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ARMSTRONG

LABORATORY

SITE SCREENING USING LASER-INDUCED FLUORESCENCE AND CONE PENETRATION TECHNOLOGIES AT HILL AFB, UTAH

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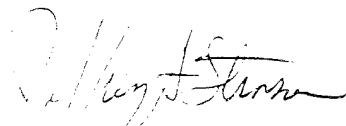
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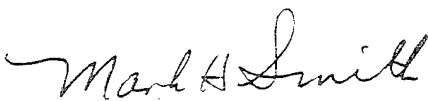
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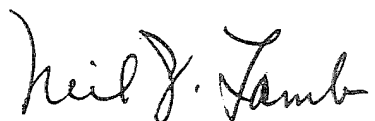
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14. Abstract This document summarizes the results of the field work conducted in December 1994 using Laser Induced Fluorescence-Piezo Cone Penetration Technology (LIF-CPT) tests, and conventional soil borings. The purpose of this site characterization effort was to identify a potential area to perform treatability studies with eight enhanced source removal technologies. The free product hydrocarbon has migrated primarily to the west of the Chemical Disposal Pits. LIF-CPT is an efficient way to quickly characterize the extent of a contamination plume when the contamination of total petroleum hydrocarbons (TPH) is in excess of 100 mg/Kg. The most efficient method for obtaining soil samples at Hill AFB OU1 is conventional drilling. CPT equipped with Raman Spectroscopy has limited capabilities for detecting TCE at OU1 because of interference with hydrocarbon fluorescence.					
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PREFACE

This report was prepared by TRW, Inc., Systems Integration Group, Test and Evaluation Engineering Services, Crystal Square 5, Suite 202, 1755 Jefferson Davis Highway, Arlington, VA 22202, Defense Evaluation Support Activity (DESA) Contract MDA970-89-C-0019, Subtask 04-20/00 - Armstrong Laboratory Site Characterization. TRW subcontractors for this effort included Praxis Environmental Technologies Inc., Applied Research Associates, Inc., R.C. Exploration Drilling, and CKY Incorporated Analytical Laboratories. This work was completed for the Armstrong Laboratory Environics Directorate (AL/EQ) as part of the Strategic Environmental Research and Development Program (SERDP).

This report identifies an area of Operable Unit 1 at Hill Air Force Base, Utah which is suitable for siting up to eight remediation technology test cells. These test cells can be used to field test the effectiveness of various technologies to remediate contaminated soil.

The author wishes to acknowledge the support provided by Mr. Kevin Bourne of the Hill AFB Environmental Management Directorate and the assistance of Montgomery Watson Operable Unit 1 personnel, including Deborah Carter-Drain, Michael Cox, Mark Augustine, and Diane Keith.

The field work was performed during December 1994. The DESA project officer was Mr. Stephen Yan, DESA/TSA.

Although the research described in this article has been funded wholly or in part by the United States Environmental Protection Agency with Strategic Environmental Research and Development funds through Contract MDA970-89-C-0019 to TRW, it has not been subjected to Agency review and therefore does not necessarily reflect the views of the Agency and no official endorsement should be inferred.

EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this effort was to characterize a portion of Operable Unit 1 (OU1) at Hill AFB, Utah with respect to its geology and geochemistry using Cone Penetration Technology (CPT). Hill AFB was chosen by Armstrong Laboratory Environics Directorate (AL/EQ) as part of the Strategic Environmental Research and Development Program (SERDP) field test sites for testing nonaqueous phase liquids (NAPLs) remediation technologies. The site was known to be contaminated with NAPLs and has an aquitard located between approximately 15 feet below the surface to the east and approximately 30 feet below the surface to the west.

The purpose of obtaining the field measurements was to identify an area of OU1 for siting eight test cells. Ideally, each of the test cells would have a clay aquitard at 20 feet or less and a contamination smear zone of four feet or more.

B. BACKGROUND

Pump-and-treat technology is the remediation technology chosen to restore ground water quality at over 75 percent of the hazardous waste sites in the United States. There is a particular need for enhancements to pump-and-treat technology that can overcome the limitations imposed by aquifer heterogeneity, sorption, and the presence of NAPLs. A number of enhanced pump-and-treat technologies have been proposed and demonstrated in the laboratory, but none have been subjected to an objective evaluation in the field.

C. SCOPE

This document summarizes the results of the field work conducted in December 1994 using Laser Induced Fluorescence-Piezo Cone Penetration Technology (LIF-CPT) tests, and conventional soil borings. The purpose of this site characterization effort was to identify a potential area for the location of remediation test cells at Hill AFB, OU1. LIF-CPT was performed at 29 locations and 16 soil samples were obtained to support chemical analysis. No ground water samples were obtained during this effort.

Section I is an introduction to the tasking and background. Section II is a summary of the various technologies used during the field activities. Section III discusses the field activities. Section IV describes the field results. The conclusion, and recommended area for the test cells is identified in Section V. The recommendation and discussion of lessons learned is presented in Section VI.

D. METHODOLOGY

For this characterization effort, the use of CPT with LIF was chosen based on a lower cost for determining the zones of contamination as compared to conventional soil sampling and analyses. The Environmental Protection Agency (EPA) originally identified an area for characterization north of the University of Florida test cell near Chemical Disposal Pit 1 (CDP1).

Data from previous site characterization efforts in the northern and west areas were incomplete. Additional locations to the west of the EPA selected area were also identified for characterization as required to meet the project objectives.

The LIF technique was used with the CPT at various locations throughout the area of interest to identify the existence and extent of hydrocarbon contamination. Measurement of depth intervals or "smear" zones containing residual hydrocarbons was the primary objective of the LIF. The CPT equipment was used to introduce the LIF into the subsurface and to log physical properties of the soil. The CPT logs yielded data on the elevation of the underlying aquitard, the depth to ground water, and the existence of low permeability lenses in the shallow, unsaturated zone at 29 locations across the site.

Raman Spectroscopy was utilized on two locations. Because of excessive background fluorescence, the Raman signal was not detectable. Raman Spectroscopy is best used to detect chlorinated compounds such as Trichloroethylene (TCE) and Perchloroethylene (PCE).

Soil samples were obtained using conventional drilling techniques because the cobbly soils inhibited using the CPT methods of soil sampling. Sixteen samples were collected, eight from potentially contaminated locations and eight from less contaminated or clean locations. These samples were sent to the lab for analysis using EPA method 8015, Nonhalogenated Volatile Organics by Gas Chromatography, and EPA method 8240/624, Volatile Organics by Gas Chromatography/Mass Spectrometry.

E. TEST DESCRIPTION

Primary data collection was obtained using a LIF-CPT on a 25-ton truck. The results were available in real time and were incorporated into the decisions on which direction to proceed with the characterization activities. Raman Spectroscopy testing was also conducted in the field at two locations. Soil samples were obtained from 16 sites to substantiate the LIF-CPT work.

F. RESULTS

In general, the results are consistent with the estimated extent of hydrocarbon NAPL contamination identified in "Draft Records Review Technical Memorandum for Operable Unit 1, Hill Air Force Base, Utah, August 1994," prepared by Montgomery Watson. The free product hydrocarbon has migrated primarily to the west of the Chemical Disposal Pits. An aquitard is located beneath the site surface which the CPT encountered at elevations ranging from 4766 to 4774 feet above mean sea level. The surface of the site is not flat and depths to the aquitard in the CPT locations ranged from 16 to 33 feet. In the northeast portion of the site, the NAPL smear zone did not exceed one foot in thickness. In the southwest portion of the site the smear zone ranged in thickness from 1 to 11 feet. The thickest smear zones correlated roughly with low spots in the top of the aquitard surface. These locations are coincident with the highest surface elevations. Migration of NAPL at the site appears to be determined by the aquitard features rather than a water table surface. For maximum contamination, an area approximately 140 feet by 120 feet was identified for the test cell locations.

G. CONCLUSION

LIF-CPT is an efficient way to quickly characterize the extent of a contamination plume when the contamination of total petroleum hydrocarbons (TPH) is in excess of 100 mg/Kg. The most efficient method for obtaining soil samples at Hill AFB OU1 is conventional drilling. CPT equipped with Raman Spectroscopy has limited capabilities for detecting TCE at OU1 because of interference with hydrocarbon fluorescence.

H. RECOMMENDATIONS

Although the area to the north and east has a shallower depth to the aquitard, 16 feet versus approximately 30 feet, it is not recommended for siting the test cells because of minimal contamination concentrations and the minimal thickness of the contamination smear zone.

Before construction, additional characterization of the area selected for the test cells is required to provide baseline data for assessing technology performance in the test cells. Characterization parameters should be coordinated with prospective testers and standardized to provide the appropriate baseline for comparison of the technologies effectiveness. Four monitoring wells are located around the perimeter of the identified area. These wells may be incorporated into the final monitoring plan for the remediation testing if this area is chosen for testing purposes. An area approximately 140 feet x 120 feet was identified, located south and west of the chemical disposal pits.

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SECTION I

INTRODUCTION

A. OBJECTIVE

The objective of this effort is to characterize a portion of Operable Unit (OU1) (see Figures 1 and 2) at Hill AFB, Utah with respect to its geology and geochemistry. The field activities were used to identify local areas of contamination at OU1 and provide an initial characterization of the smear zone. The purpose in collecting the data was to identify a heavily contaminated area for siting eight test cells. The techniques employed during this effort included the Cone Penetration Technology (CPT), Laser-induced Fluorescence spectroscopy (LIF), and Raman spectroscopy. Conventional drilling techniques were used to obtain soil samples for laboratory analyses.

The US Environmental Protection Agency/R.S. Kerr Environmental Research Laboratory (USEPA/RSKERL) and Armstrong Laboratory Environics Directorate (AL/EQ) located at Tyndall AFB, Florida will use this information to select an area at OU1 for testing of remedial technologies for removing hydrocarbons in soil.

B. BACKGROUND

Low-solubility organics such as chlorinated solvents were used and released to the environment in massive quantities during the 1950's, 60's, and 70's. These contaminants have migrated through the subsurface and entered groundwater at over 1000 DOD sites. At these sites the organic contaminants are found in one of three phases: (1) dissolved in the groundwater (dissolved phase), (2) sorbed to the aquifer solids (sorbed phase), or (3) as a separate non-aqueous-phase liquid (NAPL phase), all of which need to be removed if the groundwater is to be restored to a usable quality.

The limiting factor for satisfactory remediation at over 75 percent of the hazardous waste sites in the United States is restoration of groundwater quality. Remedial for contaminants in groundwater are limited because excavation and surface treatment is often cost prohibitive or impractical. The technology chosen at over 90 percent of the sites with contaminated groundwater is pumping followed by surface treatment. This technology, commonly known as pump-and-treat, has had some success in containing contaminant plumes and removing dissolved phase contamination in relatively homogeneous geologic formations. Major limitations to the successful use of pump-and-treat arise at heterogeneous sites with a significant clay content. Currently, pump-and-treat systems cannot efficiently extract the sorbed or NAPL phases and, therefore, have not proven to be effective at restoring contaminated groundwater when these contaminant phases are present.

Research is still needed to optimize surface treatment of the extracted groundwater and contaminants. Surface treatment is much more mature and applicable techniques usually exist if the contaminated water can be brought to the surface.

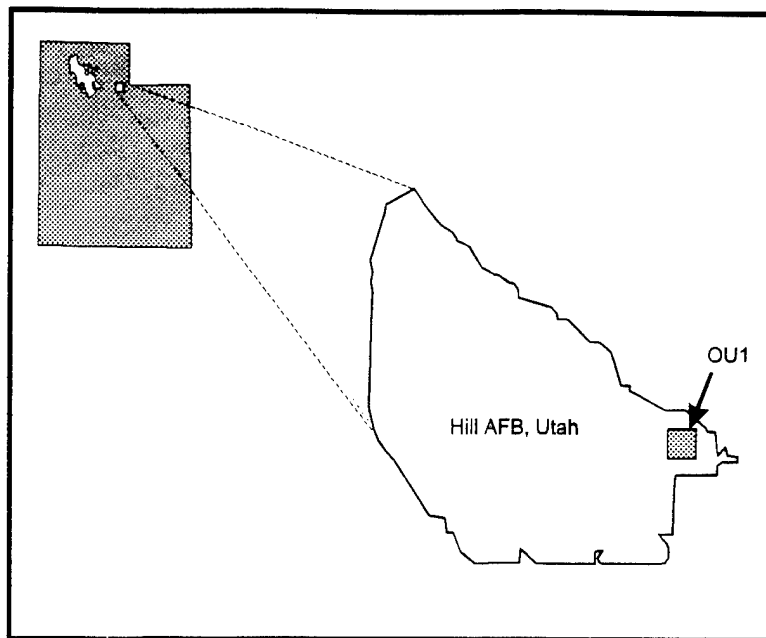


Figure 1. Hill AFB OU1 Site Characterization Location

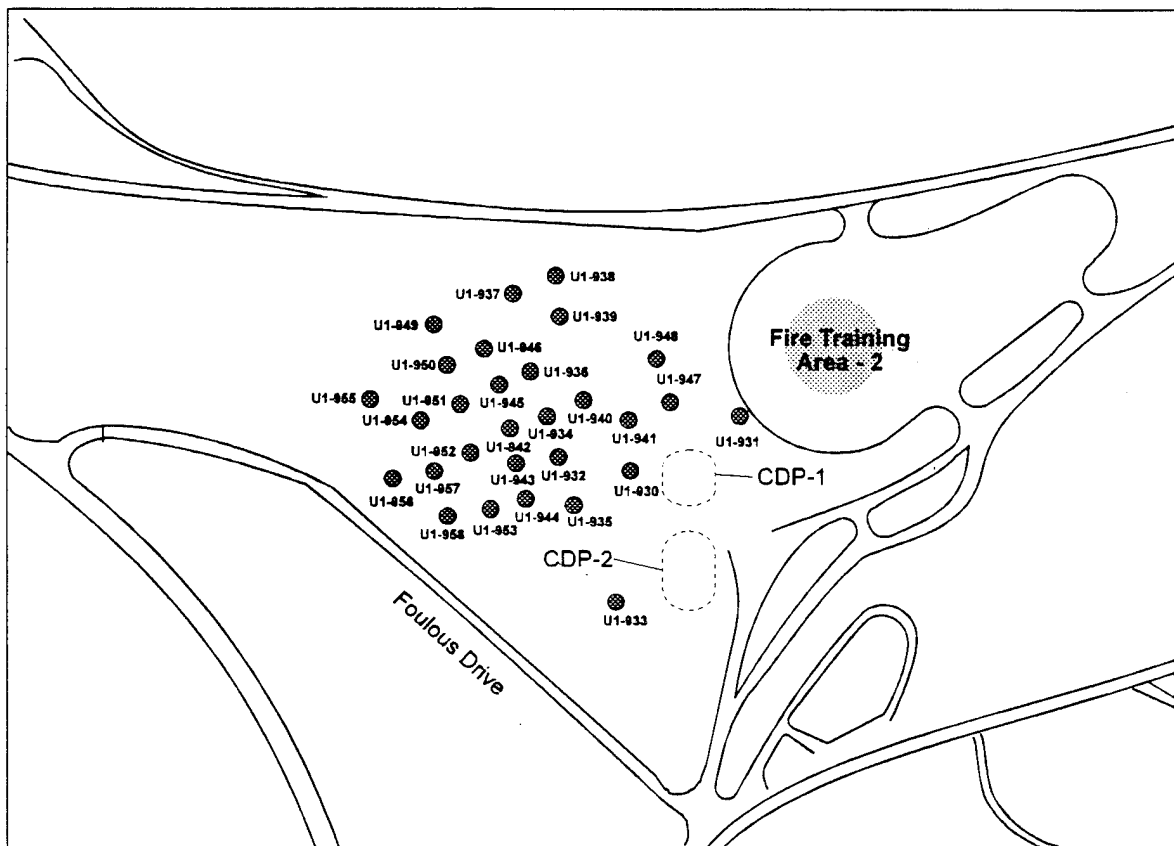


Figure 2. Hill AFB OU1 Site Characterization Area

Characteristics of contaminated aquifers that limit the success of pump-and-treat include: (a) aquifer heterogeneity, (b) sorption of the contaminant to aquifer solids, and (c) the presence of a separate immiscible non-aqueous-phase liquid. These same problems plague other in situ remediation technologies such as bioremediation.

There is a particular need for enhancements to pump-and-treat technology that can overcome the limitations imposed by aquifer heterogeneity, sorption, and the presence of NAPLs. A number of enhanced pump-and-treat technologies have been proposed and demonstrated in the laboratory, but none have been subjected to an objective evaluation in the field, nor is engineering design guidance available to allow their routine application to remediation of contaminated groundwater.

From 1954 to 1973, the CDPs at OU1 were used for the disposal of liquid wastes; primarily petroleum hydrocarbons, spent solvents, and paint thinners (Montgomery Watson, August 1994). The CDPs were excavated areas created for open burning of combustible liquid waste. Typically, drums of waste were hauled to the CDPs and emptied. In addition, 500- to 1,500-gallon tank trailers were pulled in to the CDPs and emptied. Based on interviews, waste oil, Stoddard solvent, and paint thinner were the most frequently reported materials disposed and periodically burned in the CDPs until 1967. Wastes were not burned in the CDPs after 1967, and specific chemicals disposed in the CDPs after 1967 are unknown. Fire Training Areas (FTA) are also in the vicinity of the study area as shown in Figure 2. FTA 1 was used as a practice area to extinguish simulated aircraft fires from 1958 to 1973. Petroleum products used for the exercises were stored in barrels on site. There is no evidence that spilled fuel or fuel used during the exercises was prevented from entering the soil. FTA 2 replaced FTA 1 in 1973 and is still in operation. FTA 2 consists of a concrete pad, 4 inches thick and 65 feet across. JP-4 was used as the training fuel at FTA 2 until February 1994 when it was replaced with propane.

The purpose of this study was to provide initial characterization of sites at Hill AFB so that promising remediation technologies can eventually be tested nearly side-by-side. This site was chosen because of the potential to provide an area with relatively consistent contamination of NAPL's so that side-by-side comparisons of various technologies could be conducted.

The preliminary requirements for the testing sites are:

- 4-5 feet of contaminated smear zone located above the aquitard surface.

- A relatively impermeable aquitard located no more than 30 feet below the surface, preferably 15-20 feet.

- Relative homogeneous contaminant distribution and consistent geology between the selected test sites.

C. SCOPE/APPROACH

The CPT/LIF survey was conducted to characterize areas of existing contamination for siting remediation test cells. Conventional drilling techniques were used to obtain soil samples. The samples were then tested for contaminants using EPA method 8015, Non-Halogenated Volatile Organics by Gas Chromatography, and EPA method 8240/624, Volatile Organics by Gas Chromatography/Mass Spectrometry. ASTM D422 and ASTM D854 were performed on eight soil samples to determine the physical characteristics of the top of the clay layer. ASTM 5084 was performed on one sample taken from 5 feet into the clay layer to characterize the permeability of the aquitard.

This effort was the first step in identifying an area for objective field evaluations of environmental remediation technologies. This work was conducted to select the best area within OU1 for remediation testing. The criteria used to select the area was based on the clay layer being at 30 feet or less from the surface and a contamination smear zone of 4 feet or greater, located above the aquitard. The next step will be the characterization of the selected area in more detail before test cell construction.

It is important to thoroughly characterize the test sites to evaluate the effectiveness of various remediation methods. Each test cell will be approximately 3 meters by 5 meters. Each test cell will be a self contained unit. Sheet piling walls form the outer perimeter of each cell. The sheet piling will be sealed so that flow through the walls will be prevented. The clay aquitard will provide an impermeable layer on the bottom of the test cells and will prevent the migration of contaminants out of the test cell.

SECTION II

METHODOLOGY

A. CONE PENETRATION TESTING

The electronic cone penetrometer test was originally developed for use in consolidated clay soils. Over the years, cone-and-push system designs have evolved to the point where they can now be used in strong cemented soils and even soft rocks. The penetrometer consists of an instrumented probe which is forced into the ground using a hydraulic load frame mounted on a 25-ton truck with the weight of the truck providing the necessary reaction mass. The probe has a conical tip and a friction sleeve which independently measures vertical resistance beneath the tip as well as frictional resistance on the side of the probe as a function of depth. A schematic view of the CPT penetrometer probe is shown in Figure 3. A pressure piezo-electric transducer in the cone is used to measure the pore water pressure as the probe is pushed into the ground (Piezo-CPT). In addition, the probe contains an LIF package that supplies the laser beam, directs it out a sapphire window on the side of the cone and detects the return fluoresced light from contamination sources as shown in Figure 3. Applied Research Associates, Inc. (ARA), under contract to TRW, performed the CPT-LIF and Raman Spectroscopy work. A copy of the ARA report is provided as Appendix A to this document and includes a more detailed discussion of the CPT methodology.

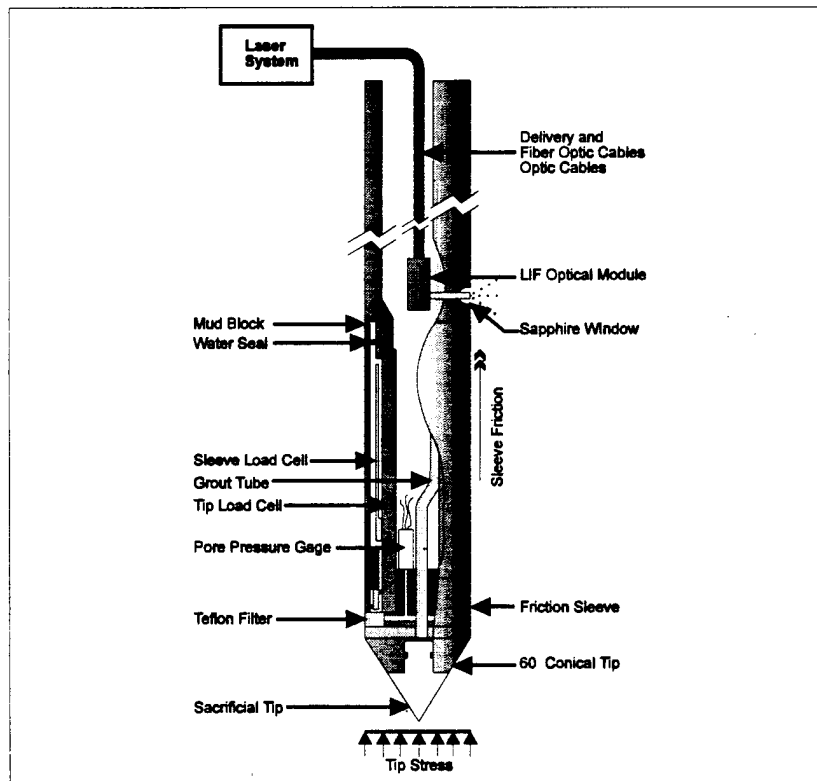


Figure 3. Schematic of Laser-Induced Fluorescence CPT Probe

The cone penetrometer test was conducted using the ARA penetrometer truck. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame. A 15 cm² penetrometer probe, (which has a 1.75-inch diameter, 60° conical tip and a 1.75-inch diameter by 6.50-inch long frictional sleeve), was used on this project. The shoulder between the base of the tip and the porous filter is 0.08 inches long. The penetrometer is normally advanced vertically into the soil at a constant rate of 48 inches/minute, although this rate must sometimes be reduced as hard layers are encountered. The electronic cone penetrometer test is conducted in accordance with ASTM D3441 Standard Method for Deep Quasi Static Cone and Friction Cone Penetration Test of Soil, 1986.

Penetration pore pressures are measured with a pressure transducer to .03 psi, located behind the tip in the lower end of the probe. Water pressures in the soil are sensed through a 250 micron porous polyethylene filter that is 0.25-inches high and 0.202-inches thick. The pressure transducer is connected to the porous filter through a pressure port as shown in Figure 3.

B. CONTAMINATION TESTING USING OPTICAL METHODS

1. Background

Optical screening technology, as applied to the environmental field and specifically to fuel fluorescence measurements, is relatively new. Research in this field has demonstrated the fluorescence characteristics of a wide range of chemical compounds. Common fuels such as waste oil, jet fuels, gasoline, and diesel fuel marine (DFM) exhibit strong fluorescence signatures, with the degree of fluorescence depending on both the optical power delivered to the sample and the excitation wavelength. Common chemical contaminants such as chlorinated hydrocarbons (TCE, PCE) are known not to fluoresce and are not a candidate for the LIF technique.

For the field tests, two optical methods were employed. Laser Induced Fluorescence (LIF) relies on the laser stimulation of a specific electronic transition in a molecule, followed by emission of light (fluorescence) at known wavelengths. An in-depth discussion of LIF procedures can be found in Appendix A. LIF is amenable to detecting only those species that fluoresce, such as petroleum fuels. Raman spectroscopy was employed to detect species that do not fluoresce, such as chlorinated hydrocarbons. In Raman spectroscopy, a chemical species is exposed to laser light at a specific wavelength. Some of this light is scattered by the species at which time some of the scattered light undergoes an alteration of wavelength. Chemicals are identified by detecting and analyzing the scattered light, which has unique wavelengths for different compounds.

2. Laser Induced Fluorescence Testing.

The laser induced fluorescence testing system used on this project was developed by the Waterways Experimental Station. The laser is a PTI 2300 nitrogen laser and emits pulsed ultraviolet (UV) energy in the 337 nm range. The UV power generated at the laser exit port is approximately 1,000 milliwatts. This light is launched into a 400 micron core fiber optic cable which transmits the light to the optical probe head contained in the CPT probe. The nitrogen laser system provides more power to the sample located outside the sapphire window than other

shorter wavelength laser systems such as a tunable dye system which produces 290 nm light. The light exits the cone via a sapphire window and the returned fluorescence enters the optical head through the same sapphire window. The returned fluorescence then travels through a 400 micrometer fiber optic cable to the detector system located in the CPT truck. The detector system consists of an EG&G photodiode array, Model 1421, controlled by an EG&G optical multichannel analyzer (OMA), Model 1460. Data transfer between the CPT data acquisition computer and the OMA occurs via a GPIB card and cable. This allows the CPT computer to present real-time profiles of the LIF results. The thickness of the smear zone was determined by relating the depth of the probe with the LIF signal return.

3. Raman Spectroscopy System.

The laser system used for the Raman testing on this project was designed and operated by EIC laboratories, Inc. of Norwood, Mass. The system consists of an Argon laser emitting 170 milliwatts of power at 514 nm. Similar to the LIF system the laser light is launched into a fiber optic cable and transmitted to an optical probe located in the cone penetrometer. The laser light shines through a sapphire window and the Raman signal is collected by the optical probe and transported via another fiber optic cable to the detector located in the CPT truck. The detector for the Raman system consists of a 270 M Spectrograph and a charge coupled detector (CCD).

Operation of the Raman system was similar to that of the LIF system, except an independent computer controlled the Raman system and no real time display of the data on the CPT computer was possible. The CCD exposure time was set at 30 seconds for a majority of the penetrations except for regions where the signal saturated the detector. During these instances the exposure time was reduced to avoid detector saturation.

4. Ground water Sampling

One of the capabilities of the CPT is that it provides a means to collect ground water samples from discrete intervals within an aquifer. Several ground water sampling devices are available and have been modified for use with CPT testing. Among these devices is ARA's proprietary discrete-interval CPT ground water sampling device (see Figure 4) that provides an efficient and reliable means of collecting ground water samples. This device is designed to be advanced to the desired depth utilizing a sacrificial tip and filter section. Upon reaching the required sampling interval, the outer push rods are retracted exposing the filter material and allowing ground water to flow inside the filter and push rods. The ground water is sampled using a small diameter Teflon bailer to collect at least one 40 ml VOA (volatile organic analysis) sample per bailer, with typical volumes of 80 to 120 ml. Since the tip and filter materials are disposable, they are left at the sampling depth and CPT push rods are fully retracted and steam cleaned before obtaining the next sample.

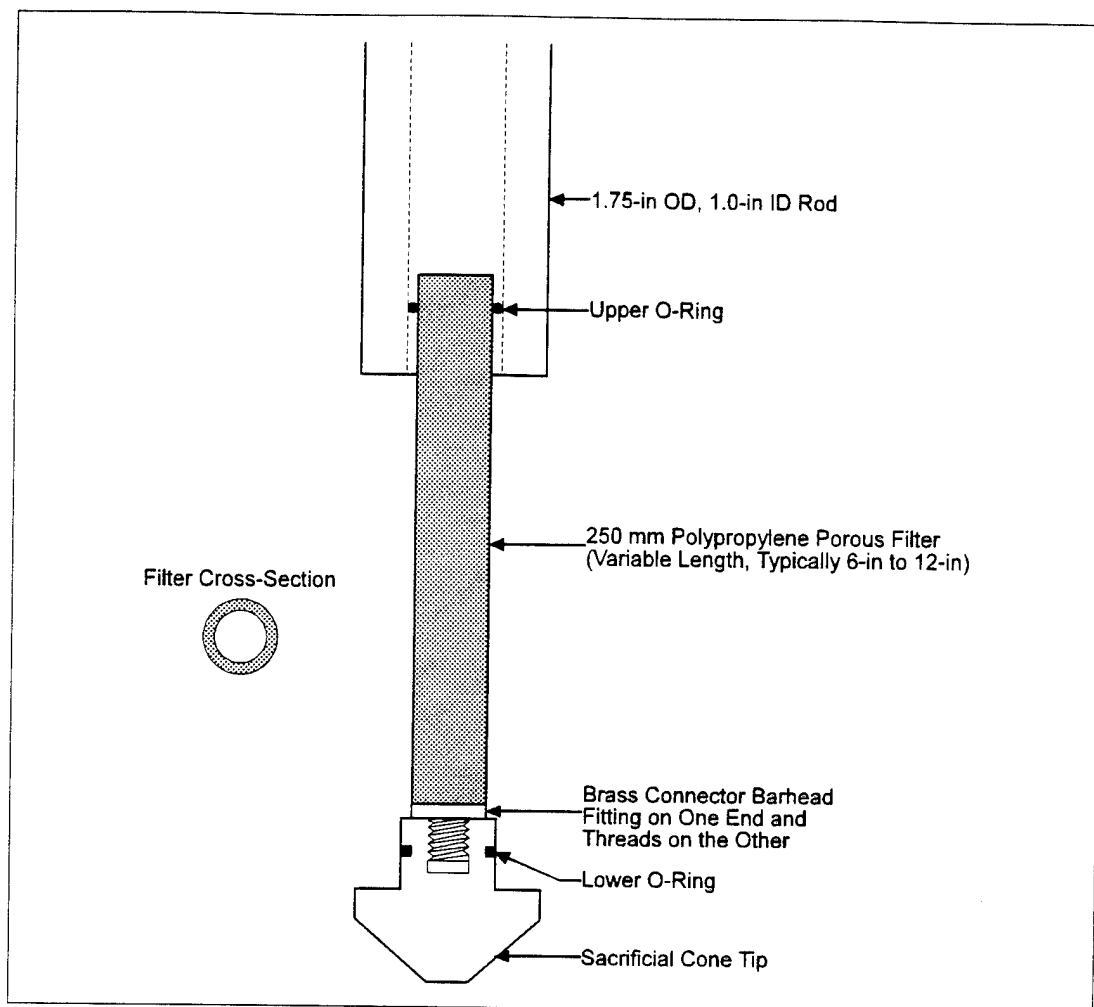


Figure 4. ARA's Discrete Interval Groundwater Sampling Device

5. Soil Sampling

Two attempts at soil sampling were conducted using the ARA CPT rig. A Mostap 35 PS FT soil sampler was used in each instance. Similar to the water samplers, the soil sampler is pushed to the desired depth in a closed position. A locking mechanism is then released which allows inner pistons to move up inside the CPT rods as the sampler is advanced to obtain the soil sample. The soil sample is held in the sample chamber by frictional forces with the side walls during retraction of the push rods. The Mostap sampler obtains samples which are 1.38 inch diameter by 20 inches long for a soil volume of 30 in^3 (481 cc).

C. SOIL TESTING USING CONVENTIONAL DRILLING METHODS

A conventional drilling rig with a 6-inch auger with 2 foot by 2-3/4 inch brass sleeves was used to collect soil samples. Soil samples were obtained at 16 locations. Eight of these locations were thought to be contaminated. The other eight were located near the edge of the contamination plume.

These soil samples were packaged, labeled and transported to CKY Laboratory, located in Torrance, California, for analysis. Each sample was analyzed using three EPA methods. Table 1 lists each method, the limits measurable by that method, the method detection limits and pertinent comments on the method. Three different methods were chosen because different soil contaminants were of interest in this effort. Of interest were total petroleum hydrocarbons (TPH) of both low and high molecular weights and specific chlorinated hydrocarbons. The results of the analyses are provided in summary form in Section IV. The complete results and accompanying quality assurance data are provided in Appendix B.

ASTM Method D422-63 for grain sizes and ASTM Method D854-83 for specific gravity of the soil were also performed on eight samples collected from contaminated locations to characterize physical properties of the soil. ASTM Method 5084 was used to measure the permeability of one sample collected from the underlying aquitard.

Table 1. EPA METHODS USED TO ANALYZE OU1 SOIL SAMPLES.

EPA Method	Summary of the Method	Principle of the Method	Limits Measured	Comments
5030/8015	This method is used to determine volatile hydrocarbons (total petroleum hydrocarbons - TPH) in soils. The detection limit for TPH in soils depends on the matrix, but can be as low as 5 mg/kg.	TPH in soil samples are concentrated by a purge and trap device that "purges" the compounds from the sample using an inert gas and then "traps" them on a sorbent column. The compounds are then desorbed from the "trap" column into a gas chromatograph, where they are separated into individual components and analyzed by a flame ionization detector.	Lower molecular weight volatile hydrocarbons (approximately C ₆ - C ₁₂) such as JP-4.	Higher molecular weight hydrocarbons may not be effectively released using Purge and Trap.
Modified 8015	This method is used to determine higher molecular weight volatile hydrocarbons (total petroleum hydrocarbons - TPH) in soils. The detection limit for TPH in soils depends on the matrix, but can be as low as 10 mg/kg.	TPH in soils are extracted with methanol and injected into a gas chromatograph, where they are separated into individual components and analyzed by a flame ionization detector.	Higher molecular weight semivolatile hydrocarbons, such as gasoline and diesel fuel.	Lower molecular weight hydrocarbons may be lost in the extraction process.
624/8240	This method is used to determine specific VOCs in a variety of matrices, including soils. The practical quantitation limit (PQL) is approximately .005 mg/kg for soil samples. Matrix effects may increase the PQLs.	Volatile organic compounds (VOCs) in soil samples are concentrated by a purge and trap device that "purges" the compounds from the sample using an inert gas and then "traps" them on a sorbent column. The compounds are then desorbed from the "trap" column into a gas chromatograph, where they are separated into individual components and analyzed by mass spectrometry.	36 specific compounds, including halogenated hydrocarbons such as TCA and Methylene Chloride.	Only the specific compounds listed in the method are reportable.

SECTION III

TEST DESCRIPTION

The objectives of the field activities were to identify local areas of significant contamination at OU1 and to characterize the smear zone. Future technology testing will require a four to five foot thick smear zone measured or evaluated from:

- (1) Soil lithology using cone penetrometer testing,
- (2) Distribution of fuel contamination with Laser-induced fluorescence, and
- (3) Distribution of chlorinated hydrocarbons with Raman spectroscopy.

These data are supplemented with the collection and analysis of soil samples. The purpose in collecting these data was to identify a heavily contaminated area for siting eight test cells. More detailed characterization in the spring of 1995 needs to be completed before test cell construction. These eight areas will be used to test promising remediation technologies.

The objective of the screening was to locate regions of elevated contamination smeared over four to five foot thick intervals near the water table. The survey was performed by pushing 29 holes with the cone penetration technique (CPT) coupled with laser-induced fluorescence (LIF) or Raman Spectroscopy (RS). The CPT-LIF was supplemented by the collection and analyses of 16 soil samples for petroleum hydrocarbons and Method 624 compounds.

A secondary objective for the screening was to determine the depth to the underlying aquitard. A depth to the aquitard of less than 30 feet was desirable to allow the use of vacuum-lift pumps in future remediation testing. This section describes the activities performed during the screening survey of OU1. The screening activities were performed north and west of the chemical disposal pits (CDPs) shown in Figure 2.

The primary contamination in the study area of OU1 consists of a non-aqueous phase liquid (NAPL) and compounds dissolved in the groundwater. The NAPL is made-up of hydrocarbons typical of waste oil and fuel with dissolved concentrations of chlorinated hydrocarbons (Montgomery Watson, August 1994). The contaminants of concern dissolved in the groundwater are primarily aromatic compounds found in fuels and chlorinated hydrocarbons typical of solvents. The NAPL has been found at or just below the water table (James M. Montgomery, February 1992). The thickness of the NAPL ranged from approximately one to ten feet and generally ended at the contact between the gravely sand and silty clay units. The approximate extent of the NAPL contamination determined by Montgomery Watson is illustrated Figure 5.

Approximately 60 potential CPT push locations were identified. The purpose in identifying 60 candidate locations was to maintain flexibility in the field. Clearance from Base Civil Engineering was required before breaking ground. Twenty-nine locations were used. CPT-LIF data were collected both inside and outside the previously estimated area of the NAPL plume. Points outside the estimated plume were collected to delineate in more detail the plume boundary to the north.

The first set of CPT pushes started just north of Chemical Disposal Pit 1 and extended north at an interval spacing of approximately 50 feet. This northern boundary of the plume had not been previously characterized. The second set of pushes started northwest of the pit and extended northwest at an interval spacing of about 50 feet to the edge of the LNAPL plume. This same procedure of extending lines to just beyond the edge of the LNAPL plume followed in the remaining pushes. The region north of the pit was surveyed first, followed by the areas west, south, and east of CDP1.

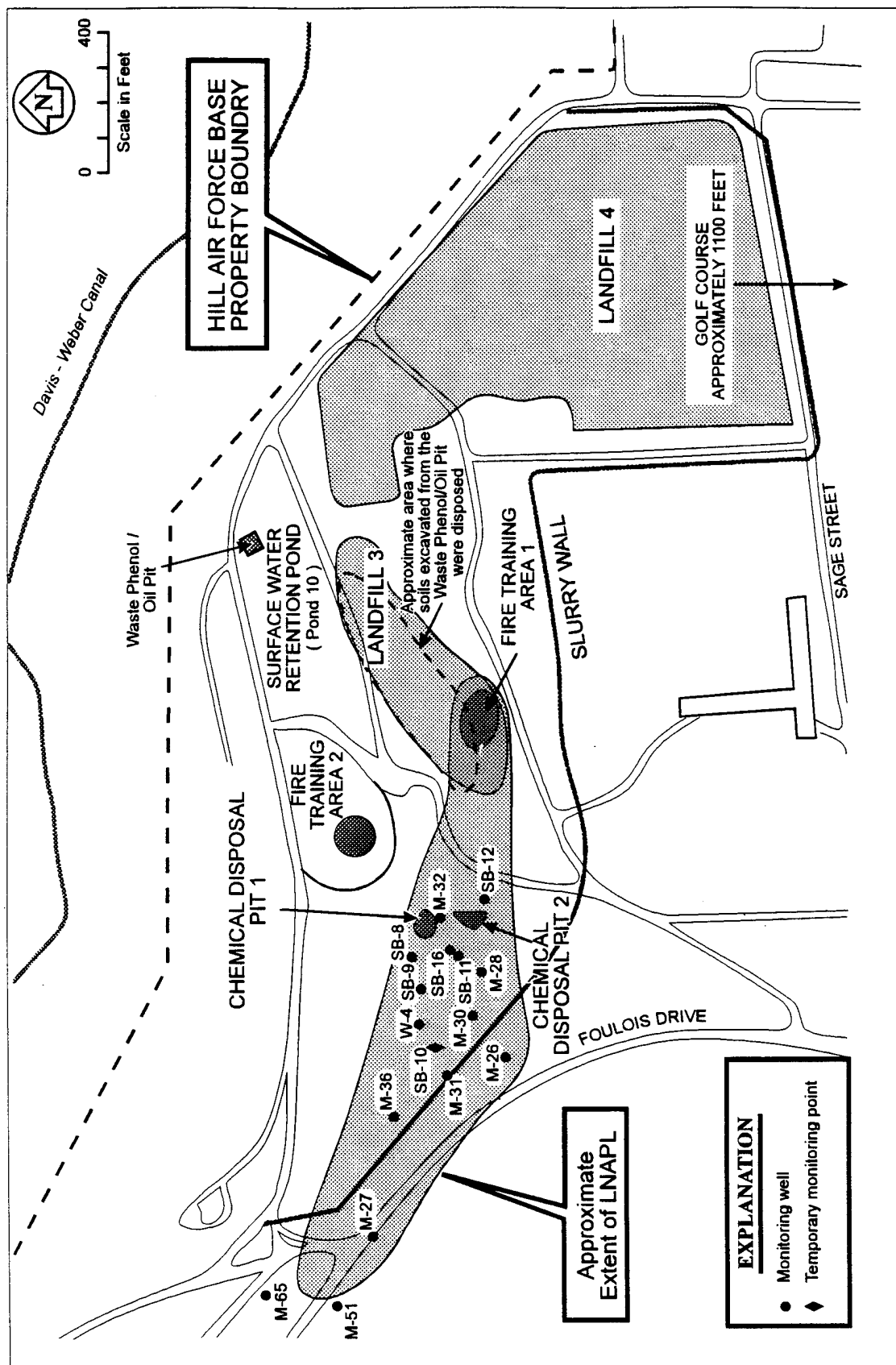


Figure 5. Current Estimates for the Boundaries of the LNAPL Plume
(Figure from Montgomery-Watson report, February 1992)

SECTION IV

TEST RESULTS

A. CONE PENETRATION TESTING - LIF

The results from the CPT-LIF effort are summarized in Table 2. The table includes the CPT locations, the surface elevations, the depths to the aquitard, and the thicknesses of the NAPL smear zone, if any. The CPT locations are illustrated in Figure 7. Details of the LIF implementation are provided in Appendix A.

In general, the LIF results were consistent with the estimates of hydrocarbon NAPL contamination identified in "Draft Records Review Technical Memorandum for Operable Unit 1, Hill Air Force Base, Utah, August 1994" prepared by Montgomery Watson. Contours estimating the smear zone thickness across the site based on the LIF results are presented in Figure 6. The free product hydrocarbon has migrated primarily to the west of the Chemical Disposal Pits. An aquitard is located beneath the site surface which the CPT encountered at elevations ranging from 4766 to 4774 feet above mean sea level. Contours of the top of the aquitard are provided in Figure 7. The contours indicate low areas in the aquitard to the west-northwest of the CDPs. The surface of the site is not flat and depths to the aquitard in the CPT locations ranged from 16 to 33 feet. In the northeast portion of the investigation area, the NAPL smear zone did not exceed one foot in thickness. In the southwest portion of the area, the smear zone ranged in thickness from 1 to 11 feet. The thickest smear zones correlated roughly with low spots in the aquitard surface and the highest surface elevations. Migration of NAPL at the site appears to be determined by the aquitard features rather than a water table surface.

The CPT data also generated logs of soil type in each location. These logs are presented in Appendix A. The logs were consistent with the characterization of the aquitard made by Montgomery Watson (1994). The "top" of the aquitard is actually the top of several laterally discontinuous layers interbedded with the overlying sands and gravels. Pore pressure measurements and CPT soil characterizations show variations consistent with interbedded sands and clays at the "top" of the aquitard. The layering allows hydraulic connection between the sands and gravel above the aquitard with sand beds or lenses embedded in the aquitard.

Table 2. SUMMARY OF LIF DATA OBTAINED IN THE FIELD

CPT Log #	Surface Elevation (MSL)* (ft)	Depth to CLAY (ft)	Soil Log #	TPH SMEAR Zone thickness (ft)	Sample Elevation (MSL) (ft)	TPH by Purge and Trap (mg/Kg)	TRPH Extraction (mg/Kg)	Sum of TPH by Both Methods (TRPH)(TPH) (mg/Kg)
U1-930	4795.29	23	U1-888	1	4773.29	530	4400	4930
U1-931	4786.86	15	N/A	0				
U1-932	4799.86	27	U1-889	1	4773.86	1100	7500	8600
U1-933	4798.25	27	N/A	6				
U1-934	4799.81	29	N/A	1				
U1-935	4799.58	29	N/A	8				
U1-936	4799.54	29	U1-891	0	4772.04	ND	ND	ND
U1-937	4799.01	28	N/A	0				
U1-938	4798.4	25	N/A	0				
U1-939	4799.37	27	N/A	0				
U1-940	4799.18	25	U1-892	0	4773.68	27	3010	3037
U1-941	4794.84	24	U1-893	0	4776.25	10	10	26
U1-942	4800.02	30	U1-890	5	4771.52	33	193	226
U1-943	4799.77	27	N/A	4				
U1-944	4800.17	31	U1-894	5	4771.17	810	1610	2420
U1-945	4799.87	29	U1-895	4	4773.37	450	2020	2500
U1-946	4799.54	29	N/A	1				
U1-947	4789.28	16	U1-896	0	4774.28	ND	ND	ND
U1-948	4789.85	17	U1-897	1	4770.85	ND	ND	ND
U1-949	4799.25	30	U1-898	0	4770.25	ND	ND	ND
U1-950	4799.4	28	N/A	2				
U1-951	4799.75	29	U1-887	7	4769.75	ND	ND	ND
U1-952	4799.91	28	N/A	7				
U1-953	4800.38	33	U1-883	4	4768.38	230	270	500
U1-954	4799.94	29	U1-884	6	4770.94	95	170	265
U1-955	4799.56	30	N/A	2				
U1-956	4800.14	32	U1-885	8	4769.64	27	42	69
U1-957	4800.05	30	U1-886	5	4771.55	1900	11000	12900
U1-958	4800.26	33	N/A	8				

*MSL = Mean Sea Level

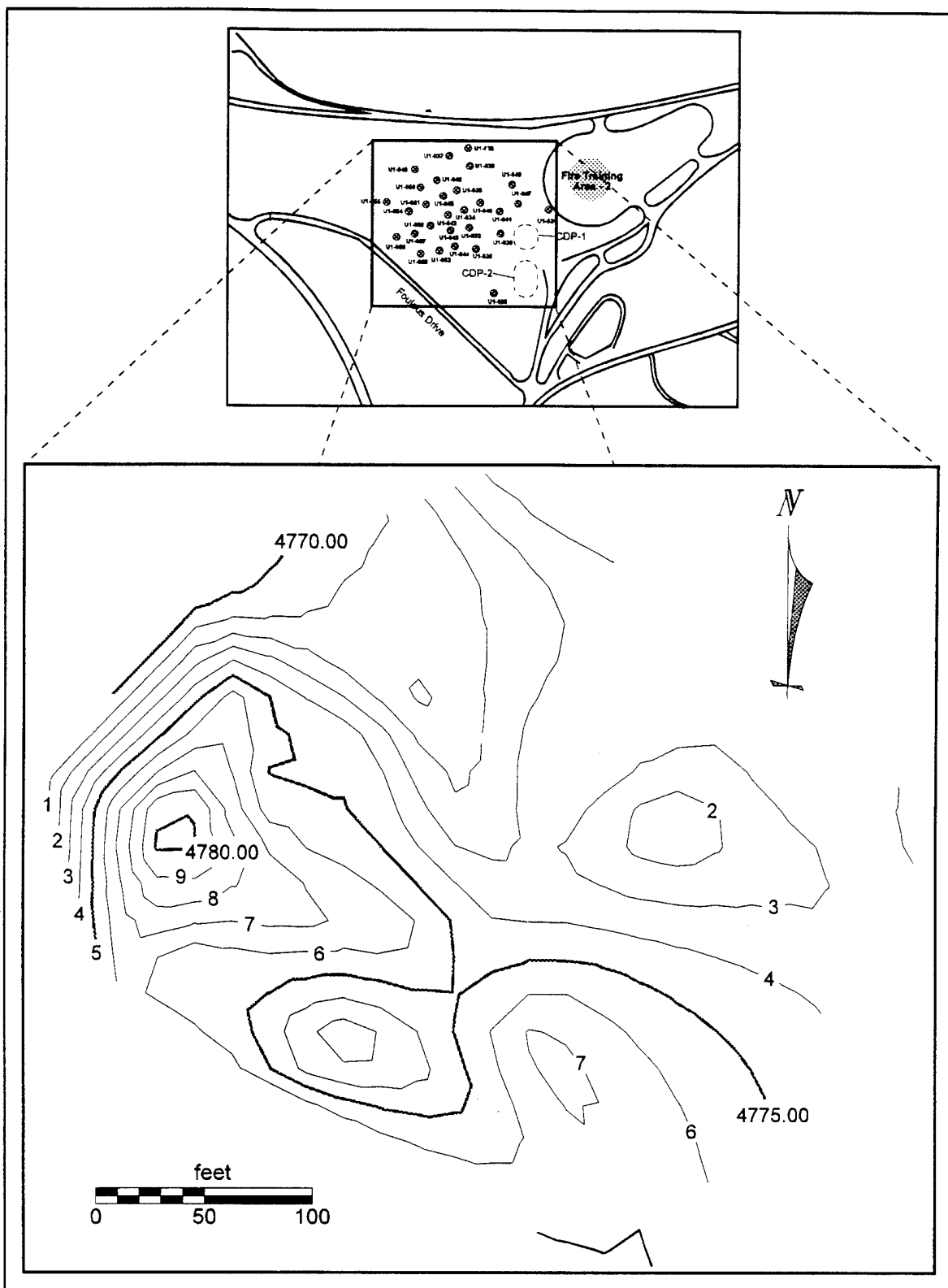


Figure 6. Thickness of Smear Zone (contour elevation 1 foot)

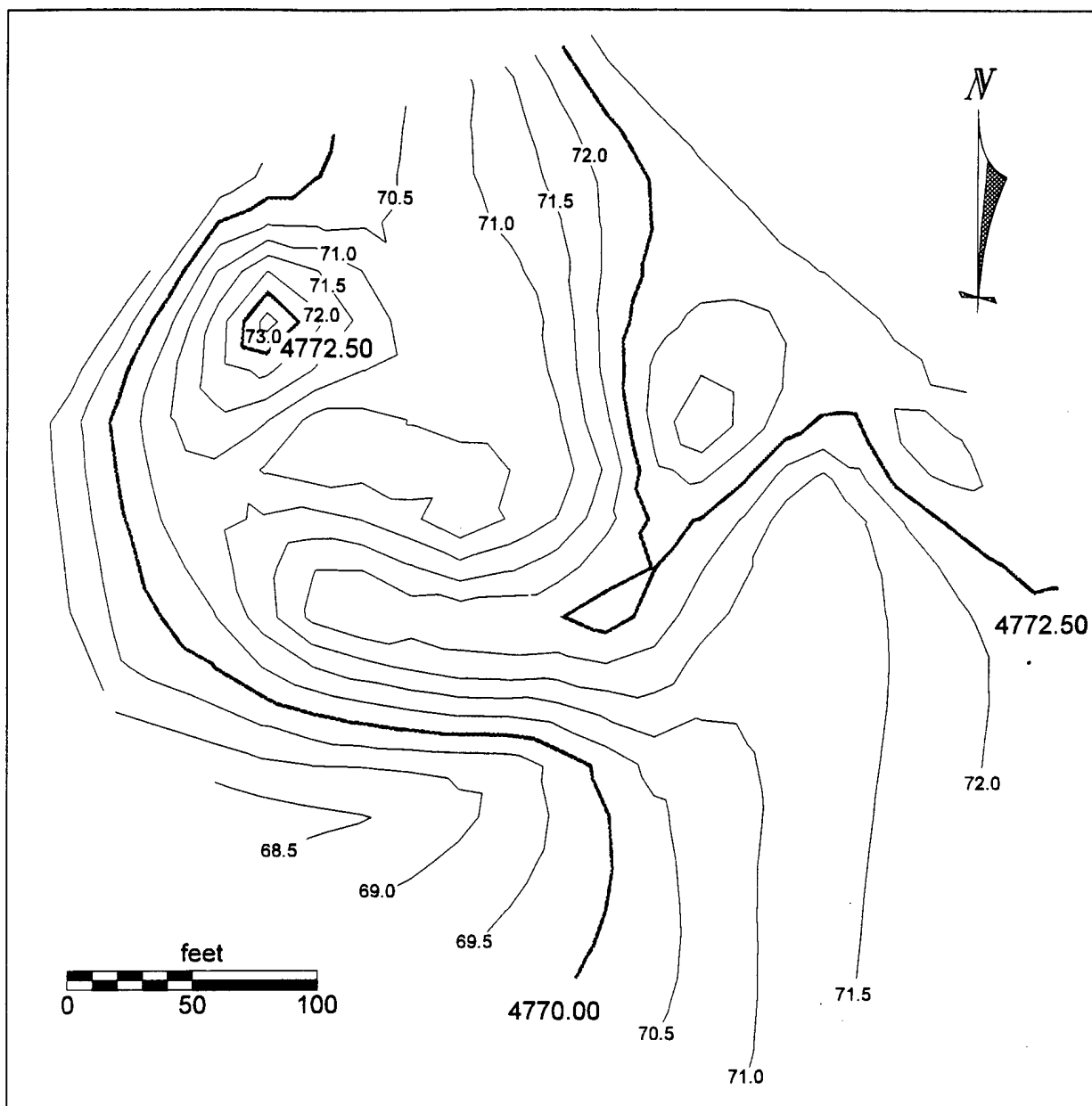


Figure 7. Elevations of Clay (contour interval 0.5 feet)

B. CONE PENETRATION TESTING - RAMAN SPECTROSCOPY

The objective of using Raman spectroscopy (RS) coupled with the CPT was to determine qualitatively the distribution of chlorinated hydrocarbons in the soil. Calibration of the Raman system in terms of signal strength and concentration is generally not possible because the signal is a very weak phenomenon, and nearly pure product is required to generate a sufficiently strong Raman signal (see Appendix A). The Air Force chose to apply the technique in this study as an informal test. The technique was used in two locations at OU1. At location U1-949, the LIF system indicated the soil was relatively free of contamination and this result was duplicated by the RS system. The LIF system indicated location U1-951 was mildly contaminated. No Raman signals were recorded at U1-951 because the fluorescence of the hydrocarbons within the soil matrix overwhelmed the Raman signal. At that point, it was decided to suspend with further RS testing. Future testing of CPT-RS should be in soils free of hydrocarbon contamination.

C. CONE PENETRATION TECHNOLOGY - WATER SAMPLING

An attempt was made to collect a water sample at a depth of 25 to 26.5 feet from location U1-932. (See Figure 2) One 40 mL VOA vial was successfully filled after many trips with the bailer. Water inflow times were slow at this location indicating the formation had very little water to release. Based upon the CPT pore pressure measurement at this location, the soil may be wet but no water table appears to be present in the CPT profile. Based on a review of the pore pressure data along with discussions with local drillers, there appears to be very little water above the clay layer that underlies the site, therefore additional water sampling was not attempted.

D. CONE PENETRATION TECHNOLOGY - SOIL SAMPLING

CPT soil sampling was attempted at location U1-942 (see Figure 2) and a depth of 15 feet. The locking mechanism consists of a ball bearing in a race; penetration forces caused the ball bearings to break the race and the tip to be pushed up into the sample tube. This clogged the sampler and prevented the collection of a sample. The locking mechanism that held the tip in the closed position was pushed open by the gravelly materials in the formation from 5 feet to 15 feet. The second attempt consisted of sending a second sampler down the same hole to a depth of 15 feet, opening the sampler, and collecting a sample from 15 to 16.5 feet. The unit survived because the hole was previously penetrated. The sample was then opened and pushed the length of the sampler. Two of the three brass sample tubes were full upon retrieval of the sampler, but the tubes were jammed into each other and the cutting shoe was ruined. Based on these experiences, and the fact that the soil samplers are designed for use in significantly softer soils, the site formations were deemed unable to be sampled using existing CPT equipment. Soil sampling at this site may be possible with the CPT, but would require a more robust soil sampler.

E. CHEMICAL ANALYSES OF SOIL SAMPLES

Sixteen soil samples were collected and analyzed by EPA Method 8015 with JP-4 as the standard, key EPA modified method 8015 for Total Recoverable Petroleum Hydrocarbons (TRHC), and by EPA Method 624/8240 for volatile organic compounds. This sampling and analysis effort was performed to substantiate the LIF results. Eight samples were collected in locations indicated to be relatively clean by CPT-LIF. The other eight samples were collected in regions shown to be contaminated. The analytical results are presented in Table 3.

Table 3. ANALYTICAL RESULTS FROM CHEMICAL ANALYSIS OF SOIL SAMPLES

Sample Location	Depth of Sample	TPH by Purge and Trap (mg/Kg)	TRPH by Extraction (mg/Kg)	Sum of Both Methods (TRPH)+(TPH) (mg/Kg)	Total Amount of Method 8240 Compounds (mg/Kg)
U1-930		530	4400	4930	5.6
U1-932		1100	7500	8600	47.7
U1-936		ND	ND	ND	ND
U1-940		27	3010	3037	0.3
U1-941		10	16	26	ND
U1-942		33	193	226	2.7
U1-944		810	1610	2420	8.5
U1-945		480	2020	2500	19.5
U1-947		ND	ND	ND	ND
U1-948		ND	ND	ND	ND
U1-949		ND	ND	ND	ND
U1-951		ND	ND	ND	ND
U1-953		230	270	500	2.6
U1-954		95	170	265	3.9
U1-956		27	42	69	1.3
U1-957		1900	11000	12900	54.3

Note that Method 8240 results are reported here in units of mg/Kg for ease of comparison with TPH data. In Appendix B, results are given in µg/Kg.

ND - non detect TRPH - total recoverable petroleum hydrocarbons TPH - total petroleum hydrocarbons

In the first laboratory analysis for Total Petroleum Hydrocarbons (TPH), only the lower molecular weight volatile hydrocarbons, such as JP-4, were measured using EPA Method 5030/8015 purge and trap analysis. The results of this analysis are shown in Table 3 under the heading TPH by Purge and Trap. With the realization that higher molecular weight hydrocarbons, not detectable by the purge and trap method, could be contributing to the LIF signal, the soil samples were analyzed using Modified EPA Method 8015, which employs extraction to capture the higher-molecular weight components. From this analysis it was determined that a significant amount of high-molecular weight compounds were present. The results of this analysis are shown in the table under the heading by Extraction. There is some overlap of the purge and trap and the extraction methods, where the same compounds may be analyzed by both. While some of the same compounds may have been determined by both methods, the error introduced by the overlap in the methods is not significant in establishing the

general trend of TPH concentrations for comparison with LIF measurements. The sum of TPH by both methods, TRPH and TPH, in the table represent a sum of the values obtained from EPA Methods 5030/8015 and Modified 8015.

The values for Method 8240/624 represent a sum of all of the compounds detected by that method. A complete list of all of the compounds is given in Appendix B. In every case, the Method 8240/624 compounds detected were one or more of the BTEX compounds (benzene, toluene, ethylbenzene and xylene). No halogenated compounds were detected, although they had been during previous characterization efforts. This result was confirmed for dichloroethene by reexamination of the laboratory data for that specific compound.

Results for the appropriate quality control tests are presented in Appendix B. Several of the samples were spiked with surrogate standards to establish the ability of specific analyses to recover these standards quantitatively. The results are generally in the 80 to 100% recovery region. This level of recovery is indicative of acceptable quality control.

During the Remedial Investigation, eleven soil samples were collected and analyzed from four soil borings in the same region as the CPT locations (James M. Montgomery, 1992). The four boring locations are identified as SB-8, SB-9, SB-10, and SB-11 in Figure 6. Results of chemical analyses on these eleven samples are summarized in Table 4. The highest concentrations of chlorinated hydrocarbons were found in SB-11 near Chemical Disposed Pit 2. Elevated concentrations of fuel hydrocarbons, using JP-8 as a standard, were found in all four soil borings. Based on these results from the Remedial Investigation, low concentrations of chlorinated hydrocarbons were expected in the current investigation.

Table 4. SUMMARY OF PREVIOUS ANALYTICAL RESULTS
(James M. Montgomery, 1992)

Soil Boring	PCE		Chlorobenzene		1, 1-DCE		1, 2-DCE		1, 1, 1-TCA		1, 2-DCA		JP-8		Depth to Aquitard
	Depth (feet)	Soil Cone (mg/Kg)	Depth (feet)	Soil Cone (mg/Kg)	Depth (feet)	Soil Cone (mg/Kg)	Depth (feet)	Soil Cone (mg/Kg)	Depth (feet)	Soil Cone (mg/Kg)	Depth (feet)	Soil Cone (mg/Kg)	Depth (feet)	Soil Cone (mg/Kg)	
SB-8	20'-22'	0.190	20'-22'	0.200	27'-29'	0.120							20'-22'	2,700	24
SB-9	23'-25'	0.018	23'-25'	0.079			32'-34'	0.037					23'-25'	5,300	29.5
SB-10							34'-36'	0.028					24'-26'	7,800	32
SB11	17'-19'	2.90	17'-19'	0.26	17'-19'	0.600			17'-19'	3.200	29'-31'	0.024	17'-19'	6,400	29
	21'-23'	2.70	21'-23'	0.40	21'-23'	0.79							21'-23'	9,300	

Other data available to evaluate the current soil sampling data are ground water concentrations measured in the region of the CPT locations. The soil samples in this effort were collected from the proximity of the water table. Two nearby ground water monitoring wells (U1-072, and U1-073) were sampled recently (1994) and four in 1990 (U1-004, U1-070, U1-072, and U1-074). The maximum concentration of DCE detected in the ground water was 21000 $\mu\text{g/L}$ with an average of 7000 $\mu\text{g/L}$. In seven sampling events, TCE was detected only twice and at concentrations less than 100 $\mu\text{g/L}$. PCE was detected three times out of seven with a maximum of 58 $\mu\text{g/L}$. For typical partitioning parameters, soils in equilibrium with ground water at the above concentrations for TCE and PCE are expected to be less than 50 $\mu\text{g/kg}$; consistent with the current findings. The equivalent soil concentration of DCE in equilibrium with ground water at 7000 $\mu\text{g/L}$ is expected to be greater than 1000 $\mu\text{g/kg}$. Therefore, one would have expected to detect DCE in the soils of the current investigation.

The use of the analytical chemical data for calibration of the LIF investigation is discussed in detail in Appendix A, Section III.B.1. In some cases the correlation between the LIF data and the TPH data was reasonable. In a few cases, the correlation was fair to poor. While the chemical analysis was not performed to substantiate each LIF measurement, it should, at a minimum, provide general trends for calibration of the instrument. There is sufficient agreement to provide these general trends, however, no one specific reason can be shown to account for the areas with little agreement. The areas where there is little agreement are problematic in the sense that no one specific reason can be shown to account for it. Possible explanations for the lack of correlation in some cases may be attributed to lack of sample homogeneity and hence lack of representativeness of the analytical chemistry sample (and indeed the LIF sample) for the compounds that are present in the local region. In the case of the chemical analysis, samples ranged from one to five grams, and could not be composited because of possible volatilization of the compounds of interest. Another possible reason for lack of correlation in some samples is that certain compounds may contribute to the soil fluorescence, but were not detectable by the laboratory methods employed.

In Summary, the correlation between the LIF and soil sampling data is weak. This is likely due to the separation between the LIF location and the soil sample location (approximately 2-3 feet) and the amount of higher molecular weight compounds present at the site. In general, LIF appears to be a valuable characterization tool for locating contaminants at concentrations greater than 100 mg/Kg.

F. PHYSICAL ANALYSIS OF SOIL SAMPLES

Samples for determination of physical properties were collected during the collection of soil samples for chemical analyses. Samples were collected at depths above and below the top of the underlying aquitard. The soil at these depths consists of interbedded sands, silts, and clays. This depth was of interest to evaluate the likelihood of contaminant removal or contaminant migration through the aquitard as a result of technology testing. Eight samples were analyzed for grain size using ASTM Method D422-63 and for specific gravity by ASTM Method D854-83.

The results of the physical analyses are summarized in Table 5. The grain size analyses describe the percentage of soil particles meeting standard sizes. The specific gravity indicates

the relative clay content in each sample. Samples with lower densities contain higher clay contents since organic matter is less dense than sand. The lowest measured specific gravities were from U1-942, U1-954, and U1-957 which had the highest clay contents. The highest specific gravities were measured in U1-944 and U1-953 which had low clay contents. The specific gravity of quartz sand of any dimension is 2.65. One anomalous measurement came from U1-932 where a low clay content was accompanied by a low specific gravity. This table also includes soil classifications determined from CPT data collected at approximately the same location and depth as samples for the physical analyses. The match between the soil grain sizes, specific gravity, and CPT characterization was generally very good.

The hydraulic conductivity (permeability) of one soil sample collected from a depth of 35.5 to 36 feet below the ground surface near location U1-942 was measured using ASTM Method 5084. The soil at this depth was characterized as a silty clay from the CPT data. The hydraulic conductivity measurement is an indicator of the vertical permeability of the underlying aquitard. The hydraulic conductivity of the sample was reported to be 1.2E-07 cm/sec which is typical of a glacial till or clay. Hydraulic conductivity of the aquitard was also measured in previous site characterization efforts in the vicinity of the CPT locations (James M. Montgomery, February 1992). The vertical permeabilities measured in those efforts were 1.29E-07 and 6.58E-08 cm/sec which are nearly identical to the current measurement. This indicates the clay aquitard can serve as a vertical barrier. In addition, James M. Montgomery measured horizontal hydraulic conductivities in soils near the CPT locations by withdrawal slug testing. The values measured ranged from 1.0E-05 to 4.0E-05 cm/sec in the aquitard and 3.0E-04 cm/sec in sands. Horizontal conductivities are generally one order of magnitude greater than vertical conductivities. For the aquitard, the measured horizontal value is two orders of magnitude greater than the vertical. This relatively high horizontal value may be the result of interbedded sand lenses in the aquitard.

Table 5. SUMMARY OF SOIL GRAIN SIZE AND SPECIFIC GRAVITY ANALYSIS

CPT Hole	Depth	Depth to clay	% > 3"	% Gravel	% Sand	% Silt	% Clay	Specific Gravity	Soil Class by CPT
U1-932	26.5-27'	27'	0.0	42.6	45.6	7.6	4.2	2.60	Gravelly Sand
U1-942	29.5-30'	30'	0.0	0.0	2.3	63.0	34.7	2.59	Silty Clay
U1-944	29.5-30'	31'	0.0	14.4	23.6	52.6	9.4	2.66	Clayey Silt
U1-951	29.5-30'	29'	0.0	0.0	6.8	69.4	23.8	2.63	Clayey Silt
U1-953	31.5-32'	33'	0.0	10.5	70.3	15.0	4.2	2.65	Clayey Silt
U1-954	30.5-31'	29'	0.0	0.0	5.7	57.4	36.9	2.61	Silty Clay
U1-956	31.5-32'	32'	0.0	24.2	18.0	39.7	18.1	2.62	Clayey Silt
U1-957	29.5-30'	30'	0.0	0.0	5.5	57.2	37.3	2.60	Silty Clay

SECTION V

CONCLUSION

A. RECOMMENDED AREA FOR TEST CELLS

For areas of maximum contamination, Figure 8 identifies the recommended area for the test cell location. This area can accommodate eight 3m x 5m test cells. The area was determined based on the LIF results as confirmed by the chemical analyses. The size of the area is approximately 140 feet x 120 feet. The plume has migrated to the south and west of Chemical Disposal Pit 1 as is depicted in the Records Review Technical Memorandum for Operable Unit 1 dated August 1994. The clay aquitard is located approximately 30 feet below the surface in this area. The primary reason for siting in this area is the thickness of the smear zone. Although the area to the north and east has a shallower depth to the aquitard, 16 feet versus approximately 30 feet, it is not recommended for siting test cells because of the minimal contaminant concentrations and the minimal thickness of the contamination smear zone. A sufficient amount of contamination must be present to test the remediation technologies. If only a thin layer of product with a low TPH is present, then it will be difficult to determine the effectiveness of the technologies.

B. PERMEABILITY OF THE CLAY LAYER

The integrity of the aquitard to function as a relatively impermeable bottom layer for the test cell is important for the technology testing. Therefore, a permeability test was performed on one clay sample taken from approximately five feet into the clay. The results of this test showed a permeability of $1.2\text{E-}07$ cm/sec, consistent with previous testing. This is sufficiently slow, to allow the clay layer to act as a vertical barrier against migration outside the test cell. There is still concern regarding interbedded sand stringers in the clay which would allow the contamination to migrate. Before the cells are constructed, additional characterization of the sand stringers located in the top several feet of the clay layer needs to be performed. It is also advisable to evaluate the potential for the remediation technologies to increase this contaminant migration of into the aquitard.

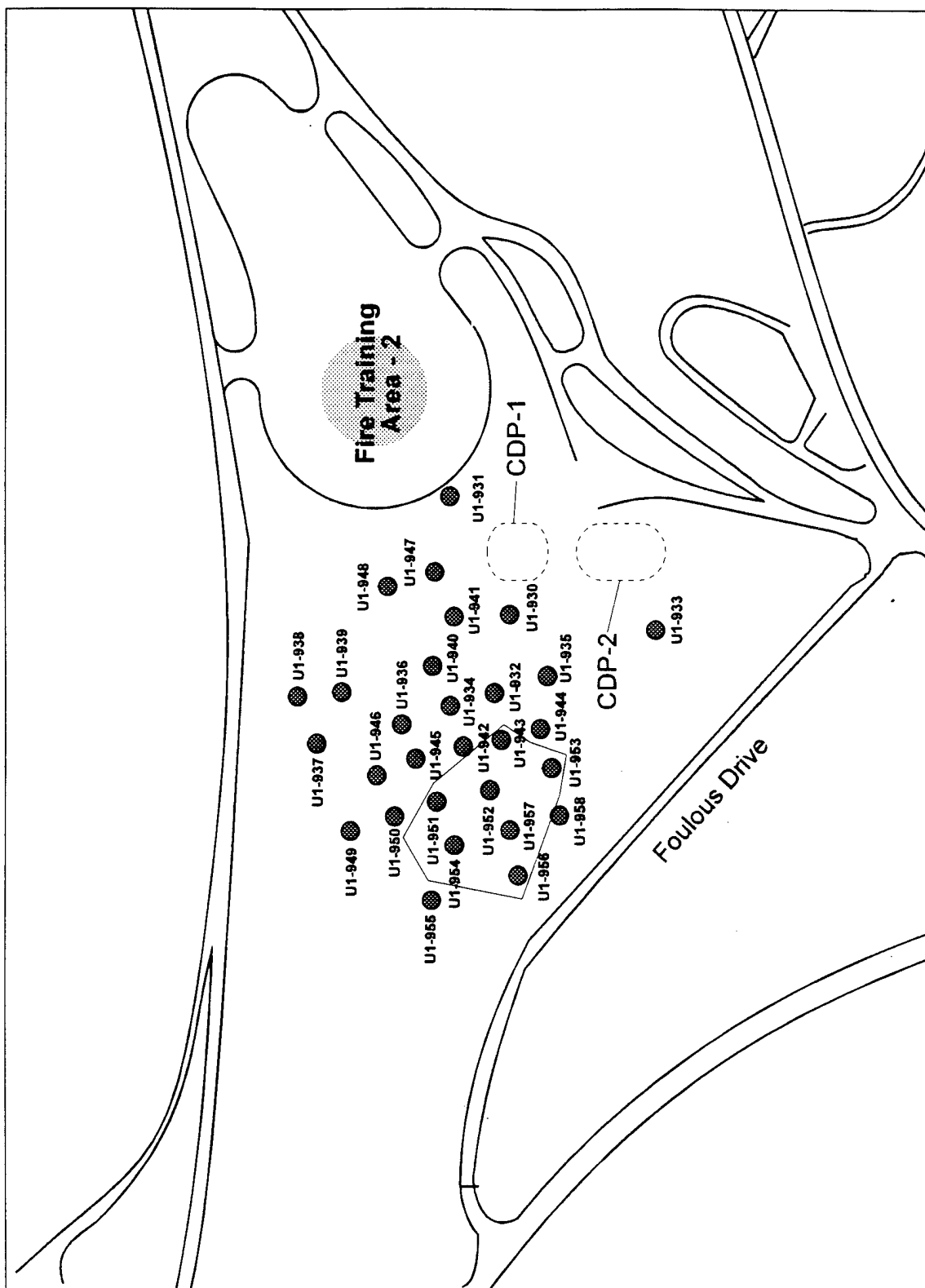


Figure 8. Recommended Future Test Cell Locations

SECTION VI

RECOMMENDATION

A. TEST CELL CONSTRUCTION

The purpose of this effort was identify the contamination plume and characterize the soils in an area at Operable Unit 1 which could be used for the siting of eight test cells. The recommendation is based primarily on the data obtained from the LIF results and confirmed by laboratory analysis of soil samples. The siting of the area in the plateau of OU1 is not highly desired by various interested parties. The depth to clay is deeper than preferred. Also of note is that Hill AFB is trying to begin remediation of the site in the near future and construction of the test cells in this area may impact that plan.

Before construction, additional characterization of the area selected for the test cells is required to provide baseline data for assessing technology performance in the test cells. Characterization parameters should be coordinated with prospective testers and standardized to provide the appropriate baseline for comparison of the effectiveness of the technologies. Four monitoring wells are located around the perimeter of the selected area. These wells may be incorporated into the final monitoring plan for the remediation testing.

B. LESSONS LEARNED

1. Raman Spectroscopy

Raman spectroscopy is intended to detect chlorinated compounds such as trichloroethylene and tetrachloroethylene in the soil. Soils contaminated with strongly fluorescing hydrocarbons and possibly soils which have a high background fluorescence may not be compatible with the RS technology. The Raman signal is very weak and the fluorescence of hydrocarbons or other materials within the soil matrix may overwhelm the Raman signal. In the future, soil samples should be analyzed prior to working in the field. Results from these analyses would be useful for determining if the system will be an effective tool for characterization.

2. CPT with Laser Additions

The CPT system itself appears to be reliable and efficient. It was noted that the connection and in-field calibration of the LIF system and the Raman system took approximately one additional day to begin collecting data at a 'production' rate. The CPT itself could probably be productive after about 4-6 hours of set-up time. The laser systems required familiarization with the site allow accurate interpretation of the data. This understanding of the real-time data, requires that at least two locations be tested and analyzed. This process takes an additional 8-10 hours. Therefore, it takes about three days for the system to begin functioning at its full capabilities.

3. Value of LIF-CPT

This investigation showed that the LIF-CPT is a valuable screening tool for locating contaminants and determining where to take soil samples and place monitoring wells. The LIF

was very useful in identifying the smear zone present at the site. The comparison of the LIF-CPT data with the soil sample analysis indicates that the LIF-CPT is capable of rough estimates of contaminant concentration. The LIF system is capable of detecting contaminants with a limit near 100 mg/Kg. Based on a daily production rate of almost 300 feet per day, initial site screening can be effectively conducted using this technique.

4. Grouting

Grouting of CPT holes in a cobbly site requires more than one day. The grout has a tendency to settle in the cobbles and therefore leaves a gap at the top of the hole. It is also best to pump the grout into the hole and not pour the grout. The grouting is much neater at the surface when it is pumped into the hole. It is also beneficial to use "hole-plug" to cap the holes, since this will minimize settling.

5. Pre- and Postmobilization Activity

The project manager should expect to spend at least 1-2 work days on the site before initiating field activities. This will allow time to ensure the site is properly staked and cleared, and necessary passes (i.e. security, camera, and building) are obtained. One to two days will be required at the end of the activity to clean-up the site and mark the locations for surveying. It is beneficial if these days are work days for the base so that any final clearances can be obtained.

6. OSHA Training

Since the site is an EPA site, it is important to obtain the proper OSHA required training before working on the site. The base and EPA can and do inspect for this training. It is important to monitor the air quality during the activity to ensure the site has not changed hazard levels. This is especially important during the warmer months, since temperature increases the volatilization of the organics.

7. Drilling Versus CPT Soil Sampling

At Hill AFB OU1 where cobbly soils are known to exist, it is cheaper to use conventional drilling techniques to obtain soil samples. In this instance, the use of the CPT rig would have cost approximately \$10,000 to obtain eight samples. This included the time for the rig and the cost to pre-push the holes to obtain the samples. It was estimated that approximately 3 days would be needed to collect samples plus demobilization time (approximately 32 hours total). Drilling the holes, knowing the depth of the clay before drilling, required only 16 hours of field work to obtain 16 samples. The cost associated with this effort was less than \$9,000. Because this driller works locally, the mobilization costs were minimized. If contaminated waste disposal or equipment decontamination had been a more expensive problem, then the CPT method may have been more efficient. The CPT method has negligible costs associated with waste disposal and equipment decontamination because of the minimal amount of time and water needed for decontamination.

8. Laboratory Calibrations

Since the "product" which is present at the site is a combination of a variety of petroleum based products, it would be beneficial to ship, for calibration standards, a sample of this "product" to the chemical laboratories. Improved analytical results may have been achieved by using a sample of the actual NAPL as the standard for EPA method 8015.

References

Freeze, R.A. and J.A. Cherry, 1979, "Groundwater," Prentice-Hall, Inc., Englewood Cliffs, NJ.

James M. Montgomery, February 1992, "Remedial Investigation Report for Operable Unit 1, Hill Air Force Base, Utah."

Montgomery Watson, August 1994, "Draft Records Review Technical Memorandum for Operable Unit 1, Hill Air Force Base, Utah."

APPENDIX - A

**Applied Research Associates, Inc.,
Laser Induced Fluorescence-Cone Penetration Testing
at Hill AFB, Ogden, Utah
in Support of the Location and Selection of Test Cells**

EDITOR'S NOTE:

**This appendix is published in the same format as submitted
by the contractor including Figure and Table designations.**

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**LASER INDUCED FLUORESCENCE-
CONE PENETRATION TESTING
AT HILL ARE FORCE BASE, OGDEN, UTAH,
IN SUPPORT OF THE
LOCATION AND SELECTION OF TEST CELLS**

**Prepared for:
TRW, Inc.**

**Prepared by:

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James D. Shinn, II, P.E.
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ARA Report No. 5200

April 3, 1995

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SECTION I

INTRODUCTION

A. OBJECTIVE AND SCOPE

Applied Research Associates, Inc. (ARA), under contract to TRW, Inc. conducted Laser Induced Fluorescence-Piezo Cone Penetration Technology Tests (LIF-CPT) as part of a site characterization effort for the location of remediation system test cells. A major goal of TRW's investigation was determining the extent and depths of a Non-aqueous Phase Liquid (NAPL) Plume located at Operable Unit 1 on Hill Air Force Base (AFB). Previously installed monitoring well had identified the existence of the plume at the site, but significantly more detail is needed for siting eight 3 x 5 m test cells. The test cells will be used to evaluate the effectiveness and costs of various remediation methods.

This report documents ARA's site investigation efforts conducted between December 12, 1994, and December 19, 1994, at Hill AFB near Ogden, Utah. Soil sampling activities were conducted by an independent driller to obtain soil samples for chemical analysis. The chemical analysis results of these samples were performed by an independent laboratory, but are reported herein for comparison to the LIF-CPT data. This report documents all cone penetration testing techniques used and the subsequent results from activities performed at Hill AFB by ARA.

B. TEST LOCATIONS

Activities performed during the project at Operable Unit 1 on Hill AFB included conducting LIF and Raman CPT soundings, soil and water sampling and a limited on site analysis of the resulting data. The majority of the effort was aimed at collecting fluorescence data to access the extent of the NAPL smear zone. ARA performed 29 CPT penetrations to an average depth of 30 feet for this effort. Table 1 presents the survey coordinates and depth of penetration for each test. Figure 1 presents a plot of the test locations.

In addition to conducting Laser Induced Fluorescence, Raman Spectroscopy measurements were made at two of the locations previously tested. The Raman system was used to measure the

Table 1.1. Summary of Tests Performed

CPT-Log#	Easting	Northing	Date Tested	Max Depth	Test Type
U1-931-1	1,873.932	289,578.94	12/13/94	18.8	LIF-CPT
U1-930-4	1,873.895	289,512.86	12/13/94	26.5	LIF-CPT
U1-947-5	1,873.849	289,596.71	12/16/94	24.5	LIF-CPT
U1-948-9	1,873.834	289,648.43	12/16/94	21.7	LIF-CPT
U1-939-15	1,873.720	289,699.16	12/15/94	29.2	LIF-CPT
U1-935-17*	1,873.737	289,468.76	12/15/94	36.0	LIF-CPT
U1-940-18	1,873.747	289,598.46	12/15/94	37.2	LIF-CPT
U1-938-20	1,873.716	289,748.87	12/15/94	13.2	LIF-CPT
U1-937-21	1,873.665	289,728.61	12/15/94	34.6	LIF-CPT
U1-946-23	1,873.632	289,659.27	12/16/94	34.7	LIF-CPT
U1-936-24	1,873.684	289,632.83	12/15/94	39.2	LIF-CPT
U1-945-25	1,873.645	289,615.60	12/16/94	32.3	LIF-CPT
U1-934-26	1,873.705	289,577.65	12/14/94	36.7	LIF-CPT
U1-942-27	1,873.661	289,562.25	12/16/94	35.6	LIF-CPT
U1-932-28	1,873.719	289,528.39	12/14/94	32.3	LIF-CPT
U1-943-29	1,873.669	289,520.97	12/16/94	33.2	LIF-CPT
U1-944-30	1,873.680	289,474.84	12/16/94	38.7	LIF-CPT
U1-953-31	1,873.638	289,464.82	12/17/94	34.6	LIF-CPT
U1-952-32	1,873.615	289,534.33	12/17/94	35.5	LIF-CPT
U1-951-33	1,873.602	289,592.55	12/17/94	32.6	LIF-CPT
U1-950-34	1,873.587	289,640.37	12/17/94	33.7	LIF-CPT
U1-949-35	1,873.571	289,690.80	12/17/94	32.8	LIF-CPT
U1-954-38	1,873.557	289,574.32	12/18/94	33.4	LIF-CPT
U1-957-39	1,873.573	289,510.94	12/18/94	32.3	LIF-CPT
U1-958-40	1,873.587	289,456.41	12/18/94	37.0	LIF-CPT
U1-956-42	1,873.523	289,501.67	12/18/94	32.4	LIF-CPT
U1-955-44	1,873.496	289,598.72	12/18/94	35.5	LIF-CPT
U1-941-46	1,873.800	289,574.63	12/15/94	28.0	LIF-CPT
U1-933-HOT	1,873.786	289,346.75	12/14/94	42.7	LIF-CPT
U1-951-33R			12/17/94	33.0	RAMAN-CPT
U1-949-35R			12/17/94	32.4	RAMAN-CPT
U1-935-17B			12/18/94	33.0	LIF-CPT
U1-942-27			12/16/94	15.0	SOIL SAMPLE
U1-942-27			12/16/94	16.5	SOIL SAMPLE
U1-932-28			12/14/94	26.5	WATER SAMPLE

*BROKE FIBER OPTIC CABLE

contamination by chlorinated compounds, but the Raman signal was overwhelmed by the fluorescence of the fuel contamination. The Raman measurements were made at locations U1-951-33 and U1-949-35. Both penetrations were terminated in the clay material underlying the site. One water sample was obtained during our activities at the site. This sample was collected at location U1-932-28 at a depth of 25 to 26 ft. Two attempts were made to gather soil samples from location U1-942-27. On both attempts, the soil sampler bent due to the significant portion of cobbles present at the site. No recovery was possible at the first depth, and only minimal recovery occurred during the second attempt. Soil sampling was abandoned at further locations.

HILL AFB

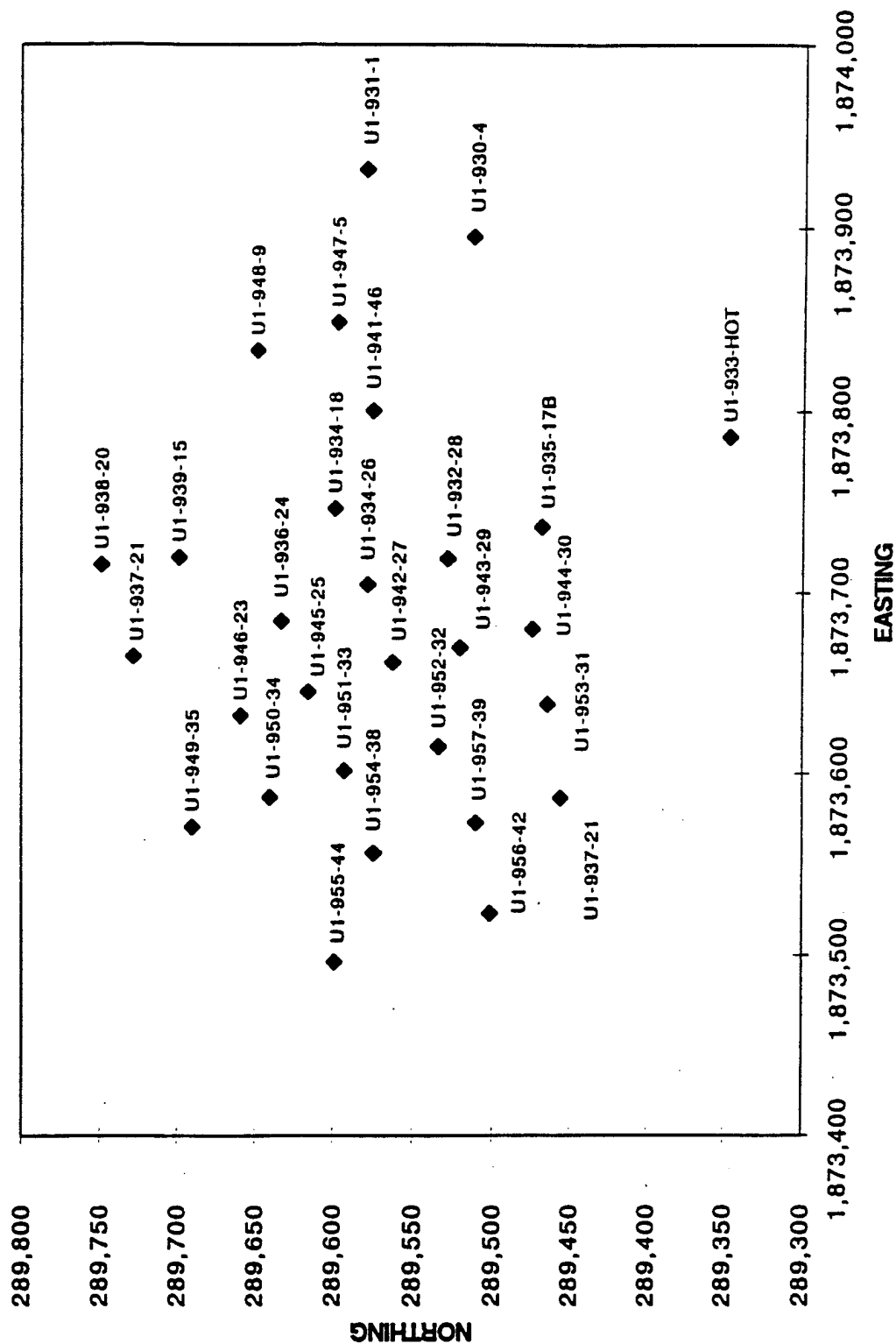


Figure 1.1 Site map of CPT locations at Hill AFB, OUI Area

C. REPORT OUTLINE

Section 2 of this report discusses the LIF-CPT equipment, field procedures and data format. In addition, the groundwater and soil sampling methods attempted are presented in this section. Section 3 discusses the data analysis methods used to interpret both the CPT for soil stratigraphy purposes and also the LIF results for site-wide comparison.

SECTION II

DATA ACQUISITION AND ANALYSIS METHODS

A. INTRODUCTION

This section contains a discussion of the cone penetration test methods including the measurement tip stress, sleeve stress, pore pressure and laser induced fluorescence. Calibration methods used during the project for each of the standard CPT sensors is also discussed in this section. Data analysis methods used to interpret the LIF measurements are presented in Section 4. This section is concluded with discussion of the sampling protocols attempted for this project, including both ground water and soil sampling procedures.

B. CONE PENETRATION TESTING

The electronic cone penetrometer test was originally developed for use in consolidated clay soils. Over the years, cone and push system designs have evolved to the point where they can now be used in strong cemented soils and even soft rocks. ARA's penetrometer consists of an instrumented probe which is forced into the ground using a hydraulic load frame mounted on a heavy truck with the weight of the truck providing the necessary reaction mass. The probe has a conical tip and a friction sleeve which independently measures vertical resistance beneath the tip as well as frictional resistance on the side of the probe as a function of depth. A schematic view of ARA's CPT penetrometer probe is shown in Figure 2.1. A pressure transducer in the cone is used to measure the pore water pressure as the probe is pushed into the ground (Piezo-CPT). In addition, a location has been made inside the probe to contain an optical package that is used to bend the laser light and shine it out a sapphire window on the side of the cone as shown in Figure 2.1.

1. Piezo Cone Penetration Test Procedures

The cone penetrometer test is conducted using the ARA penetrometer truck. The penetrometer equipment is mounted inside an 18 ft van body attached to a ten-wheel truck chassis

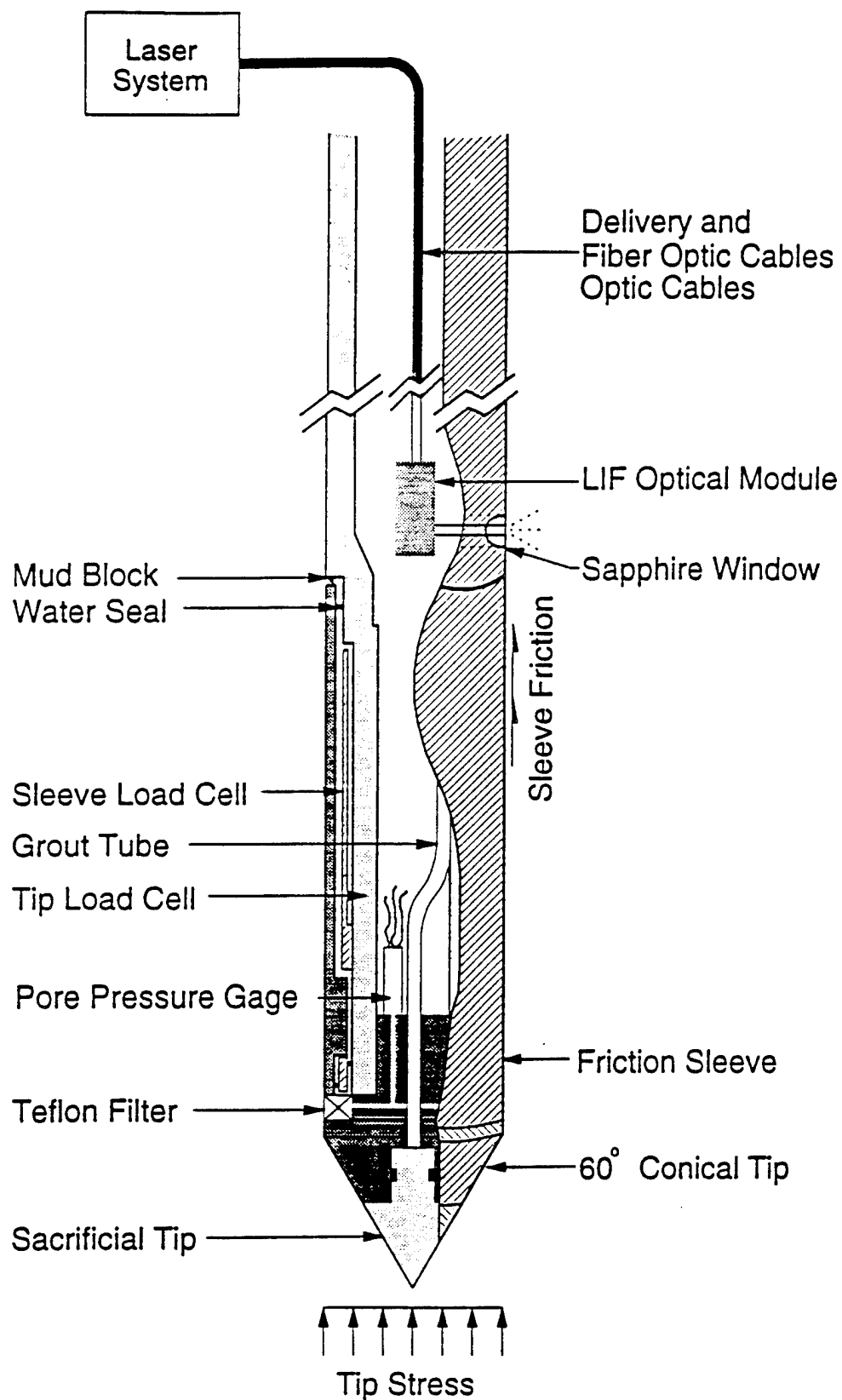


Figure 2.1 Schematic of Laser-Induced Fluorescence CPT Probe

with a turbo-charged diesel engine. Ballast in the form of metal weights and a steel water tank, which can hold 5,000 lbs of water, are added to the truck to achieve an overall push capability of 60,000 lbs. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

A 15 cm² penetrometer probe, (which has a 1.75-inch diameter by 60° conical tip and a 1.75-inch diameter by 6.50-inch long frictional sleeve), was used on this project. The shoulder between the base of the tip and the porous filter is 0.08 in long. The penetrometer is normally advanced vertically into the soil at a constant rate of 48 in/min, although this rate must sometimes be reduced as hard layers are encountered. The electronic cone penetrometer test is conducted in accordance with ASTM D3441, 1986 .

Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross section inside the probe which is instrumented with four strain gages in a full-bridge circuit. Forces are sensed by the load cells and the data is transmitted from the probe assembly via a cable running through the push tubes. The analog data is digitized, recorded, and plotted by computer in the penetrometer truck. A set of data is normally recorded each second, for a minimum resolution of about one data point every 0.8 in of cone advance. The depth of penetration is measured using an extensometer mounted inside one of the push cylinders.

As shown in Figure 2.1, the piezo-cone probe senses the pore pressure immediately behind the tip. Currently, there is no accepted standard for the location of the sensing element. ARA chose to locate the sensing element behind the tip as the filter is protected from the direct thrust of the penetrometer and the measured pore pressure can be used to correct the tip resistance data (discussed below) as recommended by Robertson and Campanella, 1988. The magnitude of the penetration pore pressure is a function of the soil compressibility and, most importantly, permeability. In freely draining soil layers, the measured pore pressures will be very close to the hydrostatic pressure computed from the elevation of the water table. When low permeability soil layers are encountered, excess pore pressures generated by the penetration process can not dissipate rapidly enough and this results in measured pore pressures which are significantly higher than the hydrostatic pressures. Whenever the penetrometer is stopped to add another section of push tube, or when a pore pressure dissipation test is run, the excess pore pressure may begin to dissipate. When the penetration is resumed, the pore pressure quickly rises to the level measured before the penetrometer was stopped. This process causes some of the spikes that may appear in the penetration pore pressure data.

2. Saturation of the Piezo-Cone

As shown in Figure 2.1, penetration pore pressures are measured with a pressure transducer located behind the tip in the lower end of the probe. Water pressures in the soil are sensed through a 250 micron porous polyethylene filter that is 0.25-inch high and 0.202-inch thick. The pressure transducer is connected to the porous filter through a pressure port as shown in Figure 2.1. The pressure port and the filter are filled with a high viscosity silicone oil.

In order for the pressure transducer to respond rapidly and correctly to changing pore pressures upon penetration, the filter and pressure port must be saturated with oil upon assembly of the probe. A vacuum pump is used to de-air the silicone oil before use and also to saturate the porous filters with oil. The probe is assembled with the pressure transducer up and the cavity above the pressure transducer filled with de-aired oil. A previously saturated filter is then placed on a tip and oil is poured over the threads. When the cone tip is then screwed into place, excess oil is ejected through the pressure port and filter thereby forcing out any trapped air.

Saturation of the piezo cone is verified with field calibrations performed before the probe is inserted into the ground. The high viscosity of the silicone oil coupled with the small pore space in the filter prevents the loss of saturation as the cone is pushed through dry soils. Saturation of the cone can be verified with a calibration check at the completion of the penetration. Extensive field experience has proven the reliability of this technique with no known case where saturation of the piezo-cone was lost.

3. Data Acquisition

Electronic data acquisition equipment for the cone penetrometer consists of an IBM compatible 486 computer with a graphics monitor and a rack of eight customized signal conditioners. Analog signals are transmitted from the probe to the signal conditioners where the CPT data is amplified and filtered at 1 Hz. The digital data are then read into memory, plotted on a graphics monitor, and written to the internal hard disk for future processing. Data displayed on screen can be used to determine site layering as it is encountered. This allows important decisions to be made in real-time directly in the field. Upon completion of the test, the penetration and resistivity data are plotted. Plots can typically be available within twenty minutes of completing the test. Floppy disks containing the data are brought to ARA's New England Division in South Royalton, Vermont, for preparation of final report plots and analysis.

4. Field Calibrations

Many variables can effectively change the calibration factors used to convert the raw instrument readouts, measured in volts, to units of force or pressure. As a quality control measure, as well as a check for instrument damage, the load cells and the pressure transducer are routinely calibrated in the field. Calibrations are completed with the probe ready to insert into the ground such that any factor affecting any component of the instrumentation system will be included and detected during the calibration.

The tip and sleeve load cells are calibrated with the conical tip and friction sleeve in place on the probe. For each calibration, the probe is placed in the push frame and loaded onto a precision reference load cell. The reference load cell is periodically calibrated in ARA's laboratory against NIST traceable standards. To calibrate the pore pressure transducer, the saturated probe is inserted into a pressure chamber with air pressure supplied by the compressor on the truck. The reference transducer in the pressure chamber is also periodically calibrated against an NIST traceable instrument in ARA's laboratory. Additionally, the extensometer, used to measure the depth of penetration, is periodically checked against a tape measure.

Each instrument is calibrated using a specially written computer code that displays the output from the reference device and the probe instrument in graphical form. During the calibration procedure, the operator checks for linearity and repeatability in the instrument output. At the completion of each calibration, this code computes the needed calibration factors using a linear regression algorithm. In general, each probe instrument is calibrated at the beginning of each day of field testing. Furthermore, the pressure transducer is recalibrated each time the porous filter is changed and the cone is resaturated. Calibrations are also performed to verify the operation of any instrument if damage is suspected.

5. Penetration Data Correction

A typical penetration profile from Hill AFB is shown in Figure 2.2. Measured tip resistance, sleeve friction, friction ratio, and pore pressure are plotted as a function of depth. When the surface elevation of the test location is unknown, the penetration data is plotted against depth; otherwise plots are prepared in terms of elevation.

927-U1-27

APPLIED RESEARCH ASSOCIATES, INC.

12/16/94

North 289562.25

East 1873661.18

Elevation 4800.02

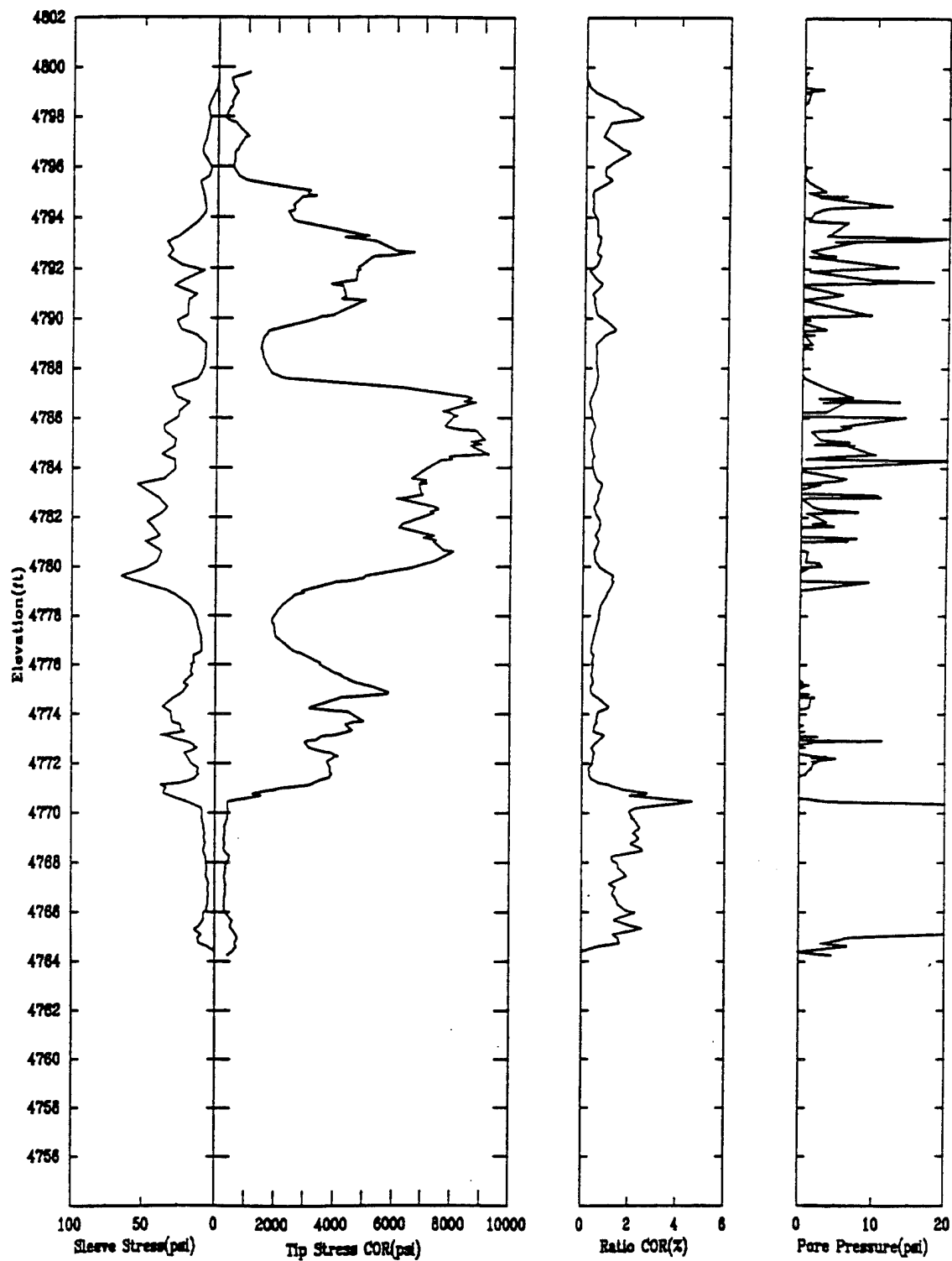


Figure 2.2 A typical penetration from the Hill AFB Site.

File 418D406.DCP

Tip resistance, q_c (lb/in²), is obtained by dividing the vertical force on the conical tip by the effective tip area of 2.405 in² for the 1.75" probe used on this project. The tip resistance is then corrected for pore pressures acting behind the conical tip, as discussed in the next section. The corrected tip resistance, q_T (lb/in²), is plotted in the penetration profile. Sleeve friction, f_s (lb/in²) is obtained by dividing the total frictional force on the sleeve by the sleeve's surface area (23.26 in²). The offset between the depth at the tip and the depth at the friction sleeve is corrected by shifting the sleeve friction profile downward so that it corresponds to the depth at the centroid of the tip. In addition to the tip resistance and sleeve friction, a friction ratio profile is plotted for each location. This ratio is simply the sleeve friction expressed as a percentage of the tip resistance at a given depth. In uncemented soils, the friction ratio can be correlated to soil type. The final profile shown in (Figure 2.2) is the pore pressure that is measured as the probe is advanced. This measurement is useful for identifying clay layers as the pore pressure rises significantly above the hydrostatic level when fine grained materials are encountered.

6. Pore Pressure Correction of Tip Stress

Cone penetrometers, by necessity, must have a joint between the tip and sleeve. Pore pressure acting behind the tip decreases the total tip resistance that would be measured if the penetrometer was without joints. The influence of pore pressure in these joints is compensated for, by using the net area concept (Robertson and Campanella, 1988). The corrected tip resistance is given by:

$$q_T = q_c + u \left(1 - \frac{A_n}{A_T} \right) \quad (2.1)$$

where:

q_T = corrected tip resistance

q_c = measured tip resistance

u = penetration pore pressure measured behind the tip

A_n = net area behind the tip not subjected to the pore pressure (1.257 in²)

A_T = projected area of the tip.

Hence, for ARA cone designs, the tip resistance is corrected as:

$$q_r = q_c + u(.1890) \quad (2.2)$$

Laboratory calibrations have verified Equation 2.2 for ARA's piezo-cone design.

A joint also exists behind the top of the sleeve (see Figure 2.1). However, since the sleeve is designed to have the same cross sectional area on both ends, the pore pressures acting on the sleeve cancel out. Laboratory tests have verified that the sleeve is not subjected to unequal end area effects. Thus, no correction for pore pressure is needed for the sleeve friction data.

The net effect of applying the pore pressure correction is to increase the tip resistance and to decrease the friction ratio. Generally, this correction is only significant when the pore pressures are high while measured tip resistance is very low.

7. Depth Correction of the Penetration Data

Any time that the cone penetrometer is stopped or pulled back during a test, misleading data can result. For instance, when the probe is stopped to add the next push rod section or when a pore pressure dissipation test is run, the excess pore pressures will dissipate towards the hydrostatic pore pressure. When the penetration is resumed, the pore pressure generally rises very quickly to the pressures experienced prior to the pause in the test. In addition, the probe is sometimes pulled back and cycled up and down at intervals in deep holes to reduce soil friction on the push tubes. This results in erroneous tip stress data when the cone is advanced in the previously penetrated hole.

To eliminate this misleading data from the penetration profile, the data is numerically edited before it is plotted or used in further analysis. Each time the penetrometer stops or backs up, as apparent from the depth data, the penetration data is not plotted. Plotting of successive data is resumed only after the tip is fully re-engaged in the soil by one tip length of new penetration. This algorithm also eliminates any data acquired at the ground surface before the tip has been completely inserted into the ground. The sleeve data is similarly treated and this results in the first data point not occurring at the ground surface, as can be seen in some tip and sleeve profiles. These procedures ensure that all of the penetration data that is plotted and used for analysis was acquired with the probe advancing fully into undisturbed soil.

C. CONTAMINATION TESTING USING OPTICAL METHODS

1. Background

Optical screening technology, as applied to the environmental field and specifically to fuel fluorescence measurements, is relatively new with the first published work conducted by Hirschfeld, et al. (1) in 1984 and Chudyk, et al. (2) in 1985. This was followed shortly thereafter by Lieberman, et al. (3) and Gillispie and St. Germain (4), and others. Research in this field has demonstrated the fluorescence characteristics of a wide range of chemical compounds. Common chemical contaminants such as chlorinated hydrocarbons (TCE, PCE) are known not to fluoresce and are not a candidate for the LIF technique. For this reason, testing for these compounds was attempted using a Raman Spectroscopy System (See Section C.3). Common fuel contaminants such as heating oil jet fuels, gasoline, and diesel fuel marine (DFM) exhibit strong fluorescence signatures, with the degree of fluorescence depending on both the optical power delivered to the sample and the excitation wavelength. The larger multi-ring components in fuels will fluoresce with long wavelength excitation sources, such as the 337 nanometer (nm) nitrogen laser used on this project. Lighter fuels, such as jet fuels and gasoline, tend to have weaker signatures when excited by the nitrogen laser, as the percentage of the multi-ring fuels is lower. In an aged fuel situation, immediately surrounding the source there may be little difference between the signature of a 337 nm excitation and a shorter excitation wavelength source. The lighter compounds in the fuels (Benzene, Toluene, Xylene's) degrade more readily and mobilize further out from the source, leaving mostly the heavier hydrocarbon compounds in this region. Further out near the leading edge of the plume, the BTEX compounds may provide a better indicator of contamination and a lower wavelength may have more utility. Another key component in the amount of fluorescence generated is the power delivered to the sample outside the sapphire window. The nitrogen laser system provides more power to the sapphire window in the CPT probe than the other lower wavelength systems. Transmission losses are also significantly less when 337 nm light is transmitted through 50 meters of fiber optic cable than shorter wavelength light, such as 290 nm, from a dye laser system. Based on these characteristics a nitrogen laser system was selected for use on this project.

2. Laser Induced Fluorescence Testing.

The laser induced fluorescence testing system used on this project was developed by the Waterways Experimental Station. The laser is a PTI 2300 nitrogen laser and emits pulsed ultraviolet (UV) energy in the 337 nm range. The UV power generated at the laser exit port is

approximately 1,000 uJ. This light is launched into a 400 micron core fiber optic cable which transmits the light to the optical probe head contained in the CPT probe. The light exits the cone via a sapphire window and the returned fluorescence enters the optical head through the same sapphire window. The returned fluorescence also travels through a 400 micron fiber optic cable to the detector system located in the CPT truck. The detector system consists of a EG&G photodiode array, Model 1421, controlled by an EG&G optical multichannel analyzer (OMA), Model 1460. Data transfer between the CPT data acquisition computer and the OMA occurs via a GPIB card and cable. This allows the CPT computer to present real-time profiles of the LIF results.

The CPT computer operates the laser system for firing the laser and collecting data. The operator instructs the OMA to begin a preprogrammed data acquisition routine. This routine consists of instructions to fire the laser and collect data for a period of 16 msec after each shot. This loop is repeated ten times and the data accumulated on the OMA. Once the loop has been completed ten times the CPT computer retrieves all the data from the OMA and resets it to begin another process. The total time required to fire the ten shots is approximately 1 sec, although the time required to retrieve the data from the OMA takes roughly 2 to 3 secs. Retrieval time is long because the entire spectrum of 1024 data points is collected. The total processing time of the routines used during the project was roughly 4 to 5 secs. This permits a vertical resolution of approximately 8 cm at the standard penetration rate of 2 cm per second in zones of interest. To increase the spatial resolution the standard penetration rate was reduced to roughly 1 cm per second during the zones of interest.

The data acquired consists of a spectrum from 350 nm to 915 nm. This detailed data was used to calculate two different values that were displayed in the field and are also presented in this report. One value consisted of the maximum intensity measured between 350 and 472 nm. The second value consisted of area under the intensity curve between 350 and 472 nm. In the field raw values were plotted, and for this report both values have been normalized for the power delivered to the sample using the procedure described in Section III. It should be noted that upon completion of the first two soundings on December 13, 1994, the system sensitivity was increased. The data from these two locations has been reprocessed using the same algorithms as all the other locations although the measured spectral ranges were slightly different. The reprocessed data from the test on December 13 is now directly comparable to the other locations.

Calibration of the spectrometer was conducted in the laboratory prior to shipment to the site. As the fluorescence signal is highly dependent upon soil and mineralogy type and hydrocarbon contaminant type, soil samples from the field are used to relate LIF intensity to fuel

contamination. This analysis was performed after the field program using a limited number of samples and is documented in Section III the data analysis section of this report.

3. Raman Spectroscopy System.

The laser system used for the Raman testing on this project was designed and operated by EIC Laboratories, Inc. of Norwood, Mass. The system consists of an Argon laser emitting 170 milliwatts of power at 514 nm. Similar to the LIF system the laser light is launched into a fiber optic cable and transmitted to an optical probe located in the cone penetrometer. The laser light shines through a sapphire window and the Raman signal is collected by the optical probe and transported via another fiber optic cable to the detector located in the CPT truck. The detector for the Raman system consists of a 270 M Spectrograph and a charge coupled detector (CCD). This system is designed for maximum sensitivity, and therefore the CCD is cooled with liquid nitrogen. Like the LIF system, the Raman measures the generated spectrum from 515 to 625 nm.

Operation of the Raman system was similar to that of the LIF system, except an independent computer controlled the Raman system and no real time display of the data on the CPT computer was possible. Because the Argon laser is a continuous excitation source, it is not necessary to fire the laser but rather to properly time the exposure interval of the CCD. The CCD exposure time was set at 30 sec for a majority of the penetration except for regions where the signal saturated the detector. During these instances the exposure time was reduced to avoid detector saturation.

Calibration of the system (i.e. the spectrometer) in terms of wavelength was performed prior to shipment and was verified in the field. Since Raman signals consist of distinct spectral fingerprints, the calibration is easily verified when calibration samples are held up to the window. Calibration in terms of signal strength and concentration is generally not possible with the Raman because the signal is a very weak phenomenon, and nearly pure product is required to generate a sufficiently strong Raman signal. As discussed in the analysis section, no Raman signals were recorded due to the fluorescence of the fuel within the soil matrix which swamped the Raman signal.

D. SAMPLING ACTIVITIES

1. Groundwater Sampling

One of the capabilities of the CPT is that it provides a means to collect groundwater samples from discrete intervals within an aquifer. Several groundwater sampling devices are available and have been modified for use with CPT testing. Among these devices is ARA's proprietary discrete-interval CPT groundwater sampling device (see Figure 2.3) that provides an efficient and reliable means of collecting groundwater samples. This device is designed to be advanced to the desired depth utilizing a sacrificial tip and filter section. Upon reaching the required sampling interval, the outer push rods are retracted exposing the filter material and allowing groundwater to flow inside the filter and push rods. The groundwater is sampled using a small diameter Teflon bailer to collect at least one 40 ml VOA per bailer, with typical volumes of 80 to 120 ml. Since the tip and filter materials are disposable, they are left at the sampling depth and CPT push rods are fully retracted and steam cleaned prior to obtaining the next sample.

An attempt was made to collect a water sample from location U1-932-28 at Hill AFB. One 40 ml VOA vial was successfully filled after many trips with the bailer. Water inflow times were slow at this location indicating the formation had very little water to release. Based upon the CPT pore pressure measurement at this location, the soil may be wet but no water table appears to be present in the CPT profile. A sample was attempted at a depth of 25 to 26.5 ft to collect either some groundwater or product from the contamination plume. Based on a review of the pore pressure data along with discussions with local drillers, there appears to be very little water within the formation above the clay layer that underlies the site, therefore making water sampling a time consuming process. After these attempts, ground water sampling with the CPT truck was abandoned due to time constraints. As will be discussed in the recommendations, water sampling points could be set with the CPT and sampled after water has collected in the CPT well points.

2. Soil Sampling

Two attempts at soil sampling were conducted as part of this effort. Both attempts used a Mostap 35 PS FT soil sampler. Similar to the water samplers, the soil sampler is pushed to the desired depth in a closed position. A locking mechanism is then released which allows inner

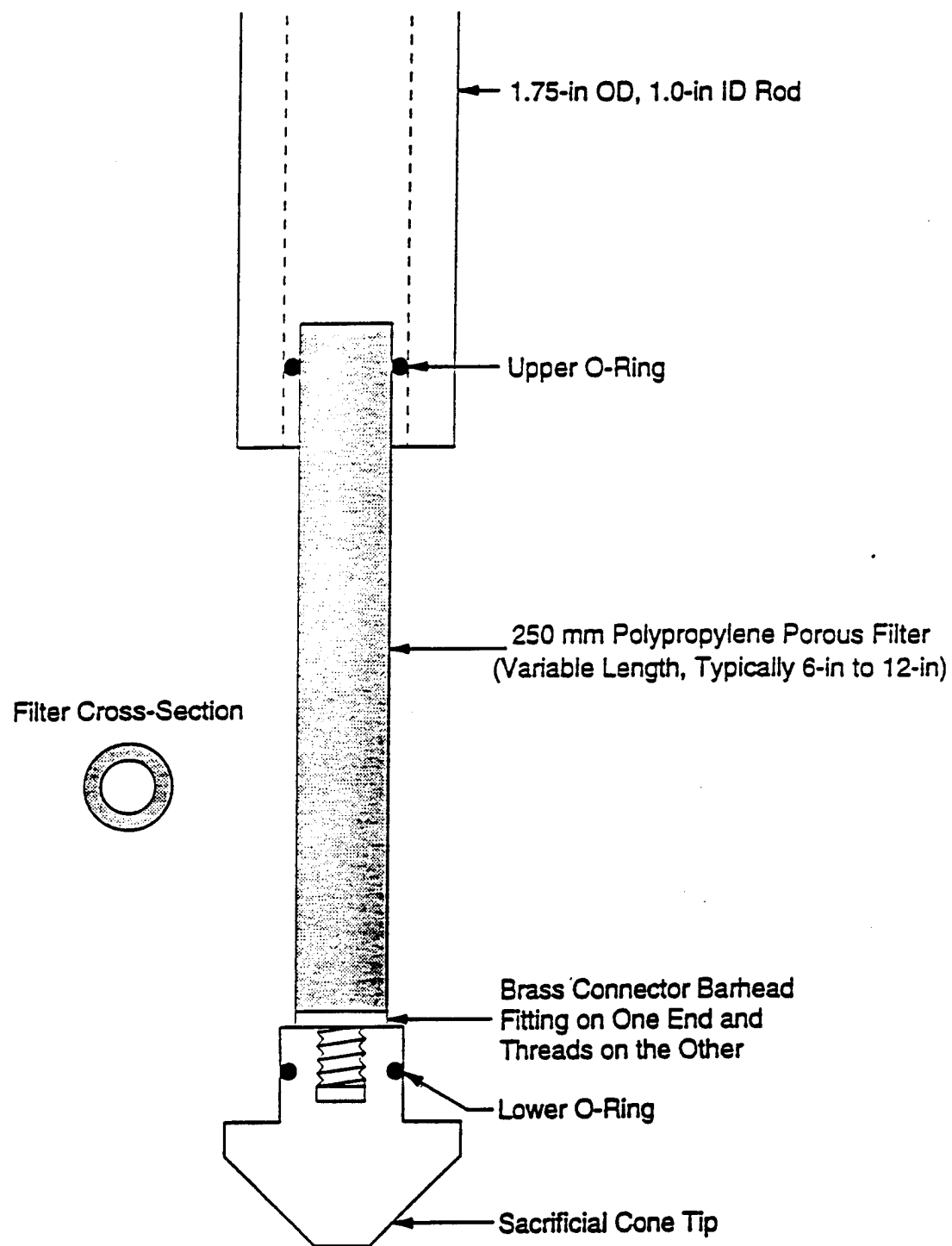


Figure 2.3 ARA's Discrete interval groundwater sampling device.

pistons to move up inside the CPT rods as the sampler is advanced to obtain the soil sample. The soil sample is held in the sample chamber by frictional forces with the side walls during retraction of the push rods. The Mostap sampler obtains samples which are 1.38 inch diameter by 20 inches long for a soil volume of 30 in³ (481 cc).

On the first attempt to collect a sample at a depth of 15 feet at location U1-942-27, the locking mechanism that holds the tip in the closed position was pushed open by the gravelly materials in the formation. The locking mechanism consists of a ball bearing in a race; penetration forces caused the ball bearings to break the race and the tip to be pushed up into the sample tube. This clogged the sampler and prevented the collection of a sample. The second attempt consisted of sending a second sampler down the same hole to a depth of 15 feet, opening the sampler, and collecting a sample from 15 to 16.5 feet.. The unit survived because the hole was previously penetrated. The sampler was then opened and pushed the length of the sampler (20 inches). Two of the three brass sample tubes were full upon retrieval of the sampler, but the tubes were jammed into each other and the cutting shoe ruined. Based on these experiences, and that the soil samplers are designed for use in soft soils, the Mostap CPT soil sampler was deemed unsuitable for this site.

SECTION III

DISCUSSION OF TEST DATA

A. OVERVIEW

Presented in this section is a discussion and analysis of the LIF-CPT penetrations and the two Raman-CPT penetrations. A comparison between the LIF data and the chemical testing is also presented and used to derive a calibration curve. These calibration curves are then used to prepare soil contamination plots. Since the Raman penetrations only yield fluorescence data and not Raman data, the fluorescence data from the nitrogen and argon laser system are compared. The method used to derive soil stratigraphy from the Piezo-Electric Cone Penetrometer Test (P-CPT) data and a discussion of a typical CPT profile in terms of the site geology is also presented.

B. Laser Induced Fluorescence data analysis

As discussed previously, the spectrum data were collected and stored at depth intervals of 8 cm for all penetrations. Figure 3.1 presents a typical spectrum recorded in a contaminated zone. Key points of interest concerning these spectrum are: (1) the spike recorded at 670 nm is the second harmonic of the laser and was used to perform power normalizations as discussed below; and (2) the broad fluorescence hump from 350 to 600 nm represents the fluorescence signal related to soil contamination.

To allow the comparison of all profiles and to establish a common level for the calibration work, all data were normalized to have the same power level on the sample. This was accomplished by averaging the peak intensity for the second harmonic laser line for all recorded spectrum. This value was treated as the average power for the entire site. The measured fluorescence, (i.e. both the maximum intensity and the area), were multiplied by the ratio of the site average power divided by the intensity of the laser line for that particular spectrum, as shown in Equation 3.1. These fluorescence results are all comparable and related to the same base value.

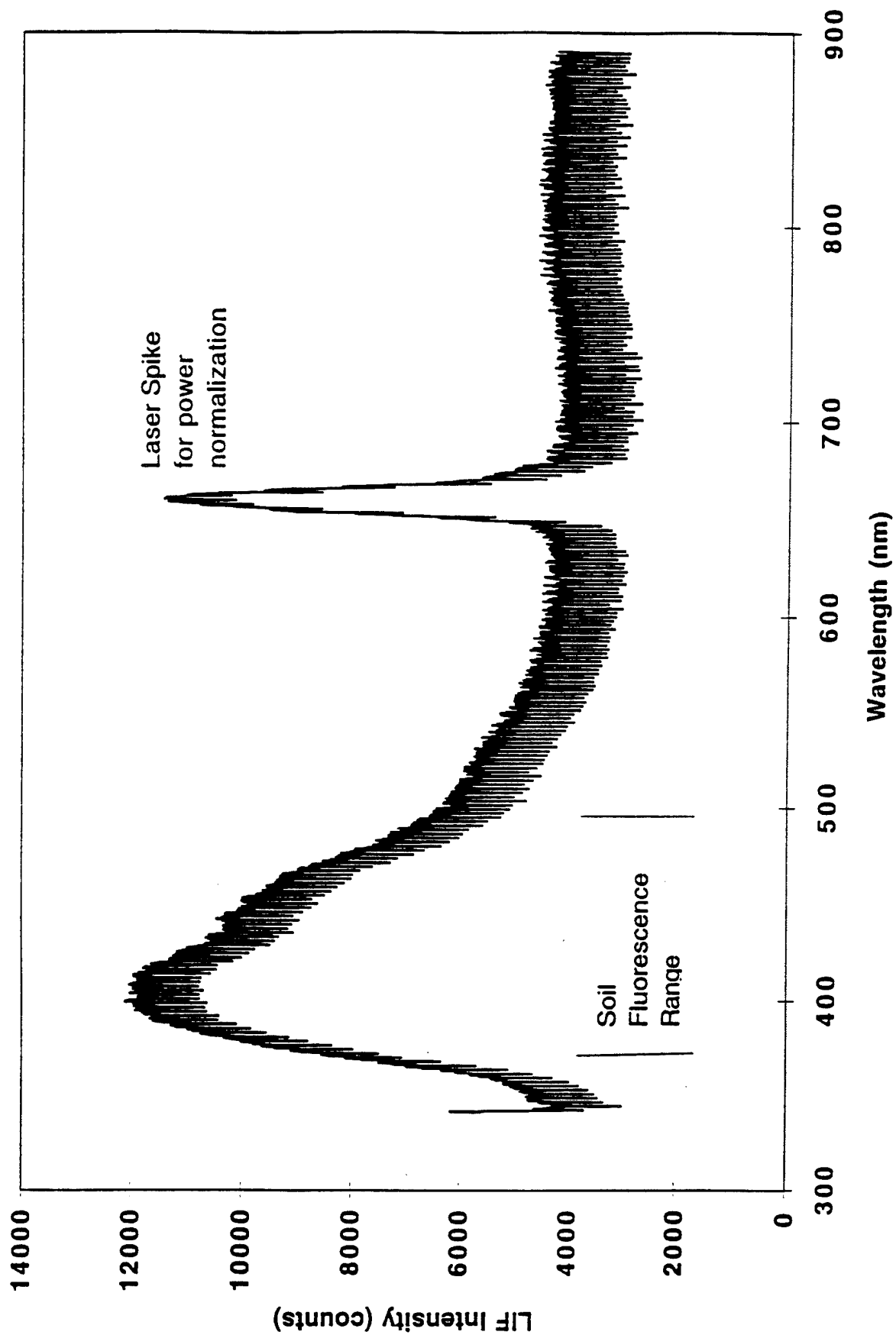


Figure 3.1 Typical Fluorescence spectrum from Nitrogen laser system for Hill AFB.

$$LIF_n = LIF_m (Psavg / Pd) \quad (3.1)$$

where

LIF_n	=	Normalized LIF intensity
LIF_m	=	Measured LIF Intensity
$Psavg$	=	Site Average Intensity of 2nd harmonic Laser Peak
Pd	=	Average Intensity of 2nd harmonic Laser Peak at depth of calculation

1. Development of a Site Calibration Curve

Using the normalized data, the LIF intensity value over the depth of the sample interval has been compared to the TRPH data supplied by TRW. Table 3.1 presents the TRPH data that were supplied along with the average LIF intensities over that interval. Of the five samples reported as non-detects by the laboratory, three represent non-detects by the LIF system (Locations 5, 9 and 35). The LIF results indicate the other two Locations, 24 and 33, are contaminated. (See Figure 3.2). At Location 33, the sample was taken above the clay material. The LIF profile between the soil sample and the top of the clay at elevation 4770 shows a large laser spike indicating pooling of the contaminant. Field notes indicate that this sample had an odor, but returned a non-detect. Based upon the location of this sample (the middle of the plume) and the high laser value recorded, it is likely that the sample is contaminated and may represent a false negative from the laboratory. Location 24 shows a very minor indication of contamination at the sample depth.

Table 3.1 Baseline Corrected LIF Counts & TRPH Data

Location Number	Sample Depth (feet)	TRPH by Purge & Trap (mg/kg)	TRPH by Extraction (mg/kg)	Sum of TRPH by both methods (mg/kg)	Average LIF Response (counts)
5	14.5 - 15.0	ND	ND	ND	ND
9	18.5 - 19.0	ND	ND	ND	ND
24	27.5 - 28.0	ND	ND	ND	300
33	26.0 - 26.5	ND	ND	ND	4700
35	29.0 - 29.5	ND	ND	ND	1

**Table 3.1 Baseline Corrected LIF Counts & TRPH
(cont.)**

Location Number	Sample Depth (feet)	TRPH by Purge & Trap (mg/kg)	TRPH by Extraction (mg/kg)	Sum of TRPH by both methods (mg/kg)	Average LIF Response (counts)
46	22.0 - 22.5	10	16	26	ND
42	30.5 - 31.0	27	42	69	1000
27	28.5 - 29.0	33	193	226	3500
38	29.0 - 29.5	95	170	265	600
31	30.5 - 31.0	230	270	500	900
31	31.0 - 31.5	400	270	670	1050
30	28.5 - 29.0	810	1610	2420	11550
25	26.5 - 27.0	480	2020	2500	1400
18	25.5 - 26.0	27	3010	3037	200
4	22.0 - 22.5	530	4400	4930	600
28	26.0 - 26.6	1108	7500	8608	ND
39	28.5 - 29.0	1900	11000	12900	1400

*ND = Non-Detect

Analytical testing determined the next two samples to have TRPH values between 10 and 100 TRPH. Based upon previous work, this level of contamination is very difficult to detect in situ using LIF systems. Of these two samples, data from the LIF system indicated one (Location 46) was non-contaminated, while the other was moderately contaminated (Location 42). Locations 46 and 42 were determined to have TRPH values of 26 and 69 ppm respectively. At Location 42, (see Figure 3.3) a large contaminated region is indicated from elevations 4,776 to 4,470 ft. However, the sample was taken from elevations 4,769.5 to 4,769, a region of transition from both highly contaminated to non-contaminated and also sand soil to clayey soil. This was part of the discrepancy.

The next four samples have TRPH values between 100 and 1000 ppm. Of these three samples, Location 38 recorded the lowest LIF response of 600 counts for a TRPH value of 265. Location 27 recorded the highest LIF response of 3,500 for this sample set. At Location 27, the sample was taken from the middle of a highly contaminated region. The second highest LIF intensity for the entire site was recorded within six inches below the sample, and the boring log sheet from the driller should have some visual inspection comments if they reached that depth. Based upon previous experience, this sample should have been visibly contaminated to record a

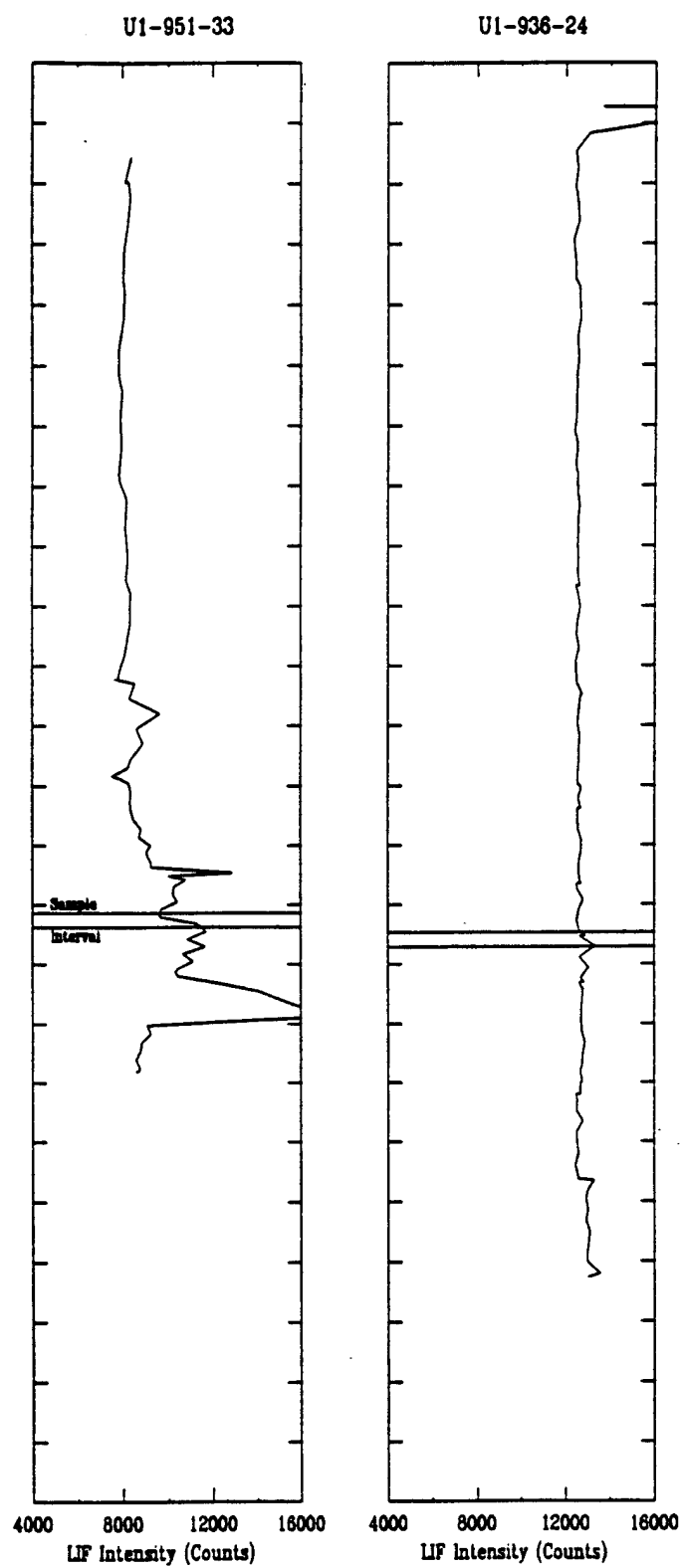


Figure 3.2. LIF intensity profiles at Locations U1-948-09, U1-951-33, and U1-936-24.

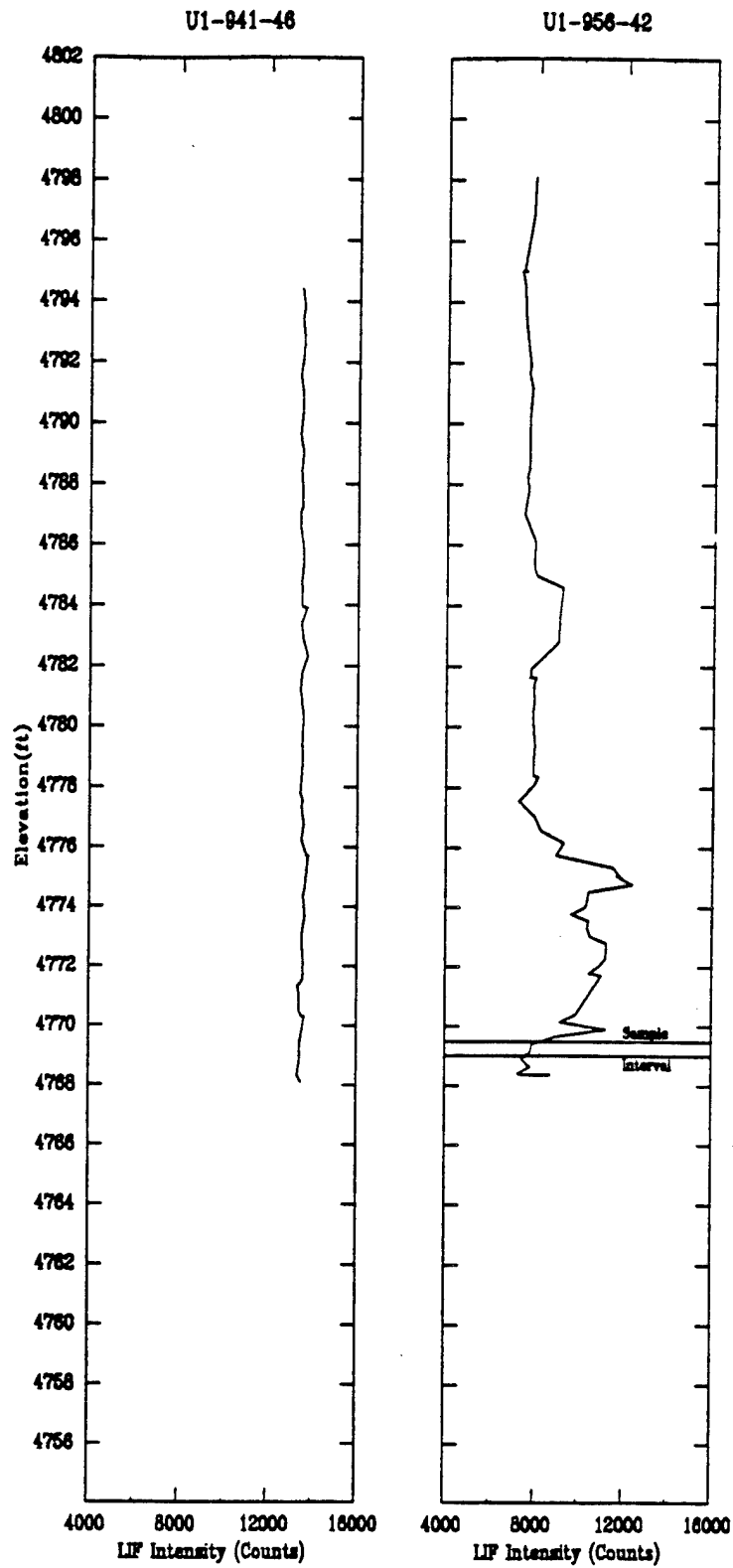


Figure 3.3 LIF intensity profiles at Locations U1-941-46 and U1-956-42.

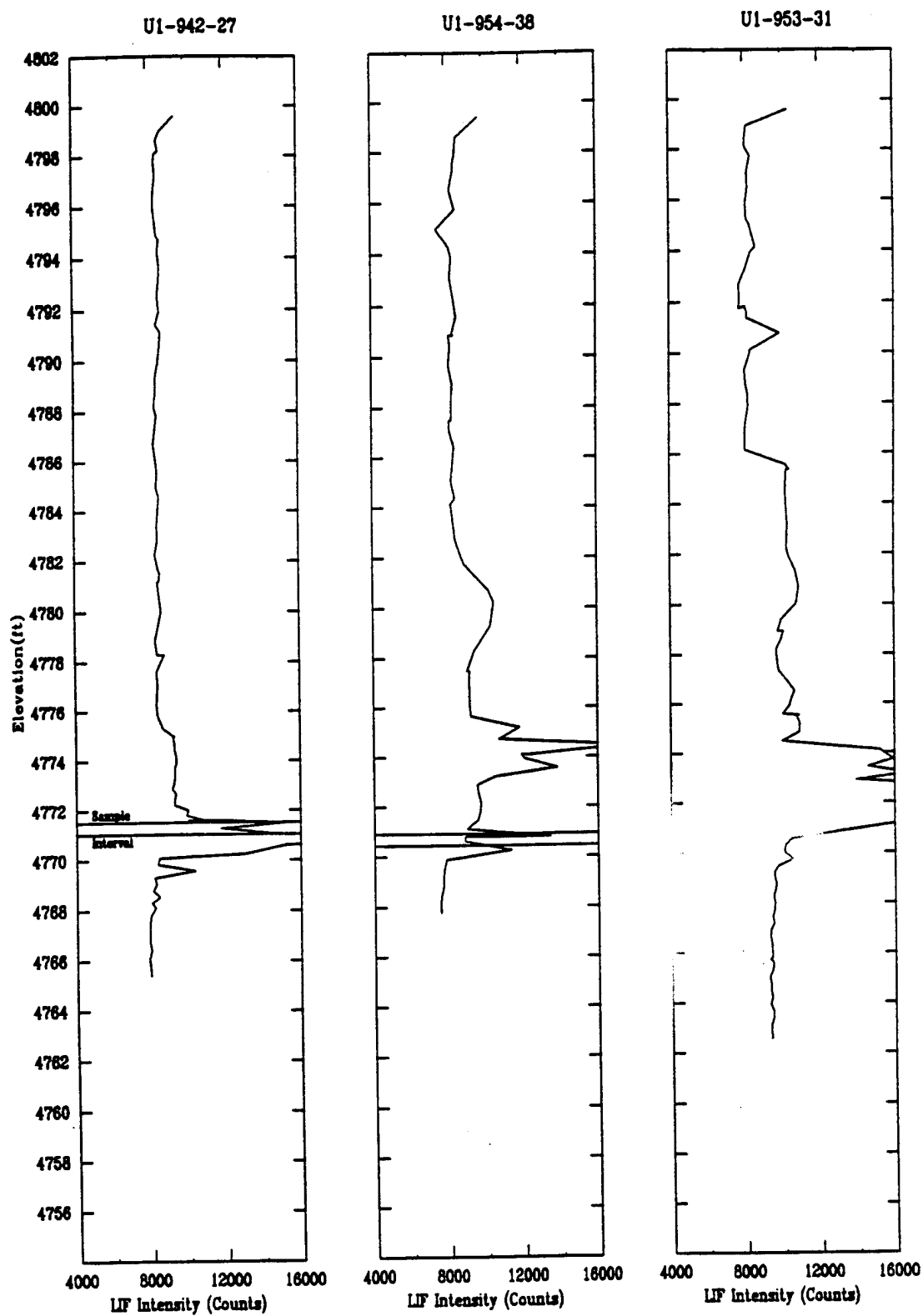


Figure 3.4 LIF intensity profiles at Locations U1-942-27, U1-954-38, and U1-953-31.

result this high. The final sample within this range was at Location 38 and recorded a TRPH of nearly 226 ppm. The LIF indicated mild contamination as the LIF count was 600 counts above baseline. As presented in Figure 3.4, a thick contaminated zone was identified roughly 4 feet above the sample location.

The next four samples returned TRPH values between 2000 and 5000 ppm. LIF values for all four of these samples ranged from minor contamination at Locations 18 and 4 to a very high value at Location 30. Location 4 was tested prior to optimization of the system and therefore probably explains the low LIF response. Subsequent to the first day, the system was significantly more sensitive. At Location 25, the LIF response indicates contamination although the response is lower than expected for a TRPH value of 2,500 ppm. The final sample within this range (Location 30) recorded a TRPH value of 810 ppm with an average laser count of 11,500. This high value is mostly due to the 25,900 counts recorded at the top of the sample. The bottom of the sample recorded 13,400 counts and the baseline for this location was determined to be 8,00 counts.

The final two samples had TRPH values of 8,608 and 12,900 for Locations 28 and 39 respectively (Figure 3.5). At Location 28, a high baseline value during the entire depth was recorded. Further investigation indicated that the laser power on this day was significantly weaker than the site average. Possible causes for the weak power were: improper alignment of the launch fiber, damaged launch fiber, or misalignment of the optical module. Of these, the last one is most likely and a check of this alignment should be included in the daily calibration. At Location 39, the laser power was very near the site average, but the laser counts were only 1,400 over the sample interval. Higher counts were recorded immediately below the sample. It is believed that the sample was obtained in a transition from non-contaminated to highly contaminated. The soil type is consistent over the sample interval, therefore eliminating that as a cause of the discrepancy.

In summary, the trends within the rough categories indicate that the LIF response increases with an increase in TRPH value. An attempt was made to establish a calibration curve from this limited data set. The correlation is very weak, as indicated in Figure 3.6, but does suggest that there may be a relationship between LIF response and TRPH levels. If additional data becomes available, then these correlations can be improved. At this time, the LIF system can be used to detect contamination above 100 ppm TRPH in a very rapid and economical manner.

One significant advantage of this approach to site characterization is that the LIF system provides a continuous profile with depth, and can be used to accurately determine the depth and

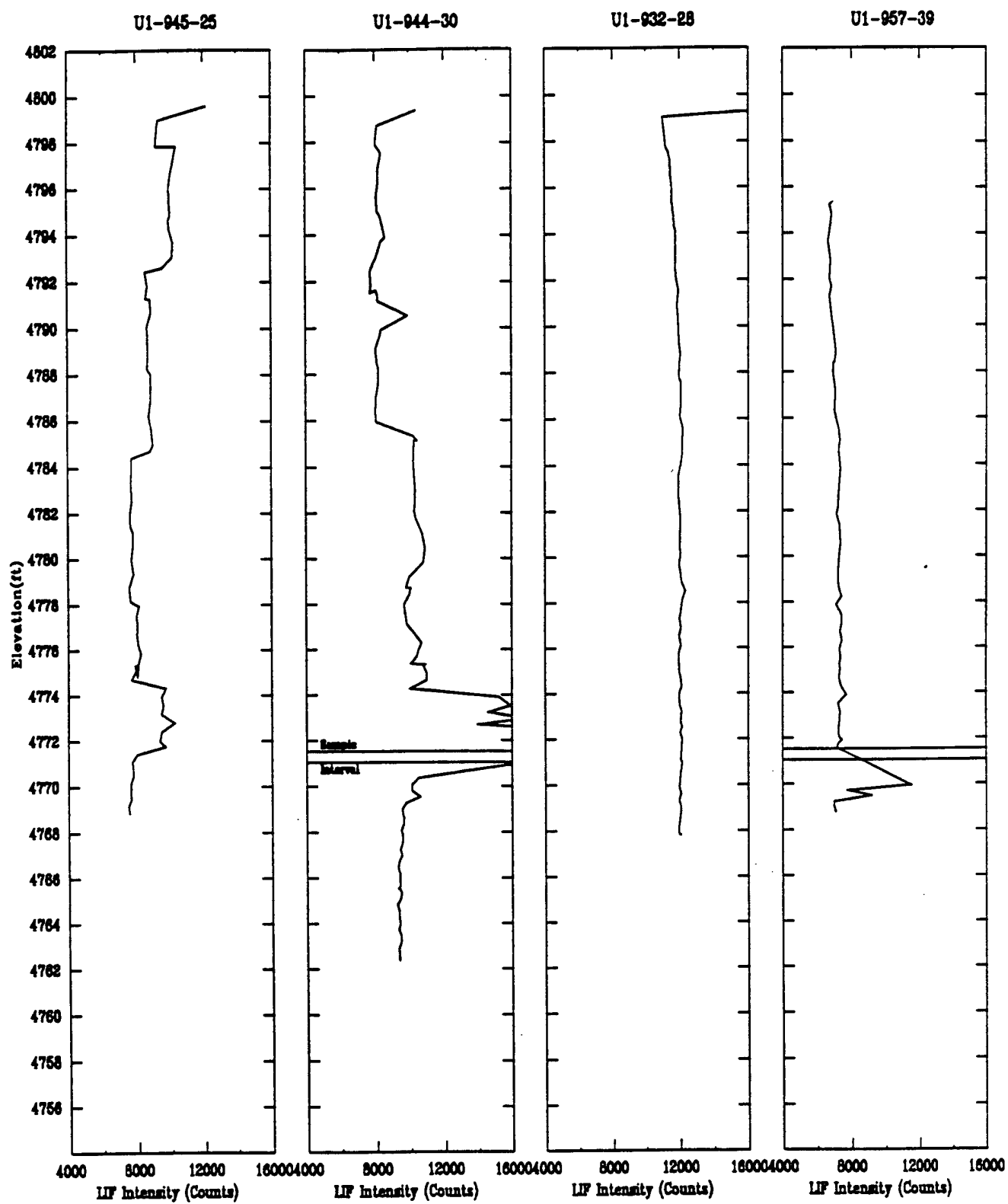


Figure 3.5 LIF intensity at Locations U1-945-25, U1-944-30, U1-932-28, and U1-957-39.

extent of any smear zone, and reduce the need to make assumptions concerning the contamination levels between samples at different depth in the same hole.

The log-log graph shown in Figure 3.6 presents the combined contamination values from the TRPH testing method (see Table 3.1) plotted versus the average LIF intensity over the corresponding sampling interval + 6 inches. This adjusts for any minor depth differences between the CPT and the drilling. A linear regression has been performed on all points not recorded as non-detects by either the laboratory analysis or the LIF screening. The results of this analysis are very encouraging considering the limited amount of data available. Overall, the LIF results can be best used as a binary tool for indicating regions of contamination above 100 ppm TRPH. With more uncertainty, the detection limit can be extended to 50 TRPH and actual contamination levels assessed from the magnitude of the intensity measurements. A large analytic database would allow the uncertainties in Figure 3.6 to be reduced.

2. Preparation of Contamination Profiles.

Using the calibration developed from the analytical data, profiles representing the TRPH values of the contamination as a function of depth were developed. A typical profile is presented in Figure 3.7 along with the laser intensity and laser area profiles. The TRPH profile was obtained by taking the normalized laser intensity profile and subtracting the median value of the upper most 40 points (i.e. this represents the baseline value for this location). After this subtraction, we multiplied the value by a calibration factor of 1.305 TRPH/count and plotted the value on a logarithmic scale as shown. Only regions of 100 ppm or greater are shown, as this represents the detection level of the system.

3. Comparison of Raman System Fluorescence.

As mentioned previously, the Raman system was unable to measure the Raman signal because it was swamped by the fluorescence signal. A profile of the fluorescence as measured by the Raman system is compared to that measured by the nitrogen system. Figure 3.8 presents the comparison for Location U1-951-33. Both profiles have been normalized by their maximum intensities at this location for comparison purposes. Both profiles indicate steady baselines in the upper 17 ft, although the argon laser appears to be more steady. From 17 to 21 ft the signal from the argon laser remains steady, while the nitrogen system indicates some potential contamination.

Hill AFB Chemical Data

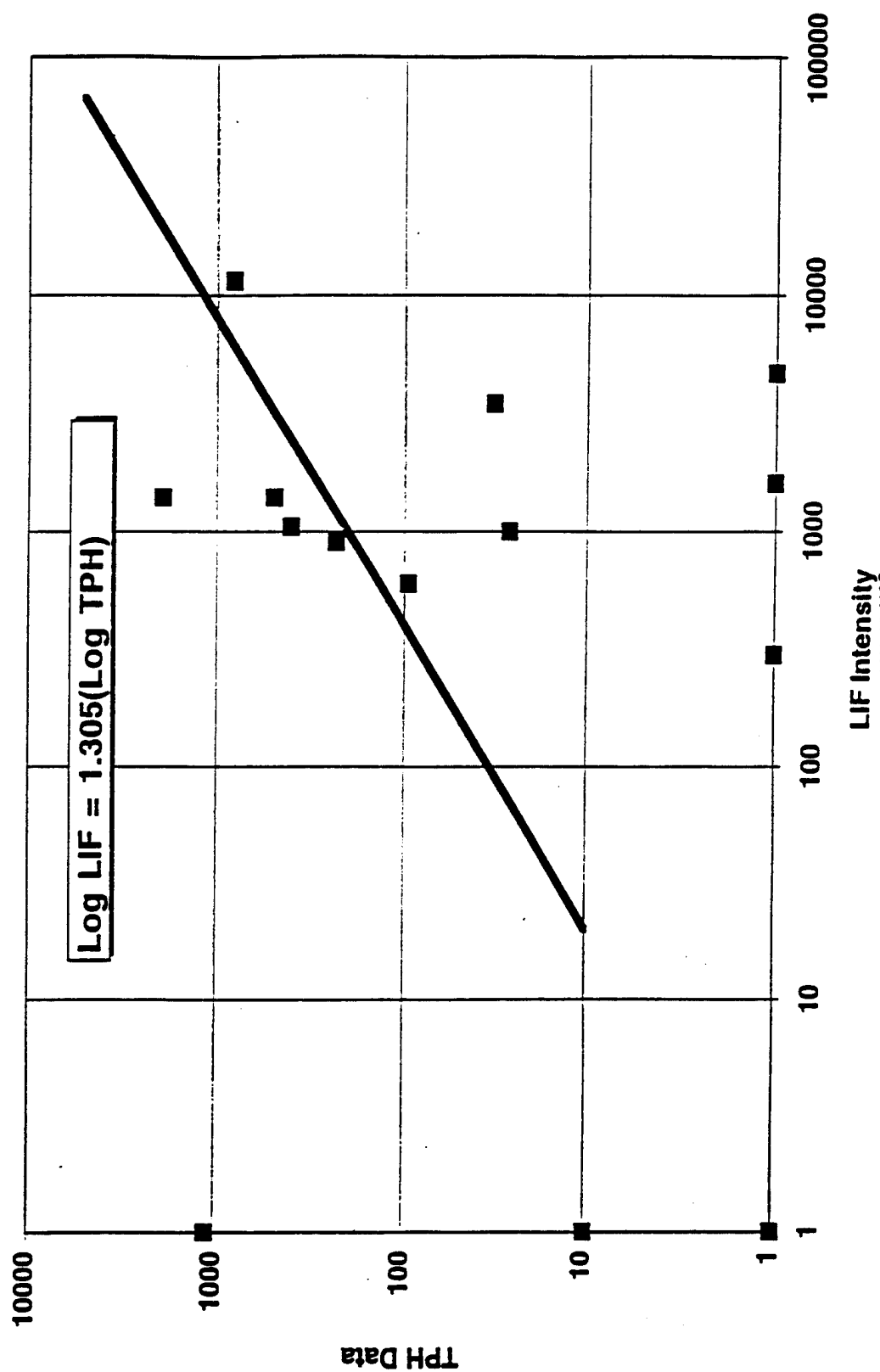


Figure 3.6 LIF calibration curve developed from Hill AFB soil sample analytical data.

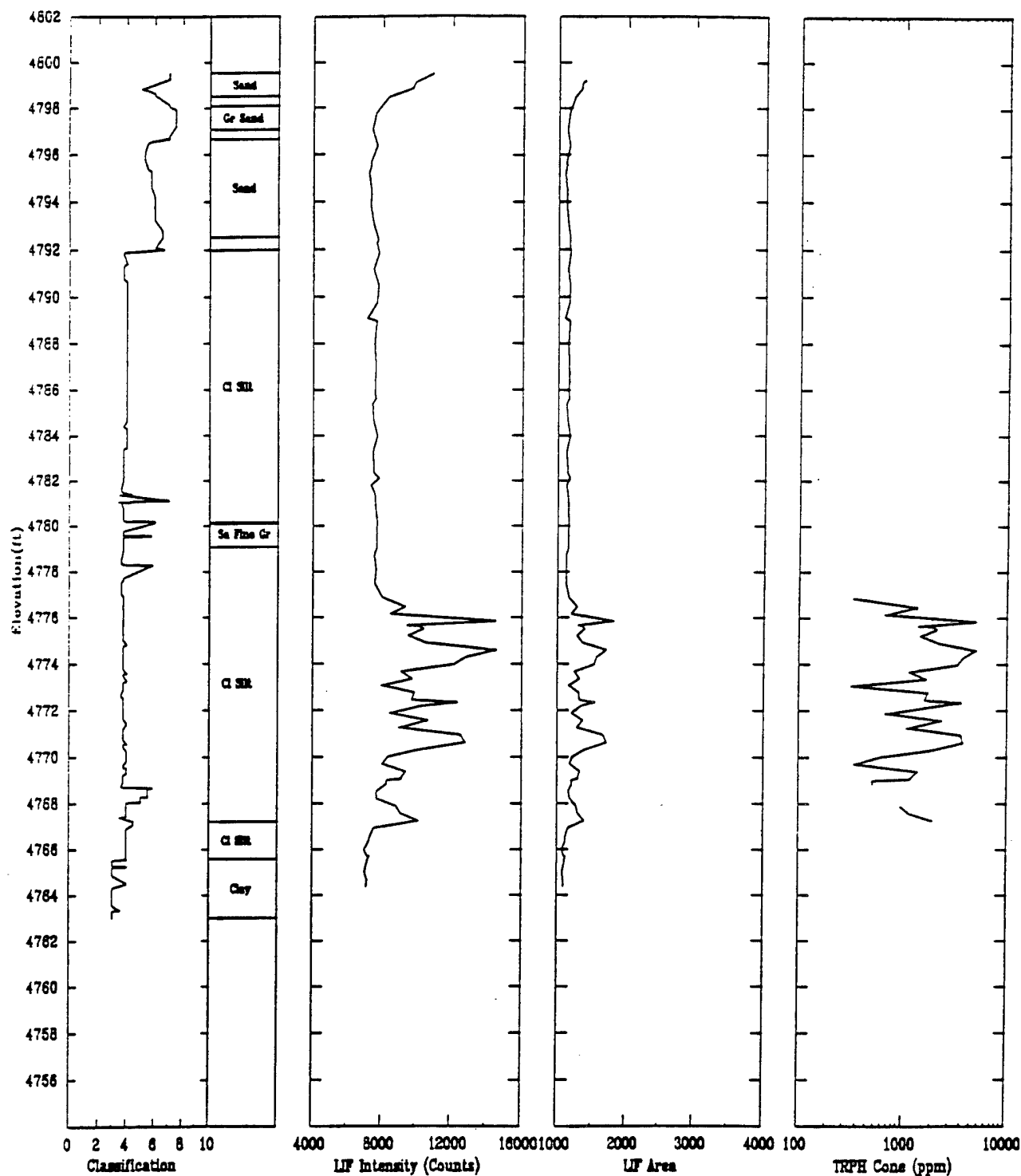


Figure 3.7. A typical profile from Hill AFB showing laser intensity and laser area profiles.

FLS 418D407.ECP

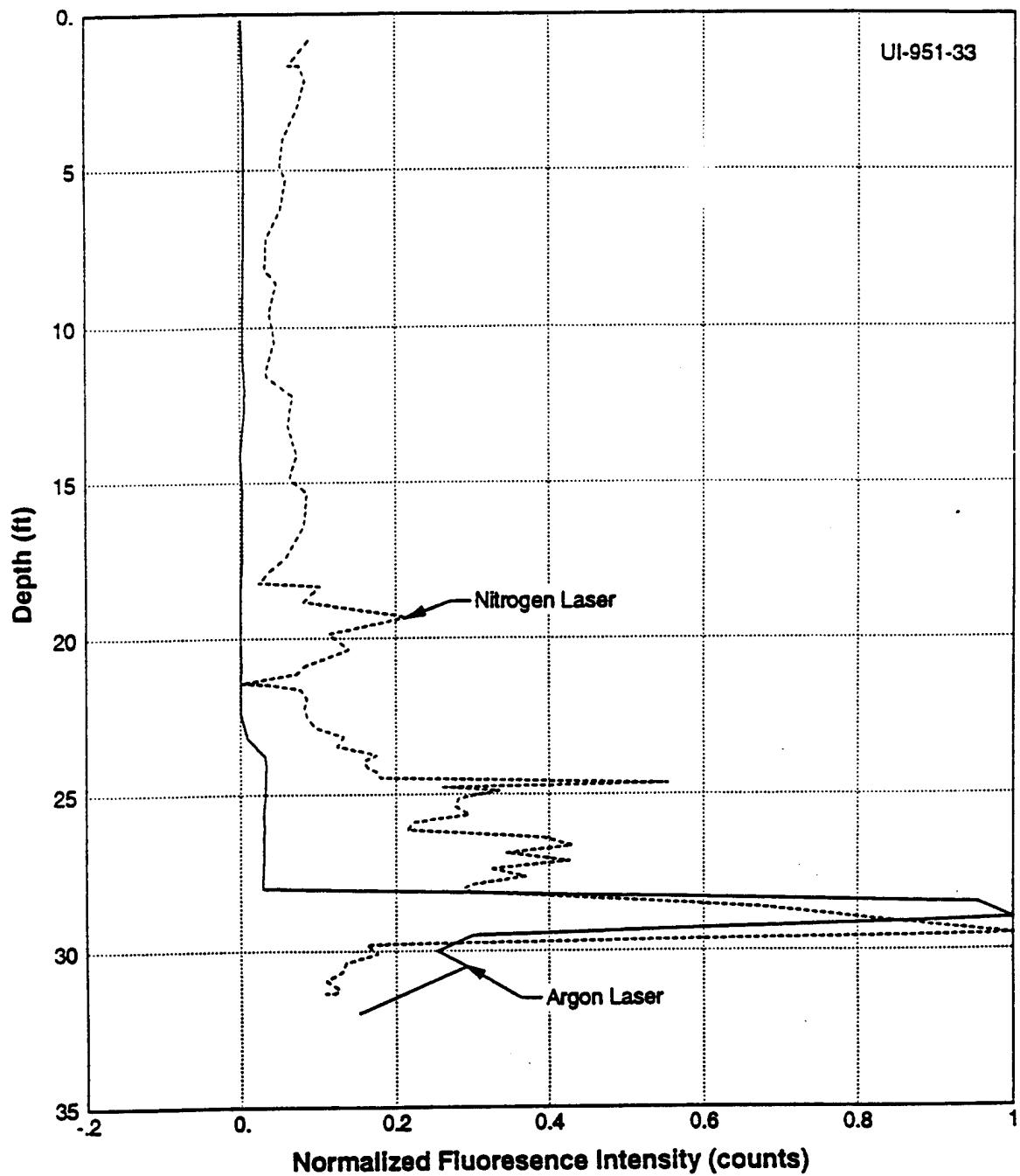


Figure 3.8 Comparison between Nitrogen and Argon laser system fluorescence response at Location UI-951-33

Both lasers indicate the smear zone exists between 23 ft and 28 ft below the ground surface. The nitrogen laser shows this layer more dramatically, indicating that it may be more sensitive to low concentration levels or smear zone constituents. At a depth of 28 ft, both systems present very high levels of contamination and each system reaches the maximum value occurring at this location. For the argon system, a count value of 300,000 was recorded. For the nitrogen system, the count value was 15,000. Below a depth of 30 ft, both laser systems show a rapid drop off in signal as the contamination decreases. In this region the argon laser is higher, possibly indicating some mild contamination but more likely a response to the clay soil material, giving rise to different background levels.

Both systems were also tested at a clean to very mildly contaminated Location (35) and the two normalized profiles are presented in Figure 3.9. Since neither laser system recorded any significant intensities, the ratios and amount of scatter are considerably higher than those in Figure 3.4. The maximum intensity for the argon system was 4,019 counts and 7,711 counts for the nitrogen system. For this location there is no difference between the response of the two systems.

4. Visualization of Entire Site Contamination

To assist in the understanding of the site's contamination areas three dimensional site representations were plotted. The first representation (Figure 3.10) presents all the regions across the site that have LIF TRPH values of over 400 ppm using the calibration factor presented previously. This indicates that a significant area of the site is contaminated at this level. The second representation (Figure 3.11) illustrates the actual TRPH data determined from the analytical testing. It should be noted that this representation is based on a very limited number of data points. The two representations compare very favorably and show contamination above 400 ppm in generally the same regions. Figure 3.11 is strongly influenced in terms of the single high TRPH value recorded at Location U1-957-39, where as Figure 3.12 presents the higher contamination region further east based on a larger collection of samples. This agrees better with the red region surrounding Location U1-932-28 in Figure 3.11. The resulting visualizations are useful for presenting a three dimensional image of the contaminated region.

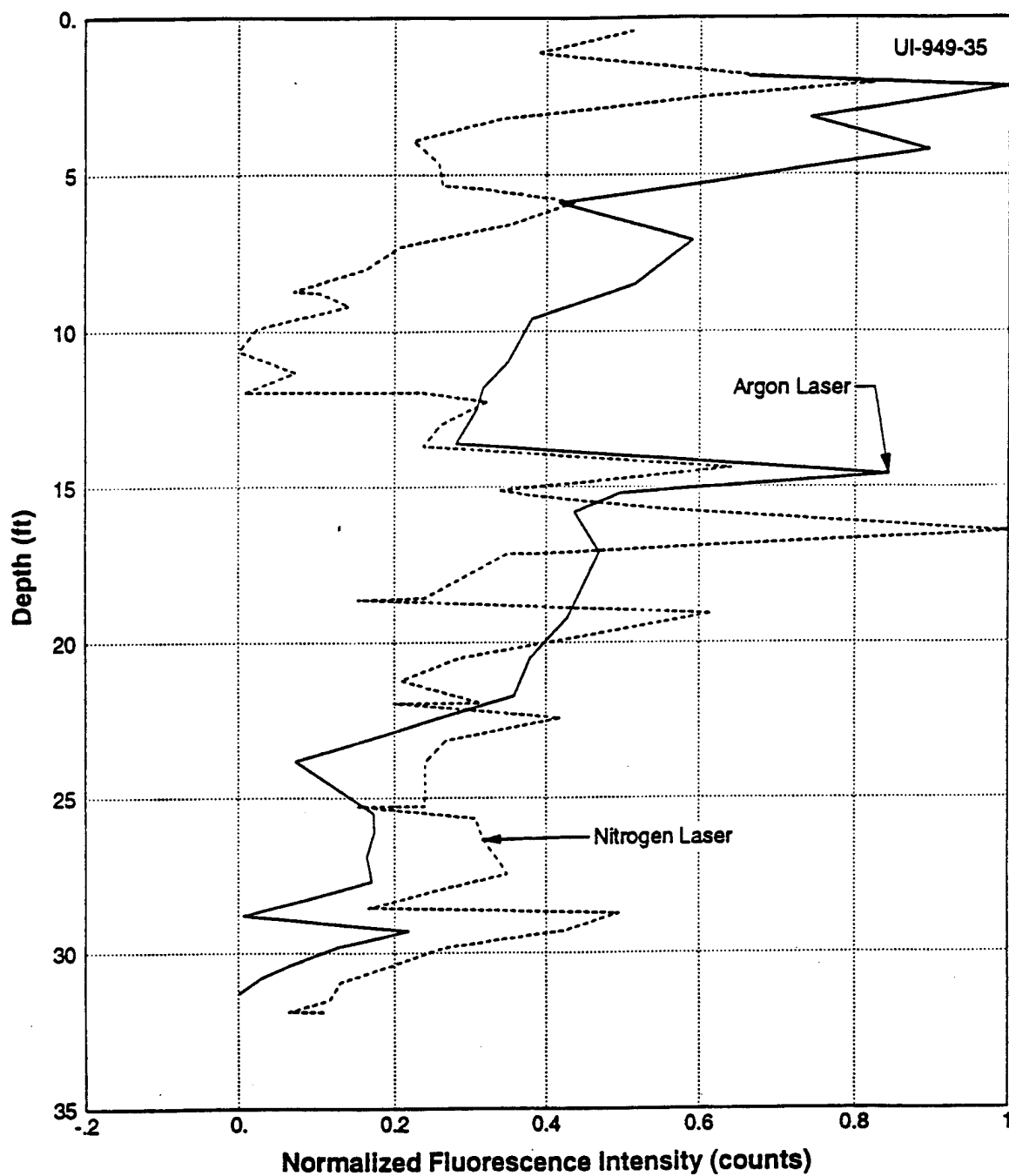


Figure 3.9 Comparison between Nitrogen and Argon laser system fluorescence response at Location UI-951-33.

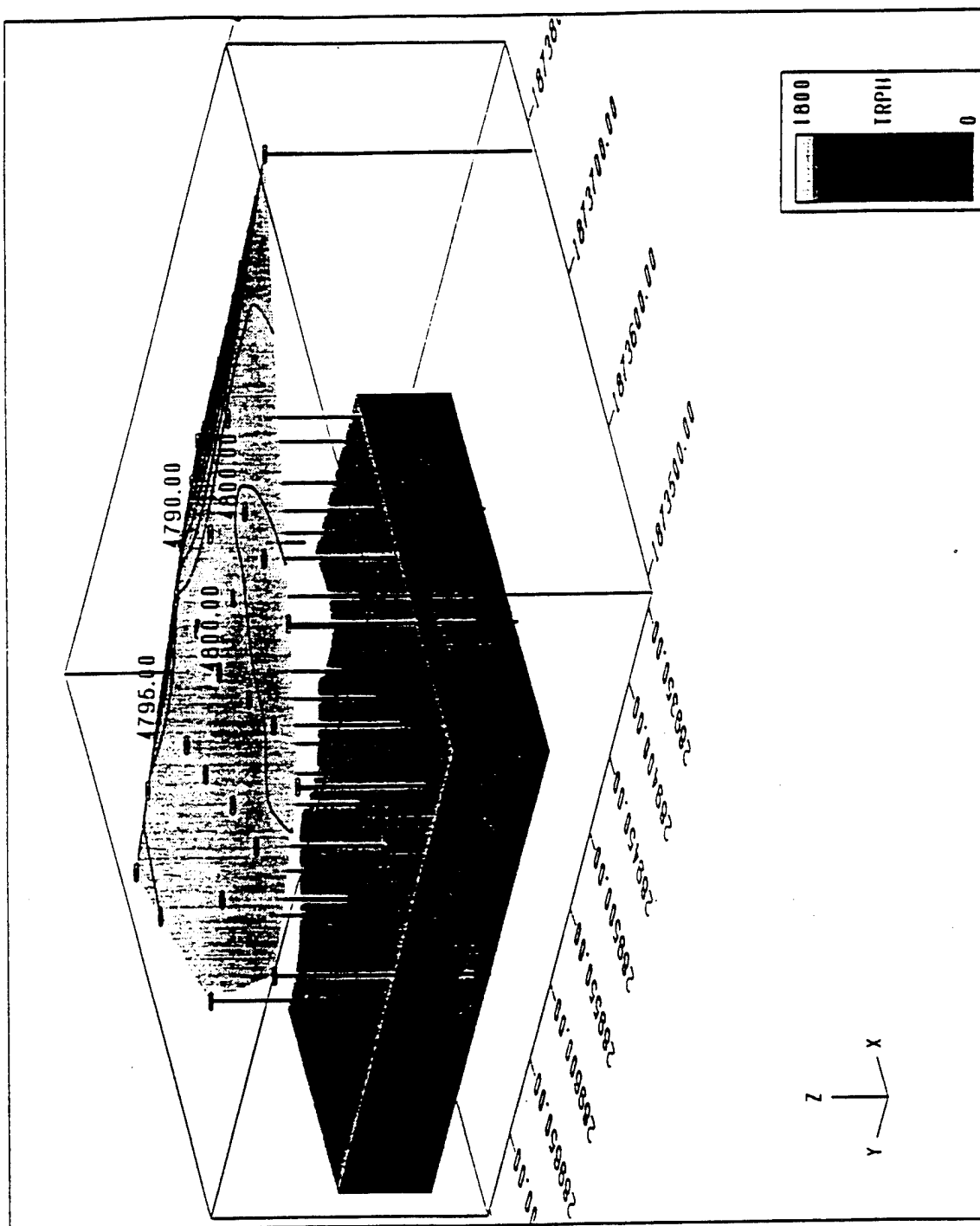


Figure 3.10 Iso Surface of region with LIF TPRPH values above 400 ppm TPRH.

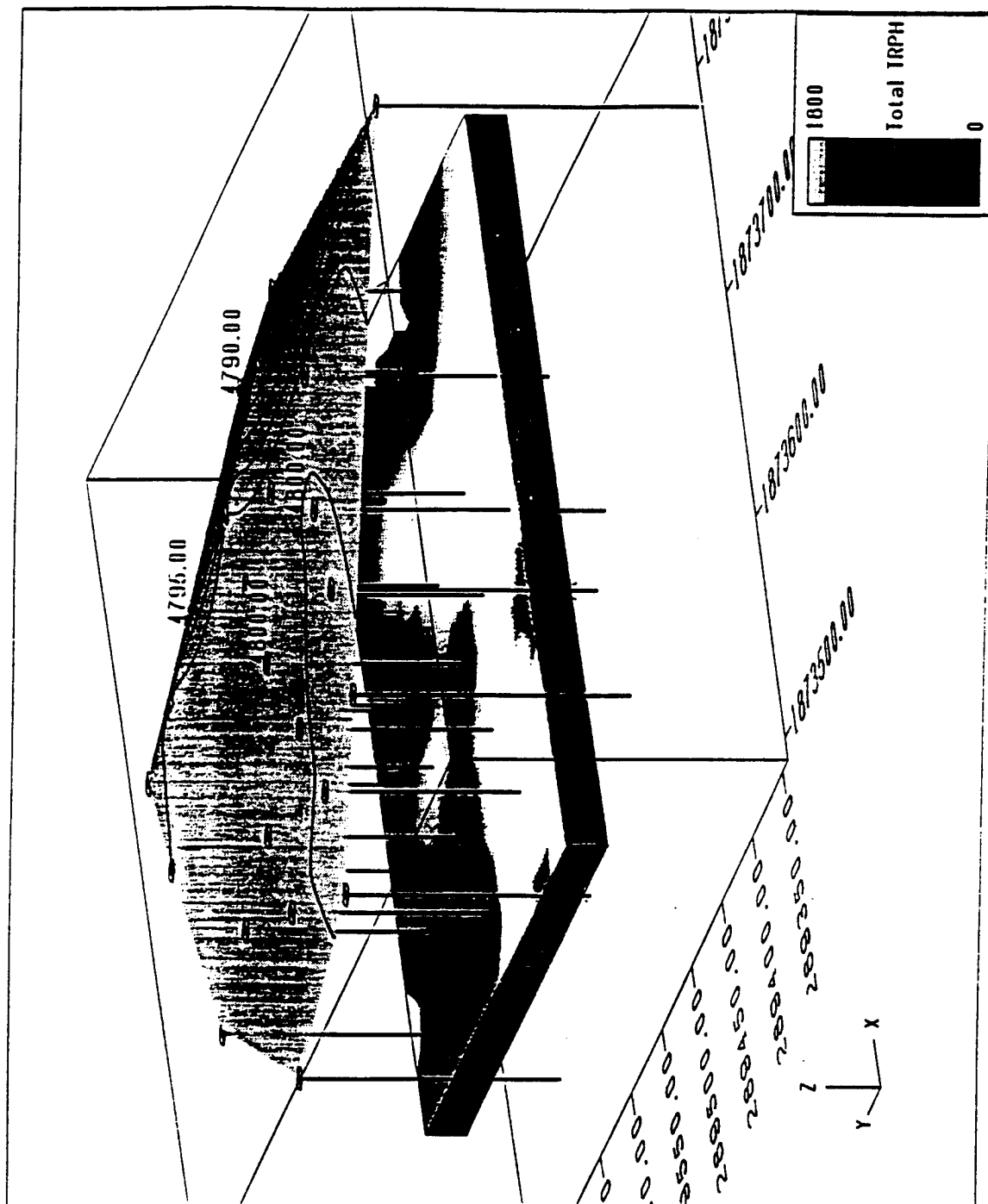


Figure 3.11 Iso Surface of soil sample TRPH values above 400 ppm.

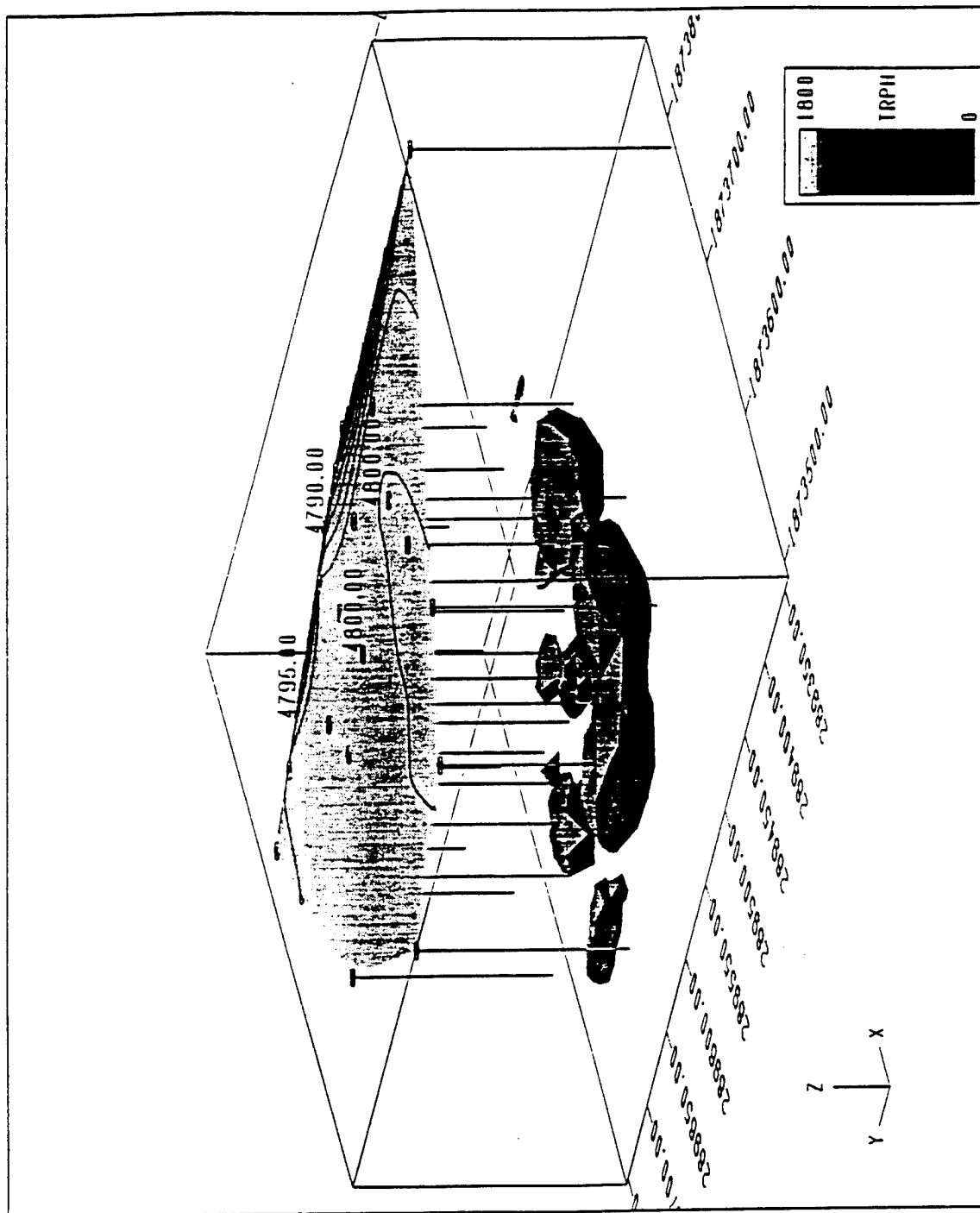


Figure 3.12 Iso Surface of region with TRPH values above 1000 ppm TRPH.

C. Soil Classification From the CPT

The tip resistance, friction ratio, and pore pressure values from CPT profiles can be used to determine a soil stratigraphy profile. The methodology used in this report to classify the soils is based on specific empirical correlations developed by Timian et al., (1992) from modified

Robertson (1988) charts. The two methods are summarized in the two charts shown in Figure 3.13. In general, clean, coarse grained soils have high strengths with relatively low sleeve friction, while finer grained soils have low strengths and high side friction (cohesion). Similarly, as shown in the second chart of Figure 3.13, a correlation exists between soil type and the ratio of tip stress to pore pressure response. Clean, coarse grained soils tend to have high strengths, but are permeable and develop little or no excess pore pressure during penetration. Fine grained soils are weak and impermeable and tend to develop high excess pore pressures during penetration.

Soil classification can be determined from the charts by comparing the normalized tip resistance to the pore pressure ratio or to the normalized friction ratio. The tip resistance is normalized according to:

$$q_n = \frac{q_T - \sigma_{vo}}{\sigma_{vo}'} \quad (3.1)$$

where:

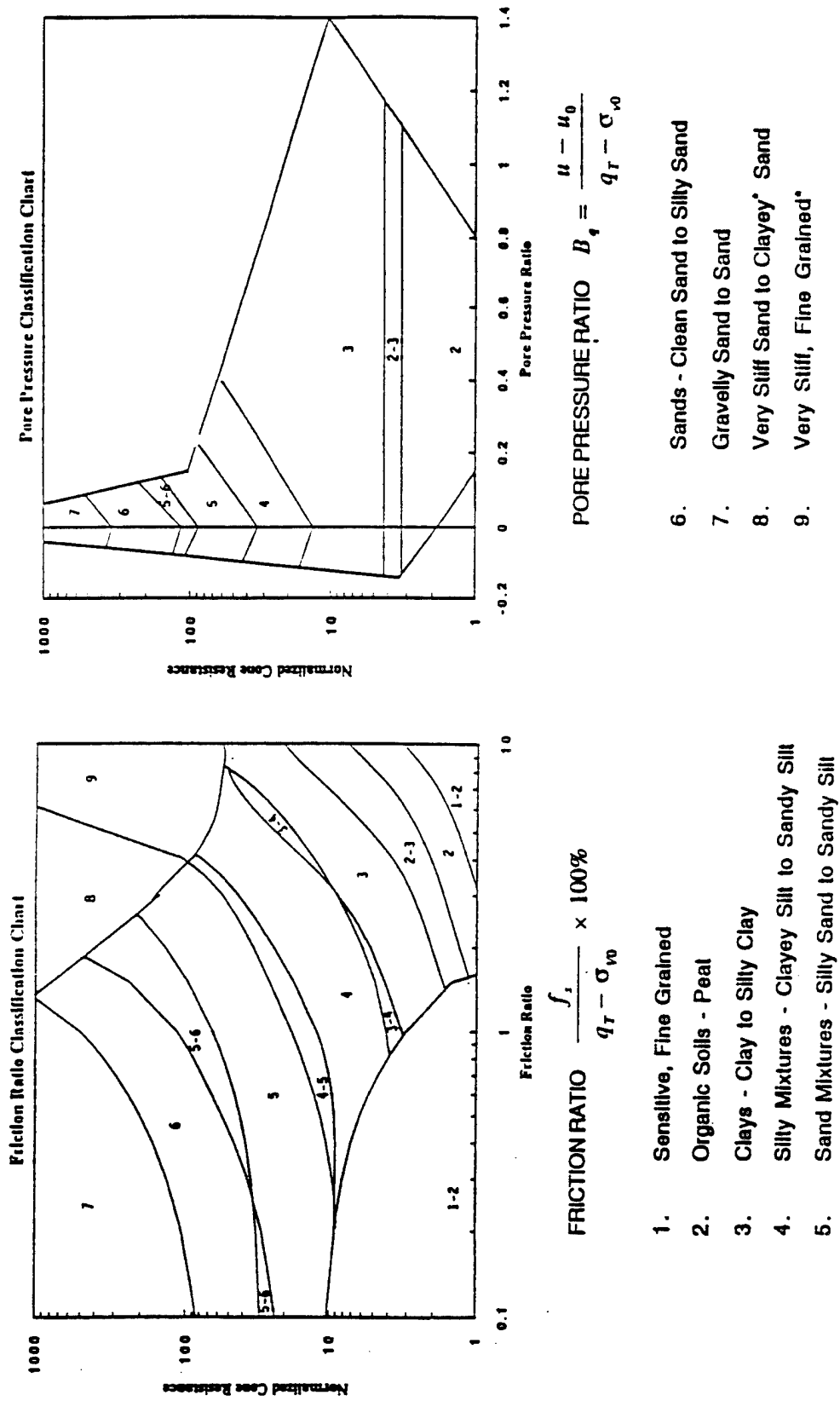
q_n	= normalized tip stress
q_T	= corrected tip resistance from Equation 2.2
σ_{vo}	= total overburden stress
σ_{vo}'	= effective overburden stress

The pore pressure ratio, B_q , is defined as:

$$B_q = \frac{u_{meas} - u_o}{q_T - s_{vo}} \quad (3.2)$$

where:

u_{meas}	= measured penetration pore pressure
u_o	= static pore pressure, determined from the water table elevation



(*) Heavily Overconsolidated or Cemented

Figure 3.13 ARA's Soil classification charts based on CPT data.

and the normalized friction ratio, f_{SN} is defined as:

$$f_{SN} = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \quad (3.3)$$

The plot of any point of the q_n versus B_q or f_{SN} value normally falls in a classification zone of Figure 3.13. The classification zone number corresponds to a soil type as shown in the figure. The classification zone number is then used to determine the Unified Soil Classification System (USCS) profile (described below) which is then plotted versus elevation for each penetration test as shown in Figure 3.14. At some depths, the CPT data will fall outside of the range of the classification chart. When this occurs, no data is plotted and a break is seen in the classification profile.

The next step in developing the soil classification profile is reconciliation of the similarities and differences between the two soil classification methods shown in Figure 3.13 into a single unified estimate, as shown in the classification profile indicated in Figure 3.14. This profile represents a point by point weighted average of the two methods, with weighting factors based on confidence levels established for each measurement used in the classifications. These confidence levels are based on measurement amplitudes, consistency, and engineering experience with CPT data.

The classification profiles are very detailed, frequently indicating significant variability in soil types over small changes in elevation. To provide a simplified soil stratigraphy for comparison to standard boring logs, a layering and generalized classification system was implemented (i.e., soil unit descriptions located to the right of the classification profile). A minimum layer thickness of 1.0 feet was selected. Layer thickness is determined based on the variability of the soil classification profile. The layer sequence is begun at the ground surface and layer thickness is determined based on deviation from the running mean of the soil classification number. Whenever an additional 6 inch increment deviates from the running mean by more than 0.50, a new layer is started, otherwise, this material is added to the layer above and the next 6 inch section is evaluated.

U1-942-27

APPLIED RESEARCH ASSOCIATES, INC.

12/16/94

North 289562.25

East 1873661.18

Elevation 4800.02

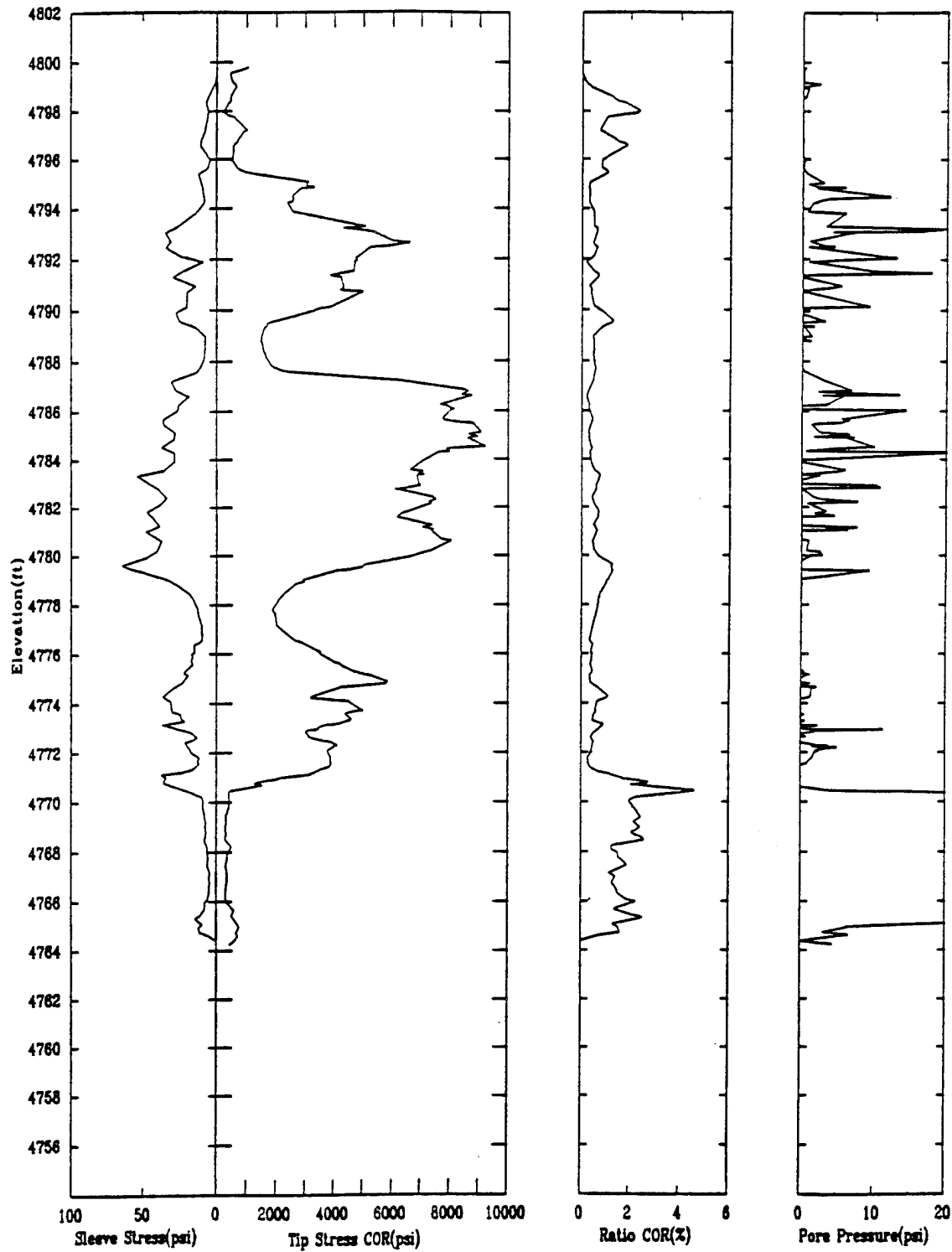


Figure 3.14 Typical LIF-CPT penetration profile from the Hill AFB sites.
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U1-942-27

APPLIED RESEARCH ASSOCIATES, INC.

12/16/94

North 289562.25

East 1873661.18

Elevation 4800.02

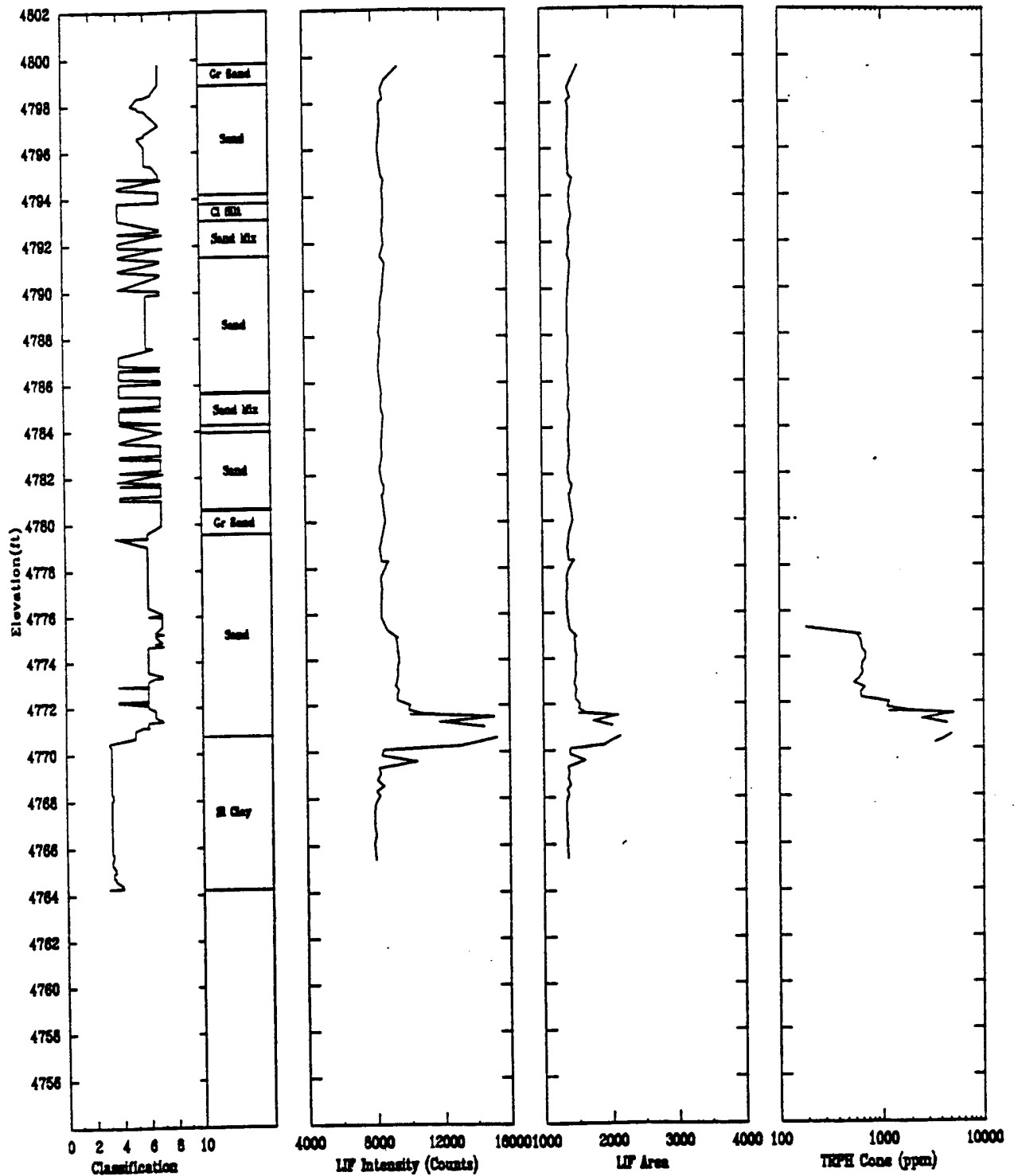


Figure 3.14. (cont'd) Typical LIF-CPT penetration profile from the Hill AFB sites.

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The soil type for the layer is determined by the mean value for the complete layer. The ten types are classified as:

<u>Classification Range</u>	<u>Soil Type</u>
1.00 - 2.25	Sensitive Clay
2.25 - 2.75	Soft Clay
2.75 - 3.25	Clay
3.25 - 3.75	Silty Clay
3.75 - 4.25	Clayey Silt
4.25 - 4.75	Sandy Fine Grained
4.75 - 5.75	Sand Mixture
5.75 - 6.75	Sand
6.75 - 7.50	Gravely Sand
7.50 - 9.00	Over Consolidated (OC)

Again, a more detailed classification can be determined from the classification profile plotted just to the left of the soil type (unit) layers. The layering provides a summary of the engineering classification of soil stratigraphy.

1. Discussion of a Typical CPT Derived Soil Stratigraphy

A typical penetration profile from Hill AFB Operable Unit 1 is presented in Figure 3.14. This profile (U1-942-27) was completed to a depth of approximately 36 ft and presents all of the geologic features present in the area. These data, as well as the other penetration data, are presented in Section VI. These plots include the sleeve stress, tip resistance, friction ratio, penetration pore pressure, along with the soil classification and soil stratigraphy calculated from the data.

Both tip and sleeve resistance are strongly dependent upon the shear strength and stiffness of a soil. As the strength and stiffness of a soil increases, so will the tip resistance and sleeve stress. The friction ratio is also a function of strength and stiffness and is strongly influenced by the cohesive strength of the soil. In clayey soils, adhesion between the soil and sleeve increases the friction acting on the sleeve, resulting in an increase in the friction ratio. This effect is used to identify soil from the tip and friction ratio, with the tip stress decreasing and the friction ratio increasing as the clay content increases. The pore

pressure profiles are also very useful for determining soil type, as fine grained materials will generate excess pore pressures and sand will generally track on the hydrostatic line below the water table.

The soil classifications and stratigraphies presented in this report are based upon empirical correlations developed by ARA for CPT data as discussed above. The discussion which follows uses both the CPT stratigraphy and the stratigraphy derived from the resistivity profile to determine the soil layering. To simplify the discussion only the major layers and dominant geologic features are discussed.

2. Discussion of Geologic Unit Encountered at Location U1-942-27

The first major geologic unit extends from the ground surface to a depth of 4 ft at Location U1-942-27. This unit consists of a silty soil and is fairly consistent. The average tip stress in this material is 600 psi and the friction ratio averages about 1.5. At a depth of 4 to 5 feet throughout the site, the Provo formation is encountered. The thickness of this unit varies across the site, with an average thickness of 25 feet on the northeast side of the site. The layer thins down in the hole due to a reduction in the ground surface elevation. This material is characterized by a very high tip stress value, indicating fairly dense soils such as gravely sand (shown on the stratigraphy profile). Although these materials are generally gravely in nature, they also have a significant amount of silt material as evidenced by the excess pore pressures generated in Figure 3.14. In general, the pore pressure profile through the Provo formation indicates that the soils have some fine grained materials present and are moist. There does not appear to be much free water that can be sampled or extracted using standard hydraulic controls in the time frame typical of CPT sampling activities.

At most locations throughout the site, three separate zones within the Provo formation can be determined. For Location U1-942-27, the upper unit begins at an elevation of 4,796 ft and extends to an elevation of 4,790. Over this depth, the tip stress averages 4,000 psi and the sleeve stress averages 30 psi. From elevation 4,790 to 4,788, both tip stress and sleeve stress decrease. The second region of Provo formation extends from elevation 4,788 to elevation 4,779 ft. This region is generally stiffer than either the upper or lower regions of the Provo formation. The average tip stress is 7,000 psi while the sleeve stress averages 40 psi. The third unit begins at elevation 4,776 ft. As before, both the tip stress and sleeve stress decrease between regions and represent a transition from gravely silt to a sandy silt material. The third region of the Provo formation is very similar to the upper most region in that the average tip stress is approximately 4,000 psi and the sleeve stress averages 30 psi.

The Provo formation is underlain by the Alpine formation at an elevation of 4,770 ft at Location U1-942-27. The Alpine formation consists of a medium clay material. The average tip stress of the clay is 200 psi and the sleeve stress averages 10 psi. These values present a ratio of approximately 2.0. A key characteristic of the clay nature of these soils is represented by the large amount of excess pore pressure generated during penetration. At Location U1-942-27 the pore pressures in the Alpine formation exceed 20 psi. This material represents the confining layer for the upper soil environment and therefore should serve as the bottom of the test cells. All penetrations were terminated in this material.

SECTION IV

SUMMARY AND CONCLUSIONS

A. SUMMARY

Applied Research Associated, Inc. completed a site investigation of Operable Unit 1 on Hill AFB near Ogden, Utah. The investigation included the use of ARA's Laser Induced Fluorescence Cone Penetrometer along with the standard CPT measurements. Soil and water sampling were also attempted as part of the CPT investigation. A total of 29 CPT tests were performed to an average depth of 30 feet.

Along with ARA's investigation efforts, TRW independently contracted soil sample collection and analysis. ARA used this analysis for developing correlations with the LIF response. The results compare favorable. The LIF-CPT and the soil sampling both revealed a contaminated region at approximately an elevation of 7,760 ft MSL. This region has a thickness of approximately five feet.

A soil classification analysis of the CPT results was also performed as part of the investigation. This analysis determines the geologic layering at the site and is presented with each profile in Section VI. In general there are three geologic formations present at the site. The first is a silty soil cap across the site to a depth of four feet. The Provo formation of the average is 25 feet thick and begins at a elevation of 4,796 feet. It consists primarily of gravely sands with a significant amount of silts present. The Alpine formation consists of a medium clay material and begins at a elevation of 4,770 feet. This formation represents the confining layer for the site and therefore should serve as the bottom of the test cells.

B. CONCLUSIONS AND RECOMMENDATIONS

During this investigation water sampling with CPT was attempted at one location. As discussed in Section II, inflow times were so slow that water sampling with the CPT truck was abandoned due to time constraints. It should be noted that the CPT truck is capable of installing one inch diameter well points. These well points could be used to recover water samples at a later time.

From the investigation using LIF-CPT, we were able to determine the locations and extent of the contamination as shown in Figures 3.10 and 3.12. The TPH data from the soil sampling effort confirms the results of the LIF as shown in Figure 3.11. This investigation has shown that the LIF-CPT is an excellent screening tool for locating contaminants and determining where to take soil samples and place monitoring wells. The LIF was very useful for identifying the smear zone present in the stratigraphy due to the fluctuations in the water table. The comparison of the LIF-CPT data with the soil sample TPH analysis demonstrates that the LIF-CPT is capable of determining rough estimates of the contaminant concentration. From this comparison a correlation between LIF Intensity and TPH was determined for this site to be 1.305 TPH/count with a detection limit of 100 ppm. The correlation is weak due to the sparse data set but is encouraging and shows that the LIF-CPT is more than a screening tool. As more soil samples are collected and analyzed, they could be used to improve the correlation between LIF Intensity and TPH concentration. Also having access to the boring logs would be useful for performing an analysis of the LIF results.

SECTION V

REFERENCES

- American Society for Testing Materials, "Standard Method for Deep Quasi-Static Cone and Friction-Cone Penetration Tests of Soil," ASTM Designation: D3441, 1986.
- Annan, A. P., P. Bauman, J.P. Greenhouse, and J.D. Redman, "Geophysics and DNAPLS," Ground Water Management, No. 5, Proceedings of the Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, Las Vegas, NV, May 1991.
- Chudyk, W., M. M. Carrabba, J. E. Kenny, "Remote Detection of Groundwater Contaminants Using Far-Ultraviolet Laser-Induced Fluorescence," Anal. Chem. 57(6), 1237-1242, 1985.
- Hirschfeld, T., T. Deaton, F. Milanovich, S.M. Klainer, C. Fitzsimmons, The Feasibility of Using Fiber Optics for Monitoring Groundwater Contaminants, Project Summary, Environmental Monitoring Systems Laboratory, U.S.E.P.A., January 1984.
- Gillispie, G.D., and R.W. St. Germain, "In situ tunable laser fluorescence analysis of hydrocarbons," North Dakota State University, Dept. of Chemistry, Fargo, ND, 1992.
- Lieberman, S.H., G.A. Theriault, S.S. Cooper, P.G. Malone, R.S. Olden, and P.W. Lurk, "Rapid, Subsurface, In Situ Field Screening of Petroleum Hydrocarbon Contamination Using Laser Induced Fluorescence Over Optical Fibers," 1992.
- Robertson, P.K. and R.G. Campanella, Guidelines for Using the CPT, CPTU and Marchetti DMT for Geotechnical Design, Vol. II, University of British Columbia, Vancouver, BC, Canada, March 1988.
- Shinn, J.D., and A.F. Rauch, "Resistivity Surveys with the Electric Cone Penetration Technique," Applied Research Associates, Inc., March 1990.

Timian, D.A., W.L. Bratton, B.E. Fisk, "Piezo Electric Cone Penetration Tests In Support of Geotechnical Investigation at Sections 6/7 and 1/9 of fresh kills Landfill, Staten Island, New York-Development of correlation's for soil classification and In-Situ Properties", Applied Research Associates, Inc., May, 1992.

SECTION VI

DATA

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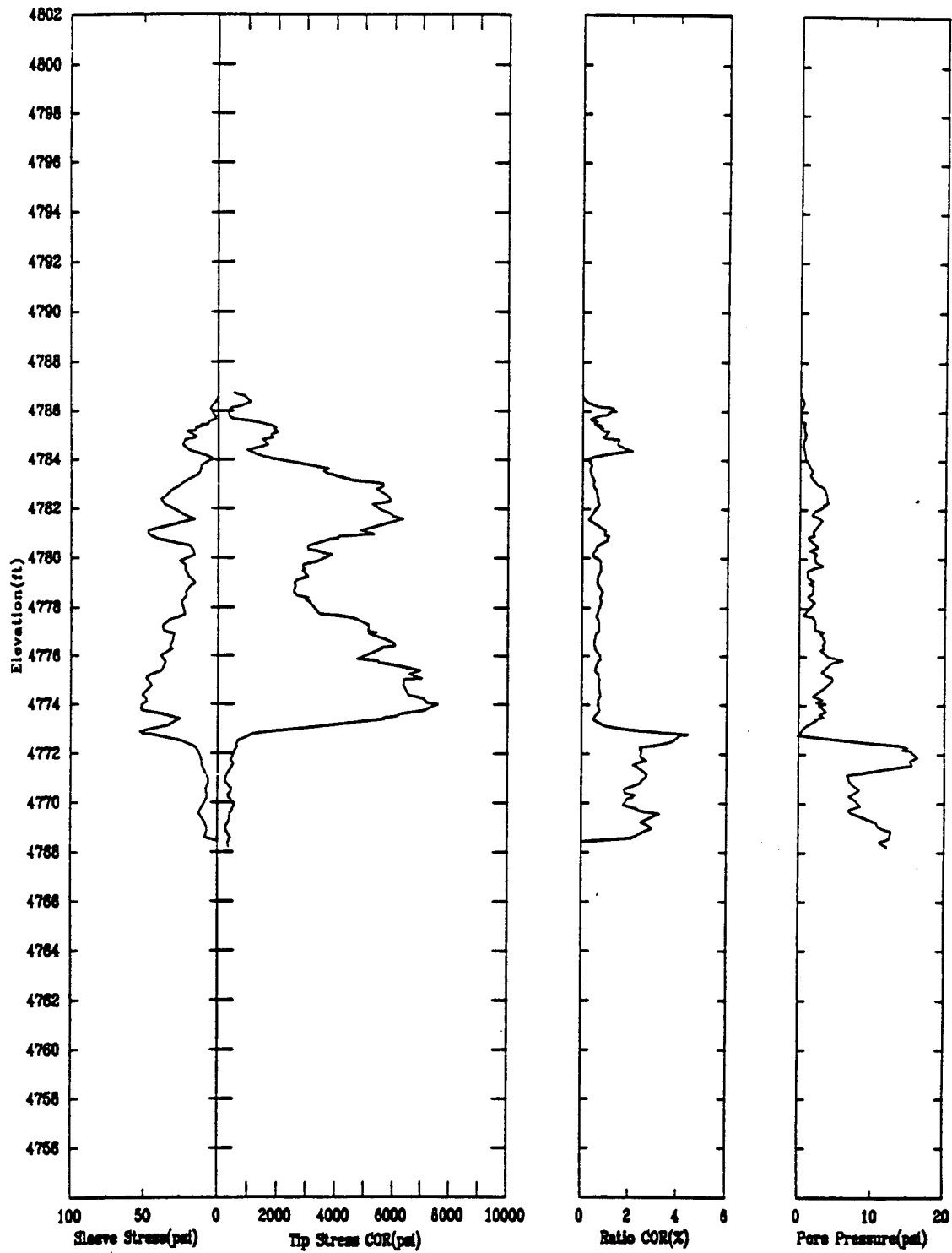
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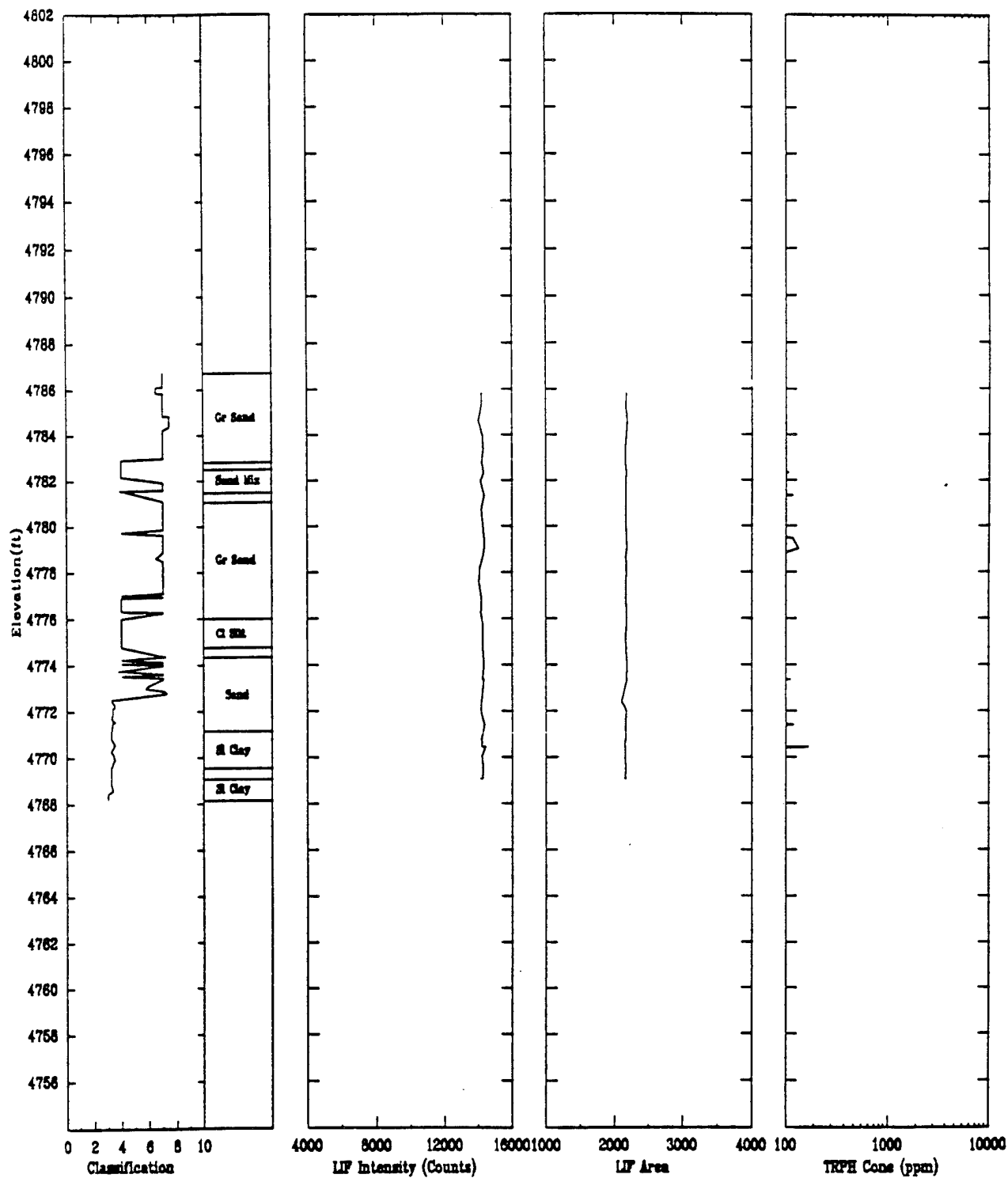
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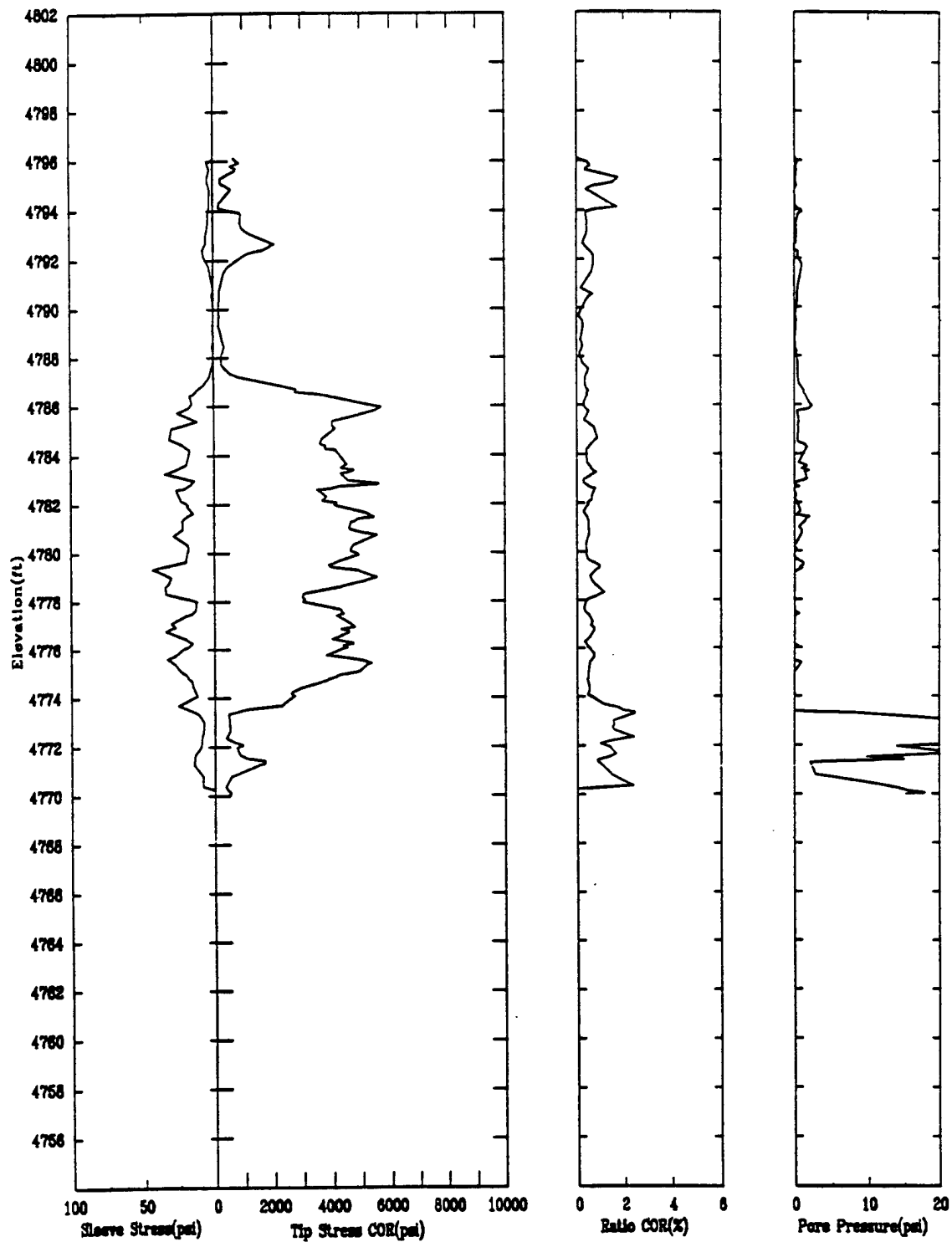
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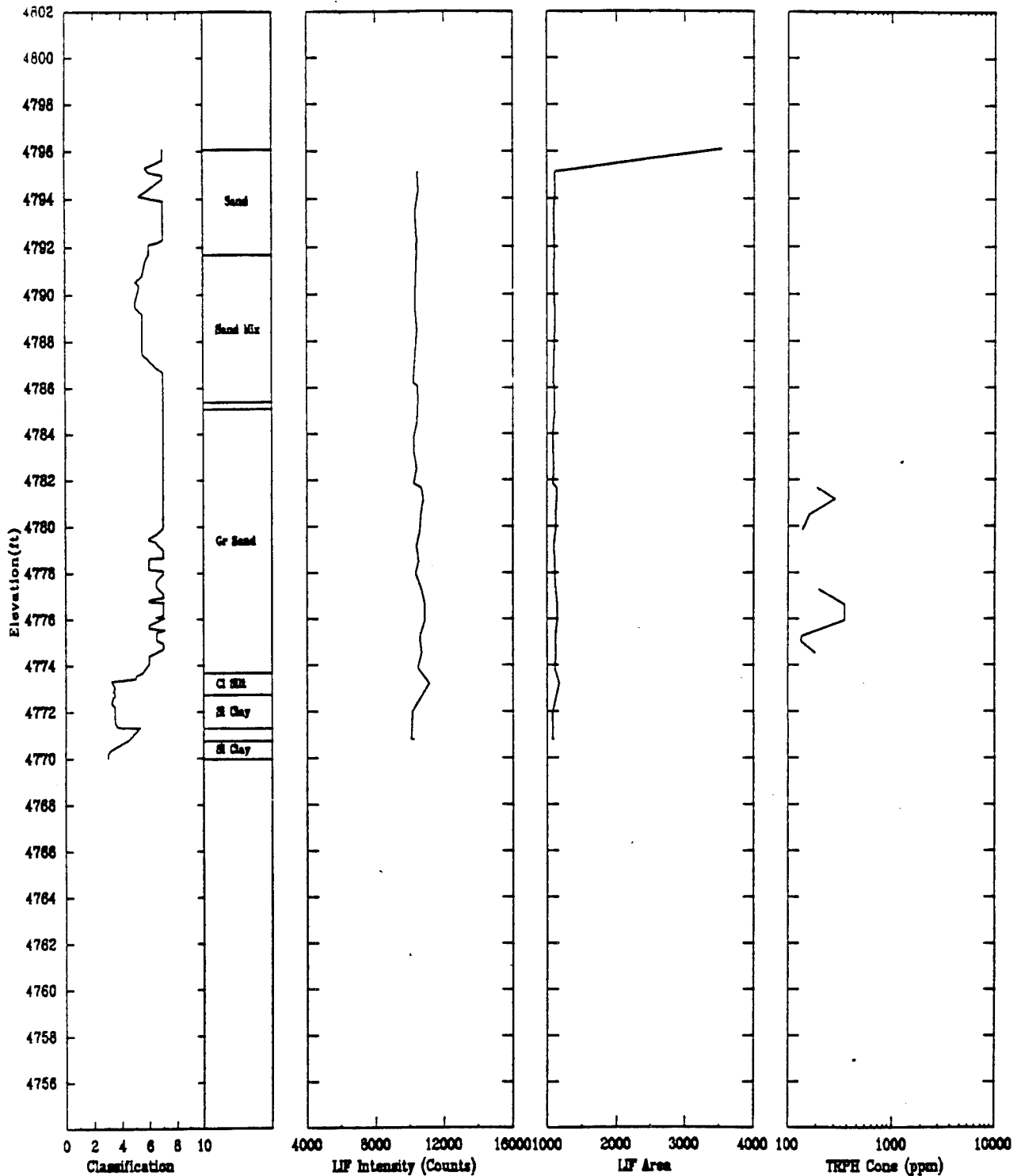
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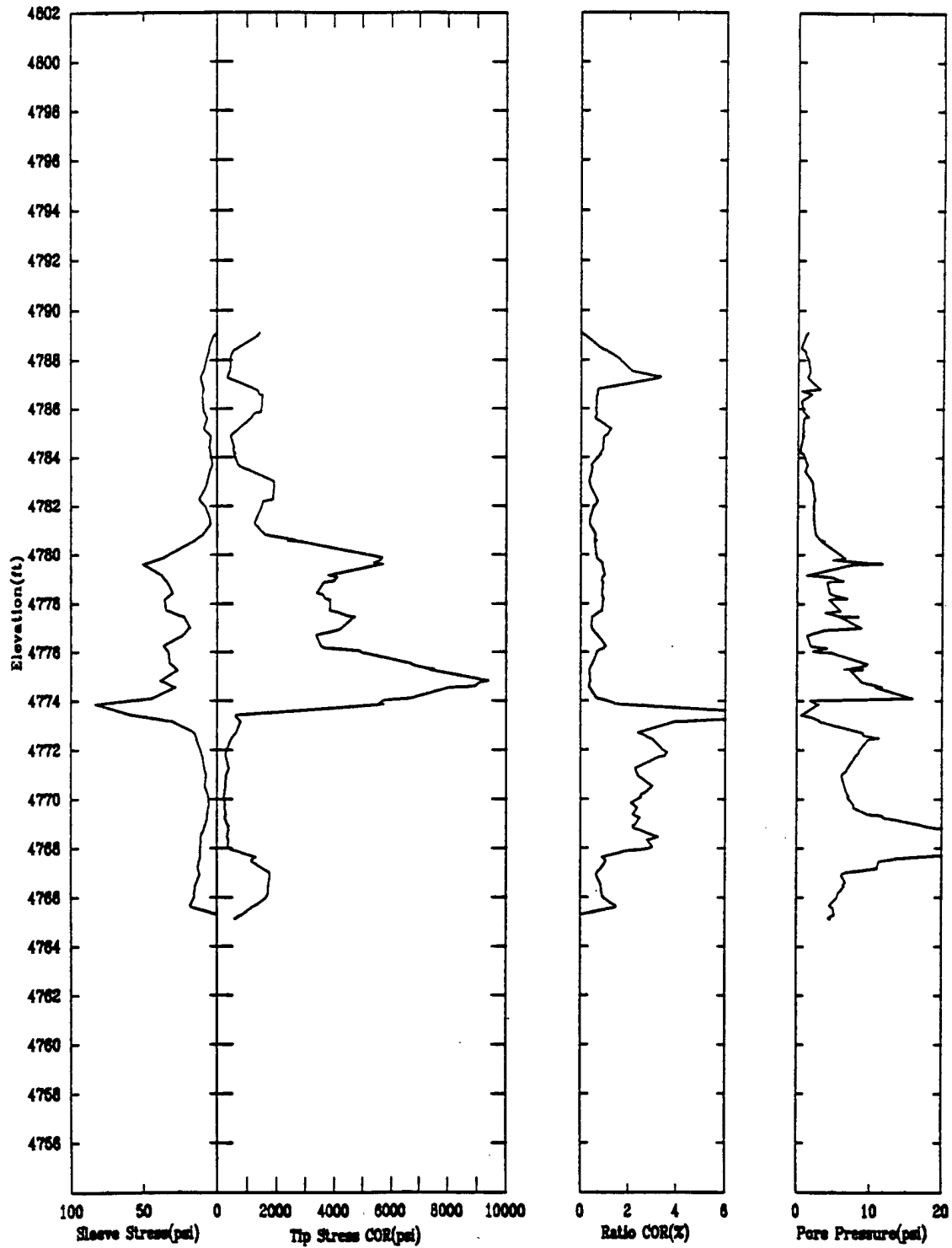
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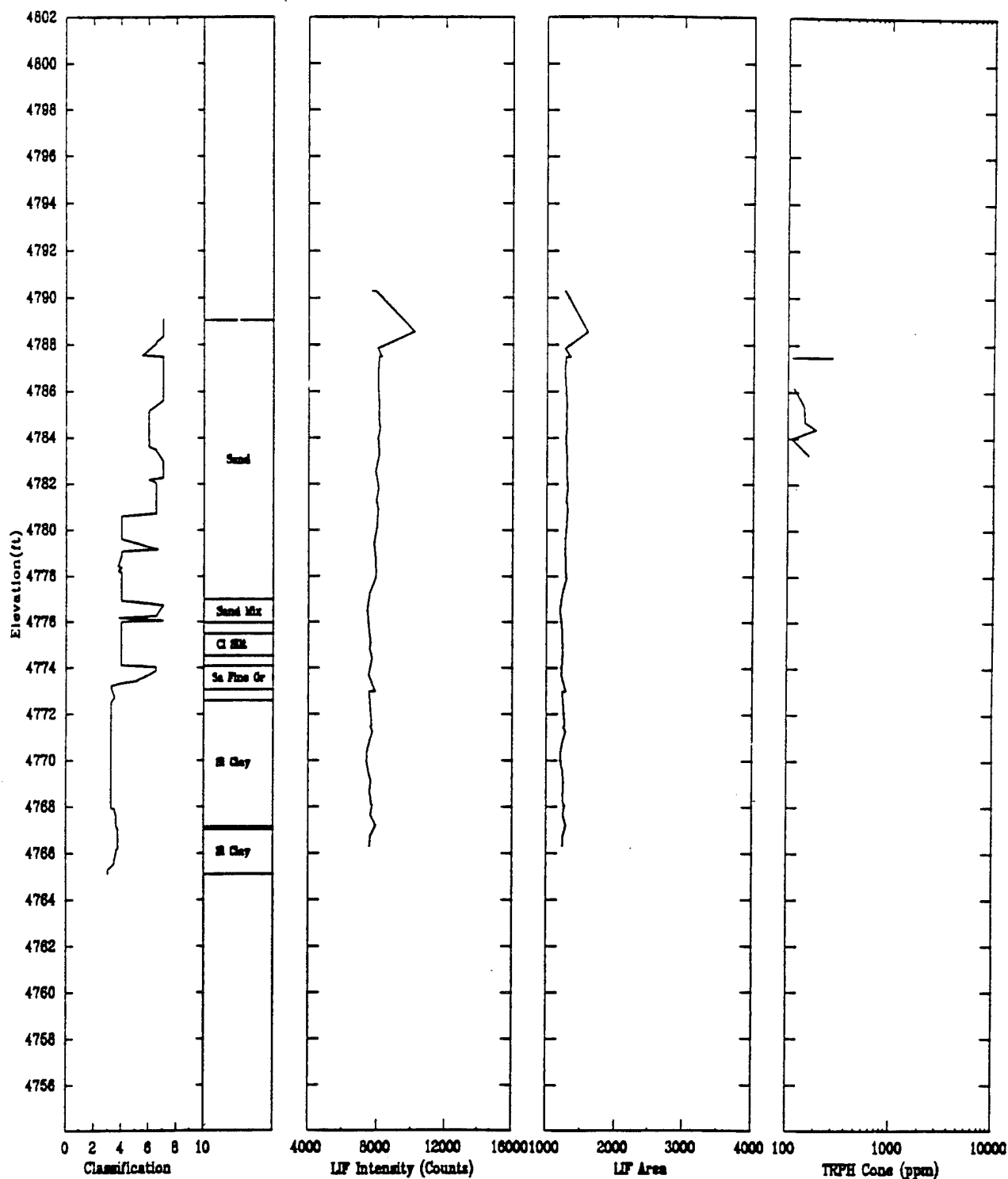
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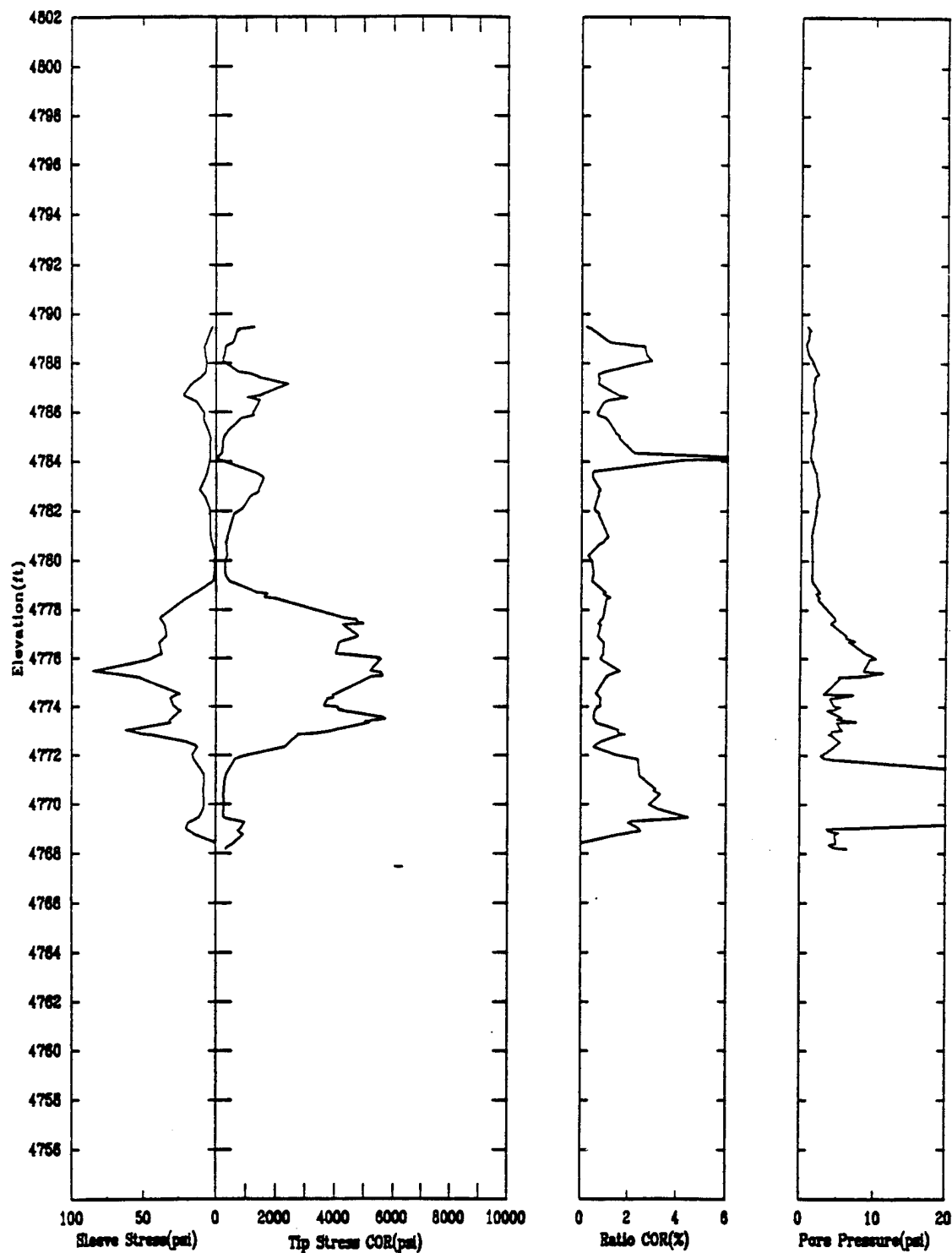
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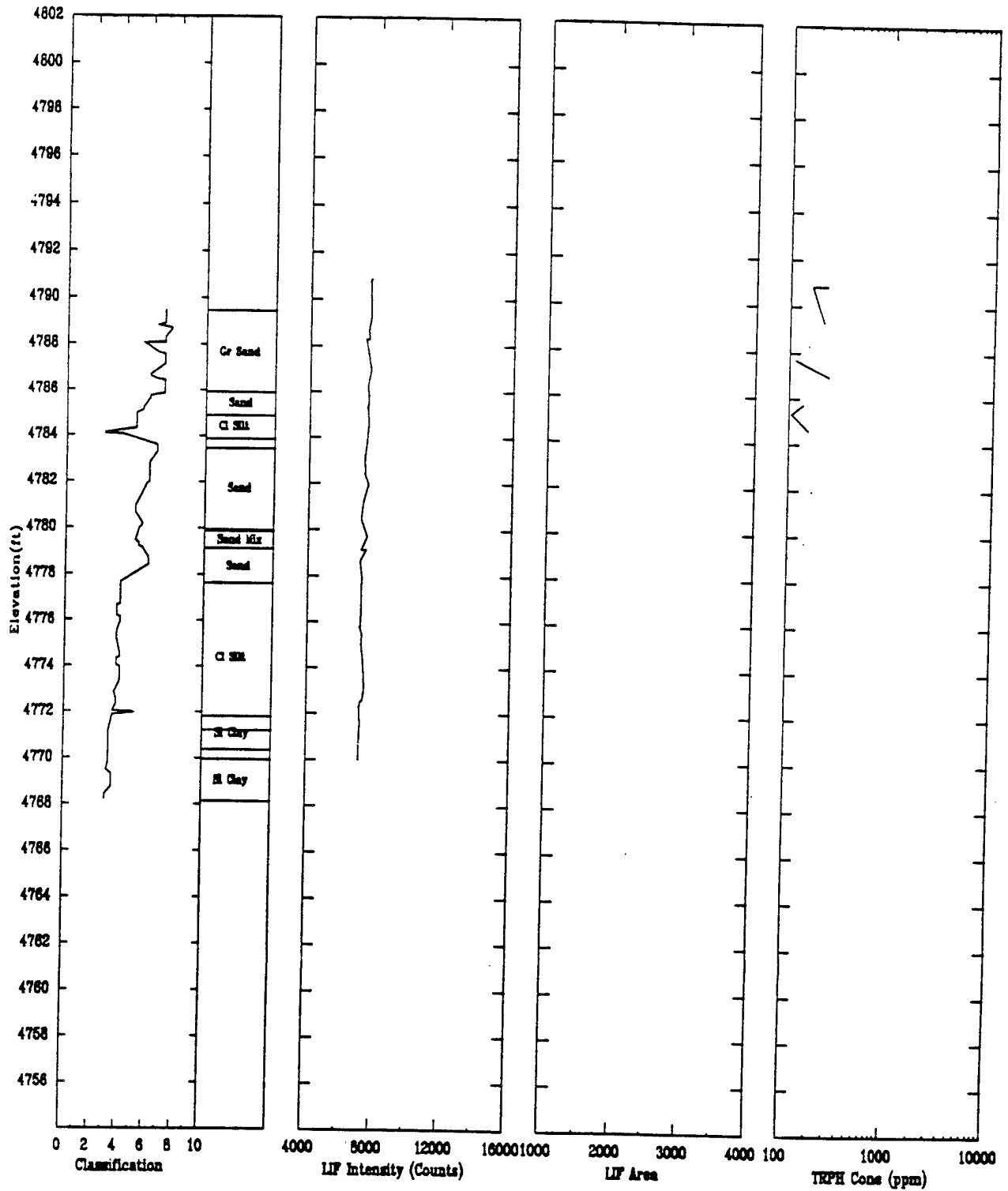
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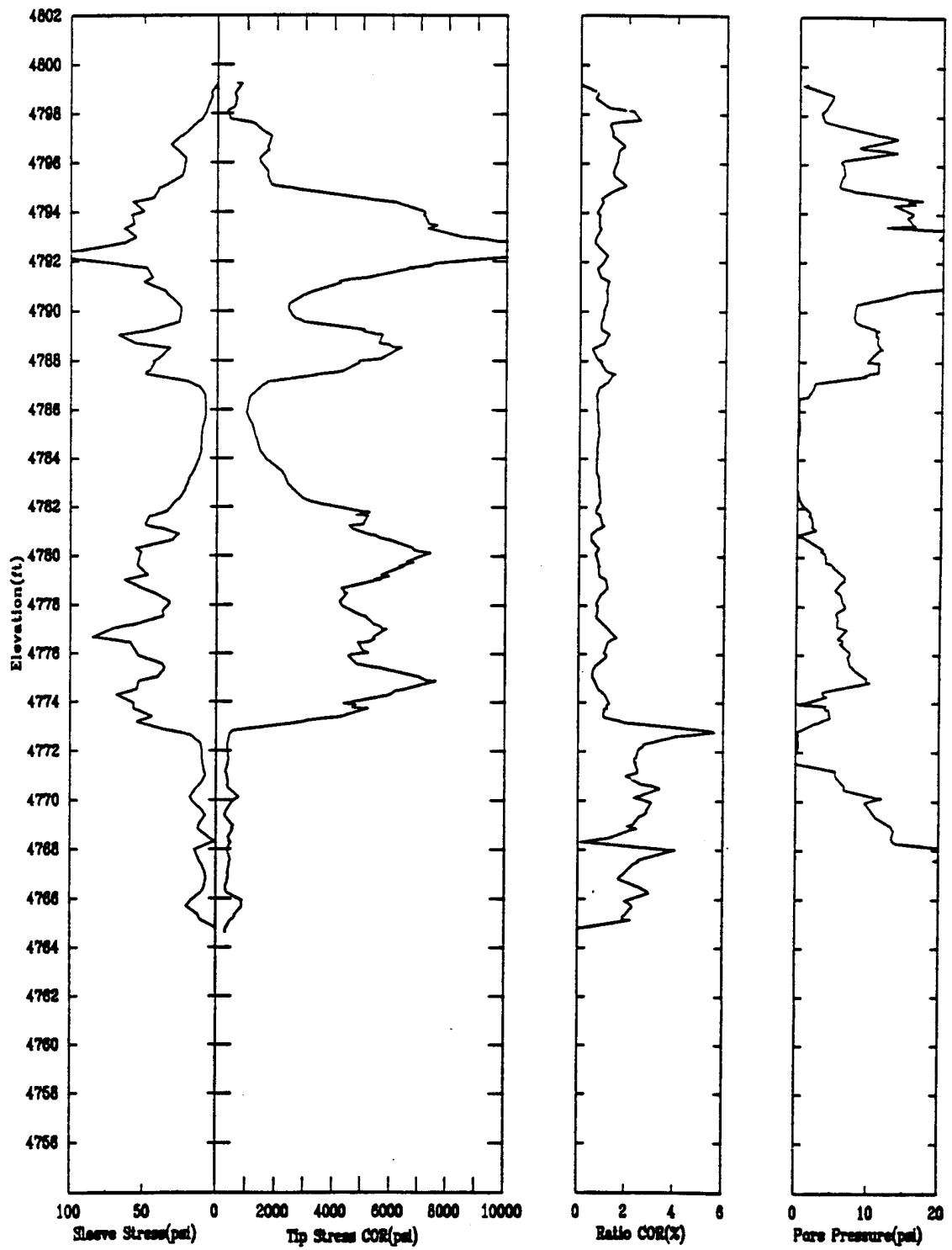
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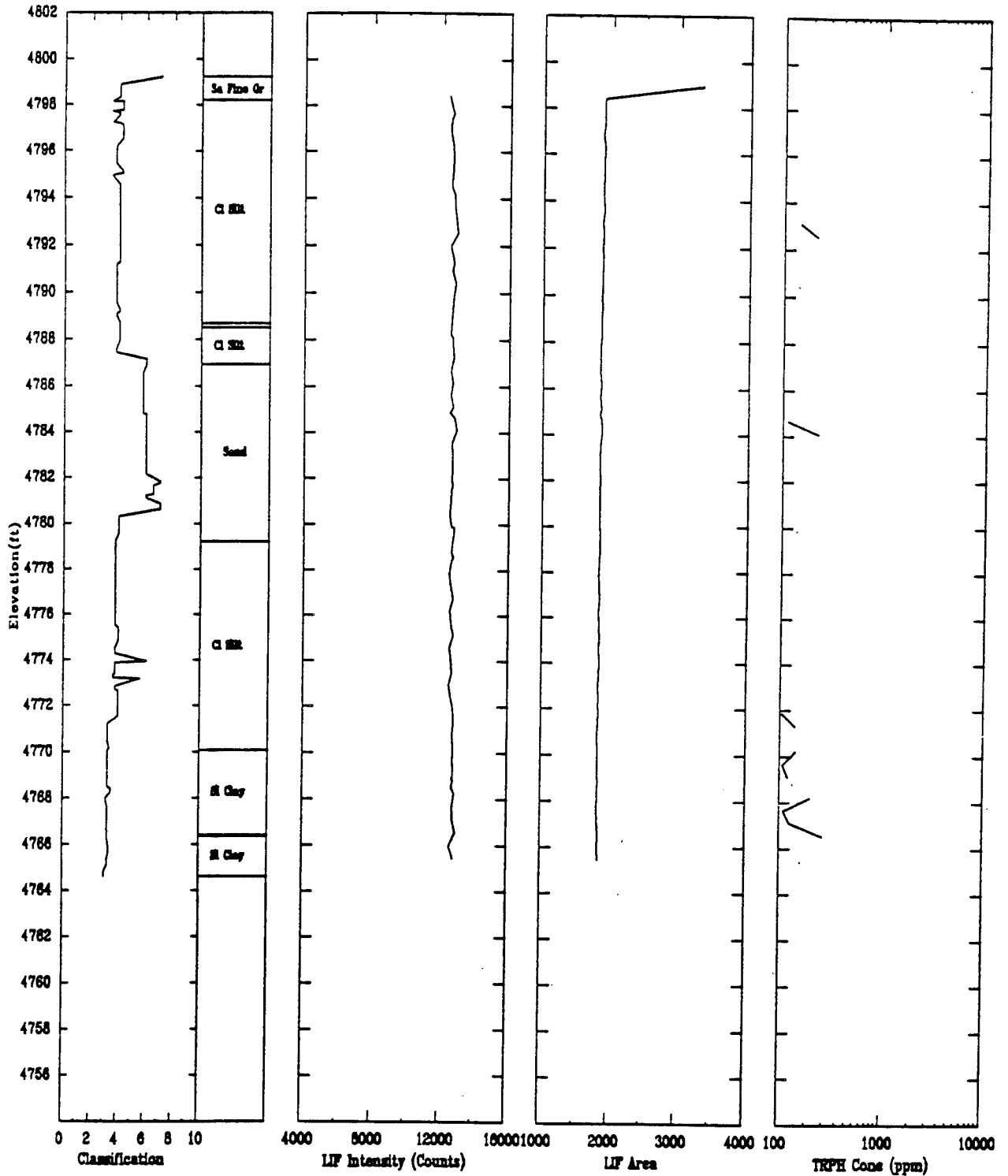
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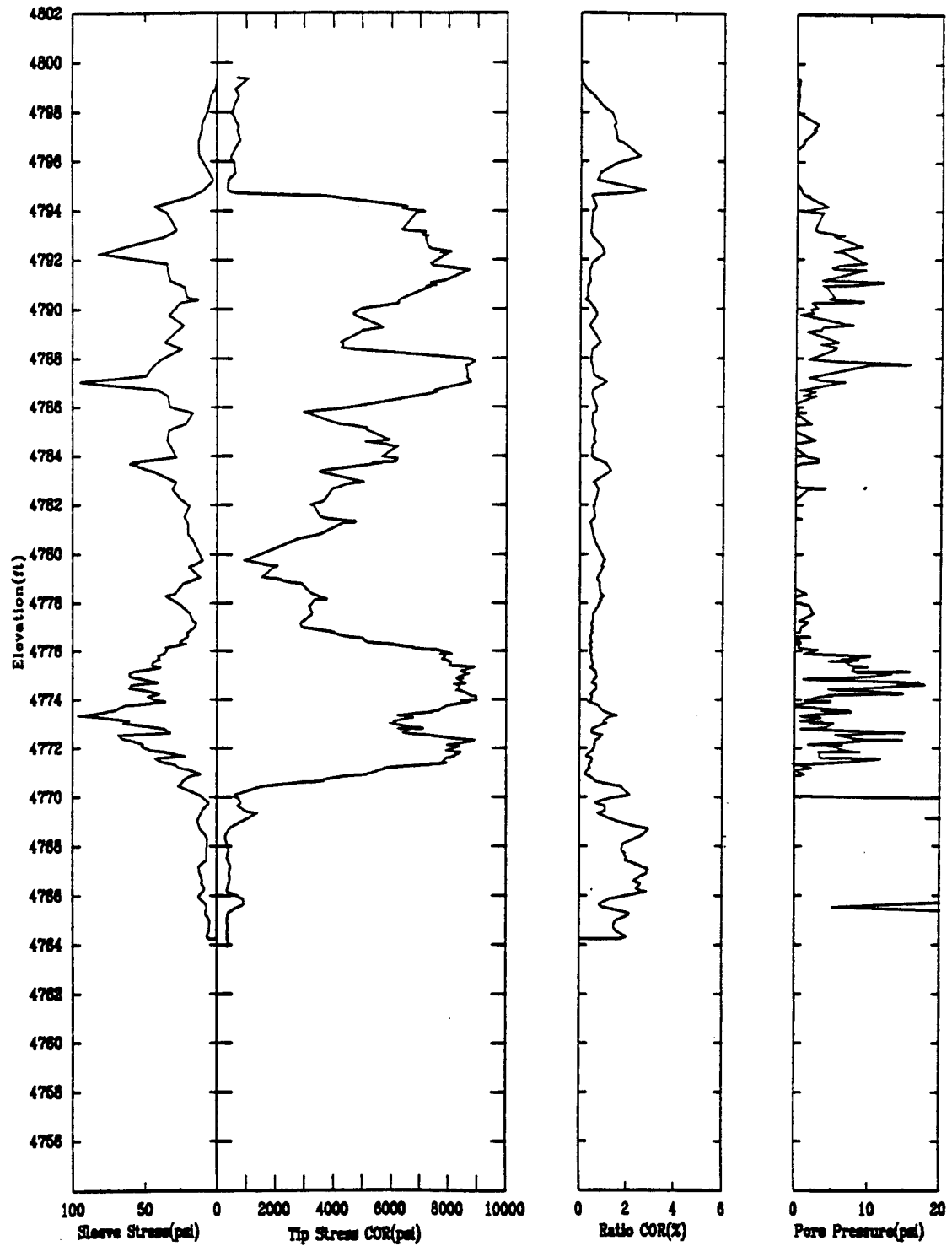
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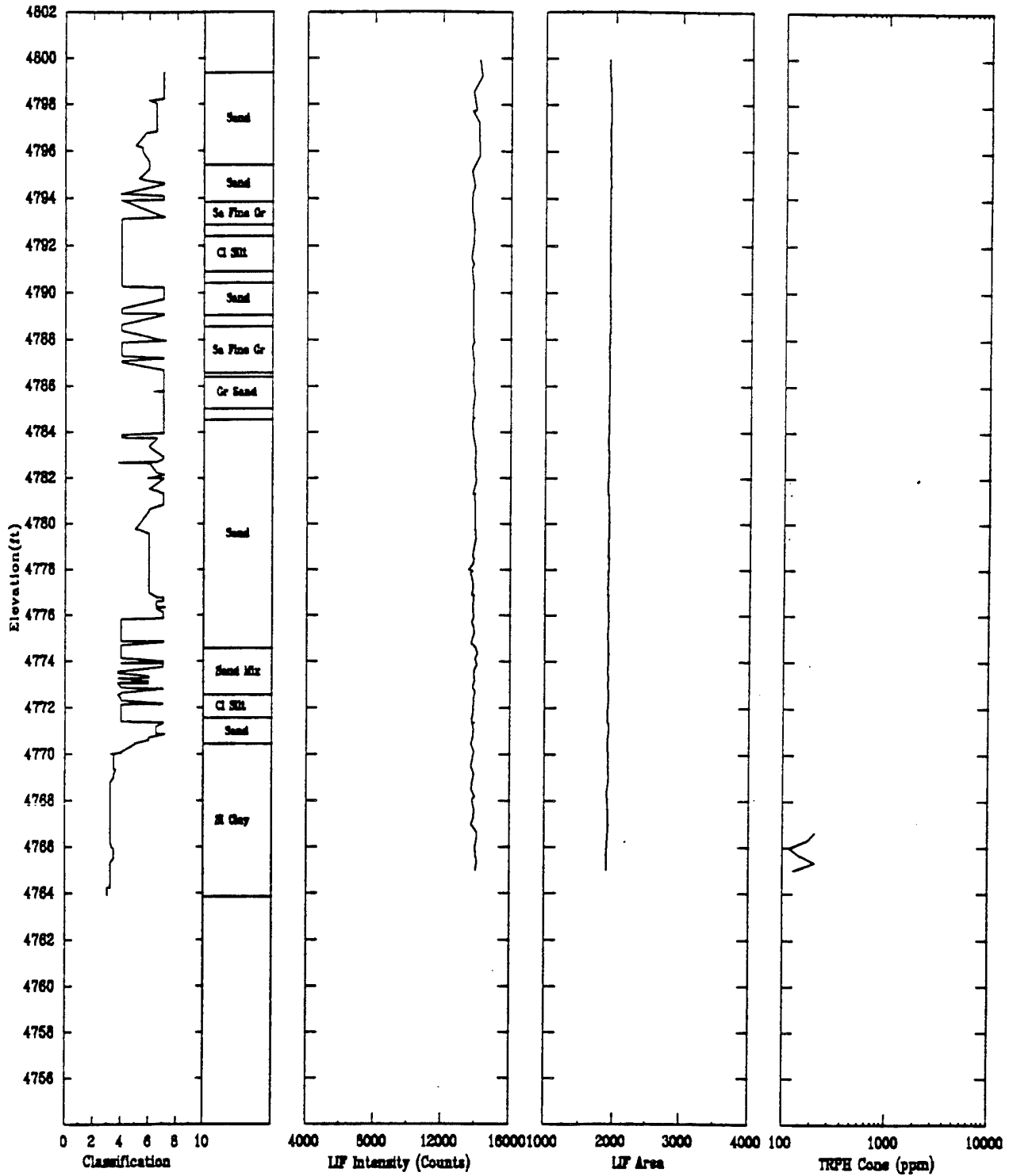
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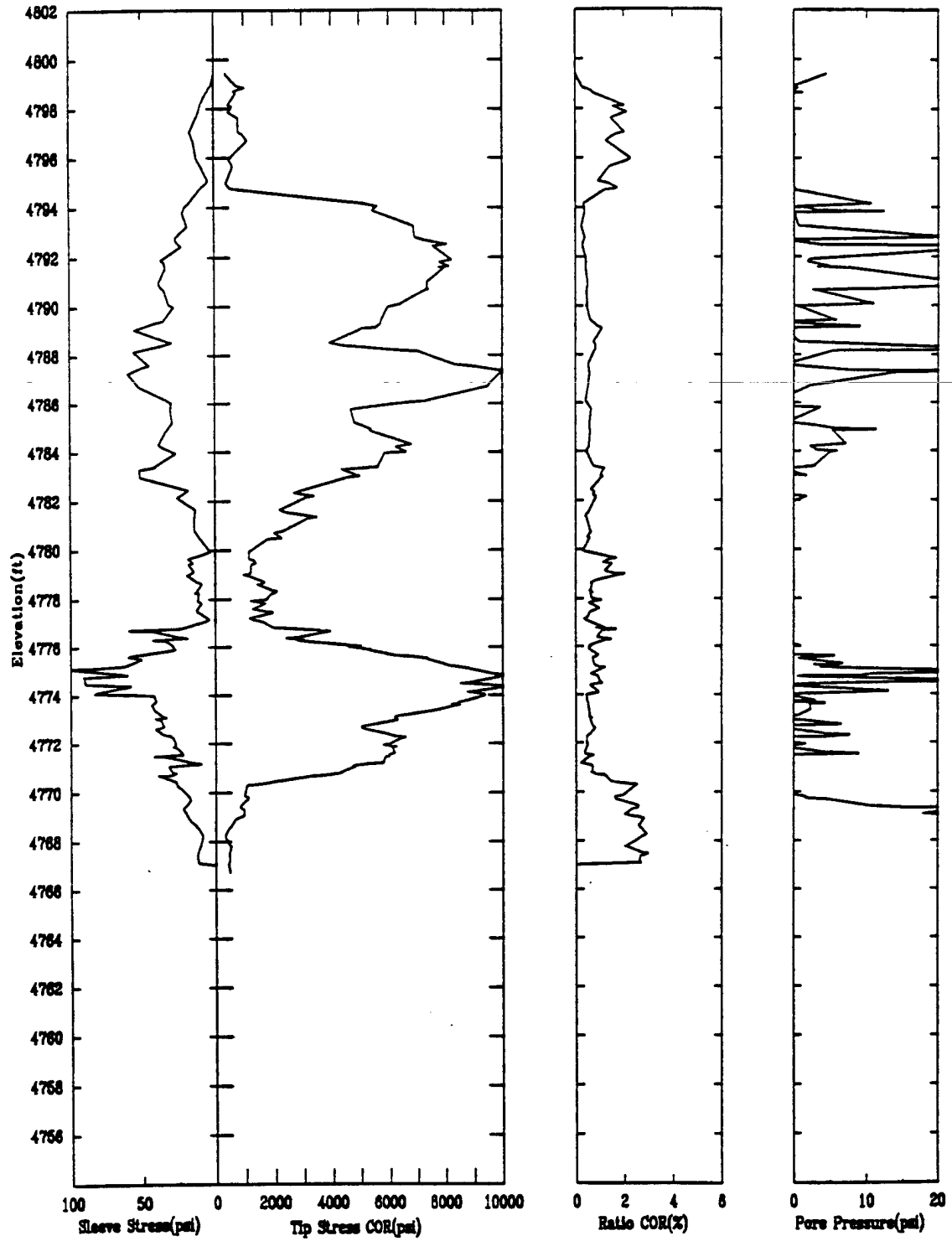
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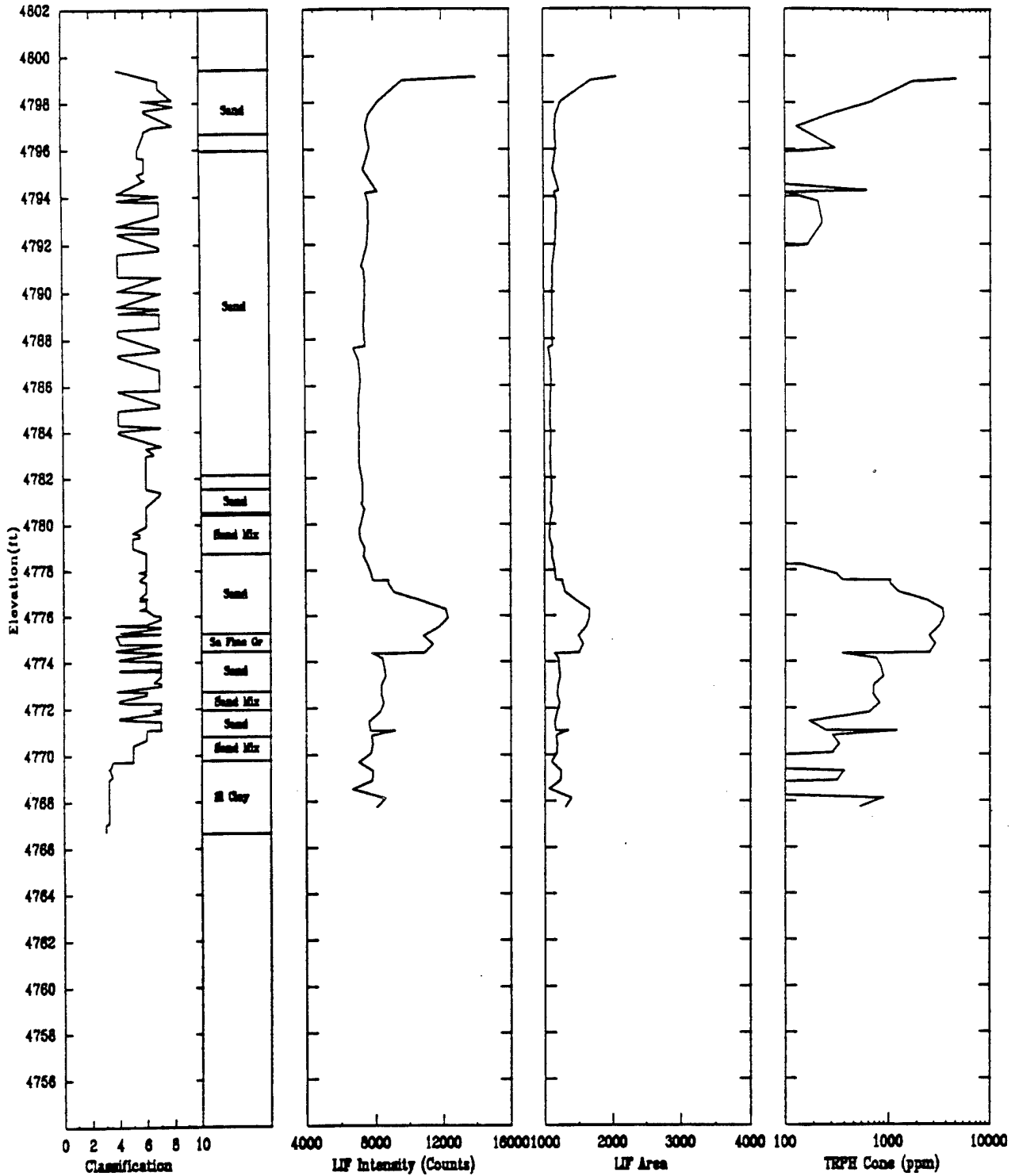
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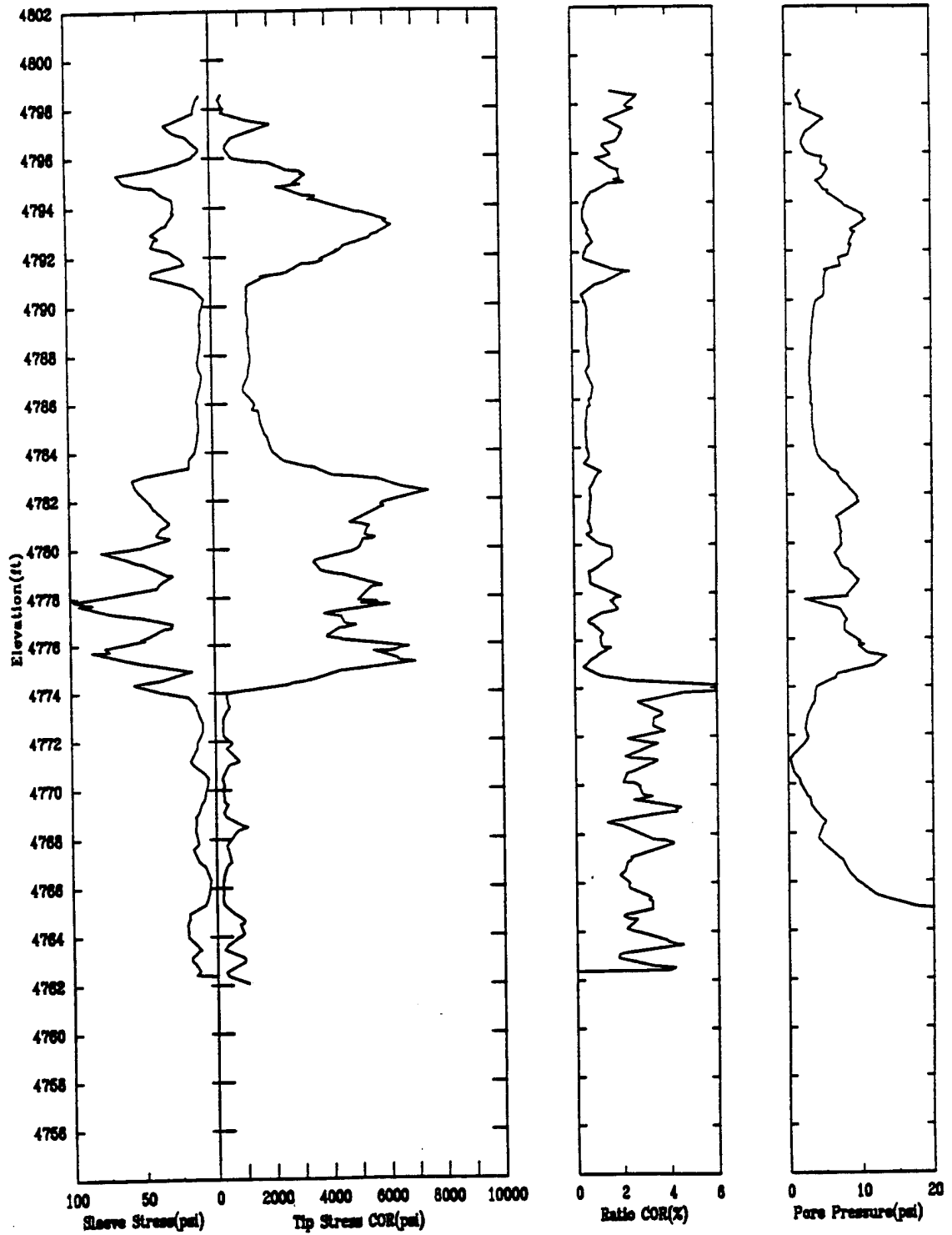
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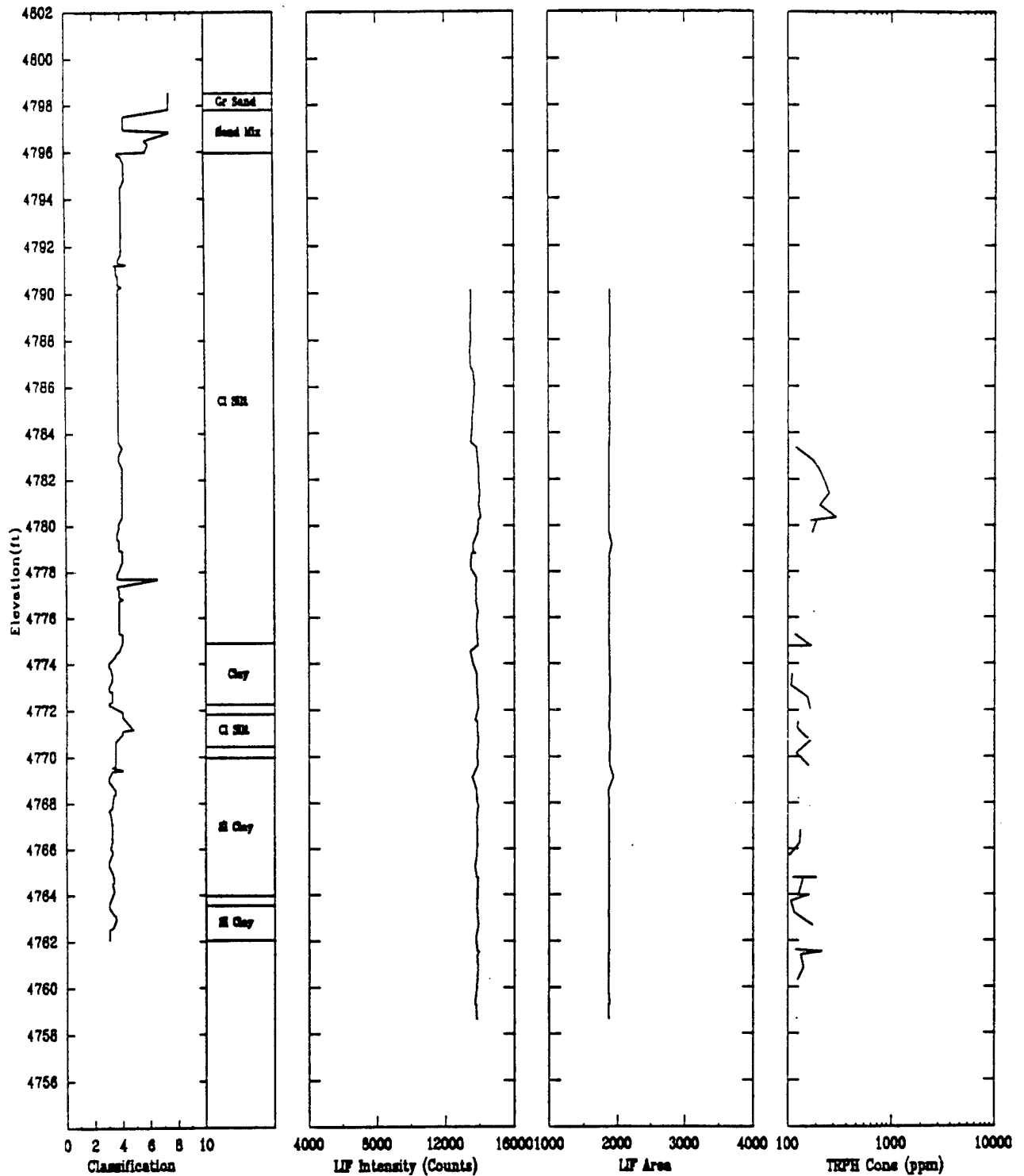
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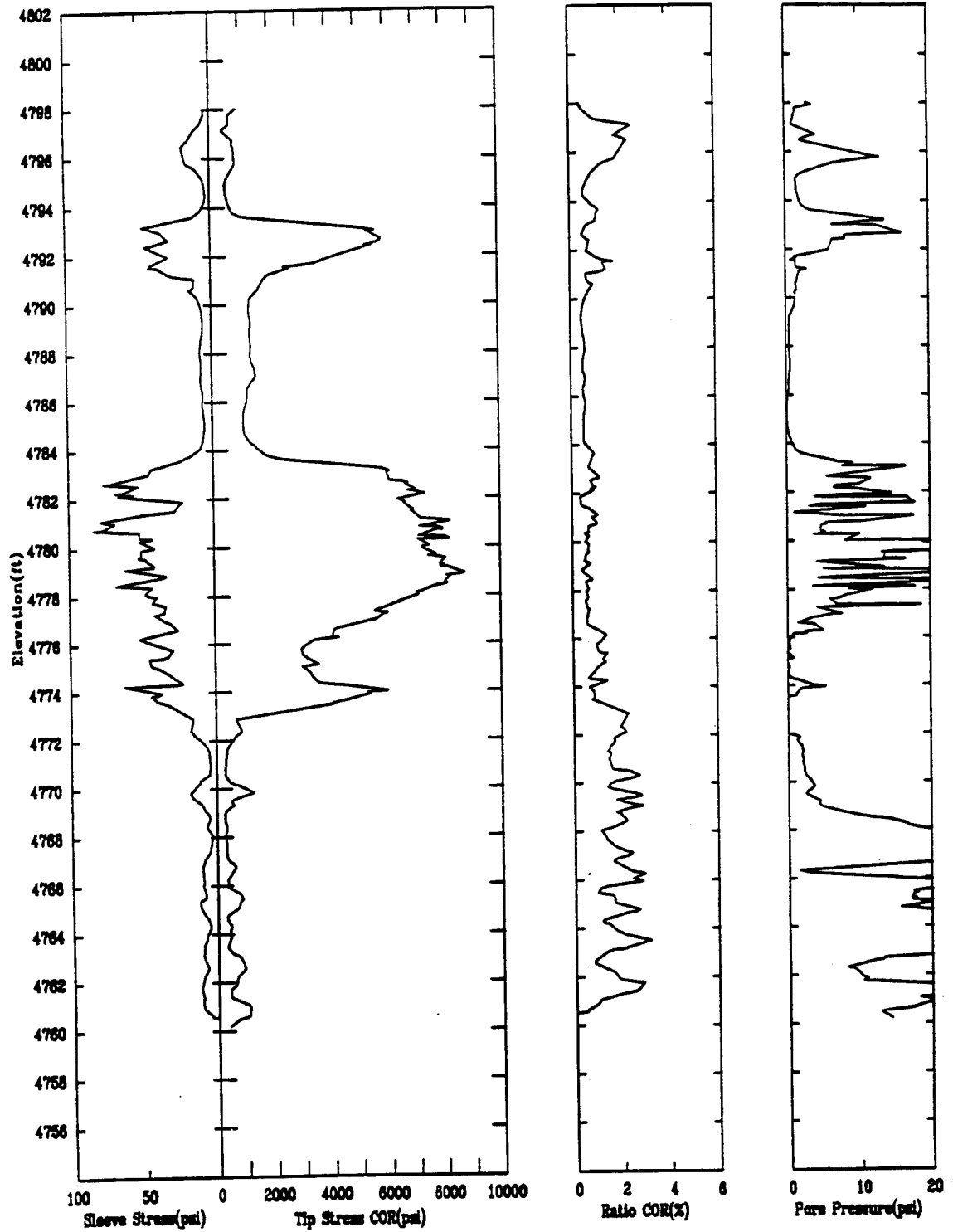
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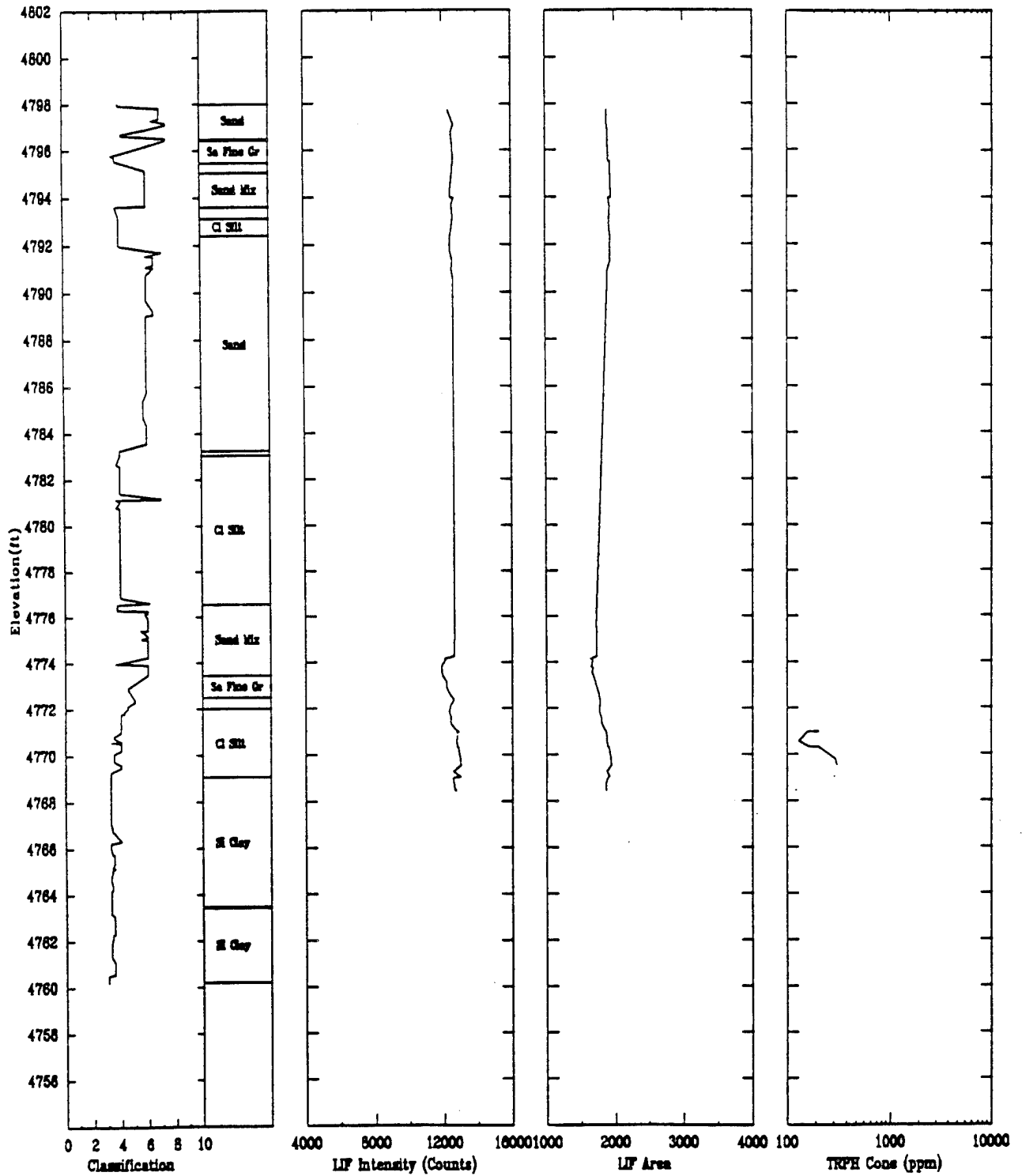
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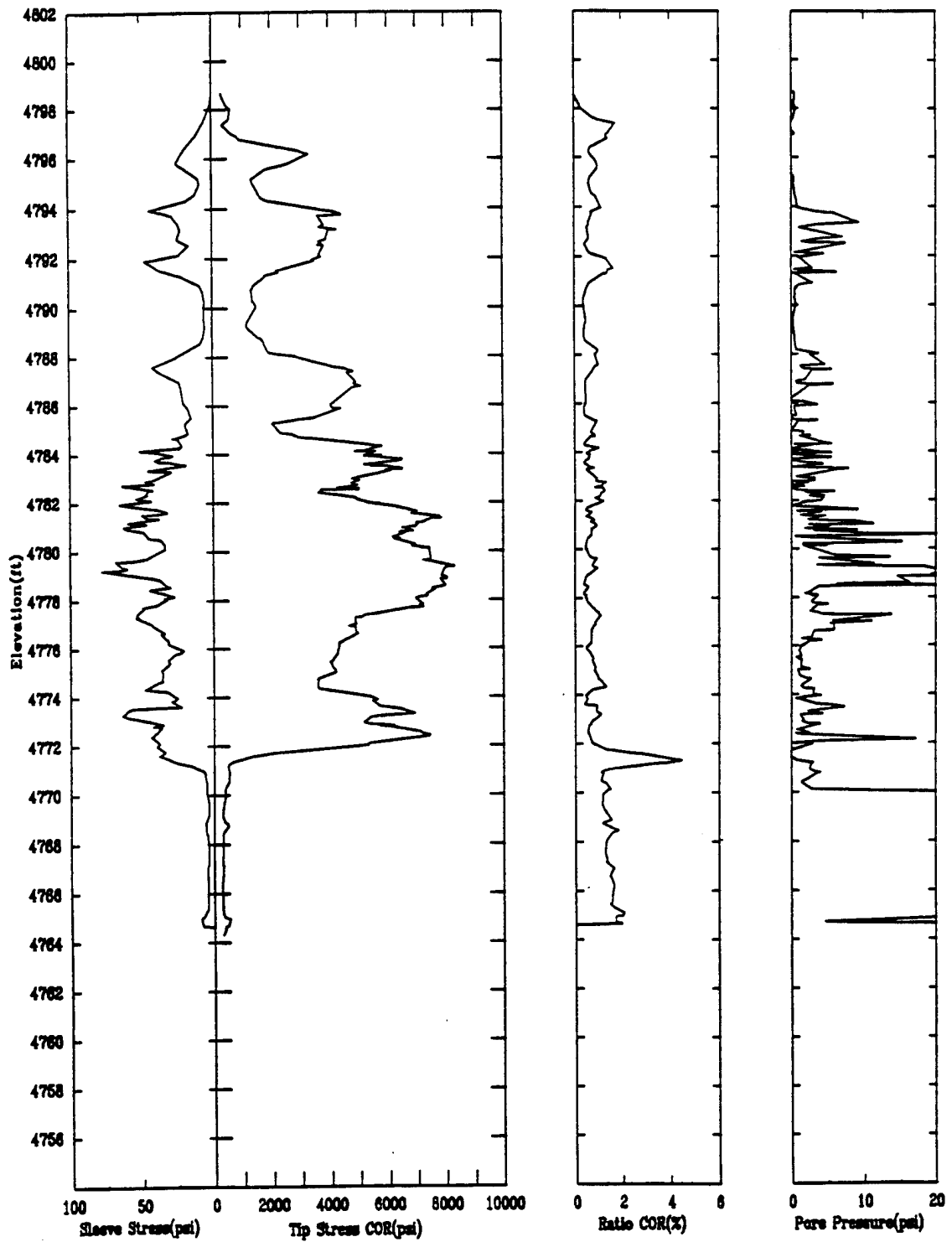
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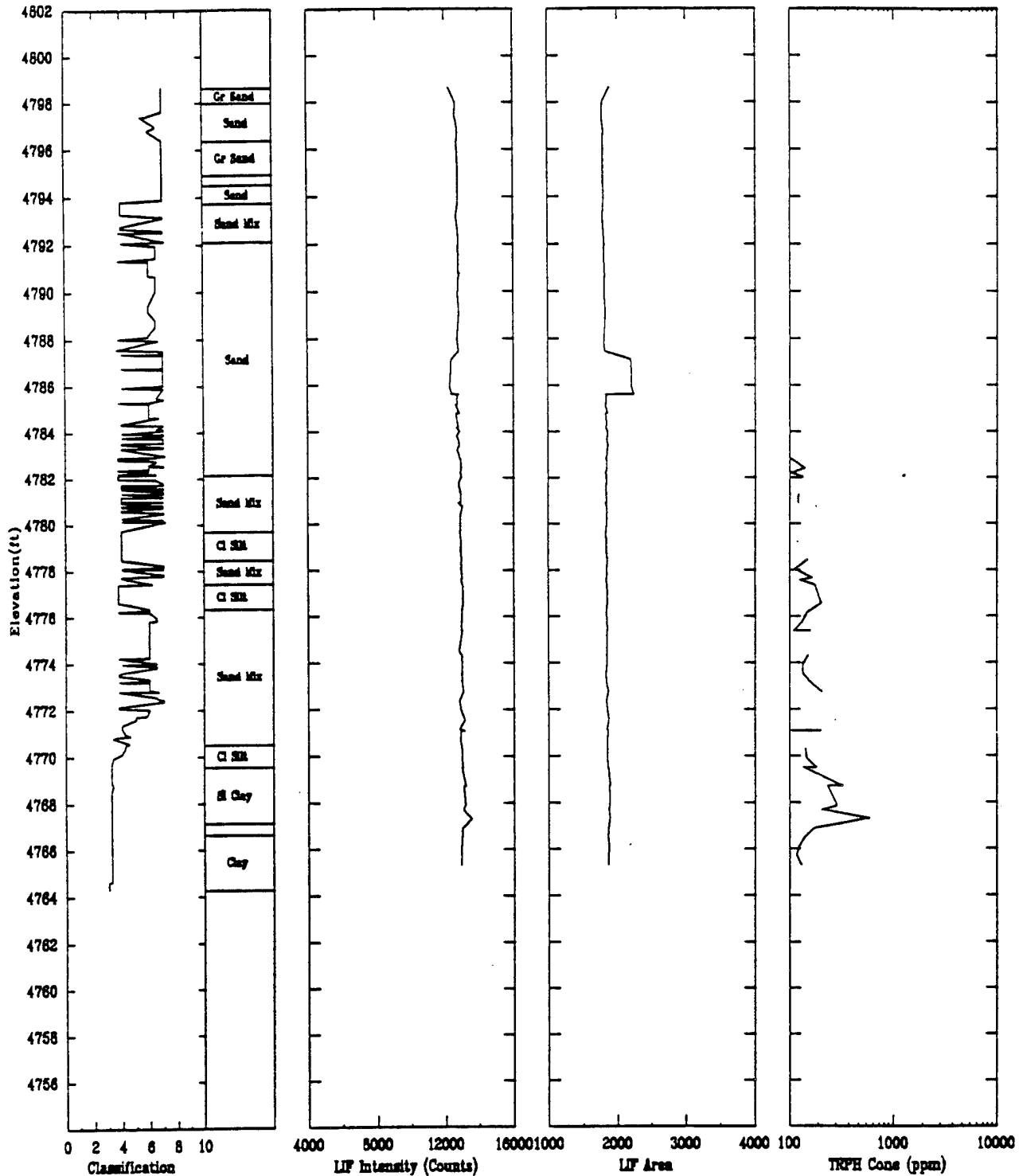
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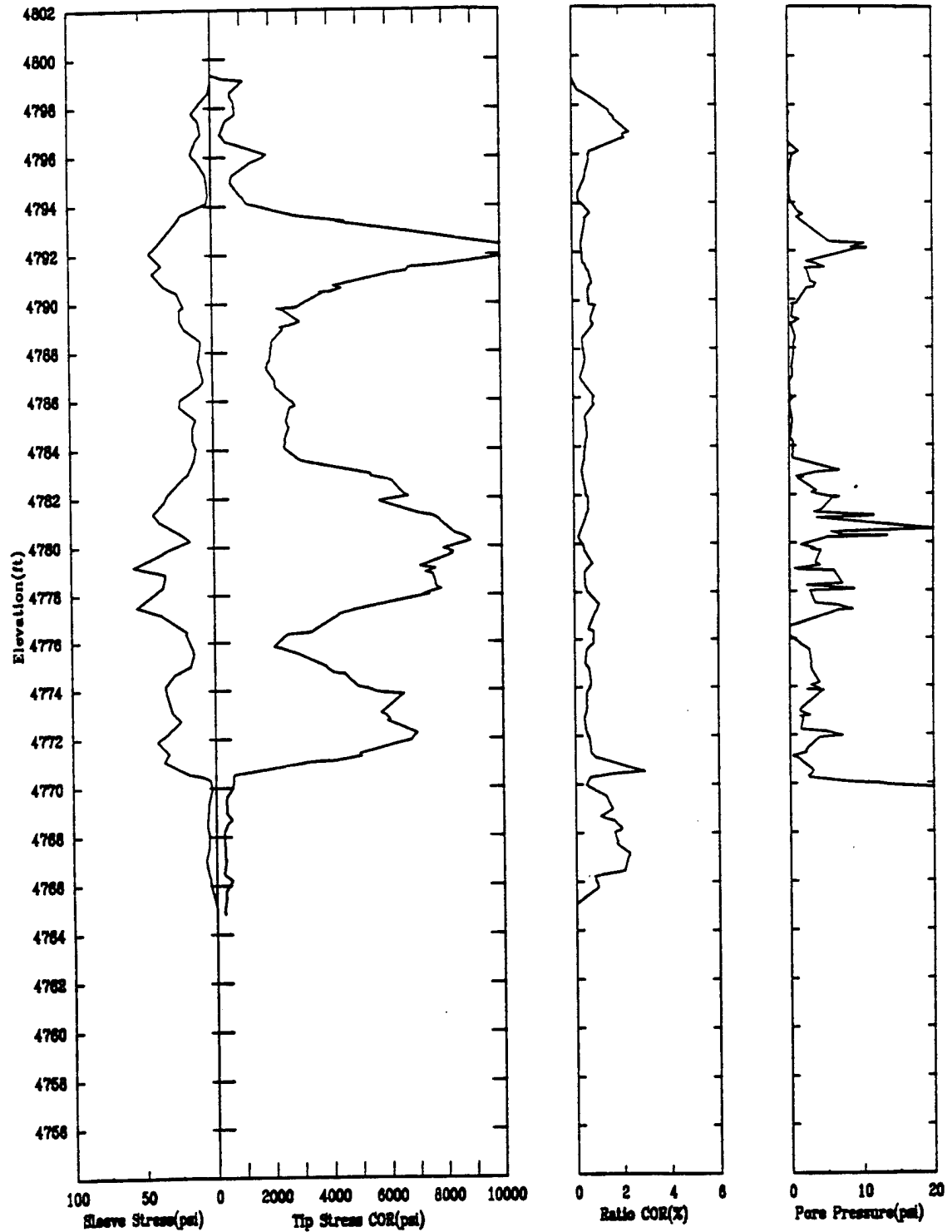
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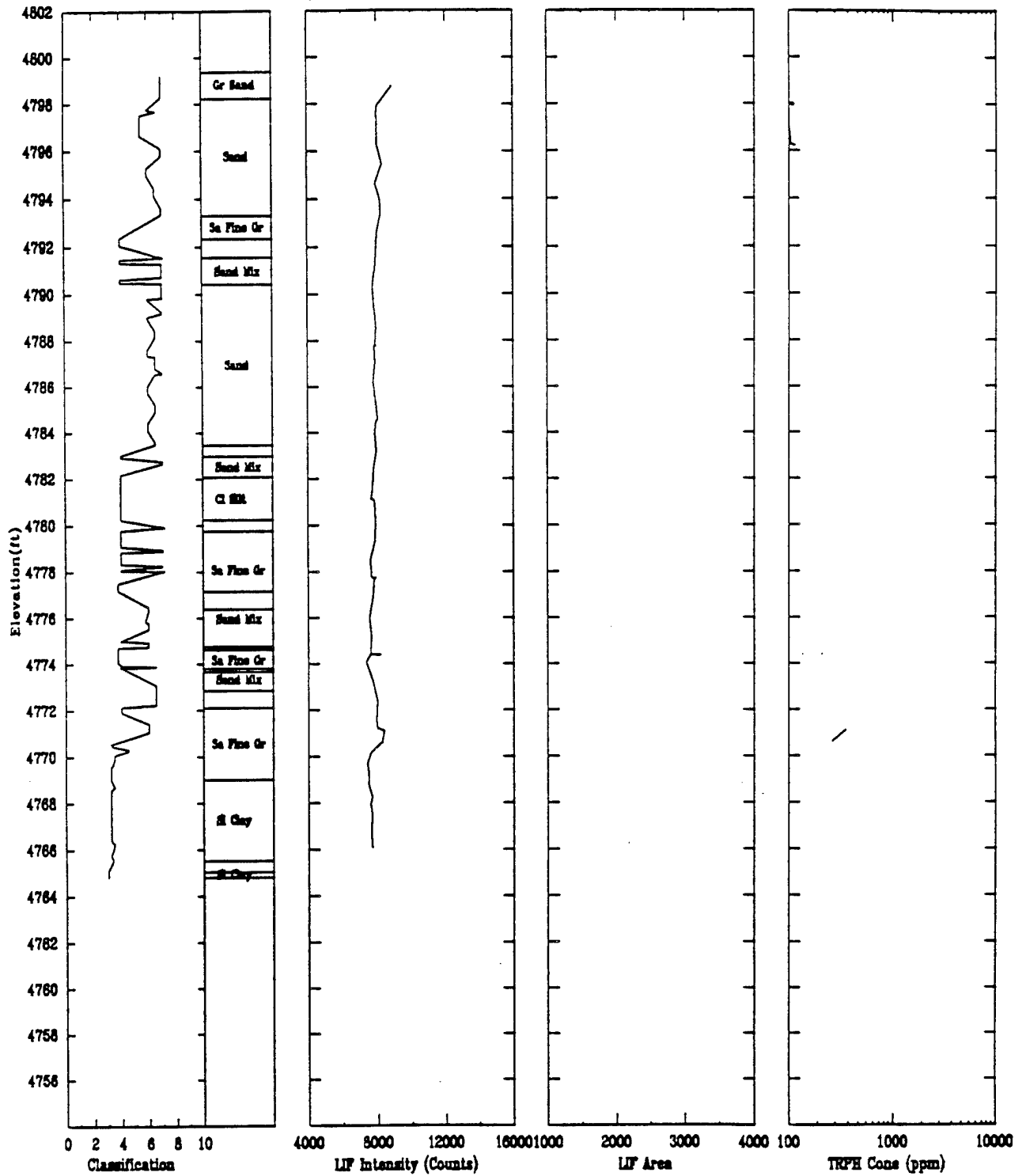
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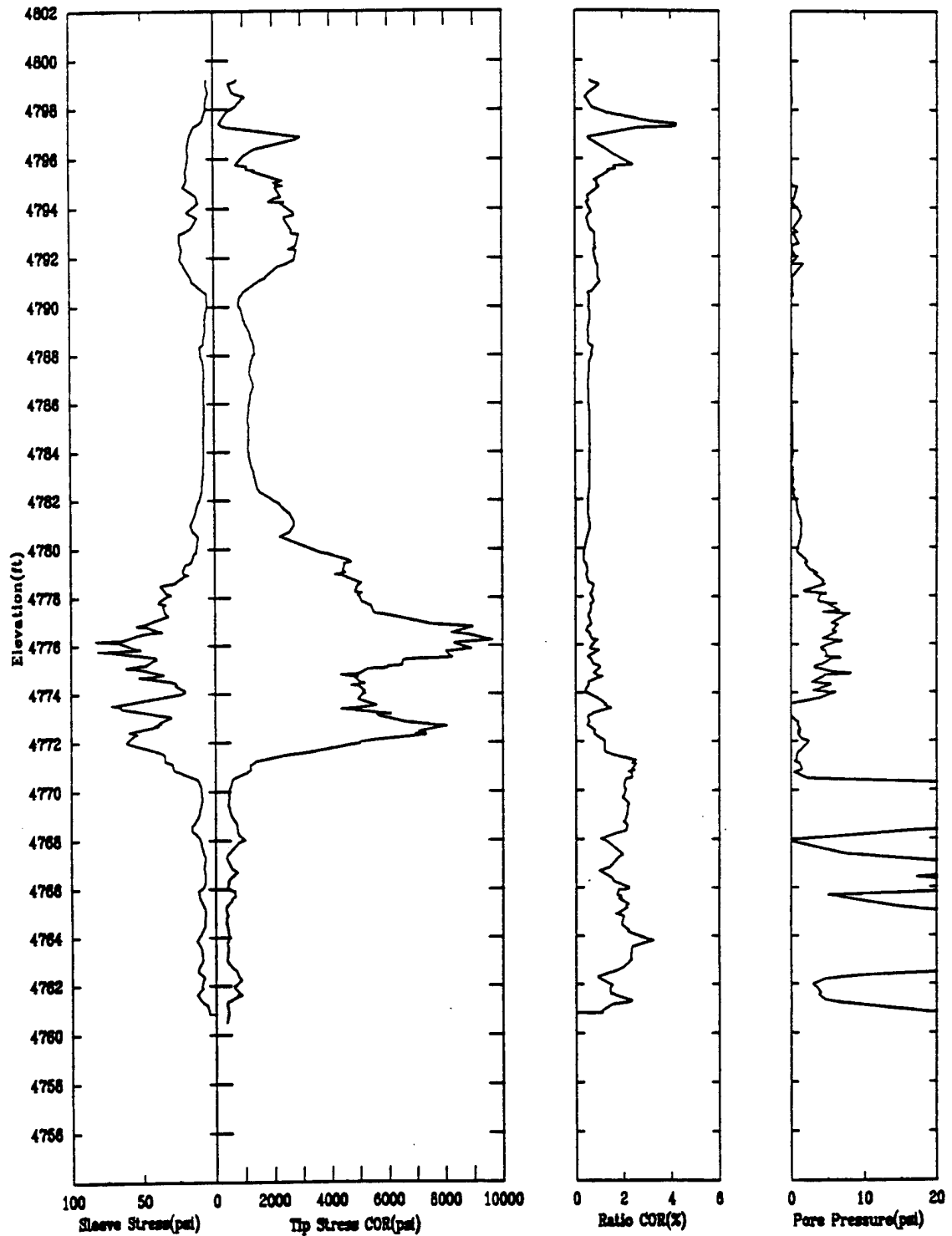
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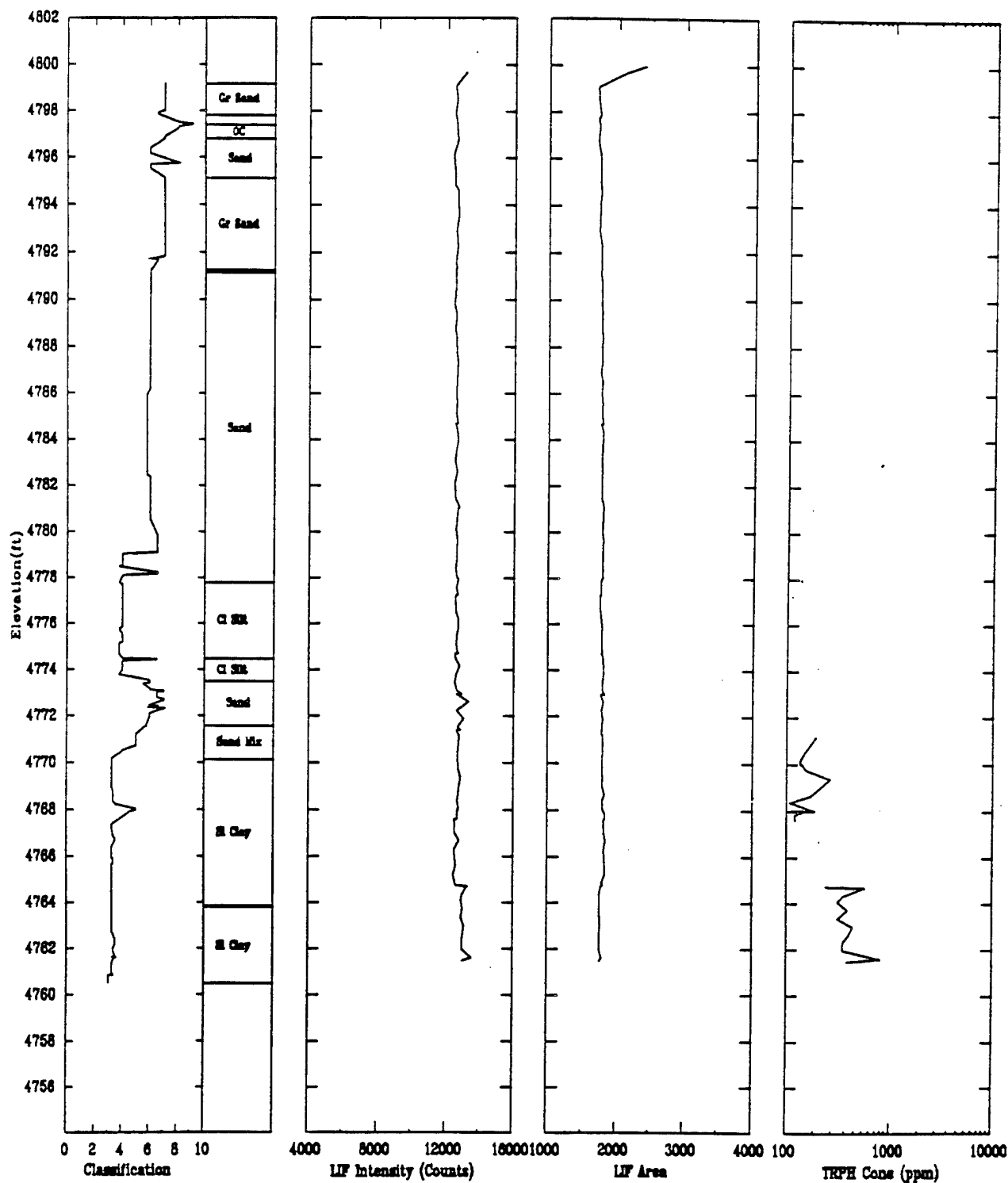
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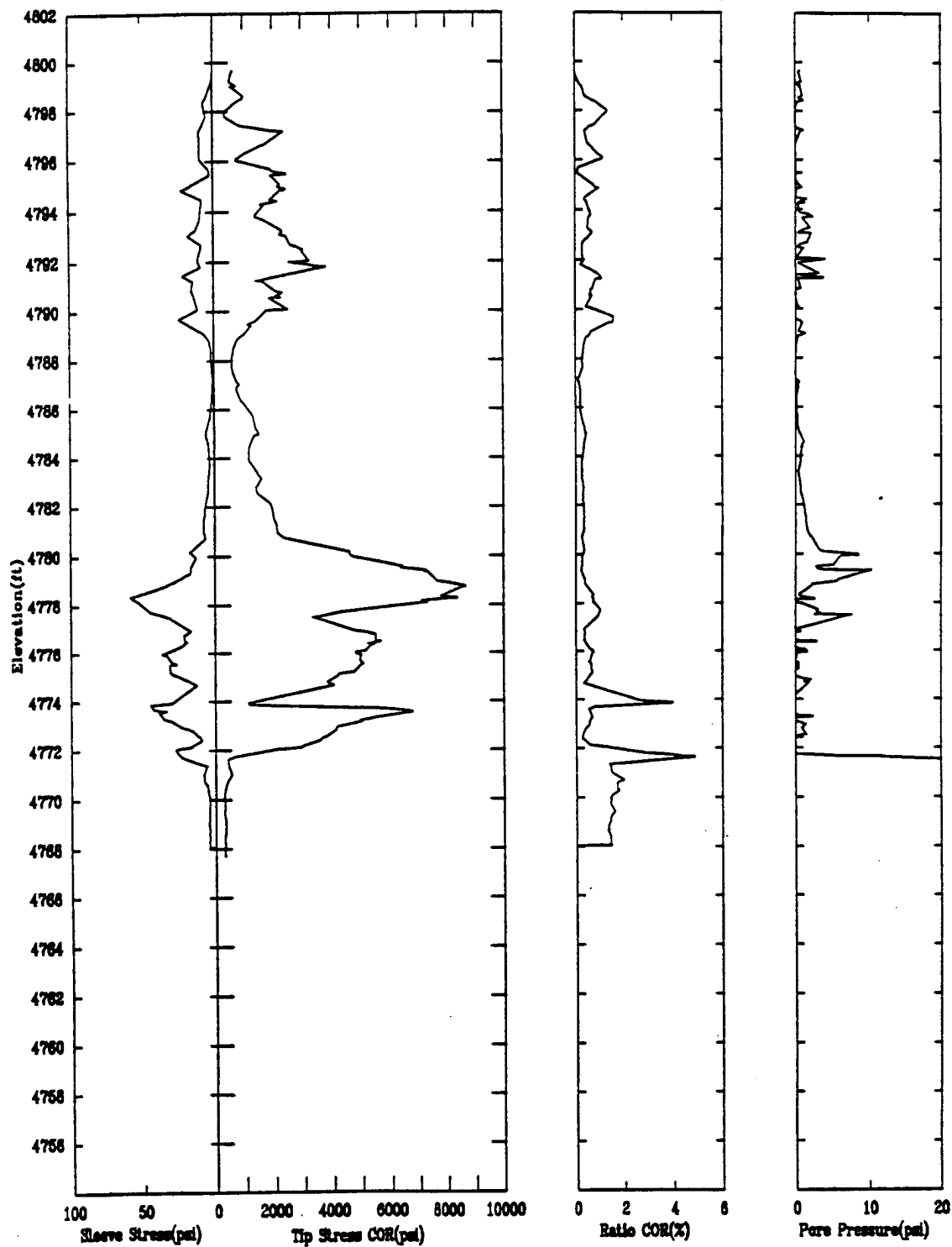
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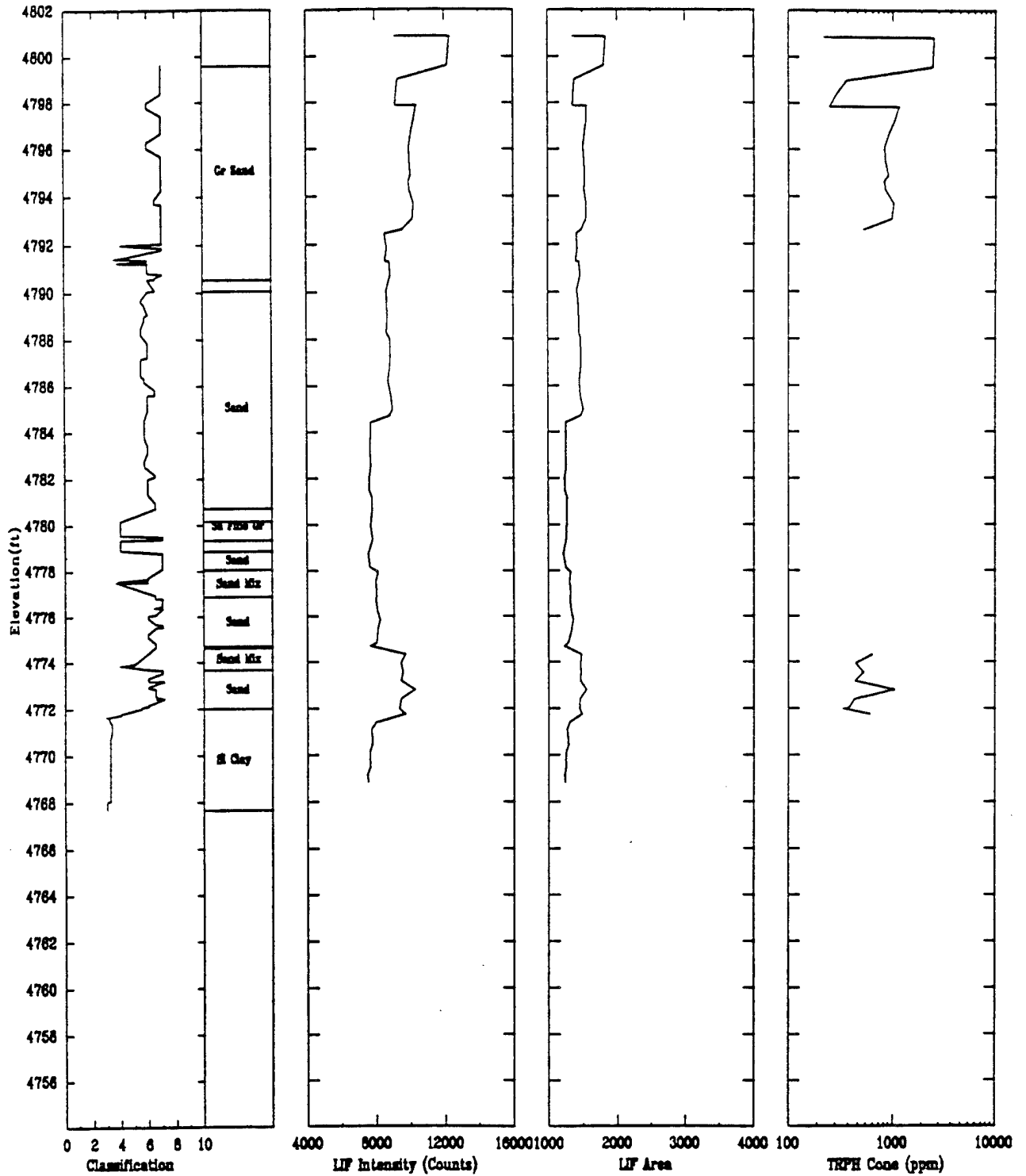
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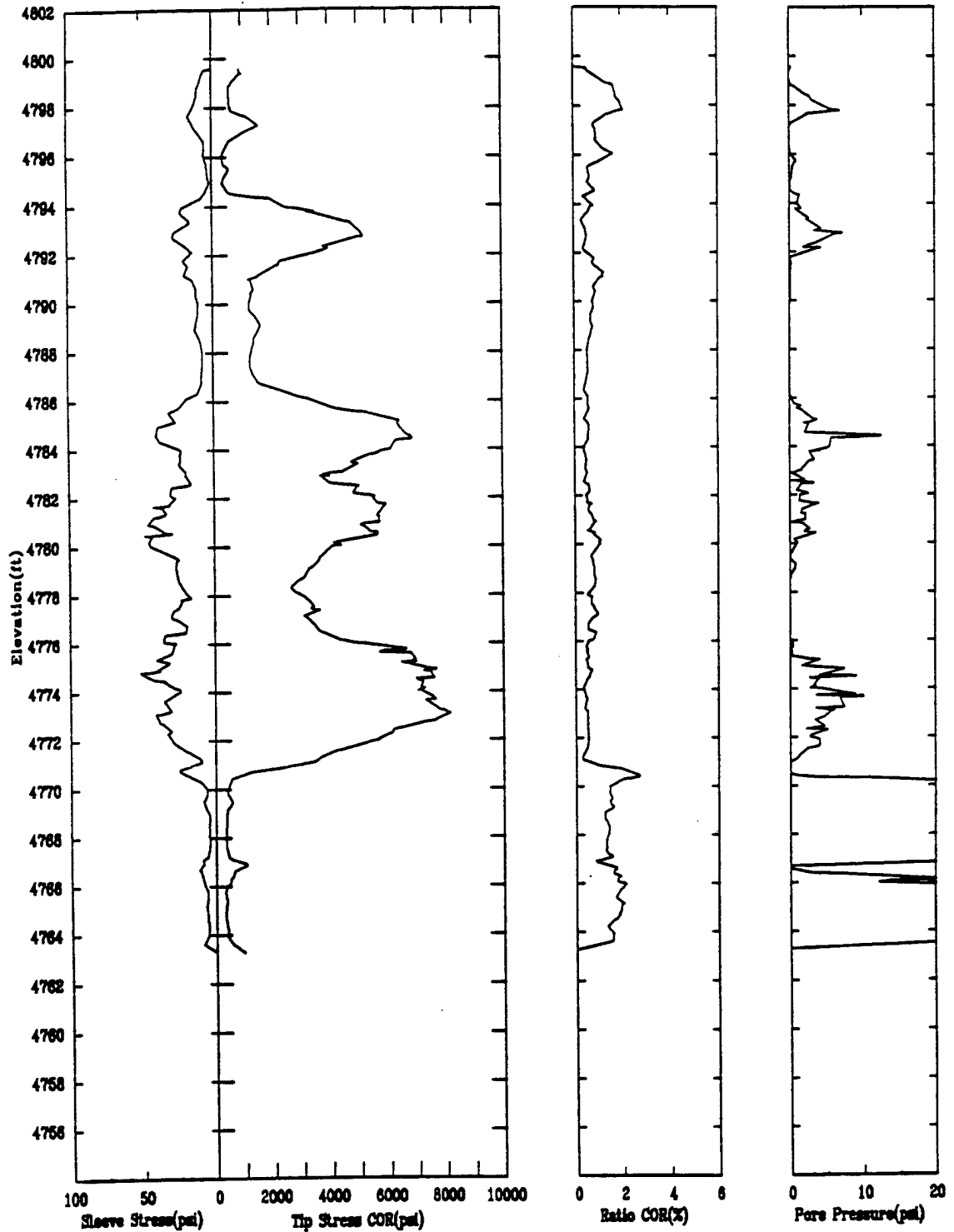
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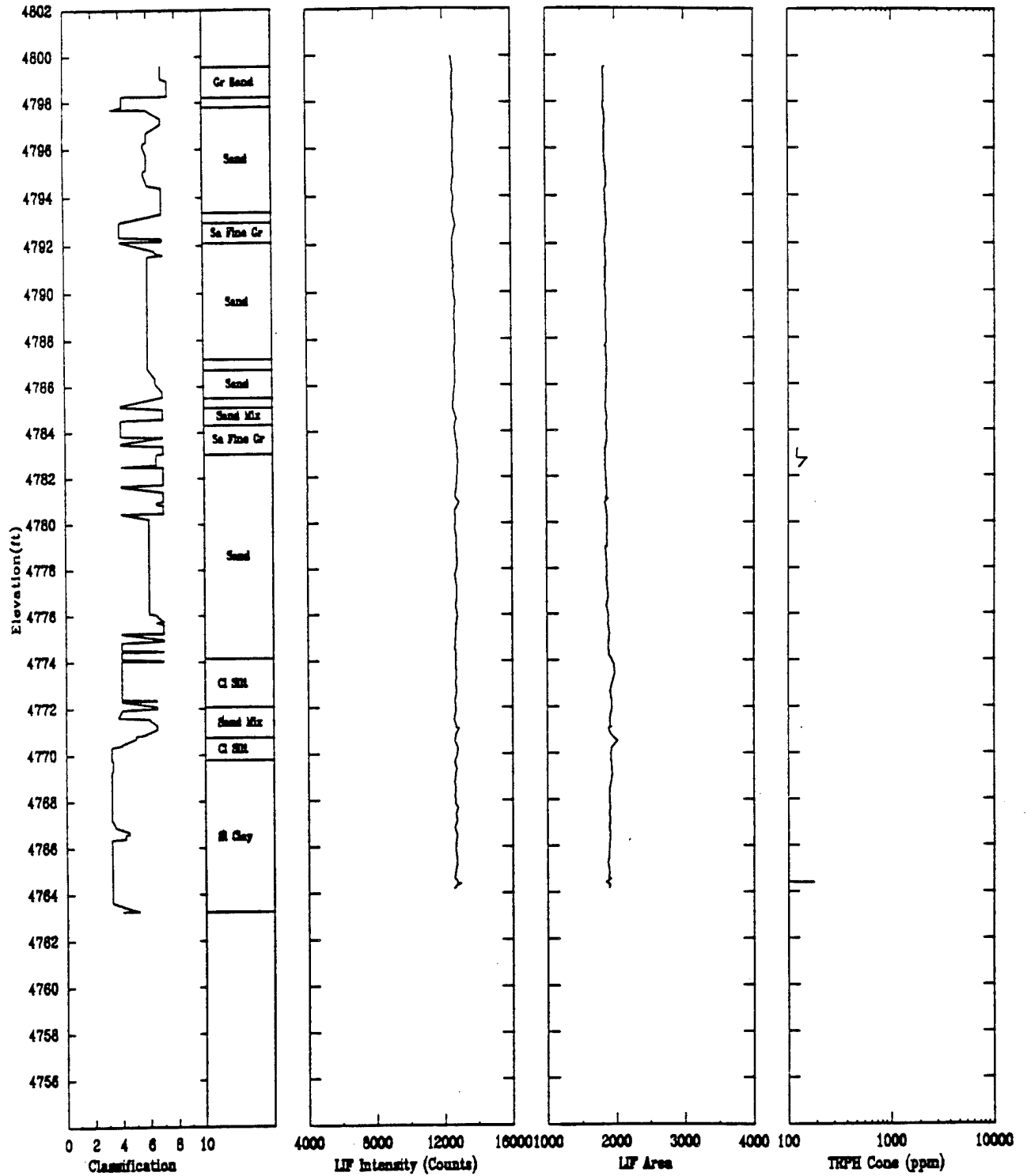
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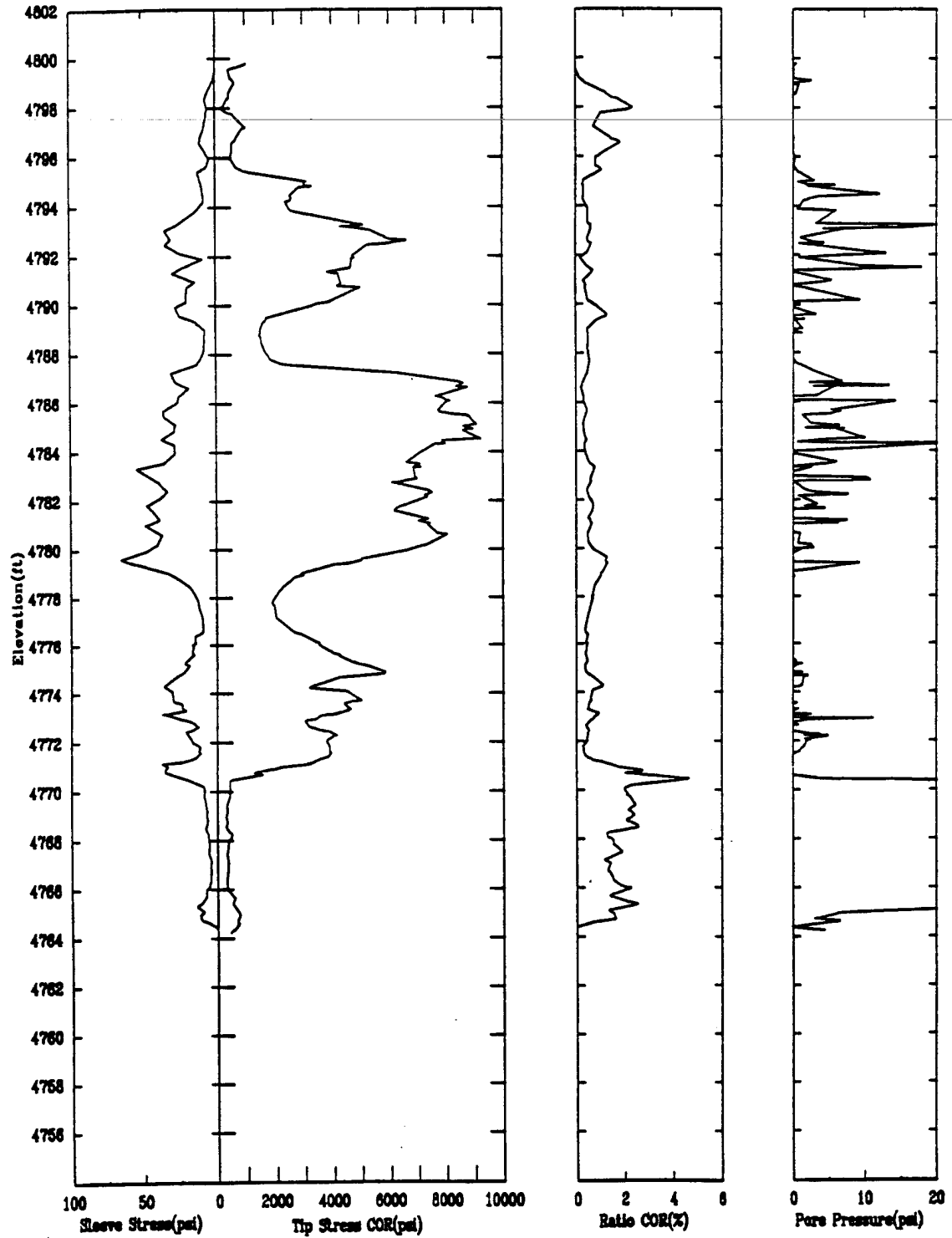
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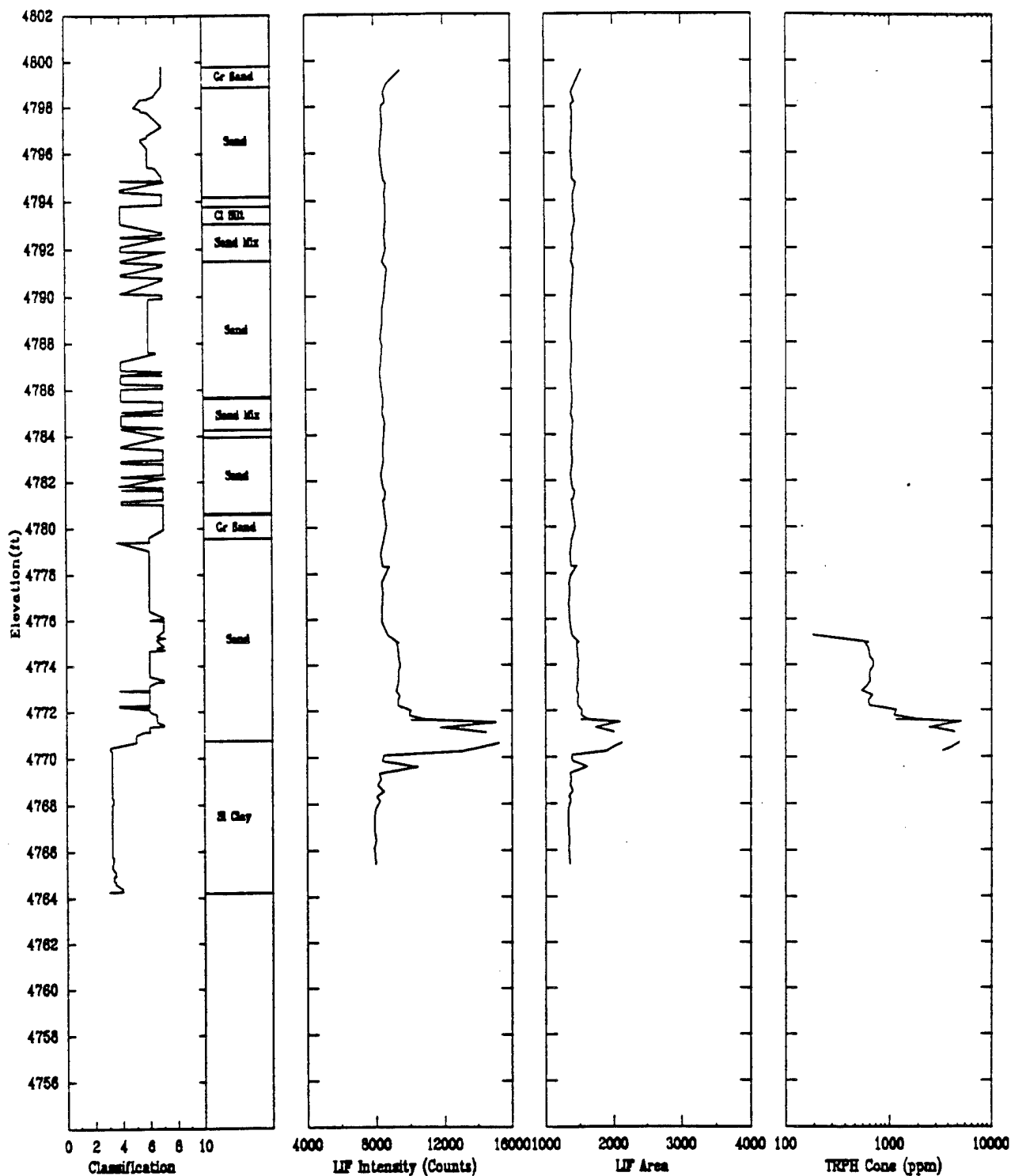
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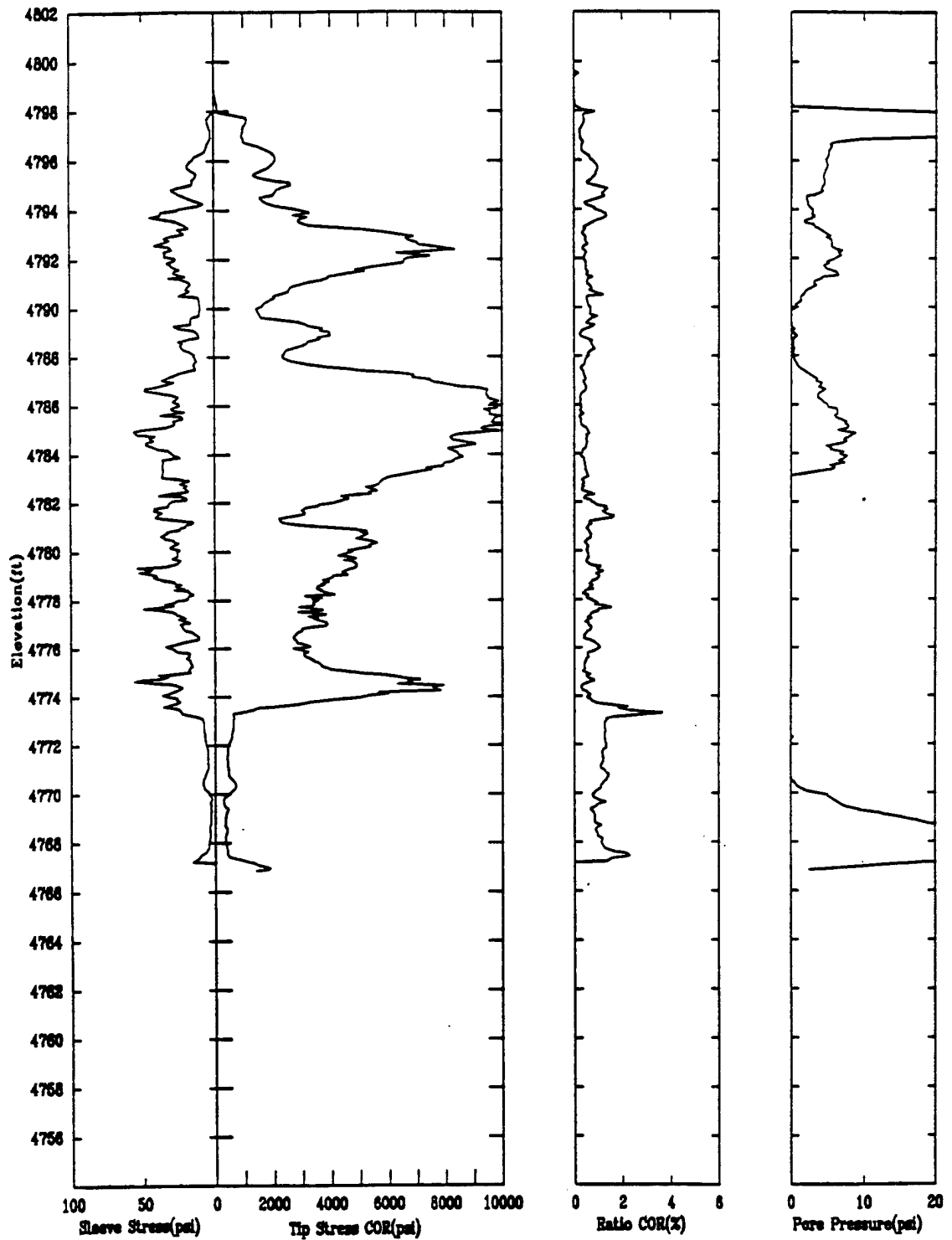
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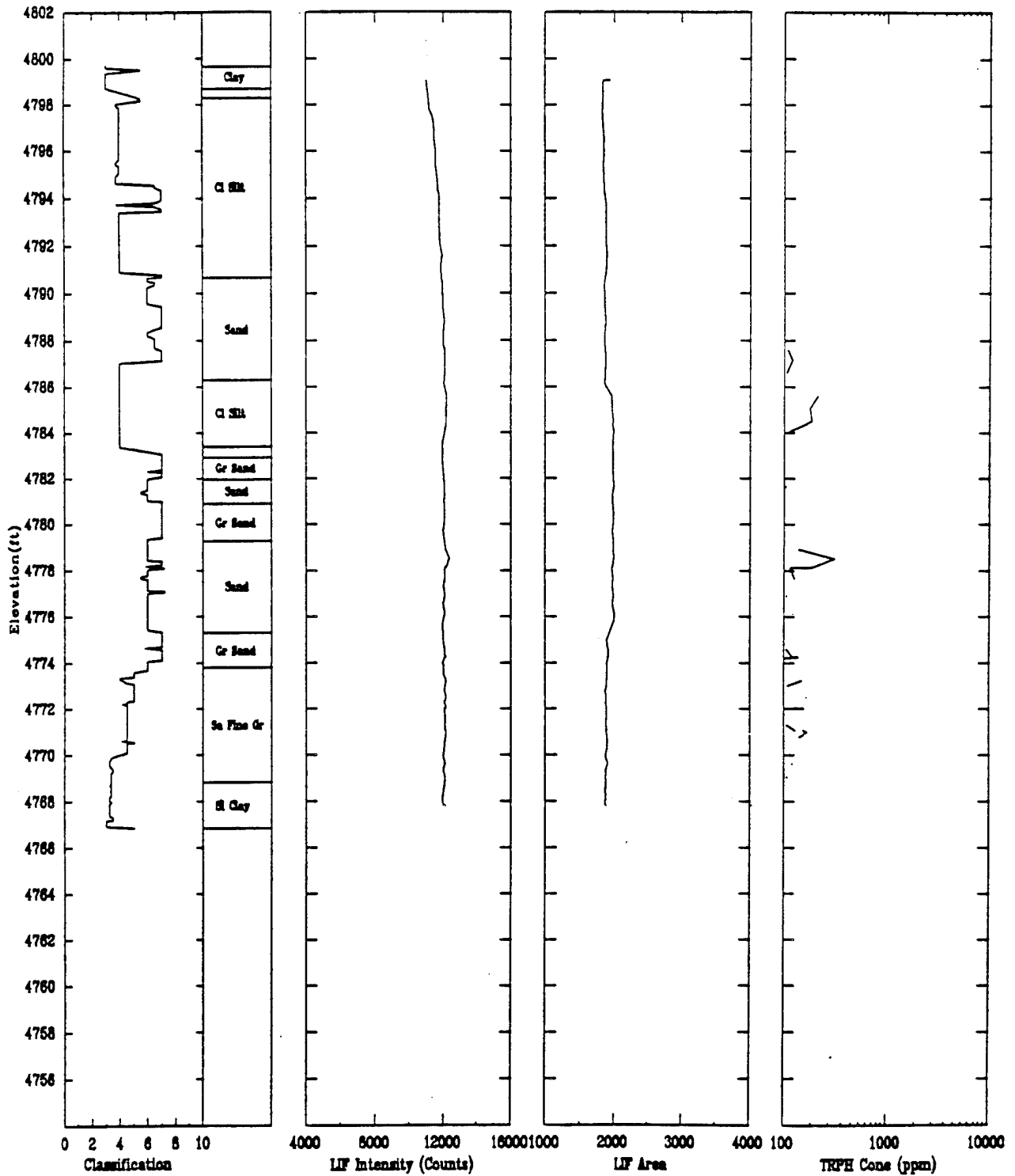
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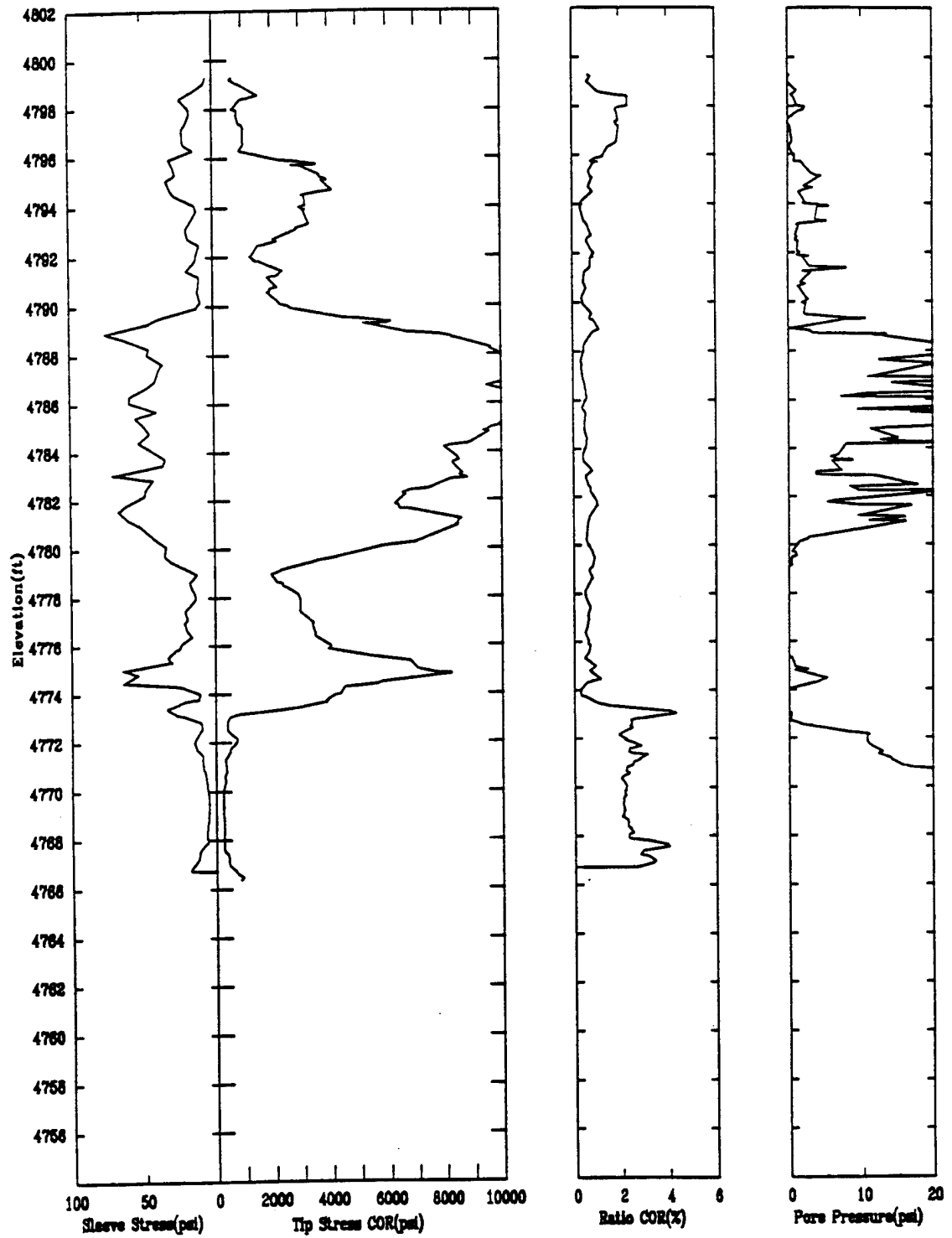
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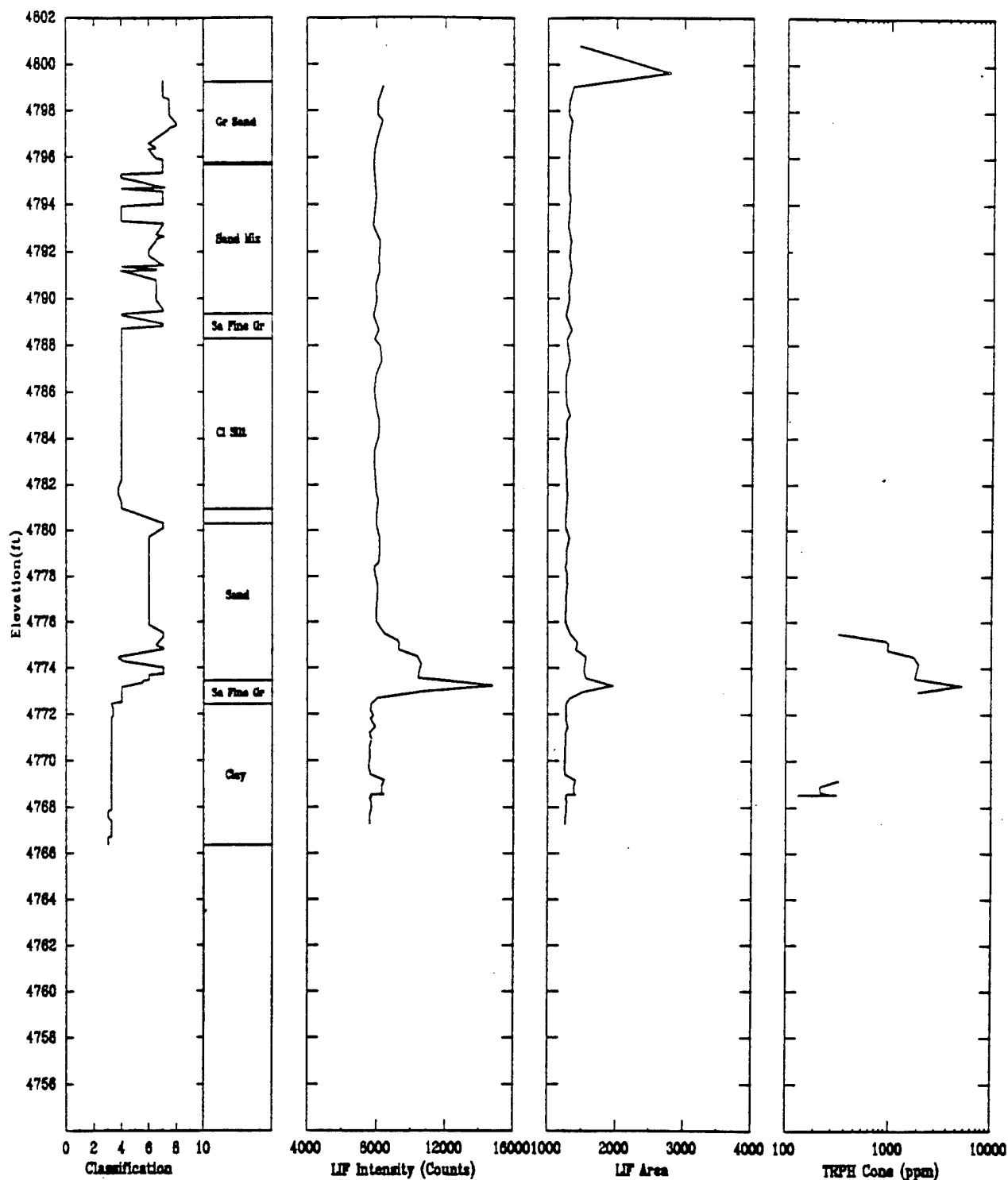
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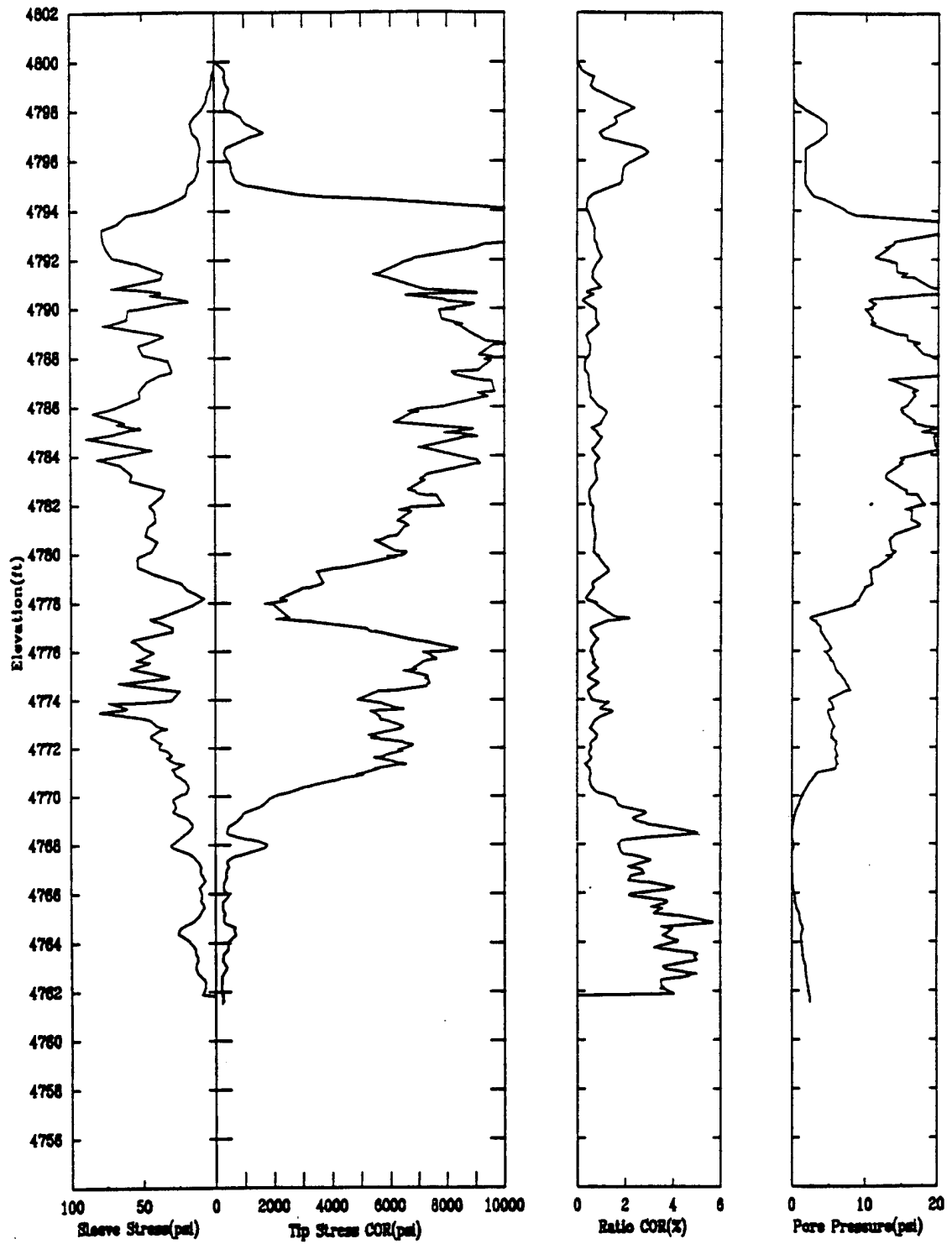
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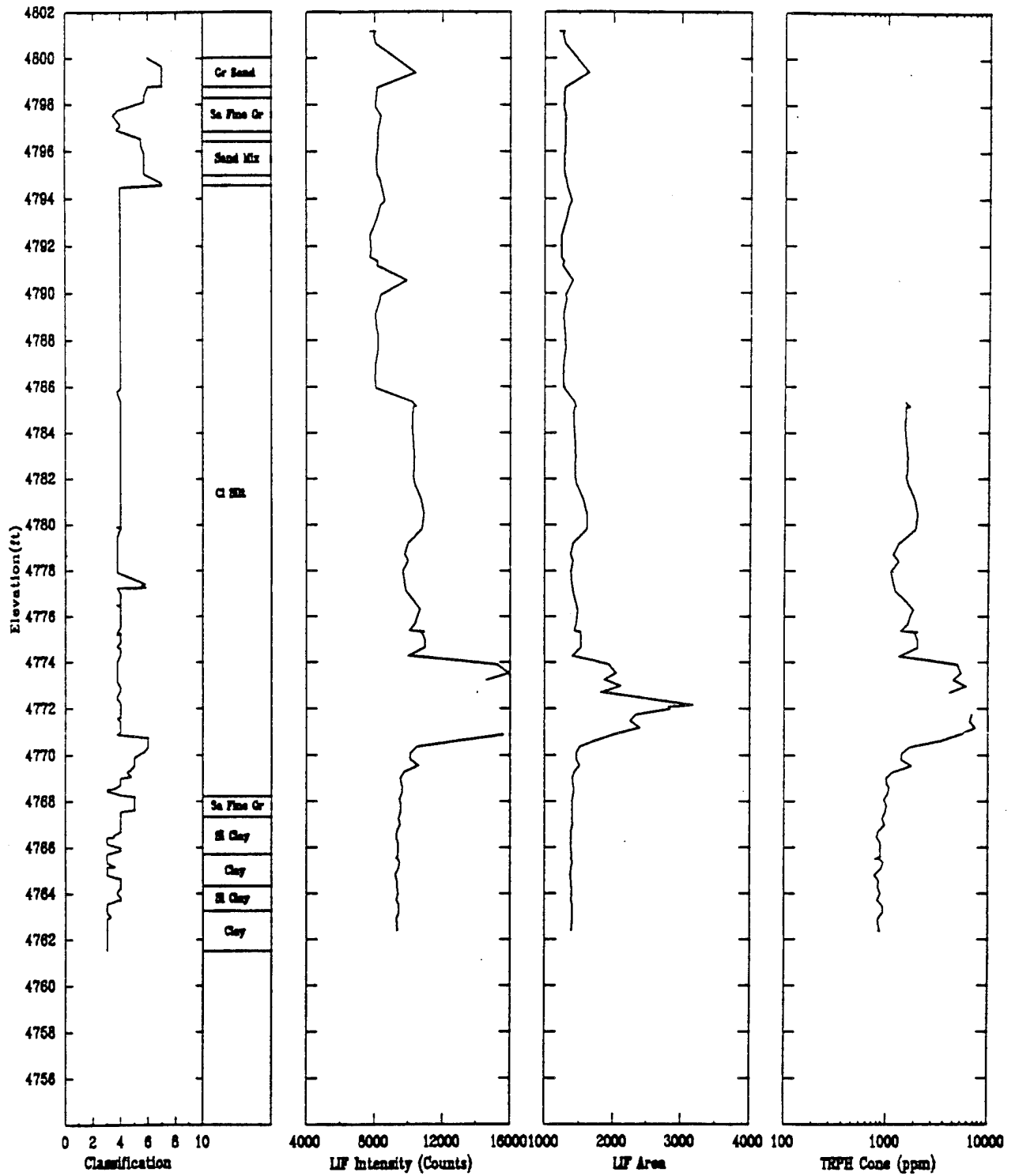
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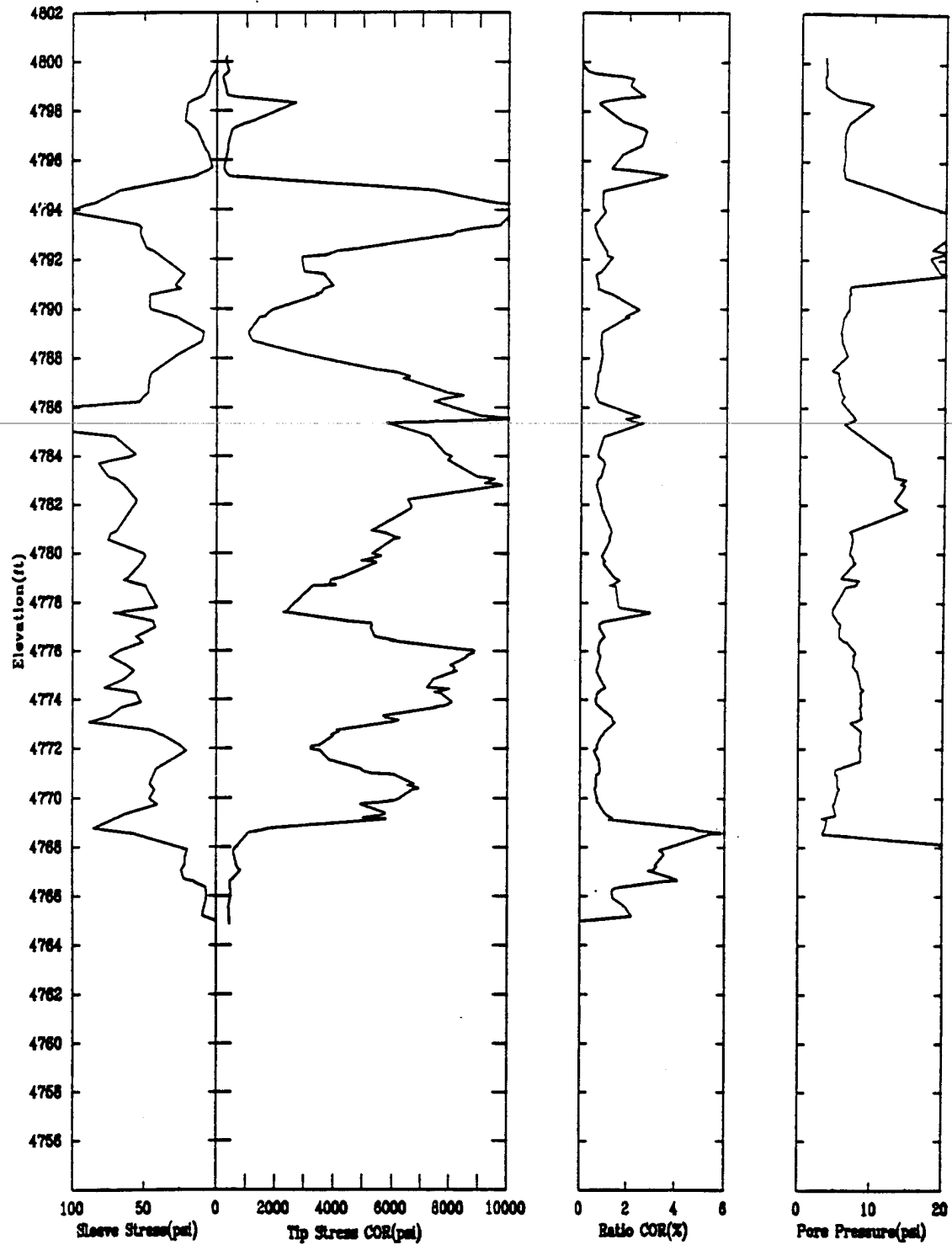
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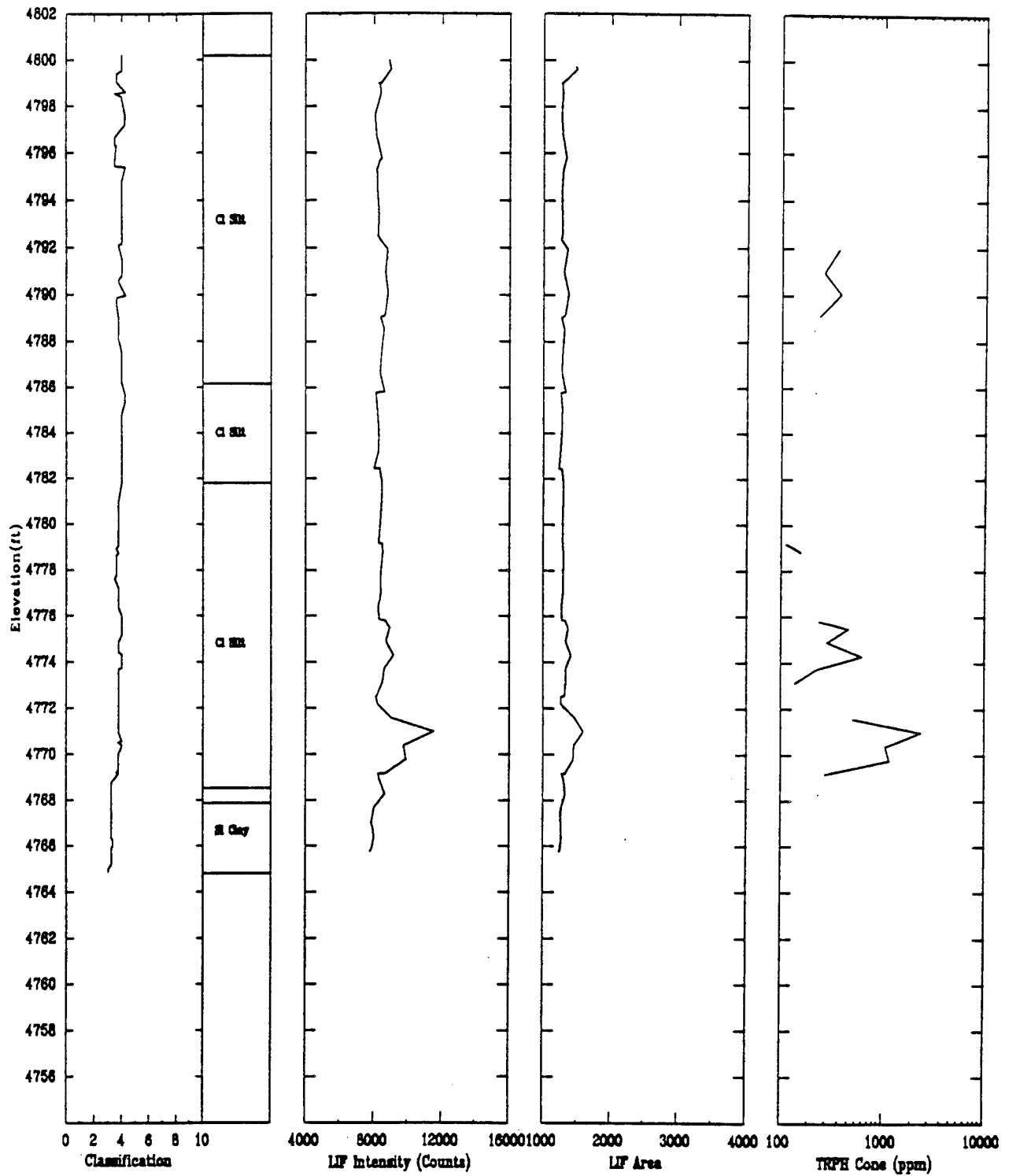
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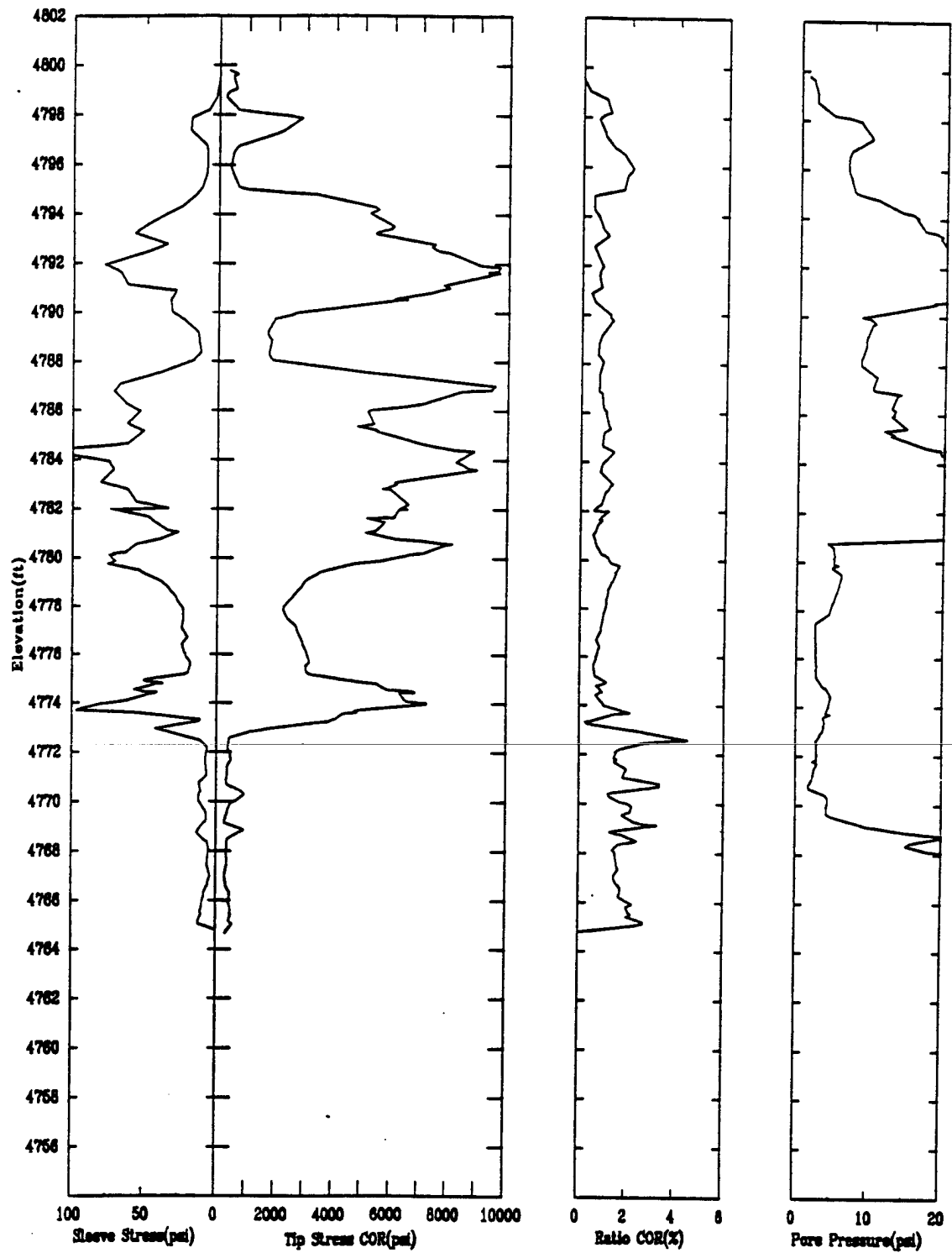
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289534.33

East 1873614.92

Elevation 4799.91



File 4170404.DCF

U1-952-32

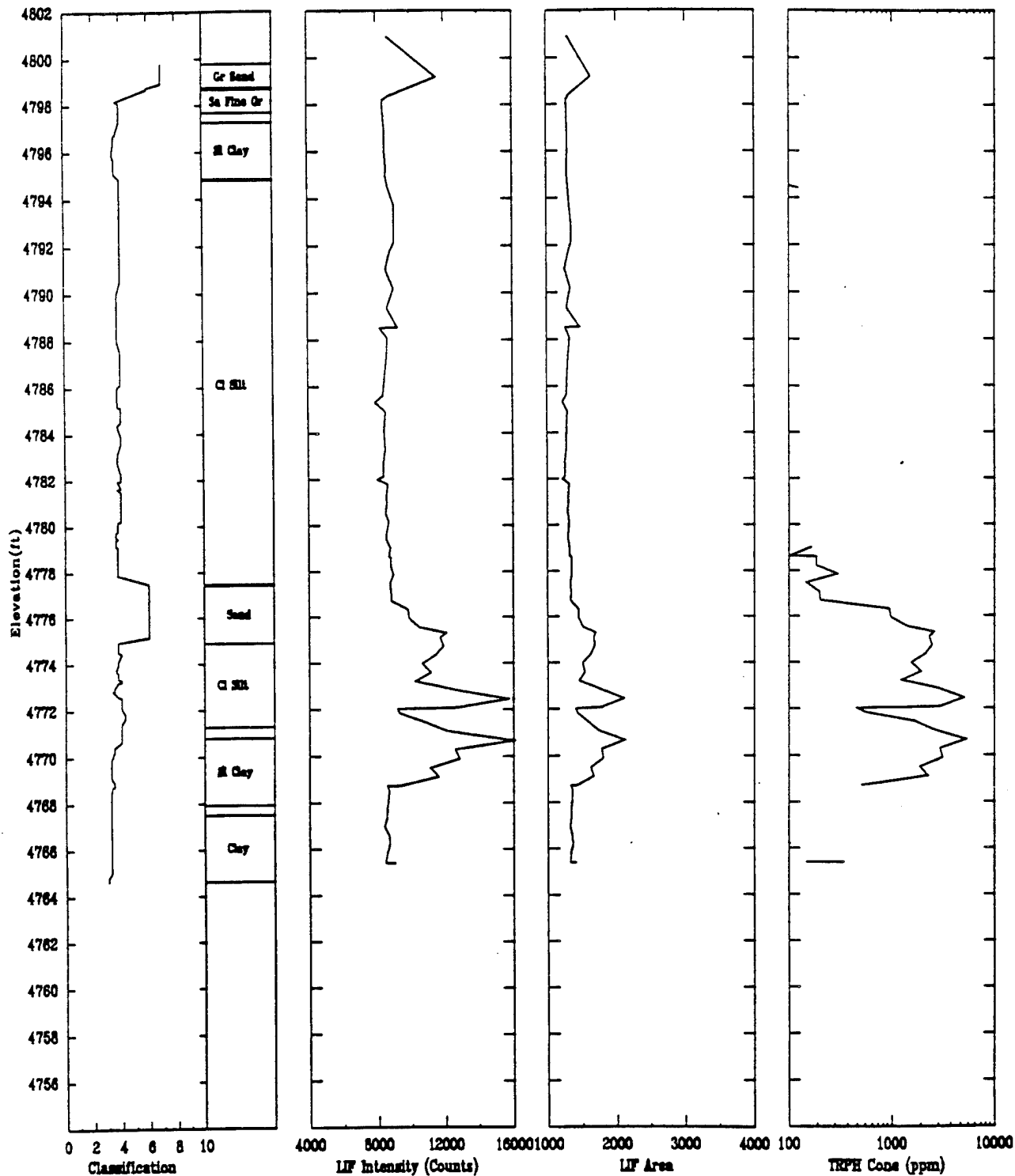
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289534.33

East 1873614.92

Elevation 4799.91



U1-951-33

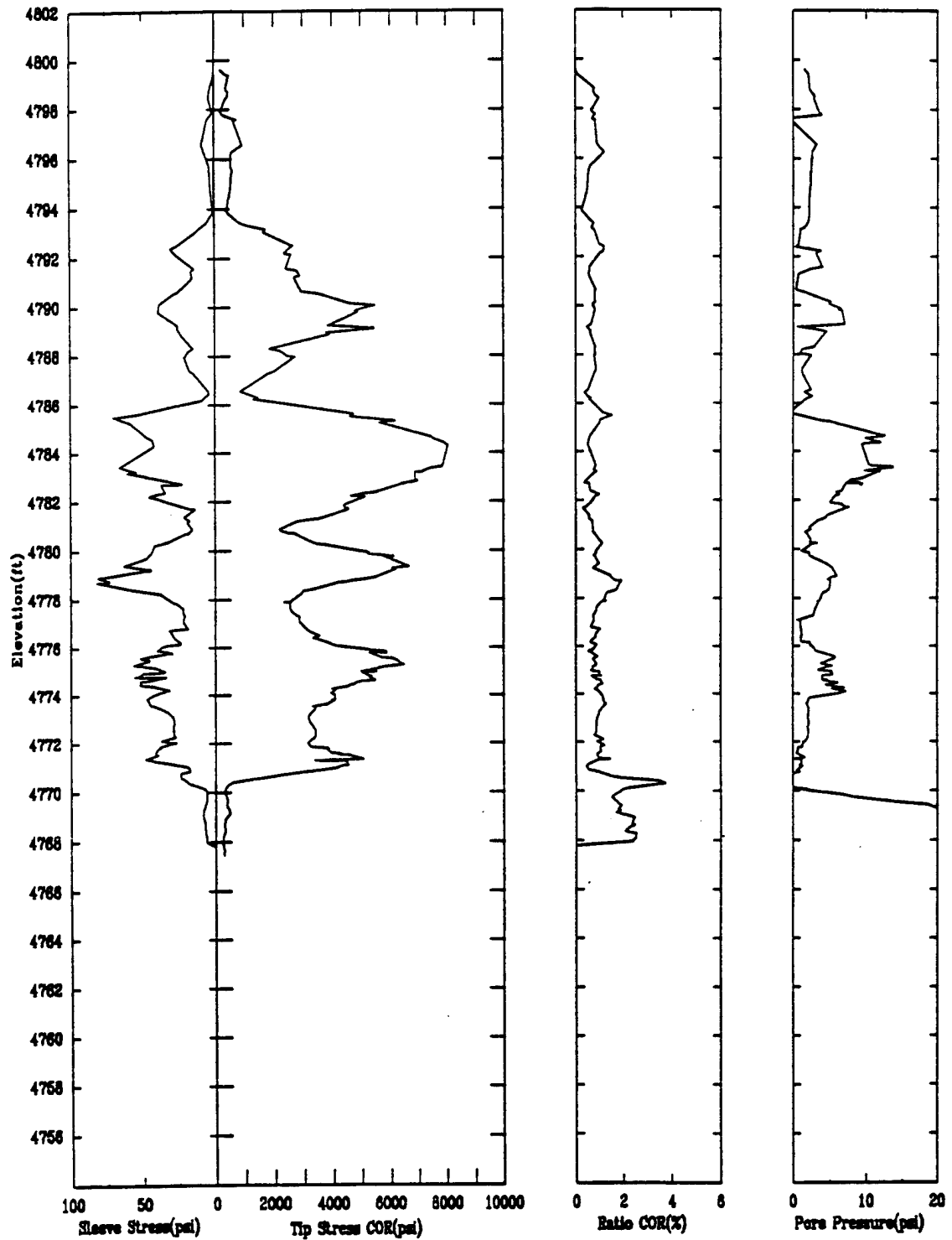
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289592.55

East 1873601.69

Elevation 4799.75



File 4170403.DCP

U1-951-33

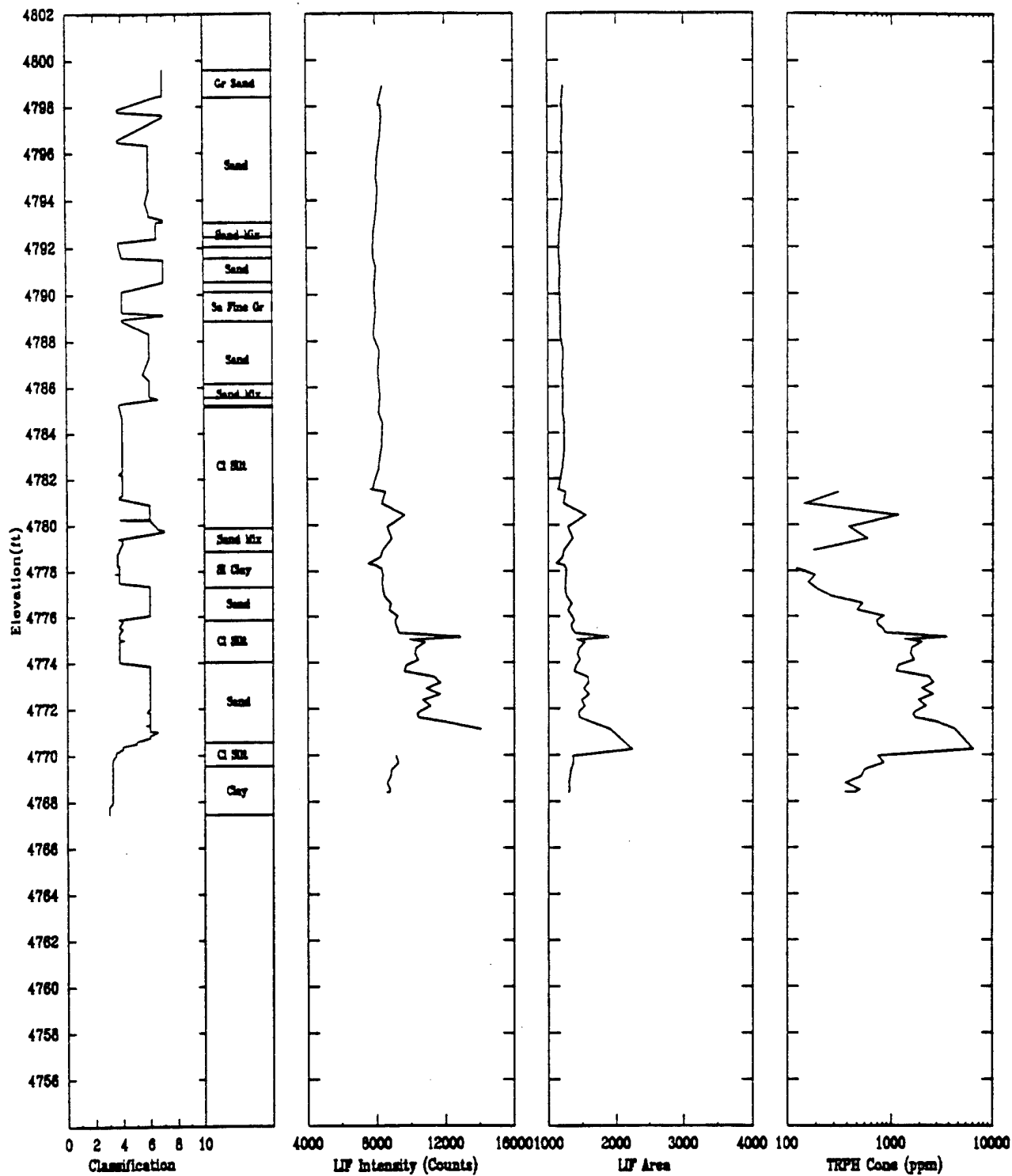
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289592.55

East 1873601.69

Elevation 4799.75



File 417D403.ECP

U1-950-34

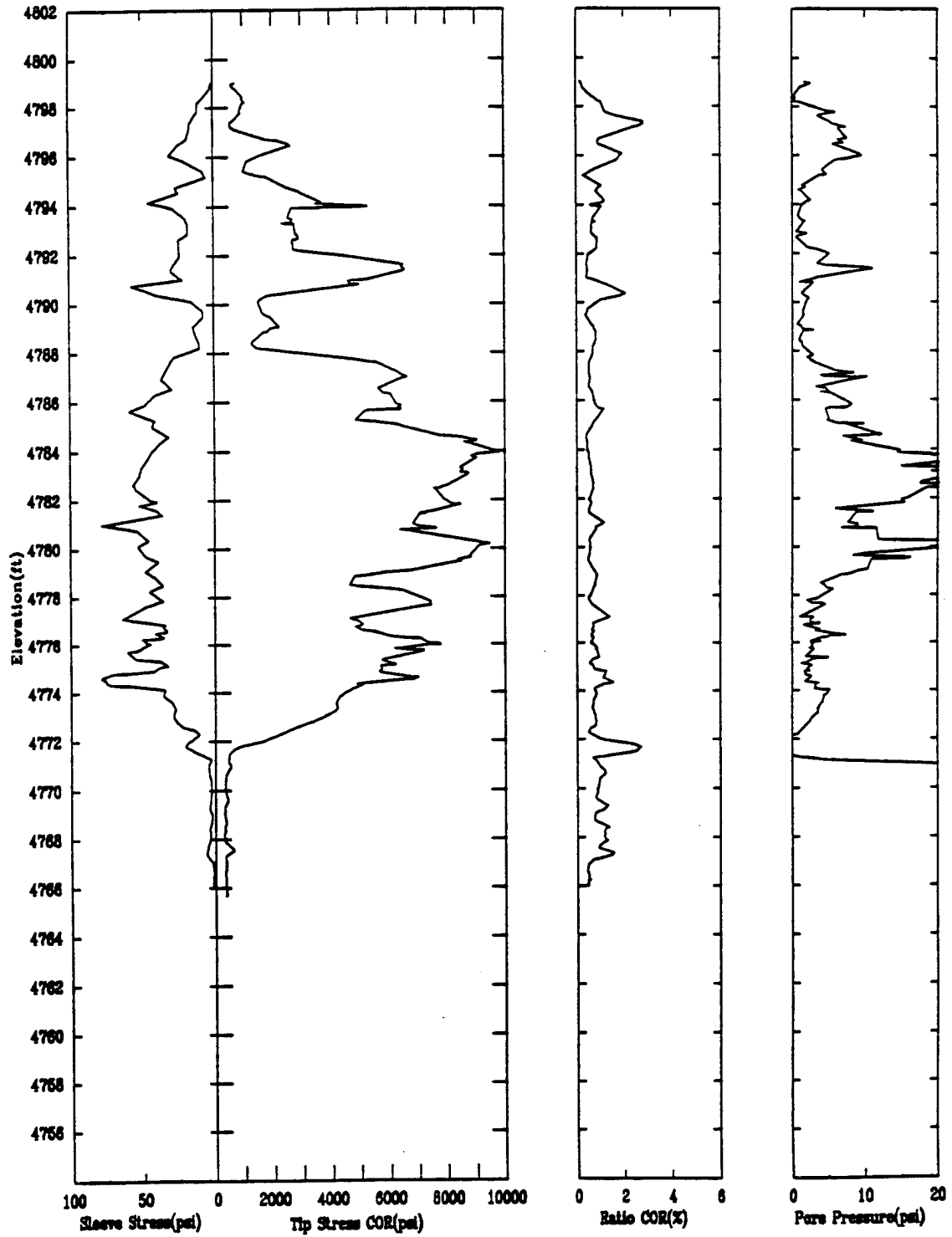
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289640.37

East 1873587.09

Elevation 4799.4



File 4170402.DCF

U1-950-34

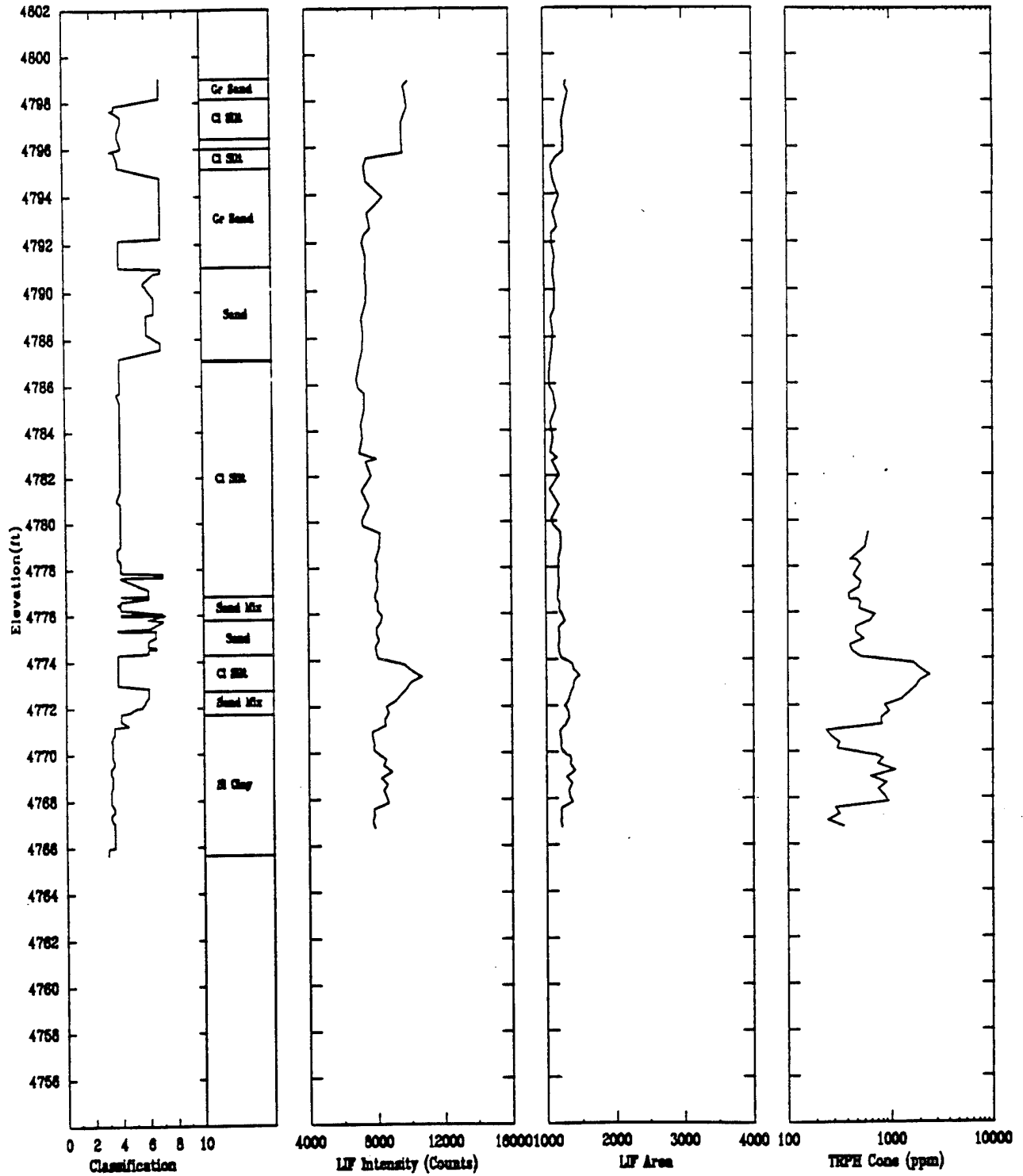
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289640.37

East 1873587.09

Elevation 4799.4



File 417D402.DCF

U1-949-35

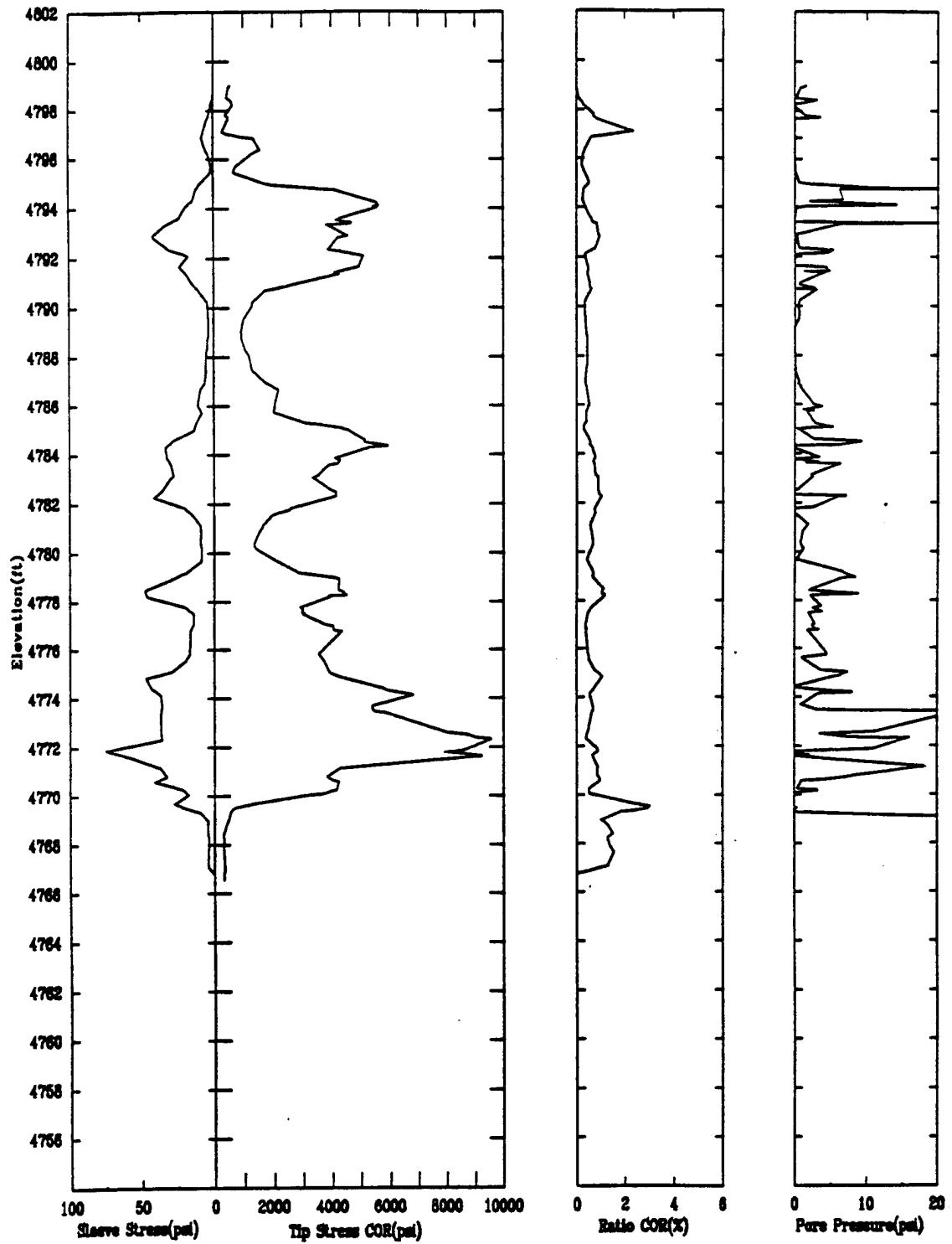
APPLIED RESEARCH ASSOCIATES, INC.

12/17/84

North 289690.8

East 1873570.98

Elevation 4799.25



File 4170481.ECP

U1-949-35

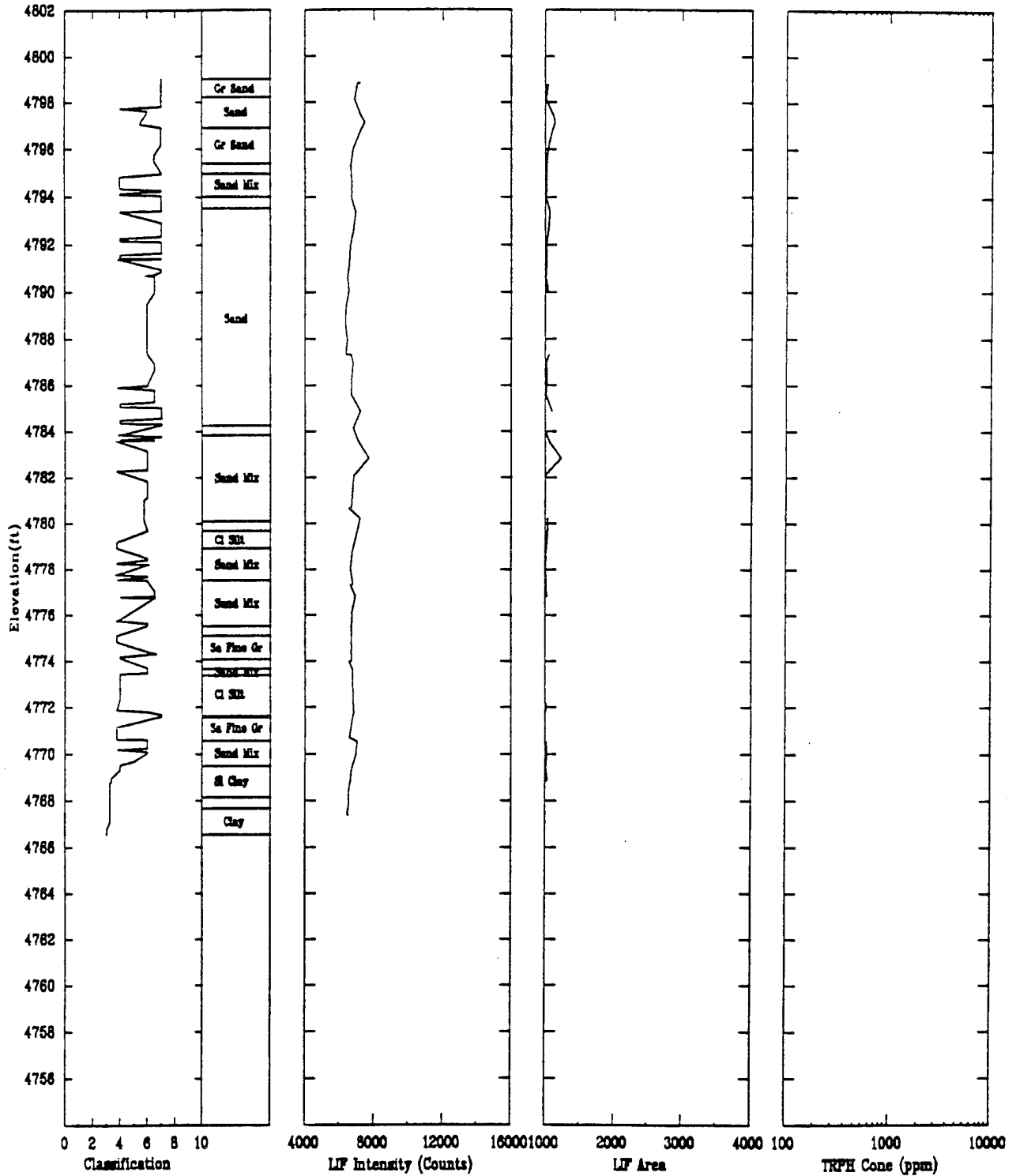
APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

North 289690.8

East 1873570.98

Elevation 4799.25



File 417D401.ECP

U1-954-38

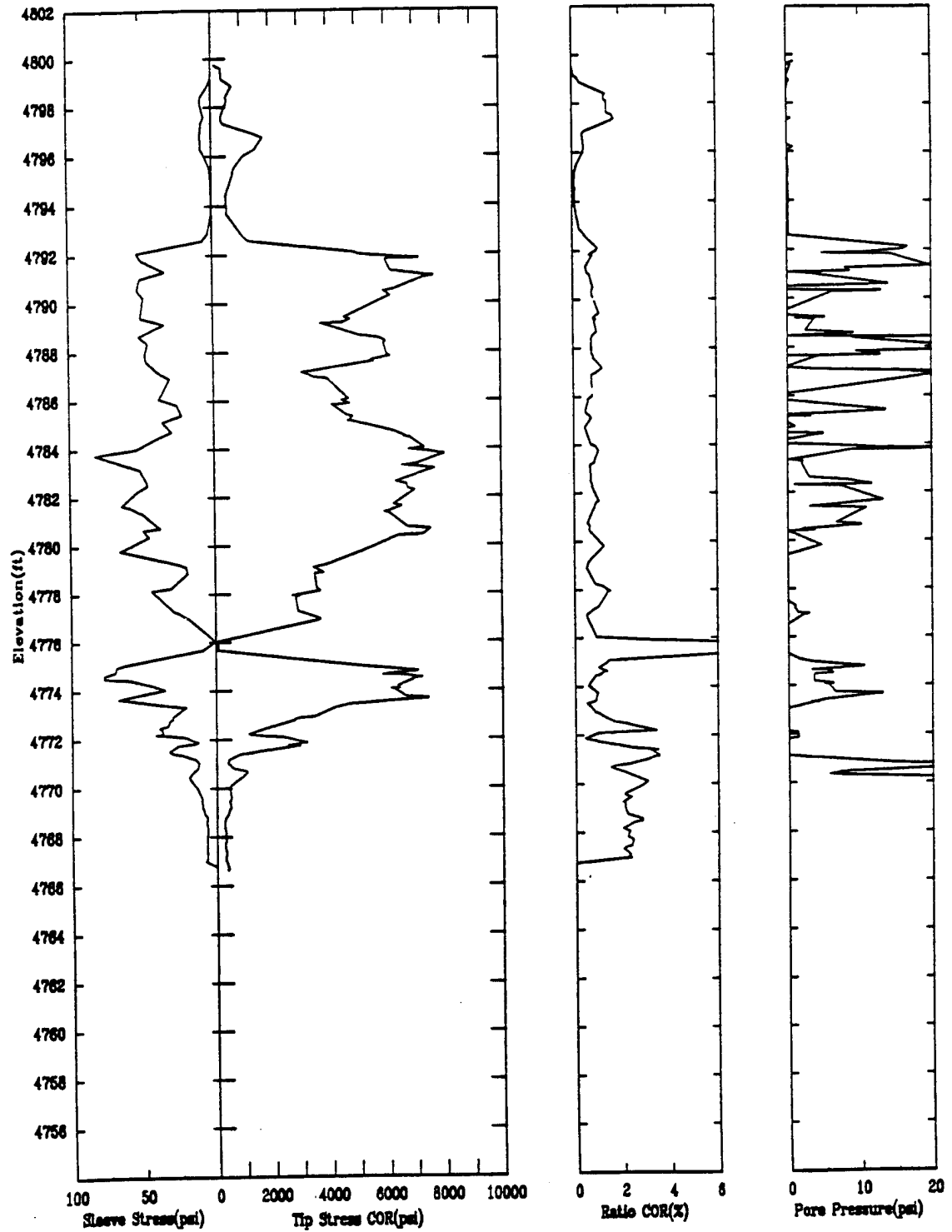
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289574.32

East 1873556.58

Elevation 4799.94



U1-954-38

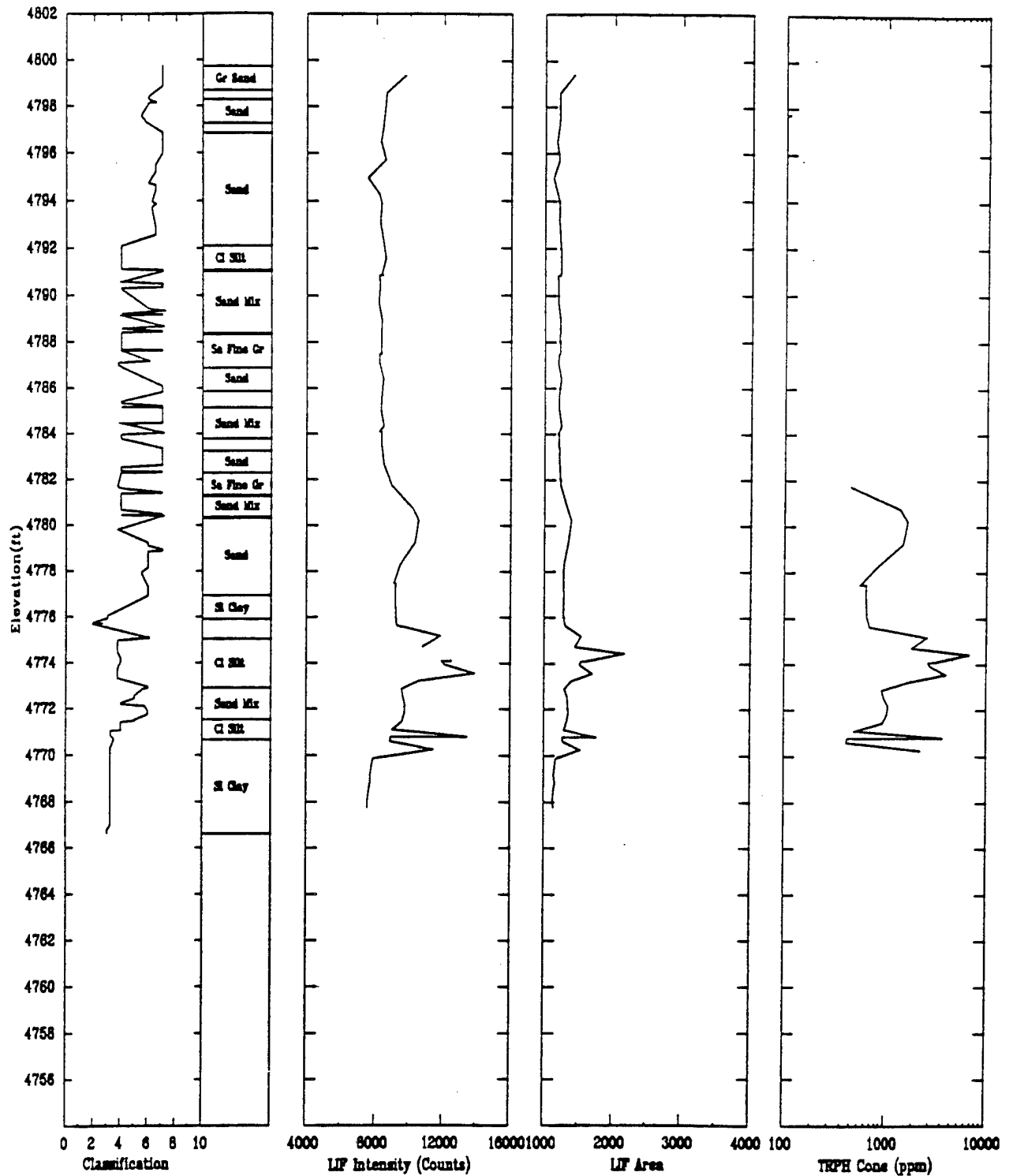
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289574.32

East 1873556.58

Elevation 4799.94



File 418D401.ECP

U1-957-39

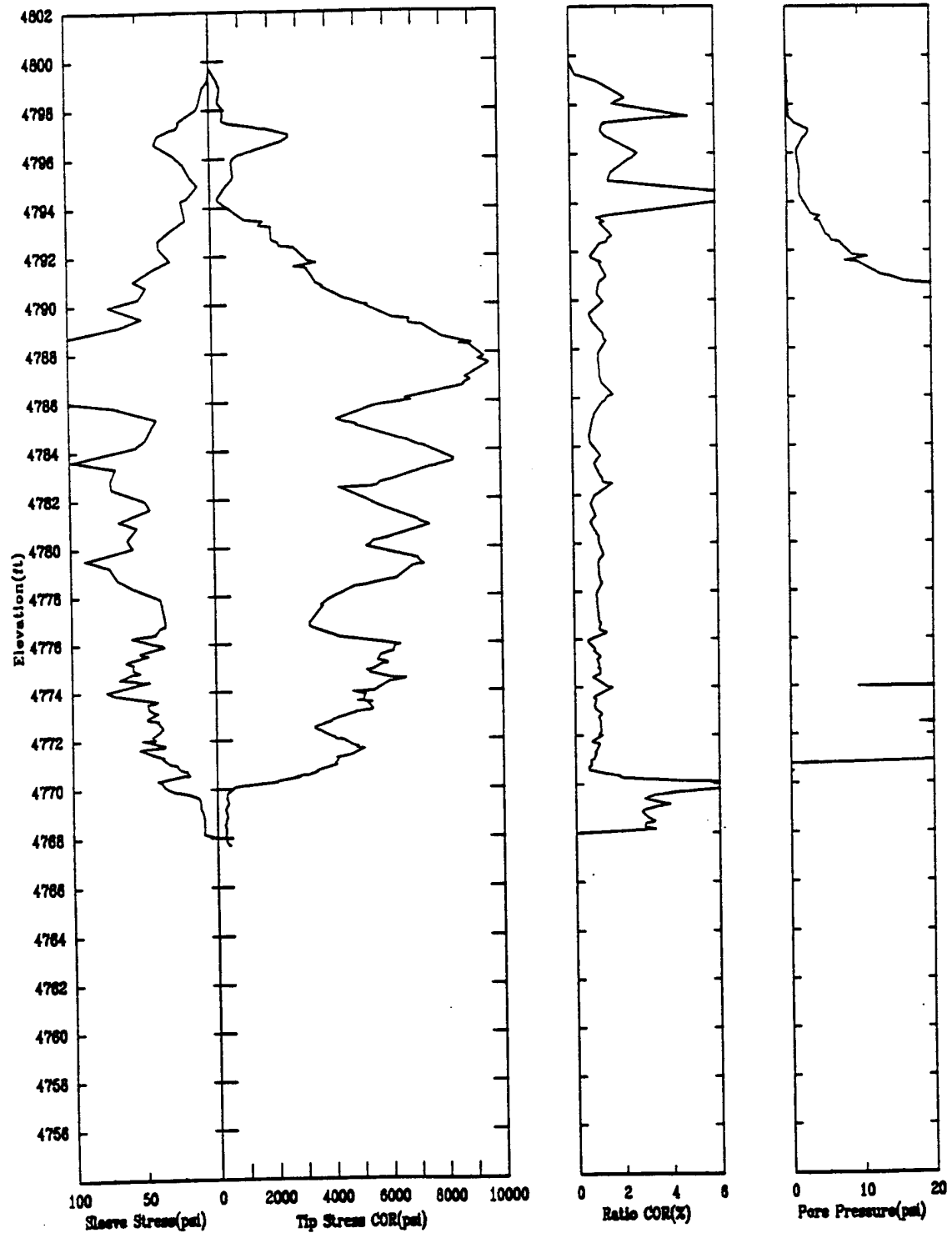
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289510.94

East 1873573.02

Elevation 4800.05



File 4120409.ECP

U1-957-39

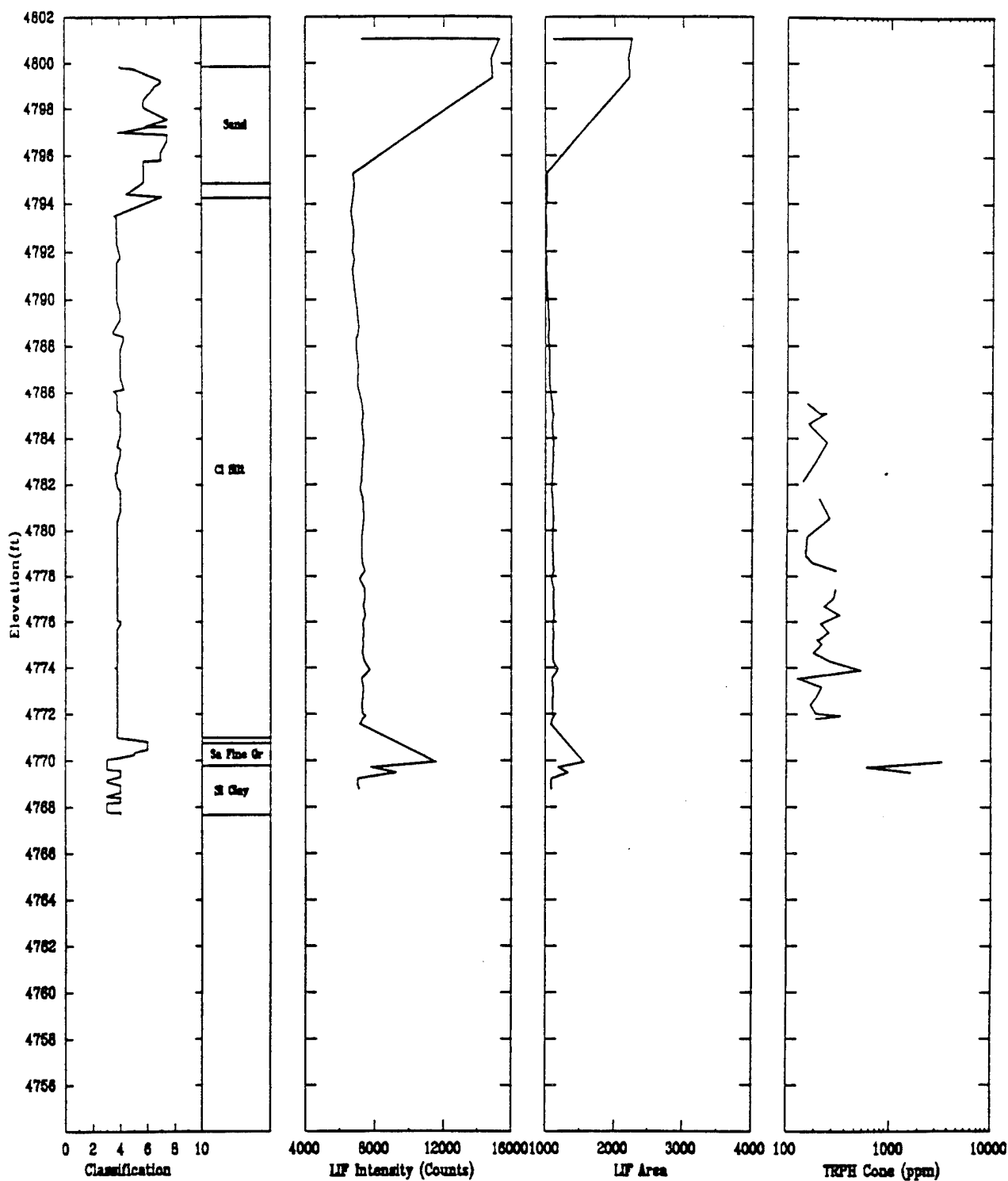
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289510.94

East 1873573.02

Elevation 4800.05

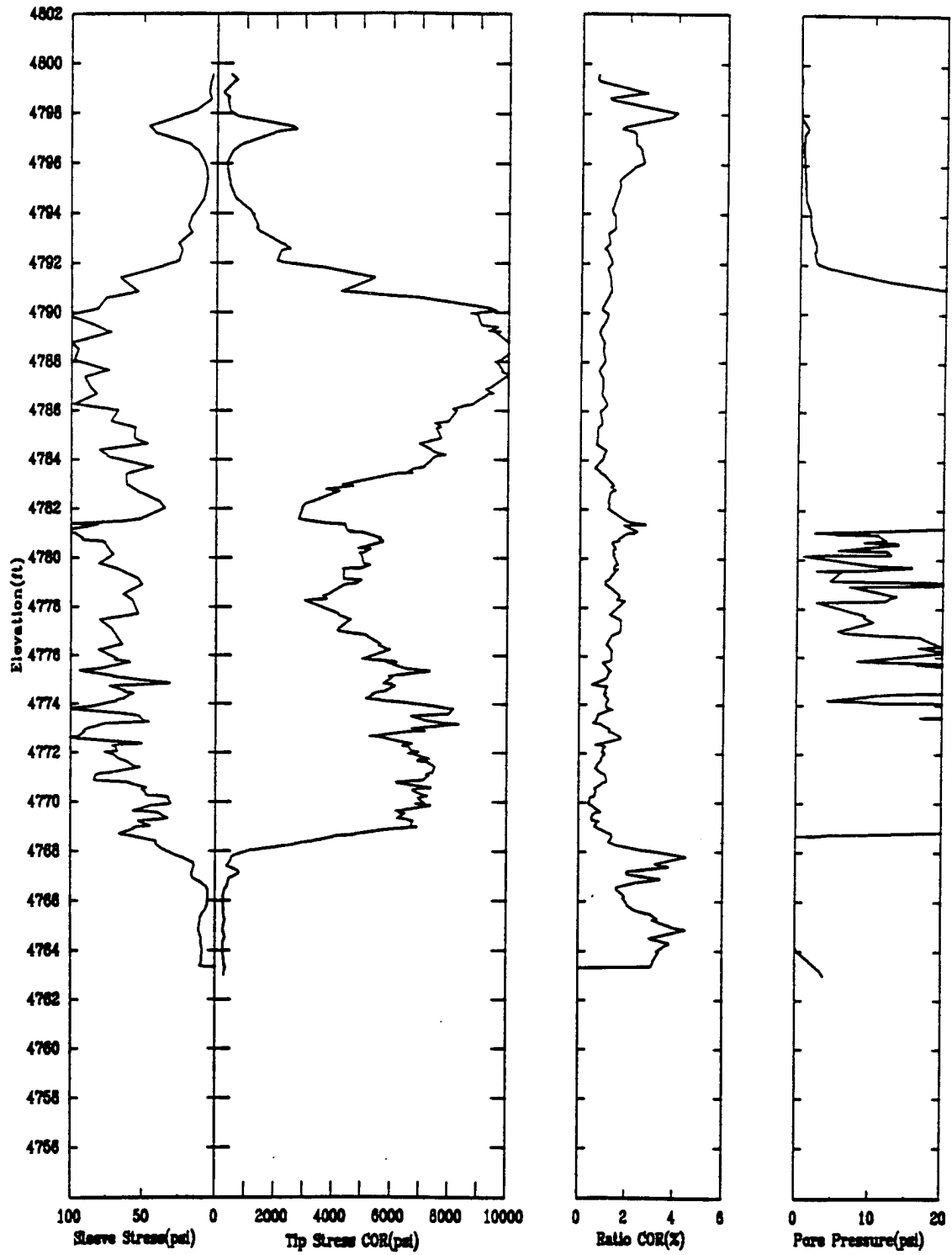


File 4120400.ECP

U1-958-40
North 289456.41

APPLIED RESEARCH ASSOCIATES, INC.
East 1873586.68

12/18/94
Elevation 4800.26



File 418D407.ECP

U1-958-40

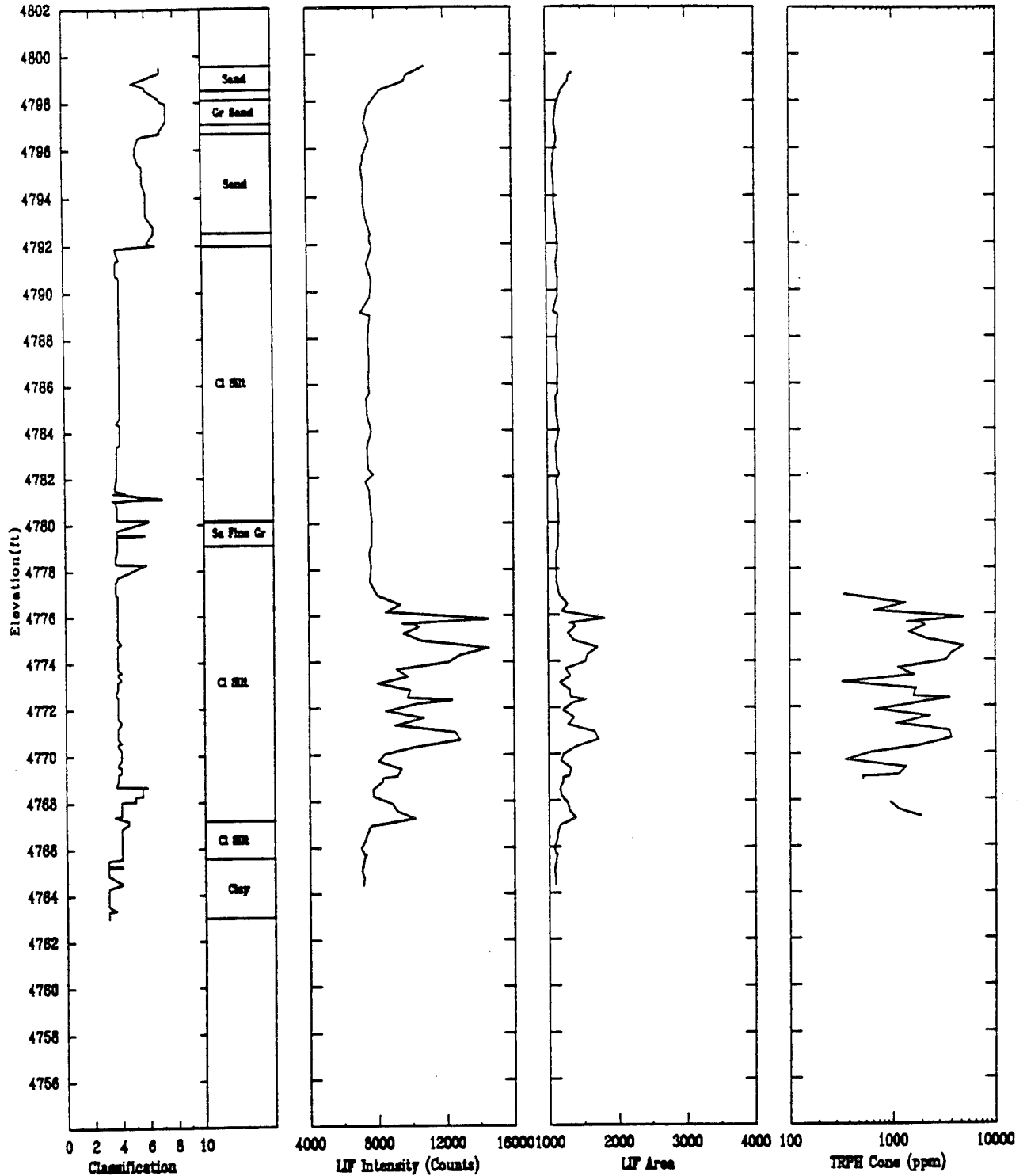
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289456.41

East 1873586.68

Elevation 4800.26



File 41SD407.ECP

U1-956-42

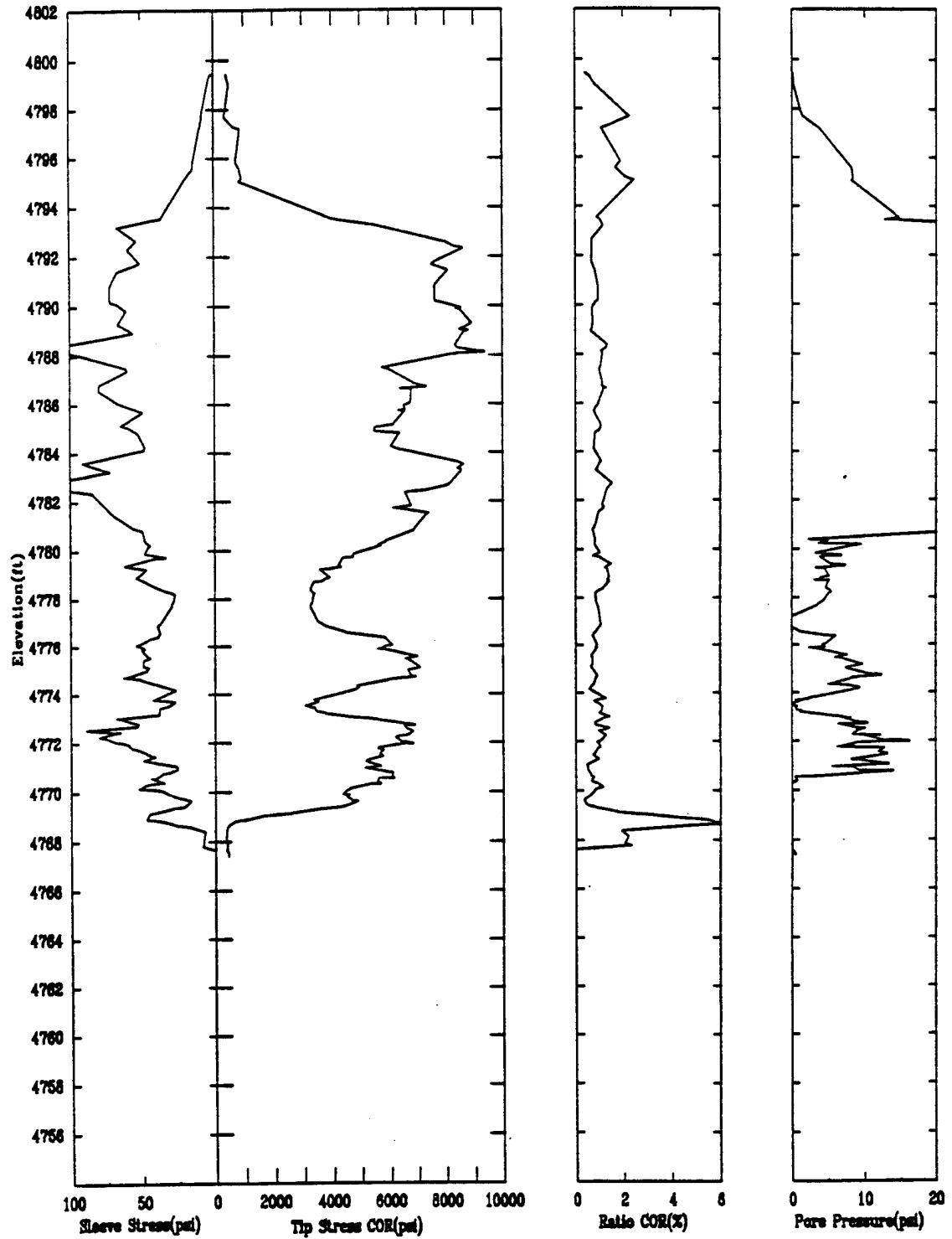
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289501.67

East 1873523.13

Elevation 4800.14



File 418D408.DCP

942-U1-42

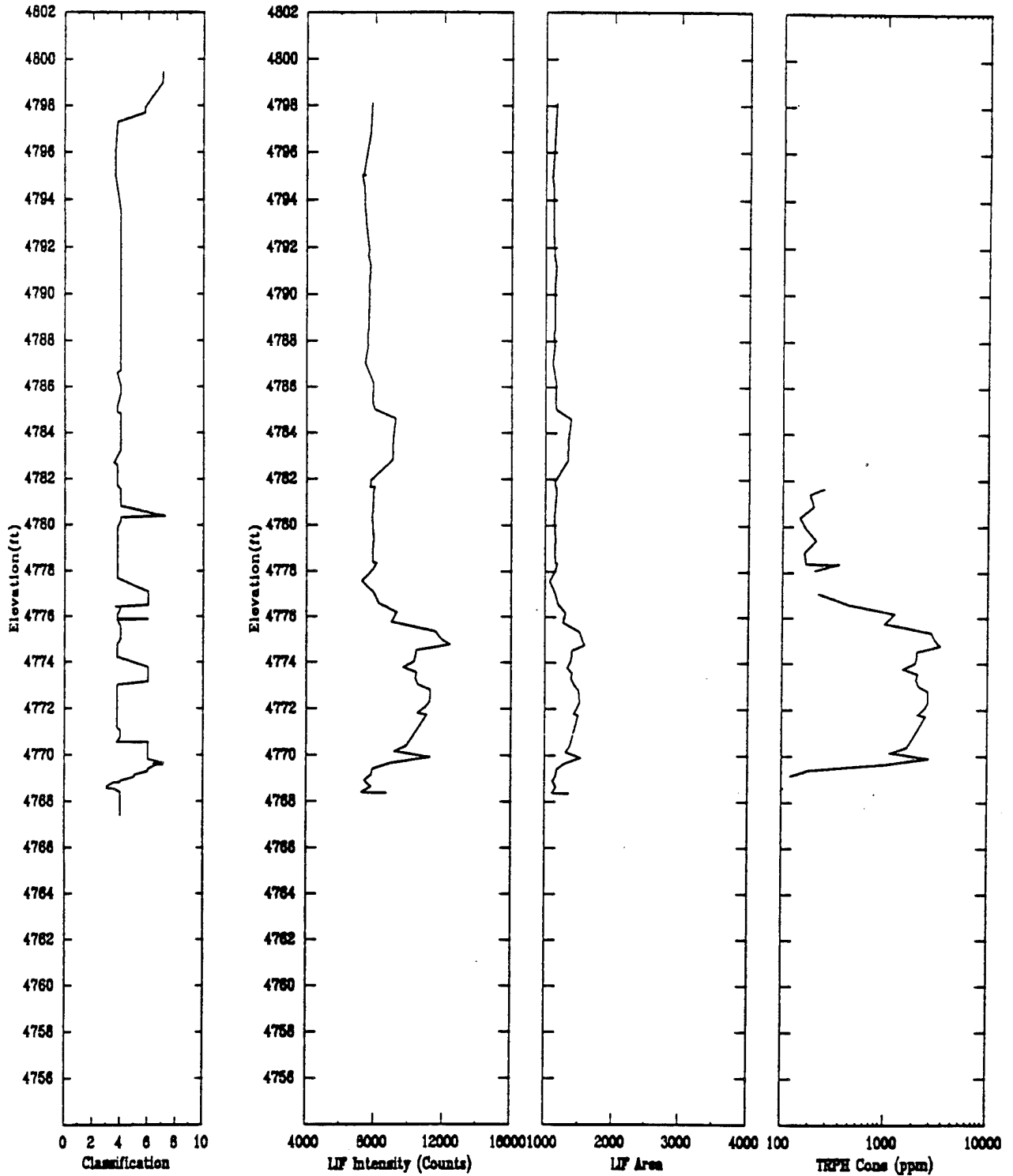
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289501.67

East 1873523.13

Elevation 4800.14



File 418D406.ECP

U1-955-44

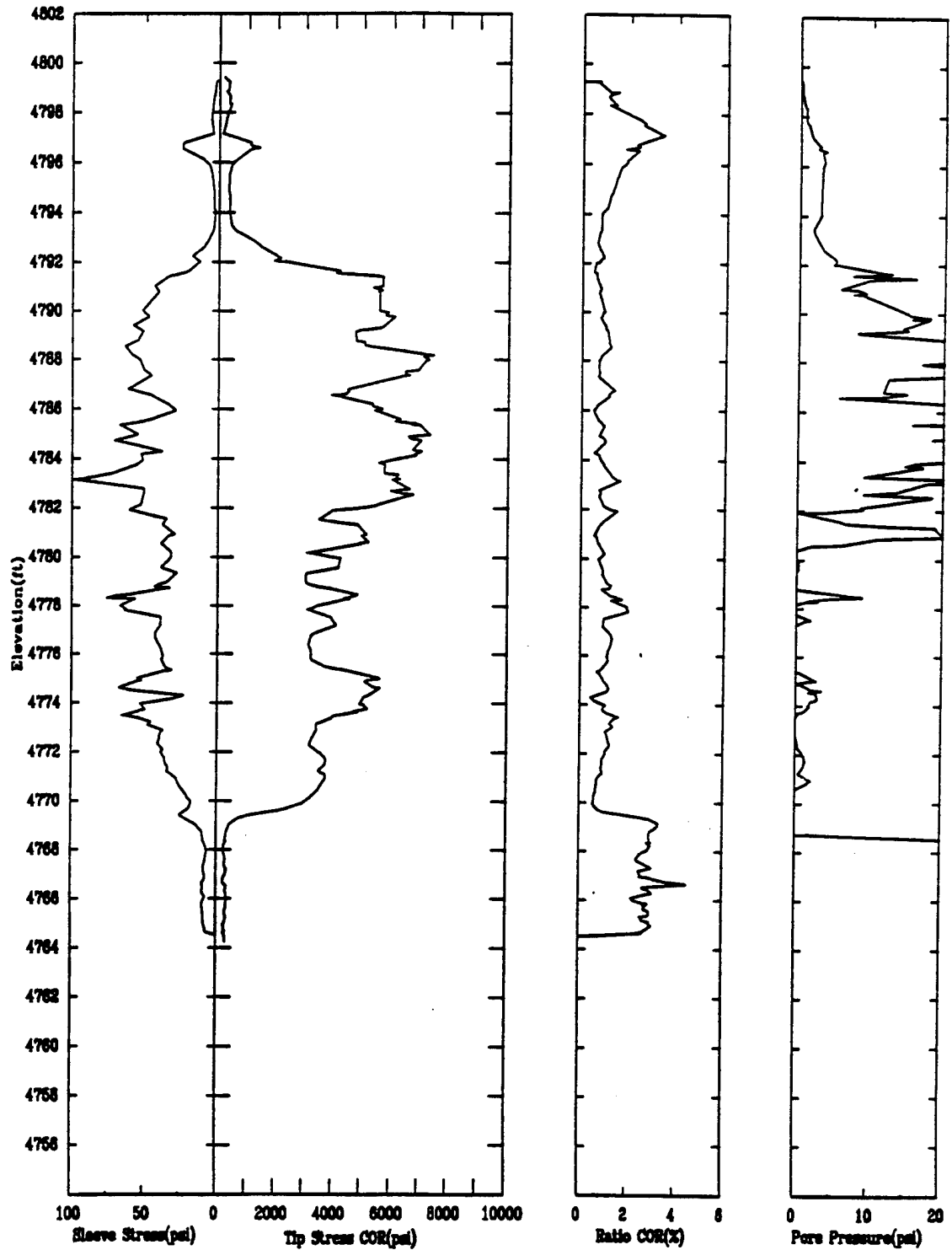
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289598.72

East 1873496.37

Elevation 4799.56



U1-955-44

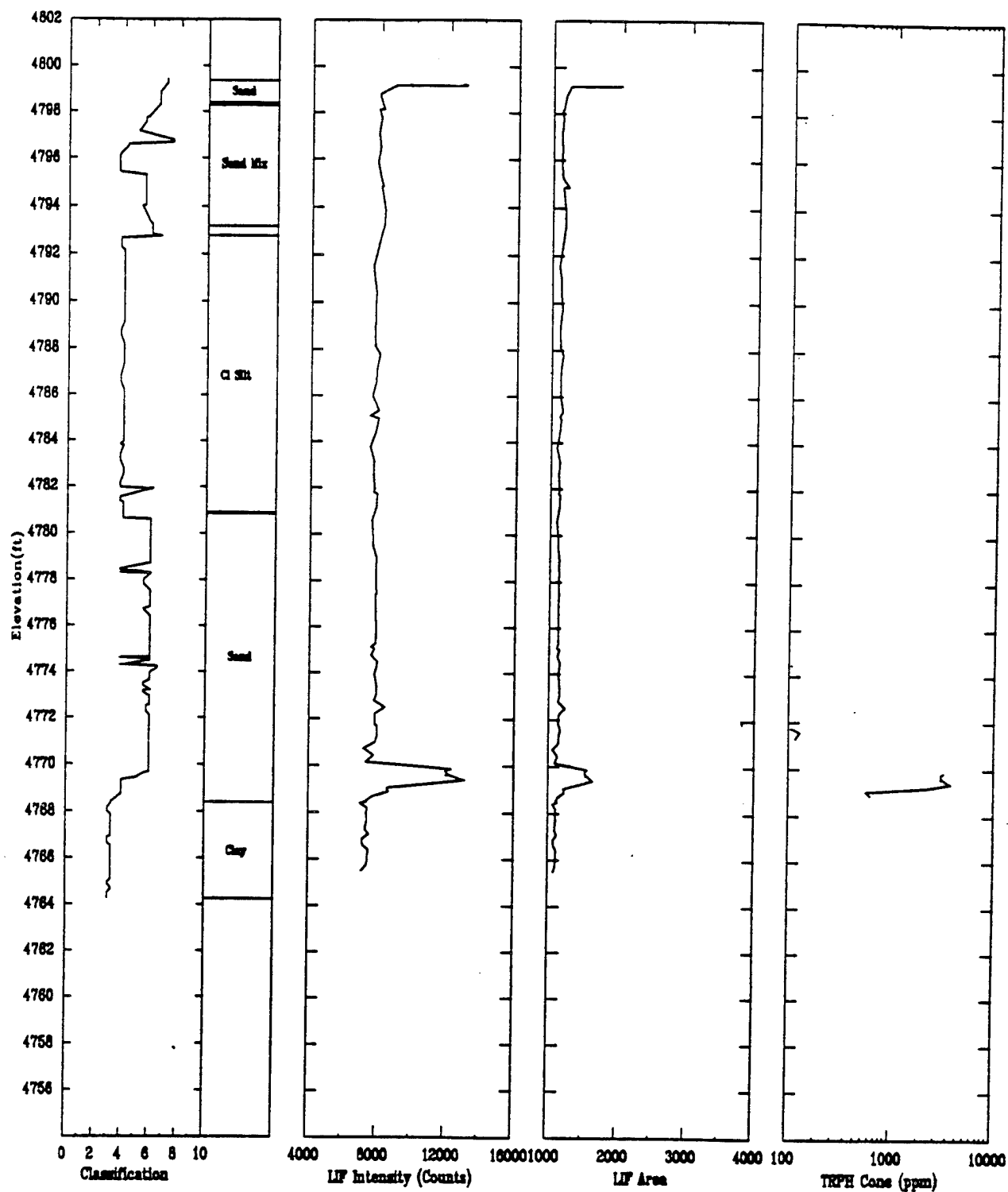
APPLIED RESEARCH ASSOCIATES, INC.

12/18/94

North 289598.72

East 1873496.37

Elevation 4799.56



File 4120405.DCP

U1-941-46

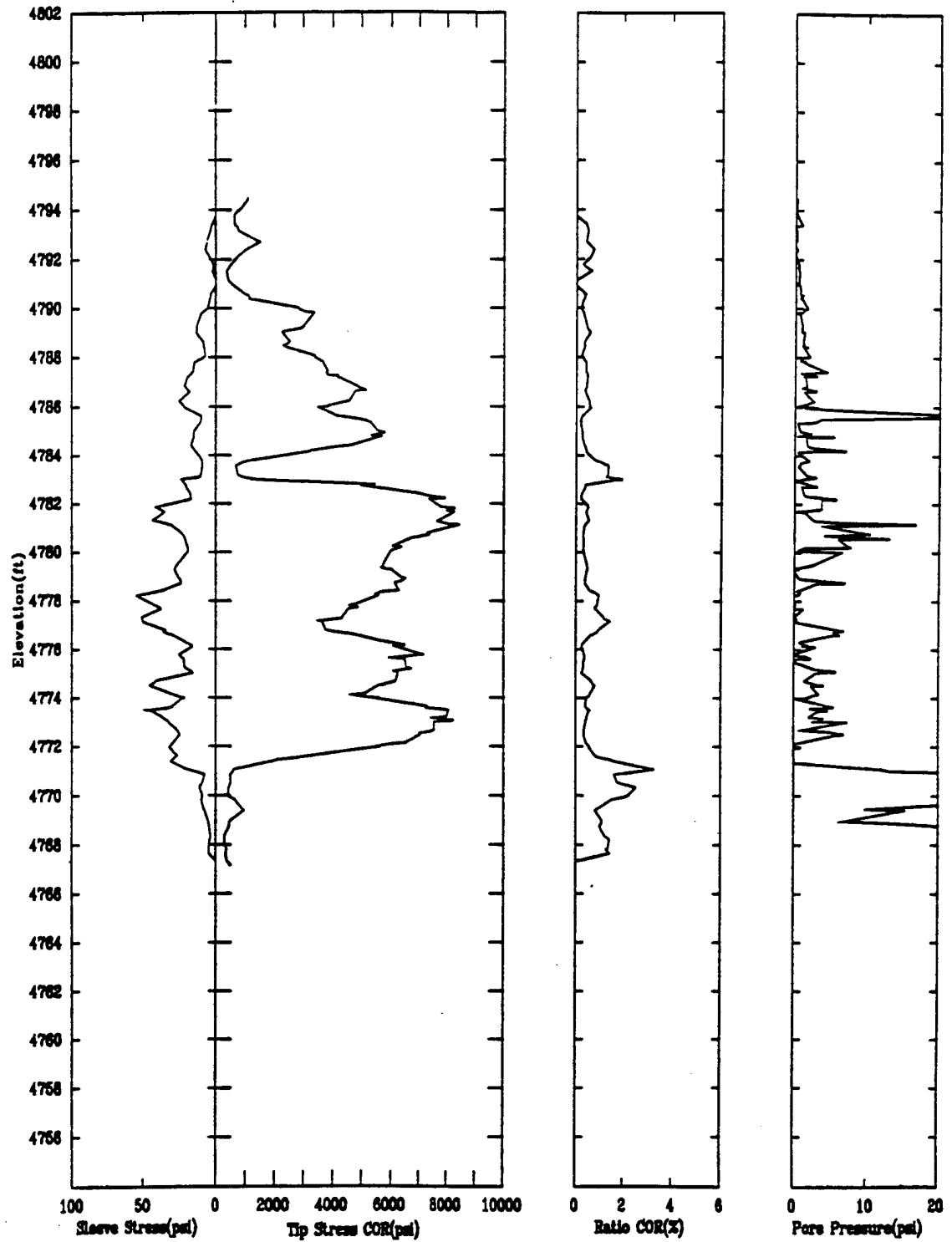
APPLIED RESEARCH ASSOCIATES, INC.

12/15/94

North 289574.63

East 1873800.37

Elevation 4794.84



File 41SD408.BCF

U1-941-46

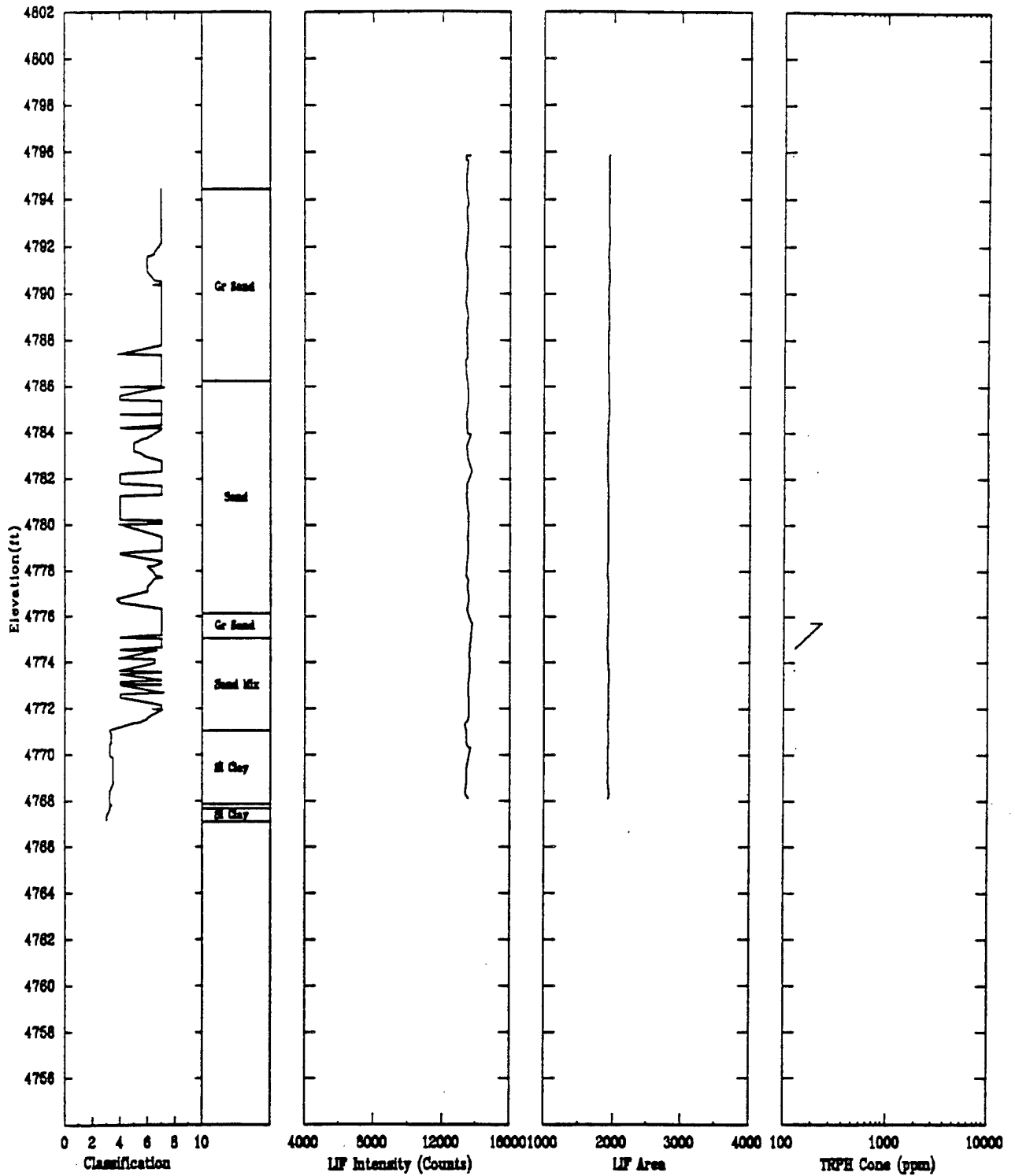
APPLIED RESEARCH ASSOCIATES, INC.

12/15/94

North 289574.63

East 1873800.37

Elevation 4794.84



File 415D408.ECP

U1-933-HOT

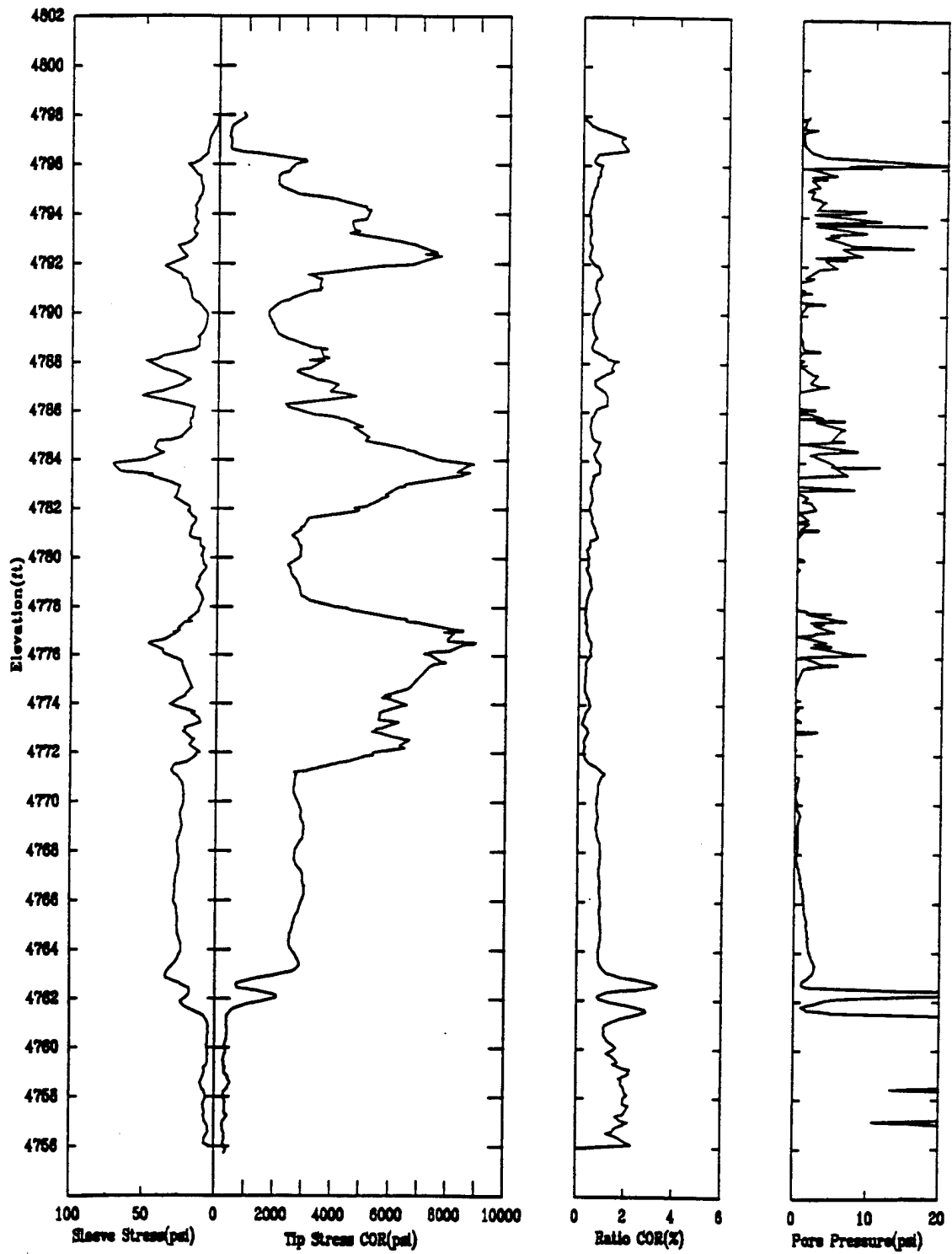
APPLIED RESEARCH ASSOCIATES, INC.

12/14/94

North 289346.75

East 1873786.23

Elevation 4798.25



File 414D433.ECP

U1-933-HOT

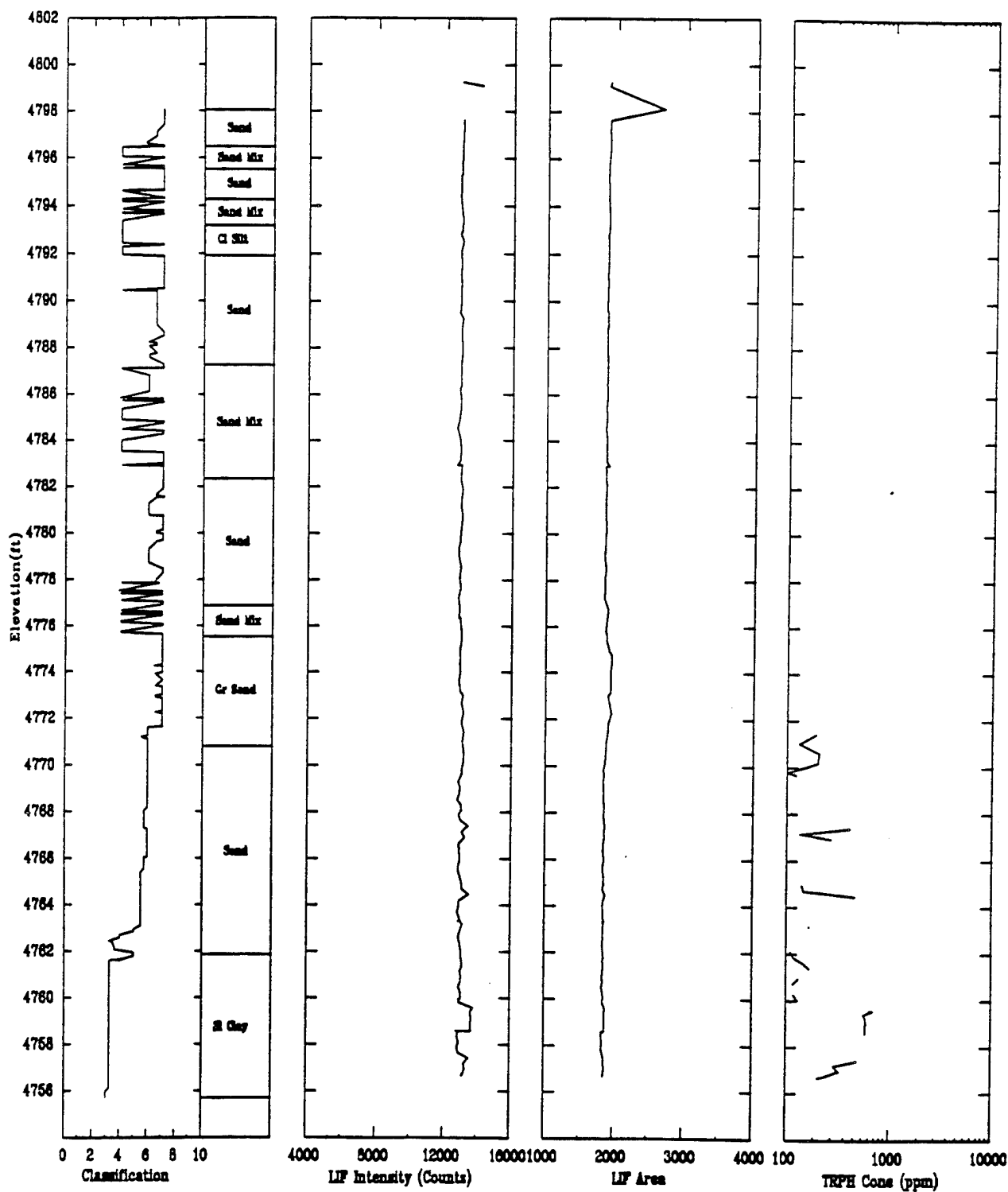
APPLIED RESEARCH ASSOCIATES, INC.

12/14/94

North 289346.75

East 1873786.23

Elevation 4798.25

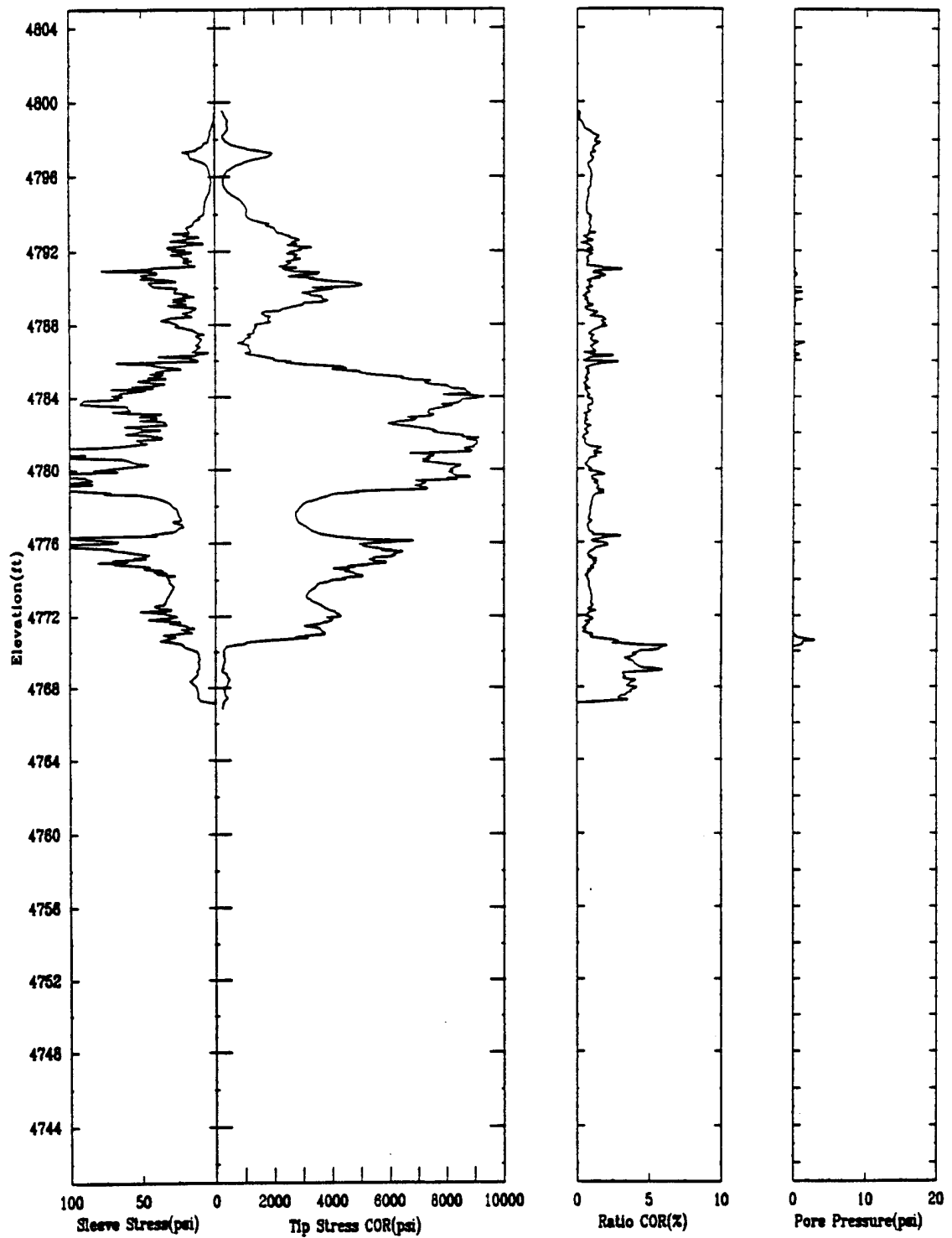


File 414D433.ECP

936-U1-33-R APPLIED RESEARCH ASSOCIATES, INC.

12/17/94

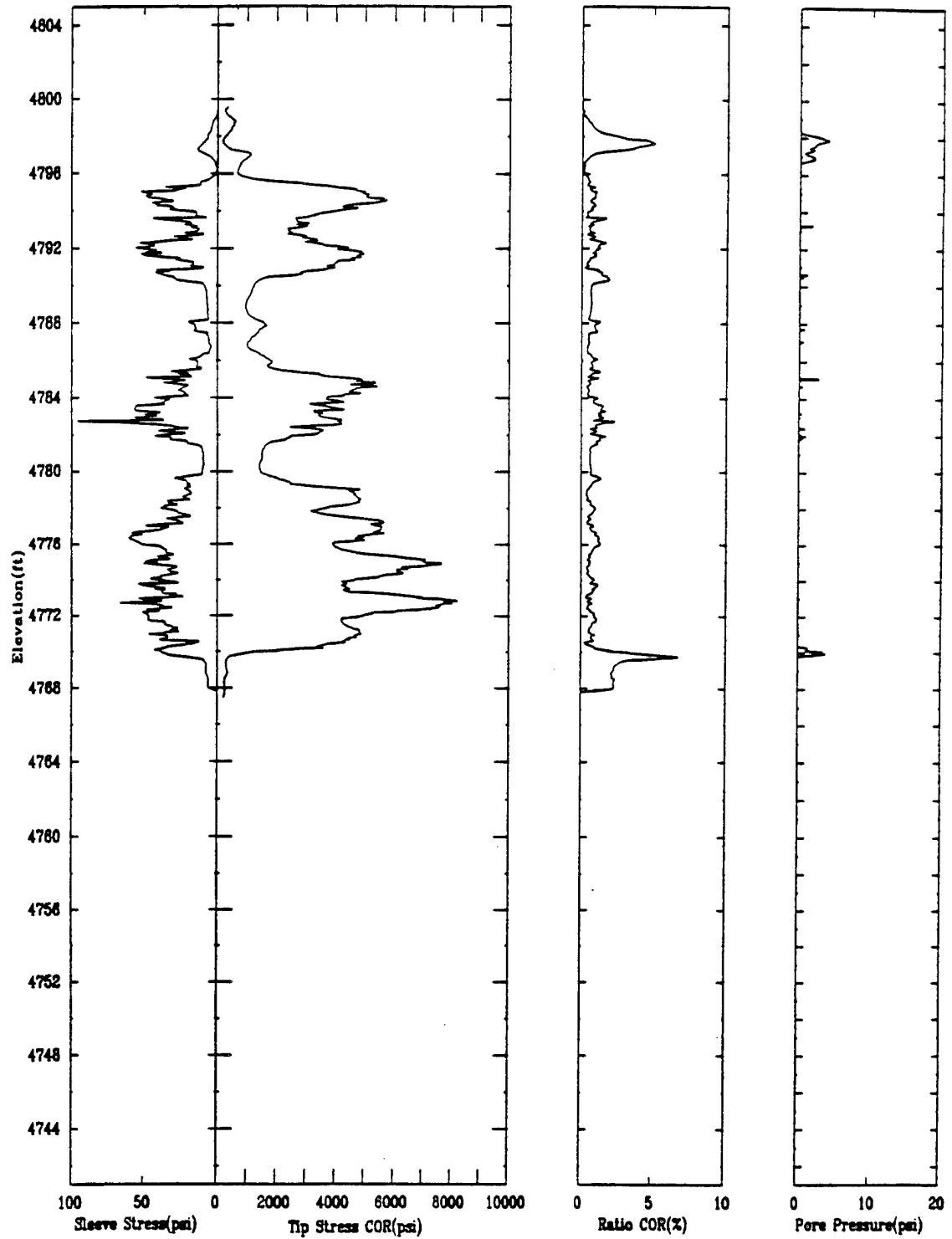
North 289592.55 East 1873601.69 Elevation 4799.75



File 417D408.ECP

934-U1-35-R APPLIED RESEARCH ASSOCIATES, INC.
North 289690.80 East 1873570.98 Elevation 4799.25

12/17/94



File 417D407.ECP

APPENDIX - B

CKY Laboratory Analytical Results

EDITOR'S NOTE:

This appendix is published in the same format as submitted by the contractor including Figure and Table designations.

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Summary of Analytical Tests

The following pages summarize the types of analysis performed on the soil samples taken from Hill Air Force Base as a part of this effort. The table below provides a correlation between the CKY Sample ID and the CPT and Soil Boring Log Numbers. Control No. is a number used internally by CKY Laboratory. Only soil matrices were investigated, i.e., there were no water samples. Analysis refers to the EPA procedure employed to analyze the samples.

CPT Log Number	Sample ID	Soil Boring Number
U1-930	4 22-22.5	U1-888
U1-931	N/A	
U1-932	28 26-26.5	U1-889
U1-933	N/A	
U1-934	N/A	
U1-935	N/A	
U1-936	24 27.5-28	U1-891
U1-937	N/A	
U1-938	N/A	
U1-939	N/A	
U1-940	18 25.5-26	U1-892
U1-941	46 22-22.5	U1-893
U1-942	27 28.5-29	U1-890
U1-943	N/A	
U1-944	30 28.5-29	U1-894
U1-945	25 26.5-27	U1-895
U1-946	N/A	
U1-947	5 14.5-15	U1-896
U1-948	9 18.5-19	U1-897
U1-949	35 29-29.5	U1-898
U1-950	N/A	
U1-951	33 28-28.5	U1-887
U1-952	N/A	
U1-953	31 31-31.5	U1-883
U1-954	38 29-29.5	U1-884
U1-955	N/A	
U1-956	42 30.5-31	U1-885
U1-957	39 28.5-29	U1-886
U1-958	N/A	

N/A - No soil sample analysis performed

A description of the analytical data is provided prior to each of the upcoming sections.

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CKY incorporated Analytical Laboratories

Date: 03-09-1995
CKY Batch No.: N9412-49

Attn.: John Lamb

TRW
One Space Park Drive
Redondo Beach, CA 90278

Subject: Laboratory Report
Project: Hill Air Force Base

Enclosed is the Laboratory report for samples received on 12/27/94. The samples were received in coolers with ice and intact; the chain-of-custody forms were properly filled out. The data reported include :

<u>Sample ID</u>	<u>Control No.</u>	<u>Matrix</u>	<u>Analysis</u>
46 22-22.5	N9412-49-01	Soil	EPA 5030/M8015 EPA 8240
30 28.5-29	N9412-49-02	Soil	EPA 5030/M8015 EPA 8240
31 31-31.5	N9412-49-03	Soil	EPA 5030/M8015 EPA 8240
31 50-50.5	N9412-49-04	Soil	EPA 5030/M8015 EPA 8240
27 28.5-29	N9412-49-05	Soil	EPA 5030/M8015 EPA 8240 EPA M8015
25 26.5-27	N9412-49-06	Soil	EPA 5030/M8015 EPA 8240
38 29-29.5	N9412-49-07	Soil	EPA 5030/M8015 EPA 8240
39 28.5-29	N9412-49-08	Soil	EPA 5030/M8015 EPA 8240
18 25.5-26	N9412-49-09	Soil	EPA 5030/M8015 EPA 8240
28 24-26.5	N9412-49-10	Soil	EPA 5030/M8015 EPA 8240
4 22-22.5	N9412-49-11	Soil	EPA 5030/M8015 EPA 8240
24 27.5-28	N9412-49-12	Soil	EPA 5030/M8015 EPA 8240
35 29-29.5	N9412-49-13	Soil	EPA 5030/M8015 EPA 8240
33 28-28.5	N9412-49-14	Soil	EPA 5030/M8015 EPA 8240

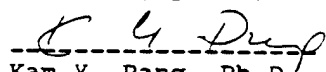
630 Maple Ave., Torrance, Calif. 90503 • Telephone 310-618-8889 • Fax: 310-618-0818

<u>Sample ID</u>	<u>Control No.</u>	<u>Matrix</u>	<u>Analysis</u>
42 30.5-31	N9412-49-15	Soil	EPA 5030/M8015 EPA 8240
5 14.5-15	N9412-49-16	Soil	EPA 5030/M8015 EPA 8240
9 18.5-19	N9412-49-17	Soil	EPA 5030/M8015 EPA 8240

The results are summarized on the following pages.

Please feel free to call if you have any questions concerning these results.

Sincerely yours,



 Kam Y. Pang, Ph.D.
 Laboratory Director

P.S. - All analyses requested for the above referenced project have been completed. Therefore, unless instructed, the remaining portions of the samples will be disposed after fifteen (15) days from the date of this report.



CKY incorporated Analytical Laboratories

Date: 03-20-1995
CKY Batch No.: N9412-49

Attn.: John Lamb, 01-2070

TRW
One Space Park Drive
Redondo Beach, CA 90278

Subject: Additional Laboratory Report
Project: Hill Air Force Base

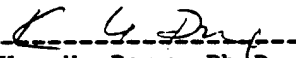
Enclosed is the additional laboratory report for samples received on 12/27/94. The samples were received in coolers with ice and intact; the chain-of-custody forms were properly filled out. The data reported include :

Sample ID	Control No.	Matrix	Analysis
46 22-22.5	N9412-49-01	Soil	EPA M8015
30 28.5-29	N9412-49-02	Soil	EPA M8015
31 31-31.5	N9412-49-03	Soil	EPA M8015
31 50-50.5	N9412-49-04	Soil	EPA M8015
27 28.5-29	N9412-49-05	Soil	EPA M8015
25 26.5-27	N9412-49-06	Soil	EPA M8015
38 29-29.5	N9412-49-07	Soil	EPA M8015
39 28.5-29	N9412-49-08	Soil	EPA M8015
18 25.5-26	N9412-49-09	Soil	EPA M8015
28 24-26.5	N9412-49-10	Soil	EPA M8015
4 22-22.5	N9412-49-11	Soil	EPA M8015
24 27.5-28	N9412-49-12	Soil	EPA M8015
35 29-29.5	N9412-49-13	Soil	EPA M8015
33 28-28.5	N9412-49-14	Soil	EPA M8015
42 30.5-31	N9412-49-15	Soil	EPA M8015
5 14.5-15	N9412-49-16	Soil	EPA M8015
9 18.5-19	N9412-49-17	Soil	EPA M8015

The results are summarized on the following pages.

Please feel free to call if you have any questions concerning these results.

Sincerely yours,


Kam Y. Pang, Ph.D.
Laboratory Director

P.S. - All analyses requested for the above referenced project have been completed. Therefore, unless instructed, the remaining portions of the samples will be disposed after fifteen (15) days from the date of this report.

630 Maple Ave., Torrance, Calif. 90503 • Telephone 310-618-8889 • Fax: 310-618-0818

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Laboratory Results from Purge and Trap TPH Analysis

The following pages contain the laboratory analytical data from the Purge and Trap analysis of the soil samples for lower molecular weight TPH. Results are provided in milligrams of contaminant per kilogram of soil (mg/kg). Note that actual soil sample sizes were one gram. The values provided are scaled up to kilograms, since mg/kg is the standard unit for this type of analysis. The analytical instrument was calibrated with JP-4, which is representative of the lower molecular weight TPH.

The % recovery surrogate is a measure of the integrity of the analysis. Before analysis, a sample is spiked with a known amount of a surrogate. When the sample is analyzed, the amount of surrogate in the sample is measured, along with the compounds of interest. The % recovery surrogate is calculated based on the ratio of the amount of surrogate detected to the amount of surrogate spiked. For these tests, bromofluorbenzene was used as the surrogate. In some cases, the % recovery surrogate could not be determined because there was matrix interference, i.e., the surrogate coeluted with the compound of interest. The % recovery surrogates reported are reasonable for these analyses.

The dilution factor (DL) represents the amount each sample had to be diluted to bring the analysis within the calibration range of the instrument. The reporting limit (RL) represents the detection limit for the method, taking into account any dilutions made.

In addition to spiking a sample with a surrogate, the sample was spiked with JP-4. Analysis for this spike proceeds similarly to the surrogate spike. The % recovery here is a measure of the accuracy of the analysis, i.e., it determines the matrix effects in the analytical sample.

EPA 5030/M8015
TOTAL PETROLEUM HYDROCARBONS BY PURGE & TRAP

CLIENT: TRW	DATE COLLECTED: 12/21/94
PROJECT: Hill Air Force Base	DATE RECEIVED: 12/27/94
BATCH NO.: N9412-49	DATE EXTRACTED: NA
MATRIX: SOIL	DATE ANALYZED: 12/28/94

SAMPLE ID	CONTROL NO	RESULT (mg/kg)	% RECOVERY SURR	DL FACTOR	RL (mg/kg)
46 22-22.5	N9412-49-01	10	*	1	5
30 28.5-29	N9412-49-02 **	810	*	50	250
31 31-31.5	N9412-49-03 **	230	*	20	100
31 50-50.5	N9412-49-04 **	400	*	50	250
27 28.5-29	N9412-49-05	33	*	1	5
25 26.5-27	N9412-49-06 **	480	*	10	50
38 29-29.5	N9412-49-07	95	*	1	5
39 28.5-29	N9412-49-08 **	1900	*	100	500
18 25.5-26	N9412-49-09	27	*	1	5
28 24-26.5	N9412-49-10 **	1100	*	50	250
4 22-22.5	N9412-49-11 **	530	*	50	250
24 27.5-28	N9412-49-12	ND	105	1	5
35 29-29.5	N9412-49-13	ND	110	1	5
33 28-28.5	N9412-49-14	ND	113	1	5
42 30.5-31	N9412-49-15	27	*	1	5
5 14.5-15	N9412-49-16	ND	113	1	5
9 18.5-19	N9412-49-17	ND	109	1	5
M. Blank	N9412-49-BLK	ND	112	1	5

SURR : Bromofluorobenzene

RL : Reporting Limit

* : Surrogate recovery could not be accurately determined due to matrix interference.

** : Analyzed on 12/29/94. Result obtained on 12/28/94 was out of calibration range.

Collection Date: 12/22/94 for N9412-49-01, -05, -06, -12, -13, -14 and -15
12/23/94 for N9412-49-11, -16 and -17

CKY QUALITY CONTROL DATA
SPIKE/SPIKE DUPLICATE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA M8015G
MATRIX: SOIL

BATCH NO.: N9412-49 DATE RECEIVED: 12/27/94
SAMPLE ID: 9 18.5-19 DATE EXTRACTED: NA
CONTROL NO.: N9412-49-17 DATE ANALYZED: 12/28/94
ACCESSION: N9412-49

Parameter	SAMPLE CONC (mg/kg)	SPIKE ADDED (mg/kg)	MS CONC (mg/kg)	MS % REC	SPIKE ADDED (mg/kg)	MSD CONC (mg/kg)	MSD % REC	% RPD
JP-4	ND	5.0	3.7	74	5.0	4.0	80	8

CKY QUALITY CONTROL DATA
SPIKE/SPIKE DUPLICATE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA M8015G
MATRIX: SOIL

BATCH NO.: N9412-49
SAMPLE ID: M. Blank
CONTROL NO.: N9412-49-BLK
ACCESSION: N9412-49

DATE RECEIVED: NA
DATE EXTRACTED: NA
DATE ANALYZED: 12/29/94

Parameter	SAMPLE CONC (mg/kg)	SPIKE ADDED (mg/kg)	MS CONC (mg/kg)	MS % REC	SPIKE ADDED (mg/kg)	MSD CONC (mg/kg)	MSD % REC	% RPD
JP-4	ND	5.0	3.9	78	5.0	4.0	80	3

CKY QUALITY CONTROL DATA
LABORATORY CONTROL SAMPLE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA M8015G
MATRIX: SOIL

BATCH NO.: N9412-49
SAMPLE ID: LCS1
CONTROL NO.: N9412-49-LCS
DATE RECEIVED: NA
DATE EXTRACTED: NA
DATE ANALYZED: 12/28/94
ACCESSION: N9412-49

PARAMETER	TRUE VALUE (mg/kg)	FOUND VALUE (mg/kg)	LCS RECOVERY (%)
JP-4	5.0	4.7	94

CKY QUALITY CONTROL DATA
LABORATORY CONTROL SAMPLE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA M8015G
MATRIX: SOIL

=====

BATCH NO.:	N9412-49	DATE RECEIVED:	NA
SAMPLE ID:	LCS2	DATE EXTRACTED:	NA
CONTROL NO.:	N9412-49-LCS	DATE ANALYZED:	12/29/94
ACCESSION:	N9412-49		

PARAMETER	TRUE VALUE (mg/kg)	FOUND VALUE (mg/kg)	LCS RECOVERY (%)
-----	-----	-----	-----
JP-4	5.0	4.3	86

Laboratory Results from Extraction TPH Analysis

The following pages contain the laboratory analytical data from the extraction analysis of the soil samples for higher molecular weight TPH. Results are provided in milligrams of contaminant per kilogram of soil (mg/kg). The column labeled H-C range describes which of two peaks coming out of the gas chromatograph can be attributed to the compounds of interest. The abbreviation C_n , where $n = 8$ to 24 , connotes a hydrocarbon with n number of carbons. The analytical instrument was calibrated with kerosene and diesel fuel for the nominal C_8 to C_{17} range, and with motor oil for the nominal C_{17+} range.

The % recovery surrogate is a measure of the integrity of the analysis. Before analysis, a sample is spiked with a known amount of a surrogate. When the sample is analyzed, the amount of surrogate in the sample is measured, along with the compounds of interest. The % recovery surrogate is calculated based on the ratio of the amount of surrogate detected to the amount of surrogate spiked. For these tests, bromofluorbenzene and hexacosane were used as the surrogates. The % recovery surrogates reported are reasonable for these analyses.

The dilution factor (DL) represents the amount each sample had to be diluted to bring the analysis within the calibration range of the instrument. The method detection limit (MDL) takes into account any dilutions made.

In addition to spiking a sample with a surrogate, the sample was spiked with diesel fuel. Analysis for this spike proceeds similarly to the surrogate spike. The % recovery here is a measure of the accuracy of the analysis, i.e., it determines the matrix effects in the analytical sample.

EPA METHOD M8015
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION (FINGERPRINT)

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	03/16/95
MATRIX:	SOIL	DATE ANALYZED:	03/18/95

SAMPLE ID	CONTROL NO	RESULT (mg/kg)	H-C RANGE	% RECOVERY		DL FACTOR	MDL (mg/kg)
				SURR1	SURR2		
46 22-22.5	N9412-49-01	16	C11-C17	56~	71	1	2
30 28.5-29	N9412-49-02	1200	C8-C17	143~	110	1	2
		410	C17+				
31 31-31.5	N9412-49-03	135	C9-C17	60	74	1	2
		135	C17+				
31 50-50.5	N9412-49-04	760	C7-C17	122	126	1	2
		390	C17+				
27 28.5-29	N9412-49-05	90	C9-C17	56~	67	1	2
		103	C17+				
25 26.5-27	N9412-49-06	1300	C8-C17	DO	61	10	20
		720	C17+				
38 29-29.5	N9412-49-07	72	C8-C17	48~	59	1	2
		98	C17+				
39 28.5-29	N9412-49-08	8000	C6-C17	182~	280~	1	2
		3000	C17+				
18 25.5-26	N9412-49-09	2200	C8-C18	95	194~	1	2
		810	C18+				
28 26-26.5	N9412-49-10	5100	C8-C17	150~	234~	1	2
		2400	C17+				
4 22-22.5	N9412-49-11	3400	C8-C17	135	137	1	2
		1000	C17+				
24 27.5-28	N9412-49-12	ND	N.A.	63	77	1	2
35 29-29.5	N9412-49-13	ND	N.A.	47~	61	1	2
33 28-28.5	N9412-49-14	ND	N.A.	44~	61	1	2
42 30.5-31	N9412-49-15	42	C10-C17	44~	60	1	2
5 14.5-15	N9412-49-16	ND	N.A.	59~	60	1	2
9 18.5-19	N9412-49-17	ND	N.A.	47~	60	1	2
DBLK01	N9412-49-B1S	ND	N.A.	58~	67	1	2

QC LIMIT:
 SURR1 : Bromobenzene
 SURR2 : Hexacosane
 MDL : Method Detection Limit
 DO : Diluted out
 C8-C16 : Kerosene
 C10-C24 : Diesel
 C24+ : Motor oil
 ~ : Out of QC limit

60-140 55-150

DATE COLLECTED: 12/22/94, for samples N9412-49-01, 05, 06, 12, 13, 14 and 15.
 12/23/94, for samples N9412-49-11, 16 and 17.
 DATE ANALYZED : 03/19/95, for samples N9412-49B-02, 04, 09, 10 and 11.
 Sample response from C6-C17 is not typical diesel pattern but results are quantified against diesel.

CKY QUALITY CONTROL DATA
SPIKE/SPIKE DUPLICATE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA M8015
MATRIX: SOIL

BATCH NO.:	N9412-49	DATE RECEIVED:	12/27/94
SAMPLE ID:	9 18.5-19	DATE EXTRACTED:	03/16/95
CONTROL NO.:	N9412-49-17	DATE ANALYZED:	03/17/95
ACCESSION:	N9412-49		

Parameter	SAMPLE CONC (mg/kg)	SPIKE ADDED (mg/kg)	MS CONC (mg/kg)	MS % REC	SPIKE ADDED (mg/kg)	MSD CONC (mg/kg)	MSD % REC	% RPD
DIESEL	ND	250	165	66	250	159	64	4
QC LIMIT:				60-140			60-140	40

CKY QUALITY CONTROL DATA
LABORATORY CONTROL SAMPLE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA M8015
MATRIX: SOIL

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BATCH NO.:	N9412-49	DATE RECEIVED:	NA
SAMPLE ID:	LCS1	DATE EXTRACTED:	03/16/95
CONTROL NO.:	N9412-49-L1W	DATE ANALYZED:	03/17/95
ACCESSION:	N9412-49		

PARAMETER	TRUE VALUE (mg/kg)	FOUND VALUE (mg/kg)	LCS RECOVERY (%)
DIESEL	250	156	62
QC LIMIT:			60-140

Results from Method 8240 for Specific Volatile Organic Compounds

The following pages contain the laboratory analytical data from EPA Method 8260 for specific volatile organic compounds. Results are provided in micrograms of contaminant per kilogram of soil ($\mu\text{g}/\text{kg}$).

The % recovery surrogate is a measure of the integrity of the analysis. Before analysis, a sample is spiked with a known amount of a surrogate. When the sample is analyzed, the amount of surrogate in the sample is measured, along with the compounds of interest. The % recovery surrogate is calculated based on the ratio of the amount of surrogate detected to the amount of surrogate spiked. For these tests, three different surrogates were used, as listed at the bottom of each page. The % recovery surrogates reported are reasonable for these analyses.

The reporting limit (RL) represents the detection limit for the method, taking into account any dilutions made.

In addition to spiking a sample with a surrogate, the sample was spiked with five of the method compounds, as described on the last two pages of this section. Analysis for these spikes proceeds similarly to the surrogate spike. The % recovery here is a measure of the accuracy of the analysis, i.e., it determines the matrix effects in the analytical sample.

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	46 22-22.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-01	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	83	
Toluene-d8	82	
Bromofluorobenzene	98	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	30 28.5-29	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-02	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	540	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	1400	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	4200	50
Styrene	ND	50
Xylenes (o)	2400	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	85	
Toluene-d8	86	
Bromofluorobenzene	194 +	

RL: Reporting Limit
+ : Matrix interference

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	31 31-31.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-03	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	100	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	ND	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	1600	50
Styrene	ND	50
Xylenes (o)	940	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	87	
Toluene-d8	82	
Bromofluorobenzene	108	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	31 50-50.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-04	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	140	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	520	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	1800	50
Styrene	ND	50
Xylenes (o)	1100	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	85	
Toluene-d8	81	
Bromofluorobenzene	108	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	27 28.5-29	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-05	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	790	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	220	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	900	50
Styrene	ND	50
Xylenes (o)	780	50
1,1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	84	
Toluene-d8	89	
Bromofluorobenzene	101	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	25 26.5-27	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-06	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	7300	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	1800	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	5300	50
Styrene	ND	50
Xylenes (o)	5100	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	82	
Toluene-d8	86	
Bromofluorobenzene	232 +	

RL: Reporting Limit
+ : Matrix interference

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	38 29-29.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-07	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	630	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	1100	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	1200	50
Styrene	ND	50
Xylenes (o)	940	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	162 +	
Toluene-d8	82	
Bromofluorobenzene	130	

RL: Reporting Limit
+ : Matrix interference

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	39 28.5-29	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-08	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	18000	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	6300	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	17000	50
Styrene	ND	50
Xylenes (o)	13000	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	80	
Toluene-d8	94	
Bromofluorobenzene	400 +	

RL: Reporting Limit
+ : Matrix interference

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	18 25.5-26	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-09	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	ND	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	ND	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	100	50
Styrene	ND	50
Xylenes (o)	160	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	80	
Toluene-d8	80	
Bromofluorobenzene	106	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/21/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	28 24-26.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-10	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	18000	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	4700	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	13000	50
Styrene	ND	50
Xylenes (o)	12000	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	84	
Toluene-d8	86	
Bromofluorobenzene	98	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/23/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	4 22-22.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-11	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	50
1,1-Dichloroethane	ND	50
2-Butanone	ND	50
Chloroform	ND	50
1,1,1-Trichloroethane	ND	50
Carbon Tetrachloride	ND	50
Benzene	ND	50
Toluene	ND	50
Carbon Disulfide	ND	50
1,2-Dichloroethane	ND	50
Trichloroethene	ND	50
1,2-Dichloropropane	ND	50
Bromodichloromethane	ND	50
2-Pentanone, 4-Methyl	ND	50
trans-1,3-Dichloropropene	ND	50
cis-1,3-Dichloropropene	ND	50
1,1,2-Trichloroethane	ND	50
Tetrachloroethene	ND	50
Dibromochloromethane	ND	50
Ethylbenzene	ND	50
Chlorobenzene	ND	50
Bromoform	ND	50
Xylenes (m/p)	ND	50
Styrene	ND	50
Xylenes (o)	5600	50
1,1,2,2-Tetrachloroethane	ND	50
1,3-Dichlorobenzene	ND	50
1,4-Dichlorobenzene	ND	50
1,2-Dichlorobenzene	ND	50

SURROGATE PARAMETER	% RECOVERY
1,4 Dichloroethane-d4	84
Toluene-d8	84
Bromofluorobenzene	284 +

RL: Reporting Limit
+ : Matrix interference

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	24 27.5-28	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-12	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	83	
Toluene-d8	84	
Bromofluorobenzene	80	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	35 29-29.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-13	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	86	
Toluene-d8	78	
Bromofluorobenzene	83	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	33 28-28.5	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-14	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	82	
Toluene-d8	82	
Bromofluorobenzene	87	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/22/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	42 30.5-31	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-15	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	10

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	500
Vinyl Chloride	ND	500
Bromomethane	ND	500
Chloromethane	ND	500
1,1-Dichloroethene	ND	50
Methylene Chloride	ND	500
trans-1,2-Dichloroethene	ND	50
cis-1,2-Dichloroethene	ND	500
1,1-Dichloroethane	ND	500
2-Butanone	ND	500
Chloroform	ND	500
1,1,1-Trichloroethane	ND	500
Carbon Tetrachloride	ND	500
Benzene	ND	500
Toluene	140	500
Carbon Disulfide	ND	500
1,2-Dichloroethane	ND	500
Trichloroethene	ND	500
1,2-Dichloropropane	ND	500
Bromodichloromethane	ND	500
2-Pentanone, 4-Methyl	ND	500
trans-1,3-Dichloropropene	ND	500
cis-1,3-Dichloropropene	ND	500
1,1,2-Trichloroethane	ND	500
Tetrachloroethene	ND	500
Dibromochloromethane	ND	500
Ethylbenzene	230	500
Chlorobenzene	ND	500
Bromoform	ND	500
Xylenes (m/p)	620	500
Styrene	ND	500
Xylenes (o)	250	500
1,1,2,2-Tetrachloroethane	ND	500
1,3-Dichlorobenzene	ND	500
1,4-Dichlorobenzene	ND	500
1,2-Dichlorobenzene	ND	500
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	80	
Toluene-d8	84	
Bromofluorobenzene	110	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/23/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	5 14.5-15	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-16	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	83	
Toluene-d8	86	
Bromofluorobenzene	76	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	12/23/94
PROJECT:	Hill Air Force Base	DATE RECEIVED:	12/27/94
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	9 18.5-19	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-17	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	82	
Toluene-d8	85	
Bromofluorobenzene	76	

RL: Reporting Limit

EPA METHOD 624/8240
VOLATILE ORGANICS BY GC/MS

CLIENT:	TRW	DATE COLLECTED:	NA
PROJECT:	Hill Air Force Base	DATE RECEIVED:	NA
BATCH NO.:	N9412-49	DATE EXTRACTED:	NA
SAMPLE ID:	BLK	DATE ANALYZED:	12/30/94
CONTROL NO.:	N9412-49-BLK	MATRIX:	SOIL
% MOISTURE:	NA	DILUTION FACTOR:	1

PARAMETERS	results (ug/kg)	RL (ug/kg)
Chloroethane	ND	50
Vinyl Chloride	ND	50
Bromomethane	ND	50
Chloromethane	ND	50
1,1-Dichloroethene	ND	5
Methylene Chloride	ND	50
trans-1,2-Dichloroethene	ND	5
cis-1,2-Dichloroethene	ND	5
1,1-Dichloroethane	ND	5
2-Butanone	ND	5
Chloroform	ND	5
1,1,1-Trichloroethane	ND	5
Carbon Tetrachloride	ND	5
Benzene	ND	5
Toluene	ND	5
Carbon Disulfide	ND	5
1,2-Dichloroethane	ND	5
Trichloroethene	ND	5
1,2-Dichloropropane	ND	5
Bromodichloromethane	ND	5
2-Pentanone, 4-Methyl	ND	5
trans-1,3-Dichloropropene	ND	5
cis-1,3-Dichloropropene	ND	5
1,1,2-Trichloroethane	ND	5
Tetrachloroethene	ND	5
Dibromochloromethane	ND	5
Ethylbenzene	ND	5
Chlorobenzene	ND	5
Bromoform	ND	5
Xylenes (m/p)	ND	5
Styrene	ND	5
Xylenes (o)	ND	5
1,1,2,2-Tetrachloroethane	ND	5
1,3-Dichlorobenzene	ND	5
1,4-Dichlorobenzene	ND	5
1,2-Dichlorobenzene	ND	5
SURROGATE PARAMETER	% RECOVERY	
1,4 Dichloroethane-d4	82	
Toluene-d8	84	
Bromofluorobenzene	76	

RL: Reporting Limit

CKY QUALITY CONTROL DATA
SPIKE/SPIKE DUPLICATE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA 8240
MATRIX: SOIL

BATCH NO.:	N9412-49	DATE RECEIVED:	12/27/94
SAMPLE ID:	9 18.5-19	DATE EXTRACTED:	NA
CONTROL NO.:	N9412-49-17	DATE ANALYZED:	12/30/94
ACCESSION:	N9412-49		

Parameter	SAMPLE CONC (ug/kg)	SPIKE ADDED (ug/kg)	MS CONC (ug/kg)	MS % REC	SPIKE ADDED (ug/kg)	MSD CONC (ug/kg)	MSD % REC	% RPD
1,1-DCE	ND	50	50	100	50	57	114	13
Benzene	ND	50	47	94	50	52	104	10
TCE	ND	50	49	98	50	54	108	10
Toluene	ND	50	49	98	50	57	114	15
Chlorobenzene	ND	50	51	102	50	56	112	9

CKY QUALITY CONTROL DATA
LABORATORY CONTROL SAMPLE ANALYSIS

CLIENT: TRW
PROJECT: Hill Air Force Base
METHOD: EPA 8240
MATRIX: SOIL

BATCH NO.: N9412-49
SAMPLE ID: LCS1
CONTROL NO.: N9412-49-LCS
DATE RECEIVED: NA
DATE EXTRACTED: NA
DATE ANALYZED: 12/30/94
ACCESSION: N9412-49

PARAMETER	TRUE VALUE (ug/kg)	FOUND VALUE (ug/kg)	LCS RECOVERY (%)
1,1-DCE	50	56	112
Benzene	50	51	102
TCE	50	54	108
Toluene	50	55	110
Chlorobenzene	50	58	116



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Calibration Data for EPA Method 8240 Analysis

The calibration data for Method 8240 analyses are presented here. These data include instrument calibration using bromofluorobenzene (bfb) and calibration for specific method (target) compounds at five different concentrations, system monitoring compounds and internal standards.

The instrument calibration shows a gas chromatogram and the associated mass spectrum for bromofluorobenzene. Method 8240 requires that the gas chromatograph/mass spectrometer be calibrated for each of the specific target masses in the bfb prior to sample analysis.

The abbreviations on the quantitation report are defined as follows:

R.T.	Retention Time (the time, in minutes for a compound to elute from the gas chromatography column)
QIon	The ion fragment mass from the mass spectrum used for quantitation
Response	The area under the peak for the QIon of interest (a measure of concentration)
Conc	Concentration of the species
Units	Concentration units (micrograms per liter)
Dev(Min)	Deviation of the actual retention time from the expected retention time in minutes
ISTD	Internal Standard, a reference compound added to samples and calibration standards, to which analytical results can be ratioed
Qvalue	Probability that the sample ion chromatogram matches the reference ion chromatogram (100 = perfect match)
%RSD	% relative standard deviation, indicator of spread of analytical results from calibration standards

bfb

Data File : C:\HPCHEM\1\DATA\D27\0101001.D

Acq Time : 27 Dec 94 12:02 pm

Sample : bfb

Misc :

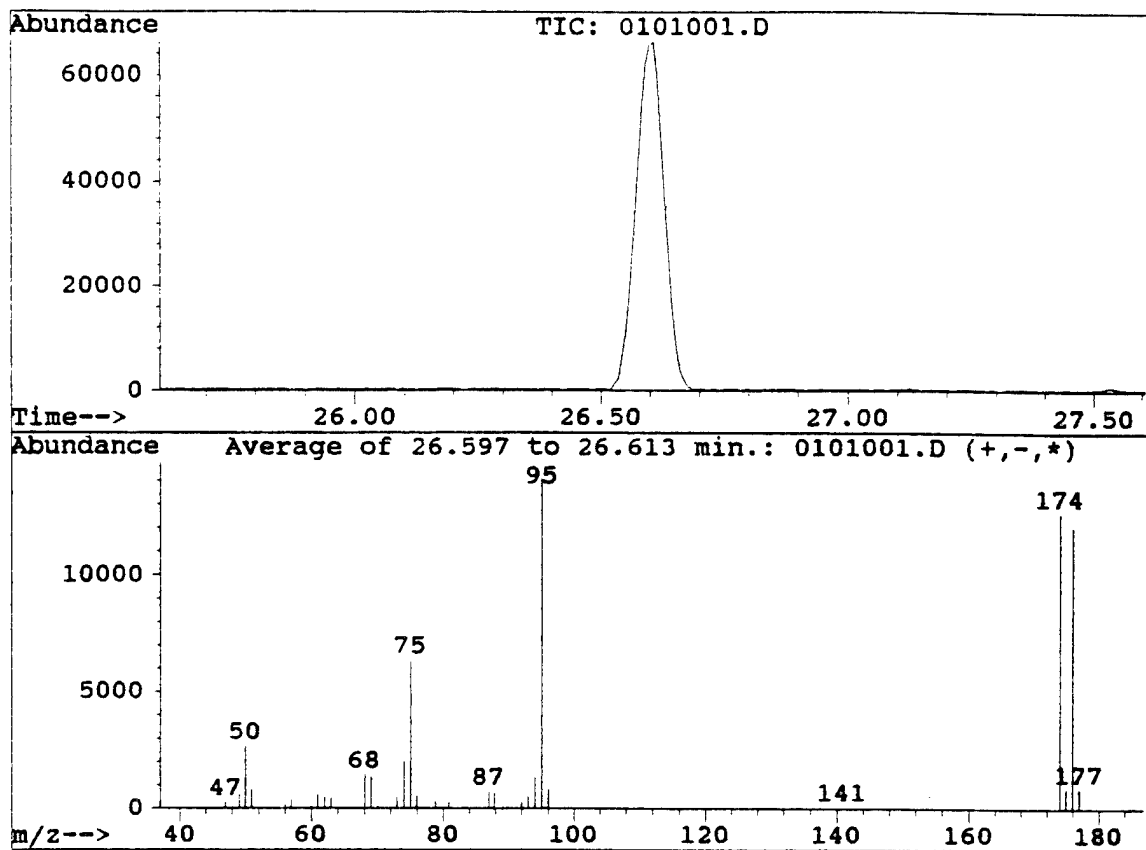
Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration



Peak Apex is scan: 2787

Target Mass	Rel. to Mass	Lower Limit%	Upper Limit%	Rel. Abn%	Raw Abn	Result Pass/Fail
50	95	8	40	18.9	2659	PASS
75	95	30	66	45.1	6340	PASS
95	95	100	100	100.0	14050	PASS
96	95	5	9	5.7	807	PASS
173	174	0	2	0.0	0	PASS
174	95	50	120	89.8	12613	PASS
175	174	4	9	6.7	847	PASS
176	174	93	101	95.4	12032	PASS
177	176	5	9	7.1	859	PASS

0101001.D CLPS3.M

Thu Feb 02 15:11:46 1995 GCMS VOA

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D27\0101001.D

Acq Time : 27 Dec 94 12:02 pm

Sample : bfb

Misc :

Quant Time: Feb 2 15:12 1995

Operator:

Inst : GC/MS

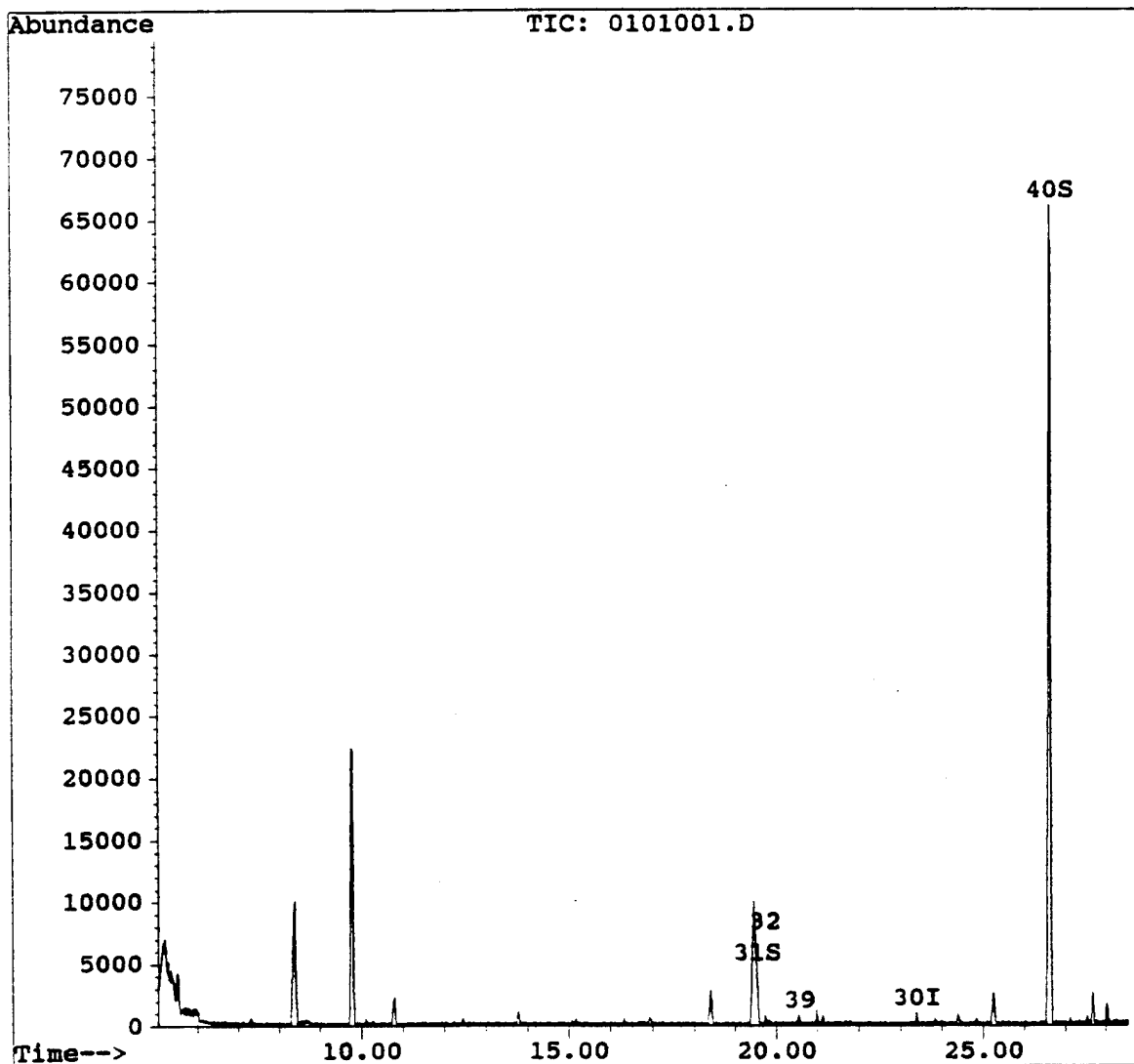
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D27\0101001.D

Acq Time : 27 Dec 94 12:02 pm

Sample : bfb

Misc :

Quant Time: Feb 2 15:12 1995

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	0.00	128	0	0.00	ug/l	-13.59
17) 1,4-Difluorobenzene	0.00	114	0	0.00	ug/l	-15.81
30) Chlorobenzene-d5	23.38	117	1232	50.00	ug/l	-0.01
System Monitoring Compounds						%Recovery
15) 1,2-Dichloroethane-d4	0.00	65	0	0.00	ug/l	
31) Toluene-d8	19.54	98	279	7.77	ug/l	#
40) Bromofluorobenzene	26.61	95	57632	4819.57	ug/l	#
Target Compounds						Qvalue
32) Toluene	19.74	92	205	2.58	ug/l	# 28
39) 2-Hexanone	20.56	43	1240	113.16	ug/l	100

(#) = qualifier out of range (m) = manual integration

0101001.D CLPS3.M

Thu Feb 02 15:12:17 1995

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0103003.D

Acq Time : 30 Dec 94 6:31 am

Sample : voa std 50 ppb 01

Misc :

Quant Time: Feb 2 16:16 1995

Operator:

Inst : GC/MS

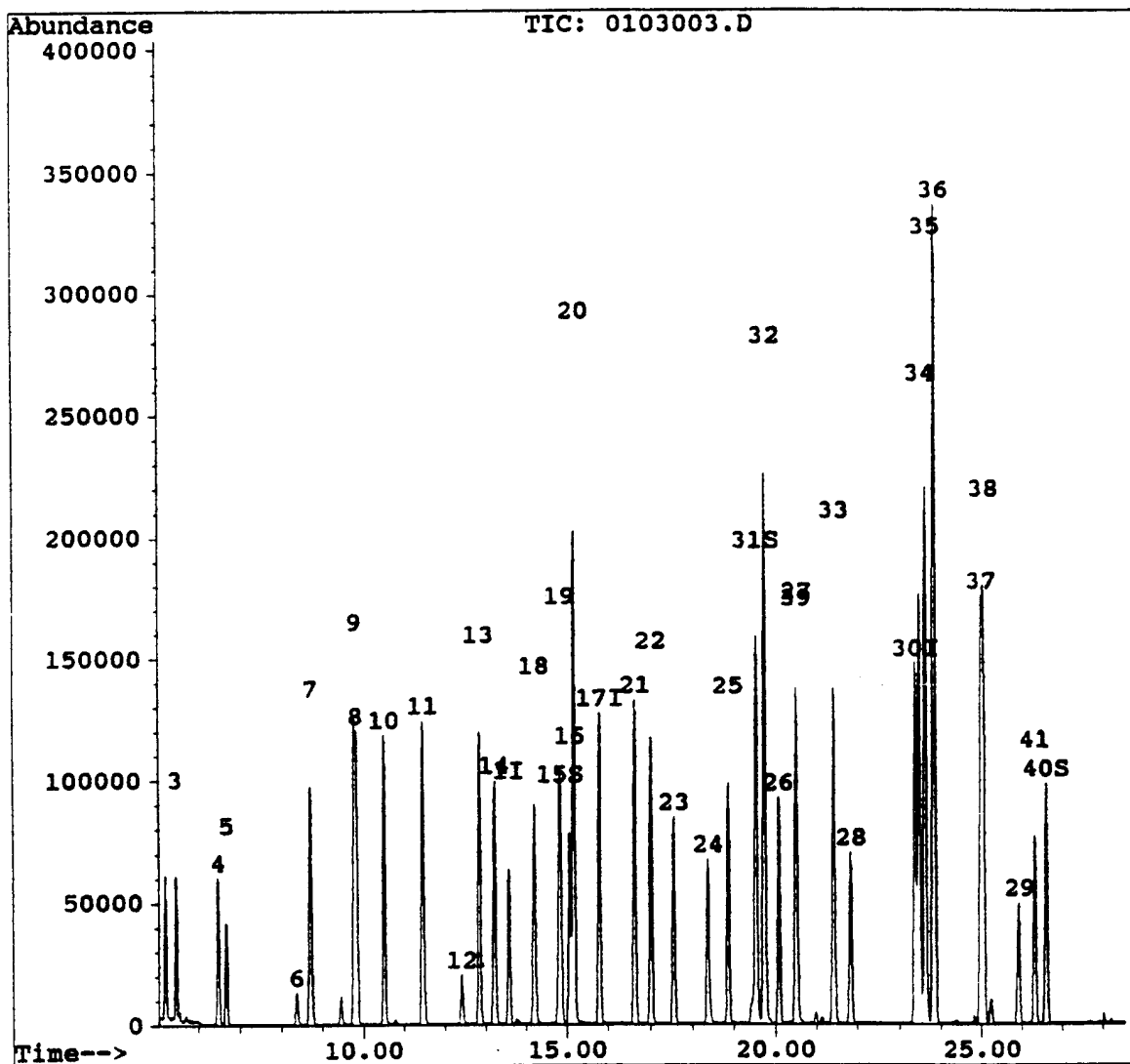
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0103003.D

Acq Time : 30 Dec 94 6:31 am

Sample : voa std 50 ppb 01

Misc :

Quant Time: Feb 2 16:16 1995

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc Unit	Qvalue
38) Styrene	25.04	104	207328	50.36 ug/l	86
39) 2-Hexanone	20.52	43	84721	45.53 ug/l	100
41) 1,1,2,2-Tetrachloroethane	26.31	83	110948	48.79 ug/l	96

(#) = qualifier out of range (m) = manual integration

0103003.D CLPS3.M

Thu Feb 02 16:16:21 1995

GCMS VOA

Page 2

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0103003.D

Acq Time : 30 Dec 94 6:31 am

Sample : voa std 50 ppb 01

Misc :

Quant Time: Feb 2 16:16 1995

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.57	128	33322	50.00	ug/l	-0.02
17) 1,4-Difluorobenzene	15.79	114	213519	50.00	ug/l	-0.02
30) Chlorobenzene-d5	23.38	117	202158	50.00	ug/l	-0.02
System Monitoring Compounds				%Recovery		
15) 1,2-Dichloroethane-d4	14.85	65	79023	41.05	ug/l	
31) Toluene-d8	19.54	98	235687	41.86	ug/l	
40) Bromofluorobenzene	26.59	95	87104	40.97	ug/l	#
Target Compounds				Qvalue		
2) Chloromethane	5.20	50	96232	60.23	ug/l	95
3) Vinyl Chloride	5.45	62	81304	59.33	ug/l	95
4) Bromomethane	6.47	94	75544	56.89	ug/l	96
5) Chloroethane	6.66	64	74297	57.50	ug/l	92
6) Acetone	8.37	43	31032	42.27	ug/l	100
7) 1,1-Dichloroethene	8.71	96	78141	55.25	ug/l	94
8) Carbon Disulfide	9.82	76	310775	54.53	ug/l	100
9) Methylene Chloride	9.77	84	103737	42.90	ug/l	97
10) 1,2-Dichloroethene (trans)	10.50	96	86965	55.81	ug/l	95
11) 1,1-Dichloroethane	11.45	63	175848	56.63	ug/l	99
12) 2-Butanone	12.41	43	55401	44.93	ug/l	100
13) 1,2-Dichloroethene [cis]	12.85	96	100385	55.51	ug/l	96
14) Chloroform	13.22	83	159999	56.55	ug/l	100
16) 1,2-Dichloroethane	15.07	62	128441	53.77	ug/l	97
18) 1,1,1-Trichloroethane	14.20	97	129722	54.43	ug/l	99
19) Carbon Tetrachloride	14.81	117	111652	56.39	ug/l	# 100
20) Benzene	15.17	78	393117	53.70	ug/l	100
21) Trichloroethene	16.63	130	88734	54.31	ug/l	92
22) 1,2-Dichloropropane	17.01	63	107170	53.13	ug/l	98
23) Bromodichloromethane	17.56	83	118730	53.33	ug/l	98
24) 2-Pentanone, 4-Methyl	18.38	43	118432	45.70	ug/l	100
25) cis-1,3-Dichloropropene	18.86	75	164841	54.35	ug/l	98
26) trans-1,3-Dichloropropene	20.08	75	140138	51.85	ug/l	99
27) 1,1,2-Trichloroethane	20.49	97	76683	50.23	ug/l	98
28) Dibromochloromethane	21.83	129	84051	51.09	ug/l	99
29) Bromoform	25.92	173	62874	47.56	ug/l	97
32) Toluene	19.73	92	237314	56.51	ug/l	90
33) Tetrachloroethene	21.42	164	86095	56.91	ug/l	98
34) Chlorobenzene	23.48	112	240409	55.38	ug/l	98
35) Ethylbenzene	23.63	106	124491	54.03	ug/l	98
36) Xylene (m&p)	23.83	106	264420	51.88	ug/l	# 81
37) Xylene[o]	24.98	106	123900	49.65	ug/l	88

(#) = qualifier out of range (m) = manual integration

0103003.D CLPS3.M

Thu Feb 02 16:16:20 1995

GCMS VOA

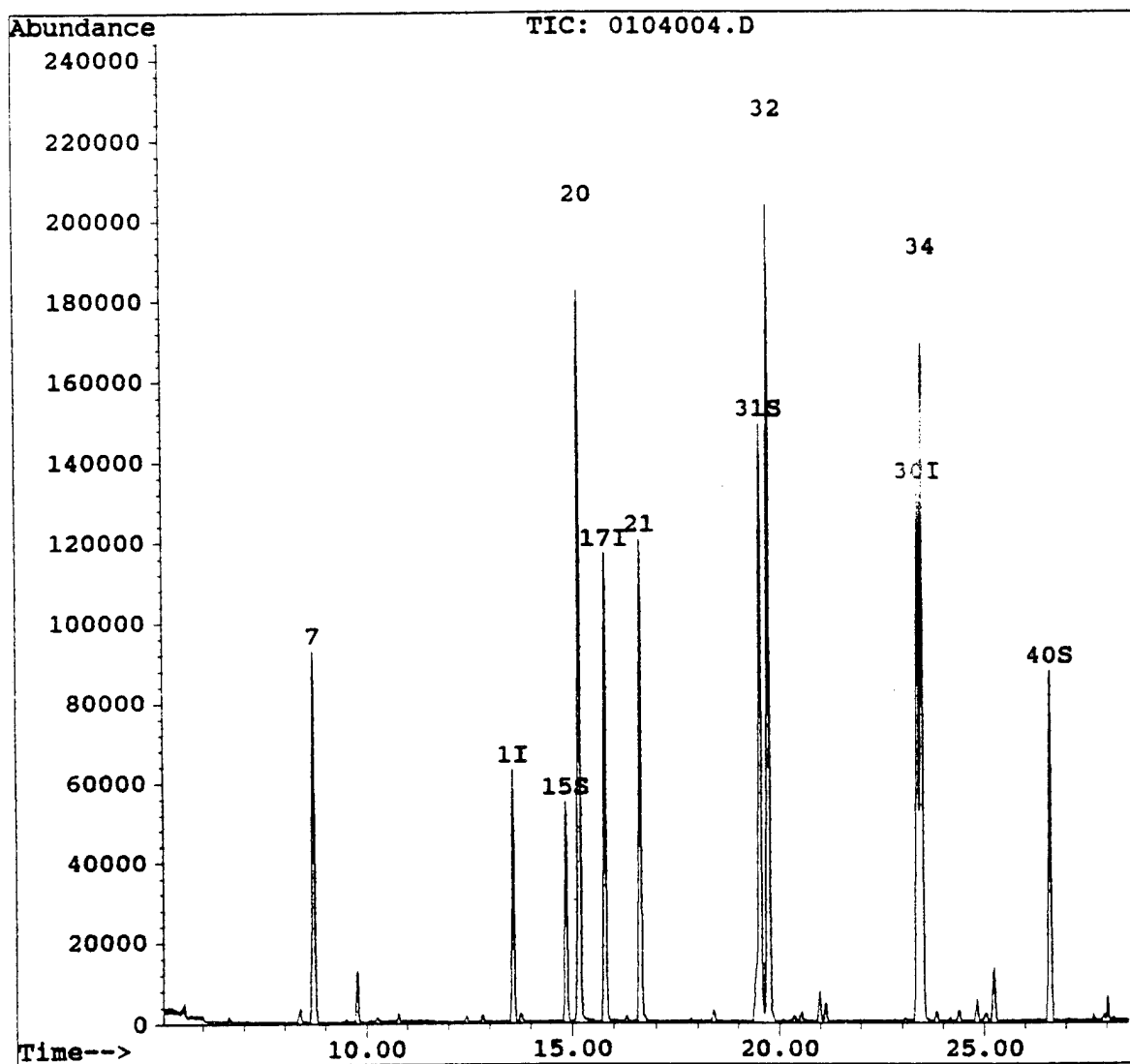
Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0104004.D
Acq Time : 30 Dec 94 7:08 am
Sample : lcs 50 ppb 01
Misc :
Quant Time: Feb 3 15:12 1995

Operator:
Inst : GC/MS
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M
Title : VOA Standards for 5 point calibration
Last Update : Fri Dec 30 03:51:20 1994
Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0104004.D

Acq Time : 30 Dec 94 7:08 am

Sample : lcs 50 ppb 01

Misc :

Quant Time: Feb 3 15:12 1995

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.58	128	31248	50.00	ug/l	-0.01
17) 1,4-Difluorobenzene	15.79	114	197553	50.00	ug/l	-0.02
30) Chlorobenzene-d5	23.39	117	187867	50.00	ug/l	-0.01
System Monitoring Compounds						%Recovery
15) 1,2-Dichloroethane-d4	14.85	65	75893	42.09	ug/l	
31) Toluene-d8	19.53	98	215090	41.06	ug/l	
40) Bromofluorobenzene	26.59	95	79960	40.43	ug/l	#
Target Compounds						Qvalue
7) 1,1-Dichloroethene	8.71	96	74710	56.41	ug/l	95
20) Benzene	15.17	78	348560	51.26	ug/l	100
21) Trichloroethene	16.63	130	81587	53.94	ug/l	92
32) Toluene	19.73	92	215756	55.15	ug/l	90
34) Chlorobenzene	23.48	112	231504	57.58	ug/l	98

(#) = qualifier out of range (m) = manual integration

0104004.D CLPS3.M

Fri Feb 03 15:12:42 1995

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0105005.D

Acq Time : 30 Dec 94 7:45 am

Sample : vblk2

Misc :

Quant Time: Feb 3 15:13 1995

Operator:

Inst : GC/MS

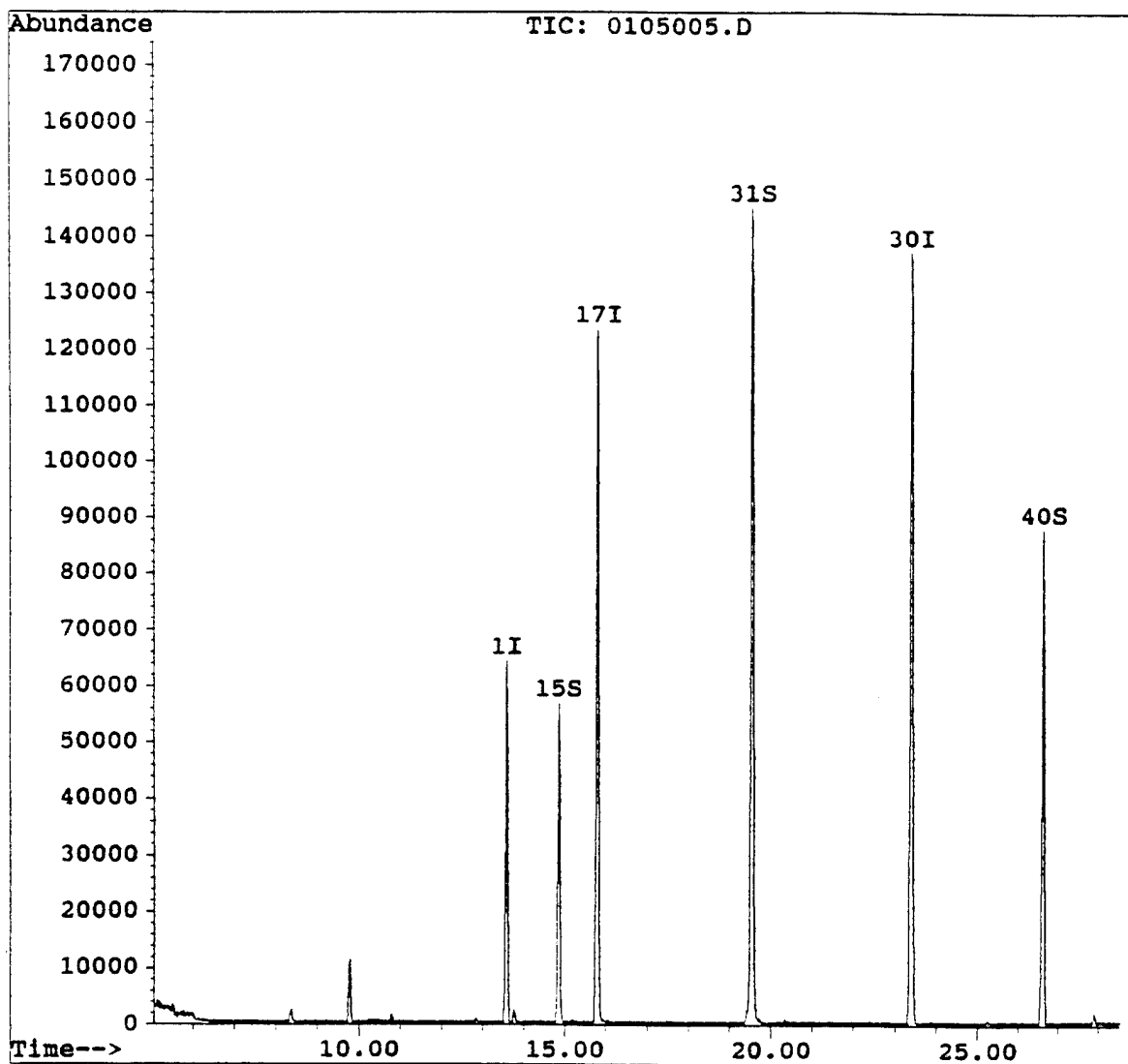
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0105005.D

Acq Time : 30 Dec 94 7:45 am

Sample : vblk2

Misc :

Quant Time: Feb 3 15:13 1995

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.57	128	32167	50.00	ug/l	-0.02
17) 1,4-Difluorobenzene	15.30	114	306333	50.00	ug/l	-0.01
30) Chlorobenzene-d5	23.33	117	134639	50.00	ug/l	-0.02
System Monitoring Compounds						Recovery
15) 1,2-Dichloroethane-d4	14.85	65	76633	41.75	ug/l	
31) Toluene-d8	14.84	62	227454	41.94	ug/l	
40) Bromofluorobenzene	26.60	95	77725	37.72	ug/l	#
Target Compounds						Qvalue

(#) = qualifier out of range (m) = manual integration

0105005.D CLPS3.M

Fri Feb 03 15:13:39 1995

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0108008.D

Acq Time : 30 Dec 94 9:35 am

Sample : n9412-49-17 ms

Misc :

Quant Time: Feb 3 15:14 1995

Operator:

Inst : GC/MS

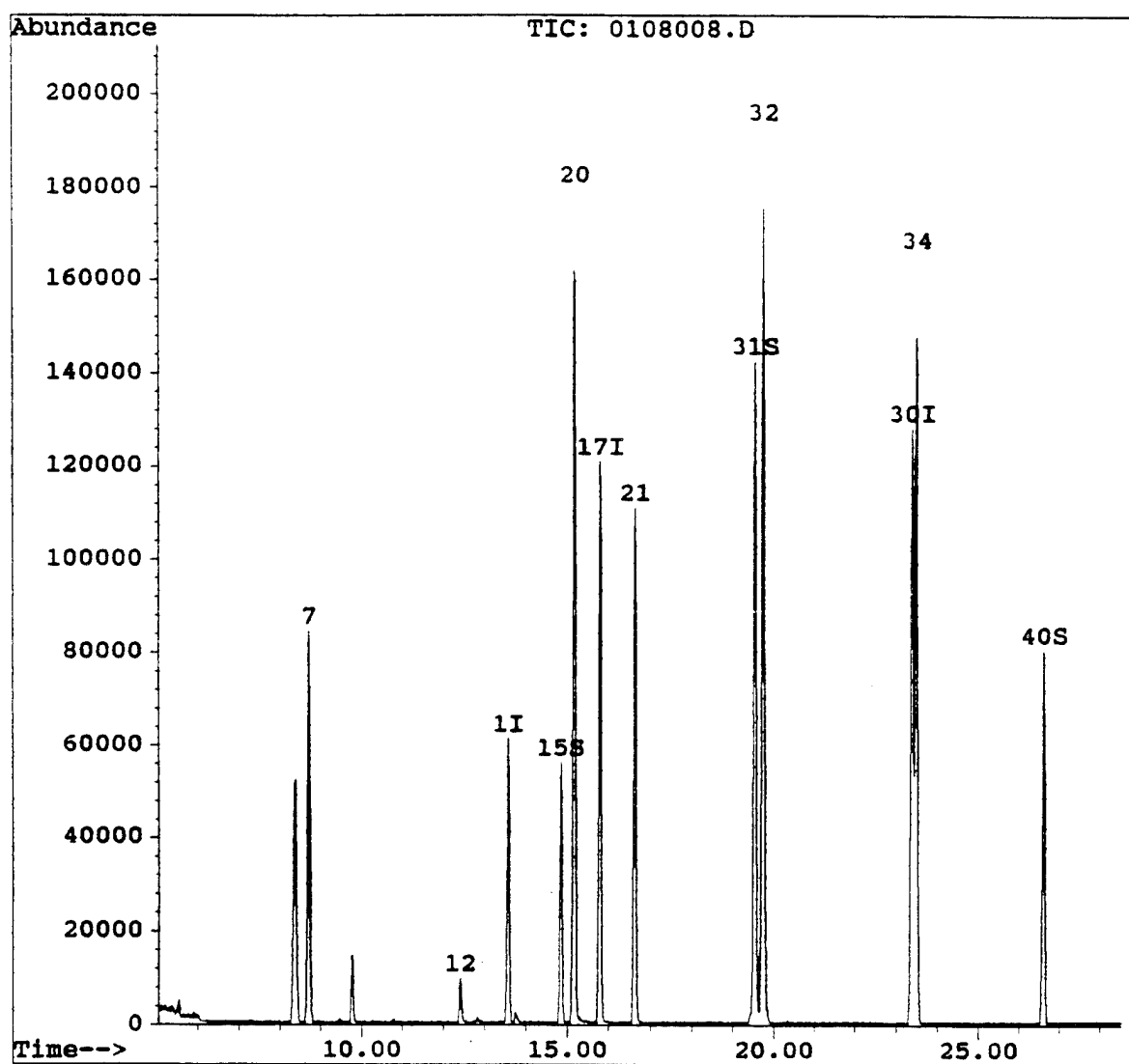
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0108008.D
 Acq Time : 30 Dec 94 9:35 am
 Sample : n9412-49-17 ms
 Misc :
 Quant Time: Feb 3 15:14 1995

Operator:
 Inst : GC/MS
 Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M
 Title : VOA Standards for 5 point calibration
 Last Update : Fri Dec 30 03:51:20 1994
 Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
11 Bromochloromethane	13.57	128	31530	50.00	ug/l	-0.02
171 1,4-Dichlorobenzene	15.78	114	188554	50.00	ug/l	-0.02
301 Chlorobenzene-d5	23.38	117	187541	50.00	ug/l	-0.02
System Monitoring Compounds						*Recovery
151 1,2-Dichloroethane-d4	14.85	65	73692	40.43	ug/l	
311 Toluene-d8	19.53	98	218377	41.80	ug/l	
401 Bromofluorobenzene	26.60	95	73241	36.82	ug/l	*
Target Compounds						Qvalue
7) 1,1-Dichloroethene	8.71	96	67601	50.15	ug/l	96
12) 2-Butanone	12.42	43	26369	19.83	ug/l	100
20) Benzene	15.17	78	322857	46.57	ug/l	100
21) Trichloroethene	16.63	130	75133	48.80	ug/l	92
32) Toluene	19.73	92	195328	49.42	ug/l	90
34) Chlorobenzene	23.48	112	208158	51.33	ug/l	97

(*) - qualifier out of range (m) = manual integration

0108008.D CLPS3.M

Fri Feb 03 15:14:45 1995

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0109009.D

Acq Time : 30 Dec 94 10:12 am

Sample : n9412-49-17 msd

Misc :

Quant Time: Feb 3 15:15 1995

Operator:

Inst : GC/MS

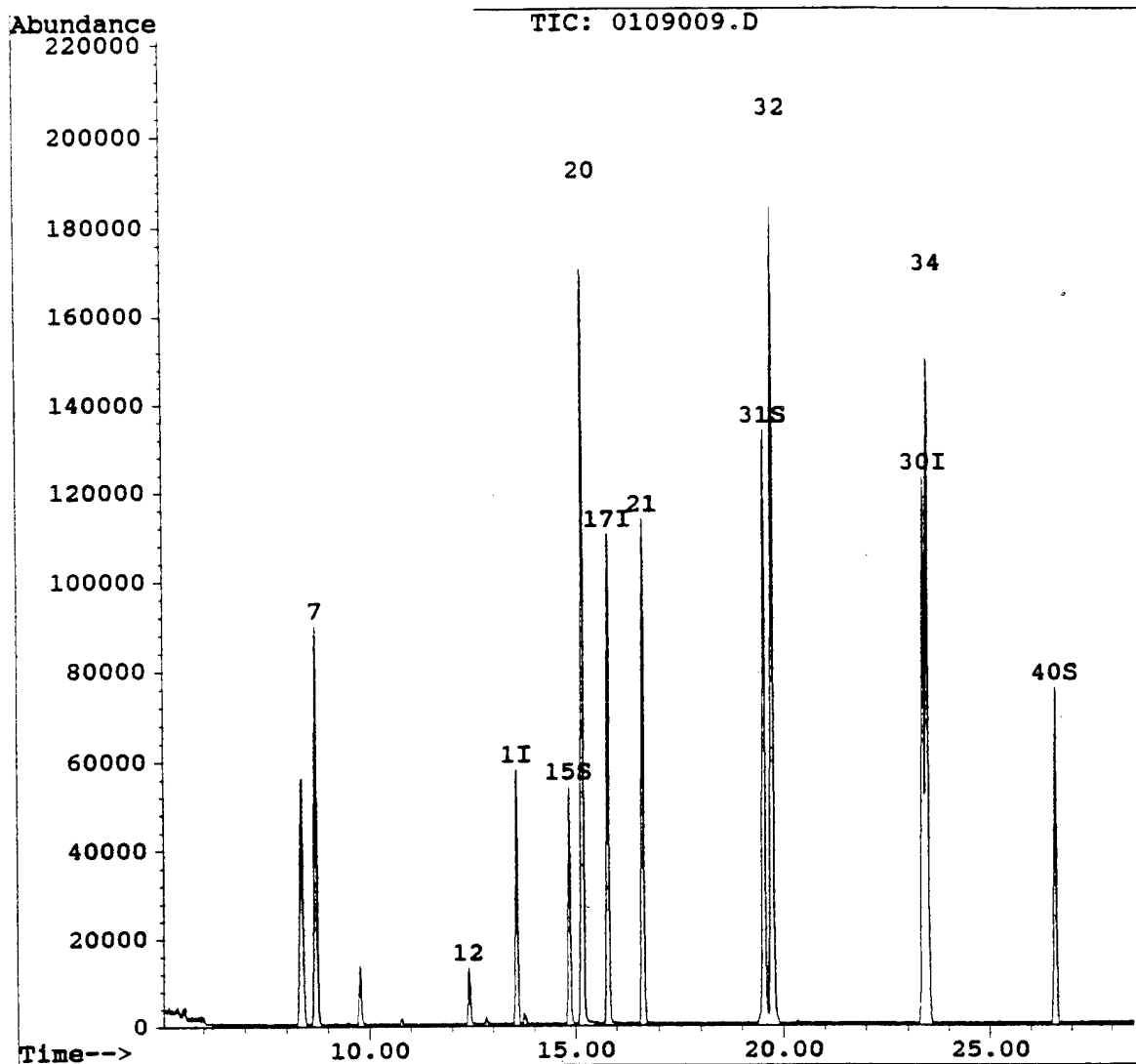
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D30\0109009.D

Acq Time : 30 Dec 94 10:12 am

Sample : n9412-49-17 msd

Misc :

Quant Time: Feb 3 15:15 1995

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.57	128	29601	50.00	ug/l	-0.02
17) 1,4-Difluorobenzene	15.79	114	187257	50.00	ug/l	-0.02
30) Chlorobenzene-d5	23.38	117	174084	50.00	ug/l	-0.02
System Monitoring Compounds						%Recovery
15) 1,2-Dichloroethane-d4	14.85	65	71829	42.05	ug/l	
31) Toluene-d8	19.53	98	203440	41.96	ug/l	
40) Bromofluorobenzene	26.59	95	69404	37.66	ug/l	#
Target Compounds						Qvalue
7) 1,1-Dichloroethene	8.71	96	71851	57.34	ug/l	98
12) 2-Butanone	12.41	43	34354	29.68	ug/l	100
20) Benzene	15.16	78	333648	51.81	ug/l	100
21) Trichloroethene	16.62	130	77005	53.70	ug/l	93
32) Toluene	19.73	92	205948	57.00	ug/l	90
34) Chlorobenzene	23.48	112	210867	56.51	ug/l	97

 (1) - QUALITIES OUT OF RANGE (M) - Manual Intervention
 0109009.D CLPS3.M

Fri Feb 03 15:15:43 1995

GCMS VOA

Page 1

Response Factor Report GC/MS

Method : C:\HPCHEM\1\METHODS\CLPS3.M
 Title : VOA Standards for 5 point calibration
 Last Update : Fri Dec 30 03:51:20 1994
 Response via : Initial Calibration

Calibration Files

1 =0401004.D 2 =0501005.D 3 =0701007.D
 4 =0901009.D 5 =1101011.D

Compound	1	2	3	4	5	Avg	%RSD
1) I Bromochloromethane	-----ISTD-----						
2) Chloromethane	3.265	2.535	2.581	2.363	2.225	2.594	15.46
3) Vinyl Chloride	2.938	2.224	2.222	2.017	1.879	2.256	18.10
4) Bromomethane	2.626	2.081	2.145	1.976	1.824	2.130	14.20
5) Chloroethane	2.471	2.049	2.083	1.909	1.800	2.062	12.37
6) Acetone	1.753	1.070	1.199	0.980	0.941	1.189	27.83
7) 1,1-Dichloroethene	2.661	2.154	2.220	2.105	1.998	2.227	11.46
8) Carbon Disulfide	10.970	8.960	9.059	8.375	7.950	9.063	12.77
9) Methylene Chloride	7.701	4.976	3.520	2.942	2.529	4.334	48.41
10) 1,2-Dichloroethene (trans)	3.051	2.430	2.460	2.320	2.167	2.486	13.53
11) 1,1-Dichloroethane	5.966	4.830	4.886	4.605	4.377	4.933	12.41
12) 2-Butanone	2.364	1.881	1.920	1.788	1.676	1.926	13.62
13) 1,2-Dichloroethene [cis]	3.374	2.798	2.862	2.673	2.554	2.852	11.04
14) Chloroform	5.373	4.317	4.480	4.188	4.007	4.473	11.90
15) S 1,2-Dichloroethane-d4	3.075	2.790	2.689	2.763	2.343	2.732	9.59
16) 1,2-Dichloroethane	4.330	3.658	3.744	3.565	3.366	3.732	9.70
7) I 1,4-Difluorobenzene	-----ISTD-----						
18) 1,1,1-Trichloroethane	0.714	0.575	0.593	0.554	0.513	0.590	12.79
19) Carbon Tetrachloride	0.583	0.483	0.495	0.459	0.431	0.490	11.69
20) Benzene	2.151	1.774	1.812	1.683	1.598	1.804	11.71
21) Trichloroethene	0.493	0.397	0.399	0.372	0.363	0.405	12.76
22) 1,2-Dichloropropane	0.582	0.483	0.502	0.465	0.439	0.494	11.00
23) Bromodichloromethane	0.639	0.540	0.550	0.520	0.480	0.546	10.71
24) 2-Pentanone, 4-Methyl	0.728	0.621	0.640	0.583	0.562	0.627	10.24
25) cis-1,3-Dichloropropene	0.884	0.737	0.748	0.707	0.657	0.747	11.35
26) trans-1,3-Dichloropropene	0.780	0.652	0.655	0.631	0.587	0.661	10.85
27) 1,1,2-Trichloroethane	0.449	0.364	0.376	0.350	0.330	0.374	12.07
28) Dibromochloromethane	0.460	0.392	0.400	0.382	0.361	0.399	9.26
29) Bromoform	0.360	0.309	0.318	0.308	0.292	0.317	8.07
30) I Chlorobenzene-d5	-----ISTD-----						
31) S Toluene-d8	1.502	1.379	1.289	1.320	1.094	1.317	11.30
32) Toluene	1.344	1.111	1.109	1.028	0.953	1.109	13.23
33) Tetrachloroethene	0.501	0.402	0.397	0.371	0.342	0.403	14.93
34) Chlorobenzene	1.373	1.133	1.132	1.060	0.995	1.139	12.56
35) Ethylbenzene	0.704	0.565	0.604	0.553	0.547	0.594	10.93
36) Xylene (m&p)	1.458	1.214	1.329	1.228	1.228	1.292	8.07
37) Xylene[o]	0.688	0.562	0.638	0.607	0.619	0.623	7.37
38) Styrene	1.139	0.942	1.059	0.992	1.023	1.031	7.18
39) 2-Hexanone	0.556	0.439	0.476	0.452	0.438	0.472	10.48
40) S Bromofluorobenzene	0.554	0.514	0.532	0.530	0.486	0.523	4.79
1) 1,1,2,2-Tetrachloroethane	0.694	0.568	0.576	0.562	0.518	0.584	11.28

(#) = Out of Range

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0401004.D

Acq Time : 29 Dec 94 1:38 pm

Sample : VOA STD 10 PPB

Misc :

Quant Time: Dec 30 3:53 1994

Operator:

Inst : GC/MS

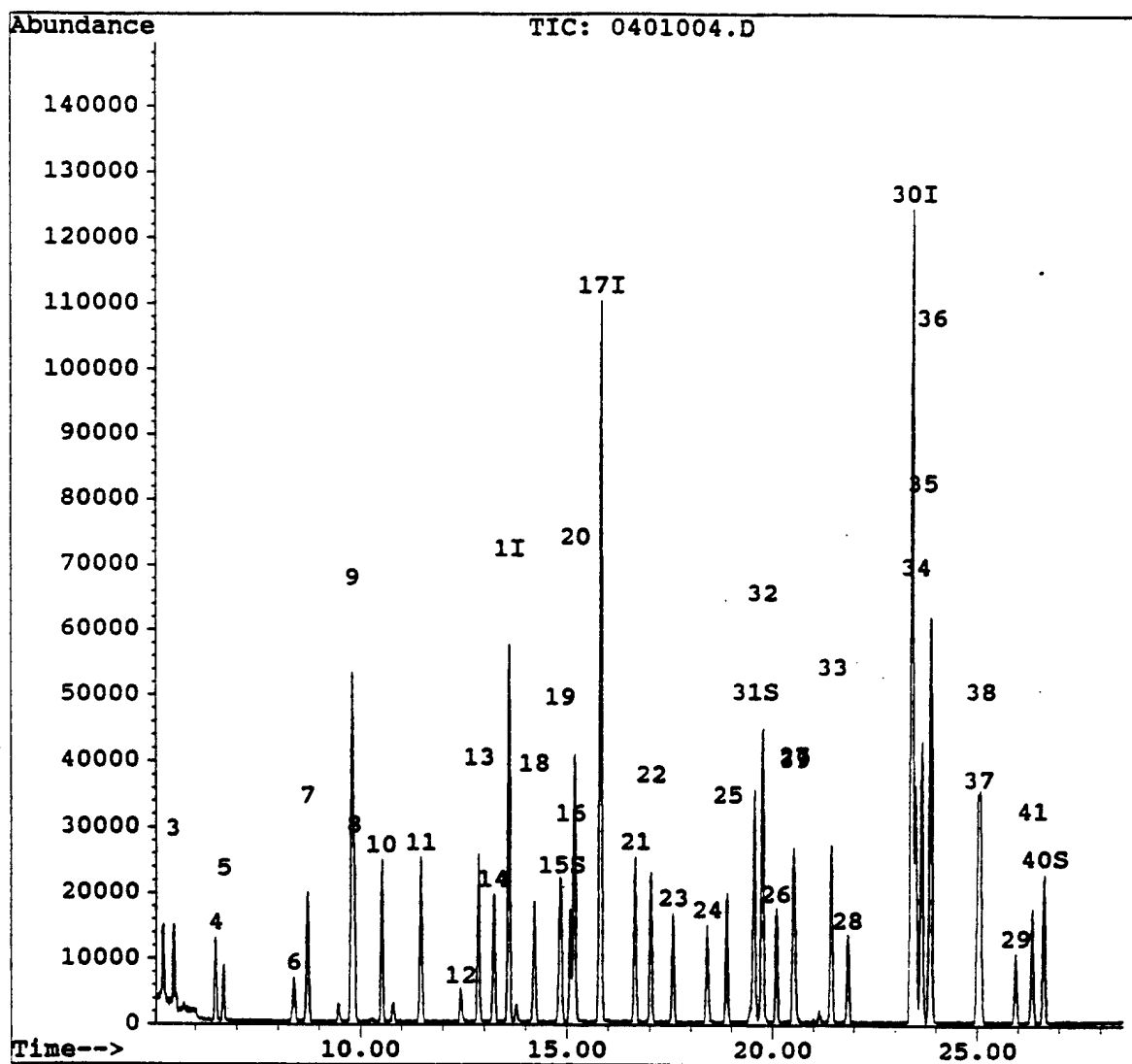
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0401004.D

Acq Time : 29 Dec 94 1:38 pm

Sample : VOA STD 10 PPB

Misc :

Quant Time: Dec 30 3:53 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.59	128	30066	50.00	ug/l	0.00
17) 1,4-Difluorobenzene	15.81	114	185679	50.00	ug/l	0.00
30) Chlorobenzene-d5	23.40	117	178343	50.00	ug/l	0.00
System Monitoring Compounds						
15) 1,2-Dichloroethane-d4	14.87	65	18489	10.27	ug/l	%Recovery
31) Toluene-d8	19.56	98	53577	10.35	ug/l	
40) Bromofluorobenzene	26.61	95	19749	7.97	ug/l	#
Target Compounds						
2) Chloromethane	5.22	50	19631	8.88	ug/l	Qvalue 97
3) Vinyl Chloride	5.47	62	17668	8.70	ug/l	95
4) Bromomethane	6.49	94	15792	8.20	ug/l	96
5) Chloroethane	6.69	64	14861	8.36	ug/l	89
6) Acetone	8.40	43	10541	10.10	ug/l	100
7) 1,1-Dichloroethene	8.72	96	15999	9.27	ug/l	97
8) Carbon Disulfide	9.84	76	65966	8.83	ug/l	100
9) Methylene Chloride	9.78	84	46306	8.13	ug/l	97
10) 1,2-Dichloroethene (trans)	10.52	96	18346	8.87	ug/l	98
11) 1,1-Dichloroethane	11.48	63	35877	9.23	ug/l	73
12) 2-Butanone	12.45	43	14215	8.79	ug/l	100
13) 1,2-Dichloroethene [cis]	12.87	96	20290	9.03	ug/l	# 86
14) Chloroform	13.24	83	32310	9.35	ug/l	100
16) 1,2-Dichloroethane	15.09	62	26036	8.84	ug/l	98
18) 1,1,1-Trichloroethane	14.20	97	26510	8.38	ug/l	96
19) Carbon Tetrachloride	14.83	117	21632	8.40	ug/l	# 100
20) Benzene	15.18	78	79870	8.80	ug/l	100
21) Trichloroethene	16.65	130	18298	9.83	ug/l	92
22) 1,2-Dichloropropane	17.03	63	21626	8.59	ug/l	98
23) Bromodichloromethane	17.57	83	23713	8.07	ug/l	99
24) 2-Pentanone, 4-Methyl	18.40	43	27025	8.69	ug/l	100
25) cis-1,3-Dichloropropene	18.89	75	32845	8.36	ug/l	98
26) trans-1,3-Dichloropropene	20.09	75	28954	8.68	ug/l	100
27) 1,1,2-Trichloroethane	20.51	97	16666	8.81	ug/l	99
28) Dibromochloromethane	21.84	129	17072	8.82	ug/l	100
29) Bromoform	25.94	173	13354	9.06	ug/l	98
32) Toluene	19.75	92	47941	8.06	ug/l	91
33) Tetrachloroethene	21.44	164	17884	8.28	ug/l	98
34) Chlorobenzene	23.50	112	48990	8.62	ug/l	98
35) Ethylbenzene	23.65	106	25096	9.95	ug/l	99
36) Xylene (m&p)	23.85	106	52022	10.13	ug/l	# 83
37) Xylene[o]	25.00	106	24532	11.20	ug/l	87

(#) = qualifier out of range (m) = manual integration

0401004.D CLPS3.M

Fri Dec 30 03:53:19 1994

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0401004.D

Acq Time : 29 Dec 94 1:38 pm

Sample : VOA STD 10 PPB

Misc :

Quant Time: Dec 30 3:53 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc	Unit	Qvalue
38) Styrene	25.07	104	40624	11.20	ug/l	83
39) 2-Hexanone	20.55	43	19843	10.09	ug/l	100
41) 1,1,2,2-Tetrachloroethane	26.34	83	24761	8.74	ug/l #	70

(#) = qualifier out of range (m) = manual integration

0401004.D CLPS3.M

Fri Dec 30 03:53:20 1994

GCMS VOA

Page 2

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0501005.D

Acq Time : 29 Dec 94 2:18 pm

Sample : VOA STD 20 PPB

Misc :

Quant Time: Dec 30 3:54 1994

Operator:

Inst : GC/MS

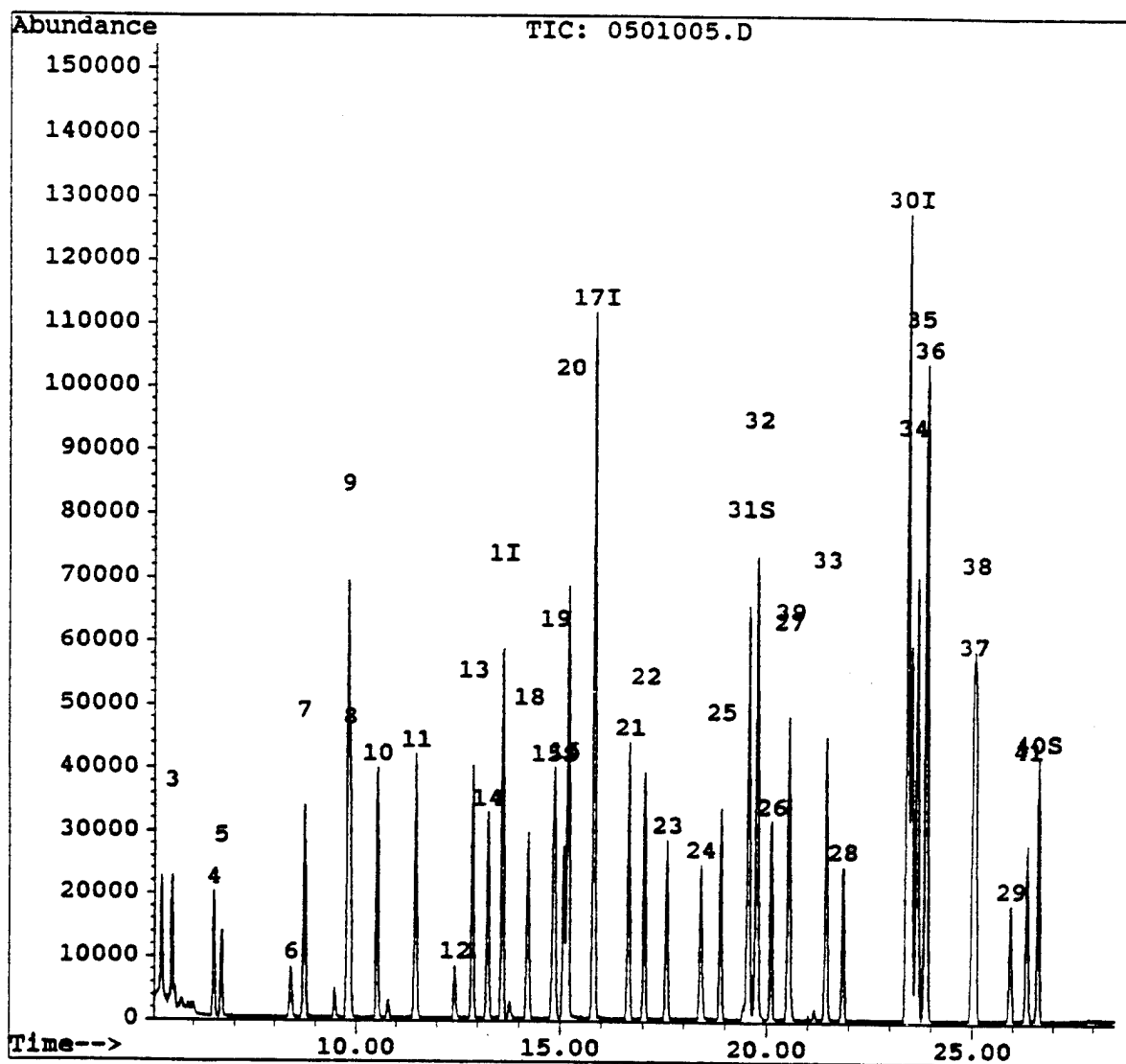
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0501005.D

Acq Time : 29 Dec 94 2:18 pm

Sample : VOA STD 20 PPB

Misc :

Quant Time: Dec 30 3:54 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.59	128	30567	50.00	ug/l	0.00
17) 1,4-Difluorobenzene	15.82	114	189033	50.00	ug/l	0.00
30) Chlorobenzene-d5	23.40	117	179012	50.00	ug/l	0.00

System Monitoring Compounds

						%Recovery
15) 1,2-Dichloroethane-d4	14.86	65	34108	18.82	ug/l	
31) Toluene-d8	19.56	98	98718	19.22	ug/l	
40) Bromofluorobenzene	26.62	95	36795	17.74	ug/l	#

Target Compounds

						Qvalue
2) Chloromethane	5.22	50	30990	17.18	ug/l	100
3) Vinyl Chloride	5.47	62	27196	16.96	ug/l	94
4) Bromomethane	6.49	94	25440	16.78	ug/l	99
5) Chloroethane	6.69	64	25053	17.57	ug/l	91
6) Acetone	8.39	43	13088	14.40	ug/l	100
7) 1,1-Dichloroethene	8.72	96	26334	17.63	ug/l	96
8) Carbon Disulfide	9.84	76	109552	17.73	ug/l	100
9) Methylene Chloride	9.79	84	60839	18.08	ug/l	98
10) 1,2-Dichloroethene (trans)	10.52	96	29711	17.36	ug/l	97
11) 1,1-Dichloroethane	11.47	63	59051	17.80	ug/l	100
12) 2-Butanone	12.43	43	22999	17.28	ug/l	100
13) 1,2-Dichloroethene [cis]	12.87	96	34213	17.87	ug/l	94
14) Chloroform	13.24	83	52788	17.61	ug/l	97
16) 1,2-Dichloroethane	15.09	62	44722	17.81	ug/l	96
18) 1,1,1-Trichloroethane	14.21	97	43513	17.04	ug/l	99
19) Carbon Tetrachloride	14.83	117	36548	17.47	ug/l	# 100
20) Benzene	15.19	78	134163	17.70	ug/l	100
21) Trichloroethene	16.65	130	30038	18.30	ug/l	92
22) 1,2-Dichloropropane	17.03	63	36519	17.45	ug/l	98
23) Bromodichloromethane	17.58	83	40799	17.38	ug/l	98
24) 2-Pentanone,4-Methyl	18.39	43	46949	17.99	ug/l	100
25) cis-1,3-Dichloropropene	18.89	75	55722	17.47	ug/l	70
26) trans-1,3-Dichloropropene	20.10	75	49331	17.74	ug/l	99
27) 1,1,2-Trichloroethane	20.52	97	27540	17.41	ug/l	98
28) Dibromochloromethane	21.85	129	29677	17.94	ug/l	97
29) Bromoform	25.94	173	23354	17.99	ug/l	96
32) Toluene	19.76	92	79580	17.47	ug/l	90
33) Tetrachloroethene	21.44	164	28802	17.33	ug/l	95
34) Chlorobenzene	23.50	112	81157	17.75	ug/l	98
35) Ethylbenzene	23.64	106	40444	17.86	ug/l	99
36) Xylene (m&p)	23.86	106	86902	18.09	ug/l	# 82
37) Xylene[o]	25.01	106	40234	18.25	ug/l	88

(#) = qualifier out of range (m) = manual integration

0501005.D CLPS3.M

Fri Dec 30 03:54:25 1994

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0501005.D

Acq Time : 29 Dec 94 2:18 pm

Sample : VOA STD 20 PPB

Misc :

Quant Time: Dec 30 3:54 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc Unit	Qvalue
38) Styrene	25.07	104	67473	18.52 ug/l	80
39) 2-Hexanone	20.54	43	31409	17.48 ug/l	100
41) 1,1,2,2-Tetrachloroethane	26.34	83	40663	17.36 ug/l	99

(#) = qualifier out of range (m) = manual integration

0501005.D CLPS3.M

Fri Dec 30 03:54:26 1994

GCMS VOA

Page 2

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0701007.D

Acq Time : 29 Dec 94 3:39 pm

Sample : VOA STD 50 PPB

Misc :

Quant Time: Dec 30 3:55 1994

Operator:

Inst : GC/MS

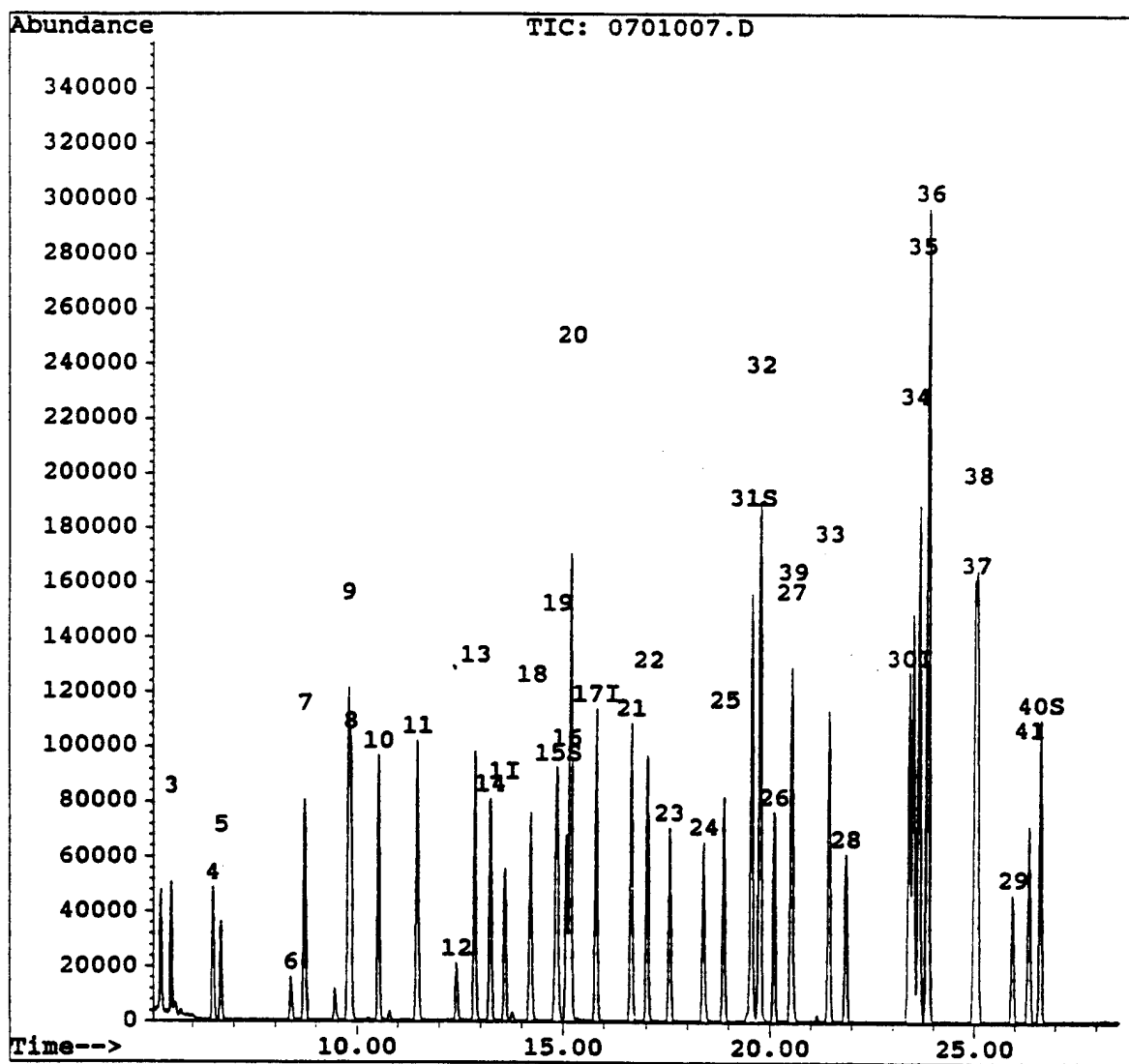
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0701007.D

Acq Time : 29 Dec 94 3:39 pm

Sample : VOA STD 50 PPB

Misc :

Quant Time: Dec 30 3:55 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.59	128	29521	50.00	ug/l	0.00
17) 1,4-Difluorobenzene	15.81	114	182958	50.00	ug/l	0.00
30) Chlorobenzene-d5	23.41	117	176899	50.00	ug/l	0.01
System Monitoring Compounds						
15) 1,2-Dichloroethane-d4	14.87	65	79373	46.86	ug/l	%Recovery
31) Toluene-d8	19.55	98	228085	46.59	ug/l	
40) Bromofluorobenzene	26.62	95	94179	51.44	ug/l	#
Target Compounds						
2) Chloromethane	5.22	50	76183	53.17	ug/l	Qvalue
3) Vinyl Chloride	5.48	62	65594	53.37	ug/l	98
4) Bromomethane	6.49	94	63315	53.47	ug/l	95
5) Chloroethane	6.69	64	61497	53.35	ug/l	99
6) Acetone	8.39	43	35387	57.09	ug/l	89
7) 1,1-Dichloroethene	8.73	96	65524	52.07	ug/l	100
8) Carbon Disulfide	9.84	76	267421	52.81	ug/l	96
9) Methylene Chloride	9.79	84	103909	51.89	ug/l	100
10) 1,2-Dichloroethene (trans)	10.53	96	72635	52.30	ug/l	97
11) 1,1-Dichloroethane	11.48	63	144226	52.09	ug/l	95
12) 2-Butanone	12.42	43	56668	52.74	ug/l	99
13) 1,2-Dichloroethene [cis]	12.86	96	84497	52.52	ug/l	100
14) Chloroform	13.24	83	132264	52.48	ug/l	95
16) 1,2-Dichloroethane	15.09	62	110526	52.10	ug/l	98
18) 1,1,1-Trichloroethane	14.22	97	108421	52.95	ug/l	98
19) Carbon Tetrachloride	14.84	117	90477	53.04	ug/l	# 100
20) Benzene	15.19	78	331587	52.78	ug/l	100
21) Trichloroethene	16.65	130	72964	51.95	ug/l	90
22) 1,2-Dichloropropane	17.04	63	91923	53.19	ug/l	99
23) Bromodichloromethane	17.58	83	100586	52.67	ug/l	97
24) 2-Pentanone, 4-Methyl	18.39	43	117069	53.40	ug/l	100
25) cis-1,3-Dichloropropene	18.89	75	136771	52.46	ug/l	100
26) trans-1,3-Dichloropropene	20.10	75	119780	51.70	ug/l	99
27) 1,1,2-Trichloroethane	20.51	97	68761	52.80	ug/l	97
28) Dibromochloromethane	21.85	129	73158	51.96	ug/l	100
29) Bromoform	25.94	173	58105	51.56	ug/l	98
32) Toluene	19.75	92	196121	53.02	ug/l	90
33) Tetrachloroethene	21.43	164	70214	52.59	ug/l	99
34) Chlorobenzene	23.50	112	200231	52.45	ug/l	97
35) Ethylbenzene	23.65	106	106900	52.96	ug/l	99
36) Xylene (m&p)	23.86	106	235187	52.76	ug/l	# 82
37) Xylene[o]	25.01	106	112927	51.71	ug/l	88

(#) = qualifier out of range (m) = manual integration

0701007.D CLPS3.M

Fri Dec 30 03:55:17 1994

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0701007.D

Acq Time : 29 Dec 94 3:39 pm

Sample : VOA STD 50 PPB

Misc :

Quant Time: Dec 30 3:55 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc	Unit	Qvalue
38) Styrene	25.07	104	187370	52.01	ug/l	86
39) 2-Hexanone	20.54	43	84126	52.03	ug/l	100
41) 1,1,2,2-Tetrachloroethane	26.34	83	101940	51.47	ug/l	97

(#) = qualifier out of range (m) = manual integration

0701007.D CLPS3.M

Fri Dec 30 03:55:19 1994

GCMS VOA

Page 2

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0901009.D

Acq Time : 29 Dec 94 5:01 pm

Sample : VOA STD 100 PPB

Misc :

Quant Time: Dec 30 3:55 1994

Operator:

Inst : GC/MS

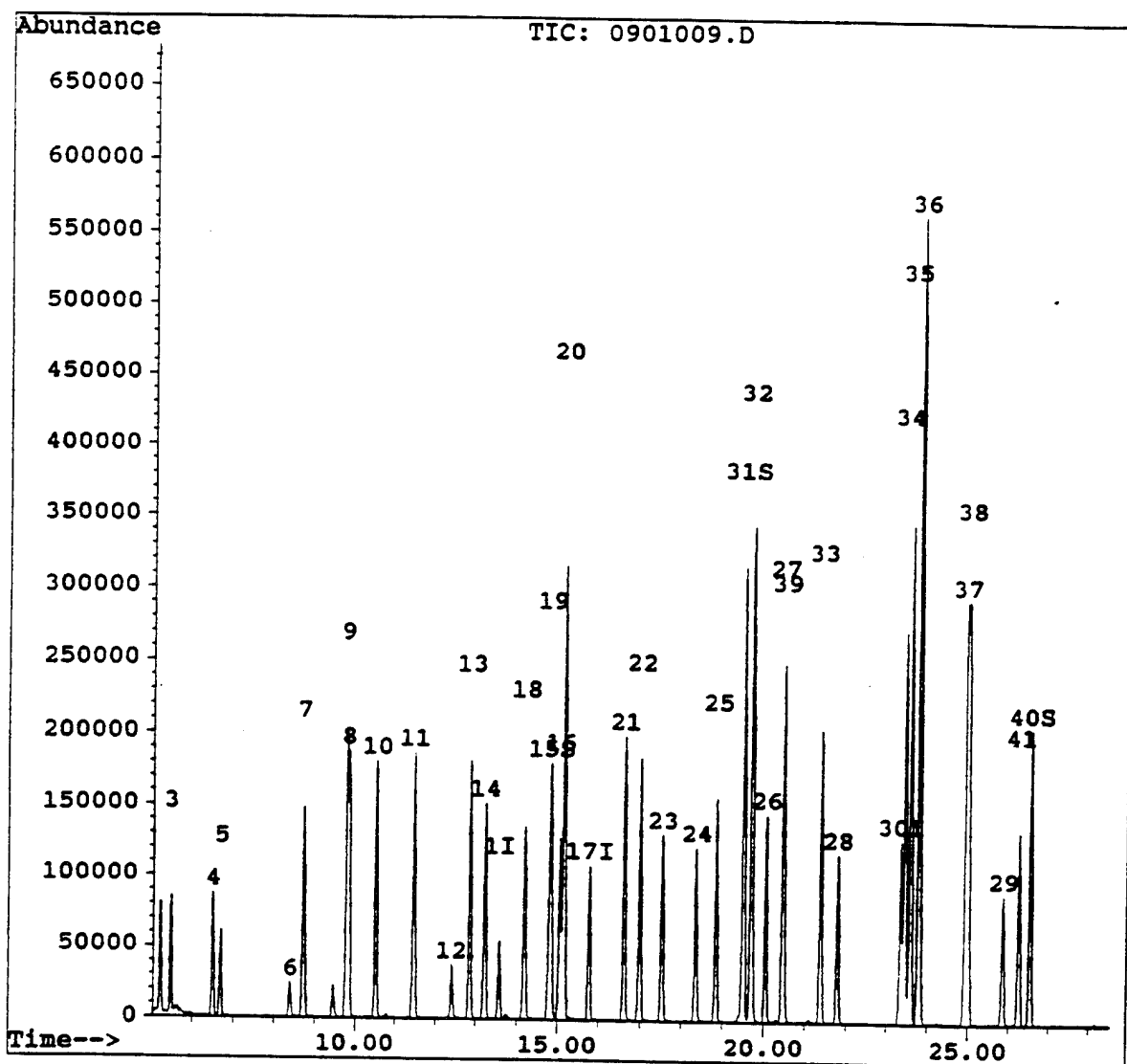
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0901009.D

Acq Time : 29 Dec 94 5:01 pm

Sample : VOA STD 100 PPB

Misc :

Quant Time: Dec 30 3:55 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.58	128	28955	50.00	ug/l	0.00
17) 1,4-Difluorobenzene	15.78	114	180189	50.00	ug/l	-0.03
30) Chlorobenzene-d5	23.34	117	170800	50.00	ug/l	-0.05

System Monitoring Compounds						%Recovery
15) 1,2-Dichloroethane-d4	14.84	65	160010	103.18	ug/l	
31) Toluene-d8	19.51	98	450910	103.30	ug/l	
40) Bromofluorobenzene	26.56	95	180923	105.76	ug/l	#

Target Compounds						Qvalue
2) Chloromethane	5.22	50	136836	102.45	ug/l	99
3) Vinyl Chloride	5.47	62	116795	102.88	ug/l	96
4) Bromomethane	6.50	94	114442	104.01	ug/l	97
5) Chloroethane	6.68	64	110539	102.47	ug/l	89
6) Acetone	8.39	43	56747	99.26	ug/l	100
7) 1,1-Dichloroethene	8.73	96	121895	102.55	ug/l	98
8) Carbon Disulfide	9.84	76	485007	102.10	ug/l	100
9) Methyl Chloride	9.79	84	170380	104.17	ug/l	98
10) 1,2-Dichloroethene (trans)	10.51	96	134334	103.44	ug/l	96
11) 1,1-Dichloroethane	11.47	63	266692	102.29	ug/l	99
12) 2-Butanone	12.40	43	103565	103.08	ug/l	100
13) 1,2-Dichloroethene [cis]	12.85	96	154779	101.89	ug/l	94
14) Chloroform	13.22	83	242512	101.81	ug/l	99
16) 1,2-Dichloroethane	15.07	62	206424	103.00	ug/l	99
18) 1,1,1-Trichloroethane	14.18	97	199602	103.98	ug/l	99
19) Carbon Tetrachloride	14.81	117	165393	103.04	ug/l	# 100
20) Benzene	15.16	78	606691	102.25	ug/l	100
21) Trichloroethene	16.61	130	134160	100.46	ug/l	91
22) 1,2-Dichloropropane	16.99	63	167405	102.49	ug/l	99
23) Bromodichloromethane	17.54	83	187245	104.38	ug/l	97
24) 2-Pentanone, 4-Methyl	18.35	43	210126	101.00	ug/l	100
25) cis-1,3-Dichloropropene	18.84	75	254824	103.98	ug/l	99
26) trans-1,3-Dichloropropene	20.06	75	227234	104.02	ug/l	99
27) 1,1,2-Trichloroethane	20.46	97	126217	102.71	ug/l	98
28) Dibromochloromethane	21.80	129	137695	103.01	ug/l	98
29) Bromoform	25.87	173	110868	103.06	ug/l	99
32) Toluene	19.70	92	351156	103.72	ug/l	90
33) Tetrachloroethene	21.38	164	126803	104.20	ug/l	98
34) Chlorobenzene	23.44	112	362187	103.00	ug/l	98
35) Ethylbenzene	23.58	106	188923	99.52	ug/l	100
36) Xylene (m&p)	23.79	106	419501	99.05	ug/l	# 82
37) Xylene[o]	24.94	106	207379	98.30	ug/l	87

(#) = qualifier out of range (m) = manual integration

0901009.D CLPS3.M

Fri Dec 30 03:56:10 1994

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\0901009.D

Acq Time : 29 Dec 94 5:01 pm

Sample : VOA STD 100 PPB

Misc :

Quant Time: Dec 30 3:55 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc	Unit	Qvalue
38) Styrene	25.01	104	338697	97.36	ug/l	87
39) 2-Hexanone	20.49	43	154360	101.33	ug/l	100
41) 1,1,2,2-Tetrachloroethane	26.28	83	191932	104.95	ug/l	97

(#) = qualifier out of range (m) = manual integration

0901009.D CLPS3.M

Fri Dec 30 03:56:11 1994

GCMS VOA

Page 2

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\1101011.D

Acq Time : 29 Dec 94 6:23 pm

Sample : VOA STD 200 PPB

Misc :

Quant Time: Dec 30 3:56 1994

Operator:

Inst : GC/MS

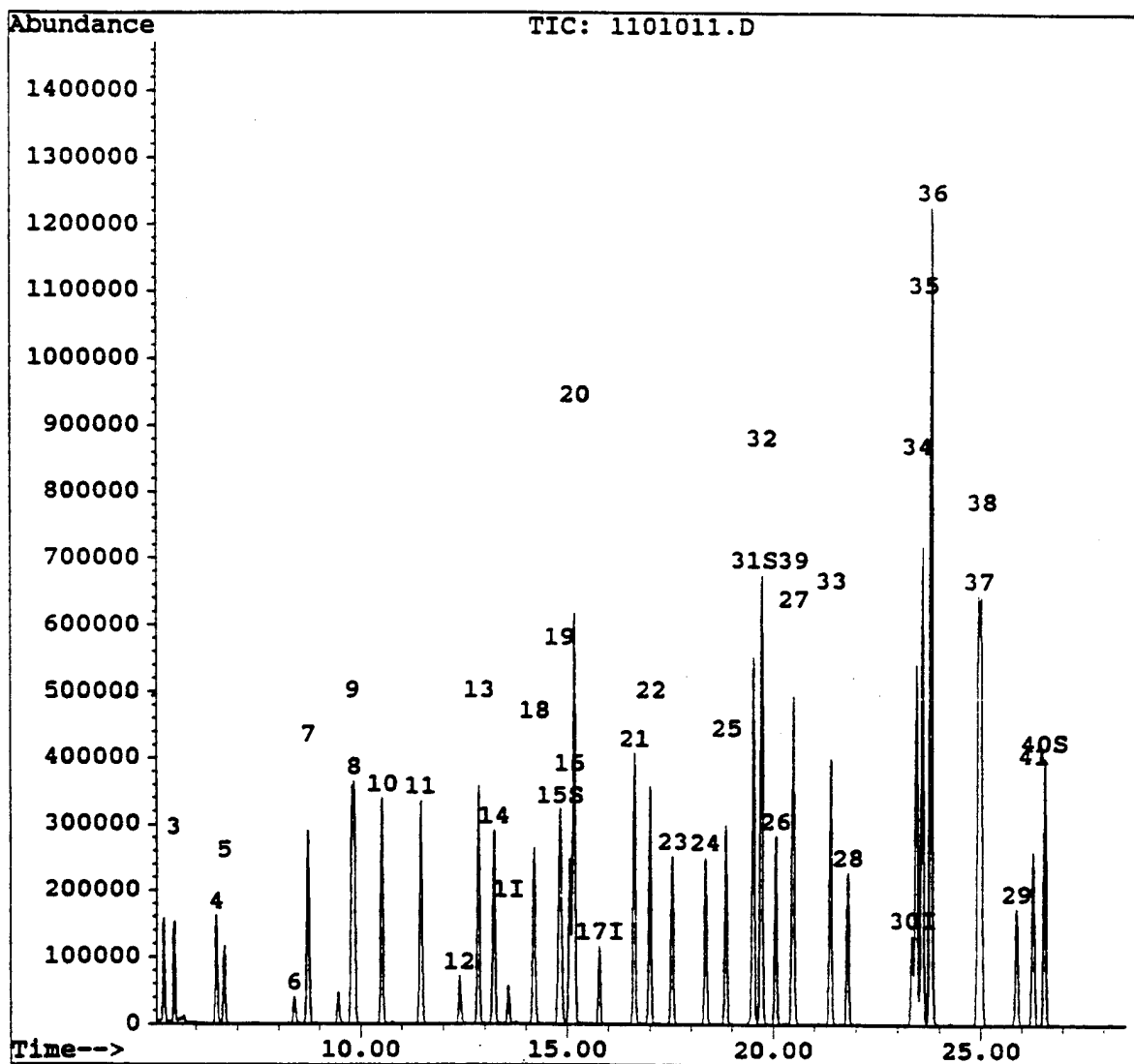
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration



Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\1101011.D

Acq Time : 29 Dec 94 6:23 pm

Sample : VOA STD 200 PPB

Misc :

Quant Time: Dec 30 3:56 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.57	128	29866	50.00	ug/l	-0.02
17) 1,4-Difluorobenzene	15.78	114	188964	50.00	ug/l	-0.04
30) Chlorobenzene-d5	23.35	117	179936	50.00	ug/l	-0.05
System Monitoring Compounds						%Recovery
15) 1,2-Dichloroethane-d4	14.84	65	279952	199.23	ug/l	
31) Toluene-d8	19.51	98	787380	199.15	ug/l	
40) Bromofluorobenzene	26.55	95	349979	197.09	ug/l	#
Target Compounds						Qvalue
2) Chloromethane	5.22	50	265777	198.32	ug/l	99
3) Vinyl Chloride	5.47	62	224510	198.09	ug/l	96
4) Bromomethane	6.48	94	217962	197.54	ug/l	98
5) Chloroethane	6.68	64	215027	198.25	ug/l	89
6) Acetone	8.39	43	112387	199.16	ug/l	100
7) 1,1-Dichloroethene	8.71	96	238704	198.48	ug/l	98
8) Carbon Disulfide	9.83	76	949778	198.53	ug/l	100
9) Methylene Chloride	9.78	84	302139	197.73	ug/l	98
10) 1,2-Dichloroethene (trans)	10.51	96	258914	198.02	ug/l	97
11) 1,1-Dichloroethane	11.46	63	522836	198.59	ug/l	100
12) 2-Butanone	12.40	43	200263	198.11	ug/l	100
13) 1,2-Dichloroethene [cis]	12.85	96	305070	198.69	ug/l	95
14) Chloroform	13.22	83	478724	198.74	ug/l	99
16) 1,2-Dichloroethane	15.06	62	402156	198.25	ug/l	99
18) 1,1,1-Trichloroethane	14.19	97	387984	197.65	ug/l	99
19) Carbon Tetrachloride	14.81	117	325483	198.05	ug/l	# 100
20) Benzene	15.16	78	1207565	198.47	ug/l	100
21) Trichloroethene	16.61	130	274025	199.46	ug/l	92
22) 1,2-Dichloropropane	16.99	63	332195	198.28	ug/l	98
23) Bromodichloromethane	17.53	83	362911	197.50	ug/l	99
24) 2-Pentanone, 4-Methyl	18.35	43	424904	198.91	ug/l	100
25) cis-1,3-Dichloropropene	18.84	75	496456	197.73	ug/l	99
26) trans-1,3-Dichloropropene	20.06	75	443862	197.86	ug/l	100
27) 1,1,2-Trichloroethane	20.47	97	249798	198.26	ug/l	98
28) Dibromochloromethane	21.80	129	272882	198.27	ug/l	99
29) Bromoform	25.88	173	220340	198.33	ug/l	99
32) Toluene	19.71	92	685956	197.73	ug/l	90
33) Tetrachloroethene	21.39	164	246098	197.61	ug/l	99
34) Chlorobenzene	23.44	112	716497	198.18	ug/l	98
35) Ethylbenzene	23.59	106	393366	199.72	ug/l	98
36) Xylene (m&p)	23.79	106	883994	199.97	ug/l	# 81
37) Xylene[o]	24.93	106	445872	200.54	ug/l	89

(#) = qualifier out of range (m) = manual integration

1101011.D CLPS3.M

Fri Dec 30 03:57:10 1994

GCMS VOA

Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\1101011.D
 Acq Time : 29 Dec 94 6:23 pm
 Sample : VOA STD 200 PPB
 Misc :
 Quant Time: Dec 30 3:56 1994

Operator:
 Inst : GC/MS
 Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M
 Title : VOA Standards for 5 point calibration
 Last Update : Fri Dec 30 03:51:20 1994
 Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) Bromochloromethane	13.57	128	29866	50.00	ug/l	-0.02
17) 1,4-Difluorobenzene	15.78	114	188964	50.00	ug/l	-0.04
30) Chlorobenzene-d5	23.35	117	179936	50.00	ug/l	-0.05

System Monitoring Compounds						%Recovery
15) 1,2-Dichloroethane-d4	14.84	65	279952	199.23	ug/l	
31) Toluene-d8	19.51	98	787380	199.15	ug/l	
40) Bromofluorobenzene	26.55	95	349979	197.09	ug/l	#

Target Compounds						Qvalue
2) Chloromethane	5.22	50	265777	198.32	ug/l	99
3) Vinyl Chloride	5.47	62	224510	198.09	ug/l	96
4) Bromomethane	6.48	94	217962	197.54	ug/l	98
5) Chloroethane	6.68	64	215027	198.25	ug/l	89
6) Acetone	8.39	43	112387	199.16	ug/l	100
7) 1,1-Dichloroethene	8.71	96	238704	198.48	ug/l	98
8) Carbon Disulfide	9.83	76	949778	198.53	ug/l	100
9) Methylene Chloride	9.78	84	302139	197.73	ug/l	98
10) 1,2-Dichloroethene (trans)	10.51	96	258914	198.02	ug/l	97
11) 1,1-Dichloroethane	11.46	63	522836	198.59	ug/l	100
12) 2-Butanone	12.40	43	200263	198.11	ug/l	100
13) 1,2-Dichloroethene [cis]	12.85	96	305070	198.69	ug/l	95
14) Chloroform	13.22	83	478724	198.74	ug/l	99
16) 1,2-Dichloroethane	15.06	62	402156	198.25	ug/l	99
18) 1,1,1-Trichloroethane	14.19	97	387984	197.65	ug/l	99
19) Carbon Tetrachloride	14.81	117	325483	198.05	ug/l	# 100
20) Benzene	15.16	78	1207565	198.47	ug/l	100
21) Trichloroethene	16.61	130	274025	199.46	ug/l	92
22) 1,2-Dichloropropane	16.99	63	332195	198.28	ug/l	98
23) Bromodichloromethane	17.53	83	362911	197.50	ug/l	99
24) 2-Pentanone, 4-Methyl	18.35	43	424904	198.91	ug/l	100
25) cis-1,3-Dichloropropene	18.84	75	496456	197.73	ug/l	99
26) trans-1,3-Dichloropropene	20.06	75	443862	197.86	ug/l	100
27) 1,1,2-Trichloroethane	20.47	97	249798	198.26	ug/l	98
28) Dibromochloromethane	21.80	129	272882	198.27	ug/l	99
29) Bromoform	25.88	173	220340	198.33	ug/l	99
32) Toluene	19.71	92	685956	197.73	ug/l	90
33) Tetrachloroethene	21.39	164	246098	197.61	ug/l	99
34) Chlorobenzene	23.44	112	716497	198.18	ug/l	98
35) Ethylbenzene	23.59	106	393366	199.72	ug/l	98
36) Xylene (m&p)	23.79	106	883994	199.97	ug/l	# 81
37) Xylene[o]	24.93	106	445872	200.54	ug/l	89

(#) = qualifier out of range (m) = manual integration
 1101011.D CLPS3.M Fri Dec 30 03:57:10 1994

GCMS VOA Page 1

Quantitation Report

Data File : C:\HPCHEM\1\DATA\D29\1101011.D

Acq Time : 29 Dec 94 6:23 pm

Sample : VOA STD 200 PPB

Misc :

Quant Time: Dec 30 3:56 1994

Operator:

Inst : GC/MS

Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\CLPS3.M

Title : VOA Standards for 5 point calibration

Last Update : Fri Dec 30 03:51:20 1994

Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc Unit	Qvalue
38) Styrene	25.00	104	736373	200.90 ug/l	87
39) 2-Hexanone	20.48	43	315378	199.08 ug/l	100
41) 1,1,2,2-Tetrachloroethane	26.27	83	372649	197.49 ug/l	98

(#) = qualifier out of range (m) = manual integration

1101011.D CLPS3.M

Fri Dec 30 03:57:11 1994

GCMS VOA

Page 2

Method Detection Limit Study

This section presents the method detection limits for specified parameters at CKY Laboratory. Method detection limit is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.

METHOD DETECTION LIMIT STUDY

Lab Name: CKY Incorporated, Pleasanton
Method: EPA 624/8240
Unit: ppb

Date: 12/10/93
Instrument: MSD 5972 HP5890 II

PARAMETER	1	2	3	4	5	6	7	AVE.	SD	MDL
Chloromethane	9.15	9.34	10.15	9.75	9.26	9.72	9.85	9.60	0.36	1.09
Vinyl Chloride	9.02	9.55	9.91	10.20	9.81	9.27	8.91	9.52	0.48	1.44
Bromomethane	9.66	9.35	9.31	9.32	10.27	10.04	9.04	9.57	0.44	1.33
Chloroethane	9.11	8.62	9.32	9.38	9.35	9.71	9.63	9.30	0.36	1.08
Trichloroethene	7.17	6.26	7.30	7.79	6.90	7.23	6.36	7.00	0.54	1.63
Acetone	9.39	9.60	8.67	9.32	9.93	10.05	9.03	9.43	0.49	1.46
1,1-DCA	9.72	9.48	10.12	10.52	9.29	10.27	9.93	9.90	0.44	1.31
Carbon Disulfide	8.41	8.88	8.64	9.86	9.13	7.44	7.88	8.61	0.80	2.40
Methylene Chloride	10.02	10.87	10.32	9.73	10.58	10.14	10.81	10.35	0.42	1.27
trans-1,2-DCE	9.72	9.20	9.09	9.42	9.10	7.54	8.48	8.94	0.72	2.17
1,1-DCA	10.62	10.08	10.64	10.23	9.75	9.52	10.39	10.17	0.43	1.28
cis-1,2-DCE	10.08	8.95	9.27	9.37	8.66	9.09	8.96	9.20	0.45	1.36
2-Butanone	8.93	8.20	9.01	9.69	10.14	9.19	10.11	9.32	0.70	2.10
Chloroform	9.95	9.45	9.44	9.55	9.83	9.90	10.28	9.77	0.31	0.93
1,2-DCA-d4	8.99	10.86	10.18	10.47	10.35	10.33	9.86	10.11	0.63	1.88
1,2-DCA	10.03	10.00	9.83	9.73	9.76	9.96	10.97	10.04	0.43	1.28
Vinyl Acetate	8.93	8.27	7.93	9.07	7.34	8.46	9.15	8.45	0.66	1.99
1,1,1-TCE	6.48	6.72	6.77	6.25	6.45	6.49	7.11	6.61	0.28	0.84
Carbon Tetrachloride	5.46	5.28	5.34	5.57	5.39	5.22	6.28	5.50	0.36	1.09
Benzene	8.70	9.00	8.91	9.35	9.01	9.06	8.97	9.00	0.19	0.58
TCE	7.91	8.84	8.89	7.95	8.72	8.69	8.42	8.49	0.41	1.23
1,2-Dichloropropane	8.80	10.08	10.63	9.75	10.35	9.73	10.55	9.98	0.63	1.90
Bromodichloromethane	7.69	7.28	7.78	7.30	7.39	7.49	7.81	7.53	0.22	0.67
cis-1,3-Dichloropropane	6.67	7.32	7.76	6.81	6.86	7.71	7.49	7.20	0.49	1.46
trans-1,3-Dichloropropane	5.76	5.83	6.51	6.05	6.44	6.54	6.83	6.25	0.36	1.09
1,1,2-TCA	7.34	9.15	10.22	8.16	9.54	9.36	9.37	9.02	0.96	2.88
Dibromochloromethane	6.15	7.04	7.81	8.12	7.99	8.29	7.80	7.57	0.75	2.24
Bromoform	5.79	6.53	7.73	7.21	7.25	7.33	7.55	7.06	0.67	2.02
4-methyl-2-pentanone	8.72	7.16	9.09	9.30	9.33	9.28	9.19	8.86	0.78	2.34
Toluene-d8	9.35	10.00	9.96	8.28	9.04	9.99	9.87	9.50	0.65	1.96
Toluene	9.34	9.02	9.33	8.49	8.70	9.73	9.02	9.09	0.42	1.28
PCE	8.75	8.25	8.35	7.60	8.06	7.90	7.75	8.09	0.39	1.18
2-Hexanone	9.63	10.47	8.95	9.85	9.78	9.87	9.85	9.77	0.45	1.34
Chlorobenzene	8.89	8.97	9.06	9.03	9.03	9.22	8.96	9.03	0.10	0.31
Ethylbenzene	8.82	9.31	9.81	9.07	9.77	8.75	8.60	9.02	0.42	1.28
M/P-Xylenes	8.99	9.45	9.76	9.34	9.23	8.86	8.79	9.20	0.35	1.04
O-Xylenes	9.18	9.26	9.59	9.38	9.06	8.93	8.81	9.17	0.27	0.80
Styrene	8.09	8.72	8.61	8.16	8.02	8.51	7.81	8.27	0.34	1.02
BFB	10.85	10.37	10.40	9.81	9.66	10.05	9.81	10.11	0.48	1.37
1,1,2,2-Tetrachloroethane	9.15	10.70	10.63	10.36	10.20	10.82	10.53	10.30	0.53	1.60
1,3-DCB	9.18	10.03	9.76	9.52	9.17	10.19	9.36	9.60	0.40	1.21
1,4-DCB	9.45	10.39	9.75	9.78	9.48	10.45	9.86	9.85	0.41	1.22
1,4-DCB	9.02	10.17	9.10	9.20	9.52	10.00	9.71	9.53	0.45	1.35

Chain of Custody

This section presents a copy of the chain of custody forms that accompanied the sample from the time they were removed from the ground, through the analysis process.

[illegible]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Storage/Disposal of Samples: Sample will be stored at CRY for 30 days at no charge and at \$10/sample/month thereafter. Disposal of sample by the Laboratory will be charged at \$10/sample.																																																																																																			

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AP412-49 → R-10A

APPENDIX - C

Soils Report

EDITOR'S NOTE:

This appendix is published in the same format as submitted by the contractor.

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Permeability	266

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GRAIN SIZE DISTRIBUTION TEST DATA

=====

Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks: 39-29.5-30
 Fig. No.: 001

Mechanical Analysis Data

Initial

Dry sample and tare= 420.39
 Tare = 0.00
 Dry sample weight = 420.39
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 66.723 Tare = 0 Sample weight = 66.723

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 8	0.00	0.00	100.0
# 10	0.00	0.00	100.0
# 16	0.00	0.00	100.0
# 30	0.03	0.00	100.0
# 50	0.13	0.00	99.8
# 100	0.32	0.00	99.3
# 200	3.17	0.00	94.5

Hydrometer Analysis Data

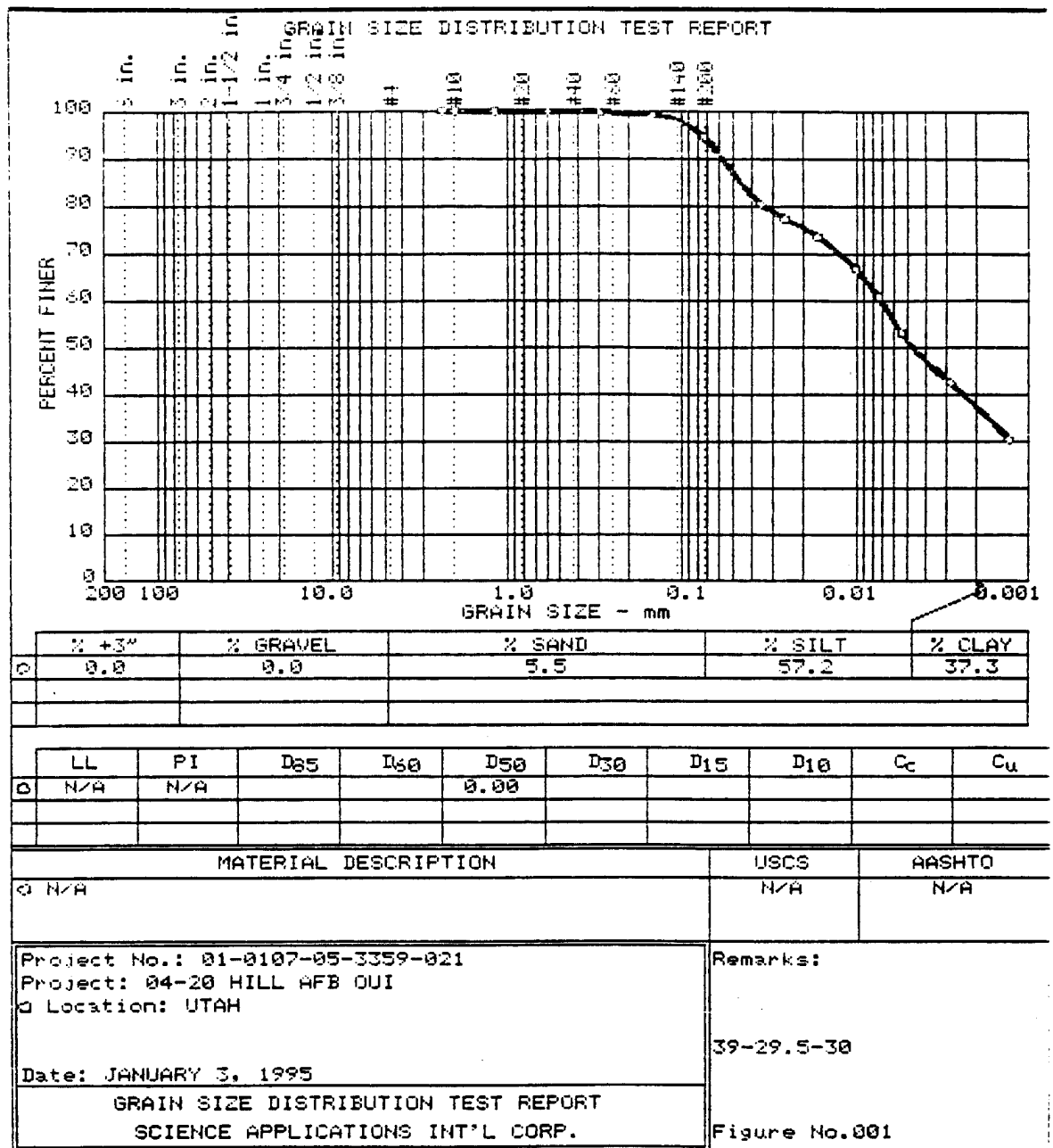
Separation sieve is number 10
 Percent -# 10 based on complete sample= 100.0
 Weight of hydrometer sample: 66.723
 Calculated biased weight= 66.72
 Table of composite correction values:
 Temp. deg C: 21.0
 Comp. corr: - 6.0
 Viscous correction only= 0
 Specific gravity of solids= 2.6
 Specific gravity correction factor= 1.012
 Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp. deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	59.0	53.0	0.0137	59.0	6.6	0.0352	80.4
2.0	21.0	57.0	51.0	0.0137	57.0	6.9	0.0255	77.3
5.0	21.0	54.5	48.5	0.0137	54.5	7.4	0.0166	73.5
15.0	21.0	50.0	44.0	0.0137	50.0	8.1	0.0101	66.7
30.0	21.0	46.0	40.0	0.0137	46.0	8.8	0.0074	60.7
60.0	21.0	41.0	35.0	0.0137	41.0	9.6	0.0055	53.1
250.0	21.0	34.0	28.0	0.0137	34.0	10.7	0.0028	42.5
1294.0	21.0	26.0	20.0	0.0137	26.0	12.0	0.0013	30.3

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 5.5
 % SILT = 57.2 % CLAY = 37.3

D85= 0.05 D60= 0.007 D50= 0.005



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks:
 28-26.5-27
 Fig. No.: 001

Mechanical Analysis Data

Initial
 Dry sample and tare= 476.06
 tare = 0.00
 Dry sample weight = 476.06
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 90.341 Tare = 0 Sample weight = 90.341

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
1.5 inches	0.00	0.00	100.0
0.75 inches	68.04	0.00	85.7
0.375 inches	88.46	0.00	67.1
# 4	46.46	0.00	57.4
# 8	39.89	0.00	49.0
# 10	8.41	0.00	47.2
# 16	9.19	0.00	42.4
# 30	23.72	0.00	30.0
# 50	24.04	0.00	17.5
# 100	7.52	0.00	13.5
# 200	3.41	0.00	11.7

Hydrometer Analysis Data

Separation sieve is number 10
 Percent -# 10 based on complete sample= 47.2
 Weight of hydrometer sample: 90.341
 Calculated biased weight= 191.32
 Table of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0

Meniscus correction only= 0

Specific gravity of solids= 2.6

Specific gravity correction factor= 1.012

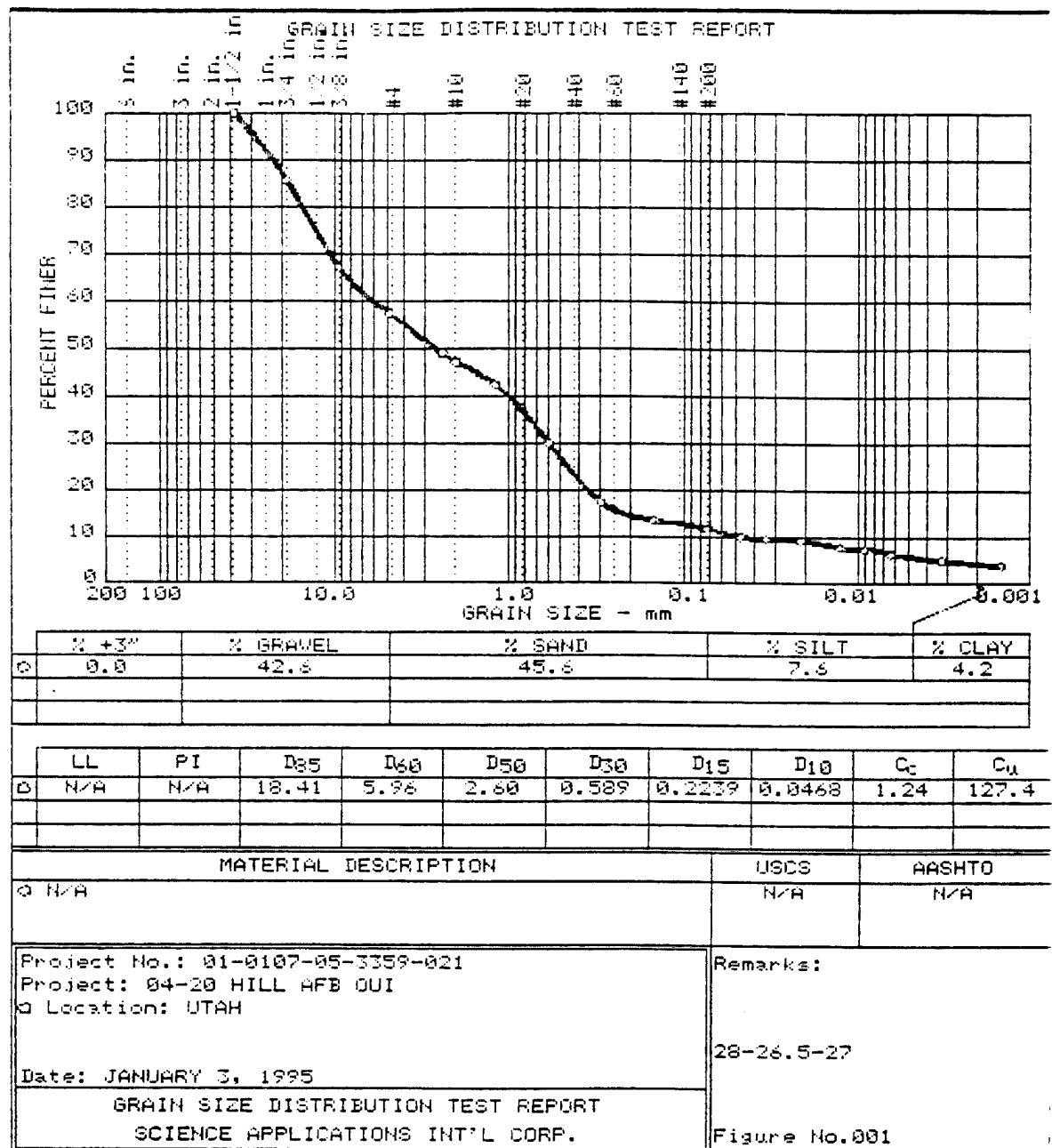
Hvdrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp. deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	25.0	19.0	0.0137	25.0	12.2	0.0478	10.0
2.0	21.0	24.0	18.0	0.0137	24.0	12.4	0.0340	9.5
5.0	21.0	23.5	17.5	0.0137	23.5	12.4	0.0216	9.3
15.0	21.0	20.5	14.5	0.0137	20.5	12.9	0.0127	7.7
30.0	21.0	20.0	14.0	0.0137	20.0	13.0	0.0090	7.4
60.0	21.0	18.0	12.0	0.0137	18.0	13.3	0.0065	6.3
250.0	21.0	15.0	9.0	0.0137	15.0	13.8	0.0032	4.8
1256.0	21.0	13.0	7.0	0.0137	13.0	14.2	0.0015	3.7

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 42.6 % SAND = 45.6
% SILT = 7.6 % CLAY = 4.2

D85= 18.41 D60= 5.957 D50= 2.600
D30= 0.5888 D15= 0.22387 D10= 0.04677
Cc = 1.2445 Cu = 127.3503



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks:
 31-31.5-32
 Fig. No.: 001

Mechanical Analysis Data

Initial

Dry sample and tare= 486.78
 re = 0.00
 Dry sample weight = 486.78
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 68.959 Tare = 0 Sample weight = 68.959

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
0.75 inches	0.00	0.00	100.0
0.375 inches	22.32	0.00	95.4
# 4	28.93	0.00	89.5
# 8	20.72	0.00	85.2
# 10	4.06	0.00	84.4
# 16	1.13	0.00	83.0
# 30	2.39	0.00	80.1
# 50	22.63	0.00	52.4
# 100	23.78	0.00	23.3
# 200	3.35	0.00	19.2

Hydrometer Analysis Data

Separation sieve is number 10
 Percent -# 10 based on complete sample= 84.4
 Weight of hydrometer sample: 68.959
 Calculated biased weight= 81.72
 ble of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0
 Meniscus correction only= 0

Specific gravity of solids= 2.65

Specific gravity correction factor= 1.000

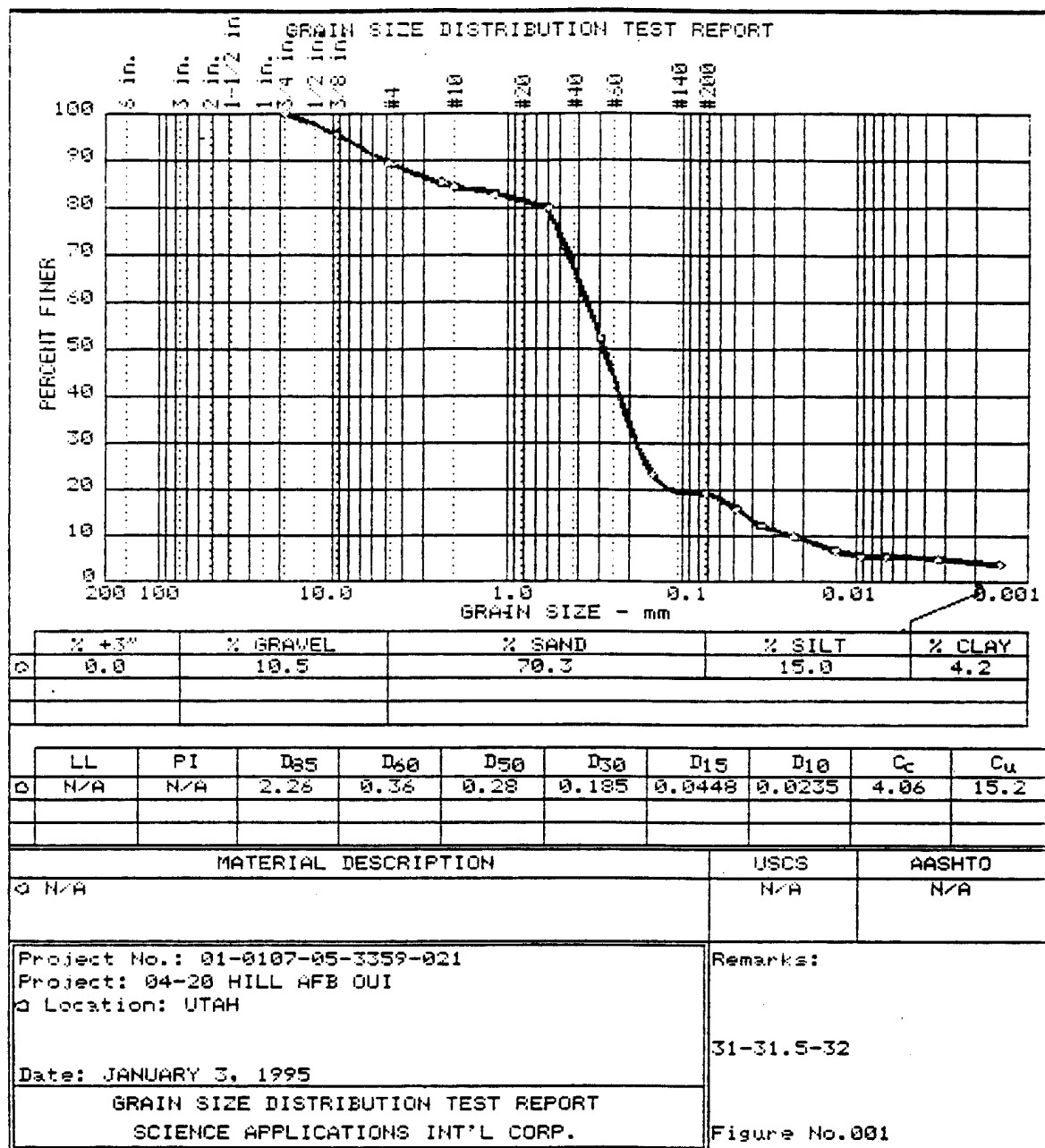
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	19.0	13.0	0.0135	19.0	13.2	0.0489	15.9
2.0	21.0	16.0	10.0	0.0135	16.0	13.7	0.0352	12.2
5.0	21.0	14.0	8.0	0.0135	14.0	14.0	0.0226	9.8
15.0	21.0	11.5	5.5	0.0135	11.5	14.4	0.0132	6.7
30.0	21.0	10.5	4.5	0.0135	10.5	14.6	0.0094	5.5
60.0	21.0	10.5	4.5	0.0135	10.5	14.6	0.0066	5.5
250.0	21.0	10.0	4.0	0.0135	10.0	14.7	0.0033	4.9
1290.0	21.0	9.0	3.0	0.0135	9.0	14.8	0.0014	3.7

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 10.5 % SAND = 70.3
% SILT = 15.0 % CLAY = 4.2

D85= 2.26 D60= 0.357 D50= 0.283
D30= 0.1847 D15= 0.04482 D10= 0.02352
Cc = 4.0598 Cu = 15.1880



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB GVI

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Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks:
 42-31.5-32
 Fig. No.: 001

Mechanical Analysis Data

Initial

Dry sample and tare= 473.17
 = 0.00
 Dry sample weight = 473.17
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 69.106 Tare = 0 Sample weight = 69.106

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
1.5 inches	0.00	0.00	100.0
0.75 inches	83.22	0.00	82.4
0.375 inches	16.50	0.00	78.9
# 4	14.59	0.00	75.8
# 8	11.62	0.00	73.4
# 10	2.99	0.00	72.8
# 16	1.34	0.00	71.3
# 30	6.10	0.00	64.9
# 50	3.99	0.00	60.7
# 100	1.65	0.00	59.0
# 200	1.13	0.00	57.8

Hydrometer Analysis Data

Separation sieve is number 10
 Percent -# 10 based on complete sample= 72.8
 Weight of hydrometer sample: 69.106
 Calculated biased weight= 94.99
 Table of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0

Meniscus correction only= 0

Specific gravity of solids= 2.62

Specific gravity correction factor= 1.007

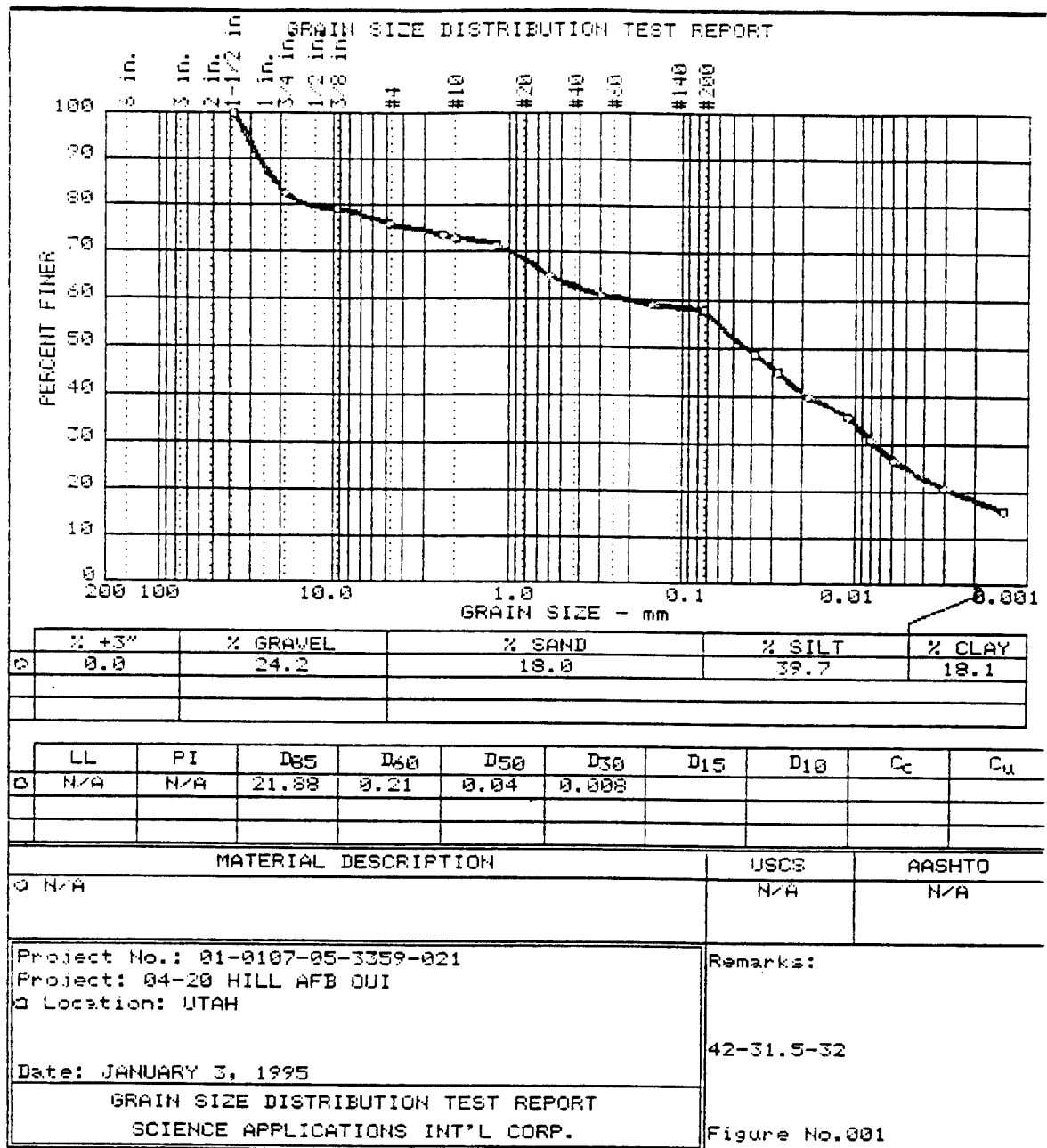
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp. deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	52.0	46.0	0.0136	52.0	7.8	0.0379	48.8
2.0	21.0	48.5	42.5	0.0136	48.5	8.3	0.0278	45.1
5.0	21.0	43.5	37.5	0.0136	43.5	9.2	0.0184	39.8
15.0	21.0	39.5	33.5	0.0136	39.5	9.8	0.0110	35.5
30.0	21.0	35.0	29.0	0.0136	35.0	10.6	0.0081	30.7
60.0	21.0	31.0	25.0	0.0136	31.0	11.2	0.0059	26.5
250.0	21.0	25.5	19.5	0.0136	25.5	12.1	0.0030	20.7
1266.0	21.0	21.0	15.0	0.0136	21.0	12.9	0.0014	15.9

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 24.2 % SAND = 18.0
% SILT = 39.7 % CLAY = 18.1

D85= 21.88 D60= 0.209 D50= 0.043
D30= 0.0077



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks:
 33-29.5-30
 Fig. No.: 001

Mechanical Analysis Data

Initial

Dry sample and tare= 407.91
 re = 0.00
 y sample weight = 407.91
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 67.903 Tare = 0 Sample weight = 67.903

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 16	0.01	0.00	100.0
# 30	0.10	0.00	99.8
# 50	0.20	0.00	99.6
# 100	0.56	0.00	98.7
# 200	3.74	0.00	93.2

Hydrometer Analysis Data

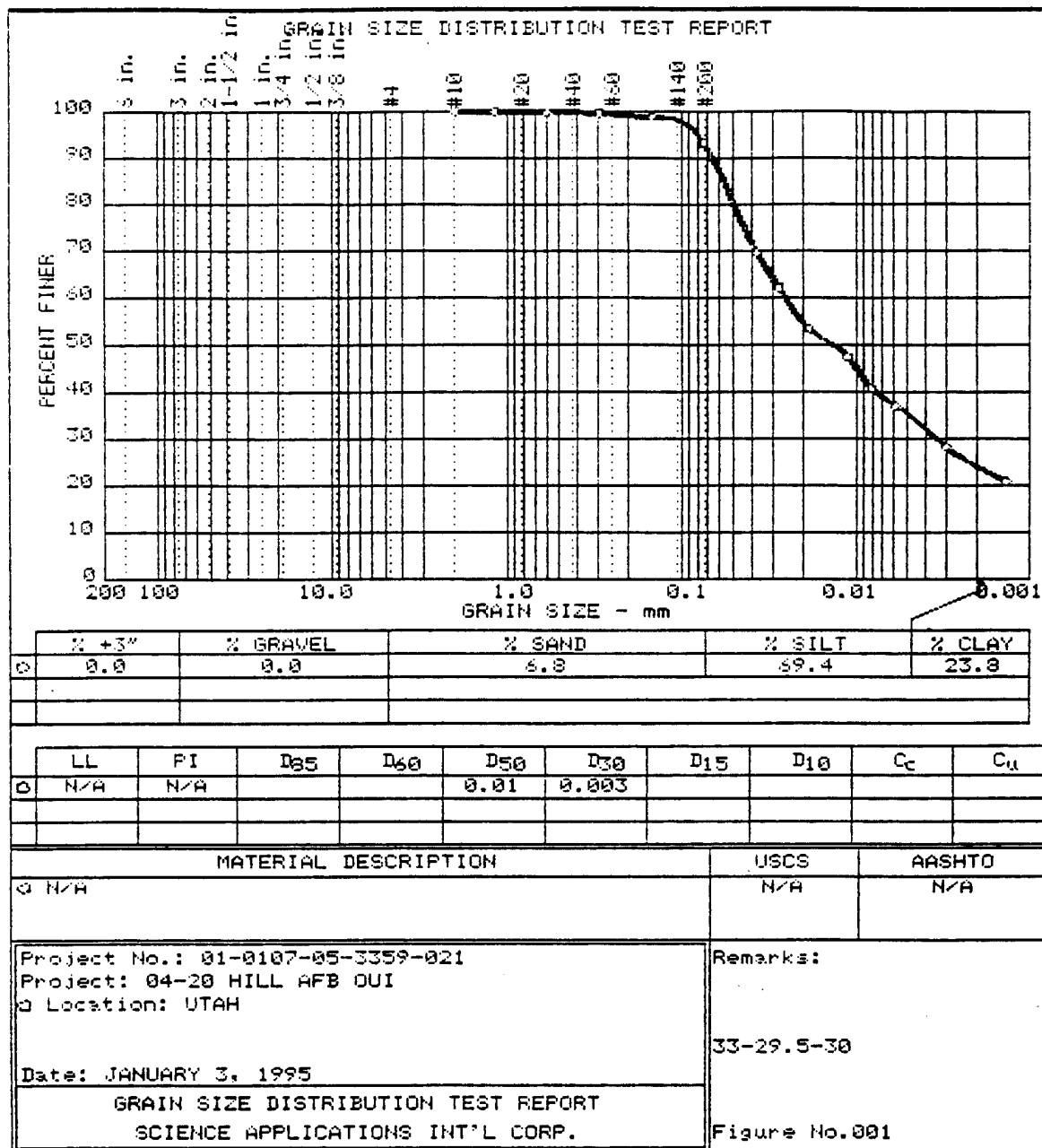
Separation sieve is number 10
 Percent -# 10 based on complete sample= 100.0
 Weight of hydrometer sample: 67.903
 Calculated biased weight= 67.90
 Table of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0
 Meniscus correction only= 0
 Specific gravity of solids= 2.63
 Specific gravity correction factor= 1.005
 Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	53.0	47.0	0.0136	53.0	7.6	0.0374	69.5
2.0	21.0	48.0	42.0	0.0136	48.0	8.4	0.0278	62.1
5.0	21.0	42.0	36.0	0.0136	42.0	9.4	0.0186	53.3
15.0	21.0	38.0	32.0	0.0136	38.0	10.1	0.0111	47.3
30.0	21.0	33.5	27.5	0.0136	33.5	10.9	0.0081	40.7
60.0	21.0	31.0	25.0	0.0136	31.0	11.2	0.0059	37.0
250.0	21.0	25.0	19.0	0.0136	25.0	12.2	0.0030	28.1
1300.0	21.0	20.0	14.0	0.0136	20.0	13.0	0.0014	20.7

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 5.8
 % SILT = 69.4 % CLAY = 23.8

D85= 0.06 D60= 0.025 D50= 0.014
 D30= 0.0034



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks: 27-29.5-30
 Fig. No.: 001

Mechanical Analysis Data

Initial
 Dry sample and tare= 449.32
 Tare = 0.00
 Dry sample weight = 449.32
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 68.577 Tare = 0 Sample weight = 68.577

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 16	0.01	0.00	100.0
# 30	0.06	0.00	99.9
# 50	0.11	0.00	99.7
# 100	0.25	0.00	99.4
# 200	1.17	0.00	97.7

Hydrometer Analysis Data

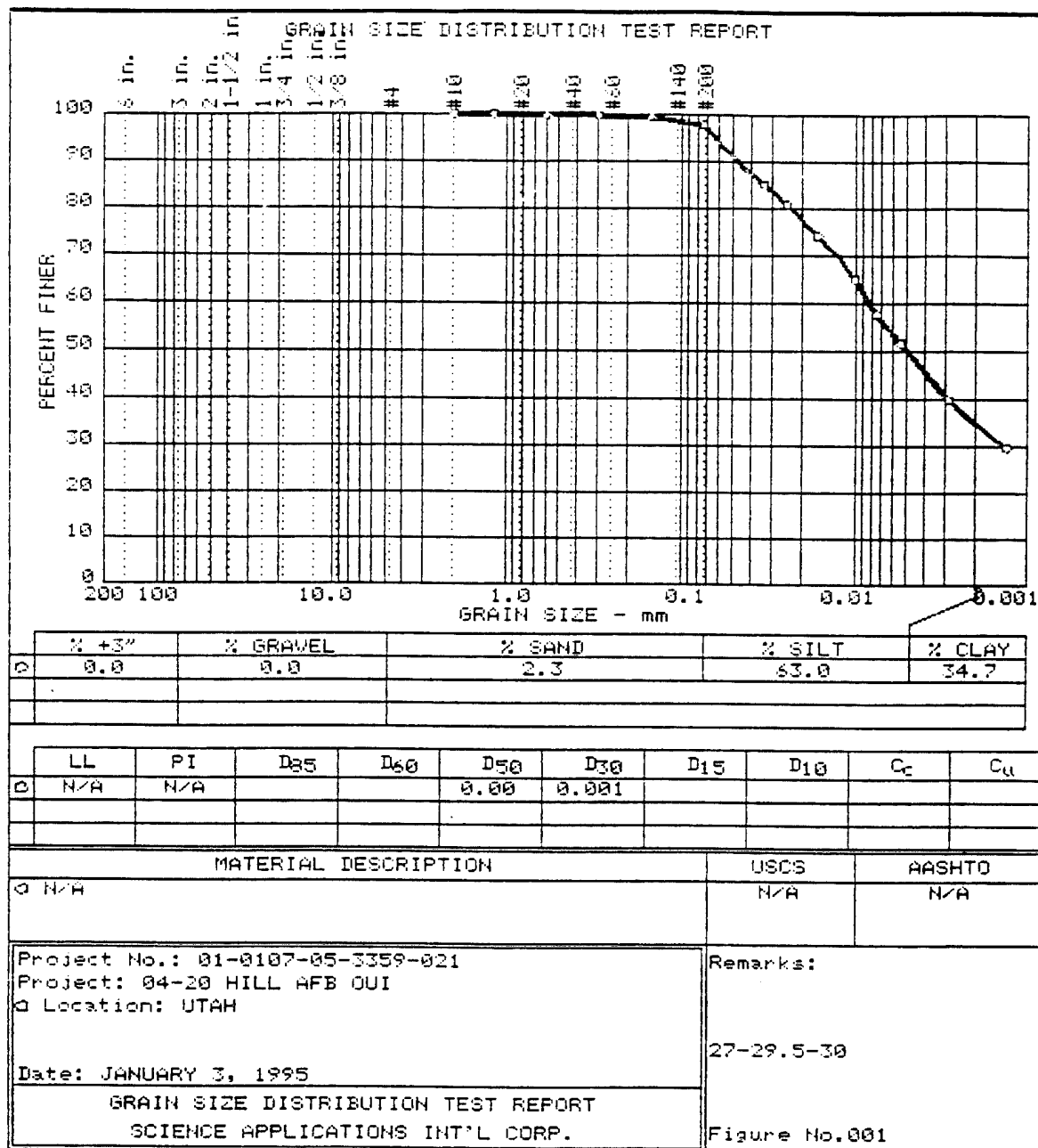
Separation sieve is number 10
 Percent -# 10 based on complete sample= 100.0
 Weight of hydrometer sample: 68.577
 Calculated biased weight= 68.58
 Table of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0
 Meniscus correction only= 0
 Specific gravity of solids= 2.59
 Specific gravity correction factor= 1.014
 Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp. deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	63.5	57.5	0.0137	63.5	5.9	0.0333	85.0
2.0	21.0	60.5	54.5	0.0137	60.5	6.4	0.0245	80.6
5.0	21.0	56.0	50.0	0.0137	56.0	7.1	0.0164	73.9
15.0	21.0	50.0	44.0	0.0137	50.0	8.1	0.0101	65.1
30.0	21.0	45.0	39.0	0.0137	45.0	8.9	0.0075	57.7
60.0	21.0	41.0	35.0	0.0137	41.0	9.6	0.0055	51.8
250.0	21.0	33.0	27.0	0.0137	33.0	10.9	0.0029	39.9
1312.0	21.0	26.0	20.0	0.0137	26.0	12.0	0.0013	29.6

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 2.3
 % SILT = 63.0 % CLAY = 34.7

D85= 0.03 D60= 0.008 D50= 0.005
 D30= 0.0013



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A Liquid limit: N/A
 AASHTO Class: N/A Plasticity index: N/A

Notes

Remarks:
 30-29.5-30
 Fig. No.: 001

Mechanical Analysis Data

Initial
 Dry sample and tare= 502.95
 Tare = 0.00
 Dry sample weight = 502.95
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 68.463 Tare = 0 Sample weight = 68.463

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
1.5 inches	0.00	0.00	100.0
0.75 inches	24.28	0.00	95.2
0.375 inches	33.96	0.00	88.4
# 4	14.08	0.00	85.6
# 8	7.87	0.00	84.1
# 10	1.92	0.00	83.7
# 16	1.07	0.00	82.4
# 30	2.85	0.00	78.9
# 50	6.94	0.00	70.4
# 100	3.20	0.00	66.5
# 200	3.65	0.00	62.0

Hydrometer Analysis Data

Separation sieve is number 10
 Percent -# 10 based on complete sample= 83.7
 Weight of hydrometer sample: 68.463
 Calculated biased weight= 81.82
 Sample of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0

Meniscus correction only= 0

Specific gravity of solids= 2.66

Specific gravity correction factor= 0.998

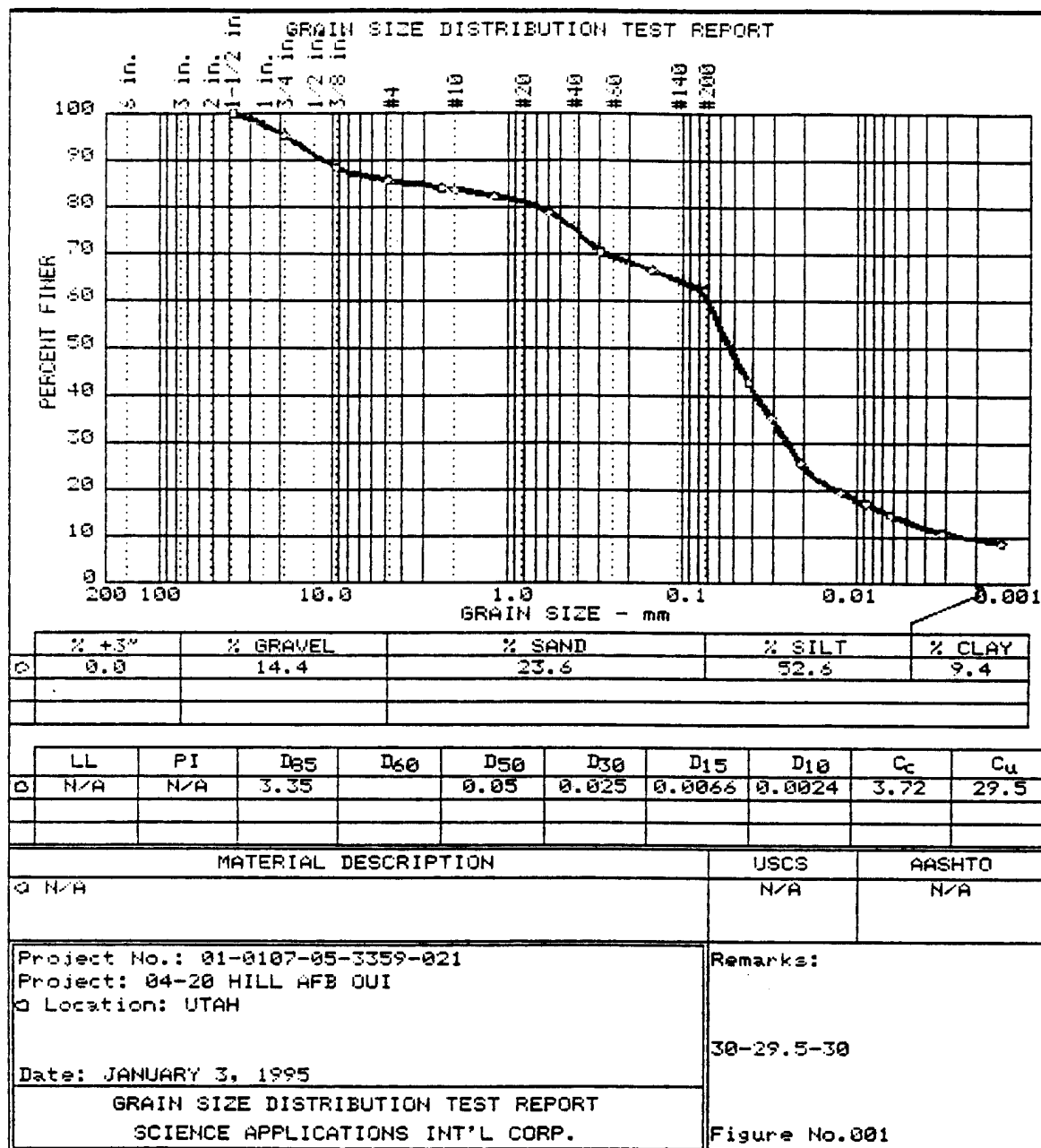
Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp, deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	41.0	35.0	0.0134	41.0	9.6	0.0416	42.7
2.0	21.0	35.0	29.0	0.0134	35.0	10.6	0.0309	35.4
5.0	21.0	27.0	21.0	0.0134	27.0	11.9	0.0207	25.6
15.0	21.0	22.0	16.0	0.0134	22.0	12.7	0.0124	19.5
30.0	21.0	20.0	14.0	0.0134	20.0	13.0	0.0089	17.1
60.0	21.0	18.0	12.0	0.0134	18.0	13.3	0.0063	14.6
250.0	21.0	15.0	9.0	0.0134	15.0	13.8	0.0032	11.0
1261.0	21.0	13.0	7.0	0.0134	13.0	14.2	0.0014	8.5

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 14.4 % SAND = 23.6
% SILT = 52.6 % CLAY = 9.4

D85= 3.35 D60= 0.070 D50= 0.054
D30= 0.0248 D15= 0.00661 D10= 0.00237
Cc = 3.7154 Cu = 29.5121



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GRAIN SIZE DISTRIBUTION TEST DATA

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Date: JANUARY 3, 1995
 Project No.: 01-0107-05-3359-021
 Project: 04-20 HILL AFB OUI

=====

Sample Data

Location of Sample: UTAH
 Sample Description: N/A
 USCS Class: N/A
 AASHTO Class: N/A

Liquid limit: N/A
 Plasticity index: N/A

Notes

Remarks: 38-30.5-31
 Fig. No.: 001

Mechanical Analysis Data

Initial

Dry sample and tare= 467.35
 " " " = 0.00
 Dry sample weight = 467.35
 Sample split on number 10 sieve
 Split sample data:
 Sample and tare = 68.917 Tare = 0 Sample weight = 68.917

Sieve tare method

Sieve	Weight retained	Sieve tare	Percent finer
# 10	0.00	0.00	100.0
# 16	0.02	0.00	100.0
# 30	0.02	0.00	99.9
# 50	0.05	0.00	99.9
# 100	0.51	0.00	99.1
# 200	3.30	0.00	94.3

Hydrometer Analysis Data

Separation sieve is number 10
 Percent -# 10 based on complete sample= 100.0
 Weight of hydrometer sample: 68.917
 Calculated biased weight= 68.92
 Table of composite correction values:
 Temp, deg C: 21.0
 Comp. corr: - 6.0
 Meniscus correction only= 0
 Specific gravity of solids= 2.61
 Specific gravity correction factor= 1.009
 Hydrometer type: 152H Effective depth L= 16.294964 - 0.164 x Rm

Elapsed time, min	Temp. deg C	Actual reading	Corrected reading	K	Rm	Eff. depth	Diameter mm	Percent finer
1.0	21.0	60.0	54.0	0.0136	60.0	6.5	0.0347	79.1
2.0	21.0	58.0	52.0	0.0136	58.0	6.8	0.0251	76.2
5.0	21.0	55.0	49.0	0.0136	55.0	7.3	0.0165	71.8
15.0	21.0	50.0	44.0	0.0136	50.0	8.1	0.0100	64.4
30.0	21.0	46.0	40.0	0.0136	46.0	8.8	0.0074	58.6
60.0	21.0	41.5	35.5	0.0136	41.5	9.5	0.0054	52.0
250.0	21.0	34.5	28.5	0.0136	34.5	10.6	0.0028	41.7
1319.0	21.0	27.0	21.0	0.0136	27.0	11.9	0.0013	30.8

Fractional Components

% + 3 in. = 0.0 % GRAVEL = 0.0 % SAND = 5.7
 % SILT = 57.4 % CLAY = 36.9

D85= 0.05 D60= 0.008 D50= 0.005

GRAIN SIZE DISTRIBUTION TEST REPORT

Grain Size (mm)	Percent Finer (%)
200	100
100	100
50	100
25	100
12.5	100
6.3	100
3.15	100
1.6	100
0.85	100
0.425	100
0.25	100
0.15	100
0.075	100
0.0475	95
0.03	85
0.02	75
0.015	65
0.01	55
0.0075	45
0.006	35
0.00425	25
0.003	15
0.002	10
0.0015	5
0.001	0

[illegible]

Project No.: 01-0107-05-3359-021	Remarks:
Project: 04-20 HILL AFB OUI	
Location: UTAH	
Date: JANUARY 3, 1995	38-30.5-31
GRAIN SIZE DISTRIBUTION TEST REPORT	
SCIENCE APPLICATIONS INT'L CORP.	Figure No.001



SPECIFIC GRAVITY DETERMINATIONS

95-003/TRW.005

MARKER	SPECIFIC GRAVITY
27-29.5-30	2.59
28-26.5-27	2.60
30-29.5-30	2.66
31-31.5-32	2.65
33-29.5-30	2.63
38-30.5-31	2.61
39-25.5-30	2.60
42-31.5-32	2.62

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 27-29½-30 Project No.: 01-0107-05-3359-021
 Customer: *Praxis/TKS* Date: 12-27-94
 Test Operator: *MPant*
 Remarks:

Flask No. 11 Thermometer ID: 10
 Balance ID: 37080033
 Weight of Flask, W_F , (dry, empty): 66.020 grams
 Weight of Flask and Oven Dry Soil, W_s : 103.379 grams
 Weight of Oven Dry Soil, $W_o = W_s - W_F$: 37.359 grams
 Weight of Flask with Soil and Water at Temperature, T_x , W_3 : 188.602 grams
 Temperature of Contents in Flask when Weight W_o was Determined, T_x : 23 °C
 Weight of Flask Filled with Water at Temperature, T_x , Taken from Table 1 of Flask Calibration, W_4 : 165.689 grams
 Specific Gravity (See Note 1): 2.59 ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_4 - W_F)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x$ (K)
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.

MPant
 Signature Project Engineer

1/3/95
 Date

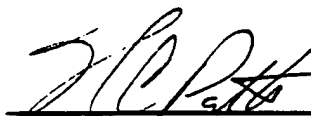
SIAC/GML-TPS

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 28-26 1/2-27 Project No.: 01-0107-05-3359-021
 Customer: PRAXIS / TRW Date: 12-27-94
 Test Operator: MPW
 Remarks:

Flask No. 9 Thermometer ID: 10
 Balance ID: 37080033
 Weight of Flask, W_e , (dry, empty): 65.784 grams
 Weight of Flask and Oven Dry Soil, W_s : 99.609 grams
 Weight of Oven Dry Soil, $W_o = W_s - W_e$: 33.825 grams
 Weight of Flask with Soil and Water at Temperature, T_w , W_w : 186.258 grams
 Temperature of Contents in Flask when Weight W_w was Determined, T_x : 23 °C
 Weight of Flask Filled with Water at Temperature, T_w , Taken from Table 1 of Flask Calibration, W_w : 165.436 grams
 Specific Gravity (See Note 1): 2.60 ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_s - W_o)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x$ (K)
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.


 Signature Project Engineer

1/3/95
 Date

SIAC/GML-TP5

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 30-29 1/2 - 30 Project No.: 01-0107-05-3359-021

Customer: Praxis / TRW Date: 12-27-94

Test Operator: M. Pruitt

Remarks:

Flask No. 14

Thermometer ID: 10

Balance ID: 37080033

Weight of Flask, W_F , (dry, empty): 64.715 grams

Weight of Flask and Oven Dry Soil, W_1 : 98.478 grams

Weight of Oven Dry Soil, $W_o = W_1 - W_F$: 33.763 grams

Weight of Flask with Soil and Water at Temperature, T_x , W_2 : 185.463 grams

Temperature of Contents in Flask when Weight W_2 was Determined, T_x : 23 °C

Weight of Flask Filled with Water at Temperature, T_w , Taken from Table 1 of Flask Calibration, W_3 : 164.411 grams

Specific Gravity (See Note 1): 2.66 ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_3 - (W_1 - W_F)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x (K)$
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.



Signature Project Engineer

12/3/95

Date

SIAC/GML-TP5

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 31-31½-32 Project No.: 01-0107-05-3359-021

Customer: PRAXIS / TRW Date: 12-27-94

Test Operator: MPaust

Remarks:

Flask No. 15 Thermometer ID: 10

Balance ID: 37080033

Weight of Flask, W_F , (dry, empty): 64.824 grams

Weight of Flask and Oven Dry Soil, W_s : 109.451 grams

Weight of Oven Dry Soil, $W_o = W_s - W_F$: 44.627 grams

Weight of Flask with Soil and Water at Temperature, T_w , W_b : 192.331 grams

Temperature of Contents in Flask when Weight W_b was Determined, T_x : 23 °C

Weight of Flask Filled with Water at Temperature, T_w , Taken from Table 1 of Flask Calibration, W_w : 164.567 grams

Specific Gravity (See Note 1): 2.65 ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_s - W_b)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x$ (K)
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.

MPaust

Signature Project Engineer

1/3/95

Date

SIAC/GML-TP5

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 33-29½-30 Project No.: 01-0107-05-3359-021
 Customer: PRAXIS / TRW Date: 12-27-94
 Test Operator: MPaint
 Remarks:

Flask No. 16 Thermometer ID: 10
 Balance ID: 37080033
 Weight of Flask, W_F , (dry, empty): 65.066 grams
 Weight of Flask and Oven Dry Soil, W_s : 99.362 grams
 Weight of Oven Dry Soil, $W_o = W_s - W_F$: 34.296 grams
 Weight of Flask with Soil and Water at Temperature, T_x , W_b : 185.970 grams
 Temperature of Contents in Flask when Weight W_b was Determined, T_x : 23 °C
 Weight of Flask Filled with Water at Temperature, T_x , Taken from Table 1 of Flask Calibration, W_w : 164.709 grams
 Specific Gravity (See Note 1): 2.63 ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_b - W_o)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x (K)$
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.

SLAC
 Signature Project Engineer

1/3/95
 Date

SLAC/GML-TP5

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 38-30½-31 Project No.: 01-0107-05-3359-021
 Customer: PRAXIS / TRW Date: 12-27-94
 Test Operator: M. Pruitt
 Remarks:

Flask No. <u>18</u>	Thermometer ID: <u>10</u>
Balance ID: <u>37080033</u>	
Weight of Flask, W_F , (dry, empty):	<u>72.467</u> grams
Weight of Flask and Oven Dry Soil, W_s :	<u>100.704</u> grams
Weight of Oven Dry Soil, $W_o = W_s - W_F$:	<u>28.237</u> grams
Weight of Flask with Soil and Water at Temperature, T_x , W_b :	<u>189.594</u> grams
Temperature of Contents in Flask when Weight W_b was Determined, T_x :	<u>23 °C</u>
Weight of Flask Filled with Water at Temperature, T_w , Taken from Table 1 of Flask Calibration, W_w :	<u>172.164</u> grams
Specific Gravity (See Note 1):	<u>2.61</u> ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_s - W_o)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x (K)$
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.


 Signature Project Engineer

NCP
12/31/95
 Date

SIAC/GML-TP5

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 39-29½-30 Project No. 01-0109-05-3359-021
 Customer: Praxis / TRW Date: 12-27-94
 Test Operator: *MPH*
 Remarks:

Flask No. 10	Thermometer ID: 10
Balance ID: 37080033	
Weight of Flask, W_F , (dry, empty):	66.228 grams
Weight of Flask and Oven Dry Soil, W_s :	99.599 grams
Weight of Oven Dry Soil, $W_o = W_s - W_F$:	33.371 grams
Weight of Flask with Soil and Water at Temperature, T_w , W_y :	186.441 grams
Temperature of Contents in Flask when Weight W_o was Determined, T_x :	23 °C
Weight of Flask Filled with Water at Temperature, T_w , Taken from Table 1 of Flask Calibration, W_a :	165.887 grams
Specific Gravity (See Note 1):	2.60 ~~grams~~

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_s - W_o)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x (K)$
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.

JCPH
 Signature Project Engineer

11/3/95
 Date

SIAC/GML-TP5

SPECIFIC GRAVITY DETERMINATION

Sample ID No.: 42-31 1/2 - 32 Project No.: 01-0107 - 05-3359-021

Customer: Praxis / TRW Date: 12-27-94

Test Operator: M. Hunt

Remarks:

Flask No. 13

Thermometer ID: 10

Balance ID: 37080033

Weight of Flask, W_F , (dry, empty): 72.577 grams

Weight of Flask and Oven Dry Soil, W_s : 99.764 grams

Weight of Oven Dry Soil, $W_o = W_s - W_F$: 27.187 grams

Weight of Flask with Soil and Water at Temperature, T_w , W_3 : 189.098 grams

Temperature of Contents in Flask when Weight W_3 was Determined, T_x : 23 °C

Weight of Flask Filled with Water at Temperature, T_w , Taken from Table 1 of Flask Calibration, W_1 : 172.270 grams

Specific Gravity (See Note 1): 2.62 grams

NOTE 1: Specific Gravity $T_x/T_x = W_o/[W_o + (W_1 - W_F)]$
 Value Based on Water at 20 °C $T_x/20 °C = T_x/T_x (K)$
 where: K = A number found by dividing the relative density of water at temperature T_x by the relative density of water at 20 °C. Value may be found in Table 1 of ASTM D854-83.



Signature Project Engineer

1/3/95

Date

SIAC/GML-TP5

$k = 1.2E-07 \text{ cm/sec}$

1.21-01 lines

PERMEABILITY TEST DATA

JOB: SATC										UNIT No: C1		BY: PS		Range		t		k			
JOB No: 10-XXX-XX										DATE STARTED: 1-24-95		BORING NO.: Hole 27(B)		SAMPLE		DESCRIPTION: Louise Mudd		PRESSURE (PSI) 4.00			

