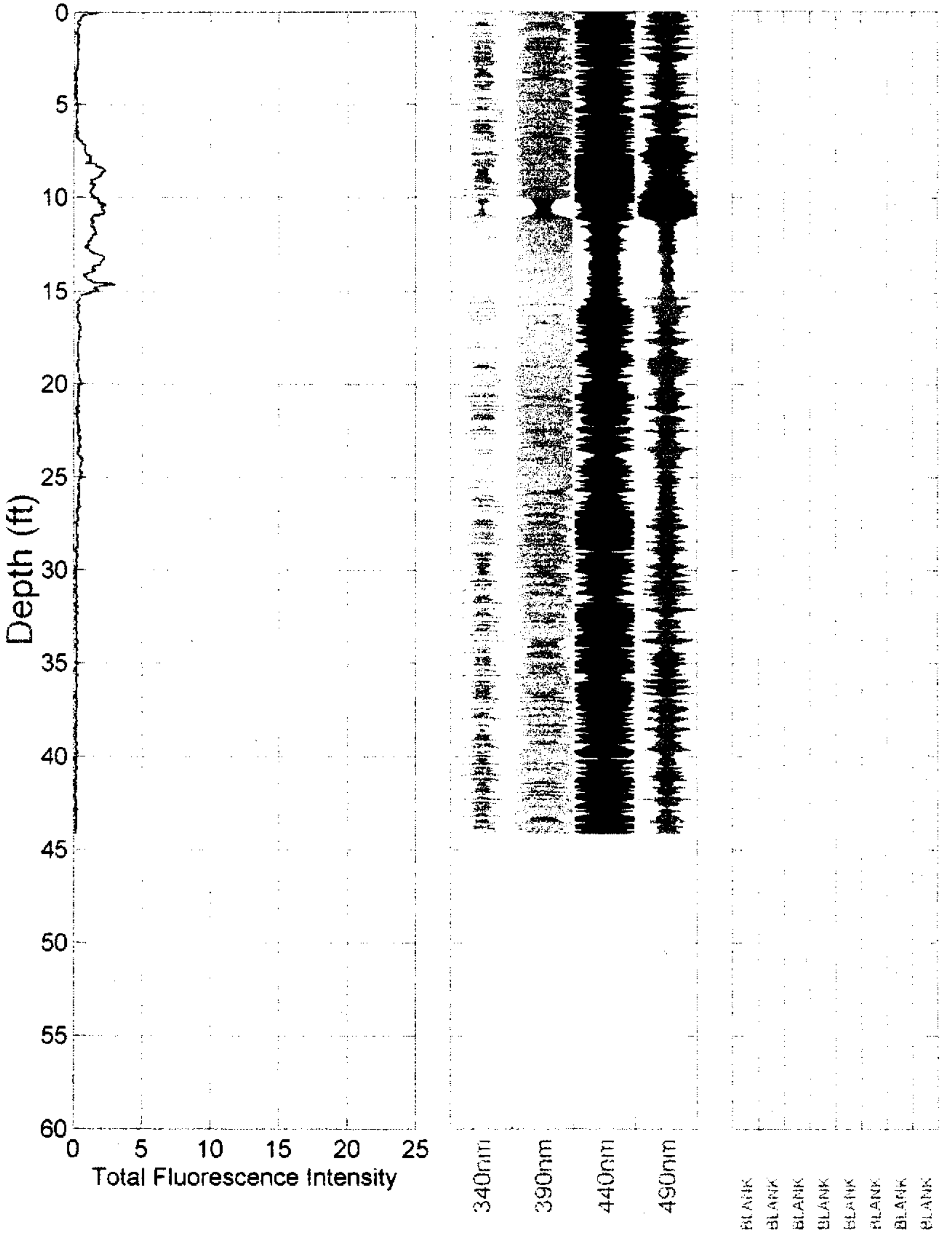


Measured LIF End Depth
44.15 ft
Measured Peak Fluorescence
2.995%

Job#: 0301-7042

Acquisition Date: 03-13-1997

RST_44

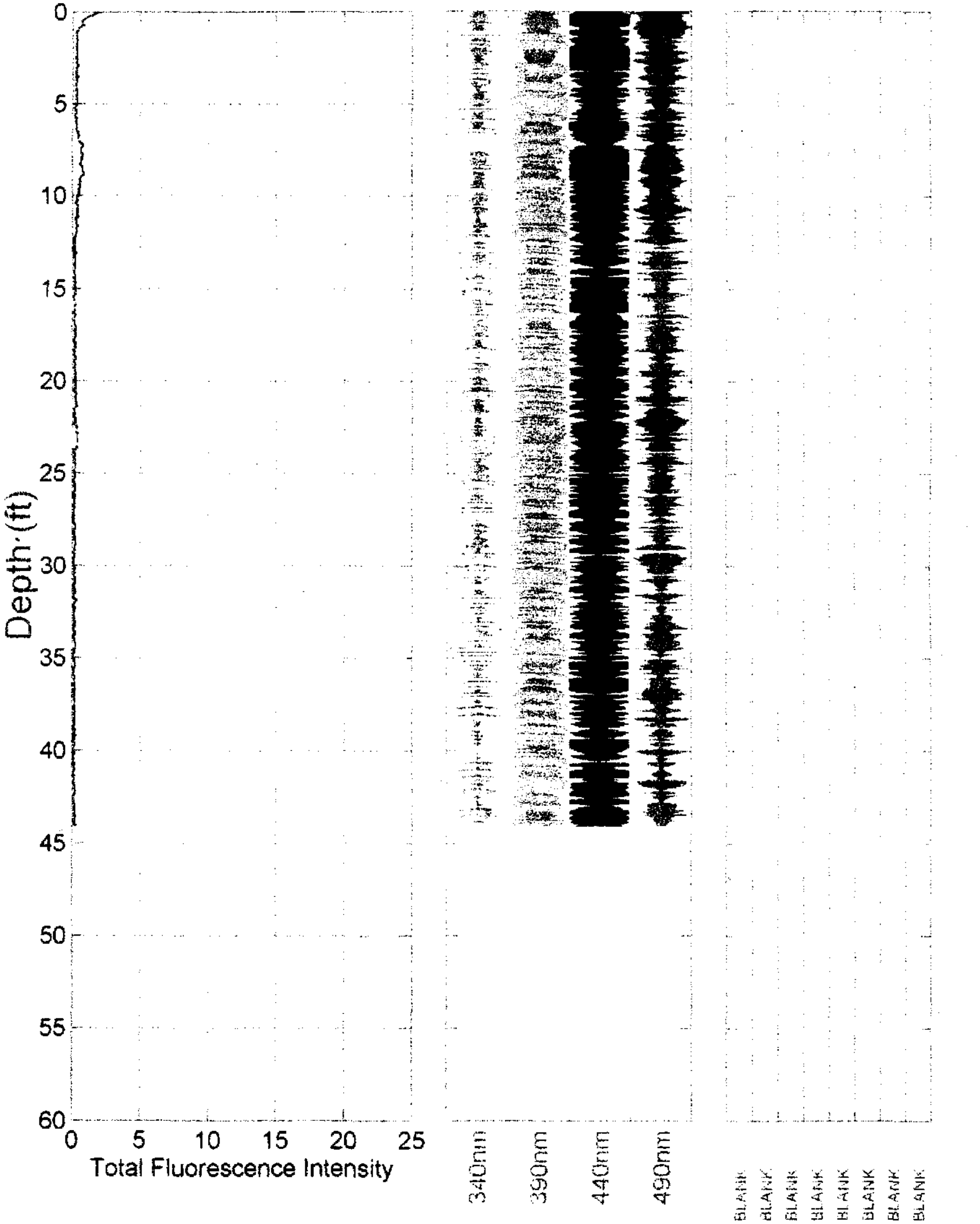


Measured LIF End Depth
44.08 ft
Measured Peak Fluorescence
1.942%

Job#: 0301-7042

Acquisition Date: 03-13-1997

RST_45

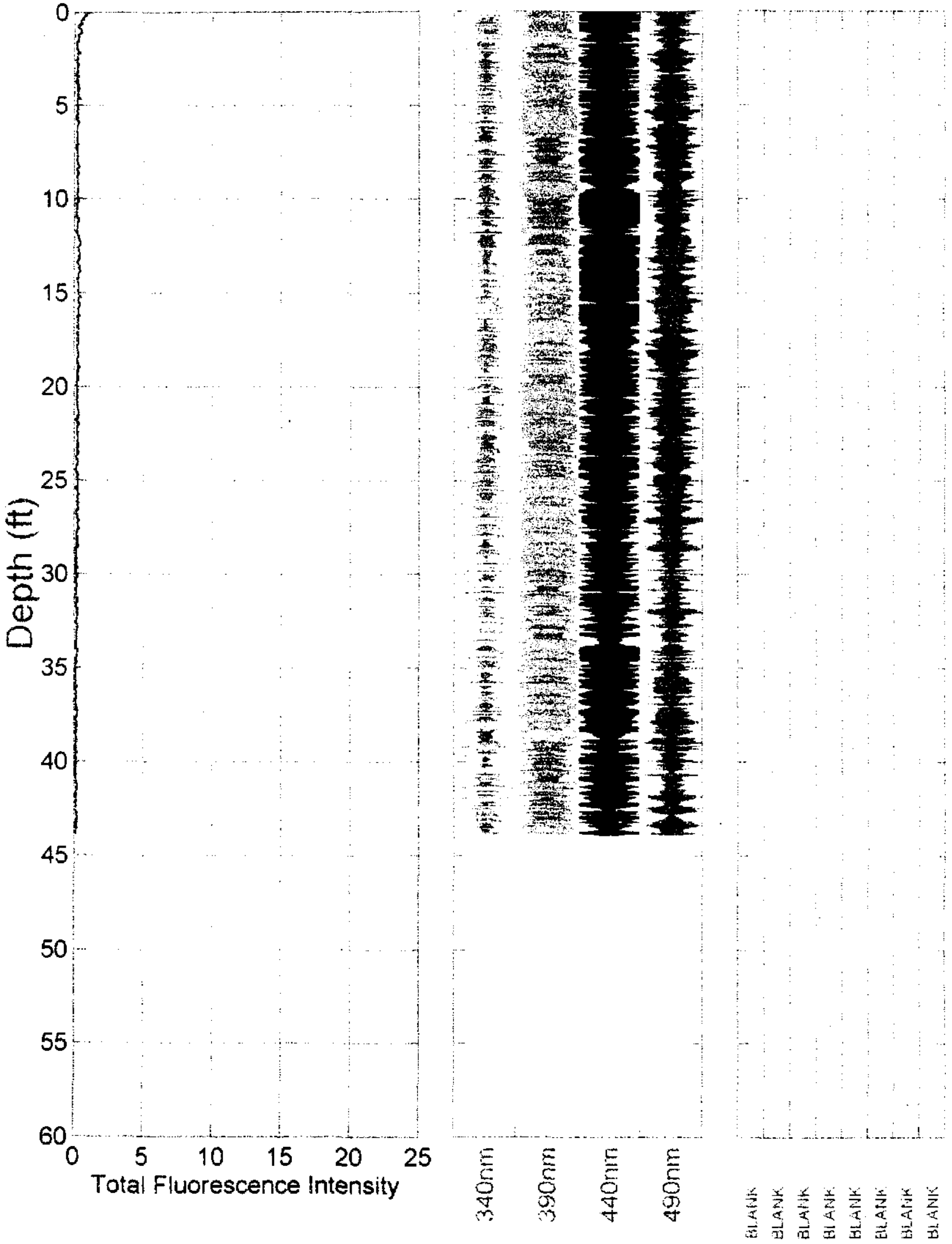


Measured LIF End Depth
43.92 ft
Measured Peak Fluorescence
1.294%

Job#: 0301-7042

Acquisition Date: 03-13-1997

RST_46

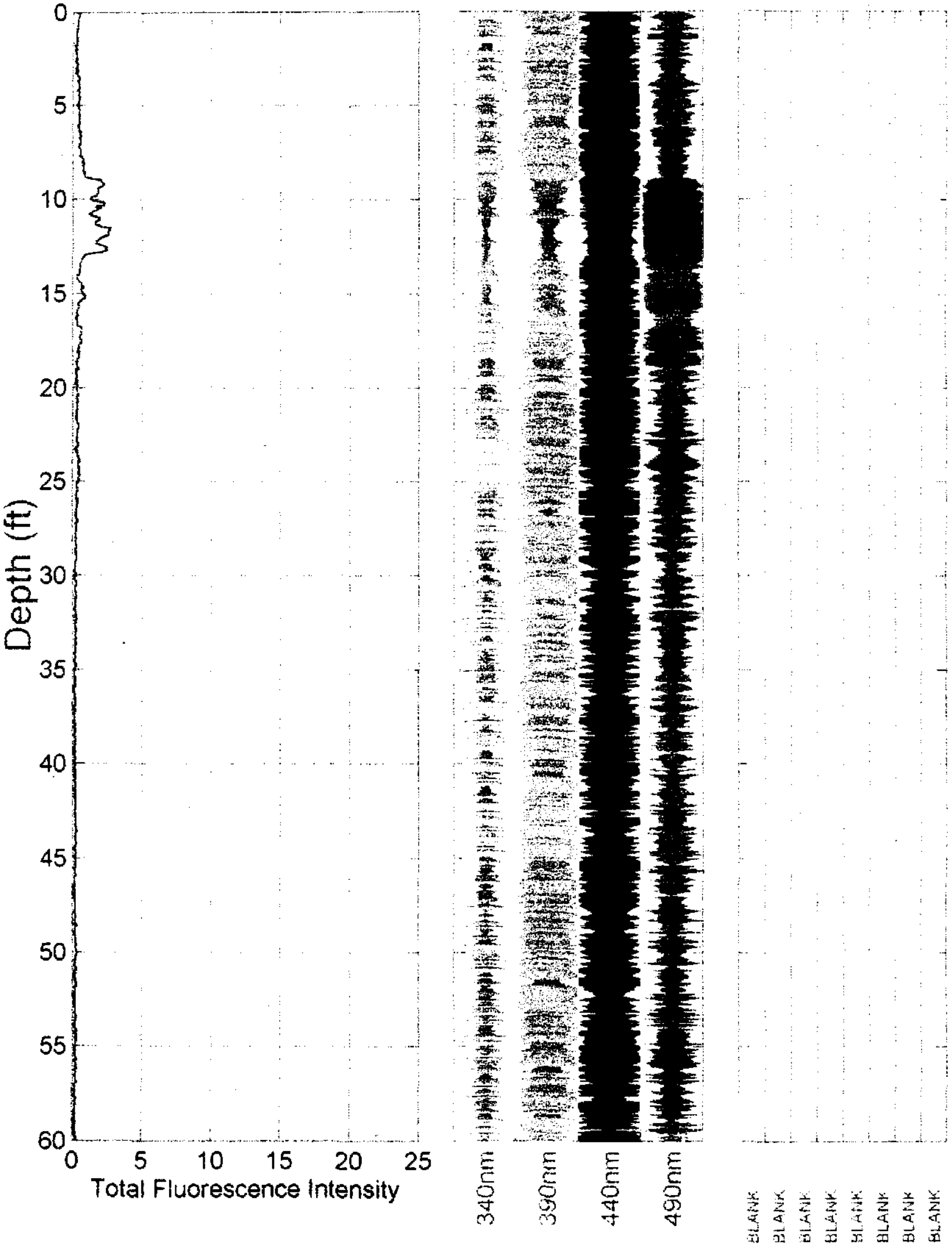


Measured LIF End Depth
65.11 ft
Measured Peak Fluorescence
2.74%

Job#: 0301-7042

Acquisition Date: 03-13-1997

RST_47

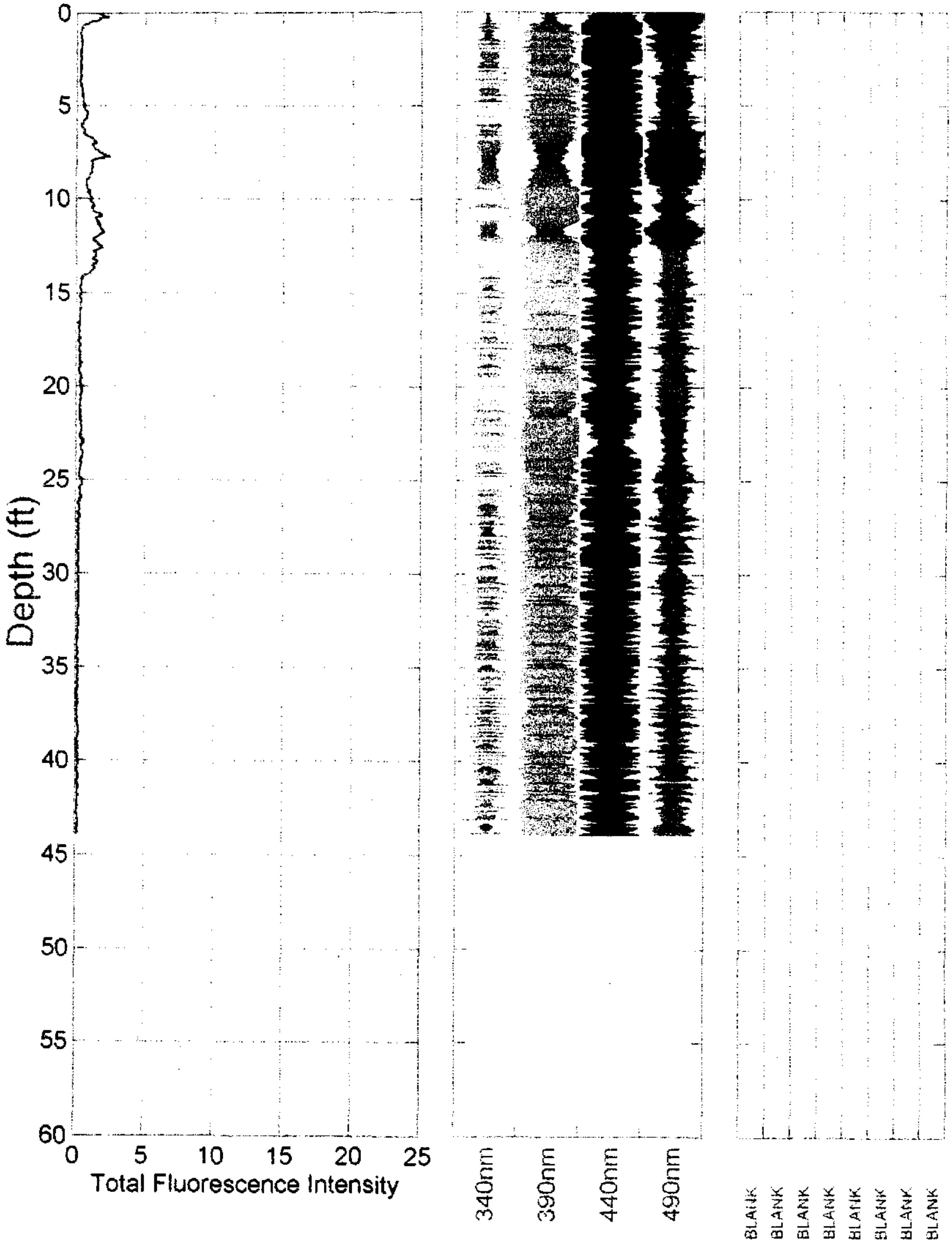


Measured LIF End Depth
43.95 ft
Measured Peak Fluorescence
2.357%

Job#: 0301-7042

Acquisition Date: 03-13-1997

RST_48

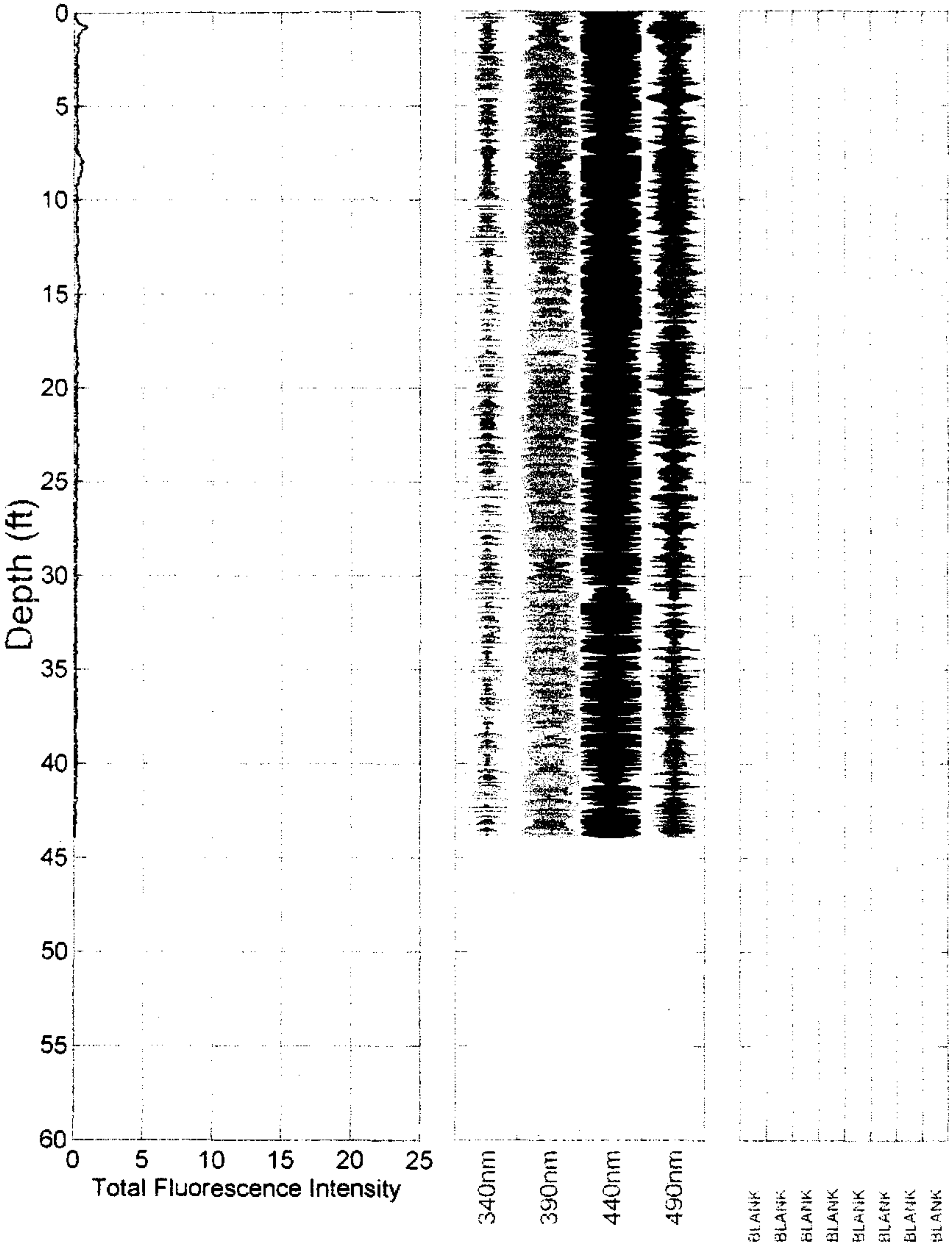


Measured LIF End Depth
43.95 ft
Measured Peak Fluorescence
0.9173%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_49

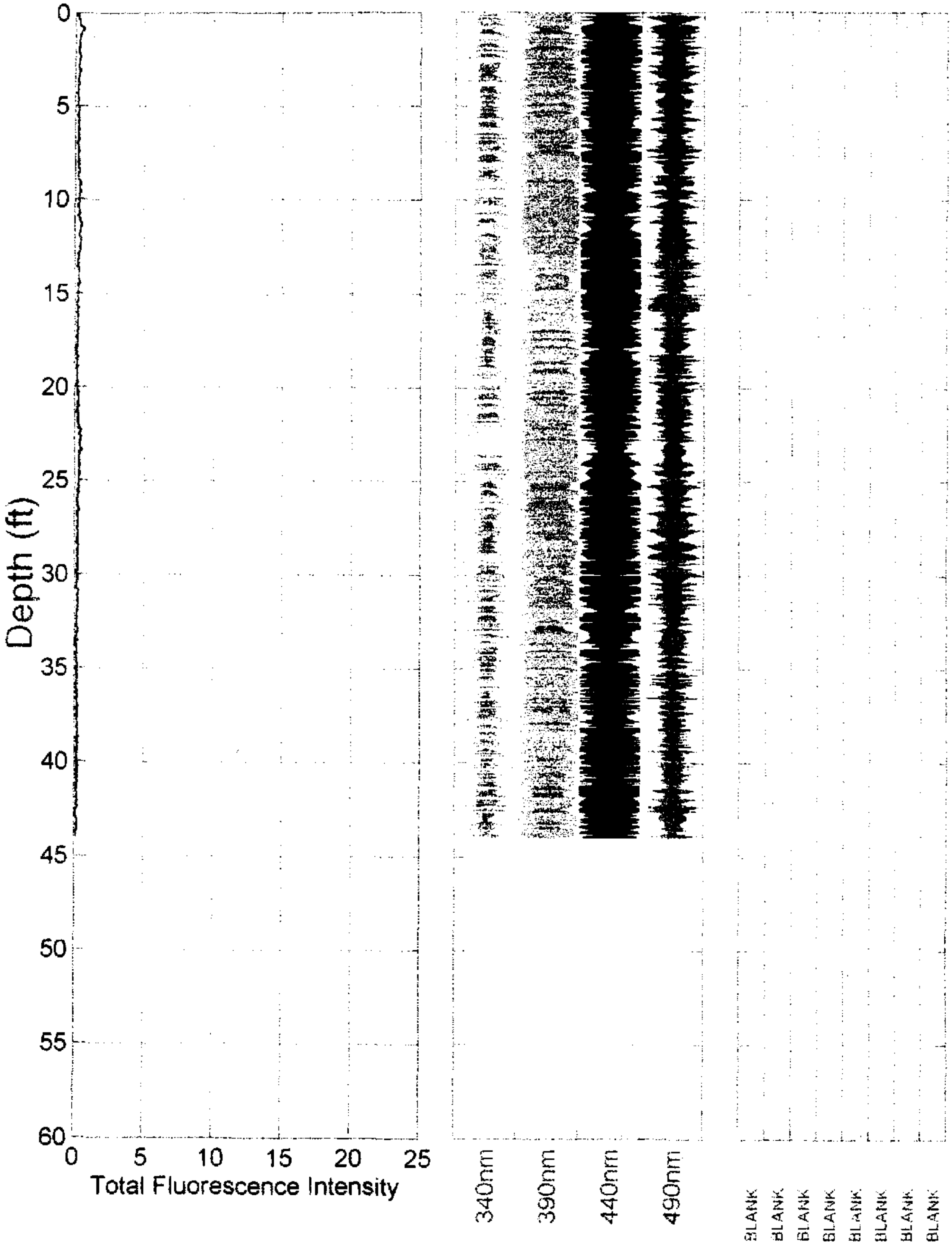


Measured LIF End Depth
43.98 ft
Measured Peak Fluorescence
0.6121%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_50

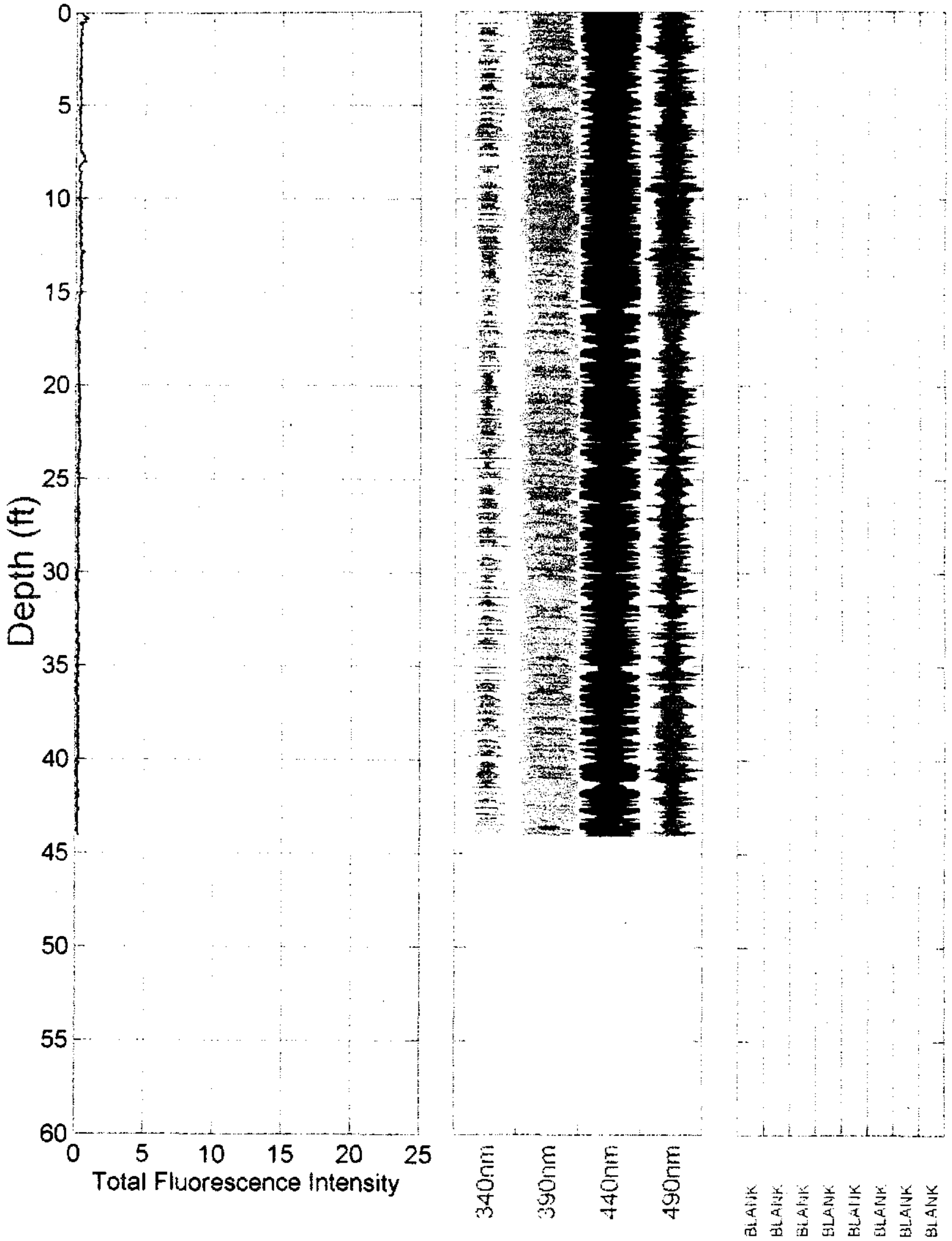


Measured LIF End Depth
44.08 ft
Measured Peak Fluorescence
0.8179%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_51

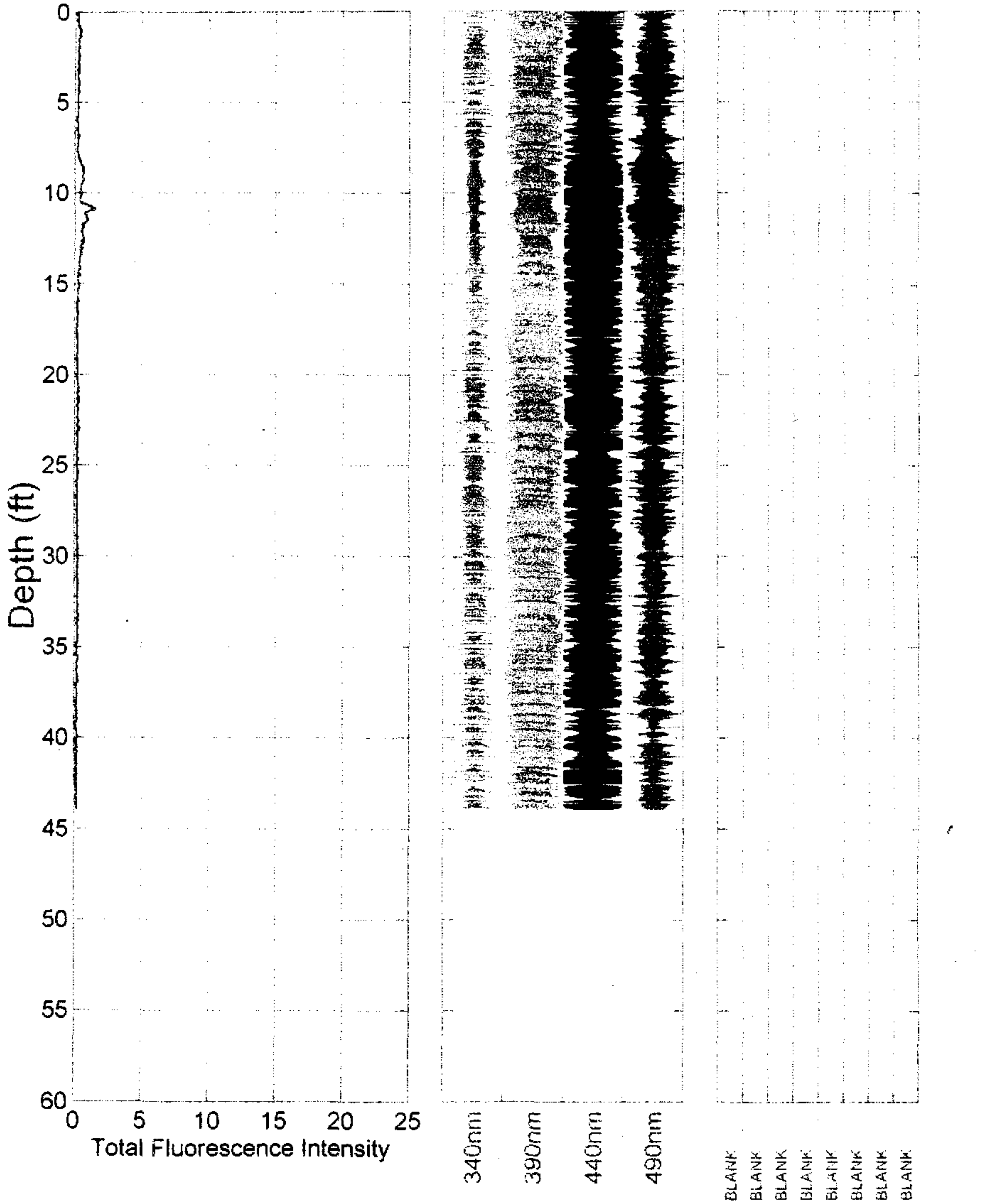


Measured LIF End Depth
43.95 ft
Measured Peak Fluorescence
1.555%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_52

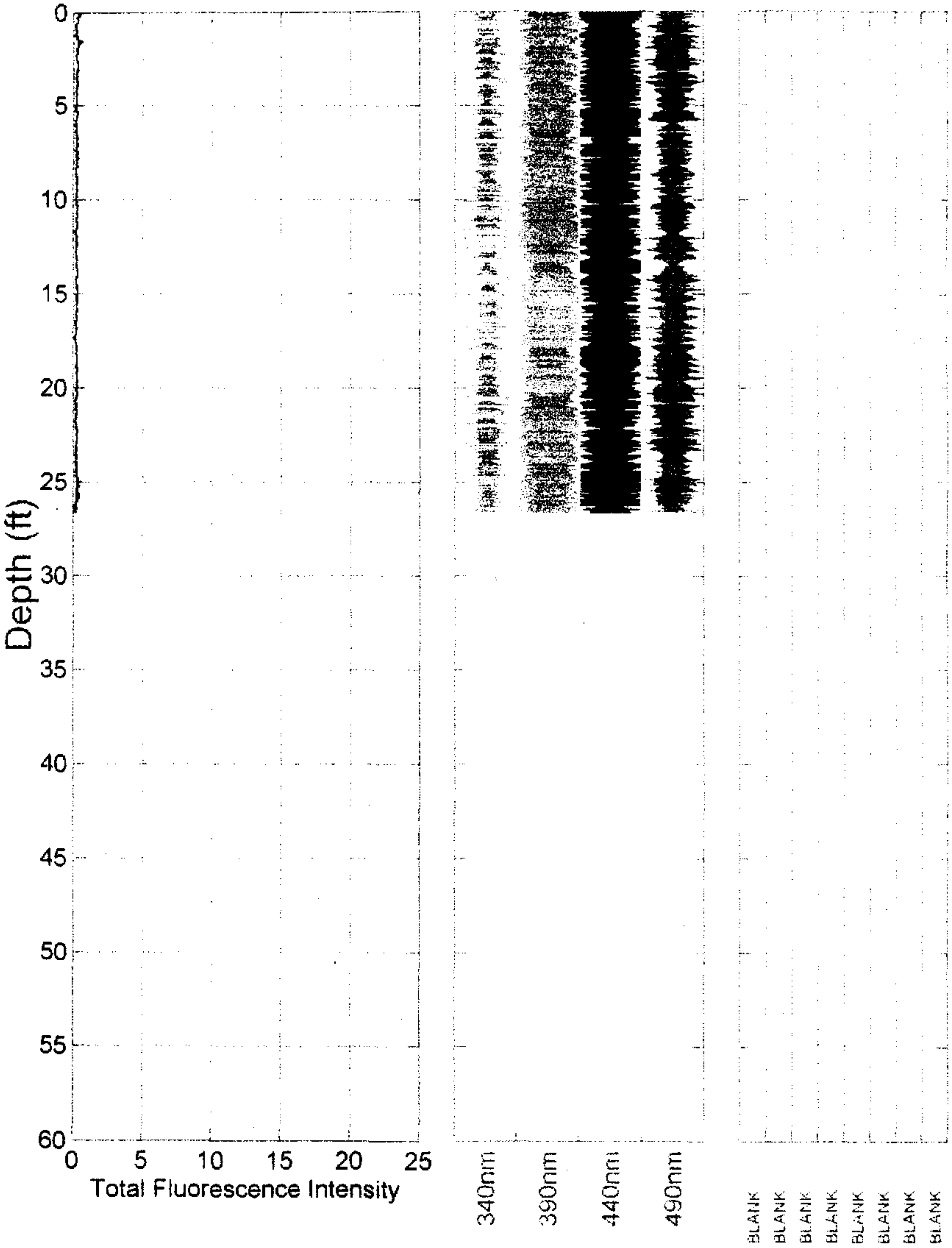


Measured LIF End Depth
26.63 ft
Measured Peak Fluorescence
0.6791%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_53

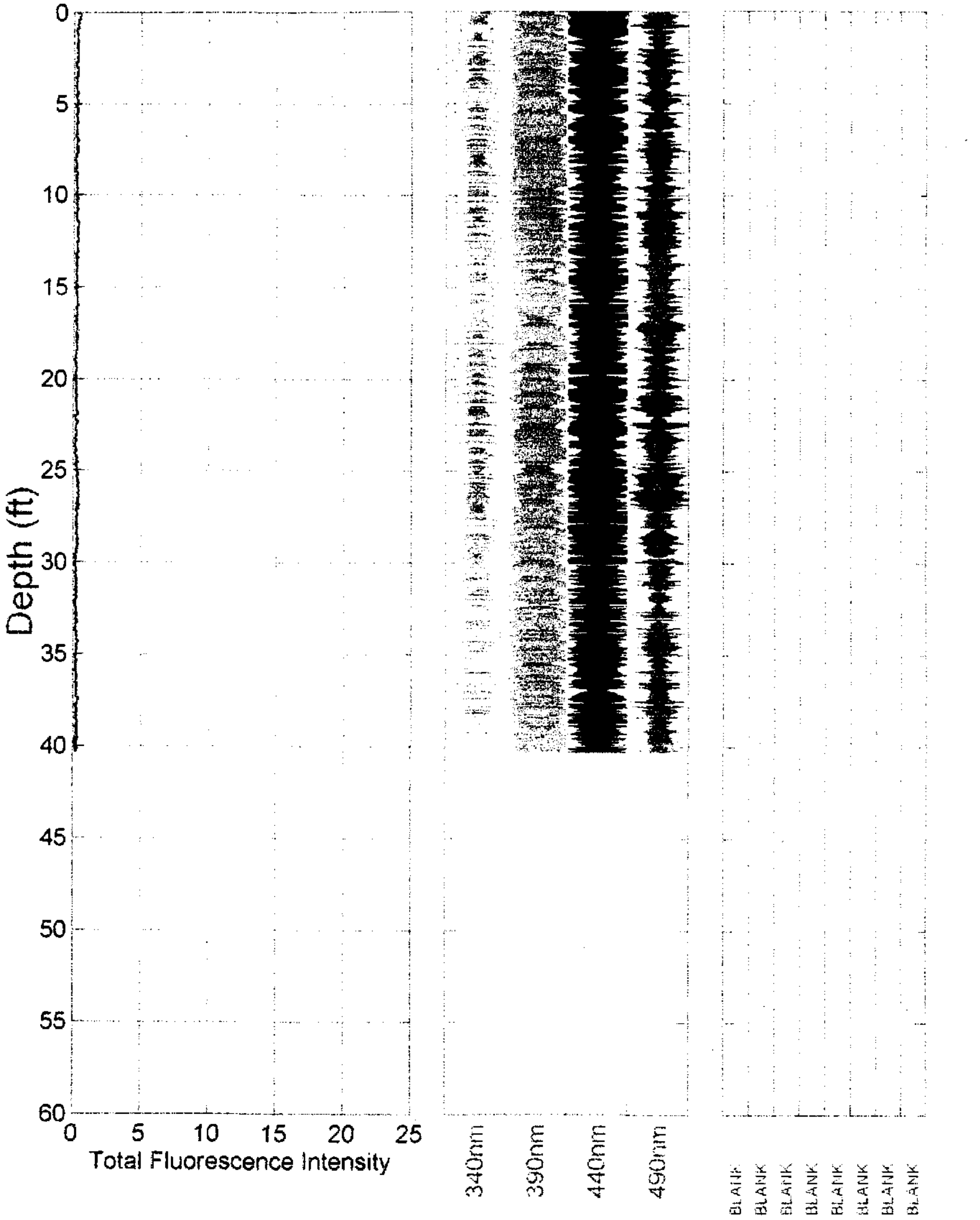


Measured LIF End Depth
40.31 ft
Measured Peak Fluorescence
0.5406%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_54

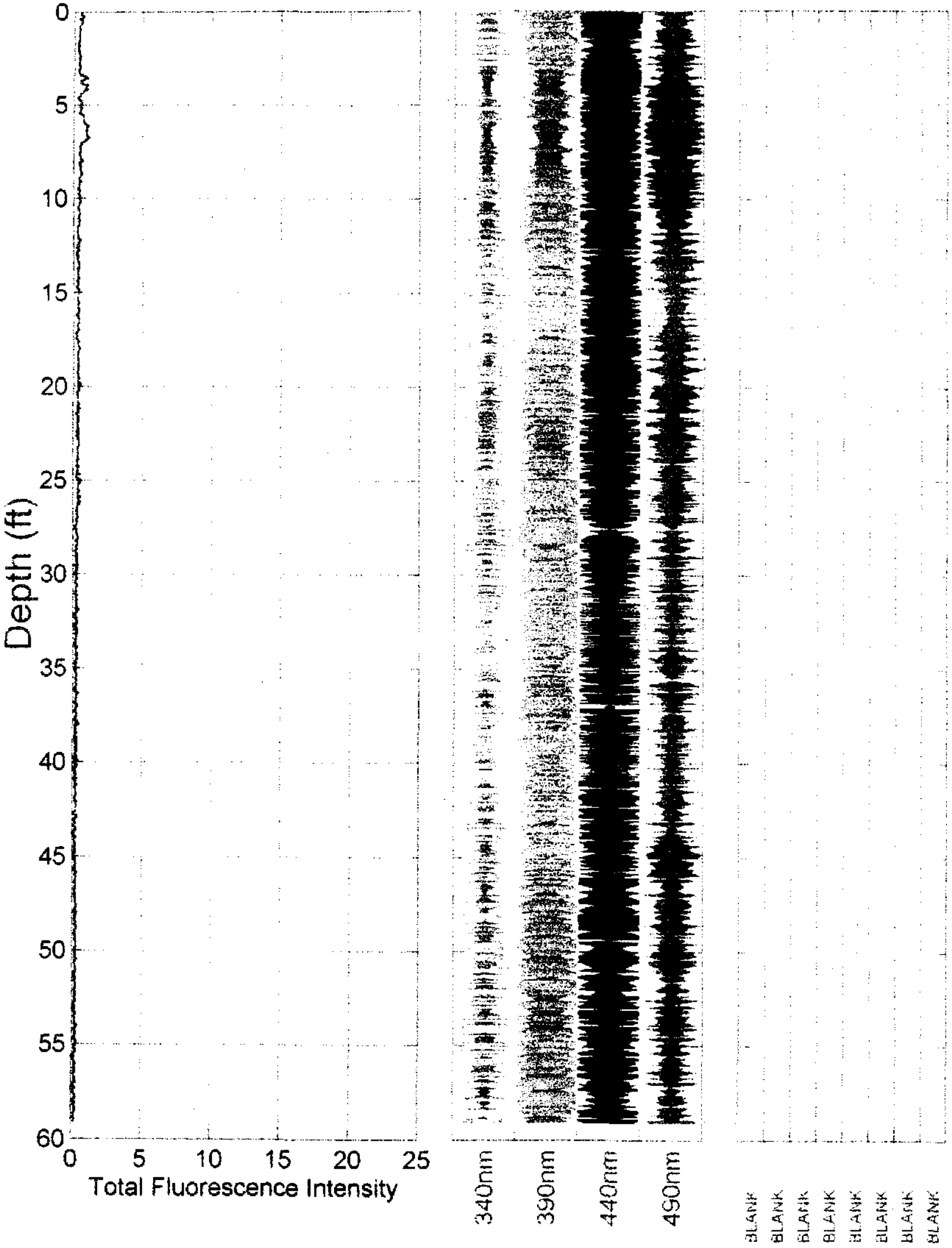


Measured LIF End Depth
59.08 ft
Measured Peak Fluorescence
1.117%

Job#: 0301-7042

Acquisition Date: 03-14-1997

RST_55

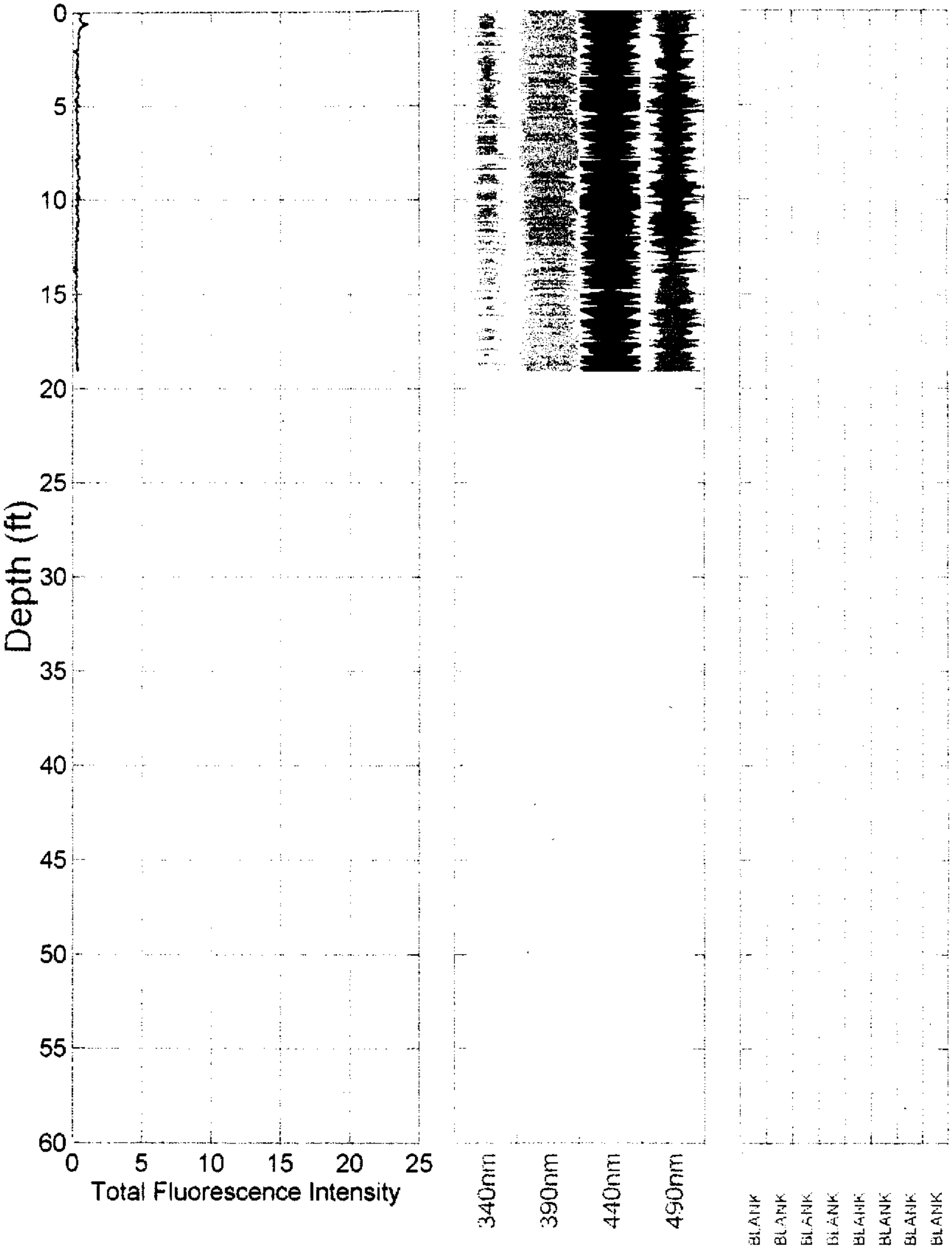


Measured LIF End Depth
19.08 ft
Measured Peak Fluorescence
1.068%

Job#: 0301-7042

Acquisition Date: 03-14-1997

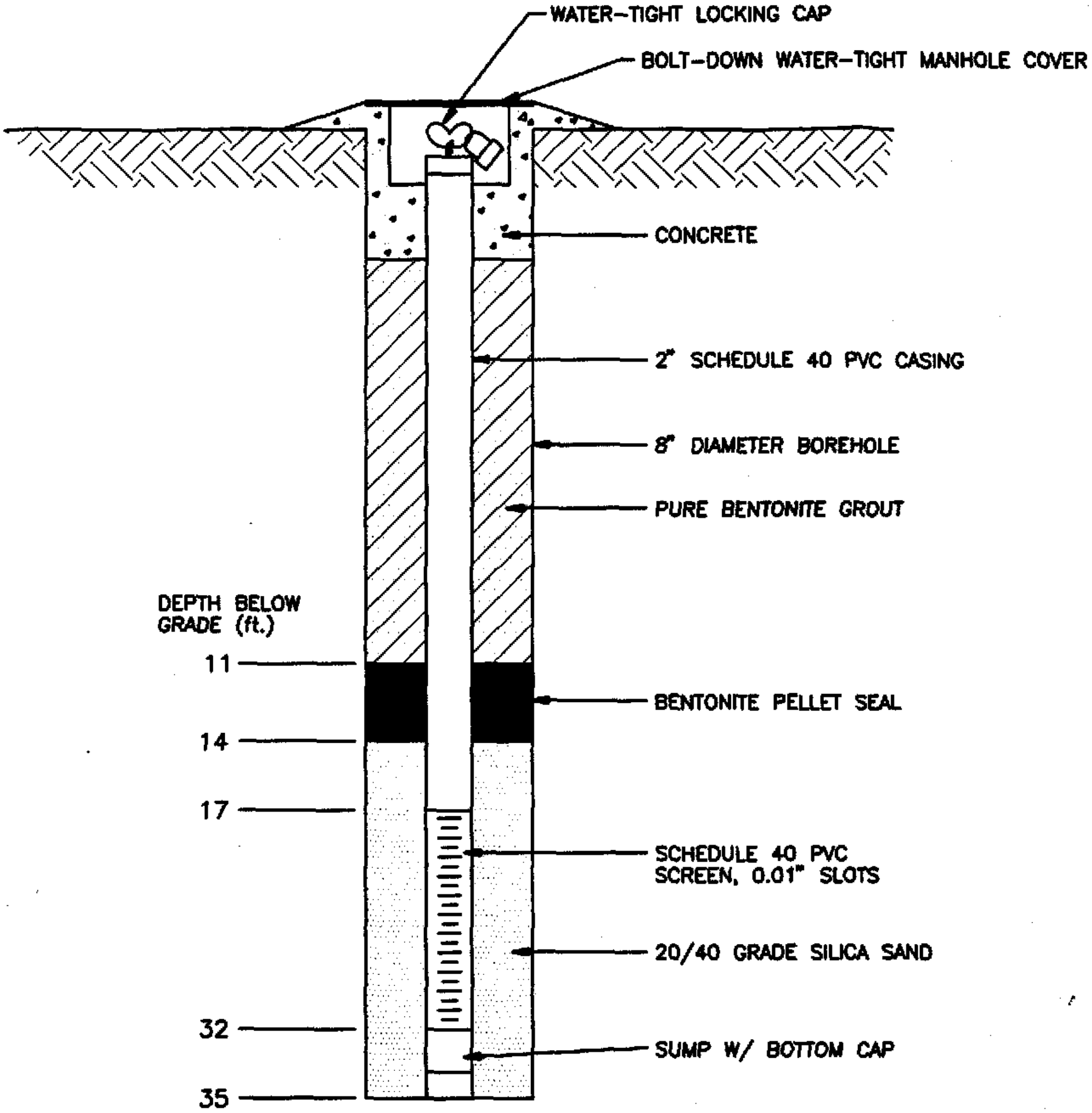
RST_56



Appendix G

Well Construction Diagrams

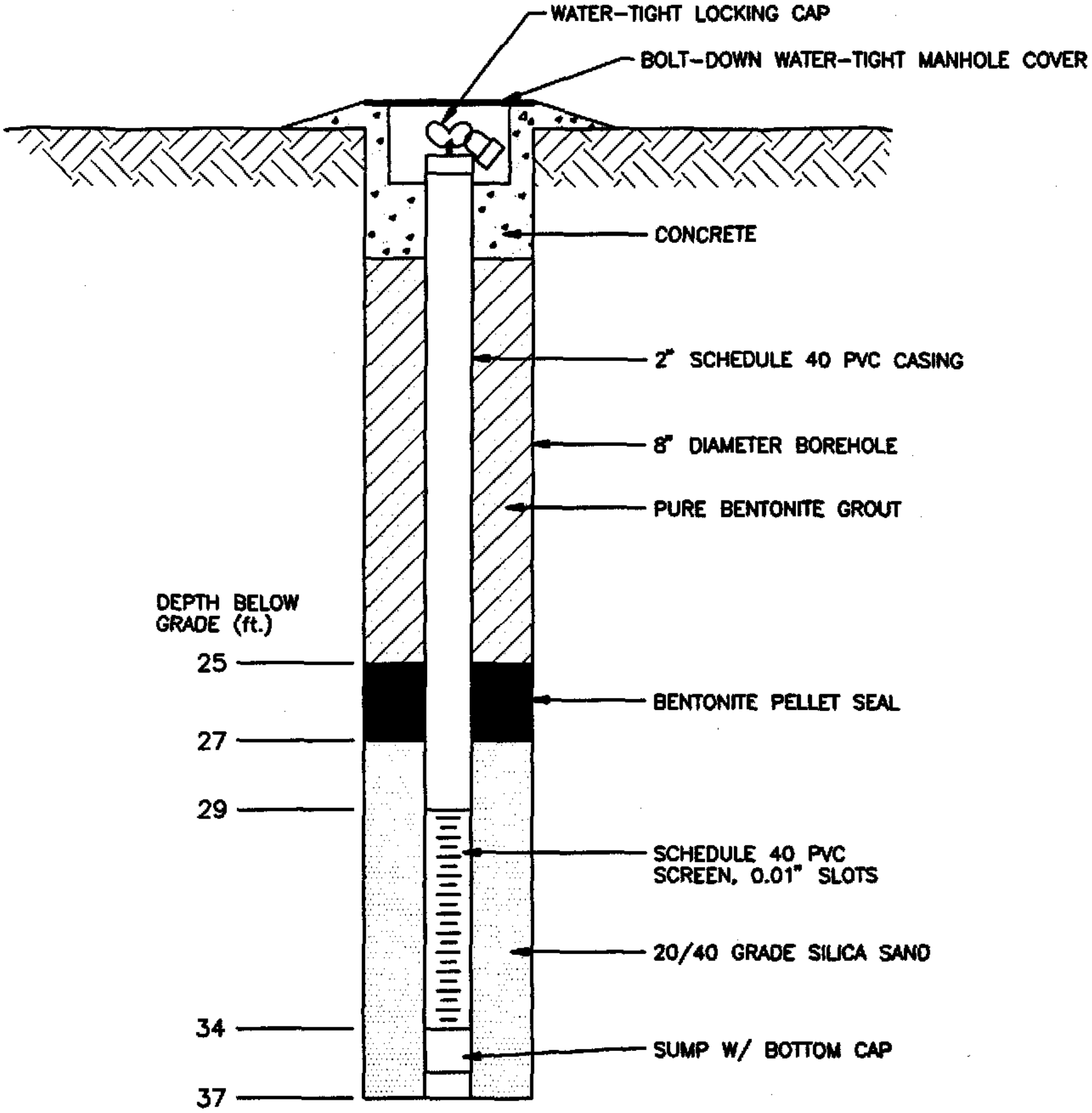
Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi



MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

SCALE: NTS
DWG. NO.: 21-02/32A

MW-01 WELL CONSTRUCTION DIAGRAM
FORMER GULF STATES CREOSOTING SITE
HATTIESBURG, MISSISSIPPI

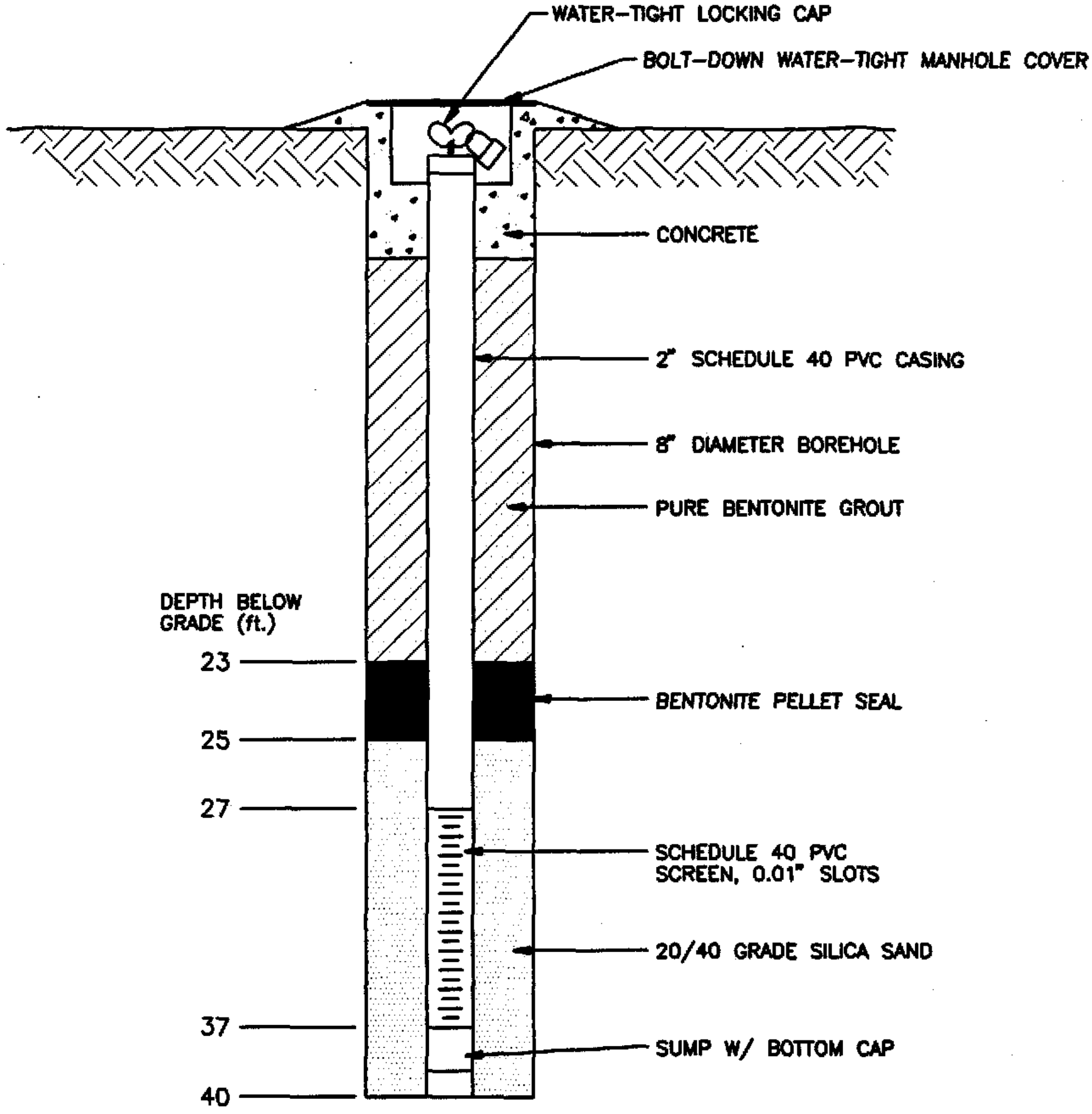


MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

SCALE: NTS

DWG. NO.: 21-02/33A

MW-03 WELL CONSTRUCTION DIAGRAM
FORMER GULF STATES CREOSOTING SITE
HATTIESBURG, MISSISSIPPI

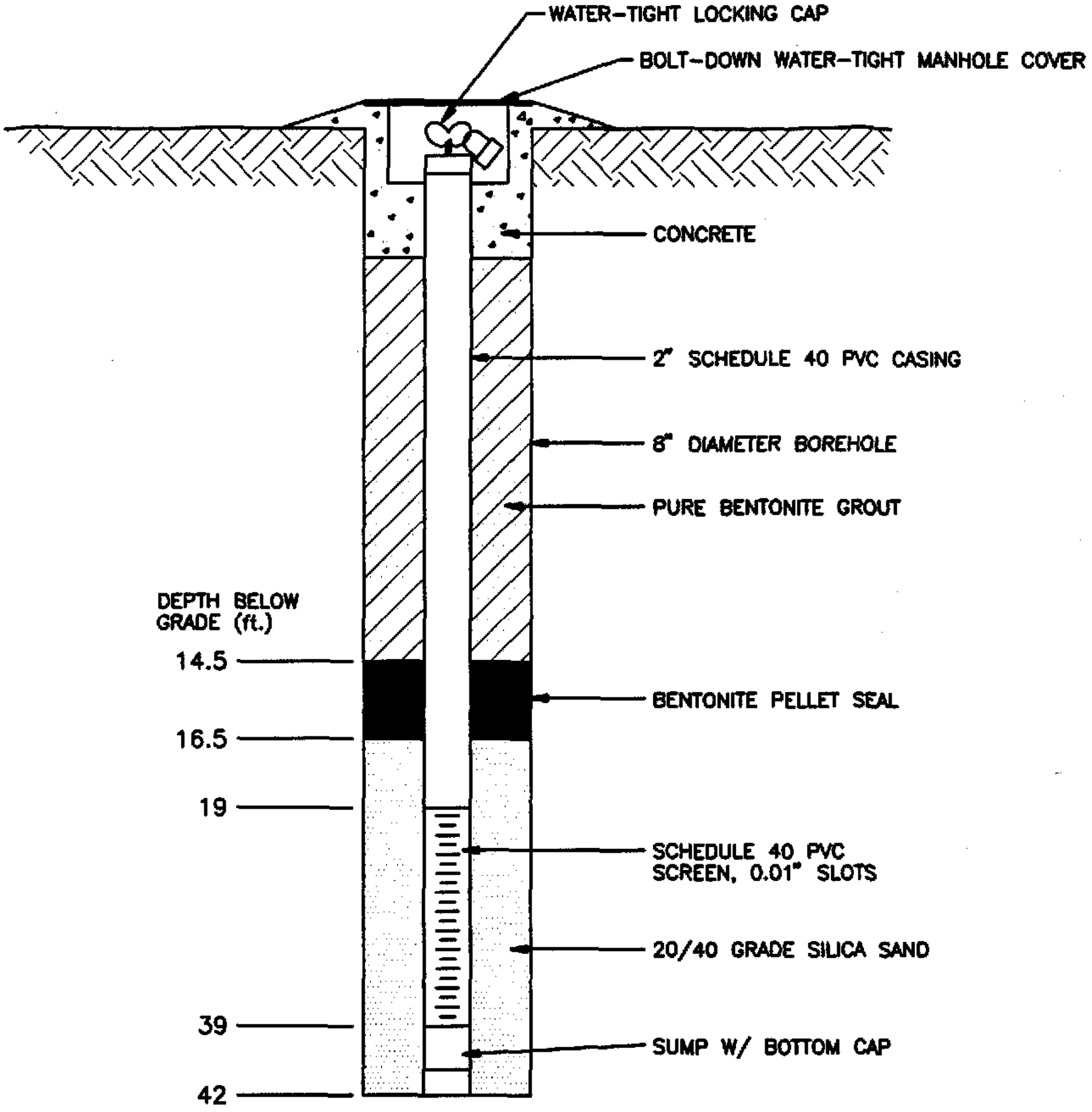


MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

SCALE: NTS

DWG. NO.: 21-02/34A

MW-04 WELL CONSTRUCTION DIAGRAM
FORMER GULF STATES CREOSOTING SITE
HATTIESBURG, MISSISSIPPI



MICHAEL PISANI & ASSOCIATES
Environmental Management and Engineering Services
New Orleans, Louisiana Houston, Texas

SCALE: NTS	DWG. NO.: 21-02/35A

MW-05 WELL CONSTRUCTION DIAGRAM
FORMER GULF STATES CREOSOTING SITE
HATTIESBURG, MISSISSIPPI

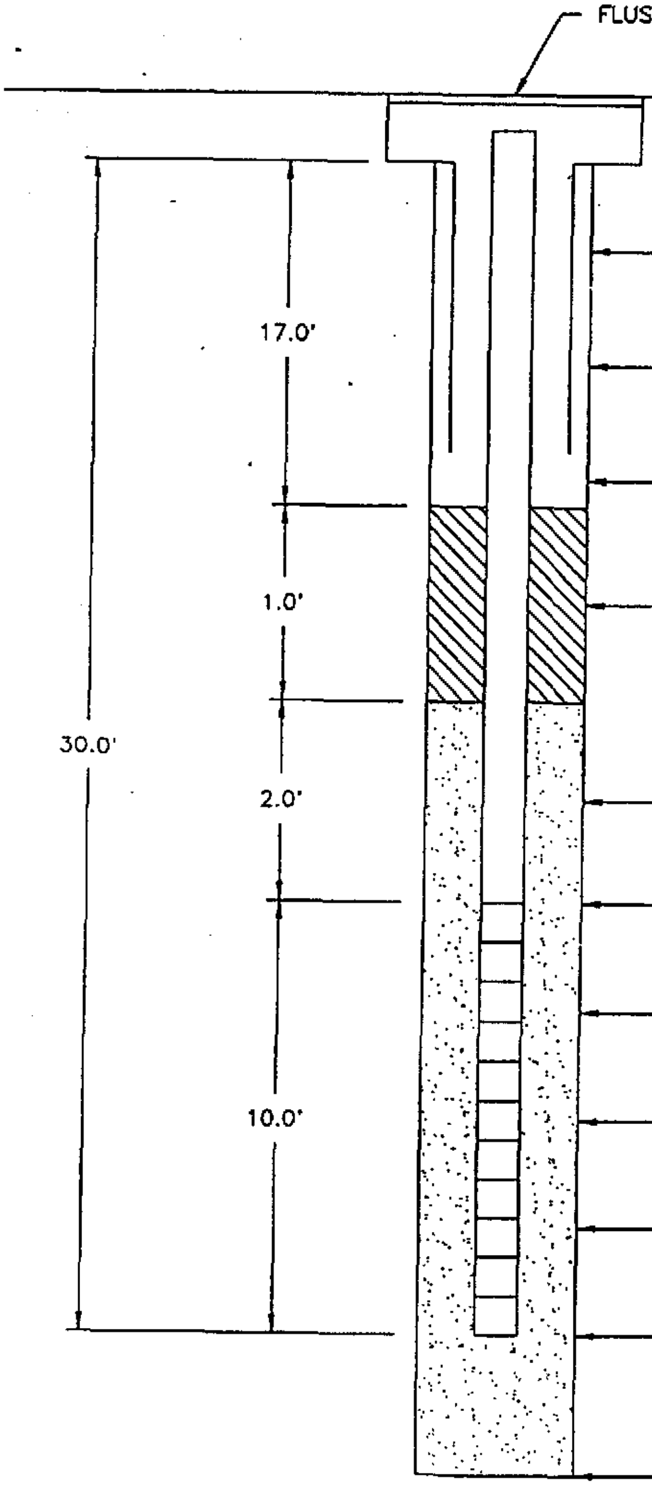
Environmental
Protection
Systems

5360 I-55 NORTH
JACKSON, MISSISSIPPI
39211

GROUNDWATER MONITORING WELL REPORT

PROJECT: GULF STATES CREOSOTE – PHASE II
LOCATION: HATTIESBURG, MISSISSIPPI
CLIENT: J.B. VAN SLYKE
CONTRACTOR:
DRILLER: GRINER DRILLING SERVICE INSPECTOR: S. KIRCHOFF
INSTALLATION DATE: MAY 26, 1994

WELL NO. 1
PROJECT NO. 1.V7101.002
LOCATION:
SEE SITE PLAN
SHEET 1 OF 1



GROUND ELEVATION	RELATIVE 99.20
THICKNESS OF SURFACE SEAL	CONCRETE GROUT 1.0'
TYPE OF BACKFILL	NATURAL FILL 1.0'–16.0'
INSIDE DIAMETER OF RISER PIPE	4.0"
BENTONITE SEAL	16.0'–17.0'
BACKFILL AROUND SCREEN	SILICA SAND 17.0'–31.0'
DEPTH TO TOP OF SCREEN BELOW SURFACE	20.0'
DIAMETER OF BOREHOLE	10.0"
TYPE OF SCREEN	PVC SLOTTED
SCREEN SIZE	0.010"
INSIDE DIAMETER OF WELL SCREEN	4.0"
DEPTH TO BOTTOM OF SCREEN BELOW SURFACE	30.0'
TOTAL DEPTH OF BORE HOLE	35.0'

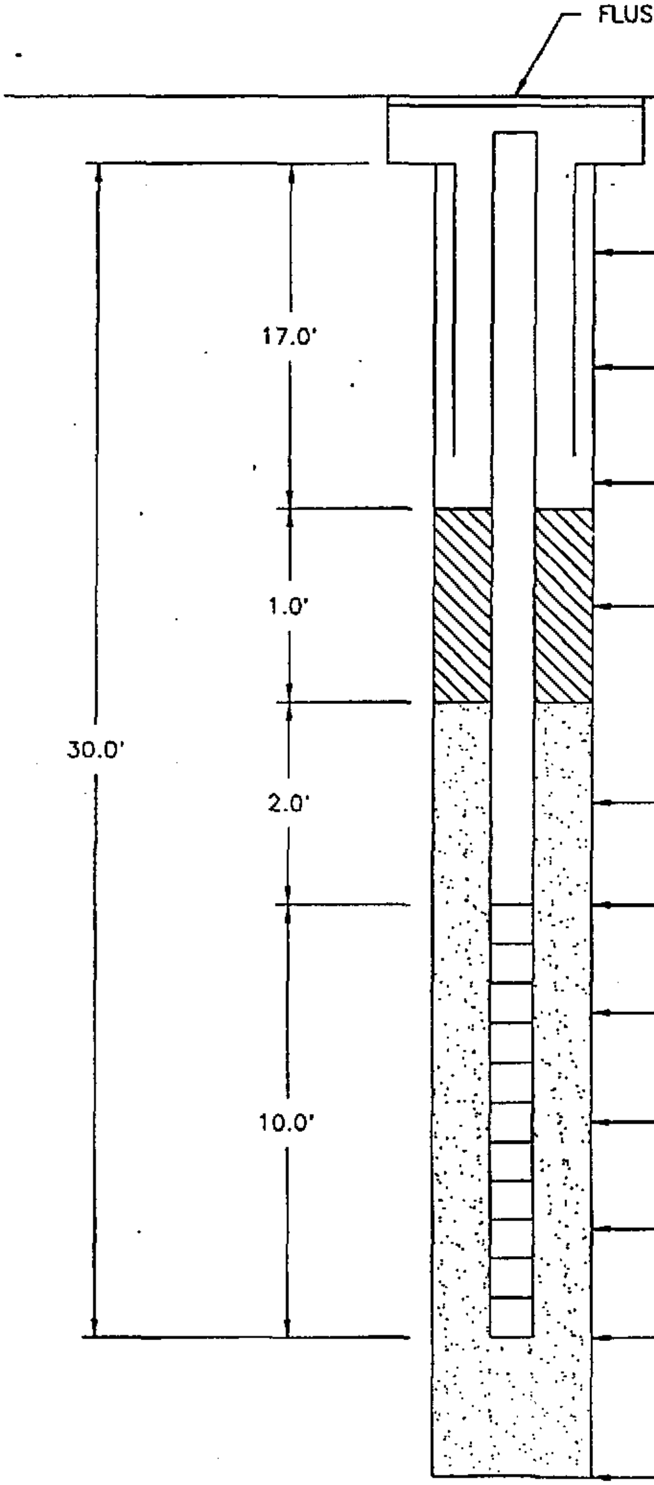
Environmental
Protection
Systems

5360 I-55 NORTH
JACKSON, MISSISSIPPI
39211

GROUNDWATER MONITORING WELL REPORT

PROJECT: GULF STATES CREOSOTE – PHASE II
LOCATION: HATTIESBURG, MISSISSIPPI
CLIENT: J.B. VAN SLYKE
CONTRACTOR:
DRILLER: GRINER DRILLING SERVICE INSPECTOR: S. KIRCHOFF
INSTALLATION DATE: MAY 25, 1994

WELL NO. 2
PROJECT NO. 1.V7101.002
LOCATION: SEE SITE PLAN
SHEET 1 OF 1



GROUND ELEVATION	RELATIVE 97.64
THICKNESS OF SURFACE SEAL	CONCRETE GROUT 1.0'
TYPE OF BACKFILL	NATURAL FILL 1.0'–16.0'
INSIDE DIAMETER OF RISER PIPE	4.0"
BENTONITE SEAL	16.0'–17.0'
BACKFILL AROUND SCREEN	SILICA SAND 17.0'–31.0'
DEPTH TO TOP OF SCREEN BELOW SURFACE	20.0'
DIAMETER OF BOREHOLE	10.0"
TYPE OF SCREEN	PVC SLOTTED
SCREEN SIZE	0.010"
INSIDE DIAMETER OF WELL SCREEN	4.0"
DEPTH TO BOTTOM OF SCREEN BELOW SURFACE	30.0'
TOTAL DEPTH OF BORE HOLE	33.0'

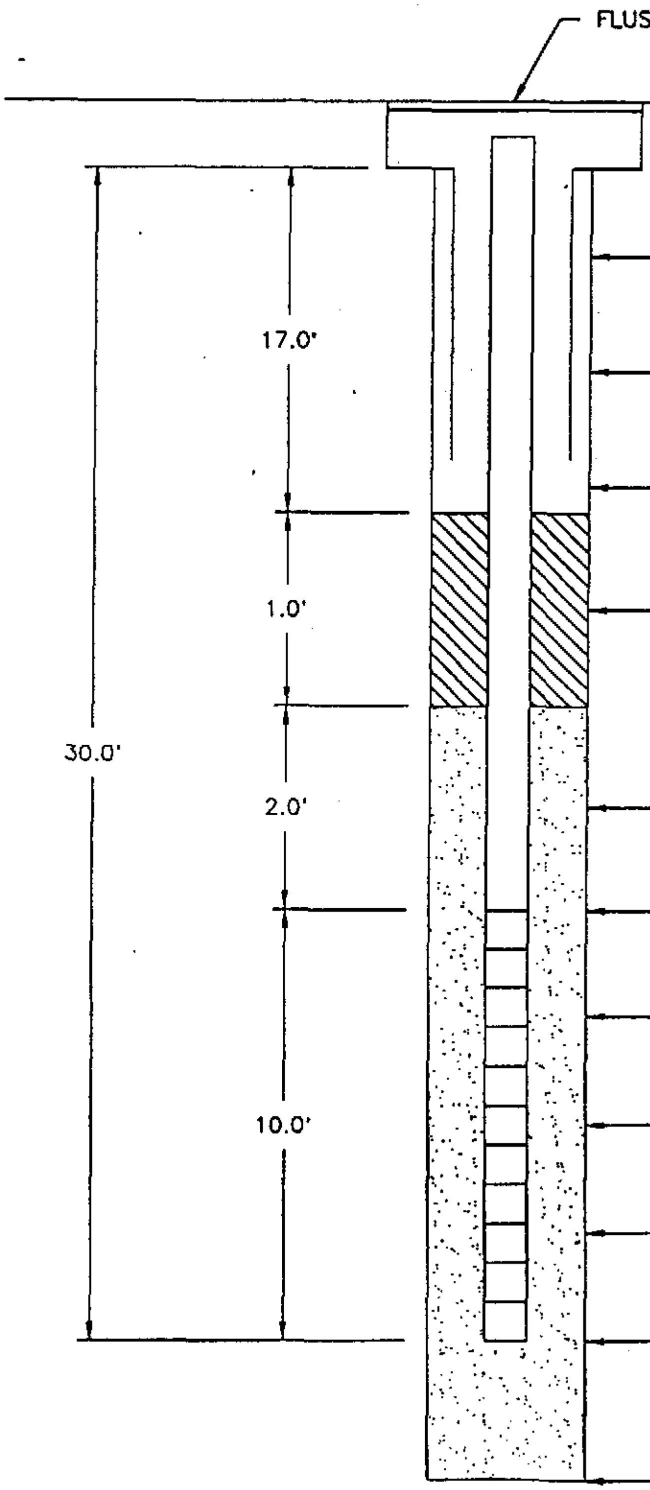
Environmental
Protection
Systems

5360 I-55 NORTH
JACKSON, MISSISSIPPI
39211

GROUNDWATER MONITORING WELL REPORT

PROJECT: GULF STATES CREOSOTE – PHASE II
LOCATION: HATTIESBURG, MISSISSIPPI
CLIENT: J.B. VAN SLYKE
CONTRACTOR:
DRILLER: GRINER DRILLING SERVICE INSPECTOR: S. KIRCHOFF
INSTALLATION DATE: MAY 25, 1994

WELL NO. 3
PROJECT NO. 1.V7101.002
LOCATION: SEE SITE PLAN
SHEET 1 OF 1



GROUND ELEVATION	RELATIVE 99.33
THICKNESS OF SURFACE SEAL	CONCRETE GROUT 1.0'
TYPE OF BACKFILL	NATURAL FILL 1.0'–16.0'
INSIDE DIAMETER OF RISER PIPE	4.0"
BENTONITE SEAL	16.0'–17.0'
BACKFILL AROUND SCREEN	SILICA SAND 17.0'–30.0'
DEPTH TO TOP OF SCREEN BELOW SURFACE	20.0'
DIAMETER OF BOREHOLE	10.0"
TYPE OF SCREEN	PVC SLOTTED
SCREEN SIZE	0.010"
INSIDE DIAMETER OF WELL SCREEN	4.0"
DEPTH TO BOTTOM OF SCREEN BELOW SURFACE	30.0'
TOTAL DEPTH OF BORE HOLE	30.0'

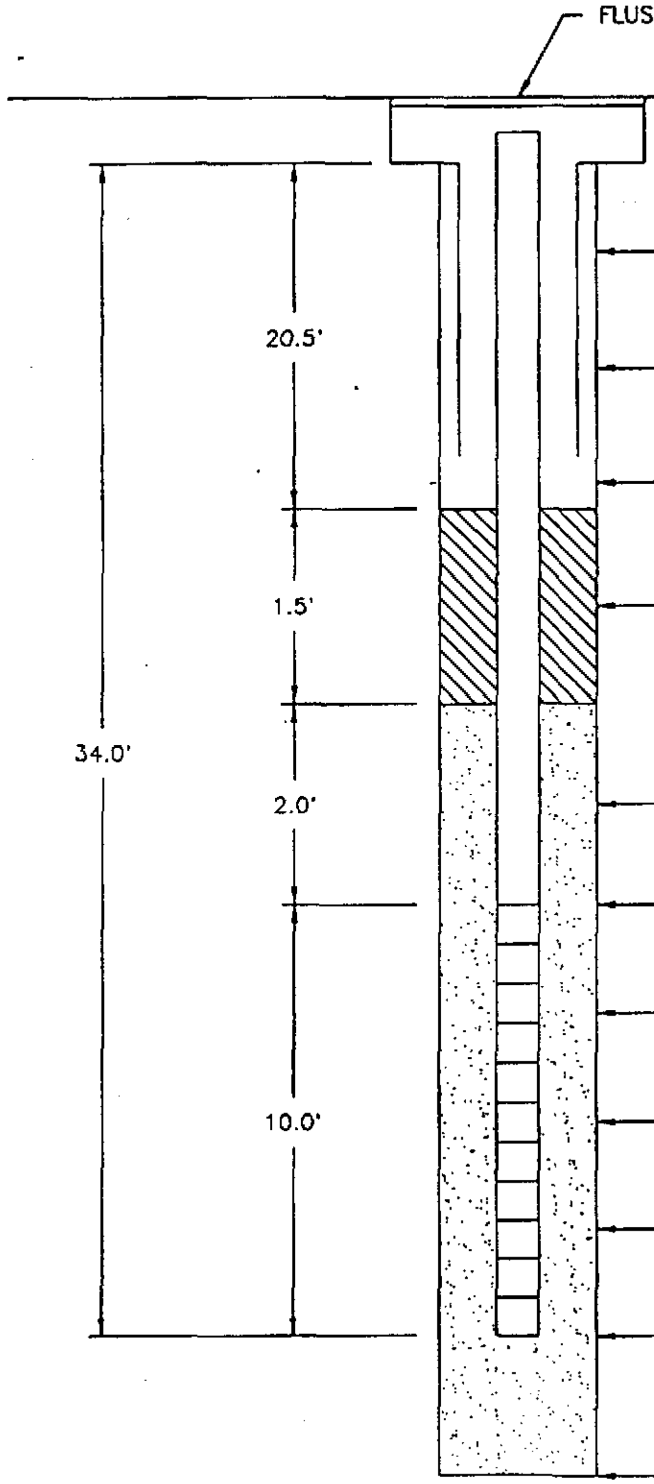
Environmental
Protection
Systems

5360 I-55 NORTH
JACKSON, MISSISSIPPI
39211

GROUNDWATER MONITORING WELL REPORT

PROJECT: GULF STATES CREOSOTE – PHASE II
LOCATION: HATTIESBURG, MISSISSIPPI
CLIENT: J.B. VAN SLYKE
CONTRACTOR:
DRILLER: GRINER DRILLING SERVICE INSPECTOR: S. KIRCHOFF
INSTALLATION DATE: MAY 26, 1994

WELL NO. 4
PROJECT NO. 1.V7101.002
LOCATION: SEE SITE PLAN
SHEET 1 OF 1



GROUND ELEVATION	RELATIVE 98.62
THICKNESS OF SURFACE SEAL	CONCRETE GROUT 1.0'
TYPE OF BACKFILL	NATURAL FILL 1.0'–19.5'
INSIDE DIAMETER OF RISER PIPE	4.0"
BENTONITE SEAL	19.5'–21.0'
BACKFILL AROUND SCREEN	SILICA SAND 21.0'–35.0'
DEPTH TO TOP OF SCREEN BELOW SURFACE	22.0'
DIAMETER OF BOREHOLE	10.0"
TYPE OF SCREEN	PVC SLOTTED
SCREEN SIZE	0.010"
INSIDE DIAMETER OF WELL SCREEN	4.0"
DEPTH TO BOTTOM OF SCREEN BELOW SURFACE	34.0'
TOTAL DEPTH OF BORE HOLE	36.0'

Appendix H

Monitoring Well Sampling Records

Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MONITOR WELL SAMPLING RECORD **WELL NO.:** Mw-04

Client: Kerr McGee
Date: 3/12/97 (1st Quarter 1997)
Location: Gulf States Creosote, Hattiesburg, MS
W.O. #: 21-02
Well No.: Mw-04
Samplers: DLA
Measuring Point Elevation:
Measuring Point: TOC

Total Well Depth (W1): 40 ft.
Height of Standing Water (H1=W1-W2): 26.65 ft.
Depth to Water (W2): 13.35 ft.
Well Diameter (D1): 2 in.
Well Volume (V1=3.14*(D1/24)^2*7.5 gal/ft^3* H1): 4.4 gallons

A minimum of 3 well casing volumes will be removed prior to sampling. Measurements of pH, specific conductance and temperature will be recorded twice for each well casing volume removed. Should the parameters not stabilize, a maximum of ten well casing volumes will be removed during purging.

PURGING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Volume Removed gal.	Cumulative Volume Removed (gal)	Temp. (oC)	Specific Conductance (umhos/cm)	pH	Color	Remarks/Initials
3/12/97	[illegible]	B	1	1	21.3	462	6.16	light brown	No odor
" "	1022	B	2	3	21.3	470	[illegible]	"	" "
"	1025	B	2	5	21.2	485	6.14	"	" "
"	[illegible]	B	3	8	21.2	475	6.14	"	" "
"	[illegible]	B	2	10	21.2	479	6.20	"	" "
" "	1107	B	2	12	21.1	475	6.20	"	" "
"	1114	B	2	14	21.2	475 ~~475~~	6.19	"	" "

SAMPLING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Samplers Initials	Sample Location Name/Number	Number of Bottles	Specific Conductance (umhos/cm)	pH	Temp. (oC)	Remarks Preservatives Analyses Requested
3/12/97	1122	B	DLA	40 ml vials	3	495	6.30	21.1	[illegible]
	1125			40 ml vials	3				MS/MSD
	1130			1 liter amber	3				$Na_2S_2O_3$
	1138			" "	3				MS/MSD
	[illegible]			1 liter plastic	1				[illegible]
	[illegible]			" "	1				MS/MSD
	[illegible]			1 liter plastic	1				HNO_3
	1149	B		" "	1				MS/MSD [illegible]

MONITOR WELL SAMPLING RECORD **WELL NO.:** MW-4

Client: Kerr McGee Date: 3/12/97 (1st Quarter 1997)
Location: Gulf States Creosote, Hattiesburg, MS W.O. # 21802
Well No.: MW-4 Samplers: DGA
Measuring Point Elevation: ____ Measuring Point: TOC

Total Well Depth (W1): 34 ft. Height of Standing Water (H1=W1-W2): 14.9 ft.
Depth to Water (W2): 19.10 ft. Well Diameter (D1): 4 in.
Well Volume ($V1=3.14*(D1/24)^2*7.5\ gal/ft^3*H1$): 9.3 gallons

A minimum of 3 well casing volumes will be removed prior to sampling. Measurements of pH, specific conductance and temperature will be recorded twice for each well casing volume removed. Should the parameters not stabilize, a maximum of ten well casing volumes will be removed during purging.

PURGING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other ____

Date	Time	Method	Volume Removed gal.	Cumulative Volume Removed (gal)	Temp. (oC)	Specific Conductance (umhos/cm)	pH	Color	Remarks/Initials
3/12/97	1745	B	5	5	24.8	63	4.34	No odor	Grey Cloudy
"	1748	B	5	10	24.8	62	4.45	"	"
"	1750	B	5	15	24.1	64	4.37	"	" "
	1802	B	5	20	24.8	62	4.44	"	" "
	1805	B	5	25	24.8	63	4.57	"	" "
	1807	B	2	27	24.8	68	4.85	"	" "

SAMPLING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other ____

Date	Time	Method	Samplers Initials	Sample Location Name/Number	Number of Bottles	Specific Conductance (umhos/cm)	pH	Temp. (oC)	Remarks Preservatives Analyses Requested
3/12/97	1810	B	DGA	RB-1	3	RB-1			40ml VOAs HCL
	1816	↓	↓	1 liter amber	3	↓			$Na_2S_2O_3$
	1820	↓	↓	1 500ml plastic	1	↓			$C_6H_8O_7$/NaOH
	1822	B	↓	1 4liter plastic	1	↓			HNO_3
	1829	↓	DGA	2×40mls		MW-4	4.85		HCL
	1831	↓	↓	4×1 liter amber	3	66	~~4.7~~	24.6	$Na_2S_2O_3$
	1839	↓	↓	500ml plastic	1	↓			$C_6H_8O_7$/NaOH
	1840	↓	↓	1 liter plastic	1	↓			HNO_3

MONITOR WELL SAMPLING RECORD

WELL NO.: MW-03

Client: Kerr McGee
Location: Gulf States Creosote, Hattiesburg, MS
Well No.: MW-03
Measuring Point Elevation:
Date: 3/12/97 (1st Quarter 1997)
W.O. #: 21-02
Samplers: Dave Ayle
Measuring Point: TOC

Total Well Depth (W1): 37 ft.
Depth to Water (W2): 13.54 ft.
Height of Standing Water (H1=W1-W2): 23.46 ft.
Well Diameter (D1): 2 in.
Well Volume ($V1=3.14^*(D1/24)^2{}^*7.5\ gal/ft^3{}^*\ H1$): 3.8 gallons

A minimum of 3 well casing volumes will be removed prior to sampling. Measurements of pH, specific conductance and temperature will be recorded twice for each well casing volume removed. Should the parameters not stabilize, a maximum of ten well casing volumes will be removed during purging.

PURGING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Volume Removed gal.	Cumulative Volume Removed (gal)	Temp. (oC)	Specific Conductance (umhos/cm)	pH	Color	Remarks/Initials
3/12/97	832	B	1	1	21.4	161	5.07	Light brown	No odor
" "	838	B	2	3	21.4	170	5.26	" "	" "
" "	849	B	2	5	21.4	181	5.34	" "	" "
" "	855	B	2	7	[illegible]	165	5.44	" "	" "
" "	[illegible]	B	2	9	21.3	157	5.44	" "	" "
" "	[illegible]	B	1	10	[illegible]	155	5.43	" "	" "
" "	[illegible]	B	1.5	11.5	21.3	[illegible]	5.43	" "	" "

SAMPLING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Samplers Initials	Sample Location Name/Number	Number of Bottles	Specific Conductance (umhos/cm)	pH	Temp. (oC)	Remarks Preservatives Analyses Requested
3/12/97	912	B	DEA	3×40ml VOAs	3				
	0926	↓	↓						
	932					155 ~~[illegible]~~	5.42	21.0	[illegible]
	935			1 liter Amber	3				$Na_2S_2O_3$
	0939			500ml Plastic	1				$C_6H_8O_6$/NaOH
				1 liter Plastic	1				HNO_3
			TB-1	2×40ml VOAs Filled by lab		Trip Blank #1			
				carried in cooler with VOAs					

MONITOR WELL SAMPLING RECORD **WELL NO.:** MW-05

Client: Kerr McGee
Date: 3/12/97 (1st Quarter 1997)
Location: Gulf States Creosote, Hattiesburg, Ms
W.O. #: 21-02
Well No.: MW-05
Samplers: DGA
Measuring Point Elevation:
Measuring Point: TOC

Total Well Depth (W1): 42 ft.
Depth to Water (W2): 19.47 ft.
Height of Standing Water (H1=W1-W2): 22.53 ft.
Well Diameter (D1): 2 in.
Well Volume (V1=3.14*(D1/24)^2*7.5 gal/ft^3* H1): 3.1 gallons

A minimum of 3 well casing volumes will be removed prior to sampling. Measurements of pH, specific conductance and temperature will be recorded twice for each well casing volume removed. Should the parameters not stabilize, a maximum of ten well casing volumes will be removed during purging.

PURGING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Volume Removed gal.	Cumulative Volume Removed (gal)	Temp. (oC)	Specific Conductance (umhos/cm)	pH	Color	Remarks/Initials
3/12/97	1247	B		1	24.2	46	5.52	light gray	DGA
	1252	"	2	3	24.1	55	5.51	" "	" "
	1255	"	2	5	24.3	79	5.55	" "	" "
	1301	"	3	8	24.2	99	5.44	" "	" "
	1305	"	2	10	24.2	97	5.49	" "	" "
	1310	"	2	12	24.1	98	5.50	" "	" "
				Total Purge					
				~12.5 gallons					

SAMPLING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Samplers Initials	Sample Location Name/Number	Number of Bottles	Specific Conductance (umhos/cm)	pH	Temp. (oC)	Remarks Preservatives Analyses Requested
3/12/97	1322	B	DGA	40 ml VOA	3				HCL
		↓	↓			103	5.55	24.5	brown & silty
	1325			1 liter amber	3				$Na_2S_2O_3$
	1335			1 500 ml [illegible]	1				$C_6H_8O_7$/NaOH
	1337			1 1 liter [illegible]	1				HNO_3

MONITOR WELL SAMPLING RECORD

WELL NO.: MW-01

Client: Kerr McGee
Date: 3/12/97 (1st Quarter 1997)
Location: Gulf States Creosote, Hattiesburg, Ms
W.O. # 21-02
Well No: MW-01
Samplers: Doug Argu
Measuring Point Elevation:
Measuring Point: TOC

Total Well Depth (W1): 35 ft.
Height of Standing Water (H1=W1-W2): 22.57 ft.
Depth to Water (W2): 12.43 ft.
Well Diameter (D1): 2 in.
Well Volume ($V1=3.14^*(D1/24)^2{}^*7.5\ gal/ft^3{}^*\ H1$): 3.7 gallons

A minimum of 3 well casing volumes will be removed prior to sampling. Measurements of pH, specific conductance and temperature will be recorded twice for each well casing volume removed. Should the parameters not stabilize, a maximum of ten well casing volumes will be removed during purging.

PURGING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Volume Removed gal.	Cumulative Volume Removed (gal)	Temp. (oC)	Specific Conductance (umhos/cm)	pH	Color	Remarks/Initials
3/12/97	1422	B	1	1	20.7	454	5.00		Clear
	1429	"	2	3	20.9	349	5.02		Slightly Cloudy
	1435	"	2	5	21.0	300	5.01		" "
	1443	"	3	8	20.9	224	4.98		" "
	1449	"	2	10	21.0	220	5.05		" "
	1455	"	2	12	20.8	173	5.00		" "
	1458	"	1	13	20.7	176	4.98		" "
	1502	"	1	14	20.7	[illegible]	5.02		" "

SAMPLING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Samplers Initials	Sample Location Name/Number	Number of Bottles	Specific Conductance (umhos/cm)	pH	Temp. (oC)	Remarks Preservatives Analyses Requested
3/12/97	1505	B	DGA	40ml VOAs	3				HCL
						150	4.97	21.6	
	1511			1 liter amber	3				$Na_2S_2O_3$
	1523			500ml plastic	1				$C_6H_8O_6$/NaOH
	1525	↓	↓	1 liter plastic	1				HNO_3

MONITOR WELL SAMPLING RECORD **WELL NO.:** Mw - 3

Client: Kerr McGee Date: 3/12/97 (1st Quarter 1997)
Location: Gulf States Creosote, Hattiesburg, Ms W.O. # 21-02
Well No.: Mw-3 Samplers: DLA
Measuring Point Elevation: Measuring Point: TOC

Total Well Depth (W1): 30 ft. Height of Standing Water (H1=W1-W2): 13.86 ft.
Depth to Water (W2): 16.11 ft. Well Diameter (D1): 4 in.
Well Volume (V1=3.14*(D1/24)^2*7.5 gal/ft^3* H1): 9.1 gallons

A minimum of 3 well casing volumes will be removed prior to sampling. Measurements of pH, specific conductance and temperature will be recorded twice for each well casing volume removed. Should the parameters not stabilize, a maximum of ten well casing volumes will be removed during purging.

PURGING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Volume Removed gal.	Cumulative Volume Removed (gal)	Temp. (oC)	Specific Conductance (umhos/cm)	pH	Color	Remarks/Initials
3/12/97	1625	B	5	5	23.5	86	4.91	[illegible]	Slightly cloudy
	1632		5	10	23.6	82	4.77	"	" "
	1634		5	15	23.6	81	4.74	"	" "
	1639		5	20	23.5	82	4.56	"	" "
	1642		6	26	23.4	82	4.60	"	Clearing [illegible]
	1645		2	28	23.4	90	4.56	"	" "

SAMPLING RECORD

Method: bailer (B) submersible (S) peristaltic (P) geoguard (G) other

Date	Time	Method	Samplers Initials	Sample Location Name/Number	Number of Bottles	Specific Conductance (umhos/cm)	pH	Temp. (oC)	Remarks Preservatives Analyses Requested
3/12/97	1649	B	DLA	40 ml VOAs	3	Mw-3			HCL
	1651			" "	3	Mw-23(Dup)			" "
	1653			~~1 liter amber~~		83	4.66	23.2	
	1655			1 liter amber	3	Mw-3			$Na_2S_2O_3$
	1658			" "	"	Mw-23(Dup)			" "
	1703			500 ml plastic	1	Mw-3			$C_6H_8O_6$ | NaOH
	1705			" "	1	Mw-23(Dup)			~~H_2SO_4~~ "
	1711			1 liter plastic	1	Mw-3			~~HCl~~ HNO_3
	1713			" "	1	Mw-23			" "

Appendix I

Slug Test Data

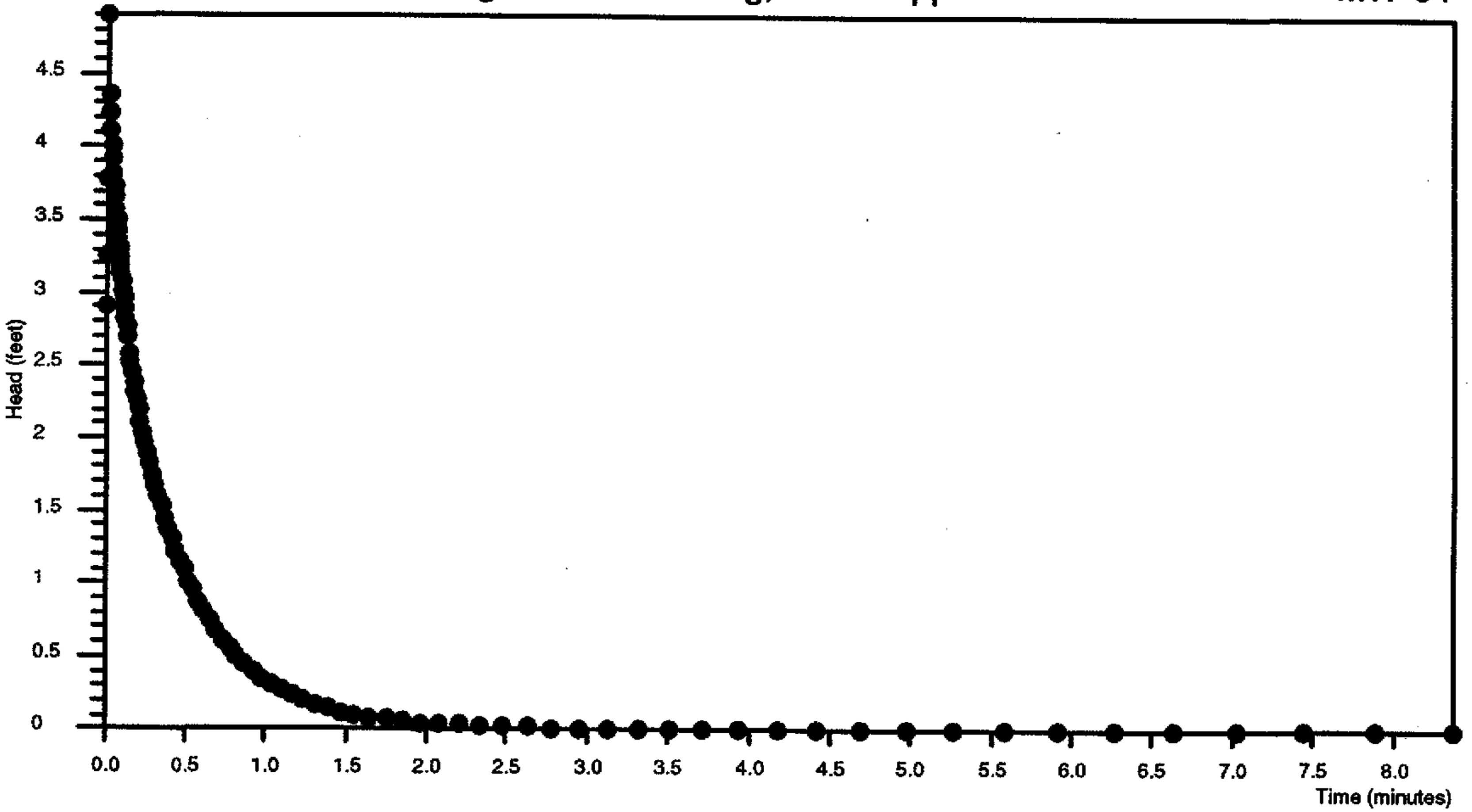
Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

MW-01 Rising Head #1 April 29, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

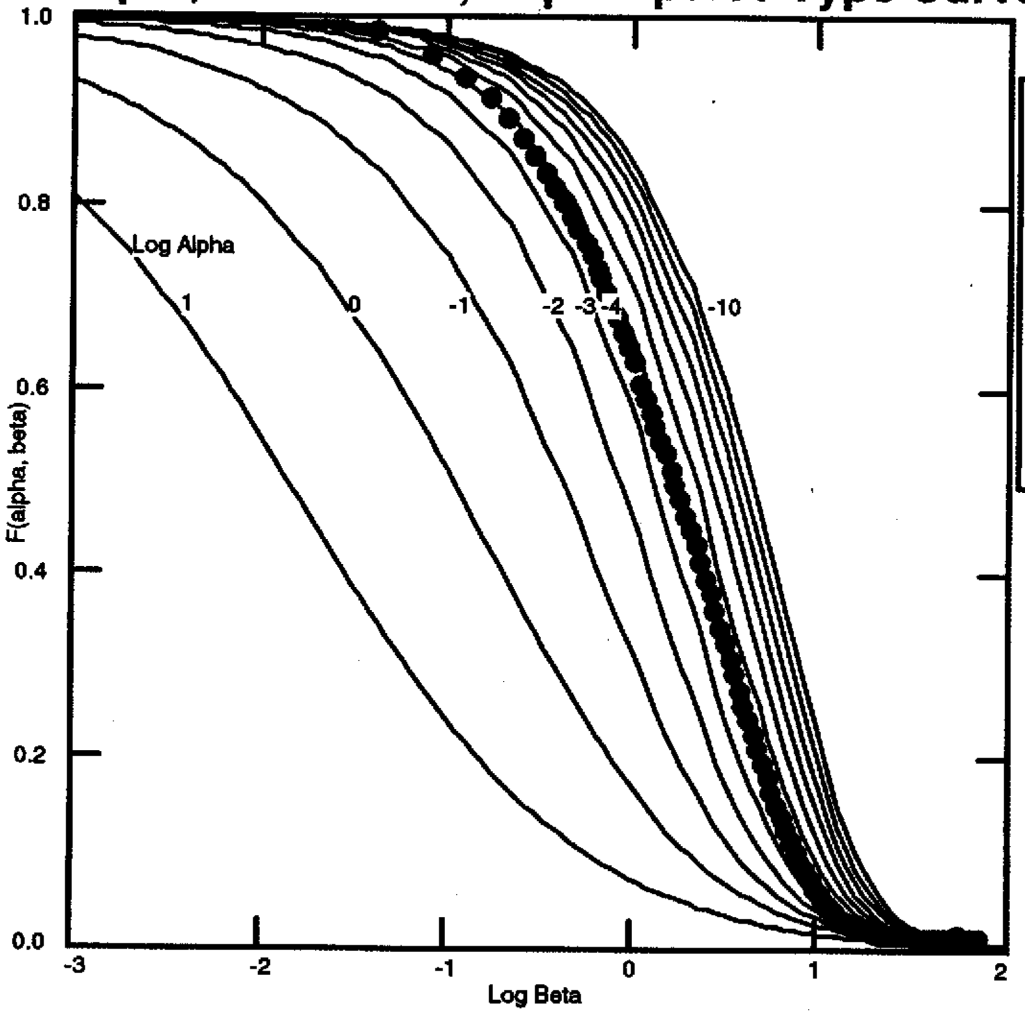
Arithmetic Graph

MW-01



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve



Well MW-01

log Beta = 2.855
F(alpha, beta) = 0.5124

Transmissivity
4.615 meters2/day

Hydraulic Conductivity
1.545 meters/day

log(Alpha) = -4.
Storativity = 5.88e-006

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 29, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.          TROLL
Serial number:        00000211
Unit name:            SP4000

Report generated:     05/01/97      10:39:00
Report from file:     A:\MW-01-A.BIN

Test name: MW-01-A

Test defined on:      04/29/97      11:33:16
Test started on:      04/29/97      11:35:53
Test stopped on:      04/29/97      11:44:38
Test extracted on:    04/29/97      17:03:48

Data gathered using Logarithmic testing
   Maximum time between data points:        2.0000           Minutes.
   Number of data samples:          98

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:     TOC
  User-defined reference:             11.330      Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:         20.216      Feet H2O


                                          Channel[1]   Channel[2]
  Date        Time         ET (min)       Fahrenheit   Feet H2O
--------    --------    ------------   -----------   -----------
04/29/97    11:35:53          0.0000         68.74         14.587
04/29/97    11:35:53          0.0050         68.75         14.239
04/29/97    11:35:53          0.0100         68.76         15.106
[illegible]29/97    11:35:53          0.0150         68.76         16.222
[illegible]29/97    11:35:54          0.0200         68.77         15.687
04/29/97    11:35:54          0.0250         68.77         15.560
04/29/97    11:35:54          0.0300         68.79         15.450
04/29/97    11:35:55          0.0350         68.79         15.344
04/29/97    11:35:55          0.0400         68.82         15.249
04/29/97    11:35:55          0.0450         68.82         15.152
04/29/97    11:35:56          0.0500         68.82         15.067
04/29/97    11:35:56          0.0550         68.82         14.986
04/29/97    11:35:56          0.0600         68.82         14.901
04/29/97    11:35:56          0.0650         68.83         14.834
04/29/97    11:35:57          0.0700         68.83         14.767
04/29/97    11:35:57          0.0750         68.83         14.702
04/29/97    11:35:57          0.0800         68.84         14.642
04/29/97    11:35:58          0.0850         68.85         14.580
04/29/97    11:35:58          0.0900         68.85         14.525
04/29/97    11:35:58          0.0950         68.85         14.460
04/29/97    11:35:59          0.1000         68.86         14.414
04/29/97    11:35:59          0.1058         68.86         14.345
04/29/97    11:35:59          0.1120         68.87         14.285
04/29/97    11:36:00          0.1185         68.87         14.222
04/29/97    11:36:00          0.1255         68.88         14.158
04/29/97    11:36:00          0.1328         68.89         14.098
04/29/97    11:36:01          0.1407         68.89         14.031
04/29/97    11:36:01          0.1490         68.93         13.916
04/29/97    11:36:02          0.1578         68.93         13.853
04/29/97    11:36:03          0.1672         68.94         13.789
04/29/97    11:36:03          0.1770         68.94         13.722
04/29/97    11:36:04          0.1875         68.94         13.653
04/29/97    11:36:04          0.1985         68.94         13.588
0[illegible]9/97    11:36:05          0.2102         68.94         13.517
[illegible]9/97    11:36:06          0.2227         68.95         13.445
04/29/97    11:36:07          0.2358         68.95         13.374
04/29/97    11:36:07          0.2498         68.95         13.300
04/29/97    11:36:08          0.2647         68.95         13.228
04/29/97    11:36:09          0.2803         68.95         13.157
04/29/97    11:36:10          0.2970         68.95         13.078
```

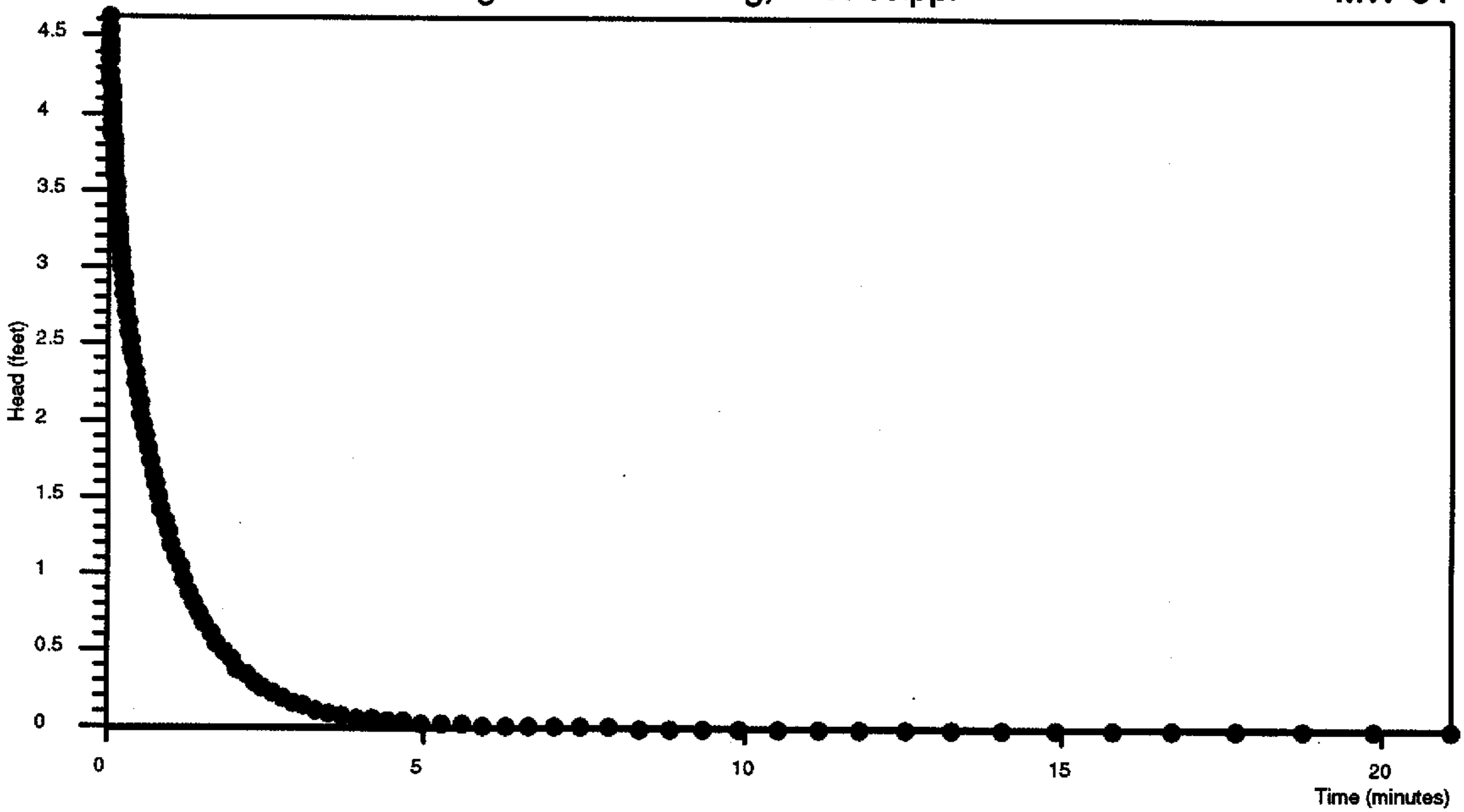
04/29/97	11:36:11	0.3147	68.95	13.007
04/29/97	11:36:13	0.3333	68.95	12.931
04/29/97	11:36:14	0.3532	68.95	12.855
04/29/97	11:36:15	0.3742	68.95	12.778
04/29/97	11:36:16	0.3963	68.95	12.700
04/29/97	11:36:18	0.4198	68.95	12.629
04/29/97	11:36:19	0.4447	68.95	12.552
[illegible]/29/97	11:36:21	0.4697	68.95	12.481
[illegible]29/97	11:36:22	0.4963	68.95	12.416
04/29/97	11:36:24	0.5247	68.95	12.340
04/29/97	11:36:26	0.5547	68.96	12.276
04/29/97	11:36:28	0.5863	68.96	12.204
04/29/97	11:36:30	0.6213	68.95	12.144
04/29/97	11:36:32	0.6580	68.95	12.073
04/29/97	11:36:34	0.6963	68.95	12.008
04/29/97	11:36:37	0.7380	68.95	11.941
04/29/97	11:36:39	0.7813	68.95	11.886
04/29/97	11:36:42	0.8280	68.95	11.830
04/29/97	11:36:45	0.8763	68.95	11.775
04/29/97	11:36:48	0.9280	68.95	11.727
04/29/97	11:36:51	0.9830	68.95	11.681
04/29/97	11:36:55	1.0413	68.95	11.639
04/29/97	11:36:59	1.1030	68.95	11.600
04/29/97	11:37:03	1.1680	68.95	11.561
04/29/97	11:37:07	1.2380	68.94	11.533
04/29/97	11:37:11	1.3113	68.93	11.503
04/29/97	11:37:16	1.3897	68.94	11.478
04/29/97	11:37:21	1.4730	68.93	11.454
04/29/97	11:37:26	1.5613	68.93	11.434
04/29/97	11:37:32	1.6547	68.93	11.418
04/29/97	11:37:38	1.7530	68.92	11.404
04/29/97	11:37:44	1.8580	68.92	11.392
04/29/97	11:37:51	1.9680	68.92	11.383
04/29/97	11:37:58	2.0847	68.91	11.374
04/29/97	11:38:05	2.2097	68.91	11.367
04/29/97	11:38:13	2.3413	68.91	11.362
04/29/97	11:38:21	2.4813	68.91	11.358
04/29/97	11:38:30	2.6297	68.89	11.353
[illegible]29/97	11:38:40	2.7863	68.89	11.348
04/29/97	11:38:50	2.9530	68.91	11.348
04/29/97	11:39:00	3.1297	68.89	11.344
04/29/97	11:39:11	3.3163	68.89	11.341
04/29/97	11:39:23	3.5147	68.97	11.344
04/29/97	11:39:36	3.7247	68.93	11.341
04/29/97	11:39:49	3.9463	68.92	11.337
04/29/97	11:40:03	4.1813	68.91	11.337
04/29/97	11:40:18	4.4297	68.89	11.337
04/29/97	11:40:34	4.6930	68.88	11.337
04/29/97	11:40:51	4.9730	68.88	11.337
04/29/97	11:41:09	5.2697	68.87	11.337
04/29/97	11:41:27	5.5830	68.86	11.337
04/29/97	11:41:47	5.9147	68.86	11.337
04/29/97	11:42:08	6.2663	68.85	11.337
04/29/97	11:42:31	6.6397	68.94	11.341
04/29/97	11:42:55	7.0347	68.88	11.337
04/29/97	11:43:20	7.4530	68.86	11.332
04/29/97	11:43:46	7.8963	68.85	11.332
04/29/97	11:44:14	8.3663	68.84	11.332

MW-01 Rising Head #2 April 29, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

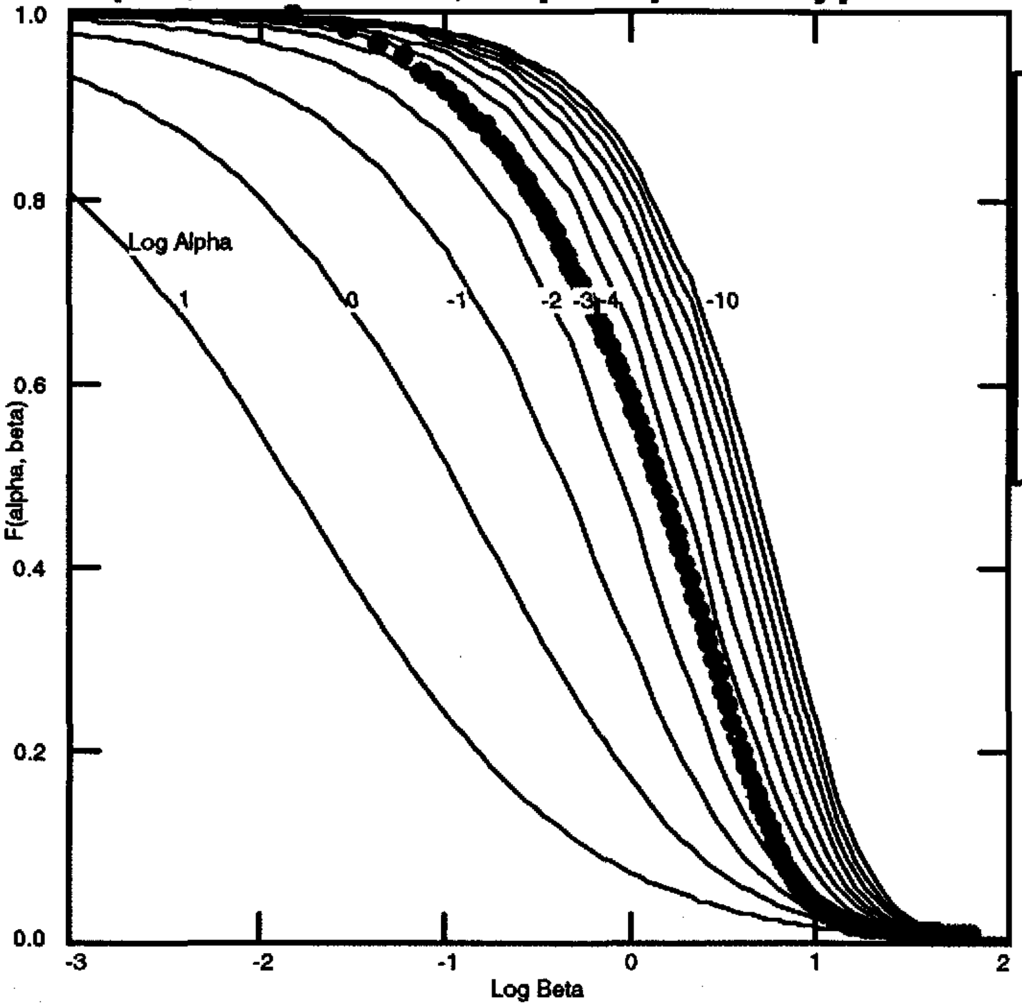
Arithmetic Graph

MW-01



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve



Well MW-01

log Beta = 2.406
F(alpha, beta) = 0.5124

Transmissivity
1.642 meters2/day

Hydraulic Conductivity
0.5496 meters/day

log(Alpha) = -3.
Storativity = 5.88e-005

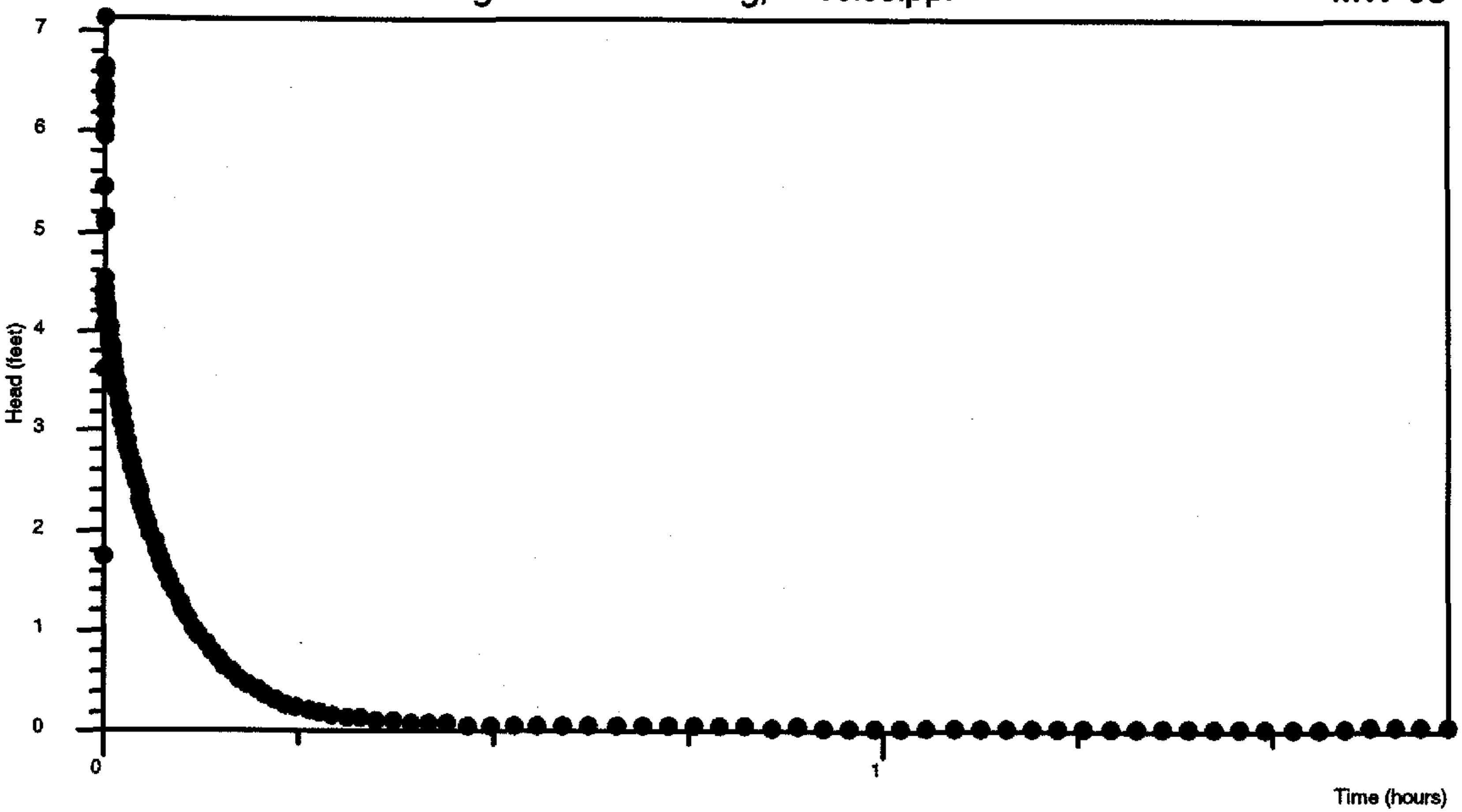
Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 29, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.            TROLL
Serial number:          00000211
Unit name:              SP4000

Report generated:       05/01/97     10:35:16
Report from file:       A:\MW-01-B.BIN

[illegible]st name: MW-01-B

Test defined on:        04/29/97     11:57:28
Test started on:        04/29/97     11:58:30
Test stopped on:        04/29/97     12:20:24
Test extracted on:      04/29/97     16:56:11

Data gathered using Logarithmic testing
   Maximum time between data points:       2.0000          Minutes.
   Number of data samples:         114

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:    TOC
  User-defined reference:           11.330     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:       20.216     Feet H2O


                                         Channel[1]   Channel[2]
  Date        Time         ET (min)     Fahrenheit   Feet H2O
--------    --------    ------------  -----------   -----------
04/29/97    11:58:30          0.0000        68.73        15.773
04/29/97    11:58:30          0.0050        68.73        15.883
[illegible]/29/97    11:58:30          0.0100        68.74        15.955
[illegible]29/97    11:58:30          0.0150        68.75        15.874
04/29/97    11:58:31          0.0200        68.75        15.803
04/29/97    11:58:31          0.0250        68.76        15.729
04/29/97    11:58:31          0.0300        68.76        15.676
04/29/97    11:58:32          0.0350        68.77        15.597
04/29/97    11:58:32          0.0400        68.78        15.542
04/29/97    11:58:32          0.0450        68.78        15.500
04/29/97    11:58:33          0.0500        68.79        15.445
04/29/97    11:58:33          0.0550        68.81        15.390
04/29/97    11:58:33          0.0600        68.81        15.353
04/29/97    11:58:33          0.0650        68.82        15.330
04/29/97    11:58:34          0.0700        68.82        15.279
04/29/97    11:58:34          0.0750        68.82        15.237
04/29/97    11:58:34          0.0800        68.83        15.198
04/29/97    11:58:35          0.0850        68.83        15.166
04/29/97    11:58:35          0.0900        68.84        15.131
04/29/97    11:58:35          0.0950        68.84        15.092
04/29/97    11:58:36          0.1000        68.85        15.060
04/29/97    11:58:36          0.1058        68.85        15.021
04/29/97    11:58:36          0.1120        68.85        14.981
04/29/97    11:58:37          0.1185        68.86        14.940
04/29/97    11:58:37          0.1255        68.86        14.894
04/29/97    11:58:37          0.1328        68.87        14.850
04/29/97    11:58:38          0.1407        68.87        14.804
04/29/97    11:58:38          0.1490        68.92        14.732
04/29/97    11:58:39          0.1578        68.92        14.686
04/29/97    11:58:40          0.1672        68.92        14.638
04/29/97    11:58:40          0.1770        68.92        14.596
04/29/97    11:58:41          0.1875        68.92        14.545
[illegible]29/97    11:58:41          0.1985        68.92        14.495
[illegible]9/97    11:58:42          0.2102        68.93        14.444
[illegible]29/97    11:58:43          0.2227        68.92        14.393
04/29/97    11:58:44          0.2358        68.93        14.338
04/29/97    11:58:44          0.2498        68.93        14.282
04/29/97    11:58:45          0.2647        68.93        14.227
04/29/97    11:58:46          0.2803        68.93        14.167
04/29/97    11:58:47          0.2970        68.93        14.112
```

04/29/97	11:58:48	0.3147	68.93	14.047
04/29/97	11:58:50	0.3333	68.93	13.985
04/29/97	11:58:51	0.3532	68.93	13.920
04/29/97	11:58:52	0.3742	68.93	13.856
04/29/97	11:58:53	0.3963	68.93	13.789
04/29/97	11:58:55	0.4198	68.93	13.722
04/29/97	11:58:56	0.4447	68.93	13.653
[illegible]/29/97	11:58:58	0.4697	68.91	13.588
[illegible]/29/97	11:58:59	0.4963	68.94	13.517
04/29/97	11:59:01	0.5247	68.94	13.445
04/29/97	11:59:03	0.5547	68.94	13.371
04/29/97	11:59:05	0.5863	68.93	13.300
04/29/97	11:59:07	0.6213	68.93	13.233
04/29/97	11:59:09	0.6580	68.93	13.148
04/29/97	11:59:11	0.6963	68.93	13.071
04/29/97	11:59:14	0.7380	68.93	12.991
04/29/97	11:59:16	0.7813	68.93	12.912
04/29/97	11:59:19	0.8280	68.92	12.832
04/29/97	11:59:22	0.8763	68.92	12.755
04/29/97	11:59:25	0.9280	68.92	12.675
04/29/97	11:59:28	0.9830	68.92	12.599
04/29/97	11:59:32	1.0413	68.92	12.518
04/29/97	11:59:36	1.1030	68.91	12.442
04/29/97	11:59:40	1.1680	68.91	12.366
04/29/97	11:59:44	1.2380	68.89	12.289
04/29/97	11:59:48	1.3113	68.89	12.216
04/29/97	11:59:53	1.3897	68.89	12.144
04/29/97	11:59:58	1.4730	68.88	12.075
04/29/97	12:00:03	1.5613	68.89	12.008
04/29/97	12:00:09	1.6547	68.88	11.943
04/29/97	12:00:15	1.7530	68.87	11.884
04/29/97	12:00:21	1.8580	68.87	11.826
04/29/97	12:00:28	1.9680	68.87	11.770
04/29/97	12:00:35	2.0847	68.86	11.720
04/29/97	12:00:42	2.2097	68.86	11.671
04/29/97	12:00:50	2.3413	68.86	11.630
04/29/97	12:00:58	2.4813	68.85	11.591
04/29/97	12:01:07	2.6297	68.85	11.556
[illegible]29/97	12:01:17	2.7863	68.84	11.524
[illegible]/29/97	12:01:27	2.9530	68.84	11.494
04/29/97	12:01:37	3.1297	68.83	11.473
04/29/97	12:01:48	3.3163	68.83	11.448
04/29/97	12:02:00	3.5147	68.83	11.429
04/29/97	12:02:13	3.7247	68.82	11.413
04/29/97	12:02:26	3.9463	68.82	11.404
04/29/97	12:02:40	4.1813	68.81	11.392
04/29/97	12:02:55	4.4297	68.79	11.383
04/29/97	12:03:11	4.6930	68.78	11.374
04/29/97	12:03:28	4.9730	68.78	11.365
04/29/97	12:03:46	5.2697	68.77	11.362
04/29/97	12:04:04	5.5830	68.76	11.358
04/29/97	12:04:24	5.9147	68.75	11.353
04/29/97	12:04:45	6.2663	68.74	11.353
04/29/97	12:05:08	6.6397	68.74	11.348
04/29/97	12:05:32	7.0347	68.73	11.348
04/29/97	12:05:57	7.4530	68.72	11.344
04/29/97	12:06:23	7.8963	68.71	11.344
04/29/97	12:06:51	8.3663	68.69	11.339
04/29/97	12:07:21	8.8647	68.68	11.335
04/29/97	12:07:53	9.3913	68.68	11.335
04/29/97	12:08:26	9.9497	68.66	11.332
04/29/97	12:09:02	10.5413	68.66	11.332
04/29/97	12:09:40	11.1680	68.65	11.332
04/29/97	12:10:19	11.8313	68.65	11.332
04/29/97	12:11:02	12.5347	68.65	11.328
04/29/97	12:11:46	13.2797	68.64	11.328
04/29/97	12:12:34	14.0697	68.64	11.328
04/29/97	12:13:24	14.9063	68.63	11.323
[illegible]29/97	12:14:17	15.7913	68.62	11.323
[illegible]29/97	12:15:13	16.7297	68.60	11.323
04/29/97	12:16:13	17.7230	68.59	11.323
04/29/97	12:17:16	18.7763	68.58	11.323
04/29/97	12:18:23	19.8913	68.59	11.323
04/29/97	12:19:34	21.0730	68.68	11.323

MW-03 Falling Head April 29, 1997 **Arithmetic Graph**

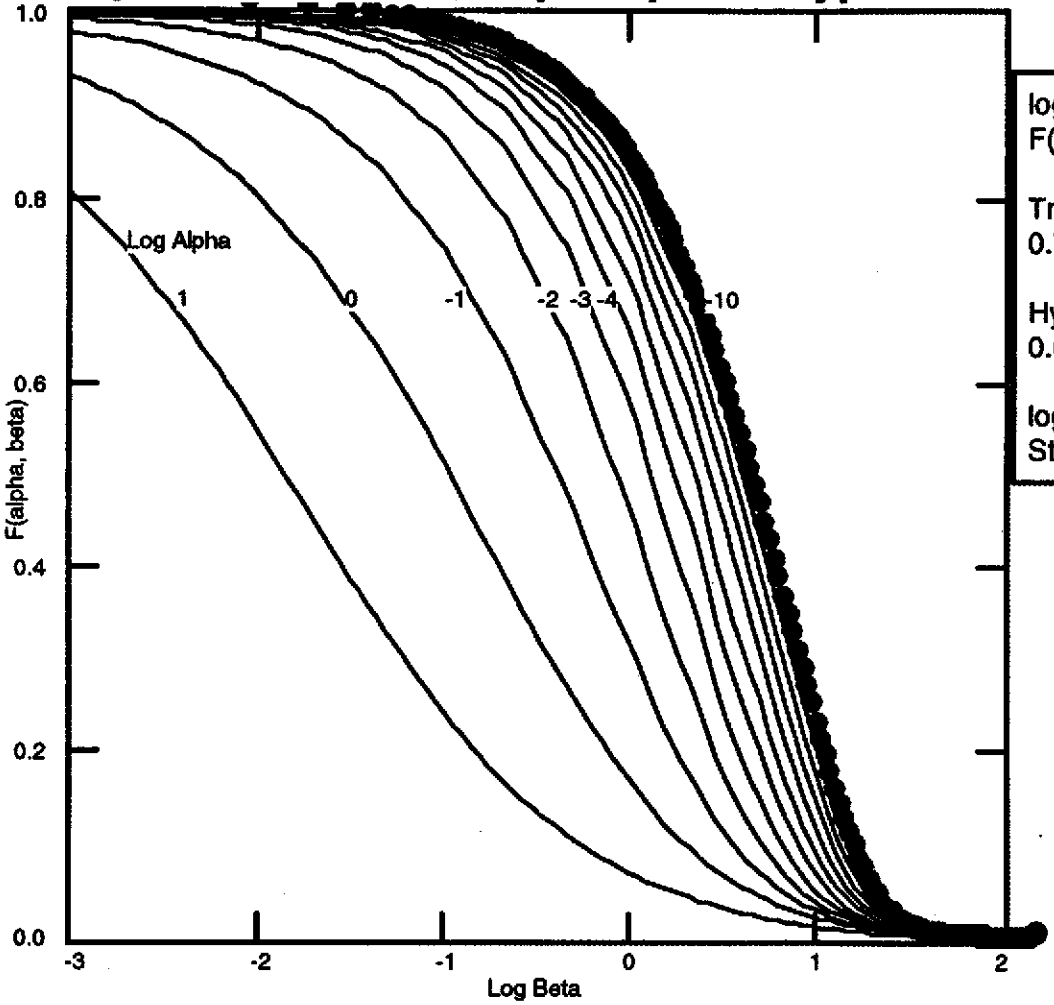
Former Gulf States Creosoting Site Hattiesburg, Mississippi MW-03



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve

Well MW-03



log Beta = 2.081
F(alpha, beta) = 0.4938

Transmissivity
0.7766 meters2/day

Hydraulic Conductivity
0.6705 meters/day

log(Alpha) = -10.
Storativity = 5.88e-012

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 29, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.           TROLL
Serial number:         00000890
Unit name:             SP4000

Report generated:      05/01/97     10:36:21
Report from file:      A:\MW-03-A.BIN

[illegible]st name: MW-03-A

Test defined on:       04/29/97     15:17:04
Test started on:       04/29/97     15:47:35
Test stopped on:       04/29/97     17:31:45
Test extracted on:     04/29/97     17:39:32

Data gathered using Logarithmic testing
   Maximum time between data points:       2.0000          Minutes.
   Number of data samples:        157

Channel number [2]
  Measurement type:    Pressure/Level
  Channel name:        OnBoard Pressure
  Specific gravity:       1.000
  Mode:     TOC
  User-defined reference:           12.110     Feet H2O
  Referenced on:       channel definition.
  Pressure head at reference:       22.496     Feet H2O

Channel number [1]
  Measurement type:    Temperature
  Channel name:        OnBoard Temp


                                        Channel[2]   Channel[1]
 Date         Time         ET (min)     Feet H2O     Fahrenheit
--------     --------    ------------  -----------  -----------
04/29/97     15:47:35        0.0000         7.712         70.63
04/29/97     15:47:35        0.0050         6.187         70.64
[illegible]/29/97     15:47:35        0.0100         5.025         70.65
[illegible]29/97     15:47:35        0.0150         5.525         70.66
04/29/97     15:47:36        0.0200         5.950         70.66
04/29/97     15:47:36        0.0250         5.717         70.67
04/29/97     15:47:36        0.0300         5.811         70.67
04/29/97     15:47:37        0.0350         6.095         70.68
04/29/97     15:47:37        0.0400         5.717         70.69
04/29/97     15:47:37        0.0450         5.486         70.69
04/29/97     15:47:38        0.0500         5.551         70.71
04/29/97     15:47:38        0.0550         5.689         70.71
04/29/97     15:47:38        0.0600         6.688         70.71
04/29/97     15:47:38        0.0650        10.390         70.72
04/29/97     15:47:39        0.0700         8.517         70.72
04/29/97     15:47:39        0.0750         6.999         70.73
04/29/97     15:47:39        0.0800         7.050         70.73
04/29/97     15:47:40        0.0850         7.853         70.73
04/29/97     15:47:40        0.0900         8.084         70.74
04/29/97     15:47:40        0.0950         7.742         70.74
04/29/97     15:47:41        0.1000         7.594         70.74
04/29/97     15:47:41        0.1058         7.763         70.75
04/29/97     15:47:41        0.1120         7.823         70.75
04/29/97     15:47:42        0.1185         7.754         70.76
04/29/97     15:47:42        0.1255         7.781         70.76
04/29/97     15:47:42        0.1328         7.807         70.77
04/29/97     15:47:43        0.1407         7.802         70.77
04/29/97     15:47:43        0.1490         7.823         70.78
04/29/97     15:47:44        0.1578         7.832         70.78
04/29/97     15:47:45        0.1672         7.846         70.78
04/29/97     15:47:45        0.1770         7.857         70.78
04/29/97     15:47:46        0.1875         7.867         70.79
04/29/97     15:47:46        0.1985         7.883         70.79
[illegible]29/97     15:47:47        0.2102         7.892         70.79
[illegible]/29/97     15:47:48        0.2227         7.911         70.79
04/29/97     15:47:49        0.2358         7.917         70.80
04/29/97     15:47:49        0.2498         7.940         70.80
04/29/97     15:47:50        0.2647         7.952         70.79
04/29/97     15:47:51        0.2803         7.970         70.79
04/29/97     15:47:52        0.2970         7.991         70.80
```

```
04/29/97   15:47:53    0.3147    8.005    70.80
04/29/97   15:47:55    0.3333    8.026    70.80
04/29/97   15:47:56    0.3532    8.049    70.80
04/29/97   15:47:57    0.3742    8.065    70.80
04/29/97   15:47:58    0.3963    8.090    70.80
04/29/97   15:48:00    0.4198    8.113    70.82
04/29/97   15:48:01    0.4447    8.139    70.82
[illegible]/29/97   15:48:03    0.4697    8.160    70.82
04/29/97   15:48:04    0.4963    8.185    70.82
04/29/97   15:48:06    0.5247    8.208    70.82
04/29/97   15:48:08    0.5547    8.238    70.82
04/29/97   15:48:10    0.5863    8.268    70.82
04/29/97   15:48:12    0.6213    8.298    70.82
04/29/97   15:48:14    0.6580    8.323    70.82
04/29/97   15:48:16    0.6963    8.358    70.82
04/29/97   15:48:19    0.7380    8.397    70.82
04/29/97   15:48:21    0.7813    8.436    70.82
04/29/97   15:48:24    0.8280    8.480    70.82
04/29/97   15:48:27    0.8763    8.519    70.82
04/29/97   15:48:30    0.9280    8.566    70.82
04/29/97   15:48:33    0.9830    8.609    70.82
04/29/97   15:48:37    1.0413    8.656    70.82
04/29/97   15:48:41    1.1030    8.709    70.82
04/29/97   15:48:45    1.1680    8.755    70.80
04/29/97   15:48:49    1.2380    8.808    70.80
04/29/97   15:48:53    1.3113    8.863    70.80
04/29/97   15:48:58    1.3897    8.919    70.80
04/29/97   15:49:03    1.4730    8.976    70.80
04/29/97   15:49:08    1.5613    9.041    70.79
04/29/97   15:49:14    1.6547    9.101    70.79
04/29/97   15:49:20    1.7530    9.165    70.79
04/29/97   15:49:26    1.8580    9.235    70.78
04/29/97   15:49:33    1.9680    9.304    70.78
04/29/97   15:49:40    2.0847    9.373    70.77
04/29/97   15:49:47    2.2097    9.447    70.77
04/29/97   15:49:55    2.3413    9.518    70.77
04/29/97   15:50:03    2.4813    9.592    70.76
[illegible]/29/97   15:50:12    2.6297    9.675    70.76
[illegible]/29/97   15:50:22    2.7863    9.751    70.76
04/29/97   15:50:32    2.9530    9.830    70.75
04/29/97   15:50:42    3.1297    9.917    70.75
04/29/97   15:50:53    3.3163    9.998    70.74
04/29/97   15:51:05    3.5147   10.081    70.74
04/29/97   15:51:18    3.7247   10.171    70.73
04/29/97   15:51:31    3.9463   10.252    70.73
04/29/97   15:51:45    4.1813   10.339    70.72
04/29/97   15:52:00    4.4297   10.425    70.72
04/29/97   15:52:16    4.6930   10.512    70.71
04/29/97   15:52:33    4.9730   10.593    70.71
04/29/97   15:52:51    5.2697   10.681    70.69
04/29/97   15:53:09    5.5830   10.766    70.68
04/29/97   15:53:29    5.9147   10.852    70.68
04/29/97   15:53:50    6.2663   10.935    70.67
04/29/97   15:54:13    6.6397   11.015    70.66
04/29/97   15:54:37    7.0347   11.103    70.65
04/29/97   15:55:02    7.4530   11.179    70.64
04/29/97   15:55:28    7.8963   11.257    70.64
04/29/97   15:55:56    8.3663   11.336    70.63
04/29/97   15:56:26    8.8647   11.407    70.62
04/29/97   15:56:58    9.3913   11.481    70.61
04/29/97   15:57:31    9.9497   11.550    70.60
04/29/97   15:58:07   10.5413   11.615    70.60
04/29/97   15:58:45   11.1680   11.670    70.58
04/29/97   15:59:24   11.8313   11.728    70.57
04/29/97   16:00:07   12.5347   11.779    70.57
04/29/97   16:00:51   13.2797   11.823    70.56
04/29/97   16:01:39   14.0697   11.866    70.56
04/29/97   16:02:29   14.9063   11.899    70.56
[illegible]/29/97   16:03:22   15.7913   11.931    70.55
04/29/97   16:04:18   16.7297   11.956    70.55
04/29/97   16:05:18   17.7230   11.977    70.55
04/29/97   16:06:21   18.7763   11.998    70.54
04/29/97   16:07:28   19.8913   12.012    70.54
04/29/97   16:08:39   21.0730   12.026    70.54
04/29/97   16:09:54   22.3247   12.037    70.54
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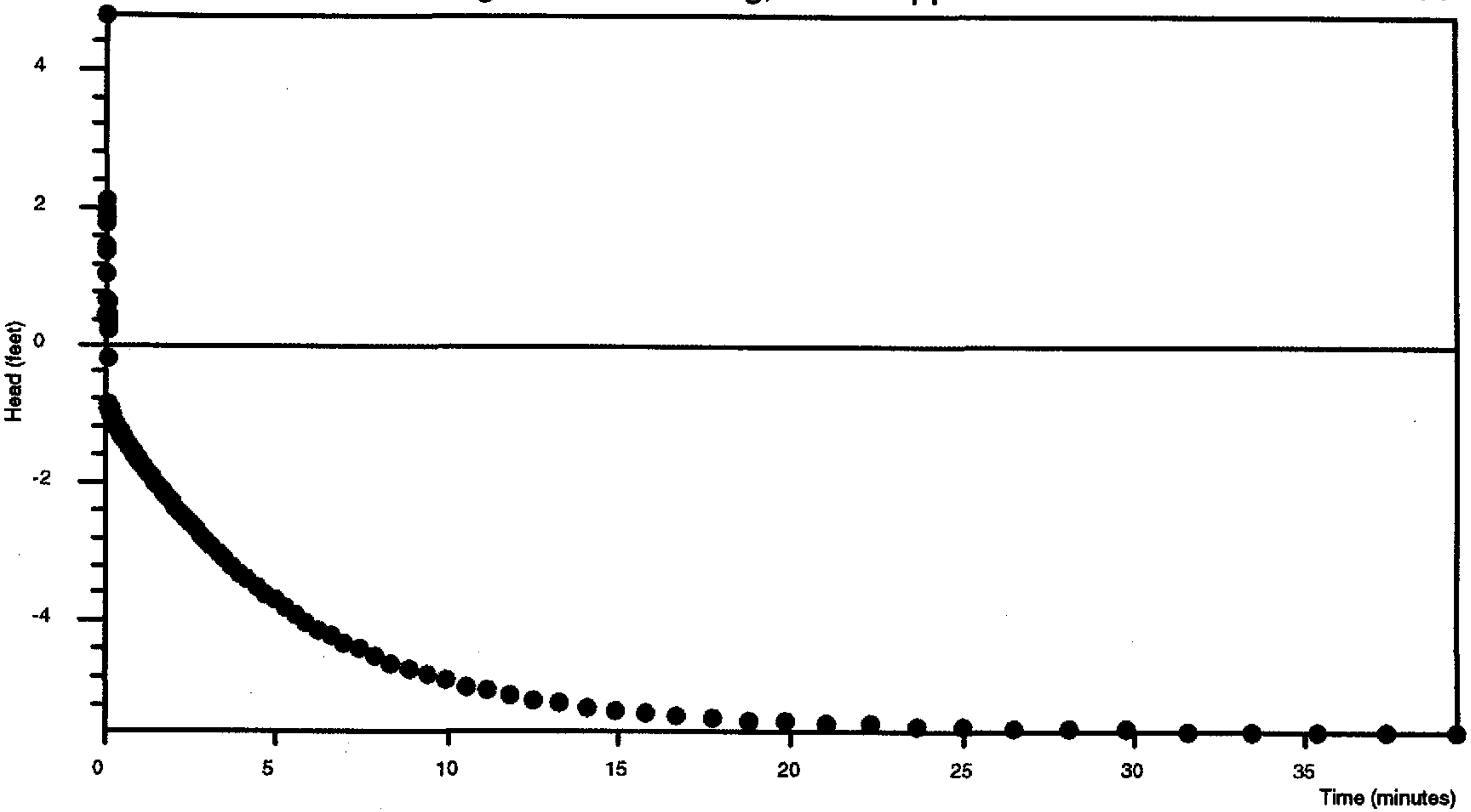
04/29/97	16:11:13	23.6497	12.046	70.53
04/29/97	16:12:38	25.0547	12.051	70.54
04/29/97	16:14:07	26.5430	12.060	70.53
04/29/97	16:15:42	28.1180	12.065	70.53
04/29/97	16:17:22	29.7863	12.067	70.53
04/29/97	16:19:08	31.5547	12.072	70.53
04/29/97	16:21:00	33.4280	12.076	70.52
4/29/97	16:22:59	35.4113	12.081	70.52
/29/97	16:24:59	37.4113	12.076	70.52
04/29/97	16:26:59	39.4113	12.081	70.52
04/29/97	16:28:59	41.4113	12.076	70.52
04/29/97	16:30:59	43.4113	12.086	70.52
04/29/97	16:32:59	45.4113	12.081	70.52
04/29/97	16:34:59	47.4113	12.086	70.52
04/29/97	16:36:59	49.4113	12.086	70.52
04/29/97	16:38:59	51.4113	12.090	70.52
04/29/97	16:40:59	53.4113	12.086	70.52
04/29/97	16:42:59	55.4113	12.090	70.52
04/29/97	16:44:59	57.4113	12.090	70.52
04/29/97	16:46:59	59.4113	12.090	70.52
04/29/97	16:48:59	61.4113	12.090	70.53
04/29/97	16:50:59	63.4113	12.090	70.52
04/29/97	16:52:59	65.4113	12.090	70.52
04/29/97	16:54:59	67.4113	12.090	70.52
04/29/97	16:56:59	69.4113	12.090	70.52
04/29/97	16:58:59	71.4113	12.095	70.52
04/29/97	17:00:59	73.4113	12.090	70.52
04/29/97	17:02:59	75.4113	12.090	70.52
04/29/97	17:04:59	77.4113	12.090	70.52
04/29/97	17:06:59	79.4113	12.090	70.52
04/29/97	17:08:59	81.4113	12.090	70.52
04/29/97	17:10:59	83.4113	12.090	70.52
04/29/97	17:12:59	85.4113	12.095	70.52
04/29/97	17:14:59	87.4113	12.095	70.52
04/29/97	17:16:59	89.4113	12.090	70.52
04/29/97	17:18:59	91.4113	12.090	70.52
04/29/97	17:20:59	93.4113	12.090	70.52
04/29/97	17:22:59	95.4113	12.090	70.53
/29/97	17:24:59	97.4113	12.086	70.52
/29/97	17:26:59	99.4113	12.086	70.52
04/29/97	17:28:59	101.4113	12.072	70.60
04/29/97	17:30:59	103.4113	12.086	70.56

MW-03 Rising Head April 29, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

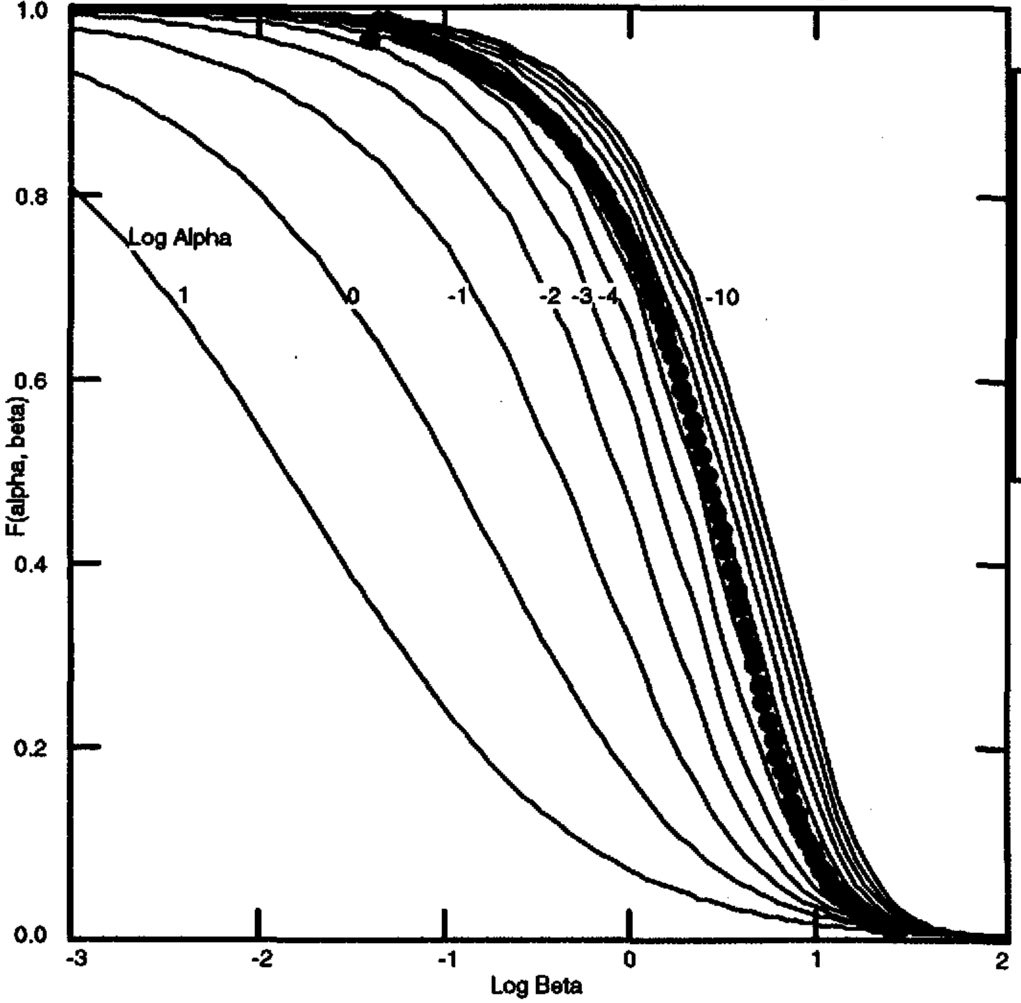
MW-03



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve

Well MW-03



log Beta = 1.771
F(alpha, beta) = 0.9365

Transmissivity
0.3807 meters2/day

Hydraulic Conductivity
0.3287 meters/day

log(Alpha) = -6.
Storativity = 5.88e-008

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 29, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.           TROLL
Serial number:         00000890
Unit name:             SP4000

Report generated:      05/01/97     10:37:07
Report from file:      A:\MW-03-B.BIN

[illegible]st name: MW-03-B

Test defined on:       04/29/97     17:36:46
Test started on:       04/29/97     17:37:53
Test stopped on:       04/29/97     18:17:59
Test extracted on:     04/29/97     18:19:01

Data gathered using Logarithmic testing
   Maximum time between data points:        2.0000           Minutes.
   Number of data samples:          125

Channel number [1]
  Measurement type:    Temperature
  Channel name:        OnBoard Temp

Channel number [2]
  Measurement type:    Pressure/Level
  Channel name:        OnBoard Pressure
  Specific gravity:       1.000
  Mode:     TOC
  User-defined reference:             12.080     Feet H2O
  Referenced on:       channel definition.
  Pressure head at reference:         22.517     Feet H2O


                                             Channel[1]   Channel[2]
  Date         Time          ET (min)      Fahrenheit   Feet H2O
--------    --------     ------------  -----------  -----------
04/29/97    17:37:53          0.0000       70.71        17.685
04/29/97    17:37:53          0.0050       70.72        17.539
04/29/97    17:37:53          0.0100       70.73        17.565
[illegible]/29/97    17:37:53          0.0150       70.74        17.475
04/29/97    17:37:54          0.0200       70.75        17.449
04/29/97    17:37:54          0.0250       70.75        17.431
04/29/97    17:37:54          0.0300       70.75        17.371
04/29/97    17:37:55          0.0350       70.76        20.328
04/29/97    17:37:55          0.0400       70.76        16.979
04/29/97    17:37:55          0.0450       70.77        17.036
04/29/97    17:37:56          0.0500       70.77        16.967
04/29/97    17:37:56          0.0550       70.78        16.972
04/29/97    17:37:56          0.0600       70.78        16.040
04/29/97    17:37:56          0.0650       70.78        16.621
04/29/97    17:37:57          0.0700       70.78        16.621
04/29/97    17:37:57          0.0750       70.79        16.268
04/29/97    17:37:57          0.0800       70.79        16.238
04/29/97    17:37:58          0.0850       70.79        16.227
04/29/97    17:37:58          0.0900       70.80        16.045
04/29/97    17:37:58          0.0950       70.80        15.939
04/29/97    17:37:59          0.1000       70.80        15.809
04/29/97    17:37:59          0.1058       70.83        15.429
04/29/97    17:37:59          0.1120       70.82        14.684
04/29/97    17:38:00          0.1185       70.83        14.767
04/29/97    17:38:00          0.1255       70.84        14.762
04/29/97    17:38:00          0.1328       70.84        14.748
04/29/97    17:38:01          0.1407       70.84        14.702
04/29/97    17:38:01          0.1490       70.87        14.693
04/29/97    17:38:02          0.1578       70.87        14.677
04/29/97    17:38:03          0.1672       70.87        14.663
04/29/97    17:38:03          0.1770       70.87        14.644
04/29/97    17:38:04          0.1875       70.87        14.633
04/29/97    17:38:04          0.1985       70.88        14.619
[illegible]29/97    17:38:05          0.2102       70.88        14.603
04/29/97    17:38:06          0.2227       70.88        14.584
04/29/97    17:38:07          0.2358       70.88        14.568
04/29/97    17:38:07          0.2498       70.88        14.555
04/29/97    17:38:08          0.2647       70.88        14.538
04/29/97    17:38:09          0.2803       70.88        14.520
04/29/97    17:38:10          0.2970       70.88        14.499
```

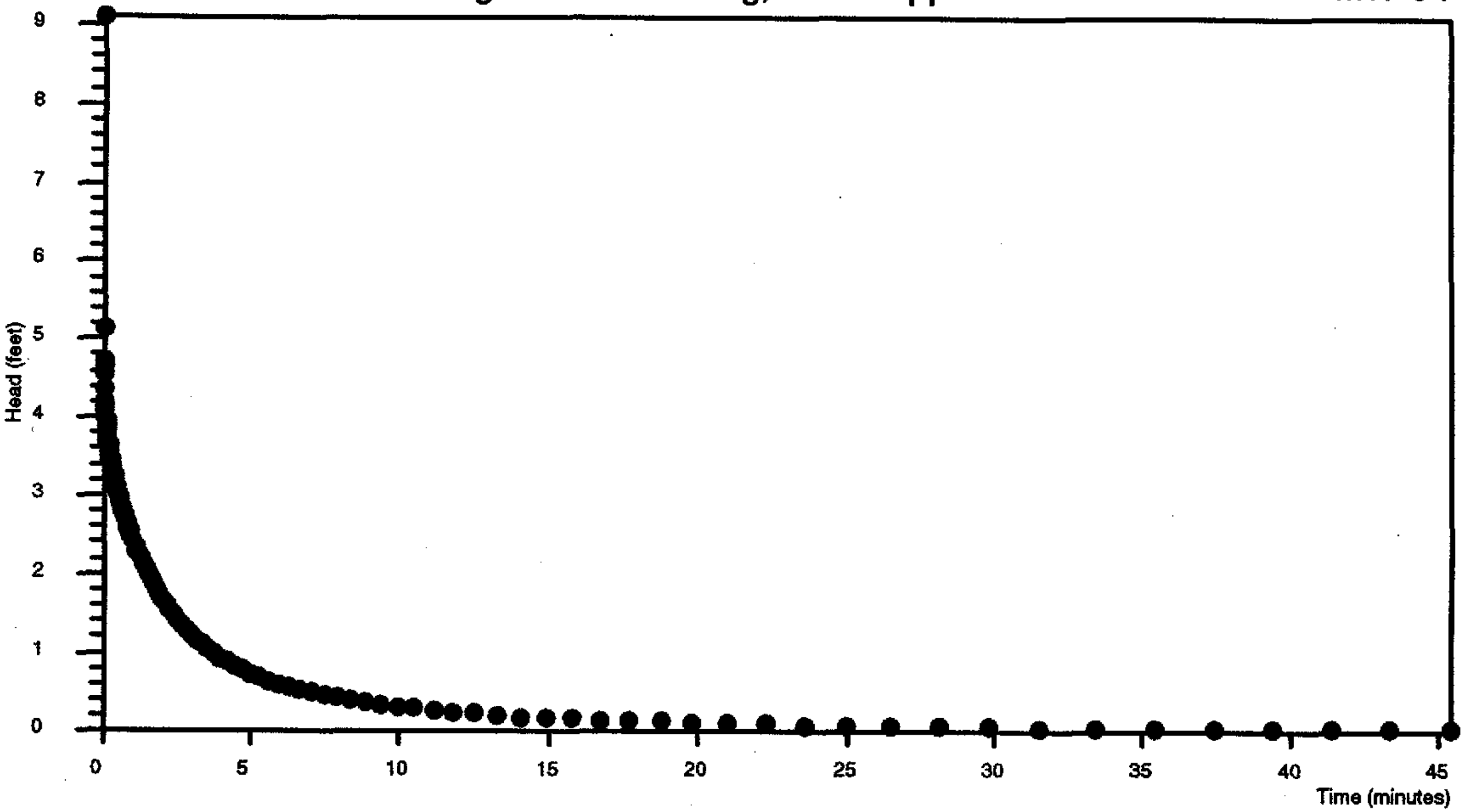
04/29/97	17:38:11	0.3147	70.88	14.481
04/29/97	17:38:13	0.3333	70.89	14.465
04/29/97	17:38:14	0.3532	70.88	14.444
04/29/97	17:38:15	0.3742	70.89	14.425
04/29/97	17:38:16	0.3963	70.89	14.400
04/29/97	17:38:18	0.4198	70.89	14.384
04/29/97	17:38:19	0.4447	70.89	14.361
[illegible]/29/97	17:38:21	0.4697	70.89	14.340
[illegible]29/97	17:38:22	0.4963	70.90	14.315
04/29/97	17:38:24	0.5247	70.90	14.292
04/29/97	17:38:26	0.5547	70.90	14.266
04/29/97	17:38:28	0.5863	70.90	14.241
04/29/97	17:38:30	0.6213	70.90	14.215
04/29/97	17:38:32	0.6580	70.90	14.188
04/29/97	17:38:34	0.6963	70.90	14.155
04/29/97	17:38:37	0.7380	70.90	14.128
04/29/97	17:38:39	0.7813	70.90	14.093
04/29/97	17:38:42	0.8280	70.90	14.059
04/29/97	17:38:45	0.8763	70.91	14.024
04/29/97	17:38:48	0.9280	70.91	13.992
04/29/97	17:38:51	0.9830	70.91	13.957
04/29/97	17:38:55	1.0413	70.91	13.913
04/29/97	17:38:59	1.1030	70.90	13.869
04/29/97	17:39:03	1.1680	70.91	13.823
04/29/97	17:39:07	1.2380	70.90	13.779
04/29/97	17:39:11	1.3113	70.90	13.731
04/29/97	17:39:16	1.3897	70.90	13.680
04/29/97	17:39:21	1.4730	70.90	13.630
04/29/97	17:39:26	1.5613	70.89	13.572
04/29/97	17:39:32	1.6547	70.90	13.512
04/29/97	17:39:38	1.7530	70.97	13.452
04/29/97	17:39:44	1.8580	70.95	13.387
04/29/97	17:39:51	1.9680	70.94	13.323
04/29/97	17:39:58	2.0847	70.94	13.254
04/29/97	17:40:05	2.2097	70.93	13.180
04/29/97	17:40:13	2.3413	70.93	13.108
04/29/97	17:40:21	2.4813	70.93	13.030
[illegible]/29/97	17:40:30	2.6297	70.91	12.947
[illegible]29/97	17:40:40	2.7863	70.90	12.861
04/29/97	17:40:50	2.9530	70.90	12.776
04/29/97	17:41:00	3.1297	70.90	12.688
04/29/97	17:41:11	3.3163	70.89	12.598
04/29/97	17:41:23	3.5147	70.89	12.504
04/29/97	17:41:36	3.7247	70.88	12.409
04/29/97	17:41:49	3.9463	70.87	12.310
04/29/97	17:42:03	4.1813	70.87	12.211
04/29/97	17:42:18	4.4297	70.87	12.112
04/29/97	17:42:34	4.6930	70.86	12.013
04/29/97	17:42:51	4.9730	70.86	11.909
04/29/97	17:43:09	5.2697	70.85	11.805
04/29/97	17:43:27	5.5830	70.84	11.706
04/29/97	17:43:47	5.9147	70.83	11.602
04/29/97	17:44:08	6.2663	70.83	11.503
04/29/97	17:44:31	6.6397	70.82	11.404
04/29/97	17:44:55	7.0347	70.80	11.304
04/29/97	17:45:20	7.4530	70.79	11.210
04/29/97	17:45:46	7.8963	70.79	11.115
04/29/97	17:46:14	8.3663	70.77	11.025
04/29/97	17:46:44	8.8647	70.77	10.935
04/29/97	17:47:16	9.3913	70.76	10.852
04/29/97	17:47:49	9.9497	70.75	10.772
04/29/97	17:48:25	10.5413	70.74	10.693
04/29/97	17:49:03	11.1680	70.74	10.624
04/29/97	17:49:42	11.8313	70.73	10.559
04/29/97	17:50:25	12.5347	70.73	10.499
04/29/97	17:51:09	13.2797	70.72	10.442
04/29/97	17:51:57	14.0697	70.71	10.396
[illegible]/29/97	17:52:47	14.9063	70.71	10.347
[illegible]29/97	17:53:40	15.7913	70.71	10.308
04/29/97	17:54:36	16.7297	70.69	10.271
04/29/97	17:55:36	17.7230	70.69	10.241
04/29/97	17:56:39	18.7763	70.69	10.213
04/29/97	17:57:46	19.8913	70.68	10.188
04/29/97	17:58:57	21.0730	70.68	10.163
04/29/97	18:00:12	22.3247	70.68	10.144

MW-04 Rising Head April 29, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

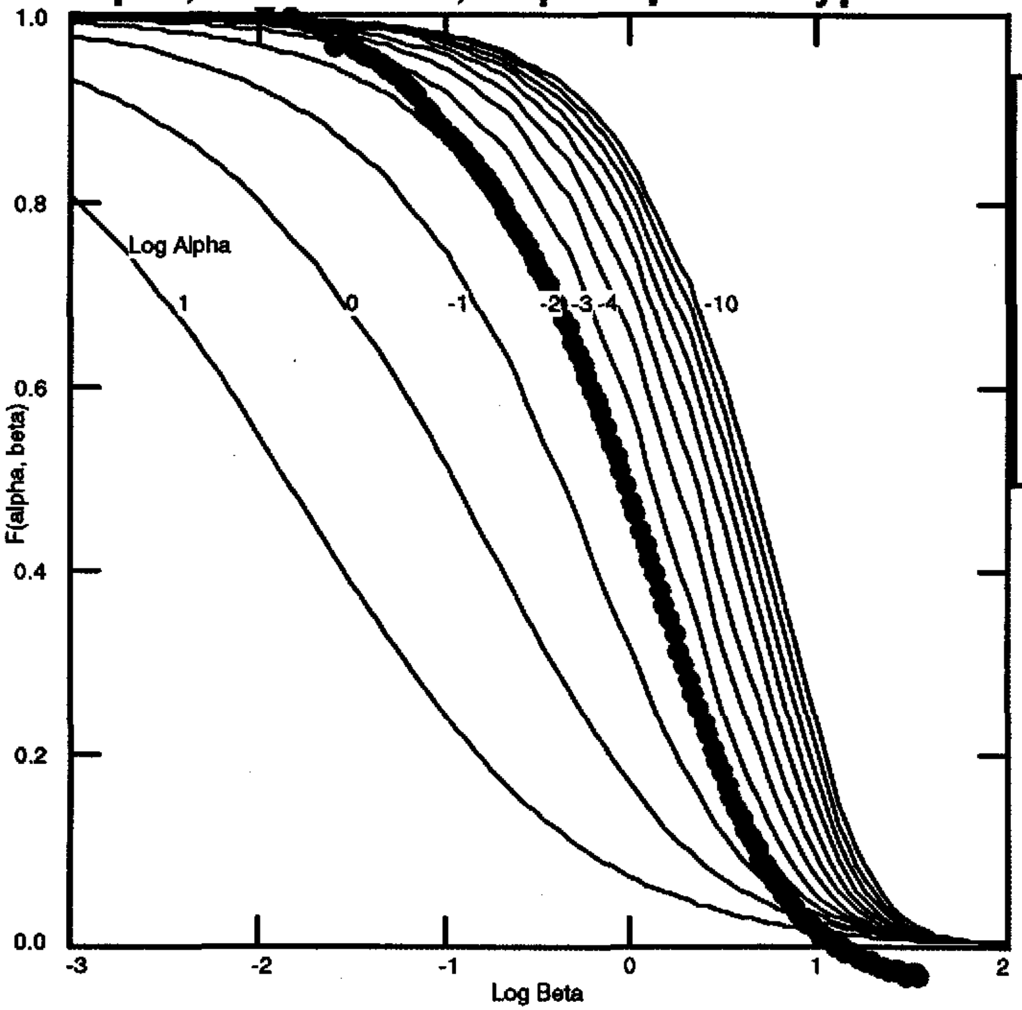
MW-04



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve

Well MW-04



log Beta = 1.802
F(alpha, beta) = 0.4628

Transmissivity
0.4088 meters2/day

Hydraulic Conductivity
0.7452 meters/day

log(Alpha) = -3.
Storativity = 5.88e-005

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 29, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.            TROLL
Serial number:          00000211
Unit name:              SP4000

Report generated:       05/01/97     10:37:40
Report from file:       A:\MW-04-A.BIN

[illegible]st name: MW-04-A

Test defined on:        04/29/97     16:17:36
Test started on:        04/29/97     16:18:32
Test stopped on:        04/29/97     17:04:37
Test extracted on:      04/29/97     17:16:33

Data gathered using Logarithmic testing
   Maximum time between data points:        2.0000           Minutes.
   Number of data samples:          128

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:     1.000
  Mode:    TOC
  User-defined reference:            12.270     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:        24.174     Feet H2O


                                          Channel[1]   Channel[2]
 Date          Time        ET (min)     Fahrenheit   Feet H2O
--------     --------    ------------  -----------   -----------
04/29/97     16:18:32       0.0000        69.35         16.547
04/29/97     16:18:32       0.0050        69.35         16.291
[illegible]/29/97     16:18:32       0.0100        69.36         17.315
[illegible]29/97     16:18:32       0.0150        69.38         17.317
04/29/97     16:18:33       0.0200        69.38         16.794
04/29/97     16:18:33       0.0250        69.39         16.884
04/29/97     16:18:33       0.0300        69.39         16.815
04/29/97     16:18:34       0.0350        69.40         16.713
04/29/97     16:18:34       0.0400        69.40         21.250
04/29/97     16:18:34       0.0450        69.41         16.160
04/29/97     16:18:35       0.0500        69.42         16.381
04/29/97     16:18:35       0.0550        69.42         16.372
04/29/97     16:18:35       0.0600        69.43         16.335
04/29/97     16:18:35       0.0650        69.43         16.289
04/29/97     16:18:36       0.0700        69.43         16.266
04/29/97     16:18:36       0.0750        69.44         16.233
04/29/97     16:18:36       0.0800        69.44         16.164
04/29/97     16:18:37       0.0850        69.45         16.199
04/29/97     16:18:37       0.0900        69.45         16.148
04/29/97     16:18:37       0.0950        69.46         16.134
04/29/97     16:18:38       0.1000        69.46         16.113
04/29/97     16:18:38       0.1058        69.46         16.093
04/29/97     16:18:38       0.1120        69.47         16.063
04/29/97     16:18:39       0.1185        69.47         16.037
04/29/97     16:18:39       0.1255        69.49         16.007
04/29/97     16:18:39       0.1328        69.50         15.977
04/29/97     16:18:40       0.1407        69.50         15.952
04/29/97     16:18:40       0.1490        69.53         15.906
04/29/97     16:18:41       0.1578        69.53         15.880
04/29/97     16:18:42       0.1672        69.53         15.846
04/29/97     16:18:42       0.1770        69.54         15.820
04/29/97     16:18:43       0.1875        69.54         15.790
04/29/97     16:18:43       0.1985        69.54         15.760
[illegible]29/97     16:18:44       0.2102        69.54         15.730
[illegible]29/97     16:18:45       0.2227        69.55         15.701
04/29/97     16:18:46       0.2358        69.55         15.671
04/29/97     16:18:46       0.2498        69.55         15.638
04/29/97     16:18:47       0.2647        69.55         15.608
04/29/97     16:18:48       0.2803        69.55         15.574
04/29/97     16:18:49       0.2970        69.55         15.539
```

```
04/29/97    16:18:50     0.3147    69.54    15.502
04/29/97    16:18:52     0.3333    69.54    15.468
04/29/97    16:18:53     0.3532    69.55    15.428
04/29/97    16:18:54     0.3742    69.55    15.391
04/29/97    16:18:55     0.3963    69.55    15.352
04/29/97    16:18:57     0.4198    69.55    15.315
04/29/97    16:18:58     0.4447    69.54    15.271
  /29/97    16:19:00     0.4697    69.54    15.232
  /29/97    16:19:01     0.4963    69.55    15.191
04/29/97    16:19:03     0.5247    69.55    15.152
04/29/97    16:19:05     0.5547    69.55    15.105
04/29/97    16:19:07     0.5863    69.54    15.064
04/29/97    16:19:09     0.6213    69.54    15.013
04/29/97    16:19:11     0.6580    69.54    14.965
04/29/97    16:19:13     0.6963    69.54    14.914
04/29/97    16:19:16     0.7380    69.54    14.863
04/29/97    16:19:18     0.7813    69.54    14.812
04/29/97    16:19:21     0.8280    69.54    14.757
04/29/97    16:19:24     0.8763    69.54    14.706
04/29/97    16:19:27     0.9280    69.54    14.651
04/29/97    16:19:30     0.9830    69.54    14.596
04/29/97    16:19:34     1.0413    69.53    14.536
04/29/97    16:19:38     1.1030    69.53    14.471
04/29/97    16:19:42     1.1680    69.53    14.416
04/29/97    16:19:46     1.2380    69.53    14.353
04/29/97    16:19:50     1.3113    69.52    14.289
04/29/97    16:19:55     1.3897    69.53    14.224
04/29/97    16:20:00     1.4730    69.52    14.167
04/29/97    16:20:05     1.5613    69.51    14.102
04/29/97    16:20:11     1.6547    69.50    14.033
04/29/97    16:20:17     1.7530    69.50    13.971
04/29/97    16:20:23     1.8580    69.50    13.906
04/29/97    16:20:30     1.9680    69.49    13.841
04/29/97    16:20:37     2.0847    69.49    13.774
04/29/97    16:20:44     2.2097    69.47    13.710
04/29/97    16:20:52     2.3413    69.47    13.648
04/29/97    16:21:00     2.4813    69.46    13.583
  /29/97    16:21:09     2.6297    69.46    13.518
   29/97    16:21:19     2.7863    69.45    13.458
04/29/97    16:21:29     2.9530    69.45    13.396
04/29/97    16:21:39     3.1297    69.44    13.336
04/29/97    16:21:50     3.3163    69.44    13.276
04/29/97    16:22:02     3.5147    69.43    13.216
04/29/97    16:22:15     3.7247    69.42    13.161
04/29/97    16:22:28     3.9463    69.42    13.106
04/29/97    16:22:42     4.1813    69.41    13.055
04/29/97    16:22:57     4.4297    69.40    13.004
04/29/97    16:23:13     4.6930    69.40    12.953
04/29/97    16:23:30     4.9730    69.39    12.905
04/29/97    16:23:48     5.2697    69.38    12.859
04/29/97    16:24:06     5.5830    69.36    12.817
04/29/97    16:24:26     5.9147    69.35    12.773
04/29/97    16:24:47     6.2663    69.34    12.736
04/29/97    16:25:10     6.6397    69.34    12.697
04/29/97    16:25:34     7.0347    69.33    12.663
04/29/97    16:25:59     7.4530    69.32    12.628
04/29/97    16:26:25     7.8963    69.31    12.598
04/29/97    16:26:53     8.3663    69.30    12.566
04/29/97    16:27:23     8.8647    69.29    12.540
04/29/97    16:27:55     9.3913    69.27    12.515
04/29/97    16:28:28     9.9497    69.26    12.487
04/29/97    16:29:04    10.5413    69.25    12.462
04/29/97    16:29:42    11.1680    69.24    12.441
04/29/97    16:30:21    11.8313    69.24    12.425
04/29/97    16:31:04    12.5347    69.23    12.404
04/29/97    16:31:48    13.2797    69.23    12.386
04/29/97    16:32:36    14.0697    69.22    12.360
04/29/97    16:33:26    14.9063    69.21    12.356
    9/97    16:34:19    15.7913    69.21    12.344
   29/97    16:35:15    16.7297    69.20    12.326
04/29/97    16:36:15    17.7230    69.20    12.319
04/29/97    16:37:18    18.7763    69.18    12.300
04/29/97    16:38:25    19.8913    69.18    12.291
04/29/97    16:39:36    21.0730    69.29    12.284
04/29/97    16:40:51    22.3247    69.25    12.275
```

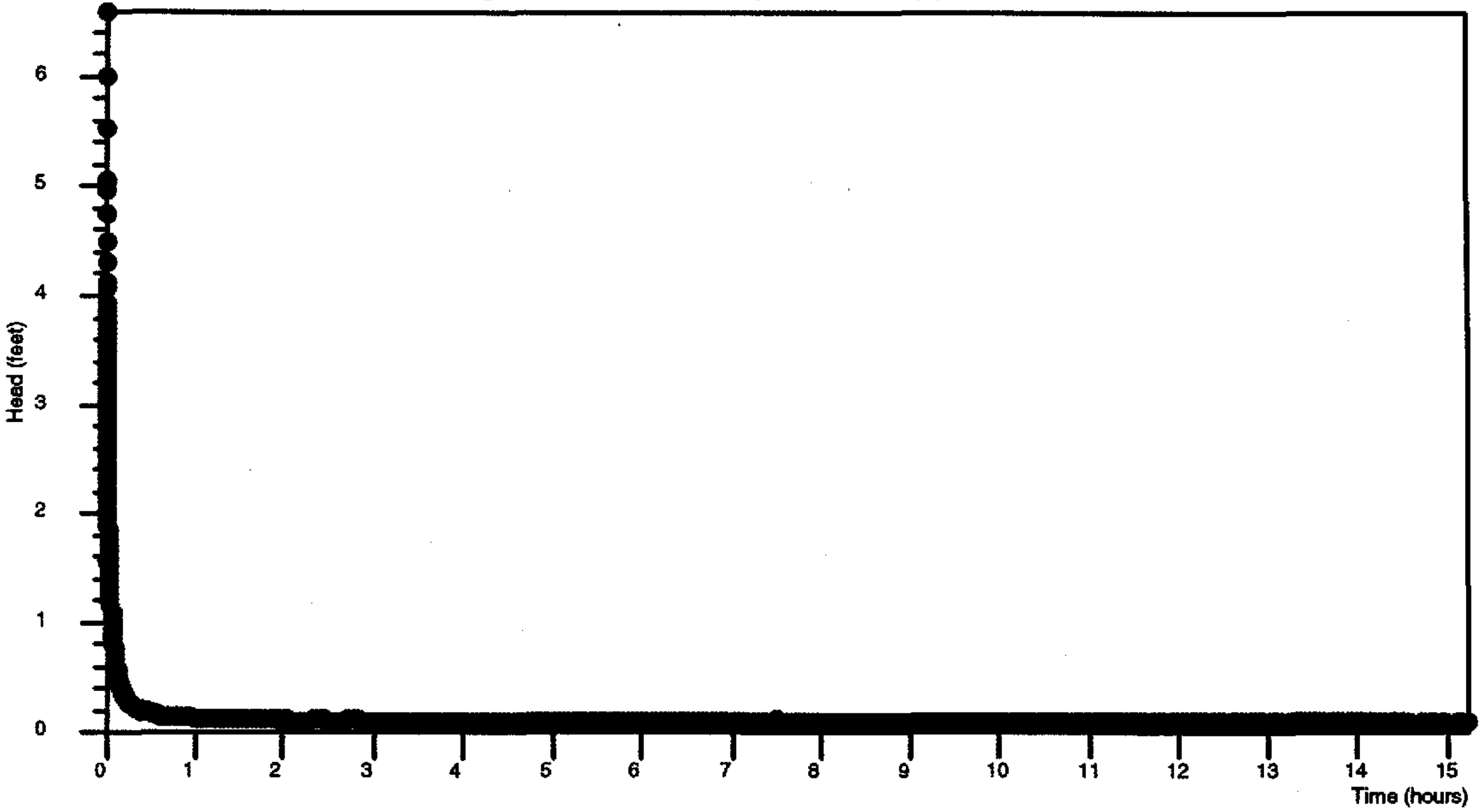
```
04/29/97    16:42:10        23.6497       69.30        12.264
04/29/97    16:43:35        25.0547       69.32        12.259
04/29/97    16:45:04        26.5430       69.33        12.250
04/29/97    16:46:39        28.1180       69.29        12.241
04/29/97    16:48:19        29.7863       69.26        12.238
04/29/97    16:50:05        31.5547       69.23        12.229
04/29/97    16:51:57        33.4280       69.21        12.224
[illegible]/29/97    16:53:56        35.4113       69.31        12.224
[illegible]/29/97    16:55:56        37.4113       69.26        12.208
04/29/97    16:57:56        39.4113       69.27        12.204
04/29/97    16:59:56        41.4113       69.24        12.208
04/29/97    17:01:56        43.4113       69.27        12.213
04/29/97    17:03:56        45.4113       69.31        12.204
```

MW-04 Falling Head April 29, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

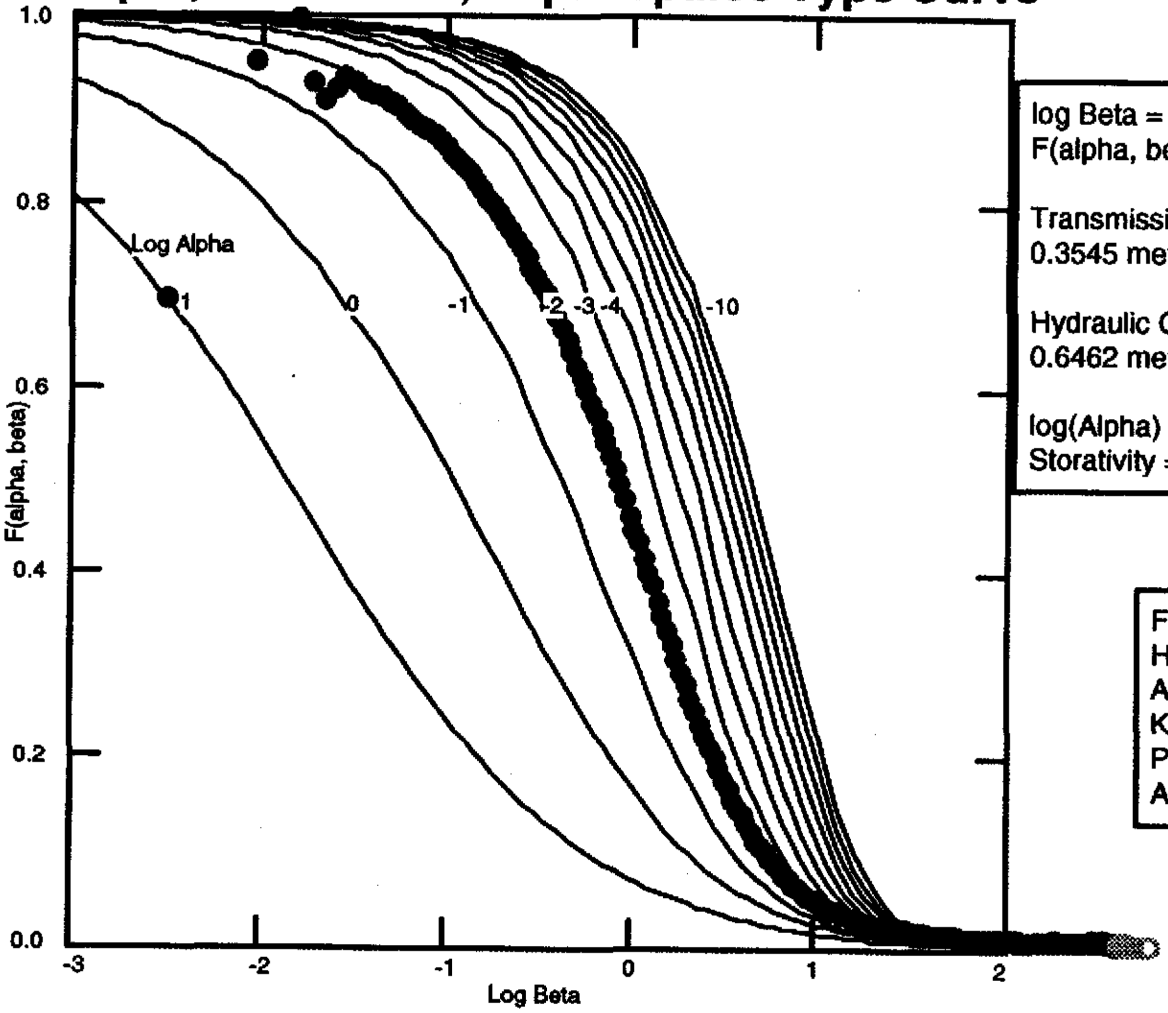
Arithmetic Graph

MW-04



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve



Well MW-04

log Beta = 1.74
F(alpha, beta) = 0.4814

Transmissivity
0.3545 meters2/day

Hydraulic Conductivity
0.6462 meters/day

log(Alpha) = -2.
Storativity = 5.88e-004

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 29, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.            TROLL
Serial number:          00000211
Unit name:              SP4000

Report generated:       05/01/97     10:44:48
Report from file:       A:\MW-04-B.BIN

Test name: MW-04-B

Test defined on:        04/29/97     17:06:05
Test started on:        04/29/97     17:13:34
Test stopped on:        04/30/97     08:27:20
Test extracted on:      04/30/97     08:28:53

Data gathered using Logarithmic testing
   Maximum time between data points:       2.0000           Minutes.
   Number of data samples:            562

Channel number [1]
  Measurement type:    Temperature
  Channel name:        OnBoard Temp

Channel number [2]
  Measurement type:    Pressure/Level
  Channel name:        OnBoard Pressure
  Specific gravity:       1.000
  Mode:     TOC
  User-defined reference:            12.400     Feet H2O
  Referenced on:       channel definition.
  Pressure head at reference:        24.242     Feet H2O


                                            Channel[1]   Channel[2]
 Date          Time           ET (min)     Fahrenheit   Feet H2O
--------     --------     ------------  -----------   -----------
04/29/97     17:13:34           0.0000         69.25        10.851
04/29/97     17:13:34           0.0050         69.26         8.330
04/29/97     17:13:34           0.0100         69.26         7.375
04/29/97     17:13:34           0.0150         69.27         6.416
04/29/97     17:13:35           0.0200         69.29         5.841
04/29/97     17:13:35           0.0250         69.30         6.882
04/29/97     17:13:35           0.0300         69.30         7.440
04/29/97     17:13:36           0.0350         69.30         7.440
04/29/97     17:13:36           0.0400         69.31         7.359
04/29/97     17:13:36           0.0450         69.32         7.666
04/29/97     17:13:37           0.0500         69.32         7.924
04/29/97     17:13:37           0.0550         69.33         8.346
04/29/97     17:13:37           0.0600         69.34         9.509
04/29/97     17:13:37           0.0650         69.34         9.285
04/29/97     17:13:38           0.0700         69.35         8.482
04/29/97     17:13:38           0.0750         69.35         8.116
04/29/97     17:13:38           0.0800         69.35         8.291
04/29/97     17:13:39           0.0850         69.36         8.561
04/29/97     17:13:39           0.0900         69.36         8.646
04/29/97     17:13:39           0.0950         69.38         8.591
04/29/97     17:13:40           0.1000         69.38         8.538
04/29/97     17:13:40           0.1058         69.38         8.561
04/29/97     17:13:40           0.1120         69.39         8.598
04/29/97     17:13:41           0.1185         69.39         8.616
04/29/97     17:13:41           0.1255         69.40         8.628
04/29/97     17:13:41           0.1328         69.41         8.648
04/29/97     17:13:42           0.1407         69.41         8.672
04/29/97     17:13:42           0.1490         69.45         8.706
04/29/97     17:13:43           0.1578         69.44         8.727
04/29/97     17:13:44           0.1672         69.45         8.752
04/29/97     17:13:44           0.1770         69.45         8.773
04/29/97     17:13:45           0.1875         69.45         8.798
04/29/97     17:13:45           0.1985         69.45         8.819
04/29/97     17:13:46           0.2102         69.46         8.847
04/29/97     17:13:47           0.2227         69.46         8.875
04/29/97     17:13:48           0.2358         69.46         8.902
04/29/97     17:13:48           0.2498         69.46         8.930
04/29/97     17:13:49           0.2647         69.46         8.960
04/29/97     17:13:50           0.2803         69.46         8.994
04/29/97     17:13:51           0.2970         69.47         9.029
```

04/29/97	17:13:52	0.3147	69.46	9.064
04/29/97	17:13:54	0.3333	69.46	9.096
04/29/97	17:13:55	0.3532	69.46	9.131
04/29/97	17:13:56	0.3742	69.46	9.170
04/29/97	17:13:57	0.3963	69.47	9.204
04/29/97	17:13:59	0.4198	69.47	9.241
04/29/97	17:14:00	0.4447	69.46	9.285
[illegible]/29/97	17:14:02	0.4697	69.47	9.322
[illegible]/29/97	17:14:03	0.4963	69.47	9.366
04/29/97	17:14:05	0.5247	69.46	9.403
04/29/97	17:14:07	0.5547	69.46	9.447
04/29/97	17:14:09	0.5863	69.47	9.488
04/29/97	17:14:11	0.6213	69.47	9.541
04/29/97	17:14:13	0.6580	69.46	9.587
04/29/97	17:14:15	0.6963	69.46	9.638
04/29/97	17:14:18	0.7380	69.47	9.689
04/29/97	17:14:20	0.7813	69.46	9.740
04/29/97	17:14:23	0.8280	69.46	9.793
04/29/97	17:14:26	0.8763	69.46	9.848
04/29/97	17:14:29	0.9280	69.46	9.899
04/29/97	17:14:32	0.9830	69.46	9.959
04/29/97	17:14:36	1.0413	69.46	10.016
04/29/97	17:14:40	1.1030	69.45	10.072
04/29/97	17:14:44	1.1680	69.45	10.132
04/29/97	17:14:48	1.2380	69.45	10.192
04/29/97	17:14:52	1.3113	69.45	10.256
04/29/97	17:14:57	1.3897	69.45	10.319
04/29/97	17:15:02	1.4730	69.44	10.383
04/29/97	17:15:07	1.5613	69.44	10.448
04/29/97	17:15:13	1.6547	69.43	10.512
04/29/97	17:15:19	1.7530	69.43	10.568
04/29/97	17:15:25	1.8580	69.43	10.639
04/29/97	17:15:32	1.9680	69.42	10.704
04/29/97	17:15:39	2.0847	69.42	10.761
04/29/97	17:15:46	2.2097	69.42	10.831
04/29/97	17:15:54	2.3413	69.41	10.895
04/29/97	17:16:02	2.4813	69.43	10.957
[illegible]/29/97	17:16:11	2.6297	69.41	11.017
[illegible]/29/97	17:16:21	2.7863	69.41	11.077
04/29/97	17:16:31	2.9530	69.40	11.147
04/29/97	17:16:41	3.1297	69.46	11.197
04/29/97	17:16:52	3.3163	69.44	11.257
04/29/97	17:17:04	3.5147	69.43	11.313
04/29/97	17:17:17	3.7247	69.42	11.368
04/29/97	17:17:30	3.9463	69.42	11.419
04/29/97	17:17:44	4.1813	69.41	11.470
04/29/97	17:17:59	4.4297	69.40	11.516
04/29/97	17:18:15	4.6930	69.39	11.562
04/29/97	17:18:32	4.9730	69.38	11.606
04/29/97	17:18:50	5.2697	69.38	11.652
04/29/97	17:19:08	5.5830	69.36	11.696
04/29/97	17:19:28	5.9147	69.35	11.733
04/29/97	17:19:49	6.2663	69.35	11.767
04/29/97	17:20:12	6.6397	69.33	11.806
04/29/97	17:20:36	7.0347	69.32	11.839
04/29/97	17:21:01	7.4530	69.32	11.869
04/29/97	17:21:27	7.8963	69.31	11.899
04/29/97	17:21:55	8.3663	69.30	11.929
04/29/97	17:22:25	8.8647	69.29	11.954
04/29/97	17:22:57	9.3913	69.27	11.979
04/29/97	17:23:30	9.9497	69.26	12.005
04/29/97	17:24:06	10.5413	69.26	12.025
04/29/97	17:24:44	11.1680	69.24	12.044
04/29/97	17:25:23	11.8313	69.24	12.065
04/29/97	17:26:06	12.5347	69.23	12.081
04/29/97	17:26:50	13.2797	69.22	12.099
04/29/97	17:27:38	14.0697	69.22	12.115
04/29/97	17:28:28	14.9063	69.21	12.129
[illegible]/29/97	17:29:21	15.7913	69.21	12.141
04/29/97	17:30:17	16.7297	69.21	12.150
04/29/97	17:31:17	17.7230	69.20	12.159
04/29/97	17:32:20	18.7763	69.20	12.171
04/29/97	17:33:27	19.8913	69.18	12.180
04/29/97	17:34:38	21.0730	69.17	12.187
04/29/97	17:35:53	22.3247	69.17	12.196

04/29/97	17:37:12	23.6497	69.17	12.205
04/29/97	17:38:37	25.0547	69.17	12.215
04/29/97	17:40:06	26.5430	69.17	12.217
04/29/97	17:41:41	28.1180	69.16	12.222
04/29/97	17:43:21	29.7863	69.16	12.231
04/29/97	17:45:07	31.5547	69.16	12.235
04/29/97	17:46:59	33.4280	69.16	12.240
/29/97	17:48:58	35.4113	69.16	12.247
29/97	17:50:58	37.4113	69.16	12.247
04/29/97	17:52:58	39.4113	69.16	12.252
04/29/97	17:54:58	41.4113	69.16	12.256
04/29/97	17:56:58	43.4113	69.16	12.261
04/29/97	17:58:58	45.4113	69.16	12.247
04/29/97	18:00:58	47.4113	69.15	12.256
04/29/97	18:02:58	49.4113	69.15	12.261
04/29/97	18:04:58	51.4113	69.16	12.261
04/29/97	18:06:58	53.4113	69.16	12.265
04/29/97	18:08:58	55.4113	69.16	12.268
04/29/97	18:10:58	57.4113	69.16	12.268
04/29/97	18:12:58	59.4113	69.16	12.272
04/29/97	18:14:58	61.4113	69.16	12.272
04/29/97	18:16:58	63.4113	69.15	12.272
04/29/97	18:18:58	65.4113	69.15	12.272
04/29/97	18:20:58	67.4113	69.16	12.272
04/29/97	18:22:58	69.4113	69.15	12.277
04/29/97	18:24:58	71.4113	69.15	12.277
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04/29/97	18:56:58	103.4113	69.15	12.291
04/29/97	18:58:58	105.4113	69.15	12.291
04/29/97	19:00:58	107.4113	69.16	12.286
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04/29/97	19:14:58	121.4113	69.15	12.295
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04/29/97	19:46:58	153.4113	69.15	12.295
04/29/97	19:48:58	155.4113	69.15	12.295
29/97	19:50:58	157.4113	69.16	12.295
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04/29/97	20:42:58	209.4113	69.15	12.298
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04/29/97	21:02:58	229.4113	69.15	12.302
04/29/97	21:04:58	231.4113	69.15	12.298
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04/29/97	21:14:58	241.4113	69.15	12.302
04/29/97	21:16:58	243.4113	69.15	12.302
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04/29/97	22:08:58	295.4113	69.15	12.302
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04/29/97	22:30:58	317.4113	69.15	12.302
04/29/97	22:32:58	319.4113	69.15	12.307

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04/29/97   22:58:58     345.4113     69.15      12.307
04/29/97   23:00:58     347.4113     69.15      12.307
04/29/97   23:02:58     349.4113     69.15      12.302
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04/29/97   23:08:58     355.4113     69.15      12.307
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04/29/97   23:14:58     361.4113     69.15      12.307
04/29/97   23:16:58     363.4113     69.15      12.307
04/29/97   23:18:58     365.4113     69.15      12.307
04/29/97   23:20:58     367.4113     69.15      12.307
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04/29/97   23:24:58     371.4113     69.16      12.302
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04/29/97   23:30:58     377.4113     69.15      12.307
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04/29/97   23:56:58     403.4113     69.15      12.302
04/29/97   23:58:58     405.4113     69.15      12.302
04/30/97   00:00:58     407.4113     69.15      12.302
04/30/97   00:02:58     409.4113     69.15      12.302
04/30/97   00:04:58     411.4113     69.16      12.302
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04/30/97   01:00:58     467.4113     69.16      12.302
04/30/97   01:02:58     469.4113     69.15      12.302
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04/30/97	01:50:58	517.4113	69.16	12.307
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04/30/97	02:08:58	535.4113	69.15	12.302
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04/30/97	02:12:58	539.4113	69.15	12.302
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04/30/97	02:26:58	553.4113	69.15	12.307
04/30/97	02:28:58	555.4113	69.15	12.307
04/30/97	02:30:58	557.4113	69.15	12.307
04/30/97	02:32:58	559.4113	69.15	12.302
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04/30/97	03:26:58	613.4113	69.16	12.307
04/30/97	03:28:58	615.4113	69.15	12.307
04/30/97	03:30:58	617.4113	69.15	12.311
04/30/97	03:32:58	619.4113	69.15	12.307

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04/30/97   03:42:58   629.4113   69.15   12.311
04/30/97   03:44:58   631.4113   69.15   12.307
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  /30/97   03:48:58   635.4113   69.15   12.307
   30/97   03:50:58   637.4113   69.16   12.307
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04/30/97   04:04:58   651.4113   69.15   12.311
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04/30/97   04:16:58   663.4113   69.15   12.311
04/30/97   04:18:58   665.4113   69.15   12.311
04/30/97   04:20:58   667.4113   69.15   12.311
04/30/97   04:22:58   669.4113   69.16   12.311
04/30/97   04:24:58   671.4113   69.16   12.311
04/30/97   04:26:58   673.4113   69.15   12.311
04/30/97   04:28:58   675.4113   69.15   12.311
04/30/97   04:30:58   677.4113   69.16   12.311
04/30/97   04:32:58   679.4113   69.15   12.311
04/30/97   04:34:58   681.4113   69.15   12.311
04/30/97   04:36:58   683.4113   69.15   12.311
04/30/97   04:38:58   685.4113   69.15   12.311
04/30/97   04:40:58   687.4113   69.16   12.311
04/30/97   04:42:58   689.4113   69.15   12.307
04/30/97   04:44:58   691.4113   69.15   12.311
04/30/97   04:46:58   693.4113   69.15   12.311
04/30/97   04:48:58   695.4113   69.15   12.311
   30/97   04:50:58   697.4113   69.16   12.307
04/30/97   04:52:58   699.4113   69.16   12.311
04/30/97   04:54:58   701.4113   69.16   12.311
04/30/97   04:56:58   703.4113   69.15   12.311
04/30/97   04:58:58   705.4113   69.16   12.311
04/30/97   05:00:58   707.4113   69.16   12.307
04/30/97   05:02:58   709.4113   69.15   12.311
04/30/97   05:04:58   711.4113   69.15   12.311
04/30/97   05:06:58   713.4113   69.15   12.311
04/30/97   05:08:58   715.4113   69.15   12.311
04/30/97   05:10:58   717.4113   69.15   12.311
04/30/97   05:12:58   719.4113   69.15   12.311
04/30/97   05:14:58   721.4113   69.15   12.311
04/30/97   05:16:58   723.4113   69.16   12.311
04/30/97   05:18:58   725.4113   69.15   12.311
04/30/97   05:20:58   727.4113   69.15   12.316
04/30/97   05:22:58   729.4113   69.16   12.311
04/30/97   05:24:58   731.4113   69.16   12.316
04/30/97   05:26:58   733.4113   69.15   12.311
04/30/97   05:28:58   735.4113   69.15   12.311
04/30/97   05:30:58   737.4113   69.15   12.311
04/30/97   05:32:58   739.4113   69.15   12.316
04/30/97   05:34:58   741.4113   69.15   12.311
04/30/97   05:36:58   743.4113   69.15   12.311
04/30/97   05:38:58   745.4113   69.16   12.316
04/30/97   05:40:58   747.4113   69.16   12.311
04/30/97   05:42:58   749.4113   69.15   12.316
04/30/97   05:44:58   751.4113   69.16   12.311
04/30/97   05:46:58   753.4113   69.15   12.316
04/30/97   05:48:58   755.4113   69.16   12.311
   30/97   05:50:58   757.4113   69.15   12.311
   30/97   05:52:58   759.4113   69.16   12.311
04/30/97   05:54:58   761.4113   69.15   12.311
04/30/97   05:56:58   763.4113   69.16   12.311
04/30/97   05:58:58   765.4113   69.15   12.316
04/30/97   06:00:58   767.4113   69.15   12.316
04/30/97   06:02:58   769.4113   69.15   12.316
```
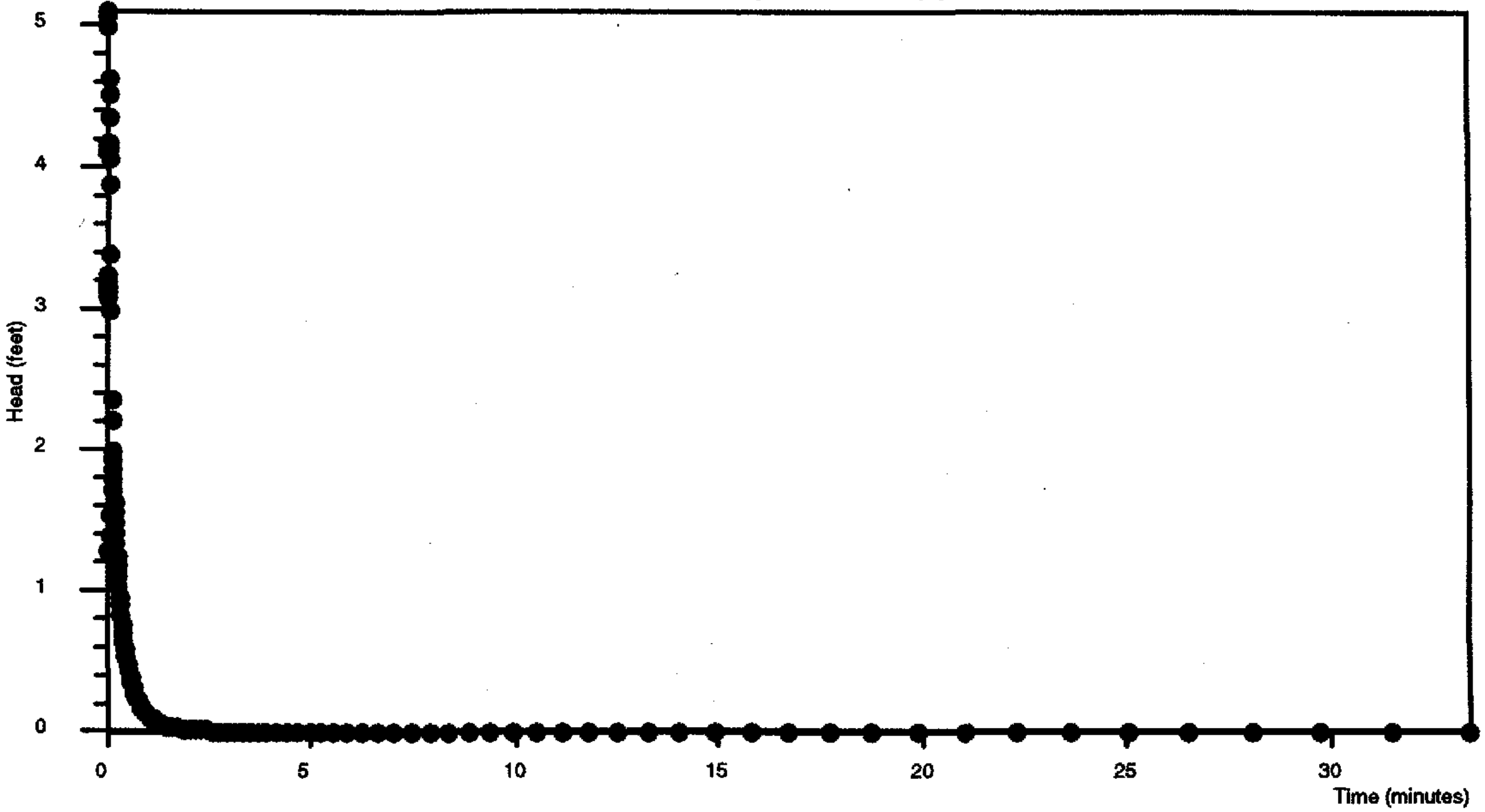

04/30/97	06:04:58	771.4113	69.15	12.316
04/30/97	06:06:58	773.4113	69.16	12.316
04/30/97	06:08:58	775.4113	69.16	12.316
04/30/97	06:10:58	777.4113	69.15	12.316
04/30/97	06:12:58	779.4113	69.15	12.316
04/30/97	06:14:58	781.4113	69.15	12.316
04/30/97	06:16:58	783.4113	69.15	12.316
[illegible]/30/97	06:18:58	785.4113	69.15	12.316
[illegible]/30/97	06:20:58	787.4113	69.15	12.316
04/30/97	06:22:58	789.4113	69.15	12.316
04/30/97	06:24:58	791.4113	69.15	12.316
04/30/97	06:26:58	793.4113	69.15	12.316
04/30/97	06:28:58	795.4113	69.15	12.316
04/30/97	06:30:58	797.4113	69.15	12.316
04/30/97	06:32:58	799.4113	69.15	12.316
04/30/97	06:34:58	801.4113	69.15	12.316
04/30/97	06:36:58	803.4113	69.16	12.316
04/30/97	06:38:58	805.4113	69.16	12.316
04/30/97	06:40:58	807.4113	69.15	12.316
04/30/97	06:42:58	809.4113	69.16	12.316
04/30/97	06:44:58	811.4113	69.16	12.316
04/30/97	06:46:58	813.4113	69.15	12.316
04/30/97	06:48:58	815.4113	69.15	12.316
04/30/97	06:50:58	817.4113	69.15	12.316
04/30/97	06:52:58	819.4113	69.15	12.316
04/30/97	06:54:58	821.4113	69.15	12.316
04/30/97	06:56:58	823.4113	69.15	12.316
04/30/97	06:58:58	825.4113	69.16	12.316
04/30/97	07:00:58	827.4113	69.15	12.316
04/30/97	07:02:58	829.4113	69.15	12.311
04/30/97	07:04:58	831.4113	69.15	12.311
04/30/97	07:06:58	833.4113	69.16	12.311
04/30/97	07:08:58	835.4113	69.15	12.316
04/30/97	07:10:58	837.4113	69.15	12.316
04/30/97	07:12:58	839.4113	69.16	12.316
04/30/97	07:14:58	841.4113	69.16	12.316
04/30/97	07:16:58	843.4113	69.16	12.316
[illegible]/30/97	07:18:58	845.4113	69.15	12.316
[illegible]/30/97	07:20:58	847.4113	69.15	12.316
04/30/97	07:22:58	849.4113	69.15	12.316
04/30/97	07:24:58	851.4113	69.15	12.316
04/30/97	07:26:58	853.4113	69.16	12.316
04/30/97	07:28:58	855.4113	69.15	12.316
04/30/97	07:30:58	857.4113	69.16	12.316
04/30/97	07:32:58	859.4113	69.16	12.316
04/30/97	07:34:58	861.4113	69.16	12.316
04/30/97	07:36:58	863.4113	69.15	12.316
04/30/97	07:38:58	865.4113	69.15	12.316
04/30/97	07:40:58	867.4113	69.15	12.321
04/30/97	07:42:58	869.4113	69.16	12.316
04/30/97	07:44:58	871.4113	69.16	12.316
04/30/97	07:46:58	873.4113	69.16	12.316
04/30/97	07:48:58	875.4113	69.16	12.321
04/30/97	07:50:58	877.4113	69.15	12.321
04/30/97	07:52:58	879.4113	69.15	12.321
04/30/97	07:54:58	881.4113	69.16	12.321
04/30/97	07:56:58	883.4113	69.15	12.316
04/30/97	07:58:58	885.4113	69.16	12.316
04/30/97	08:00:58	887.4113	69.15	12.316
04/30/97	08:02:58	889.4113	69.15	12.316
04/30/97	08:04:58	891.4113	69.15	12.316
04/30/97	08:06:58	893.4113	69.15	12.321
04/30/97	08:08:58	895.4113	69.16	12.321
04/30/97	08:10:58	897.4113	69.16	12.316
04/30/97	08:12:58	899.4113	69.16	12.316
04/30/97	08:14:58	901.4113	69.15	12.321
04/30/97	08:16:58	903.4113	69.15	12.321
04/30/97	08:18:58	905.4113	69.15	12.321
[illegible]/30/97	08:20:58	907.4113	69.15	12.311
04/30/97	08:22:58	909.4113	69.17	12.311
04/30/97	08:24:58	911.4113	69.16	12.311
04/30/97	08:26:58	913.4113	69.26	12.311

MW-05 Falling Head April 30, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

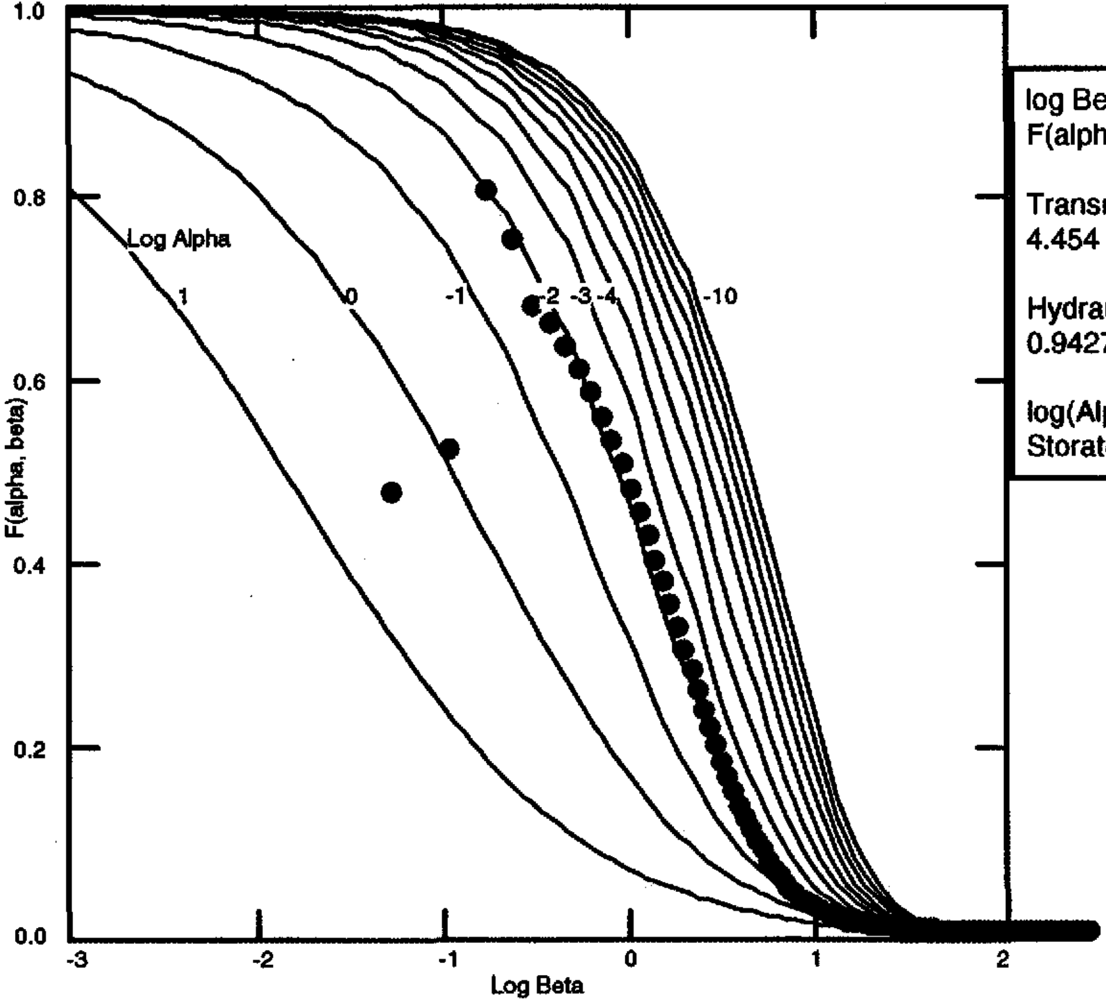
MW-05



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve

Well MW-05



log Beta = 2.839
F(alpha, beta) = 0.5186

Transmissivity
4.454 meters2/day

Hydraulic Conductivity
0.9427 meters/day

log(Alpha) = -2.
Storativity = 5.88e-004

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 30, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

```
IN_SITU INC.          TROLL
Serial number:        00000211
Unit name:            SP4000

Report generated:     05/01/97     10:43:07
Report from file:     A:\MW-05-A.BIN

[illegible]st name: MW-05-A

Test defined on:      04/30/97     10:03:24
Test started on:      04/30/97     10:08:12
Test stopped on:      04/30/97     10:43:27
Test extracted on:    04/30/97     10:51:48

Data gathered using Logarithmic testing
   Maximum time between data points:        2.0000           Minutes.
   Number of data samples:           122

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:     TOC
  User-defined reference:          17.720     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:      19.849     Feet H2O


                                            Channel[1]   Channel[2]
  Date         Time         ET (min)     Fahrenheit   Feet H2O
--------    --------    ------------  -----------   -----------
04/30/97    10:08:12          0.0000        73.80        16.421
04/30/97    10:08:12          0.0050        73.81        14.509
[illegible]/30/97    10:08:12          0.0100        73.81        14.613
[illegible]/30/97    10:08:12          0.0150        73.83        14.539
04/30/97    10:08:13          0.0200        73.84        14.587
04/30/97    10:08:13          0.0250        73.84        13.556
04/30/97    10:08:13          0.0300        73.86        12.624
04/30/97    10:08:14          0.0350        73.86        13.526
04/30/97    10:08:14          0.0400        73.86        14.507
04/30/97    10:08:14          0.0450        73.87        14.456
04/30/97    10:08:15          0.0500        73.88        12.604
04/30/97    10:08:15          0.0550        73.88        12.701
04/30/97    10:08:15          0.0600        73.88        13.602
04/30/97    10:08:15          0.0650        73.89        13.817
04/30/97    10:08:16          0.0700        73.90        13.632
04/30/97    10:08:16          0.0750        73.90        13.063
04/30/97    10:08:16          0.0800        73.90        13.526
04/30/97    10:08:17          0.0850        73.91        13.566
04/30/97    10:08:17          0.0900        73.91        13.344
04/30/97    10:08:17          0.0950        73.91        13.178
04/30/97    10:08:18          0.1000        73.93        13.077
04/30/97    10:08:18          0.1058        73.93        14.311
04/30/97    10:08:18          0.1120        73.94        14.710
04/30/97    10:08:19          0.1185        73.95        16.315
04/30/97    10:08:19          0.1255        73.95        16.174
04/30/97    10:08:19          0.1328        73.95        15.349
04/30/97    10:08:20          0.1407        73.96        15.501
04/30/97    10:08:20          0.1490        74.00        15.720
04/30/97    10:08:21          0.1578        74.00        15.771
04/30/97    10:08:22          0.1672        74.00        15.847
04/30/97    10:08:22          0.1770        74.00        15.923
04/30/97    10:08:23          0.1875        74.02        15.997
[illegible]/30/97    10:08:23          0.1985        74.02        16.073
[illegible]30/97    10:08:24          0.2102        74.02        16.149
04/30/97    10:08:25          0.2227        74.02        16.225
04/30/97    10:08:26          0.2358        74.02        16.301
04/30/97    10:08:26          0.2498        74.03        16.380
04/30/97    10:08:27          0.2647        74.03        16.456
04/30/97    10:08:28          0.2803        74.03        16.532
04/30/97    10:08:29          0.2970        74.03        16.603
```

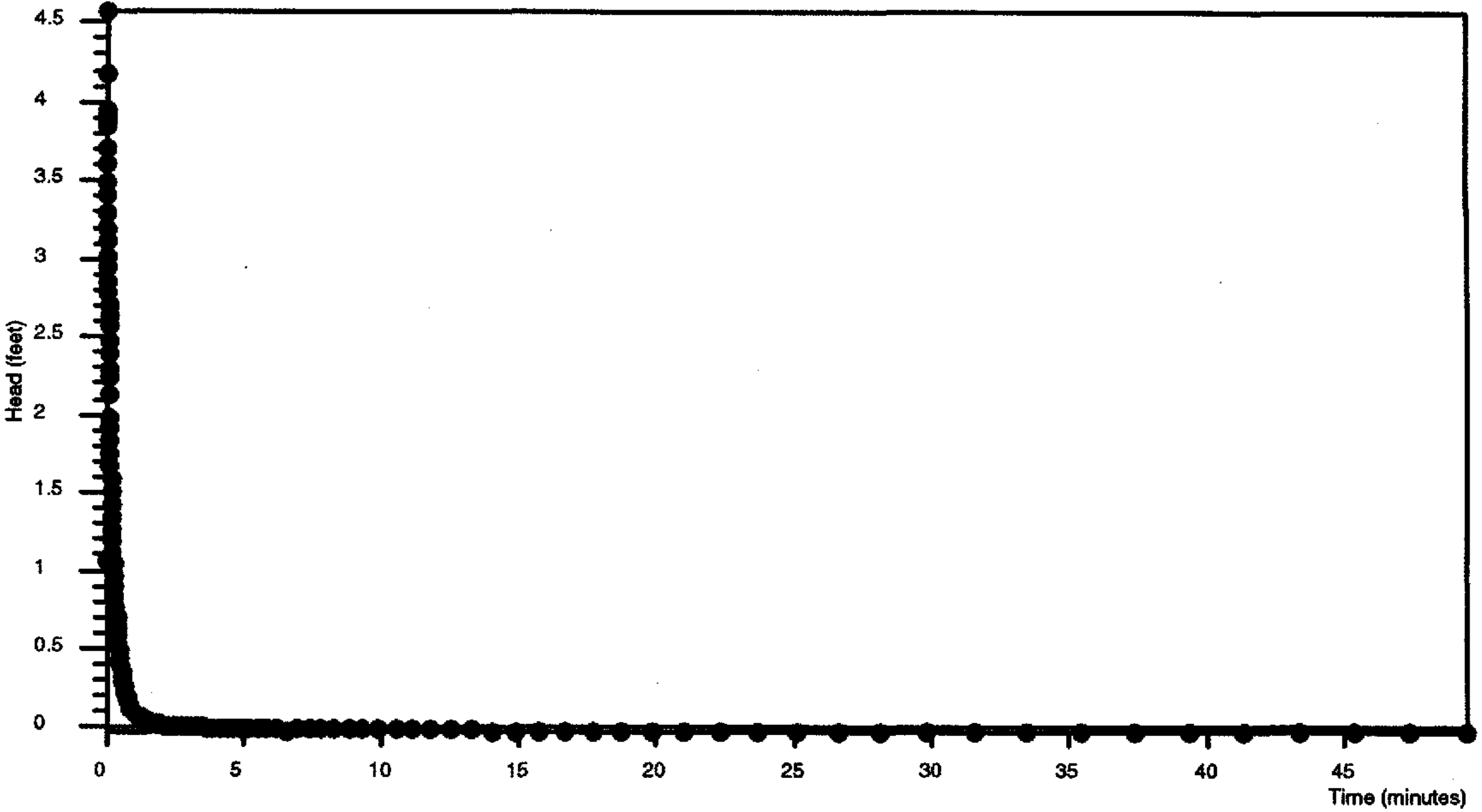
```
 04/30/97    10:08:30        0.3147      74.03        16.677
 04/30/97    10:08:32        0.3333      74.04        16.749
 04/30/97    10:08:33        0.3532      74.03        16.816
 04/30/97    10:08:34        0.3742      74.03        16.885
 04/30/97    10:08:35        0.3963      74.04        16.949
 04/30/97    10:08:37        0.4198      74.04        17.012
 04/30/97    10:08:38        0.4447      74.04        17.072
 [illegible]/30/97    10:08:40        0.4697      74.04        17.127
 [illegible]/30/97    10:08:41        0.4963      74.04        17.178
 04/30/97    10:08:43        0.5247      74.03        17.224
 04/30/97    10:08:45        0.5547      74.04        17.272
 04/30/97    10:08:47        0.5863      74.03        17.314
 04/30/97    10:08:49        0.6213      74.03        17.358
 04/30/97    10:08:51        0.6580      74.04        17.390
 04/30/97    10:08:53        0.6963      74.04        17.429
 04/30/97    10:08:56        0.7380      74.04        17.459
 04/30/97    10:08:58        0.7813      74.04        17.489
 04/30/97    10:09:01        0.8280      74.04        17.515
 04/30/97    10:09:04        0.8763      74.04        17.540
 04/30/97    10:09:07        0.9280      74.04        17.561
 04/30/97    10:09:10        0.9830      74.04        17.579
 04/30/97    10:09:14        1.0413      74.03        17.595
 04/30/97    10:09:18        1.1030      74.05        17.611
 04/30/97    10:09:22        1.1680      74.04        17.621
 04/30/97    10:09:26        1.2380      74.05        17.634
 04/30/97    10:09:30        1.3113      74.12        17.641
 04/30/97    10:09:35        1.3897      74.09        17.651
 04/30/97    10:09:40        1.4730      74.08        17.660
 04/30/97    10:09:45        1.5613      74.08        17.662
 04/30/97    10:09:51        1.6547      74.07        17.667
 04/30/97    10:09:57        1.7530      74.06        17.671
 04/30/97    10:10:03        1.8580      74.07        17.681
 04/30/97    10:10:10        1.9680      74.06        17.685
 04/30/97    10:10:17        2.0847      74.06        17.685
 04/30/97    10:10:24        2.2097      74.06        17.688
 04/30/97    10:10:32        2.3413      74.05        17.688
 04/30/97    10:10:40        2.4813      74.05        17.692
 [illegible]/30/97    10:10:49        2.6297      74.05        17.697
 [illegible]/30/97    10:10:59        2.7863      74.04        17.697
 04/30/97    10:11:09        2.9530      74.04        17.697
 04/30/97    10:11:19        3.1297      74.04        17.697
 04/30/97    10:11:30        3.3163      74.04        17.701
 04/30/97    10:11:42        3.5147      74.03        17.701
 04/30/97    10:11:55        3.7247      74.03        17.701
 04/30/97    10:12:08        3.9463      74.03        17.701
 04/30/97    10:12:22        4.1813      74.03        17.706
 04/30/97    10:12:37        4.4297      74.02        17.706
 04/30/97    10:12:53        4.6930      74.02        17.706
 04/30/97    10:13:10        4.9730      74.02        17.706
 04/30/97    10:13:28        5.2697      74.00        17.711
 04/30/97    10:13:46        5.5830      74.00        17.711
 04/30/97    10:14:06        5.9147      73.99        17.711
 04/30/97    10:14:27        6.2663      73.99        17.713
 04/30/97    10:14:50        6.6397      73.99        17.711
 04/30/97    10:15:14        7.0347      73.98        17.711
 04/30/97    10:15:39        7.4530      73.98        17.711
 04/30/97    10:16:05        7.8963      73.97        17.713
 04/30/97    10:16:33        8.3663      73.96        17.713
 04/30/97    10:17:03        8.8647      73.97        17.711
 04/30/97    10:17:35        9.3913      73.96        17.711
 04/30/97    10:18:08        9.9497      73.95        17.711
 04/30/97    10:18:44       10.5413      73.95        17.713
 04/30/97    10:19:22       11.1680      73.94        17.713
 04/30/97    10:20:01       11.8313      73.94        17.711
 04/30/97    10:20:44       12.5347      73.93        17.711
 04/30/97    10:21:28       13.2797      73.93        17.713
 04/30/97    10:22:16       14.0697      73.93        17.713
 04/30/97    10:23:06       14.9063      73.93        17.713
 [illegible]/30/97    10:23:59       15.7913      73.91        17.711
 04/30/97    10:24:55       16.7297      73.91        17.713
 04/30/97    10:25:55       17.7230      73.91        17.711
 04/30/97    10:26:58       18.7763      73.91        17.713
 04/30/97    10:28:05       19.8913      73.91        17.713
 04/30/97    10:29:16       21.0730      73.91        17.711
 04/30/97    10:30:31       22.3247      73.91        17.713
```

MW-05 Rising Head April 30, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

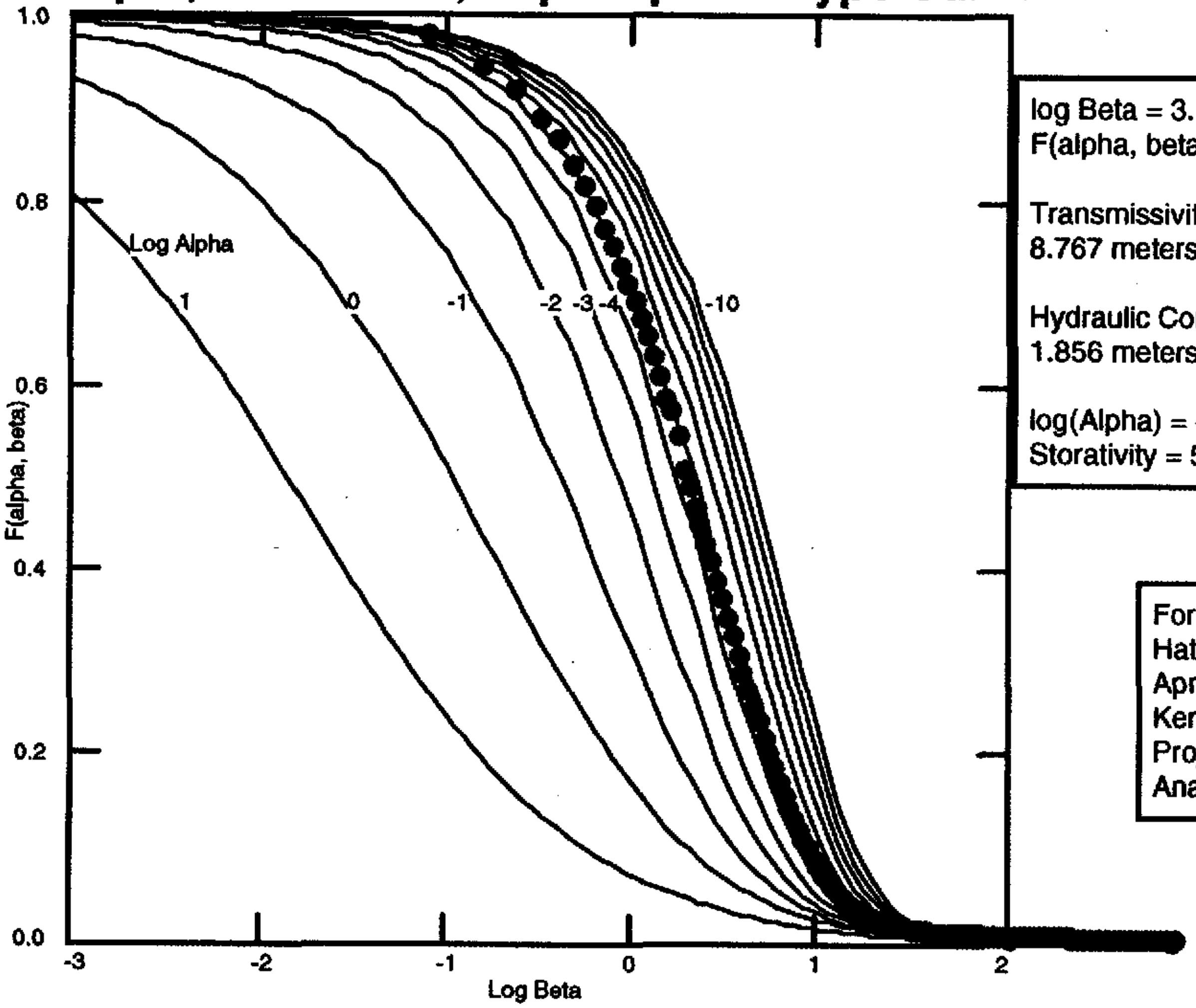
MW-05



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

Cooper, Bredehoeft, Papadopulos Type Curve

Well MW-05



log Beta = 3.133
F(alpha, beta) = 0.5031

Transmissivity
8.767 meters2/day

Hydraulic Conductivity
1.856 meters/day

log(Alpha) = -5.
Storativity = 5.88e-007

Former Gulf States Creosoting Site
Hattiesburg, Mississippi
April 30, 1997
Kerr-McGee
Project Number 21-02
Analysis by Starpoint Software

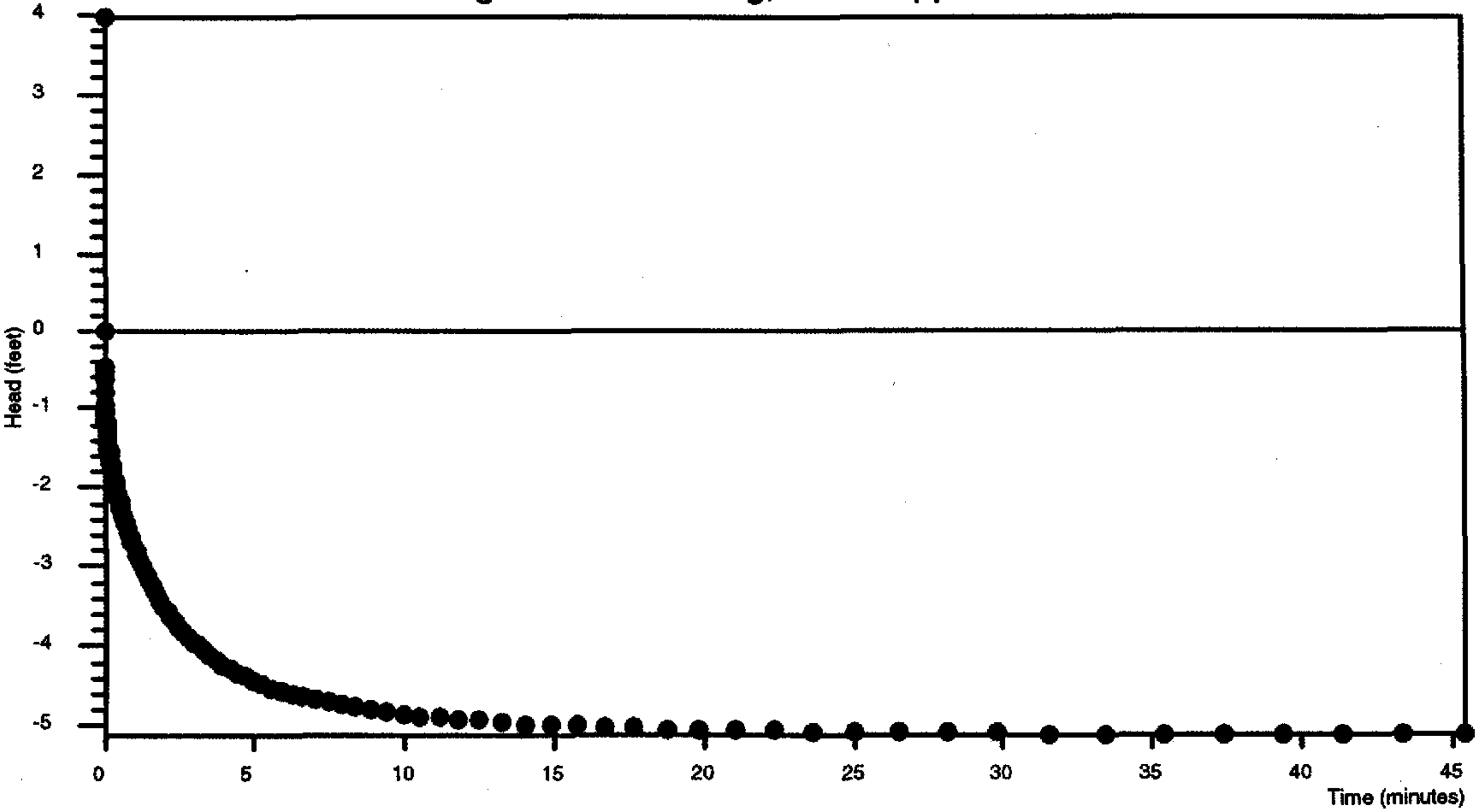
```
IN_SITU INC.          TROLL
Serial number:        00000211
Unit name:            SP4000

Report generated:     05/01/97     10:46:18
Report from file:     A:\MW-05-B.BIN

[illegible]t name: MW-05-B

Test defined on:      04/30/97     10:45:25
Test started on:      04/30/97     10:46:16
Test stopped on:      04/30/97     11:36:31
Test extracted on:    04/30/97     11:39:41

Data gathered using Logarithmic testing
   Maximum time between data points:       2.0000           Minutes.
   Number of data samples:            130

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:     TOC
  User-defined reference:              17.720     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:          19.849     Feet H2O


                                      Channel[1]   Channel[2]
  Date        Time       ET (min)     Fahrenheit   Feet H2O
--------    --------    ------------  -----------  -----------
04/30/97    10:46:16         0.0000        74.06        21.565
04/30/97    10:46:16         0.0050        74.08        18.765
04/30/97    10:46:16         0.0100        74.08        21.590
[illegible]30/97    10:46:16         0.0150        74.08        21.616
04/30/97    10:46:17         0.0200        74.09        22.271
04/30/97    10:46:17         0.0250        74.11        21.879
04/30/97    10:46:17         0.0300        74.11        21.650
04/30/97    10:46:18         0.0350        74.12        21.549
04/30/97    10:46:18         0.0400        74.13        21.413
04/30/97    10:46:18         0.0450        74.13        21.316
04/30/97    10:46:19         0.0500        74.13        21.191
04/30/97    10:46:19         0.0550        74.14        21.106
04/30/97    10:46:19         0.0600        74.15        20.995
04/30/97    10:46:19         0.0650        74.15        20.908
04/30/97    10:46:20         0.0700        74.15        20.822
04/30/97    10:46:20         0.0750        74.15        20.728
04/30/97    10:46:20         0.0800        74.16        20.652
04/30/97    10:46:21         0.0850        74.17        20.564
04/30/97    10:46:21         0.0900        74.17        20.490
04/30/97    10:46:21         0.0950        74.18        20.414
04/30/97    10:46:22         0.1000        74.18        20.347
04/30/97    10:46:22         0.1058        74.18        20.269
04/30/97    10:46:22         0.1120        74.19        20.181
04/30/97    10:46:23         0.1185        74.19        20.091
04/30/97    10:46:23         0.1255        74.20        20.001
04/30/97    10:46:23         0.1328        74.20        19.943
04/30/97    10:46:24         0.1407        74.22        19.840
04/30/97    10:46:24         0.1490        74.25        19.692
04/30/97    10:46:25         0.1578        74.26        19.616
04/30/97    10:46:26         0.1672        74.26        19.535
04/30/97    10:46:26         0.1770        74.26        19.454
04/30/97    10:46:27         0.1875        74.26        19.369
04/30/97    10:46:27         0.1985        74.27        19.293
[illegible]30/97    10:46:28         0.2102        74.27        19.212
[illegible]/30/97    10:46:29         0.2227        74.27        19.132
04/30/97    10:46:30         0.2358        74.26        19.053
04/30/97    10:46:30         0.2498        74.27        18.972
04/30/97    10:46:31         0.2647        74.26        18.896
04/30/97    10:46:32         0.2803        74.26        18.820
04/30/97    10:46:33         0.2970        74.27        18.744
```

```
04/30/97   10:46:34     0.3147    74.26    18.675
04/30/97   10:46:36     0.3333    74.27    18.608
04/30/97   10:46:37     0.3532    74.27    18.536
04/30/97   10:46:38     0.3742    74.27    18.467
04/30/97   10:46:39     0.3963    74.27    18.407
04/30/97   10:46:41     0.4198    74.27    18.347
04/30/97   10:46:42     0.4447    74.27    18.292
[illegible]/30/97   10:46:44     0.4697    74.27    18.241
[illegible]/30/97   10:46:45     0.4963    74.27    18.190
04/30/97   10:46:47     0.5247    74.27    18.144
04/30/97   10:46:49     0.5547    74.27    18.103
04/30/97   10:46:51     0.5863    74.27    18.064
04/30/97   10:46:53     0.6213    74.27    18.024
04/30/97   10:46:55     0.6580    74.27    17.992
04/30/97   10:46:57     0.6963    74.27    17.957
04/30/97   10:47:00     0.7380    74.27    17.927
04/30/97   10:47:02     0.7813    74.27    17.902
04/30/97   10:47:05     0.8280    74.27    17.877
04/30/97   10:47:08     0.8763    74.26    17.856
04/30/97   10:47:11     0.9280    74.27    17.837
04/30/97   10:47:14     0.9830    74.26    17.821
04/30/97   10:47:18     1.0413    74.26    17.807
04/30/97   10:47:22     1.1030    74.25    17.791
04/30/97   10:47:26     1.1680    74.25    17.782
04/30/97   10:47:30     1.2380    74.25    17.775
04/30/97   10:47:34     1.3113    74.24    17.766
04/30/97   10:47:39     1.3897    74.25    17.757
04/30/97   10:47:44     1.4730    74.24    17.752
04/30/97   10:47:49     1.5613    74.24    17.745
04/30/97   10:47:55     1.6547    74.23    17.741
04/30/97   10:48:01     1.7530    74.23    17.736
04/30/97   10:48:07     1.8580    74.23    17.731
04/30/97   10:48:14     1.9680    74.22    17.727
04/30/97   10:48:21     2.0847    74.22    17.722
04/30/97   10:48:28     2.2097    74.22    17.722
04/30/97   10:48:36     2.3413    74.22    17.720
04/30/97   10:48:44     2.4813    74.20    17.715
[illegible]/30/97   10:48:53     2.6297    74.20    17.715
[illegible]/30/97   10:49:03     2.7863    74.19    17.715
[illegible]/30/97   10:49:13     2.9530    74.19    17.711
04/30/97   10:49:23     3.1297    74.18    17.711
04/30/97   10:49:34     3.3163    74.18    17.711
04/30/97   10:49:46     3.5147    74.17    17.711
04/30/97   10:49:59     3.7247    74.17    17.706
04/30/97   10:50:12     3.9463    74.17    17.706
04/30/97   10:50:26     4.1813    74.16    17.706
04/30/97   10:50:41     4.4297    74.16    17.706
04/30/97   10:50:57     4.6930    74.15    17.701
04/30/97   10:51:14     4.9730    74.15    17.701
04/30/97   10:51:32     5.2697    74.13    17.701
04/30/97   10:51:50     5.5830    74.23    17.701
04/30/97   10:52:10     5.9147    74.16    17.701
04/30/97   10:52:31     6.2663    74.15    17.701
04/30/97   10:52:54     6.6397    74.14    17.692
04/30/97   10:53:18     7.0347    74.12    17.697
04/30/97   10:53:43     7.4530    74.11    17.697
04/30/97   10:54:09     7.8963    74.09    17.697
04/30/97   10:54:37     8.3663    74.08    17.697
04/30/97   10:55:07     8.8647    74.07    17.697
04/30/97   10:55:39     9.3913    74.07    17.697
04/30/97   10:56:12     9.9497    74.06    17.697
04/30/97   10:56:48    10.5413    74.04    17.697
04/30/97   10:57:26    11.1680    74.03    17.697
04/30/97   10:58:05    11.8313    74.03    17.697
04/30/97   10:58:48    12.5347    74.02    17.697
04/30/97   10:59:32    13.2797    74.00    17.697
04/30/97   11:00:20    14.0697    74.00    17.692
04/30/97   11:01:10    14.9063    73.99    17.692
[illegible]30/97   11:02:03    15.7913    73.99    17.688
[illegible]/30/97   11:02:59    16.7297    73.98    17.692
04/30/97   11:03:59    17.7230    73.98    17.688
04/30/97   11:05:02    18.7763    73.97    17.692
04/30/97   11:06:09    19.8913    73.97    17.688
04/30/97   11:07:20    21.0730    73.97    17.688
04/30/97   11:08:35    22.3247    73.96    17.688
```

04/30/97	11:09:54	23.6497	73.96	17.688
04/30/97	11:11:19	25.0547	73.96	17.688
04/30/97	11:12:48	26.5430	73.96	17.688
04/30/97	11:14:23	28.1180	73.95	17.688
04/30/97	11:16:03	29.7863	73.96	17.685
04/30/97	11:17:49	31.5547	73.95	17.688
04/30/97	11:19:41	33.4280	73.95	17.685
[illegible]/30/97	11:21:40	35.4113	73.96	17.688
[illegible]/30/97	11:23:40	37.4113	73.95	17.688
04/30/97	11:25:40	39.4113	73.95	17.685
04/30/97	11:27:40	41.4113	73.96	17.685
04/30/97	11:29:40	43.4113	73.95	17.692
04/30/97	11:31:40	45.4113	73.96	17.681
04/30/97	11:33:40	47.4113	73.96	17.676
04/30/97	11:35:40	49.4113	74.03	17.685

MW-3 Falling Head April 30, 1997 **Arithmetic Graph**

Former Gulf States Creosoting Site Hattiesburg, Mississippi MW-3



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

```
IN_SITU INC.            TROLL
Serial number:          00000211
Unit name:              SP4000

Report generated:       05/01/97     10:53:15
Report from file:       A:\MW-3-A.BIN

Test name: MW-3-A

Test defined on:        04/30/97     13:03:22
Test started on:        04/30/97     13:13:55
Test stopped on:        04/30/97     13:58:08
Test extracted on:      04/30/97     14:42:07

Data gathered using Logarithmic testing
   Maximum time between data points:      2.0000           Minutes.
   Number of data samples:          127

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:    TOC
  User-defined reference:              14.580     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:          12.180     Feet H2O


                                              Channel[1]   Channel[2]
  Date         Time          ET (min)       Fahrenheit   Feet H2O
 --------     --------     ------------    -----------  -----------
 04/30/97     13:13:55          0.0000         72.81        12.789
 04/30/97     13:13:55          0.0050         72.81        10.886
 04/30/97     13:13:55          0.0100         72.82        10.817
 04/30/97     13:13:55          0.0150         72.83        12.002
 04/30/97     13:13:56          0.0200         72.83         9.539
 04/30/97     13:13:56          0.0250         72.84         8.549
 04/30/97     13:13:56          0.0300         72.84        10.005
 04/30/97     13:13:57          0.0350         72.84         9.649
 04/30/97     13:13:57          0.0400         72.85         9.984
 04/30/97     13:13:57          0.0450         72.87        10.376
 04/30/97     13:13:58          0.0500         72.87        10.180
 04/30/97     13:13:58          0.0550         72.87        10.817
 04/30/97     13:13:58          0.0600         72.89        10.362
 04/30/97     13:13:58          0.0650         72.89        10.311
 04/30/97     13:13:59          0.0700         72.90        10.457
 04/30/97     13:13:59          0.0750         72.90        10.600
 04/30/97     13:13:59          0.0800         72.91        11.001
 04/30/97     13:14:00          0.0850         72.91        10.766
 04/30/97     13:14:00          0.0900         72.91        10.358
 04/30/97     13:14:00          0.0950         72.92        11.128
 04/30/97     13:14:01          0.1000         72.92        11.543
 04/30/97     13:14:01          0.1058         72.92        10.337
 04/30/97     13:14:01          0.1120         72.93        10.745
 04/30/97     13:14:02          0.1185         72.93        10.708
 04/30/97     13:14:02          0.1255         72.94        10.708
 04/30/97     13:14:02          0.1328         72.94        10.895
 04/30/97     13:14:03          0.1407         72.96        10.729
 04/30/97     13:14:03          0.1490         72.99        10.759
 04/30/97     13:14:04          0.1578         72.99        10.821
 04/30/97     13:14:05          0.1672         72.99        10.819
 04/30/97     13:14:05          0.1770         72.99        10.826
 04/30/97     13:14:06          0.1875         73.00        10.847
 04/30/97     13:14:06          0.1985         72.99        10.847
 04/30/97     13:14:07          0.2102         73.00        11.061
 04/30/97     13:14:08          0.2227         73.00        10.872
 04/30/97     13:14:09          0.2358         73.01        10.796
 04/30/97     13:14:09          0.2498         73.00        10.916
 04/30/97     13:14:10          0.2647         73.01        10.927
 04/30/97     13:14:11          0.2803         73.00        10.953
 04/30/97     13:14:12          0.2970         73.00        10.957
```

```
04/30/97    13:14:13        0.3147      73.00       10.976
04/30/97    13:14:15        0.3333      73.00       10.997
04/30/97    13:14:16        0.3532      73.01       11.013
04/30/97    13:14:17        0.3742      73.00       11.038
04/30/97    13:14:18        0.3963      73.00       11.061
04/30/97    13:14:20        0.4198      73.00       11.082
04/30/97    13:14:21        0.4447      73.00       11.107
   30/97    13:14:23        0.4697      72.99       11.133
   30/97    13:14:24        0.4963      73.00       11.153
04/30/97    13:14:26        0.5247      73.00       11.179
04/30/97    13:14:28        0.5547      72.99       11.209
04/30/97    13:14:30        0.5863      72.99       11.234
04/30/97    13:14:32        0.6213      72.99       11.264
04/30/97    13:14:34        0.6580      72.99       11.294
04/30/97    13:14:36        0.6963      72.98       11.329
04/30/97    13:14:39        0.7380      72.98       11.366
04/30/97    13:14:41        0.7813      72.97       11.400
04/30/97    13:14:44        0.8280      72.97       11.437
04/30/97    13:14:47        0.8763      72.97       11.476
04/30/97    13:14:50        0.9280      72.97       11.516
04/30/97    13:14:53        0.9830      72.97       11.552
04/30/97    13:14:57        1.0413      72.96       11.748
04/30/97    13:15:01        1.1030      72.94       11.638
04/30/97    13:15:05        1.1680      72.94       11.684
04/30/97    13:15:09        1.2380      72.93       11.728
04/30/97    13:15:13        1.3113      72.93       11.778
04/30/97    13:15:18        1.3897      72.92       11.825
04/30/97    13:15:23        1.4730      72.91       11.880
04/30/97    13:15:28        1.5613      72.91       11.935
04/30/97    13:15:34        1.6547      72.90       11.981
04/30/97    13:15:40        1.7530      72.89       12.041
04/30/97    13:15:46        1.8580      72.88       12.097
04/30/97    13:15:53        1.9680      72.88       12.152
04/30/97    13:16:00        2.0847      72.87       12.210
04/30/97    13:16:07        2.2097      72.85       12.270
04/30/97    13:16:15        2.3413      72.85       12.330
04/30/97    13:16:23        2.4813      72.84       12.401
   30/97    13:16:32        2.6297      72.83       12.457
   30/97    13:16:42        2.7863      72.82       12.526
04/30/97    13:16:52        2.9530      72.81       12.583
04/30/97    13:17:02        3.1297      72.81       12.653
04/30/97    13:17:13        3.3163      72.80       12.715
04/30/97    13:17:25        3.5147      72.79       12.784
04/30/97    13:17:38        3.7247      72.78       12.856
04/30/97    13:17:51        3.9463      72.77       12.925
04/30/97    13:18:05        4.1813      72.75       12.992
04/30/97    13:18:20        4.4297      72.74       13.059
04/30/97    13:18:36        4.6930      72.73       13.128
04/30/97    13:18:53        4.9730      72.73       13.195
04/30/97    13:19:11        5.2697      72.71       13.269
04/30/97    13:19:29        5.5830      72.71       13.331
04/30/97    13:19:49        5.9147      72.70       13.405
04/30/97    13:20:10        6.2663      72.69       13.472
04/30/97    13:20:33        6.6397      72.69       13.536
04/30/97    13:20:57        7.0347      72.68       13.598
04/30/97    13:21:22        7.4530      72.67       13.668
04/30/97    13:21:48        7.8963      72.67       13.730
04/30/97    13:22:16        8.3663      72.67       13.790
04/30/97    13:22:46        8.8647      72.67       13.850
04/30/97    13:23:18        9.3913      72.67       13.910
04/30/97    13:23:51        9.9497      72.67       13.963
04/30/97    13:24:27       10.5413      72.68       14.018
04/30/97    13:25:05       11.1680      72.68       14.074
04/30/97    13:25:44       11.8313      72.68       14.122
04/30/97    13:26:27       12.5347      72.68       14.168
04/30/97    13:27:11       13.2797      72.69       14.210
04/30/97    13:27:59       14.0697      72.69       14.256
04/30/97    13:28:49       14.9063      72.69       14.295
   30/97    13:29:42       15.7913      72.69       14.330
04/30/97    13:30:38       16.7297      72.70       14.362
04/30/97    13:31:38       17.7230      72.70       14.390
04/30/97    13:32:41       18.7763      72.70       14.417
04/30/97    13:33:48       19.8913      72.70       14.440
04/30/97    13:34:59       21.0730      72.74       14.461
04/30/97    13:36:14       22.3247      72.85       14.482
```

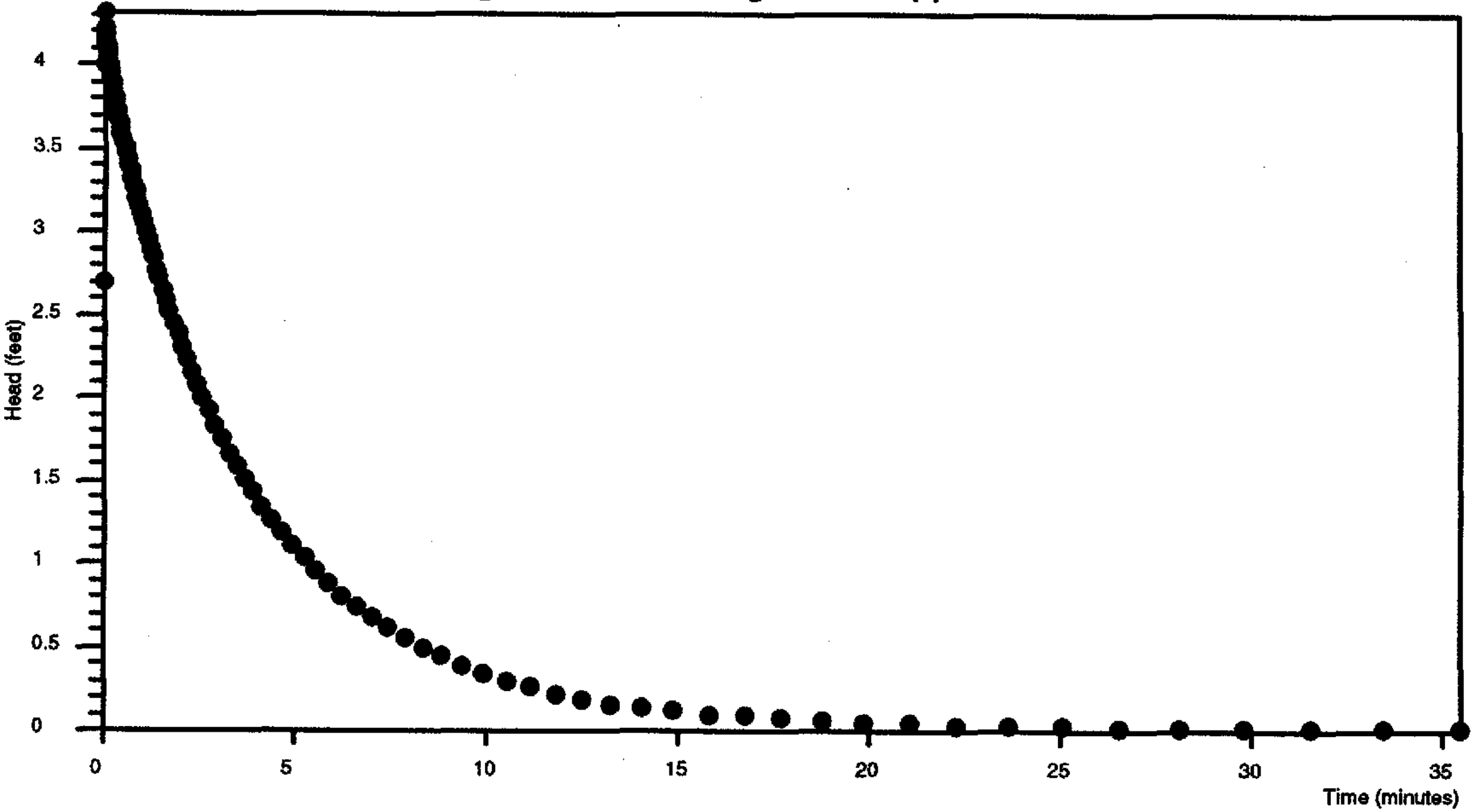
04/30/97	13:37:33	23.6497	72.83	14.500
04/30/97	13:38:58	25.0547	72.80	14.512
04/30/97	13:40:27	26.5430	72.78	14.526
04/30/97	13:42:02	28.1180	72.80	14.537
04/30/97	13:43:42	29.7863	72.78	14.546
04/30/97	13:45:28	31.5547	72.83	14.551
04/30/97	13:47:20	33.4280	72.79	14.558
/30/97	13:49:19	35.4113	72.75	14.563
30/97	13:51:19	37.4113	72.78	14.567
04/30/97	13:53:19	39.4113	72.74	14.567
04/30/97	13:55:19	41.4113	72.73	14.572
04/30/97	13:57:19	43.4113	72.72	14.572

MW-3 Rising Head April 30, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

MW-3



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

```
IN_SITU INC.             TROLL
Serial number:           00000211
Unit name:               SP4000

Report generated:        05/06/97     10:46:05
Report from file:        A:\MW-3-B.BIN

[illegible]st name: MW-3-B

Test defined on:         04/30/97     13:59:52
Test started on:         04/30/97     14:03:13
Test stopped on:         04/30/97     14:39:23
Test extracted on:       04/30/97     14:40:54

Data gathered using Logarithmic testing
   Maximum time between data points:      2.0000          Minutes.
   Number of data samples:          123

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:    TOC
  User-defined reference:          14.580     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:      12.180     Feet H2O


                                          Channel[1]    Channel[2]
  Date        Time        ET (min)       Fahrenheit    Feet H2O
 --------   --------    ------------    -----------   -----------
 04/30/97   14:03:13         0.0000          72.75        17.250
 04/30/97   14:03:13         0.0050          72.77        18.546
 [illegible]/30/97   14:03:13         0.0100          72.78        18.772
 [illegible]30/97   14:03:13         0.0150          72.78        18.853
 04/30/97   14:03:14         0.0200          72.78        18.768
 04/30/97   14:03:14         0.0250          72.79        18.758
 04/30/97   14:03:14         0.0300          72.80        18.756
 04/30/97   14:03:15         0.0350          72.80        18.742
 04/30/97   14:03:15         0.0400          72.81        18.731
 04/30/97   14:03:15         0.0450          72.82        18.717
 04/30/97   14:03:16         0.0500          72.83        18.705
 04/30/97   14:03:16         0.0550          72.83        18.682
 04/30/97   14:03:16         0.0600          72.84        18.682
 04/30/97   14:03:16         0.0650          72.84        18.680
 04/30/97   14:03:17         0.0700          72.84        18.657
 04/30/97   14:03:17         0.0750          72.85        18.657
 04/30/97   14:03:17         0.0800          72.85        18.645
 04/30/97   14:03:18         0.0850          72.87        18.636
 04/30/97   14:03:18         0.0900          72.87        18.625
 04/30/97   14:03:18         0.0950          72.88        18.611
 04/30/97   14:03:19         0.1000          72.88        18.611
 04/30/97   14:03:19         0.1058          72.88        18.595
 04/30/97   14:03:19         0.1120          72.89        18.590
 04/30/97   14:03:20         0.1185          72.90        18.585
 04/30/97   14:03:20         0.1255          72.90        18.565
 04/30/97   14:03:20         0.1328          72.91        18.555
 04/30/97   14:03:21         0.1407          72.91        18.544
 04/30/97   14:03:21         0.1490          72.96        18.528
 04/30/97   14:03:22         0.1578          72.94        18.519
 04/30/97   14:03:23         0.1672          72.96        18.502
 04/30/97   14:03:23         0.1770          72.96        18.489
 04/30/97   14:03:24         0.1875          72.97        18.479
 04/30/97   14:03:24         0.1985          72.96        18.459
 [illegible]0/97   14:03:25         0.2102          72.97        18.442
 [illegible]/30/97   14:03:26         0.2227          72.97        18.429
 04/30/97   14:03:27         0.2358          72.97        18.408
 04/30/97   14:03:27         0.2498          72.97        18.396
 04/30/97   14:03:28         0.2647          72.97        18.371
 04/30/97   14:03:29         0.2803          72.97        18.357
 04/30/97   14:03:30         0.2970          72.97        18.336
```

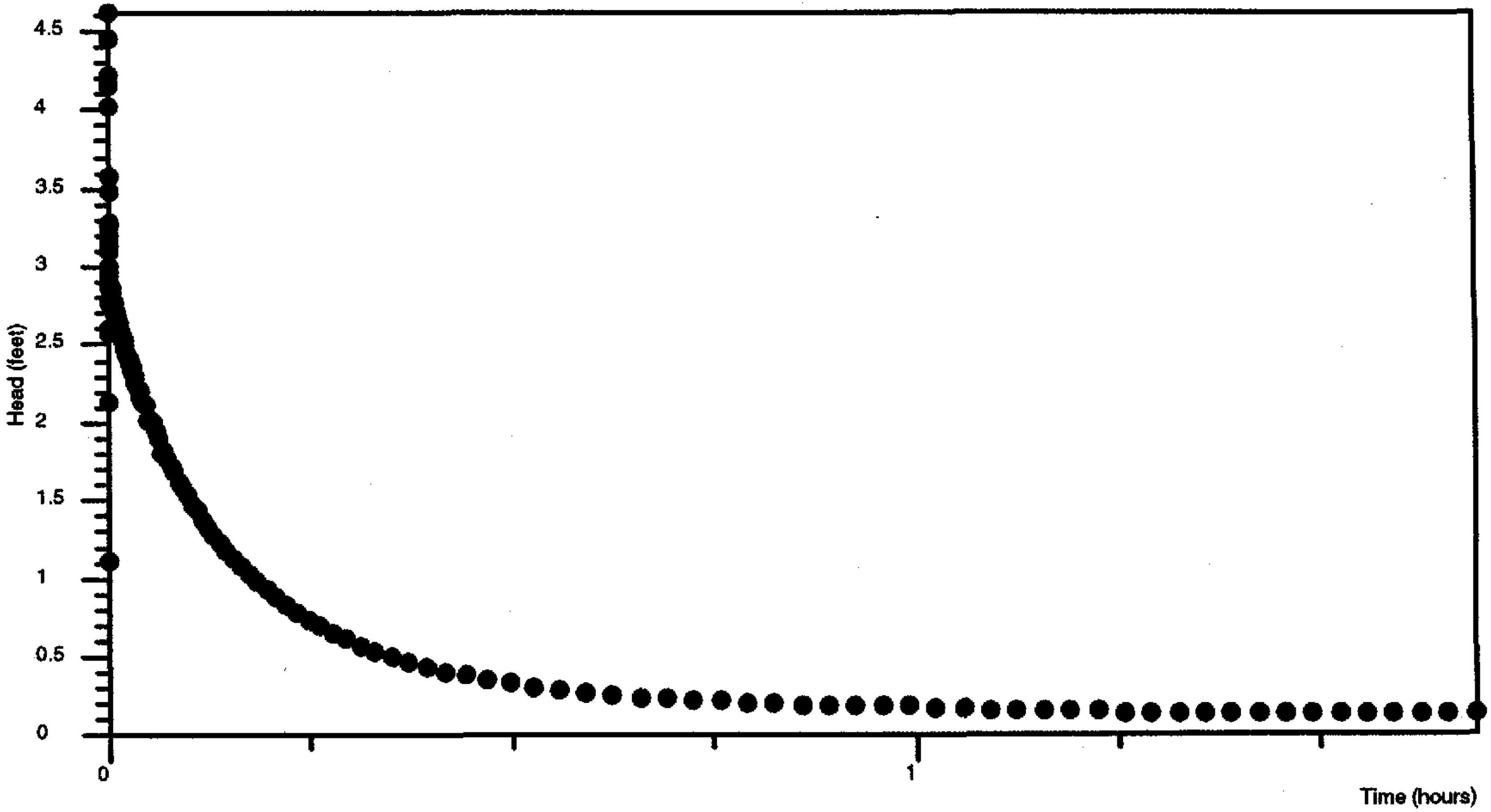
04/30/97	14:03:31	0.3147	72.97	18.316
04/30/97	14:03:33	0.3333	72.97	18.293
04/30/97	14:03:34	0.3532	72.98	18.272
04/30/97	14:03:35	0.3742	72.97	18.251
04/30/97	14:03:36	0.3963	72.97	18.226
04/30/97	14:03:38	0.4198	72.97	18.200
04/30/97	14:03:39	0.4447	72.97	18.175
[illegible]/30/97	14:03:41	0.4697	72.97	18.145
[illegible]/30/97	14:03:42	0.4963	72.97	18.115
04/30/97	14:03:44	0.5247	72.97	18.090
04/30/97	14:03:46	0.5547	72.97	18.055
04/30/97	14:03:48	0.5863	72.97	18.027
04/30/97	14:03:50	0.6213	72.97	17.988
04/30/97	14:03:52	0.6580	72.97	17.953
04/30/97	14:03:54	0.6963	72.97	17.921
04/30/97	14:03:57	0.7380	72.97	17.877
04/30/97	14:03:59	0.7813	72.97	17.836
04/30/97	14:04:02	0.8280	72.97	17.797
04/30/97	14:04:05	0.8763	72.97	17.755
04/30/97	14:04:08	0.9280	72.97	17.711
04/30/97	14:04:11	0.9830	72.97	17.660
04/30/97	14:04:15	1.0413	72.97	17.610
04/30/97	14:04:19	1.1030	72.96	17.559
04/30/97	14:04:23	1.1680	72.96	17.508
04/30/97	14:04:27	1.2380	72.96	17.448
04/30/97	14:04:31	1.3113	72.96	17.395
04/30/97	14:04:36	1.3897	72.96	17.331
04/30/97	14:04:41	1.4730	72.94	17.271
04/30/97	14:04:46	1.5613	72.94	17.208
04/30/97	14:04:52	1.6547	72.94	17.139
04/30/97	14:04:58	1.7530	72.94	17.072
04/30/97	14:05:04	1.8580	72.93	17.008
04/30/97	14:05:11	1.9680	72.93	16.936
04/30/97	14:05:18	2.0847	72.92	16.865
04/30/97	14:05:25	2.2097	72.92	16.784
04/30/97	14:05:33	2.3413	72.92	16.706
04/30/97	14:05:41	2.4813	72.92	16.629
[illegible]/30/97	14:05:50	2.6297	72.92	16.549
[illegible]30/97	14:06:00	2.7863	72.91	16.477
04/30/97	14:06:10	2.9530	72.91	16.387
04/30/97	14:06:20	3.1297	72.91	16.309
04/30/97	14:06:31	3.3163	72.90	16.223
04/30/97	14:06:43	3.5147	72.90	16.147
04/30/97	14:06:56	3.7247	72.89	16.067
04/30/97	14:07:09	3.9463	72.88	15.981
04/30/97	14:07:23	4.1813	72.88	15.896
04/30/97	14:07:38	4.4297	72.87	15.820
04/30/97	14:07:54	4.6930	72.87	15.739
04/30/97	14:08:11	4.9730	72.84	15.663
04/30/97	14:08:29	5.2697	72.83	15.587
04/30/97	14:08:47	5.5830	72.83	15.511
04/30/97	14:09:07	5.9147	72.82	15.437
04/30/97	14:09:28	6.2663	72.81	15.361
04/30/97	14:09:51	6.6397	72.80	15.296
04/30/97	14:10:15	7.0347	72.79	15.229
04/30/97	14:10:40	7.4530	72.78	15.169
04/30/97	14:11:06	7.8963	72.77	15.107
04/30/97	14:11:34	8.3663	72.75	15.052
04/30/97	14:12:04	8.8647	72.74	14.996
04/30/97	14:12:36	9.3913	72.74	14.946
04/30/97	14:13:09	9.9497	72.73	14.902
04/30/97	14:13:45	10.5413	72.72	14.846
04/30/97	14:14:23	11.1680	72.71	14.814
04/30/97	14:15:02	11.8313	72.70	14.775
04/30/97	14:15:45	12.5347	72.71	14.745
04/30/97	14:16:29	13.2797	72.70	14.719
04/30/97	14:17:17	14.0697	72.69	14.694
04/30/97	14:18:07	14.9063	72.69	14.678
[illegible]30/97	14:19:00	15.7913	72.68	14.655
[illegible]/30/97	14:19:56	16.7297	72.68	14.643
04/30/97	14:20:56	17.7230	72.68	14.630
04/30/97	14:21:59	18.7763	72.67	14.618
04/30/97	14:23:06	19.8913	72.67	14.609
04/30/97	14:24:17	21.0730	72.67	14.602
04/30/97	14:25:32	22.3247	72.67	14.593

MW-4 Falling Head April 30, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

MW-4



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

```
IN_SITU INC.           TROLL
Serial number:         00000890
Unit name:             SP4000

Report generated:      05/01/97     11:32:42
Report from file:      A:\MW-4-A.BIN

[illegible]t name: MW-4-A

Test defined on:       04/30/97     09:17:19
Test started on:       04/30/97     09:27:30
Test stopped on:       04/30/97     11:09:37
Test extracted on:     04/30/97     11:28:21

Data gathered using Logarithmic testing
   Maximum time between data points:        2.0000           Minutes.
   Number of data samples:         156

Channel number [1]
  Measurement type:    Temperature
  Channel name:        OnBoard Temp

Channel number [2]
  Measurement type:    Pressure/Level
  Channel name:        OnBoard Pressure
  Specific gravity:       1.000
  Mode:     TOC
  User-defined reference:              17.590      Feet H2O
  Referenced on:       channel definition.
  Pressure head at reference:          13.459      Feet H2O


                                        Channel[1]   Channel[2]
  Date        Time        ET (min)    Fahrenheit   Feet H2O
--------    --------    ------------ ----------- -----------
04/30/97    09:27:30          0.0000       75.47        13.144
04/30/97    09:27:30          0.0050       75.48        14.118
[illegible]/30/97    09:27:30          0.0100       75.49        14.316
[illegible]/30/97    09:27:30          0.0150       75.49        13.373
04/30/97    09:27:31          0.0200       75.50        12.985
04/30/97    09:27:31          0.0250       75.51        13.433
04/30/97    09:27:31          0.0300       75.51        14.450
04/30/97    09:27:32          0.0350       75.52        16.484
04/30/97    09:27:32          0.0400       75.52        15.456
04/30/97    09:27:32          0.0450       75.53        13.571
04/30/97    09:27:33          0.0500       75.53        14.014
04/30/97    09:27:33          0.0550       75.53        14.978
04/30/97    09:27:33          0.0600       75.54        15.013
04/30/97    09:27:33          0.0650       75.55        14.321
04/30/97    09:27:34          0.0700       75.55        14.390
04/30/97    09:27:34          0.0750       75.55        14.812
04/30/97    09:27:34          0.0800       75.57        14.699
04/30/97    09:27:35          0.0850       75.57        14.489
04/30/97    09:27:35          0.0900       75.57        14.618
04/30/97    09:27:35          0.0950       75.58        14.724
04/30/97    09:27:36          0.1000       75.58        14.621
04/30/97    09:27:36          0.1058       75.59        14.653
04/30/97    09:27:36          0.1120       75.59        14.720
04/30/97    09:27:37          0.1185       75.60        14.591
04/30/97    09:27:37          0.1255       75.60        14.708
04/30/97    09:27:37          0.1328       75.60        14.634
04/30/97    09:27:38          0.1407       75.61        14.699
04/30/97    09:27:38          0.1490       75.63        14.683
04/30/97    09:27:39          0.1578       75.63        14.699
04/30/97    09:27:40          0.1672       75.64        14.704
04/30/97    09:27:40          0.1770       75.64        14.713
04/30/97    09:27:41          0.1875       75.64        14.717
[illegible]/30/97    09:27:41          0.1985       75.64        14.720
[illegible]30/97    09:27:42          0.2102       75.65        14.729
04/30/97    09:27:43          0.2227       75.65        14.738
04/30/97    09:27:44          0.2358       75.65        14.743
04/30/97    09:27:44          0.2498       75.65        14.750
04/30/97    09:27:45          0.2647       75.65        14.759
04/30/97    09:27:46          0.2803       75.65        14.768
04/30/97    09:27:47          0.2970       75.66        14.777
```

04/30/97	09:27:48	0.3147	75.65	14.784
04/30/97	09:27:50	0.3333	75.66	14.789
04/30/97	09:27:51	0.3532	75.66	14.798
04/30/97	09:27:52	0.3742	75.66	14.807
04/30/97	09:27:53	0.3963	75.66	14.814
04/30/97	09:27:55	0.4198	75.66	14.824
04/30/97	09:27:56	0.4447	75.66	14.837
[illegible]/30/97	09:27:58	0.4697	75.68	14.847
[illegible]/30/97	09:27:59	0.4963	75.68	14.854
04/30/97	09:28:01	0.5247	75.66	14.867
04/30/97	09:28:03	0.5547	75.68	14.877
04/30/97	09:28:05	0.5863	75.68	14.888
04/30/97	09:28:07	0.6213	75.68	14.907
04/30/97	09:28:09	0.6580	75.68	14.914
04/30/97	09:28:11	0.6963	75.68	14.923
04/30/97	09:28:14	0.7380	75.68	14.941
04/30/97	09:28:16	0.7813	75.69	14.957
04/30/97	09:28:19	0.8280	75.69	14.971
04/30/97	09:28:22	0.8763	75.69	14.983
04/30/97	09:28:25	0.9280	75.68	15.001
04/30/97	09:28:28	0.9830	75.68	15.017
04/30/97	09:28:32	1.0413	75.68	15.038
04/30/97	09:28:36	1.1030	75.68	15.057
04/30/97	09:28:40	1.1680	75.68	15.073
04/30/97	09:28:44	1.2380	75.68	15.096
04/30/97	09:28:48	1.3113	75.66	15.117
04/30/97	09:28:53	1.3897	75.66	15.142
04/30/97	09:28:58	1.4730	75.66	15.165
04/30/97	09:29:03	1.5613	75.65	15.186
04/30/97	09:29:09	1.6547	75.65	15.216
04/30/97	09:29:15	1.7530	75.65	15.236
04/30/97	09:29:21	1.8580	75.65	15.266
04/30/97	09:29:28	1.9680	75.65	15.294
04/30/97	09:29:35	2.0847	75.64	15.329
04/30/97	09:29:42	2.2097	75.64	15.359
04/30/97	09:29:50	2.3413	75.64	15.389
04/30/97	09:29:58	2.4813	75.63	15.423
04/30/97	09:30:07	2.6297	75.63	15.458
[illegible]30/97	09:30:17	2.7863	75.62	15.469
04/30/97	09:30:27	2.9530	75.62	15.569
04/30/97	09:30:37	3.1297	75.61	15.569
04/30/97	09:30:48	3.3163	75.61	15.599
04/30/97	09:31:00	3.5147	75.60	15.647
04/30/97	09:31:13	3.7247	75.59	15.684
04/30/97	09:31:26	3.9463	75.58	15.783
04/30/97	09:31:40	4.1813	75.58	15.772
04/30/97	09:31:55	4.4297	75.57	15.822
04/30/97	09:32:11	4.6930	75.55	15.866
04/30/97	09:32:28	4.9730	75.54	15.912
04/30/97	09:32:46	5.2697	75.61	15.965
04/30/97	09:33:04	5.5830	75.57	16.007
04/30/97	09:33:24	5.9147	75.54	16.060
04/30/97	09:33:45	6.2663	75.52	16.111
04/30/97	09:34:08	6.6397	75.50	16.159
04/30/97	09:34:32	7.0347	75.48	16.210
04/30/97	09:34:57	7.4530	75.46	16.261
04/30/97	09:35:23	7.8963	75.43	16.314
04/30/97	09:35:51	8.3663	75.40	16.364
04/30/97	09:36:21	8.8647	75.39	16.417
04/30/97	09:36:53	9.3913	75.36	16.468
04/30/97	09:37:26	9.9497	75.34	16.514
04/30/97	09:38:02	10.5413	75.30	16.567
04/30/97	09:38:40	11.1680	75.27	16.618
04/30/97	09:39:19	11.8313	75.25	16.667
04/30/97	09:40:02	12.5347	75.22	16.717
04/30/97	09:40:46	13.2797	75.18	16.766
04/30/97	09:41:34	14.0697	75.15	16.807
04/30/97	09:42:24	14.9063	75.12	16.860
[illegible]30/97	09:43:17	15.7913	75.10	16.897
[illegible]/30/97	09:44:13	16.7297	75.06	16.936
04/30/97	09:45:13	17.7230	75.04	16.980
04/30/97	09:46:16	18.7763	75.03	17.020
04/30/97	09:47:23	19.8913	75.03	17.054
04/30/97	09:48:34	21.0730	75.02	17.091
04/30/97	09:49:49	22.3247	75.00	17.121

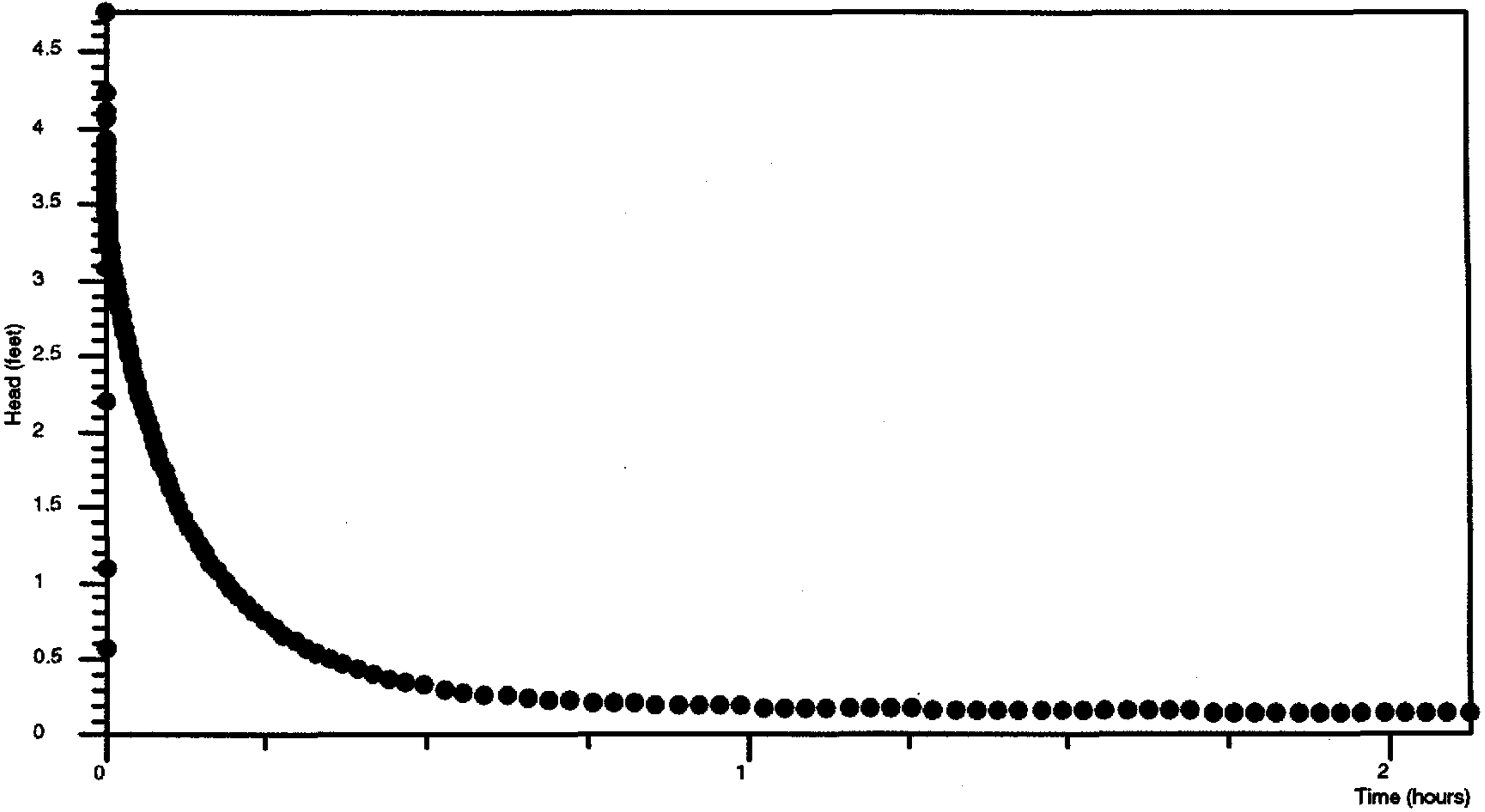
04/30/97	09:51:08	23.6497	75.00	17.153
04/30/97	09:52:33	25.0547	75.00	17.179
04/30/97	09:54:02	26.5430	75.01	17.209
04/30/97	09:55:37	28.1180	75.02	17.234
04/30/97	09:57:17	29.7863	75.02	17.255
04/30/97	09:59:03	31.5547	75.02	17.278
04/30/97	10:00:55	33.4280	75.03	17.299
/30/97	10:02:54	35.4113	75.04	17.315
/30/97	10:04:54	37.4113	75.06	17.333
04/30/97	10:06:54	39.4113	75.06	17.345
04/30/97	10:08:54	41.4113	75.06	17.359
04/30/97	10:10:54	43.4113	75.06	17.368
04/30/97	10:12:54	45.4113	75.05	17.372
04/30/97	10:14:54	47.4113	75.05	17.384
04/30/97	10:16:54	49.4113	75.04	17.384
04/30/97	10:18:54	51.4113	75.03	17.393
04/30/97	10:20:54	53.4113	75.04	17.398
04/30/97	10:22:54	55.4113	75.08	17.402
04/30/97	10:24:54	57.4113	75.16	17.407
04/30/97	10:26:54	59.4113	75.13	17.409
04/30/97	10:28:54	61.4113	75.12	17.414
04/30/97	10:30:54	63.4113	75.11	17.419
04/30/97	10:32:54	65.4113	75.10	17.428
04/30/97	10:34:54	67.4113	75.08	17.432
04/30/97	10:36:54	69.4113	75.07	17.437
04/30/97	10:38:54	71.4113	75.07	17.437
04/30/97	10:40:54	73.4113	75.08	17.439
04/30/97	10:42:54	75.4113	75.10	17.444
04/30/97	10:44:54	77.4113	75.11	17.444
04/30/97	10:46:54	79.4113	75.13	17.449
04/30/97	10:48:54	81.4113	75.14	17.449
04/30/97	10:50:54	83.4113	75.15	17.453
04/30/97	10:52:54	85.4113	75.15	17.453
04/30/97	10:54:54	87.4113	75.15	17.453
04/30/97	10:56:54	89.4113	75.16	17.453
04/30/97	10:58:54	91.4113	75.16	17.453
04/30/97	11:00:54	93.4113	75.16	17.458
04/30/97	11:02:54	95.4113	75.16	17.453
30/97	11:04:54	97.4113	75.16	17.453
/30/97	11:06:54	99.4113	75.26	17.453
04/30/97	11:08:54	101.4113	75.28	17.458

MW-4 Rising Head April 30, 1997

Former Gulf States Creosoting Site Hattiesburg, Mississippi

Arithmetic Graph

MW-4



Project Number 21-02 for Kerr-McGee
Analysis by Starpoint Software

```
IN_SITU INC.          TROLL
Serial number:        00000890
Unit name:            SP4000

Report generated:     05/01/97     11:33:45
Report from file:     A:\MW-4-B.BIN

[illegible]st name: MW-4-B

Test defined on:      04/30/97     11:11:46
Test started on:      04/30/97     11:15:25
Test stopped on:      04/30/97     13:23:19
Test extracted on:    04/30/97     13:25:30

Data gathered using Logarithmic testing
   Maximum time between data points:       2.0000           Minutes.
   Number of data samples:        169

Channel number [1]
  Measurement type:   Temperature
  Channel name:       OnBoard Temp

Channel number [2]
  Measurement type:   Pressure/Level
  Channel name:       OnBoard Pressure
  Specific gravity:      1.000
  Mode:     TOC
  User-defined reference:            17.460     Feet H2O
  Referenced on:      channel definition.
  Pressure head at reference:        13.592     Feet H2O


                                          Channel[1]   Channel[2]
  Date          Time        ET (min)     Fahrenheit   Feet H2O
--------      --------    ------------  -----------  -----------
04/30/97      11:15:25          0.0000        75.37       17.904
04/30/97      11:15:25          0.0050        75.38       19.526
04/30/97      11:15:25          0.0100        75.39       18.432
[illegible]30/97      11:15:25          0.0150        75.40       18.421
04/30/97      11:15:26          0.0200        75.40       19.530
04/30/97      11:15:26          0.0250        75.41       20.411
04/30/97      11:15:26          0.0300        75.42       21.263
04/30/97      11:15:27          0.0350        75.42       22.081
04/30/97      11:15:27          0.0400        75.43       21.004
04/30/97      11:15:27          0.0450        75.43       21.556
04/30/97      11:15:28          0.0500        75.43       21.449
04/30/97      11:15:28          0.0550        75.44       21.168
04/30/97      11:15:28          0.0600        75.46       21.387
04/30/97      11:15:28          0.0650        75.46       21.226
04/30/97      11:15:29          0.0700        75.46       21.196
04/30/97      11:15:29          0.0750        75.46       21.237
04/30/97      11:15:29          0.0800        75.46       21.113
04/30/97      11:15:30          0.0850        75.47       21.147
04/30/97      11:15:30          0.0900        75.47       21.117
04/30/97      11:15:30          0.0950        75.48       21.078
04/30/97      11:15:31          0.1000        75.48       21.073
04/30/97      11:15:31          0.1058        75.49       21.053
04/30/97      11:15:31          0.1120        75.49       21.013
04/30/97      11:15:32          0.1185        75.49       21.002
04/30/97      11:15:32          0.1255        75.50       20.979
04/30/97      11:15:32          0.1328        75.50       20.967
04/30/97      11:15:33          0.1407        75.51       20.944
04/30/97      11:15:33          0.1490        75.53       20.907
04/30/97      11:15:34          0.1578        75.53       20.894
04/30/97      11:15:35          0.1672        75.53       20.880
04/30/97      11:15:35          0.1770        75.54       20.864
04/30/97      11:15:36          0.1875        75.54       20.847
04/30/97      11:15:36          0.1985        75.54       20.829
[illegible]30/97      11:15:37          0.2102        75.55       20.808
04/30/97      11:15:38          0.2227        75.55       20.794
04/30/97      11:15:39          0.2358        75.55       20.778
04/30/97      11:15:39          0.2498        75.54       20.760
04/30/97      11:15:40          0.2647        75.54       20.744
04/30/97      11:15:41          0.2803        75.55       20.725
04/30/97      11:15:42          0.2970        75.55       20.704
```

04/30/97	11:15:43	0.3147	75.54	20.688
04/30/97	11:15:45	0.3333	75.55	20.674
04/30/97	11:15:46	0.3532	75.55	20.654
04/30/97	11:15:47	0.3742	75.55	20.635
04/30/97	11:15:48	0.3963	75.55	20.619
04/30/97	11:15:50	0.4198	75.55	20.601
04/30/97	11:15:51	0.4447	75.55	20.584
[illegible]/30/97	11:15:53	0.4697	75.57	20.566
[illegible]/30/97	11:15:54	0.4963	75.57	20.545
04/30/97	11:15:56	0.5247	75.57	20.531
04/30/97	11:15:58	0.5547	75.57	20.511
04/30/97	11:16:00	0.5863	75.57	20.494
04/30/97	11:16:02	0.6213	75.57	20.467
04/30/97	11:16:04	0.6580	75.57	20.455
04/30/97	11:16:06	0.6963	75.57	20.437
04/30/97	11:16:09	0.7380	75.57	20.411
04/30/97	11:16:11	0.7813	75.57	20.391
04/30/97	11:16:14	0.8280	75.57	20.372
04/30/97	11:16:17	0.8763	75.57	20.351
04/30/97	11:16:20	0.9280	75.57	20.326
04/30/97	11:16:23	0.9830	75.55	20.305
04/30/97	11:16:27	1.0413	75.54	20.278
04/30/97	11:16:31	1.1030	75.55	20.252
04/30/97	11:16:35	1.1680	75.54	20.227
04/30/97	11:16:39	1.2380	75.54	20.202
04/30/97	11:16:43	1.3113	75.54	20.176
04/30/97	11:16:48	1.3897	75.54	20.146
04/30/97	11:16:53	1.4730	75.53	20.112
04/30/97	11:16:58	1.5613	75.52	20.082
04/30/97	11:17:04	1.6547	75.53	20.047
04/30/97	11:17:10	1.7530	75.52	20.012
04/30/97	11:17:16	1.8580	75.52	19.978
04/30/97	11:17:23	1.9680	75.51	19.943
04/30/97	11:17:30	2.0847	75.51	19.909
04/30/97	11:17:37	2.2097	75.50	19.869
04/30/97	11:17:45	2.3413	75.50	19.828
04/30/97	11:17:53	2.4813	75.49	19.789
[illegible]/30/97	11:18:02	2.6297	75.48	19.745
[illegible]/30/97	11:18:12	2.7863	75.48	19.699
04/30/97	11:18:22	2.9530	75.47	19.650
04/30/97	11:18:32	3.1297	75.47	19.609
04/30/97	11:18:43	3.3163	75.46	19.556
04/30/97	11:18:55	3.5147	75.46	19.510
04/30/97	11:19:08	3.7247	75.43	19.456
04/30/97	11:19:21	3.9463	75.43	19.401
04/30/97	11:19:35	4.1813	75.42	19.350
04/30/97	11:19:50	4.4297	75.41	19.293
04/30/97	11:20:06	4.6930	75.40	19.237
04/30/97	11:20:23	4.9730	75.39	19.182
04/30/97	11:20:41	5.2697	75.38	19.127
04/30/97	11:20:59	5.5830	75.36	19.067
04/30/97	11:21:19	5.9147	75.35	19.007
04/30/97	11:21:40	6.2663	75.34	18.944
04/30/97	11:22:03	6.6397	75.33	18.884
04/30/97	11:22:27	7.0347	75.31	18.824
04/30/97	11:22:52	7.4530	75.35	18.764
04/30/97	11:23:18	7.8963	75.34	18.700
04/30/97	11:23:46	8.3663	75.31	18.645
04/30/97	11:24:16	8.8647	75.30	18.580
04/30/97	11:24:48	9.3913	75.29	18.520
04/30/97	11:25:21	9.9497	75.27	18.460
04/30/97	11:25:57	10.5413	75.27	18.402
04/30/97	11:26:35	11.1680	75.26	18.342
04/30/97	11:27:14	11.8313	75.25	18.287
04/30/97	11:27:57	12.5347	75.24	18.236
04/30/97	11:28:41	13.2797	75.28	18.179
04/30/97	11:29:29	14.0697	75.26	18.128
[illegible]/30/97	11:30:19	14.9063	75.25	18.082
[illegible]/30/97	11:31:12	15.7913	75.24	18.033
04/30/97	11:32:08	16.7297	75.24	17.989
04/30/97	11:33:08	17.7230	75.23	17.943
04/30/97	11:34:11	18.7763	75.23	17.899
04/30/97	11:35:18	19.8913	75.23	17.865
04/30/97	11:36:29	21.0730	75.22	17.828
04/30/97	11:37:44	22.3247	75.22	17.793

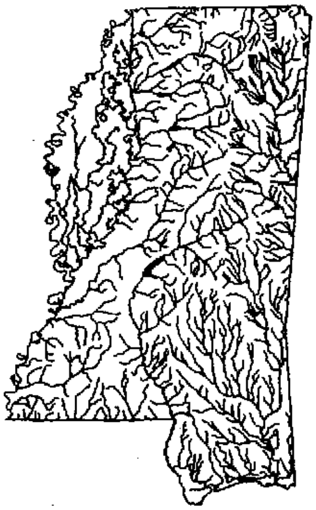
04/30/97	11:39:03	23.6497	75.22	17.759
04/30/97	11:40:28	25.0547	75.23	17.729
04/30/97	11:41:57	26.5430	75.23	17.701
04/30/97	11:43:32	28.1180	75.24	17.676
04/30/97	11:45:12	29.7863	75.24	17.655
04/30/97	11:46:58	31.5547	75.25	17.634
04/30/97	11:48:50	33.4280	75.24	17.616
04/30/97	11:50:49	35.4113	75.24	17.600
[illegible]30/97	11:52:49	37.4113	75.25	17.586
[illegible]/30/97	11:54:49	39.4113	75.25	17.572
04/30/97	11:56:49	41.4113	75.26	17.565
04/30/97	11:58:49	43.4113	75.26	17.556
04/30/97	12:00:49	45.4113	75.26	17.547
04/30/97	12:02:49	47.4113	75.26	17.542
04/30/97	12:04:49	49.4113	75.27	17.535
04/30/97	12:06:49	51.4113	75.28	17.530
04/30/97	12:08:49	53.4113	75.28	17.526
04/30/97	12:10:49	55.4113	75.29	17.521
04/30/97	12:12:49	57.4113	75.30	17.521
04/30/97	12:14:49	59.4113	75.30	17.517
04/30/97	12:16:49	61.4113	75.30	17.512
04/30/97	12:18:49	63.4113	75.30	17.512
04/30/97	12:20:49	65.4113	75.30	17.507
04/30/97	12:22:49	67.4113	75.31	17.507
04/30/97	12:24:49	69.4113	75.31	17.505
04/30/97	12:26:49	71.4113	75.33	17.500
04/30/97	12:28:49	73.4113	75.34	17.500
04/30/97	12:30:49	75.4113	75.35	17.500
04/30/97	12:32:49	77.4113	75.35	17.496
04/30/97	12:34:49	79.4113	75.35	17.496
04/30/97	12:36:49	81.4113	75.35	17.496
04/30/97	12:38:49	83.4113	75.36	17.496
04/30/97	12:40:49	85.4113	75.36	17.491
04/30/97	12:42:49	87.4113	75.36	17.491
04/30/97	12:44:49	89.4113	75.37	17.491
04/30/97	12:46:49	91.4113	75.37	17.491
04/30/97	12:48:49	93.4113	75.37	17.491
04/30/97	12:50:49	95.4113	75.37	17.491
[illegible]0/97	12:52:49	97.4113	75.38	17.487
[illegible]0/97	12:54:49	99.4113	75.38	17.487
04/30/97	12:56:49	101.4113	75.38	17.487
04/30/97	12:58:49	103.4113	75.39	17.482
04/30/97	13:00:49	105.4113	75.39	17.482
04/30/97	13:02:49	107.4113	75.39	17.477
04/30/97	13:04:49	109.4113	75.39	17.477
04/30/97	13:06:49	111.4113	75.39	17.475
04/30/97	13:08:49	113.4113	75.40	17.477
04/30/97	13:10:49	115.4113	75.40	17.477
04/30/97	13:12:49	117.4113	75.40	17.477
04/30/97	13:14:49	119.4113	75.40	17.477
04/30/97	13:16:49	121.4113	75.40	17.475
04/30/97	13:18:49	123.4113	75.40	17.475
04/30/97	13:20:49	125.4113	75.40	17.470
04/30/97	13:22:49	127.4113	75.50	17.475

Appendix J

Water Well Search Records

Project No. 21-02
Former Gulf States Creosoting Site
Hattiesburg, Mississippi

U.S. Department of the Interior
U.S. Geological Survey
Water Resources Division



MISSISSIPPI DISTRICT

☐ Because of your interest in water resources in the State of Mississippi, a copy of our latest publication is enclosed.

☑ The enclosed information is supplied in response to your recent request.

Bill Oakley

308 South Airport Road
Pearl, Mississippi 39208-6649

(601) 965-4600

MARCH 3, 1849

WATER WELLS LOCATED WITHIN HATTIESBURG QUAD FORREST CO MS.

LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
A001 UNIV SO MS	SESWS14T05NR14W	312056	0892138	-	195	--	--	--
A002 USM GOLF COURSE	SWNES36T05NR14W	312112	892153	-	195	--	--	--
A003 UNIV SOU MISS	SWNES36T05NR14W	312109	892132	-	195	--	--	--
A004 WEST HILLS C CL	SWSES36T05NR14W	312052	0892136	U	248	236.00	--	--
A008 STANDARD OIL CO	NENES36T05NR14W	312132	892203	H	165	155.00	--	--
A024 RAWLS SPGS W A	NWSWS25T05NR14W	312203	0892154	P	705	675.00	--	220.00
A031 E P FILLINGAME	----S25T05NR14W	312210	892130	H	105	100.00	--	--
A035 BROWN CONSTR CO	NWNES25T05NR14W	312228	892137	H	60.0	50.00	--	35.00
A036 BILL MACK	SWNES35T05NR14W	312113	892230	H	140	120.00	--	12.00
A039 RAWLS SPGS W A	NESWS25T05NR14W	312217	892152	P	680	640.00	--	200.00
A044 BROOME CONST CO	NESWS25T05NR14W	312210	892120	H	60.0	50.00	--	30.00
A063 L E RHIAN	NESWS35T05NR14W	312114	892214	H	185	165.00	185.00	45.00
A067 CHURCH OF GOD	SWSES25T05NR14W	312141	892114	H	285	255.00	285.00	74.00
A075 SONNY RHIAN	NESWS35T05NR14W	312114	0892230	H	780.	680.	780.	25.
B001 HATTIESBURG	NESES31T05NR13W	312109	0892009	P	419	334.00	--	1065.00
B002 HATTIESBURG	SWNWS32T05NR13W	312109	0891942	P	622	537.00	--	970.00
						--	--	760.
B003 HATTIESBURG	NWSWS32T05NR13W	312105	0891949	-	610	530.00	--	953.00
B004 HATTIESBURG	SWNWS32T05NR13W	312105	0891949	-	450.	--	--	953.00
B005 HATTIESBURG	NESWS32T05NR13W	312115	0891923	P	621	534.00	--	990.00
B006 HATTIESBURG	SWNES32T05NR13W	312115	0891936	U	444	352.00	--	964.00
B007 HATTIESBURG	NESWS32T05NR13W	312115	0891923	P	635	503.00	--	908.00
B009 UNION TEX CO	NWNES26T05NR13W	312224	891616	N	260	230.00	--	400.00
B010 WARREN PETR CO.	SWNWS25T05NR13W	312154	891543	U	289	259.00	--	90.00
B011 WARREN PETRO CO	NWSWS25T05NR13W	312154	891543	N	292	262.00	--	325.00
B012 WARREN PETR CO	SESWS26T05NR13W	312143	0891612	-	289	268.00	--	90.00
B014 MOBIL OIL CO.	NENWS26T05NR13W	312227	891614	U	252	222.00	--	300.00
B017 HATTIESBURG	NESES31T05NR13W	312107	0892006	P	607	540.00	--	1000.00
B018 JACK GANDY	NENES33T05NR13W	312135	891754	H	50.0	--	--	--
B020 TEXACO OIL CO	NWNWS31T05NR13W	312136	892052	H	58.0	52.00	--	--
B021 C G CARGILL	----S29T05NR13W	312214	891942	H	96.0	--	--	--
B023 HATTIESBURG	NWSWS32T05NR13W	312106	891951	P	607	544.00	--	1000.00
B026 CHARLES LYLES	SENWS25T05NR13W	312155	891515	H	145	140.00	--	--
B027 LEWIS R SIMS	----S25T05NR13W	312142	891519	H	82.0	77.00	--	--
B028 H F SUMRALL	NWNES31T05NR13W	312111	892049	H	70.0	65.00	--	--
B029 WATSON	----S28T05NR13W	312205	891828	H	65.0	60.00	--	--
B030 CHAS WADE	----S33T05NR13W	312127	891820	H	55.0	50.00	--	--
B031 CHAS. WADE	----S33T05NR13W	312127	891820	H	55.0	50.00	--	--
B032 HATTIESBURG EQP	----S35T05NR13W	312115	891611	H	25.0	20.00	--	--
B033 CARGILE	NENES29T05NR13W	312227	891900	H	87.0	82.00	--	8.00

DATE: 05/15/97 WATER WELLS LOCATED WITHIN HATTIESBURG QUAD FORREST CO MS. PAGE 1b

AQUIFER CODE	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	ALTITUDE OF LAND SURFACE (FEET)	DATA RELI-ABILITY
122HBRG	100.00	01-01-58	240.00	C
122HBRG	--	--	--	C
122HBRG	--	--	--	C
122HBRG	86.00	10-30-81	225.00	C
122HBRG	22.00	10-01-64	--	C
122CTHL	86.00	06-01-66	235.00	C
122HBRG	82.00	07-01-69	170.00	U
122MOCN	11.00	02-01-72	150.00	C
122HBRG	92.00	07-01-71	400.00	C
122CTHLM	115.00	10-29-81	230.00	C
122CTHLU	19.00	02-01-72	--	C
122CTHLU	105.00	11-20-79	240.00	U
122CTHLU	61.00	09-26-80	202.00	U
122CTHL	145.	01-04-96	255.	U
122CTHLU	10.00	04-01-66	161.00	C
122CTHLM	77.00	08-31-81	161.00	C
--				
122CTHLM	31.00	12-01-64	164.00	C
122CTHLU	8.00	09-01-55	160.00	C
122CTHLM	34.00	09-01-55	160.00	C
122CTHLU	28.00	05-14-81	160.3	C
122CTHLM	20.00	08-01-55	160.00	C
122CTHLU	3.00	11-01-56	152.00	C
122CTHLU	50.00	09-01-53	170.00	C
122CTHLU	50.00	01-01-54	170.00	C
122CTHLU	2.00	09-01-55	153.00	C
122CTHLU	6.00	09-01-58	154.00	C
122CTHLM	37.00	01-01-65	160.00	C
122HBRG	--	--	158.00	C
122HBRG	--	--	175.00	C
122HBRG	--	--	--	U
122CTHLM	42.00	09-01-66	155.00	C
122HBRG	--	--	--	C
122HBRG	--	--	--	U
122HBRG	--	--	--	C
122HBRG	--	--	--	U
122HBRG	32.00	01-01-66	--	U
122HBRG	32.00	01-01-66	--	U
122HBRG	12.00	01-01-60	--	M
122HBRG	38.00	09-01-67	--	C

LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
B034 C WILLIAMSON	SENWS29T05NR13W	312202	891909	H	65.0	60.00	--	--
B035 C J MORGAN	SWNES28T05NR13W	312152	891839	H	75.0	70.00	--	--
B052 C F WILLIAMS	SENWS29T05NR13W	312202	891906	H	65.0	60.00	--	--
B054 LOVELL COOLEY	SESES28T05NR13W	312140	0891750	H	82.0	78.00	--	30.00
B055 BARRON HENDRY	SESWS25T05NR13W	312148	891529	H	65.0	60.00	--	12.00
B056 S BROMFIELD	NWSES36T05NR13W	312117	891531	H	82.0	77.00	--	20.00
B057 AMERICAN S&G CO	NESWS33T05NR13W	312121	891814	H	106	101.00	--	17.00
B058 MCMAHAN	SENWS31T05NR13W	312109	892025	H	105	100.00	--	10.00
B059 B UNDERWOOD	NWSES35T05NR13W	312112	891624	H	75.0	70.00	--	26.00
B060 W H RATCLIFF	NWSWS36T05NR13W	312108	891542	H	55.0	50.00	--	20.00
B061 HERSHEL MOHLER	NWNES36T05NR13W	312141	891526	H	60.0	55.00	--	20.00
B062 J C PITTMAN	SESES29T05NR13W	312152	891756	H	68.0	63.00	--	15.00
B063 LAUREL HALMIX C	NWNWS34T05NR13W	312126	891736	-	106	96.00	--	18.00
B068 LAGRACE MOTEL	SWNES31T05NR13W	312115	892030	H	86.0	76.00	--	26.00
B069 GLENDALE UTIL DST	--SWS28T05NR13W	312152	0891848	U	654	614.00	--	300.00
B070 LAGRACE MOTEL	SWNES31T05NR13W	312115	0892031	H	87.0	77.00	--	30.00
B073 DOPHIN SIMS	NWSES28T05NR13W	312227	891836	H	75.0	70.00	--	10.00
B074 N J CARPENTER	NENWS28T05NR13W	312215	891803	H	65.0	60.00	--	10.00
B075 S J WILLIAMSON	SESES30T05NR13W	312145	892008	H	90.0	85.00	--	20.00
B076 HAPPY ACRES	SWNES35T05NR13W	312104	891645	U	100	80.00	--	250.00
B077 G E WEITAN	SWNWS29T05NR13W	312207	891945	H	108	98.00	--	30.00
B078 LAUREL HOT MIX	NENES33T05NR13W	312124	891845	H	97.0	87.00	--	15.00
B079 ETHEL GORDY	NENWS28T05NR13W	312230	891810	H	85.0	80.00	--	22.00
B080 ENTERPRISE PROD	NWNWS25T05NR13W	312225	0891545	N	320	268.00	--	500.00
B081 ENTERPRISE PROD	NWNWS25T05NR13W	312225	891545	N	352	284.00	--	500.00
B082 PMA PROC. DIV	NWSES35T05NR13W	312115	891615	U	100	80.00	--	305.00
B084 AMERICAN SAND	SWSWS33T05NR13W	312057	0891838	H	94.0	89.00	--	12.00
B085 RANDY POWELL	SESES35T05NR13W	312049	891601	H	25.0	20.00	--	--
B086 RUSSELL	SESES35T05NR13W	312048	891602	H	25.0	20.00	--	--
B093 ENTERPRISE GAS	SWNWS25T05NR13W	312202	891541	-	--	--	--	--
B098 REO HINTON	----S27T05NR13W	312150	891715	H	82.0	72.00	--	30.00
B100 PMA PORK PROC DIC	NWSES35T05NR13W	312114	891615	U	96.0	76.00	--	315.00
B101 AMERICAN SAND	--NES32T05NR13W	312130	891910	H	96.0	91.00	--	15.00
B103 MOBILE OIL CORP	NESWS35T05NR13W	312112	891619	N	254	204.00	254.00	550.00
B105 HATTIESBURG STORAGE	SWNWS25T05NR13W	312208	891544	N	315.	215.00	315.00	1000.00
						--	--	1005
B106 HATTIESBURG STORAGE	SWNWS25T05NR13W	312208	891544	N	330	230.00	330.00	1000.00
B111 ENTERPRISE PROD	NENWS25T05NR13W	312226	0891527	N	390	340.00	--	892.00
B112 WARREN PETROLEUM	NWSWS25T05NR13W	312154	0891542	N	324.	237.	262.	350.
						272.	324.	--

AQUIFER CODE	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	ALTITUDE OF LAND SURFACE (FEET)	DATA RELI-ABILITY
122HBRG	23.00	01-01-68	--	C
122HBRG	--	--	--	C
122HBRG	--	--	--	C
122HBRG	25.00	06-01-68	170.00	C
122HBRG	22.00	01-01-69	185.00	C
122HBRG	23.00	01-01-69	170.00	C
122HBRG	27.00	01-01-69	160.00	C
122HBRG	82.00	02-01-69	160.00	C
122HBRG	8.00	03-01-69	140.00	C
122HBRG	32.00	04-01-69	160.00	C
122HBRG	21.00	06-01-69	175.00	C
122HBRG	20.00	06-01-69	160.00	C
122HBRG	34.00	06-01-69	150.00	C
122HBRG	86.00	02-01-70	185.00	C
122CTHLM	50.00	02-01-69	183.00	C
122HBRG	31.00	03-01-70	185.00	C
122HBRG	41.00	07-01-70	180.00	C
122HBRG	21.00	11-01-70	170.00	C
122HBRG	12.00	12-01-70	150.00	C
122HBRG	17.00	12-01-70	130.00	C
122HBRG	38.00	01-01-71	170.00	C
122HBRG	17.00	03-01-71	170.00	C
122HBRG	31.00	07-01-71	170.00	C
122CTHLU	119.00	08-01-71	250.00	C
122CTHLU	119.00	08-01-71	250.00	C
122HBRG	15.00	10-29-81	145.	C
122HBRG	30.00	12-01-71	150.00	C
122HBRG	11.00	11-01-71	150.00	C
122HBRG	13.00	11-01-71	150.00	C
--	--	--	220.00	C
122HBRG	22.00	05-01-74	--	U
122HBRG	15.00	10-29-81	140.00	C
122HBRG	25.00	09-01-75	--	U
122CTHLU	24.00	11-30-77	140.00	C
122CTHLU	66.00	12-30-77	200.00	C
--				
122CTHLU	88.00	01-15-78	220.00	U
122CTHLU	129.00	03-01-75	250.00	C
122CTHLU	82.	11-19-82	160.	C
--				

WATER WELLS LOCATED WITHIN HATTIESBURG QU[illegible] FORREST CO MS.

LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
B114 HATTIESBURG	SESES31T05NR13W	312110	0891945	U	--	--	--	--
B120 WARREN PETRO CO	SWNWS25T05NR13W	312206	891534	N	372	281.00	372.00	1100.00
B123 UNION TEX CO	NWNES26T05NR13W	312228	891615	N	256	206.00	256.00	1000.00
B126 AM SAND & GRAVEL	SENWS33T05NR13W	312120	891827	H	110	105.00	110.00	6.00
B128 HATTIESBURG	NESES31T05SR13W	312112	0892005	P	497.	358.	421.	1500.
						475.	497.	--
B129 HATTIESBURG	NESES31T05NR13W	312108	0891941	P	634.	599.	634.	1500.
B130 WARREN PETROLEUM	SWSWS25T05NR13W	312212	0891542	N	382	301	382	1250
B131 HATTIESBURG C C	SENWS31T05NR13W	312116	0892034	I	270.	240.	270.	210.
D002 HATTIESBURG AAB	NENWS36T04NR13W	311621	0891512	U	195	165.00	--	297.00
D003 HATTIESBURG	NESWS36T04NR13W	311602	891506	U	200	--	--	--
D004 HATTIESBURG	SENES15T04NR13W	311836	0891701	P	485	435.00	--	1200.00
D005 HATTIESBURG	NENES15T04NR13W	311847	0891702	P	678	628.00	--	1200.00
D006 HATTIESBURG	NENES15T04NR13W	311847	0891702	P	673	623.00	--	1200.00
D007 HATTIESBURG	SENES15T04NR13W	311803	0891644	P	688	618.00	--	1200.00
D008 HATTIESBURG	NESES15T04NR13W	311834	891701	U	710	610.00	--	--
D009 MARSHALL DURBIN	--NWS23T04NR13W	311804	891645	N	678	628.00	--	350.00
D010 MARSHALL DURBIN	--NWS23T04NR13W	311804	891647	N	678	638.00	--	550.00
D011 DIXIE PINE PROD	NWSES23T04NR13W	311723	891607	-	740	695.00	--	250.00
D012 DIXIE PINE PROD	SENWS23T04NR13W	311723	891610	U	727	665.00	--	1000.00
D013 COASTAL CHEM CO	SWNWS03T04NR13W	312019	891745	U	325	283.00	--	--
D014 DIXIE PINE PROD	SENWS23T04NR13W	312015	891851	U	501	410.00	--	600.00
D016 HERCULES PWD CO	SWNWS04T04NR13W	312016	891707	N	451	381.00	--	1387.00
D018 SOUTHERN RR	NENES10T04NR13W	311953	891653	U	410	350.00	--	--
D019 CENTRAL PKNG CO	NWSWS11T04NR13W	311936	891642	U	420	390.00	--	60.00
D020 MISS POWER CO	NWNES11T04NR13W	311935	0891613	E	110	90.00	--	400.00
D021 MISS POWER CO	NENES11T04NR13W	312002	891545	E	112	92.00	--	400.00
D022 MISS POWER CO	NENES11T04NR13W	312002	891546	U	108	88.00	--	--
D023 CRYSTAL ICE CO	NENES11T04NR13W	311954	891553	U	360	--	--	--
D025 E TRAVILLION HS	SWSWS25T04NR13W	311624	0891545	U	580	540.00	--	200.00
D026 BEV DRIVE IN	SENWS27T04NR13W	311639	891702	H	40.0	--	--	--
D027 CEN FORREST ATT CR	SENES27T04NR13W	311633	891650	H	360	340.00	--	--
D028 PETAL	NWNWS01T04NR13W	312037	0891548	-	124	90.00	--	600.00
D029 PETAL	SWSWS01T04NR13W	312002	0891544	P	134.	103.00	--	750.00
D030 EAST FORREST UTL	NWNWS01T04NR13W	312039	891545	U	390	322.00	--	500.00
D031 CLINTON LUMBER CO	NWNES02T04NR13W	312035	891627	U	390	--	--	--
D032 BEVERLY DRIVE-IN	SENWS27T04NR13W	311642	0891701	U	50.0	--	--	--
D033 JOS DELIA	NWSWS27T04NR13W	311653	891748	H	55.0	--	--	--
D034 JOS DELIA	NWSWS27T04NR13W	311653	891748	H	55.0	--	--	--
D035 PEPSI COLA BOT	NWNWS05T04NR13W	312043	891950	U	346	--	--	--

AQUIFER CODE	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	ALTITUDE OF LAND SURFACE (FEET)	DATA RELI- ABILITY
--	--	--	175.	U
122CTHLU	130.00	09-01-79	250.00	C
122CTHLU	23.00	06-01-80	143.00	U
122HBRG	62.00	07-14-84	135.00	U
122CTHLU	50.	10-05-91	180.	U
--				
122CTHLM	117.	10-15-91	195.	C
122CTHLU	112	07-01-92	238	U
122CTHLU	33.6	10-20-96	150.	U
122HBRG	13.00	10-01-63	143.00	C
122HBRG	10.00	01-01-59	145.00	C
122CTHLU	30.00	11-06-87	143.00	C
122CTHLM	20.00	12-01-64	143.00	C
122CTHLM	20.00	04-01-64	143.00	C
122CTHLM	20.00	06-01-64	143.00	C
122CTHLM	80.00	02-15-76	140.00	C
122CTHLM	65.00	09-01-61	150.00	U
122CTHLM	11.00	01-01-63	150.00	U
122CTHLM	6.00	10-01-50	148.00	C
122CTHLM	26.00	06-01-55	148.00	C
122CTHLU	9.00	11-01-63	145.00	C
122CTHLU	--	--	--	C
122CTHLU	14.00	01-01-53	168.00	C
122CTHLU	14.00	11-01-63	--	C
122CTHLU	--	--	140.00	C
122HBRG	11.	02-01-48	135.00	C
122HBRG	16.00	10-01-63	135.00	C
122HBRG	17.00	11-01-63	135.00	C
122CTHLU	8.00	04-01-63	--	C
122CTHLU	3.00	09-01-57	150.	C
122HBRG	--	--	--	C
122CTHLU	--	--	--	C
112TRCS	10.00	03-01-64	155.	C
110ALVM	--	--	154.	U
122CTHLU	3.00	01-01-43	160.00	C
122CTHLU	25.00	05-01-64	151.00	C
122HBRG	--	--	185.	C
122HBRG	--	--	--	C
122HBRG	10.00	01-01-59	--	C
122CTHLU	49.00	07-01-58	210.00	C

LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
D036 REV BERRY BELL	NENWS21T04NR13W	311802	891813	H	320	314.00	--	--
D038 HERCULES POWDER	NWSWS04T04NR13W	312015	0891842	U	687	591.00	--	1000.00
D039 COASTAL CHEMICAL	NWSWS03T04NR13W	312020	0891737	U	350	310.00	350.00	483.00
D040 WOMACK ICE CO.	SENWS03T04NR13W	312021	891711	U	105	100.00	--	12.00
D041 WOMACK ICE CO	SENWS03T04NR13W	312021	891710	U	18.0	13.00	--	16.00
D042 PALMERS CRSN	NESES27T04NR13W	311656	0891702	U	642	600.00	--	300.00
D043 PALMERS CROSSING W	SENES27T04NR13W	311654	891701	U	326	325.00	--	--
D044 PALMERS CRSN	NESES27T04NR13W	311640	0891659	U	642	600.00	--	300.00
D045 CENTRAL W A	NESES22T04NR13W	311735	0891650	U	694	650.00	--	250.00
D046 CENTRAL W A	SENES22T04NR13W	311736	0891658	U	672	632.00	--	252.00
D047 H S LITTLE	----S06T04NR13W	312031	892035	H	60.0	--	--	--
D048 R O BLACKWELL	----S06T04NR13W	312031	0892036	H	185	175.00	--	6.00
D049 LEON PRINGLE	NWNWS09T04NR13W	311948	891842	H	576	556.00	--	--
D051 GEORGE DRAUGHIN	NESWS12T04NR13W	311936	891512	H	23.0	21.00	--	--
D052 GEO DRAUGHIN	NESWS12T04NR13W	311933	891513	H	33.0	--	--	--
D053 VAN HOOK	SENES07T04NR13W	311942	892011	H	362	--	--	--
D054 D M WARD	SESWS22T04NR13W	311721	891717	H	120	--	--	--
D055 KENNISON	--NWS05T04NR13W	312029	891928	H	138	132.00	--	--
D056 U S M	NENES07T04NR13W	311957	892004	U	--	--	--	--
D057 W D CARPENTER	NESES12T04NR13W	311933	891510	H	35.0	31.00	--	--
D058 C M LINGEL	SESWS02T04NR13W	312008	891622	H	78.0	74.00	--	--
D059 ERNIE ELKINS	NWSWS30T04NR13W	311656	892053	H	60.0	55.00	--	--
D060 HERCULES PWD CO	SWNWS04T04NR13W	312029	891810	N	671	570.00	--	1000.00
D061 MURRAY ENVELOPE	NESWS04T04NR13W	312029	891811	N	105	95.00	--	72.00
D062 EDD WALTERS	----S14T04NR13W	311837	891614	H	48.0	43.00	--	--
D063 GEO VARNADO	----S23T04NR13W	311800	891900	H	120	115.00	--	--
D064 JAMES WEBB	----S27T04NR13W	311656	891658	H	78.0	73.00	--	--
D065 M RAYBORN	----S14T04NR13W	311900	891600	H	89	84.00	--	--
D066 PAUL RAYBORN	----S14T04NR13W	311901	891600	H	94.0	89.00	--	--
D067 M RAYBORN	----S14T04NR13W	311900	0891601	H	100	95.00	--	--
D068 RAY BRELAND	----S14T04NR13W	311900	891600	H	106	101.00	--	--
D069 J D LEWIS	SESES08T04NR13W	311901	891910	S	360	--	--	--
D070 MURRAY ENVELOPE	NENES04T04NR13W	312035	891820	N	422	402.00	--	158.00
D072 PINE BURR PK CO	NESES15T04NR13W	311845	891650	N	662	610.00	--	450.00
D073 L A PRINCE	NENWS11T04NR13W	311957	891612	H	105	100.00	--	30.00
D074 MASONITE CORP	SENWS35T04NR13W	311501	891618	N	160	150.00	--	50.00
D075 MASONITE CORP	SENWS35T04NR13W	311501	891618	N	160	150.00	--	70.00
D076 BOB CHAIN	NWNES30T04NR13E	311713	892029	H	50.0	45.00	--	15.00
D077 WHSY RADIO STAT	NWNES02T04NR13W	312041	891629	H	60.0	55.00	--	7.00
D078 ROSS RAYBOURN	----S23T04NR13W	311739	891624	H	110	105.00	--	8.00

AQUIFER CODE	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	ALTITUDE OF LAND SURFACE (FEET)	DATA RELI- ABILITY
122CTHLU	32.00	09-01-51	183.00	C
122CTHLM	36.00	09-01-65	168.00	C
122CTHLU	5.00	05-26-65	145.00	C
122HBRG	--	--	156.00	C
--	8.00	04-01-65	156.00	C
122CTHLU	48.00	11-01-65	185.00	C
122CTHLU	--	--	185.00	C
122CTHLU	64.00	11-19-81	155.00	C
122CTHLM	27.00	04-01-66	158.00	C
122CTHLM	47.00	11-19-81	155.00	C
122HBRG	--	--	--	U
122HBRG	80.00	01-01-58	--	U
122CTHLM	16.00	01-01-54	--	C
122HBRG	5.00	11-01-57	--	C
122HBRG	--	--	--	C
122CTHLU	--	--	--	C
122HBRG	--	--	--	C
122HBRG	49.00	12-01-57	--	U
122MOCN	6.00	12-01-40	211.00	C
122HBRG	18.00	09-01-60	--	C
122HBRG	12.00	08-01-60	--	C
122HBRG	50.00	08-01-66	--	C
122CTHLM	26.00	03-01-67	168.00	C
111ALVM	31.00	02-01-67	140.00	C
122HBRG	33.00	10-01-62	--	M
122HBRG	16.00	02-01-62	--	M
122HBRG	18.00	02-01-61	--	M
122HBRG	76.00	11-01-60	--	M
122HBRG	--	--	--	M
122HBRG	76.00	11-01-60	--	M
122HBRG	16.00	10-01-60	--	M
122CTHLU	--	--	--	C
122CTHLU	21.00	07-01-68	140.00	C
122CTHLM	50.00	07-01-68	155.00	C
122HBRG	17.00	03-01-70	145.00	C
122HBRG	15.00	11-01-68	170.00	C
122HBRG	15.00	01-01-68	170.00	C
122HBRG	17.00	03-01-69	--	C
122HBRG	18.00	10-01-69	145.00	C
122HBRG	26.00	08-01-69	--	C

LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
D079 E P FILLENGAME	----S30T04NR13W	311645	892024	H	485	465.00	--	20.00
D080 CUMMINGS	NWSWS30T04NR13W	311657	892038	H	417	407.00	--	7.00
D081 STEWART	SENWS19T04NR13W	311733	892018	H	65.0	60.00	--	7.00
D082 BONNIE LEIGH	----S31T04NR13W	311542	892024	H	430	425.00	--	6.00
D083 DAVID COX	NWSWS30T04NR13W	311648	892050	H	60.0	55.00	--	5.00
D084 MARSHALL DURBIN	----S13T04NR13W	311942	891524	N	684	634.00	--	400.00
D085 M BREWER	----S10T04NR13W	311930	891812	H	358	348.00	--	14.00
D086 BEESON ACADEMY	SENWS27T04NR13W	311651	891727	H	523	508.00	--	26.00
D087 ROY LIVIRETT	SENWS01T04NR13W	312015	891524	H	20.0	15.00	--	10.00
D088 BEVERLY DRIVE-IN	SWSES27T04NR13W	311627	891733	H	340	325.00	--	35.00
D089 MASONITE CORP	SENES26T04NR13W	311633	891600	H	162	152.00	--	30.00
D090 LEE TAYLOR	----S25T04NR13W	311645	891515	H	126	121.00	--	--
D091 BEESON ACDY	SWSES27T04NR13W	311629	891727	H	52.0	42.00	--	12.00
D092 RICHARD PARKER	NENWS03T04NR13W	312038	891720	H	80.0	60.00	--	--
D093 ROGER BLACKWELL	SWNWS30T04NR13W	311640	892050	H	65.0	60.00	--	6.00
D094 TJ MILLER	NWSES30T04NR13W	311655	892037	H	72.0	62.00	--	14.00
D095 HUGH MCCARDLE	NESWS01T04NR13W	312027	891514	H	35.0	30.00	--	5.00
D096 JOE TATUM	NENWS22T04NR13W	311758	891707	H	125	115.00	--	65.00
D097 RAY LIVERETT	NENWS03T04NR13W	312043	891713	H	65.0	60.00	--	10.00
D098 LEE RUSTIN	NESWS03T04NR13W	312030	891730	H	58.0	53.00	--	18.00
D099 HATTIESBURG IND PK	NWSWS36T04NR13W	311554	891538	H	796	756.00	796.00	30.00
D100 MS POWER CO	NWSWS10T04NR13W	311928	0891737	U	650	620.00	650.00	70.00
D101 BILLY MOORE	--NWS30T04NR13W	311701	0892041	H	400	380.00	400.00	10.00
D102 MARSHALL DURBIN	SWSWS14T04NR13W	311822	891638	N	672	622.00	672.00	500.00
D103 MS POWER CO	NWSWS10T04NR13W	311928	0891734	A	650	620.00	650.00	70.00
D104 MS TANK	SESES06T04NR13W	312004	0891957	N	700	660.00	700.00	300.00
D105 MP&L	NESWS10T04NR13W	311927	0891734	A	122	92.00	122.00	100.00
D106 CIVIL DEFENSE	NENWS15T04NR13W	311823	891758	H	672	667.00	672.00	10.00
D107 HATTIESBURG	SWSWS05T04NR13W	311958	0891950	U	690.	650.	690.	198.
D108 HATTIESBURG	SWSWS05T04NR13W	311958	0891958	U	640.	630.	640.	--
D109 BFGOODRICH	SWNWS04T04NR13W	312024	0891846	N	641.	611.	641.	150.
D110 PETAL	NWNWS01T04NR13W	312044	0891542	P	128.	88.	128.	500.
D111 HATTIESBURG	SESWS06T04NR13W	311956	0892037	P	800	685	800	750
D112 HATTIESBURG	SWSWS05T04NR13W	311956	0892027	P	710	605	666	1251
						679	710	--
D114 HATTIESBURG	NENES15T04NR13W	311851	0891650	P	664.	601.	664.	1000.
D115 TIMBERTON GOLF CLUB	SWNWS32T04NR13W	311600	0891944	R	450	430	450	19
D116 MURRY ENVELOPE	S04T04NR13W	312033	0891814	N	265	245	265	40
D117 NORDAN SMITH	S20T04NR13W	311735	0891938	N	415.	400.	415.	90.
D118 HERCULES CORP	SWNWS04T04NR13W	312028	0891842	N	668.	578.	595.	980.

AQUIFER CODE	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	ALTITUDE OF LAND SURFACE (FEET)	DATA RELI- ABILITY
122MOCN	183.00	09-01-69	--	U
122CTHLU	178.00	02-01-70	355.00	C
122HBRG	25.00	02-01-70	265.00	C
122CTHLU	198.00	03-01-70	--	C
122HBRG	34.00	04-01-70	355.00	C
122CTHLM	53.00	08-01-70	150.00	U
122CTHLU	70.00	06-01-70	--	U
122CTHLU	52.00	09-01-70	195.00	C
122HBRG	10.00	07-01-70	190.00	C
122CTHLU	50.00	07-01-70	190.00	C
122HBRG	18.00	08-01-70	150.00	C
122HBRG	--	--	140.00	U
112LTRC	31.00	07-01-71	180.00	C
112LTRC	17.00	10-01-71	140.00	C
122MOCN	32.00	03-01-72	300.00	C
121CRNL	47.00	07-01-72	--	C
--	12.00	11-01-72	--	C
122HBRG	60.00	12-01-72	--	C
122MOCN	12.00	07-01-74	--	C
122MOCN	12.00	07-01-74	--	C
122CTHLM	30.00	10-05-79	165.00	C
122CTHLM	80.00	11-10-79	154.00	C
122HBRG	215.00	07-31-80	350.00	C
122CTHLM	69.00	11-01-80	148.00	C
122CTHLM	80.00	11-10-79	154.00	C
122CTHLM	80.00	12-10-80	204.00	C
122HBRG	23.00	08-15-81	155.00	C
122CTHLM	71.00	04-12-83	155.00	C
122CTHLM	85.	09-04-85	206.	C
122CTHLM	85.	09-04-85	206.00	C
122CTHLM	59.	01-15-88	165.	U
122HBRG	19.	08-15-88	155.	U
122CTHLM	109.8	11-11-89	220	C
122CTHLM	83	11-18-88	200	C
--				
122CTHLM	97.	10-01-91	143.	C
122CTHL	206	12-09-92	300	C
122HBRG	--	--	150	U
122CTHL	85.	06-13-94	240.	U
122CTHL	49.	07-03-96	162.	C

LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
D118 HERCULES CORP	SWNWS04T04NR13W	312028	0891842	N	668.	615.	668.	--
D119 NORDAN SMITH	S20T04NR13W	311751	0891928	N	415.	395.	415.	85.
D130 HATTIESBURG	NWSES10T04NR13W	311930	0891730	U	390	310.00	390.00	--
D133 BFGOODRICH	SENES05T04NR13W	312029	0891900	N	654	614	654	275
E002 H CRANFORD	SESES02T04NR14W	312007	892202	H	150	--	--	--
E007 EARL NIX	NWSES12T04NR14W	311938	892139	H	342	--	--	--
E008 W L SAUCIER	SWNWS12T04NR14W	311933	892158	H	284	274.00	--	--
E009 DAISY SAUCIER	SWNWS12T04NR14W	311923	0892137	H	310	305.00	--	4.00
E010 J Q HUGH	SWNES12T04NR14W	311916	892149	H	110	--	--	--
E013 HAL FOX	NWNES13T04NR14W	311854	0892139	H	513	503.00	--	--
E014 HARVEY TAYLOR	SESES23T04NR14W	311723	892205	H	187	--	--	--
E018 A D SAUCIER	SWNWS12T04NR14W	311909	0892202	H	97.0	94.00	--	--
E019 J Z WARD	SWNES01T04NR14W	312020	892133	H	40.0	--	--	--
E026 E W COLLINS	SWSES26T04NR14W	311629	0892221	H	420	--	--	--
E030 MARGRET LAIRD	NENES14T04NR14W	311900	892211	H	40.0	--	--	--
E035 JOE F WHITE	----S10T04NR12W	311940	891730	H	26.0	21.00	--	--
E044 HERBERT DRAIN	NWSES25T04NR14W	311653	892141	H	100	--	--	--
E045 D S STEWART	NENES25T04NR14W	311709	892106	H	30.0	--	--	--
E046 CHESTER MOULDER	----S25T04NR14W	311700	892101	D	69.0	--	--	--
E047 O W COLLINS	SWSES25T04NR14W	311631	892219	H	49.0	--	--	--
E066 SAM MYER	SENES35T04NR14W	311600	892207	H	85.0	--	--	--
E068 C L DEWS	NENES36T04NR14W	311623	892103	H	--	--	--	--
E072 L O ENGLISH	SWNES23T04NR14W	311740	892230	H	168	--	--	--
E074 W RUFF	SESWS25T04NR14W	311629	892129	U	--	--	--	--
E085 DAVID COX	SESES36T04NR14W	311547	892103	H	50.0	45.00	--	--
E091 PHILIP PHUGH	SWSWS24T04NR14W	311723	892148	H	55.0	50.00	--	15.00
E092 W G MCDONALD	SESES23T04NR14W	311730	892205	H	50.0	45.00	--	5.00
E107 B F COURTNEY	----S25T04NR14W	311700	892130	H	122	117.00	--	4.00
E108 S WALKER	----S11T04NR14W	311936	892224	H	155	145.00	--	6.00
E109 LEON BRYANT	NESES25T04NR14W	311700	892136	H	67.0	62.00	--	12.00
E110 PHILIP PUGH	SWNWS24T04NR14W	311733	892154	H	57.0	52.00	--	--
E111 RICHBURG GROCRY	SENES25T04NR14W	311642	892100	H	80.0	75.00	--	10.00
E112 BENTON LOTT	NWNWS25T04NR14W	311715	892148	H	57.0	52.00	--	7.00
E118 DOC JOHNSON	SENES36T04NR14W	311554	892127	H	92.0	87.00	--	8.00
E121 WALLACE WHITE	NESWS35T04NR14W	311603	892227	H	85.0	80.00	--	13.00
E124 LAMAR PARK SUBDIV	SESWS12T04NR14W	311913	0892127	U	721	671.00	--	150.00
E135 LAMAR PARK W A	SENWS14T04NR14W	311834	892218	Z	42.0	--	--	--
E138 BILLY HAMBRY	NWSES24T04NR14W	311745	892131	H	39.0	34.00	--	15.00
E141 LAMAR PARK W A	SESWS12T04NR14W	311912	892128	P	714.	664.00	--	315.00
						--	--	315

AQUIFER CODE	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	ALTITUDE OF LAND SURFACE (FEET)	DATA RELI-ABILITY
--	49.	07-03-96	162.	C
122CTHLU	85.	06-20-96	230.	U
122CTHLU	-7.00	06-12-50	152.00	C
122CTHLM	56.3	07-01-90	165	U
121PLCN	70.00	11-01-61	--	C
122MOCN	110.00	11-01-61	--	C
122MOCN	80.00	11-01-61	--	C
122HBRG	--	--	250.00	C
121PLCN	--	--	--	C
122MOCN	75.00	11-01-61	250.00	C
122MOCN	--	--	--	C
112TRCS	--	--	250.00	C
121CRNL	15.00	11-01-61	--	C
122HBRG	--	--	--	C
121CRNL	20.00	11-01-61	--	C
112LTRC	16.00	08-01-62	230.00	U
121CRNL	40.00	11-01-61	--	C
121CRNL	15.00	11-01-61	--	C
122HBRG	--	--	--	C
121CRNL	30.00	11-01-61	--	C
121CRNL	50.00	11-01-61	--	C
--	25.00	11-01-61	--	C
122MOCN	159.00	12-01-64	315.00	C
122MOCN	--	--	--	C
121CRNL	30.00	05-01-68	--	U
121CRNL	34.00	10-01-68	335.00	C
121CRNL	28.00	10-01-68	325.00	C
121CRNL	98.00	09-01-69	--	U
121CRNL	92.00	09-01-69	--	U
121CRNL	39.00	02-01-70	370.00	C
121CRNL	39.00	02-01-70	310.00	C
121CRNL	45.00	02-01-70	355.00	C
121CRNL	31.00	03-01-70	--	C
121CRNL	41.00	08-01-70	300.00	C
121CRNL	24.00	07-01-70	280.00	C
122MOCN	140.00	08-01-71	280.00	U
--	--	--	300.00	C
121CRNL	22.00	04-01-71	270.00	C
122CTHL	143.00	08-01-71	280.	C
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LOCAL WELL NUMBER	LAND-NET LOCATION	LATITUDE (DEGREES)	LONGITUDE (DEGREES)	PRIMARY USE OF WATER	DEPTH OF WELL (FEET)	TOP OF OPEN INTERVAL (FEET)	BOTTOM OF OPEN INTERVAL (FEET)	DISCHARGE (GPM)
E145 BILLIE HARBERRY	NENES24T04NR14W	311800	892101	H	38.0	33.00	--	15.00
E156 MRS PEACOCK	NENES35T04NR14W	311622	892203	H	82.0	77.00	--	--
E189 LAMAR PARK W A	SESWS12T04NR14W	311904	0892122	P	714.	664.00	--	300.00
E198 BEN COURTNEY	SWNES25T04NR14W	311638	892130	H	108	100.00	--	4.00
E210 LAMAR PARK W A	SWSES12T04NR14W	312046	0892119	P	740.	650.00	670.00	300.00
						700.00	740.00	--
E211 AMOCO PROD	SWNES02T04NR14W	312024	892217	Z	510	468.00	510.00	75.00
E214 HATTIESBURG	SWNES12T04NR14W	311938	0892111	-	680.	640.	680.	177.
E215 HATTIESBURG	SWNES12T04NR14W	311938	0892111	U	660.	650.	660.	--
E219 HATTIESBURG	SENWS11T04NR14W	311930	0892228	-	--	--	--	--
E220 HATTIESBURG	SESES24T04NR14W	311725	0892101	U	1000.	910.	920.	--
						939.	960.	--
						979.	1000.	--
E221 HATTIESBURG	SESES24T04NR14W	311725	0892102	U	960.	940.	960.	--
E222 HATTIESBURG	SESES24T04NR14W	311725	0892101	U	720.	650.	660.	100.
						680.	720.	--
E223 HATTIESBURG	NWS11T04NR14W	311937	0892222	P	790	669	790	1531
F036 LEE WILBORN	----S02T03NR13W	311500	891617	H	225	215.00	--	--
F038 M D CONN	NENWS04T03NR13W	311518	891817	H	115	110.00	--	13.00
F041 JAMES M TRIGG	NWSES03T03NR13W	311505	891725	H	75.0	70.00	--	7.00
F042 ADAM WALLS JR	SWSWS04T03NR13W	311510	891810	H	60.0	55.00	--	12.00
F044 HOOD LUMBER CO	SWNES03T03NR13W	311509	891702	H	167	157.00	167.00	36.00
F046 BRADFORD CASSIE	----S01T03NR13W	311509	891535	U	--	--	--	--
H074 LEO LADNER	NESES01T03NR14W	311513	892100	H	23.0	18.00	--	--
H075 GRACE THOMPSON	NESES01T03NR14W	311506	892100	H	70.0	65.00	--	15.00
H076 JOHN GRACE	NESES01T03NR14W	311512	892101	H	49.0	44.00	--	15.00
H077 H MCCLENDON	NESES01T03NR14W	311507	892059	H	72.0	67.00	--	11.00
H081 JAMES STEPHENS	NESES01T03NR14W	311505	892108	H	155	150.00	--	12.00
H082 C CHAMBLISS	NESES01T03NR14W	311506	892107	H	175	170.00	--	12.00
H084 ROY HARTFIELD	NESES01T03NR14W	311506	892109	H	27.0	22.00	--	10.00
H086 B J FORD	NESES01T03NR14W	311507	892108	H	165	160.00	--	8.00
H087 J E GRAHAM	NESES01T03NR14W	311514	892107	H	23.0	18.00	--	14.00
H088 JACK MCRANEY	NESES01T03NR14W	311510	892110	H	292	282.00	--	15.00
H093 JOHN MCFARLAND	NESES01T03NR14W	311505	892100	H	65.0	60.00	--	8.00
H094 J C LOTT	NESES01T03NR14W	311504	892101	H	60.0	55.00	--	11.00

e No. 1)))) COUNTY GRID = D ((((
13/97

FIPS	WELL #	PERMIT #	SEC	TWN	RNG	DATE	USE	OWNER	DEPTH	CASING	STATIC	CAS LNTH	SCRN LNTH	PUMP HP	PUMP CAP.	PUMP SET
35	D2000		20	04N		07/03/62	HOME	W.E. WARD	32	2	21	0	5		0	0
35	D2001					11/01/62	HOME	JACK & SANDBORD	68	2	36	0	5		0	0
35	D2002					01/13/63	HOME	B.B. PLACOCK	72	2	28	66	6		0	0
35	D2003					05/27/63	HOME	G.G. GRODDR	41	2	27	35	6		0	0
35	D2004					07/10/63	HOME	T.J. SMITH	66	2	21	60	6		0	0
35	D2005					05/19/64	HOME	REACL MC COFFEY	130	4	21	121	5		0	0
35	D2006		19	04N	13W	01/04/78	HOME	TURNER JONES	400	4	103	315	10	.75	0	0
35	D2007		30	04N	13W	11/28/78	HOME	DALE BROCKMAN	100	4	50	80	20	.75	0	0
35	D2008		30	04N	13W	11/14/78	HOME	M. C. F. BILLINGSBUR	140	4	70	120	20	.75	0	0
35	D2009		05	04N	13W	06/12/79	HOME	MR MITCHELL SMITH	350	2		330	20		0	0
35	D2010		30	04N	13W	04/30/82	HOME	KEVIN BREAKNER	120	2	60	110	10	1	0	0
35	D2011		30	04N	13W	06/30/83	HOME	ROBY SIMS	54	4	40	44	10	.5	0	0
35	D2012		35	04N	13W	12/09/83	COMME	INTER BRO OF BOILMAK	60	2	30	55	5	1	0	0
35	D2013		30	04N	13W	04/30/84	HOME	A.E. HASTON	440	4	190	430	10	1	0	0
35	D2014		30	04N	13W	05/03/84	HOME	BOBBY SHANDS	76	4	41	66	10	.5	0	0
[illegible]	D2015		20	04N	13W	05/28/84	HOME	DANNY BRYANT	60	2	38	55	5	1	0	0
35	D2016		03	04N	13W	07/05/86	HOME	J C MORTEN	60	4	48	50	10	.5	0	0
35	D2017		25	04N	13W	11/07/86	HOME	GRAY WALTERS	118	2	31	113	5		0	0
35	D2018		30	04N	13W	08/23/86	HOME	MR E.L. TURNER	42	2	21	37	5		8	35
35	D2019		30	04N	13W	08/25/86	HOME	PAUL FERRELL	76	4	51	66	10		10	65
35	D2020		19	04N	13W	03/31/87	COMME	ESSCO HEATING & AIR	200	2		0	0		0	0
35	D2021		30	04N	13W	04/28/87	HOME	TOXIE MORRIS	60	4	41	50	10		10	55
35	D2022		26	04N	13W	07/21/88	IRRIG	MS TIE & TIMBER	135	2	18	115	20		75	80
35	D2023		08	04N	13W	06/20/93	IRRIG	BREAZEALE	340	4		320	20	.5	0	0

FOR: DAVID UPTHEGROVE