# REAL-TIME IN SITU DETECTION OF ORGANIC CONTAMINANTS BY LASER-INDUCED FLUORESCENCE SYSTEM

Final Topical Report

*Prepared for:*

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99-EERC-08-07

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## DISCLAIMER



## EERC DISCLAIMER



## ACKNOWLEDGMENT

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## EXECUTIVE SUMMARY

The ability of a truck mounted laser-induced fluorescence (LIF) sensor to detect polycyclic aromatic hydrocarbons (PAHs) in contaminated soils was demonstrated at a well-characterized, active Superfund site in St. Louis Park, Minnesota. LIF imaging is an optical technique in which the fluorescence of compounds irradiated by a laser is measured. LIF can be used to detect either subsurface petroleum hydrocarbons or uranium and provides a method to rapidly survey a site. Various versions of LIF systems have been tested, including hand-held, airborne, and cone penetrometer-mounted systems. The technology used for this demonstration was provided by Dakota Technologies, Inc. (DTI), of Fargo, North Dakota, and was deployed in a percussion soil probing device mounted on a light truck. The weight of the truck including the LIF equipment was 12,500 lb.

The Superfund site, Number 980609804, was contaminated with coal tars, creosote, and carcinogenic PAHs. Ten 10-ft-deep soil penetrations were made, each requiring approximately 20 to 25 min to complete LIF measurements and grout. The resulting fluorescence intensity profiles permitted delineation of the interface between the 5- to 8-ft-thick uncontaminated fill and the underlying PAH-contaminated materials. The LIF-generated data were compared with laboratory soil analysis at selected locations. It was shown that LIF is not capable of detailed hydrocarbon speciation, but the results indicated a correspondence of high total PAH concentrations with peaks on the fluorescence intensity record. In addition, LIF-generated continuous profiles illustrated PAH distribution better than laboratory analysis that represented a wider sampling interval.

Based on information provided by DTI, 300 ft of pushes can be advanced per day under normal conditions. The estimated cost per foot of measured and recorded soil profile ranges from about \$8/ft to \$18/ft including grouting. These estimates do not include permit fees, health plan development costs, or mobilization/demobilization costs, which vary with each location. DTI’s LIF sensor costs compare favorably to costs for conventional drilling, sampling, and analyses (which range from \$50/ft to \$100/ft) as well as the costs for the U.S. Navy’s LIF sensor technology (\$12/ft to \$20/ft).

The results of the field demonstration showed that the field-deployed LIF method can provide information on hot spots and contaminant plume geometry in real time, to guide the sampling effort and enable accurate placement and construction of monitoring wells. Minimal wastes are generated and worker exposure to potentially hazardous materials is substantially less than during conventional drilling and sampling activities. The LIF technology can be easily deployed in various settings and has the ability to provide quality screening-level data in a timely, cost-effective, and environmentally acceptable manner.

# REAL-TIME IN SITU DETECTION OF ORGANIC CONTAMINANTS BY LASER-INDUCED FLUORESCENCE SYSTEM

## 1.0 INTRODUCTION AND BACKGROUND

This report summarizes the results of the field demonstration of a laser-induced fluorescence (LIF) method for characterization of brownfields and other contaminated sites. The technology was provided and demonstrated by Dakota Technologies, Inc. (DTI), of Fargo, North Dakota. LIF generates continuous data on the distribution of polycyclic aromatic hydrocarbons (PAHs) within the soil profile. The sensor used to record real-time data is deployed into the soil using a modified truck-mounted Geoprobe percussion soil probing device. The summary of observations described in the following text represents an independent evaluation of the performance, usefulness, and economics of the demonstrated technology for characterization at PAH-contaminated sites.

The LIF technology was tested and evaluated at a well-characterized, active Superfund site located in St. Louis Park, Minnesota. The site location is shown in Figure 1. Wastes (including carcinogenic PAHs) from Reilly Tar & Chemical Corporation were originally disposed on the site and discharged to an adjacent wetland. In accordance with the Consent Decree for the Reilly Site, the City began to fill the property with clean soil in 1985. The results of the site characterization conducted by ENSR indicate that the site is currently covered by up to 12 ft of clean fill. The underlying bog area is impacted as deep as 65 ft by coal tars, creosote, and petroleum chemicals.

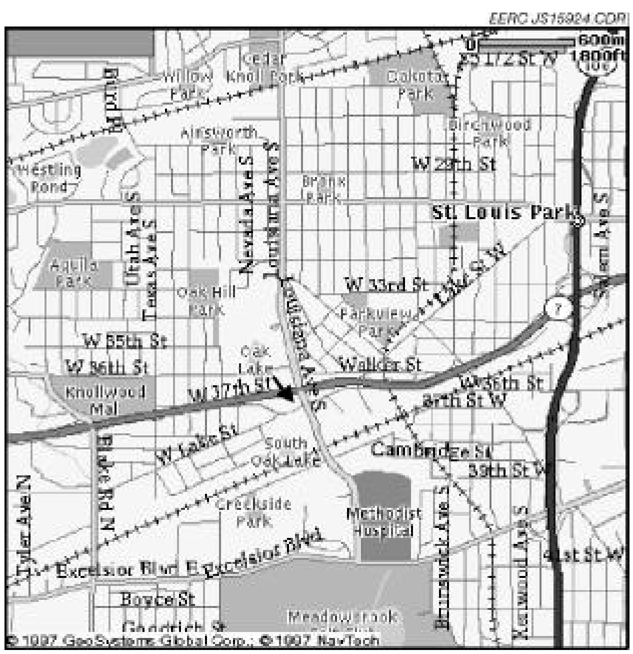



Figure 1. Site location.

## 2.0 TECHNOLOGY DESCRIPTION

Laser-induced fluorescence imaging (LIFI) is an optical technique in which the fluorescence of compounds irradiated by a laser is measured. The system uses a pulsed excimer laser with a light wavelength of 308 nanometers. LIFI, which can be used to detect either subsurface petroleum hydrocarbons or uranium, provides a method to rapidly survey a site. It can be used to identify contaminant “hot spots,” assist in waste cleanup activities, and monitor remedial progress, but is not sufficiently developed to permit accurate contaminant quantitation. Various versions of LIFI systems have been tested, including hand-held, airborne, and direct push technology systems. The LIF sensor discussed in this report was deployed in a percussion soil probing device.

The LIF sensor used a wavelength-tunable ultraviolet laser source to induce a fluorescence response in the petroleum hydrocarbons. Measurement of the fluorescence was made through a sapphire window on a probe that was pushed into the ground using a percussion soil probing device. Feedback was applied to the hydraulics of the percussion hammer to emulate an ASTM penetration rate of 2 cm/sec for cone penetrometers. Optical fibers integrated with the geotechnical probe and cone penetrometer umbilical carried the fluorescence measurement to the optical detector located in the truck (EPA, 1997a).

## 3. 0 FIELD DEMONSTRATION

The major objectives of the field demonstration were to 1) verify the technology performance at a well-characterized contaminated site and 2) evaluate the technology’s baseline economics. The demonstration was conducted by DTI on December 1, 1998, and was monitored by the Energy & Environmental Research Center (EERC), the lead environmental consulting firm for the site; ENSR; and the Minnesota Pollution Control Agency (MPCA). DTI operators drilled and recorded information on PAH distribution in the soil at ten different locations on the south end of the site, as shown in Figure 2. Five of the soil profiles, SLP–1 through SLP–5, were located so as to provide supplemental PAH distribution information in a W–E cross section between ENSR borings. The remaining five borings were located where ENSR had previously documented and analyzed soil cores. These preexisting analytical data were compared to the LIF demonstration results since a limited budget precluded laboratory analyses during this project. The tenth hole was located in an uncontaminated area so as to gather background contamination data. The soil profiles were analyzed to a depth of 10 ft. In general, material identified as coal tar-related PAHs were detected at depths starting from 5 to 8 ft below the surface. Following the measurements, all of the 1-in.-diameter borings were plugged with Volclay Grout II in compliance with Minnesota environmental standards.

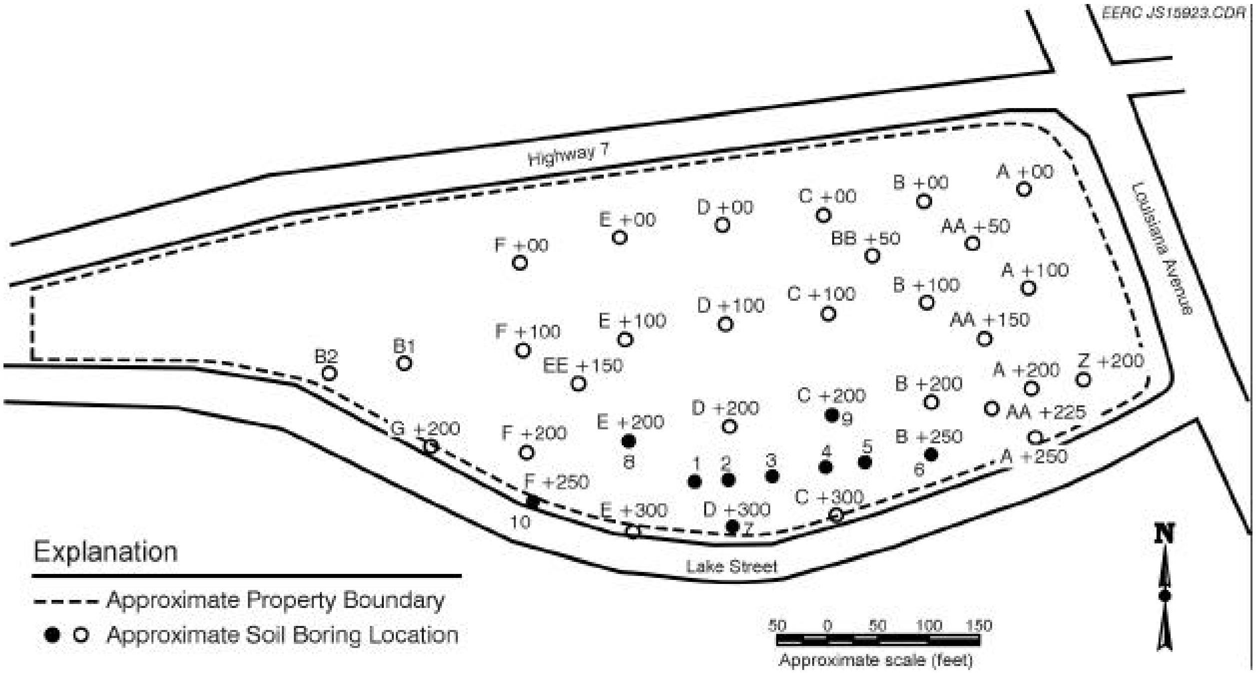



Figure 2. Location of test borings.

# 4.0 RESULTS

## 4.1 Performance Evaluation

Soil profile measurements from SLP–1 through SLP–5 are provided in Appendix A. The resulting profiles, when aligned in a cross section as shown in Figure 3, demonstrate that two- and three-dimensional models of the site contamination can be easily derived from the LIF method. The response for the 5- to 8-ft-thick uncontaminated fill contrasts with the fluorescence noted for PAH-contaminated underlying materials. Generation of a plot and grouting the borehole took DTI operators approximately 20 to 25 min. The shape of the curve representing fluorescence intensity shows clearly defined zones that are enriched with PAHs. The selected peaks, or data points on the curve, can be further analyzed and their waveforms compared to "calibration" graphs. This is shown in Appendix B. The calibration or reference samples are prepared from soil materials that have been saturated with specific fuels to illustrate the difference between the corresponding waveforms or "fingerprints" and the false color presentation. The false color coding of the generated graphical profiles does not pertain to response intensity; however, the shape of either calibration curves or curves derived from soils saturated with diesel fuels typically are different waveforms with a much stronger signal than, for example, creosote.

Demonstration Borings SLP–6 through SLP–10 were placed at the locations of ENSR Boreholes B250, D300, E200, C200, and F250, as shown in Figure 2. LIF profiles, soil logs, and relevant laboratory analyses for these boreholes are provided in Appendix C.

EERC JS15925.CDR

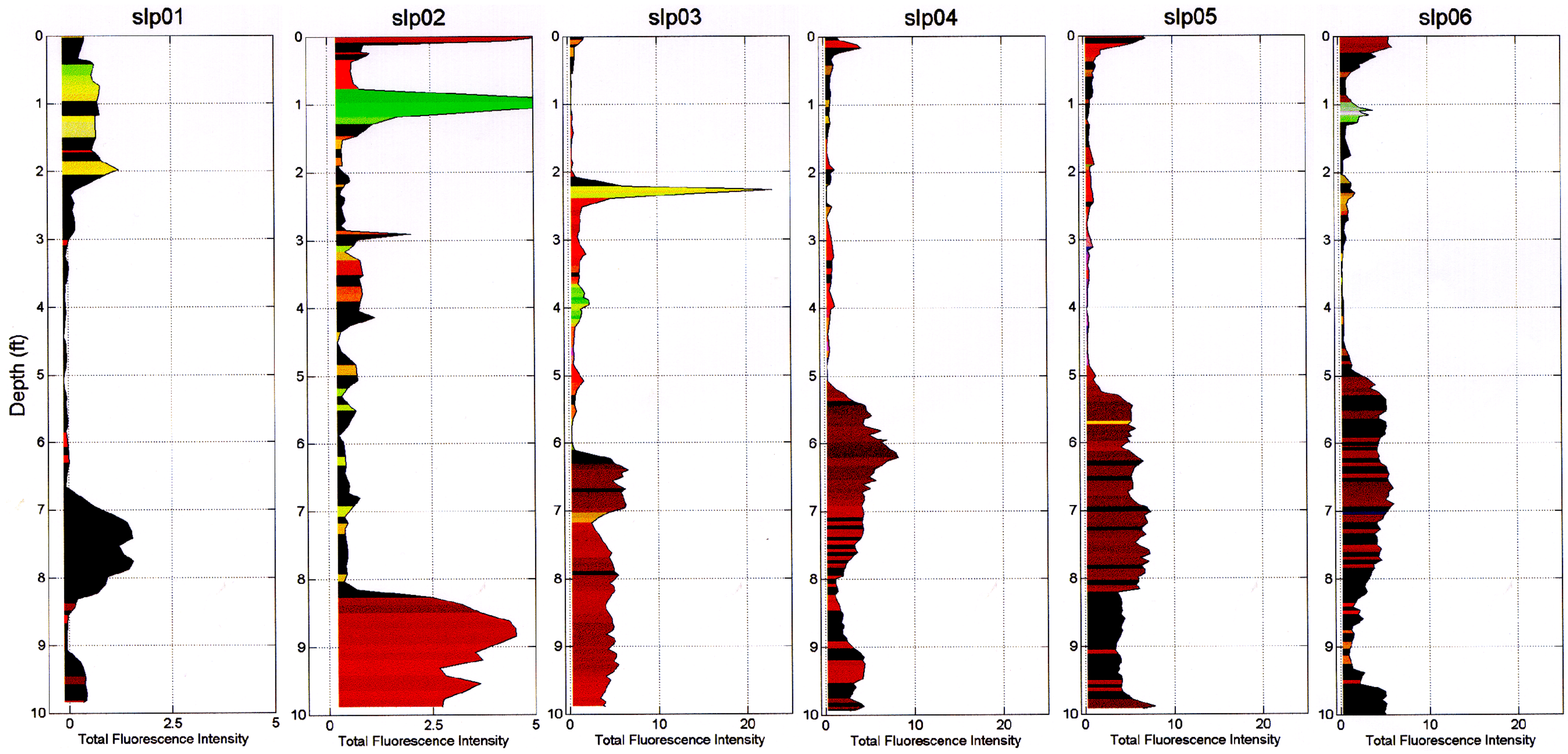



Figure 3. Cross-Sections SLP – 1–6.

Comparison between the LIF and the analytical data indicate that high total PAH concentrations corresponded well with peaks on fluorescence intensity record. Although not quantitative, the LIF-generated continuous profiles illustrated PAH distribution much better than one laboratory analysis that typically represents a specific 2- to 3-ft-long interval.

A detailed evaluation of soil parameters with respect to their influence on fluorescence measurements was beyond the scope of this project. It is reasonable, however, to expect that a higher fluorescence intensity would be associated with more permeable soils that had been exposed to PAHs for a prolonged period of time so as to become fully saturated.

The primary application of the demonstrated LIF system is as a screening-level investigation. Analysis by standard laboratory techniques of site-specific soil samples could be used for LIF sensor calibration immediately prior to field detection. Such calibration could enhance the semiquantitative capabilities of the demonstrated technology.

The detailed, real-time data regarding the nature and occurrence of subsurface contamination provided by the Geoprobe-mounted LIF would result in optimizing the characterization and monitoring activities at brownfield sites. In particular, application of the LIF technology to a brownfield site can be used to guide the collection of soil samples to be analyzed for compliance purposes and the placement of monitoring wells. The data generated by the LIF may also be used to design more effective and efficient remediation strategies by allowing designers to target very specific, well-defined zones of contamination.

### 4.2 Limits of the Technology

Site accessibility is naturally limited by the size and weight of the truck carrying the cone penetrometer and LIF equipment. For this demonstration, all of the equipment, including a Ford four-wheel drive truck as demonstrated by DTI, weighed 12,500 lb (6.25 tons/5.7 metric tonnes). This specific configuration is significantly more mobile and flexible than heavier drilling equipment.

Applicability of LIF to a given site depends in large part on the cone penetrometer probe's ability to penetrate various materials. The presence of gravel, boulders, cobbles, cementitious materials, and various buried debris, bricks, concrete blocks, etc., in fill materials can severely limit the use of a penetrometer. As is the case with other intrusive characterization methods, it is important to delineate all underground utilities and structures prior to initiating screening activities on site.

Fluorescence intensity readings are affected by different LIF response to various petroleum hydrocarbons, sensitivity to variations in the soil matrix, and spectral overlap in complex samples. Aliphatic hydrocarbons, single-ring aromatics, and most two-ring PAHs do not contribute to the LIF signal. The fluorescence properties of a hydrocarbon mixture may also change as a result of changed chemical composition due to weathering, biodegradation, and volatilization after long-term exposure to and interaction with the environment (EPA, 1997b). Soil matrix properties that affect LIF sensitivity include soil grain size, mineralogy, moisture content, and surface area. Details of these factors are provided in the cited EPA document.

### 4.3 Cost Evaluation and Other Considerations

The following costs provided by DTI are based on an 8-hr day. Typical production per day is 200–300 ft of measured soil profile in Minnesota and 300–500 ft in North Dakota. The differences are due to state grouting regulations. Costs are as follows:

| | |
|---|---|
| Mobilization fee (includes two people) | \$2.50/mile |
| Per diem (Minnesota, two people) | \$258/day |
| LIF Fee (operator and LIF equipment) | \$1500/day |
| Geoprobe (probe operator and equipment) | \$1500/day |
| Grouting (\$2.00/ft in MN, \$1.10/ft in ND) | \$600/day |
| | |
| TOTAL | \$3858/day plus mobilization fee |

Under normal conditions, 300 ft of pushes can be easily advanced per day. The estimated cost per foot of measured and recorded soil profile ranges from about \$8/ft (in North Dakota) to \$18/ft (in Minnesota), including grouting. These estimates do not include costs for permit fees, health plan development, and mobilization/demobilization costs which vary with each location. These costs compare favorably to conventional drilling, which ranges from \$15/ft to \$20/ft for drilling and installation of monitoring wells and between \$50/ft and \$100/ft for drilling and site characterization sampling. In addition, the costs to analyze total petroleum hydrocarbon (TPH) content or recoverable TPH average \$90 to \$150 per analyzed soil sample.

## 5.0 CONCLUSIONS

- The comparison of LIF-generated data with the soil analysis at selected locations indicates that high total PAH concentrations corresponded well with fluorescence intensity peaks.

- The fluorescence intensity profiles obtained during the demonstration permitted delineation of the interface between the uncontaminated 5- to 8-ft-thick fill and underlying PAH-contaminated materials.

- Continuous profiles illustrate PAH distribution better than laboratory analysis that represents a wider sampling interval.

- At \$8/ft to \$18/ft, the estimated cost of using DTI’s LIF sensor compares favorably to the cost for conventional drilling, sampling, and analyses (\$50/ft to \$100/ft) as well as the costs estimated for the U.S. Navy’s LIF sensor/cone penetrometer technology (\$12/ft to \$20/ft).

- LIFI is not capable of detailed hydrocarbon speciation.

The field-deployed LIF method can provide information on hot spots and contaminant plume geometry in real time, to guide the sampling effort and enable accurate placement and construction of monitoring wells. Minimal wastes are generated, and worker exposure to potentially hazardous materials is substantially less than during conventional drilling and sampling activities. The results of the field demonstration show that the LIF technology can be easily deployed in various settings and has the ability to provide quality screening-level data in a timely, cost-effective, and environmentally acceptable manner.

## 6.0 ACKNOWLEDGMENTS

The authors wish to express their thanks to Steve Adamek and Randy St. Germain of DTI for field demonstration and data on LIF technology. The indispensable support by Bill Gregg of ENSR in providing the demonstration site access and background information is gratefully acknowledged.

## 7.0 REFERENCES

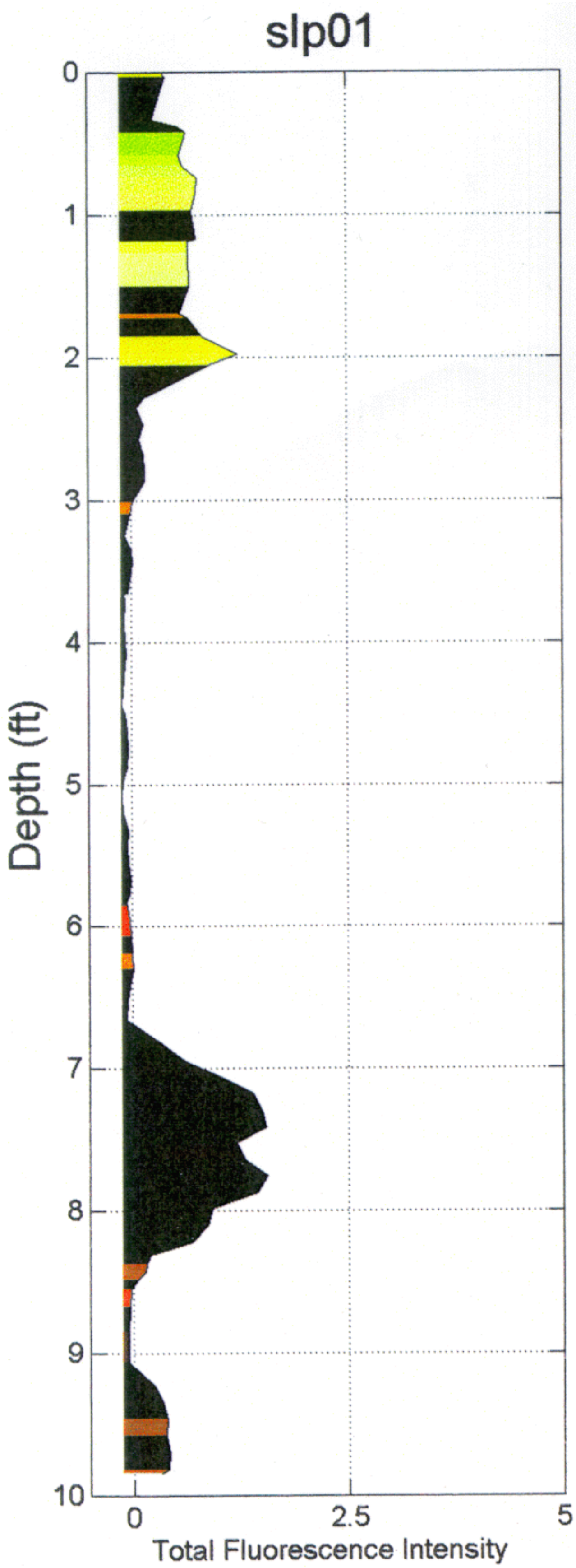
EPA, 1997a, Environmental technology verification program verification statement—rapid optical screening tool (ROST): U.S. Environmental Protection Agency; No. EPA-VS-SCM-01, EPA National Exposure Research Laboratory, Las Vegas, Nevada.

EPA, 1997b, Innovative technology verification report—site characterization and analysis penetrometer system (SCAPS) laser-induced fluorescence (LIF) sensor and support system: U.S. Environmental Protection Agency; Pub. No. EPA/600/R-97/019, National Exposure Research Laboratory: Las Vegas, Nevada.

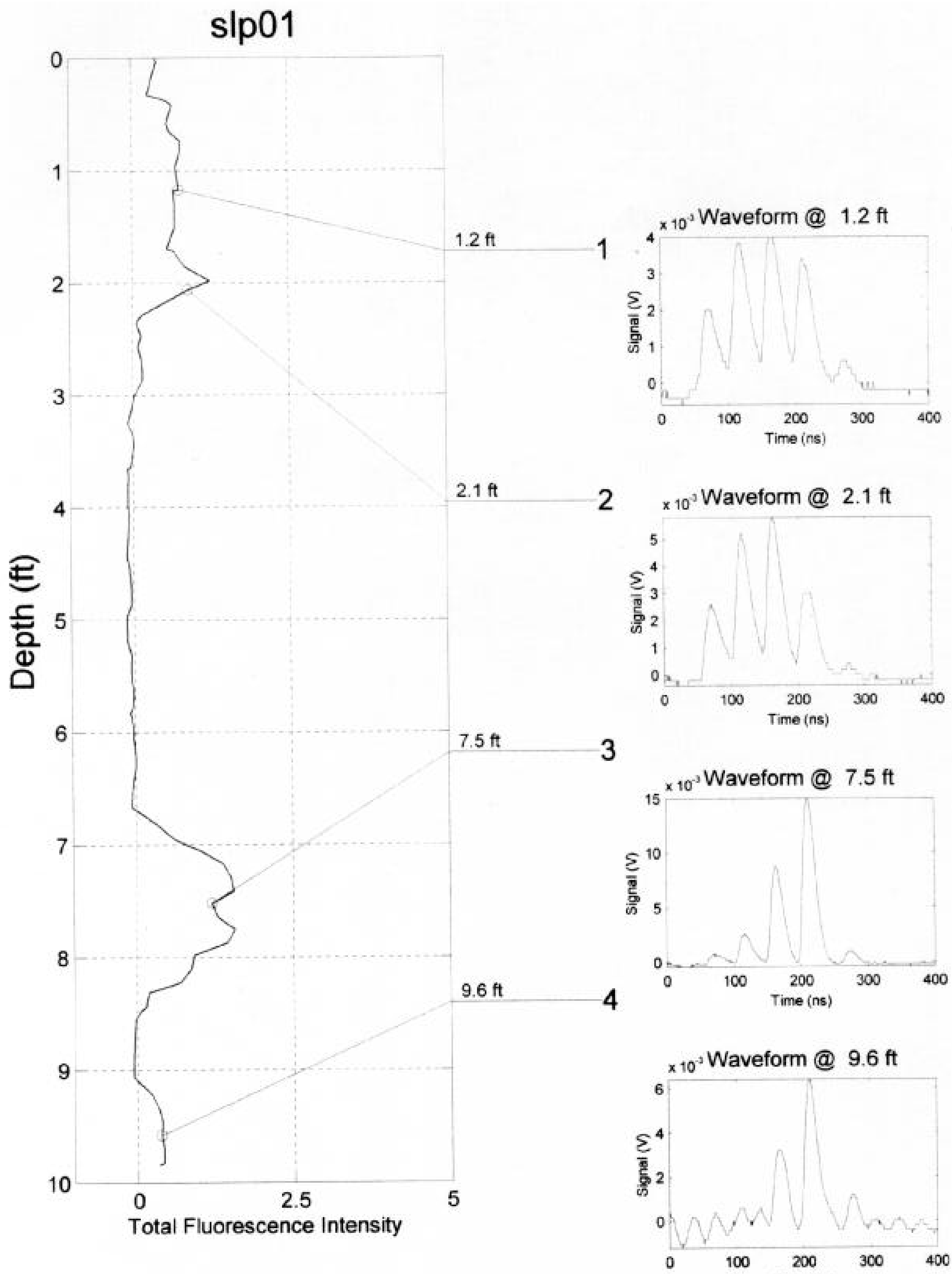
Federal Remediation Technologies Roundtable, 1999, Field Sampling and Analysis Technologies Matrix Version 1.0: URL http://www.frtr.gov/site/index.html (accessed March 18, 1999).

# APPENDIX A

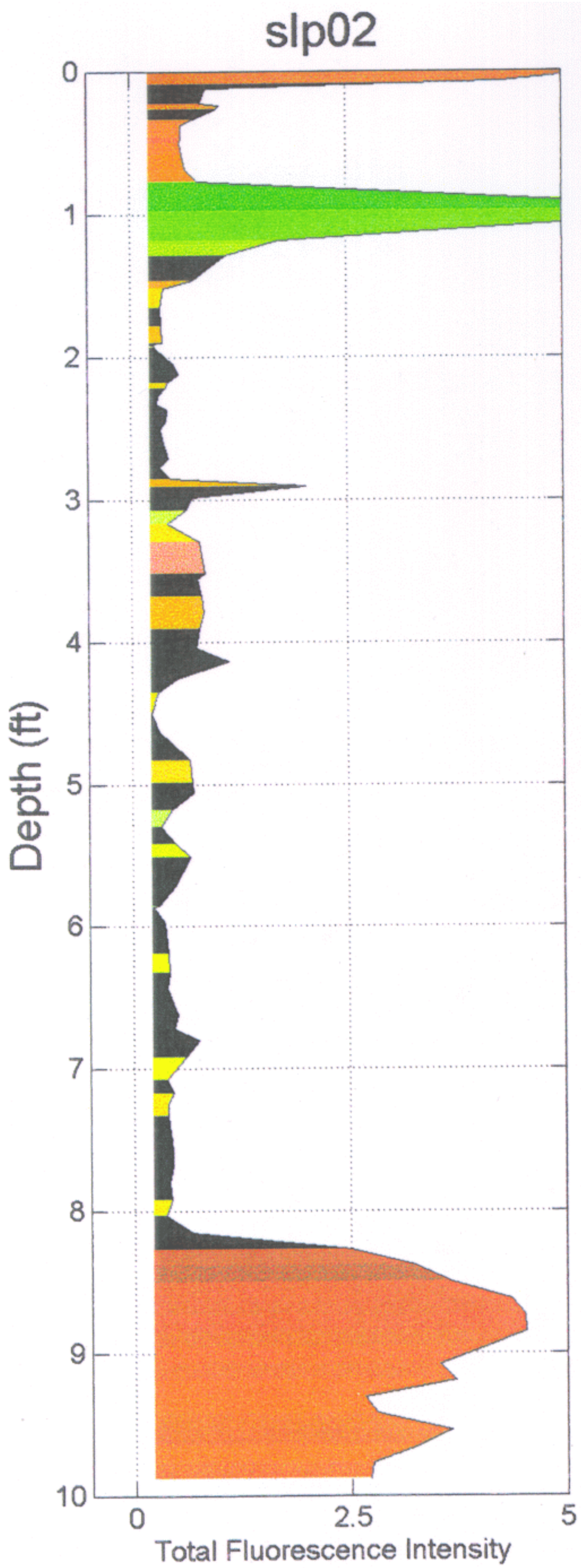
# SOIL PROFILES SLP 1–8

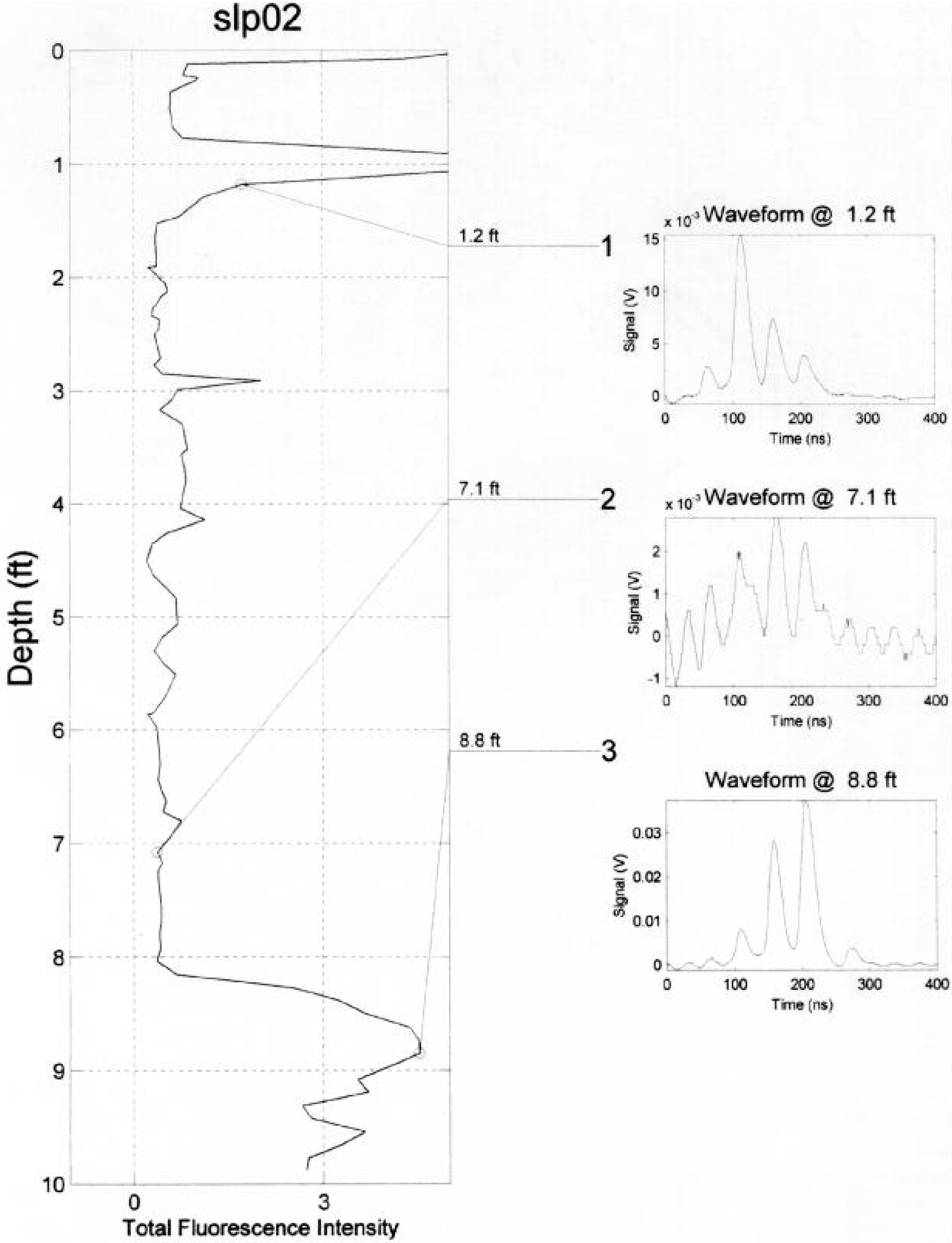


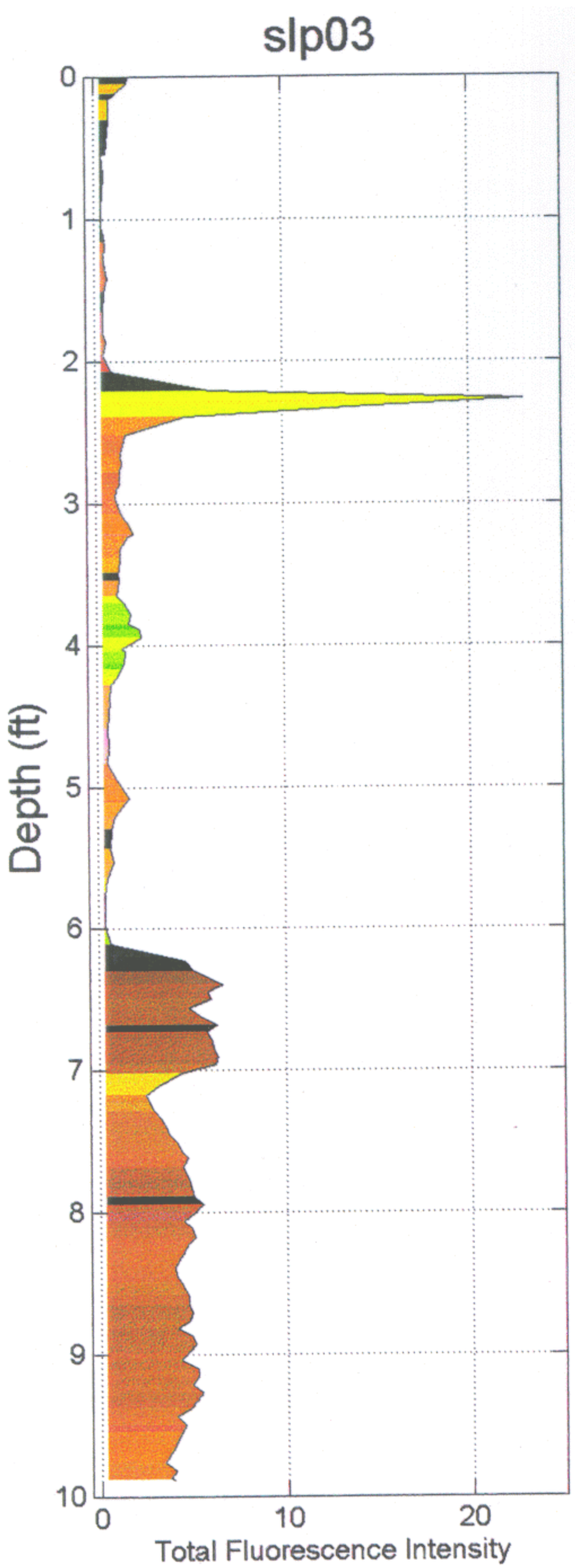
slp01
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
2.5
5
Total Fluorescence Intensity

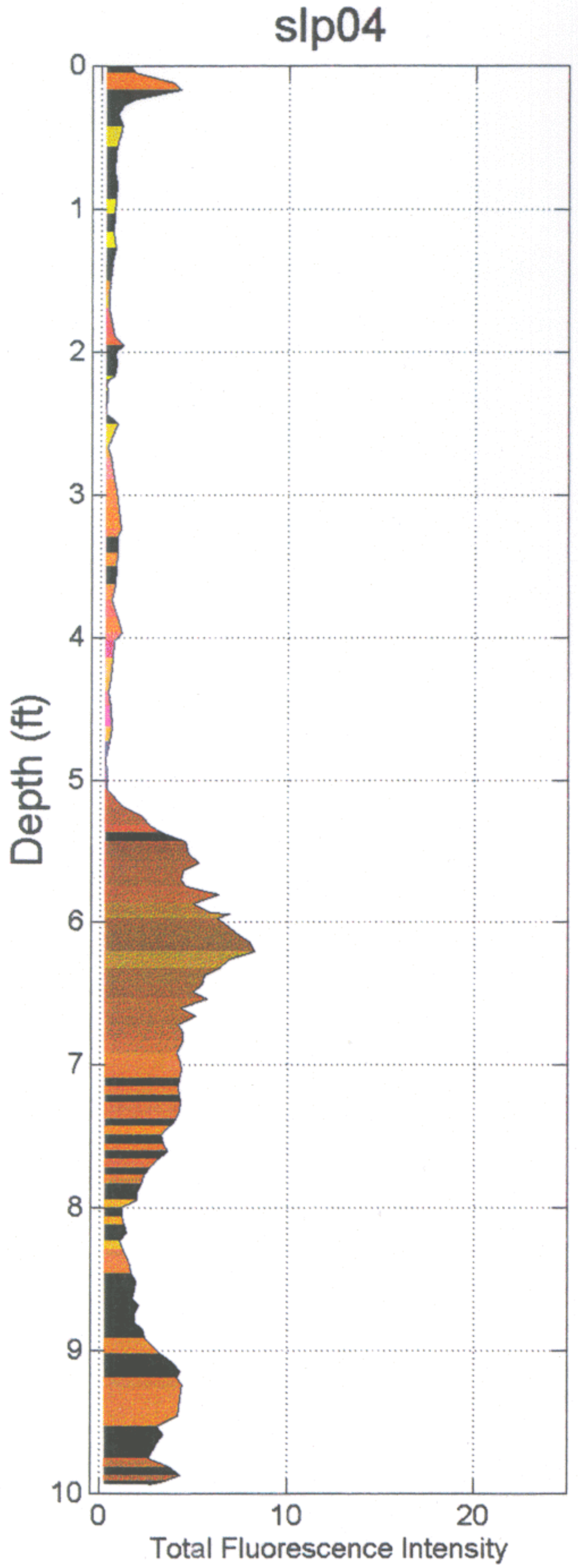


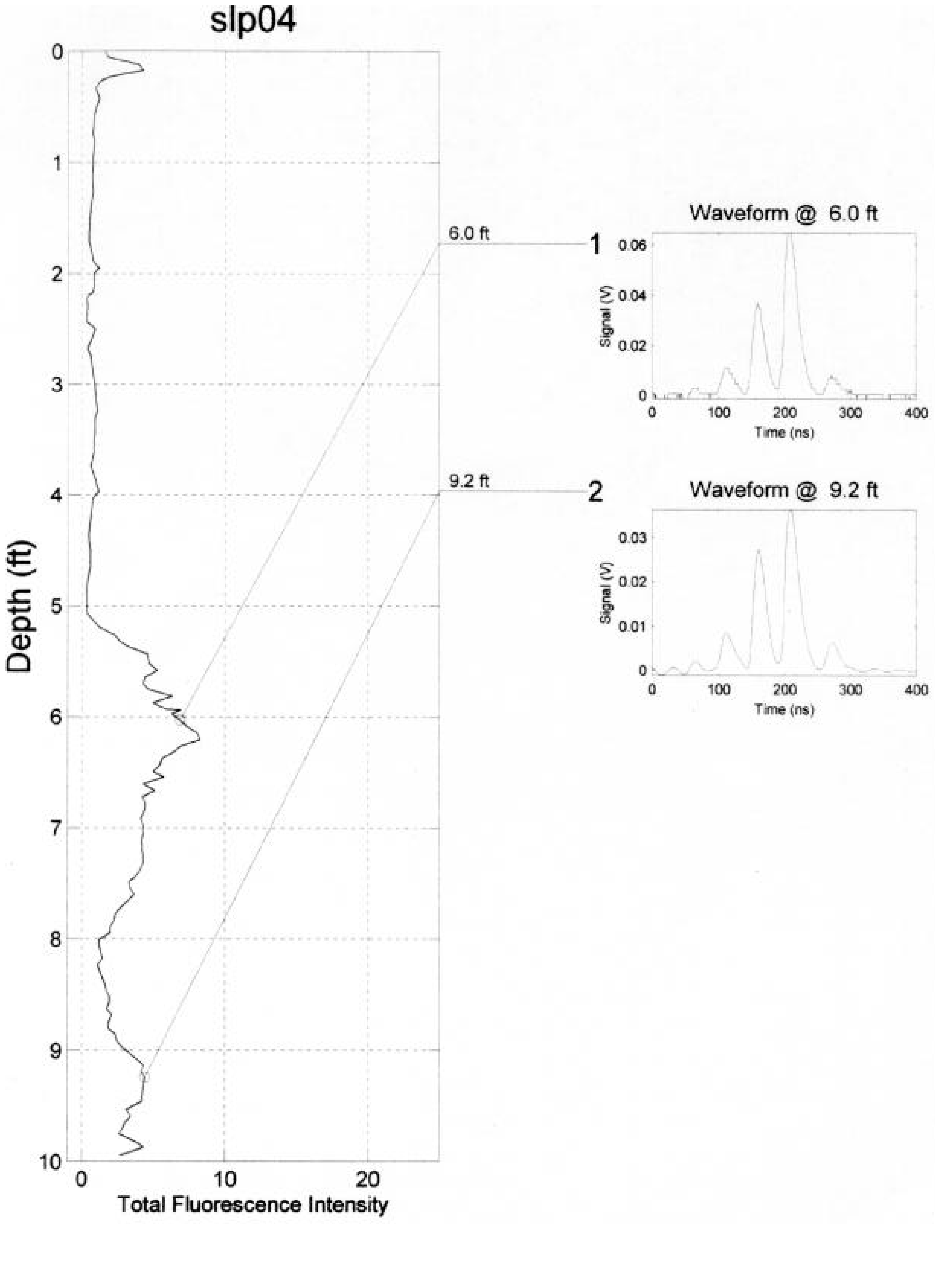
slp01
Depth (ft)
Total Fluorescence Intensity
1.2 ft
2.1 ft
7.5 ft
9.6 ft
1
2
3
4
x 10^-3 Waveform @ 1.2 ft
x 10^-3 Waveform @ 2.1 ft
x 10^-3 Waveform @ 7.5 ft
x 10^-3 Waveform @ 9.6 ft
Signal (V)
Time (ns)

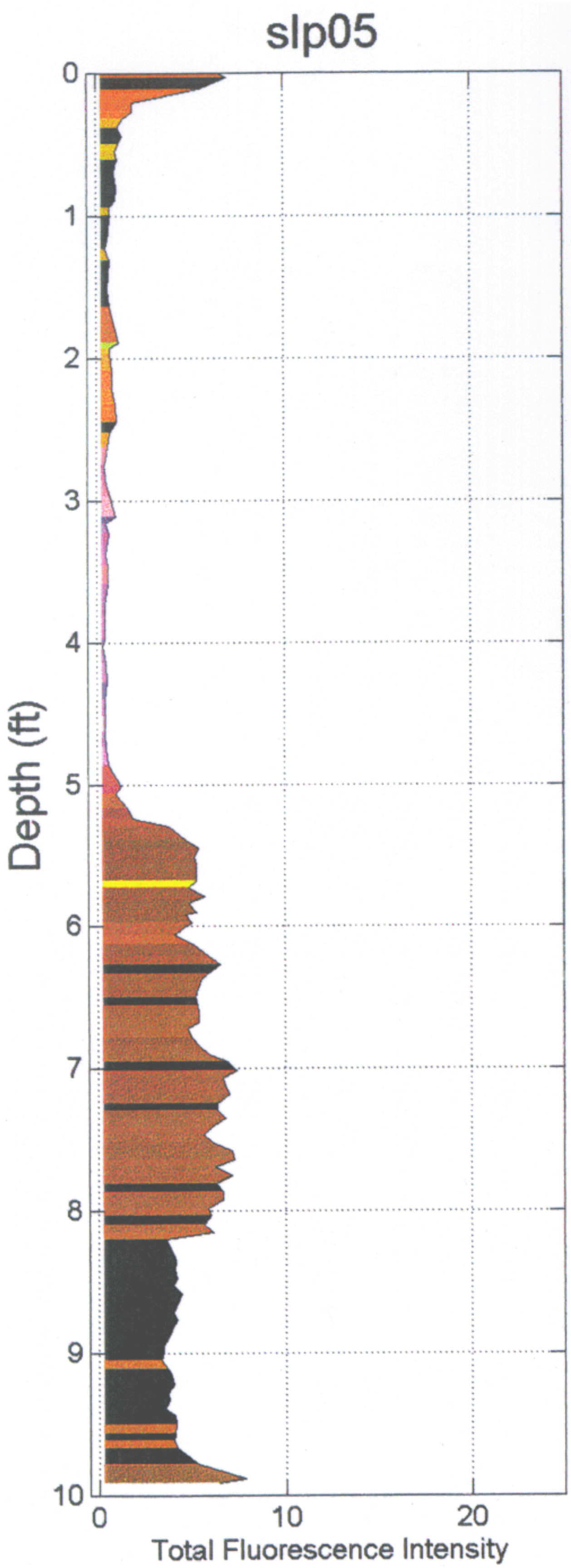

slp02
Depth (ft)
Total Fluorescence Intensity
0
1
2
3
4
5
6
7
8
9
10
0
2.5
5


slp02
Depth (ft)
Total Fluorescence Intensity
1.2 ft
7.1 ft
8.8 ft
1
2
3
x 10⁻³ Waveform @ 1.2 ft
x 10⁻³ Waveform @ 7.1 ft
Waveform @ 8.8 ft
Signal (V)
Time (ns)

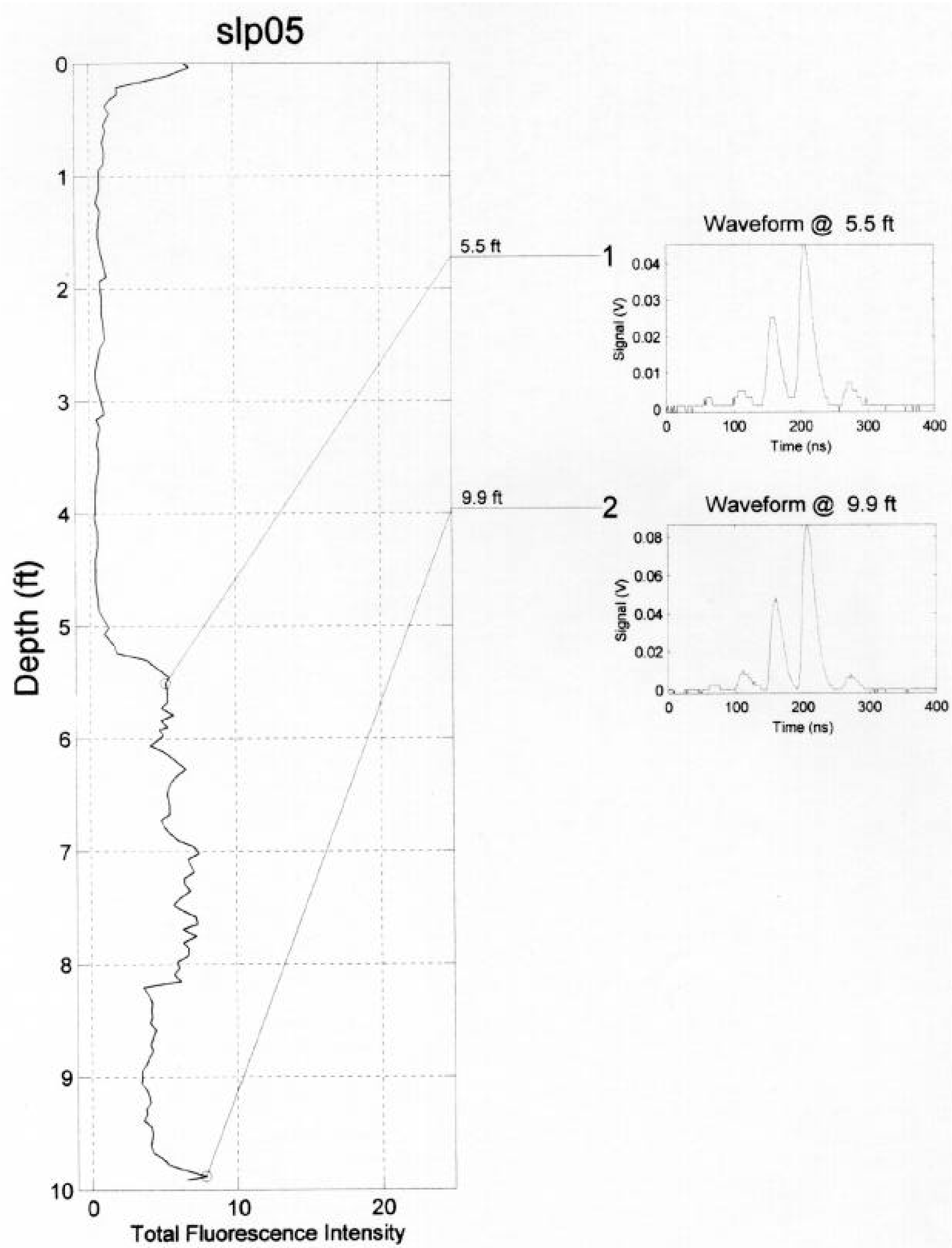

slp03
Depth (ft)
Total Fluorescence Intensity
0
1
2
3
4
5
6
7
8
9
10
0
10
20


slp04
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
Total Fluorescence Intensity


slp04
Depth (ft)
Total Fluorescence Intensity
6.0 ft
9.2 ft
1
2
Waveform @ 6.0 ft
Waveform @ 9.2 ft
Signal (V)
Time (ns)



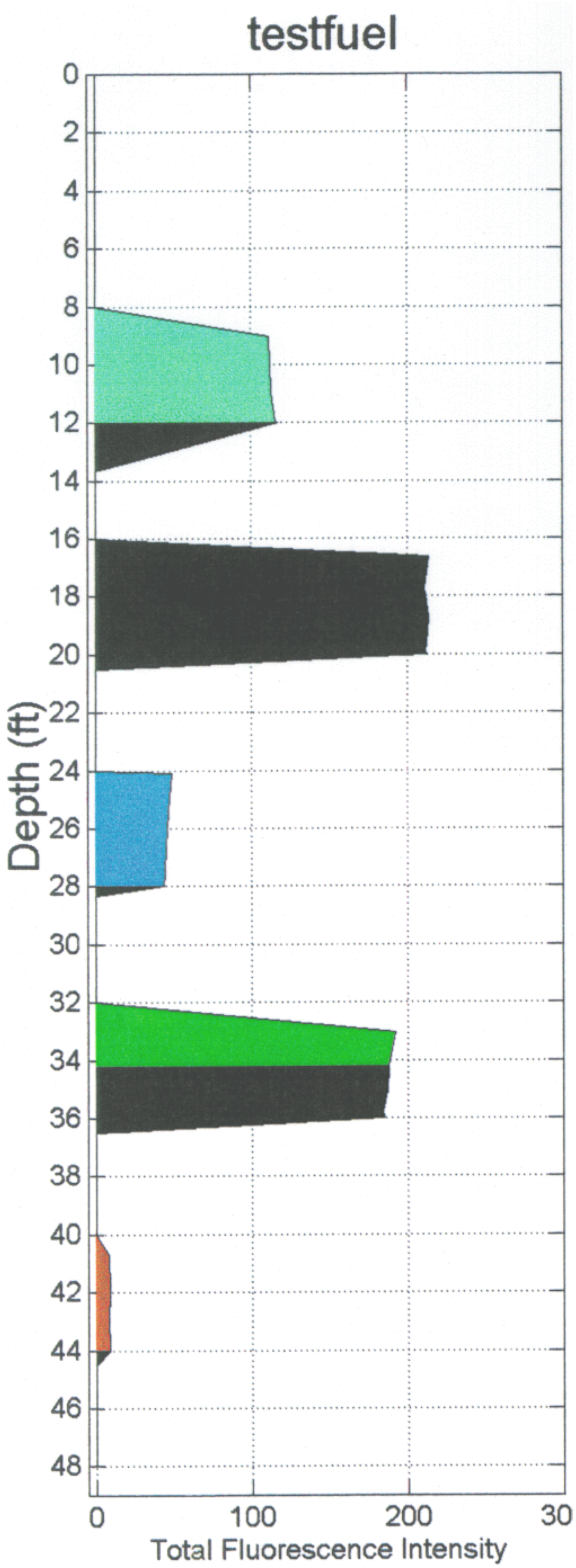
slp05
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
Total Fluorescence Intensity



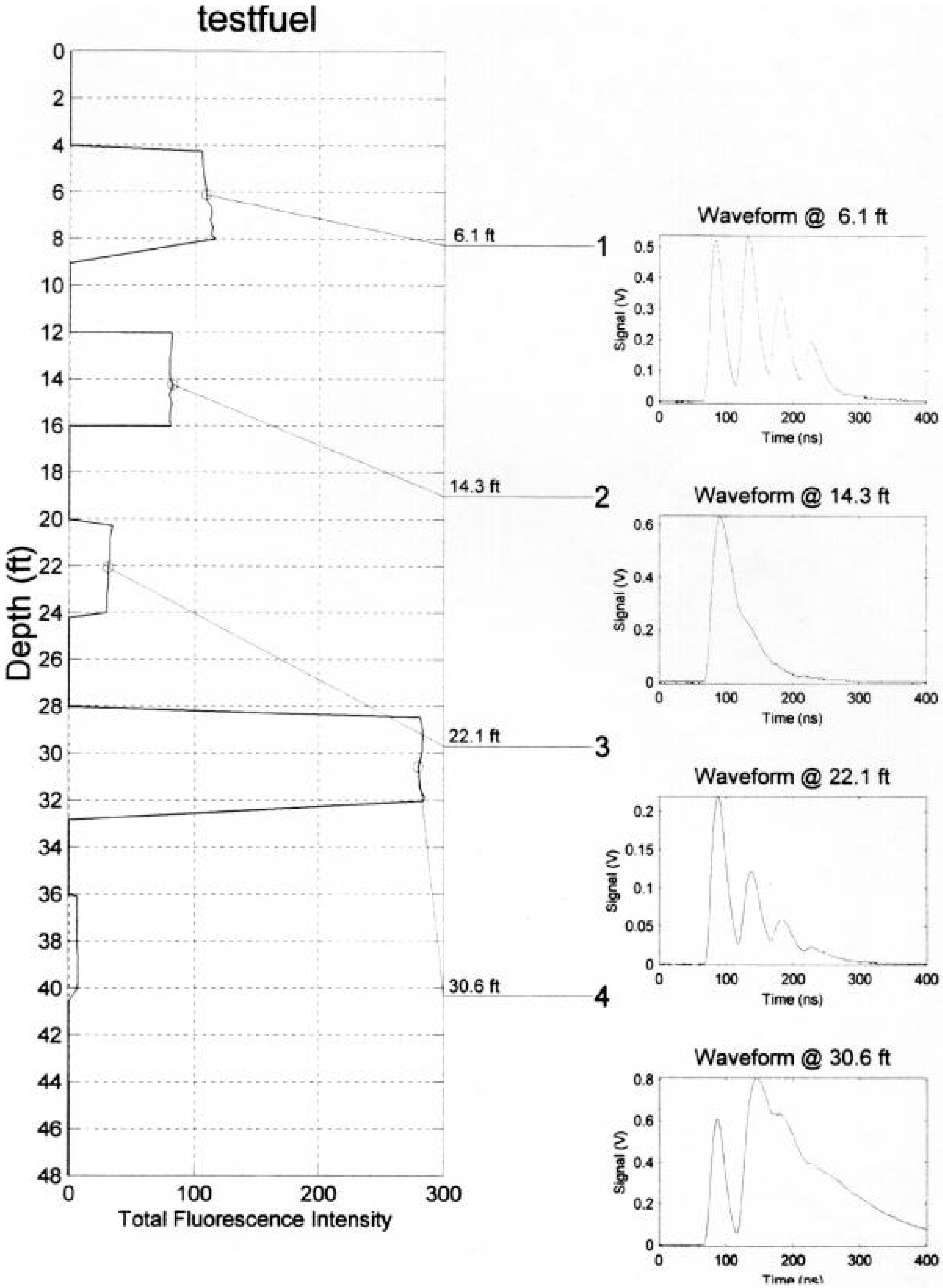
slp05
Depth (ft)
Total Fluorescence Intensity
5.5 ft
9.9 ft
1
2
Waveform @ 5.5 ft
Waveform @ 9.9 ft
Signal (V)
Time (ns)

# APPENDIX B

# TEST FUEL – CALIBRATION



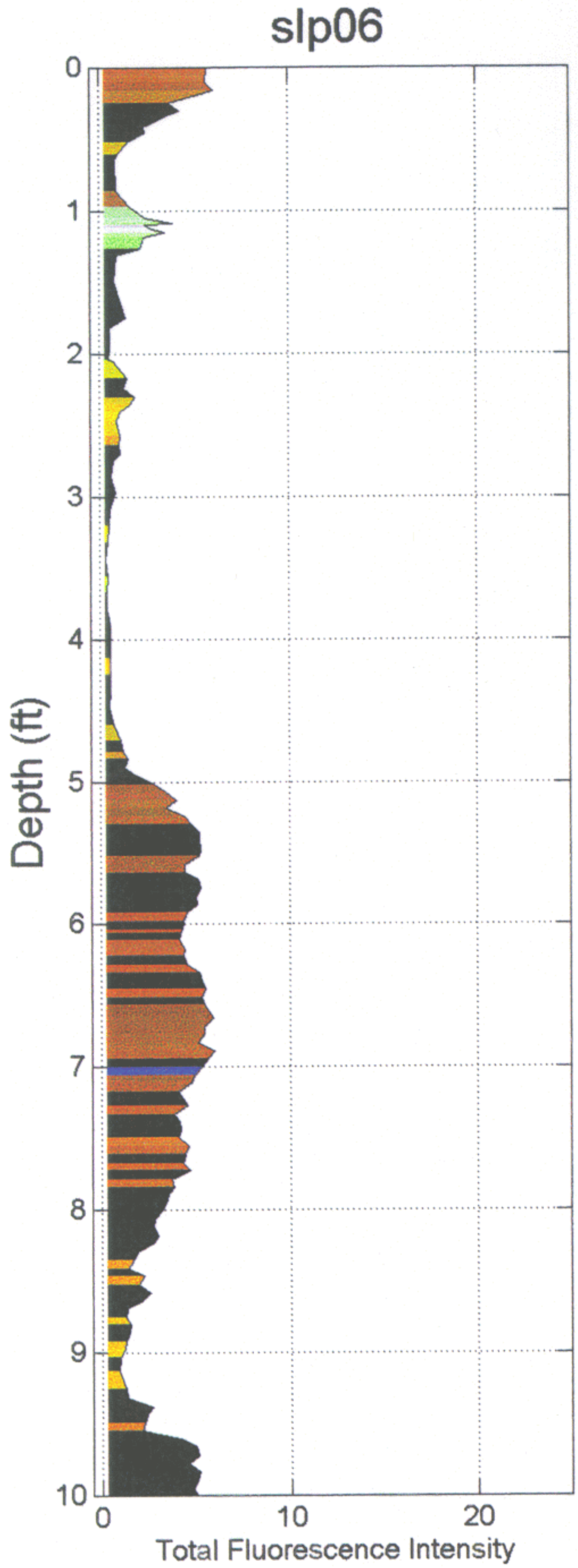
testfuel
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
0
100
200
30
Total Fluorescence Intensity

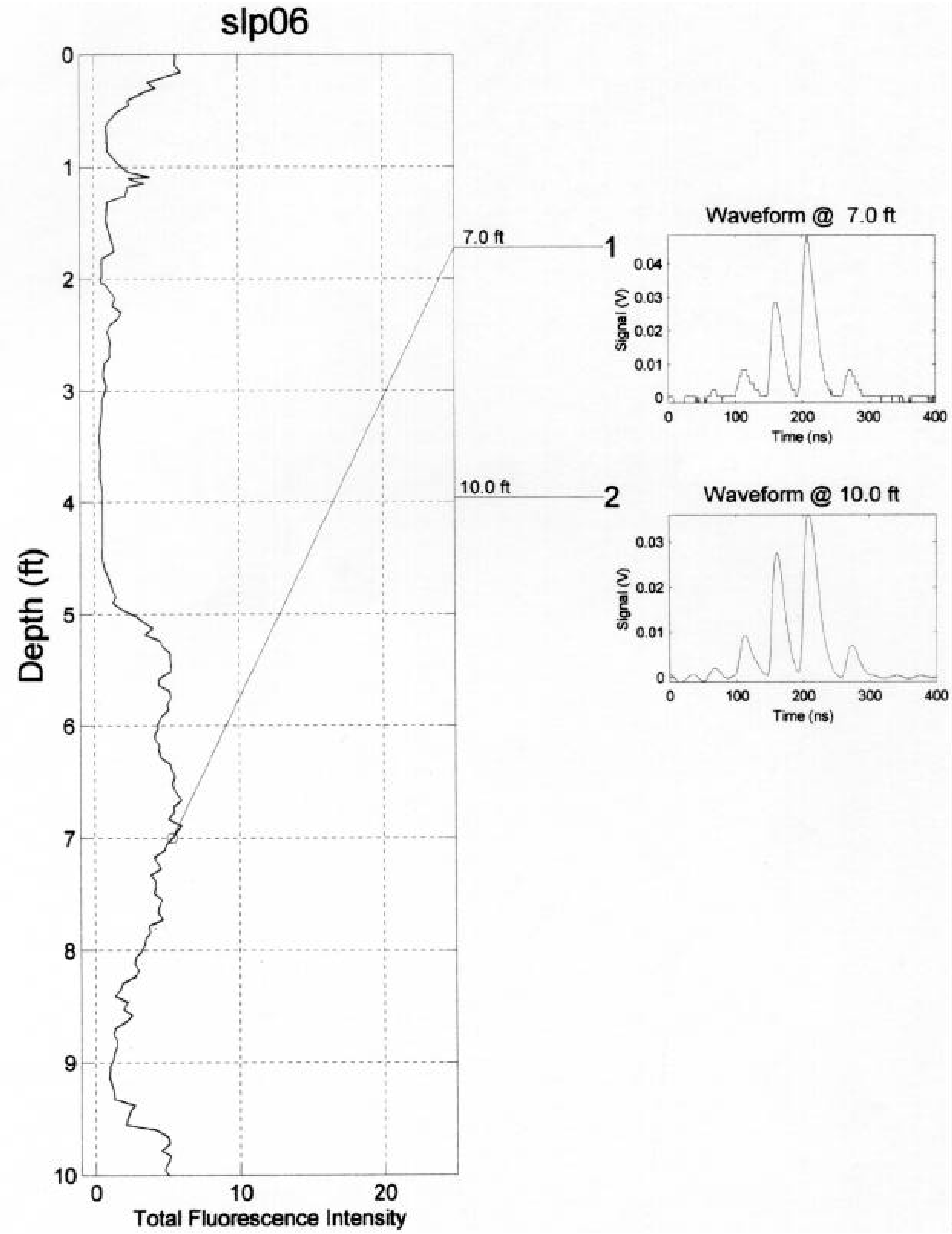


testfuel
Depth (ft)
Total Fluorescence Intensity
6.1 ft
14.3 ft
22.1 ft
30.6 ft
1
2
3
4
Waveform @ 6.1 ft
Waveform @ 14.3 ft
Waveform @ 22.1 ft
Waveform @ 30.6 ft
Signal (V)
Time (ns)

# APPENDIX C

# SOIL PROFILES SLP 6–10 WITH LABORATORY ANALYSIS AND SOIL LOGS


slp06
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
Total Fluorescence Intensity



slp06
Depth (ft)
Total Fluorescence Intensity
0
1
2
3
4
5
6
7
8
9
10
0
10
20
7.0 ft
10.0 ft
1
2
Waveform @ 7.0 ft
Signal (V)
0.04
0.03
0.02
0.01
0
0
100
200
300
400
Time (ns)
Waveform @ 10.0 ft
Signal (V)
0.03
0.02
0.01
0
0
100
200
300
400
Time (ns)

NET NATIONAL ENVIRONMENTAL TESTING, INC.

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613
Tel: (319) 277-2401
Fax: (319) 277-2425

# ANALYTICAL REPORT

Pete Moore
ENSR-ST. LOUIS PARK
4500 Park Glen
Suite #210
St. Louis Park, MN 55416

09/29/1998

NET Job Number: 98.11773

NET Sample Number: 472447

Project ID: PAH Soils #1620-018

Sample ID: B + 250 4-6' Project #1620-018

Date Taken: 09/17/1998 Date Received: 09/19/1998

| Analyte | Result | Units | Result Flag | Analyst | Date Analyzed | Method | Quantitation Limit |
|---|---|---|---|---|---|---|---|
| % Solids | 82.66 | % | | sas | 09/24/1998 | | |
| Prep. BNA - NONAQUEOUS | complete | | | asz | 09/24/1998 | SW 3540 | |
| BNA - 8270 NONAQUEOUS | | | | | | | |
| Benzo(a)anthracene | 23.0 | ug/g | | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Benzo(b)fluoranthene | 13.8 | ug/g | | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Benzo(k)fluoranthene | 13.8 | ug/g | | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Benzo(a)pyrene | 12.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Chrysene | 19.5 | ug/g | | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Dibenzo(a,h)anthracene | <5.9 | ug/g | | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Indeno(1,2,3-cd)pyrene | 4.0 | ug/g | J | ccb | 09/25/1998 | SW 8270C | 5.9 |
| Total PAH | 86.8 | ug/g | | rlb | 09/29/1998 | | |

J - Variability is increased: result is below linear calibration range.

R.L. Bindert
Operations Manager

Project No: 1620-018
Client: City of St. Louis Park - EDA
Project: Phase II Site Investigation

Location: 7250 State Highway 7

# Log of Borehole: B+250

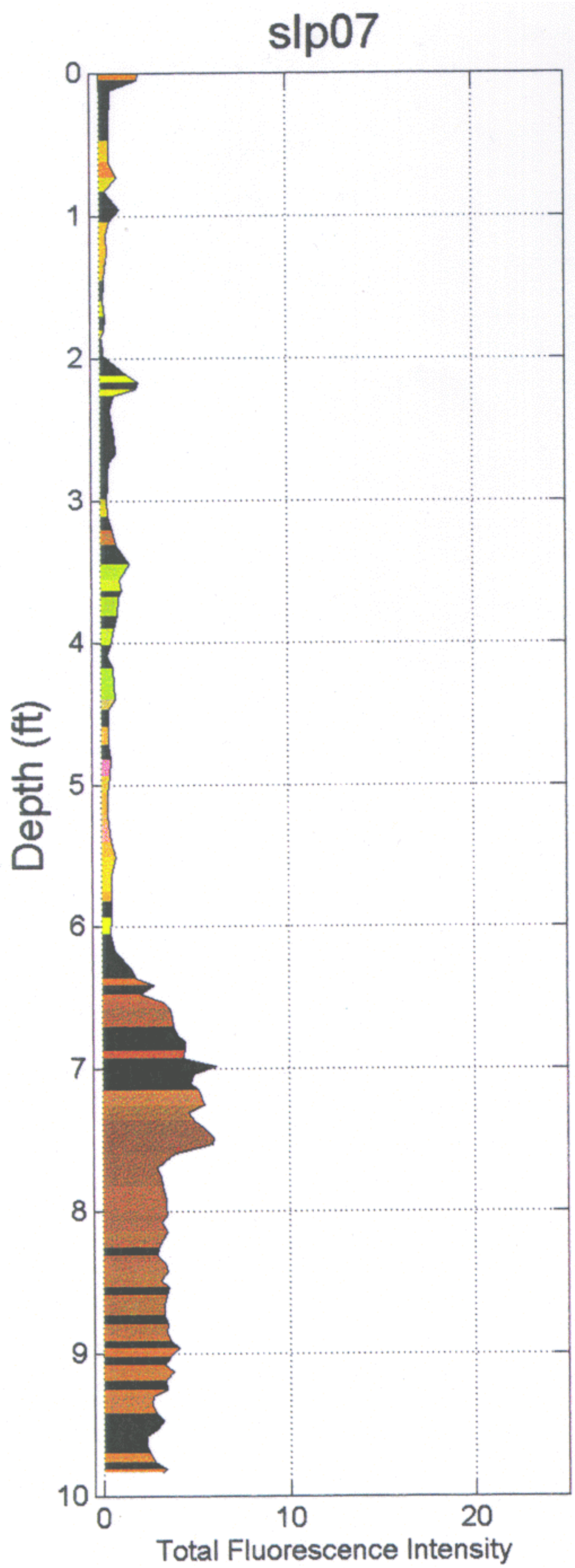
File Name: R:\ENSR\1620-018\B-250.LOG

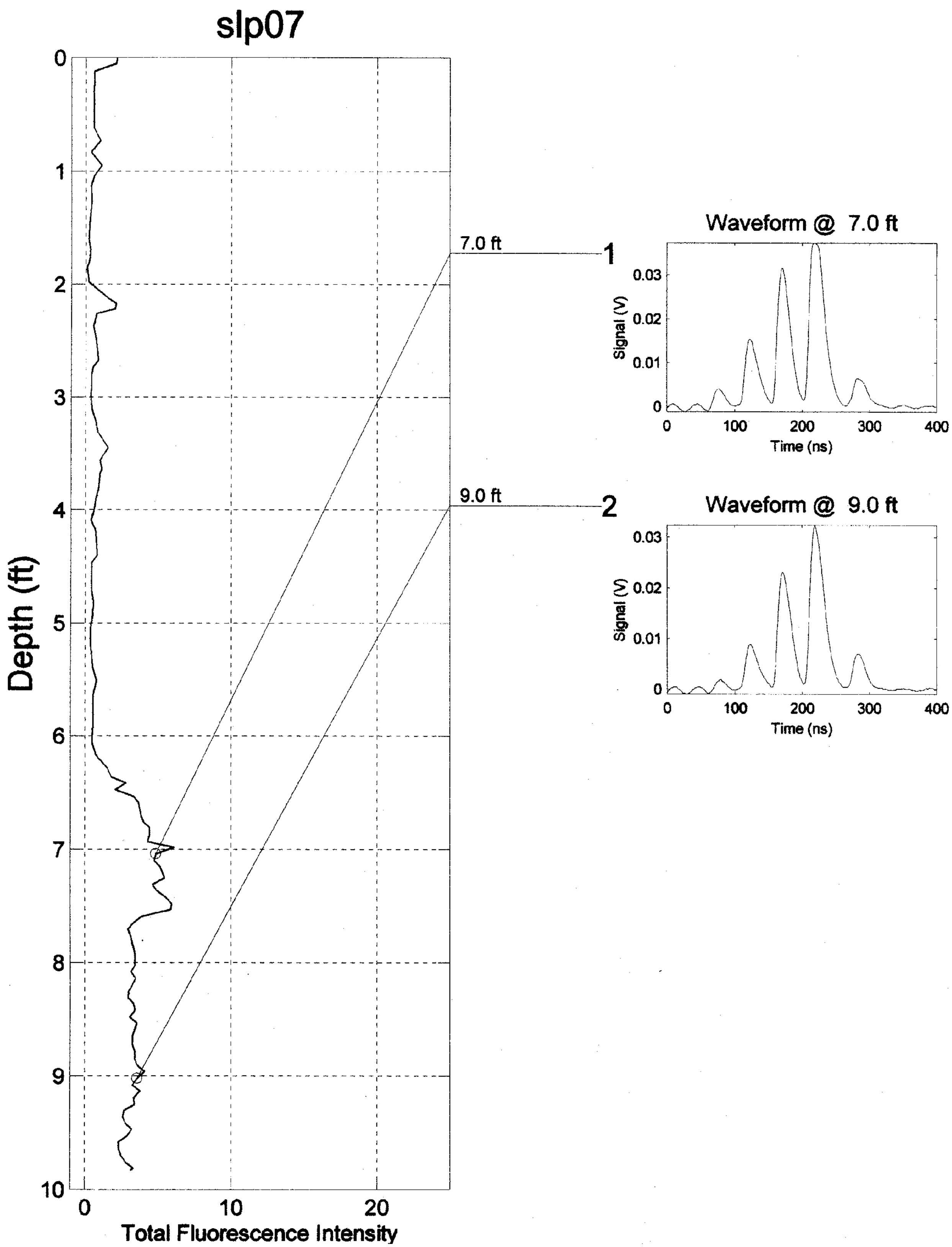
ENSR Corporation
4500 Park Glen Road Suite 210
St. Louis Park, MN 55416

| Depth | Description | Soil Symbol | PID | Comments |
|---|---|---|---|---|
| 0 | SOD | | | |
| 0–4 | Brown SAND with gravel and silt | | 0 | |
| 4–7.5 | Brown SAND with peat, gravel and silt | | 33 | Collected soil sample from 4 to 6' for cPAH analysis |
| | | | 78 | Stained soil |
| 7.5–8 | Dark brown PEAT | | | |
| 8 | End of Borehole | | | |
| | Total Boring Depth = 8ft. | | | |

Drilled by: Bergerson Caswell
Drill Date: September 17, 1998
Drill Method: Simco Earthprobe 200

Inspected By: Peter Moore
cPAH concentration: 86.8 ppm
Methane Concentration: Not Collected


slp07
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
Total Fluorescence Intensity


slp07
Depth (ft)
Total Fluorescence Intensity
7.0 ft
9.0 ft
1
2
Waveform @ 7.0 ft
Waveform @ 9.0 ft
Signal (V)
Time (ns)

NATIONAL ENVIRONMENTAL TESTING, INC.

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613
Tel: (319) 277-2401
Fax: (319) 277-2425

# ANALYTICAL REPORT

Pete Moore
ENSR-ST. LOUIS PARK
4500 Park Glen
Suite #210
St. Louis Park, MN 55416

09/29/1998

NET Job Number: 98.11773

NET Sample Number: 472445

Project ID: PAH Soils #1620-018

Sample ID: D + 300 4-6' Project #1620-018

Date Taken: 09/17/1998 Date Received: 09/19/1998

| Analyte | Result | Units | Result Flag | Analyst | Date Analyzed | Method | Quantitation Limit |
|---|---|---|---|---|---|---|---|
| % Solids | 94.19 | % | | sas | 09/24/1998 | | |
| Prep, BNA - NONAQUEOUS | complete | | | asz | 09/24/1998 | SW 3540 | |
| BNA - 8270 NONAQUEOUS | | | | | | | |
| Benzo(a)anthracene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Benzo(b)fluoranthene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Benzo(k)fluoranthene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Benzo(a)pyrene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Chrysene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Dibenzo(a,h)anthracene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Indeno(1,2,3-cd)pyrene | <1.7 | ug/g | | ccb | 09/25/1998 | SW 8270C | 1.7 |
| Total PAH | --- | ug/g | | rlb | 09/29/1998 | | |

R.L. Bindert
Operations Manager

NATIONAL ENVIRONMENTAL TESTING, INC.

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613
Tel: (319) 277-2401
Fax: (319) 277-2425

# ANALYTICAL REPORT

Pete Moore
ENSR-ST. LOUIS PARK
4500 Park Glen
Suite #210
St. Louis Park, MN 55416

09/29/1998

NET Job Number: 98.11773

NET Sample Number: 472459

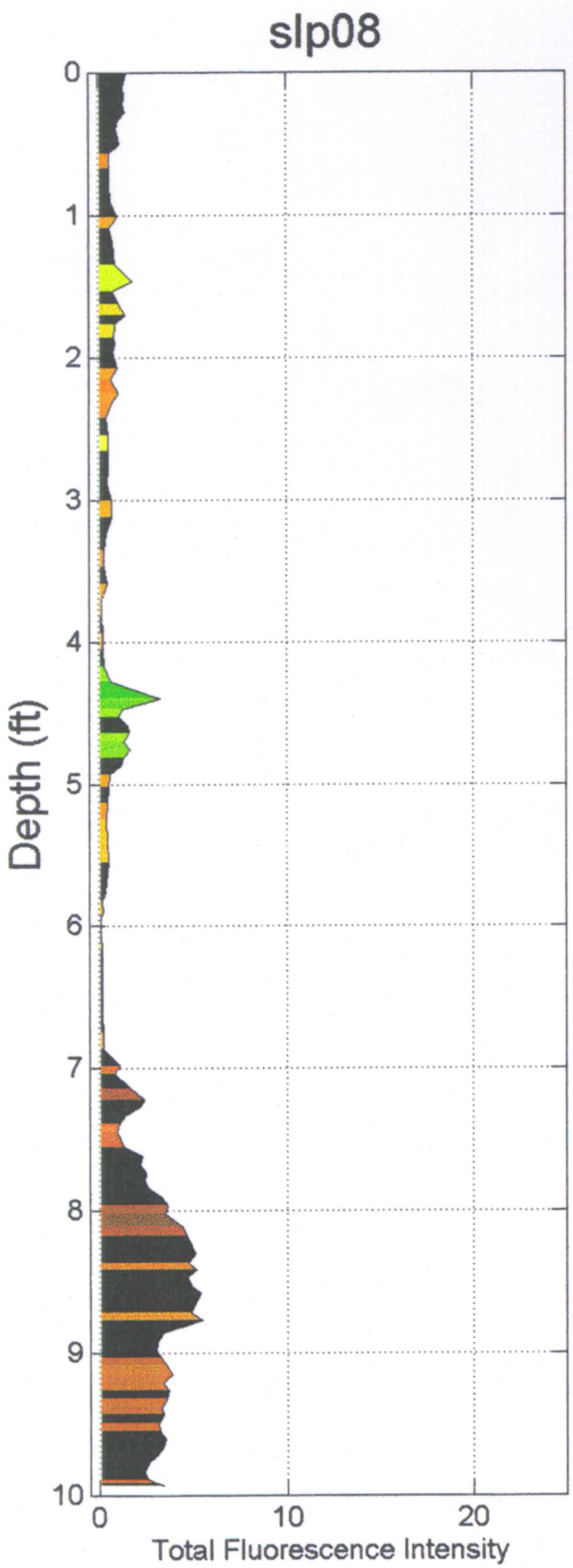
Project ID: PAH Soils #1620-018

Sample ID: D + 300 7-8' Project #1620-018

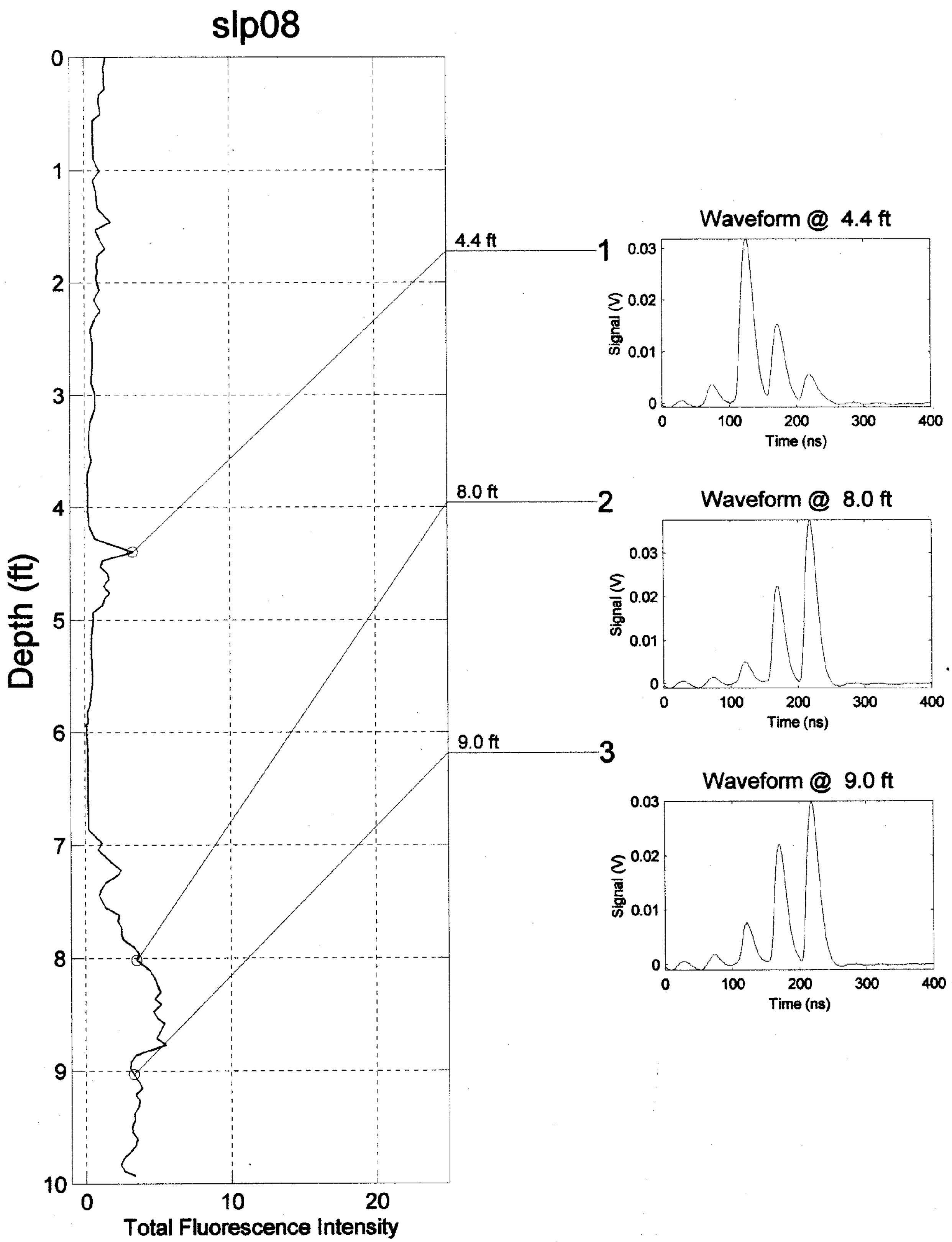
Date Taken: 09/17/1998 Date Received: 09/19/1998

| Analyte | Result | Units | Result Flag | Analyst | Date Analyzed | Method | Quantitation Limit |
|---|---|---|---|---|---|---|---|
| % Solids | 84.02 | % | | sas | 09/24/1998 | | |
| Prep, BNA - NONAQUEOUS | complete | | | asz | 09/24/1998 | SW 3540 | |
| BNA - 8270 NONAQUEOUS | | | | | | | |
| Benzo(a)anthracene | 355 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Benzo(b)fluoranthene | 210 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Benzo(k)fluoranthene | 193 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Benzo(a)pyrene | 198 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Chrysene | 331 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Dibenzo(a,h)anthracene | 28.9 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Indeno(1,2,3-cd)pyrene | 65.1 | ug/g | | ccb | 09/26/1998 | SW 8270C | 20 |
| Total PAH | 1,381 | ug/g | | rlb | 09/29/1998 | | |

R.L. Bindert
Operations Manager



slp08
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
Total Fluorescence Intensity


slp08
Depth (ft)
Total Fluorescence Intensity
4.4 ft
8.0 ft
9.0 ft
1
2
3
Waveform @ 4.4 ft
Waveform @ 8.0 ft
Waveform @ 9.0 ft
Signal (V)
Time (ns)

NATIONAL ENVIRONMENTAL TESTING, INC.®

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# ANALYTICAL REPORT

Pete Moore
ENSR-ST. LOUIS PARK
4500 Park Glen
Suite #210
St. Louis Park, MN 55416

09/29/1998

NET Job Number: 98.11773

NET Sample Number: 472439

Project ID: PAH Soils #1620-018

Sample ID: E + 200 4-7' Project #1620-018

Date Taken: 09/17/1998 Date Received: 09/19/1998

| Analyte | Result | Units | Result Flag | Analyst | Date Analyzed | Method | Quantitation Limit |
|---|---|---|---|---|---|---|---|
| % Solids | 82.67 | % | | sas | 09/24/1998 | | |
| Prep, BNA - NONAQUEOUS | complete | | | clj | 09/20/1998 | SW 3540 | |
| BNA - 8270 NONAQUEOUS | | | | | | | |
| Benzo(a)anthracene | 9.9 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Benzo(b)fluoranthene | 8.2 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Benzo(k)fluoranthene | 8.9 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Benzo(a)pyrene | 8.8 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Chrysene | 10.2 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Dibenzo(a,h)anthracene | <2.3 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Indeno(1,2,3-cd)pyrene | 3.5 | ug/g | | dmd | 09/23/1998 | SW 8270C | 2.3 |
| Total PAH | 49.5 | ug/g | | rlb | 09/29/1998 | | |

R.L. Bindert
Operations Manager

Project No: 1620-018
Client: City of St. Louis Park - EDA
Project: Phase II Site Investigation

Location: 7250 State Highway 7

# Log of Borehole: E+200

File Name: R:\ENSR\1620-018\E-200.LOG

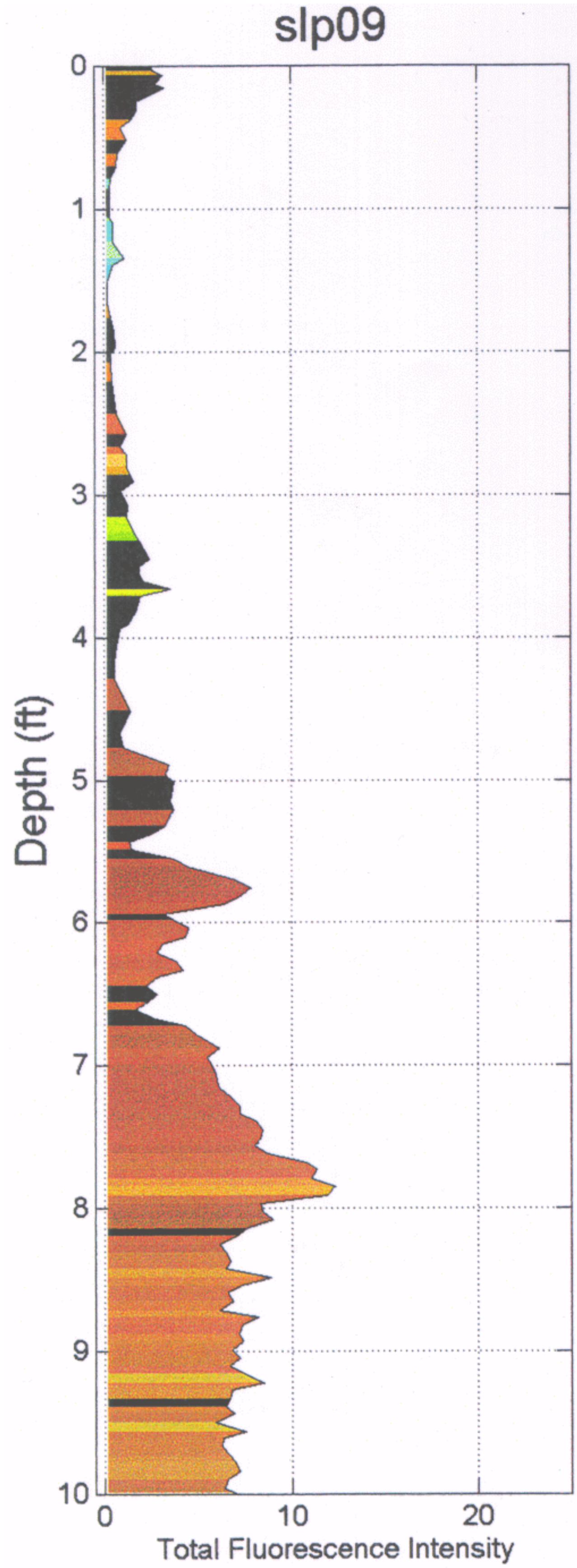
ENSR

ENSR Corporation
4500 Park Glen Road Suite 210
St. Louis Park, MN 55416

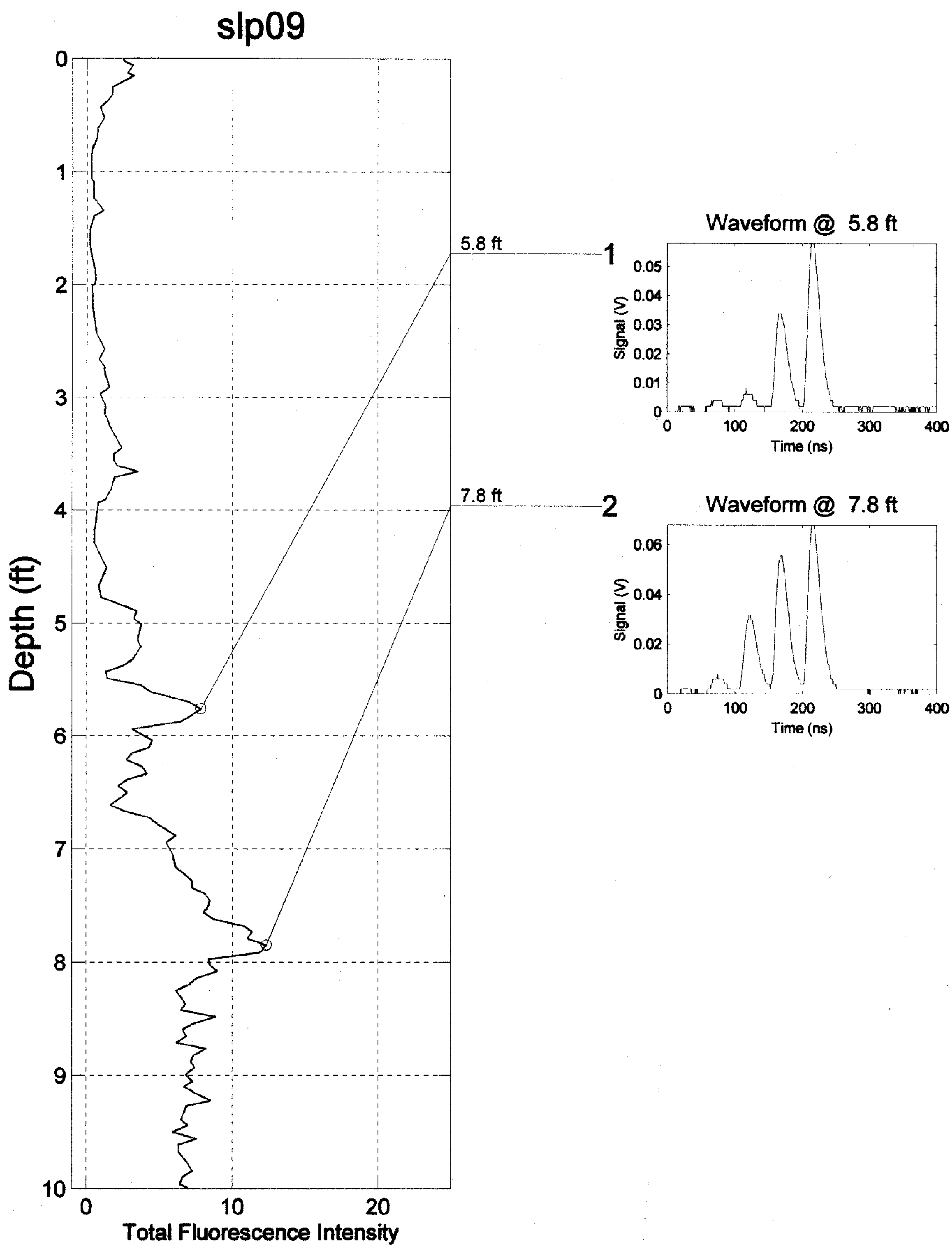
| Depth | Description | Soil Symbol | PID | Comments |
|---|---|---|---|---|
| 0 | SOD | | | |
| 0–5 | Dark brown CLAY with gravel, silt and organics | | 0 | Collected soil sample from 4 to 7' for cPAH analysis |
| 5–7 | As above with a 4 inch thick layer of calcium hydroxide sludge | | 0 | Refusal of sampling probe |
| 7 | End of Borehole<br>Total Boring Depth = 7 ft. | | | |

Drilled by: Bergerson Caswell
Drill Date: September 17, 1998
Drill Method: Simco Earthprobe 200

Inspected By: Peter Moore
cPAH concentration: 49.5 ppm
Methane Concentration: Not Collected



slp09
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
Total Fluorescence Intensity


slp09
Depth (ft)
Total Fluorescence Intensity
5.8 ft
7.8 ft
1
2
Waveform @ 5.8 ft
Signal (V)
Time (ns)
Waveform @ 7.8 ft
Signal (V)
Time (ns)

NATIONAL ENVIRONMENTAL TESTING, INC.

Cedar Falls Division
704 Enterprise Drive
Cedar Falls, IA 50613
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# ANALYTICAL REPORT

Pete Moore
ENSR-ST. LOUIS PARK
4500 Park Glen
Suite #210
St. Louis Park, MN 55416

09/29/1998

NET Job Number: 98.11773

NET Sample Number: 472426

Project ID: PAH Soils #1620-018

Sample ID: C + 200 6-8' Project #1620-018

Date Taken: 09/17/1998 Date Received: 09/19/1998

| Analyte | Result | Units | Result Flag | Analyst | Date Analyzed | Method | Quantitation Limit |
|---|---|---|---|---|---|---|---|
| % Solids | 86.20 | % | | sas | 09/22/1998 | | |
| Prep, BNA - NONAQUEOUS | complete | | | clj | 09/20/1998 | SW 3540 | |
| BNA - 8270 NONAQUEOUS | | | | | | | |
| Benzo(a)anthracene | 1.1 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Benzo(b)fluoranthene | 0.53 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Benzo(k)fluoranthene | 0.54 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Benzo(a)pyrene | 0.47 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Chrysene | 0.90 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Dibenzo(a,h)anthracene | <0.40 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Indeno(1,2,3-cd)pyrene | <0.40 | ug/g | | dmd | 09/21/1998 | SW 8270C | 0.40 |
| Total PAH | 3.5 | ug/g | | rlb | 09/29/1998 | | |

R.L. Bindert
Operations Manager

Project No: 1620-018
Client: City of St. Louis Park - EDA
Project: Phase II Site Investigation

Location: 7250 State Highway 7

# Log of Borehole: C+200

File Name: R:\ENSR\1620-018\C-200.LOG

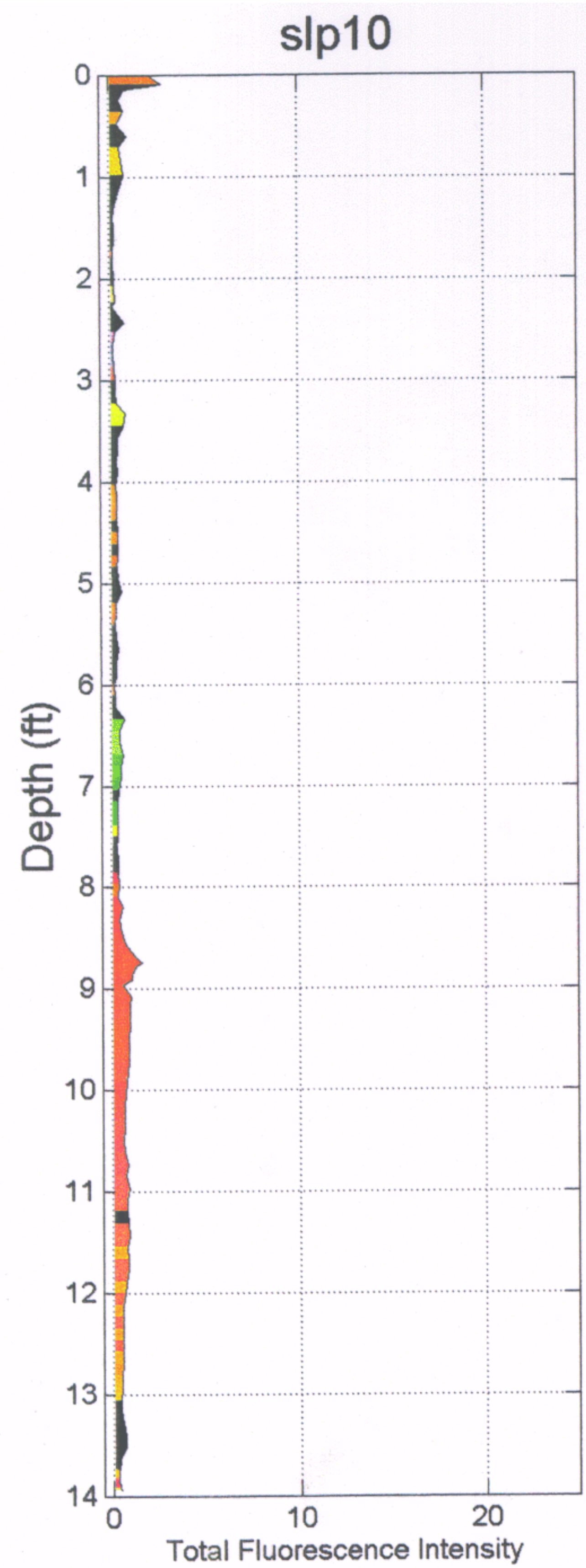
ENSR

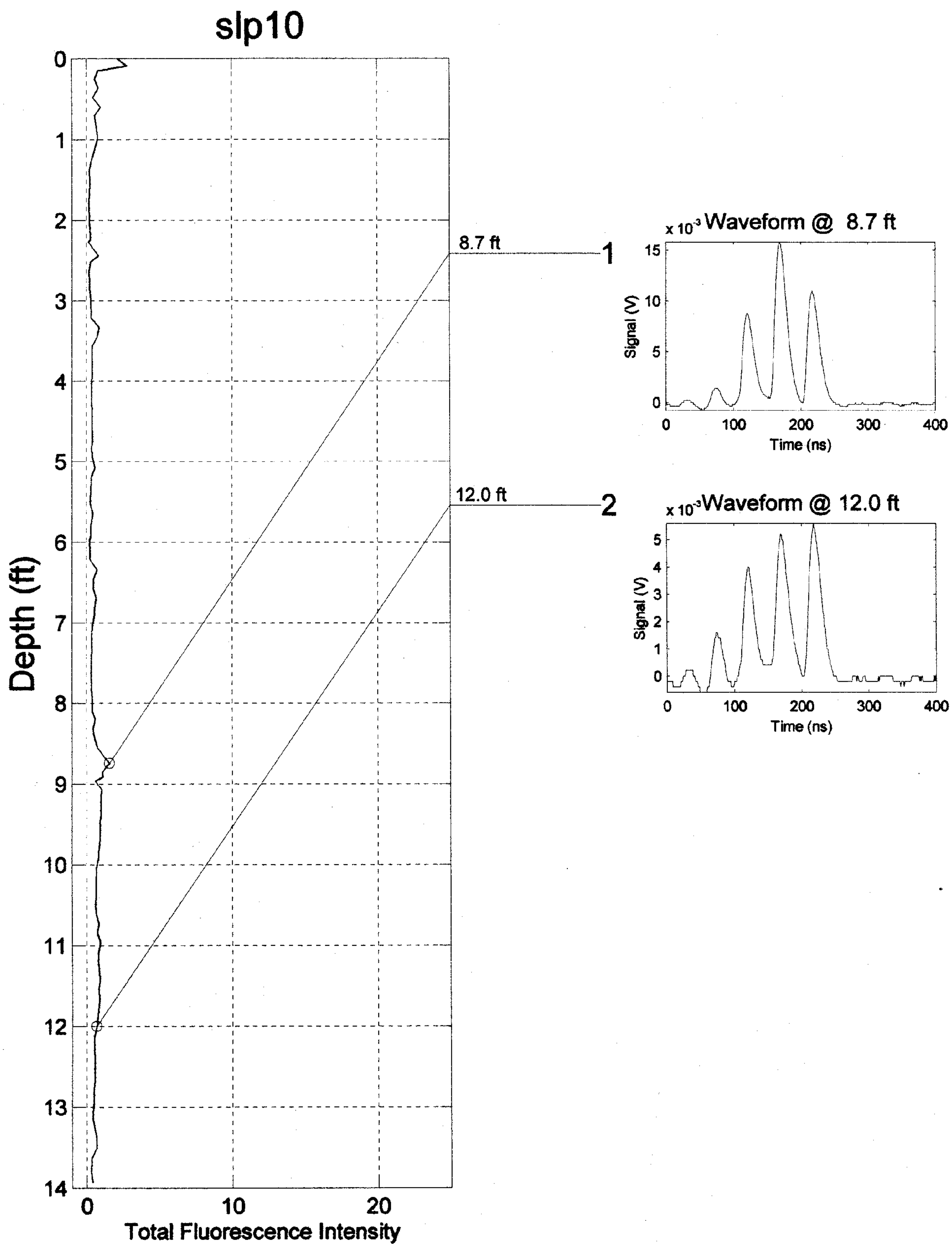
ENSR Corporation
4500 Park Glen Road Suite 210
St. Louis Park, MN 55416

| Depth | Description | Soil Symbol | PID | Comments |
|---|---|---|---|---|
| 0–0.5 | SOD | | | |
| 0.5–6 | Dark brown SAND with gravel, silt and organics | | 0 | |
| | | | 0 | |
| 6–8 | Dark brown SLIGHTLY SILTY SAND with organics | | 0 | Collected soil sample from 6 to 8' for cPAH analysis |
| 8 | End of Borehole<br>Total Boring Depth = 8 ft. | | | |

Drilled by: Bergerson Caswell
Drill Date: September 17, 1998
Drill Method: Simco Earthprobe 200

Inspected By: Peter Moore
cPAH concentration: 3.5 ppm
Methane Concentration: Not Collected


slp10
Depth (ft)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
10
20
Total Fluorescence Intensity


slp10
Depth (ft)
Total Fluorescence Intensity
8.7 ft
12.0 ft
1
2
x 10⁻³ Waveform @ 8.7 ft
x 10⁻³ Waveform @ 12.0 ft
Signal (V)
Time (ns)

NATIONAL ENVIRONMENTAL TESTING, INC.®

Cedar Falls Division
704 Enterprise Drive
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# ANALYTICAL REPORT

Pete Moore
ENSR-ST. LOUIS PARK
4500 Park Glen
Suite #210
St. Louis Park, MN 55416

09/29/1998

NET Job Number: 98.11773

NET Sample Number: 472442

Project ID: PAH Soils #1620-018

Sample ID: F + 250 8-10' Project #1620-018

Date Taken: 09/17/1998 Date Received: 09/19/1998

| Analyte | Result | Units | Result Flag | Analyst | Date Analyzed | Method | Quantitation Limit |
|---|---|---|---|---|---|---|---|
| % Solids | 76.06 | % | | sas | 09/24/1998 | | |
| Prep, BNA - NONAQUEOUS | complete | | | asz | 09/24/1998 | SW 3540 | |
| BNA - 8270 NONAQUEOUS | | | | | | | |
| Benzo(a)anthracene | <11 | ug/g | | ccb | 09/25/1998 | SW 8270C | 11 |
| Benzo(b)fluoranthene | 16.4 | ug/g | | ccb | 09/25/1998 | SW 8270C | 11 |
| Benzo(k)fluoranthene | 10.4 | ug/g | | ccb | 09/25/1998 | SW 8270C | 11 |
| Benzo(a)pyrene | 12.2 | ug/g | | ccb | 09/25/1998 | SW 8270C | 11 |
| Chrysene | <11 | ug/g | | ccb | 09/25/1998 | SW 8270C | 11 |
| Dibenzo(a,h)anthracene | <11 | ug/g | | ccb | 09/25/1998 | SW 8270C | 11 |
| Indeno(1,2,3-cd)pyrene | 6.6 | ug/g | J | ccb | 09/25/1998 | SW 8270C | 11 |
| Total PAH | 45.6 | ug/g | | rlb | 09/29/1998 | | |

J - Variability is increased: result is below linear calibration range.

R.L. Bindert
Operations Manager

Project No: 1620-018
Client: City of St. Louis Park - EDA
Project: Phase II Site Investigation

Location: 7250 State Highway 7

# Log of Borehole: F+250

File Name: R:\ENSR\1620-018\F-250.LOG

ENSR

**ENSR Corporation**
**4500 Park Glen Road Suite 210**
**St. Louis Park, MN 55416**

| Depth | Description | Soil Symbol | PID | Comments |
|---|---|---|---|---|
| 0–0.4 | SOD | | | |
| 0.4–5 | Brown SAND with gravel and silt | | 0 | |
| 5–8 | Dark brown PEAT with sand and silt | | 0 | |
| 8–10 | Dark brown SAND with gravel | | 0 | Collected soil sample from 8 to 10' for cPAH analysis |
| 10–12 | Dark brown PEAT | | | |
| 12 | End of Borehole<br>Total Boring Depth = 12 ft. | | | |

Drilled by: Bergerson Caswell
Drill Date: September 17, 1998
Drill Method: Simco Earthprobe 200

Inspected By: Peter Moore
cPAH concentration: 45.6 ppm
Methane Concentration: Not Collected