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FINAL

INTRINSIC REMEDIATION

ENGINEERING EVALUATION/COST ANALYSIS

for

SITE SS27/XYZ

DOVER AIR FORCE BASE

DOVER, DELAWARE

January 1996

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

DOVER AIR FORCE BASE
DOVER, DELAWARE

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EXECUTIVE SUMMARY

This report presents the results of the investigation performed by Parsons Engineering Science, Inc. (Parsons ES) at Dover Air Force Base (AFB), Delaware to evaluate the use of intrinsic remediation (natural attenuation) with long-term monitoring (LTM) as a remedial option for dissolved benzene, toluene, ethylbenzene, and total xylenes (BTEX) contamination in the shallow saturated zone. Parsons ES conducted the field investigation during April 1994 at Site SS27/XYZ (currently known as fueling pads AA, BB, and CC). The source of the contamination is assumed to be from leaking pipelines and associated equipment. BTEX and total volatile hydrocarbons (TVH) were determined to be dissolved in groundwater and adsorbed to soils. Residual light nonaqueous-phase liquid (LNAPL) was found throughout the soil column, both above and below the groundwater interface. Also, mobile LNAPL (free product) was observed at several existing wells and monitoring points. This study focused on the impact of the dissolved BTEX and residual and mobile LNAPL in the shallow groundwater system at the site. Potential electron acceptors were analyzed to quantify ongoing biodegradation. Site history and the results of soil and groundwater investigations conducted previously are also summarized in this report.

An important component of this study was an assessment of the potential for groundwater contaminants to migrate from Site SS27/XYZ to potential receptor exposure points. The Bioplume II model was used to estimate the rate and direction of dissolved BTEX movement through the shallow saturated zone under the influence of advection, dispersion, sorption, and biodegradation. Input parameters for the Bioplume II model were obtained from data collected by Parsons ES during April 1994. Extensive site-specific data were used for model calibration and implementation. Model parameters not measured at the site were either obtained from previous site

characterization data or supplemented using established literature values for similar aquifer materials. A comparison to analytical model results also is provided as a check on the Bioplume II model results.

Groundwater anal results indicate that natural attenuation mechanisms are reducing BTEX concentrations at the site. The Air Force therefore proposes to implement intrinsic remediation with LTM for dissolved BTEX contamination found in groundwater at Site SS27/XYZ. However, fate and transport modeling results suggest that without active source remediation, dissolved BTEX concentrations may cross the Dover AFB property boundary at concentrations above Delaware water quality standards. Therefore, the Air Force also proposes to install a bioslurping and bioventing system to remediate residual and mobile LNAPL contamination in the source area. During 1995, AFCEE and D[illegible] AFB conducted a bioslurping pilot study at the former ST27/XYZ Site to eval[illegible] effectiveness of this technology. As a result, Dover AFB has designed a bioslurping system and currently plans to install that system at the site in April 1996.

The Air Force proposes to use five LTM wells to verify Bioplume II model predictions and to monitor long-term migration and degradation of dissolved BTEX. Also, six point-of-compliance (POC) monitoring wells are proposed to establish a compliance boundary for the site. In order to monitor effectiveness of the intrinsic remediation program, these wells should be sampled annually for at least 24 years. If the data collected during this period support the anticipated effectiveness of intrinsic remediation, the sampling frequency can be reduced to once every other year. The groundwater samples should be analyzed for BTEX compounds by US Environmental Protection Agency Method SW8020. If BTEX concentrations in groundwater from the POC wells exceed Delaware's groundwater quality standards of 5 micrograms per liter (µg/L) for benzene, 1,000 µg/L for toluene, 700 µg/L for ethylbenzene, or

10,000 µg/L for total xylenes, additional corrective actions may be required to remediate groundwater at the site.

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SECTION 1

INTRODUCTION

Parsons Engineering Science, Inc. (Parsons ES) has prepared this engineering report to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated groundwater near the fuel pump station (Building 950) at Site SS27/XYZ, Dover Air Force Base (AFB), Delaware. Previous investigations have determined that JP-4 had been released into the soil and shallow groundwater at the site. The main emphasis of the work described herein was to evaluate the potential for naturally occurring degradation mechanisms to reduce dissolved fuel-hydrocarbon concentrations in groundwater to levels that are protective of human health and the environment.

1.1 SCOPE AND OBJECTIVES

Parsons ES was retained by the United States Air Force Center for Environmental Excellence (AFCEE) to conduct site characterization and groundwater modeling in support of intrinsic remediation with long-term monitoring (LTM). Intrinsic remediation is a risk management strategy that relies on natural attenuation to control receptor exposure to contaminants in the subsurface. The scope of work for this project includes the following tasks:

- Reviewing existing hydrogeologic data and soil and groundwater quality data for the site;
- Conducting supplemental site characterization activities to determine the nature and extent of soil and groundwater contamination and to collect geochemical data in support of intrinsic remediation;

- Developing a conceptual hydrogeologic model of the shallow saturated zone, including the current distribution of contaminants;
- Determining whether natural biodegradation processes are occurring in site groundwater;
- Designing and calibrating the Bioplume II model for site hydrogeologic conditions;
- Performing sensitivity analyses with a range of model input parameters to ensure that several contaminant fate and transport scenarios are considered;
- Determining whether naturally occurring processes are sufficient to minimize the benzene, toluene, ethylbenzene, and total xylenes (BTEX) plume expansion so that state groundwater quality standards are met at a downgradient point of compliance (POC);
- Conducting a preliminary exposure pathways analysis for fuel hydrocarbon contamination in groundwater;
- Developing remedial action objectives (RAOs) and reviewing available remedial technologies;
- Using model results to recommend the most appropriate remedial option based on specific effectiveness, implementability, and cost criteria; and
- Providing a LTM plan that includes POC wells, and a sampling and analysis plan.

During April 1994, Parsons ES and Applied Research Associates, Inc. (ARA) performed site characterization activities for the intrinsic remediation investigation. These activities consisted of cone penetrometer testing (CPT), in conjunction with laser-induced fluorometry (LIF), using ARA's cone penetrometer truck. Initially, site

lithology and the extent of the light nonaqueous-phase liquid (LNAPL) plume were determined concurrently using the CPT and LIF probe. Evaluation of these data determined the need for additional groundwater sampling locations. Permanent and temporary monitoring points were then installed to characterize the site hydrogeology and groundwater geochemistry and to further delineate the contaminant plume. Parsons ES then sampled soil and groundwater and measured water levels and LNAPL thicknesses at the newly installed test locations. When appropriate, Parsons ES also collected data from existing monitoring wells.

Site-specific data were input into the Bioplume II model to develop a contaminant fate and transport model for the site. Using the results of the model, a preliminary exposure pathway analysis was performed. As part of the Engineering Evaluation/Cost Analysis (EE/CA), this modeling effort had three primary objectives: 1) to predict the future extent and concentration of a dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the potential for downgradient receptors to be exposed to contaminant concentrations that exceed standards intended to be protective of human health and the environment; and 3) to provide technical support during regulatory negotiations for intrinsic remediation with LTM, as appropriate.

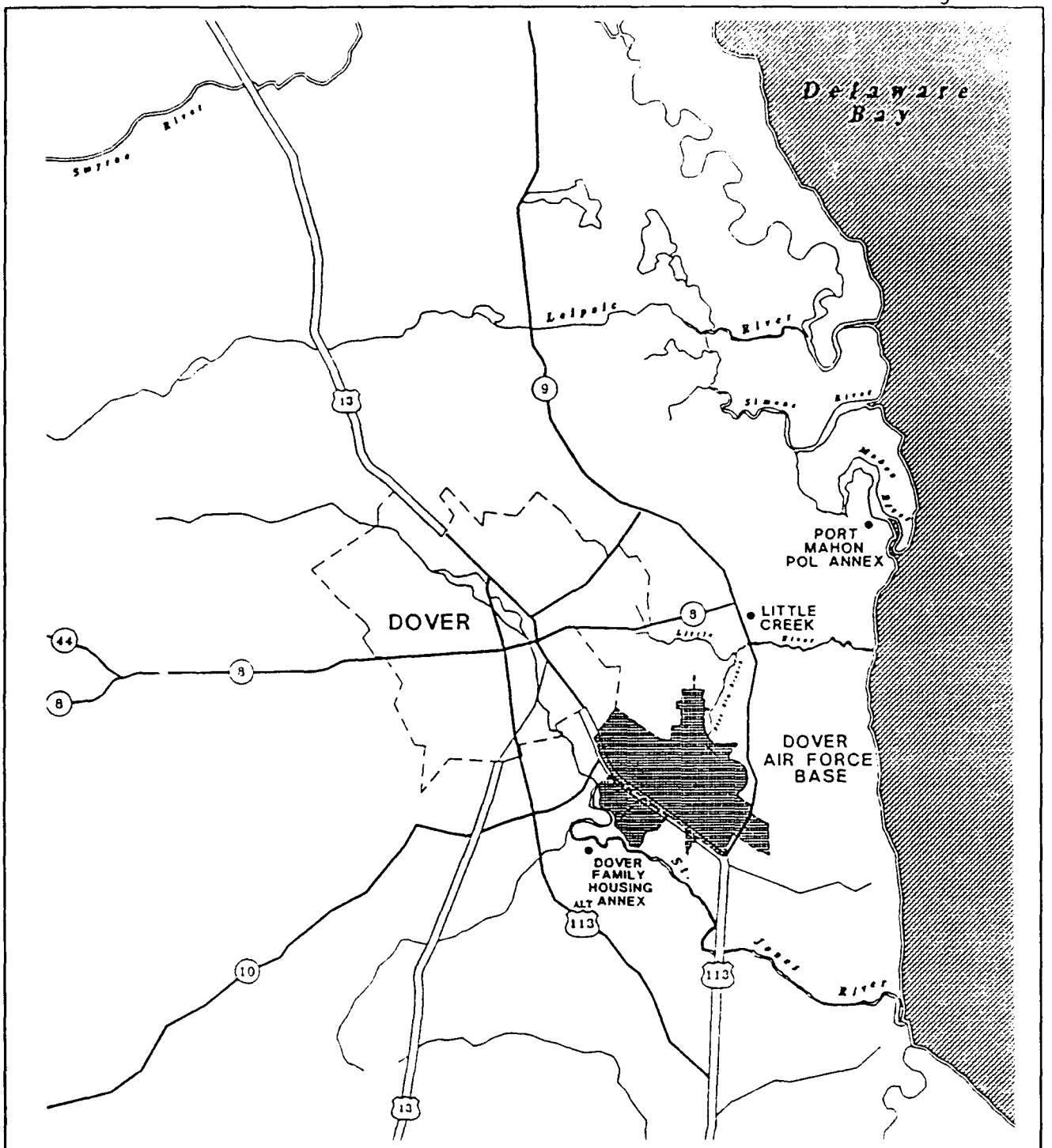
Several remedial options were evaluated during this EE/CA, including mobile LNAPL recovery using bioslurping, bioventing, creation of a downgradient hydraulic barrier using groundwater extraction and treatment (i.e., pump and treat), biosparging, and natural contaminant attenuation with LTM. Hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options were collected under this program. However, the field work conducted under this program was oriented toward the collection of hydrogeologic data to be used as input into Bioplume II and to support intrinsic remediation.

This report contains nine sections, including this introduction, and six appendices. Section 2 summarizes site characterization activities. Section 3 summarizes the physical characteristics of the study area. Section 4 describes the nature and extent of soil and groundwater contamination and the geochemistry of soil and groundwater at the site. Section 5 describes the conceptual hydrogeologic model developed for the site, Bioplume II model assumptions and input parameters, sensitivity analyses, model output, and the results of the Bioplume II modeling. Section 6 describes remedial alternatives evaluation criteria and presents a comparative analysis of selected options. Section 7 presents the LTM plan for the site. Section 8 presents the conclusions of this work and provides recommendations for further work at the site. Section 9 lists the references used to develop this document. Appendix A contains boring logs and well completion diagrams. Appendix B presents groundwater elevation and LNAPL thickness data. Appendix C contains soil and groundwater analytical results. Appendix D contains gridded numerical model input parameters and model calibration results. Appendix E contains analytical model results for comparison to the Bioplume II results. Appendix F contains a diskette of the Bioplume II model output in American Standard Code for Information Interchange (ASCII) format. Appendix G contains the costing worksheets and present worth calculations developed during the comparative analysis of selected remedial options.

1.2 FACILITY BACKGROUND

Dover AFB is situated 3.5 miles southeast of the center of Dover, Delaware at 39° 08'N latitude, 77° 01'W longitude. The Base is in Kent County, which is in the center half of Delaware. Figure 1.1 is a regional location map showing Dover AFB and the surrounding area. Dover AFB consists of approximately 4,000 acres of land including annexes, easements, and leased property. The land area surrounding Dover AFB is relatively flat. The surrounding properties include light commercial and residential

Figure 1.1



0 1 2 3 4 5

Approximate Scale in Miles

N

Source: Dames & Moore and HAZWRAP, 1993.

Regional Location Map

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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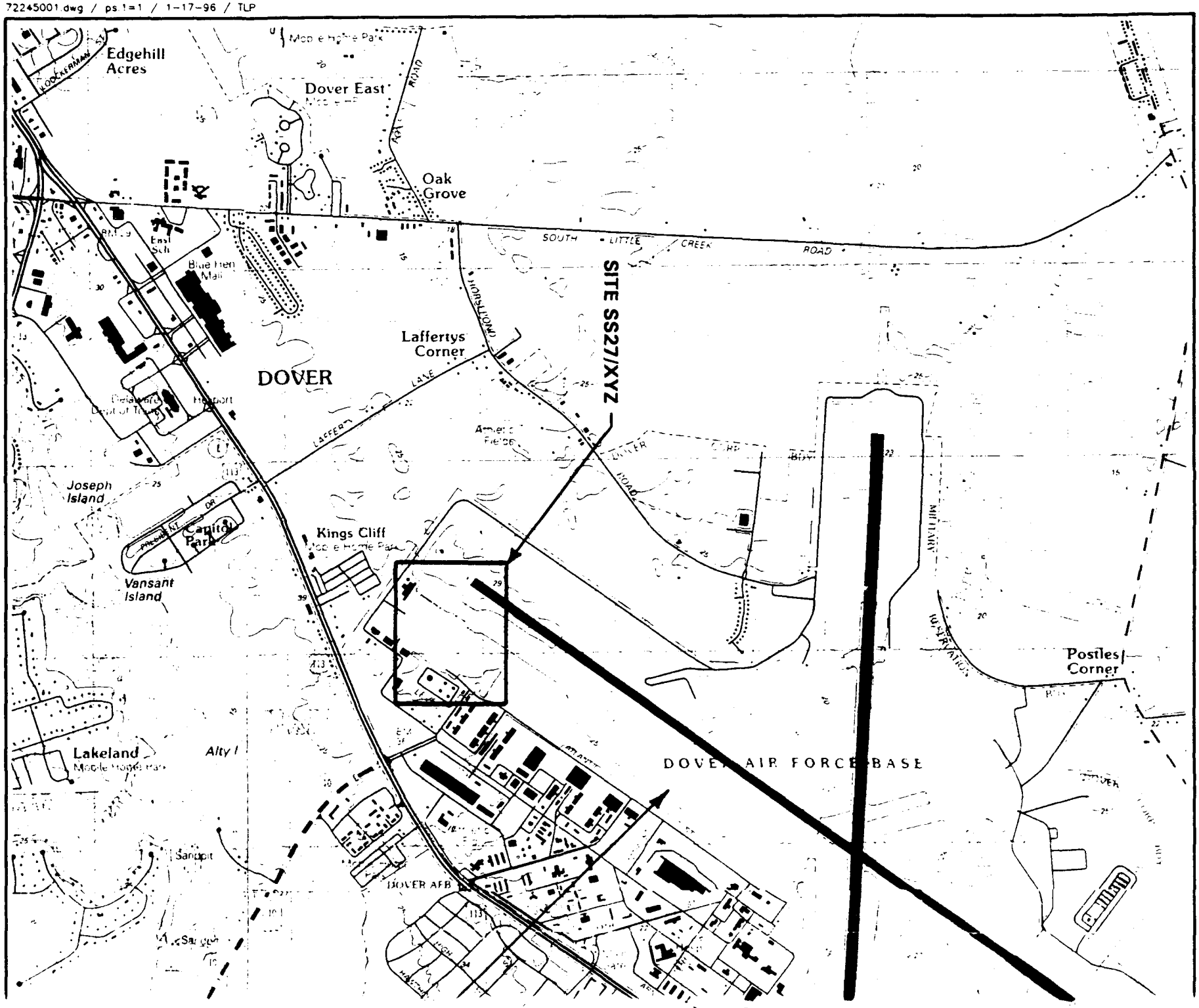
properties, croplands, and wetlands. Figure 1.2 is a regional US Geological Survey (USGS) topographical map showing Dover AFB, the St. Jones River, and surrounding topographical features. The primary regional hydrological influences are the St. Jones River, which is located about 2,500 feet southwest of Site SS27/XYZ, and Delaware Bay, which is located approximately 4 miles east of Dover AFB. The primary direction of groundwater flow at Site SS27/XYZ is toward the St. Jones River.

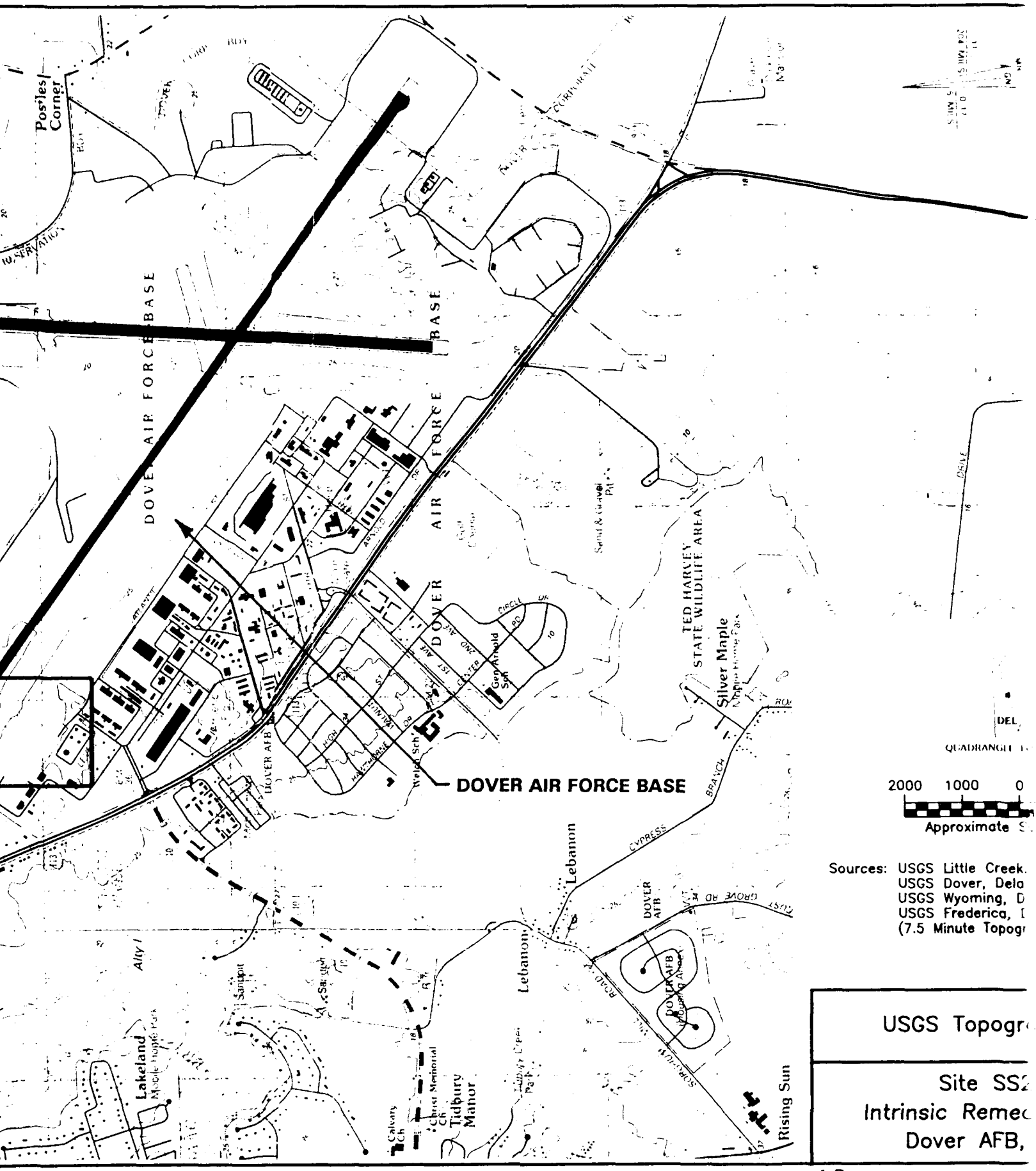
The Base has operated since 1941, and is currently a member of the Air Mobility Command (AMC), which hosts the 436th Support Group (SPTG). The Base's main mission is to provide global strategic airlift capability, primarily with C-5 Galaxy transport aircraft. Jet fuel (JP-4) leaks from underground infrastructure have created the contamination present at Site SS27/XYZ, which is located at the northwest end of the NW/SE runway (Figure 1.3). For the purposes of the work described herein, Site SS27/XYZ includes the area of the northwest apron, the northwest corner of the NW/SE runway, the former X, Y, and Z refueling pads (currently known as the AA, BB, and CC refueling pads), and all adjacent areas that contain monitoring wells, monitoring points, and potential receptors of groundwater contamination originating at the site.

1.2.1 Operational History

Leaks emanating from subsurface fuel lines and/or ancillary equipment have contaminated soil and groundwater at Site SS27/XYZ (Figure 1.4). Building 950 has served as a fuel pumping station for refueling pads X, Y, and Z (former names) since fueling operations began. Underground fuel lines are used to transfer JP-4 jet fuel from the fuel pump station at building 950 to the fuel hydrants at pads X, Y, and Z (Figure 1.4). Site SS27/XYZ was included in the Installation Restoration Program (IRP) process at the Base because Base personnel reported fuel floating on rainwater

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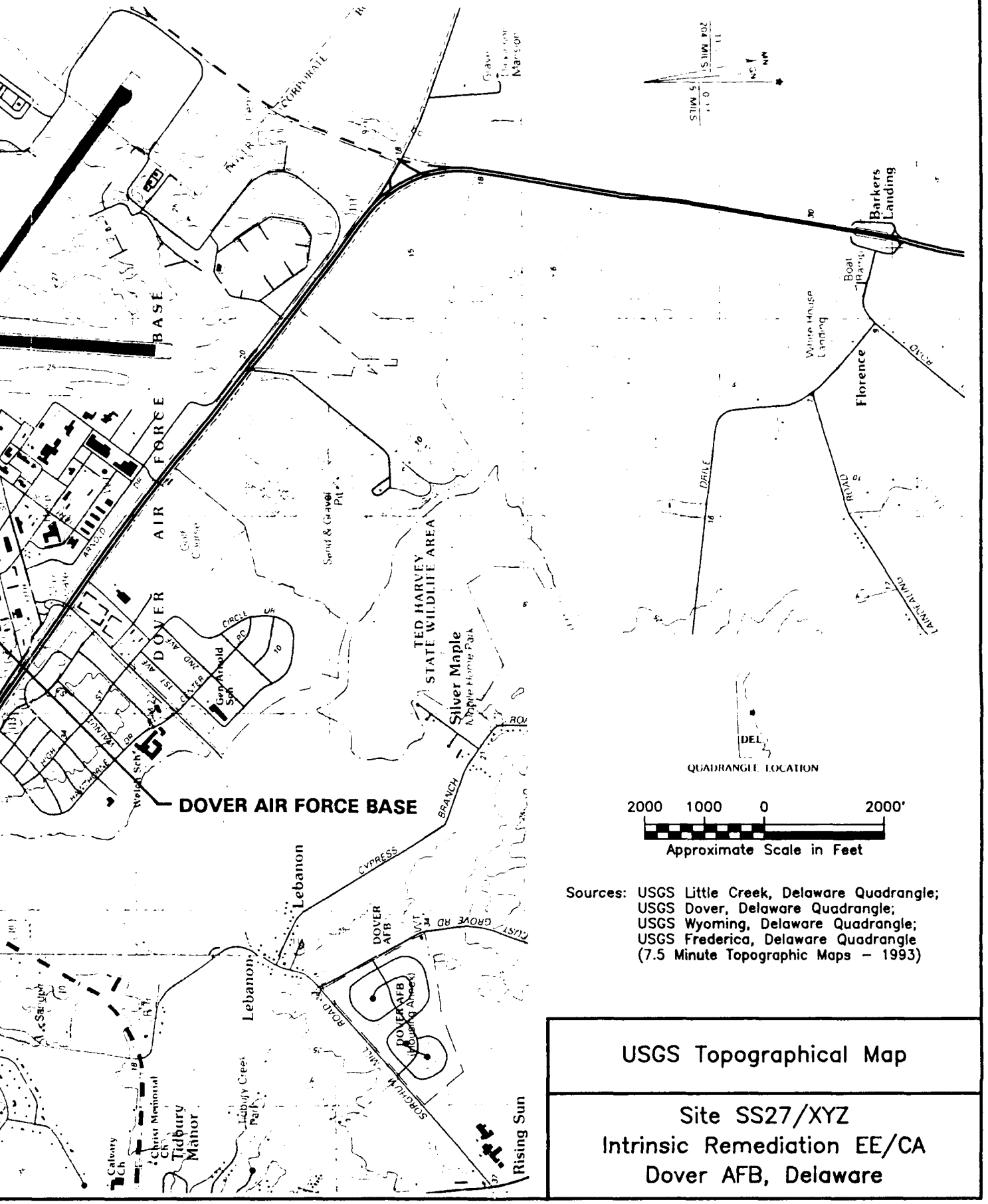
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Site SS2
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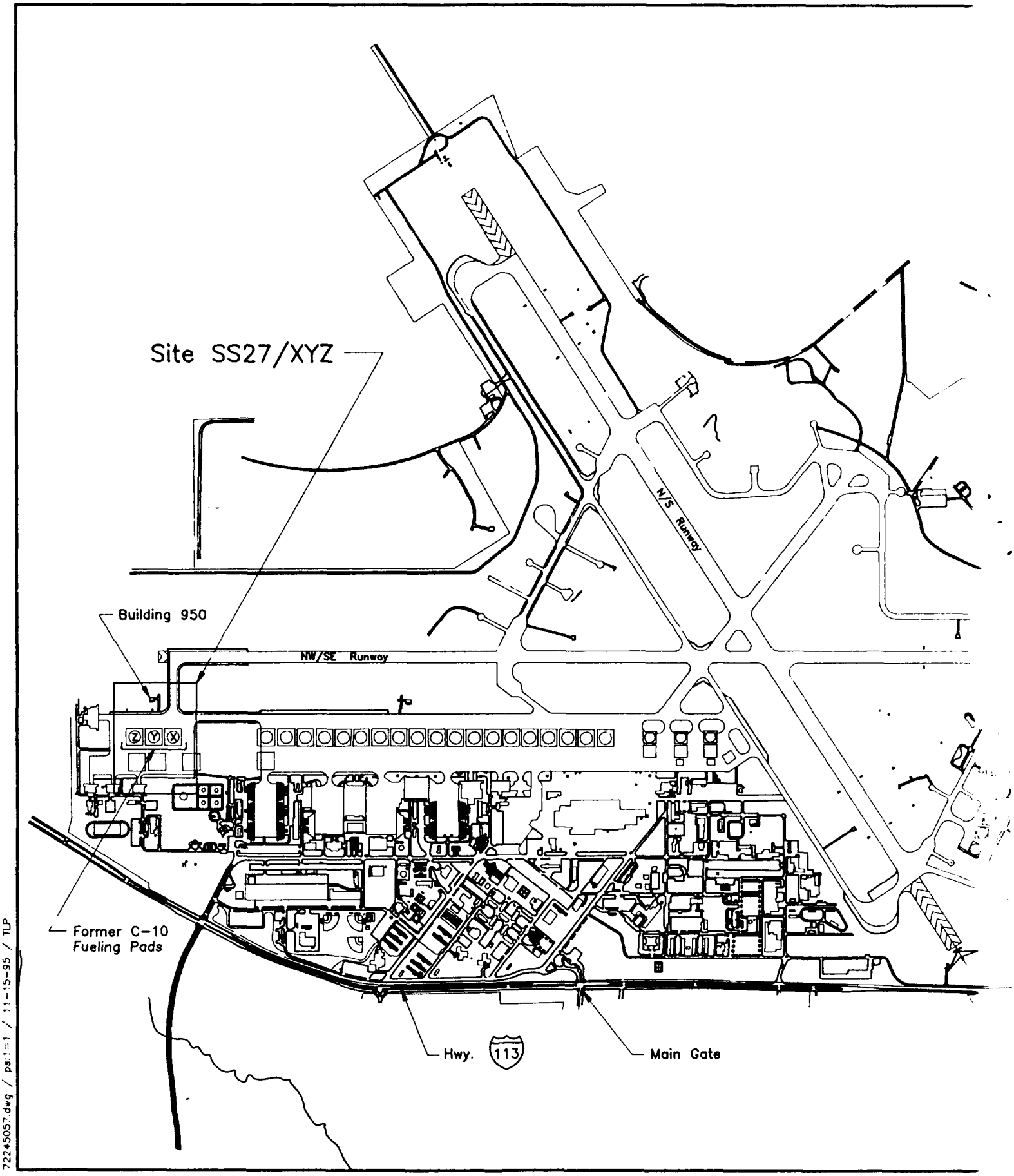
Figure 1.2



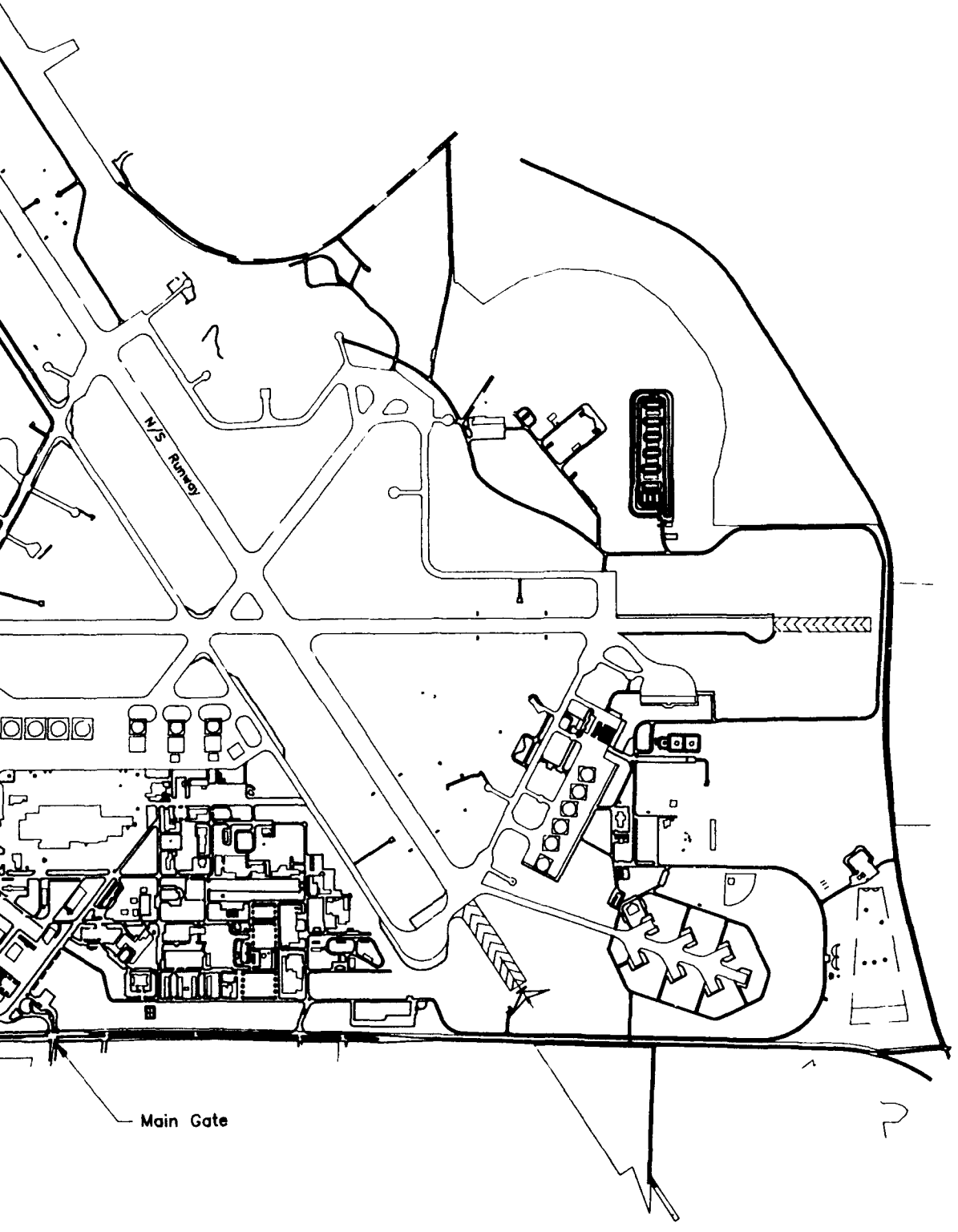
Sources: USGS Little Creek, Delaware Quadrangle;
USGS Dover, Delaware Quadrangle;
USGS Wyoming, Delaware Quadrangle;
USGS Frederica, Delaware Quadrangle
(7.5 Minute Topographic Maps – 1993)

USGS Topographical Map

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware



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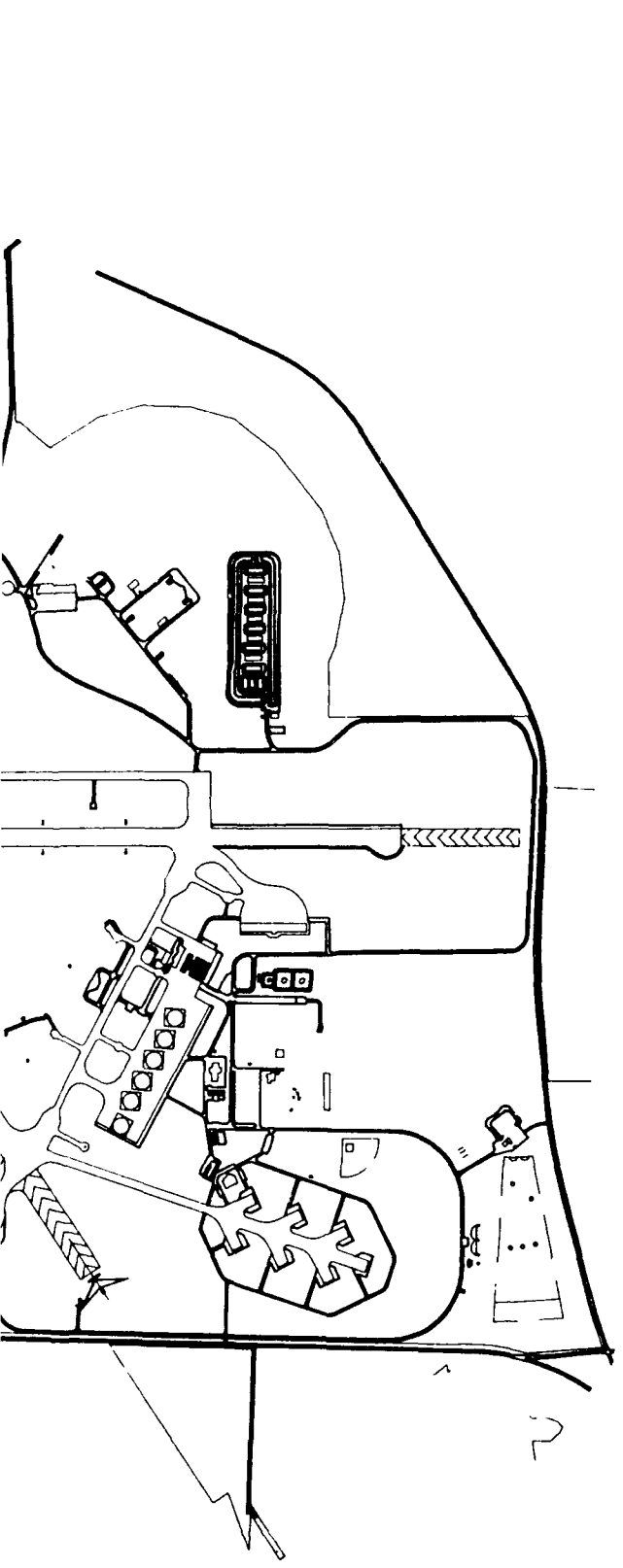
1500'

Source:

Dov

Intrinsic
Dov

Figure 1.3



1500' 750' 0 1500'

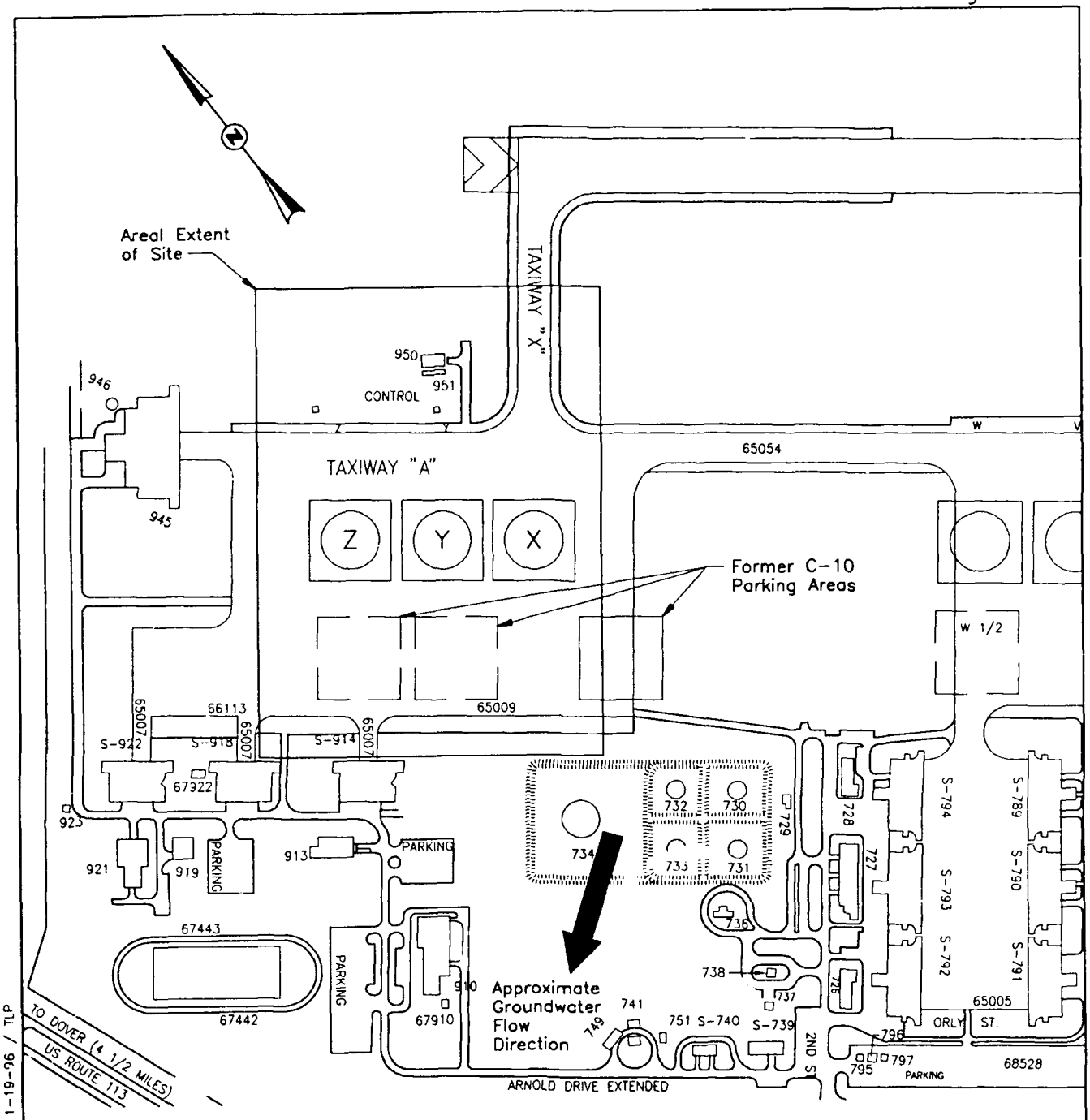
Approximate Scale in Feet

Source: Dover AFB, 1994.

Dover AFB Site Map

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 1.4



LEGEND

——— Approximate location of underground fuel transfer lines.

Ⓩ Former C-10 fueling pad.

Site Map Showing
Subsurface Fuel Line Locations

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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that collects in control pits in front of building 950 [Science Applications International Corporation (SAIC), 1989].

Soil and groundwater contamination was detected at Site SS27/XYZ in June 1984 during preliminary site characterization activities conducted as part of the Phase II IRP investigations (SAIC, 1986). A second soil and groundwater investigation was conducted at the site in 1989 (SAIC, 1989). More recently, additional site characterization activities, including a soil gas survey, soil borings, monitoring well installations, and soil and groundwater sampling, were conducted at Site SS27/XYZ [Dames & Moore and Hazardous Waste Remedial Actions Program (HAZWRAP), 1993]. The results of the most recent study revealed an area of elevated petroleum hydrocarbon concentrations along the fuel lines, though the distribution suggests that fuel constituents extend beneath the fueling pad (Figure 1.4). Other tests performed at the site as part of the Basewide remedial investigation/feasibility study (RI/FS) program included leak tests on all underground JP-4 pipelines in 1991 [Tracer Research Cooperation (TRC), 1991]; and a Basewide ecological risk assessment conducted in 1993 (HAZWRAP, 1993a). For a 2-year period beginning in April 1991, quarterly Basewide water level measurements were taken at all accessible monitoring wells at Dover AFB (HAZWRAP, 1991a, 1991b, 1991c, 1992a, 1992b, 1992c, 1992d, and 1993b). An interpretation of the 2 years of water level data was performed in 1993 (HAZWRAP, 1993c).

A synopsis of site characterization activities conducted at the site to date is provided in the 1993 Current Situation Report (Dames & Moore and HAZWRAP, 1993). Site SS27/XYZ has been the subject of two previous environmental investigations in which a groundwater contaminant plume was identified. Dissolved constituents included benzene, 1,4-dichlorobenzene, ethylbenzene, and xylene (Dames & Moore and HAZWRAP, 1993), resulting from the release of JP-4 fuel into the subsurface.

1.2.2 Current Remedial Activities

Presently, the Base is using a skimmer system to recover free product from several monitoring wells at Site SS27/XYZ. Under a separate AFCEE program, a bioslurping demonstration project was performed at the site during 1995. The Base is currently proceeding with expansion of the product recovery system through the use of the bioslurping and product skimming technologies. The remedial systems are expected to be operational after April 1996.

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

This section presents the methods and procedures used by Parsons ES to collect the site-specific data at Dover AFB for the intrinsic remediation demonstration. Prior investigations (SAIC, 1989; Dames & Moore and HAZWRAP, 1993) have approximately delineated the dissolved and adsorbed contaminant plumes. As a first task, Parsons ES reviewed water level and chemical concentration data (Dames & Moore and HAZWRAP, 1993) from existing site wells to estimate CPT, LIF, and groundwater monitoring point locations. Parsons ES marked these locations on a map for use by Dover AFB to obtain the necessary utility clearances.

The site characterization activities proceeded in four phases. Parsons ES and ARA utilized several investigative techniques to characterize the site for the intrinsic remediation demonstration. Phase I consisted of characterizing the site lithology and free product plume. These activities were performed concurrently, using ARA's CPT and LIF probe. Phase II consisted of soil boring and sampling using ARA's Mostap-35® soil sampler. Phase III included the installation of temporary and permanent monitoring points. The monitoring points consisted of 0.5-inch- or 1.5-inch-diameter screens and casings, as discussed in subsequent sections of this report. Sampling locations were surveyed by ARA during Phase III. Phase IV consisted of groundwater sampling from previously installed wells and newly installed monitoring points.

For the purposes of this report, the term "drilling" was used generally to indicate CPT/LIF testing and monitoring point installation using direct push technologies. To minimize confusion among CPT/LIF test points, soil sample locations, and monitoring

point installations, Parsons ES utilized a single prefix (CPT) for all tests at a single location. The field log books and laboratory reports utilize additional prefixes to distinguish between sample types. Construction details of ARA-installed monitoring points, CPT/LIF tests, and soil sample locations are presented in Table 2.1. Monitoring wells, monitoring points, and test locations are shown on Figure 2.1. Data collected under this program were used to aid interpretation of the physical setting (Section 3) and contaminant distribution (Section 4), and to develop the conceptual site model (Section 5).

Parsons ES collected the following physical, chemical, and hydrogeologic data during the field work phase of the EE/CA:

- Detailed analysis of subsurface media, including soil core and groundwater samples;
- Estimation of extent and thickness of mobile LNAPL in monitoring wells;
- Potentiometric data by measuring the depth from reference datum to water table within monitoring wells and CPT monitoring points;
- Location of potential groundwater recharge and discharge areas;
- BTEX and total volatile hydrocarbon (TVH) concentrations in soil using contract laboratory analytical methods;
- Total organic carbon (TOC) concentrations in select soil samples;
- Dissolved oxygen (DO), nitrate, ferrous iron, sulfate, methane, and TOC concentrations in groundwater;

TABLE 2.1

CPT ACTIVITY AND MONITORING POINT COMPLETION SUMMARY
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a]	Northing (ft)	Easting (ft)	CPT[b] Profile Available (Y/N)	LIF[c] Profile Available (Y/N)	Soil Sample[d] Interval (ft bls)[e]	Datum Elevation[f] (ft msl)[g]	Ground Elevation (ft msl)	Total Depth (ft bls)	Inner Well Diameter (inches)	Screen Length (ft)	Depth to Screen		Permanent or Temporary (P/T)
											Top (ft bls)	Base (ft bls)	
CPT Test Locations													
CPT-01S	413590	480024	Y	Y	NS[h]	26.48	26.50	17.00	0.50	3.28	13.72	17.00	P
CPT-02S	413721	480113	Y	Y	NS	25.51	25.89	13.00	0.50	3.28	9.72	13.00	T
CPT-03S	413754	479968	Y	Y	NS	25.64	26.16	13.00	0.50	3.28	9.72	13.00	T
CPT-04S	413863	479748	Y	Y	NS	26.31	26.44	17.00	0.50	3.28	13.72	17.00	T
CPT-05S	NM[i]	NM	Y	Y	NS	NA[j]	NM	NA	NA	NA	NA	NA	Abandoned
CPT-06S	413657	480522	Y	Y	NS	24.10	24.95	16.60	0.50	3.28	13.32	16.60	P
CPT-07S	415476	479293	Y	Y	NS	25.85	25.18	15.00	0.50	3.28	11.72	15.00	T
CPT-07D	415475	479294	Y	Y	13.0 - 16.0	25.83	25.18	28.20	0.50	3.28	24.92	28.20	T
CPT-08P	NM	NM	Y	Y	8.0 - 10.0	NA	NM	12.10	0.50	3.28	8.82	12.10	Abandoned
CPT-08S	414102	479416	Y	Y	13.7 - 15.7	26.18	26.45	16.6	0.50	6.56	10.04	16.60	P
CPT-08D	NM	NM	Y	Y	NS	NM	NM	27.30	0.50	3.28	24.02	27.30	P
CPT-09S	414644	479271	Y	Y	NS	23.98	24.16	18.60	0.50	6.56	12.04	18.60	P
CPT-10S	414410	479107	Y	Y	NS	NM	25.79	18.60	0.50	6.56	12.04	18.60	T
CPT-11P	NM	NM	Y	Y	NS	NM	NM	13.00	0.50	3.28	9.72	13.00	T
CPT-11S	NM	NM	Y	Y	NS	NM	NM	18.80	0.50	3.28	15.52	18.80	T
CPT-12P	NM	NM	Y	Y	NS	NA	NM	5.10	0.50	3.28	1.82	5.10	Abandoned
CPT-12S	413955	479095	Y	Y	14.0 - 16.0	26.24	26.36	17.80	0.50	3.28	14.52	17.80	P
CPT-12D	413955	479103	Y	Y	NS	26.23	26.36	23.40	0.50	3.28	20.12	23.40	P
CPT-13S	414106	479154	Y	Y	NS	27.03	27.16	17.30	0.50	3.28	14.02	17.30	T
CPT-14S	413951	479626	Y	Y	13.0 - 15.0	NM	26.46	16.90	1.50	3.28	13.62	16.90	P
CPT-15S	414104	479746	Y	Y	NS	25.44	25.65	17.90	0.50	3.28	14.62	17.90	T
CPT-16S	414307	479748	Y	Y	7.0 - 9.0	NM	24.97	13.40	0.50	3.28	10.12	13.40	P
CPT-16D	414307	479748	Y	Y	11.0 - 13.0	NM	24.97	24.10	0.50	3.28	20.82	24.10	P
CPT-17S	413912	479430	Y	Y	NS	26.98	27.06	18.80	0.50	3.28	15.52	18.80	T
CPT-18S	413813	479294	Y	Y	NS	26.11	26.34	18.70	0.50	6.56	12.14	18.70	T

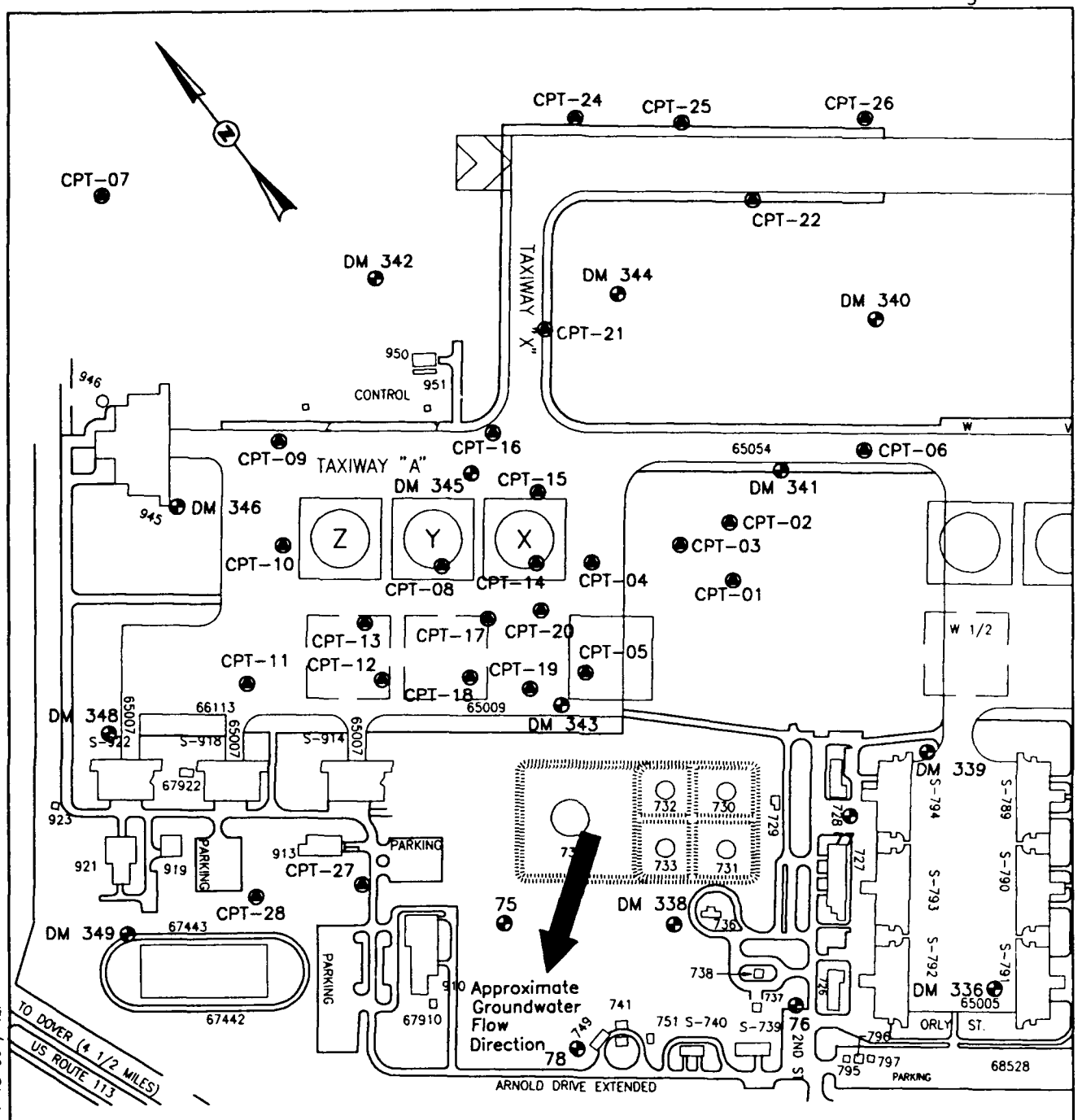
TABLE 2.1 (Concluded)

CPT ACTIVITY AND MONITORING POINT COMPLETION SUMMARY
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a]	Northing (ft)	Easting (ft)	CPT[b] Profile Available (Y/N)	LIF[c] Profile Available (Y/N)	Soil Sample[d] Interval (ft bls)[e]	Datum Elevation[f] (ft msl)[g]	Ground Elevation (ft msl)	Total Depth (ft bls)	Inner Well Diameter (inches)	Screen Length (ft)	Depth to Screen		Permanent or Temporary (P/T)
											Top (ft bls)	Base (ft bls)	
CPT Test Locations													
CPT-19P	413733	479484	Y	Y	NS	NA	26.56	10.10	1.50	3.28	6.82	10.10	Abandoned
CPT-19S	413733	479484	Y	Y	9.0 - 11.0	NM	26 56	15.90	1.50	3.28	12.62	15.90	P
CPT-19D	413733	479484	Y	Y	15.0 - 17.0	NM	26.56	26.00	0.50	3.28	22.72	26.00	P
CPT-20S	413842	479557	Y	Y	NS	26.74	27.00	15.40	0.50	3.28	12.12	15.40	T
CPT-21S	414447	480032	Y	Y	NS	24.42	24.05	14.90	0.50	3.28	11.62	14.90	T
CPT-22S	414388	480694	Y	Y	13.0 - 15.0	25.92	26.11	17.90	0.50	3.28	14.62	17.90	P
CPT-22D	414388	480694	Y	Y	NS	NM	26.11	30.40	0.50	3.28	27.12	30.40	P
CPT-23S[k]	NM	NM	Y	Y	NS	NA	NM	NA	NA	NA	NA	NA	Abandoned
CPT-24S	NM	NM	Y	Y	NS	NA	NM	15.60	0.50	3.28	12.32	15.60	Abandoned
CPT-25S	414674	480669	Y	Y	NS	26.59	26.63	20.90	0.50	3.28	17.62	20.90	P
CPT-26S	414382	481072	Y	Y	NS	24.88	25.07	23.20	0.50	6.56	16.64	23.20	P
CPT-27S	413518	478754	Y	N	NS	26.04	26.29	17.40	0.50	3.28	14.12	17.40	P
CPT-27D	413518	478754	Y	N	NS	NM	26.29	28.40	0.50	3.28	25.12	28.40	P
CPT-28S	413685	478465	Y	N	NS	27.47	27.04	20.40	0.50	3.28	17.12	20.40	P
CPT-29S	NM	NM	Y	N	NS	NM	NM	16.30	0.50	3.28	13.09	16.30	T

[a] See Figure 2.1 for CPT test locations.
[b] CPT = Cone Penetrometer test to determine soil lithology.
[c] LIF = Laser-induced fluorescence test.
[d] Sampled soil using a Mostap-35 soil sampler.
[e] ft bls = feet below land surface.
[f] Datum elevation refers to top of casing for monitoring points and to land surface for CPT test points.
[g] ft msl = feet above mean sea level.
[h] NS = no sample was collected.
[i] NM = not measured.
[j] NA = not applicable.
[k] CPT rod refusal at 7 ft bls; no monitoring point was installed.

Figure 2.1



LEGEND

DM 341 ⊕ Monitoring well.

CPT-01 ⊕ Monitoring point and CPT test location installed by CPT rig.

Z Former C-10 fueling pad.

Sampling Locations

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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- Temperature, reduction/oxidation (redox) potential, total alkalinity, and pH of groundwater; and

- BTEX, trimethylbenzene (TMB), and TVH concentrations in groundwater.

Section 2.1 describes the procedures used to determine site lithology, delineate mobile LNAPL (free product), and sample soil. Section 2.2 discusses the procedures for installing monitoring points and developing monitoring wells. Section 2.3 presents the procedures for groundwater sampling.

2.1 CONE PENETROMETRY, LASER-INDUCED FLUOROMETRY, AND SOIL SAMPLING ACTIVITIES

CPT-related activities took place between 11 April 1994 and 22 April 1994. CPT and LIF testing and soil sampling were accomplished using the procedures described in the following sections. Parsons ES and the ARA staff performed lithologic logging (with CPT) and LNAPL delineation (with LIF) during Phase I of the field activities. These tests were performed concurrently during one push with the ARA cone penetrometer truck, providing an expedient and effective means of investigating the site.

2.1.1 Pre-Drilling Activities

Parsons ES obtained all necessary digging, drilling, and groundwater monitoring well installation permits prior to mobilization. In addition, all utility lines were located and proposed drilling locations were cleared prior to any drilling activities. The ARA staff used an onsite potable water supply for drilling, equipment cleaning, and grouting. The Dover AFB point of contact verified this source prior to use.

2.1.2 Cone Penetrometry Procedures

Twenty-nine CPT tests (Table 2.1) were performed at the Site SS27/XYZ (CPT-01 through CPT-29). CPT lithologic information and boring logs from previous investigations were utilized to delineate subsurface geological conditions. Appendix A contains CPT lithologic logs. Parsons ES developed soil descriptions and lithologic cross-sections to compare stratigraphy beneath Site SS27/XYZ. This stratigraphic information is discussed in Section 3. Periodic soil samples were collected in Phase II field activities to visually compare CPT-computed readings to actual soil samples. Observed soil types corresponded very well to the CPT data.

The intrinsic remediation study utilized a cone penetrometer truck to conduct CPT testing at Site SS27/XYZ. The truck's weight and the weight of water contained in the ballast tank provides the necessary reaction mass to force an instrumented probe into the ground. The penetrometer equipment is mounted on an 18-foot van body attached to a 10-wheel truck chassis with a turbo-charged diesel engine. A pair of large hydraulic cylinders bolted to the truck frame provide the penetration force, with an overall push capability of 45,000 pounds.

The penetrometer probe is of standard dimensions, having a 1.7-inch outside-diameter (OD), 60-degree conical tip, and a 1.7-inch-OD by 5.27-inch-long friction sleeve. A pressure gauge located above the cone tip monitors the pore water pressure so that corrected estimates of water depth and permeability can be made. 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 inside the probe is a cylinder of uniform cross section that contains four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized,

recorded, and plotted by computer in the penetrometry truck. The penetrometer is usually advanced into the soil at a constant rate of 48 inches per minute, although this rate must sometimes be reduced (e.g., when hard layers are encountered). The magnitude of the penetration force is a function of compressibility and, most importantly, permeability.

2.1.3 Laser-Induced Fluorometry

LIF was utilized during Phase I field activities to delineate areas of free product and elevated soil hydrocarbon concentrations. Twenty-six LIF tests (Table 2.1) were performed at Site SS27/XYZ (CPT-1 through CPT-26). Parsons ES further delineated the potential hydrocarbon source area using the LIF data in combination with soil analytical results. This information is summarized in Section 4. Direct printouts of the LIF logs are provided in Appendix A.

ARA's LIF system utilizes a nitrogen-based laser optics fluorometer tool, which scans for fluorescent compounds as it is pushed though the soil. The known propensity of aromatic or chlorinated hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology, in conjunction with CPT technology, to detect gross hydrocarbon contamination and soil characteristics simultaneously. The LIF/CPT system has a sapphire window in the side of the CPT probe, which allows a laser to scan the soil for fluorescent compounds as the LIF/CPT penetrometer rod pushes through soil. Assuming that aromatic hydrocarbons are simultaneously solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. The push rods act as a conduit for the fiber optic cable and a 6-pair electrical conductor. This wiring connects the laser spectrometer and CPT data acquisition systems to the CPT probe.

The basic laser system components (Figure 2.2) of the CPT/LIF instrumentation are a Nd:YAG® pump laser, two separate and independent rhodamine dye lasers, frequency-doubling crystals which convert the visible-dye laser output to ultraviolet, a fiber optic probe, a monochromator for wavelength resolution of the return fluorescence, a photomultiplier tube to convert photons into an electrical signal, a digital oscilloscope for waveform capture, and a control computer. The cone penetrometer's fiber optic probe consists of a delivery and collection fiber, a protective sheath, a fiber optic mount within the cone, and a sapphire window (Figure 2.2). The uphole portion of the system is adaptable to either groundwater monitoring fiber optic probes or an optical cone penetrometer probe. Optimal wavelengths to be used during a continuous CPT push are determined during each push. The computer selects the wavelength with the strongest fluorescence signal to correlate contamination. Past experience suggested that a wavelength of less than 275 nanometers (nm) may be appropriate for detecting the fluorescence of BTEX compounds.

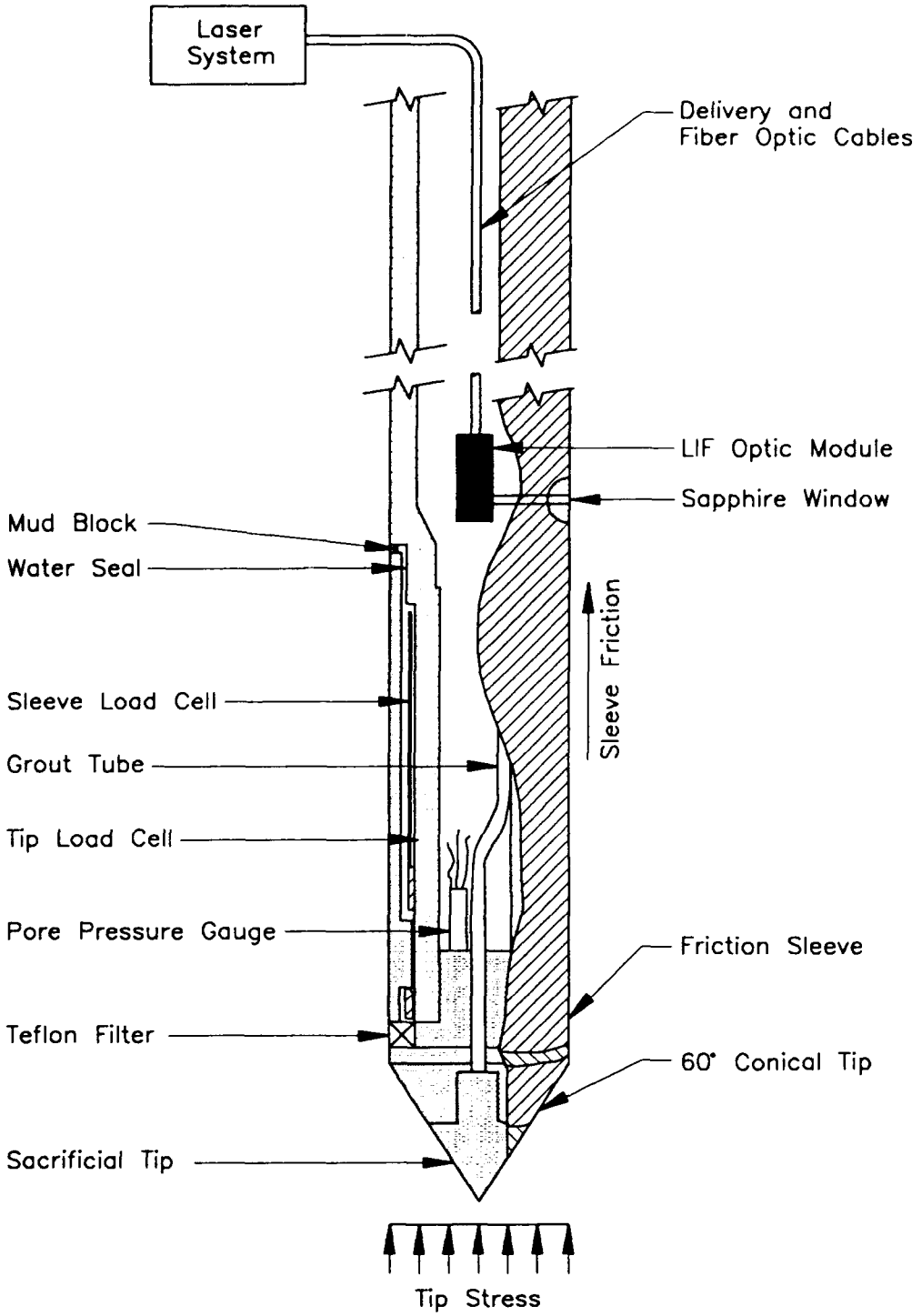
2.1.4 Soil Sampling Procedures

Parsons ES collected soil samples using the CPT rig during Phase II of the field activities. Soil sampling fulfilled four purposes:

- To validate the lithological data collected during CPT tests;
- To determine actual hydrocarbon concentrations in soils;
- To correlate the LIF laser direct readings to actual laboratory results; and
- To determine background soil geochemistry.

Parsons ES chose seven CPT locations (CPT-07, CPT-08, CPT-12, CPT-14, CPT-16, CPT-19, and CPT-22) from which to collect soil samples (Table 2.1). These samples, in combination with the LIF data, provide horizontal and vertical delineation of hydrocarbon contamination in site soils. At selected locations, Parsons ES collected

Figure 2.2



Schematic of Laser-Induced Fluorescence Cone Penetrometer Probe

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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soil samples from the interval that contained the highest LIF reading. Overall, 10 soil samples were collected, including duplicates and quality assurance/quality control (QA/QC) samples. The field logs and analytical reports reference these soil samples with a CPT prefix followed by a number. This number refers to the CPT location indicated on all EE/CA report figures. To minimize confusion within tables and figures, the CPT prefix is utilized in this report.

Soil sampling was accomplished during this investigation using a Mostap-35® stainless steel soil sampler, which was approximately 1 inch in diameter and 2 feet long. The sampler was coupled to the penetrometer rod and pushed into the soil. While the Mostap-35® sampler was in position, soil was prevented from entering the sampling tube until the desired depth was achieved. To operate the unit, the sampling tube was pushed to the required depth and then raised a few inches. The driller unlocked the cone from inside the truck, allowing the cone to automatically retract into the sampler barrel during sample collection. The ARA operator then pulled the sampling apparatus from the ground as quickly as possible. The Mostap-35® sampling apparatus allowed collection of a 2-foot-long continuous sample. Recovery efficiencies for samples in saturated soils were occasionally reduced because of spillage of the soil from the device after extraction. To mitigate this problem, soil samples were compressed *in situ* with the penetrometer and Mostap-35® assembly to expel the pore water before extraction. Compressed soil samples were then extracted and measured to give a description of the soil stratigraphy accurate for the length of soil core taken.

Soil samples were obtained from discrete depth intervals at each location. The sampling depth(s) typically corresponded to the interval(s) with the highest LIF reading(s). Soil was removed from the sampler and placed in clean glass jars for laboratory analysis. Also, a portion of the soil sample was placed in a clean glass jar for photoionization detector (PID) headspace measurements. Because LIF peak

readings were generally observed in thin lenses within the soil profile, sample length was minimized in order to correlate LIF readings to the analytical results.

The Parsons ES field hydrogeologist observed CPT and LIF testing, soil sampling, and monitoring point installation activities. The field hydrogeologist maintained descriptive notes of subsurface materials recovered. Observed soil classification types compared very favorably to the soil classifications determined by the CPT tests.

2.1.5 Equipment Decontamination Procedures

Prior to arriving onsite, and between each test location, CPT push rods were cleaned with the CPT steam-cleaning system (rod cleaner) as the rods were withdrawn from the ground. A vacuum system located beneath the CPT truck was used to recover cleaning water. Use of this system resulted in nearly 100-percent recovery of steam-cleaning rinseate from the rod cleaner. Rinseate was generated only as the rods moved past the cleaner, thereby minimizing liquid waste generation. Only potable water was used for decontamination. Rinseate was collected in 55-gallon drums provided by ARA. Filled 55-gallon drums were then transferred to an oil/water separator designated by the Dover AFB point of contact.

The soil sampling apparatus was disassembled upon sample collection and manually cleaned with a high-pressure steam/hot water wash. Contaminated soils (i.e., cuttings) were not generated during the field activities. Fuel, lubricants, and other similar substances were handled in a manner consistent with accepted safety procedures and standard operating practices. Well completion materials were not stored near or in areas that could be affected by these substances.

2.2 GROUNDWATER MONITORING POINT INSTALLATION AND MONITORING WELL DEVELOPMENT

Monitoring wells installed in the vicinity of Site SS27/XYZ during previous investigations were constructed using standard hollow-stem auger (HSA) drilling techniques. Standard split-spoon sampling was performed during well construction. Parsons ES reviewed boring logs for selected monitoring wells (Dames & Moore and HAZWRAP, 1993) to determine potential monitoring point screen interval locations prior to drilling. During Phase II of the investigation, ARA installed multi-depth groundwater sampling points at 29 locations using the CPT rig. As a result, 34 additional sampling points were available to Parsons ES for groundwater sampling. Groundwater samples were collected from 28 of the monitoring points. Parsons ES also utilized groundwater data collected from existing site monitoring wells by Dames & Moore, Inc. All monitoring wells and monitoring points were utilized to determine groundwater elevation.

2.2.1 Groundwater Monitoring Point Locations and Completion Intervals

A total of 40 monitoring points were installed at 29 locations to help characterize the shallow groundwater flow system at Site SS27/XYZ. The chosen monitoring point locations were selected to provide the hydrogeologic data necessary to adequately characterize the site. Several of the points, located within shallow and perched areas of the aquifer, did not yield groundwater and were abandoned. The 27 usable monitoring point locations are identified as CPT-01 through CPT-04, CPT-06 through CPT-22, and CPT-24 through CPT-29. Table 2.1 presents well completion details for the monitoring points located on the site. These locations are shown on Figure 2.1.

Dover AFB supplied horizontal and vertical top-of-casing location data for selected existing monitoring wells to aid this investigation. Upon completion of Phase III

activities, ARA surveyed the top of casing horizontal and vertical locations for the newly installed monitoring points. These measurements were recorded relative to the existing monitoring wells. As a result, survey data are relative to the Dover AFB co-ordinate grid system. Data are summarized in Table 2.1.

2.2.2 Groundwater Monitoring Point Installation Procedures

This section describes the procedures and equipment used for installation of new groundwater monitoring points with the CPT apparatus.

2.2.2.1 Monitoring Point Installation

Forty groundwater monitoring points were installed at 29 locations under this program. Detailed monitoring point installation procedures are described in the following paragraphs. At nine of the locations, two or three separate points (each screened at a different depth) were installed. At these locations, points installed in the shallow aquifer zone were designated with the suffix "S" and deep points were designated with the suffix "D. Four points were installed in a perched groundwater zone and designated with the suffix "P" (e.g., CPT-02S, CPT-02D, and/or CPT-02P). Six of the points did not yield water and were abandoned (Table 2.1). Monitoring point completion diagrams are included in Appendix A.

2.2.2.1.1 Monitoring Point Materials Decontamination

Monitoring point construction materials were inspected by the field hydrogeologist and determined to be clean and acceptable prior to use. All monitoring point construction materials were factory sealed. Materials were inspected for possible external contamination before use. Materials that could not be cleaned to the satisfaction of the field hydrogeologist were not used.

2.2.2.1.2 Monitoring Point Screen and Casing

The Parsons ES field hydrogeologist considered the LIF data and hydraulic characteristics of the stratum to select the screened interval for each monitoring point. During set-up at each new monitoring point location, ARA first cored through any existing concrete to allow access to the ground surface. A steel conical tip was inserted onto a 3.28-foot section of screen. Then, the screen and tip were hydraulically forced into the ground to the required depth. Due to the direct-push nature of the CPT and the fact that there is no annular space, a discrete sand pack was not installed. Construction details were noted on a Monitoring Point Installation Record form (Appendix A) and are summarized in Table 2.1. Monitoring point screens were constructed of flush-threaded, Schedule 40 polyvinyl chloride (PVC) with a 0.5-inch or 1.5-inch inside diameter (ID). The screens were factory slotted with 0.010-inch openings. Each monitoring point had a 3.28-foot or 6.56-foot screen length (i.e., 1 or 2 screen sections were used).

Blank casing with flush-mounted threads was added in 3.28-foot increments as the screen was pushed into the ground. Monitoring point casing was constructed of Schedule 40 PVC with an ID of either 0.5 inch or 1.5 inches. During monitoring well construction, Parsons ES initially attempted to install 1.5-inch-diameter monitoring points within the perched interval (i.e., monitoring points designated as "P") and the shallow interval (i.e., monitoring points designated as "S") to facilitate free product measurement. However, many if the 1.5-inch-diameter screens became clogged during installation. As a result, many of the 1.5-inch-diameter monitoring points were removed and subsequently replaced with 0.5-inch-diameter material.

All monitoring point casing sections were flush-threaded; glued joints were not used. Upon monitoring point completion to the proper termination depth, the monitoring

point casing was cut to approximately 4 inches above land surface. The field hydrogeologist verified and recorded the hole depth and the lengths of all casing sections. All lengths and depths were measured to the nearest 0.1 foot. The casing was fitted with a plastic cap constructed of the same type of material as the casing. The cap was vented to maintain ambient atmospheric pressure within the well casing. Barriers were then installed at each point until the point was either finished with a protective flush-mounted cover or permanently abandoned. This information became part of the permanent field record for the site.

2.1.3 Flush-Mount Protective Cover

Monitoring points CPT-01S, CPT-06S, CPT-08S, CPT-08D, CPT-09S, CPT-12S, CPT-12D, CPT-14S, CPT-16S, CPT-16D, CPT-19S, CPT-19D, CPT-22S, CPT-22D, CPT-25S, CPT-26S, CPT-27S, CPT-27D, and CPT-28S were constructed to serve as permanent groundwater monitoring points. After sample collection, the remaining monitoring points were abandoned and grouted to the surface. Each permanent monitoring point was completed with an at-grade protective cover. Protective covers consist of 6-inch ID steel manways with flush-mounted steel covers. The at-grade covers were cemented in place. All permanent monitoring points were completed with concrete pads that slope gently away from the protective casing to facilitate runoff during precipitation events.

2.2.2.2 Monitoring Point Development

Prior to sampling, newly installed monitoring points were developed with a peristaltic pump. Monitoring point development removes sediment from inside the monitoring point casing and flushes fines from the formation adjacent to the monitoring point screen. The pump's suction tubing was regularly lowered to the bottom of the

monitoring point so that fines were agitated and removed from the monitoring point with the development water. Development was continued until turbidity was minimized and the pH, temperature, specific conductivity, DO concentration, and redox potential of the groundwater had stabilized to within 10 percent in consecutive readings. Parsons ES designated three well volumes as a minimum requirement during development and purging. Generally, the volume of purge water removed from each monitoring point greatly exceeded this requirement. All monitoring point development waters were collected in 55-gallon drums and transported to the Dover AFB designated drum storage area.

2.2.2.3 Water Level Measurements

Water levels were measured at each monitoring point prior to purging and sampling. Measurements were made using an electric water level probe capable of recording to the nearest 0.01 foot. Mobile LNAPL thickness could not be determined within the 0.5-inch-diameter monitoring points due to the width of the oil/water interface probe. However, the field hydrogeologist looked for the presence of an oily phase during monitoring point development. Where present, mobile LNAPL thicknesses were measured in existing monitoring wells. During the last day on the site, water levels were measured in all site monitoring wells and monitoring points to obtain a snapshot of the groundwater surface at the site. This information was utilized to develop the potentiometric (groundwater) surface map utilized during Bioplume II model calibration.

2.2.2.4 Monitoring Point Location and Datum Survey

The locations and elevations of the new monitoring points were surveyed by ARA personnel soon after monitoring point completion. The horizontal locations were

measured relative to established Dover AFB coordinates. Horizontal coordinates were measured to the nearest 1 foot. Vertical location of the adjacent ground surface was measured relative to monitoring wells with known northing, easting, and top-of-casing elevation data. Survey results are presented in Table 2.1. Dover AFB provided survey data for selected monitoring wells.

2.3 GROUNDWATER SAMPLING

This section describes the procedures used for collecting groundwater quality samples. Parsons ES followed these sampling procedures in order to maintain a high degree of QC on the project. Existing monitoring wells were sampled by Parsons ES personnel while new monitoring points were being installed. Sampling of monitoring wells and points is described in Section 2.3.3.1. Sample analysis was performed by Evergreen Analytical, Inc., Wheatridge, Colorado (Evergreen Analytical).

Activities that occurred during groundwater sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the well integrity (for monitoring well sampling), including
  - Protective cover, cap and lock,
  - External surface seal and pad,
  - Well stick-up, cap, and datum reference, and
  - Internal surface seal;
- Groundwater sampling, including
  - Water level measurements,

- Visual inspection of water,
- Well casing or monitoring point evacuation, and
- Sampling;

- Sample preservation and transport, including
  - Sample preparation,
  - Onsite measurement of physical parameters,
  - Sample labeling,
  - Completion of chain-of-custody record, and
  - Packaging of samples for Evergreen Analytical via overnight courier;
- Sample delivery.

Detailed groundwater sampling and handling procedures are presented in following sections.

2.3.1 Groundwater Sampling Locations

Groundwater samples were collected from existing monitoring wells and from newly installed groundwater monitoring points.

2.3.1.1 Monitoring Well Sampling Locations

Groundwater samples were collected by Dames & Moore, Inc. from existing monitoring wells (DM 341S, DM 341D, DM 341DD, DM 342S, DM 342D, DM 343S, DM 343D, DM 344S, DM 344D, and DM 345S) as part of a Basewide

sampling initiative. Locations of these wells are indicated on Figure 2.1. Dames & Moore, Inc.'s sampling activities were conducted during the same general time period as the intrinsic remediation investigation.

2.3.1.2 Monitoring Point Locations

Groundwater samples for laboratory analyses were collected from 28 monitoring points across the site. The deep and shallow intervals were sampled at CPT-08, CPT-12, CPT-16, CPT-19, CPT-22, and CPT-27. Shallow samples only were collected at CPT-02, CPT-06, CPT-07, CPT-09, CPT-10, CPT-13 through CPT-15, CPT-18, CPT-21, CPT-25, CPT-26, CPT-28, and CPT-29. A shallow sample and a perched-zone sample were collected at CPT-11. Monitoring points were sampled using a peristaltic pump and dedicated tubing. Locations of groundwater monitoring points are indicated on Figure 2.1.

2.3.2 Preparation for Sampling

All equipment used for sampling was assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials were gathered prior to leaving the office.

2.3.2.1 Equipment Cleaning

All portions of sampling and test equipment that contacted the samples were thoroughly cleaned before use. This equipment included the water level probe and cable, lifting line, test equipment for onsite use, and other equipment that contacted the samples or was placed downhole. The following cleaning protocol was used:

- Cleaned with potable water and phosphate-free laboratory detergent;

- Rinsed with potable water;
- Rinsed with distilled or deionized water;
- Rinsed with isopropanol;
- Air dried prior to use.

Any deviations from these procedures were documented in the field scientist's field notebook and on the groundwater sampling form.

2.3.2.2 Equipment Calibration

As required, field analytical equipment were calibrated according to the manufacturer's specifications prior to field use. This applied to equipment used for onsite chemical measurements of DO, redox potential, pH, specific conductivity, and temperature.

2.3.3 Sampling Procedures

Special care was taken to prevent cross-contamination of the groundwater, groundwater samples, and sampling equipment. Water level probes and cable used to determine static water levels and well total depths were thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 2.3.2.1. Sample probes for onsite parameter measurement were placed in a flow-through container that was installed downstream of the peristaltic pump. Samples were collected upstream of the flow-through chamber. In addition, the sampler donned a new pair of disposable nitrile gloves at each sampling station.

2.3.3.1 Groundwater Monitoring Well and Monitoring Point Sampling

2.3.3.1.1 Preparation of Location

The area around each monitoring well/point was cleared of foreign materials, such as brush, rocks, and debris prior to sampling. This prevented sampling equipment from inadvertently contacting debris around the monitoring well/point.

2.3.3.1.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring well or monitoring point, the static water level was measured. An electric water level probe was used to measure the depth to groundwater to the nearest 0.01 foot below the datum. After measuring the static water level, the field scientist slowly lowered the water level probe to the bottom of the monitoring point. The total depth was measured to the nearest 0.01 foot.

2.3.3.1.3 Monitoring Well/Point Purging

The volume of water to be purged from the monitoring well/point was calculated. The field scientist purged at least three times the calculated volume from the well/point using a peristaltic pump. All purge water was placed in 35-gallon pails and disposed of at a Dover AFB-designated onsite oil/water separator.

2.3.3.1.4 Sample Extraction

High-density polyethylene (HDPE) tubing and a peristaltic pump were used to extract groundwater samples from the monitoring points. The suction end of the tubing was slowly lowered down the casing to prevent splashing. A dedicated disposable bailer was used to collect the groundwater sample from monitoring wells. The samples were transferred directly into the appropriate sample container(s), with water carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Sample containers were filled completely (zero headspace) to minimize volatilization. Excess water collected during sampling was placed into the 35-gallon pails used for monitoring well/point purge waters and then disposed at a Dover AFB-designated onsite oil/water separator.

2.3.4 Onsite Chemical Parameter Measurement

Many parameters of groundwater can change significantly within a short time following sample acquisition. As a result, these parameters were measured in the field immediately after collection. During groundwater sampling for all direct reading instruments (e.g., DO, redox, pH, temperature, and electric conductivity), an Erlenmeyer flask was installed downstream from the peristaltic pump to form a flow-through chamber for the sampling probes. As a result, a continuous measurement from the direct reading instruments was possible. The extracted groundwater flowed over the probes while immersed in the Erlenmeyer flask. This effectively produced a flow-through cell that minimizes aeration of the sample. Pumping continued until a constant reading was observed. Then, the steady values were recorded. Several of the field parameters typically do not become constant and may indefinitely fluctuate mildly between observed maximum and minimum values (e.g., DO and redox).

2.3.4.1 Dissolved Oxygen Measurements

DO measurements were taken using an Orion® model 840 DO meter using the above described procedures. DO concentrations were determined while the probe was immersed in an Erlenmeyer flask. This effectively minimized aeration of the sample. DO concentrations were recorded after the readings stabilized. In all cases, the lowest DO concentration was recorded.

2.3.4.2 Reduction/Oxidation Potential Measurements

Redox potential measurements were taken using an Orion® model 290A redox potential meter. Redox potential measurement never actually stabilized to a discrete value. As a result, the midpoint between the observed minimum and maximum values was recorded after no net upward or downward trend was observed.

2.3.4.3 Temperature, pH, and Electric Conductance

Temperature, pH, and electric conductance were determined with an Orion® model 290A meter with an ion select probe. These parameters were recorded after the readings stabilized and generally represent the average reading after stabilization.

2.3.5 Sample Handling

2.3.5.1 Sample Preservation

Evergreen Analytical added any necessary chemical preservatives to the sample containers prior to shipment to the site.

2.3.5.2 Sample Containers and Labels

Sample containers and appropriate container lids were provided by Evergreen Analytical. The sample containers were filled as described in Section 2.3.3.1.4, and the container lids were tightly closed. The sample label was firmly attached to the container side, and the following information was legibly and indelibly written on the label:

- Facility name;
- Sample identification;

- Sample type (e.g., groundwater);
- Sampling date;
- Sampling time;
- Preservatives added; and,
- Sample collector's initials.

2.3.5.3 Sample Shipment

The samples were sealed, labeled, and placed in an iced cooler. Then, coolers were packaged for transport to Evergreen Analytical via Federal Express® priority delivery. The following packaging and labeling procedures were followed:

- Sample was packaged to prevent leakage or vaporization from its container;
- Shipping container was labeled with
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

Generally, the packaged samples were hand-delivered directly to the Federal Express® facility at the end of each day.

2.4 AQUIFER TESTING

2.4.1 Slug Testing

Parsons ES conducted slug tests on six existing monitoring wells at Site SS27/XYZ to estimate the hydraulic conductivity in the shallow aquifer. Slug tests are single-well hydraulic tests used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test. Rising head slug tests were performed in monitoring wells DM 341S, DM 341D, DM 343S, DM 343D, DM 345S, and DM 349S. Detailed slug testing procedures are presented in the *Draft Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring Option for Natural Attenuation of Dissolved-Phase Fuel Contamination in Groundwater* (Wiedemeier *et al.*, 1995), hereafter referred to as the Technical Protocol document. To perform these tests, Parsons ES used a slug that was constructed of a sealed plastic PVC pipe filled with sand. A Hermit Environmental Data Logger, manufactured by In-Site, Inc. (model SE 1000c) was used to monitor water level recovery in each well over time. All down-well equipment was decontaminated prior to each test.

2.4.2 Slug Test Data Analysis

Data obtained during slug testing were analyzed using AQTESOLV™ software (Geraghty & Miller, 1991b)and the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The results of slug testing are presented in Section 3.3.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section incorporates data collected during investigations by SAIC (1986 and 1989) and Dames & Moore and HAZWRAP (1993) with data from more recent investigations conducted by Parsons ES. The investigative techniques used by Parsons ES to determine the physical characteristics of Site SS27/XYZ are discussed in Section 2.

3.1 SURFACE FEATURES

3.1.1 Topography and Surface Water Hydrology

Site SS27/XYZ is located in the inner margin of the Atlantic Coastal Plain Physiographic Province, between the St. Jones River to the west and south, the Little River to the north, and Delaware Bay to the east (Figure 1.1). The area surrounding Dover AFB is relatively flat, sloping more steeply along the banks of the surface water features. The ground surface at the Base is nearly level, with the exception of erosional features caused by stream channel development. Site SS27/XYZ is located at approximately 30 feet above mean sea level (msl).

The Dover area is drained by the St. Jones and Little Rivers, which discharge to Delaware Bay. Minor tributaries and wetland areas are located throughout the surrounding areas and on Dover AFB. Surface water runoff at Site SS27/XYZ that is not intercepted by the Base storm water drainage system flows overland northward toward a small surface water drainage ditch, which eventually drains to the Little River. This drainage ditch likely contains water intermittently during periods of

groundwater discharge from base flow. Standing water was not observed within this channel during the field activities. There are no other natural or man-made surface water bodies in the vicinity of Site SS27/XYZ. Several manmade features exist at or near the site that influence surface water runoff. These features are discussed in Section 3.1.2.

3.1.2 Manmade Features

Land surface cover at Site SS27/XYZ and adjacent areas consists of the concrete aircraft fueling apron, grassy landscaped areas, asphalt paving, concrete overlays, buildings, and other impervious structures. The majority of the precipitation that falls on the Base either infiltrates into the subsurface or is captured by the storm water drainage system. Numerous subsurface utilities, including fuel pipelines, are located in the vicinity of Site SS27/XYZ. Figure 1.4 shows the subsurface fuel line layout in the vicinity of Site SS27/XYZ. Subsurface utilities in the vicinity of the site may have some influence on groundwater flow because the water table ranges from about 5 to 12 feet below land surface (bls), which is within the typical range of utility trench depths. Utility trenches also may affect subsurface infiltration and flow of water and contaminants in the vadose zone.

3.2 REGIONAL GEOLOGY AND HYDROGEOLOGY

Dover AFB is located in the Atlantic Coastal Plain Physiographic Province, a wide, wedge-shaped belt of Cretaceous to Recent unconsolidated sedimentary deposits of sand, gravel, silt, clay, limestone, chalk, and marl that dip to the southeast (Foster, 1950). Approximately eight unconsolidated sedimentary formations are present beneath Dover AFB, extending as much as 1,400 feet bls. These formations are composed of

various lithologies including gravel; fine to coarse sand; silt; clay; glauconitic sands, silts, and silty clays; interbedded clays; and variegated clays (Pickett and Benson, 1983). The Columbia Formation, which is present at the surface and dominates the surficial geology in Delaware, was deposited under fluvial conditions, forming broad discontinuous deposits of sand, silty sand, silty clay, and gravelly sand. The unconsolidated, unconfined, water-bearing sand layer is characterized by reddish-brown to tan, yellow, or light-gray, poorly sorted coarse- to medium-grained sand and gravel. Interbedded silt and clay lenses are observed above and below the water table, and create zones of perched groundwater.

The Columbia aquifer beneath Dover AFB is from 25 to greater than 70 feet thick. The Calvert Formation unconformably underlies the Columbia Formation at Dover AFB (Dames & Moore and HAZWRAP, 1993). The Calvert Formation consists of three silty layers separated by interbedded sand layers. The Calvert Formation is about 300 feet thick in the area of Dover AFB (Dames & Moore and HAZWRAP, 1993).

The uppermost hydrogeologic unit at Dover AFB consists of an unconfined aquifer within the Columbia Formation. Groundwater flow directions within the surficial unconfined aquifer follow the surface topography, toward the St. Jones and Little Rivers or Delaware bay. The upper silt of the Calvert Formation forms the lower confining unit for the unconfined Columbia aquifer. Groundwater at Site SS27/XYZ is generally encountered at depths ranging from 5 to 12 feet bls.

3.3 SITE GEOLOGY AND HYDROGEOLOGY

Characterization of the vadose zone and shallow unconfined aquifer at Site SS27/XYZ has been the objective of several investigations. For this study, 29

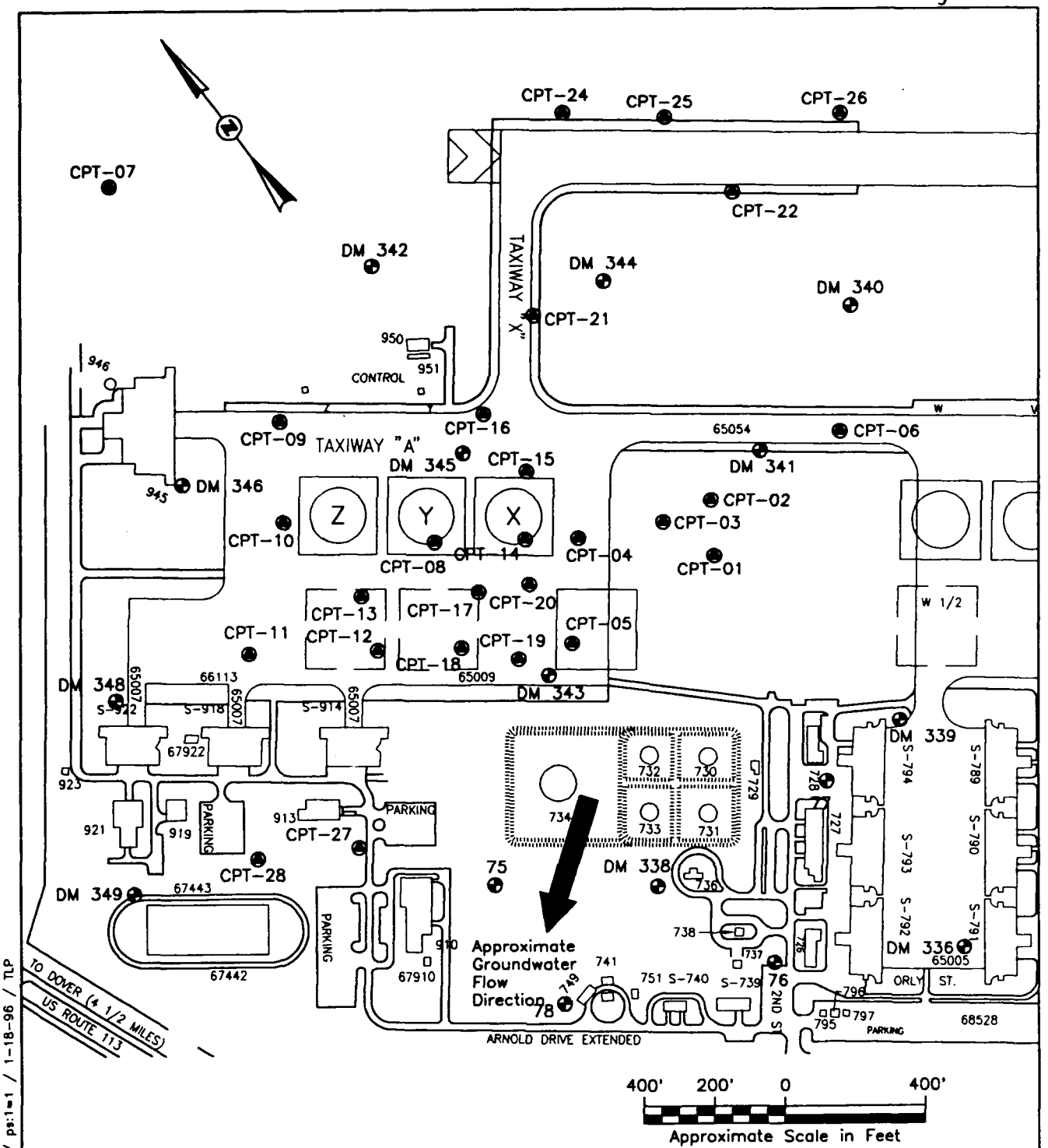
locations were investigated using CPT, 26 in conjunction with LIF, to examine site lithology and hydrocarbon contamination. Parsons ES utilized a combination of pre-existing monitoring wells and CPT-installed monitoring points to characterize the dissolved BTEX and mobile LNAPL plumes. These include 10 4-inch-diameter groundwater monitoring wells at the site (DM 341S, DM 341D, DM 341DD, DM 342S, DM 342D, DM 343S, DM 343D, DM 344S, DM 344D, and DM 345S), and 19 permanent 0.5-inch- or 1.5-inch-diameter monitoring points (CPT-01S, CPT-06S, CPT-08S, CPT-08D, CPT-09S, CPT-12S, CPT-12D, CPT-14S, CPT-16S, CPT-16D, CPT-19S, CPT-19D, CPT-22S, CPT-22D, CPT-25S, CPT-26S, CPT-27S, CPT-27D, and CPT-28S). Fifteen temporary monitoring points (CPT-02S, CPT-03S, CPT-04S, CPT-07S, CPT-07D, CPT-10S, CPT-11P, CPT-11S, CPT-13S, CPT-15S, CPT-17S, CPT-18S, CPT-20S, CPT-21S, and CPT-29S) also were installed.

Figure 3.1 shows the locations of the monitoring wells and the monitoring points. To minimize confusion among CPT test points, LIF test points, and monitoring point installations, a single prefix (CPT) was used to label all locations of CPT testing and all monitoring points installed with the cone penetrometer rig. Table 2.1 presents a summary of the actual tests performed and monitoring point completion information.

3.3.1 Lithology and Stratigraphic Relationships

The sediments underlying Site SS27/XYZ consist of naturally deposited fluvial sands, which coarsen with depth and are interbedded with laterally discontin is lenses of clay and gravel. The Columbia Formation is about 25 to 35 feet thick beneath Site SS27/XYZ. At Site SS27/XYZ, the sediments of the Columbia Formation consist of sand and gravel with discontinuous silty clay lenses. Five to 10 feet of gravelly sand is present at the surface. Underlying these sediments are laterally discontinuous lenses of

Figure 3.1



LEGEND

DM 341 ● Monitoring well.

CPT-01 ● Monitoring point and CPT test location installed by CPT rig.

② Former C-10 fueling pad.

Monitoring Well and CPT Locations

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

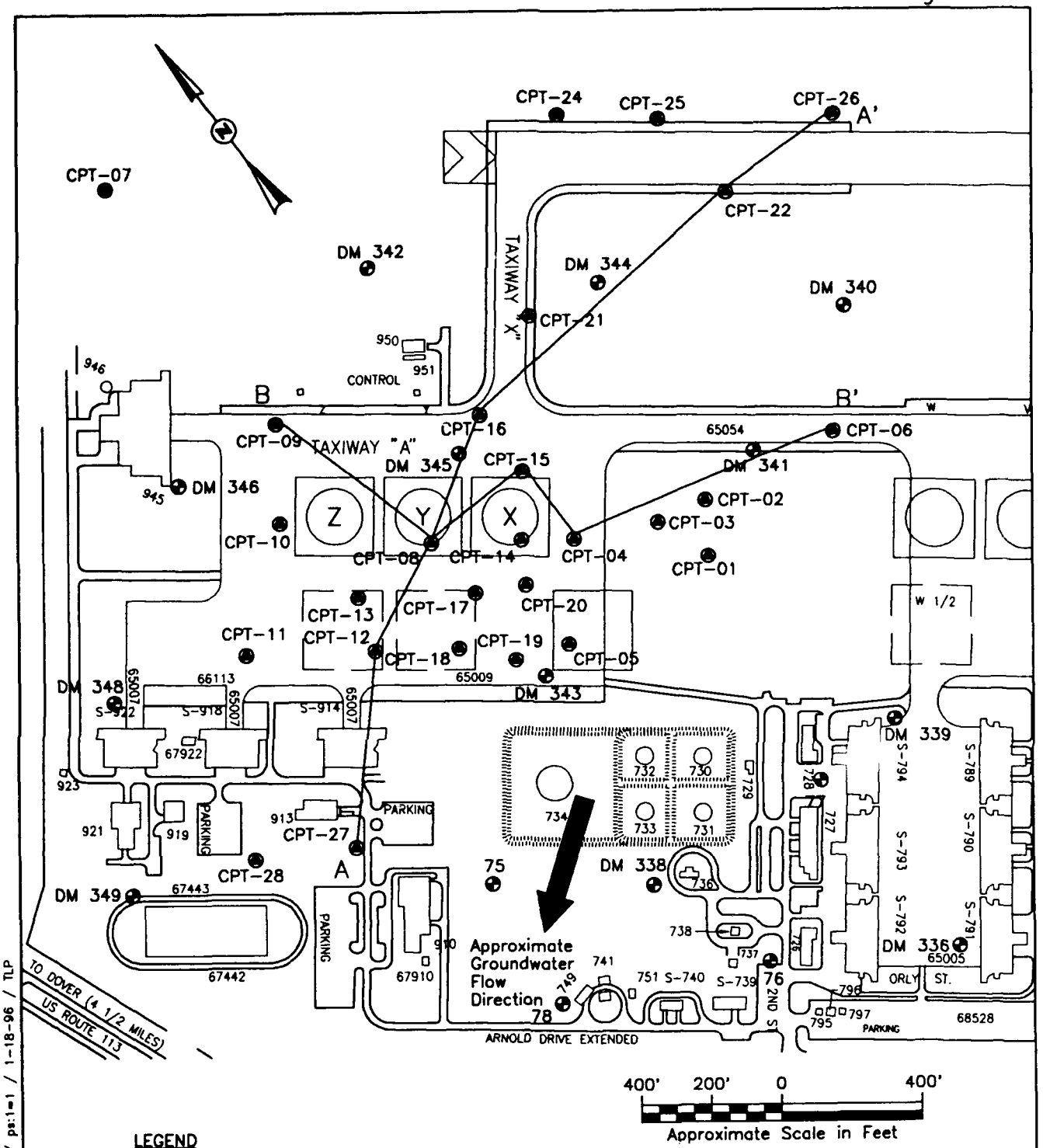
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silty clay from 2 to 5 feet thick. This in turn is underlain by gravelly sand, below which the silty clays of the upper Calvert Formation are present. A silty clay unit, probably the upper Calvert Formation, was observed at about 30 feet bls. In boring logs from monitoring wells drilled at various sites at Dover AFB, the upper portion of the Calvert Formation was described as gray to dark gray, firm, dense clay with thin laminations of silt and fine sand (Dames & Moore and HAZWRAP, 1993). Because these are fluvial sediments, many units are discontinuous and vary in thickness. Some strata pinch out entirely within the study area. The discontinuous silty clay layers within the Columbia Formation may act to form localized perched aquifers, resulting in relatively shallow regions of localized hydrocarbon contamination, as observed at CPT-11 (Appendix A).

The stratigraphic relationships at the site are illustrated by hydrogeologic sections A-A' and B-B'. Figure 3.2 shows the location of these sections. Figure 3.3 displays hydrogeologic section A-A', which is oriented approximately parallel to the primary direction of groundwater flow at Site SS27/XYZ. Figure 3.4 displays hydrogeologic section B-B', which is oriented approximately perpendicular to the direction of groundwater flow at the site. The silty clay lenses shown in hydrogeologic sections A-A' and B-B' do not appear to create either a continuous perching unit or an upper confining unit within the Columbia aquifer. Groundwater levels measured in monitoring points and wells at the site do not appear to be influenced by the lenses of silty clay with the exception of perched groundwater observed at some locations.

Figure 3.2



LEGEND

DM 341 ⊕ Monitoring well.

CPT-01 ● Monitoring point and CPT test location installed by CPT rig.

A——A' Hydrogeologic cross-section.

② Former C-10 fueling pad.

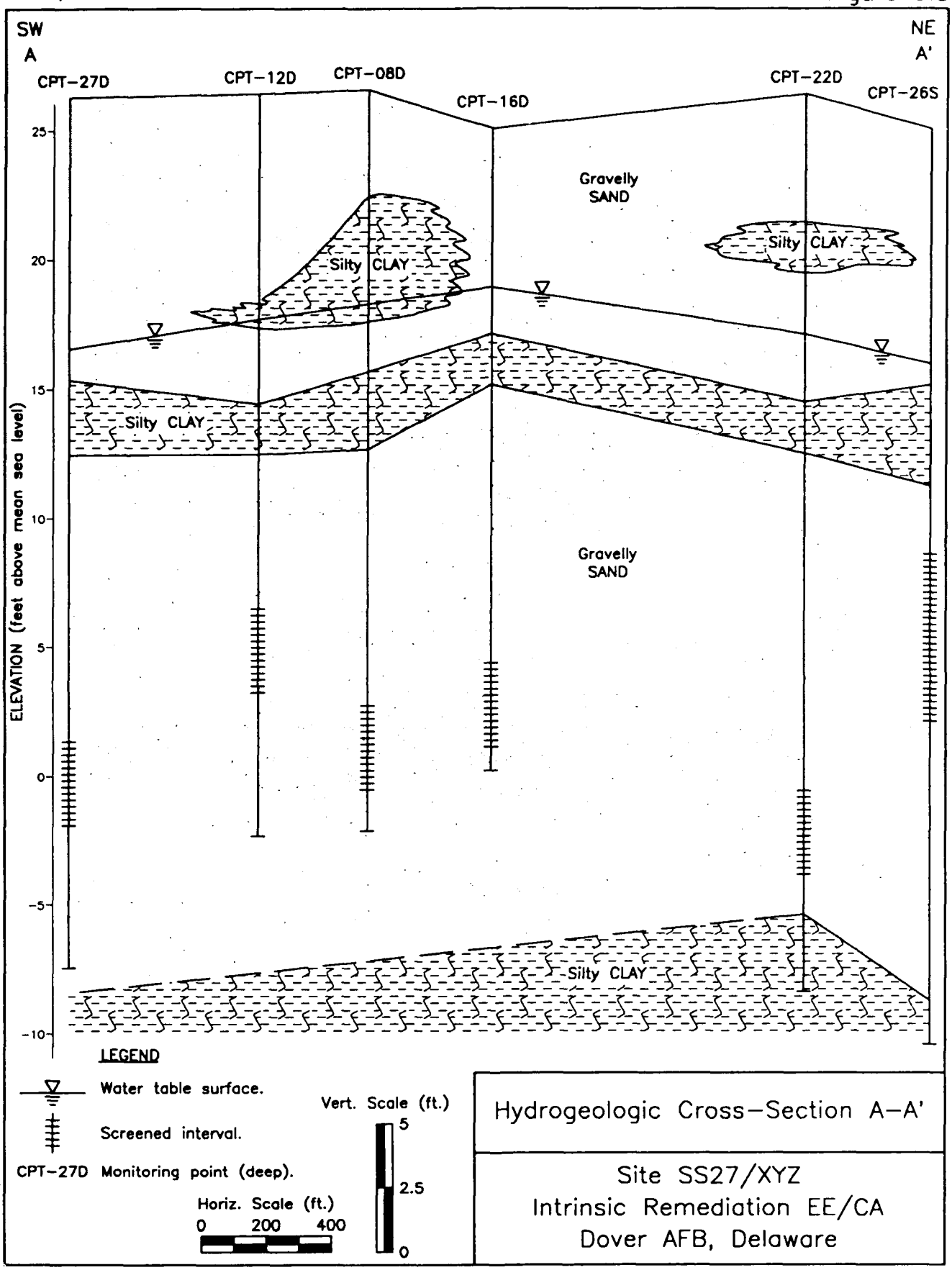
Hydrogeologic Cross-Section Locations

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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Figure 3.3

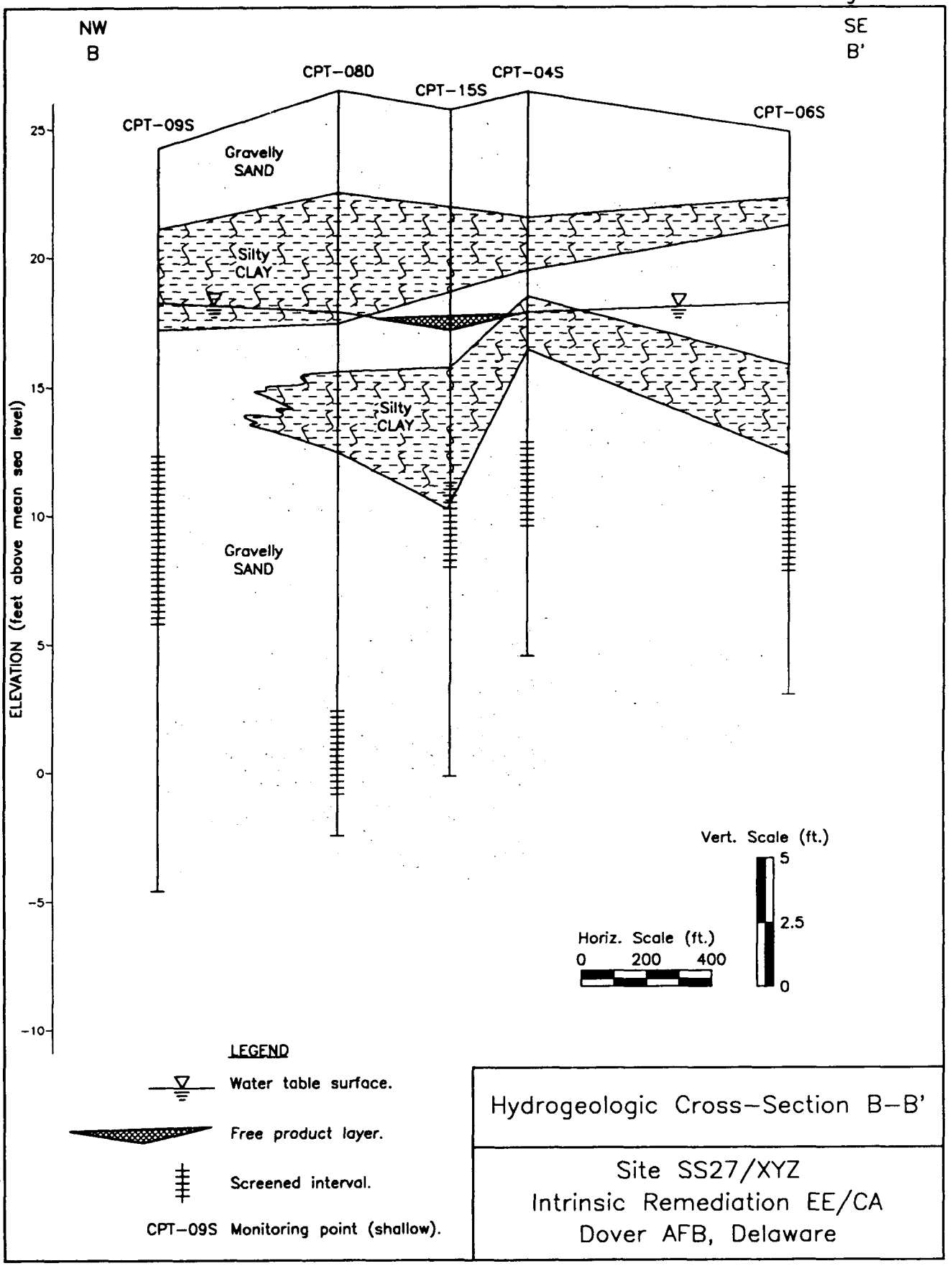


Hydrogeologic Cross-Section A-A'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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Figure 3.4



Hydrogeologic Cross-Section B-B'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

72245056.dwg / 1=1 / 1-19-96 / TLP

3.3.2 Groundwater Hydraulics

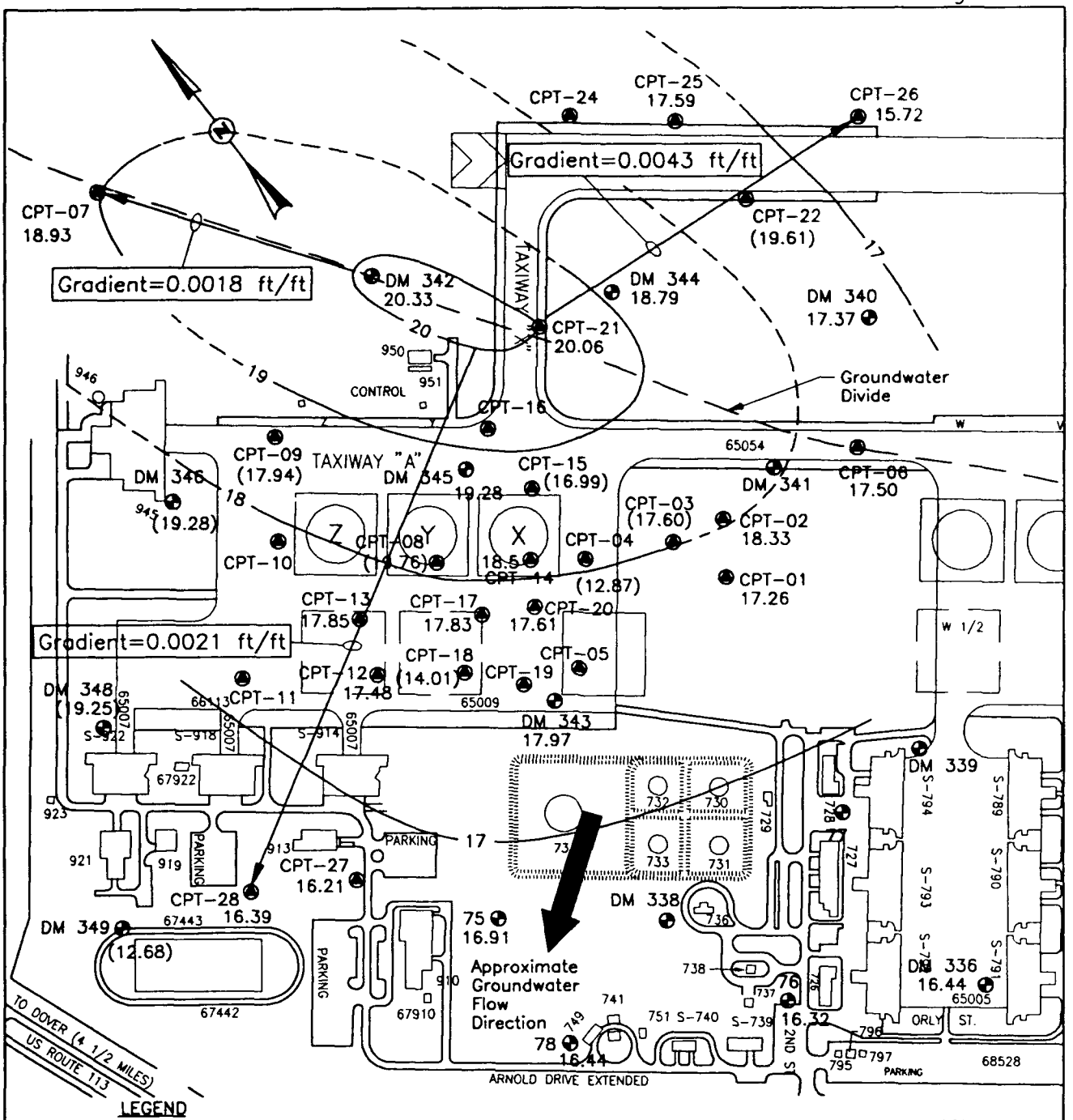
3.3.2.1 Groundwater Flow Direction and Gradient

Groundwater elevations within the shallow aquifer range from approximately 13 to 20 feet msl. Figure 3.5 shows a map of the water table surface of the unconfined aquifer at the site based on groundwater elevations measured in monitoring points and monitoring wells (see Tables 3.1 and 3.2). Groundwater elevations observed in some wells were anomalous and were not used in construction of the water table surface map. The water levels in DM 346 and DM 348, for example, are much higher than in surrounding wells and monitoring points, possibly due to a perched water table in that vicinity or due to localized groundwater flow patterns that do not appear to affect plume migration.

Groundwater in the unconfined aquifer at the site, according to groundwater elevations in site monitoring wells and monitoring points, flows radially from the contaminant source area at Site SS27/XYZ (see Figure 3.5). A well-documented divergent groundwater divide is located parallel to and beneath the NW/SE runway adjacent to Site SS27/XYZ (Dames & Moore and HAZWRAP, 1993). For the purpose of this project, the primary direction of groundwater flow is considered to be to the southwest toward the St. Jones River. Choosing southwest as the primary direction of groundwater flow is supported by the distribution of contaminants (as shown in Section 4.3).

A Basewide groundwater level summary report was developed by Dames & Moore, Inc. and HAZWRAP (1993) that evaluated the relative position of the groundwater divide from May 1991 to January 1993. Over this 2.5-year period, data from eight

Figure 3.5



LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
— 20.0 —	Water table surface contour (feet above mean sea level), dashed where inferred.
12.68	Water table surface elevation (feet above mean sea level).
(12.68)	Data not used to develop contours.
←	Approximate groundwater flow direction.
②	Former C-10 fueling pad.

400' 200' 0 400'

Approximate Scale in Feet

Potentiometric Surface Map for Shallow Wells and Monitoring Points April 21,1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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TABLE 3.1

WATER LEVEL ELEVATION DATA FROM MONITORING POINTS
APRIL 21, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Measurement Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Total Depth (ft bls)[d]	LNAPL Observed (Y/N)	Water Depth (ft)	Water Level Elevation (ft msl)
Monitoring Points							
CPT-01S	413590	480024	26.48	17.00	N	9.22	17.26
CPT-02S	413721	480113	25.51	13.00	N	7.18	18.33
CPT-03S	413754	479968	25.64	13.00	N	8.04	17.60
CPT-04S	413863	479748	26.31	17.00	N	8.50	17.81
CPT-05S	NM[e]	NM	NA[f]	NA	N	NM	NA
CPT-06S	413657	480522	24.10	16.60	N	6.60	17.50
CPT-07S	415476	479293	25.85	15.00	N	6.92	18.93
CPT-07D	415475	479294	25.83	28.20	N	7.02	18.81
CPT-08P	NM	NM	NA	12.10	N	DRY	NA
CPT-08S	414102	479416	26.18	16.6	N	8.42	17.76
CPT-08D	NM	NM	NM	27.30	N	8.52	NA
CPT-09S	414644	479271	23.98	18.60	N	6.04	17.94
CPT-10S	414410	479107	NM	18.60	N	7.85	NM
CPT-11P	NM	NM	NM	13.00	N	6.15	NM
CPT-11S	NM	NM	NM	18.80	N	8.70	NM
CPT-12P	NM	NM	NA	5.10	N	DRY	NA
CPT-12S	413955	479095	26.24	17.80	N	8.76	17.48
CPT-12D	413955	479103	26.23	23.40	N	8.83	17.40
CPT-13S	414106	479154	27.03	17.30	N	9.18	17.85
CPT-14S	413951	479626	NM	17.60	N	NM	NM
CPT-15S	414104	479746	25.44	17.90	Y[g]	8.45	16.99
CPT-16S	414307	479748	NM	13.40	N	5.65	NM
CPT-16D	414307	479748	NM	24.10	N	6.06	NM
CPT-17S	413912	479430	26.98	18.80	N	9.35	17.63
CPT-18S	413813	479294	26.11	18.70	Y[g]	12.10	14.01
CPT-19P	413733	479484	NA	10.10	N	NA	NA
CPT-19S	413733	479484	NM	15.90	N	8.96	NM
CPT-19D	413733	479484	NM	26.00	N	8.85	NM
CPT-20S	413842	479557	26.74	15.40	N	9.13	17.61
CPT-21S	414447	480032	24.42	14.90	N	4.36	20.06
CPT-22S	414388	480694	25.92	17.90	N	6.31	19.61
CPT-22D	414388	480694	NM	30.40	N	9.33	NM
CPT-23S	NM	NM	NA	NA	N	NA	NA
CPT-24S	NM	NM	NA	15.60	N	DRY	NA
CPT-25S	414674	480669	26.59	20.90	N	9.00	17.59
CPT-26S	414382	481072	24.88	23.20	N	9.16	15.72
CPT-27S	413518	478754	26.04	17.40	N	9.83	16.21
CPT-27D	413518	478754	NA	28.40	N	NA	NA
CPT-28S	413685	478465	27.47	20.40	N	11.08	16.39
CPT-29S	NM	NM	NM	16.30	N	NM	NM

[a] See Figure 3.1 for measurement locations.
[b] Datum is top of casing.
[c] ft msl = feet above mean sea level.
[d] ft bls = feet below land surface.
[e] NM = Not measured.
[f] NA = Not available.
[g] Emulsification was observed in monitoring point during sampling.

TABLE 3.2

WATER LEVEL ELEVATION DATA FROM MONITORING WELLS
APRIL 19, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

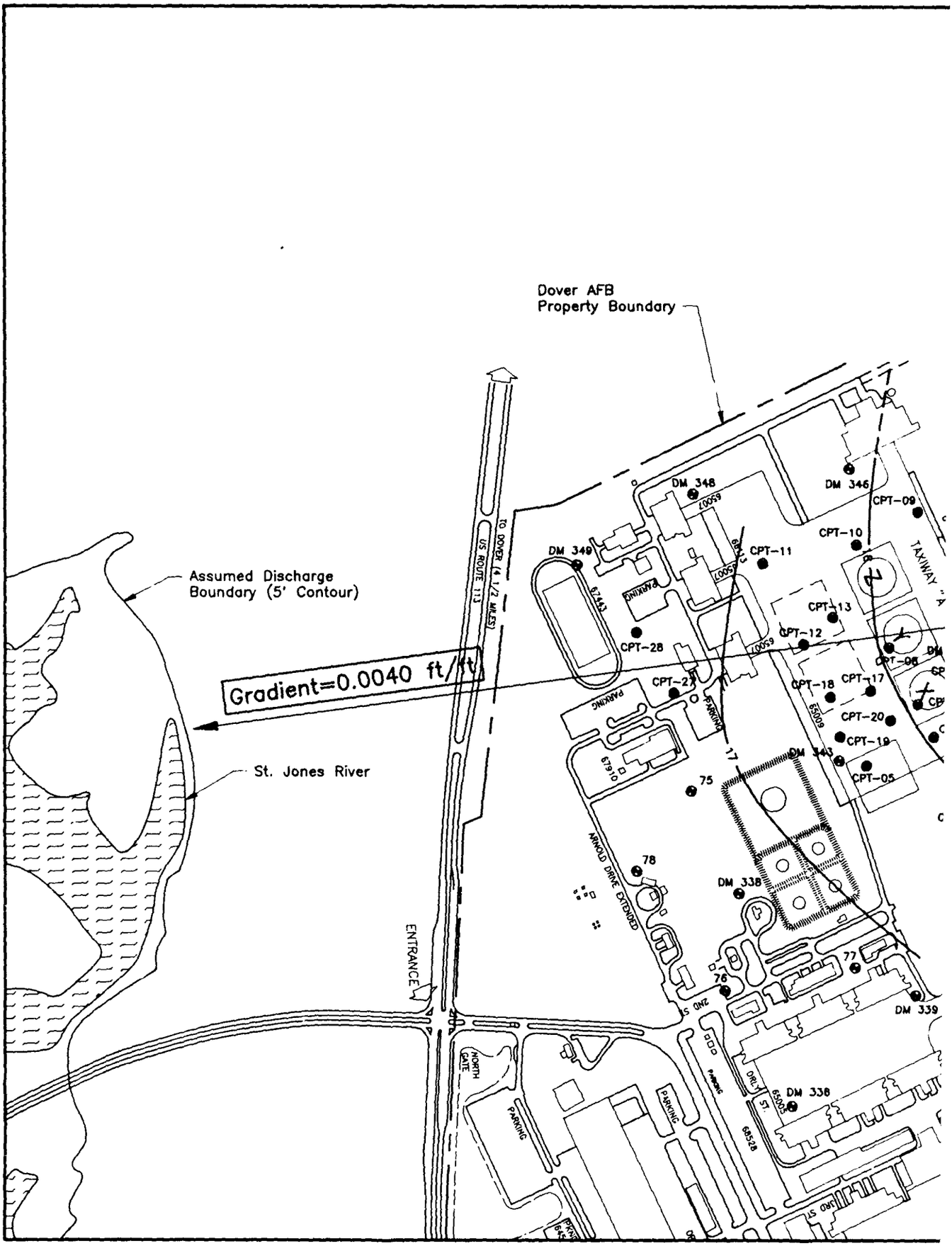
Measurement Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Ground Elevation (ft msl)	Total Depth[d] (ft)	Product Thickness Observed on April 19, 1994 (ft)	Water Depth[e] (ft)	Water Level Elevation (ft msl)
Monitoring Wells								
75S	413225	478969	27.18	25.43	27.66	0.00	10.27	16.91
75D	413236	478978	27.10	25.36	35.86	0.00	10.41	16.69
76S	412555	479452	30.90	28.76	29.60	0.00	14.58	16.32
76D	412549	479447	30.88	28.68	37.42	0.00	14.56	16.32
77S	412880	479886	23.97	24.68	18.23	0.00	NM[f]	NM
77D	412889	479894	23.49	24.02	22.64	0.00	NM	NM
78S	412821	478908	29.66	28.18	30.68	0.00	13.22	16.44
78D	412827	478900	29.95	28.40	37.71	0.00	13.52	16.43
DM 204S	415508	480856	24.91	22.24	16.00	0.00	6.87	18.04
DM 204D	415504	480861	24.76	22.28	34.00	0.00	6.73	18.03
DM 336S	412263	479909	24.37	24.61	16.00	0.00	7.93	16.44
DM 336D	412262	479912	24.38	24.66	36.00	0.00	8.53	15.85
DM 338S	412932	479324	28.68	26.24	20.00	0.00	NM	NM
DM 338D	412935	479321	28.83	26.17	39.00	0.00	NM	NM
DM 339S	412894	480158	24.81	25.13	14.50	0.00	NM	NM
DM 339D	412891	480157	24.74	25.13	28.00	0.00	NM	NM
DM 340S	413925	480765	22.16	22.29	18.50	0.00	4.79	17.37
DM 341S	413750	480309	25.42	26.06	19.00	0.00	NM	NM
DM 341D	413755	480303	25.60	26.05	28.00	0.00	NM	NM
DM 342S	414840	479750	24.94	25.19	19.00	0.00	4.61	20.33
DM 342D	414838	479748	25.09	25.02	28.00	0.00	4.72	20.37
DM 343S	413597	479448	26.62	26.93	18.00	0.00	8.65	17.97
DM 343D	413603	479439	26.62	26.93	30.00	0.00	8.60	18.02
DM 344S	414415	480259	23.44	23.36	18.00	2.70 (6.88[g])	9.67	13.77
DM 344D	414408	480263	23.49	23.37	30.00		4.36	19.13
DM 345S	414255	479634	25.60	26.03	19.00	0.00	6.32	19.28
DM 346S	414670	478942	29.62	26.82	22.00	0.00	10.34	19.28
DM 346D	414674	478945	29.56	26.84	45.00	0.00	10.28	19.28
DM 347S	NA[h]	NA	NA	NA	NA	0.00	9.48	NA
DM 347D	NA	NA	NA	NA	NA	0.00	9.50	NA
DM 348S	414290	478418	29.27	26.15	20.00	0.00	10.02	19.25
DM 348D	414295	478421	29.13	26.09	34.00	0.00	11.26	17.87
DM 349S	413817	478125	32.43	29.72	28.00	0.00	19.75	12.68
DM 349D	413821	478130	32.00	29.40	35.00	0.00	19.34	12.66

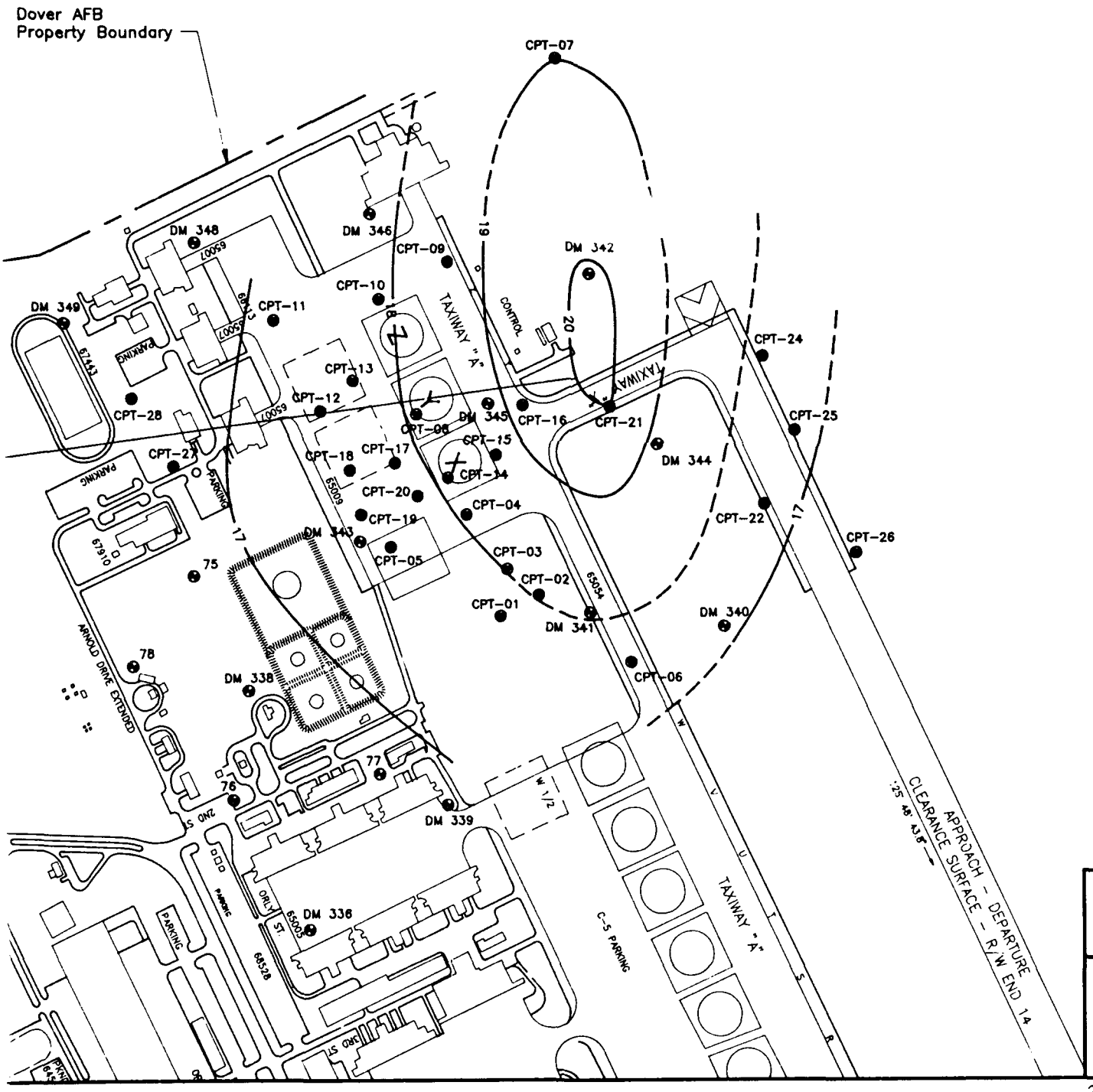
[a] See Figure 3.1 for measurement locations.
[b] Datum elevation refers to top of casing.
[c] ft msl = feet above mean sea level.
[d] Total depth of well measured from the top of casing.
[e] Measured from the top of casing.
[f] NM = not measured.
[g] Maximum product thickness observed on April 14, 1994.
[h] NA = not available.

separate water level measurement rounds indicate the location of the groundwater divide may vary over time. The divide migrated laterally from east to west over a distance of approximately 2,000 feet. However, the general direction and orientation of the divide did not vary. The median location of the groundwater divide and typical groundwater flow direction, as reported by Dames & Moore and HAZWRAP (1993), closely approximated the groundwater flow patterns determined by Parsons ES in April 1994 (Figure 3.5).

The hydraulic gradient toward the southwest is relatively low in the area of Site SS27/XYZ and increases substantially toward the St. Jones River. The observed horizontal hydraulic gradient (Figure 3.5) at Site SS27/XYZ was 0.0021 foot per foot (ft/ft) toward the southwest. The overall hydraulic gradient from the source area to the St. Jones River is approximately 0.004 ft/ft (Figure 3.6). The horizontal hydraulic gradients in the remaining directions are 0.0043 ft/ft (to the northeast) and 0.0175 ft/ft (to the northwest).

Parsons ES calculated vertical gradients across the site at several of the multi-depth monitoring points. Vertical gradients ranged from 0.009 ft/ft (downward) at CPT-07 to 0.014 ft/ft (downward) at CPT-12. The average vertical hydraulic gradient was 0.012 ft/ft (downward). Overall, the reported vertical gradients appear relatively consistent among locations. Vertical gradient variances can be caused by several factors, including localized infiltration zones (e.g., storm retention ditches, leaking utility piping), regional discharge areas (e.g., rivers or lakes), presence of inconsistent surface cover, and varying lithologies. The reported vertical gradients vary only slightly among the multi-depth monitoring points. However, the presence of the silty clay layer located at approximately 5 to 10 feet above msl (Figure 3.3) likely inhibits


Dover AFB
Property Boundary
Assumed Discharge
Boundary (5' Contour)
St. Jones River
Gradient=0.0040 ft/ft
TO DOVER (4 1/2 MILES)
US ROUTE 113
ENTRANCE
NORTH GATE
ARNOLD DRIVE EXTENDED
2ND ST
DM 348
DM 346
DM 349
DM 343
DM 338
DM 339
DM 336
CPT-09
CPT-10
CPT-11
CPT-13
CPT-12
CPT-28
CPT-18
CPT-17
CPT-20
CPT-19
CPT-05
75
76
77
78
PARKING
65009
65007
65013
67143
67910
65008
65028
72245058.dwg + 722450X1.dwg / ps:1=1 / 1-23-96 / TLP



DM 341

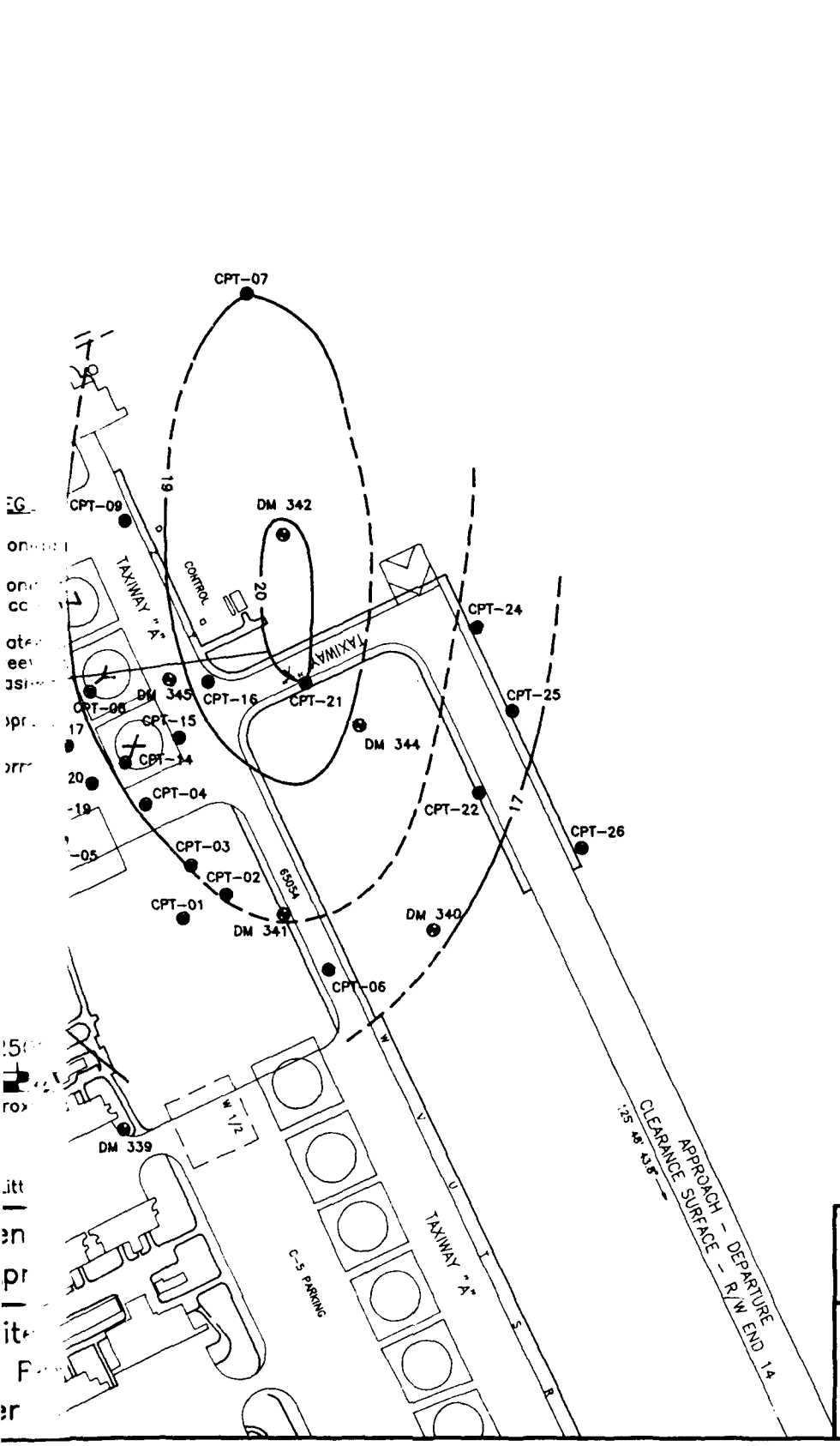
CPT-01

— 20.0

Source:

Overall

Intri



LEGEND

DM 341 ●	Monitoring well.
CPT-01 ●	Monitoring point and CPT test location installed by CPT rig.
—20.0—	Water table surface contour (feet above mean sea level), dashed where inferred.
←	Approximate groundwater flow direction.
②	Former C-10 fueling pad.

500' 250' 0 500'

Approximate Scale in Feet

Source: USGS Little Creek, Delaware Quad, 1993

Overall Potentiometric Surface Map
April 21, 1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

contaminant migration below this formation. Observed vertical and horizontal migration patterns of dissolved BTEX and inorganic geochemical parameters are discussed in Section 4.

3.3.2.2 Hydraulic Conductivity

Hydraulic conductivity in the surficial unconfined aquifer was estimated using rising head slug tests as described in Section 2.4. Slug tests were performed in monitoring wells DM 341S, DM 341D, DM 343S, DM 343D, DM 345S, and DM 349S. The results of these slug tests are summarized in Table 3.3. The average hydraulic conductivity (Table 3.3) for the surficial unconfined aquifer as determined from these tests is 0.042 foot per minute (ft/min) or 6.9×10^{-4} foot per second (ft/sec). Appendix A contains the slug test data and calculations.

3.3.2.3 Effective Porosity

Because of the difficulty involved in accurately determining effective porosity, accepted literature values for the type of soil comprising the shallow saturated zone were used. The aquifer materials primarily consist of a gravelly sand and also include interbedded noncontinuous silty clay lenses. Freeze and Cherry (1979) give a range of effective porosity for sand and gravel. Based on these data, the effective porosity for the aquifer may range from 0.25 to 0.50. To be conservative (lower effective porosity results in greater groundwater velocity), the effective porosity for sediments of the shallow saturated zone is assumed to be 0.30.

3.3.2.4 Advective Groundwater Velocity

Darcy's Law was used to calculate the advective groundwater flow velocity in the

TABLE 3.3

SLUG TEST RESULTS
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Well Location[a/]	Test	Hydraulic Conductivity[b/] (ft/min)	Hydraulic Conductivity (ft/sec)
Monitoring Wells			
DM 341S	Rising Head (#1)	0.031	0.00052
DM 341S	Rising Head (#2)	0.049	0.00082
DM 341D	Rising Head (#1)	0.096	0.0016
DM 341D	Rising Head (#2)	0.13	0.0021
DM 343S	Rising Head (#1)	0.00081	0.000014
DM 343S	Rising Head (#2)	0.00086	0.000014
DM 343D	Rising Head (#2)	0.012	0.00021
DM 345S	Rising Head (#1)	0.055	0.00092
DM 345S	Rising Head (#2)	0.044	0.00073
DM 349S	Rising Head (#2)	0.037	0.00061
DM 349S	Rising Head (#3)	0.029	0.00049
	Average	0.042	0.00069

[a/] See Figure 3.1.

[b/] Hydraulic conductivity calculated using AQTESOLV™.

surficial aquifer at Site SS27/XYZ. The groundwater flow velocity toward the primary southwestern flow direction is approximately 0.42 ft/day, or 161 feet per year (ft/yr). The groundwater flow velocity was calculated based on an average hydraulic conductivity of 0.042 ft/min, an estimated effective porosity of 0.30, and the observed site hydraulic gradient of 0.0021 ft/ft. Using the calculated overall hydraulic gradient from the source area to the St. Jones River (0.004 ft/ft), the groundwater flow velocity from the site to the river is approximately 292 ft/yr. In the other flow directions at Site SS27/XYZ, groundwater velocities are 314 ft/yr to the northeast and 131 ft/yr to the northwest based on calculated hydraulic gradients.

3.3.3 Preferential Flow Paths

No preferential contaminant migration pathways were identified at the site. Although numerous subsurface utilities underlie the area of investigation, no effects on contaminant distribution or groundwater flow pattern were noted. As shown on Figure 1.4, the subsurface fuel lines were the probable source of the fuel contamination at Site SS27/XYZ, but the distribution of contaminants in groundwater appears to be related to flow of groundwater in relation to the location of the groundwater divide adjacent to the site and not to preferential migration in the subsurface fuel line trenches.

3.3.4 Groundwater Use

Groundwater from the surficial unconfined aquifer at Dover AFB is not exploited for potable water supply. There are no known drinking water supply wells on or near the Base. Potable water supply for the Base and the surrounding area is obtained from the Cheswold and Piney Point aquifers, which are located beneath the Columbia aquifer. Two confining units separate the surfical Columbia aquifer and the Cheswold

aquifer (Dames & Moore and HAZWRAP, 1993). The first confining unit is comprised of a 20-foot-thick layer of silt and clay. The second confining unit is approximately 90 feet thick and is comprised of silt, clayey sand, sandy silt, and sandy clay. A third confining unit forms the base of the Cheswald aquifer and the upper confining unit for the Piney Point aquifer. This formation is a silt and clay unit that is approximately 90 feet thick.

3.4 CLIMATOLOGICAL CHARACTERISTICS

The Dover area has a continental climate because of its close proximity to the Atlantic Ocean and the west to east atmospheric flow. Spring and fall are characterized by a succession of warm and cold periods associated with storm activity. Summers and winters are humid, intensifying the respective heat and cold of the seasons (Flohn, 1969). The mean precipitation for the Base is approximately 61.5 inches per year (Dames & Moore and HAZWRAP, 1993). Daily temperatures, on average, range from 25 to 89 degrees Fahrenheit (Dames & Moore and HAZWRAP, 1993). The annual evaportranspiration rate for the Delaware region is approximately 33 inches per year (Eagleman, 1975). Potential net infiltration of precipitation into the subsurface was calculated to be 13 to 16 inches annually (Engineering-Science, Inc., 1983). Actual infiltration rates at Dover AFB may be much lower than this due to the amount of impermeable cover and the storm water drainage system at the Base.

SECTION 4

NATURE AND EXTENT OF CONTAMINATION AND SOIL AND GROUNDWATER GEOCHEMISTRY

4.1 SOURCE OF CONTAMINATION

The fuel pumping station at Site SS27/XYZ is currently in operation. As early as 1984, a fuel release was suspected in the area due to the presence of fuel observed floating on the surface of water in nearby manholes (Dames & Moore and HAZWRAP, 1993). The exact date, volume, and the origin of the release are unclear. Due to the presence of the numerous subsurface fuel lines, pumps, and fueling hydrants in this vicinity, it is likely that the observed distribution of subsurface fuel contamination is attributable to several past releases. Given the observed distribution of contamination, leaks along the subsurface fuel pipelines are probably the major sources of contamination, with minor contributions from surface spills related to fueling operations. Dover AFB corrected these leaks in 1993 due to the installation of new underground piping systems in the area of the leaks.

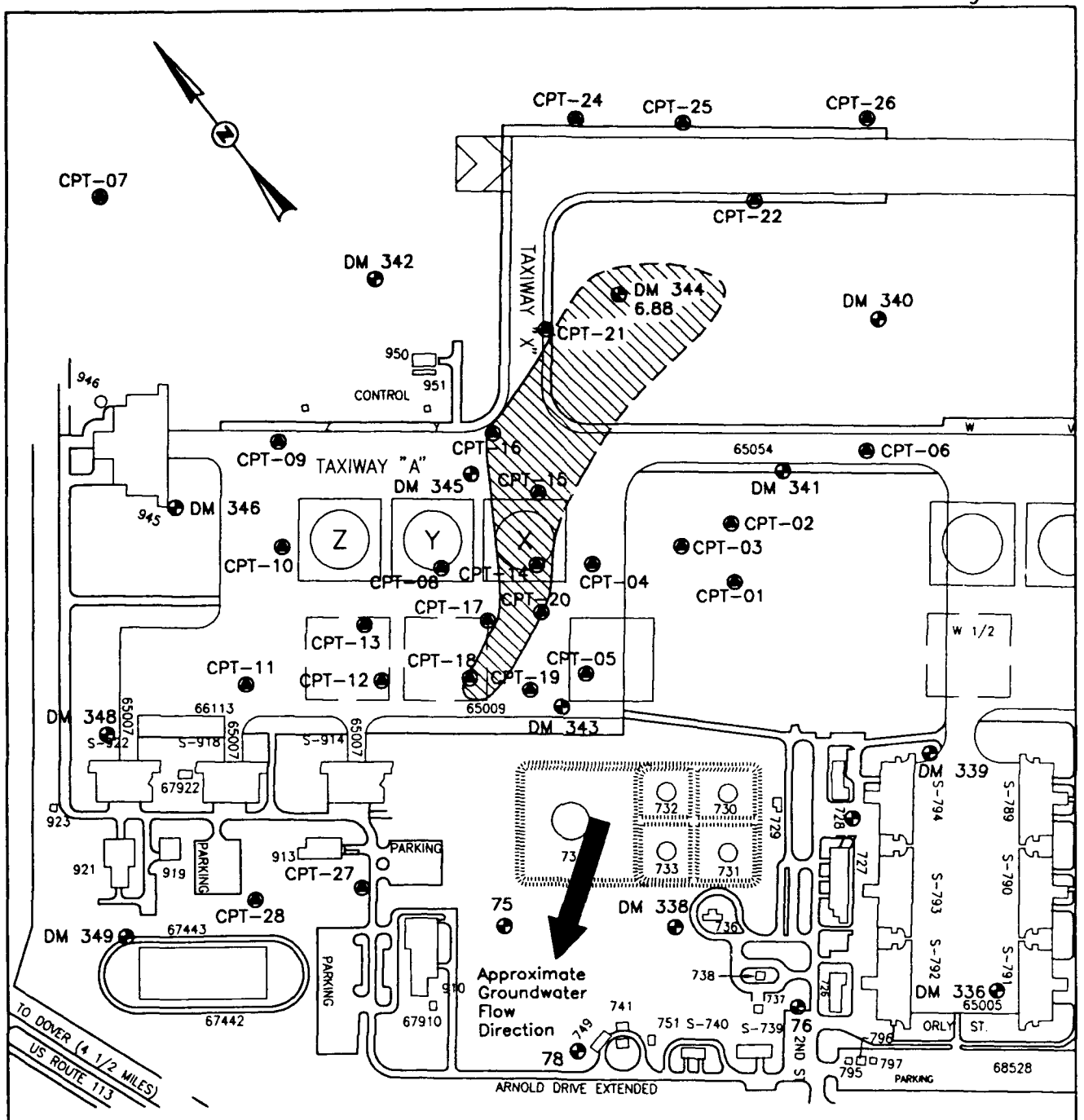
Remedial activities performed onsite have included mobile LNAPL recovery from several site monitoring wells. A mobile LNAPL recovery and remediation pilot study using bioslurping was performed at Site SS27/XYZ during 1995 through a separate AFCEE program. The bioslurping tests, as well as other field testing, were performed to further evaluate the distribution and recoverability of LNAPL at the site. As indicated by the LIF data, the analytical results from soil samples, and the presence of mobile LNAPL in several monitoring wells and monitoring points, areas of significant free product and/or residual LNAPL soil contamination remain at the site. These areas are acting as a continuing source for groundwater contamination.

4.2 MOBILE LNAPL CONTAMINATION

Mobile LNAPL is defined as the LNAPL that is free to flow in the aquifer and that will flow from the aquifer matrix into a well under the influence of gravity. The approximate extent of mobile LNAPL observed at Site SS27/XYZ is shown on Figure 4.1. Mobile LNAPL was observed in monitoring well DM 344S during this EE/CA investigation (see Table 3.2). The measured thicknesses of the mobile LNAPL varied in DM 344S from 2.7 feet to 6.88 feet during this investigation. The thicknesses of mobile LNAPL could not be measured in any of the monitoring points because the ID of the monitoring points is too narrow to allow the introduction of an oil/water interface probe. However, the presence of mobile LNAPL was indicated in monitoring points CPT-15S and CPT-18S by the concentrations of BTEX detected in groundwater samples. On the basis of the solubility of BTEX in water, a maximum of about 23 milligrams per liter (mg/L) [23,000 micrograms per liter (μg/L)] of total BTEX can be dissolved in groundwater from JP-4 (Wiedemeier *et al.*, 1995). The total BTEX concentrations reported in CPT-15S and CPT-18S were 11,300,000 μg/L and 22,900 μg/L, respectively. These results suggest that the sample from CPT-15S contained a mixture of fuel and water, while the sample CPT-18S may represent groundwater in equilibrium with JP-4 fuel.

The relationship between measured LNAPL thickness and the amount of mobile LNAPL in the subsurface at a site is difficult to quantify without field testing. It is well documented that LNAPL thickness measurements taken in groundwater monitoring wells are not indicative of actual mobile LNAPL thicknesses in the formation (de Pastrovich *et al.*, 1979; Blake and Hall, 1984; Hall *et al.*, 1984; Hampton and Miller, 1988; Hughes *et al.*, 1988; Abdul *et al.*, 1989; Testa and Paczkowski, 1989; Kemblowski and Chiang, 1990; Lehnard and Parker, 1990; Mercer and Cohen, 1990; Ballestero *et al.*, 1994). It has been noted by these authors that the

Figure 4.1



LEGEND

DM 341 — Monitoring well.

CPT-01 — Monitoring point and CPT test location installed by CPT rig.

6.88 — Mobile LNAPL thickness (feet).

Approximate extent of mobile LNAPL plume.

Note: LNAPL was observed during sampling of CPT-15S and CPT-18S. Actual thickness could not be determined.

Former C-10 fueling pad.

400' 200' 0 400'

Approximate Scale in Feet

Approximate Extent of Mobile LNAPL
April 14, 1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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PARSONS ENGINEERING SCIENCE, INC.

thickness of LNAPL measured in a monitoring well is greater than the actual mobile LNAPL thickness present in the aquifer and, according to Mercer and Cohen (1990), measured LNAPL thickness in wells is typically 2 to 10 times greater than the actual mobile LNAPL thickness in the formation.

4.3 SOIL CHEMISTRY

4.3.1 Residual Contamination

Residual LNAPL is defined as the LNAPL that is trapped in subsurface material by cohesive and capillary forces. Therefore, residual LNAPL will not flow through the aquifer, nor will it flow from the aquifer matrix into a well under the influence of gravity. The following sections describe the residual LNAPL contamination found at the site.

4.3.1.1 Soil BTEX Contamination

Residual hydrocarbon contamination resulting from vertical and lateral migration of free and dissolved hydrocarbons was found over a wide area at Site SS27/XYZ. Table 4.1 contains analytical results for BTEX and TVH in soil samples. Figure 4.2 shows the extent of contaminated soil as determined from laboratory analytical results and LIF data. Because LIF direct printouts indicate background signal noise ranging from 0 to 200 relative intensity (counts), LIF readings of up to approximately 200 counts were considered to be background for this site.

Soil samples for laboratory analysis of BTEX and TVH were collected from six CPT locations. A total of nine soil samples were analyzed for BTEX and TVH, including samples from two depth intervals at three of the CPT locations (see Table 4.1). Analyses of soil samples for total BTEX by US Environmental Protection Agency

TABLE 4.1

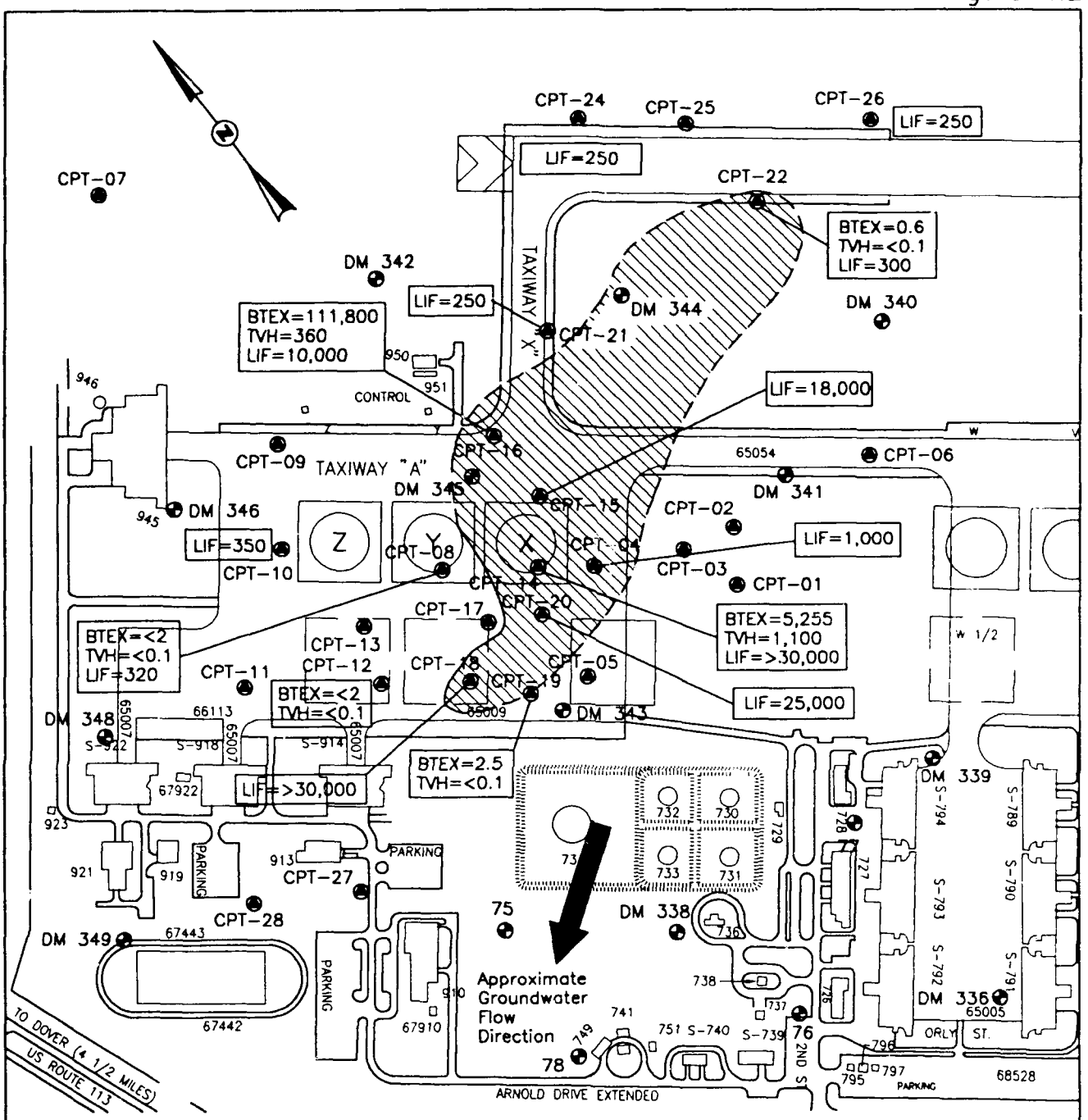
FUEL HYDROCARBON COMPOUNDS AND TOTAL ORGANIC CARBON DETECTED IN SOIL
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a/]	Sample Depth (ft bls)[b/]	Benzene (µg/kg)	Toluene (µg/kg)	Ethyl-benzene (µg/kg)	m,p-Xylene (µg/kg)	o-Xylene (µg/kg)	Total BTEX[c/] (µg/kg)	Total Volatile Hydrocarbons[d/] (mg/kg)	Total Organic Carbon[e/] (mg/kg)	Maximum LIF[f/] Results	
										Relative Intensity	Depth (ft bls)
Soil Test Locations											
CPT-01		NS[g/]	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 42
CPT-02		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 35
CPT-03		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 31
CPT-04		NS	NS	NS	NS	NS	NS	NS	NS	1,200	2
CPT-05		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 21
CPT-06		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 21
CPT-07	16 - 18	NS	NS	NS	NS	NS	NS	NS	0.05 <	< 200	1 - 24
CPT-08	8 - 10	2 <	2 <	2 <	2 <	2 <	2 <	0.1 <	NS	320	10
	14 - 16	2 <	2 <	2 <	2 <	2 <	2 <	0.1 <	NS		
CPT-09		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 28
CPT-10		NS	NS	NS	NS	NS	NS	NS	NS	350	13
CPT-11		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 28
CPT-12	14 - 16	2 <	2 <	2 <	2 <	2 <	2 <	0.1 <	NS	< 200	1 - 28
CPT-13		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 22
CPT-14	13 - 15	75 J	590	590	3,100	900	5,255	1,100 E	1700	> 30,000	4 - 6
CPT-15		NS	NS	NS	NS	NS	NS	NS	NS	1,800	8
CPT-16	7 - 9	8,800	36,000 E	33,000 E	18,000	16,000	111,800	360	NS	1,100	8
	11 - 13	0.4 <	0.4 <	0.4 <	0.5 J	0.4 <	0.5	0.4	NS		
CPT-17		NS	NS	NS	NS	NS	NS	NS	NS	< 200	1 - 28
CPT-18		NS	NS	NS	NS	NS	NS	NS	NS	> 30,000	12, 15
CPT-19	9 - 11	2 <	2 <	2 <	2 <	2 <	2 <	0.2	800	< 200	4 - 28
	15 - 17	0.6 J	1.4 J	0.4 <	0.5 J	0.4 <	2.5	0.1 <	NS		
CPT-20		NS	NS	NS	NS	NS	NS	NS	NS	25,000	14
CPT-21		NS	NS	NS	NS	NS	NS	NS	NS	250	9
CPT-22	13 - 15	0.4 <	0.6	0.4 <	0.4 <	0.4 <	0.6	0.1 <	0.55	300	7
CPT-23		NS	NS	NS	NS	NS	NS	NS	NS	NS	
CPT-24		NS	NS	NS	NS	NS	NS	NS	NS	< 200	2 - 25
CPT-25		NS	NS	NS	NS	NS	NS	NS	NS	< 200	3 - 35
CPT-26		NS	NS	NS	NS	NS	NS	NS	NS	250	9
CPT-27		NS	NS	NS	NS	NS	NS	NS	NS	NS	
CPT-28		NS	NS	NS	NS	NS	NS	NS	NS	NS	
CPT-29		NS	NS	NS	NS	NS	NS	NS	NS	NS	

a/ See Figure 4.2 for sample location.
b/ ft bls = feet below land surface.
c/ Quantified by Method SW8020.
d/ Quantified by Method SW5030/8015 (modified).
e/ Quantified by Method A5310C.
f/ LIF = Laser-Induced Fluorescence readings (relative intensity).
A background LIF reading of 200 (relative intensity) was assumed.
g/ NS = not sampled.

Qualifiers:
< Compound concentration less than the reportable detection limit.
J Indicates an estimated value when the compound is detected, but is below the Practical Quantification Limit.
E Estimated value.

Figure 4.2



LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
BTEX=5,255	Total benzene, toluene, ethylbenzene and xylenes concentration (µg/kg) by SW8020.
TVH=1,100	Total volatile hydrocarbon concentration (mg/kg) by SW8015 (modified).
LIF=>30,000	Laser-induced fluorometry intensity (counts). LIF reading of <200 was considered background.
	Region containing residual LNAPL and/or soil hydrocarbon contamination.
Z	Former C-10 fueling pad.

400' 200' 0 400'

Approximate Scale in Feet

Soil Hydrocarbon Contamination as Indicated by CPT/LIF Results and Laboratory Analytical Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

72245059.dwg + 722450X1.dwg / ps:1=1 / 1-19-96 / TLP

(USEPA) Method SW8020 indicated total BTEX concentrations in soil ranged from less than 2 micrograms per kilogram (μg/kg) to 111,800 μg/kg. Benzene was detected in soil samples from CPT-14, CPT-16, and CPT-19 at concentrations ranging from 0.6 μg/kg to 8,800 μg/kg. The shallow soil sample at CPT-16 (from 7 to 9 feet bls) contained 111,800 μg/kg of total BTEX, while the deeper sample (from 11 to 13 feet bls) contained only 0.5 μg/kg of total BTEX. At CPT-19, both the shallow sample (from 9 to 11 feet bls) and deeper sample (from 15 to 17 feet bls) had BTEX concentrations at or below practical quantification limits (i.e., "J" qualified, estimated values). These data suggest that the area is located close to a release and that CPT-19 is located in an area some distance from a release toward which contamination has migrated (See Figure 4.2).

The laboratory results and LIF data indicate that contaminated soil extends along the groundwater flow direction from the area between CPT-22 and DM 344 to at least CPT-18, and laterally from CPT-16 to between CPT-04 and CPT-03. The area of soil contamination is approximately 1,500 feet long by 300 to 600 feet wide. The areal extent of soil contamination is similar to the areal extent of mobile LNAPL contamination, with additional lateral spreading of the residual soil contamination.

4.3.1.2 Soil TVH Contamination

Table 4.1 also shows soil TVH data, which have a practical quantification limit of 0.1 milligram per kilogram (mg/kg). The results of the TVH analyses [by USEPA Method SW5030/8015 (modified)] correlate well with BTEX results. Theoretically, because BTEX is a subset of TVH, the areas of BTEX and TVH contamination should be the same. TVH concentrations at Site SS27/XYZ range from less than 0.1 mg/kg to 1,100 mg/kg. Figure 4.2 shows the TVH data along with the BTEX and LIF data.

4.3.2 Total Organic Carbon

TOC concentrations are used to estimate the amount of organic matter sorbed to soil particles or trapped in the interstices of a soil matrix. The TOC concentration in the saturated zone is an important parameter used to estimate the amount of contaminant that could potentially be sorbed to the aquifer matrix. Sorption results in retardation of the contaminant plume relative to the advective groundwater velocity. Parsons ES obtained soil core samples from CPT-07, CPT-14, CPT-19, and CPT-22 for TOC analysis (see Table 4.1). The soil samples from CPT-14 and CPT-19 contained TOC concentrations of 1,700 mg/kg and 800 mg/kg, respectively. However, CPT-14 was contaminated by petroleum hydrocarbons. Samples from CPT-07 and CPT-22, which were relatively free from petroleum hydrocarbon contamination, contained TOC concentrations of less than 0.05 mg/kg and 0.55 mg/kg, respectively.

4.4 GROUNDWATER CHEMISTRY

4.4.1 Dissolved BTEX Contamination

Parsons ES collected groundwater samples from 28 of the monitoring points installed during this investigation in April 1994. During the same time period, Dames & Moore, Inc. sampled many of the existing monitoring wells on-Base, including wells at Site SS27/XYZ, as part of a Basewide groundwater sampling event. The groundwater analytical data collected during these investigations are summarized in Table 4.2.

Figure 4.3 is an isopleth map that shows the distribution of total BTEX dissolved in groundwater in April 1994. Isopleths are drawn based on the maximum BTEX concentration detected at each location. Two vertical concentration profiles were also generated for dissolved BTEX, as well as for other dissolved constituents at the site. A

TABLE 4.2

FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a/]	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	m,p-Xylene (µg/L)	o-Xylene (µg/L)	Total BTEX[b/] (µg/L)	Total Trimethyl-benzenes[b/] (µg/L)	Total Volatile Hydro-carbons[c/] (mg/L)	Total Extractable Hydro-carbons[c/] (mg/L)
Groundwater Monitoring Points									
CPT-02S	0.4 J	2.3 J	0.4 <	0.8 J	0.4 J	3.5	1.2 <	0.2	0.5 <
CPT-06S	0.4 <	7.4	0.4 <	0.9 J	0.4 J	8.3	0.2 <	0.2	0.5 <
CPT-07S	0.4 <	15	0.4 J	1.5 J	0.4 J	17.3	0.2 <	0.2	0.5 <
CPT-08S	0.9 J	7.4	0.4 J	1 J	0.5 J	10.2	0.9 J	0.2	0.7
CPT-08D	7.7	19	2.6 J	5.1	2.4	36.8	7.6 J	0.4	0.5 UJ
CPT-09S	2.2 J	2.6 J	0.4 <	1.3 J	0.4 J	6.1	0.6 J	0.2	0.5 <
CPT-10S	0.4 <	3.9 J	0.4 <	0.4 J	0.4 J	4.3	1.2 <	0.1 <	0.5 <
CPT-10S (Dup.)	0.9 J	6.5	0.4 J	0.9 J	0.4 J	9.1	1.1 <	0.2	0.7
CPT-11P	0.4 <	6.5	0.4 <	0.9 J	0.4 J	7.4	0.4 <	0.2	0.5 <
CPT-11S	0.4 <	8.8	0.5 J	1.3 J	0.4 J	11	0.4 <	0.2	0.5 <
CPT-12S	0.4 J	3.7 J	0.4 <	0.6 J	0.4 J	4.7	0.4 <	0.2	0.5 <
CPT-12D	1.7 J	8.3	1.1 J	2.5 J	1.1	14.7	2.8 J	0.1 <	0.5 UJ
CPT-13S	0.9 J	5.6	0.8 J	1.9 J	1.1 J	10.3	0.8 <	NR	NR
CPT-14S	920	430	210	600	190	2350	455	14	5.9 J
CPT-14S (Dup.)	960	460	240	730	210	2600	744	NS[d/]	NS
CPT-15S	970,000 E	2,500,000 E	1,600,000 E	4,200,000	2,000,000 E	11,300,000	11,600,000 E	NS	NS
CPT-16S	14	34	54	44	11	157	180	1.1	2.5
CPT-16D	350 E	64	28	24	14	480	61	NS	NS
CPT-18S	6,500	13,000	820	1,600	1,000	22,900	980	NS	NS
CPT-19S	0.4 <	2.8 UJ	0.4 <	0.9 J	0.5 J	4.2	2.3	0.1 <	0.5 UJ
CPT-19D	22	49	12	38	15	136	22	0.4	0.5 UJ
CPT-21S	55	150	30	99	44	378	32	1.4	0.8
CPT-22S	6.7	45	7	32	16	107	26	0.5	0.5 UJ
CPT-22D	1.1 J	14	0.7 J	2.1 J	0.9 J	18.8	2.8 J	NS	NS
CPT-25S	1.2 J	13	2.1 J	5.5	3.4	25.2	8.1	0.1 <	0.5 UJ
CPT-26S	0.9 J	6.1	1.5 J	3.9 J	2.7	15.1	6.5	NS	NS
CPT-27S	0.7 J	6	1.5 J	4.6	1.7	14.5	6.9 J	0.2	0.5 <
CPT-27D	5.4	18	1.7 J	3.7 J	2.5	31.3	2.0 J	NS	NS
CPT-28S	5	54	5	19	6	89	8.7 J	NS	NS
CPT-29S	0.4 <	22	0.5 J	1.6 J	0.6 J	24.7	1.8 J	NS	NS
CPT-29S (Dup.)	0.4 <	21	0.6 J	1.7 J	0.9 J	24.2	2.0 J	NS	NS

TABLE 4.2 (CONCLUDED)

FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a/]	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	Total BTEX[b/] (µg/L)	Total Trimethyl-benzenes[b/] (µg/L)	Total Volatile Hydro-carbons[c/] (mg/L)	Total Extractable Hydro-carbons[c/] (mg/L)
Monitoring Wells								
DM 341S[e/]	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 341D	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 341DD	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 342S	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 342D	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 343S	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 343D	1 <	1 <	1 <	1 <	4 <	NS	NS	NS
DM 344S	26,000 E	49,000 E	66,000 E	270,000 E	411,000 E	1,900,000 E	NS	NS
DM 344D	560	42 <	82	5 J	647 J	NS	NS	NS
DM 345S	8 <	0.8 <	16	13	29	NS	NS	NS
DM 345S (Dup.)	8 <	0.8 <	16	14	30	NS	NS	NS

[a/] See Figure 4.3 for sample locations.

[b/] Quantified by Method SW8020.

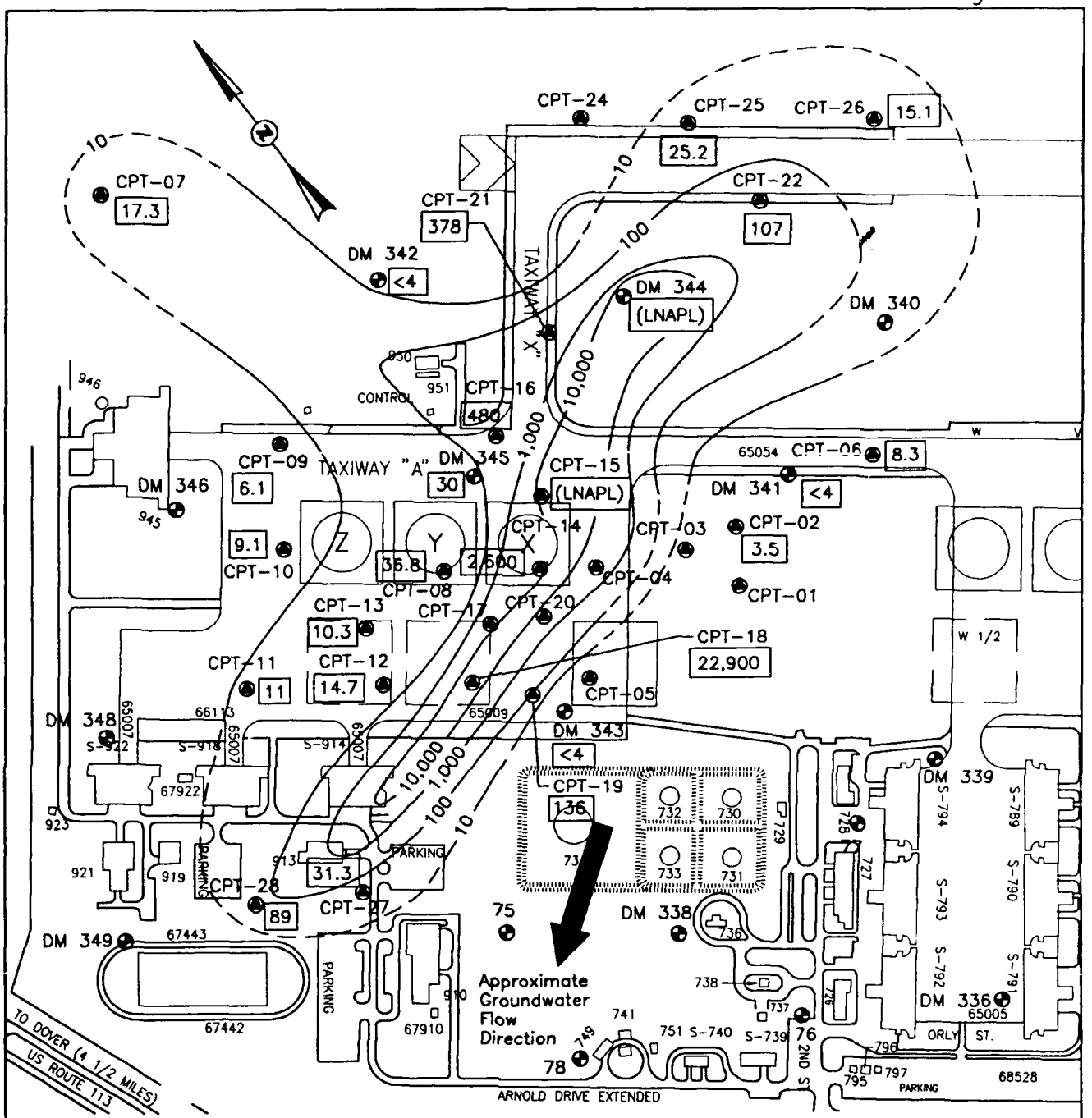
[c/] Quantified by SW8015 (modified).

[d/] Not sampled.

[e/] Samples from Dames & Moore, Inc. monitoring wells (e.g., DM 341S) were collected by Dames & Moore, Inc. and analyzed by a laboratory using different QA/QC standards. As a result, detection limits vary.

Qualifiers:
- < Compound concentration is less than reportable detection limit.
- J Indicates an estimated value when the compound is detected, but is below the Practical Quantification Limit.
- E Extrapolated value.
- UJ Not detected above the the reported quantification limit. However, the reported quantification limit is approximate.

Figure 4.3



LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
89	Total benzene, toluene, ethylbenzene and xylenes (BTEX) concentration (µg/L).
—10—	Total BTEX concentration (µg/L) contour, dashed where inferred.
(LNAPL)	LNAPL emulsified in sample.
②	Former C-10 fueling pad.

400' 200' 0 400'

Approximate Scale in Feet

Total Dissolved BTEX Isopleth Map
April 1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

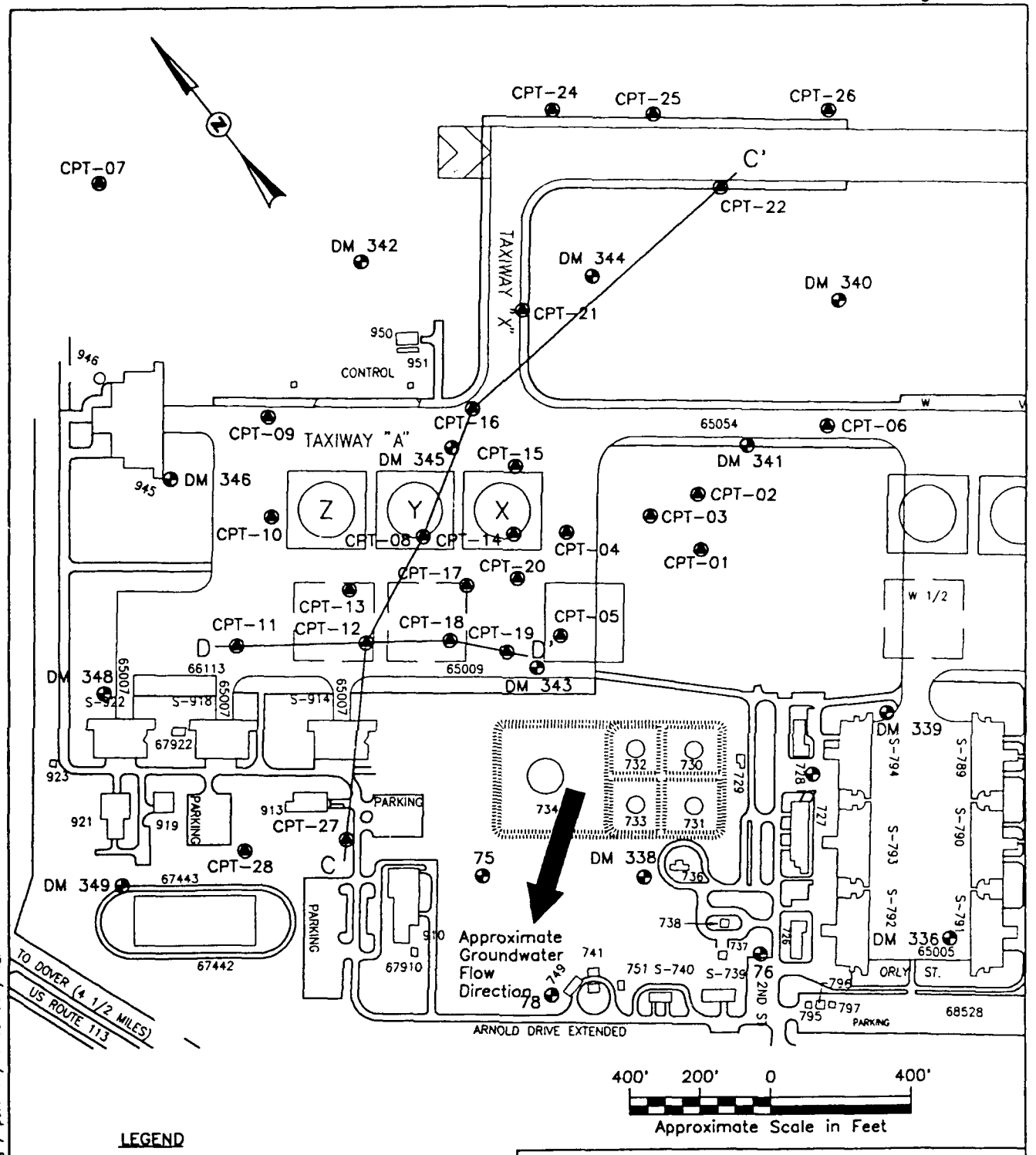
72245060.dwg + 722450X1.dwg / ps:1=1 / 1-19-96 / TLP

cross-section location map showing the locations for the concentration profiles is shown in Figure 4.4. Figure 4.5 is the vertical profile of BTEX concentrations along the center line of the contaminant plume in the primary direction of groundwater flow (cross-section C-C'). Figure 4.6 shows a vertical profile of BTEX concentrations perpendicular to the direction of groundwater flow (cross-section D-D').

The primary direction of migration of dissolved BTEX contamination in groundwater is to the southwest (the primary direction of flow at Site SS27/XYZ). Dissolved BTEX contamination also appears to have migrated from the source area at Site SS27/XYZ to the northeast and to the northwest (the secondary directions of flow). As delineated by the 10-μg/L total BTEX isopleth, the overall dimensions of the contaminant plume from the northeast to southwest edges are approximately 3,000 feet long by 750 feet wide. In the primary direction of flow (southwest), the plume extends approximately 1,700 feet downgradient from the source area. The plume also extends approximately 1,300 feet to the northeast from the source area. In the northwest direction of migration, the plume extends about 1,500 feet from the source area to the vicinity of CPT-07.

The BTEX plume, as reported by Dames & Moore and HAZWRAP (1993), included an additional lobe trending to the south. The length of this lobe was reported to be 300 feet. However, the data evaluated during this investigation does not suggest the presence of this southward-trending plume lobe.

The vertical profile shown in Figure 4.5 suggests that the plume has migrated downward in the vicinity of CPT-16 and CPT-08. As shown in the profile, at CPT-22, greater BTEX concentrations were present within shallower zones of the aquifer in the upgradient area of the site. However, the vertical profile perpendicular to the direction of groundwater flow shown in Figure 4.6 shows greater concentrations of BTEX at



LEGEND

DM 341 ⊕ Monitoring well.

CPT-01 ⊕ Monitoring point and CPT test location installed by CPT rig.

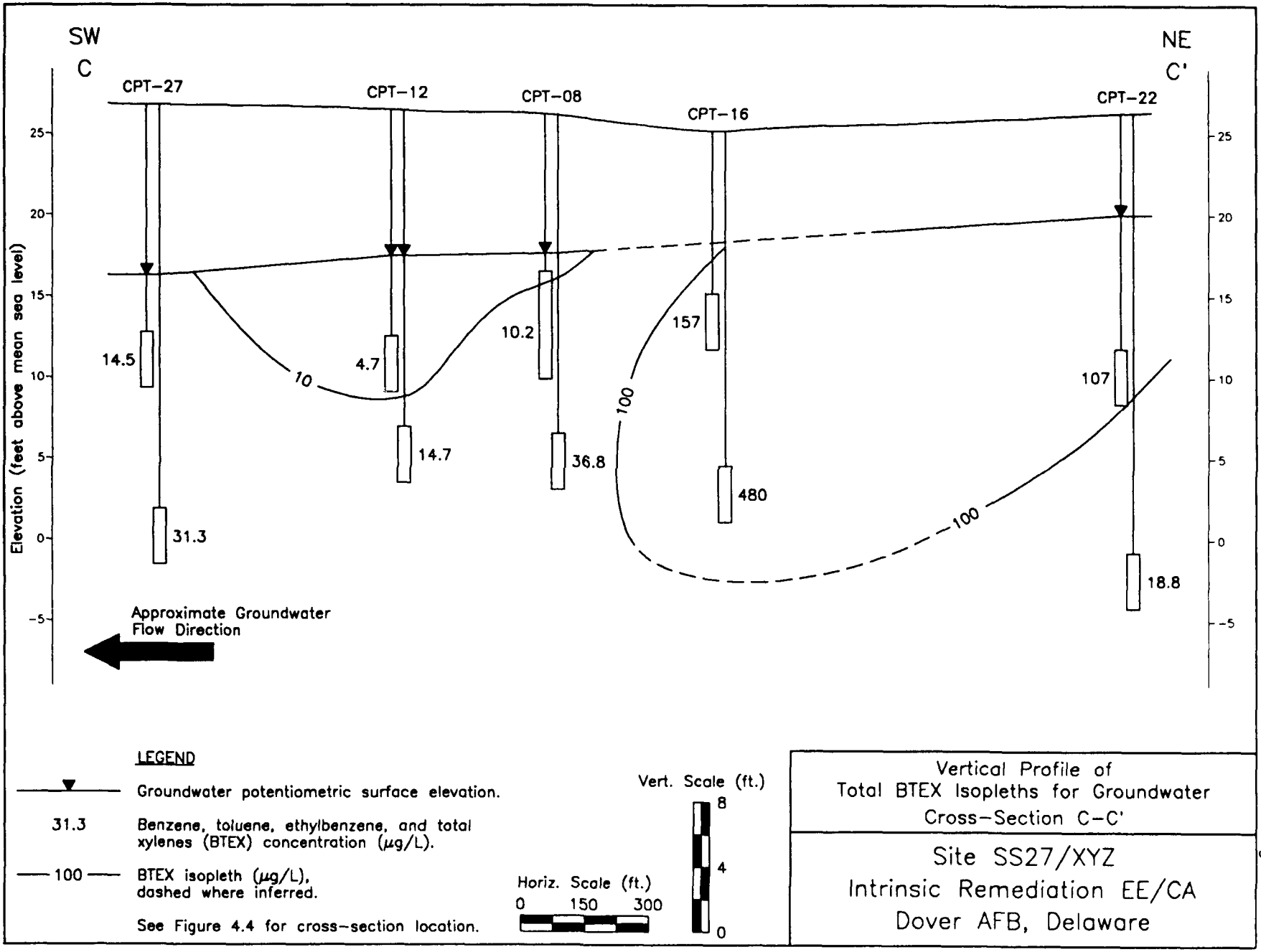
C—C' Cross-section.

Ⓩ Former C-10 fueling pad.

Cross-Section Location Map for Dissolved Groundwater Constituents

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

72245003.dwg + 722450X1.dwg / ps:1=1 / 1-19-96 / TLP

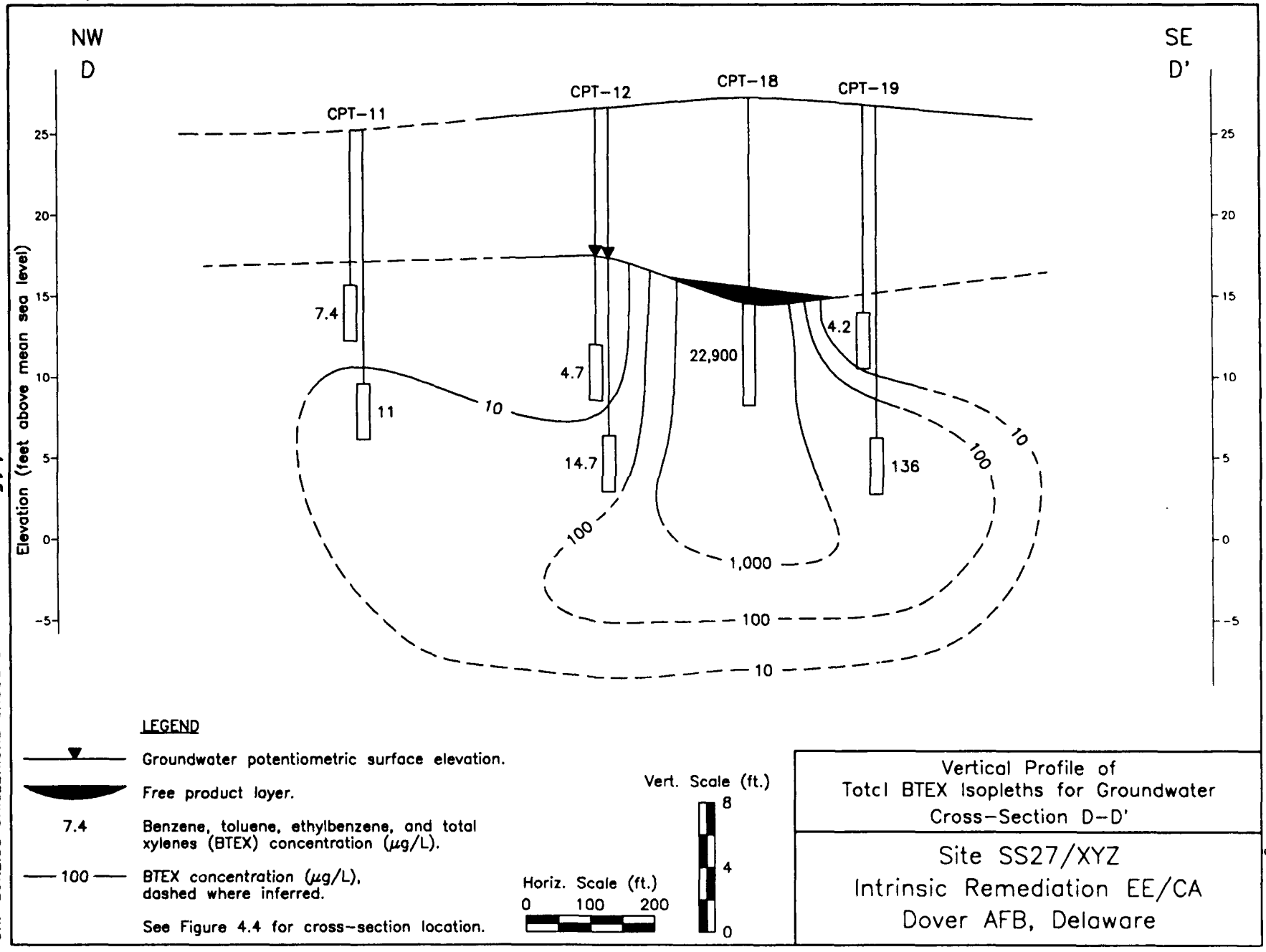


Vertical Profile of
Total BTEX Isopleths for Groundwater
Cross-Section C-C'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.5

72245069.dwg / 1=1 / 1-19-96 / TLP



Vertical Profile of
Totcl BTEX Isopleths for Groundwater
Cross-Section D-D'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.6

depth in the profiled monitoring point clusters. The vertical BTEX profile (Figure 4.6) also suggests that lateral spreading of the BTEX plume occurs as the plume migrates downward through the aquifer. This pattern may also result from seasonal variations in location and orientation of the groundwater divide, which may cause additional lateral dispersion of BTEX constituents. Where groundwater elevation data were collected in monitoring point and monitoring well clusters, downward gradients always were observed. The confining layer present at approximately 30 feet bls likely will retard vertical migration of dissolved BTEX. Both monitoring wells DM 344S and DM 344D are screened within the shallow surficial aquifer. However, comparison of BTEX concentrations (Table 4.2) indicate that vertical migration is minimized at this location.

Thirteen monitoring points and wells at Site SS27/XYZ that were sampled during this investigation contained groundwater with reportable dissolved benzene concentrations above the Delaware groundwater standard and the federal maximum contaminant level (MCL) of 5 μg/L (BNA, 1994). Three of the monitoring points and wells at the site (DM 344S, CPT-15S, and CPT-18S) contained BTEX concentrations that exceeded the theoretical solubility of BTEX for JP-4 and water (22,600 μg/L). This suggests that emulsification of mobile LNAPL in the water samples had occurred. Where detected at levels not reflective of emulsification, benzene concentrations ranged from 0.4 μg/L at CPT-02S and CPT-12S to 960 μg/L at CPT-14S (Table 4.2). Concentrations exceeded the Delaware groundwater standards and federal MCLs (BNA, 1994) for toluene (1,000 μg/L), ethylbenzene (700 μg/L), and xylenes (10,000 μg/L) only in the monitoring points and wells where mobile LNAPL was suspected.

4.4.2 Groundwater Geochemistry

Microorganisms obtain energy for cell production and maintenance by facilitating

the transfer of electrons from electron donors to electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Potential electron donors at Site SS27/XYZ are natural organic carbon constituents and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992). Electron acceptors are elements or compounds that occur in relatively oxidized states and include DO (O_2), nitrate (NO_3^{-2}), ferric iron (Fe^{+3}), sulfate (SO_4^{-2}), and carbon dioxide (CO_2). Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). Typically, DO is utilized first by aerobic organisms as the primary electron acceptor. After the DO is consumed, anaerobic microorganisms typically use electron acceptors in the following order of preference: nitrate, ferric iron, sulfate, and finally carbon dioxide.

Depending on the types of electron acceptors present (e.g., nitrate, sulfate, carbon dioxide), pH conditions, and redox potential, anaerobic biodegradation can occur by denitrification, ferric iron reduction, sulfate reduction, or methanogenesis. Other, less common anaerobic degradation mechanisms such as manganese reduction and nitrate reduction may dominate if the physical and chemical conditions in the subsurface favor these reactions. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990). Environmental conditions and microbial competition will ultimately determine which processes will dominate. Vroblesky and Chapelle (1994) show that the dominant terminal electron accepting process can vary both temporally and spatially in a fuel-hydrocarbon-contaminated aquifer.

Electron acceptor concentration data obtained at Site SS27/XYZ indicate that intrinsic remediation of hydrocarbons in the shallow aquifer may be occurring by

aerobic oxidation, denitrification, ferric iron reduction, and sulfate reduction. This is evidenced by significant changes in groundwater geochemistry in comparison to background conditions. Areas of the site which show the greatest variation in concentrations of geochemical parameters generally correspond well with areas of low redox potential and high BTEX concentration. Table 4.3 summarizes groundwater geochemical data gathered during the intrinsic remediation site investigation at Dover AFB. Geochemical parameters for Site SS27/XYZ are discussed in the following sections.

4.4.2.1 Dissolved Oxygen

DO concentrations were measured at monitoring points and monitoring wells during April 1994. Table 4.3 includes a summary of measured DO concentrations. Figure 4.7 is an isopleth map showing the horizontal distribution of DO concentrations in groundwater at Site SS27/XYZ. Figures 4.8 and 4.9 show vertical profiles of DO along the cross-sections shown in Figure 4.4. Comparisons of Figure 4.3 with Figure 4.7, Figure 4.5 with Figure 4.8, and Figure 4.6 with Figure 4.9 show graphically that both the horizontal and vertical distribution of groundwater with elevated total BTEX concentrations correspond to the distribution of groundwater with reduced DO concentrations. The lowest measured DO concentration at the site was 0.1 mg/L, measured at CPT-02S. These data provide a strong indication that aerobic biodegradation of the BTEX compounds is occurring at the site. Given that high background DO concentrations were measured at the site at monitoring points CPT-07D (5.2 mg/L) and CPT-11P (6.1 mg/L) and at monitoring wells DM 342D (7.4 mg/L), DM 346S (7.5 mg/L), and DM 348S (8.3 mg/L), it is likely that DO is an important electron acceptor at Site SS27/XYZ.

TABLE 4.3

GROUNDWATER GEOCHEMICAL DATA
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a/]	Water Temp.[b/] (C)	pH[b/]	Dissolved Oxygen[b/] (mg/L)	Redox Potential[b/] (mV)	PID Headspace[b/] (ppmv)	Total Alkalinity[c/] (mg/L)	Nitrate[d/] (mg/L)	Nitrite[d/] (mg/L)	Sulfate[d/] (mg/L)	Hydrogen Sulfide[d/] (mg/L)	Ferrous Iron[d/] (mg/L)
Groundwater Monitoring Points											
CPT-01S	12.7	4.79	0.4	-47.6	NS[e/]	NS	NS	NS	NS	NS	NS
CPT-02S	NS	5.67	0.1	-356.0	NS	110	0.3	0.002	28.6	0.072	0.65
CPT-03S	13.1	5.84	5.0	NS	2.8	NS	1.1	0.00	25.1	0.022	0.34
CPT-04S	13.1	5.88	0.3	6.3	2.9	NS	1.3	0.002	24.8	0.027	1.73
CPT-06S	14.0	6.01	0.5	93.1	0	38	0.0	0.00	59.6	0.006	1.74
CPT-07S	14.7	5.25	4.9	191.2	0.8	21.8	2.7	0.001	16.8	0.022	0.26
CPT-07D	14.8	5.30	5.2	187.4	7	NS	0.0	0.001	28.1	0.049	0.10
CPT-08S	15.8	5.37	0.4	-161.4	4.3	36.8	0.2	0.006	25.9	0.027	2.05
CPT-08D	16.2	4.86	0.3	130.0	NS	15.3	0.8	0.001	50.7	0.026	1.80
CPT-09S	14.2	6.19	0.7	NS	28	102	0.0	0.00	40.3	0.017	1.68
CPT-10S	14.2	6.28	0.5	-370.3	2.6	40.5	3.5	0.004	22.8	0.016	1.56
CPT-11P	14.1	5.47	6.1	148.8	497	9.22	10.6	0.048	26.1	0.000	1.71
CPT-11S	14.9	5.34	0.4	39.1	15	11.8	18.4	0.014	8.7	0.019	1.00
CPT-12S	14.7	4.93	0.3	88.6	2.5	23.5	2.6	0.003	4.0	0.035	1.46
CPT-12D	15.5	4.92	0.4	129.6	NS	12.6	0.2	0.001	53.6	0.025	0.23
CPT-13S	15.5	5.26	0.4	NS	NS	21.8	1.1	0.00	30.4	0.040	1.30
CPT-14S	16.9	6.02	0.6	-104.0	300	198	1.3	0.009	9.6	0.041	1.49
CPT-15S	14.0	5.81	0.3	-153.0	NS	NS	NS	NS	NS	0.000	NS
CPT-16S	17.0	5.72	4.2	-119.8	NS	122	1.7	0.006	7.4	0.021	1.61
CPT-16D	16.5	6.08	0.3	-431.0	NS	195	NS	NS	NS	0.000	NS
CPT-17S	14.0	5.73	0.3	9.6	8.6	NS	0.8	0.004	48.8	0.193	1.55
CPT-18S	14.0	6.38	0.5	-94.0	NS	155	0.3	0.00	4.9	0.000	1.57
CPT-19S	13.7	5.96	0.4	-82.3	1959	163	0.6	0.003	64.1	0.022	1.35
CPT-19D	15.5	4.95	0.6	115.1	167	13.5	0.1	0.001	27.4	0.010	0.09
CPT-20S	12.1	5.70	0.4	-90.2	458	NS	NS	NS	NS	0.000	NS
CPT-21S	NS	NS	1.0	NS	NS	23.1	1.1	0.001	18.8	0.026	1.70
CPT-22S	13.1	7.31	0.6	108.8	10.7	NS	1.1	0.004	33.1	0.012	0.35
CPT-22D	15.0	6.15	0.3	285.0	NS	NS	NS	NS	NS	0.000	NS
CPT-25S	13.0	6.03	0.5	136.7	2.9	NS	0.0	0.005	60.4	0.064	1.27
CPT-26S	13.5	6.23	0.8	37.4	NS	NS	0.1	0.00	18.8	0.061	1.36
CPT-27S	15.0	4.47	2.2	185.0	NS	5.00	0.1	0.014	32.9	0.033	0.16
CPT-27D	17.3	4.96	0.6	88.4	NS	8.50	NS	NS	NS	0.000	NS
CPT-28S	20.7	6.29	0.2	-102.5	NS	52.6	NS	NS	NS	0.000	NS
CPT-29S	15.5	5.38	1.9	380.0	NS	NS	NS	NS	NS	0.000	NS

TABLE 4.3 (CONCLUDED)

GROUNDWATER GEOCHEMICAL DATA
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Sample Location[a/]	Water Temp.[b/] (C)	pH[b/]	Dissolved Oxygen[b/] (mg/L)	Redox Potential[b/] (mV)	PID Headspace[b/] (ppmv)	Total Alkalinity[c/] (mg/L)	Nitrate[d/] (mg/L)	Nitrite[d/] (mg/L)	Sulfate[d/] (mg/L)	Hydrogen Sulfide[d/] (mg/L)	Ferrous Iron[d/] (mg/L)
Monitoring Wells											
DM 204S	10.6	6.50	2.0	229	NS	NS	NS	NS	NS	NS	NS
DM 204D	11.7	6.47	0.3	-233	NS	NS	NS	NS	NS	NS	NS
DM 339S	14.3	5.67	0.3	-209	NS	NS	NS	NS	NS	NS	NS
DM 339D	16.5	5.81	0.2	-216	NS	NS	NS	NS	NS	NS	NS
DM 340S	10.1	4.80	NS	352	NS	NS	NS	NS	NS	NS	NS
DM 341S	NS	5.54	2.0	221	NS	NS	NS	NS	NS	NS	NS
DM 341D	NS	5.50	3.3	238	NS	NS	NS	NS	NS	NS	NS
DM 342S	10.1	5.29	NS	59.7	NS	NS	NS	NS	NS	NS	NS
DM 342D	11.7	5.72	7.4	36.5	NS	NS	NS	NS	NS	NS	NS
DM 343D	17.0	5.50	0.3	120	NS	NS	NS	NS	NS	NS	NS
DM 343S	14.7	5.67	0.2	166	NS	NS	NS	NS	NS	NS	NS
DM 346D	15.8	6.18	4.5	359	NS	NS	NS	NS	NS	NS	NS
DM 346S	13.5	5.47	7.5	373	NS	NS	NS	NS	NS	NS	NS
DM 348S	9.9	5.99	8.3	235	NS	NS	NS	NS	NS	NS	NS
DM 348D	13.1	5.60	4.8	275	NS	NS	NS	NS	NS	NS	NS

[a/] See Figure 4.5 for sample locations.

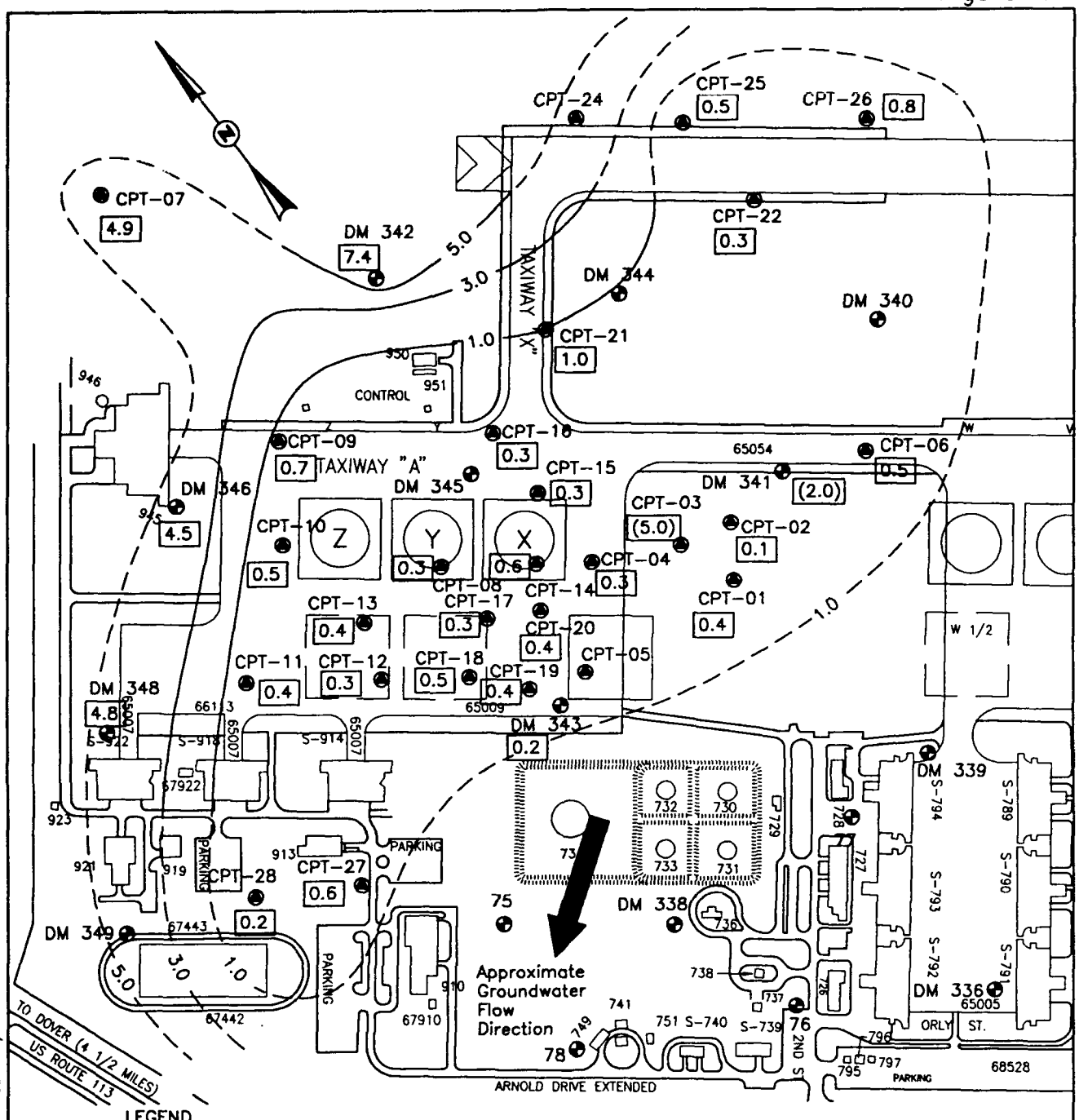
[b/] Quantified by portable field instruments. See Section 2.

[c/] Quantified by Method A403.

[d/] Quantified by Hach field tests.

[e/] NS = Not sampled.

Figure 4.7



LEGEND

DM 341 ●	Monitoring well.
CPT-01 ●	Monitoring point and CPT test location installed by CPT rig.
0.2	Dissolved oxygen concentration (mg/L).
(5.0)	Data not used to develop contours.
—1.0—	Dissolved oxygen isopleth (mg/L), dashed where inferred.
Z	Former C-10 fueling pad.
Note:	Interval with most conservative value is reported.

400' 200' 0 400'

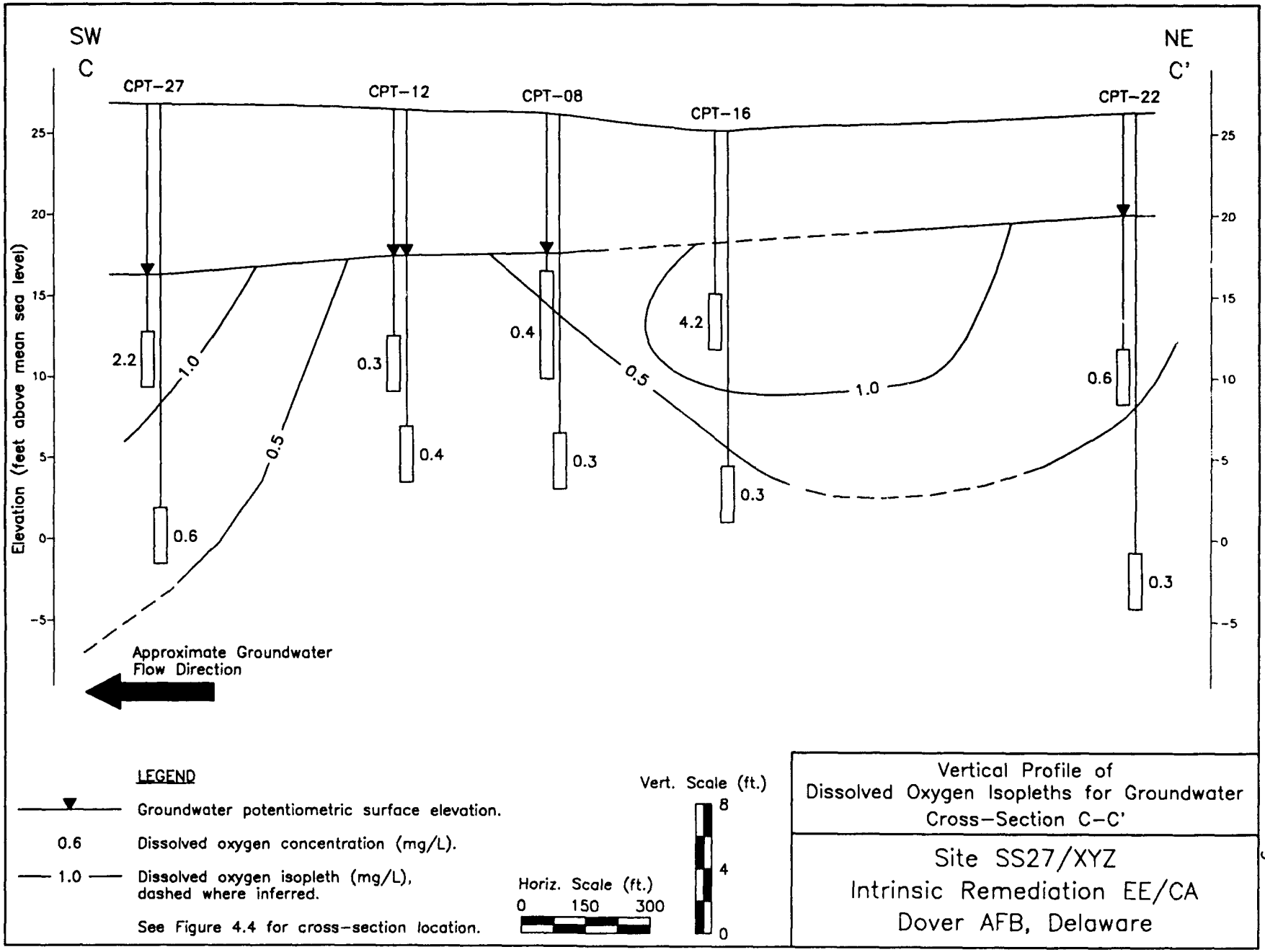
Approximate Scale in Feet

Dissolved Oxygen Isopleth Map
April 1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

72245061.dwg + 722450X1.dwg / ps:1=1 / 1-22-96 / TLP

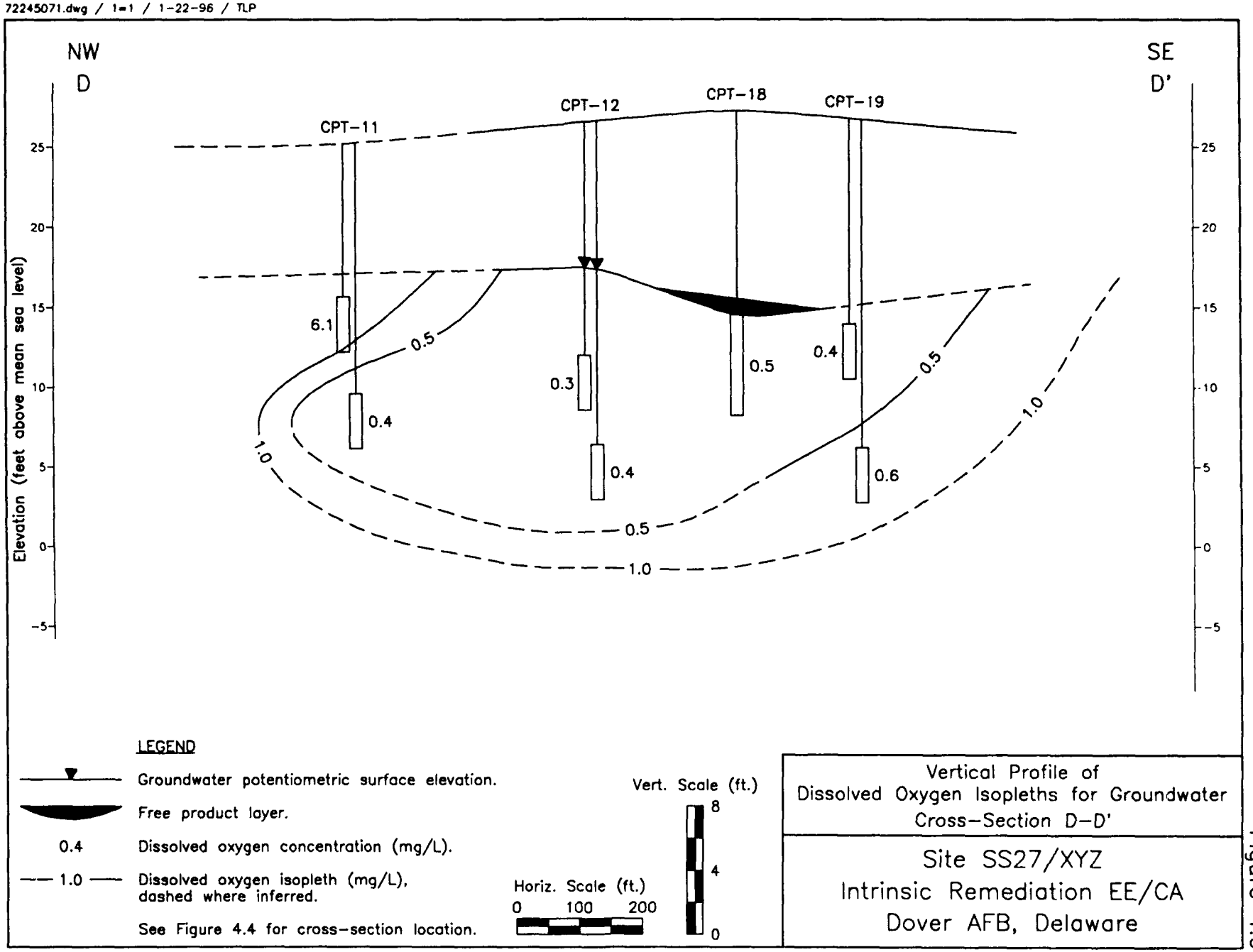
PARSONS ENGINEERING SCIENCE, INC.



Vertical Profile of Dissolved Oxygen Isopleths for Groundwater Cross-Section C-C'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.8



Vertical Profile of
Dissolved Oxygen Isopleths for Groundwater
Cross-Section D-D'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.9

The following equations describe the overall stoichiometry of aromatic hydrocarbon mineralization caused by microbial biodegradation. In the absence of microbial cell production, the oxidation (mineralization) of benzene to carbon dioxide and water is given by:

$$C_6H_6 + 7.5O_2 \rightarrow 6CO_{2(g)} + 3H_2O$$

Therefore, 7.5 moles of oxygen are required to metabolize 1 mole of benzene. On a mass basis, the ratio of oxygen to benzene is given by:

Molecular weights:	Benzene	6(12) + 6(1) = 78 gm
	Oxygen	7.5(32) = 240 gm
	Mass Ratio of Oxygen to Benzene = 240/78 = 3.08:1	

Therefore, in the absence of microbial cell production, 3.08 mg of oxygen are required to completely metabolize 1 mg of benzene.

Similar calculations can be applied for toluene (3.13 oxygen to 1 toluene), ethylbenzene (3.17 oxygen to 1 ethylbenzene), and xylenes (3.17 oxygen to 1 xylene). The average mass ratio of oxygen to total BTEX is thus 3.14:1. This means that approximately 0.32 mg of BTEX is mineralized for every 1.0 mg of DO consumed. As a conservative estimate, a background DO concentration of 5 mg/L was assumed. Under this assumption, the shallow groundwater at this site has the capacity to assimilate 1.6 mg/L (1,600 μg/L) of total BTEX. This may be a conservative estimate of the assimilative capacity of DO because microbial cell mass production was not taken into account by the stoichiometry shown above.

When cell mass production is accounted for, the mineralization of benzene to carbon dioxide and water is given by:

$$C_6H_6 + 2.5O_2 + HCO_3^{-1} + NH_4^{+1} \rightarrow C_5H_7O_2N + 2CO_{2(g)} + 2H_2O$$

Note that only 2.5 moles of DO are required to mineralize 1 mole of benzene when cell mass production is taken into account. On a mass basis, the ratio of DO to benzene is given by:

Molecular weights: Benzene $6(12) + 6(1) = 78$ gm

Oxygen $2.5(32) = 80$ gm

Mass ratio of oxygen to benzene = 80/78 = 1.03:1

On the basis of these stoichiometric relationships, 1.03 mg of oxygen are required to convert 1 mg of benzene into biomass, CO_2, and H_2O. Similar calculations can be made for toluene, ethylbenzene, and xylenes. Based on these calculations, approximately 0.97 mg of BTEX is converted into biomass and mineralized to carbon dioxide and water for every 1.0 mg of DO consumed. With an assumed background DO concentration of approximately 5 mg/L, the shallow groundwater at Site SS27/XYZ has the capacity to assimilate up to 4.8 mg/L (4,800 μg/L) of total BTEX if microbial cell mass production is taken into account.

4.4.2.2 Nitrate/Nitrite

Concentrations of nitrate + nitrite (as nitrogen) were measured in groundwater monitoring points in April 1994. Table 4.3 includes a summary of these concentrations. The measured nitrate concentrations were generally on the order of 10 to 1,000 times greater than nitrite concentrations. As a result, only nitrate concentrations were considered to be an important indicator of ongoing denitrification at the site. Relatively high nitrate concentrations were observed at CPT-11P (10.6 mg/L) and CPT-11S (18.4 mg/L). The BTEX concentrations detected in both of these monitoring points were relatively low. More moderate nitrate concentrations

were observed at CPT-10S (3.5 mg/L), CPT-07S (2.7 mg/L), and CPT-12S (2.6 mg/L), which also had low BTEX concentrations. Based upon these data, background nitrate concentrations at the site may range from 3 mg/L to 18 mg/L. Figure 4.10 is an isopleth map showing the distribution of nitrate + nitrite (as nitrogen) concentrations. Comparison with Figure 4.3 shows graphically that areas with elevated total BTEX concentrations generally have decreased nitrate + nitrite concentrations. Figures 4.11 and 4.12 are vertical profiles of nitrate concentrations along cross-sections C-C' and D-D', respectively.

The moderate to low nitrate concentrations observed in the center of the BTEX plume indicate that anaerobic biodegradation of BTEX is occurring through the microbially mediated process of denitrification. Nitrate reduction may be a significant removal mechanism if actual background nitrate concentrations are as high as 18 mg/L. However, as a conservative assumption, an assumed background nitrate concentration of 5.0 mg/L was utilized to estimate assimilative capacity by denitrification.

In the absence of microbial cell production, the biodegradation of benzene to carbon dioxide and water by the denitrification process is given by:

$$6\,NO_3^- + 6H^+ + C_6H_6 \rightarrow 6H_2O + 3N_{2(g)}$$

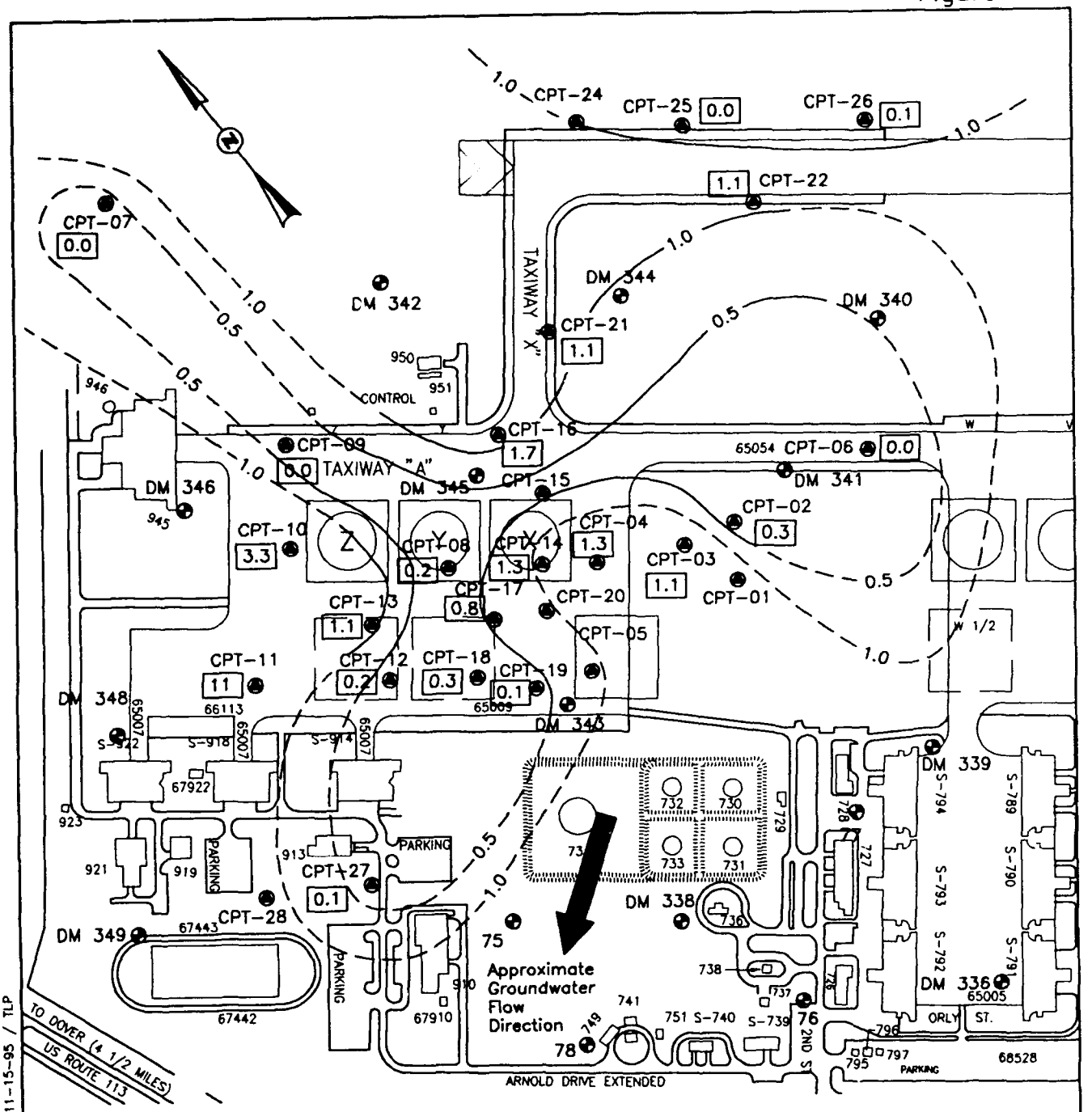
Based on this relationship, 6 moles of nitrate are required to mineralize 1 mole of benzene. On a mass basis, the ratio of nitrate to benzene is given by:

Molecular weights: Benzene $6(12) + 6(1) = 78$ gm

Nitrate $14 + 3(16) = 62$ gm

Mass ratio of nitrate to benzene $= 6(62)/78 = 4.77:1$

Figure 4.10



LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
1.1	Dissolved nitrate and nitrite concentration (mg/L as nitrogen).
—1.0—	Dissolved nitrate and nitrite isopleth (mg/L as nitrogen), dashed where inferred.
②	Former C-10 fueling pad.
Note:	Interval with most conservative value is reported.

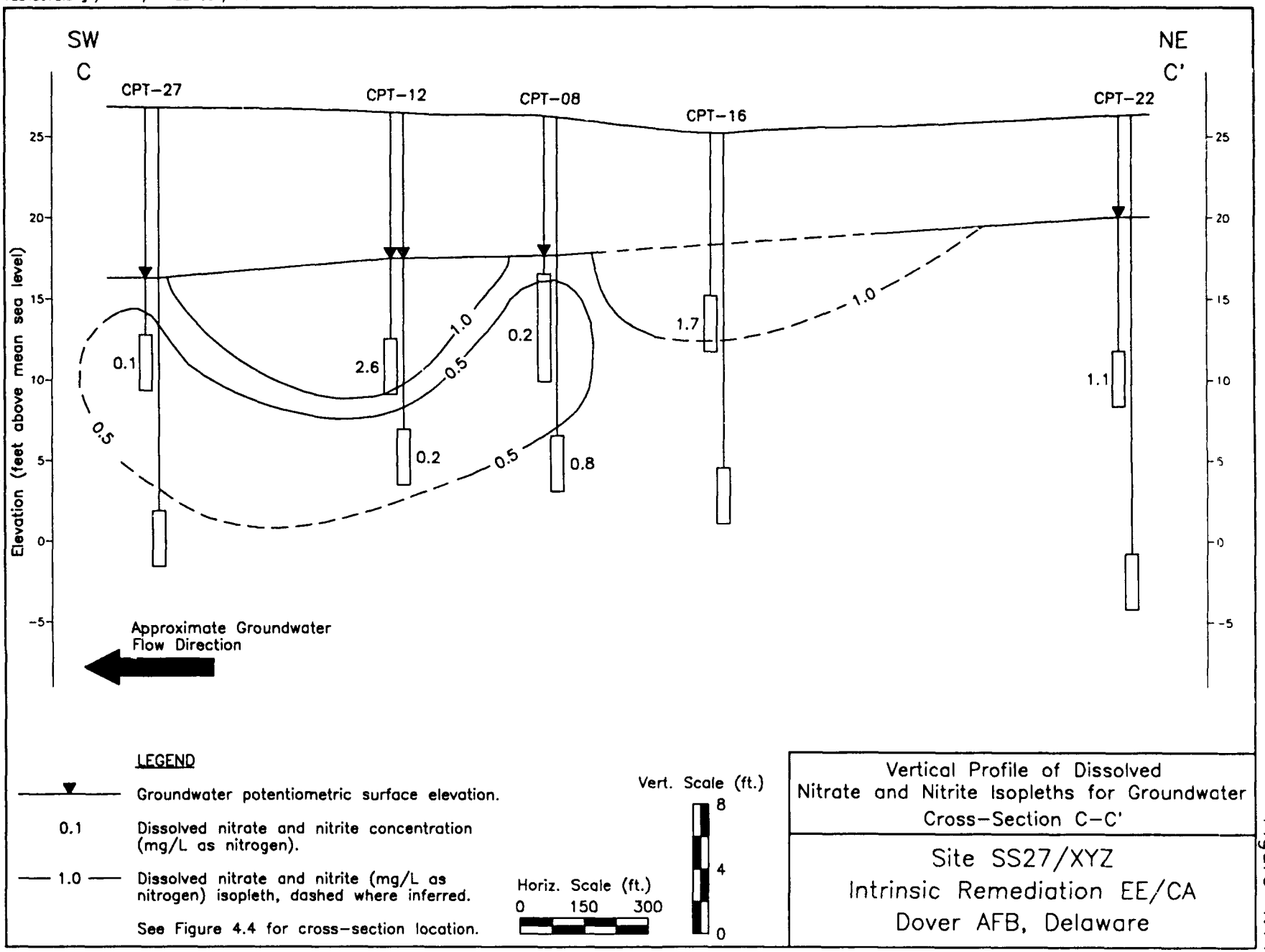
400' 200' 0 400'

Approximate Scale in Feet

Nitrate and Nitrite (as Nitrogen) Isopleth Map for Groundwater

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

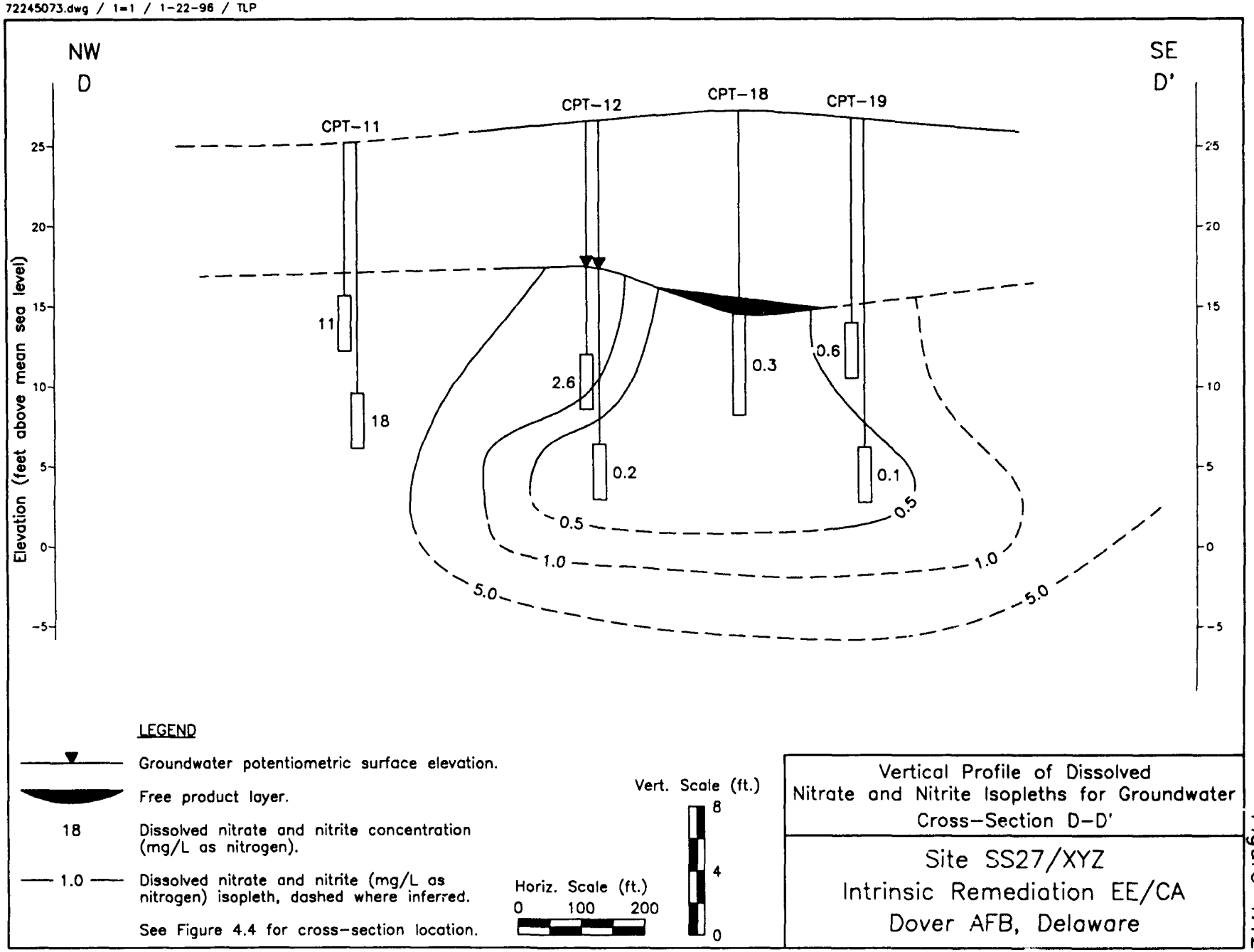
72245062.dwg + 722450X1.dwg / ps:1=1 / 11-15-95 / TLP



Vertical Profile of Dissolved Nitrate and Nitrite Isopleths for Groundwater Cross-Section C-C'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.11



Vertical Profile of Dissolved Nitrate and Nitrite Isopleths for Groundwater Cross-Section D-D'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

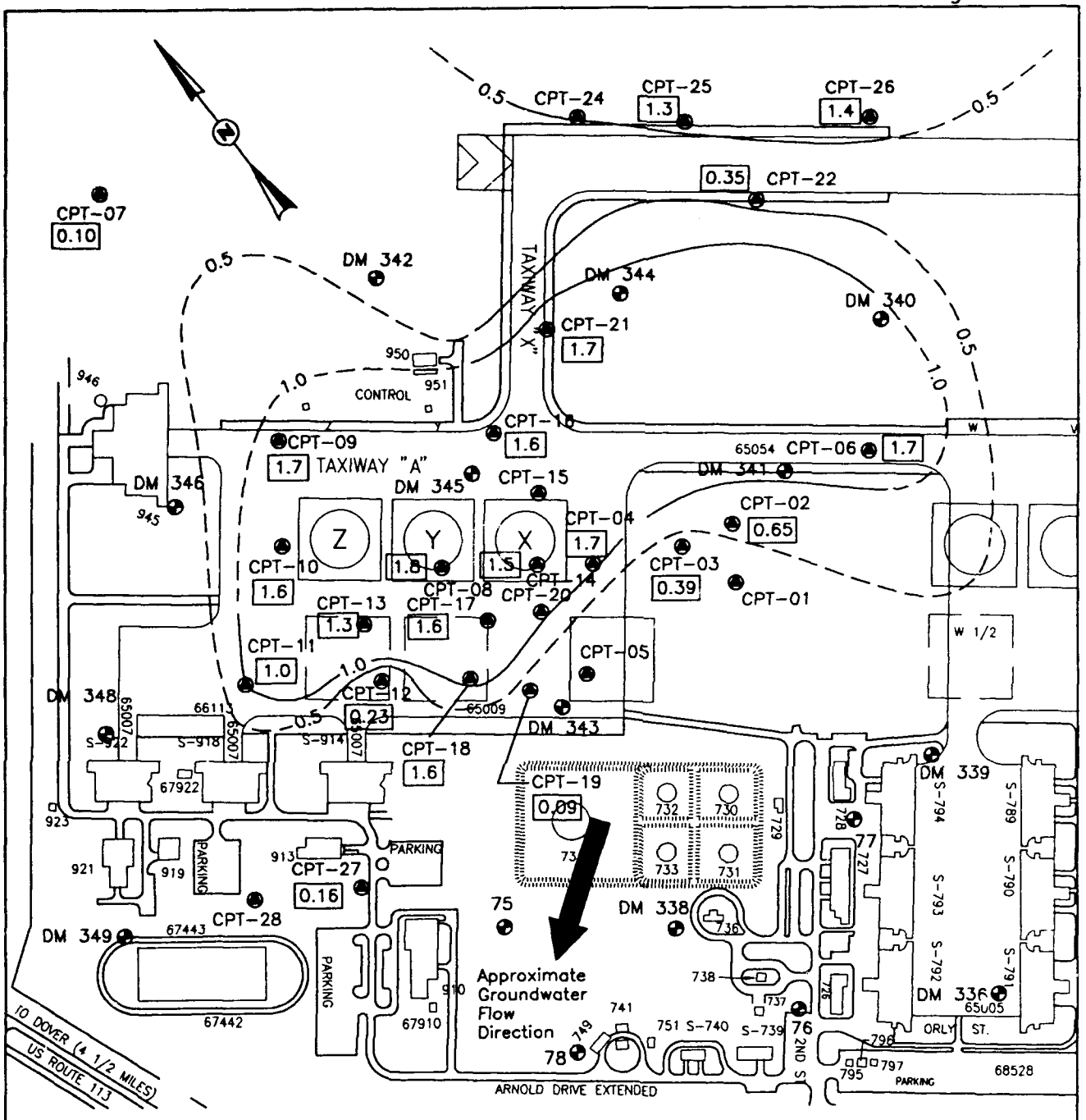
Figure 4.12

In the absence of microbial cell production, 4.77 mg of nitrate are required to completely mineralize 1 mg of benzene. Similar calculations can be completed for toluene (4.85 mg of nitrate to 1 mg toluene), ethylbenzene (4.92 mg nitrate to 1 mg ethylbenzene), and the xylenes (4.92 mg nitrate to 1 mg xylene). The average mass ratio of nitrate consumed to total BTEX degraded is 4.86:1. This means that approximately 0.20 mg of BTEX is mineralized for every 1.0 mg of nitrate consumed. With an assumed background nitrate concentration of 5 mg/L, the shallow groundwater at this site has the capacity to assimilate 1.0 mg/L (1,000 μg/L) of total BTEX during denitrification. This may be a conservative estimate of the assimilative capacity of nitrate because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1).

4.4.2.3 Ferrous Iron

Ferrous iron concentrations were measured at groundwater monitoring points in April 1994 and are included in the data summary in Table 4.3. Figure 4.13 is an isopleth map showing the distribution of ferrous iron in groundwater. Figures 4.14 and 4.15 are vertical profiles of measured ferrous iron concentrations at Site SS27/XYZ. Comparison of Figures 4.13 and 4.3 shows graphically that the areal distribution of Figure 4.13 higher ferrous iron concentrations correspond well to areas of higher BTEX concentrations. This suggests that ferric iron is being reduced to ferrous iron during biodegradation of BTEX compounds. The highest measured ferrous iron concentrations were generally detected in monitoring points that exhibited the highest BTEX concentrations (in the central portion of the contaminant plume). Detection of ferrous iron at some monitoring points outside the area of highest BTEX contamination may be due to ferrous iron which was generated in the more contaminated groundwater

Figure 4.13



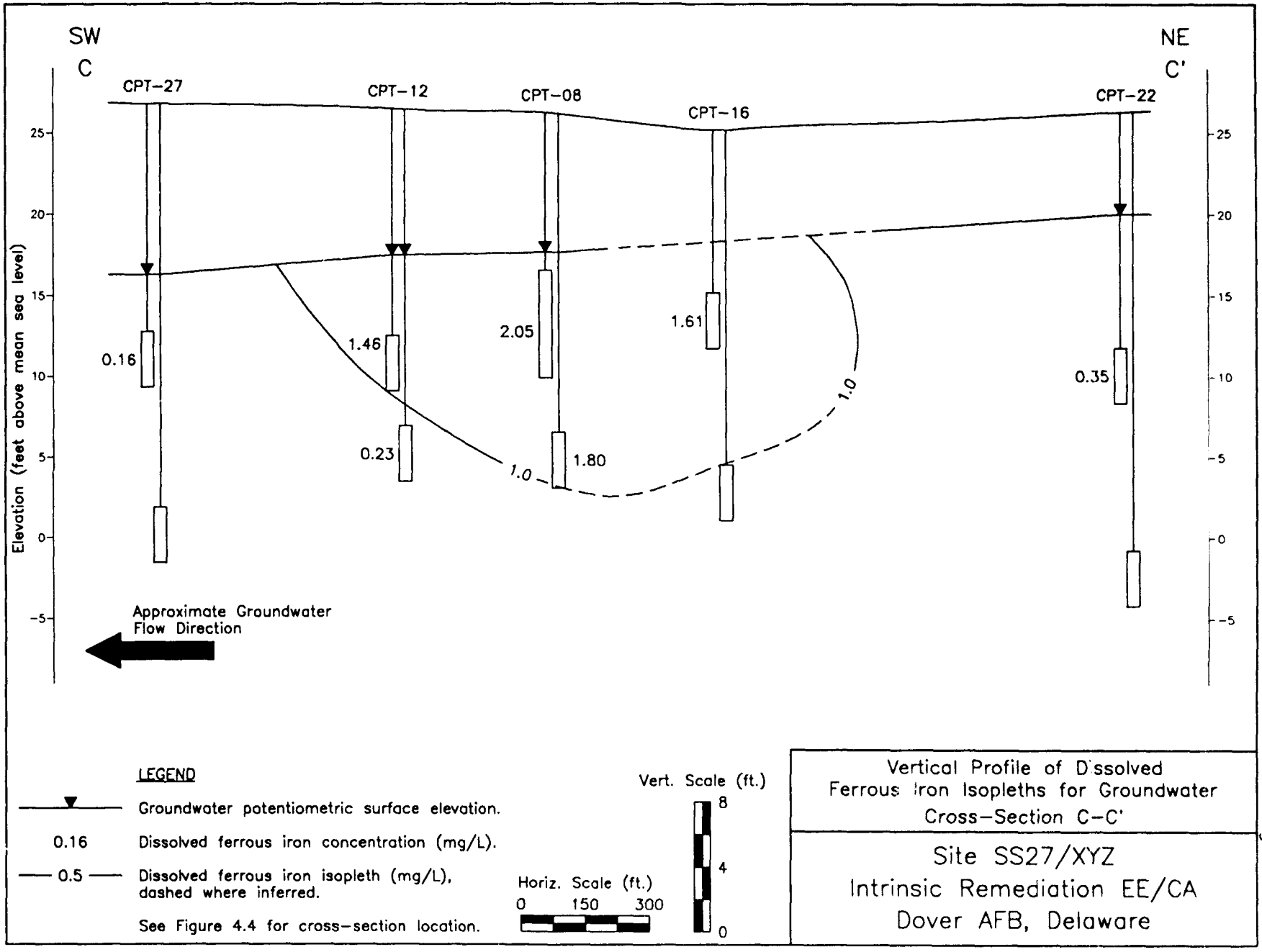
LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
0.16	Dissolved ferrous iron concentration (mg/L).
—1.0—	Dissolved ferrous iron isopleth (mg/L), dashed where inferred.
Z	Former C-10 fueling pad.
Note:	Interval with most conservative value is reported.

Ferrous Iron Isopleth Map for Groundwater

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

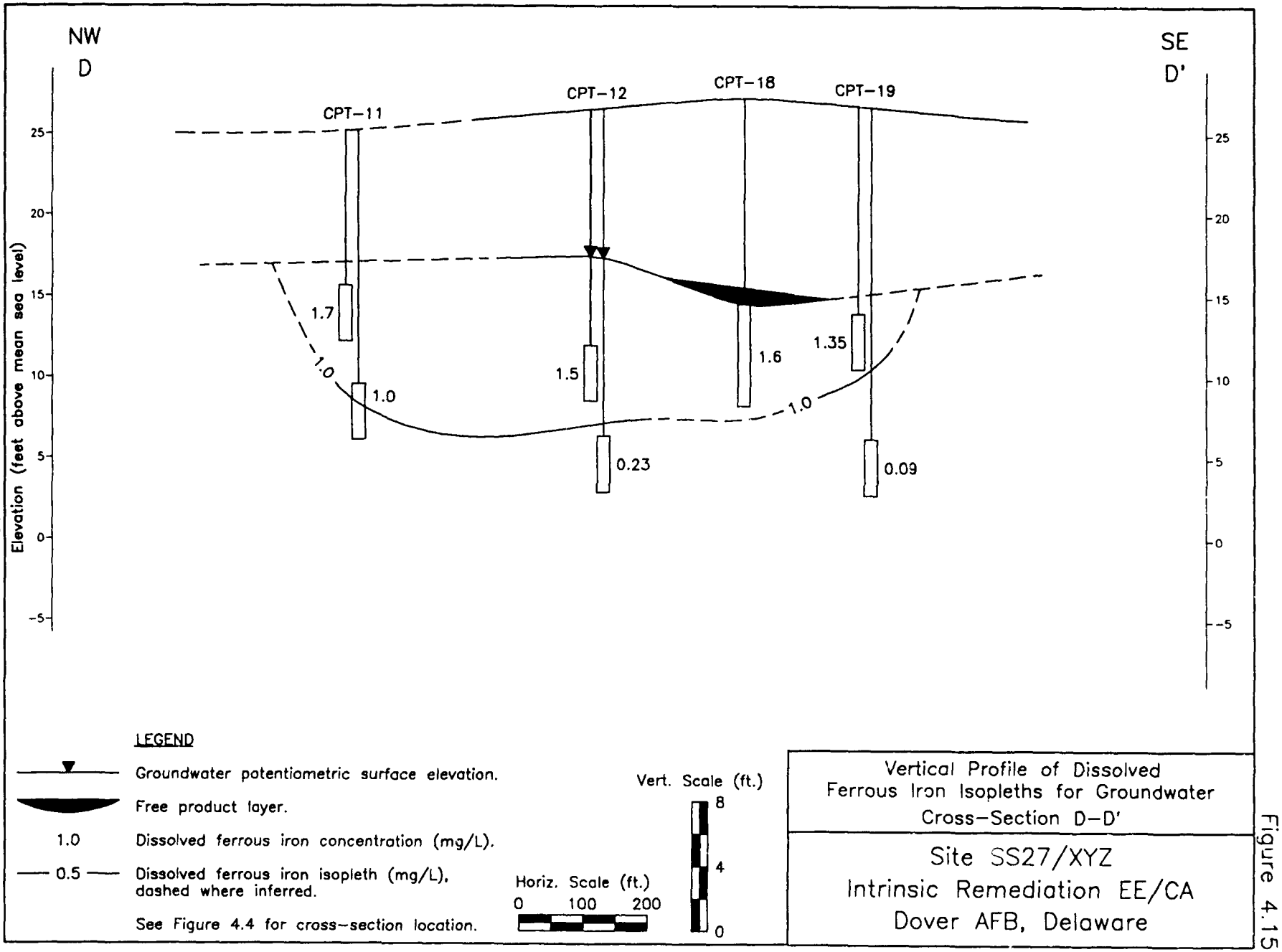
72245063.dwg + 722450X1.dwg / ps:1=1 / 1-22-96 / TLP



Vertical Profile of Dissolved Ferrous Iron Isopleths for Groundwater Cross-Section C-C'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.14



Vertical Profile of Dissolved Ferrous Iron Isopleths for Groundwater Cross-Section D-D'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.15

and then migrated out from the plume center. In anaerobic groundwater, movement of dissolved ferrous iron is not retarded by the aquifer matrix as is dissolved BTEX.

The following equations describe the overall stoichiometry of benzene degradation by iron reduction. In the absence of microbial cell production, the mineralization of benzene by iron reduction is given by:

$$60H^+ + 30Fe(OH)_{3(aq)} + C_6H_6 \rightarrow 6CO_{2(g)} + 30\ Fe_2^{+} + 78H_2O$$

Therefore, 30 moles of ferric iron are required to metabolize 1 mole of benzene. On a mass basis, the ratio of ferric iron to benzene is given by:

Molecular weights: Benzene 6(12) + 6(1) = 78 gm

Ferric Iron 30(106.85) = 3200 gm

Mass ratio of ferric iron to benzene = 3200/78 = 41.0:1

Therefore, in the absence of microbial cell production, 41.0 mg of ferric iron are required to completely metabolize 1 mg of benzene. Alternatively, the mass ratio of ferrous iron produced during respiration to benzene degraded can be calculated and is given by:

Molecular weights: Benzene 6(12) + 6(1) = 78 gm

Ferrous Iron 30(55.85) = 1675 gm

Mass ratio of ferrous iron to benzene = 1675/78 = 21.5:1

Therefore, 21.5 mg of ferrous iron are produced during mineralization of 1 mg of benzene. Similar calculations can be completed for toluene (21.86 mg of Fe^{2+} produced during mineralization of 1 mg of toluene), ethylbenzene (22 mg of Fe^{2+}

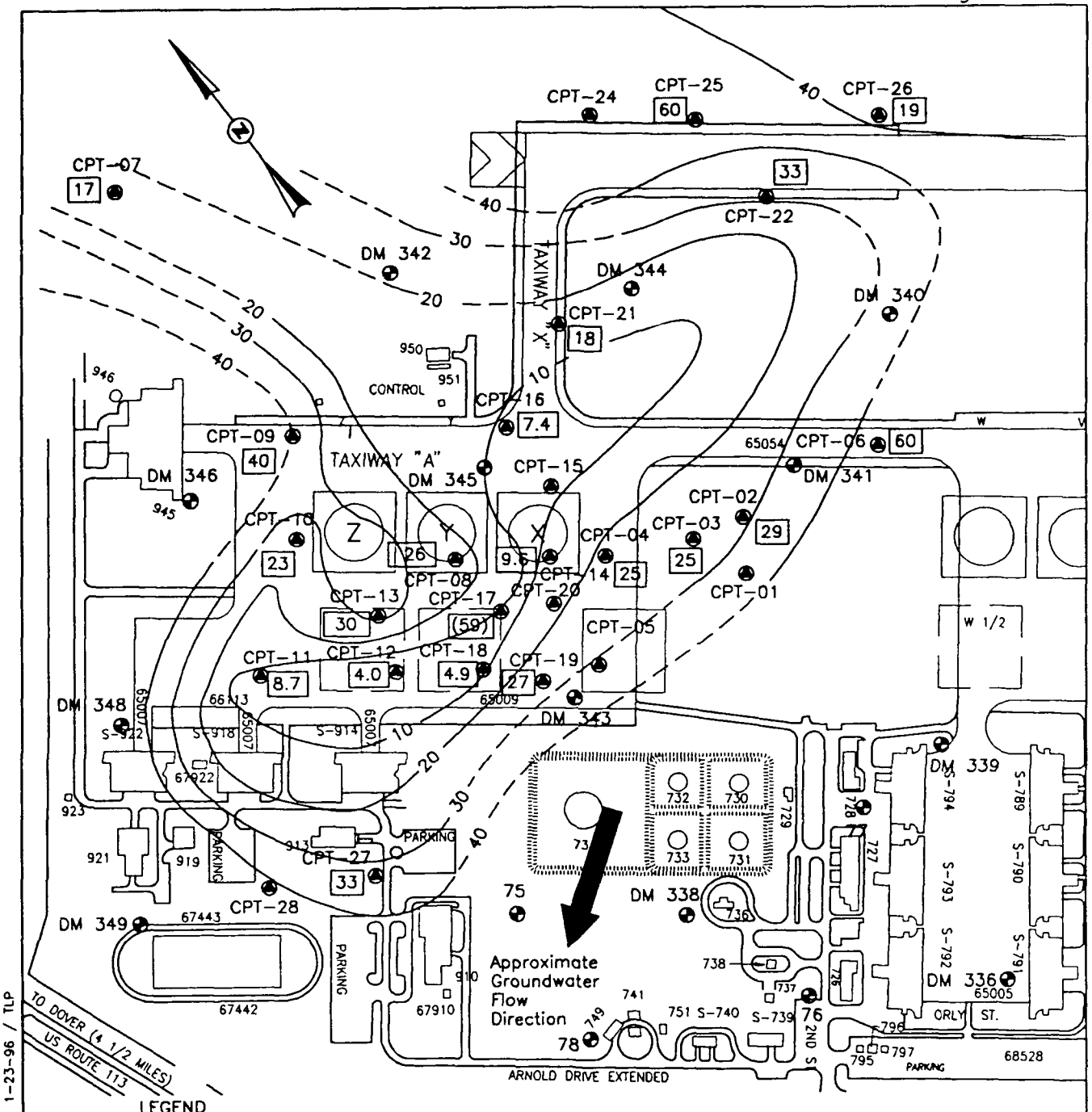
produced during mineralization of 1 mg of ethylbenzene), and the xylenes (22 mg of Fe^{2+} produced during mineralization of 1 mg of xylene). The average mass ratio of Fe^{2+} produced during total BTEX mineralization is thus 21.81:1. This means that approximately 1 mg of BTEX is mineralized for every 21.8 mg of Fe^{2+} produced.

The highest measured Fe^{2+} concentration was 2.05 mg/L. This suggests that the shallow groundwater at this site has the capacity to assimilate 0.094 mg/L (94 μg/L) of total BTEX during iron reduction. This may be a conservative estimate of the assimilative capacity of iron in groundwater because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1). In addition, this calculation is based on measured ferrous iron concentrations and not on the amount of ferric hydroxide available in the aquifer. Therefore, iron assimilative capacity could be much greater.

4.4.2.4 Sulfate

Sulfate concentrations were measured at groundwater monitoring points in April 1994. Table 4.3 includes a summary of sulfate concentrations measured at the site. Figure 4.16 is an isopleth map showing the horizontal distribution of sulfate ion in groundwater. Figures 4.17 and 4.18 are vertical profiles of the distribution of sulfate along cross-sections C-C' and D-D'. Comparison of Figures 4.17 and 4.3 shows graphically that the areas with lowest sulfate ion concentrations in groundwater correspond to areas with highest BTEX concentrations. This suggests that sulfate is being reduced during biodegradation of BTEX compounds. The highest measured sulfate ion concentration was 64.1 mg/L measured at CPT-19S. Relatively high sulfate concentrations were also measured at CPT-25S (60.4 mg/L), CPT-06S (59.6 mg/L), and CPT-12D (53.6 mg/L) which are located at the fringes of the BTEX plume. Background sulfate concentrations may range from 50 mg/L to 65 mg/L. As a

Figure 4.16



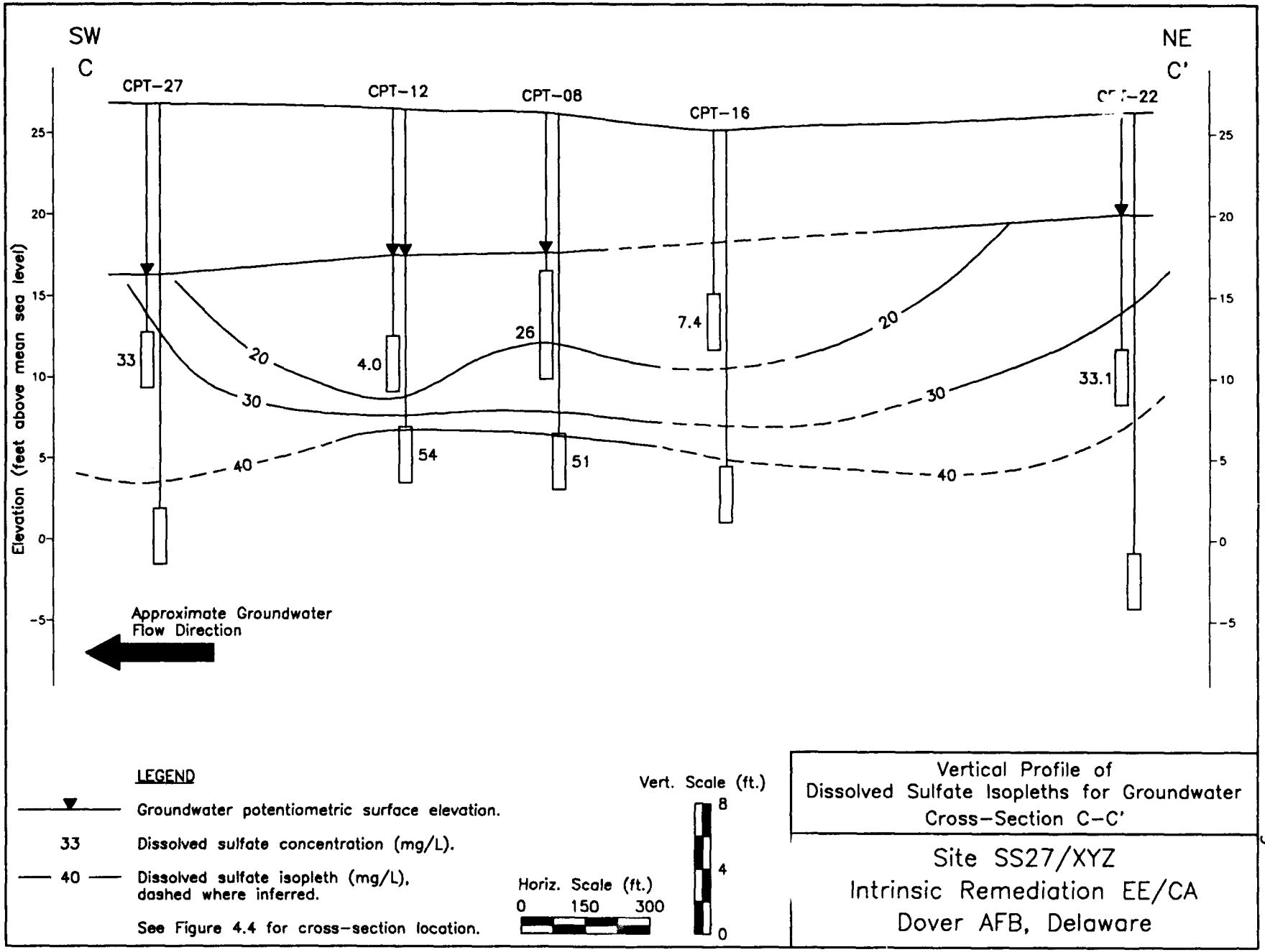
LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
33	Dissolved sulfate concentration (mg/L).
(59)	Data not used to develop contours.
—40—	Dissolved sulfate isopleth (mg/L), dashed where inferred.
Z	Former C-10 fueling pad.
Note:	Interval with most conservative value is reported.

Sulfate Isopleth Map for Groundwater

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

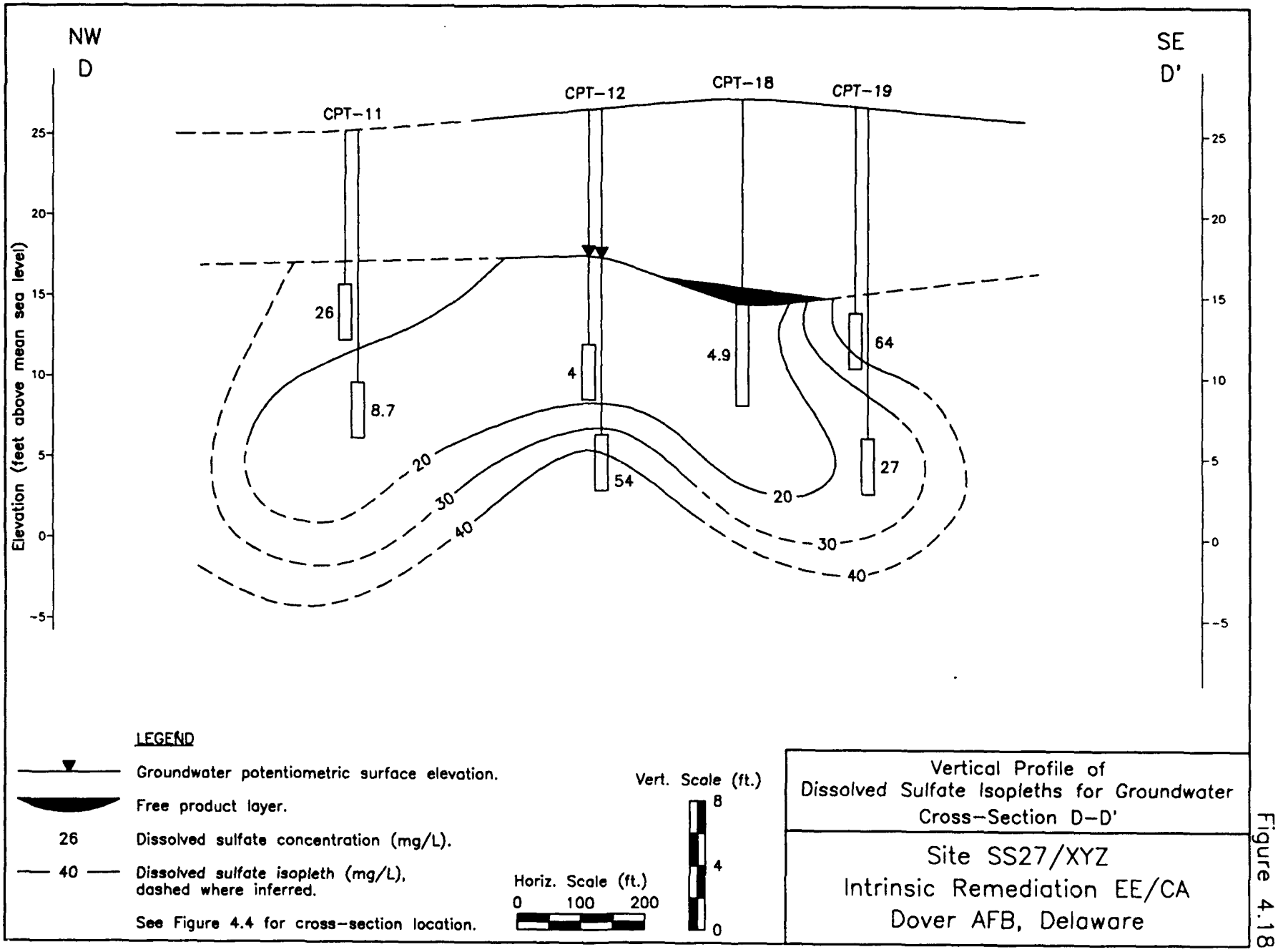
72245064.dwg + 722450X1.dwg / ps:1=1 / 1-23-96 / TLP



Vertical Profile of
Dissolved Sulfate Isopleths for Groundwater
Cross-Section C-C'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.17



Vertical Profile of
Dissolved Sulfate Isopleths for Groundwater
Cross-Section D-D'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.18

conservative estimate, the background sulfate concentration for Site SS27/XYZ was assumed to be 50 mg/L. Sulfate concentrations were lowest at monitoring points CPT-12S (4.0 mg/L), CPT-18S (4.9 mg/L), CPT-16S (7.4 mg/L), CPT-11S (8.7 mg/L), and CPT-14S (9.6 mg/L). With the exception of CPT-11S, these locations are near the center of the BTEX plume. In general, sulfate concentrations were reduced to below 10 mg/L near the center of the BTEX plume.

Hydrogen sulfide is an end product of the sulfate reduction reaction. Concentrations of hydrogen sulfide (see Table 4.3) were measured in site monitoring points in April 1994. However, the distribution of hydrogen sulfide concentrations measured in groundwater samples at the site do not correlate well with the distribution of sulfate concentrations. The lack of a regular trend in hydrogen sulfide concentrations may be due to the strong affinity of certain aquifer matrix materials for the sulfide ion. High levels of iron and manganese compounds are generally contained within aquifer matrices. The sulfide ion will react with iron and manganese to form insoluble metallic sulfides. The presence of hydrogen sulfide does, however, provide further evidence of sulfate reduction at the site.

The following equations describe the overall stoichiometry of BTEX oxidation by sulfate reduction caused by anaerobic microbial biodegradation. In the absence of microbial cell mass production, the biodegradation of benzene is given by:

$$7.5H^+ + 3.75SO_4^{2-} + C_6H_6 \rightarrow 6CO_{2(g)} + 3.75H_2S_{(g)} + 3H_2O$$

Therefore, 3.75 moles of sulfate are required to mineralize 1 mole of benzene. On a mass basis, the ratio of sulfate to benzene is given by:

Molecular weights:	Benzene	6(12) + 6(1) = 78 gm
	Sulfate	32.06+4(16) =96.06 gm

Mass ratio of sulfate to benzene = 3.75(96.06)/78 = 4.6:1

Therefore, in the absence of microbial cell production, 4.6 mg of sulfate are required to completely mineralize 1 mg of benzene. Similar calculations can be completed for toluene (4.7 mg sulfate to 1 mg toluene), ethylbenzene (4.75 mg sulfate to 1 mg ethylbenzene), and the xylenes (4.75 mg sulfate to 1 mg xylene). The average mass ratio of sulfate to total BTEX is thus 4.7:1. This means that approximately 0.21 mg of BTEX is mineralized for every 1.0 mg of sulfate consumed. Assuming a background sulfate concentration of 50 mg/L, the shallow groundwater at Site SS27/XYZ has the capacity to assimilate 10.5 mg/L (10,500 μg/L) of total BTEX during sulfate reduction. Again, this may be a conservative estimate of the assimilative capacity of sulfate because microbial cell mass production has not been taken into account by the stoichiometry shown above (see Section 4.3.2.1).

4.4.2.5 Methane

Anomalously high methane concentrations were detected in groundwater at Site SS27/XYZ during the field investigation: reported laboratory concentrations exceeded methane solubility by several orders of magnitude. As a result, and as a conservative assumption, methane concentrations were not considered for assimilative capacity calculations.

4.4.2.6 Reduction/Oxidation Potential

Redox potentials were measured at groundwater monitoring points and existing monitoring wells in April 1994. Redox potential is a measure of the relative tendency of a solution to accept or transfer electrons. The redox potential of a groundwater system depends on which electron acceptor is being reduced by microbes during BTEX oxidation. The measured redox potential in groundwater at Site SS27/XYZ ranged

from 380 millivolts (mV) to -431 mV. Redox potential data are included in the groundwater geochemical data summary in Table 4.3. Figure 4.19 is an isopleth map that graphically illustrates the horizontal distribution of redox potential in groundwater at the site. Figures 4.20 and 4.21 show the vertical profiles of redox potential in groundwater at the site along cross-sections C-C' and D-D'. Redox potential values fall below -200 mV in an area encompassing CPT-16, CPT-02, and CPT-10. In general, areas at the site with low redox potentials coincide with areas of high BTEX contamination, low DO, nitrate, and sulfate concentrations, and elevated ferrous iron concentrations.

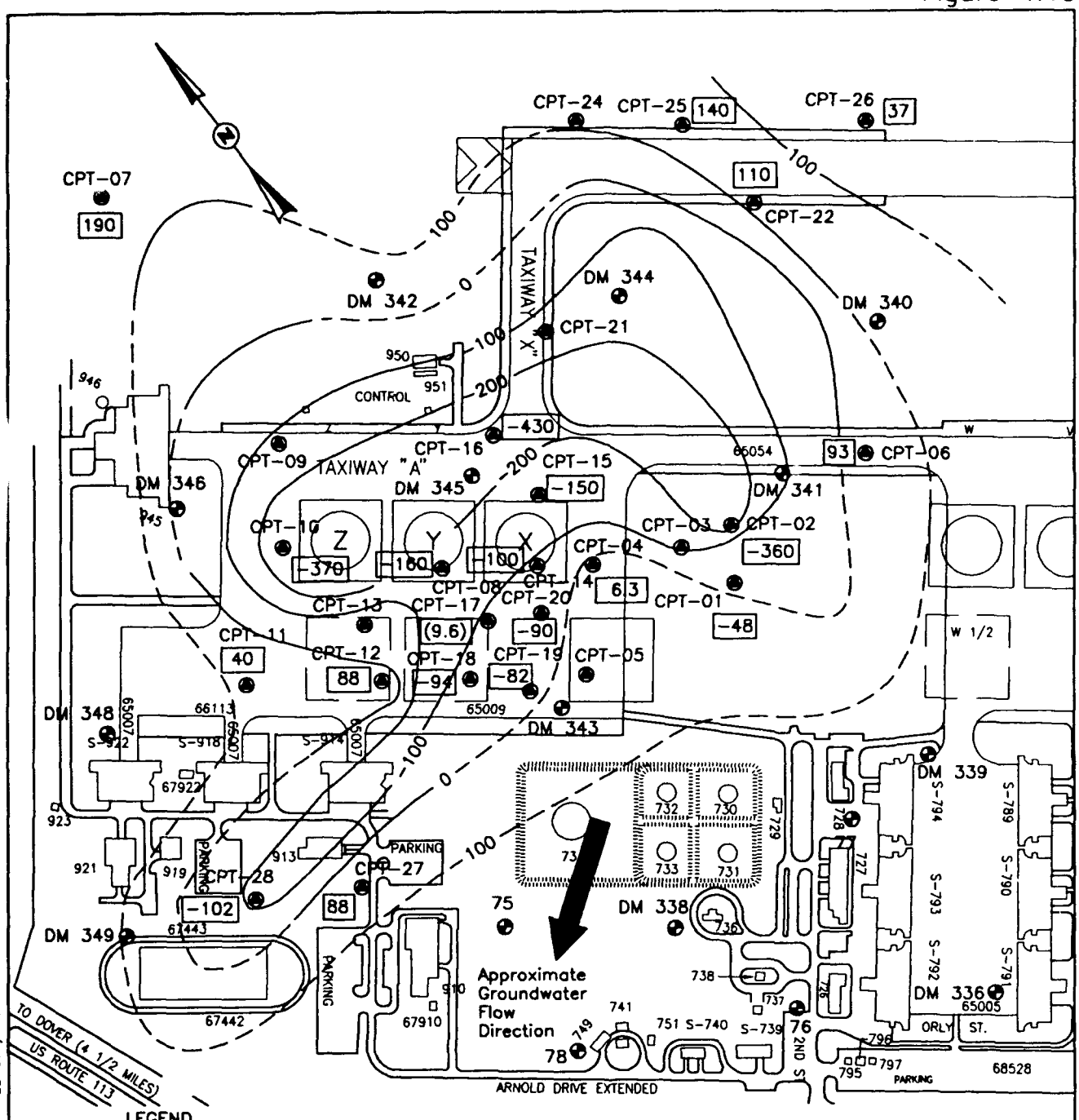
4.4.2.7 Alkalinity

Total alkalinity (expressed as calcium carbonate) was measured at groundwater monitoring points in April 1994. The total alkalinity data are summarized in Table 4.3. Alkalinity is a measure of groundwater's ability to buffer changes in pH, which may be caused by the addition of biologically generated acids. Total alkalinity at the site is in the low to moderate range for groundwater, varying from 5 mg/L to 198 mg/L at CPT-14S. The ability of groundwater at the site to neutralize acids generated by biodegradation of BTEX may be limited in areas with lower alkalinity levels.

4.4.2.8 pH

Measurements of pH were taken in groundwater monitoring points and monitoring wells at Site SS27/XYZ in April 1994. A summary of pH data is included in Table 4.3. The pH of a solution is the negative logarithm of the hydrogen ion concentration [H^+]. Groundwater pH at the site ranges from 4.47 to 7.31. The majority of groundwater samples had pH ranging between 5.5 and 6.5. This is on the

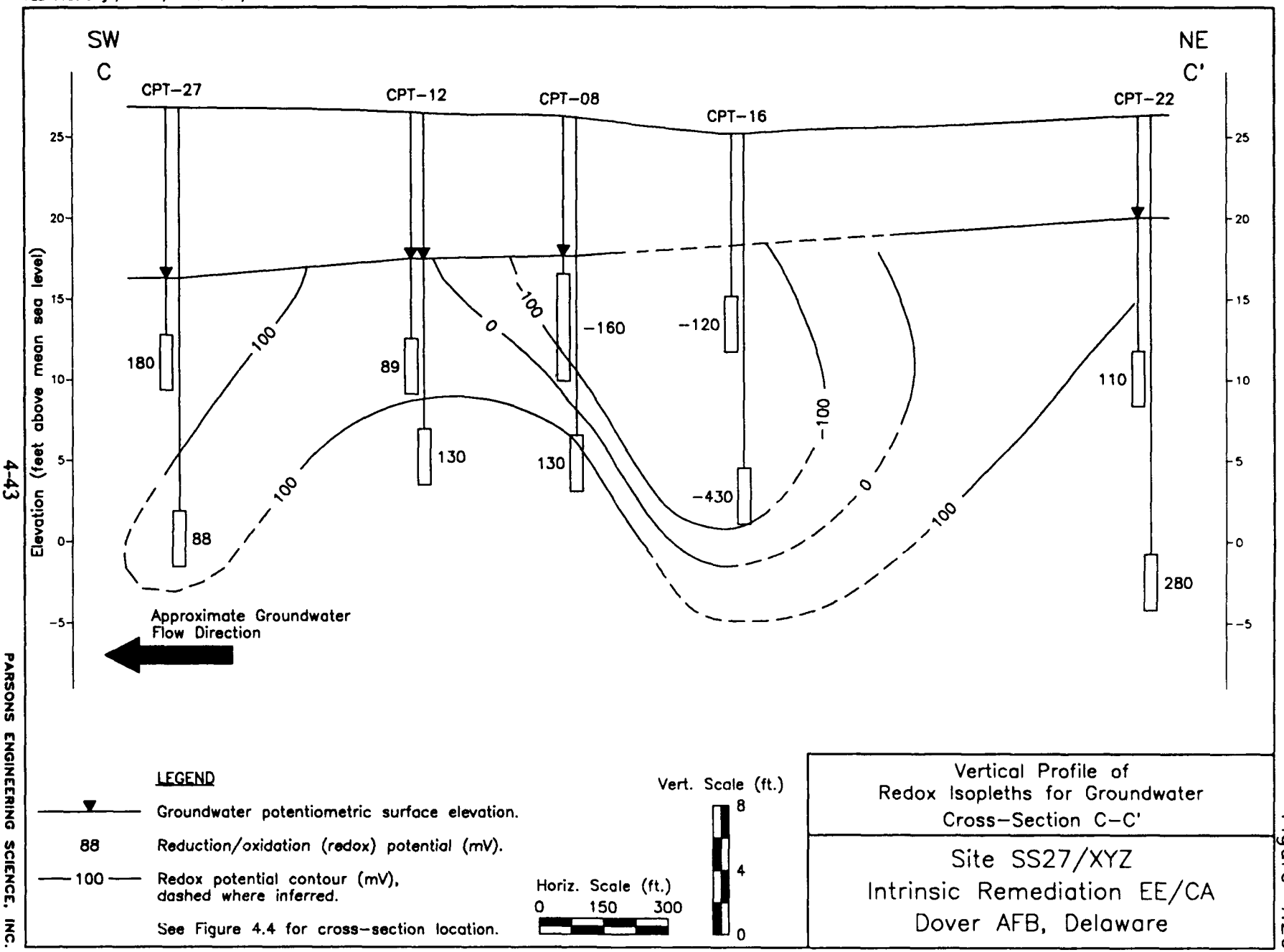
Figure 4.19



Redox Potential Map for Groundwater

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

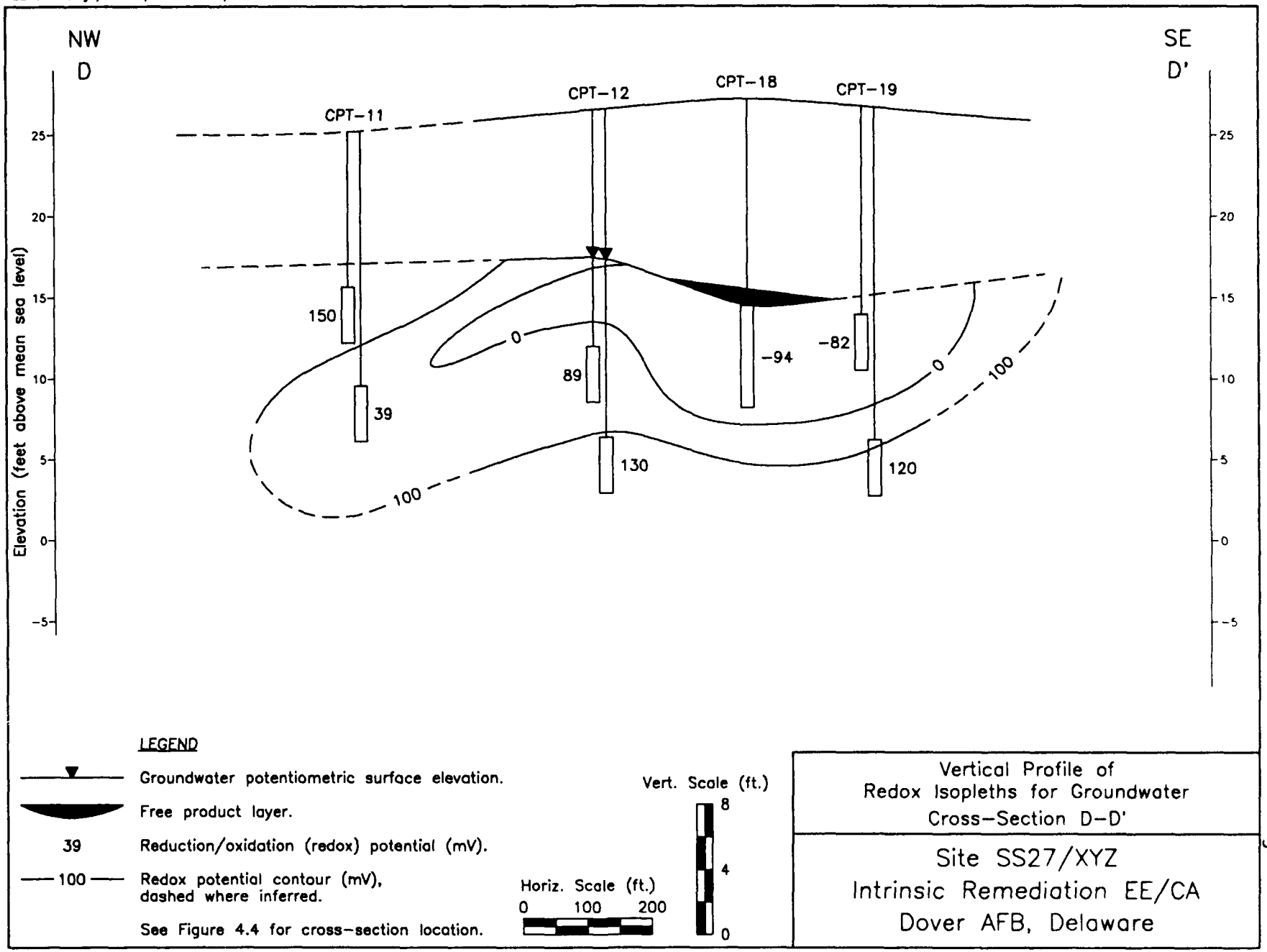
72245066.dwg + 722450X1.dwg / ps:1=1 / 1-22-96 / TLP



Vertical Profile of
Redox Isopleths for Groundwater
Cross-Section C-C'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.20



Vertical Profile of
Redox Isopleths for Groundwater
Cross-Section D-D'

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Figure 4.21

lower end of the acceptable range for BTEX degrading microbes. Lower pH values (lower than 4.5 to 5.5) are generally considered to be less than optimal for BTEX biodegradation. The groundwater geochemistry discussed in previous sections of this report suggests high potential for natural attenuation of BTEX constituents which are not inhibited by lower aqueous pH.

4.4.2.9 Temperature

Groundwater temperature was measured at groundwater monitoring points and existing monitoring wells in April 1994. Table 4.3 includes a summary of groundwater temperature data. Temperature affects the types and gro vth rates of bacteria that can be supported in the groundwater environment, with higher temperatures gener ally resulting in higher growth rates. Temperatures in the shallow aquifer ranged from 9.9 degrees Celsius (°C) to 20.7°C. The average groundwater temperature was 14.0°C. This temperature range is conducive for degradation of BTEX by microorganisms.

4.4.3 Expressed Assimilative Capacity

The data presented in the preceding sections suggest that mineralization of BTEX compounds is occurring through the microbially mediated processes of aerobic respiration, denitrification, iron reduction, and sulfate reduction. On the basis of the stoichiometry presented in these sections, the expressed BTEX assimilative capacity of groundwater at Site SS27/XYZ is at least 13,194 μg/L (Table 4.4). Because of the uncertainty inherent in these calculations, they are meant as a qualitative, or at best semi-quantitative, estimate of the inherent capability of the groundwater at the site, in conjunction with indigenous microorganisms, to degrade fuel hydrocarbons. The calculated assimilative capacity also may be conservative because it does not account

TABLE 4.4

EXPRESSED ASSIMILATIVE CAPACITY OF SITE GROUNDWATER
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Electron Acceptor or Process	Expressed BTEX Assimilative Capacity (μg/L)
Dissolved Oxygen	1,600
Denitrification	1,000
Ferric Hydroxide	94
Sulfate Reduction	10,500
Methanogenesis	0[a/]
Expressed Assimilative Capacity	13,194
Highest Observed Total BTEX Concentration	22,900

[a/] Methane data were anomalous, therefore, the assimilative capacity due to methanogenesis was not considered for this calculation.

for microbial cell mass production or natural attenuation via methanogenesis, conservative values were utilized for the observed background concentrations which were the basis of these calculations, and observed ferrous iron concentrations may not be the maximum achievable. The highest measured total BTEX concentration was at CPT-15S, which contained 11,300,000 µg/L. The sample from this well contained emulsified JP-4 fuel. Because this datum exceeds the predicted aqueous solubility of BTEX in a mixture of JP-4 and water (23,000 µg/L), it was considered to be invalid. The next highest BTEX concentration was measured at CPT-18S (22,900 µg/L). This sample location likely contained mobile LNAPL, as the measured concentration is slightly below the predicted aqueous solubility of BTEX from JP-4. The next highest dissolved BTEX concentration was 2,600 µg/L measured at CPT-14S. Although assimilative capacity in the source area may be insufficient to completely degrade all dissolved BTEX, on the basis of the calculations presented in the preceding sections and on site observations, groundwater at Site SS27/XYZ has sufficient assimilative capacity to reduce spreading and migration of the dissolved BTEX plume.

SECTION 5

GROUNDWATER MODEL

5.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

In order to help estimate degradation rates for dissolved BTEX compounds at Site SS27/XYZ and to help predict the future migration of these compounds, Parsons ES modeled the fate and transport of the dissolved BTEX plume. The modeling effort had three primary objectives: 1) to predict the future extent and concentration of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the potential for downgradient receptors to be exposed to BTEX concentrations that exceed regulatory levels intended to be protective of human health and the environment; and 3) to provide technical support for the natural attenuation remedial option at post-modeling regulatory negotiations. The model was developed using site-specific data and conservative assumptions about governing physical and chemical processes. Due to the conservative nature of the model input, the reduction in contaminant mass resulting from natural attenuation is expected to exceed model predictions. This analysis is not intended to represent a baseline assessment of potential risks posed by site contamination.

The Bioplume II model was used to estimate the potential for dissolved BTEX migration and degradation by naturally occurring mechanisms operating at Site SS27/XYZ. The Bioplume II code incorporates advection, dispersion, sorption, and biodegradation to simulate contaminant plume migration and degradation. The model is based upon the USGS Method of Characteristics (MOC) two-dimensional (2-D) solute transport model of Konikow and Bredehoeft (1978). The model was modified by researchers at Rice University to include a biodegradation component that is

activated by a superimposed DO plume. Based on the work of Borden and Bedient (1986), the model assumes a reaction between DO and BTEX that is instantaneous relative to the advective groundwater velocity. Bioplume II solves the USGS 2-D solute transport equation twice, once for hydrocarbon concentrations in the aquifer and once for a DO plume. The two plumes are combined using superposition at every particle move to simulate the instantaneous, biologically-mediated, reaction between hydrocarbons and oxygen.

In recent years, it has become apparent that anaerobic processes such as denitrification, iron reduction, sulfate reduction, and methanogenesis can be important BTEX degradation mechanisms (Grbic'-Galic' and Vogel, 1987; Lovley *et al.*, 1989; Grbic'-Galic', 1990; Hutchins, 1991; Beller *et al.*, 1992; Edwards *et al.*, 1992; Edwards and Grbic'-Galic', 1992). As evidenced from the data specified in Section 4, anaerobic biodegradation is occurring at Site SS27/XYZ. As a conservative estimate only oxygen and nitrate were used as electron acceptors during Bioplume II modeling.

Parsons ES calculated first-order decay coefficients by applying methods specified by Wiedemeier *et al.* (1995) to site-specific data. First-order decay coefficient calculations are presented in Appendix F. Due to the variability of the site data, a range of potential first-order decay coefficients was determined during this step. Then, Parsons ES utilized an analytical model (Bear, 1979), using a single apparent value for first-order decay coefficient, to assess contaminant migration rates along the three predominant flow directions. This analytical model incorporates one-dimensional advection, dispersion, retardation, and first-order decay. A comparison between numerical and analytical model results was then performed as a check on the calibrated Bioplume II input parameters.

After model calibration, Parsons ES developed potential remedial alternatives for the site. The calibrated Bioplume model was used to evaluate these potential remedial alternatives to determine effectiveness for remediating the site contaminants. Parsons ES utilized an additional analytical model (van Genuchten and Alves, 1982) to check the results of the numerical model during simulation of the remedial alternatives. This analytical model incorporates one-dimensional advection, dispersion, retardation, first-order decay, and a decaying source term. The following subsections discuss in more detail numerical model setup, input parameters and assumptions, model calibration, and simulation results. Bioplume model input data is contained in Appendix D. Output files are contained in ASCII format on diskettes within Appendix E. Analytical model results are presented in Appendix F.

5.2 CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

Prior to developing a groundwater model, it is important to determine if sufficient data are available to provide a reasonable estimate of aquifer conditions. In addition, it is important to ensure that any limiting assumptions can be justified. The most important assumption made when using the Bioplume II model is that oxygen-limited biodegradation is occurring at the site. The Bioplume II model assumes that the limiting factors for biodegradation are: 1) the presence of an indigenous hydrocarbon-degrading microbial population, and 2) sufficient background electron acceptor concentrations. Data and information presented in Sections 3 and 4 suggest that oxygen, nitrate, ferric hydroxide, and sulfate are being used as electron acceptors for aerobic and anaerobic biodegradation. To be conservative, only oxygen and nitrate were used as electron acceptors in the Bioplume II model presented herein.

Based on the data presented in Section 3, the shallow saturated zone was conceptualized and modeled as a shallow unconfined aquifer composed of silty sand

(Figures 3.3 and 3.4). The use of a 2-D model is appropriate at Site SS27/XYZ because the saturated interval is relatively homogenous, and the local flow system, as defined by gradients and the basal confining unit, will likely minimize downward vertical migration of dissolved BTEX contamination. The vertical BTEX concentration profiles (Figures 4.5 and 4.6) suggest minor downward migration may be occurring in the vicinity of the source area. This may be due to diffusion of BTEX away from the source area. A downward migration trend is not prevalent throughout the remaining sections of the plume. Because residual and mobile LNAPL contamination still exists at the site, model simulations include continuing sources of dissolved BTEX contamination.

5.3 INITIAL MODEL SETUP

Where possible, the initial setup for this model was based on site data. Where site-specific data were not available (e.g., effective porosity, reaeration coefficient), reasonable assumptions for the types of materials comprising the shallow aquifer were made based on widely accepted literature values. The following sections describe the basic model setup. A sensitivity analysis was performed by varying input values for the parameters, known to have the most significant effects on model results. Those Bioplume II model parameters that were varied during model calibration are discussed in Section 5.4.2.1.

5.3.1 Grid Design and Boundary Conditions

The maximum grid size for the Bioplume II model is limited to 20 columns by 30 rows, and the dimensions of each cell can range from 0.1 to 999.9 feet. A grid size of 20 cells (transverse or x direction) by 30 cells (longitudinal or y direction) was used to model Site SS27/XYZ. The grid was oriented so that the positive y-axis was parallel to the overall direction of groundwater flow. Each grid cell was 120 feet wide by

120 feet long. The model grid covers an area of 8,640,000 square feet, or approximately 200 acres. The full extent of the model grid is indicated on Figure 5.1.

Model boundaries are mathematical statements that represent hydrogeologic boundaries, such as areas of specified head (e.g., surface water bodies or contour lines of constant hydraulic head) or specified flux. Hydrogeologic boundaries are represented by three mathematical statements that describe the hydraulic head at the model boundaries. These include:

1) Specified-head boundaries (Dirichlet condition) for which the head is determined as a function of location and time only. Surface water bodies exhibit constant head conditions. Specified-head boundaries are expressed mathematically as:

$$\text{Head} = f(x,y,z,t)$$

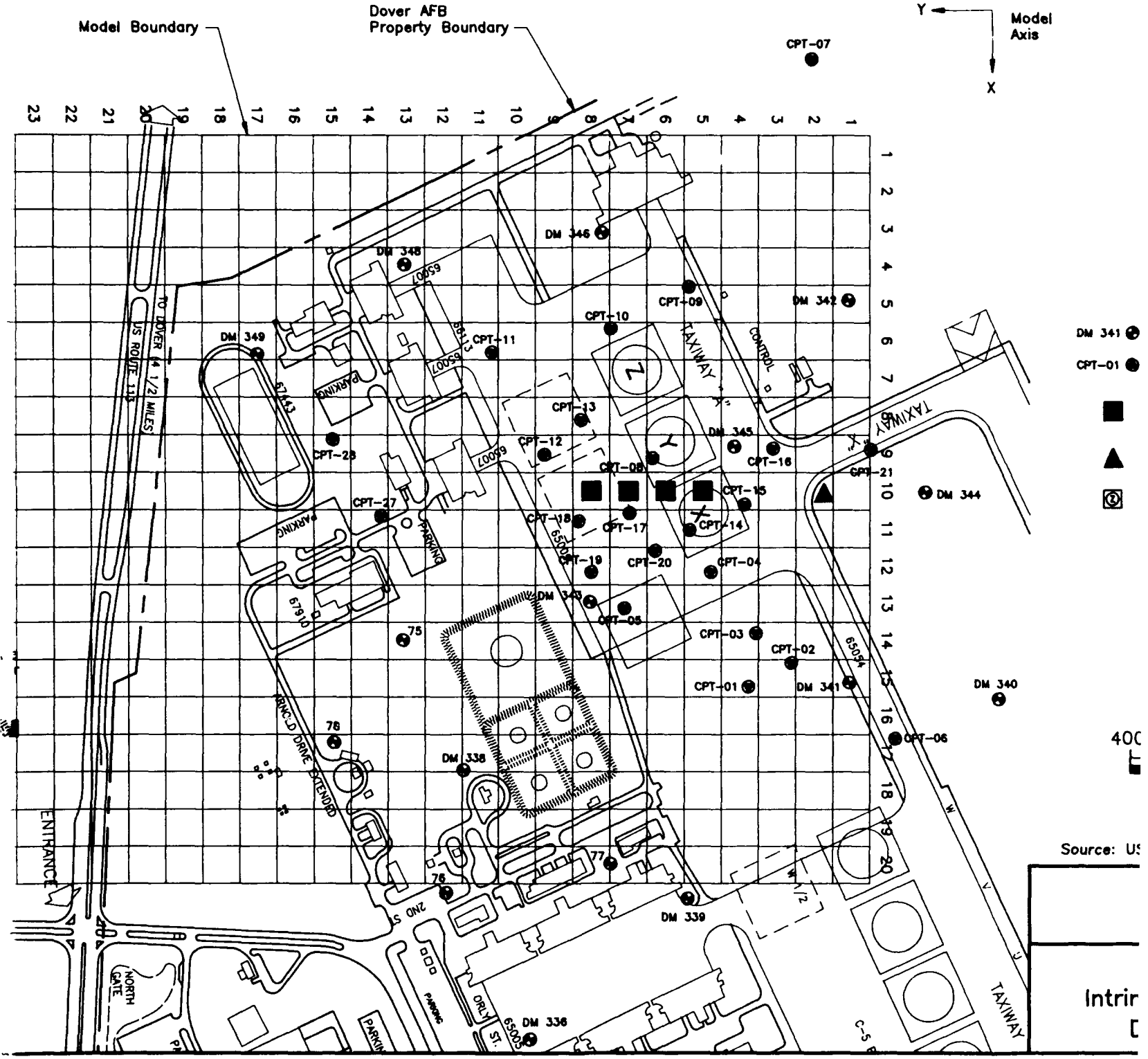
where f is the function symbol, x, y, and z are position coordinates, and t is time.

2) Specified-flow boundaries (Neumann conditions) for which the mathematical description of the flux across the boundary is given. The flux is defined as a volumetric flow rate per unit area (e.g., $ft^3/ft^2/day$). No-flow boundaries are a special type of specified-flow boundary and are set by specifying the flux to be zero. Examples of no-flow boundaries include groundwater divides and impermeable hydrostratigraphic units. Specified-flux boundaries are expressed mathematically as:

$$\text{Flux} = f(x,y,z,t)$$

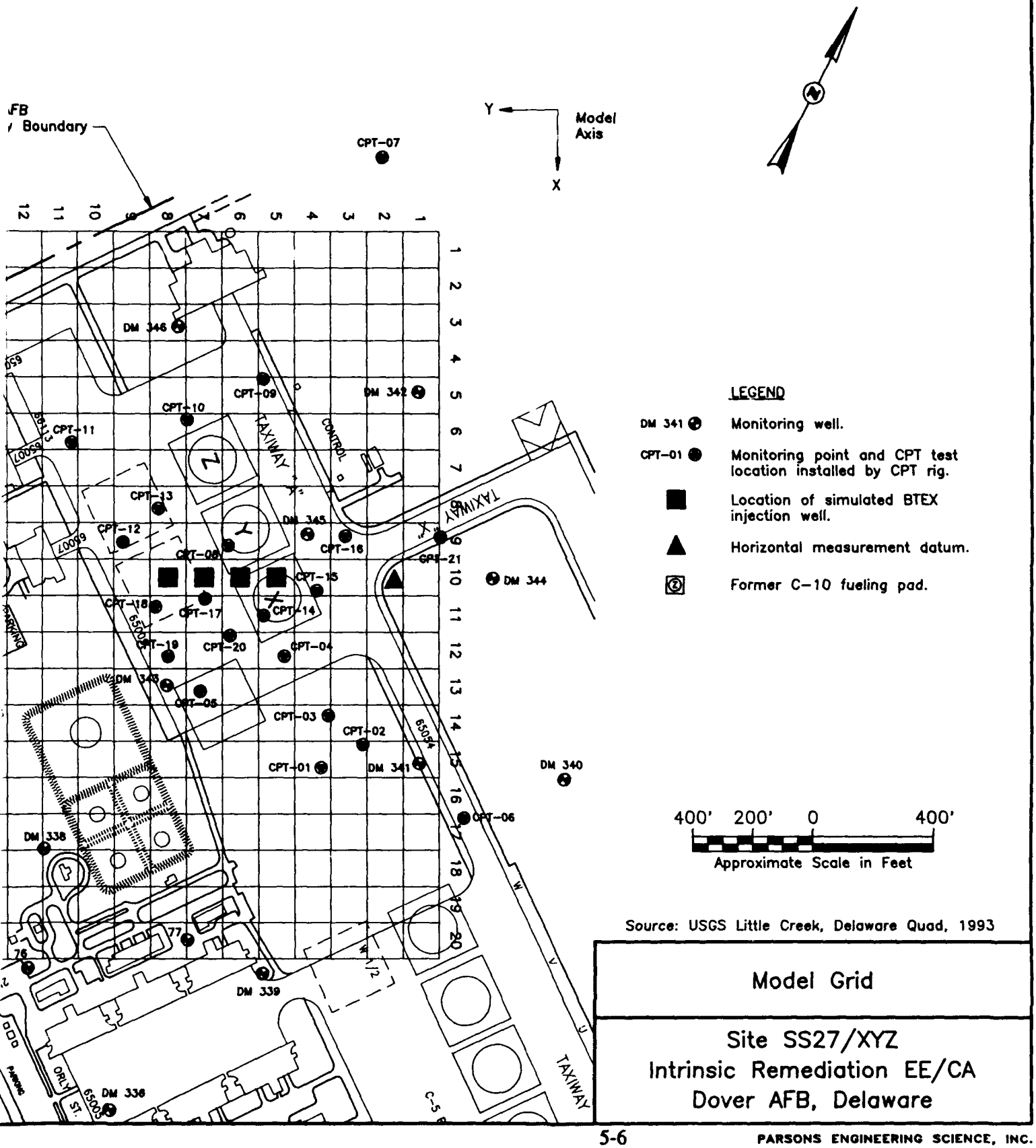
3) Head-dependent flow boundaries (Cauchy or mixed-boundary conditions) where the flux across the boundary is calculated from a given boundary head value.

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Source: US

Intrir



Source: USGS Little Creek, Delaware Quad, 1993

Model Grid

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

This type of flow boundary is sometimes referred to as a mixed-boundary condition because it is a combination of a specified-head boundary and a specified-flow boundary. Head-dependent flow boundaries are used to model leakage across semipermeable boundaries. Head-dependent flow boundaries are expressed mathematically as (Bear, 1979):

$$Flux = (Ho - H)K'/B'$$

Where:
- H = Head in the zone being modeled (generally the zone containing the contaminant plume)
- Ho = Head in external zone (separated from plume by semipermeable layer)
- K' = Hydraulic conductivity of semipermeable layer
- B' = Thickness of semipermeable layer.

Natural hydraulic boundaries are modeled using a combination of the three types of model boundary conditions listed above. When possible, hydrologic boundaries such as surface water bodies, groundwater divides, contour lines, or hydrologic barriers should coincide with the perimeter of the model. In areas lacking obvious hydrologic boundaries, specified-head or specified-flux boundaries can be specified at the model perimeter if the boundaries are far enough removed from the contaminant plume that transport calculations are not affected. Bioplume II requires the entire model domain to be bounded by zero-flux cells (also known as no-flow cells), with other boundary conditions established within the subdomain specified by the no-flow cells.

Specified-head boundaries for the model were set on the northeastern and southwestern perimeter of the model grid to simulate the primary (southwestern) groundwater flow direction at the site. The hydraulics at Site SS27/XYZ are relatively complicated because the actual site conditions include a groundwater divide and two

additional lateral plume migration pathways. To simplify the model, the lateral migration pathways were not included within the calibrated numerical model and were modeled using analytical methods. Heads for the specified-head boundaries were set at the approximate location of the water table indicated by water level data. The head of the northeastern boundary (upgradient) was estimated to be from 20.3 to 17.4 feet above msl in order to simulate the slight mounding effect observed at the upgradient boundary. This boundary coincides with the groundwater divide and potential recharge area. However, in order to simulate the source area with a decreasing source term and to minimize erroneous boundary interferences, the upgradient boundary was not modeled as a constant source boundary for BTEX.

Parsons ES selected the St. Jones River as the model downgradient boundary due to its potential influence on contaminant plume migration. Most of the St. Jones River is a tidal estuary that includes marsh lands, swamps, and open channel stream flow. The head of the downgradient model boundary was approximated by the USGS topographic map 5.0-foot contour that borders the St. Jones River (Figure 5.1). Due to the lack of site-specific data from this area, the downgradient model boundary head was assumed to be constant. This assumption does not affect the simulation of this migration pathway due to the relatively long migration distance required to reach the downgradient model boundary.

The northwestern and southeastern (lateral) model boundaries were configured as no-flow (specified flux) boundaries. Flux through these boundaries is assumed to be zero because flow is generally parallel to these boundaries.

5.3.2 Groundwater Elevation and Gradient

The April 1994 water table elevation map presented in Figure 3.5 was used to define the starting heads for input into the Bioplume II model. Primary groundwater flow in

the vicinity of Site SS27/XYZ is to the southwest, with an average gradient of approximately 0.0021 ft/ft (see Section 3.3.2.1). Very similar gradients were also reported by previous consultants (Dames & Moore and HAZWRAP, 1993). HAZWRAP (1993a) reported that the location of the groundwater divide (the upgradient model boundary) varies seasonally (see Section 3.3.2.1). Parsons ES chose a median location for the upgradient model boundary and calibrated the numerical model under steady-state conditions. Any increased effects on BTEX plume dispersion caused by seasonal variations were taken into account by calibration of the model (with respect to longitudinal and lateral dispersivity) to present day plume dimensions. As described in Section 5.4.1, the model was calibrated to the observed April 1994 water table.

5.3.3 BTEX Concentrations

The total dissolved BTEX concentration obtained from laboratory analytical results for each well and monitoring point location was used for model development. At each multidepth monitoring point, the highest BTEX concentration observed at that location was used as the representative concentration. Table 4.2 presents dissolved BTEX concentration data. Figures 4.3, 4.5, and 4.6 show the spatial distribution of dissolved BTEX compounds in April 1994.

The BTEX plume observed in April 1994 has three lobes that result from one primary (southwestern lobe) and two secondary (northwestern and northeastern lobes) migration pathways. The shape and distribution of the total BTEX plume is the result of the release location with respect to the groundwater divide and advective-dispersive transport, sorption, and biodegradation of dissolved BTEX contamination. The plume covers an area of approximately 2,820,000 square feet (64 acres). As described in

Section 5.4.2, the simulated BTEX plume was calibrated to closely approximate the observed BTEX plume along the primary (southwestern) flow path.

5.3.4 Electron Acceptors (Oxygen and Nitrate)

As discussed previously, the Bioplume II model assumes an instantaneous reaction between the BTEX plume and the DO plume. The discussion presented in Section 4 suggests that DO, nitrate, ferric iron, and sulfate are being used as electron acceptors for biodegradation of BTEX compounds at Site SS27/XYZ. To be conservative, the total BTEX plume at the site was modeled assuming that DO and nitrate were the only electron acceptors being utilized for the biodegradation of BTEX compounds at a rate that is instantaneous relative to the advective groundwater flow velocity.

Two groundwater samples collected in uncontaminated portions of the aquifer suggest that the background DO concentration at the site may be as high as 7.5 mg/L (DM 346S) and 8.3 mg/L (DM 348S). Background oxygen levels were assumed to be 5 mg/L for Bioplume II model development. Table 4.3 presents DO data for the site. Figure 4.7 is a DO isopleth map, and Figures 4.8 and 4.9 show the vertical DO profiles. Gridded oxygen input data are included in Appendix D. Nitrate and nitrite concentrations in groundwater were determined from site monitoring wells and monitoring points. Groundwater samples collected from uncontaminated portions of the aquifer suggest that background nitrate concentrations ranged from 11 to 18 mg/L (as nitrogen). However, due to spatial position of the nitrate plume (Figure 4.10) and the uncertainty of true background sample locations, background nitrate levels were assumed to be 5 mg/L (as nitrogen) for Bioplume II model development. Table 4.3 presents nitrate data for the site. Figure 4.8 is a nitrate isopleth map, and Figures 4.9 and 4.10 show the vertical profiles.

The upgradient specified-head cells in the Bioplume II model require background DO (or electron acceptors) to be input as a single constant concentration at each upgradient boundary cell. The upgradient boundary is located at the groundwater divide and is influenced only by rainwater infiltration. Rainwater is typically saturated with oxygen, which suggests that the upgradient boundary condition for oxygen may be 8 to 10 mg/L. However, input of nitrate concentrations within the boundary condition is not appropriate. Typical rainwater nitrate concentrations are reported to be less than 0.5 mg/L (as nitrogen) (Freeze and Cherry, 1979). As a result, only oxygen concentrations were included within the upgradient boundary definition.

As stated earlier, background oxygen and nitrate concentrations were determined from the site data. These data were utilized as an initial condition for the model. To establish this initial condition, oxygen and nitrate concentrations must be gridded. The nitrate concentration was converted to an oxygen equivalent to allow input of multiple electron acceptors. To accomplish this, the equivalent weight of oxygen was added to the nitrate, expressed as N, to convert to ionic nitrate:

Molecular weight of N = 14 gm/mole

Molecular weight of O = 16 gm/mole

Molecular weight of NO_3^- = 62 gm/mole

The percentage of N in NO_3^- is 14/62 = 22.58 percent. Therefore, 1 gm of NO_3^- (as N) is equivalent to 1/0.2258 = 4.43 gm of ionic NO_3^-. To convert nitrate (as N) into ionic nitrate concentrations, the measured nitrate (as N) concentration must be multiplied by 4.43.

Assuming complete mineralization of benzene to carbon dioxide and water, the reactions for aerobic respiration and denitrification are as follows:

Aerobic Respiration

$$C_6H_6 + 7.5O_2 = 6CO_2 + 3H_2O$$

Denitrification

$$6NO_3^- + 6H^+ + C_6H_6 = 6CO_2 + 6H_2O + 3N_{2(g)}$$

Based on this stoichiometry, 7.5 moles of DO are required to biodegrade 1 mole of benzene, and 6 moles of nitrate are required to biodegrade 1 mole of benzene. On a mass basis:

$$(7.5 \text{ moles } O_2)(32 \text{ gm/mole } O_2) = 240 \text{ gm } O_2$$

$$(6 \text{ moles } NO_3^-)(62 \text{ gm/mole } NO_3^-) = 372 \text{ gm } NO_3^-$$

From these relationships, it is apparent that, on a mass basis, more ionic nitrate than DO is required to oxidize a unit mass of benzene. By dividing the mass of ionic nitrate required to degrade one mole of benzene by the mass of DO required to degrade one mole of benzene, a ratio is derived that can be applied to ionic nitrate concentrations to obtain equivalent oxygen concentrations. This ratio is:

$240 \text{ gm } O_2/372 \text{ gm } NO_3^- = 0.645 \text{ gm of } O_2\text{-equivalent ionic nitrate per gram of } NO_3^-$

Therefore, 10 gm of NO_3^- has an O_2 equivalence of:

$$(10 \text{ gm } NO_3^-)(0.645 \text{ gm of } O_2\text{-equivalent ionic nitrate per gm of } NO_3^-) = 6.45 \text{ gm}$$

From these relationships, the following calculation must be performed to convert NO_3^- (as N) to an equivalent DO concentration for model input:

$$(NO_3^-(\text{as N}) \text{ (gm/L)})(4.43 \text{ gm } NO_3^- \text{ (ion)/gm } NO_3^-(\text{as N}))(0.645 \text{ gm } O_2 \text{ eq./gm } NO_3^-)$$

This relationship was used to convert measured nitrate (as N) concentrations into oxygen-equivalent ionic nitrate concentrations. For example, the 5 mg/L (as nitrogen) background nitrate concentration is converted to 14.5 mg/L (as O_2 equivalent). To do this, an isopleth map of nitrate (as N) was prepared and gridded. Gridded values of nitrate (as N) were then used in the relationship presented above to determine ionic NO_3^- as DO equivalence. These values were then added to existing DO concentrations previously gridded at the site and used as input into the Bioplume II model. Converted ionic nitrate concentrations were combined with DO concentrations for a total oxygen/ionic nitrate electron map.

5.3.5 Anaerobic Degradation Rates

In order to calculate first-order decay rate constants in the anaerobic core of the plume, the apparent degradation rate must be normalized for the effects of dilution caused by dispersion and sorption. This is accomplished by normalizing the concentration of each contaminant to the concentration of a component of JP-4 (a tracer) that has similar sorptive properties as BTEX, but that is fairly biologically recalcitrant. Observed concentration data can be normalized to 1,3,5-TMB, 1,2,4-TMB, and 1,2,3-TMB or another tracer with similar physiochemical properties. The TMB suite serves as a good tracer because it is known to be recalcitrant to microbial degradation under anaerobic conditions, and has sorptive properties similar to the BTEX compounds.

First-order anaerobic decay constants were calculated based on BTEX and TMB data from April 1994 (presented in Table 4.2). Rate-constant calculations are included in Appendix F. The calculated first-order decay rates for this site are relatively low. Calculated rate constants for Site SS27/XYZ ranged from 0.0003 to 0.002 day^{-1} along the southwestern primary flow path, 0.0009 to 0.004 day^{-1} along the northwestern

secondary flow path, and 0.0008 to 0.003 day^{-1} along the northeastern flow path. A review of recent literature indicates that higher rate constants have been observed at other sites. For example, Chapelle (1994) reported that at two different sites with anaerobic conditions, the anaerobic rate constants were both approximately 0.01 day^{-1}. Wilson *et al.* (1994) report first-order anaerobic biodegradation rates of 0.05 to 1.3 $week^{-1}$ (0.007 to 0.185 day^{-1}). Stauffer *et al.* (1994) report rate constants of 0.01 day^{-1} and 0.018 day^{-1} for benzene and p-xylene, respectively.

A major controlling factor for the rate of biodegradation is the quantity of electron acceptors that are flushed from upgradient areas through the contaminated zone. The relatively low decay coefficients are likely controlled by the divergent groundwater flow divide and the recharge area present at the model's upgradient boundary. Because rainwater contains relatively low concentrations of nitrate, iron, and sulfate, groundwater infiltration alone can not supply adequate quantities of these constituents. However, it appears that infiltration, in combination with the natural background concentrations reported in Section 4, provides an adequate supply of electron acceptors to biodegrade the dissolved hydrocarbon constituents located in lateral and downgradient portions of the plume. Because nitrate was included in the initial condition for the Bioplume II model, and to be conservative, first-order decay was not included within the numerical model.

Analytical models were utilized to determine site specific first-order decay rates along each of the three flow paths by computing solutions for various values of the decay coefficient, then comparing model results to the observed plume distribution. Results of the analytical model performed along the primary (southwestern) flow path agreed with the results of the calibrated Bioplume II model. The analytical models were also utilized to predict contaminant travel distances along the secondary (northwestern and northeastern) flow paths.

5.4 MODEL CALIBRATION

Model calibration is an important component in the development of any numerical groundwater model. Calibration of the flow model demonstrates that the model is capable of matching hydraulic conditions observed at the site; calibration of a contaminant transport model superimposed upon the calibrated flow model helps verify that contaminant loading and transport conditions are being appropriately simulated. The numerical flow model presented herein was calibrated by altering transmissivity in a trial-and-error fashion until simulated heads approximated observed field values within a prescribed accuracy. After calibration of the flow component, the numerical transport model was calibrated by altering hydraulic and solute transport parameters in a trial-and-error fashion until the simulated BTEX plume approximated observed field values. Table 5.1 lists input parameters used for the Bioplume II modeling effort. Model input is included in Appendix D and model output is provided in ASCII format on diskettes within Appendix E.

5.4.1 Water Table Calibration

The shallow water table at Site SS27/XYZ was assumed to be influenced only by continuous recharge and discharge at the constant-head cells established at the upgradient and downgradient model boundaries. The water levels observed at the site during April 1994 were utilized as input for the constant-head cells. To be conservative, recharge to the aquifer through rainfall (which would add water, thereby increasing dilution of the plume) was not included in the model. Potential recharge at infiltration zones and other water sources (apart from the upgradient boundary) was omitted because of a lack of reliable data during non-steady-state conditions. Only the transmissivity values were varied to calibrate the water table surface. The model was calibrated under steady-state conditions.

TABLE 5.1
BIOPLUME II MODEL INPUT PARAMETERS
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Parameter	Description	CAL Calibrated Model Setup	SR8	SR6
NTIM	Max. number of time steps in a pumping	5	3	3
NPMP	Number of Pumping Periods	1	8	8
NX	Number of nodes in the X direction	20	20	20
NY	Number of node s in the Y direction	30	30	30
NPMAX	Maximum number of Particles NPMAX=(NX-2)(NY-2)(NPTPND) + (N_S[a])(NPTPND) + 250	4966	4966	4966
NPNT	Time step interval for printing data	1	1	1
NITP	Number of iteration parameters	7	7	7
NOBS	Number of observation points	0	0	0
MAX	Maximum allowable number of iterations in ADIP[b]	200	200	200
NWEC	Number of pumping or injection wells	4	14	14
NPTPND	Initial number of particles per node	9	9	9
NCODES	Number of node identification codes	2	2	2
NPNTMV	Particle movement interval (IMOV)	0	0	0
NPNTVL	Option for printing computed velocities	0	0	0
NPNTD	Option to print computed dispersion equation coefficients	0	0	0
NPDELC	Option to print computed changes in concentration	0	0	0
NPNCHV	Option to punch velocity data	0	0	0
NREACT	Option for biodegradation, retardation and decay	1	1	1
PINT	Pumping period (years)	50	50	50
TOL	Convergence criteria in ADIP	0.001	0.001	0.001
POROS	Effective porosity	0.35	0.35	0.35
BETA	Characteristic length (long. dispersivity; feet)	25	25	25
S	Storage Coefficient	0 (Steady-State)	0	0
TIMX	Time increment multiplier for transient flow	NA[c]	NA	NA
TINIT	Size of initial time step (seconds)	NA	NA	NA
XDEL	Width of finite difference cell in the x direction (feet)	120	120	120
YDEL	Width of finite difference cell in the y direction (feet)	120	120	120
DLTRAT	Ratio of transverse to longitudinal dispersivity	0.1	0.1	0.1
CELDIS	Maximum cell distance per particle move	0.5	0.5	0.5
ANFCTR	Ratio of Tyy to Txx	1 (Isotropic)	1	1
DK	Distribution coefficient	0.0211	0.0211	0.0211
RHOB	Bulk density of the solid (grams/cubic centimeter)	1.6	1.6	1.6
THALF	Half-life of the solute	0	0	0
DEC1	Anaerobic decay coefficient	0	0	0
DEC2	Reaeration coefficient (day^{-1})	0.003	0.003	0.003
F	Stoichiometric Ratio of Hydrocarbon to Oxygen	3.1	3.1	3.1

[a] N_S = Number of nodes which represent fluid sources

[b] ADIP = Alternating - direction implicit procedure (subroutine for solving groundwater flow equation)

[c] NA = Not applicable

Hydraulic conductivity is an important aquifer characteristic that determines the ability of the water-bearing strata to transmit groundwater. Transmissivity is the product of the hydraulic conductivity and the thickness of the aquifer. An accurate estimate of hydraulic conductivity is important to help quantify advective groundwater flow velocities and to define the flushing potential of the aquifer and the quantity of electron-acceptor-charged groundwater that is entering the site from upgradient locations. As indicated by the work of Rifai *et al.* (1988), the Bioplume II model is particularly sensitive to variations in hydraulic conductivity. Lower values of hydraulic conductivity result in a slower-moving plume that degrades at a slower rate because less oxygen, nitrate, iron, sulfate, and carbon dioxide is available for biodegradation. Higher values of hydraulic conductivity result in a faster-moving plume that degrades faster because more electron acceptors are available for biodegradation. Saturated thickness data from previous reports, geologic logs, and water level measurements were used in conjunction with the average hydraulic conductivity as determined by Parsons ES (6.94×10^{-4} feet/second) to estimate an initial uniform transmissivity of 0.0174 ft^2/sec for the entire model domain. Based upon the hydrologic cross-sections (Figure 3.3 and 3.4) and monitoring well construction details, the saturated thickness is 25 feet.

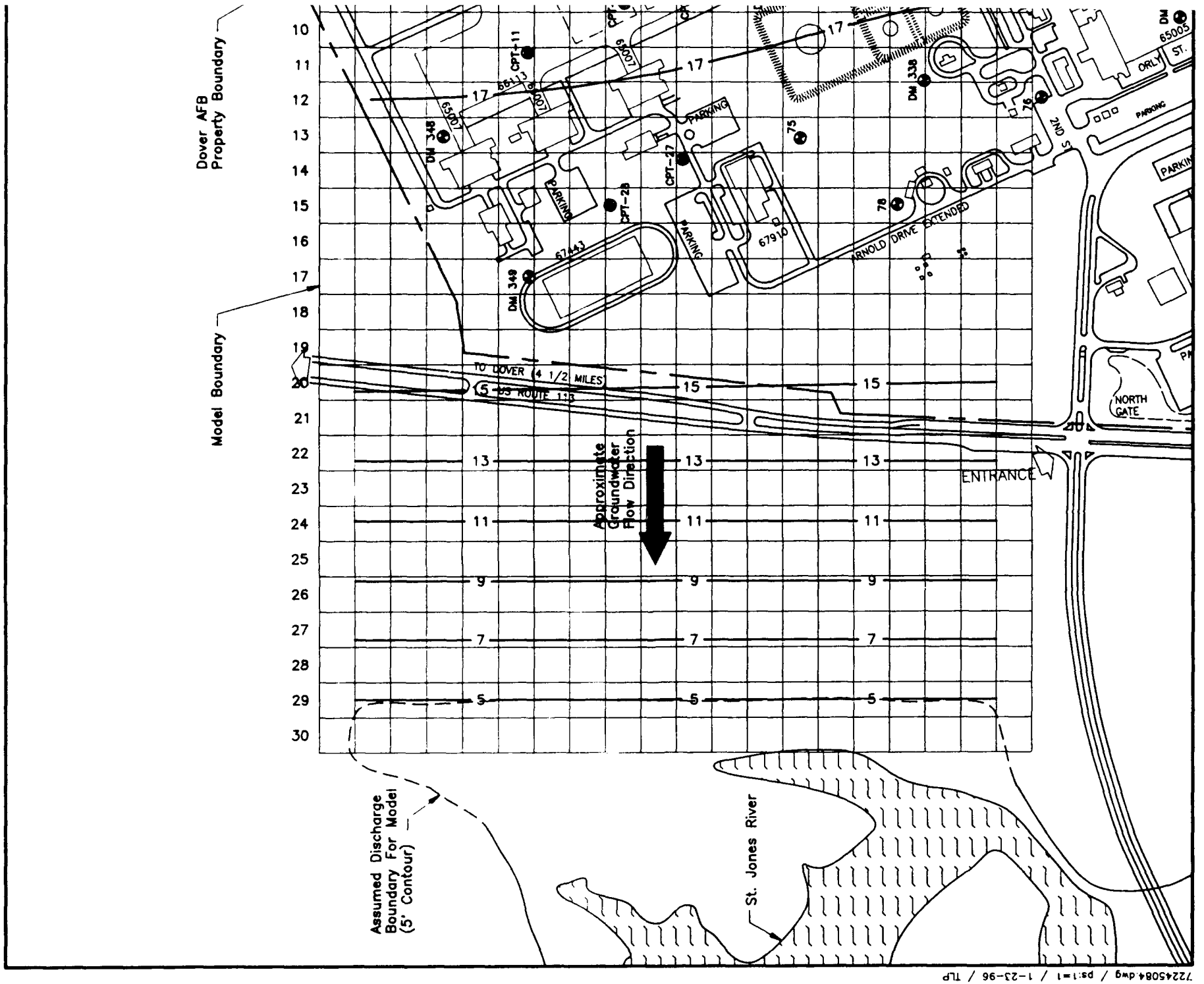
The original fuel release at Site SS27/XYZ was first noted during 1984. However, it is unknown if this release occurred from a point source or over a length of pipeline. Due to the distance between the suspected release location and the downgradient edge of the plume, the time required to form the plume observed in April 1994 may range from 8 to 15 years. The initial simulations were run to determine if the initial parameters (such as transmissivity) would produce reasonable plume configurations after 8 to 15 years, and to provide a preliminary estimate of BTEX injection rates (see Section 5.4.2 for additional information on BTEX injection). The simulation

incorporating the original hydraulic conductivity and saturated thickness values closely approximated the assumed travel time, and thus was utilized within the model.

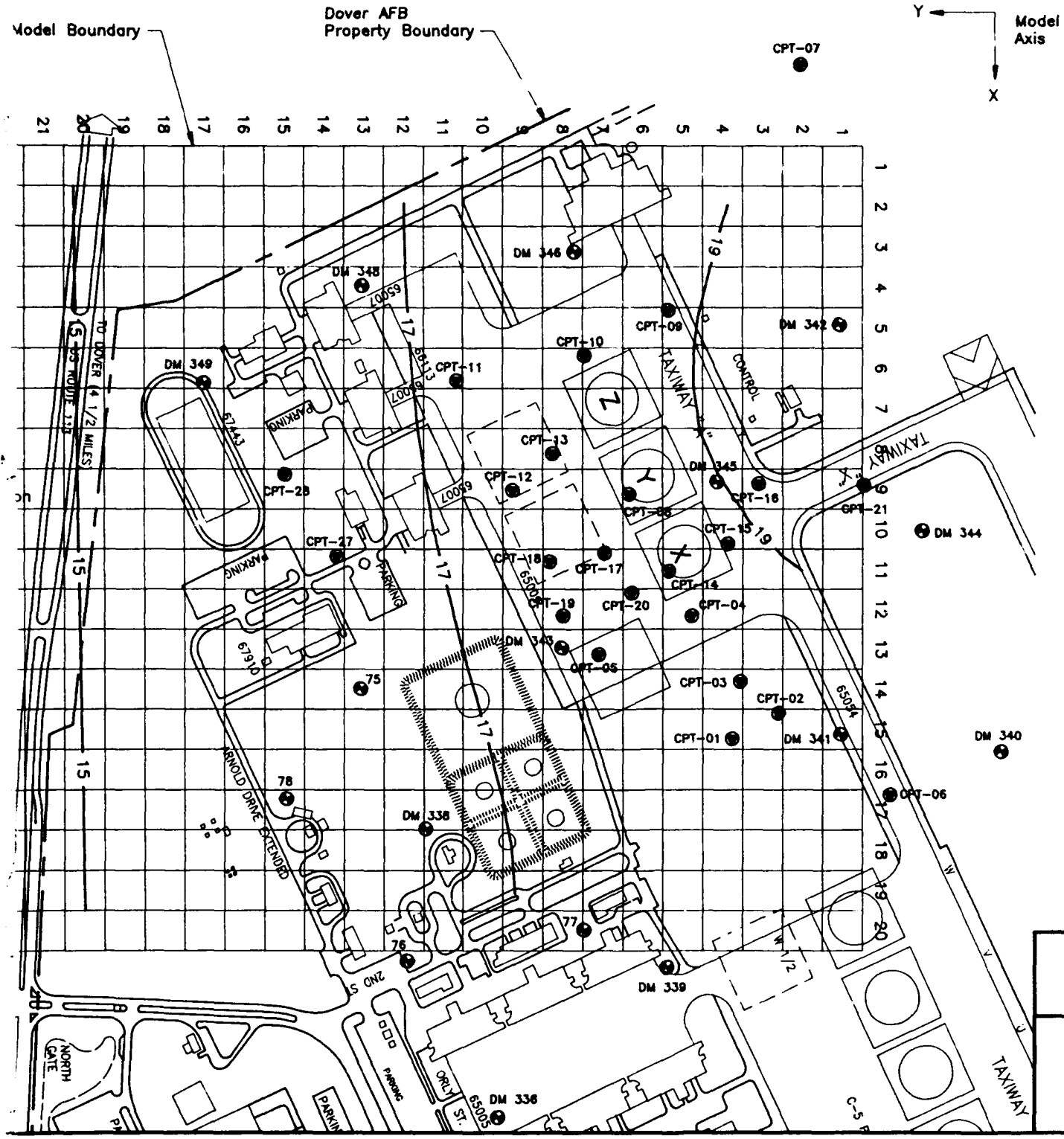
As noted within Section 3, the measured average hydraulic gradient along the primary (southwestern) flow pathway was 0.0021 ft/ft and the overall hydraulic gradient from the upgradient site boundary to the St. Jones River was 0.0041 ft/ft. The steeper gradients in the vicinity of the St. Jones River are likely a result of groundwater discharge to the river. In order to simulate these steeper gradients in the downgradient portion of the model domain, transmissivity values were decreased by a factor of 5.5 downgradient of CPT-28. Because slug test data at best provide a measurement of conductivity within an order-of-magnitude, this change is not excessive. Model sensitivity to transmissivity (hydraulic conductivity times saturated thickness) is discussed in Section 5.5.

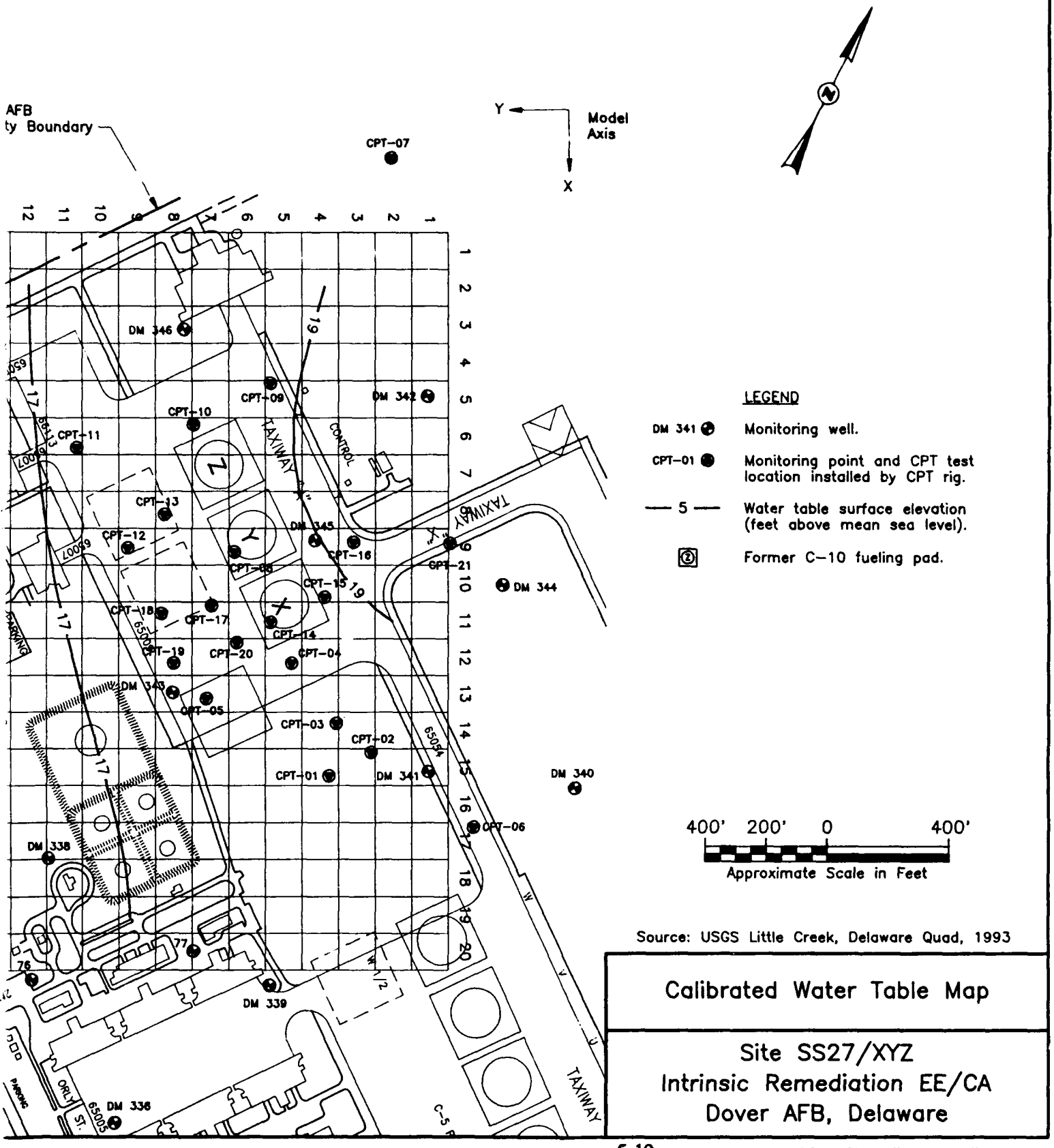
Figure 5.2 shows the calibrated water table. Because the northwestern and southeastern (lateral) model boundaries were configured as no-flow (specified flux), groundwater flow within the model is primarily parallel to these boundaries. As a result, the divergent flow patterns observed in the model (Figure 5.2) are not as prominent as those observed at the site (Figure 3.5)

Calibrated model transmissivities ranged from 3.1×10^{-3} to 1.7×10^{-2} ft^2/sec. Water level elevation data from cells associated with nine monitoring wells and monitoring points were used to compare measured and simulated heads for calibration. The nine selected cell locations each contained one of the following wells or monitoring points: DM 343S, DM 345S, 75S, CPT-2S, CPT-4S, CPT-9S, CPT-12S, CPT-27S, and CPT-28S. The root mean squared (RMS) error is commonly used to express the average difference between simulated and measured water level elevations. The RMS



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Model Boundary
Dover AFB
Property Boundary
Y
X
Model
Axis
CPT-07
DM 346
DM 348
DM 349
DM 342
CPT-09
CPT-10
CPT-11
CPT-13
CPT-12
CPT-28
CPT-27
CPT-18
CPT-17
CPT-19
CPT-20
CPT-04
CPT-14
CPT-15
CPT-16
CPT-21
DM 345
DM 344
DM 343
CPT-05
CPT-03
CPT-02
CPT-01
DM 341
DM 340
CPT-06
DM 338
DM 339
DM 336
75
76
77
78
TAXIWAY "X"
TAXIWAY
CONTROL
PARKING
ARNOLD DRIVE EXTENDED
2ND ST.
ORLY ST.
NORTH GATE
TAXIWAY
65007
67443
67910
65004
65005
15
17
19
LEGE
DM 341 Monit
CPT-01 Monit
locat
5 Wate
(feet
Form
400' 200
Approxi
Source: USGS Little
Calibrated
Site
Intrinsic R
Dover



Source: USGS Little Creek, Delaware Quad, 1993

Calibrated Water Table Map

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

error is the average of the squared differences between measured and simulated heads, and can be expressed as:

$$RMS = \left[\frac{1}{n} \cdot \sum_{i=1}^{n} \left[\left(h_m - h_s \right)_i \right]^2 \right]^{0.5}$$

Where: n = the number of points where heads are being compared

h_m = measured head value

h_s = simulated head value.

The RMS error between observed and calibrated values at the nine comparison points was 0.81 ft over the domain of the test well population. This corresponds to a calibration error of 5.4 percent (water levels dropped a maximum of 15 feet over the length of the model grid). RMS error calculations are summarized in Appendix D. A plot of measured vs. calibrated heads shows a random distribution of points around a straight line, as shown in Appendix D. Deviation of points from a straight line should be randomly distributed in a plot of results from computer simulations (Anderson and Woessner, 1992).

In solving the groundwater flow equation, Bioplume II establishes the water table surface and calculates an overall hydraulic balance that accounts for the numerical difference between flux into and out of the system. The hydraulic mass balance for the calibrated model was excellent, with 99.86 percent of the water flux into and out of the system being numerically accounted for (i.e., a 0.14 percent error). According to Anderson and Woessner (1992), a mass balance error of around 1 percent is acceptable, while Konikow (1978) indicates an error of less than 0.1 percent is ideal.

5.4.2 BTEX Plume Calibration

Model input parameters affecting the distribution and concentration of the simulated BTEX plume were modified so that model predictions matched dissolved total BTEX concentrations observed in April 1994. To do this, model runs were made using the calibrated steady-state hydraulic parameters coupled with the introduction of contaminants. For this site, the calibration also involved a time element. The original release was first noted near Building 950 during 1984. However, it is unknown if this release had just occurred or if it occurred from a point source or over a length of pipeline. The calibrated Bioplume II model for this site utilizes injection wells to simulate contaminant release from the source area depicted in Figure 4.1. Due to the position of the suspected release point with respect to the modeled locations of the source cells, and accounting for advection and plume retardation, the time required to form the plume observed in April 1994 may range from 8 to 10 years. A formation time of 9 years was utilized during model calibration. This assumption is conservative since a shorter formation time results in a faster moving plume. As a result, the plume calibration simulations were made with a time constraint of 9 years; in other words, computed BTEX plume concentrations and configurations were compared to April 1994 data after 9 years of simulation time incorporating the introduction of contaminants into the groundwater.

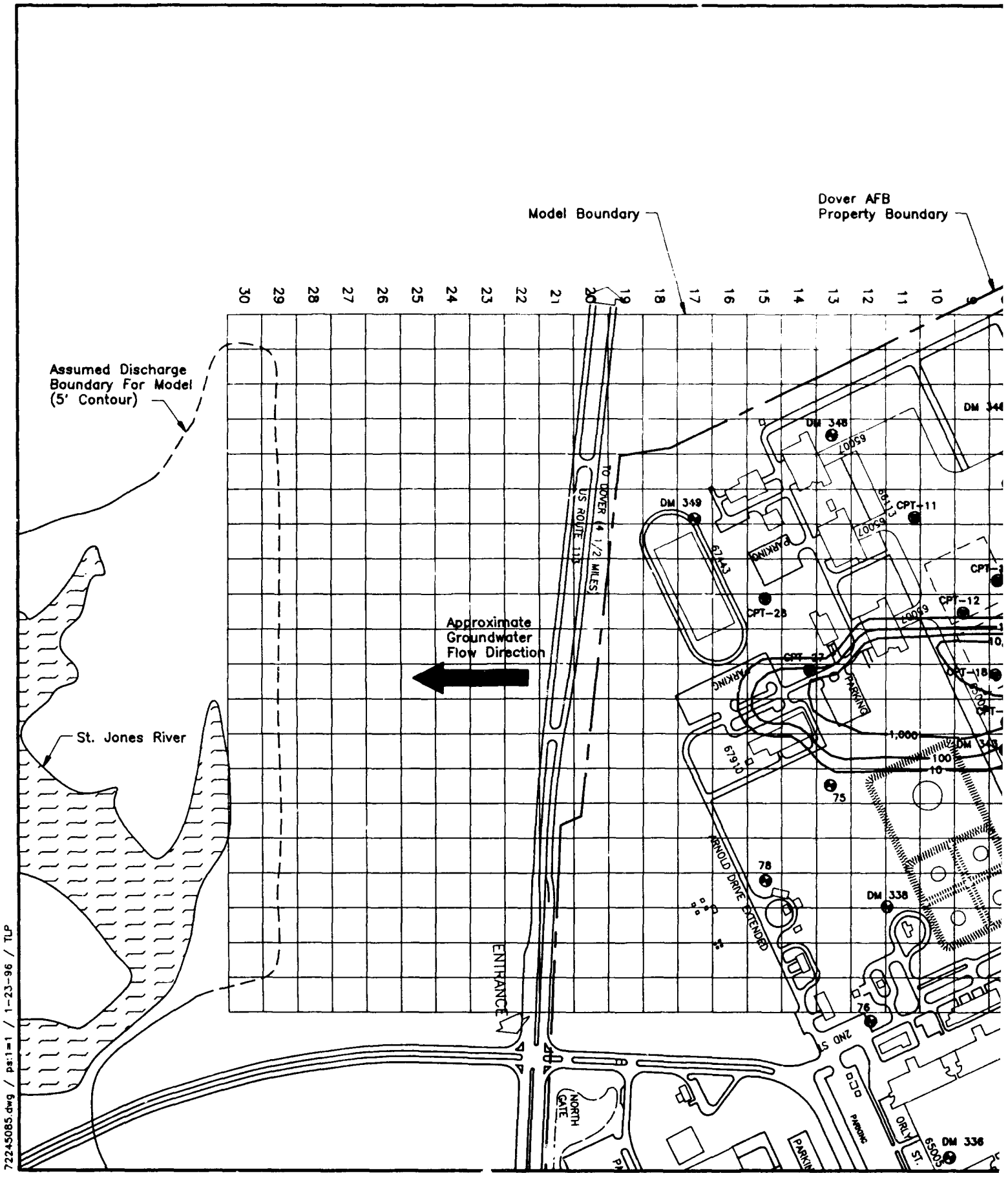
Because mobile and residual LNAPL are present in the vicinity of the water table at the site, it was necessary to include model injection wells to simulate partitioning of BTEX compounds from the LNAPL into the groundwater. The locations of the injection wells are shown on Figure 5.1. Initial locations and numbers of injection wells were based on the known locations of mobile and residual LNAPL (see Figure 4.1 and 4.2). Then, the initial numbers and locations of the injection wells and injection concentrations were varied in a trial-and-error fashion until the resulting

BTEX distribution after 9 years of simulation time closely approximated the BTEX distribution observed in April 1994.

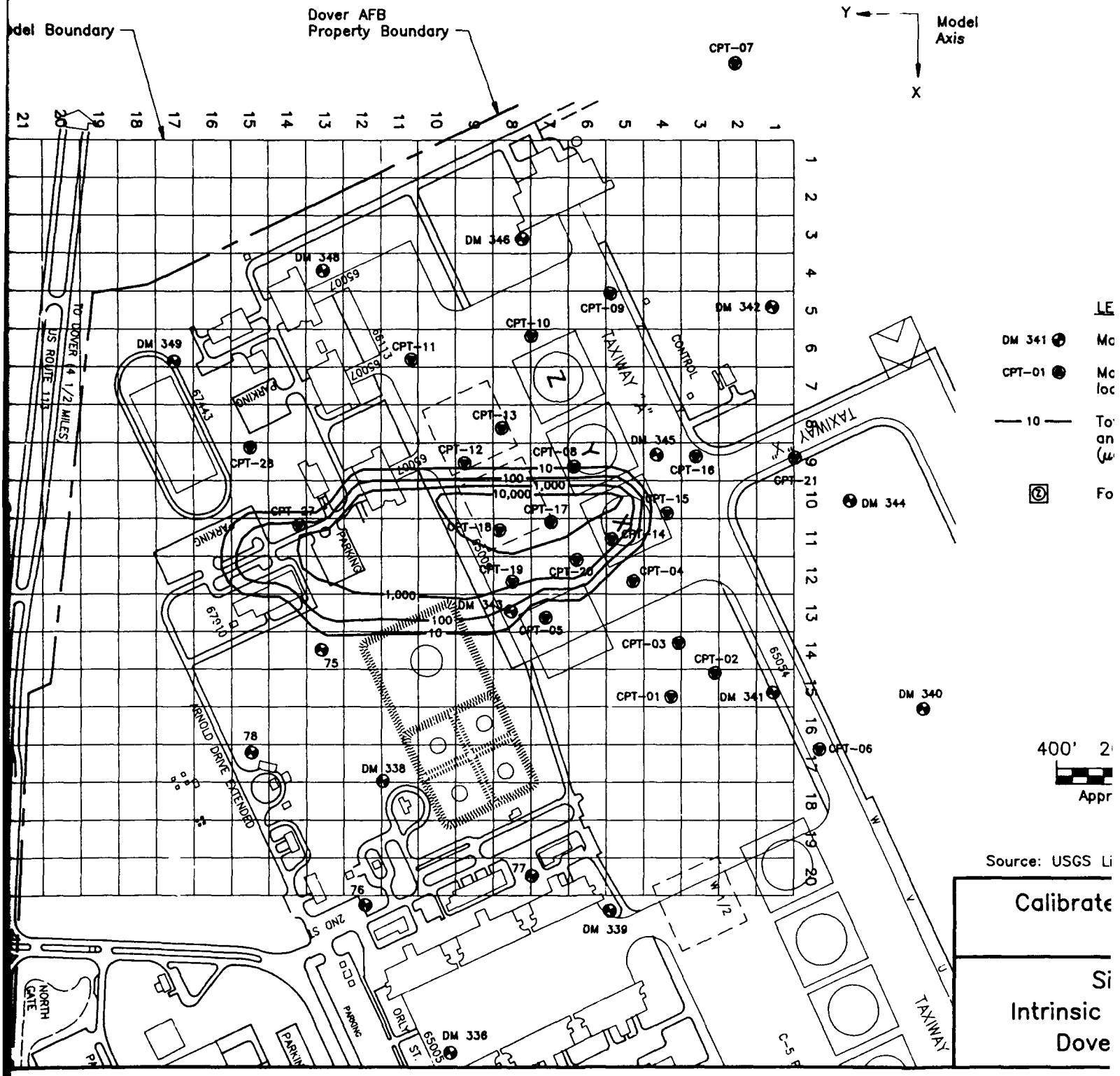
While the term "injection well" suggests contaminants are being introduced at a point, Bioplume II assumes that contamination introduced at a well instantly equilibrates throughout the entire cell in which the well is located. The injection rate for the cells was set at 4.6×10^{-6} cubic feet per second (ft^3/sec), a value low enough so that the flow calibration and water balance were not affected. Relatively high BTEX concentrations were injected in upgradient injection wells because of the low pumping rate and the influx of oxygen introduced at the upgradient constant head cells. Replenishment of oxygen quickly degraded BTEX concentrations at the head of the plume, which in turn required larger injection concentrations of BTEX to produce observed BTEX contours.

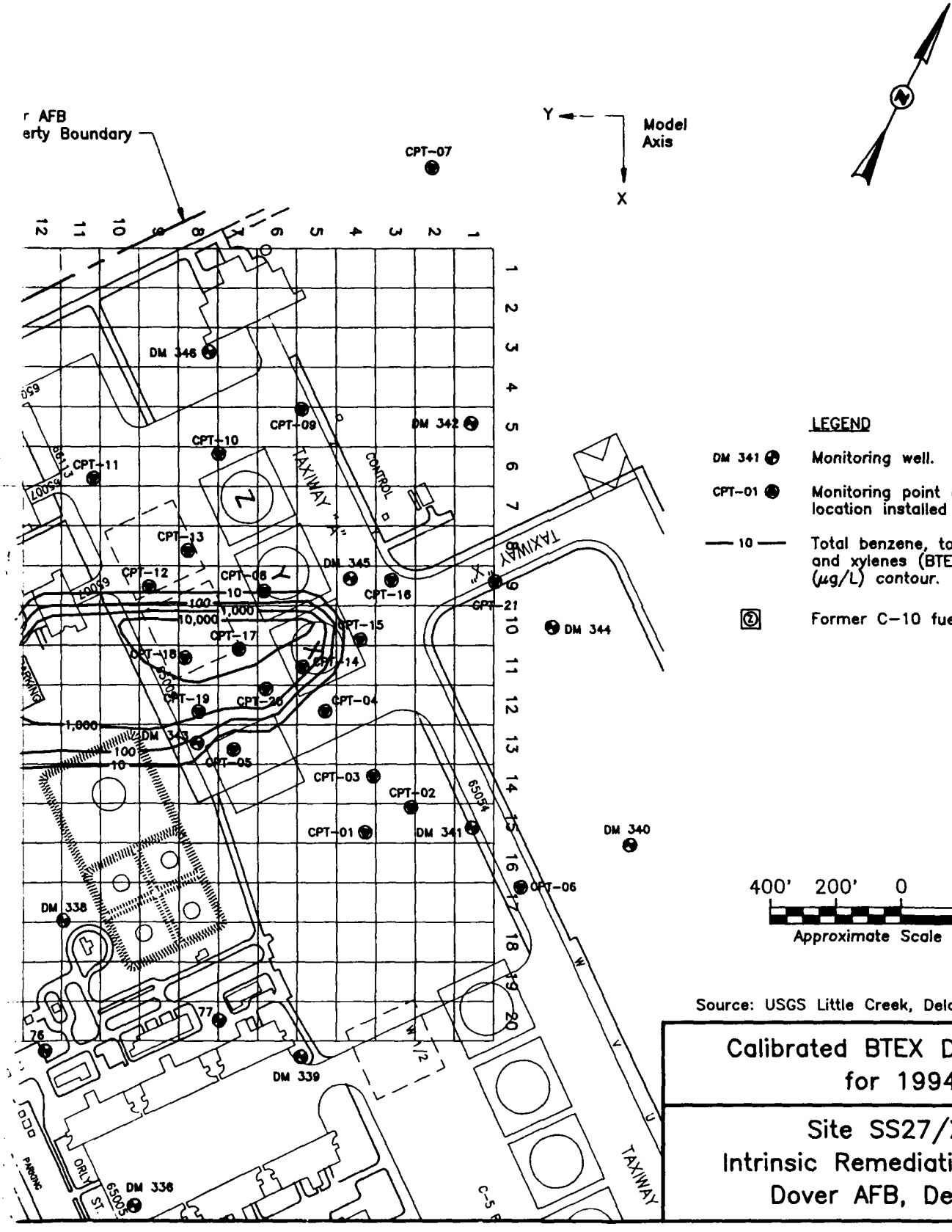
Total BTEX injection concentrations were determined by varying the injection concentration for the various wells until the modeled total BTEX plume approximated the total BTEX plume observed in April 1994. By varying the injection well concentrations, the reaeration coefficient, the coefficient of retardation, and the longitudinal dispersivity, the BTEX plume was calibrated reasonably well to the observed 1994 BTEX distribution in terms of migration distance and BTEX concentrations in the source area. The calibrated dissolved BTEX plume configuration is shown on Figure 5.3.

As discussed in Section 5.3.1, the site's BTEX migration patterns result from the presence of a groundwater divide at the upgradient site boundary. Due to these complications, the numerical model included only migration along the primary (southwestern) flow direction. As a result, the calibrated BTEX distribution for 1994



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Dover AFB
Property Boundary
Model Axis
Y
X
CPT-07
DM 346
DM 348
DM 349
DM 342
DM 345
DM 344
DM 343
DM 341
DM 340
DM 339
DM 338
DM 336
CPT-10
CPT-09
CPT-11
CPT-13
CPT-12
CPT-08
CPT-28
CPT-22
CPT-16
CPT-21
CPT-15
CPT-17
CPT-18
CPT-14
CPT-19
CPT-20
CPT-04
CPT-05
CPT-03
CPT-02
CPT-01
CPT-06
75
76
77
78
TAXIWAY "A"
CONTROL
TAXIWAY
PARKING
PARKING
PARKING
PARKING
ARNOLD DRIVE EXTENDED
2ND ST.
ORLY ST.
NORTH GATE
TAXIWAY
TO DOVER (4 1/2 MILES)
US ROUTE 113
65007
65007
65007
65007
65054
65005
67443
67510
8613
10
100
1,000
10,000
1,000
100
10
LE
DM 341
Mo
CPT-01
Mo
loc
10
To
an
(μ
Fo
400'
Appr
Source: USGS Li
Calibrate
Si
Intrinsic
Dove



LEGEND

DM 341 — Monitoring well.

CPT-01 — Monitoring point and CPT test location installed by CPT rig.

— 10 — Total benzene, toluene, ethylbenzene and xylenes (BTEX) concentration ($\mu g/L$) contour.

Former C-10 fueling pad.

Source: USGS Little Creek, Delaware Quad, 1993

Calibrated BTEX Distribution for 1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

(Figure 5.3) and all subsequent numerical model results do not include the secondary (northwestern and northeastern) flow pathways.

The calibrated model plume (Figure 5.3), while not identical to the southwestern lobe of the observed BTEX plume (Figure 4.3), is very similar. Differences in modeled and actual plume shapes and concentrations are caused by physical, chemical, and biological variations within the shallow saturated zone that result from natural aquifer heterogeneity that cannot be reproduced in a model that assumes homogeneous conditions. The downgradient extent of the computed 10-µg/L, 100-µg/L, 1,000-µg/L, and 10,000-µg/L contours (Figure 5.3) are all very similar to the respective contours observed in April 1994 (Figure 4.3) along the primary (southwestern) flow direction. The computed 1,000-µg/L and 10,000-µg/L contours are slightly wider than the observed contours. However, these differences are relatively minor. In addition, the predicted direction of groundwater flow is approximately 7 degrees south of the BTEX distribution observed in April 1994. This difference is the result of the diverse flow field reported at the site that is not fully accounted for by the steady-state numerical model. Because the downgradient discharge boundary (St. Jones River) is well defined, the minor directional deviation of plume travel will not seriously affect predictions.

The maximum computed BTEX concentration was 21,900 µg/L, which was much lower than the concentration observed at CPT-15S (11,300,000 µg/L) and similar to the value reported at CPT-18S (22,900 µg/L). The maximum simulated concentration was located in a cell just upgradient of CPT-15S and CPT-18S. The field samples collected from these monitoring points likely contained mobile LNAPL (emulsified JP-4 fuel) that resulted in concentrations near or higher than the predicted BTEX solubility limit. During model calibration, Parsons ES observed that loading rates high

enough to produce BTEX concentrations over 30,000 µg/L in the source area resulted in a plume that was much longer and wider than the observed plume.

5.4.2.1 Discussion of Parameters Varied During Plume Calibration

As noted previously, the transport parameters varied during plume calibration were dispersivity, the coefficient of retardation, and the reaeration coefficient. Varying transport parameters such as the retardation factor and the longitudinal dispersivity within reasonable ranges did not increase the plume length substantially. Transport parameters were generally varied with the intent of altering plume migration so that the observed plume extent was reproduced. While these parameters were varied with this common intent, each had a slightly different impact on the size and shape of the simulated plume.

5.4.2.1.1 Dispersivity

Much controversy surrounds the concepts of *dispersion* and *dispersivity*. Longitudinal dispersivity values are typically considered to be scale dependent. In other words, for a given sediment type, dispersivity values will depend upon the distance traveled by the solute. Gelhar *et al.* (1985) performed a critical review of various field experiments and found the longitudinal dispersivities varied from 0.03 foot to 18,000 feet. It may be inferred from the study that longitudinal dispersivity may range from 15 to 300 feet for the plume length reported for Site SS27/XYZ. Longitudinal dispersivity was originally estimated as 43 feet, using one-tenth (0.1) of the distance between center of the source area and the longitudinal centroid of the April 1994 plume (see Figure 4.4). Dispersivity estimation calculations are included in Appendix D. Transverse dispersivity values generally are estimated as one-tenth (0.1) of the longitudinal dispersivity values (Domenico and Schwartz, 1990).

During plume calibration, longitudinal dispersivity was decreased to 25 feet from the original estimate of 43 feet. This allowed the computed BTEX plume contours to separate uniformly along the plume centerline, which matched the BTEX distribution observed in April 1994.

5.4.2.1.2 Coefficient of Retardation

Retardation of the BTEX compounds relative to the advective velocity of the groundwater occurs when BTEX molecules are sorbed to the aquifer matrix. The coefficients of retardation for the BTEX compounds were calculated based on measured TOC concentrations in the soils in and near the saturated zone at the site, an assumed soil bulk density of 1.6 grams/cubic centimeter (Freeze and Cherry, 1979), and published values of the soil sorption coefficient (K_{oc}) for the BTEX compounds, as listed by Wiedemeier *et al.* (1995). The results of these calculations are summarized in Table 5.2.

Typically, the minimum retardation coefficient is used as a conservative assumption. The lower the assumed coefficient of retardation, the farther the BTEX plume will migrate downgradient. However, the minimum fraction organic carbon measured for the site was below the reportable method detection limit (Table 4.1). The native environment of the site prior to development was grassy and swampy wetland, which typically contains relatively high natural levels of organic carbon. As a result, the average retardation coefficient calculated for the BTEX compounds (R=1.11) was used for initial model input. Since this value is relatively low for soils of this origin, the resulting retardation coefficient is conservative. During plume calibration, the coefficient of retardation was gradually raised from the initial value of 1.11 to a value of 3, and also decreased to a value of 1. This analysis suggests that the initial retardation coefficient (R=1.11) adequately describes the formation of the BTEX

TABLE 5.2

CALCULATION OF RETARDATION COEFFICIENTS
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Compound	K_{oc} (L/kg [a/])	Fraction Organic Carbon[b/]			Distribution Coefficient K_d (L/kg)			Bulk Density (L/kg)[d/]	Effective Porosity[d/]	Coefficient of Retardation		
		Maximum	Minimum	Average	Maximum[c1/]	Minimum[c2/]	Average[c3/]			Maximum	Minimum	Average
Benzene	79	0.0008	5.00E-08	0.00027	0.063	0.0000040	0.0211	1.60	0.30	1.34	1.00	1.11
Toluene	190	0.0008	5.00E-08	0.00027	0.152	0.000010	0.051	1.60	0.30	1.81	1.00	1.27
Ethylbenzene	468	0.0008	5.00E-08	0.00027	0.374	0.000023	0.125	1.60	0.30	3.00	1.00	1.67
m-Xylene	405	0.0008	5.00E-08	0.00027	0.324	0.000020	0.108	1.60	0.30	2.73	1.00	1.58
o-Xylene	422	0.0008	5.00E-08	0.00027	0.338	0.000021	0.113	1.60	0.30	2.80	1.00	1.60
p-Xylene	357	0.0008	5.00E-08	0.00027	0.286	0.000018	0.095	1.60	0.30	2.52	1.00	1.51

NOTES:

[a/] From technical protocol (Wiedemeier et al., 1995).

[b/] From site data in noncontaminated area (see Table 4.1).

[c1/] K_d = Maximum Fraction Organic Carbon x K_{oc}.

[c2/] K_d = Minimum Fraction Organic Carbon x K_{oc}.

[c3/] K_d = Average Fraction Organic Carbon x K_{oc}.

[d/] Literature values.

plume observed in April 1994. As a result, this value was used in the final model simulations.

5.4.2.1.3 Reaeration Coefficient

The reaeration coefficient is a first-order rate constant used by Bioplume II to simulate the replenishment of oxygen into the groundwater by soil-gas diffusion and rainwater infiltration. A reaeration coefficient of 0.003 day^{-1} was initially estimated, based on other documented Bioplume II modeling efforts (see, for example, Rifai *et al.*, 1988). Use of the reaeration coefficient is justified at this site because of the shallow water table and the relatively high DO concentrations observed in site groundwater at background locations. Reaeration at the site is likely less significant in the source area where the concrete runway and apron inhibit precipitation recharge and soil gas exchange with the atmosphere. However, downgradient areas of the plume, which do not contain concrete cover, likely have higher rates of reaeration. The Bioplume II model utilizes a constant reaeration coefficient for the entire site. During plume calibration, the reaeration coefficient was varied from the initial value of 0.003 day^{-1} to 0.0 day^{-1} to evaluate the effects of surface cover. This analysis suggested that the initial reaeration coefficient (0.003 day^{-1}) adequately describes the formation of the present-day BTEX plume. As a result, this value was used in the final model simulations.

5.5 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to determine the effect of varying model input parameters on model output. According to the work of Rifai *et al.* (1988), the Bioplume II model is most sensitive to changes in the coefficient of reaeration, the coefficient of anaerobic decay, and the hydraulic conductivity of the media. It is less sensitive to changes in the retardation factor, porosity, and dispersivity. A first-order

anaerobic decay coefficient was not used because nitrate was included in the original oxygen map to simulate anaerobic biodegradation at the site. Because the coefficient of anaerobic decay was set to zero, the sensitivity analysis was conducted by varying the hydraulic conductivity (and therefore transmissivity) and the coefficient of reaeration. Because of the potential for large dispersivity values at the site (large scale), a sensitivity analysis was also performed for this parameter. A sensitivity analysis was also performed for the retardation coefficient.

To perform the sensitivity analyses, individual runs of the model were made with the same input as the calibrated model, except that one of the aforementioned parameters was varied. The models were run for 9 years, just as the calibrated model, so that the independent effect of each variable could be assessed in relation to the predicted BTEX distribution for 1994 (Figure 5.3). As a result, eight sensitivity runs of the calibrated model were made, with the following variations:

1) Hydraulic conductivity uniformly increased by a factor of 5;

2) Hydraulic conductivity uniformly decreased by a factor of 5;

3) Longitudinal dispersivity increased to 50 feet;

4) Longitudinal dispersivity decreased to 5 feet;

5) Reaeration coefficient increased to 0.03 day^{-1};

6) Reaeration coefficient decreased to 0.0003 day^{-1};

7) Retardation coefficient increased to 3; and

8) Retardation coefficient decreased to 1 (i.e. no retardation).

The results of the sensitivity analyses are shown graphically in Figures 5.4, 5.5, 5.6, and 5.7. These figures display the predicted BTEX distribution for 1994 versus distance along the centerline of the plume. This manner of displaying data is useful because the plume is relatively narrow and migrates parallel to the model grid. Furthermore, the figures allow easy visualization of the changes in BTEX concentration caused by varying model input parameters.

Uniformly increasing the hydraulic conductivity in the model by half an order of magnitude (model K x 5) drastically increased the migration rate and biodegradation rate of the plume (Figure 5.4). In relation to the calibrated plume, the plume formed in the model with the higher hydraulic conductivity had a lower peak (due to increased biodegradation) and was spread much further downgradient (due to increased advective flow rates). An increased influx of electron acceptors in the highly conductive aquifer increased biodegradation of the plume in the source area. Also, the higher groundwater velocity produced greater downgradient spreading of the BTEX plume. In contrast, decreasing the hydraulic conductivity by a half-order of magnitude slowed plume migration, which in turn caused a slight increase in modeled BTEX levels in the source area and a decreased downgradient plume extent. Increased BTEX concentrations in the source area are caused by a reduction in the amount of electron acceptors being brought into contact with the plume from upgradient locations.

Figure 5.5 illustrates the effects of varying longitudinal dispersivity. Altering longitudinal dispersivity with the specified range did not greatly effect the overall length or peak concentration of the BTEX plume. This suggests that the model is relatively insensitive to dispersivity. Adjusting the dispersivity did not affect the migration distance of the BTEX plume and only slightly affected the peak concentrations. Theoretically, a reduced dispersivity value minimizes spreading of the plume into more electron acceptor-rich portions of the aquifer. Conversely, increasing

FIGURE 5.4
PLOT OF TOTAL BTEX VS DISTANCE ALONG PLUME CENTERLINE WITH VARYING HYDRAULIC CONDUCTIVITY SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA DOVER AFB, DELAWARE

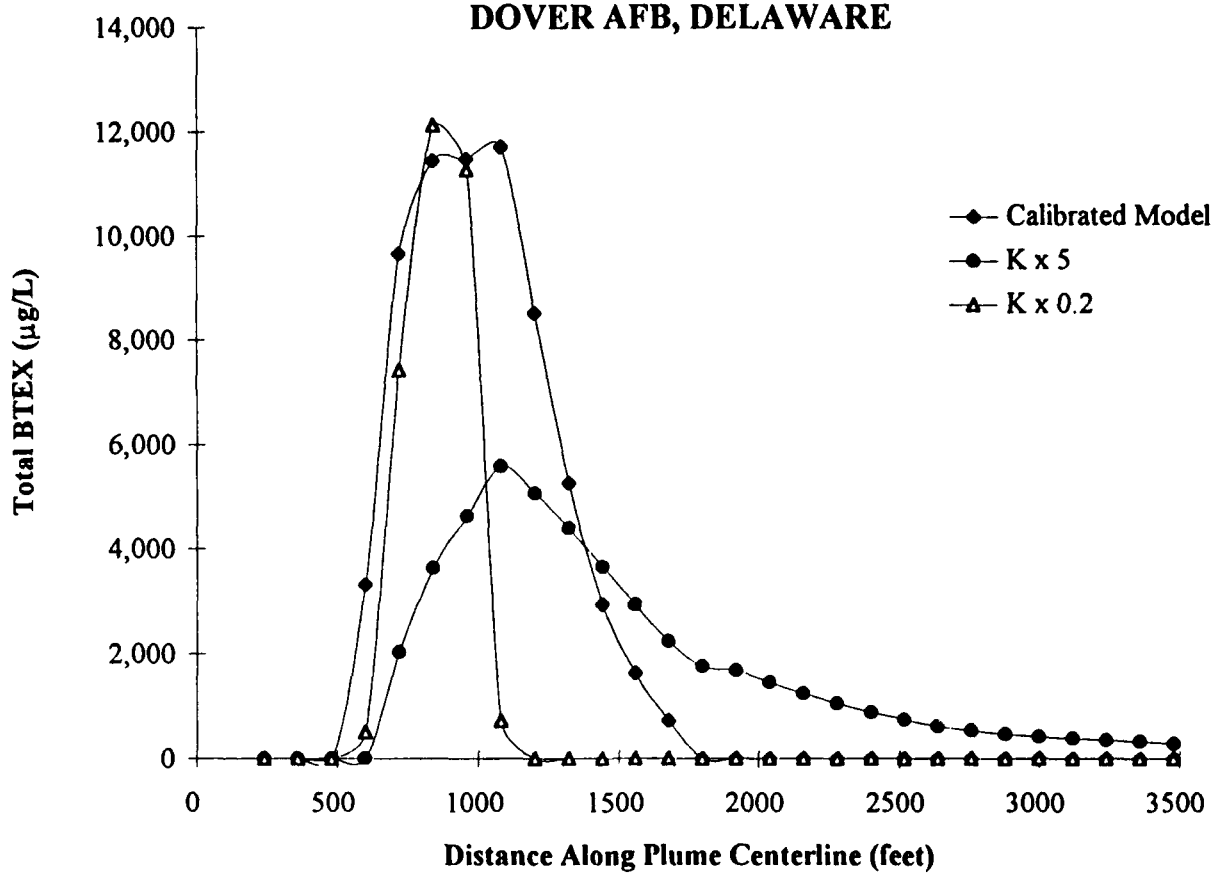


FIGURE 5.5
PLOT OF TOTAL BTEX VS DISTANCE ALONG PLUME CENTERLINE WITH VARYING LONGITUDINAL DISPERSIVITY
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

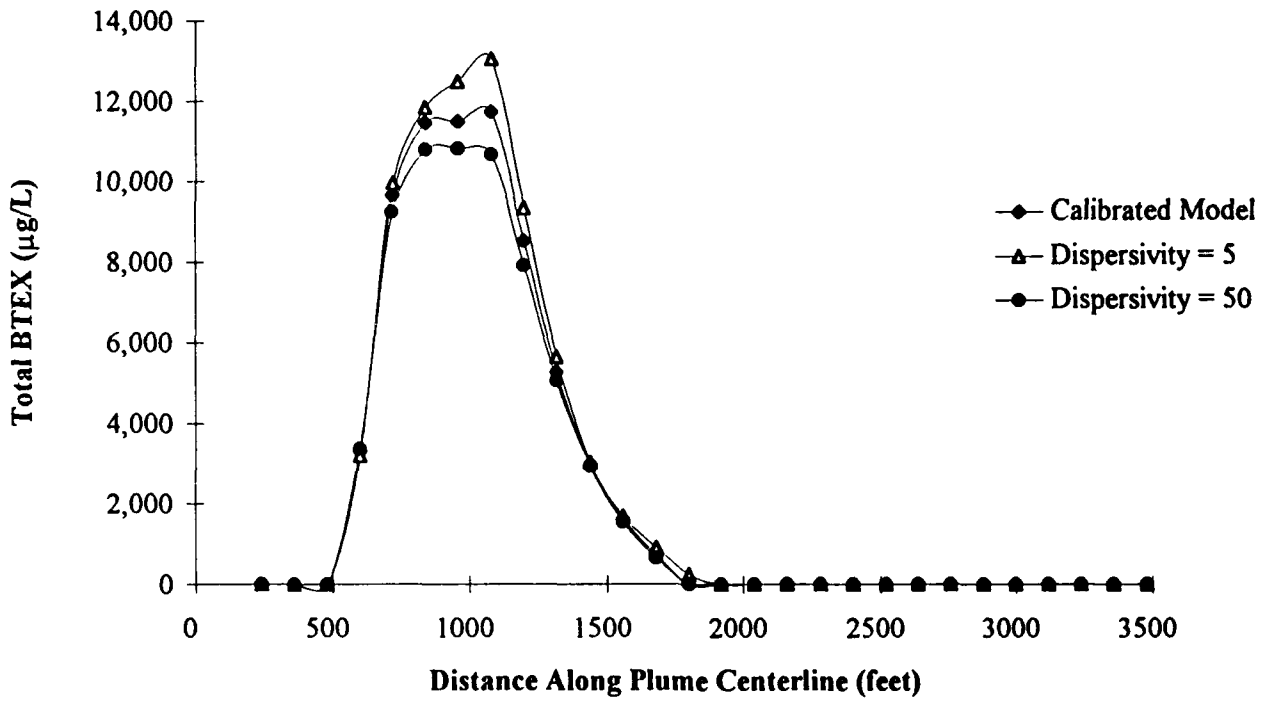
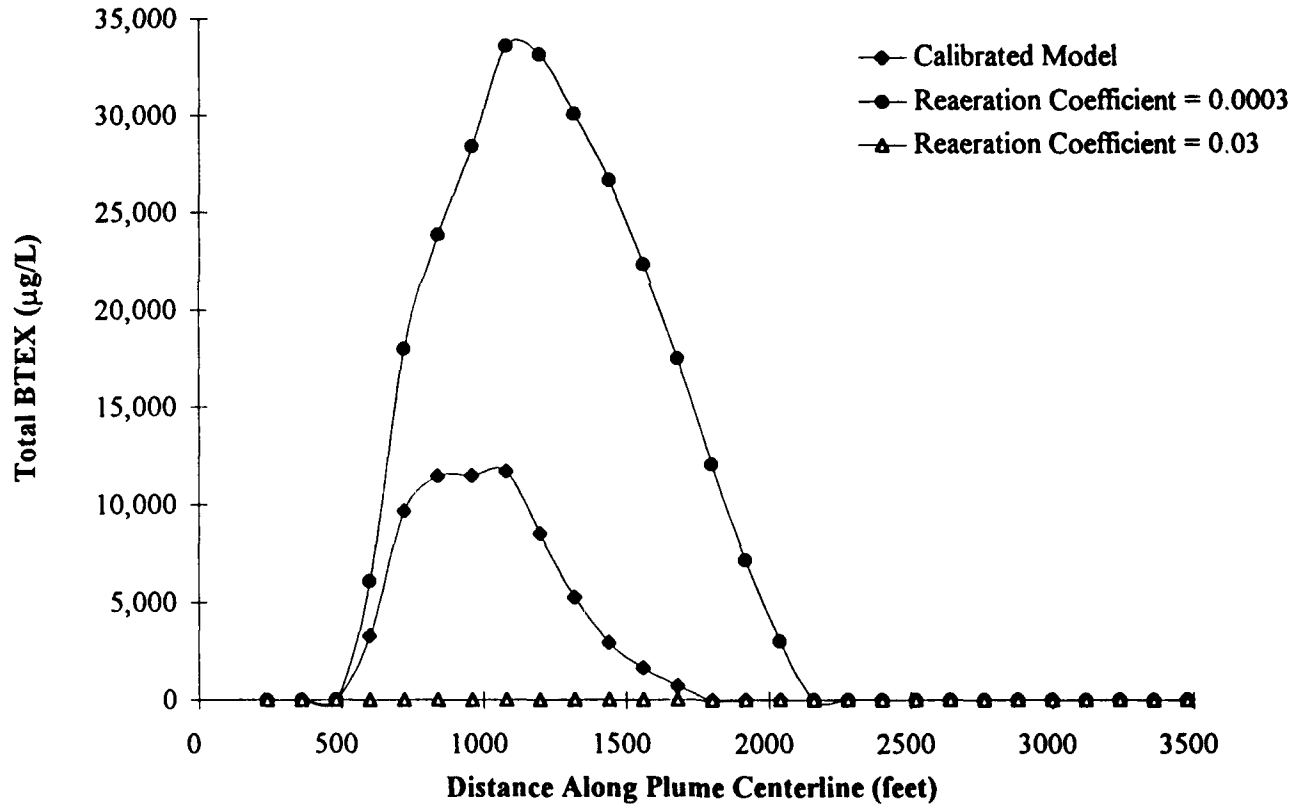


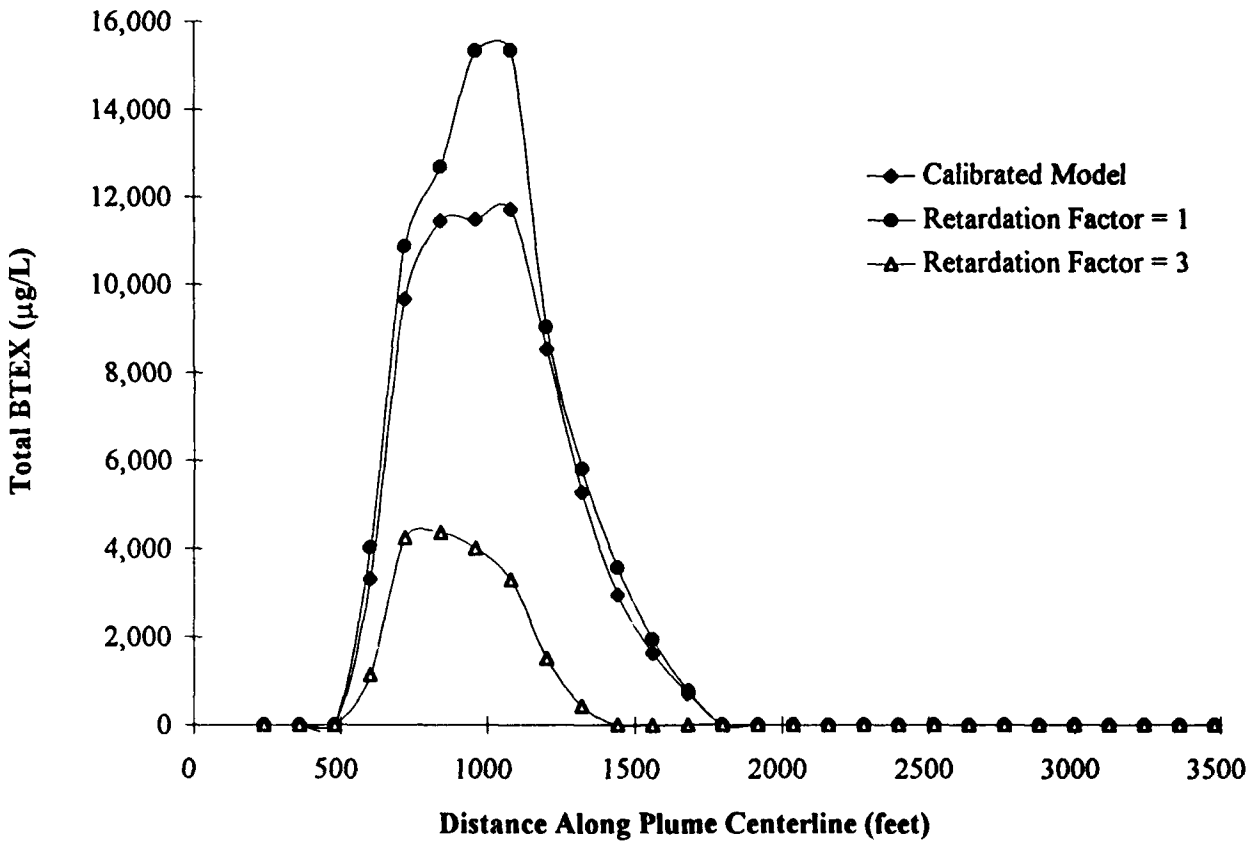
FIGURE 5.6
PLOT OF TOTAL BTEX VS DISTANCE ALONG PLUME CENTERLINE WITH VARYING REAERATION COEFFICIENT
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE



Q:\722450 06050\RD9601BC\SENSITIV XLS

1/25/96 12 PM

FIGURE 5.7
PLOT OF TOTAL BTEX VS DISTANCE ALONG PLUME CENTERLINE WITH VARYING RETARDATION COEFFICIENT
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE



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dispersivity should produce lower BTEX peak concentrations in the source area due to increased diffusion. Large changes in peak concentrations and migration distance were not observed.

The effect of varying the coefficient of reaeration is shown in Figure 5.6. Increasing the reaeration coefficient from 0.003 day^{-1} to 0.03 day^{-1} significantly decreased BTEX concentrations and restricted plume migration. This result is not indicative of the actual site conditions. By reducing the reaeration coefficient by an order of magnitude (to 0.0003 day^{-1}), the length of the modeled BTEX plume increased greatly, as did the maximum concentration. The predicted downgradient end of the plume extended approximately 400 feet past its location observed in April 1994.

Figure 5.7 shows the sensitivity of the model to the coefficient of retardation. The coefficient of retardation was decreased from the calibrated value of 1.11 to 1, which results in no retardation. Removing retardation from the model significantly increased the maximum BTEX concentrations, however, the downgradient extent of the plume was not significantly affected. Increasing the coefficient of retardation to 3.00 (the highest value obtained from site data) significantly decreased the peak plume concentrations and limited the migration of the plume.

The results of the sensitivity analysis suggest that the calibrated model used for this report is reasonable. Increasing the coefficient of reaeration, hydraulic conductivity, or the coefficient of retardation greatly affects the predicted BTEX concentration and distribution. Reducing the coefficient of reaeration lengthens the plume to beyond reasonable distances, based on observations made at the site in April 1994.

5.6 MODEL RESULTS

The Bioplume II model was run under steady-state conditions with no contaminant

source removal (model CAL), annual source removal over an 8-year period (model SR8), and annual source removal over a 6-year period (model SR6). These simulations were run until the plume reached steady-state equilibrium (model CAL) or until the plume disappeared (models SR8 and SR6). Gridded model input data and model calibration data is included are Appendix D. Bioplume II output files are provided on diskettes in ASCII format in Appendix E. As previously mentioned, continuing sources of groundwater contamination at the site exist in the form of soil contamination and mobile and residual LNAPL contamination. Model results suggest that contaminant source reduction in concert with natural attenuation can significantly reduce the longevity of the dissolved BTEX plume at the site.

Although the results of each model run varied depending on the amount of decrease in source injection concentration over time, two consistent conclusions were reached:

1) The plume shape in each simulation is elongated due to rapid advective transport of BTEX contamination and rapid biodegradation of BTEX at the plume periphery; and

2) When plume migration is compared starting from the time of source removal completion (8 years for model SR8 and 6 years for model SR6), there are minimal differences between the two models. The BTEX plume is predicted to cross the downgradient Dover AFB property boundary at concentrations below regulatory levels, regardless of the source removal scenario. Furthermore, the BTEX plume is predicted to recede back onto Dover AFB property within 7 years under both source removal scenarios. This happens because replenished electron acceptor concentrations eventually exceed the dissolved BTEX concentrations introduced into the aquifer by a ratio of greater than 3.1:1.

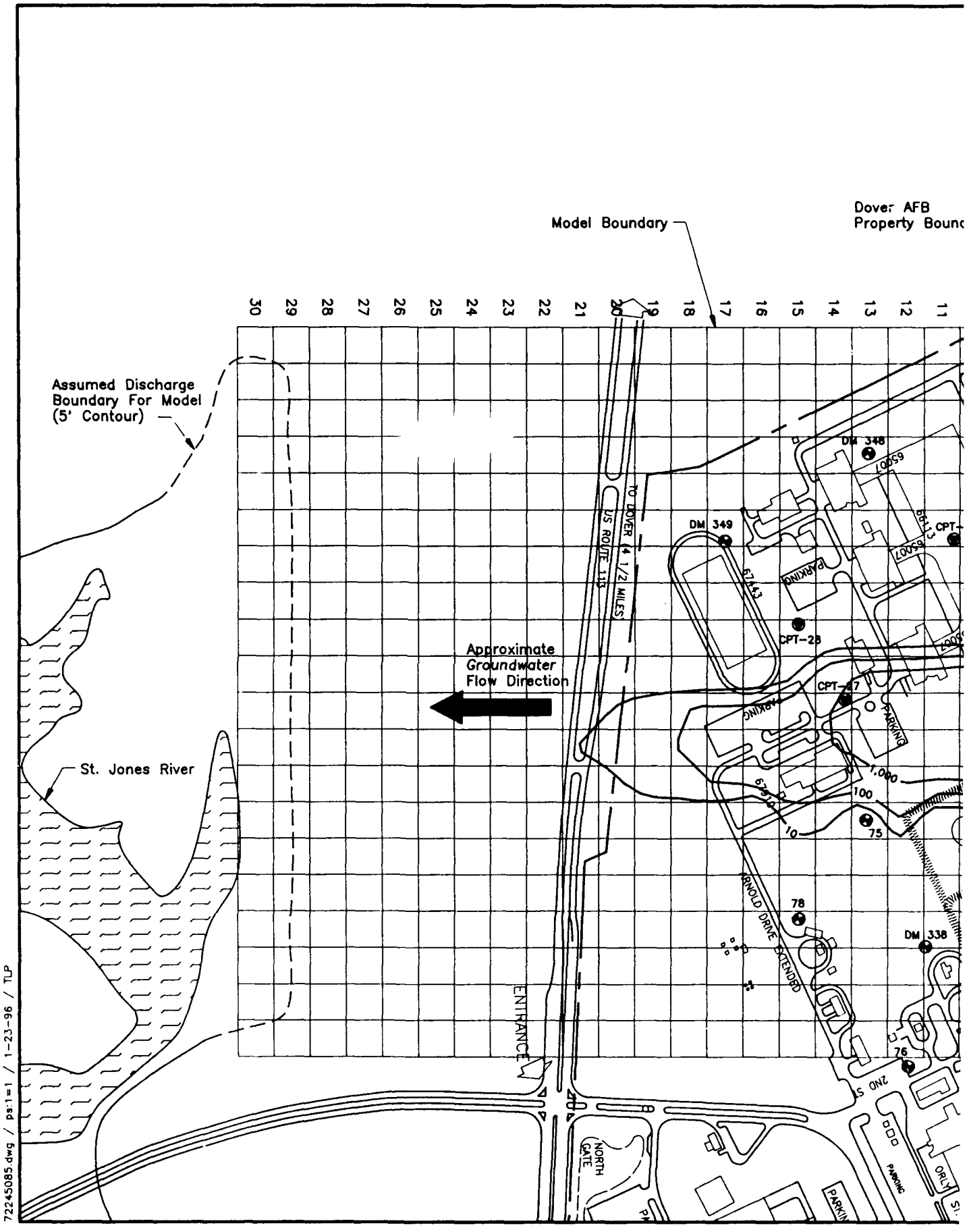
The following sections describe the results of each model scenario. Comparisons to analytical models are provided for each simulation as a check on numerical model results. To simplify discussions regarding predicted cleanup time frames, model results that vary over time are referenced to the number of years relative to 1995 (i.e., the number of years into the future). Likewise, plume migration distances were measured from a common location near the suspected point of release. This measurement point is located near the intersection of Taxiway X and the fueling apron southwest of monitoring well DM 344 (see Figure 5.1).

5.6.1 No Source Removal (Model CAL)

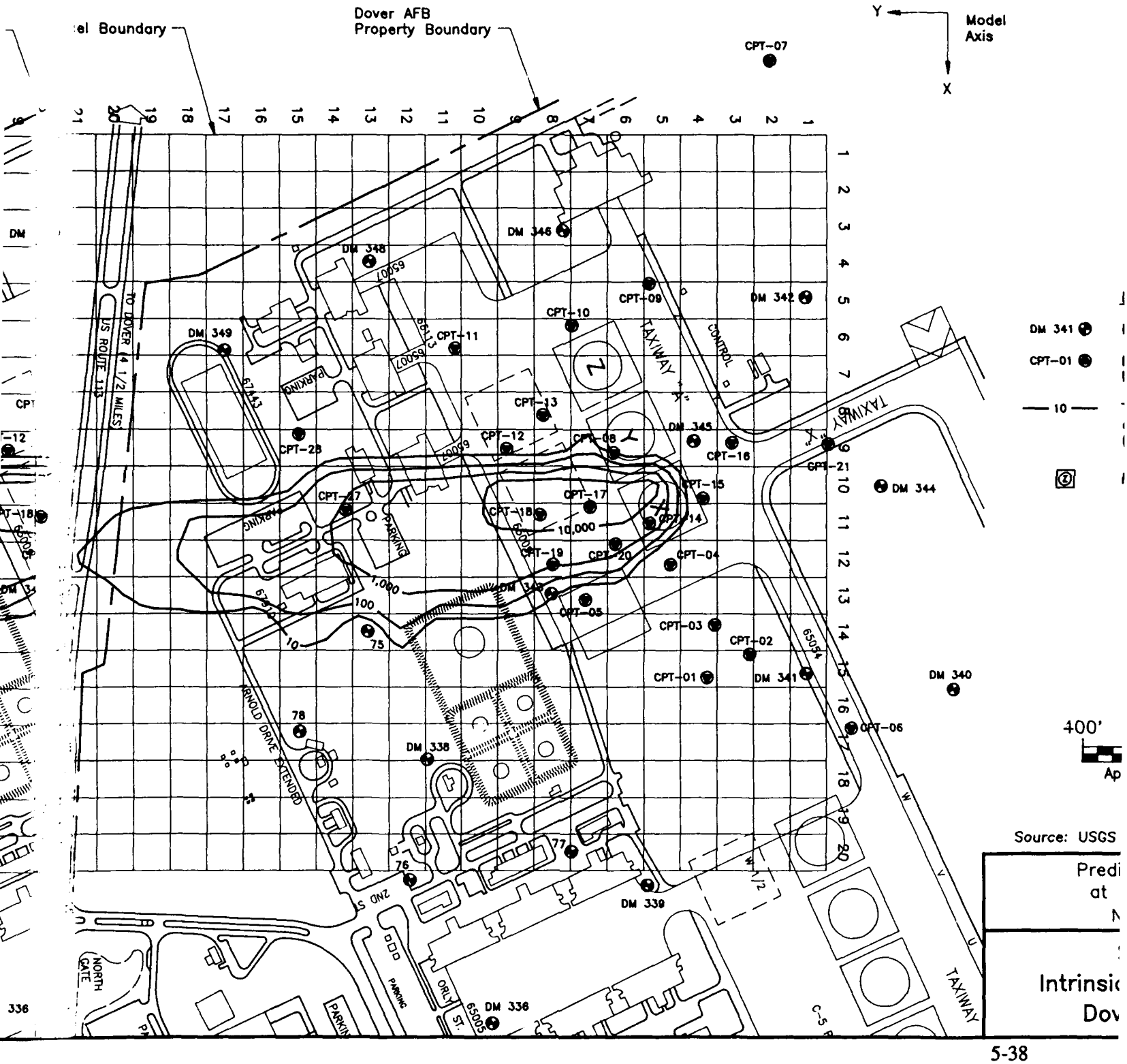
5.6.1.1 Bioplume II Model Results (Model CAL)

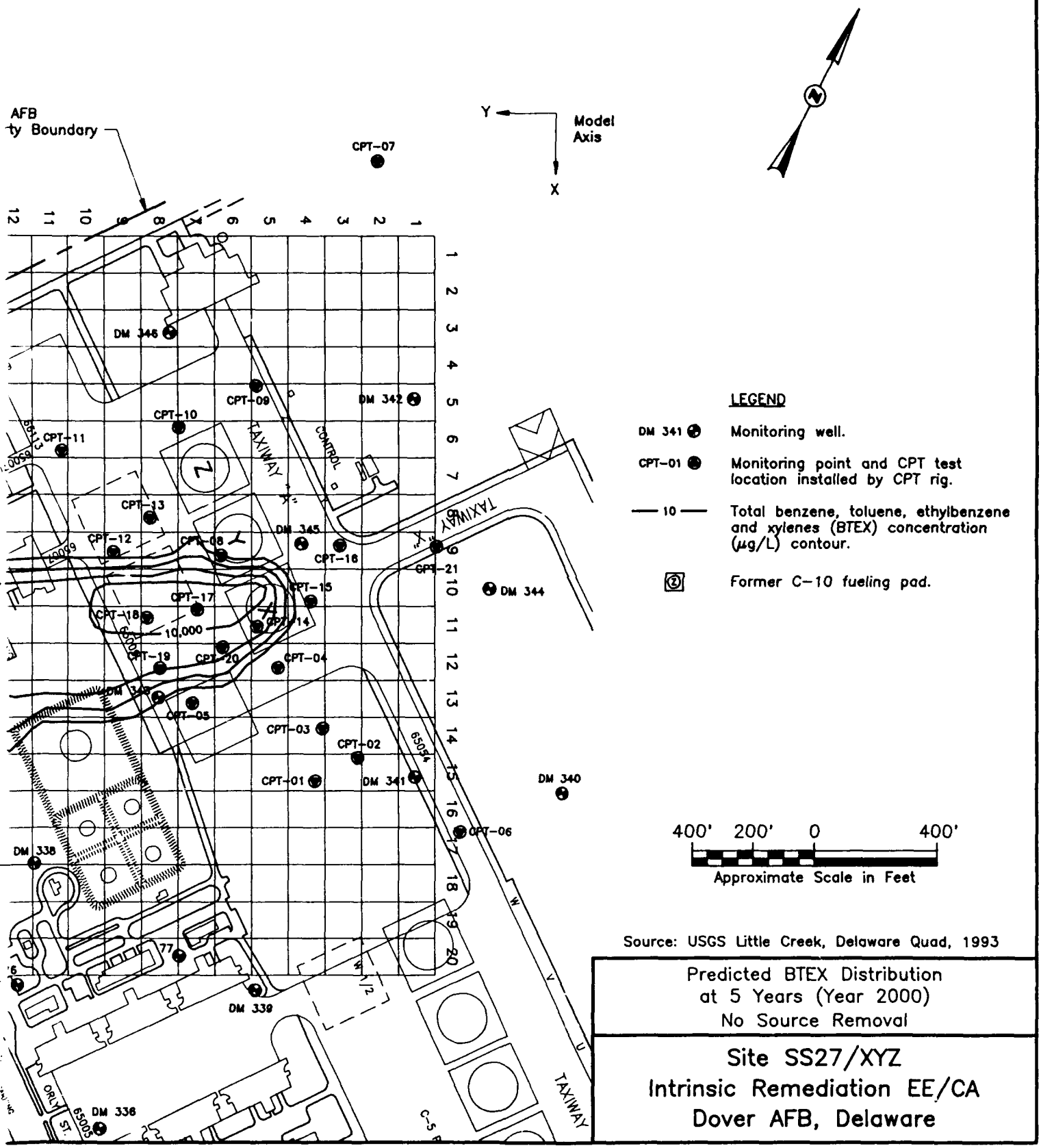
Model CAL simulated the migration and biodegradation of the BTEX plume assuming no source weathering or removal. First-order decay was not included within the model. This model assumed that the conditions that produced the calibrated model continued, including injection of BTEX compounds at the same rates that produced the observed plume. This simulation was run to predict BTEX distributions for 40 years from the observed 1994 plume, or 50 years from the presumed 1984 original fuel release (i.e., model predictions until the year 2035).

Parsons ES calculated the rate of BTEX migration for model year 2000 (Figure 5.8) and year 2012 (Figure 5.9) by measuring displacement of the plume's leading edge as compared to the calibrated BTEX distribution for 1994 (Figure 5.3). During the period from year 1994 to year 2000, the model suggests that the plume migration rate will be approximately 100 ft/yr. This rate decreased to 22 ft/yr between the model years 2000 and 2012. These contaminant migration rates are relatively slow, as compared to the advective groundwater velocity (292 ft/yr) calculated in Section 3.3.2.4. The



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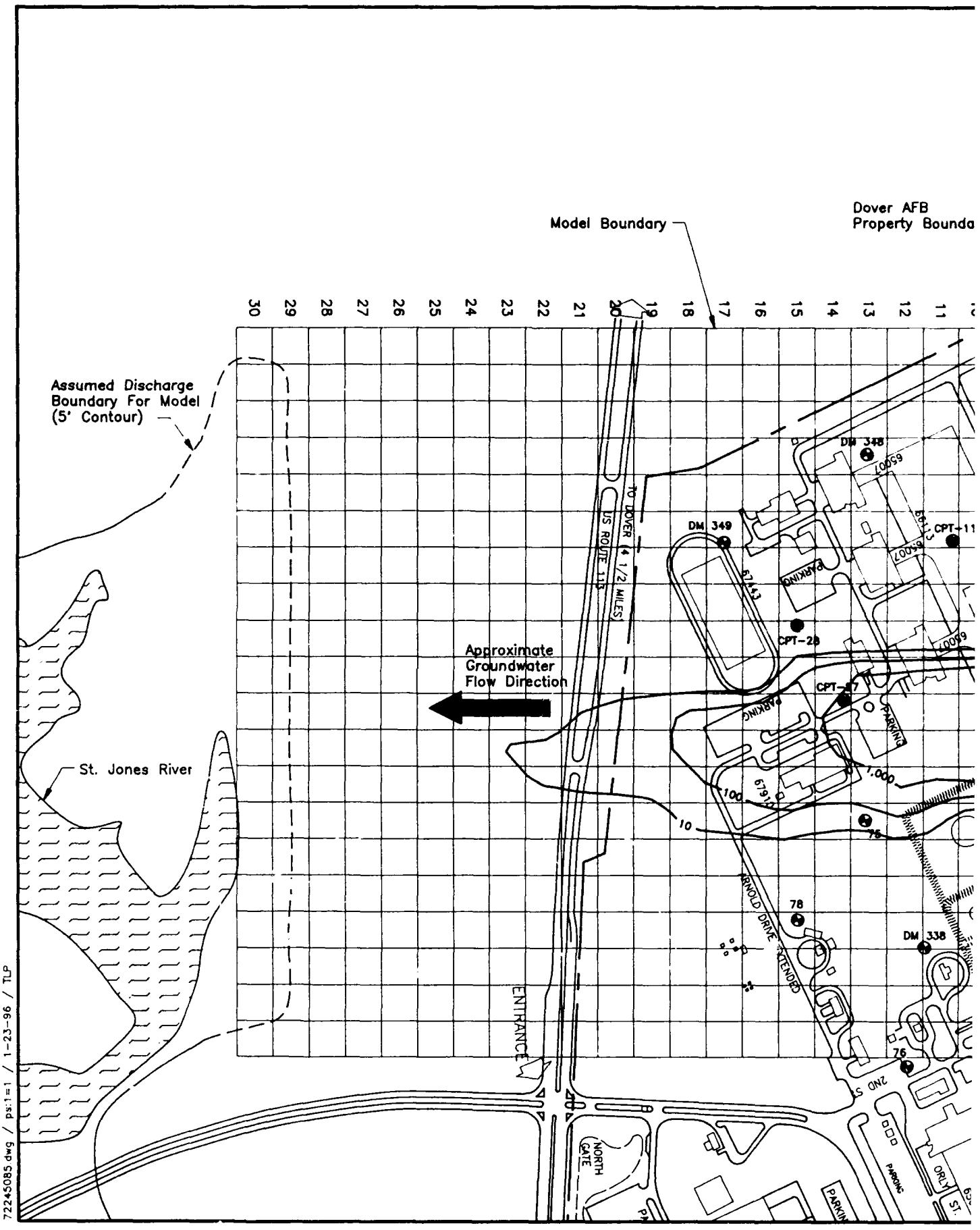

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Source: USGS



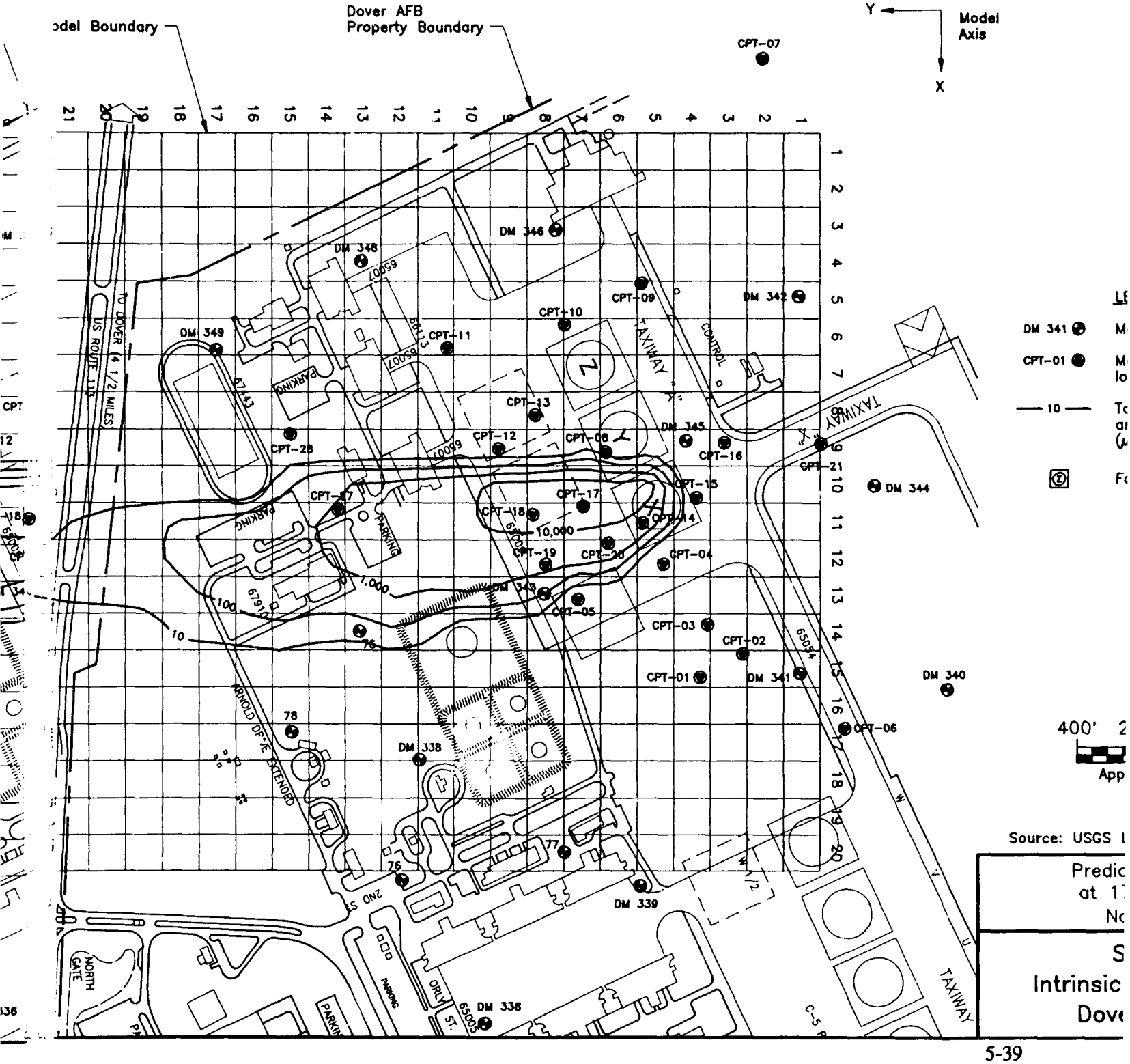
Source: USGS Little Creek, Delaware Quad, 1993

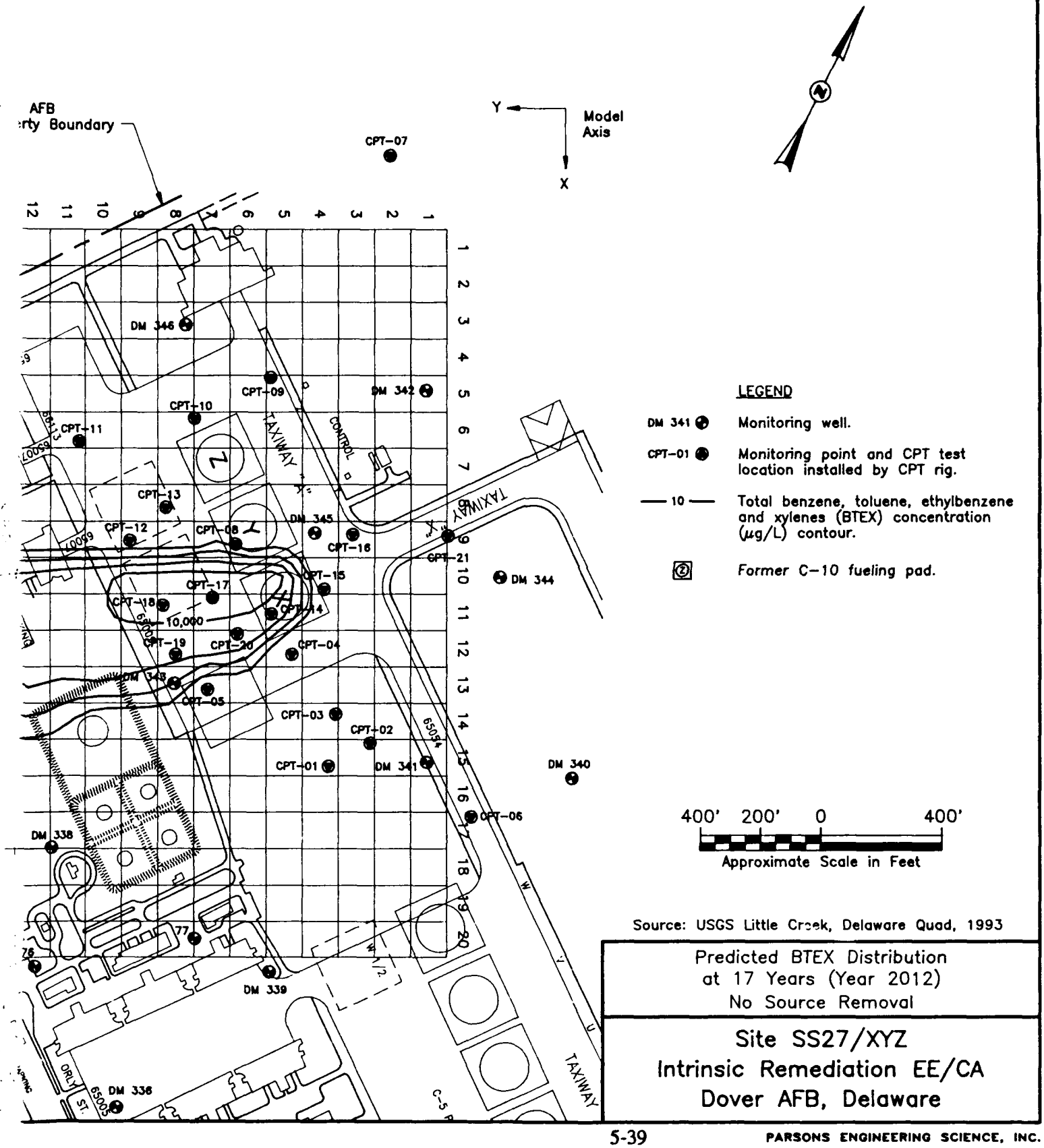
Predicted BTEX Distribution
at 5 Years (Year 2000)
No Source Removal

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware



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CPT-08
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TO DOVER (4 1/2 MILES)
US ROUTE 113
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Source: USGS Little Creek, Delaware Quad, 1993

Predicted BTEX Distribution
at 17 Years (Year 2012)
No Source Removal

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

differences between these values are primarily due to the affects of biodegradation, adsorption, and dispersion. The decrease in the modeled plume migration rate from the year 2000 to year 2012 is due to decreased BTEX concentrations along the plume fringes. Electron acceptors have a higher solubility than the BTEX constituents. As a result, the electron acceptors migrate faster and are replenished more quickly than the BTEX constituents. Due to these circumstances, the BTEX compounds migrate longitudinally and diffuse laterally until electron acceptor availability exceeds that of the BTEX constituents. Eventually, an equilibrium is established between the electron acceptors and BTEX constituents as the BTEX plume migration rate decreases and stalls.

The Bioplume II model CAL suggests that the plume will cross the Dover AFB property line within 5 years (year 2000) and will reach steady-state equilibrium within approximately 17 years (year 2012). Initially, the maximum BTEX concentration in the plume was 21,900 µg/L during year 1995 (Table 5.3). The maximum BTEX concentration gradually increased to the steady-state value of 24,500 µg/L after year 2012. This value is slightly above the predicted solubility of BTEX from JP-4 in contact with water (22,900 µg/L). These model results suggest that if no additional remedial measures are taken, BTEX contamination may remain at the site for a long period of time. The maximum total BTEX concentration predicted to cross the Dover AFB property boundary is 72 µg/L.

5.6.1.2 Comparison of Bioplume II Results to Analytical Model Results for Model CAL

First-order decay coefficients were calculated using BTEX and TMB groundwater data from the April 1994 sampling event and methods specified by Wiedemeier *et al.* (1995). These rate constant calculations are included in Appendix F. As discussed in Section 5.3.5, rate constants calculated for Site SS27/XYZ ranged from 0.0003 to

TABLE 5.3

SUMMARY OF BIOPLUME II MODEL RESULTS
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Model Year	Maximum BTEX[a] Concentration in Plume (µg/L)			Maximum BTEX Concentration to Cross Dover AFB Property Boundary (µg/L)		
	CAL	SR8	SR6	CAL	SR8	SR6
1994	21,900	21,900	21,900	Does not Cross	Does not Cross	Does not Cross
2000	24,000	10,200	5,300	25	Does not Cross	Does not Cross
2008	----	3,100	3,800	----	23	18
2012	24,500	2,400	3,100	72	Receeded	Receeded

[a] Benzene, toluene, ethylbenzene, and total xylene concentrations (µg/L).

0.002 day^{-1} along the southwestern primary flow path, 0.0009 to 0.004 day^{-1} along the northwestern secondary flow path, and 0.0008 to 0.003 day^{-1} along the northeastern flow path. As a check on the results of model CAL, Parsons ES compared numerical results obtained from Bioplume II to results obtained from a steady-state one-dimensional analytical model (Bear, 1979), which incorporates one-dimensional advection, dispersion, retardation, and first-order decay.

Parsons ES calibrated the analytical model by first varying the first-order decay coefficient within the specified range until a close match was obtained between the predicted and observed BTEX values along a flow path. Specific values for first-order decay rate constants were calculated along the primary (southwestern) flow path (0.0018 day^{-1}), the secondary northwestern flow path (0.0019 day^{-1}), and the secondary northeastern flow path (0.0072 day^{-1}). The decay constants calculated for the southwestern and northwestern flow paths were within the specific ranges discussed within Section 5.3.5. However, the calibrated decay coefficient for the northeastern flow path was slightly higher than the predetermined range. All the decay coefficients determined in this manner reasonably describe the observed BTEX migration and provide an adequate correlation to the Bioplume II results. At no time during the simulation does the plume threaten potential receptors. This is further supported by use of an analytical model (Appendix F) to calculate BTEX concentrations at the St. Jones River, the closest potential receptor exposure point. The conservative one-dimensional model suggests that maximum BTEX concentrations that might reach the river would be 3 µg/L. This concentration would be reduced further if a 2-D model was utilized that accounted for lateral dispersion.

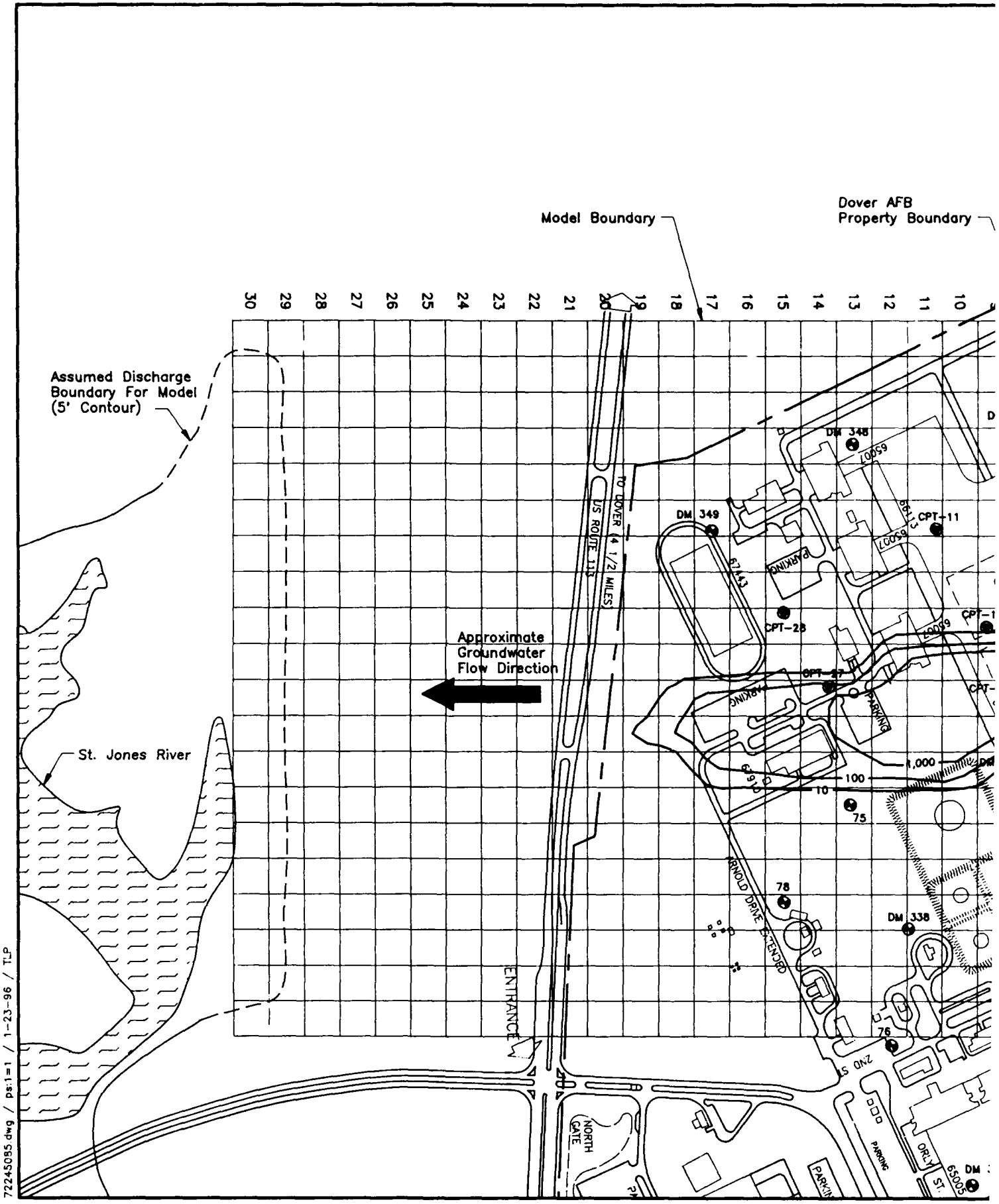
5.6.2 Twelve-Percent Annual Source Removal (Model SR8)

5.6.2.1 Bioplume II Model Results (Model SR8)

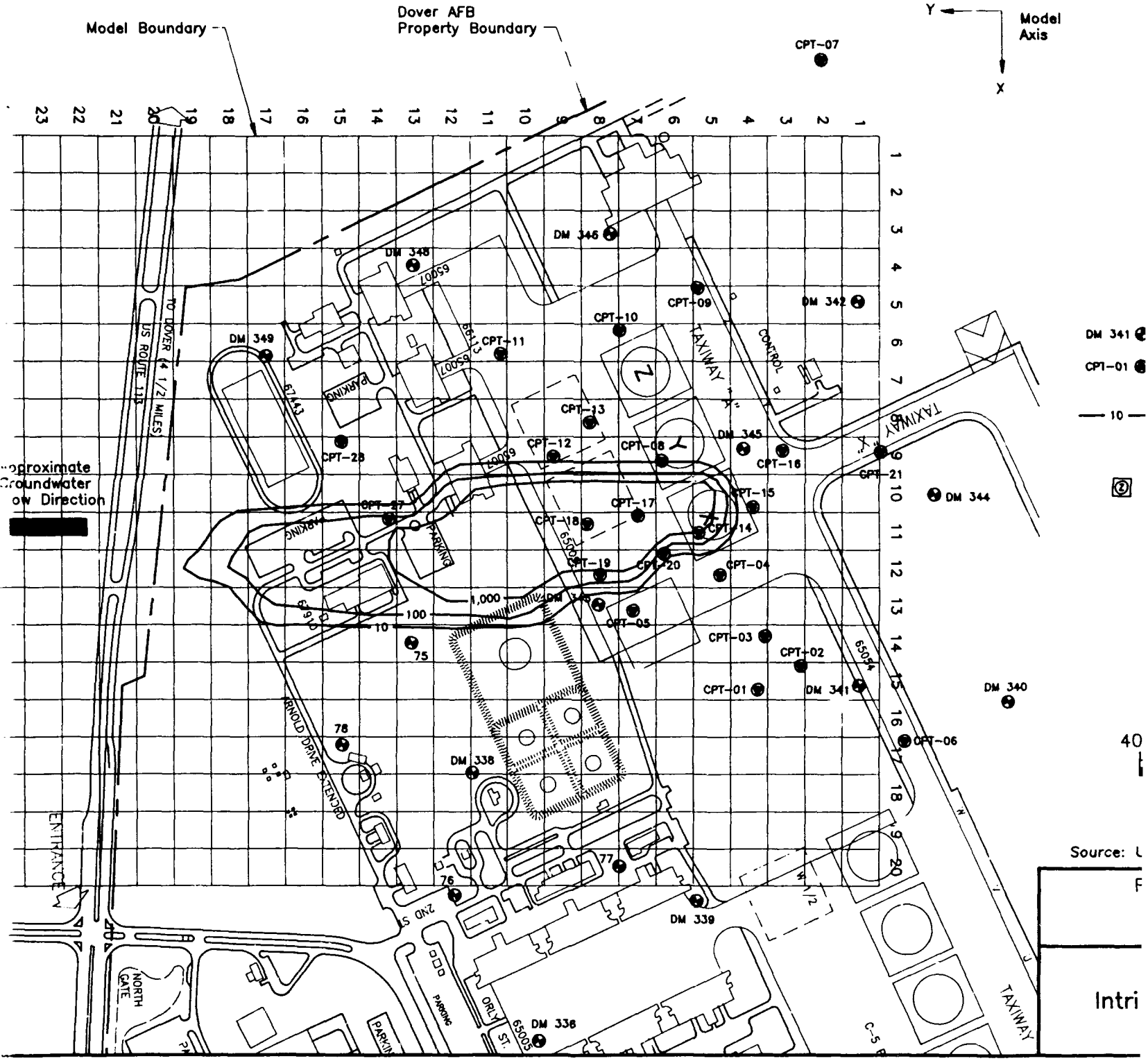
Model SR8 simulated the migration and biodegradation of the BTEX plume assuming an annual reduction in BTEX source concentrations over an 8-year period. Source removal is assumed to result from natural weathering and implementation of bioslurping and bioventing technologies. This time period was considered a practical limit for currently available remedial technologies based on the present-day LNAPL distribution, presence of clay and silt lenses below the site, presence of a permanent concrete cover over the site, and restricted site access due to the ongoing C-5 aircraft training and maintenance operations.

Model SR8 is identical to model CAL with the exception of the annual source removal term. After the formation of the plume to the present conditions, the concentration of hydrocarbons introduced into the system by the injection wells was reduced by 12.5 percent of the original amount per year for 8 years. Figure 5.3 shows the BTEX distribution during year 1994 prior to initiation of any remedial activities. Figures 5.10, 5.11, and 5.12 show the results of this model at 5 years (year 2000), 13 years (year 2008), and 17 years (year 2012) after initiation of source removal, respectively. Five years after initiation of source removal (Figure 5.10), the plume configuration had changed slightly as compared to the model CAL results (Figure 5.8). The maximum BTEX concentration was reduced to 10,200 μg/L (Table 5.3), and the plume had not yet crossed the Dover AFB property.

Thirteen years (year 2008) after initiation of source removal (Figure 5.11), the plume was reduced to approximately 40 percent of its original area. Also, the dissolved BTEX plume crossed the downgradient property boundary at a maximum

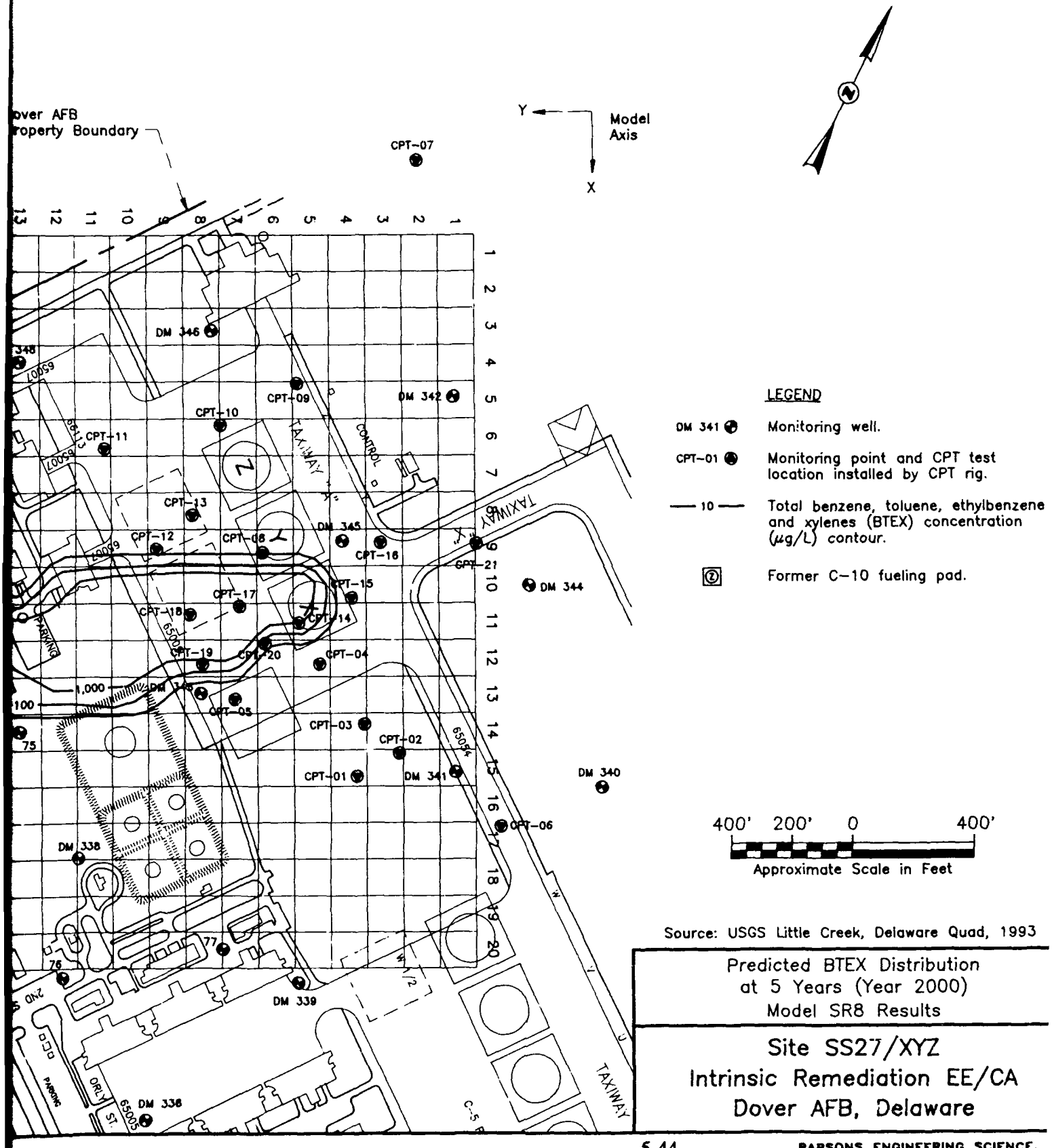


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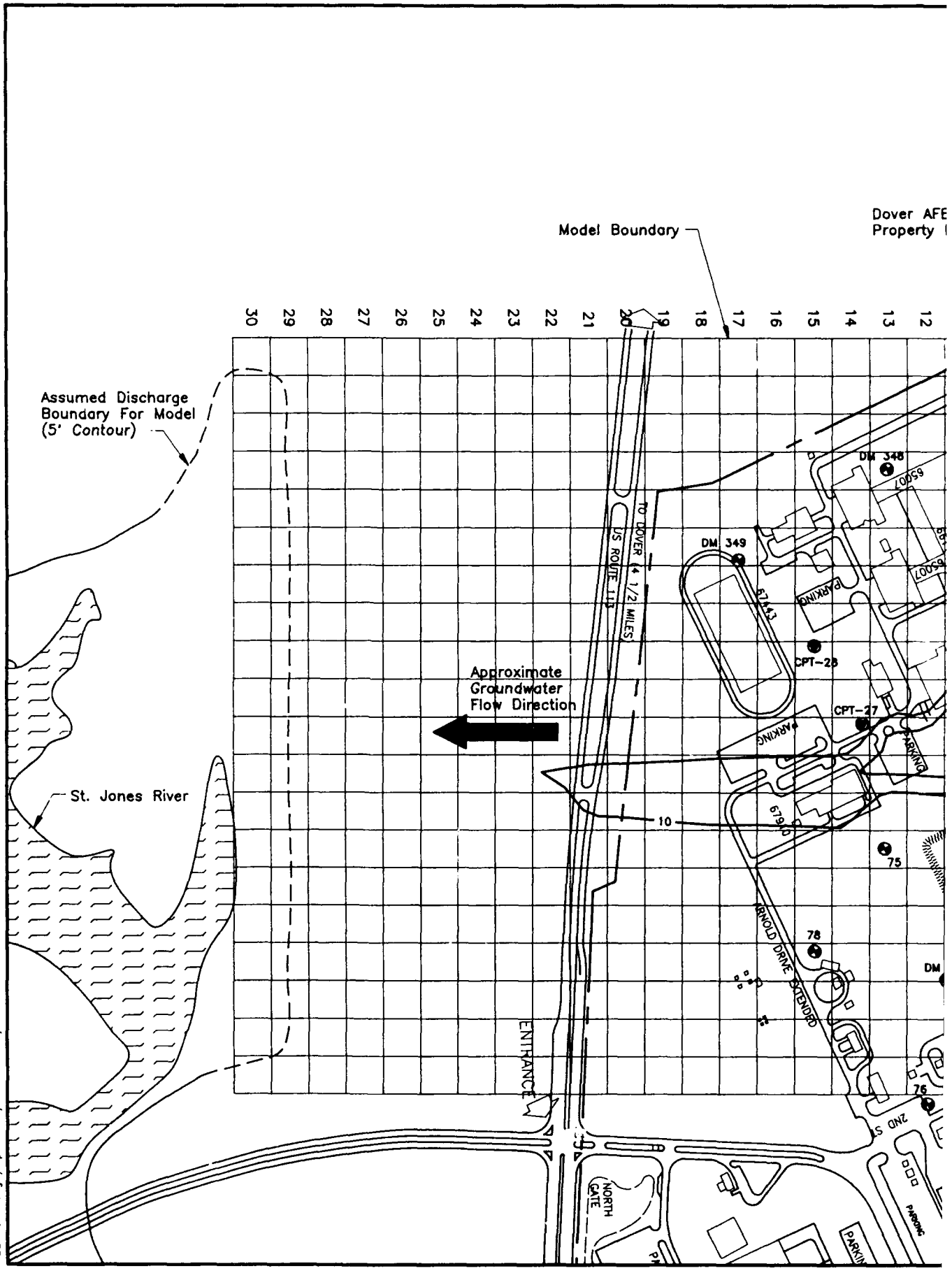
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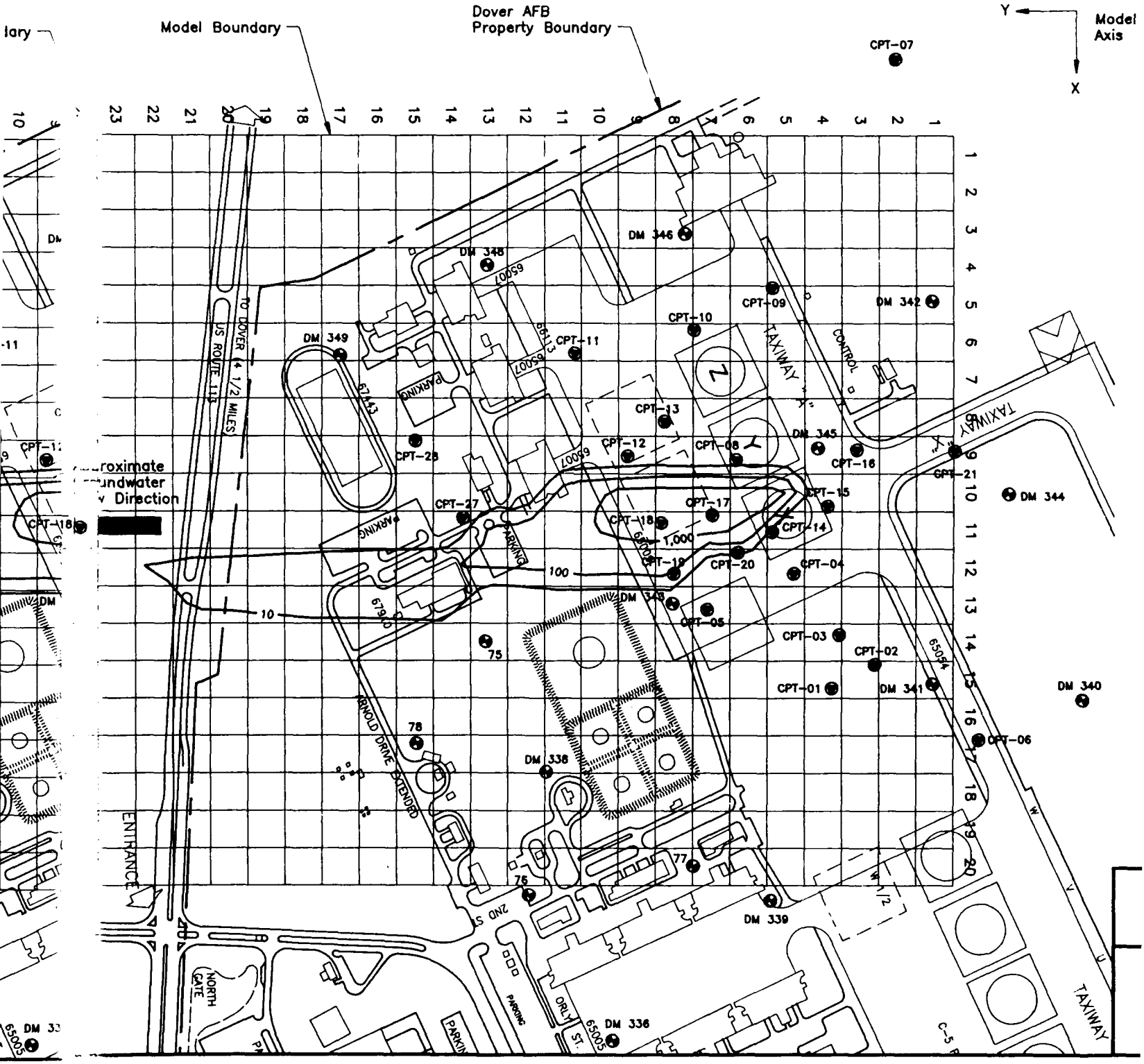
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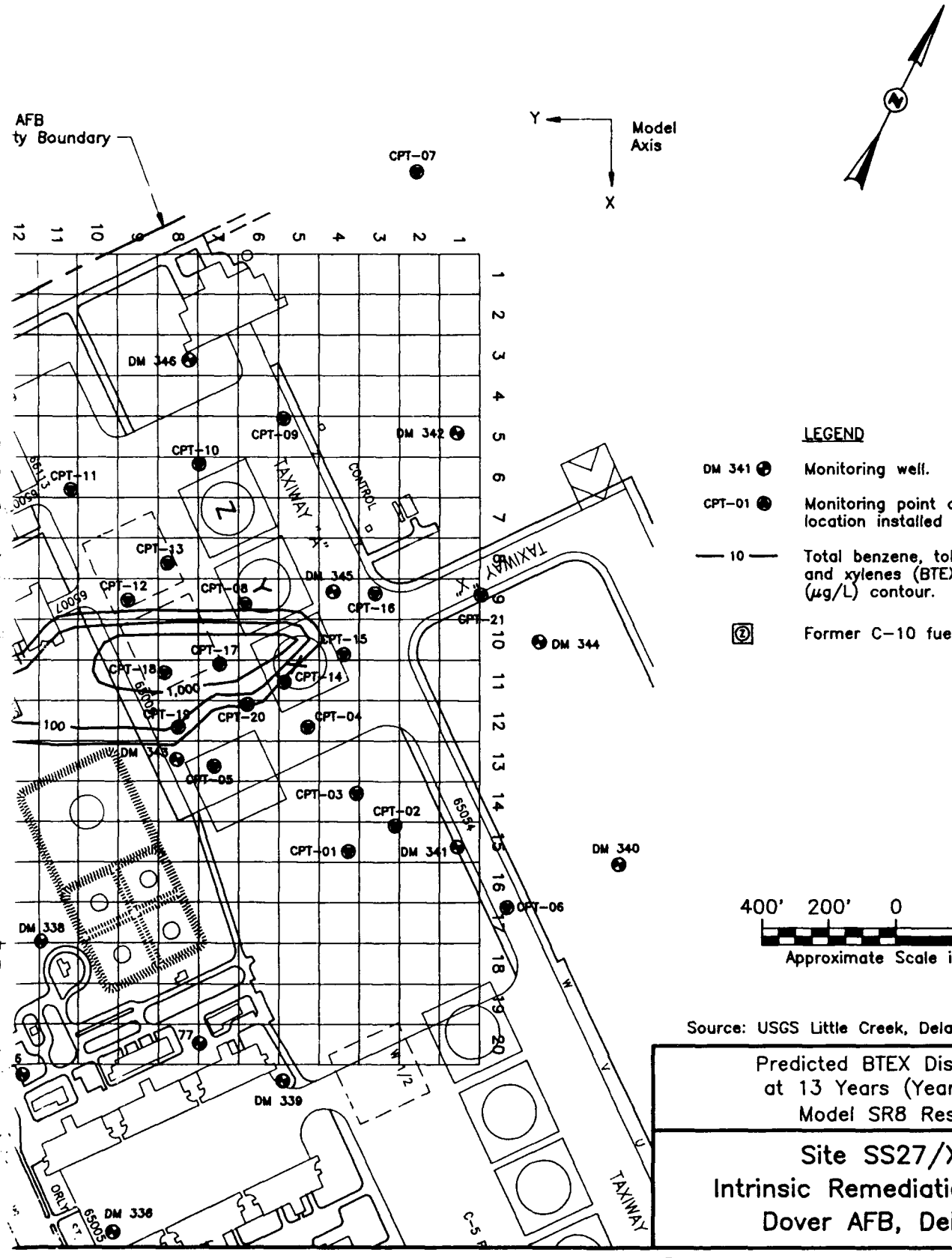
Predicted BTEX Distribution
at 5 Years (Year 2000)
Model SR8 Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware



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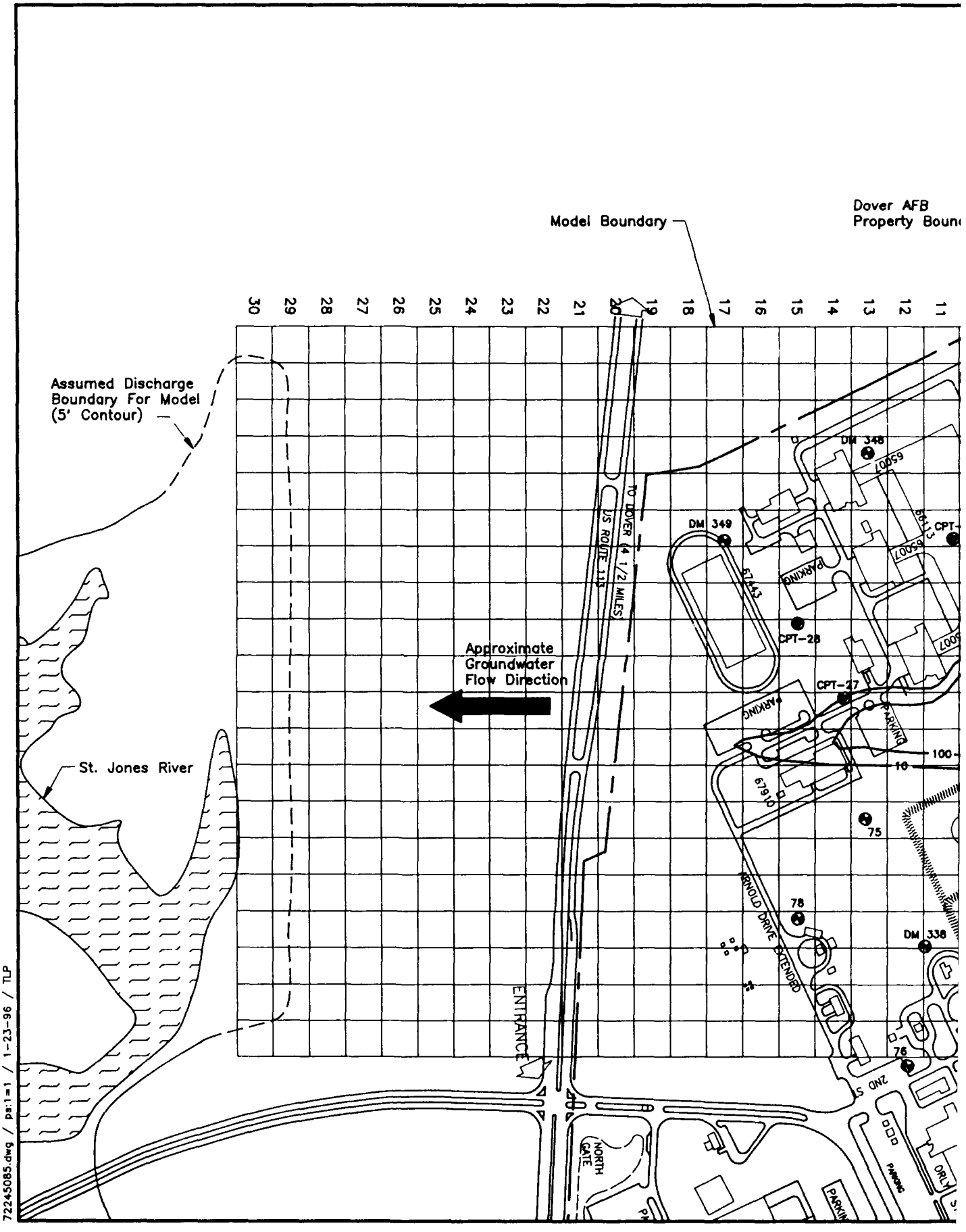

Model Boundary
Dover AFB
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TO DOVER (4 1/2 MILES)
US ROUTE 113
ARNOLD DRIVE EXTENDED
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NORTH GATE
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ORLY ST.
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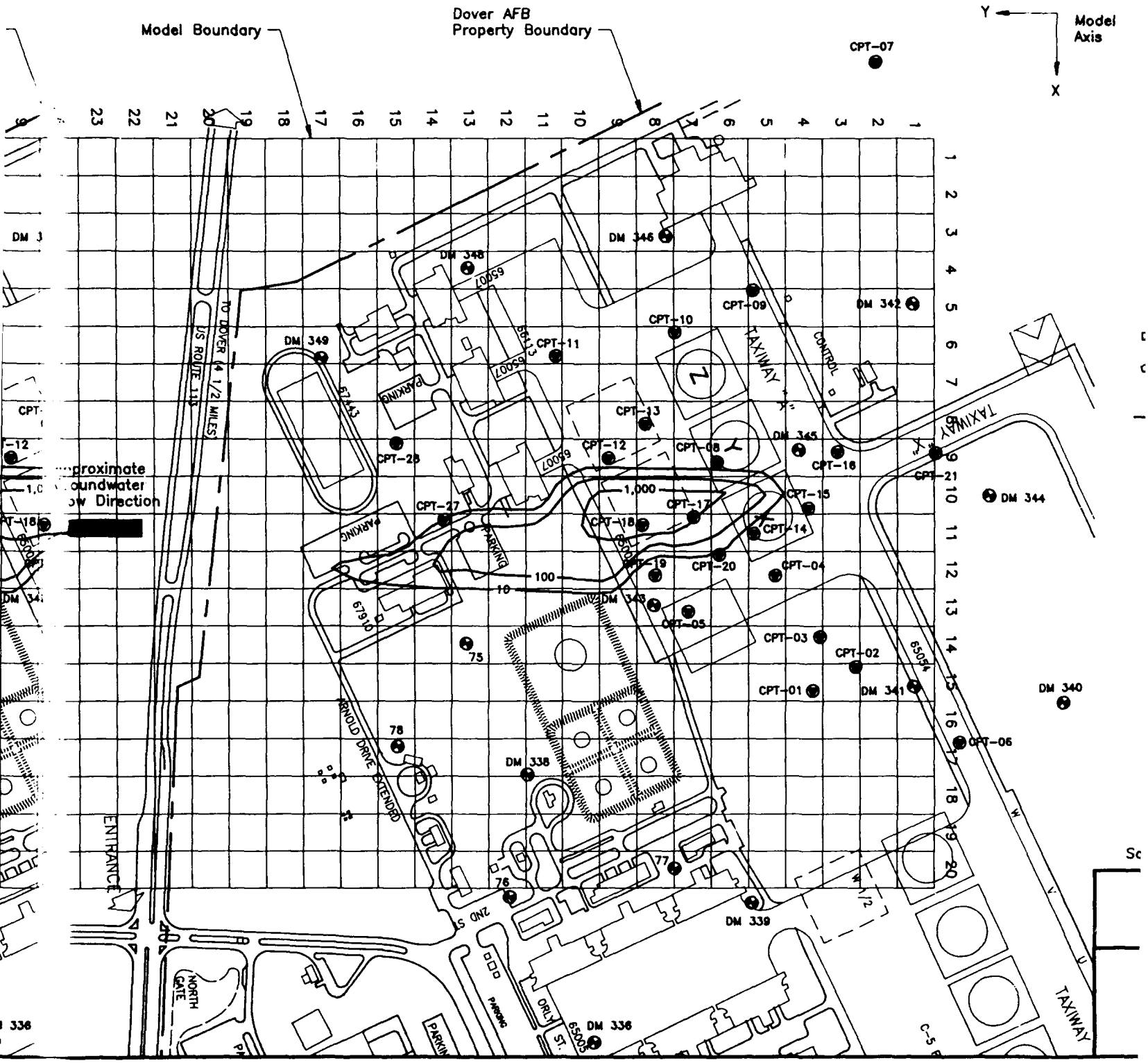
Source: USGS Little Creek, Delaware Quad, 1993

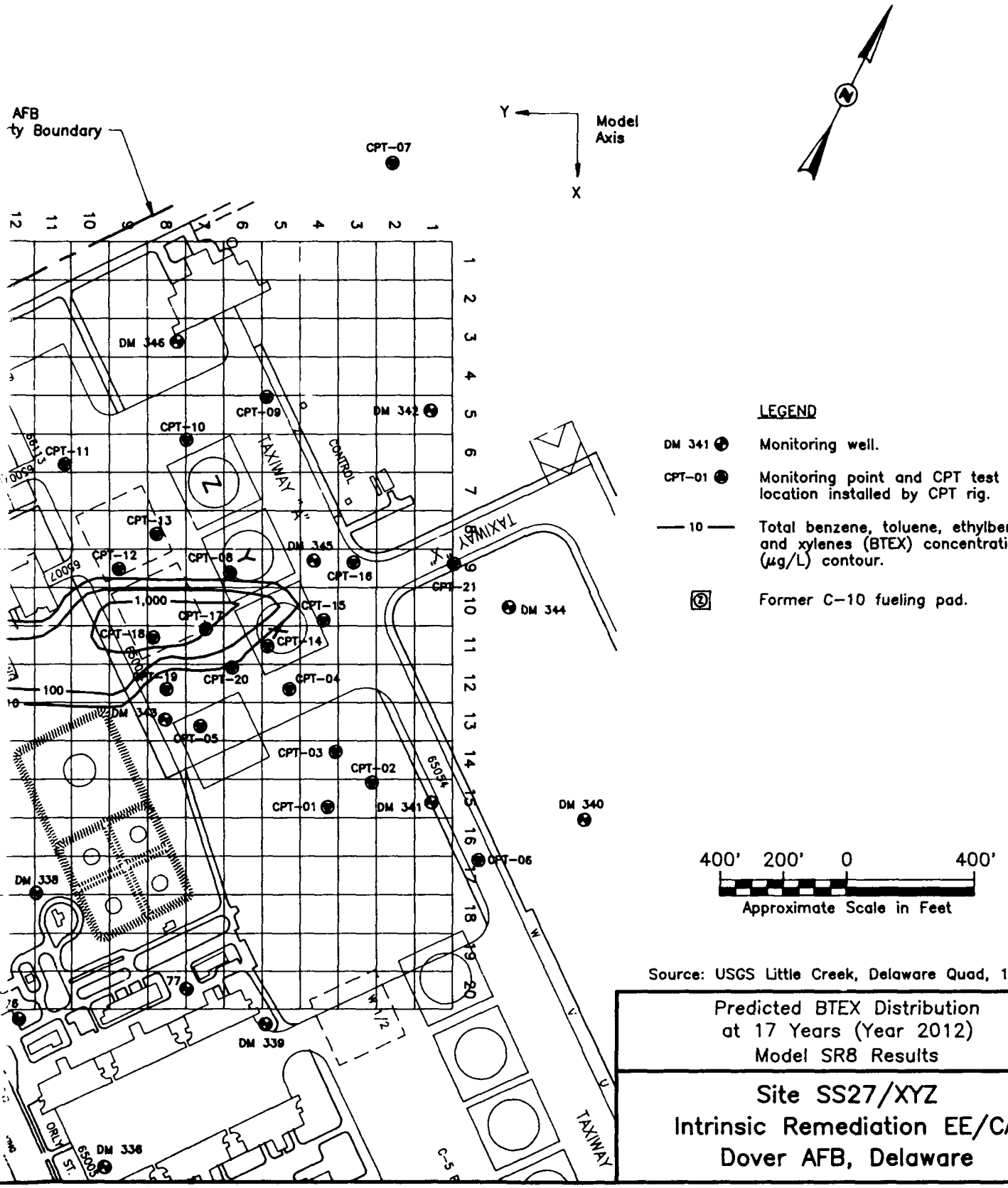
Predicted BTEX Distribution
at 13 Years (Year 2008)
Model SR8 Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware



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ORLY ST.
DM 336
TAXIWAY
CONTROL
Approximate
Groundwater
Flow Direction



Source: USGS Little Creek, Delaware Quad, 1993

Predicted BTEX Distribution
at 17 Years (Year 2012)
Model SR8 Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

concentration of 23 µg/L (Table 5.3). The maximum BTEX concentration in the plume was reduced to 3,100 µg/L. The model suggests that the plume will recede onto Dover AFB property approximately 14 years (year 2009) after initiation of source removal. This occurs because replenished electron acceptor concentrations eventually exceed the dissolved BTEX concentrations introduced into the aquifer by a ratio greater than 3.1:1.

Seventeen years after initiation of source removal (year 2012), the maximum BTEX concentration in the center of the plume decreased to 2,400 µg/L (Table 5.3), and the simulated BTEX plume had receded further upgradient. The plume disappears 25 years (year 2020) after initiation of source removal. This suggests that Delaware groundwater standards will be met throughout the site within 25 years under this model scenario. At no time during the simulation does the plume threaten potential receptors.

As discussed previously, the model suggests that the maximum total BTEX concentration to cross the Dover AFB property will be 23 µg/L. However, the Bioplume II model does not distinguish individual BTEX constituent concentrations. Due to this circumstance (and other model limitations), Parsons ES can not determine with certainty whether applicable groundwater quality standards will be violated. However, a relative assessment of risk can be made. The total BTEX concentration in JP-4 fuel is approximately 11 percent benzene (Arthur D. Little, 1987). As a result, the 23 µg/L total BTEX that may cross the Dover AFB property boundary may represent 2.5 µg/L benzene. This benzene concentration is below the Delaware standard and federal MCL for benzene (5 µg/L). The MCLs for the other BTEX constituents are much higher than benzene. As a result, the model suggests that toluene, ethylbenzene, and xylenes do not pose a significant threat to off-Base groundwater quality. The actual fraction of benzene in the aquifer will constantly decrease with time as the fraction of benzene remaining in the JP-4 decreases. At some

point in time, all benzene will have preferentially weathered from the JP-4 making it impossible for the dissolution of any more benzene into groundwater. Because the modeling efforts utilized conservative assumptions, these boundary concentrations represent a worst-case basis.

5.6.2.2 Comparison of Bioplume II Results to Analytical Model Results for Model SR8

The first-order decay coefficient for the BTEX source was calculated assuming a 95-percent reduction of BTEX concentration at the source over an 8-year period. The calculated first-order decay coefficient for source removal is 0.0000176 day^{-1}. The first-order decay rate for BTEX (0.0018 day^{-1}) along the primary flow path is described in Section 5.6.1.2. These decay coefficients were used in a one-dimensional analytical model (van Genuchten and Alves, 1982) to check the Bioplume II model results. This model incorporates one-dimensional advection, dispersion, retardation, and first-order decay of both the source and the solute concentrations. The analytical model results were compared to calculated BTEX concentrations from the numerical model results. For the primary (southwestern) flow direction, the analytical model predicted a maximum BTEX concentration of approximately 55 μg/L 1,380 feet downgradient from the source area (the approximate location of CPT-28). The observed concentration of BTEX at CPT-28 in April 1994 was 89 μg/L, which is reasonably close to the predicted concentration. The analytical model then predicts the BTEX concentration at CPT-28 to degrade by approximately 0.3 μg/L every year (Appendix F).

Parsons ES evaluated the transport of BTEX from the source area to the property boundary in the southwest direction (the POC in this direction) using the analytical model for comparison to the Bioplume II results. The Bioplume II results predicted that the BTEX plume would cross the boundary, approximately 2,000 feet from the

source area, before receding. The analytical model predicted that a maximum of 3 μg/L total BTEX would cross the boundary approximately 15 years after initiating source reduction. As with the numerical model, this value for total BTEX is below the Delaware groundwater quality standard and the federal MCL for benzene (5 μg/L). The MCLs for the other BTEX constituents are much higher than benzene. As a result, none of the BTEX constituents would pose a significant threat to groundwater quality under this model scenario. Based upon these data, the analytical model results suggest that BTEX concentrations will not exceed regulatory standards at the POC in the primary direction of flow. In general, these analytical model results agree with the Bioplume II model predictions and also indicate the conservative nature of the Bioplume II model assumptions.

Transport in the northwestern and northeastern directions of groundwater flow was also evaluated using the one-dimensional analytical model. The analytical model predicted a maximum concentration at CPT-07 of 8 μg/L at 12 years after the initial release (year 1997). This closely approximates the BTEX concentration of 17.3 μg/L observed during April 1994. The maximum BTEX concentration predicted for the northwest POC (about 1,700 feet downgradient from the source area) was approximately 2.5 μg/L at 16 years after the initial release (year 2001). Based upon the previous discussion, this value is below the MCL for benzene (5 μg/L). For the northeastern flow direction, BTEX concentrations were evaluated at CPT-26 and the POC approximately 2,500 feet downgradient. At CPT-26 (830 feet downgradient), the maximum predicted BTEX concentration was 28 μg/L at approximately 3 years after the initial release (year 1988) versus the observed BTEX concentration of 15.1 μg/L during April 1994. At the POC in the northeastern flow direction, the maximum BTEX concentration predicted was 0.00006 μg/L (i.e., well below laboratory detection levels) at approximately 8 years after the initial release (year 1993). As a result, the

analytical model suggests that the BTEX plume may never impact the northeast or the northwest property boundaries.

5.6.3 Seventeen-Percent Annual Source Removal (Model SR6)

5.6.3.1 Bioplume II Model Results (Model SR6)

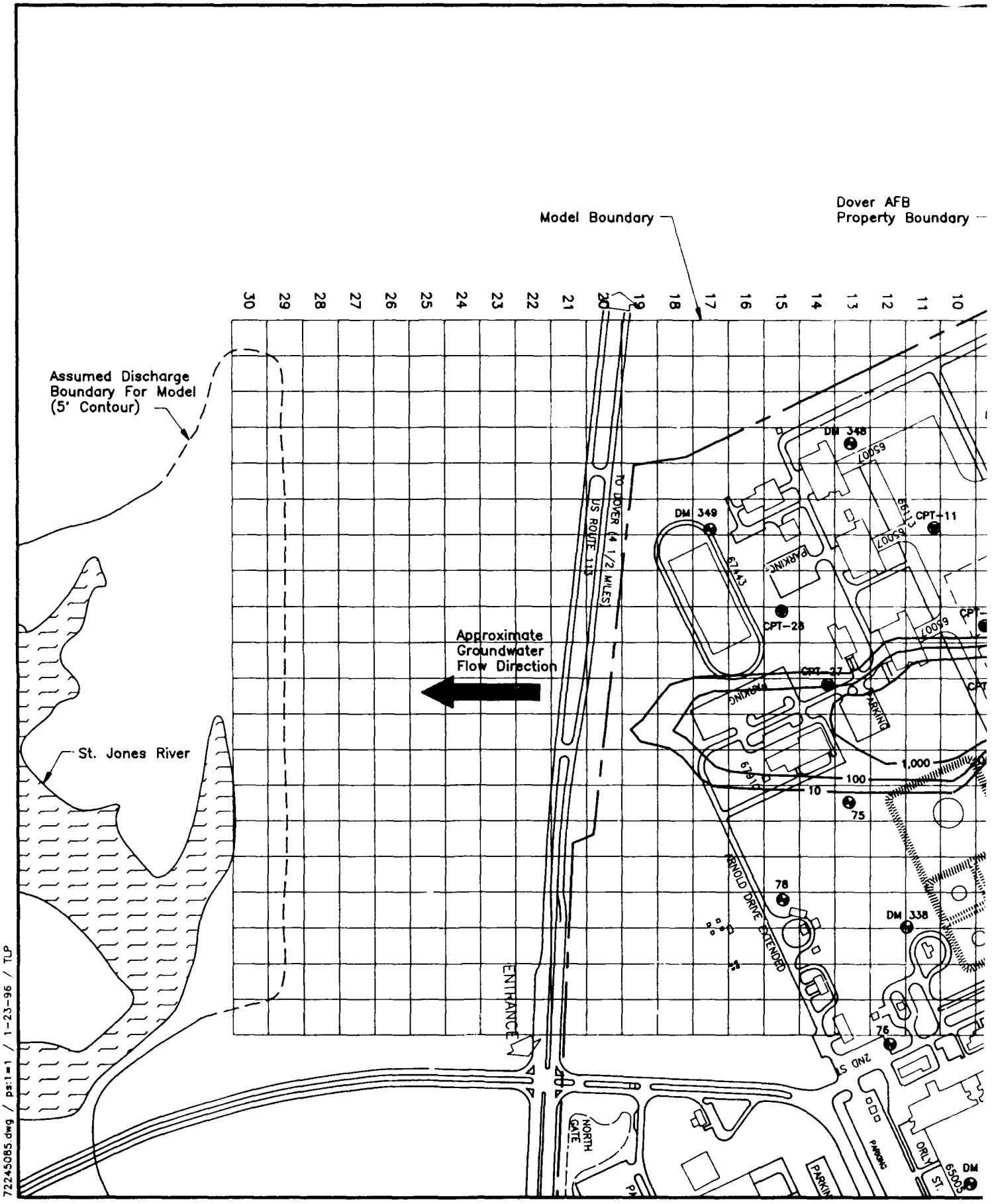
Model SR6 simulated the migration and biodegradation of the BTEX plume assuming an annual 17-percent reduction in source BTEX concentrations over a 6-year period. These reductions are assumed to result from natural weathering and implementation of a comprehensive system that removes soil gas, skims free-product, and re-oxygenates oxygen-depleted soils. The proposed system incorporates a soil vapor extraction (SVE) system, product skimming from wells, and biosparging. The 6-year source removal time period was considered to approach the practical limits for currently available remedial technologies based on the present day LNAPL distribution, presence of clay and silt lenses below the site, presence of a permanent concrete cover over the site, and restricted site access due to the ongoing C-5 aircraft training and maintenance operations. This system is considered to remove the source from the site 2 years faster than the model SR8 scenario. This difference is due to the SVE system, which is slightly more efficient than bioventing for removing volatile hydrocarbons from the vadose zone soils. However, once the volatile hydrocarbons are removed, the systems should perform similarly.

Model SR6 is identical to models CAL and SR8 with the exception of the annual source removal term. After the formation of the plume to the present (1994) conditions, the concentration of hydrocarbons introduced into the system by the injection wells was reduced by 16.7 percent of the original amount per year for 6 years. The model simulation initiates source reductions during year 1995. The

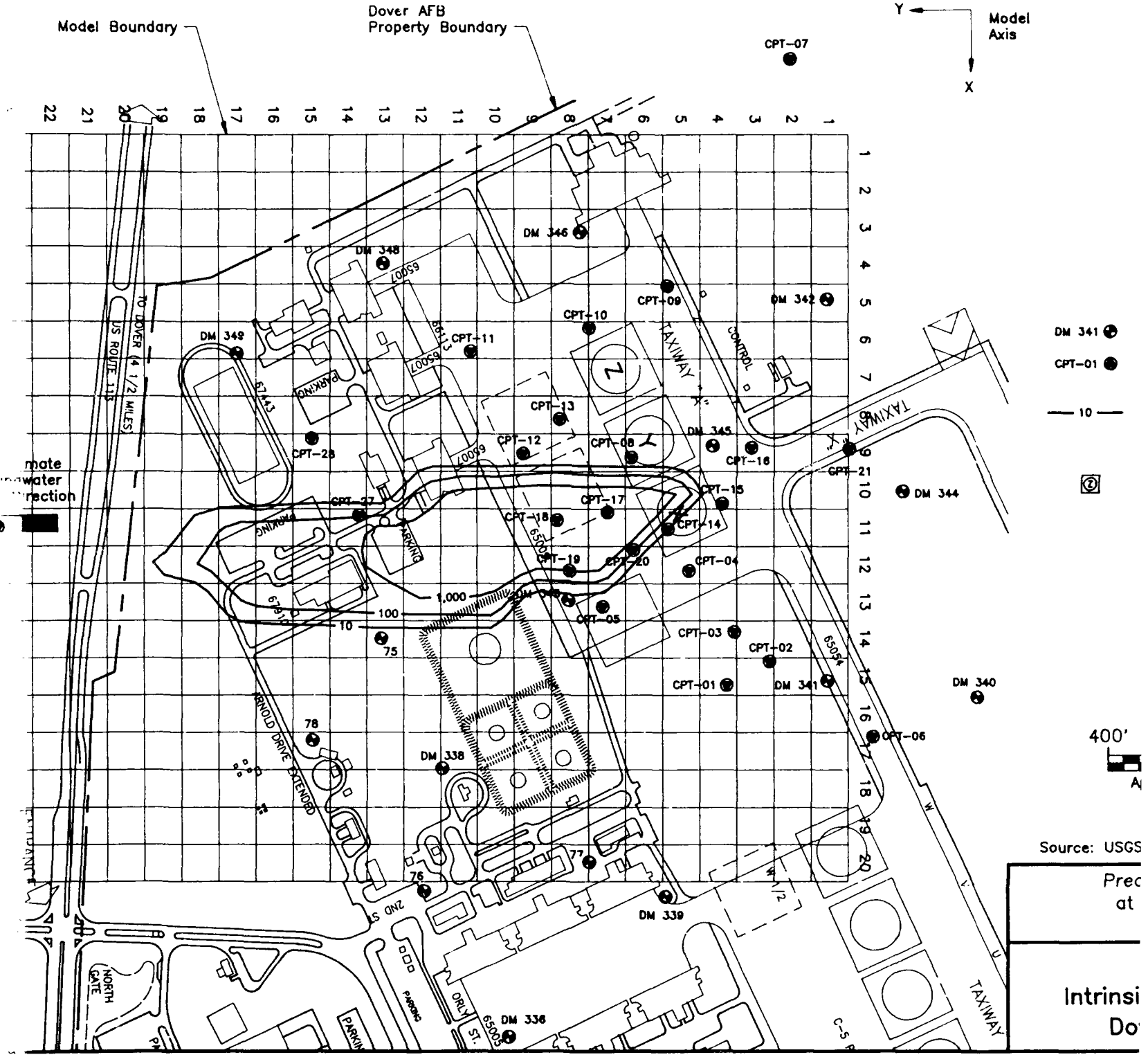
source reduction is complete after 6 years (e.g., by the year 2000). Figures 5.13, 5.14, and 5.15 show the results of this model 5 years after initiation of source removal (year 2000), 13 years after initiation of source removal (year 2008), and 17 years after initiation of source removal (year 2012), respectively.

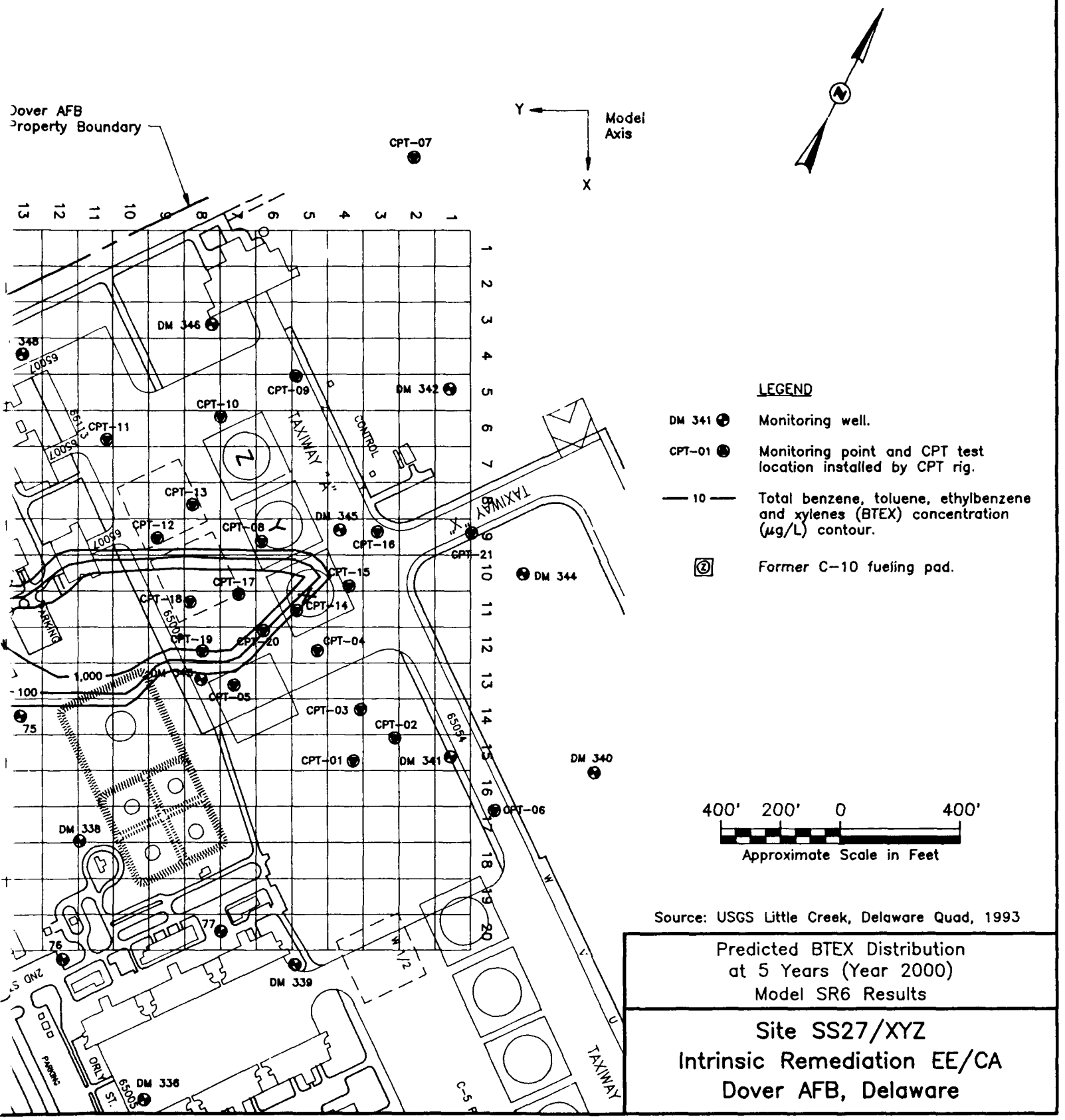
Five years after initiation of source removal (Figure 5.13), the plume had changed slightly as compared to the model SR8 results (Figure 5.10). The maximum BTEX concentration was reduced to 5,300 μg/L (Table 5.3). Thirteen years (year 2008) after initiation of source removal (Figure 5.14), the plume was, again, approximately 40 percent of its original area. The maximum BTEX concentration was reduced to 3,800 μg/L and the leading edge of the BTEX plume crosses the Dover property boundary. However, the maximum BTEX concentration that crossed the property line was 18 μg/L. With a benzene fraction of 11 percent of total BTEX in JP-4, this would be equivalent to approximately 2 μg/L benzene at the base boundary with both the state standard and Federal MCL equal to 5 μg/L. The model also suggests that the plume will recede onto the Dover AFB property approximately 14 years (year 2008) after initiation of source removal. This result was also predicted by model SR8. Again, this occurs because replenished electron acceptor concentrations eventually exceed the dissolved BTEX concentrations introduced into the aquifer by a ratio greater than 3.1:1.

Seventeen years (year 2012) after initiation of source removal, the maximum BTEX concentration in the center of the plume decreased to 3,100 μg/L (Table 5.3). The simulated BTEX plume had receded further upgradient and no longer posed a threat by off-site migration. Again, the plume disappeared 25 years (year 2020) after initiation of source removal. This suggests that the Delaware groundwater standards will be met throughout the plume within 25 years under both model SR8 and SR6 scenarios. There are no appreciable differences in the BTEX distributions over time between the two



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Model Boundary
Dover AFB
Property Boundary
Y
X
Model
Axis
CPT-07
DM 346
DM 348
DM 349
DM 342
DM 341
CPT-01
10
CPT-09
CPT-10
CPT-11
CPT-13
CPT-12
CPT-08
CPT-28
CPT-27
CPT-17
CPT-18
CPT-19
CPT-20
CPT-15
CPT-14
CPT-16
CPT-21
DM 345
DM 344
CPT-04
CPT-05
CPT-03
CPT-02
CPT-01
DM 341
DM 340
CPT-06
1,000
100
10
75
78
DM 338
76
77
DM 339
DM 336
TAXIWAY
CONTROL
PARKING
ARNOLD DRIVE EXTENDED
2ND ST.
NORTH GATE
TO DOVER (4 1/2 MILES)
US ROUTE 113
65007
65054
65005
67443
400'
Source: USGS
Prec
at
Intrinsi
Do
5-52

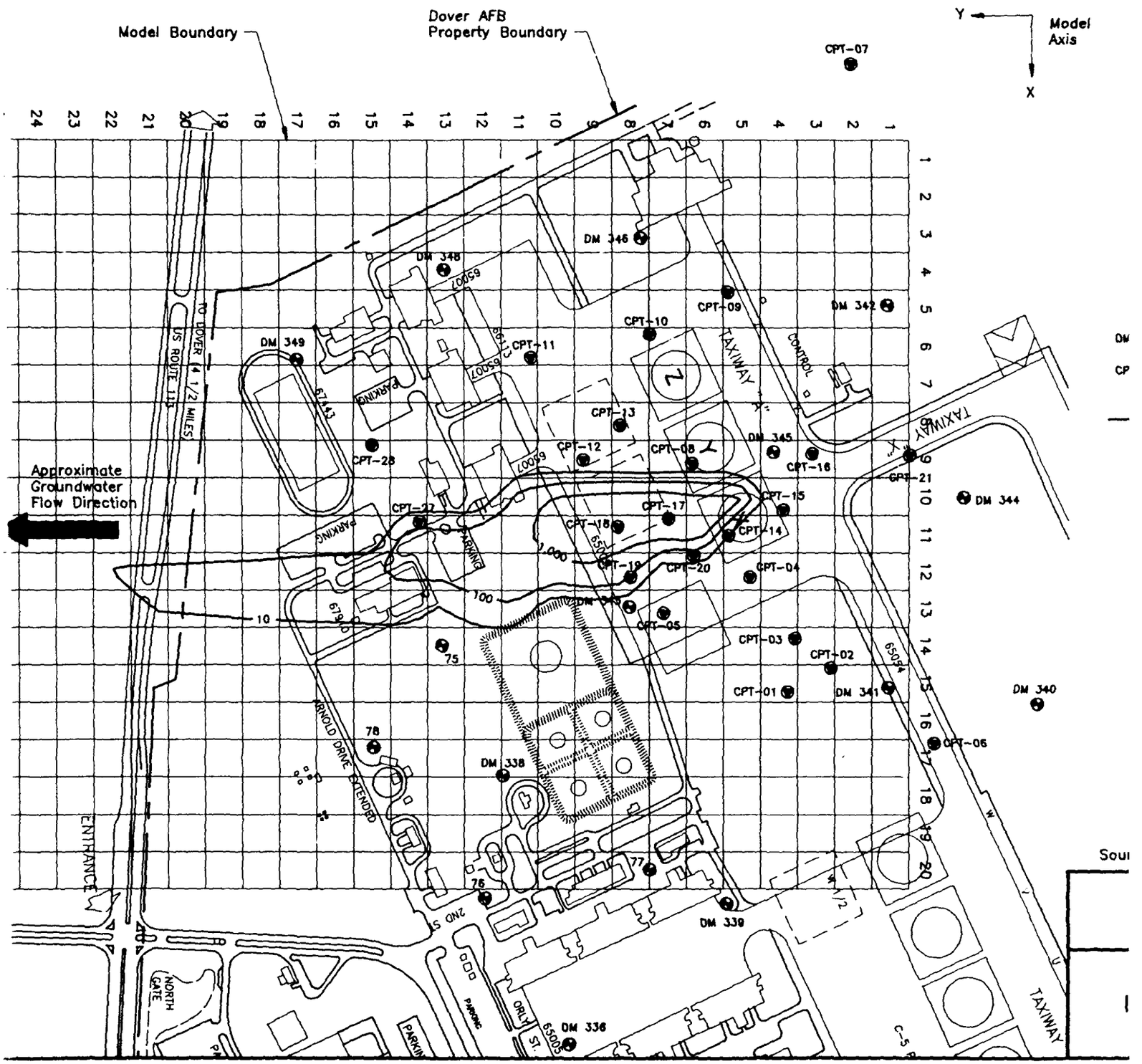


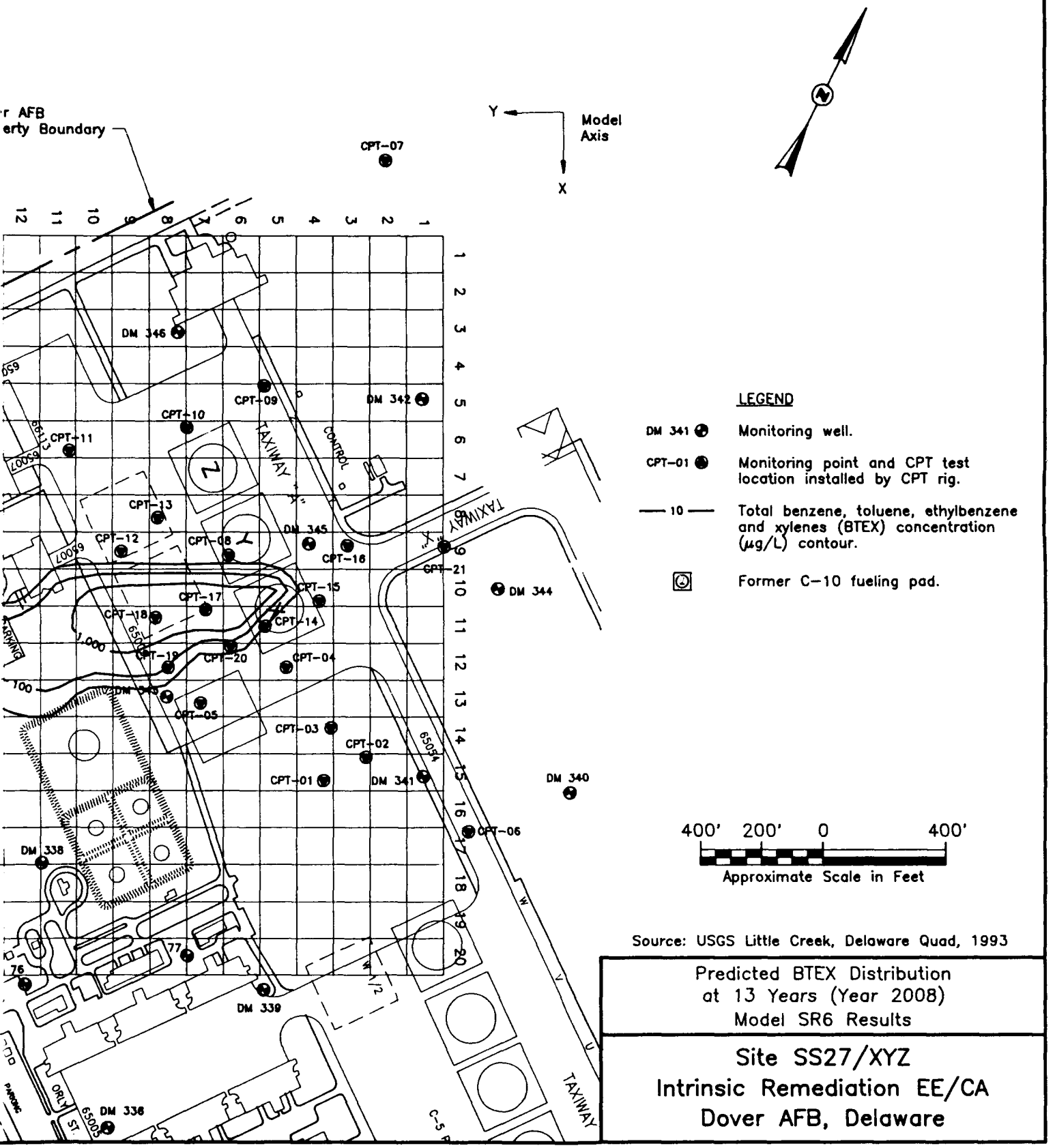
Source: USGS Little Creek, Delaware Quad, 1993

Predicted BTEX Distribution
at 5 Years (Year 2000)
Model SR6 Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

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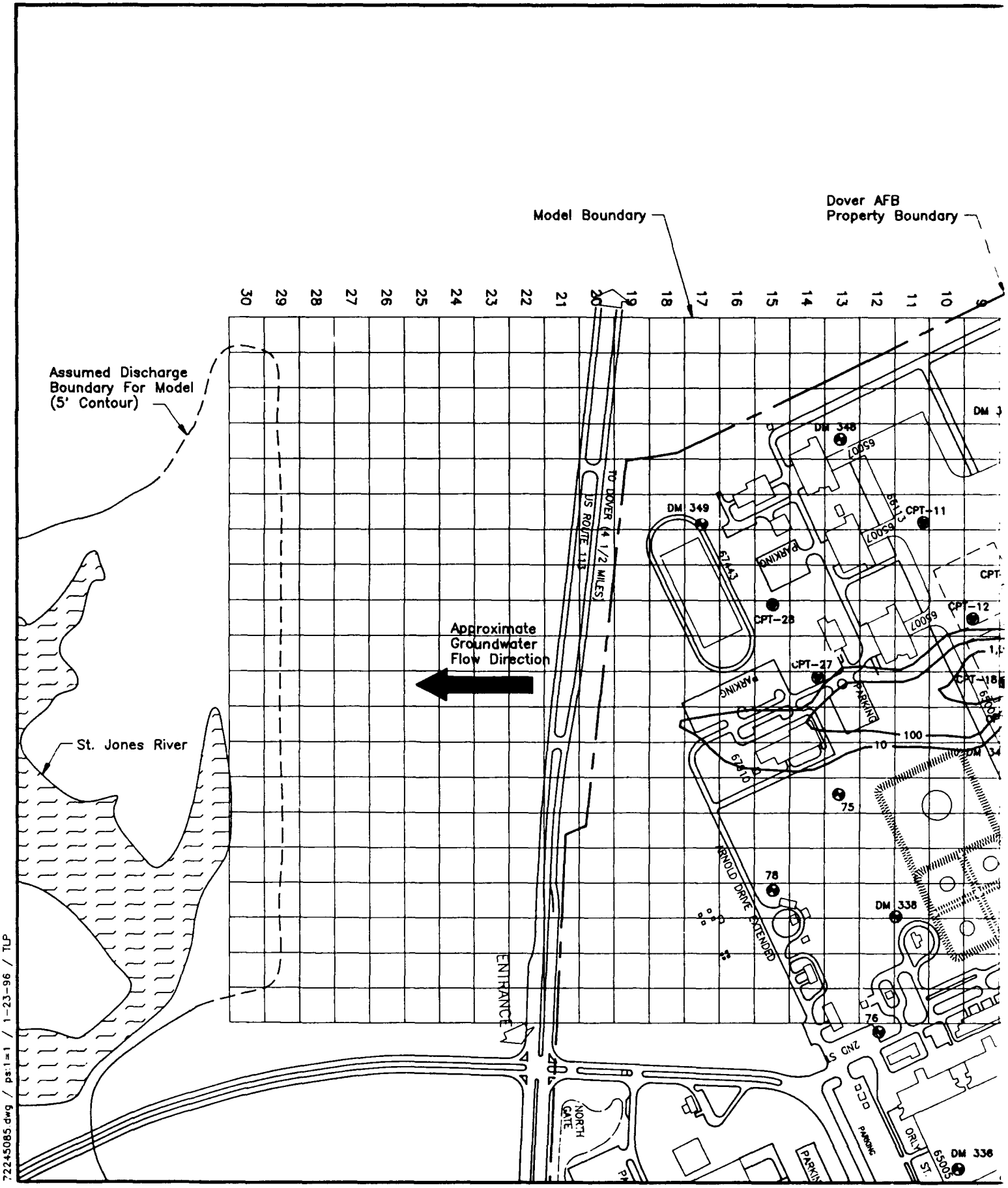

Model Boundary
Dover AFB
Property Boundary
Y
X
Model
Axis
CPT-07
DM 346
DM 348
DM 342
DM 349
CPT-09
CPT-10
CPT-11
CPT-13
CPT-28
CPT-12
CPT-08
DM 345
CPT-16
CPT-21
DM 344
CPT-15
CPT-17
CPT-18
CPT-14
CPT-22
CPT-19
CPT-20
CPT-04
DM 343
CPT-05
CPT-03
CPT-02
CPT-01
DM 341
DM 340
CPT-06
DM 338
DM 339
DM 336
75
76
77
78
TAXIWAY
CONTROL
PARKING
ORLY ST.
2ND ST.
ARNOLD DRIVE EXTENDED
ENTRANCE
NORTH GATE
TO DOVER
US ROUTE 113
Approximate
Groundwater
Flow Direction
100
10
C-5



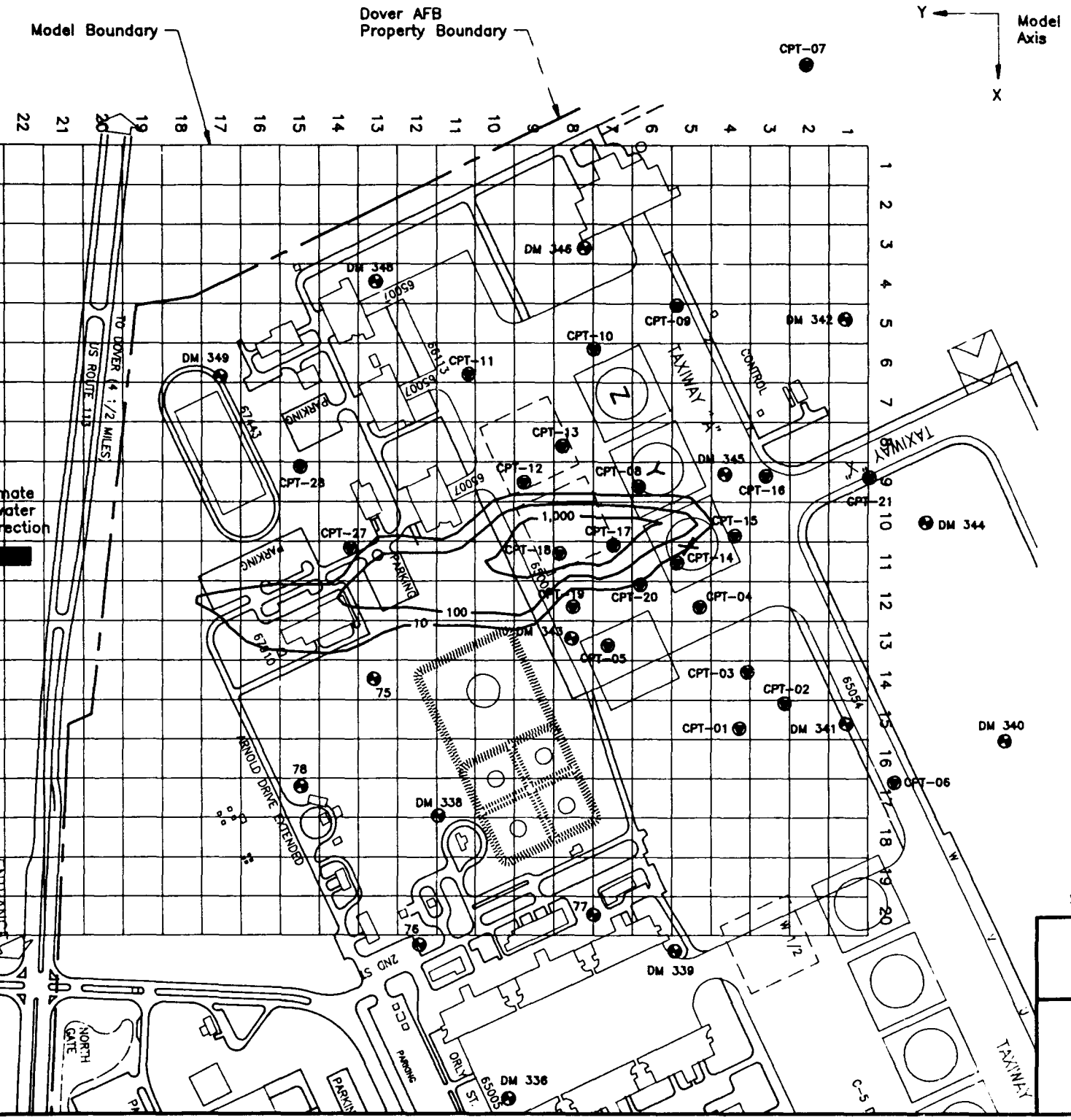
Source: USGS Little Creek, Delaware Quad, 1993

Predicted BTEX Distribution
at 13 Years (Year 2008)
Model SR6 Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

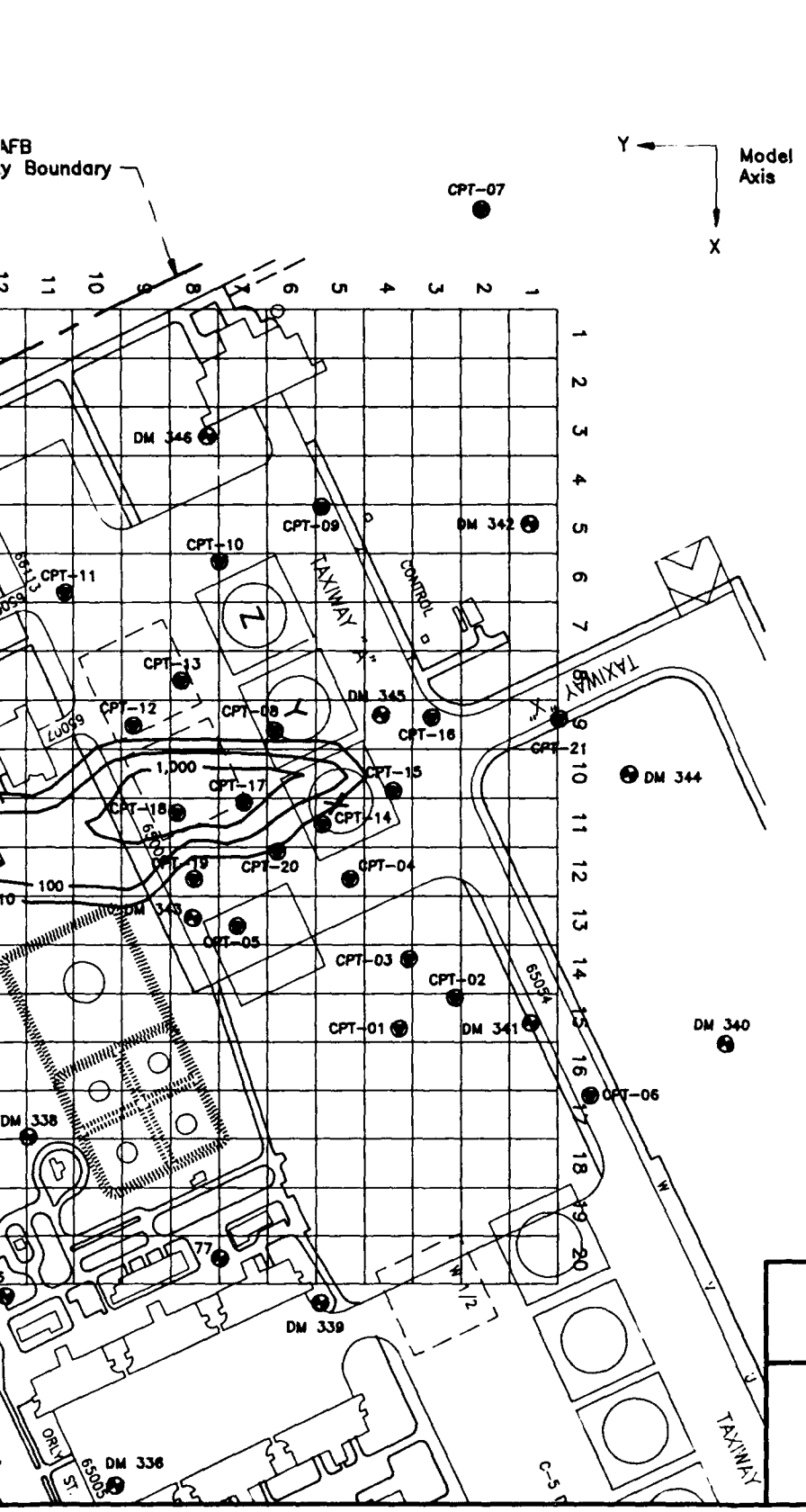


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Predi
at

Intrinsic
Dov



Source: USGS Little Creek, Delaware Quad, 1993

Predicted BTEX Distribution
at 17 Years (Year 2012)
Model SR6 Results

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

source removal scenarios. The BTEX plume does not threaten potential receptors at any time during these simulations. The maximum concentration that crosses the Dover AFB boundary would likely be below applicable groundwater standards for all BTEX compounds. This result is conservative because the benzene fraction in the mobile and residual LNAPL will decrease over time. This source reduction was not simulated by the numerical model.

5.6.3.2 Comparison of Bioplume II Results to Analytical Model Results for Model SR6

The first-order decay coefficient for the BTEX source was calculated assuming a 95-percent reduction of BTEX concentration at the source over the 6-year source removal time frame. The calculated first-order source decay coefficient is 0.0000234 day^{-1}. The one-dimensional analytical model results using this source decay coefficient were nearly identical to those described in Section 5.6.2.2 for the 8-year source removal scenario. However, the 8-year analytical model using the source decay coefficient of 0.0000176 day^{-1} is slightly more conservative than this 6-year model. The peak BTEX concentrations were the same, with slightly different slopes as the maximum BTEX concentrations decayed toward zero.

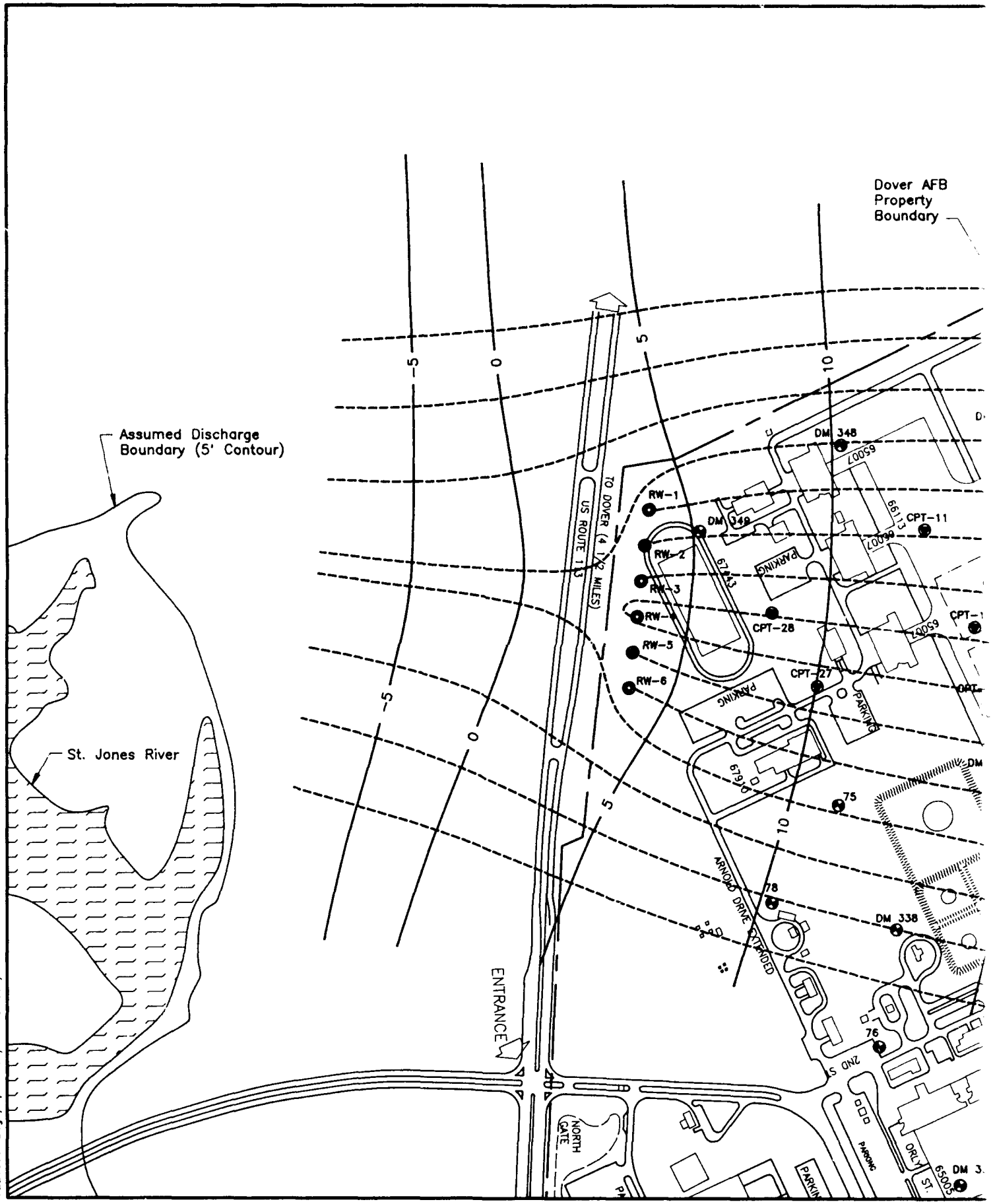
5.6.4 Effectiveness of a Hydraulic Barrier at the Dover AFB Property Boundary

The previous sections discuss the potential for BTEX contamination to migrate off the Dover AFB property. In the event that natural attenuation is the only future remedial action performed at the site, the model predicts the maximum concentration at the property boundary may reach 72 µg/L. The implementation of source removal technologies can decrease this concentration to less than 18 µg/L. Parsons ES evaluated the use of a hydraulic barrier to reduce or eliminate the threat of off-Base migration along the primary southwestern flow path. QuickFlow™ (Geraghty &

Miller, Inc., 1991a) was utilized to evaluate the hydraulic characteristics of the site and determine an optimal recovery well placement. This design was optimized to capture dissolved BTEX constituents prior to off-Base migration using a minimum groundwater extraction rate. This design process ensures cost effectiveness for the recovery systems and other ancillary aboveground treatment equipment.

Parsons ES utilized the steady-state module within QuickFlow™ for simulating groundwater flow at the time. This module employs analytical functions developed by Strack (1989) for calculating flow within a horizontal plane under homogeneous and isotropic conditions. QuickFlow™ results were compared to capture-zone calculations (Javandel and Tsang, 1986; Keely and Tsang, 1983) to check the results of the model. The design recovery well network consists of six 6-inch recovery wells located along the Base property line downgradient from the BTEX plume. The overall design flow rate from this system is 54 gallons per minute. This rate would be sufficient to capture the dissolved BTEX constituents prior to reaching the Dover AFB boundary. Extraction well locations and predicted capture zone streamlines are presented on Figure 5.16. Capture zone calculations and QuickFlow™ model results are in Appendix F.

POC wells are to be installed at the site to monitor groundwater quality along downgradient property boundaries. POC wells are discussed in more detail in Section 7. In the event that POC wells become affected by BTEX contamination exceeding promulgated or negotiated standards, then a hydraulic barrier system could be installed to control off-site migration. Based upon the model efforts discussed in Sections 5.6.2.1 and 5.6.3.1, BTEX contamination could reach the Base boundary 4 to 6 years after initiation of source removal technologies. However, the total BTEX concentrations at the property boundary should be less than the Delaware groundwater quality standards.



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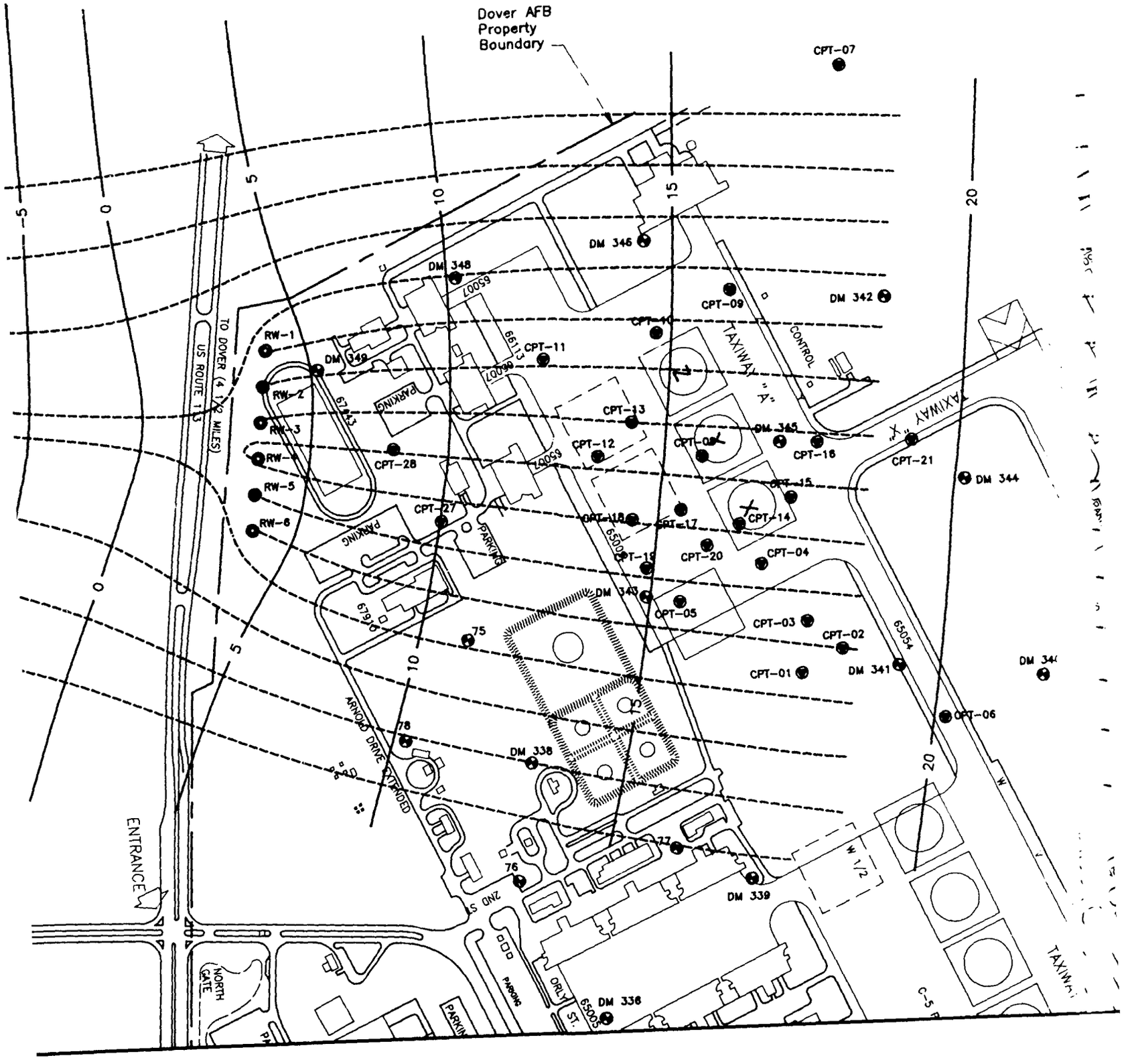
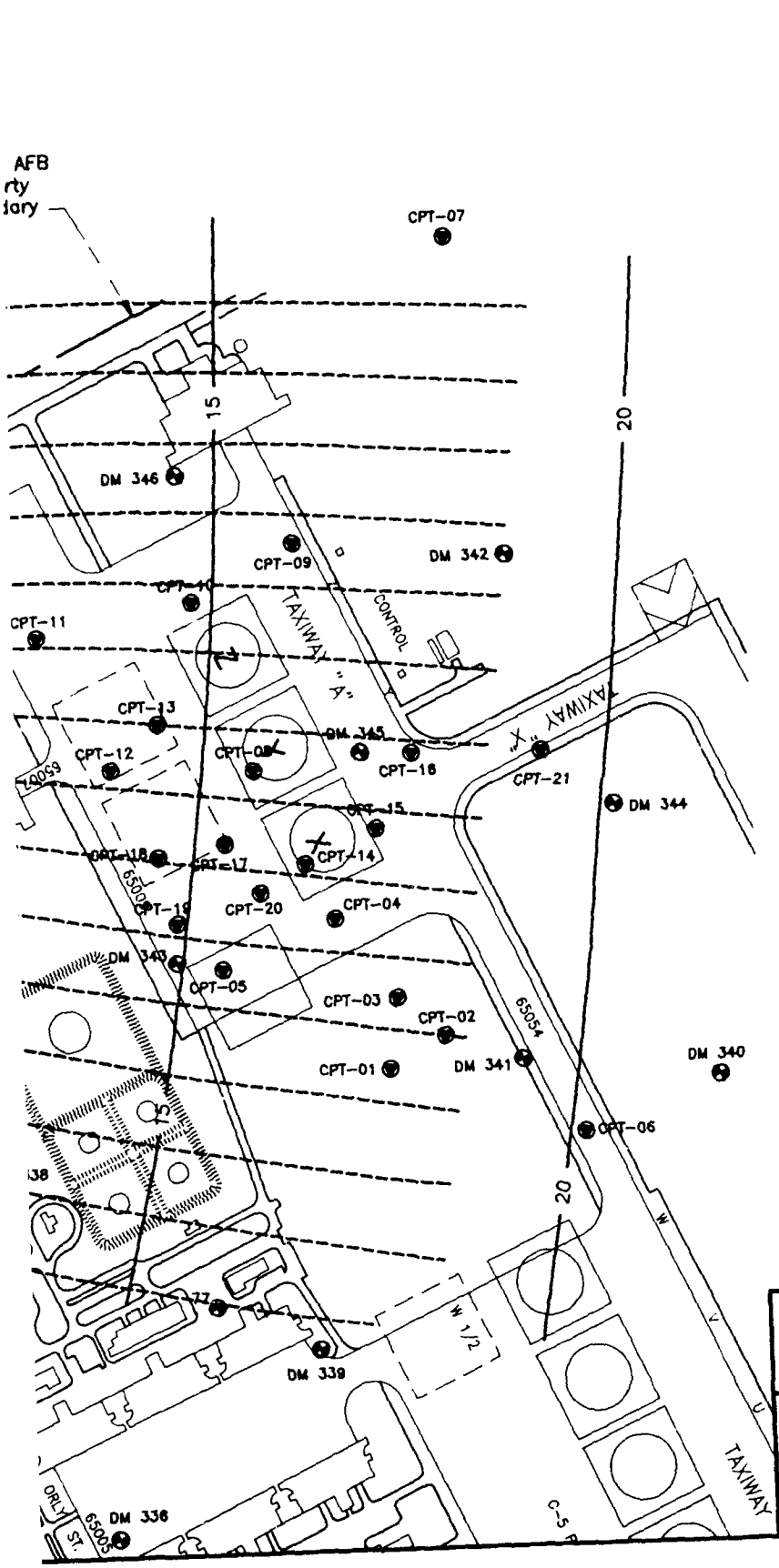

Dover AFB
Property
Boundary
CPT-07
DM 346
DM 348
CPT-09
DM 342
CPT-10
CPT-11
RW-1
RW-2
RW-3
RW-4
RW-5
RW-6
DM 349
TO DOVER (4 1/2 MILES)
US ROUTE 113
PARKING
67443
65007
66113
CPT-28
CPT-27
CPT-13
CPT-12
CPT-08
DM 345
CPT-16
CPT-21
DM 344
CPT-15
CPT-14
CPT-18
CPT-17
CPT-19
CPT-20
CPT-04
DM 343
CPT-05
CPT-03
CPT-02
CPT-01
DM 341
CPT-06
65054
67916
75
78
DM 338
ARNOLD DRIVE EXTENDED
ENTRANCE
NORTH GATE
76
77
DM 339
2ND ST.
ORLY ST.
DM 336
65005
TAXIWAY "A"
CONTROL
W 1/2
C-5
5
0
10
15
20

Figure 5.16



LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
RW-1	Proposed recovery well.
— 5 —	Predicted equipotential line from QuickFlow™ (feet above mean sea level).
-------	Predicted streamline from QuickFlow™.
(2)	Former C-10 fueling pad.

Note:

1. QuickFlow™ steady-state model results assume extraction rates of 9 gallons per minute per recovery well.

400' 200' 0 400'

Approximate Scale in Feet

Sources: QuickFlow™ (Geraghty & Miller, Inc., 1991a)
USGS Little Creek, Delaware Quad, 1993

Predicted Groundwater Capture Zone From QuickFlow™ Model

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

PARSONS ENGINEERING SCIENCE, INC.

5.7 CONCLUSIONS

The results of three Bioplume II model scenarios for Site SS27/XYZ suggest that the dissolved BTEX plume front is not likely to migrate more than 400 feet downgradient from its April 1994 position. The first scenario, model CAL, conservatively assumed that conditions that produced the calibrated model would remain constant (i.e., there would be no weathering of mobile or residual LNAPL and no reduction in source loading rates). The second and third scenarios (models SR8 and SR6, respectively) assumed that source area remediation would reduce BTEX loading rates. Model CAL results suggest that within 20 years, the BTEX plume will reach its maximum extent, approximately 400 feet beyond the southwestern Base property boundary before stabilizing.

Results of SR8 and SR6 suggest that after source reduction and removal, the BTEX plume will migrate no more than 300 feet beyond the southwestern Base property boundary. This is still 800 feet up gradient from the nearest known receptor point; the wetlands along the St. Jones River. Under the assumption of source reduction, the maximum predicted BTEX concentrations at the property boundary ranged from 18 to 23 µg/L, with benzene concentrations estimated below levels of regulatory concern (Table 5.3). Model simulations conducted during this project are conservative for several reasons, including the following:

1) Aerobic respiration, denitrification, iron reduction, and sulfate reduction are all likely occurring at this site; however, only DO and nitrate are considered as electron acceptors during model simulations.

2) Redox potentials suggest that methanogenesis is probably occurring; however, analytical results for methane were not of sufficient quality to evaluate this

degradation pathway.

3) The stoichiometry used to determine the ratio between DO plus nitrate-equivalent DO and BTEX assumed that no microbial cell mass was produced during the reaction. As discussed in Section 4.3.2.1, this approach may be conservative by a factor of three.

4) The highest DO concentration observed at the site was 8.3 mg/L. The highest DO concentration assumed during model simulations was 5.0 mg/L. In addition, the highest observed nitrate concentration observed at the site was 18.4 mg/L (as nitrogen). The highest nitrate concentration assumed during model simulations was 5 mg/L.

5) Model CAL assumed no weathering of LNAPL in the source area; however, the partitioning of BTEX from mobile or residual JP-4 LNAPL will decrease over time, and the concrete cover at the site probably limits the leaching of BTEX from soils that contain residual LNAPL.

Because these conservative assumptions were utilized within the model, the models represent worst-case scenarios. The BTEX constituents may never cross the AFB property boundary. Alternatively, actual concentrations that may cross the site boundary should be much lower than the values predicted. None of the models suggest that BTEX concentrations will reach the nearest potential receptor exposure point southwest of the site (i.e., the St. Jones River). During implementation of intrinsic remediation at the site, administrative controls and restrictions would be placed on groundwater downgradient of the site as an additional protective measure. As a result, any risk posed by BTEX constituents crossing the property boundary is likely negligible once a remedial system is employed.

Models CAL, SR8, and SR6 represent a continuum of probable scenarios at Site SS27/XYZ. Model CAL represents the "worst case" in that it assumes BTEX dissolution into the aquifer will continue indefinitely, although BTEX loading rates should decrease as the residual product weathers and the continuing dissolution removes more and more contaminant mass. Model SR8 and SR6 are more optimistic predictions that assume source remediation will result in proportional decreases in BTEX dissolution. It is likely that future site conditions will fall somewhere between these endpoints, with the plume not migrating as far as indicated by CAL, but with BTEX concentrations in the source area persisting longer than predicted by SR8 and SR6.

The results of the one-dimensional analytical modeling correlated well to the results of the numerical groundwater modeling. Although the BTEX concentrations predicted with the analytical models differed somewhat from those predicted using Bioplume II and also differed somewhat from those measured at CPT monitoring points, the magnitudes of the concentrations were comparable. The results of the analytical models closely matched observed concentrations of contaminants at discrete points using first-order decay combined with advection, dispersion, and retardation. The range of first-order decay coefficients calculated for the individual groundwater flow directions matched fairly well with the first-order decay coefficients determined from calibration of the analytical models. Based on these preliminary findings, analytical models with first-order decay of solute and/or source concentrations may be successfully used in support of natural attenuation as the selected corrective action alternative at petroleum contaminated sites. The continued comparison of analytical techniques to the more rigorous numerical evaluations at other sites under the intrinsic remediation program will allow further validation of analytical modeling approaches.

SECTION 6

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents the development and comparative analysis of four groundwater remedial alternatives for Site SS27/XYZ at Dover AFB. The intent of this evaluation is to determine if intrinsic remediation is an appropriate and cost-effective remedial technology to consider when developing final remedial strategies for Site SS27/XYZ, especially when combined with other conventional remedial technologies.

Section 6.1 presents the evaluation criteria used to evaluate groundwater remedial alternatives. Section 6.2 discusses the development of remedial alternatives considered as part of this demonstration project. Section 6.3 provides a brief description of each of these remedial alternatives. Section 6.4 provides a more detailed analysis of the remedial alternatives using the defined remedial alternative evaluation criteria. The results of this evaluation process are summarized in Section 6.5.

6.1 REMEDIAL ALTERNATIVE EVALUATION CRITERIA

The evaluation criteria used to identify appropriate remedial alternatives were adapted from those recommended by the USEPA (1988) for selecting remedies for Superfund sites (OSWER Directive 9355.3-01). These criteria included (1) long-term effectiveness and permanence, (2) technical and administrative implementability, and (3) relative cost. The following sections briefly describe the scope and purpose of each evaluation criterion. This report focuses on the potential use of intrinsic remediation and source reduction technologies to reduce BTEX concentrations within the shallow groundwater to levels that meet regulatory action levels.

6.1.1 Long-Term Effectiveness and Permanence

Each remedial technology or remedial alternative (which can be a combination of remedial approaches such as intrinsic remediation and institutional controls) was analyzed to determine how effectively it will minimize groundwater contaminant plume expansion so that groundwater quality standards can be achieved at a downgradient POC. The expected technical effectiveness was evaluated based on case histories from other sites with similar conditions. The ability to minimize potential impacts on surrounding facilities and operations was considered. Also, the ability of each remedial alternative to protect both current and potential future receptors from potential risks was qualitatively assessed by conservatively estimating whether a potential receptor exposure pathway involving groundwater would be completed, either now or in the future. These evaluation criteria also include permanence and the ability to reduce contaminant mass, toxicity, and volume. Time to implementation and time until protection is achieved are discussed. Long-term reliability for providing continued protection, including an assessment of potential for failure of the technology and the potential threats resulting from such a failure, was also evaluated.

6.1.2 Implementability

The technical implementation of each remedial technology or remedial alternative was evaluated in terms of technical feasibility and availability. Potential shortcomings and difficulties in construction, operations, maintenance, and monitoring are presented and weighed against perceived benefits. Requirements for any post-implementation site controls such as LTM and land use restrictions are described. Details on administrative feasibility in terms of the likelihood of public acceptance and the ability to obtain necessary approvals are discussed.

6.1.3 Cost

The total cost (discounted present worth) of each remedial alternative was estimated for relative comparison. An estimate of capital costs, and operations and post-implementation costs for site monitoring and controls is included. An annual discount rate of 5 percent was utilized in the present worth calculations to represent the cost of the monies to be expended to the remediation project (USEPA, 1988). The annual discount rate was applied to all capital equipment purchases, all annual operating costs, and annual expenditures. Annual operating costs were assumed to remain constant over the life of the project. Costing worksheets are provided in Appendix G.

6.2 FACTORS INFLUENCING ALTERNATIVES DEVELOPMENT

Several factors were considered during the identification and screening of remedial technologies for addressing shallow groundwater contamination at Dover AFB, Site SS27/XYZ. Factors considered included the objectives of the natural attenuation demonstration program; contaminant, groundwater, and soil properties; present and future land use; and potential exposure pathways. The following sections briefly describe each of these factors and how they were used to narrow the list of potentially applicable remedial technologies to the final remedial alternatives considered for Site SS27/XYZ.

6.2.1 Program Objectives

The intent of the intrinsic remediation demonstration program sponsored by AFCEE is to develop a systematic process for scientifically investigating and documenting natural subsurface attenuation processes that can be factored into overall site remediation plans. The objectives of this program and the specific study at Site SS27/XYZ are to provide solid evidence of intrinsic remediation of dissolved fuel hydrocarbon so that this information can be used to develop an effective groundwater remediation strategy. A secondary goal of this

multi-site initiative is to provide a series of regional case studies that demonstrate that natural processes of contaminant degradation can often reduce contaminant concentrations in groundwater to below acceptable cleanup standards before completion of potential exposure pathways.

Because the objective of this program is to study natural processes in the saturated zone rather than all contaminated media (e.g., vadose zone soil, soil gas, etc.), technologies have been evaluated based on their potential impact on shallow groundwater and phreatic soils. Technologies that can reduce vadose zone contamination and partitioning of contaminants into groundwater have also been evaluated. Many of the source removal technologies evaluated in this section also will reduce soil and soil gas contamination, but it is important to emphasize that the remedial alternatives developed in this document are not intended to remediate all contaminated site media. However, remediation of contamination in the vadose zone can reduce contaminant leaching, further increasing the effectiveness of natural attenuation mechanisms.

Additional program objectives set forth by AFCEE include cost effectiveness and minimization of remediation waste. Technologies that may meet these criteria include institutional controls, SVE, bioventing, biosparging, bioslurping, groundwater pump and treat, and intrinsic remediation. Soil excavation, slurry walls, sheet piling, carbon adsorption, *ex situ* biological or chemical treatment, and onsite/offsite disposal are not attractive technology candidates for this site.

6.2.2 Contaminant Properties

The site-related contaminants considered as part of this demonstration at Site SS27/XYZ are the BTEX compounds. The source of this contamination is weathered JP-4 present as mobile LNAPL and residual LNAPL contamination in the vadose zone, capillary fringe, and saturated soil on the site property. The physiochemical characteristics of both JP-4 and the individual

BTEX compounds will greatly influence the effectiveness and selection of a remedial technology.

Petroleum hydrocarbon mixtures, such as JP-4, are comprised of numerous compounds with different physiochemical characteristics. JP-4 is manufactured by blending various petroleum distillate products such as naphtha, gasoline, and kerosene [Biomedical and Environmental Information Analysis (BEIA), 1989]. The reported major compound categories of JP-4, in decreasing order of prominence, are paraffins, monocycloparaffins, dicycloparaffins, alkylbenzenes, indans, tetralins, and naphthalenes (BEIA, 1989). JP-4 is classified as an LNAPL with a liquid density of approximately 0.75 gram per cubic centimeter (g/cc) at 20°C (BEIA, 1989). Because JP-4 is less dense than water, the LNAPL may become concentrated in the capillary fringe. Some of the individual JP-4 constituents sorb very well to the soil matrix, others dissolve quickly into percolating groundwater, and yet others may volatilize into soil vapor. This "weathering" process results in variable distributions of individual JP-4 components in the soil, soil gas, and groundwater with time and distance from the release (BEIA, 1989). Constituents in JP-4 range from slightly to highly soluble in water, with an overall solubility of approximately 300 mg/L (BEIA, 1989). JP-4 can also act as a primary substrate for biological metabolism. Simultaneous biodegradation of aliphatic, aromatic, and alicyclic hydrocarbons has been observed. In fact, mineralization rates of hydrocarbons in mixtures, such as JP-4, may be faster than mineralization of the individual constituents as a result of cometabolic pathways (Jamison *et al.*, 1975; Perry, 1984).

The BTEX compounds are generally volatile, highly soluble in water, and adsorb less strongly to soil than other hydrocarbons in the petroleum mixture. These characteristics allow the BTEX compounds to leach more rapidly from contaminated soil into groundwater and migrate as dissolved contamination (Lyman *et al.*, 1992). All of the BTEX compounds are highly amenable to *in situ* degradation by both biotic and abiotic mechanisms.

Benzene is very volatile with a vapor pressure of 76 millimeters of mercury (mm Hg) at 20°C and a Henry's Law Constant of approximately 0.0054 atmosphere-cubic meters per mole (atm-m^3/mol) at 25°C (Hine and Mookerjee, 1975; Jury *et al.*, 1991). The solubility of pure benzene in water at 20°C has been reported to be 1,780 mg/L (Verschueren, 1983). Benzene is normally biodegraded to carbon dioxide, with catechol as a short-lived intermediate (Hopper, 1978; Ribbons and Eaton, 1992).

Toluene is also volatile, with a vapor pressure of 22 mm Hg at 20°C and a Henry's Law Constant of about 0.0067 atm-m^3/mol at 25°C (Pankow and Rosen, 1988; Hine and Mookerjee, 1975). Toluene sorbs more readily to soil media relative to benzene, but still is very mobile. The solubility of pure toluene in water at 20°C is approximately 515 mg/L at 20°C (Verschueren, 1983). Toluene has been shown to degrade to pyruvate, acetaldehyde, and completely to carbon dioxide via the intermediate catechol (Hopper, 1978; Wilson *et al.*, 1986; Ribbons and Eaton, 1992).

Ethylbenzene has a vapor pressure of 7 mm Hg at 20°C and a Henry's Law Constant of 0.0066 atm-m^3/mol (Pankow and Rosen, 1988; Valsaraj, 1988). Ethylbenzene sorbs more strongly to soils than benzene but less strongly than toluene (Abdul *et al.*, 1987). Pure ethylbenzene is also less soluble than benzene and toluene in water at 152 mg/L at 20°C (Verschueren, 1983; Miller *et al.*, 1985). Ethylbenzene ultimately degrades to carbon dioxide via its intermediate 3-ethylcatechol (Hopper, 1978; Ribbons and Eaton, 1992).

The three isomers of xylene have vapor pressures ranging from 7 to 9 mm Hg at 20°C and Henry's Law Constants of between 0.005 and 0.007 atm-m^3/mol at 25°C (Mackay and Wolkoff, 1973; Hine and Mookerjee, 1975; Pankow and Rosen, 1988). Of all of the BTEX compounds, xylenes sorb most strongly to soil, but still can leach from soil into the groundwater (Abdul *et al.*, 1987). Pure xylenes have water solubilities of 152 to 160 mg/L at 20°C (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Isnard and Lambert, 1988).

Xylenes can degrade to carbon dioxide via pyruvate carbonyl intermediates (Hopper, 1978; Ribbons and Eaton, 1992).

On the basis of these physiochemical characteristics, intrinsic remediation, SVE, bioventing, bioslurping, biosparging, and groundwater extraction/air stripping technologies all could be effective at collecting, destroying, and/or treating BTEX contaminants at Site SS27/XYZ.

6.2.3 Site-Specific Conditions

Two general categories of site-specific characteristics were considered when identifying remedial technologies for comparative evaluation as part of this demonstration project. The first category was physical characteristics such as groundwater depth, gradient, flow direction, and soil type, which influence the types of remedial technologies most appropriate for the site. The second category involved assumptions about future land use and potential receptor exposure pathways. Each of these site-specific characteristics have influenced the selection of remedial alternatives included in the comparative evaluation.

6.2.3.1 Groundwater and Soil Characteristics

Site geology and hydrogeology will have a profound effect on the transport of contaminants and the effectiveness and scope of required remedial technologies at a given site. Hydraulic conductivity is perhaps the most important aquifer parameter governing groundwater flow and contaminant transport in the subsurface. The velocity of the groundwater and dissolved contamination is directly related to the hydraulic conductivity of the saturated zone. Rising head slug tests, completed at Site SS27/XYZ during April 1994, indicated a range of hydraulic conductivities for the shallow aquifer from 1.2 to 180 ft/day, with an average value of about 60 ft/day. These moderate to high values of hydraulic conductivity are characteristic of the sandy aquifer materials observed at the site (see Sections 3 and 5 of this report). The average

hydraulic conductivity in combination with the relatively flat hydraulic gradient observed at this site yields a moderate groundwater flow velocity of 161 ft/year. This moderate velocity directly influences the fate and transport of contaminants by controlling the rate of contaminant migration. As a result, the shallow groundwater contaminant plume at the site has migrated relatively slowly. The average value for hydraulic conductivity, when used as input data for the Bioplume II model, adequately reproduced the observed extent of the contaminant plume within a reasonable time frame.

Although a moderate to high hydraulic conductivity can result in considerable plume expansion and migration, this same characteristic will also enhance the effectiveness of remedial technologies, such as groundwater extraction, biosparging, and intrinsic remediation. For example, it should be less expensive and time-consuming to capture and treat the contaminant plume using a network of extraction wells in areas of moderate to high hydraulic conductivity. The effectiveness of biosparging may also be increased in sandy aquifers because of reduced entry pressures and increased radius of influence. Greater hydraulic conductivity also increases the amount of contaminant mass traveling through the biosparging network. Contaminant recovery may also be maximized when contaminants are not significantly sorbed to and retarded by phreatic soil. The low TOC content of uncontaminated aquifer materials at Dover AFB (less than 0.000055 percent) will tend to minimize sorption and allow mobility of BTEX compounds.

The movement of contaminants within the subsurface away from the source also will increase the effectiveness of natural biodegradation processes by distributing the contaminant mass into areas enriched with electron acceptors. To satisfy the requirements of indigenous microbial activity and intrinsic remediation, the aquifer must also provide an adequate and available carbon or energy source, electron acceptors, essential nutrients, proper ranges of pH, temperature, and redox potential.

Data collected as part of the field work phase of this demonstration project and described in Sections 3 and 4 of this document indicate that Site SS27/XYZ is characterized by adequate and available carbon/energy sources and electron acceptors that support measurable biodegradation of JP-4 contamination by indigenous microorganisms. DO, sulfate, nitrate, and ferrous iron represent significant sources of electron acceptor capacity for the biodegradation of BTEX compounds at the site. Further, because fuel hydrocarbon-degrading microorganisms have been known to thrive under a wide range of temperature and pH conditions (Freeze and Cherry, 1979), the physical and chemical conditions of the groundwater and phreatic soil at Site SS27/XYZ are not likely to inhibit microorganism growth.

Fuel hydrocarbon-degrading microorganisms are ubiquitous, and as many as 28 hydrocarbon-degrading isolates (bacteria and fungi) have been discovered in different soil environments (Davies and Westlake, 1979; Jones and Eddington, 1968). Indigenous microorganisms have a distinct advantage over microorganisms injected into the subsurface to enhance biodegradation because indigenous microorganisms are well adapted to the physical and chemical conditions of the subsurface in which they reside (Goldstein *et al.*, 1985). Microbe addition was not considered a viable remedial technology for Site SS27/XYZ.

6.2.3.2 Potential Exposure Pathways

An exposure pathways analysis identifies the potential human and ecological receptors that could potentially come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a potential mechanism(s) of release, a pathway of transport to an exposure point, an exposure point, and a receptor. If any of these elements do not exist, the exposure pathway is considered incomplete, and receptors will not come into contact with site-related contamination. Evaluation of the potential long-term effectiveness of any remedial

technology or remedial alternative as part of this demonstration project includes determining if the approach will be sufficient and adequate to minimize plume expansion so that potential exposure pathways involving shallow groundwater are incomplete.

Assumptions about current and future land uses at a site form the basis for identifying potential receptors, potential exposure pathways, reasonable exposure scenarios, and appropriate remediation goals. USEPA (1991) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be used to guide the identification of potential exposure pathways and to determine the level to which the site must be remediated. The source area consists of fuel storage and delivery infrastructure in the vicinity of Building 950 and the former fueling pads X, Y, and Z (currently AA, BB, and CC), and associated facilities. The groundwater plume originating from Site SS27/XYZ is migrating to the southwest, northwest, and northeast and has impacted shallow groundwater in an irregularly shaped area within the Dover AFB property boundaries (Figure 4.3). The fueling pads, taxiways, and runways located in the vicinity of Site SS27/XYZ overlie most of the contaminant plume. Warehouses, roadways, maintenance buildings, and office buildings are located on adjacent properties. The current land use within the contaminant plume is entirely industrial (Air Force operations). Land use in downgradient areas includes residential areas.

Under reasonable current land use assumptions, potential receptors include worker populations. It is unlikely that workers could be exposed to site-related contamination in phreatic soils or shallow groundwater unless this material is removed during future construction excavations or remedial activities. As groundwater is located at a depth of approximately 5 to 12 feet bls, it is possible that utility workers could be exposed to shallow groundwater contamination. Shallow groundwater is not currently used to meet any water supply demands at Dover AFB. All on-Base water supply demands are met by water supply wells owned by Dover AFB completed into the Cheswold and Piney Point aquifers (Mikula,

1995). These aquifers are much deeper than and separated from the shallow groundwater by multiple confining units (see Section 3). The Dover AFB water supply wells range in depth from 268 to 697 feet bls, and are all greater than 1,800 feet in horizontal distance from Site SS27/XYZ (Mikula, 1995). The mobile home park adjacent to Dover AFB is supplied with drinking water from the Tidewater County Utility Department (Mikula, 1995). Exposure pathways involving other environmental media such as shallow soils and soil gas in the source area were not considered as part of this project, but should be considered in overall site remediation decisions. In the event future construction activities are planned for Site SS27/XYZ, special precautions should be taken to ensure environmental safety and limit worker exposure.

Assumptions about hypothetical future land uses must also be made to ensure that the remedial technology or alternative considered for shallow groundwater at the site is adequate and sufficient to provide long-term protection. No changes in land use are anticipated in the foreseeable future, so the assumption of continued industrial land use at the Base is appropriate. As a result, potential future receptors include only worker populations on the Base and residential populations outside the Dover AFB property. The potential future exposure pathways involving workers are identical to those under current conditions provided shallow groundwater is not used to meet industrial water demands.

Migration of contaminated shallow groundwater resulting in a discharge into the St. Jones River could represent a future completed exposure pathway to off-Base human or ecological receptors via dermal contact or possible ingestion. However, it is very unlikely that detectable concentrations could reach the river. The St. Jones River is located approximately 2,000 feet downgradient from the leading edge of the contaminant plume. A conservative tracer would require approximately 7 years to reach the river. However, fate and transport modeling suggests that the contaminant plume will not travel this distance due to natural attenuation. In the unlikely event that contaminants reach the St. Jones River, BTEX concentrations probably

will be instantly diluted to below analytical detection limits. In summary, the use of intrinsic remediation technology at this site will require that the source area be maintained as industrial property and that restrictions on groundwater use be enforced in the area downgradient of Site SS27/XYZ to the St. Jones River.

In the northwestern and northeastern groundwater flow directions, the results of analytical modeling suggest that concentrations of BTEX will not exceed MCLs outside the property boundaries in these directions even if the BTEX source is continuous through time (i.e., no source remediation is implemented). If source removal technologies such as SVE, bioventing, mobile LNAPL recovery (bioslurping), biosparging, or groundwater pump and treat are implemented, they will have some impact on the short- and long-term land use options and will require some level of institutional control and worker protection during remediation.

6.2.3.3 Remediation Goals for Shallow Groundwater

Model CAL results suggest that BTEX compounds are not likely to move more than 400 feet downgradient from the southwestern Base property boundary (i.e., approximately 800 feet upgradient from the St. Jones River), assuming contaminants are indefinitely introduced into the aquifer at a constant rate. Without source removal, the contaminant plume should reach steady-state conditions within 30 years. The Base property boundary is considered the POC in this document even though the conservative models predict potential future impact from BTEX contamination. If contaminant concentrations do reach the Base boundary in excess of regulatory levels, then current land use and foreseeable future groundwater use should be reevaluated, and technologies designed to limit plume migration (e.g., hydraulic barriers and sparge curtains) may need to be considered. Monitoring of a downgradient LTM well will serve to confirm model predictions. If contaminant concentrations exceed model predictions, supplemental remedial actions could be evaluated prior to POC impact.

For the northwestern and northeastern flow directions, BTEX contamination is not expected to migrate to the POC boundaries in concentrations approaching MCLs (see Section 5.6.2.2). If source area remediation proceeds via bioslurping or bioventing, and as residual LNAPL weathers, BTEX loading rates will decrease, and the extent of BTEX migration will likely be much more limited. Therefore, locations near the property boundaries in these directions have been identified as the POCs for contaminant concentrations in groundwater because this appears to be the maximum extent of future contaminant migration. These are suitable locations for monitoring and for demonstrating compliance with protective groundwater quality standards, such as promulgated federal MCLs or Delaware groundwater quality standards.

This remedial strategy assumes that compliance with promulgated, single-point remediation goals throughout the plume are not necessary if site-related contamination does not pose a threat to human health or the environment (i.e., the exposure pathways are incomplete). Thus, the magnitude of required remediation in areas that can be placed under institutional control is different from the remediation that is required in areas that may be available for unrestricted use. The primary RAO for shallow groundwater within and downgradient from Site SS27/XYZ is limited plume expansion to prevent exposure of downgradient receptors to concentrations of BTEX in groundwater at levels that exceed regulatory standards intended to be protective of human health and the environment. This means that viable remedial alternatives must be able to achieve concentrations that minimize plume migration and/or expansion. The RAO for shallow groundwater at the POCs is attainment of Delaware's groundwater quality standards (equivalent to the federal drinking water MCLs) for each of the BTEX compounds, as listed in Table 6.1. Although it is unlikely that shallow groundwater would be ingested by humans, this level of long-term protection is appropriate, because the shallow groundwater in this area is classified by Delaware as a potential potable water source.

TABLE 6.1

POINT-OF-COMPLIANCE REMEDIATION GOALS
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Compound	Delaware Groundwater Quality Standards and Federal MCLs[a/] (µg/L)
Benzene	5
Toluene	1,000
Ethylbenzene	700
Total Xylenes	10,000

[a/] Source: BNA (1994)

In summary, available data suggest that there is currently no completed potential receptor exposure pathway at Site SS27/XYZ. It is not likely that potential exposure pathways involving shallow groundwater would be completed under future land use assumptions, provided use of groundwater as a potable or industrial source of water is prohibited by institutional controls within the source area, the Dover AFB property boundaries, and approximately 400 feet downgradient from the southwestern property boundary. Thus, institutional controls are likely to be a necessary component of any groundwater remediation strategy for this site. The required duration of these institutional controls may vary depending on the effectiveness of the selected remedial technology at reducing contaminant mass and concentration in the groundwater.

6.2.4 Summary of Remedial Technology Screening

Several remedial technologies have been identified and screened for use in treating the shallow groundwater at Site SS27/XYZ. Table 6.2 identifies the initial remedial technologies considered as part of this demonstration and those retained for detailed comparative analysis.

TABLE 6.2

INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

General Response Action	Technology Type	Process Option	Implementability	Retain
Long-Term Monitoring	Periodic Groundwater Monitoring	Confirmation Wells	Many existing wells are available to confirm the progress of remediation.	Yes
		Point-of-Compliance Wells	Sufficient distance exists between the plume and point-of-compliance to locate several wells.	Yes
Institutional Controls	Groundwater Use Control	Land Use Control/Regulate Well Permits	Plume area is currently within the Base boundary and land-use and groundwater use are under Base jurisdiction.	Yes
		Seal/Abandon Existing Wells	No production wells are known to exist in the existing or predicted plume area.	No
		Point-of-Use Treatment	No groundwater is extracted from the plume area for any use.	No
	Public Education	Meetings/ Newsletters	Base public relations and environmental management offices have many information avenues to inform workers and residents.	Yes
Containment of Plume	Hydraulic Controls	Passive Drain Collection	No likely receptors downgradient of site. Installation disruptive to base operations. Prohibitive due to groundwater depth.	No
		Minimum Pumping/Gradient Control	Vertical pumping wells could be located downgradient of the leading edge of plume to intercept and halt the advance of the plume.	Yes
	Physical Controls	Slurry Walls/Grout Curtains	Requires significant disruption of a Base operations. Limited effectiveness.	No
		Sheet Piling	Requires significant disruption to Base operations. Limited effectiveness.	No
	Reactive/Semi-Permeable Barriers	Biologically Active Zones	Natural biodegradation of BTEX compounds can be stimulated by allowing contaminated groundwater to flow through an aquifer zone which has enhanced oxygen and nutrient conditions. Not practical for excessive contaminant concentrations.	No

TABLE 6.2 (Continued)

INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

General Response Action	Technology Type	Process Option	Implementability	Retain
In Situ Treatment	Biological	Oxygen and/or Nutrient Enhanced Biodegradation (Biosparging)	Differs from biologically active zone in that oxygen and/or nutrients are injected in source area and allowed to migrate downgradient. This method can more rapidly reduce higher BTEX concentrations in and immediately downgradient of the source area.	Yes
	Chemical/ Physical	Intrinsic Remediation	A combination of natural biological, chemical, and physical removal mechanisms which occur to varying degrees on every site. Groundwater sampling at Site SS27/XYZ indicates that this is a major, ongoing remediation process.	Yes
		Air Sparging (Volatilization)	Injection of air into contaminated aquifer creating a mass transfer of BTEX into air bubbles and into vadose zone.	Yes
Aboveground Groundwater Treatment	Groundwater Extraction	Vertical Pumping Wells	Entire groundwater plume is pumped by installing numerous wells with submersible pumps. High cost and major disruption to area. Not effective until residual LNAPL is remediated.	No
		Downgradient Horizontal Drains	See Passive Drain Collection.	No
	Biological	Bioreactors	High flow rates require excessive retention times and large reactors. BTEX is often volatilized in these systems.	No
	Chemical/ Physical	Air Stripping	Cost-effective technology for removing varying concentrations of BTEX at higher flow rates. Permitting for air emissions may be required. Not effective as a final remediation measure unless the residual LNAPL is remediated.	Yes
		Activated Carbon	Cost prohibitive for more concentrated BTEX. Creates a carbon disposal problem.	No
		UV/Ozone Reactors	High flow rates require excessive retention times and large, expensive reactors.	No

TABLE 6.2 (Continued)

INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

General Response Action	Technology Type	Process Option	Implementability	Retain
Aboveground Treatment	Direct Discharge to Industrial Waste Water Treatment Plant (IWWTP)	IWWTP	Viable option when an IWWTP is available and capable of handling BTEX and hydraulic loading. Plume dimensions and sandy conditions would require very high hydraulic loading in order to control the plume.	No
Treated Groundwater Disposal	Discharge to IWWTP or Sanitary Sewer	IWWTP	Viable option when access to industrial sewer exists and hydraulic loading is acceptable. Same as above.	No
		Sanitary Sewer	Viable option when access to sanitary sewer exists and hydraulic loading is acceptable.	Yes
	Treated Groundwater Reinjection	Vertical Injection Wells	Not recommended due to clogging and high maintenance.	No
		Injection Trenches	Less clogging than wells, but large trenches are required and can be subject to injection well permitting.	No
	Discharge to Surface Waters	Storm Drains	Viable option but generally requires NPDES or other discharge permit. Groundwater extraction is unlikely.	No
Source Removal/Soil Remediation	Mobile LNAPL Recovery	Dual-Pump Systems	Best suited for sites with >1 foot mobile LNAPL where aboveground groundwater treatment already exists	No
		Skimmer Pumps/Bailers/ Wicks	Best suited for sites with <1 foot mobile LNAPL where groundwater pumping is undesirable.	Yes
		Total Fluids Pumping	Best suited for sites with thin saturated zones where excessive groundwater will not be pumped.	No
		Bioslurping	Combined vapor extraction, bioventing, and mobile LNAPL recovery system has been operated at some sites with limited success. Minimal product at site.	Yes
		Hand Bailing	The limited quantity of mobile LNAPL at the site makes this method cost-effective on a short-term basis.	No
	Excavation/ Treatment	Biological Landfarming	Deep excavation is not feasible at this site due to surface structures.	No

TABLE 6.2 (Concluded)

INITIAL TECHNICAL IMPLEMENTABILITY SCREENING OF
TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER REMEDIATION
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

General Response Action	Technology Type	Process Option	Implementability	Retain
Source Removal/Soil Remediation (cont'd)	Excavation/ Treatment (cont'd)	Thermal Desorption	Deep excavation is not feasible at this site due to surface structures and ongoing base operations.	No
	In Situ	Bioventing	Air injection to stimulate biodegradation of fuel residuals.	Yes
		Soil Vapor Extraction	Sandy soils with a deep groundwater table suggest this option may be successful and economical. May require off-gas treatment.	Yes

Screening was conducted systematically by considering the program objectives of the AFCEE intrinsic remediation demonstration, physiochemical properties of the BTEX compounds, and other site-specific characteristics such as hydrogeology, land use assumptions, potential exposure pathways, and appropriate remediation goals. All of these factors will influence the technical effectiveness, implementation, and relative cost of technologies for remediating shallow groundwater underlying and migrating from the site. The remedial technologies retained for development of remedial alternatives and comparative analysis include institutional controls, intrinsic remediation, LTM, bioslurping, bioventing, biosparging, SVE, mobile LNAPL skimming, and groundwater pumping to effect a hydraulic barrier (combined with *ex situ* treatment of pumped water).

6.3 BRIEF DESCRIPTION OF REMEDIAL ALTERNATIVES

This section describes how remedial technologies retained from the screening process were combined into four remedial alternatives for Site SS27/XYZ. Sufficient information on each remedial alternative has been provided to facilitate a comparative analysis of effectiveness, implementability, and cost in Section 6.4.

6.3.1 Alternative 1 - Intrinsic Remediation, Continued Mobile LNAPL Recovery, and Institutional Controls with Long-Term Groundwater Monitoring

Currently, Dover AFB uses a solar-powered skimmer to remove mobile LNAPL from monitoring well DM 344S. Approximately 1 to 2 gallons of LNAPL are recovered per day from this 2-inch-diameter well. In addition, LNAPL is skimmed from well 68S using a truck-mounted mobile skimmer; however, this well is close to the flight line and skimming operations are limited as a result of flight-line operations. Under this alternative, intrinsic remediation of dissolved BTEX would be used to supplement the limited source removal achieved by the current skimming operations. Intrinsic remediation is achieved when naturally occurring attenuation mechanisms bring about a reduction in the total mass of a contaminant in

the soil or dissolved in groundwater. Intrinsic remediation results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Destructive attenuation mechanisms include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution (caused by dispersion and infiltration), and volatilization. In some cases, intrinsic remediation will reduce dissolved contaminant concentrations below numerical concentration goals, thus protecting human health and the environment. Based on the existing evidence of intrinsic remediation described in Section 4, these processes are occurring at Site SS27/XYZ and will continue to reduce contaminant mass in the plume area.

The Bioplume II model CAL (presented in Section 5) describes a treatment scenario that includes the calibrated BTEX plume formed with source cells to simulate the continuous leaching of BTEX from mobile and residual LNAPL material. As discussed in Section 5.6.1, model CAL results suggest that intrinsic remediation will stabilize the dissolved BTEX plume within 20 years and that the plume could extend to a maximum of 400 feet downgradient from the southwestern property boundary of Dover AFB (Figure 5.9). Model CAL assumes that the mobile and residual LNAPL will be a continuous, constant source of contaminants, indefinitely. In reality, the hydrocarbon leaching rate will diminish over time. As a result, model CAL conservatively describes contaminant conditions assumed for evaluation of Alternative 1. Actual plume dimensions will likely be smaller than those predicted, particularly in light of the continuing removal of mobile LNAPL.

Implementation of Alternative 1 would require the use of institutional controls such as land use restrictions and LTM. Land use restrictions may include placing long-term restrictions on soil excavation within the source area and long-term restrictions on groundwater well installations within and downgradient from the source area. The intent of these restrictions would be to reduce potential receptor exposure to contaminants by legally restricting activities that could create exposure points within areas affected by site-related contamination.

As a minimum, groundwater monitoring would be conducted annually for 30 years as part of this remedial technology to evaluate the progress of natural attenuation processes. Based on the potential plume migration suggested by model CAL, it is likely that benzene concentrations that exceed the state standard of 5 µg/L would not migrate more that 400 feet downgradient from the southwestern property boundary of the Base. This would be true even if it were assumed that model contaminant concentrations are all benzene rather than total BTEX. In addition, analytical model results suggest that BTEX concentrations would not exceed Delaware groundwater standards at the northwestern and northeastern property boundaries downgradient from Site SS27/XYZ.

Because there are no apparent downgradient receptors, POC wells can be placed at or near the southwestern, northwestern, and northeastern property boundaries downgradient from Site SS27/XYZ. In addition, LTM wells within the existing BTEX plume will be used to monitor the effectiveness of intrinsic remediation. LTM wells are further described in Section 7.2.1. Detection of benzene at concentrations exceeding 5 µg/L at the POC wells may require additional evaluation and modeling to assess BTEX migration, to determine if any BTEX will reach the St. Jones River or other off-Base receptors, and to determine if additional corrective actions would be necessary. Land use restrictions may also require reevaluation.

Public education on the selected alternative would be developed to inform Base personnel and local residents of the scientific principles underlying source reduction and intrinsic remediation. This education could be accomplished through public meetings, presentations, press releases, and posting of signs where appropriate. Periodic site reviews could also be conducted every year using data collected from the long-term groundwater monitoring program. The purpose of these periodic reviews would be to evaluate the extent of contamination, assess contaminant migration and attenuation through time, document the effectiveness of source removal and institutional controls at the site, and reevaluate the need for additional remedial actions at the site.

6.3.2 Alternative 2 - Intrinsic Remediation, Mobile LNAPL Recovery, Hydraulic Barrier, and Institutional Controls with Long-Term Groundwater Monitoring

Alternative 2 is similar to Alternative 1 and includes intrinsic remediation, LNAPL recovery through continued operation of the existing skimmer system, institutional controls, and LTM. However, Alternative 2 also includes the installation of a hydraulic barrier system that would be located southwest of Site SS27/XYZ along the Base property boundary. Under this alternative, intrinsic remediation through natural attenuation mechanisms would continue. Based on the evidence described in Section 4, these processes are occurring and will continue to reduce contaminant mass in the plume area. Continued LNAPL skimming for the removal of mobile LNAPL would be the same as discussed for Alternative 1. Implementation of Alternative 2 would also require the use of institutional controls such as land use restrictions, which place long-term restrictions on soil excavation within the source area, and LTM to monitor BTEX contamination within and downgradient of the site. These restrictions would reduce potential on-Base receptor exposure to contaminants by legally restricting activities within areas affected by site-related contamination. The hydraulic barrier system would be installed to prevent the migration of dissolved BTEX beyond the Base boundary. As discussed for Alternative 1, groundwater monitoring would be conducted annually for 30 years as part of this remedial option.

The Alternative 2 remediation scenario was simulated using Bioplume II and analytical models based upon conservative assumptions. These models predict that the maximum total BTEX concentration to cross the property boundary will be approximately 72 µg/L (Table 5.3). Due to the conservative nature of the models, it is probable that BTEX concentrations may never exceed the Delaware groundwater standards (Table 6.1) across the property boundary. As a result, the hydraulic barrier system would likely be implemented only as a response measure should dissolved BTEX constituents migrate closer than 1-year travel time from the Base property boundary (approximately 161 feet). Under this alternative,

three sentry wells would be installed at this distance to monitor BTEX migration toward the Base property boundary.

The design of this hydraulic barrier would conform closely to the criteria discussed within Section 5.6.4, with wells located along the southwestern property boundary, downgradient from monitoring point CPT-28. Actual design specifications (i.e., well spacing, screen interval, slot size, etc.) would depend upon an aquifer pump test to be performed within this area of the site. For the purposes of this analysis, a system of six, 35-foot recovery wells were assumed to be constructed of PVC screen and casing and pumped at a total flow rate of 54 gallons per minute for 30 years. The recovered water is assumed to be treated by an air stripper unit. Volatile air emissions would be treated with vapor-phase activated carbon, and the treated water would be discharged to a sanitary sewer.

6.3.3 Alternative 3 - Intrinsic Remediation with Bioslurping and Bioventing in Source Area, Oil/Water Separation, Off-gas Treatment, and Institutional Controls with Long-Term Groundwater Monitoring

This alternative is identical to Alternative 1 except that bioslurping and bioventing would be used to reduce the volume of mobile and residual LNAPL within the source area at Site SS27/XYZ. These systems would be designed to complement the operating skimmer system. Bioslurping is a vacuum-mediated free product recovery and bioremediation technique that is applicable for the remediation and removal of measurable layers of mobile LNAPL on groundwater. A bioslurping system consists of a "slurp" tube that extends through a groundwater monitoring well into the LNAPL layer. Product is drawn into the tube as air is removed from the tube with a vacuum extraction pump. In addition to the removal of LNAPL, oxygenated air is drawn into the pore spaces of the contaminated soils adjacent to the extraction well, promoting aerobic biodegradation (bioventing). Air emissions from the bioslurper system may be treated with either vapor-phase activated carbon or an internal combustion engine. Minimal groundwater is extracted using bioslurping technology, resulting

in a significant cost advantage over traditional pumping systems, which generate large quantities of waste water requiring treatment and disposal. Extracted groundwater could be treated using an oil/water separator, and discharged through an air stripper into the storm water or sanitary sewer system. Each of these features makes bioslurping with supplemental bioventing an attractive technology at this site. By reducing the quantity of both mobile and residual LNAPL within the source area, these technologies would reduce the predicted length of time required for intrinsic remediation to complete groundwater remediation.

During 1995, a pilot-scale bioslurping test was performed at the site under a separate AFCEE program. Pilot study results can be used to design a full-scale bioslurping and bioventing system capable of remediation of the mobile and residual LNAPL. For this analysis, bioslurping results were unavailable; therefore, the conceptualized system was assumed to consist of a combination of 15 wells manifolded to the bioslurping and bioventing blowers, and 8 monitoring points. For the purposes of this estimate, the wells were assumed to be constructed of PVC screen and casing. The bioslurping wells would be located in the center of the area underlain by mobile LNAPL (Figure 4.1), and the bioventing wells would be located on the periphery of the contaminated area near oxygen depleted soils.

Model SR8 assumes significant BTEX loading rate reductions occur due to bioslurping and bioventing. In model SR8, the source contaminant mass is reduced by 12.5 percent of the original amount per year over an 8-year period. This time period is typical for remediation systems (such as bioslurping/bioventing) employed under the diverse conditions present at Site SS27/XYZ. After 8 years of source removal, the Bioplume II model predicts that the combination of source reduction and intrinsic remediation will significantly reduce the size and concentrations of the BTEX plume. Under this scenario, model results show that it is unlikely that BTEX compounds would migrate more than 300 feet (Figure 5.11) beyond the southwestern property boundary. The dissolved BTEX plume should disappear within 25 years of initiation of treatment.

As with Alternative 1, institutional controls and LTM would be required. However, due to the shorter time frame, monitoring would only continue for 24 years. POC wells would be installed in the same locations described under Alternative 1.

6.3.4 Alternative 4 - Intrinsic Remediation with Combined Soil Vapor Extraction/Bioventing/Biosparging and LNAPL Recovery in Source Area, Off-gas Treatment with Internal Combustion Engine, and Institutional Controls with Long-Term Groundwater Monitoring

This alternative is identical to Alternative 1 except that an expanded skimmer system would be combined with bioventing, SVE, and biosparging in order promote aggressive source removal. For this analysis, 10 additional wells were conceptualized for the installation of an automated skimmer system along the centerline of the LNAPL plume. Bioventing, SVE, and biosparging could easily be combined at this site by injecting air several feet below the groundwater surface and allowing air (oxygen) to move upward through the capillary fringe and into the contaminated vadose zone. SVE would then be utilized to extract the volatilized hydrocarbons from the subsurface. These emissions would be collected via a vacuum blower and treated with an internal combustion engine. For the purpose of this estimate, the remedial system was assumed to consist of 15 wells, manifolded to SVE, bioventing, and air sparging blowers. The wells were assumed to be constructed of PVC screen and casing. Ten PVC monitoring points were also specified.

The primary difference between SVE and bioventing is the rate at which air is moved through the subsurface. Bioventing employs low air-flow rates in order to promote biodegradation, whereas SVE utilizes larger air volumes to optimize volatilization. Due to the relatively high BTEX concentrations at the site, bioventing alone may not supply adequate oxygen to the subsurface. Contaminant loading rates would eventually decrease, but more slowly than if SVE, biosparging, and bioventing were combined with product skimming. As a result, bioventing could be optimized by initially operating the bioventing system in a SVE

mode to remove the high concentrations of BTEX. Biosparging would also increase the DO content of the groundwater and promote more rapid degradation of BTEX compounds in the plume and in saturated soil.

Model SR6 was run to simulate this scenario. Model SR6 is similar to model SR8, except that model SR6 assumes more rapid reductions in the hydrocarbon loading rates to simulate a more aggressive treatment alternative with free product skimming in combination with SVE, biosparging, and bioventing. This combined treatment system was assumed to be capable of removing mobile and residual LNAPL contamination from the vadose zone and the saturated zone in approximately 6 years. As a result, in model SR6, the source is reduced by 16.7 percent of the original amount every year for 6 years. After 6 years of source removal, the Bioplume II model predicts that the combination of source reductions and intrinsic remediation will significantly reduce the size and concentration of the BTEX plume. Under this scenario, model results show that it is unlikely that BTEX compounds would migrate more than 300 feet (Figure 5.13) beyond the southwestern property boundary. This distance is similar to the distance predicted by bioventing alone (model SR8). However, the maximum total BTEX concentration that crosses the property boundary was 18 µg/L (versus 23 µg/L for SR8), and again, the plume entirely dissipates within 25 years.

As described for Alternatives 1, 2, and 3, institutional controls and LTM would be required. However, due to the shorter remediation time frame, monitoring would continue for 24 years. POC wells would be installed in the same locations indicated in Section 6.3.1.

6.4 EVALUATION OF ALTERNATIVES

This section provides a comparative analysis based on the effectiveness, implementability and cost criteria for the four previously discussed remedial alternatives. A summary of this evaluation is presented in Section 6.5.

6.4.1 Alternative 1 - Intrinsic Remediation, Continued Mobile LNAPL Recovery, and Institutional Controls with Long-Term Groundwater Monitoring

6.4.1.1 Effectiveness

Section 5 of this document presents the results of the Bioplume II model completed to evaluate the intrinsic remediation alternative at Site SS27/XYZ. Continued BTEX injection into groundwater was incorporated into model CAL to simulate the effects of continuous leaching of hydrocarbons from the source area. The CAL model results suggest that natural attenuation mechanisms will limit contaminant migration and reduce contaminant mass and toxicity downgradient from the source; however, the model results also suggest that intrinsic remediation in conjunction with the currently operating skimmer may not be sufficient to prevent the contaminant plume from exceeding the Delaware groundwater standard of 5 µg/L for benzene at the Base boundary. Groundwater monitoring at the POC wells and LTM wells will ensure the protectiveness of this alternative. In the event BTEX compounds are detected in a POC well at concentrations that exceed Delaware groundwater standards, this alternative does not cease to be protective. The St. Jones River is located over 3,000 feet from Site SS27/XYZ, and it is the only known potential receptor exposure point in the primary (southwestern) flow direction. There are no known receptor exposure points in the two secondary groundwater flow directions. Analytical model predictions in the northwestern and northeastern flow directions suggest that BTEX concentrations will not approach Delaware groundwater standards at the proposed POC well locations near the Base property boundaries in those directions from the site. In the event BTEX compounds are detected in POC wells, the site conditions would be reevaluated to determine if additional remedial actions are appropriate for the site.

The effectiveness of this remedial alternative requires that excavations or drilling within the source area be conducted only by properly protected site workers. Reasonable land use

assumptions for the plume area indicate that exposure is unlikely unless excavation or drilling activities bring contaminated soil to the surface. Long-term land use restrictions would be required to ensure that shallow groundwater will not be pumped or removed for potable use within, and approximately 3,000 feet in all directions from the source. Existing health and safety plans should be enforced to reduce risks from any proposed remedial installation and during installation of additional POC and LTM wells.

Compliance with program goals is one component of the long-term effectiveness evaluation criterion. Alternative 1 will satisfy program objectives designed to promote intrinsic remediation as a component of site remediation and to scientifically document naturally occurring processes. Alternative 1 is based on the effectiveness of naturally occurring processes that minimize contaminant migration and reduce contaminant mass over time, and the effectiveness of institutional controls. Under this alternative, annual LTM would continue for 30 years. This time frame was chosen because it is a few years longer than the modeled period of time required for the plume to reach steady-state conditions, assuming no source reduction. During this time period, predicted dissolved benzene concentrations will exceed the Delaware groundwater standard (and federal MCL) within the center of the BTEX plume. On the basis of conservative model results, these standards may also be exceeded at the POC wells along the Base boundary at some point in the future. As described earlier, Bioplume II model results suggest that naturally occurring processes will limit further BTEX plume migration to within 400 feet downgradient from the southwestern property boundary.

6.4.1.2 Implementability

Alternative 1 is not technically difficult to implement. Mobile LNAPL is presently skimmed from monitoring wells DM 344S and 68S at Site SS27/XYZ as described above. In addition, installation of POC wells and annual groundwater monitoring are both standard procedures. Long-term management efforts will be required to ensure that proper sampling

procedures are followed. Periodic site visits and sampling will be performed to confirm the adequacy and completeness of LTM data and verify the effectiveness of this remediation approach. There may also be administrative concerns associated with long-term enforcement of groundwater use restrictions. Future land use within the source area may be impacted by leaving contaminated soil and groundwater in place. Regulators, Base officials, Base employees, and the public would have to be informed of the benefits and limitations of the intrinsic remediation option. Educational programs are not difficult to implement, and typically regulatory reaction to this alternative has been positive.

6.4.1.3 Cost

Aside from the administrative concerns associated with enforcement of long-term land use restrictions and long-term groundwater monitoring programs, this remedial alternative should provide reliable, cost-effective protection. For cost comparison purposes, it is assumed that mobile LNAPL skimming will continue for a period of 6 years. At that time, recoverable mobile LNAPL will likely have been removed from site recovery wells. For costing purposes, Parsons ES assumed intrinsic remediation and LTM will continue for a 30-year period.

The cost of Alternative 1 is summarized in Table 6.3. A more complete breakdown and present worth analysis of these costs is provided in Appendix G. Capital costs include the construction of six new POC wells and one new LTM well. The total present worth cost of continued mobile LNAPL recovery for a period of 6 years, and implementation of the LTM plan for 30 years is $281,100. Also included are the costs of maintaining institutional controls for a total of 30 years.

TABLE 6.3

ALTERNATIVE 1 - COST ESTIMATE
INTRINSIC REMEDIATION AND LNAPL RECOVERY WITH INSTITUTIONAL CONTROLS AND LONG-TERM GROUNDWATER MONITORING
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

	Capital Costs ($)
Install 6 POC wells and 1 LTM well	$17,055
Operation, Maintenance, and Monitoring Costs	**Annual Cost ($)**
Continued LNAPL Recovery and Reporting (6 years)	$11,025
Annual Groundwater Monitoring of 5 LTM and 6 POC wells (30 years)	$3,704
Annual Reporting (30 years)	$3,910
Maintain Institutional Controls/Public Education (30 years)	$5,000
Project Management (30 years)	$975
Present Worth of Alternative 1 [a/]	**$281,100**

[a/] Based on an annual discount factor of 5 percent (USEPA, 1988).

See Appendix G for breakdown of costs and present worth analysis.

6.4.2 Alternative 2 - Intrinsic Remediation, Mobile LNAPL Recovery, Hydraulic Barrier, and Institutional Controls and Long-Term Groundwater Monitoring

6.4.2.1 Effectiveness

The effectiveness of Alternative 2 is enhanced relative to Alternative 1 by ensuring that dissolved JP-4 constituents will not cross the Dover AFB property boundary. This system will be effective at controlling offsite BTEX migration once a hydraulic barrier is created. This technology is not complicated with respect to design and operation and should provide a safe and efficient means to control offsite migration. Air stripping is a proven technology for removing volatiles from extracted groundwater. Properly designed systems can remove typical BTEX contaminants with efficiencies from 95 to greater than 99 percent. The treated water was assumed to be pumped to a local sanitary sewer system so that the risk of onsite contamination is reduced further. This alternative complies with the program goals because natural attenuation remains the predominant method to remediate the site.

6.4.2.2 Implementability

The equipment associated with this remedial option is relatively common within the environmental industry. Packaged treatment units can be purchased from vendors and installed relatively easily at the site. As part of the LTM plan, three sentry wells would be used to monitor the potential for dissolved BTEX contaminants to migrate to within 1-year travel time from the Base property boundary. In addition, three monitoring wells would be installed downgradient of the hydraulic barrier system to evaluate system effectiveness. These wells would be installed en lieu of the POC wells. Should dissolved JP-4 constituents be detected within these sentry wells, then the hydraulic barrier system would be designed and installed. Because the packaged treatment units are easy to implement, the 1-year travel time assumption is protective of the assumed POC boundary (property line).

Several permits may be required to implement this alternative. The pump-and-treat system is assumed to discharge the treated water to a local sanitary sewer. As a result, a pretreatment and discharge permit may be required. Also, an air emissions permit may be required, even though vapor-phase activated carbon is planned for the air stream. Typically, implementation of any corrective action plan will require approval from the local environmental agency.

6.4.2.3 Cost

The total present worth of this alternative is estimated at $727,300. Table 6.4 lists the costs for Alternative 2 based upon the implementation of the previously discussed remedial components. The cost differences between Alternative 2 and Alternative 1 are due solely to the design and implementation of the hydraulic barrier, which incorporates an additional pump-and-treat technology to protect the compliance boundary. For the purpose of cost comparison, this alternative assumes that the existing LNAPL recovery system would be operated for an additional 6 years. The hydraulic barrier system, institutional controls, and annual LTM would be implemented for 30 years.

6.4.3 Alternative 3 - Intrinsic Remediation with Bioslurping and Bioventing in Source Area, Oil/Water Separation, Off-gas Treatment, and Institutional Controls with Long-Term Groundwater Monitoring

6.4.3.1 Effectiveness

Two additional Bioplume II models (SR6 and SR8) were performed to evaluate the effectiveness of source reductions typically associated with selected remedial alternatives. Model SR8 simulates the effects of a combined bioslurping and bioventing system that reduces the source concentration at a rate of 12.5 percent of the original concentration every year for 8 years. Model results suggest that if bioslurping/bioventing is chosen as a source reduction alternative, the BTEX plume will be significantly reduced in size and concentration. Under

TABLE 6.4

ALTERNATIVE 2 - COST ESTIMATE
INTRINSIC REMEDIATION, LNAPL RECOVERY, HYDRAULIC BARRIER, AND INSTITUTIONAL CONTROLS AND LONG-TERM GROUNDWATER MONITORING
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

	Capital Costs ($)
Install 3 Sentry wells, 3 effectiveness wells and 1 LTM well	$17,055
Design/Install 6 Extraction Wells and Air Stripper	$109,161
Operation, Maintenance, and Monitoring Costs	**Annual Cost ($)**
Continued LNAPL Recovery and Reporting (6 years)	$11,025
Hydraulic Barrier System Operation (30 years)	$21,609
Annual Groundwater Monitoring of 5 LTM and 6 POC wells (30 years)	$3,704
Annual Reporting (30 years)	$3,910
Maintain Institutional Controls/Public Education (30 years)	$5,000
Project Management (30 years)	$1,625
Present Worth of Alternative 2 [a/]	**$727,300**

[a/] Based on an annual discount factor of 5 percent (USEPA, 1988).

See Appendix G for breakdown of costs and present worth analysis.

this scenario, model results show that it is unlikely that BTEX compounds would migrate more than 300 feet downgradient from the southwest property boundary. The maximum total BTEX concentration within the plume should be reduced to approximately 3,100 µg/L 13 years after initiation of source remediation (year 2008). Benzene concentrations are not expected to exceed 5 µg/L at the proposed POC well locations.

As discussed in Section 6.4.1, the effectiveness of this remedial alternative requires that excavations or drilling within the source area be conducted only by properly protected site workers. Reasonable land use assumptions for the plume area indicate that exposure is unlikely unless excavation or drilling activities bring contaminated soil to the surface. As with Alternative 1, long-term land and groundwater use restrictions will be required.

Alternative 3 will satisfy program objectives designed to promote intrinsic remediation as a component of site remediation and to scientifically document naturally occurring processes. This alternative relies on the bioslurping/bioventing system to remove mobile and residual LNAPL from Site SS27/XYZ within an 8-year period. Once BTEX loading rates are reduced, intrinsic remediation will then minimize contaminant migration and reduce contaminant mass in groundwater.

6.4.3.2 Implementability

Alternative 3 is not technically difficult to implement. Mobile LNAPL removal at Site SS27/XYZ would be conducted through bioslurping from wells in the area underlain by free product. The bioslurping system would consist of a series of wells connected by piping to a blower and placed under a vacuum to remove mobile LNAPL (and contaminated groundwater) from the wells. The recovered fluids would pass through an oil/water separator, where the petroleum product would be diverted to a storage tank. The contaminated water stream would be treated with an air stripper. From the air stripper, the off-gas stream could be treated using

vapor-phase activated carbon or an internal combustion engine. Once mobile LNAPL has been removed to the extent practicable, the bioslurping wells would be used as additional bioventing wells.

Bioventing would be conducted at the periphery of the LNAPL plume, in areas that are oxygen deficient. The bioventing system would consist of a series of air injection wells connected to a small blower by underground piping. This equipment is fairly common within the environmental industry.

6.4.3.3 Cost

The cost of Alternative 3 is summarized in Table 6.5. A more complete breakdown and present worth analysis of these costs are provided in Appendix G. Capital costs include the same construction of six new POC wells and one new LTM well as in Alternative 1. In addition, Alternative 3 includes costs for the 15 wells and 8 monitoring points for the combined bioslurping/bioventing system, a bioslurping blower, a bioventing blower, an oil/water separator, an internal combustion engine, and an air stripper. A bioventing pilot test also was included in this estimate because *in situ* respiration tests were not performed previously on site. For the purpose of cost comparison, the bioslurping/bioventing system is estimated to operate for 8 years. LTM would begin during the bioslurping/bioventing system installation and continue for a total of 24 years. The estimated total present worth of mobile LNAPL removal using bioslurping, the bioslurping/bioventing system, and implementation of the LTM plan is $566,400. Also included are the costs of maintaining institutional controls and annual groundwater monitoring for a total of 24 years.

TABLE 6.5

ALTERNATIVE 3 - COST ESTIMATE
INTRINSIC REMEDIATION WITH BIOSLURPING AND BIOVENTING IN SOURCE AREA, OIL/WATER SEPARATION, OFF-GAS TREATMENT, WITH INSTITUTIONAL CONTROLS AND LONG-TERM GROUNDWATER MONITORING
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

	Capital Costs ($)
Install 6 POC wells and 1 LTM well	$17,055
Design/Install Bioslurping/Bioventing System (15 wells, 8 monitoring points)	$214,265

Operation, Maintenance, and Monitoring Costs	Annual Cost ($)
Bioslurping/Bioventing Operations and Reporting (8 years)	$20,019
Annual Groundwater Monitoring of 5 LTM and 6 POC wells (24 years)	$3,7014
Annual Reporting (24 years)	$3,910
Maintain Institutional Controls/Public Education (24 years)	$5,000
Project Management (24 years)	$4,225
Present Worth of Alternative 3 [a/]	**$566,400**

[a/] Based on an annual discount factor of 5 percent (USEPA, 1988).

See Appendix G for breakdown of costs and present worth analysis.

6.4.4 Alternative 4 - Intrinsic Remediation with Combined Soil Vapor Extraction/Bioventing/Biosparging and LNAPL Recovery in Source Area, Off-gas Treatment with Internal Combustion Engine, and Institutional Controls with Long-Term Groundwater Monitoring

6.4.4.1 Effectiveness

An additional Bioplume II model (SR6) was performed to evaluate the effectiveness of source reduction associated with an SVE system in combination with bioventing, biosparging, and mobile LNAPL skimming. Model SR6 assumed source concentrations would be reduced at a rate of 16.7 percent of the original concentration every year for 6 years. Model results suggest that if SVE, bioventing, biosparging, and product skimming are chosen as the remedial alternative, the BTEX plume will be significantly reduced in size and concentration. Under this scenario, BTEX concentration reductions in this alternative occur slightly faster than with bioslurping and bioventing alone (Alternative 3). Model results suggest that it is unlikely that BTEX compounds would migrate more than 300 feet beyond the southwestern property boundary. The maximum dissolved BTEX concentration within the plume would be reduced to approximately 3,100 µg/L after 17 years of treatment. Benzene concentrations are not expected to exceed the state groundwater standard of 5 µg/L at the proposed POC well locations. The effectiveness of this remedial alternative requires the same land and groundwater use restrictions and institutional controls as discussed for Alternatives 1, 2, and 3.

Alternative 4 will satisfy program objectives designed to promote intrinsic remediation as a component of site remediation and to scientifically document naturally occurring processes. This alternative is based on the effectiveness of the combined SVE, bioventing, and biosparging system to reduce residual and dissolved BTEX concentrations at Site SS27/XYZ within a 6-year period. Product skimming would remove mobile LNAPL as a source of groundwater contamination. Once leaching rates are reduced, intrinsic remediation processes would then minimize contaminant migration and reduce contaminant mass in the groundwater.

6.4.4.2 Implementability

Alternative 4 is not technically difficult to implement. Mobile LNAPL skimming from wells that contain free product would be expanded to include 10 additional (new) wells. SVE/bioventing and biosparging technology is easy to implement. However, due to high BTEX concentrations in the soils, some form of off-gas treatment during SVE likely would be required. For the purposes of this cost estimate, Parsons ES assumed that an internal combustion engine would be used to treat the SVE emissions, and that air emission permits would be obtained from the State of Delaware. Components of an SVE, bioventing, and biosparging system are readily obtainable. The SVE system would likely operate for a period of time to maximize the removal of BTEX. Later, the SVE system could be converted to a bioventing system by reducing (and possibly reversing) air flow.

6.4.4.3 Cost

The cost of Alternative 4 is summarized in Table 6.6. A more complete breakdown and present worth analysis of these costs are provided in Appendix G. Costs to perform short-term pilot testing for the SVE, biosparging, and bioventing systems were included in this analysis. Capital costs are limited to the construction of six new POC wells, one new LTM well, 10 new skimming wells, 15 new SVE wells, and the combined SVE, bioventing, and biosparging system. As with Alternatives 1 and 2, mobile LNAPL skimming is proposed to continue for 6 years. The combined SVE, bioventing, and biosparging systems are assumed also to operate for 6 years. LTM will be initiated upon remedial system installation and continue for 24 years. The estimated total present worth of mobile LNAPL removal, the SVE, bioventing, and biosparging systems, and implementation of the LTM plan is $752,700. Also included are the costs of maintaining institutional controls for a total of 24 years.

TABLE 6.6

ALTERNATIVE 4 - COST ESTIMATE
INTRINSIC REMEDIATION WITH COMBINED SOIL VAPOR EXTRACTION/BIOVENTING/BIOSPARGING AND LNAPL RECOVERY IN SOURCE AREA, OFF-GAS TREATMENT WITH INTERNAL COMBUSTION ENGINE, AND INSTITUTIONAL CONTROLS AND LONG-TERM GROUNDWATER MONITORING
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

	Capital Costs ($)
Install 6 POC wells and 1 LTM well	$17,055
Design/Install 15-well/8-monitoring-point SVE/Bioventing/Biosparging System	$240,429
Design/Install 10-well LNAPL Recovery System	$108,867

Operation, Maintenance, and Monitoring Costs	Annual Cost ($)
LNAPL Recovery and Reporting (6 years)	$16,359
SVE/Bioventing/Biosparging Operation and Reporting (6 years)	$22,993
Annual Groundwater Monitoring of 5 LTM and 6 POC wells (24 years)	$3,704
Annual Reporting (24 years)	$3,910
Maintain Institutional Controls/Public Education (24 years)	$5,000
Project Management (24 years)	$4,225
Present Worth of Alternative 4 [a/]	**$752,700**

[a/] Based on an annual discount factor of 5 percent (USEPA, 1988).

See Appendix G for breakdown of costs and present worth analysis.

6.5 RECOMMENDED REMEDIAL APPROACH

Four remedial alternatives have been evaluated for remediation of the shallow groundwater at Site SS27/XYZ. Components of the evaluated alternatives include intrinsic remediation with LTM, mobile LNAPL recovery, bioslurping with oil/water separation, bioventing, biosparging, SVE with off-gas treatment by an internal combustion engine, and the implementation of a groundwater pump-and-treat hydraulic barrier, all in combination with institutional controls. Tables 6.2, 6.3, 6.4, 6.5, and 6.6 summarize the results of the alternatives evaluation based upon effectiveness, implementability, and cost criteria.

Based on this evaluation, the Air Force recommends Alternative 3 as achieving the best combination of risk reduction and cost effectiveness. In the event that pilot testing results suggest that bioslurping and bioventing alone can not remove mobile and residual LNAPL from the site within a suitable time frame, then SVE in combination with bioventing, biosparging, and mobile LNAPL skimming would be the preferred alternative (Alternative 4). A bioslurping pilot study was performed at Site SS27/XYZ under a separate AFCEE program during 1995. It is likely that natural attenuation with mobile LNAPL recovery alone (Alternative 1) may not accomplish the remedial objectives for the site, due to extensive mobile and residual LNAPL contamination at the site. Based on all the effectiveness criteria, Alternative 3 will make maximum use of intrinsic remediation mechanisms to reduce dissolved plume migration and toxicity while minimizing BTEX concentrations that might reach the POC by providing additional residual and mobile LNAPL reduction in the source area. Implementation of Alternative 3 will require land and groundwater use controls to be enforced for approximately 24 years after startup of the full-scale bioventing and bioslurping systems, along with annual groundwater monitoring for 24 years.

The final evaluation criterion used to compare each of the four remedial alternatives was cost. It is the opinion of the Air Force that the additional costs of Alternatives 2 and 4 over

Alternative 3 are not justified. Remediation time frames for Alternatives 3 and 4 are similar, and projected plume travel distances are very similar. Without further evaluation, the remediation time frame for Alternative 2 is at least 30 years. In the event that pilot studies indicate that bioslurping and bioventing will not remediate the mobile and residual LNAPL within a suitable time period, then Alternative 4 would be the preferred alternative.

SECTION 7

LONG-TERM MONITORING PLAN

7.1 OVERVIEW

In keeping with the requirements of the preferred remedial alternative for Site SS27/XYZ (bioslurping, bioventing, and intrinsic remediation with LTM), a long-term groundwater monitoring plan was developed. The purpose of this component of the preferred remedial alternative for the site is to assess conditions over time, confirm the effectiveness of bioslurping, bioventing, and naturally occurring processes at reducing contaminant mass and minimizing contaminant migration, and to evaluate the need for additional remediation.

The LTM plan consists of identifying the location of two separate groundwater monitoring networks and developing a groundwater sampling and analysis strategy. The LTM plan was devised to demonstrate attainment with both levels of site-specific remediation goals and to verify the predictions of the Bioplume II model developed for Site SS27/XYZ. The strategy described in this section is designed to monitor plume migration and concentrations over time, and to verify that intrinsic remediation is occurring at rates sufficient to protect potential receptors. In the event that data collected under this LTM program indicate that naturally occurring processes (in addition to bioslurping and bioventing) are insufficient to protect human health and the environment, contingency controls to augment the beneficial effects of intrinsic remediation would be necessary.

7.2 MONITORING NETWORKS

Two separate sets of wells will be installed at the site as part of the intrinsic remediation with LTM remedial alternative. The first set will consist of five LTM wells located within the observed BTEX plume to verify the results of the Bioplume II modeling effort and to ensure that natural attenuation is occurring at rates sufficient to minimize plume expansion (i.e., to meet the first level of RAOs for the site). These LTM wells will consist of existing and proposed wells screened within the shallow aquifer to provide short-term confirmation and verification of the quantitative groundwater modeling results. The second set of groundwater monitoring wells are POC wells that will be located downgradient from the source area in each of the three directions described in previous sections. The purpose of the POC wells is to verify that no BTEX compounds exceeding Delaware groundwater standards migrate to the area where groundwater may affect potential receptors (i.e., meet the second level of RAOs for the site). This POC well network will consist of six groundwater monitoring wells screened across the shallow aquifer: three monitoring wells in the primary (southwestern) direction of groundwater flow, one in the northwestern direction, and two in the northeastern direction. The LTM and POC wells will be sampled annually for analysis of the parameters listed in Tables 7.1 and 7.2, respectively.

7.2.1 Long-Term Monitoring Wells

Five groundwater wells and monitoring points within the existing BTEX contaminant plume will be used to monitor the effectiveness of intrinsic remediation in reducing total contaminant mass and minimizing contaminant migration at Site SS27/XYZ. One well in the downgradient portion of the existing plume in each of the three flow directions will be monitored. In addition, one new monitoring well and one monitoring point near the plume source area will be monitored.

TABLE 7.1

LONG-TERM MONITORING ANALYTICAL PROTOCOL
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Ferrous (Fe^{2+})	Colorimetric A3500-Fe D	Field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Annually	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Ferrous (Fe^{2+})	Colorimetric Hach 25140-25	Alternate method; field only	Elevated ferrous iron concentrations may be indicative of the anaerobic biodegradation process of iron reduction	Annually	Collect 100 mL of water in a glass container	Field
Temperature	E170.1	Field only	Metabolism rates for microorganisms depend on temperature	Annually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to Method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume II model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Annually	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods[a/]	Aerobic and anaerobic processes are pH-sensitive	Annually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same ground water system	Annually	Collect 100–250 mL of water in a glass or plastic container	Field
Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base

TABLE 7.1 (Concluded)

LONG-TERM MONITORING ANALYTICAL PROTOCOL
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Sulfate (SO_4^{-2})	IC method E300 or method SW9056 or Hach SulfaVer 4 method	Method E300 is a Handbook method; method SW9056 is an equivalent procedure. Hach method is Photometric	Substrate for anaerobic microbial respiration	Annually	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base or field (for Hach method)
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of ground water influences and is influenced by biologically mediated reactions; the redox potential of ground water may range from more than 200 mV to less than -400 mV	Annually	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Methane	RSKSOP-114 modified to analyze water samples for methane by headspace sampling with dual thermal conductivity and flame ionization detection.	Method published and used by the US Environmental Protection Agency National Risk Management Research Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis)	Annually	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps (zero headspace); cool to 4°C	Fixed-base
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

a/ Protocol methods are presented by Wiedemeier *et al.*, 1995

TABLE 7.2

POINT-OF COMPLIANCE MONITORING ANALYTICAL PROTOCOL
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

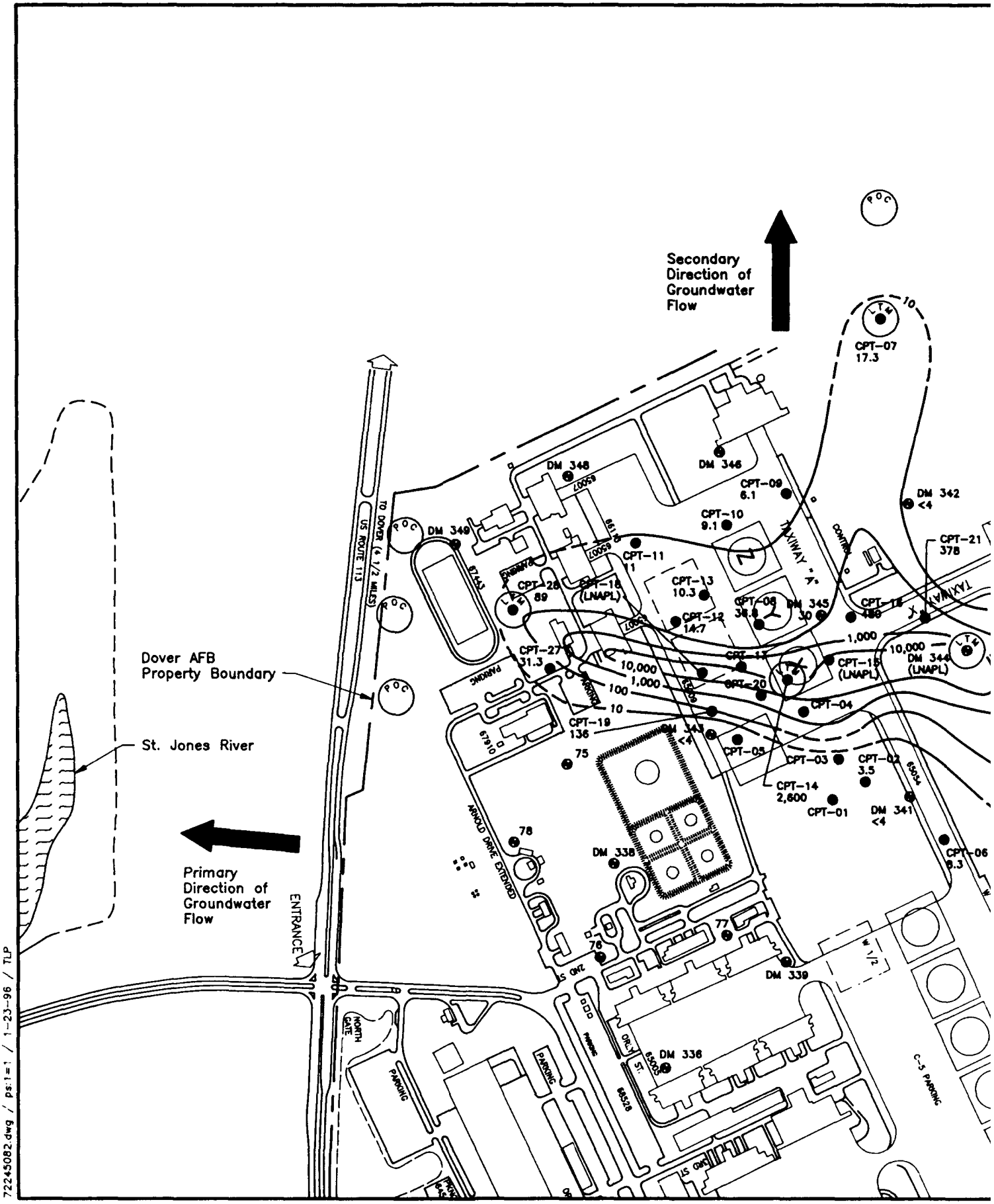
Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Temperature	E170.1	Field only	Well development	Annually	N/A	Field
Dissolved Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Annually	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen in situ	Field
pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods[a/]	Aerobic and anaerobic processes are pH-sensitive	Annually	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same ground water system	Annually	Collect 100–250 mL of water in a glass or plastic container	Field
Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of ground water influences and is influenced by biologically mediated reactions; the redox potential of ground water may range from more than 200 mV to less than -400 mV	Annually	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Aromatic hydrocarbons (BTEX)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkylbenzenes	BTEX is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance	Annually	Collect water samples in a 40 mL VOA vial with zero headspace; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

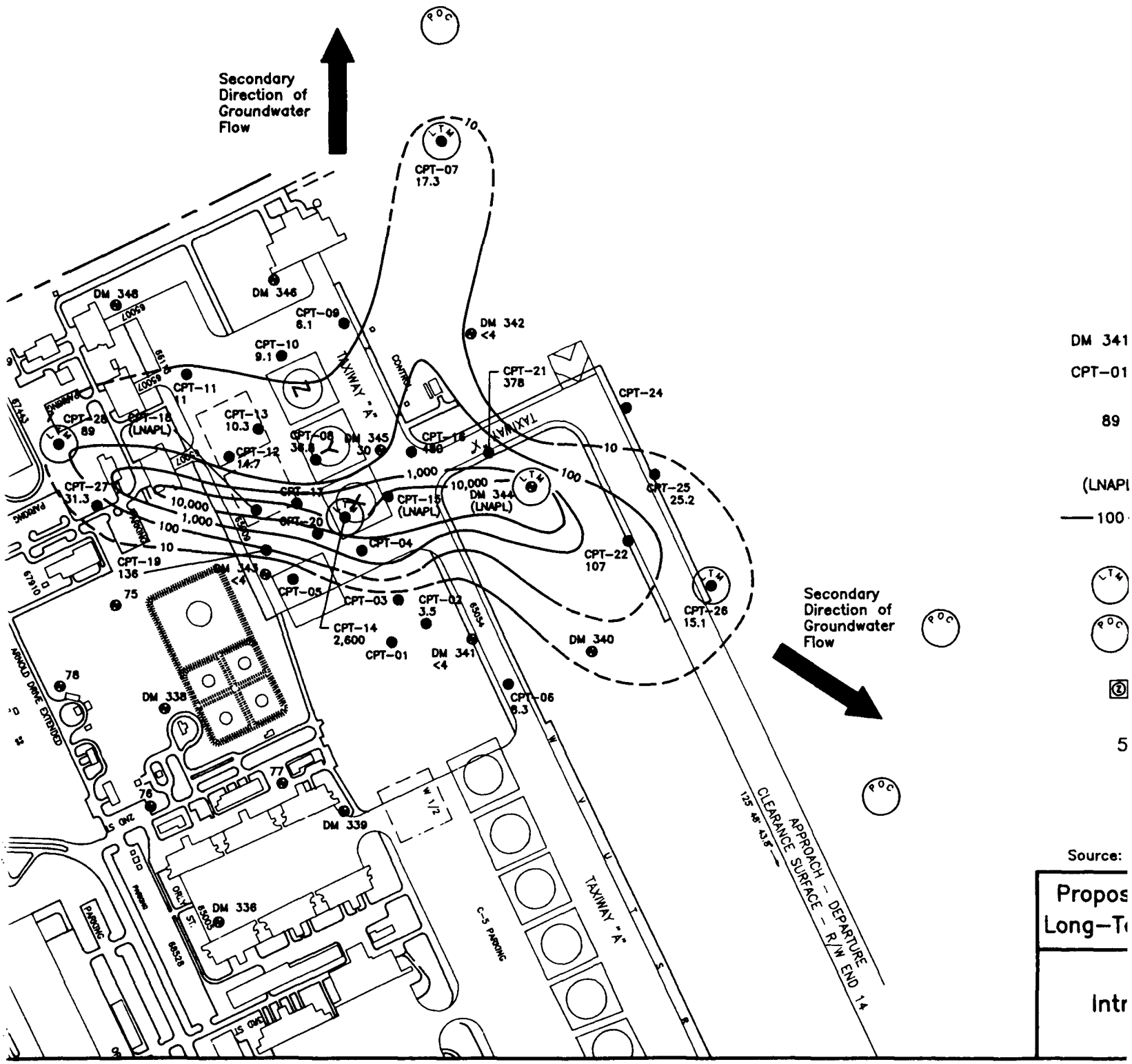
a/ Protocol methods are presented by Wiedemeier *et al.*, 1995

Existing wells and monitoring points will be utilized for LTM at four locations. Monitoring well DM 344S and monitoring point CPT-14S will be used to monitor conditions near the plume core. CPT-26S will be used to monitor conditions within the plume in the northeastern flow direction, and CPT-28S will be used to monitor conditions within the plume in the southwestern (primary) flow direction. One new LTM well should be installed within the plume in the northwestern flow direction. Figure 7.1 identifies the proposed locations of the new well and the existing wells or points to be used for LTM. This network will supplement the POC wells to provide early confirmation of model predictions and to allow additional response time if necessary. The new LTM well will be constructed with a 10-foot screen, with approximately 8 feet of the screen below the water table. All LTM wells will be sampled and analyzed for the parameters listed in Table 7.1 to verify the effectiveness of the intrinsic remediation remedial alternative.

7.2.2 Point-of-Compliance Wells

Three sets of POC monitoring wells should be installed downgradient of the source area in each groundwater flow direction. The first set of POC wells will be located approximately 2,000 feet downgradient from the source area in the primary (southwestern) direction of flow along the Dover AFB property boundary. One POC well will be located approximately 1,700 feet downgradient from the source area in the northwestern direction of flow (past the location of CPT-07, at the Dover AFB property boundary near the perimeter road). Two POC wells will be located approximately 2,000 feet downgradient from the source area in the northeastern direction of flow (past the location of CPT-26). Figure 7.1 shows the proposed locations of these POC wells. The purpose of the POC wells is to verify that contaminated groundwater that exceeds Delaware groundwater standards does not


Secondary Direction of Groundwater Flow
Dover AFB Property Boundary
St. Jones River
Primary Direction of Groundwater Flow
ENTRANCE
TO DOVER (6 1/2 MILES)
US ROUTE 113
ARNOLD DRIVE EXTENDED
NORTH GATE
PARKING
C-5 PARKING
CONTROL TOWER
RUNWAY
DM 348
DM 346
DM 349
DM 342 <4
DM 345 30
DM 344 (LNAPL)
DM 343 <4
DM 341 <4
DM 339
DM 338
DM 336
CPT-07 17.3
CPT-09 6.1
CPT-10 9.1
CPT-11 1
CPT-13 10.3
CPT-12 14.7
CPT-08 38.8
CPT-16 486
CPT-21 378
CPT-28 89
CPT-18 (LNAPL)
CPT-27 31.3
CPT-17
CPT-15 (LNAPL)
CPT-20
CPT-04
CPT-19 136
CPT-05
CPT-03
CPT-02 3.5
CPT-14 2,600
CPT-01
CPT-06 8.3
1,000
10,000
100
10
75
78
77
76
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DM 341

CPT-01

89

(LNAPL

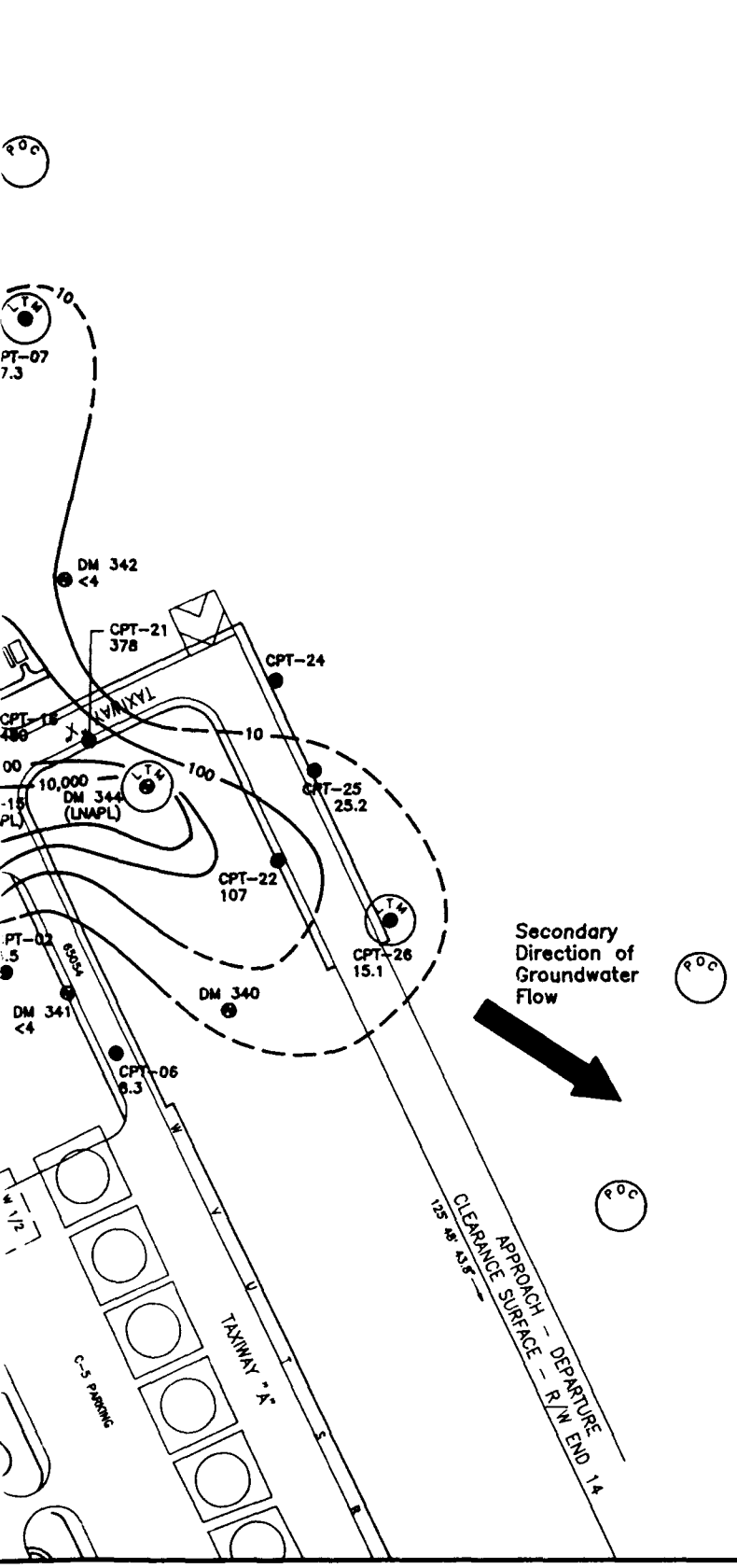
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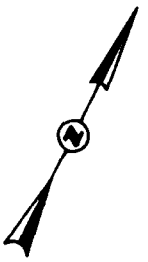
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Source:

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LEGEND

DM 341 ⊕	Monitoring well.
CPT–01 ●	Monitoring point and CPT test location installed by CPT rig.
89	Total benzene, toluene, ethylbenzene and xylene (BTEX) concentration (μg/L) by SW8020.
(LNAPL)	LNAPL present in sample.
—— 100 ——	Total BTEX concentration (μg/L) contour (April 1994), dashed where inferred.
LT4	Proposed long–term monitoring well.
POC	Proposed point–of–compliance monitoring well.
②	Former C–10 fueling pad.

500' 250' 0 500'

Approximate Scale in Feet

Source: USGS Little Creek, Delaware Quad, 1993

Proposed Point–of–Compliance and Long–Term Monitoring Well Placement

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

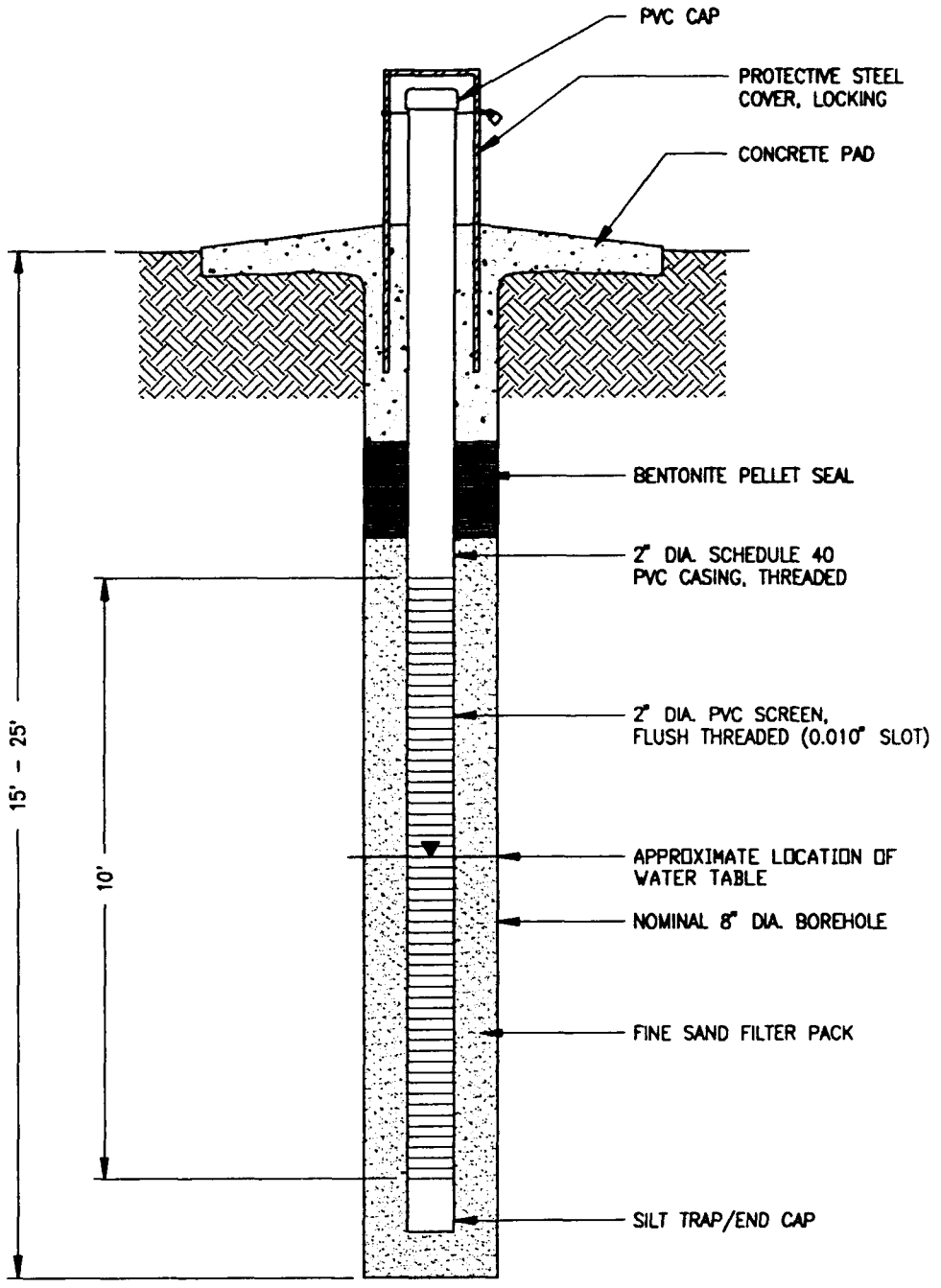
migrate beyond the area under institutional control. Although under Alternative 3 model results suggest that the contaminant plume will not migrate beyond these locations at concentrations exceeding regulatory standards, these POC wells are the technical mechanisms used to demonstrate protection of human health and the environment and compliance with site-specific numerical remediation goals. These POC wells will be installed and monitored for the parameters listed in Table 7.2 to assure that the selected remedy is providing the anticipated level of contaminant reduction and remediation at the site.

As with the LTM wells, the POC wells also will be screened in the same hydrogeologic unit as the contaminant plume. Data presented in this report concerning the nature and extent of contamination at the site suggest that a 10-foot screen with approximately 8 feet of screen below the groundwater surface will be sufficient to intercept the contaminant plume at this site. Figure 7.2 is a proposed groundwater monitoring well completion diagram for the LTM and POC wells.

7.3 GROUNDWATER SAMPLING

To ensure that sufficient contaminant removal is occurring at Site SS27/XYZ to protect human health and the environment and meet site-specific remediation goals, the long-term groundwater monitoring plan includes a comprehensive sampling and analysis plan. LTM and POC wells will be sampled and analyzed annually to verify that naturally occurring processes are effectively reducing contaminant mass and mobility. Reduction in toxicity will be implied by contaminant mass reduction. The sampling and analysis plan also will be aimed at assuring that intrinsic remediation can achieve site-specific remediation concentration goals for BTEX compounds and protect human health and the environment. It may be necessary to sample additional site media under this alternative (e.g., soil gas, exhaust emissions, treated water) in order

Figure 7.2



Proposed Monitoring Well Completion Diagram

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

Note: Drawing is not to scale.

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to operate and maintain the remedial system. Any additional sampling requirements will be specified in the operations and maintenance manuals developed for the installed systems.

7.3.1 Analytical Protocol

All LTM and POC wells in the LTM program will be sampled and analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of intrinsic remediation at the site. Water level measurements will be made during each sampling event. Groundwater samples will be analyzed for the parameters listed in Tables 7.1 and 7.2. A site-specific groundwater sampling and analysis plan should be prepared prior to initiating the LTM program.

7.3.2 Sampling Frequency

Assuming remedial Alternative 3 is implemented, each of the LTM and POC sampling points will be sampled once each year for 24 years. If the data collected during this time period supports the anticipated effectiveness of the intrinsic remediation alternative at this site, the sampling frequency can be reduced to once every other year for all wells in the LTM program. If the data collected at any time during the monitoring period indicate the need for additional remedial activities at the site, sampling frequency should be adjusted accordingly. The groundwater samples should be analyzed for BTEX compounds by USEPA Method SW8020. If BTEX concentrations in groundwater from the POC wells exceed the Delaware groundwater standards of 5 µg/L for benzene, 1,000 µg/L for toluene, 700 µg/L for ethylbenzene, or 10,000 µg/L for total xylenes, additional corrective actions may be required to remediate groundwater and source material at the site.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of an assessment conducted to evaluate the use of intrinsic remediation (natural attenuation) for remediation of fuel-hydrocarbon-contaminated groundwater at Site SS27/XYZ, Dover AFB, Delaware. Specifically, the finite-difference numerical groundwater model Bioplume II was used in conjunction with site-specific geologic, hydrologic, and laboratory analytical data to simulate the migration and biodegradation of fuel hydrocarbon compounds dissolved in groundwater. Supplemental analytical models also were run to validate the numerical model results. Groundwater contaminant and geochemical data strongly suggest that aerobic biodegradation of fuel hydrocarbons is occurring at the site. In addition, the data also suggest that anaerobic biodegradation is occurring via sulfate reduction, denitrification, and iron reduction.

To collect the data necessary for the intrinsic remediation demonstration, Parsons ES collected and analyzed soil and groundwater samples from the site. Physical and chemical data collected under this program were supplemented with data collected during previous site characterization events. Site-specific geologic, hydrologic, and laboratory analytical data were then used in the Bioplume II numerical groundwater model to simulate the effects of advection, dispersion, sorption, and biodegradation on the fate and transport of the dissolved BTEX plume. Extensive site-specific data were used for model implementation. Model parameters that could not be obtained from existing site data were estimated using widely accepted literature values for sediments similar to those found at the site. Conservative aquifer parameters were used to

construct the Bioplume II model for this study. Therefore, the model results presented herein represent conservative scenarios.

For one simulation (model CAL), it was assumed that BTEX compounds will continue to enter the aquifer at a constant rate. That rate was the same loading rate used to produce the initial calibrated model. Therefore, the results presented for model CAL represent a worst-case scenario, in which the BTEX plume equilibrates after 25 to 30 years, with the leading edge of the plume stabilizing approximately 400 feet beyond the southwestern property boundary located downgradient from CPT-28. In a second simulation (model SR8), it was assumed that BTEX loading rates were decreased at a constant rate by a combined bioslurping and bioventing system over an 8-year period. A third simulation (model SR6) assumed that BTEX loading rates were decreased at a constant rate over a 6-year period by utilizing a combination of components: a SVE system utilizing an internal combustion engine, a mobile LNAPL skimming system, and a bioventing/biosparging system. These time periods were considered practical limits for currently available remedial technologies due to the current LNAPL distribution, presence of clay and silt lenses below the site, and restricted site access due to the ongoing C-5 aircraft training and maintenance operations.

Models SR8 and SR6 had similar results. Both models predicted that the dissolved JP-4 constituents will cross the property boundary within approximately 7 years (year 2002), regardless of the source removal scenarios. However, BTEX concentrations are not predicted to exceed state groundwater standards in any off-Base extensions of the plume. After an additional 7 years time (year 2009) the models suggest that the plume will recede back onto Dover AFB property and continue to biodegrade. After 25 years (year 2020), the models suggest that the dissolved constituents will completely degrade via natural attenuation in combination with source

removal. This occurs because replenished electron acceptor concentrations eventually exceed the dissolved BTEX concentrations introduced into the aquifer by a ratio greater than 3.1:1.

Actual dissolved BTEX degradation rates observed during LTM at the site will probably be greater than predicted by model CAL and possibly less than those predicted by model SR8 or model SR6. This will result in faster removal rates of the BTEX compounds and a shorter plume migration distance than predicted by model CAL. In addition, source reduction using a combined bioslurping/bioventing system should recover mobile LNAPL and enhance diffusion of oxygen into groundwater across the soil gas-water interface. Increased diffusion causes increased groundwater reaeration, which further enhances biodegradation of dissolved petroleum hydrocarbons (Barr, 1993).

The results of this study suggest that natural attenuation of BTEX compounds is occurring at Site SS27/XYZ to the extent that the dissolved concentrations of these compounds in groundwater should be reduced to levels below current regulatory guidelines long before potential downgradient receptors could be adversely affected (i.e., the potential contaminant migration pathway will not be complete for any of the potential receptors described in Section 6.2). Based on the distance to the most likely downgradient receptor exposure point (approximately 3,800 feet to the St. Jones River), rates of BTEX plume migration and degradation predicted by model SR8, and the cost effectiveness of Alternative 3 as compared to the other remedial alternatives, the Air Force proposes to implement a combined bioslurping and bioventing system coupled with continued mobile LNAPL skimming, natural attenuation, institutional controls, and LTM as the remedial option for Site SS27/XYZ. To accomplish this recommendation, and groundwater use in and downgradient from the source area

should be restricted for a period of approximately 24 years or until groundwater contaminant concentrations decrease below Delaware groundwater standards. In the event that construction activities are necessary in this area, proper health and safety protocols and personal protective equipment must be utilized. Groundwater samples will be collected during LTM to monitor plume migration, allowing continual reevaluation of this time frame.

To verify the results of the Bioplume II modeling effort, and to ensure that natural attenuation is occurring at rates sufficient to protect potential downgradient receptors, groundwater from one existing monitoring well (DM 344S) and three existing monitoring points (CPT-14S, CPT-26S, and CPT-28S), one additional proposed LTM well, and six proposed POC wells should be sampled annually and analyzed for the parameters listed in Tables 7.1 and 7.2. This well distribution, as shown on Figure 7.1, affords long-term monitoring and protection for the migration pathways observed during the April 1994 sampling event. If dissolved BTEX concentrations in the POC wells are found to exceed the Delaware groundwater standards (and federal MCLs) of 5 µg/L for benzene, 1,000 µg/L for toluene, 700 µg/L for ethylbenzene, or 10,000 µg/L for total xylenes, additional evaluation or corrective action may be necessary at this site.

SECTION 9

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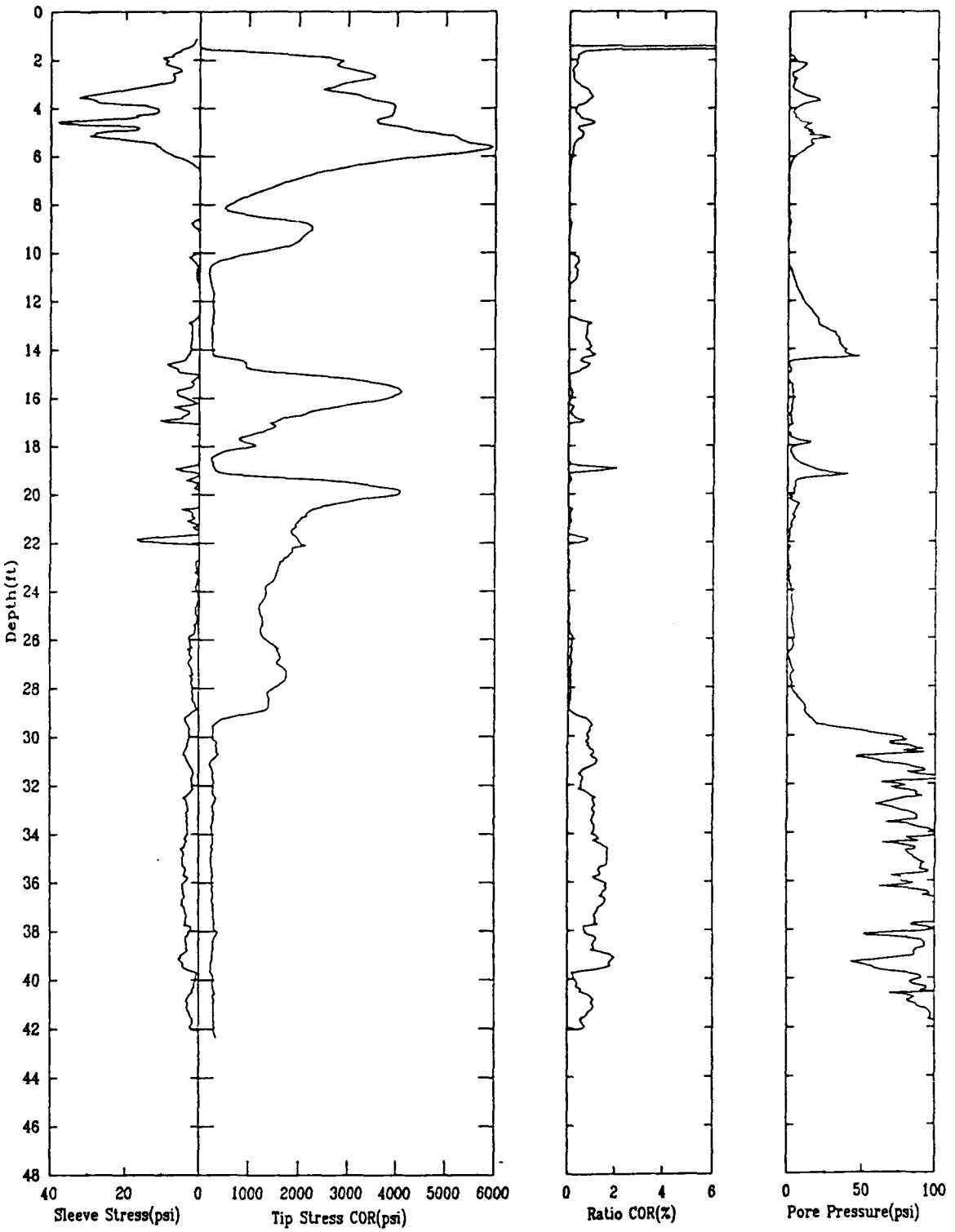
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APPENDIX A

BORING LOGS, WELL COMPLETION DIAGRAMS, AND SLUG TEST RESULTS

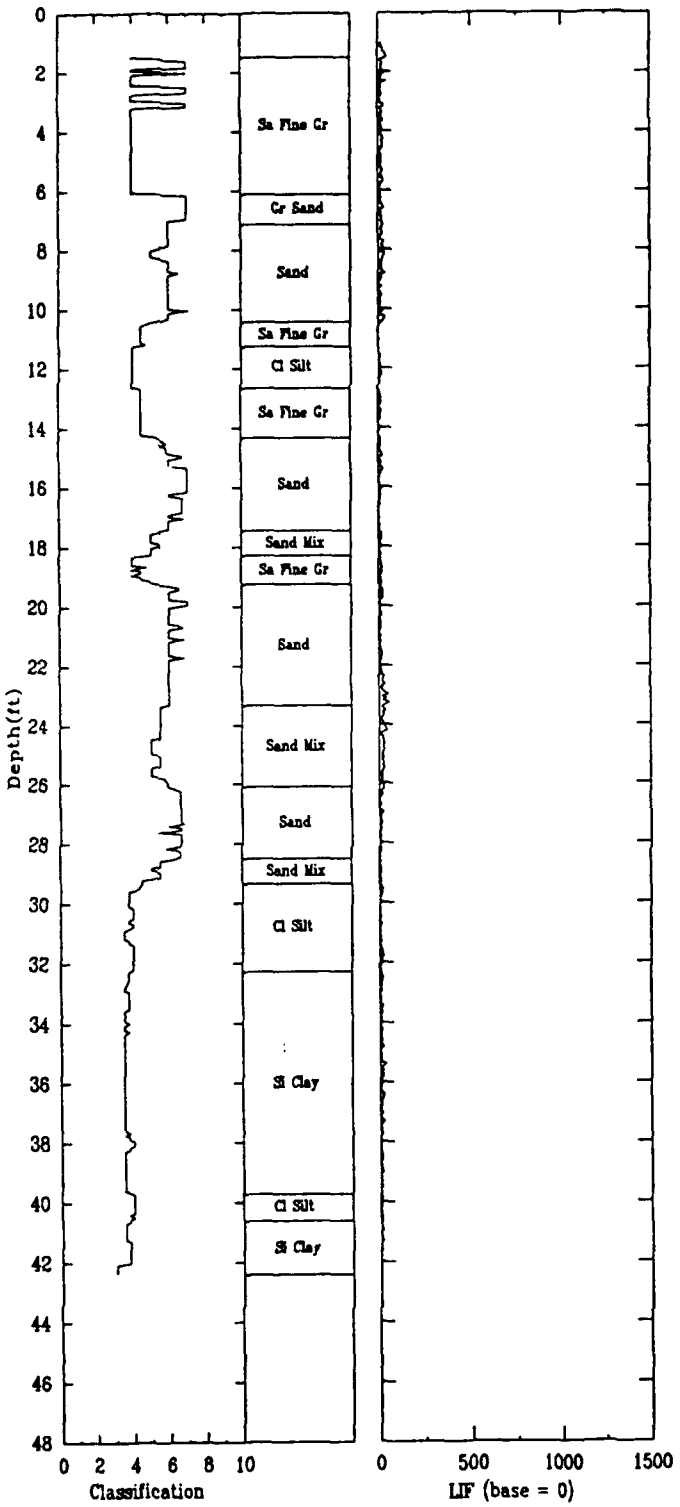
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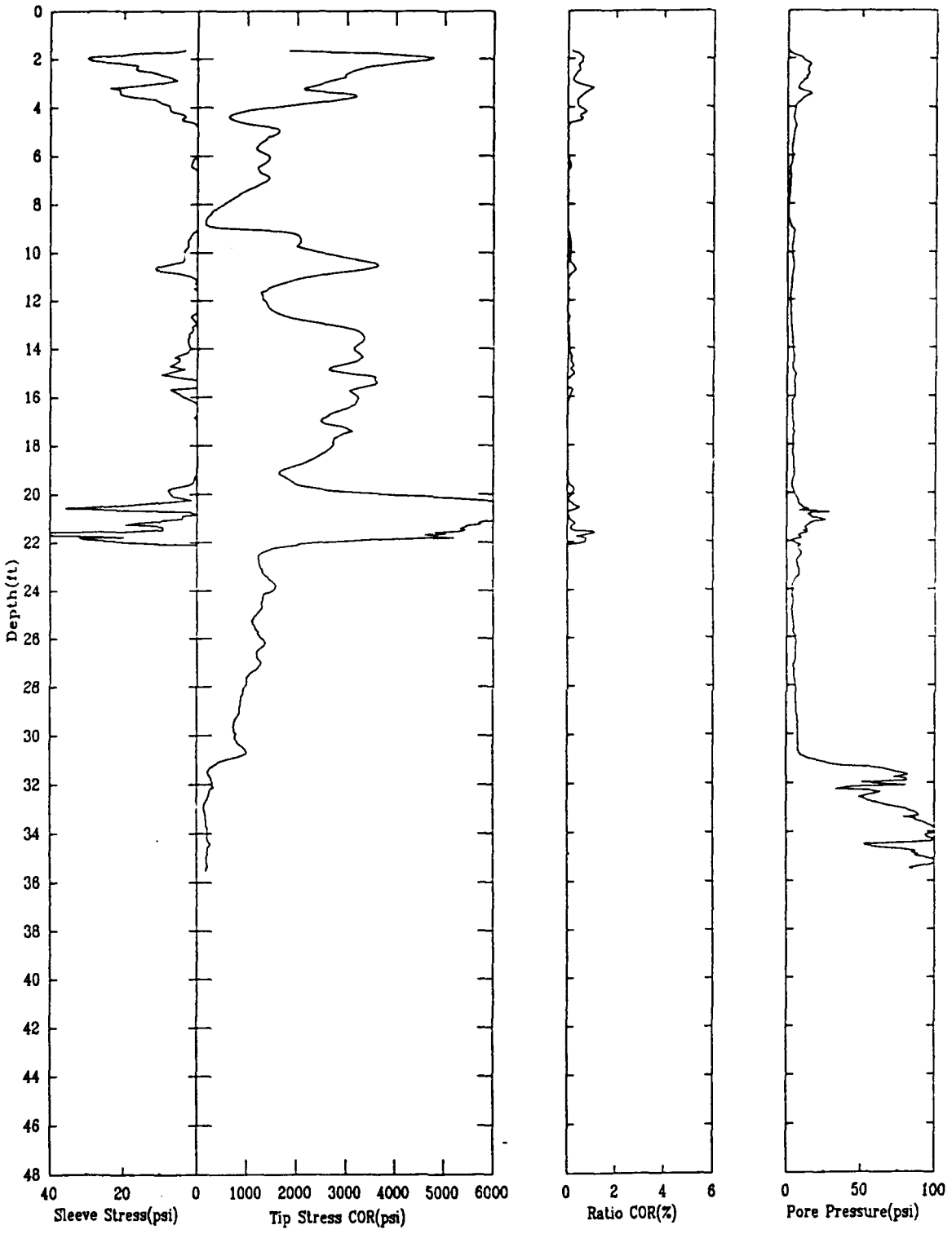
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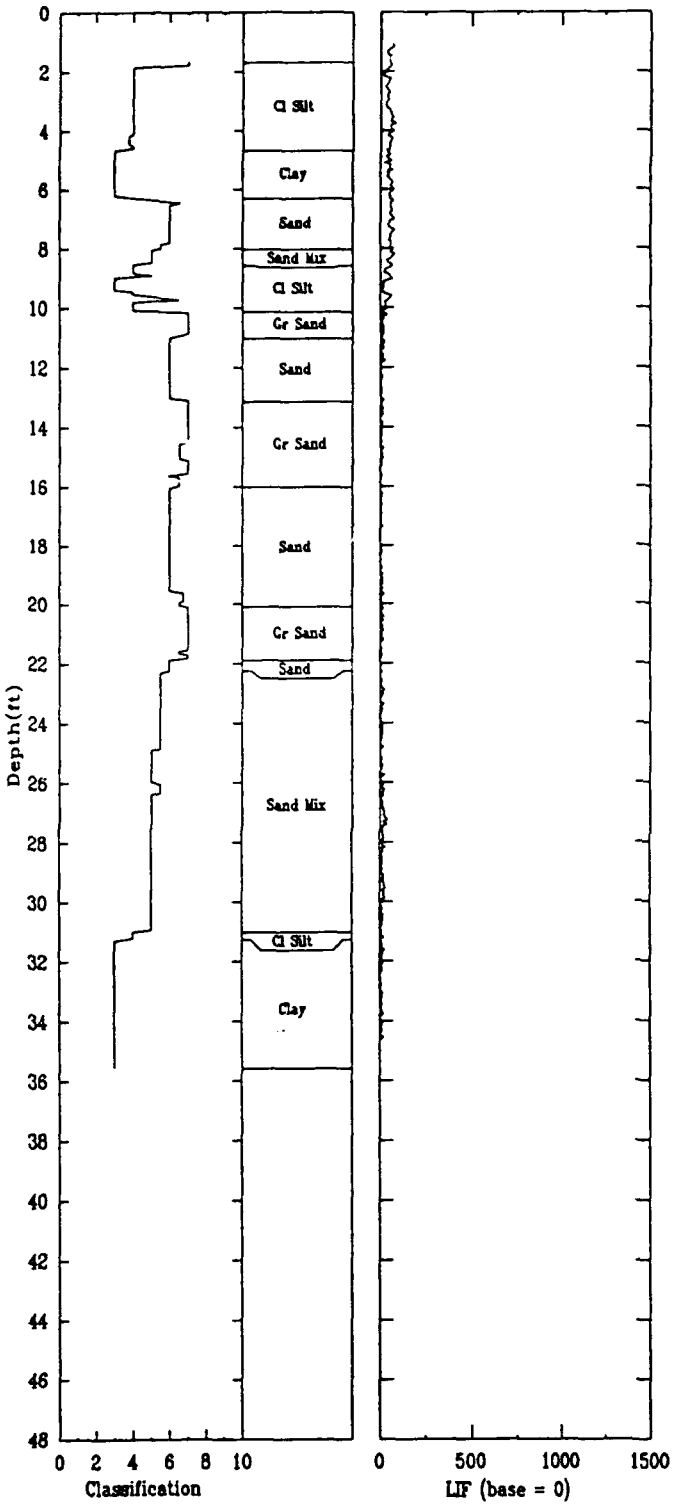
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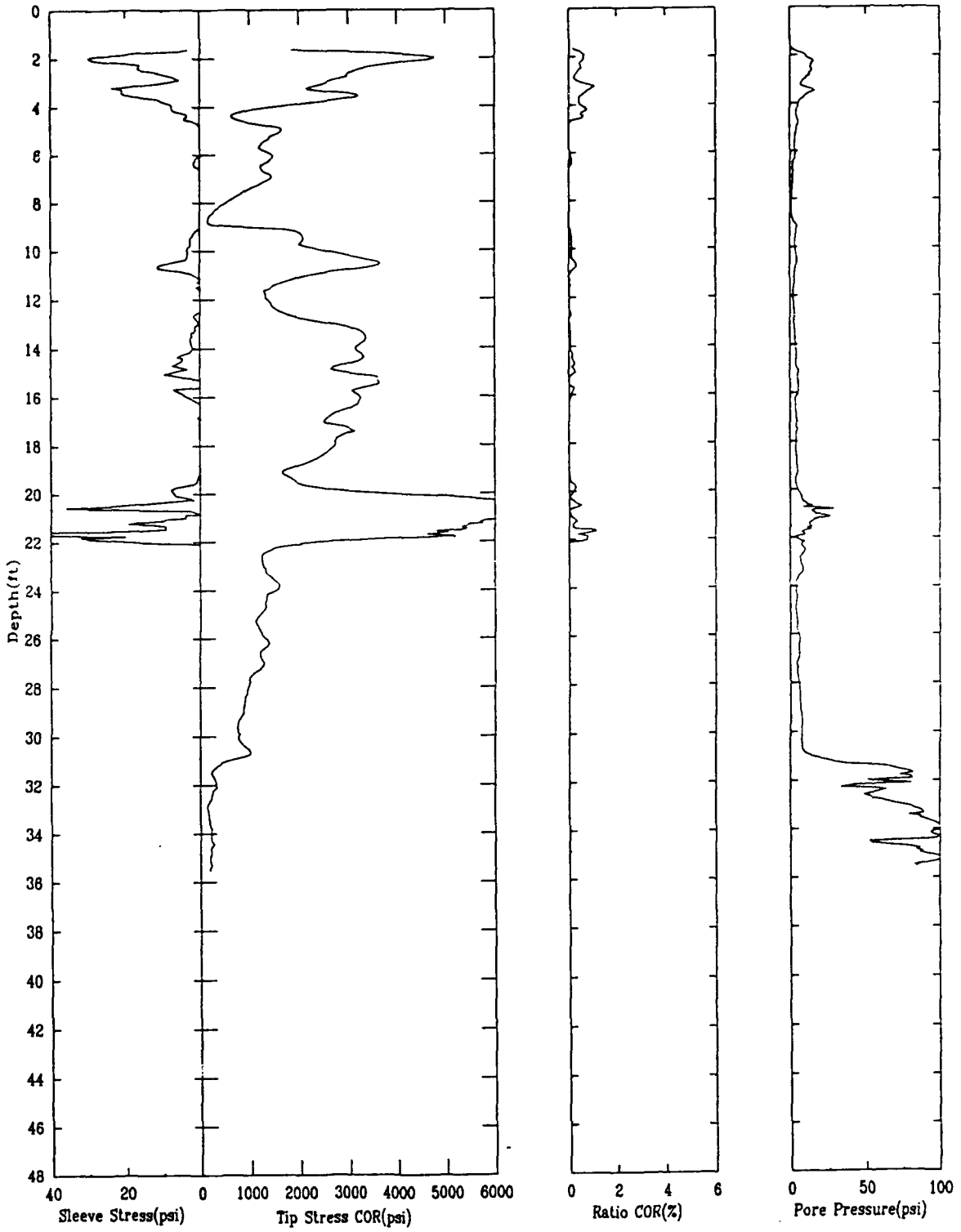
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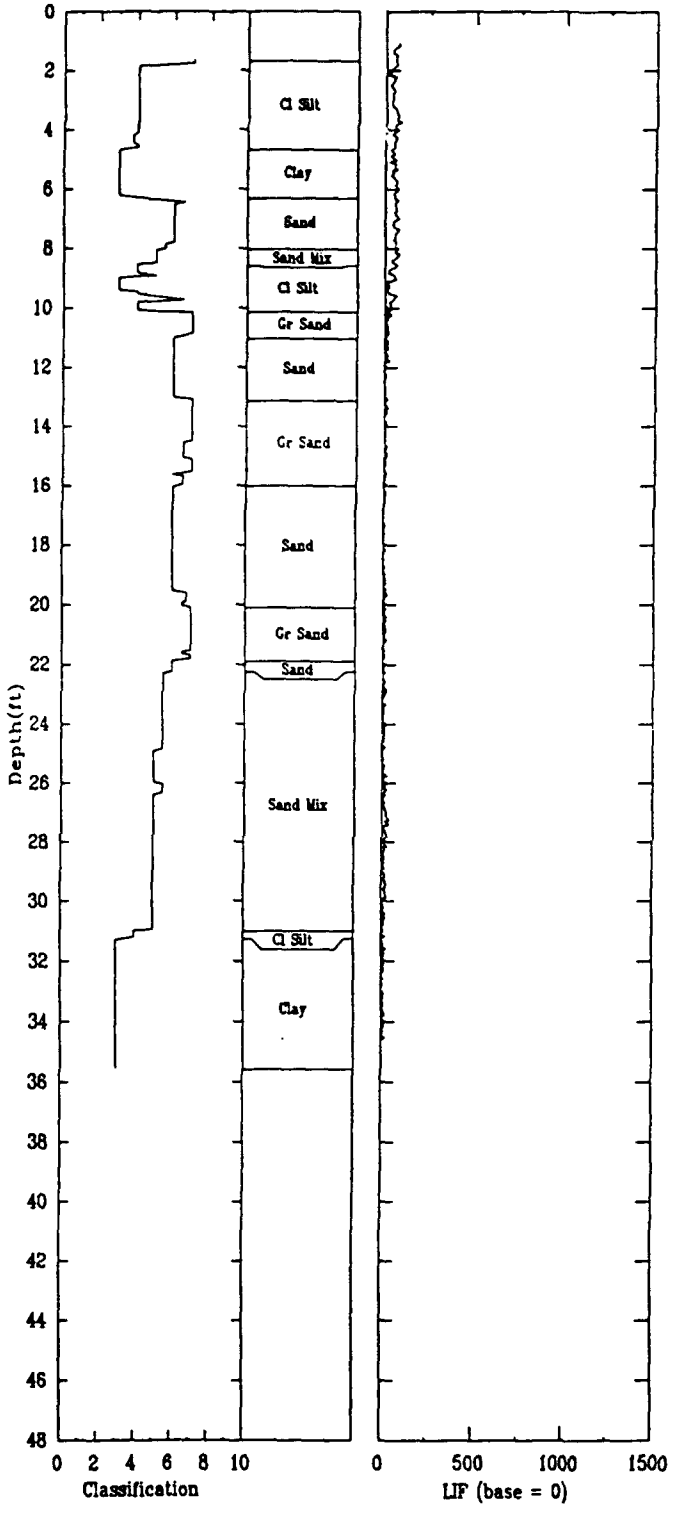
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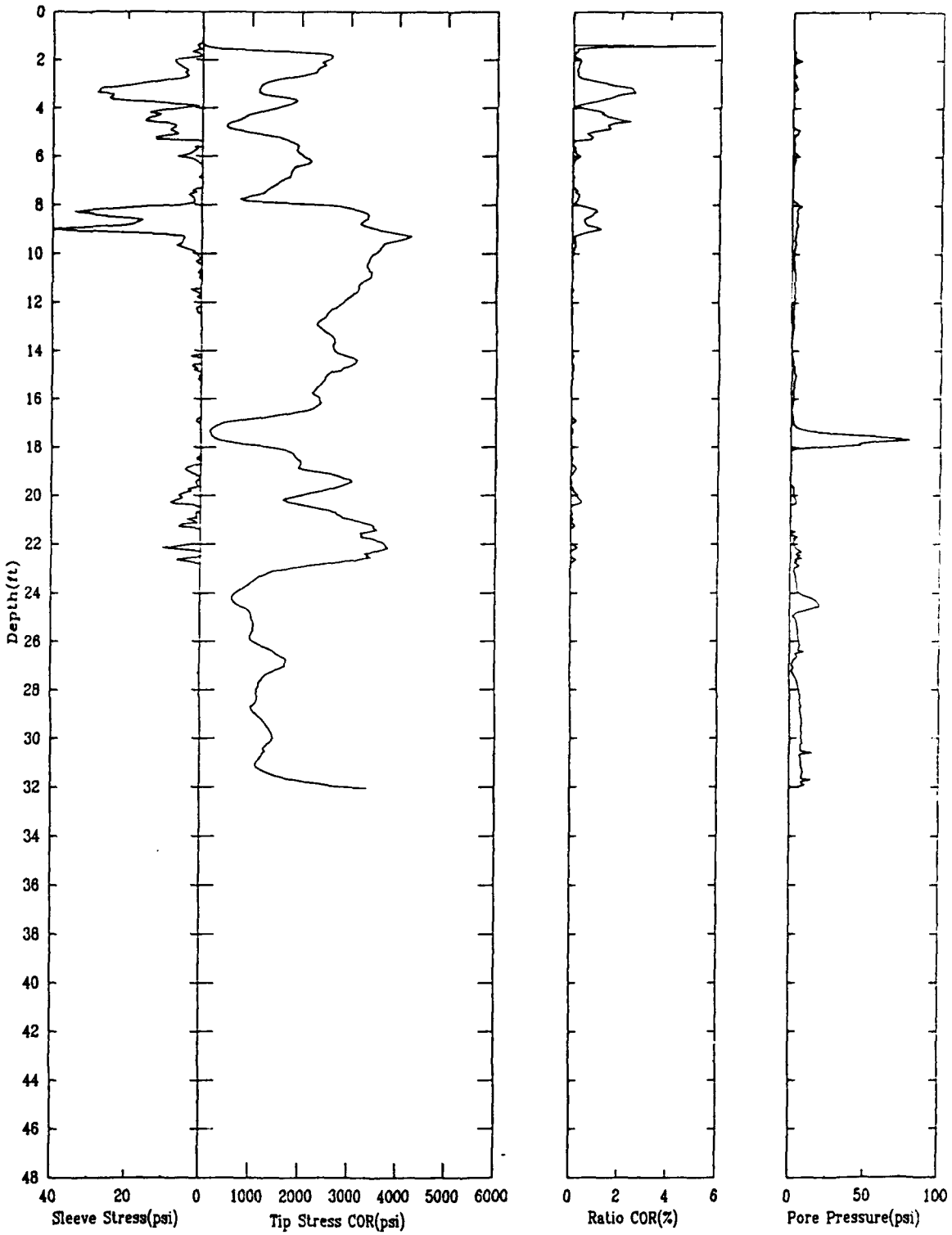
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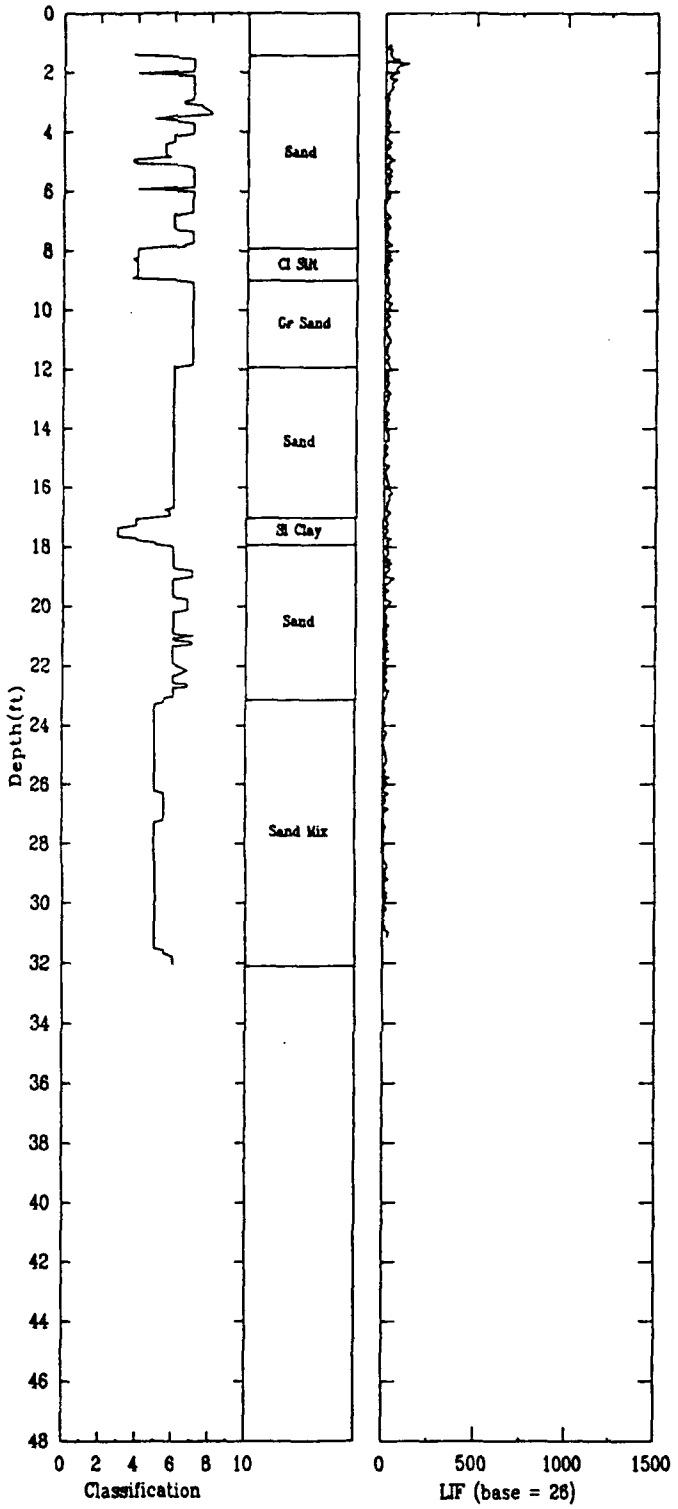
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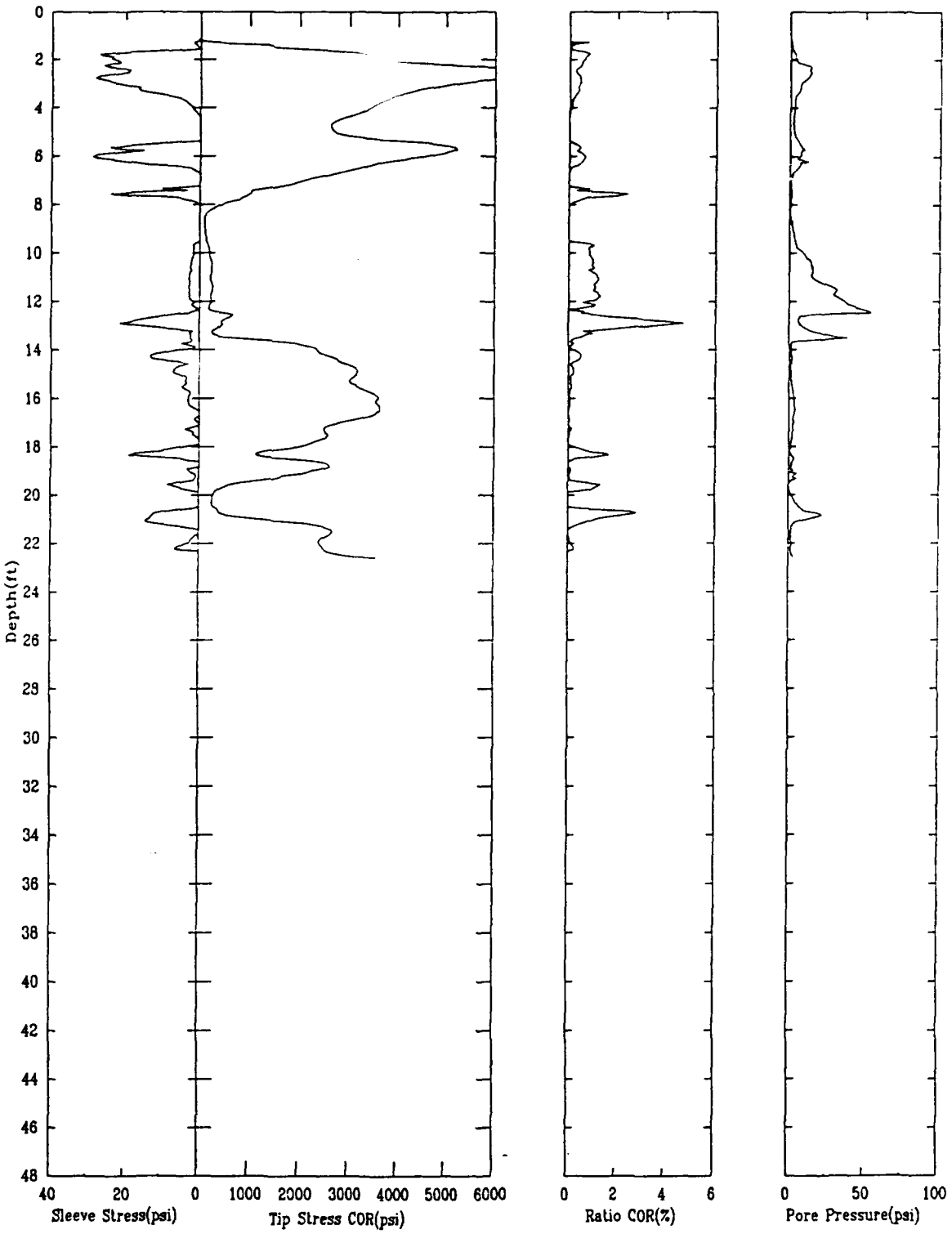
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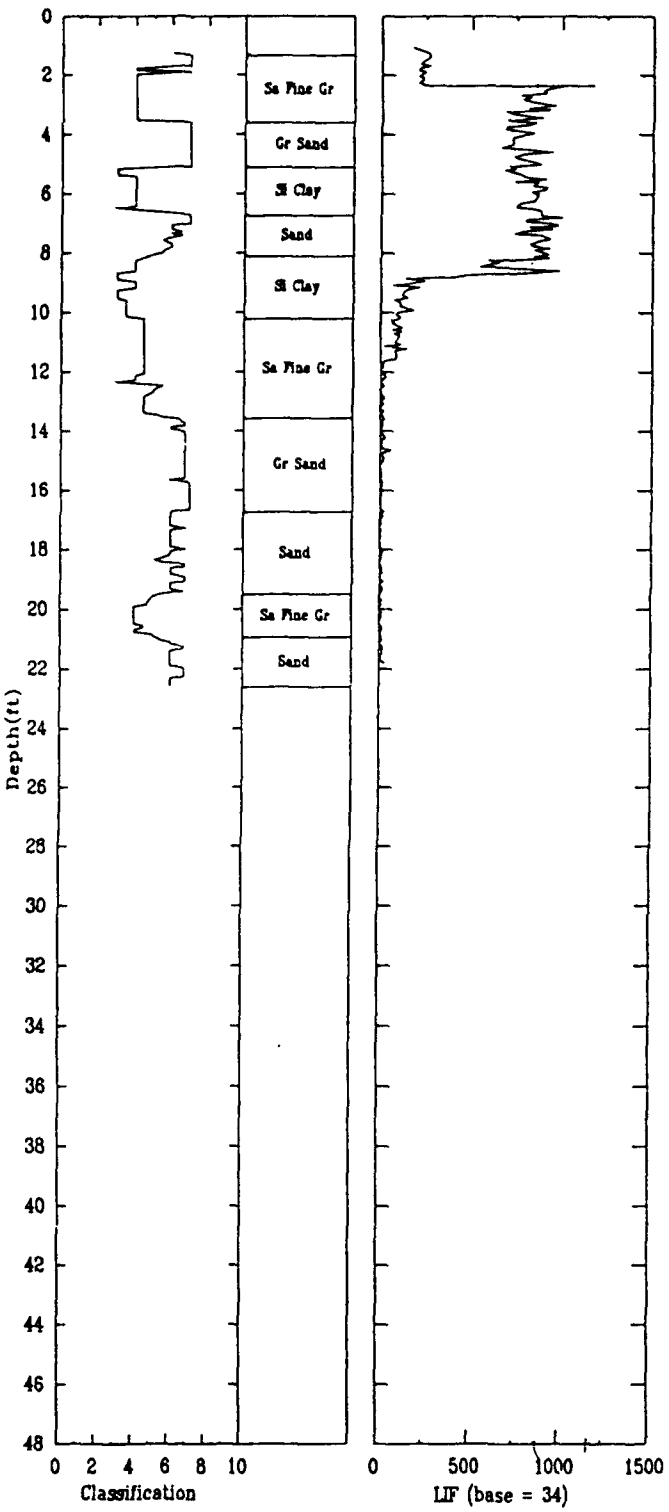
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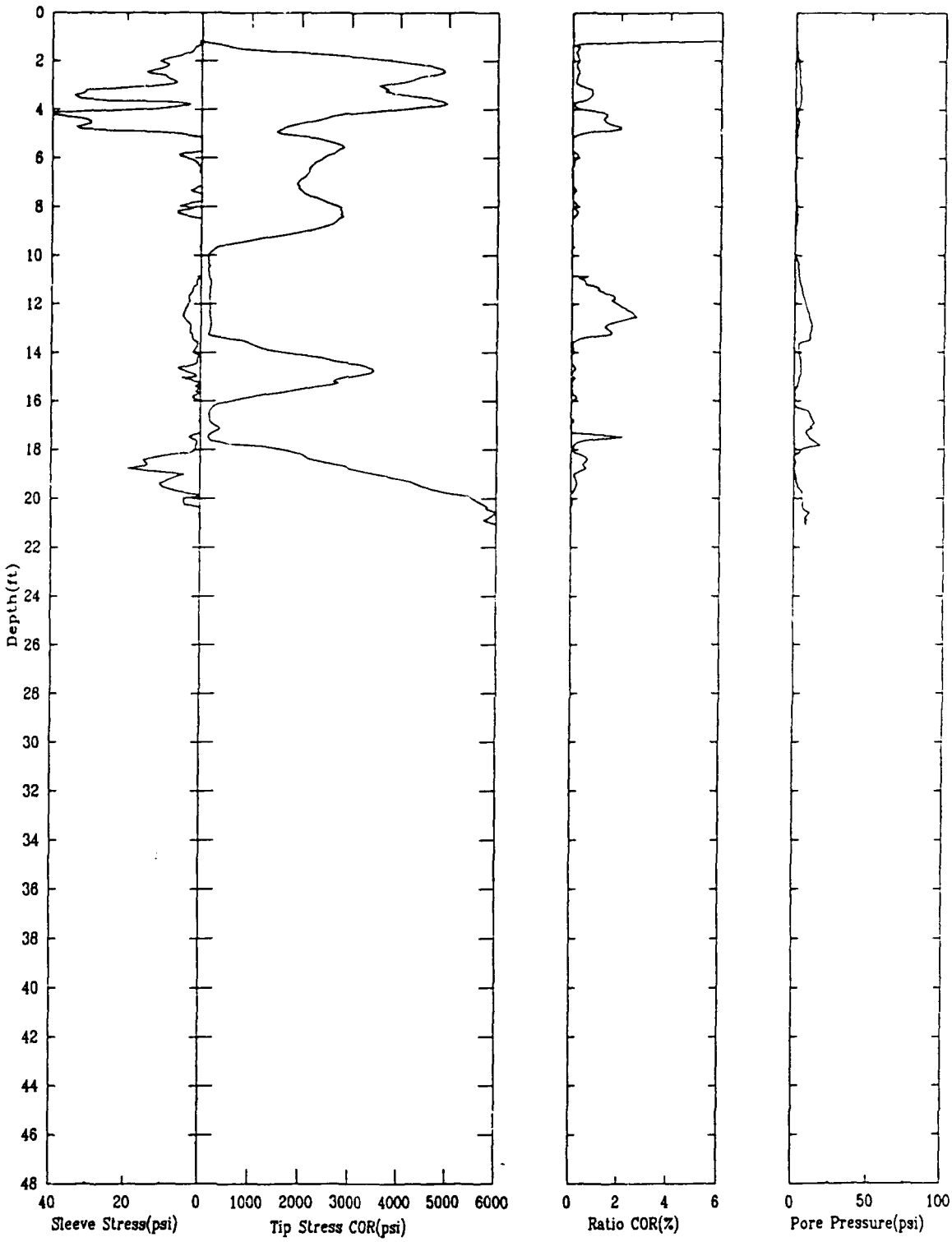
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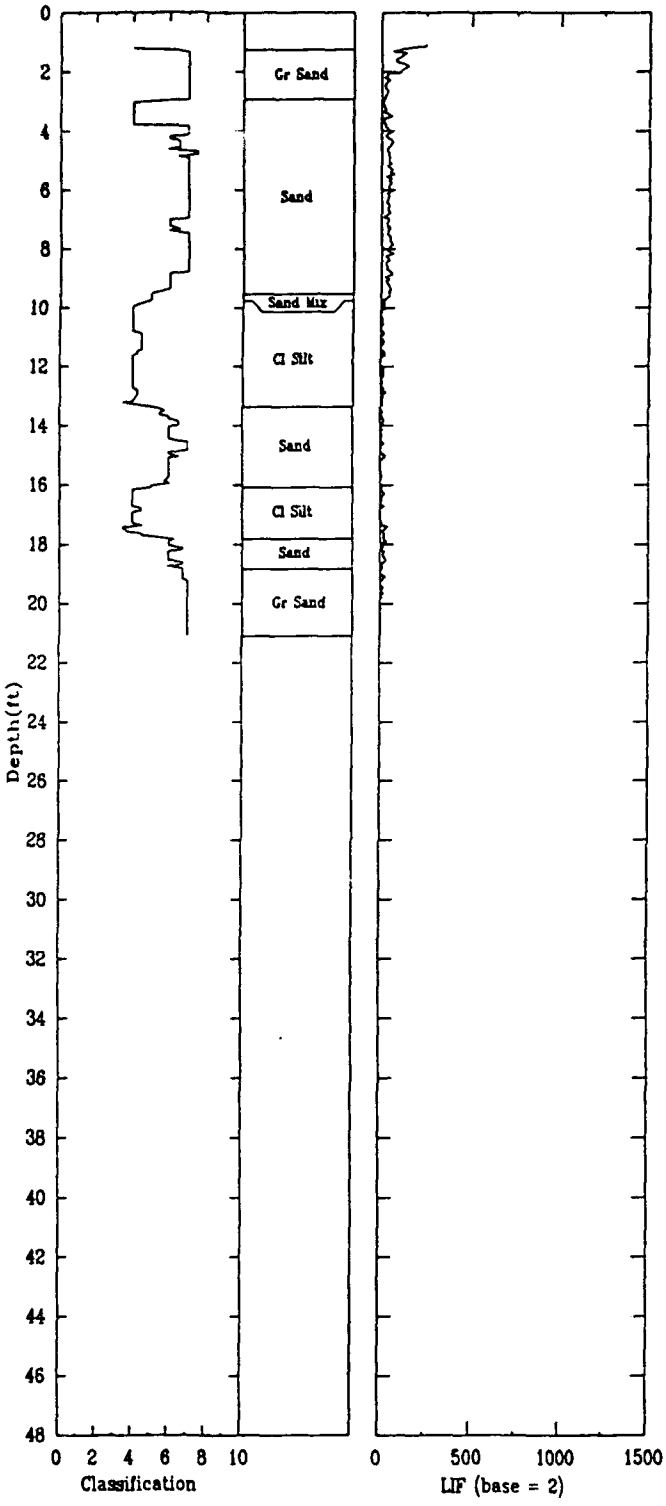
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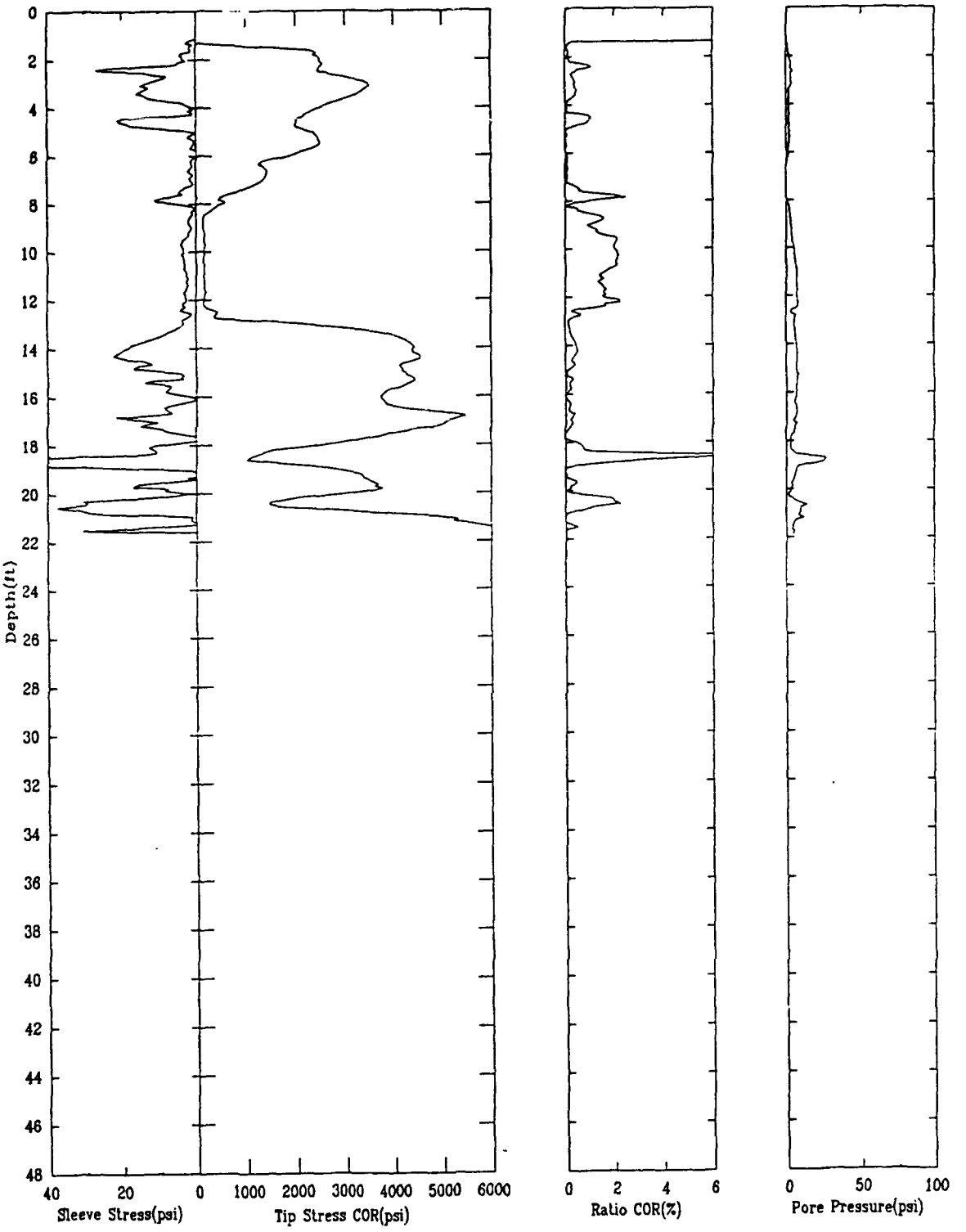
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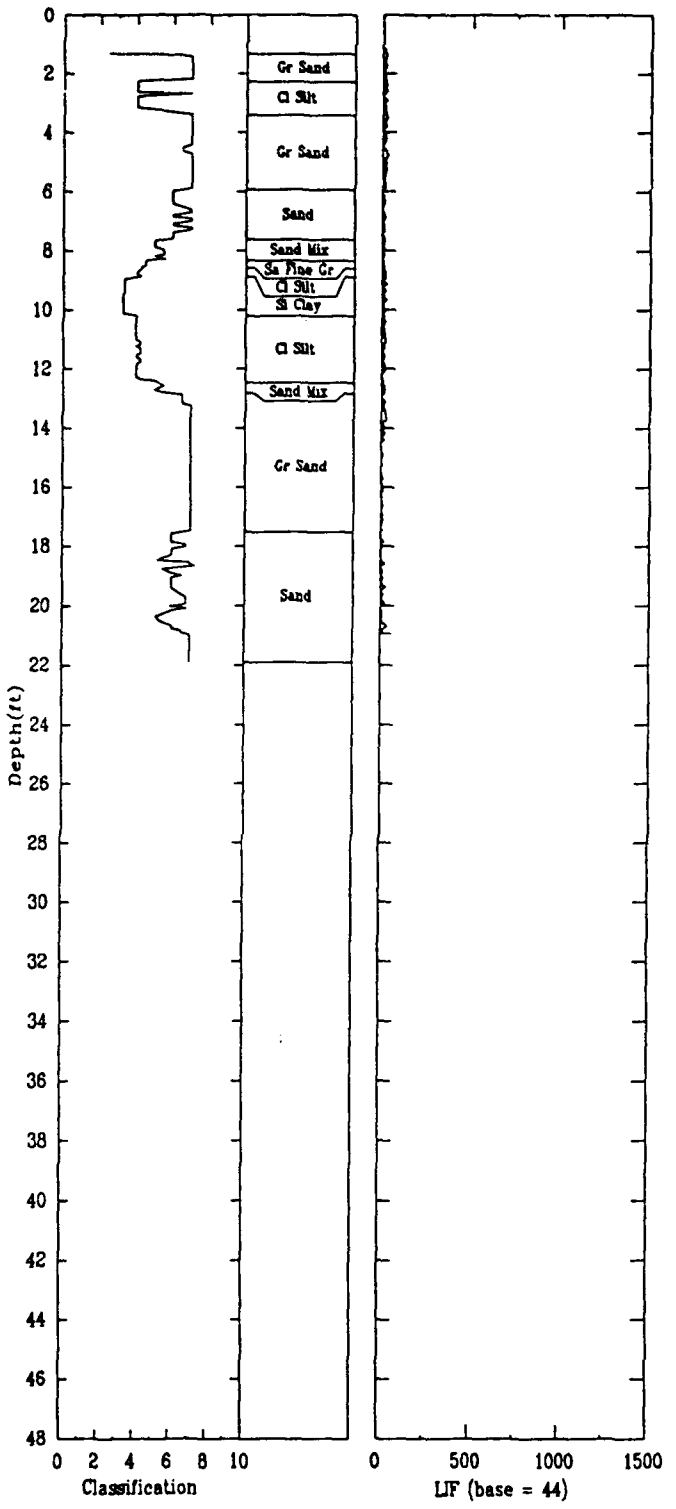
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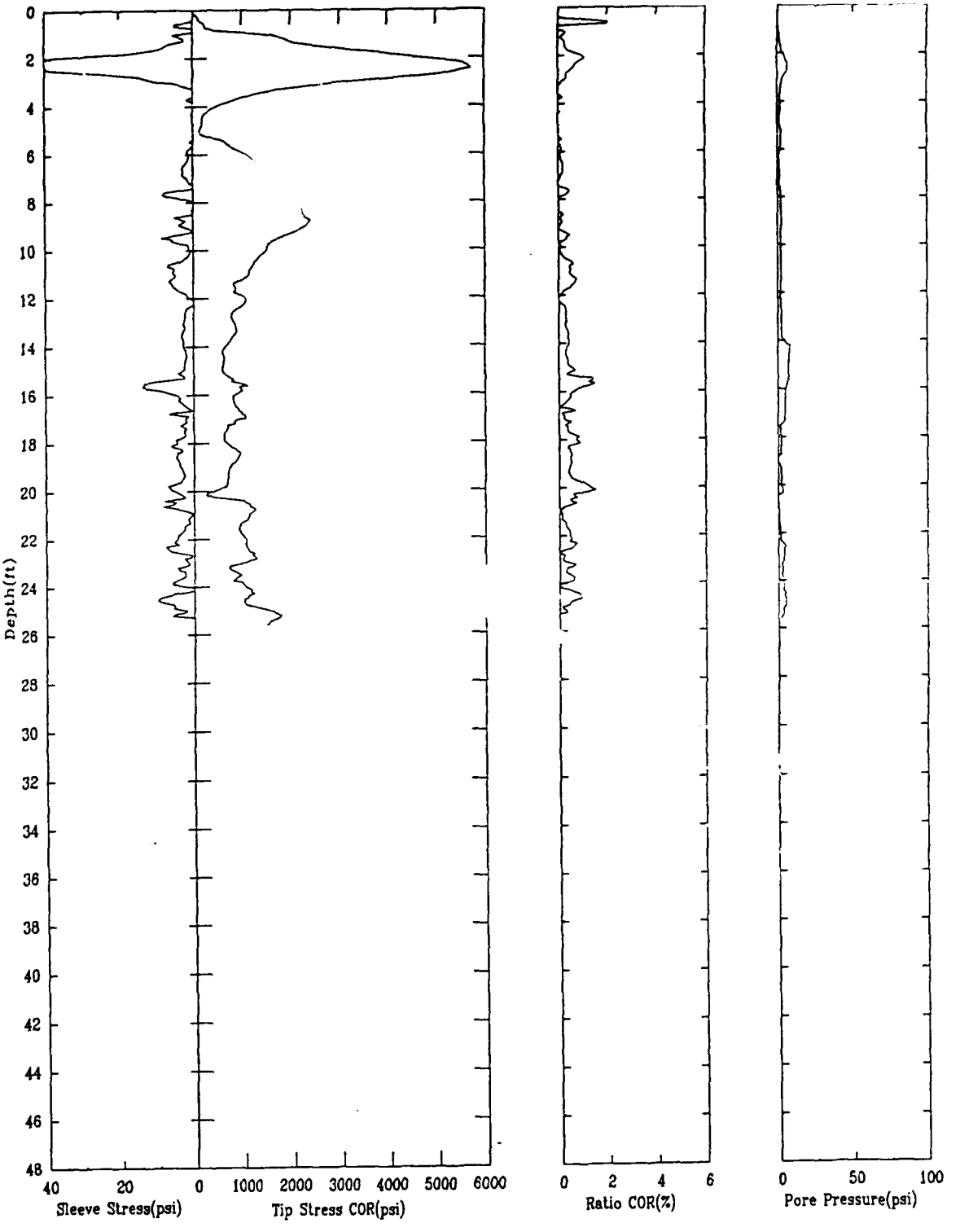
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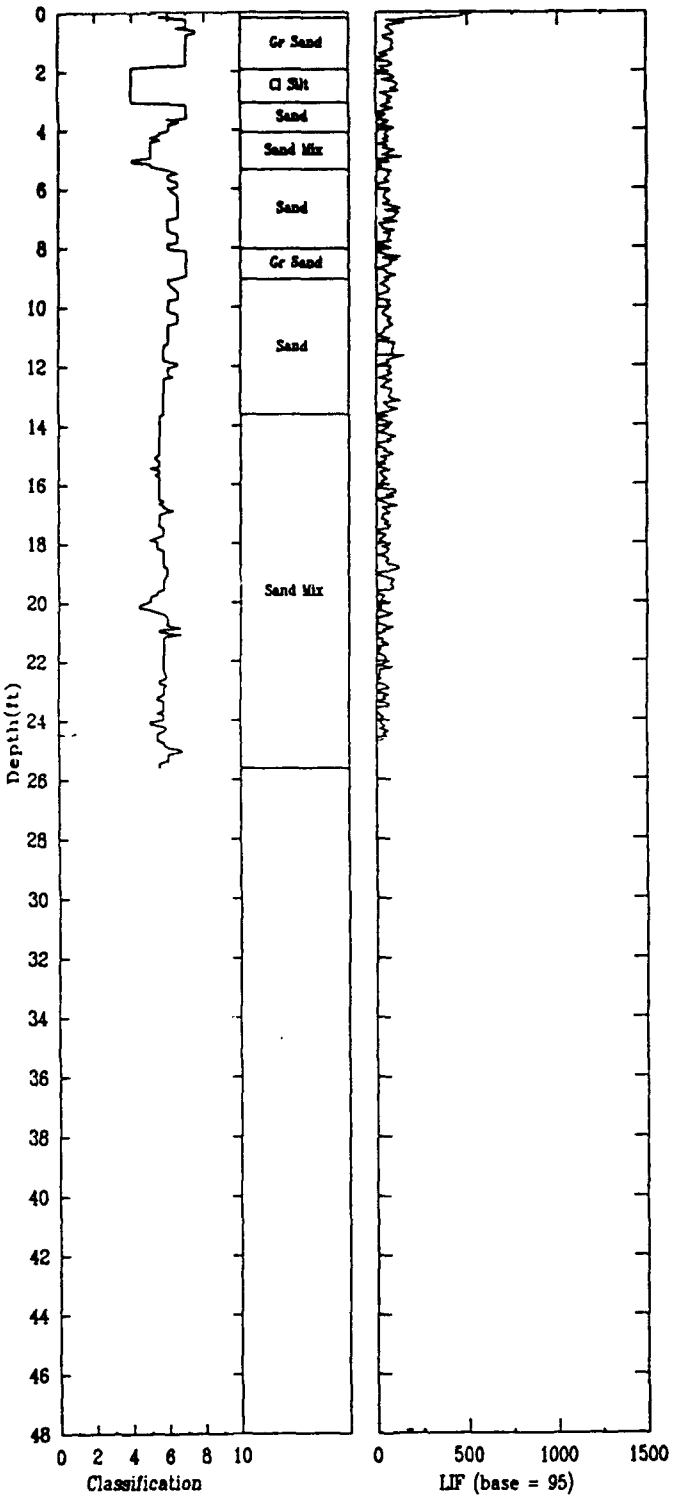
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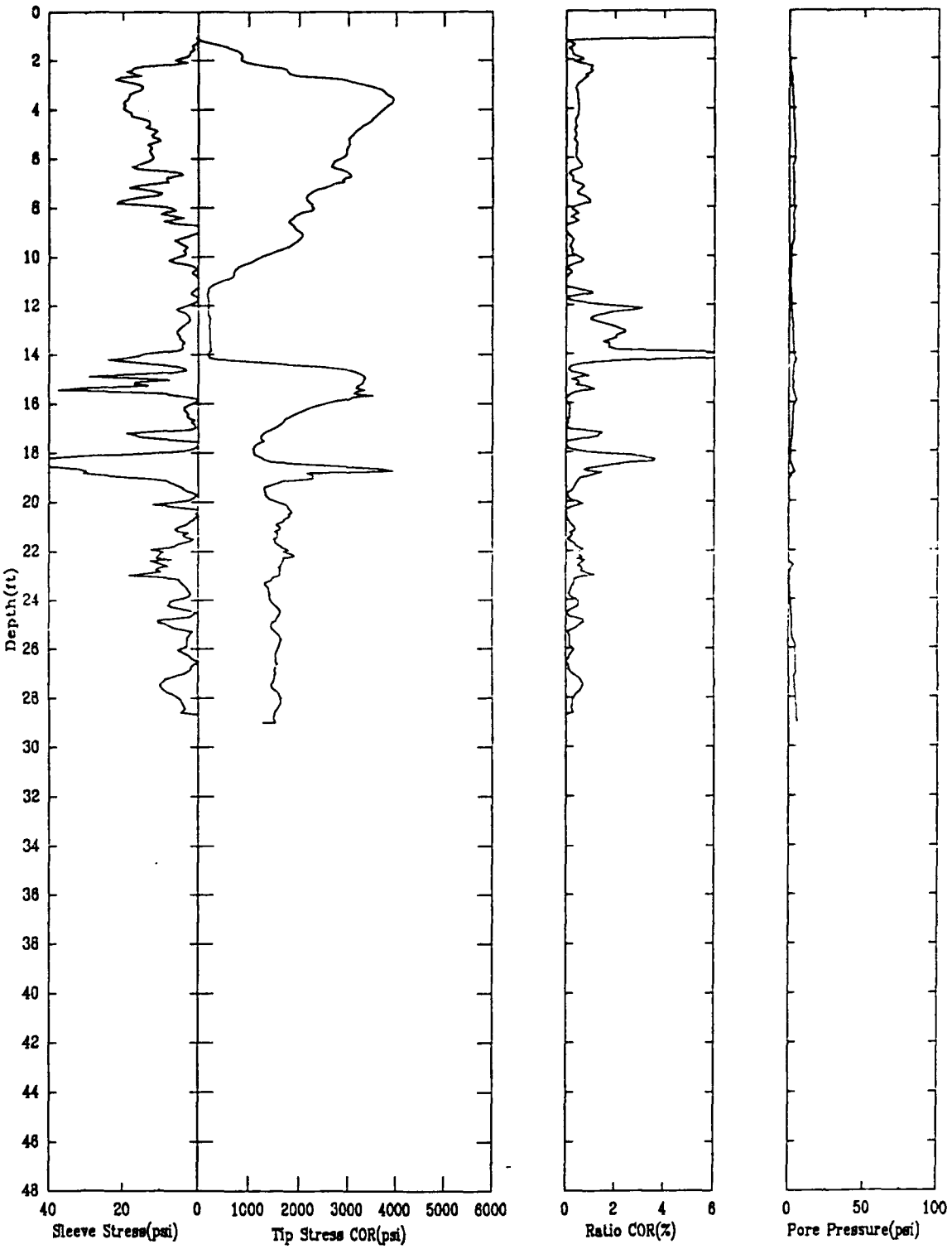
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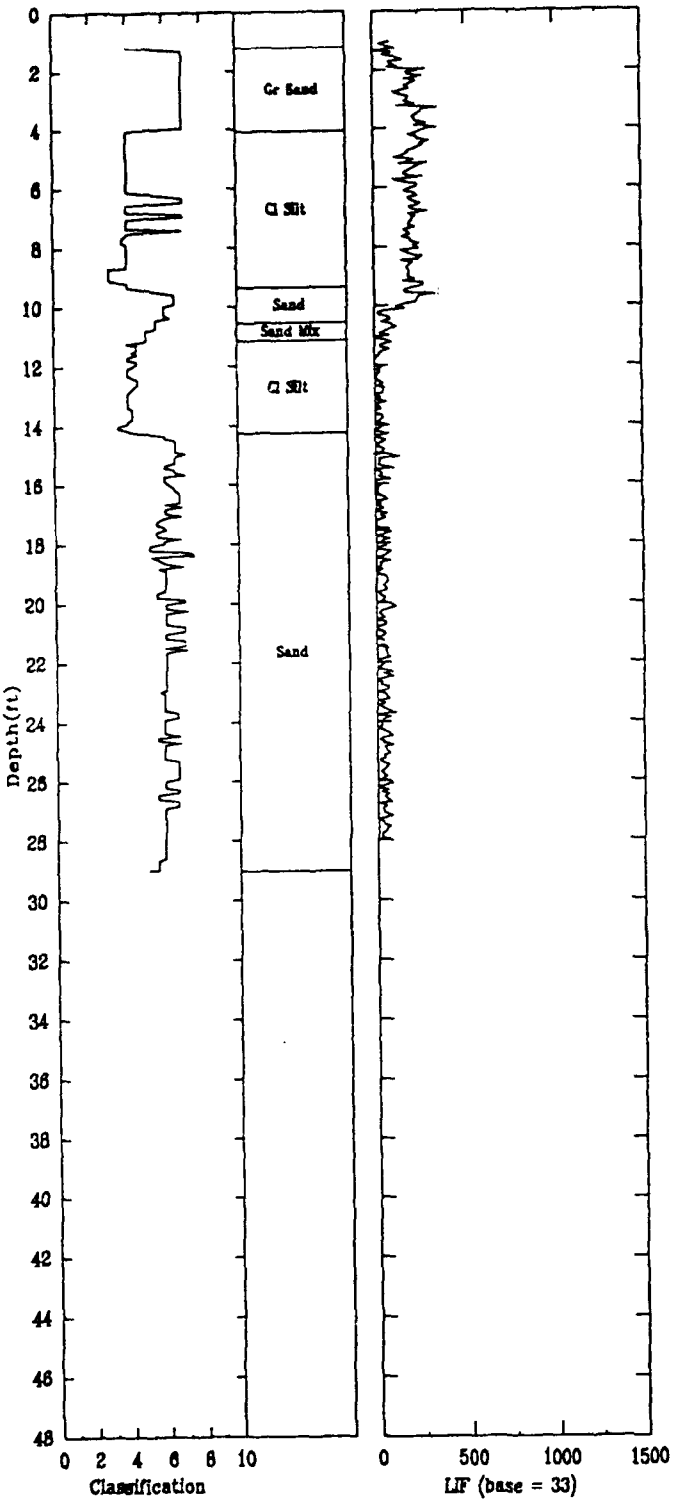
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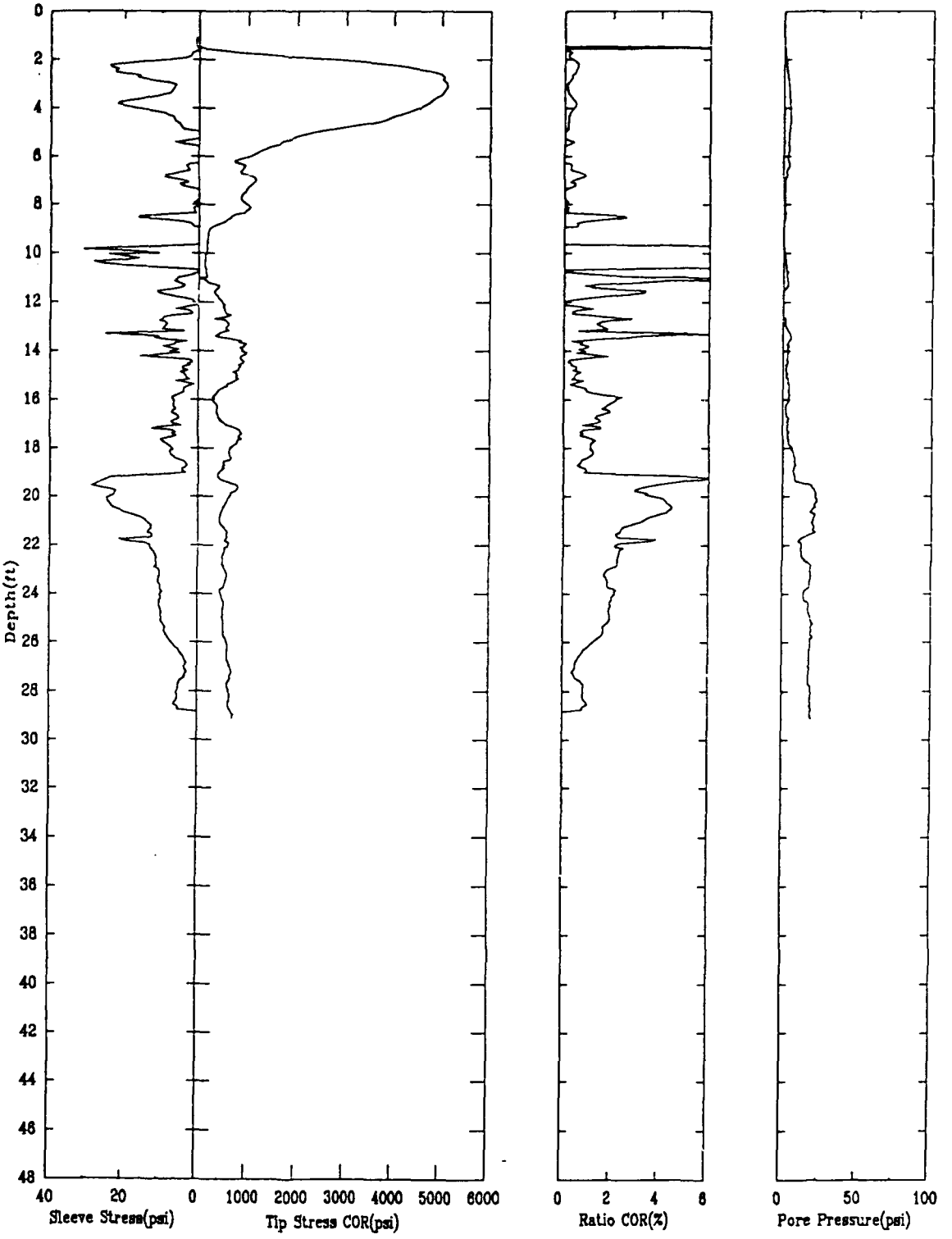
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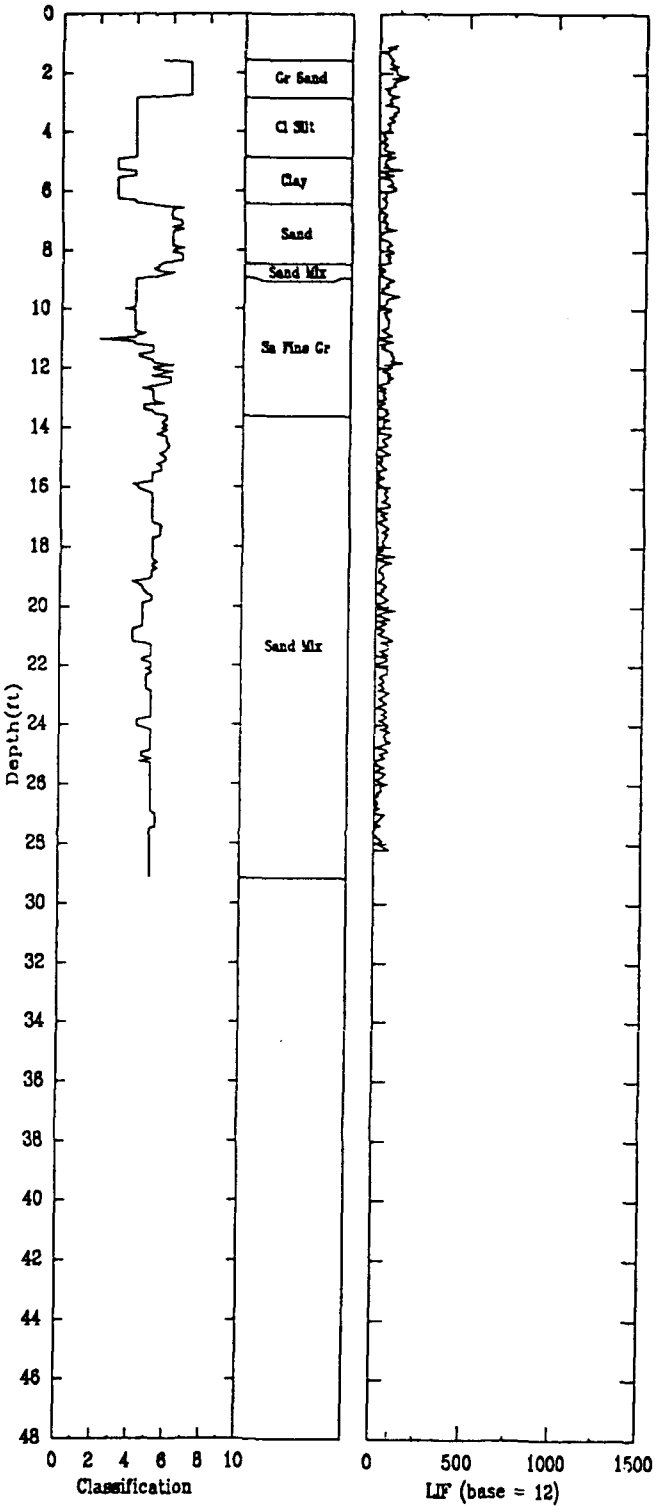
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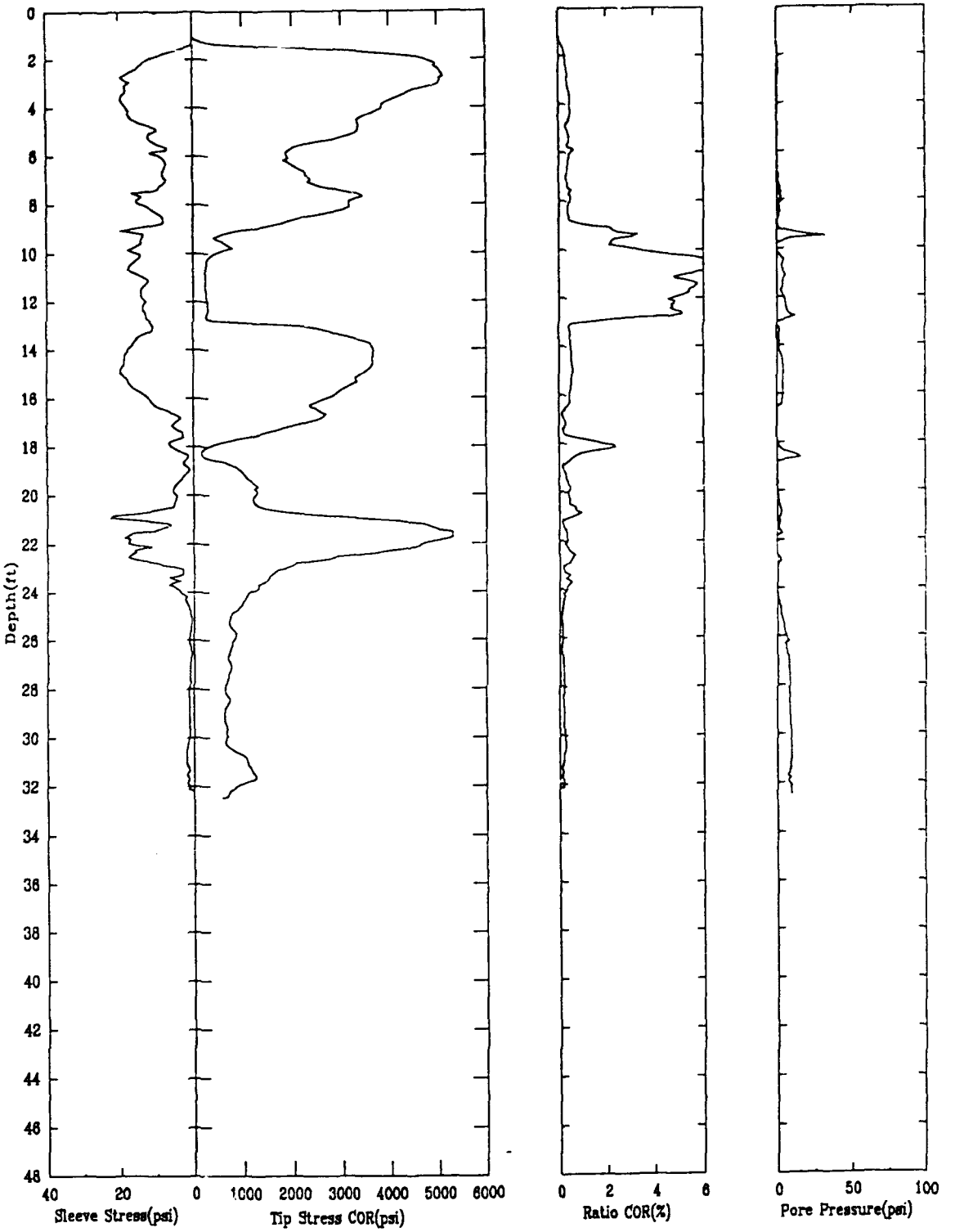
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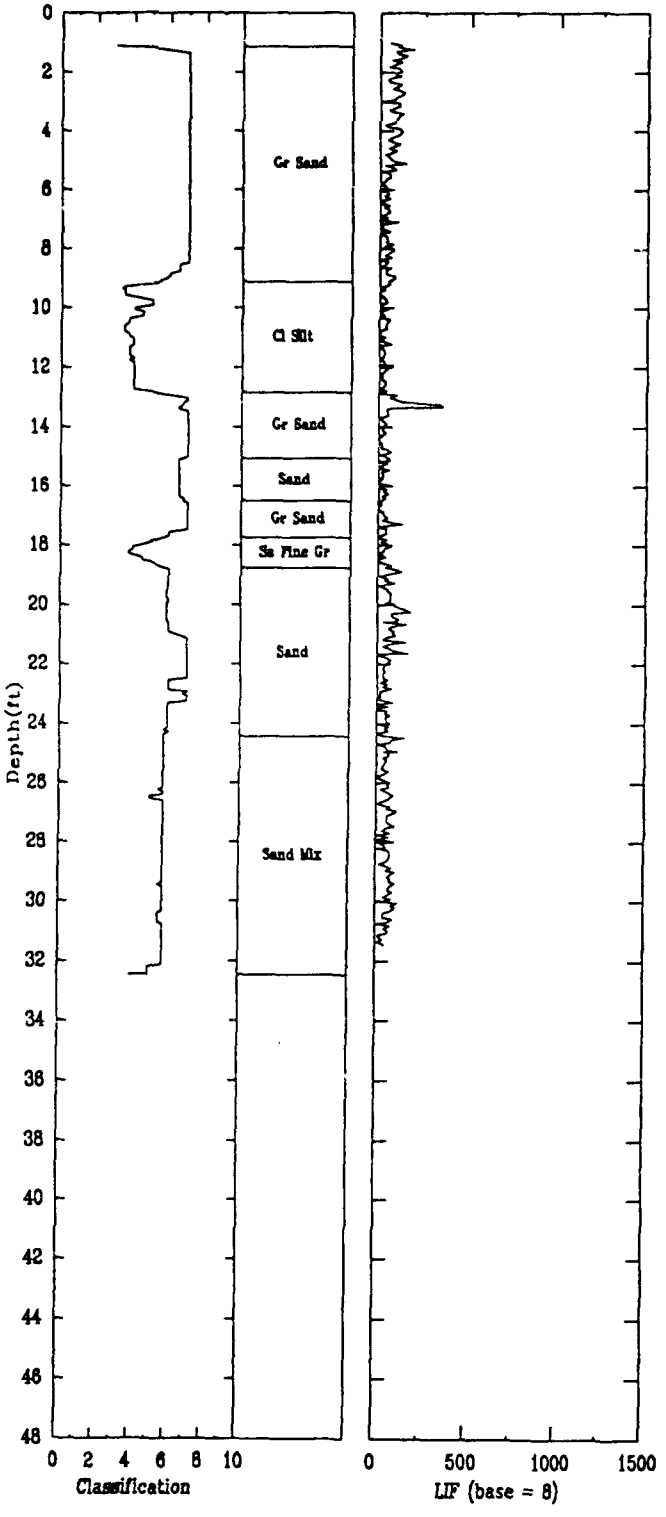
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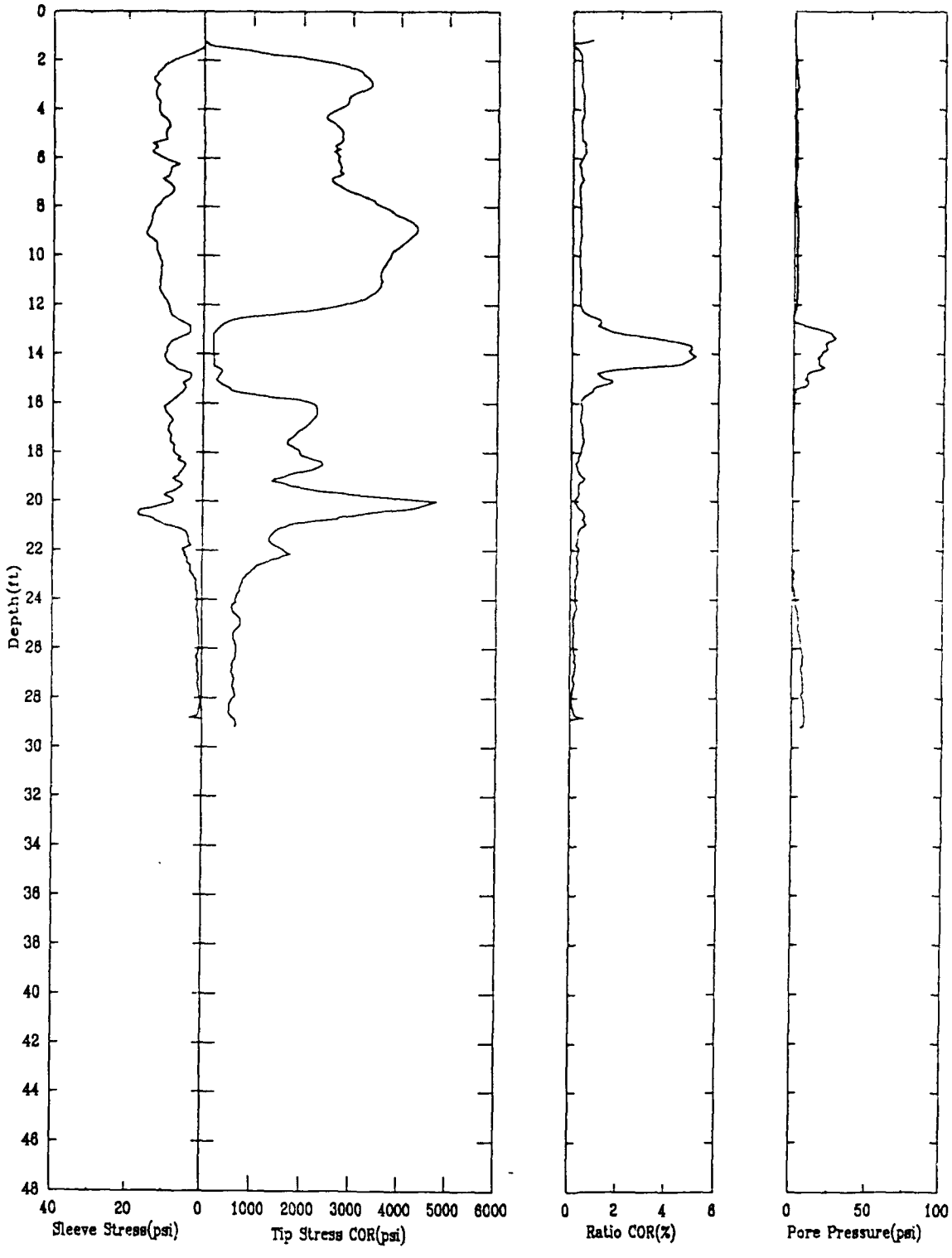
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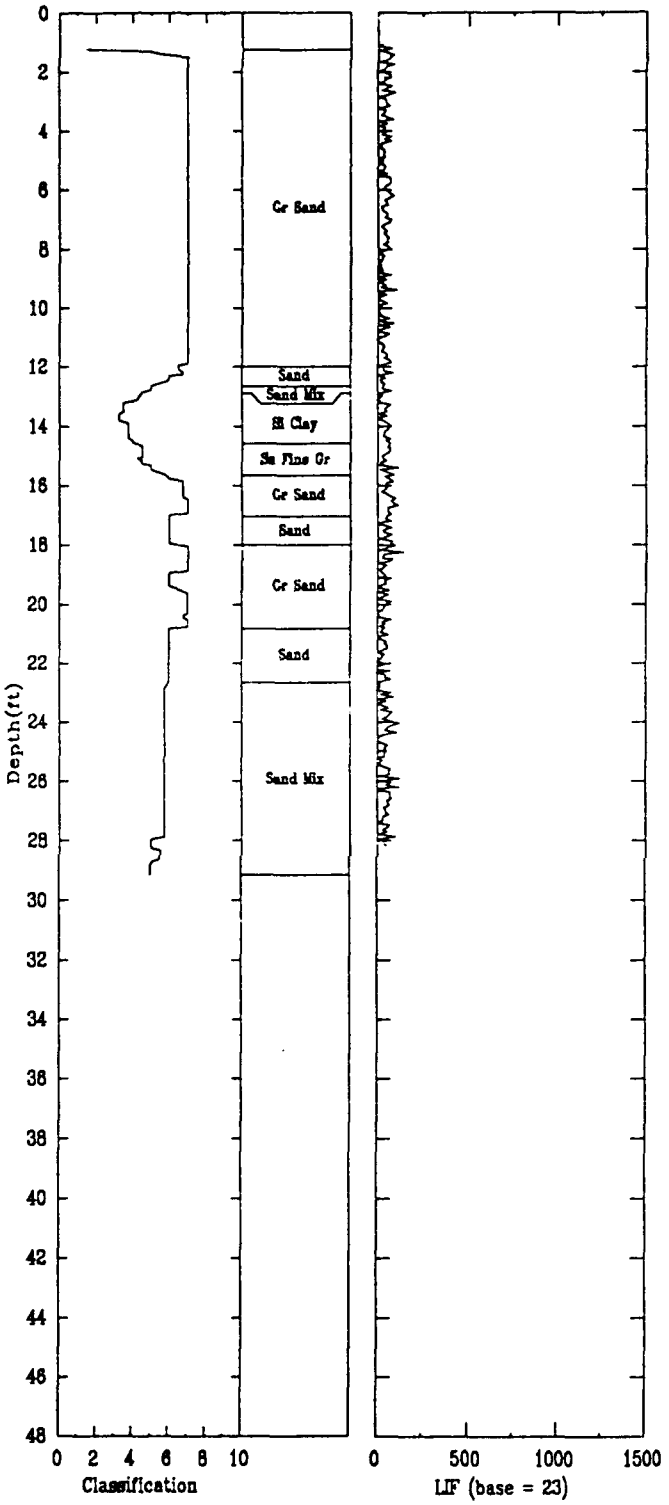
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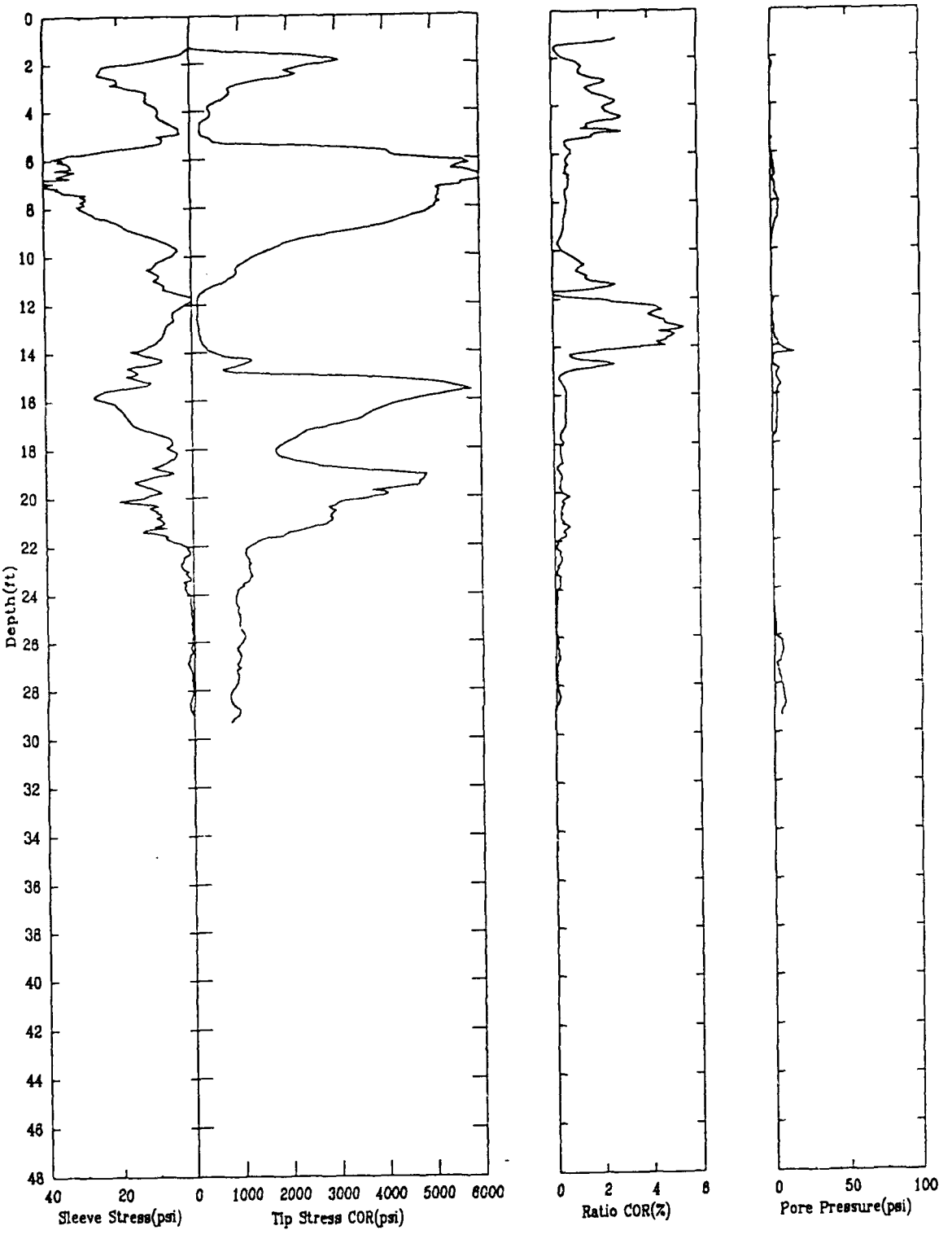
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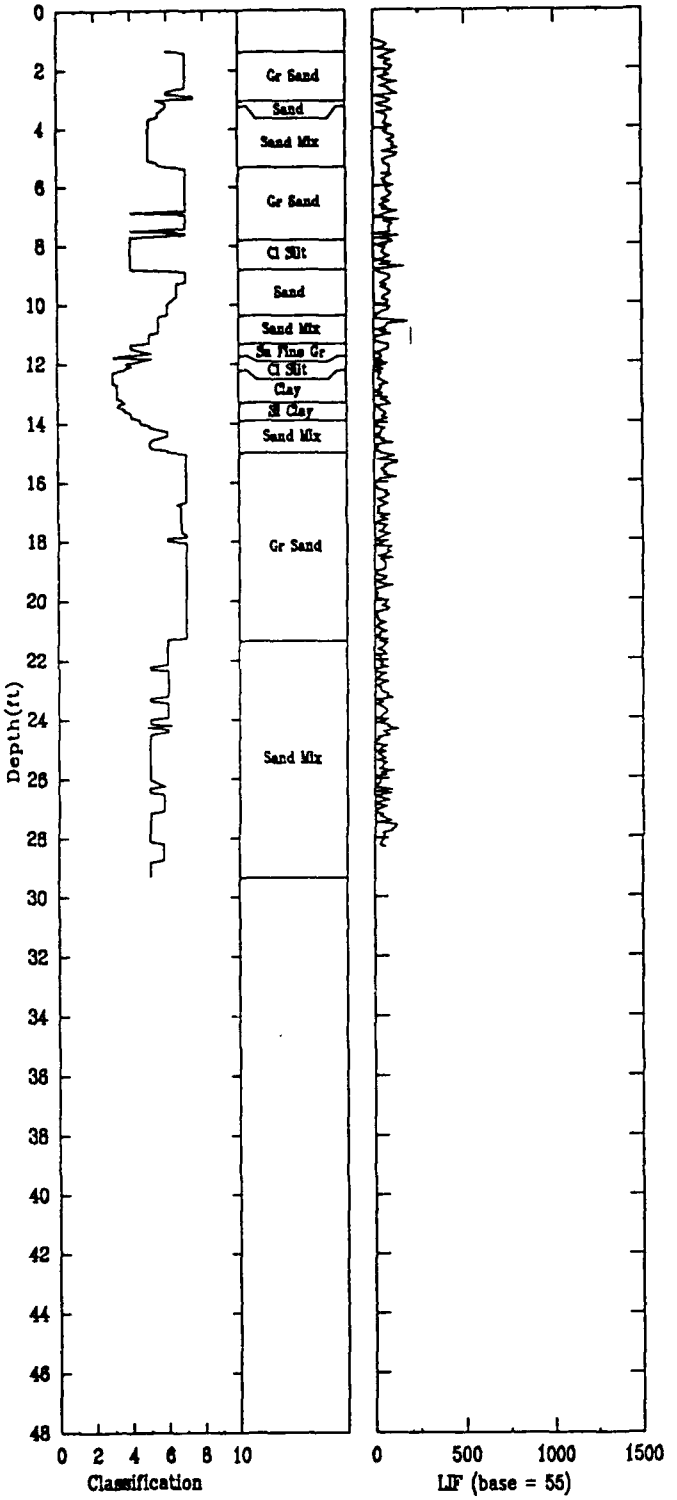
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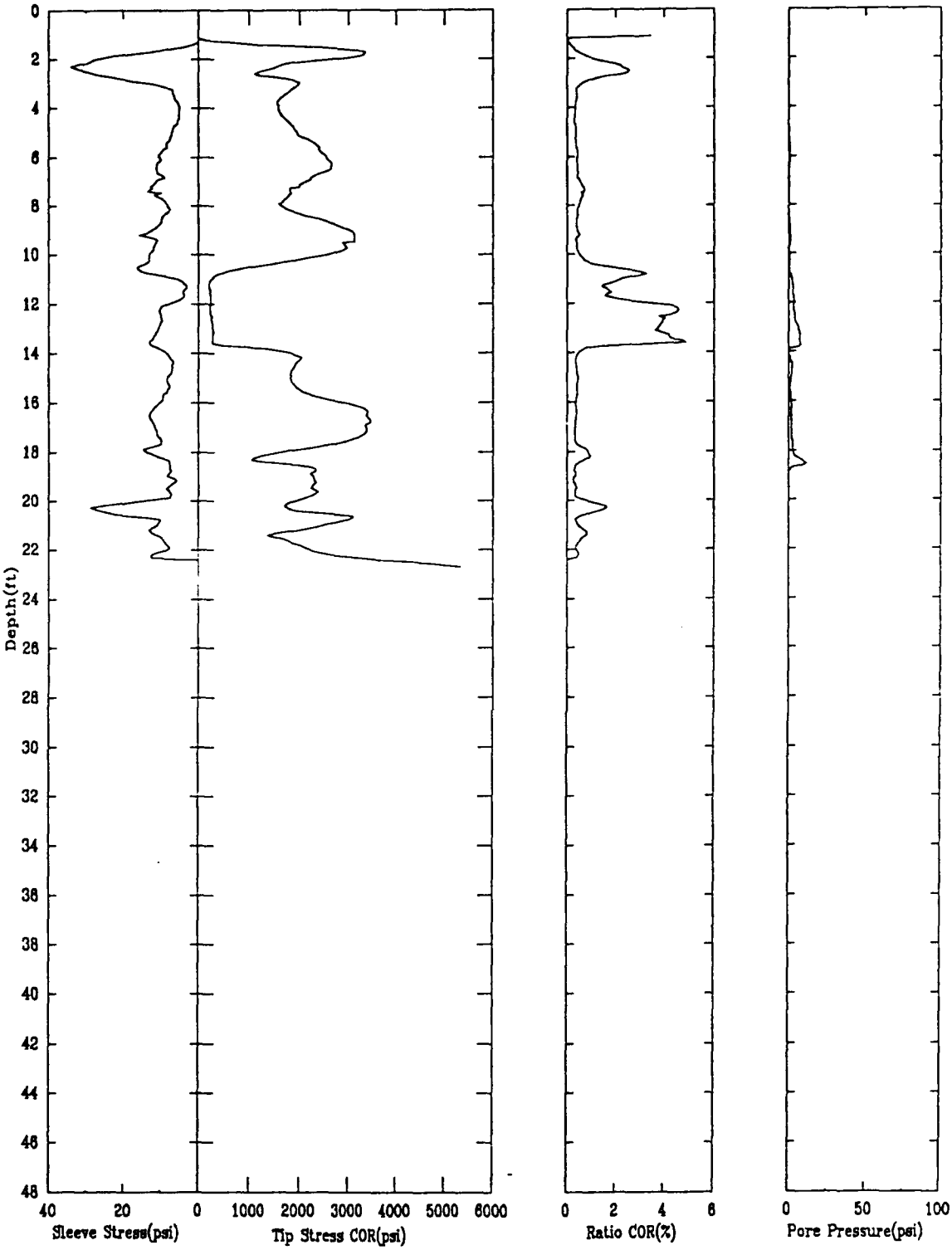
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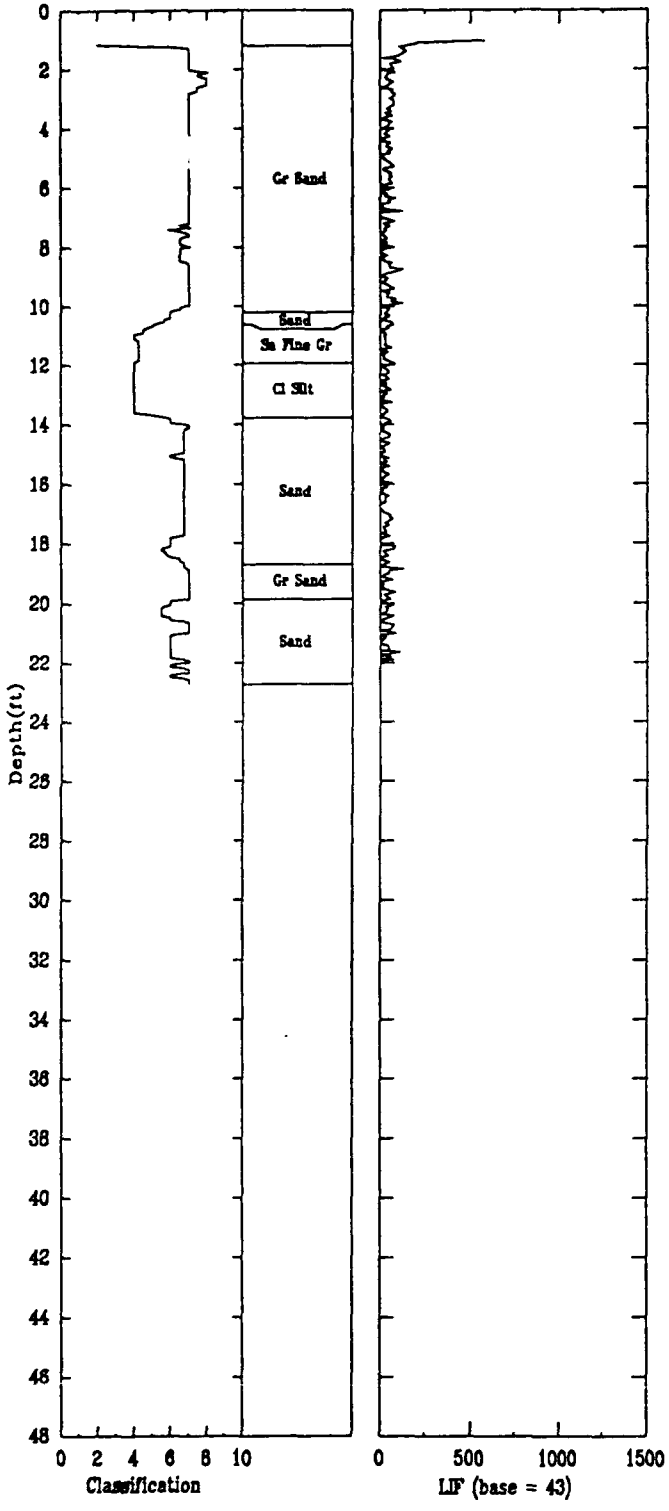
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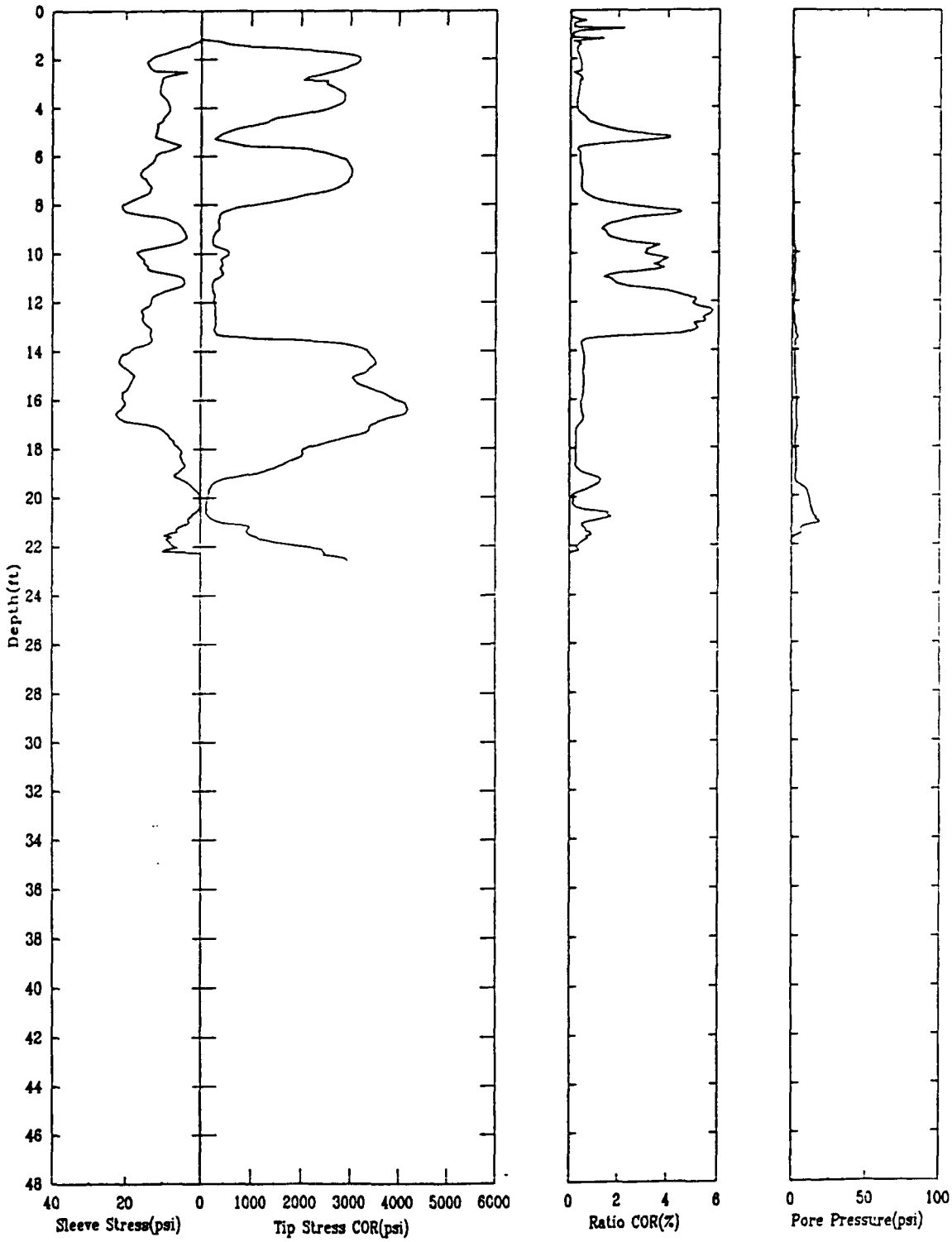


Figure 4. LIF-CPT profiles for XYZCPT-14-LIF.

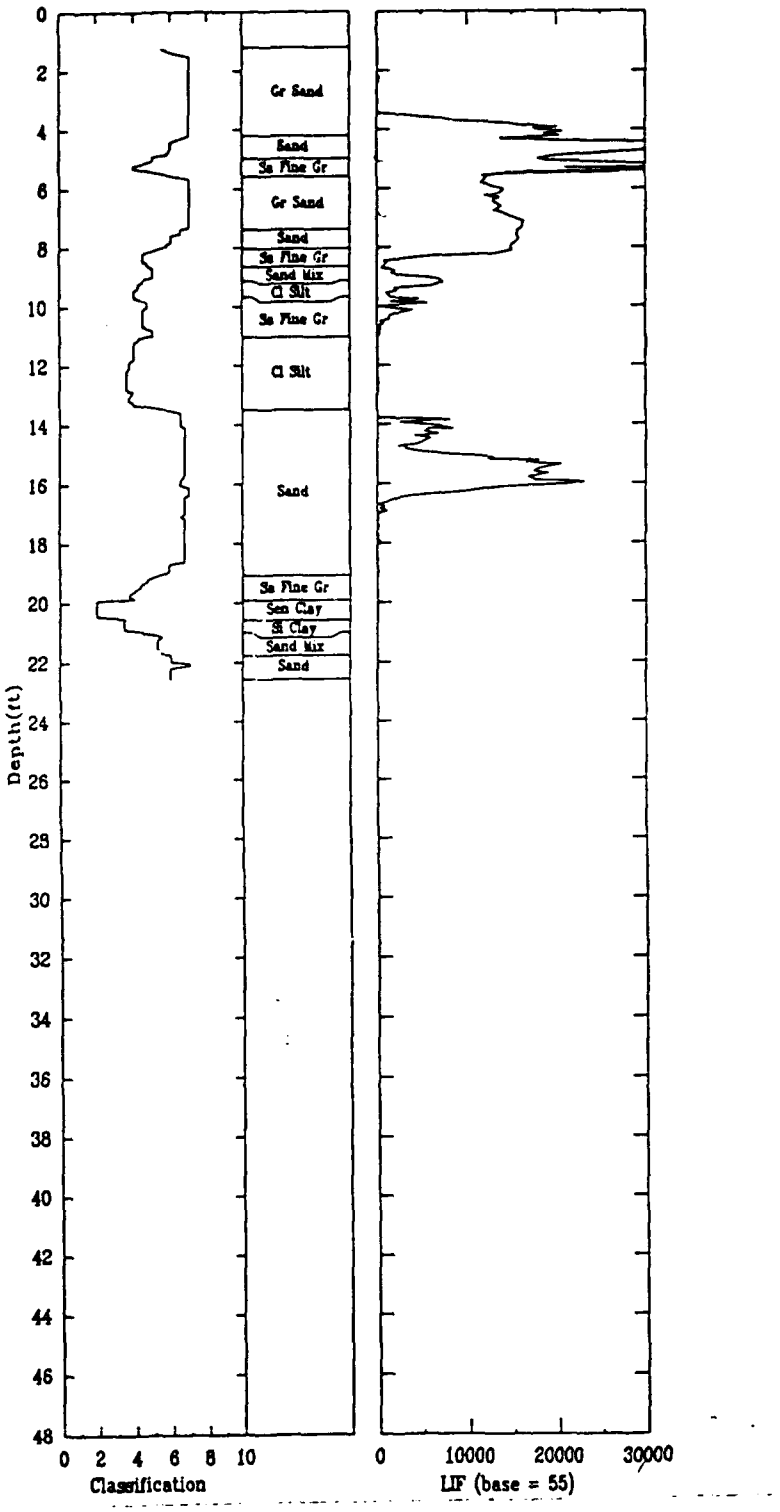
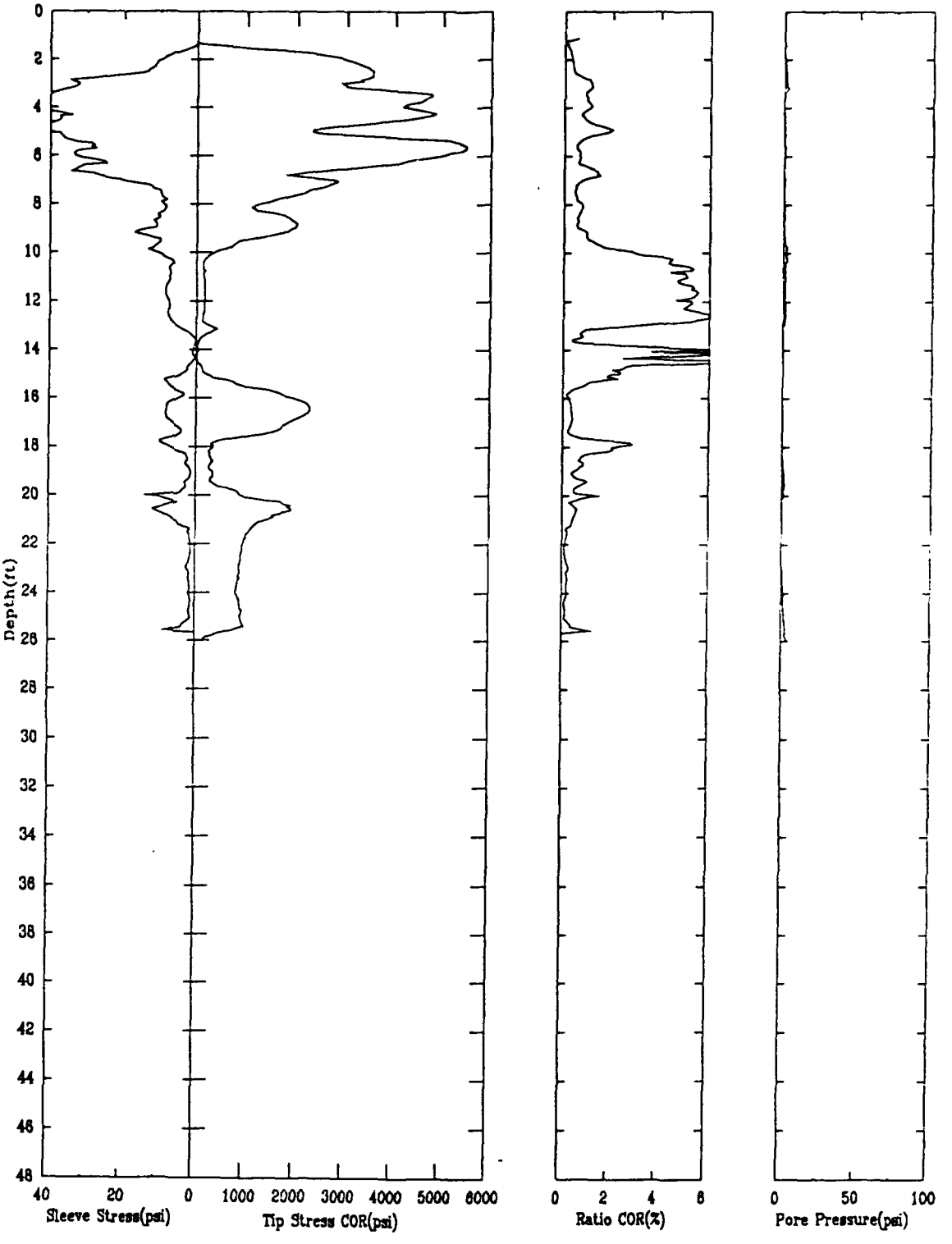


Figure 4. LIF-CPT profiles for XYZCPT-14-LIF (continued).

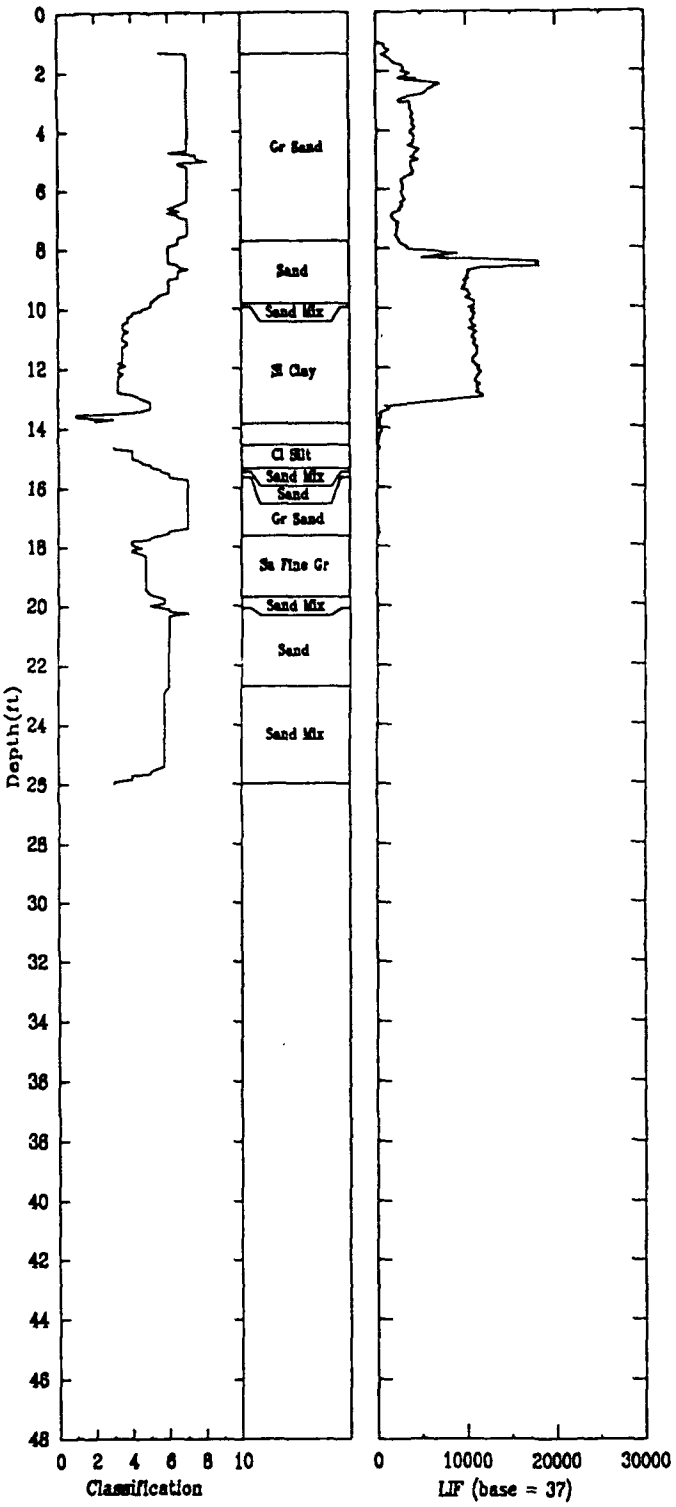
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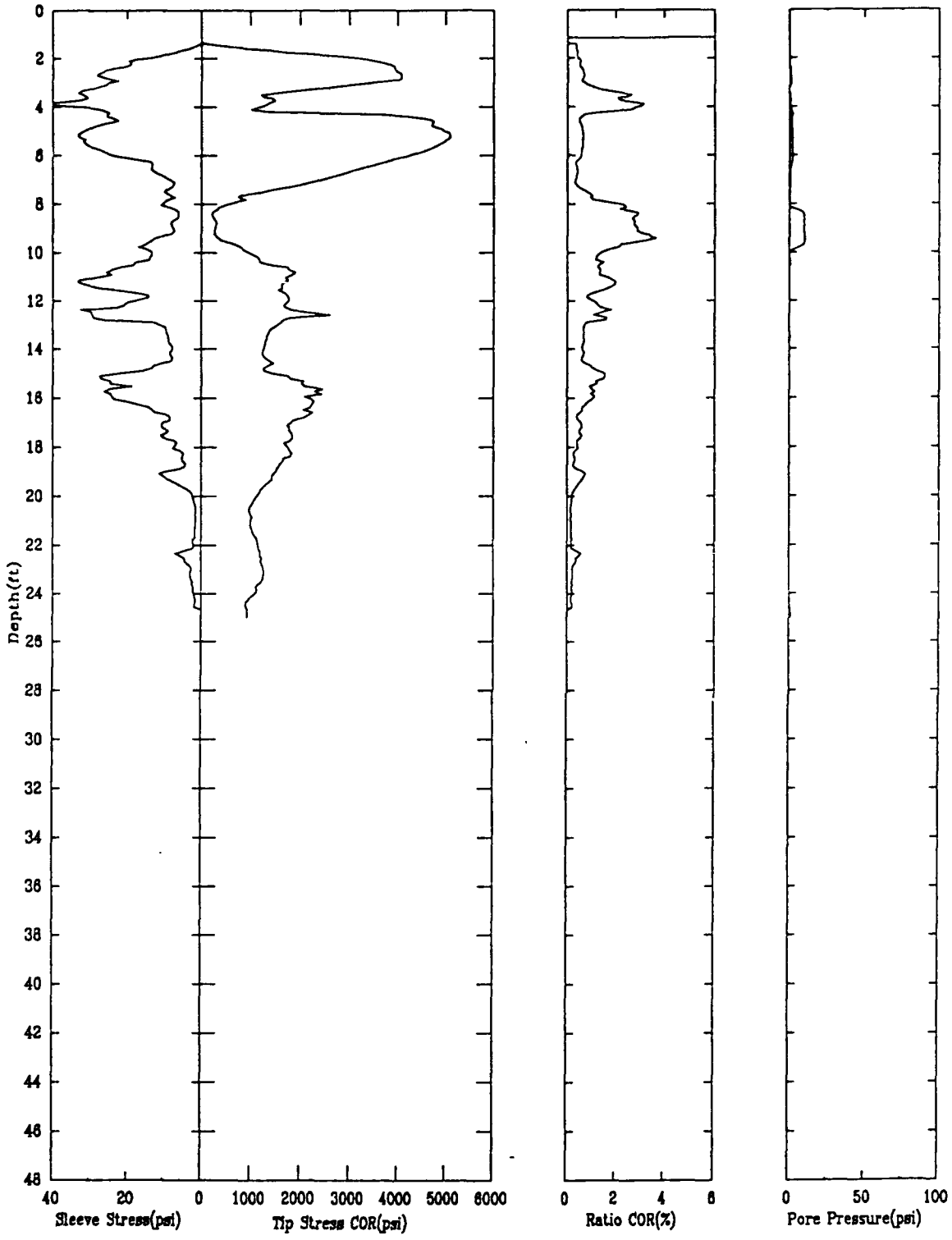
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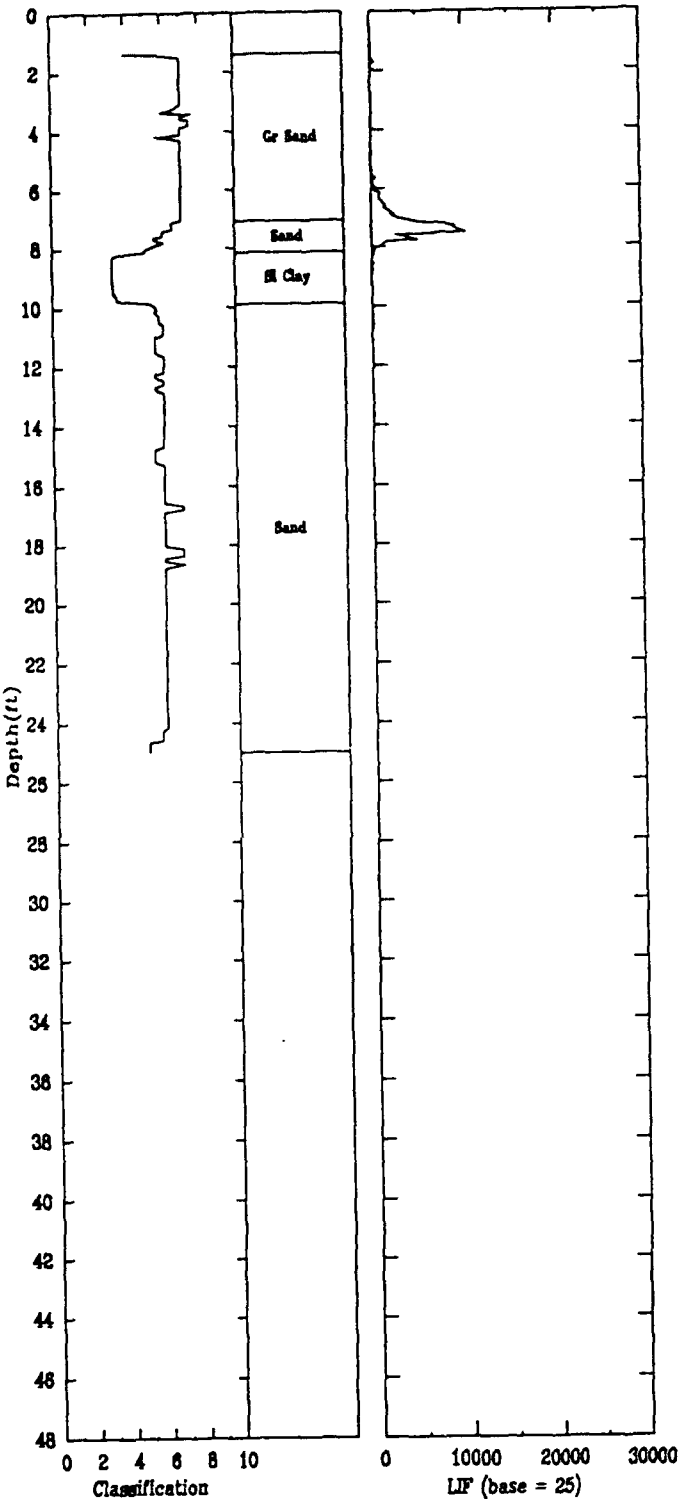
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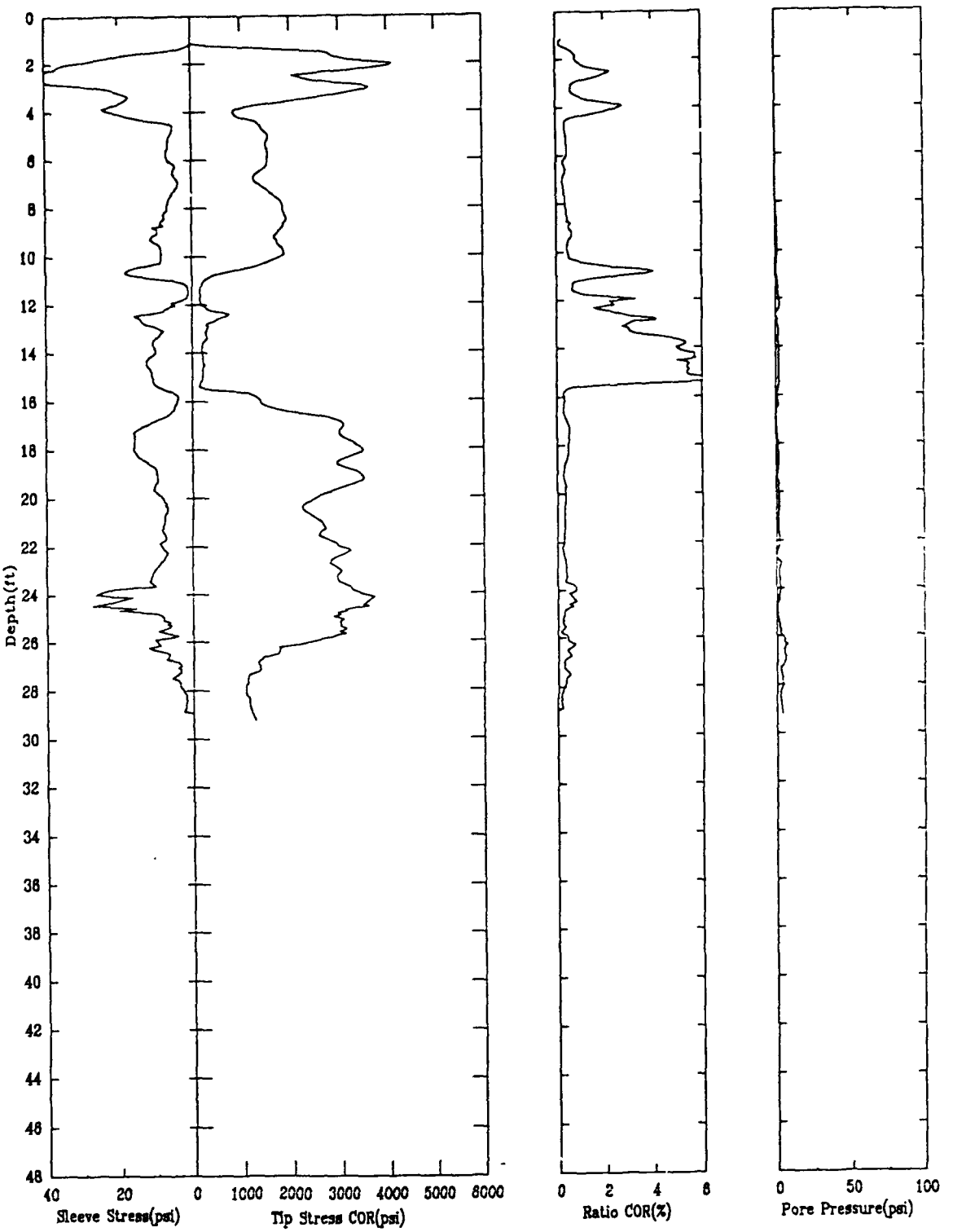
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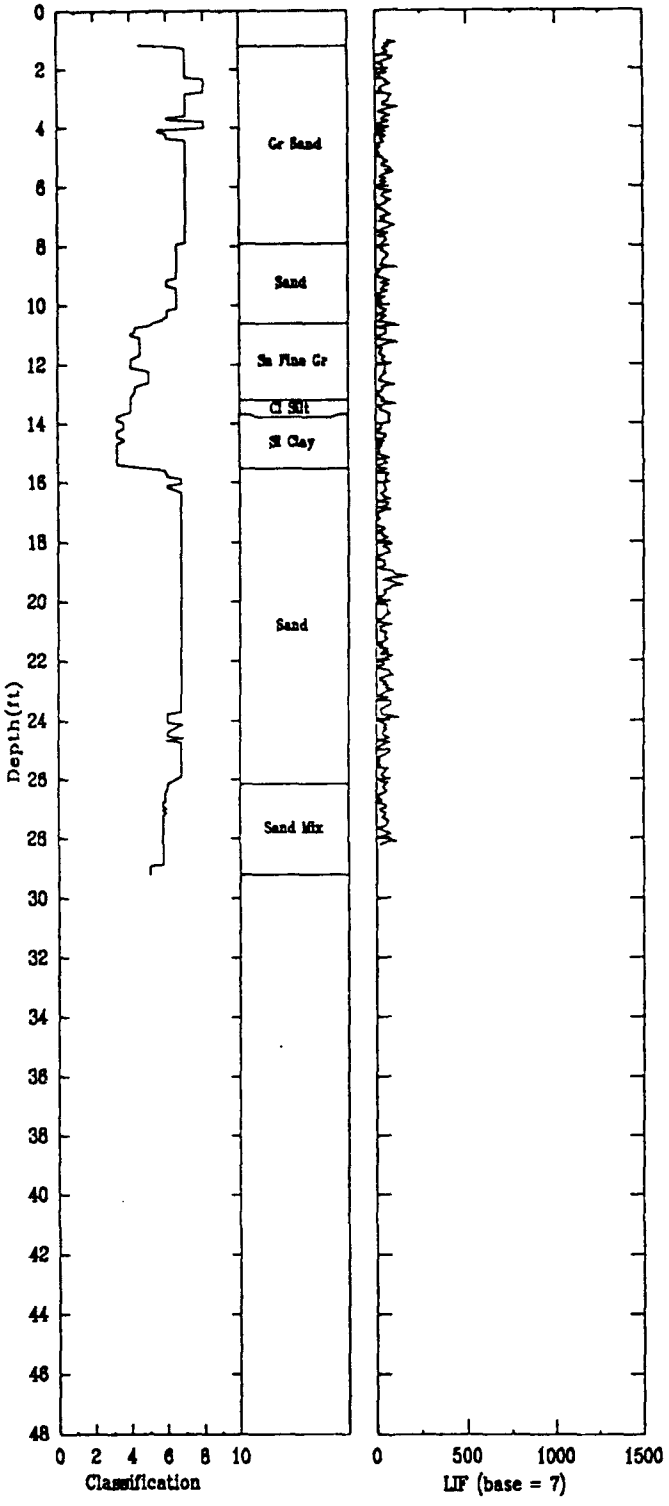
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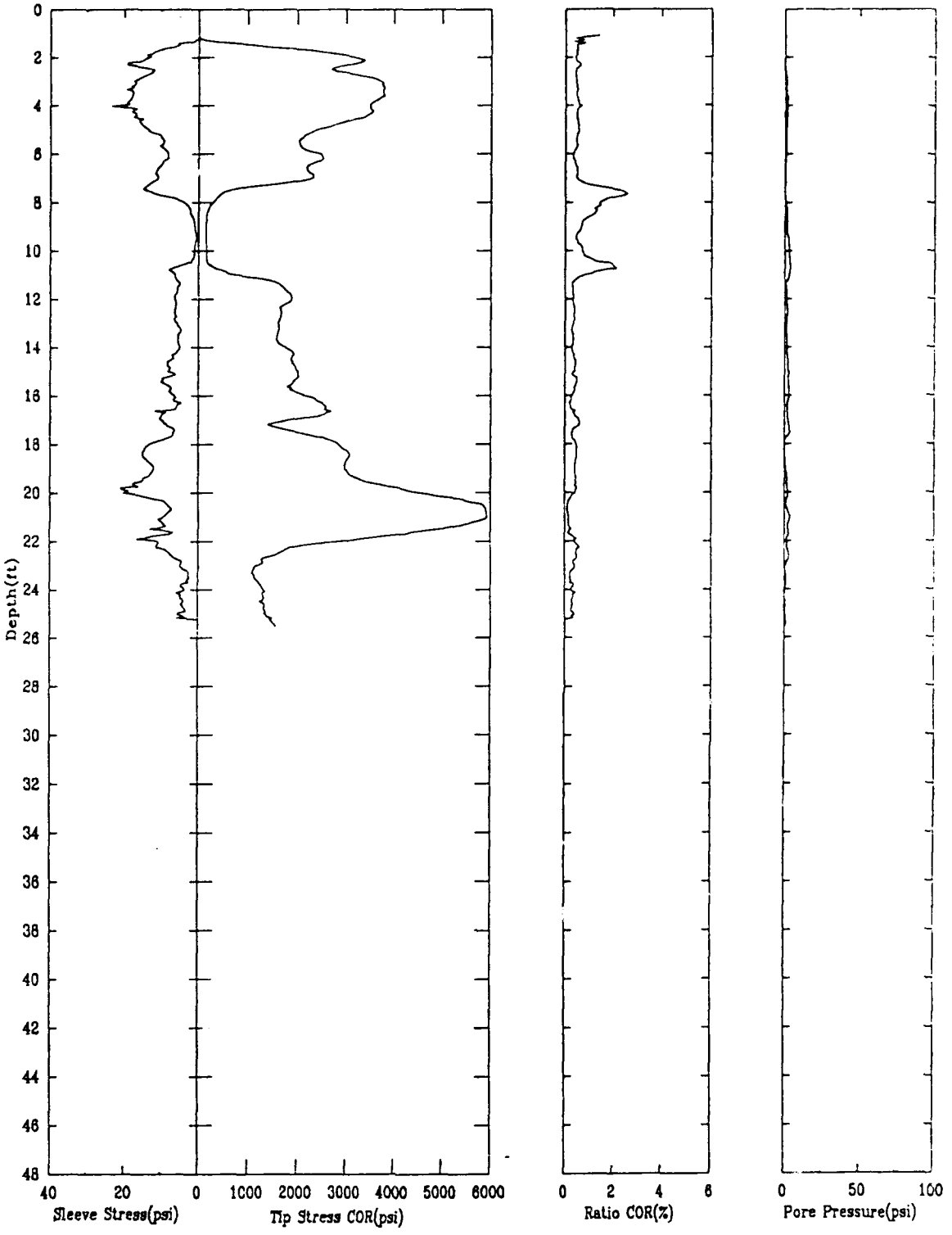
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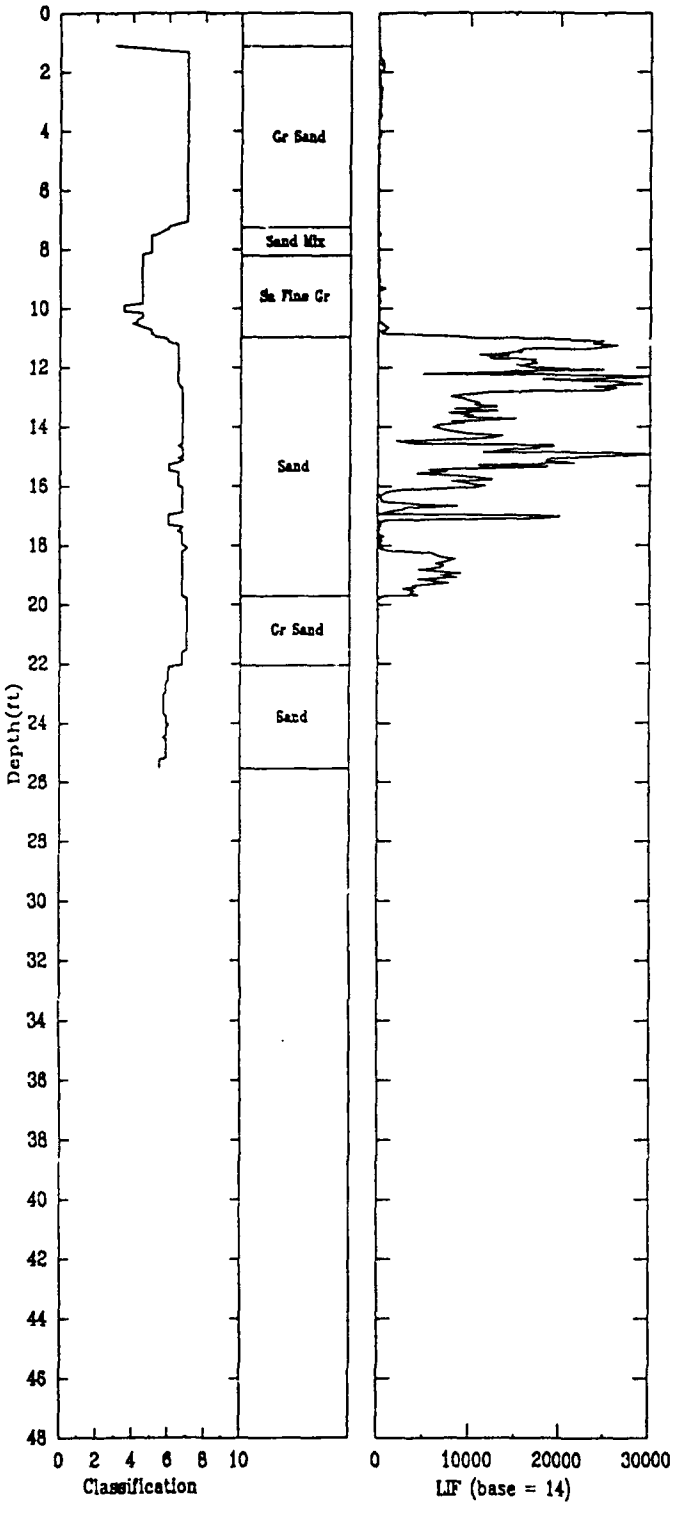
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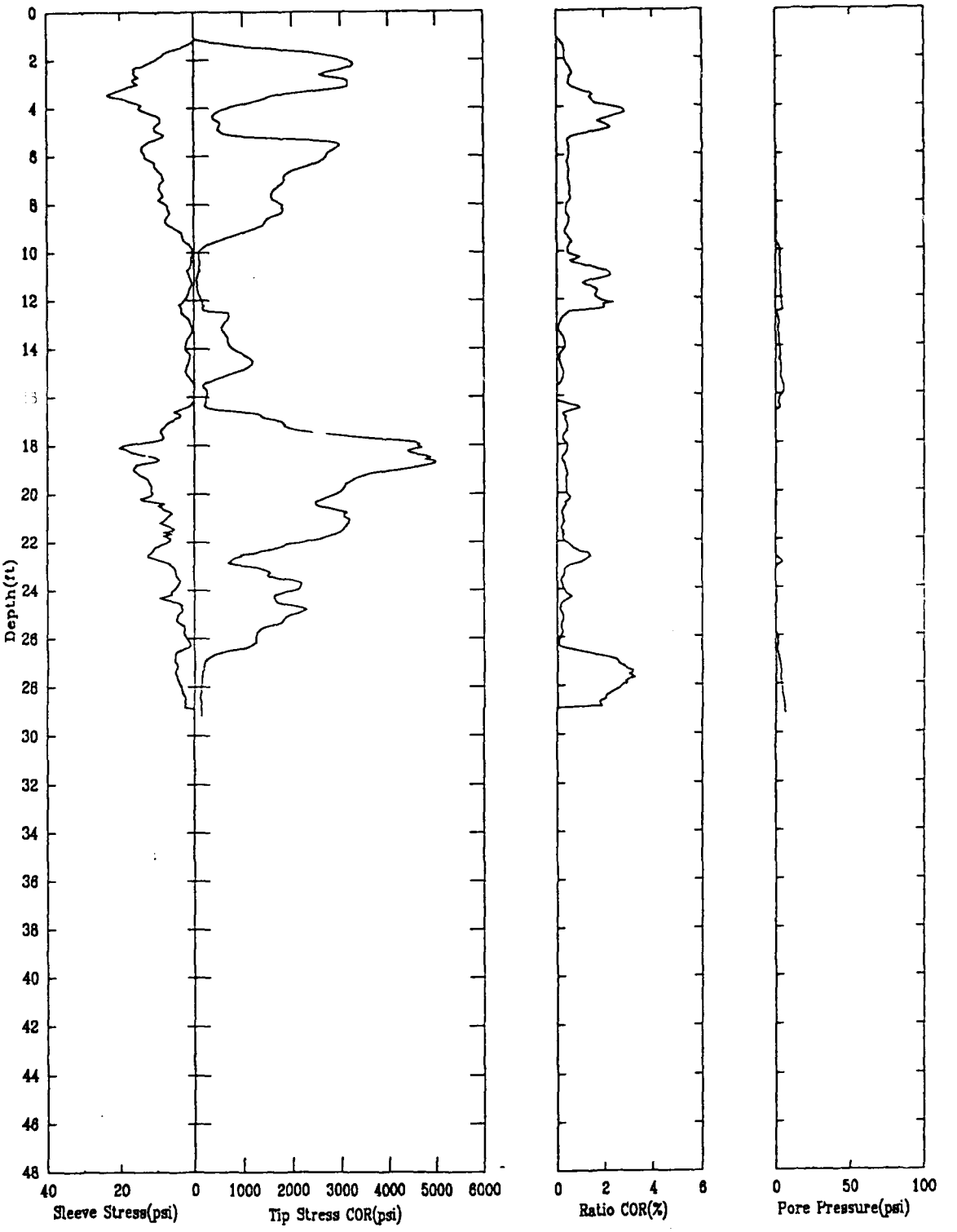
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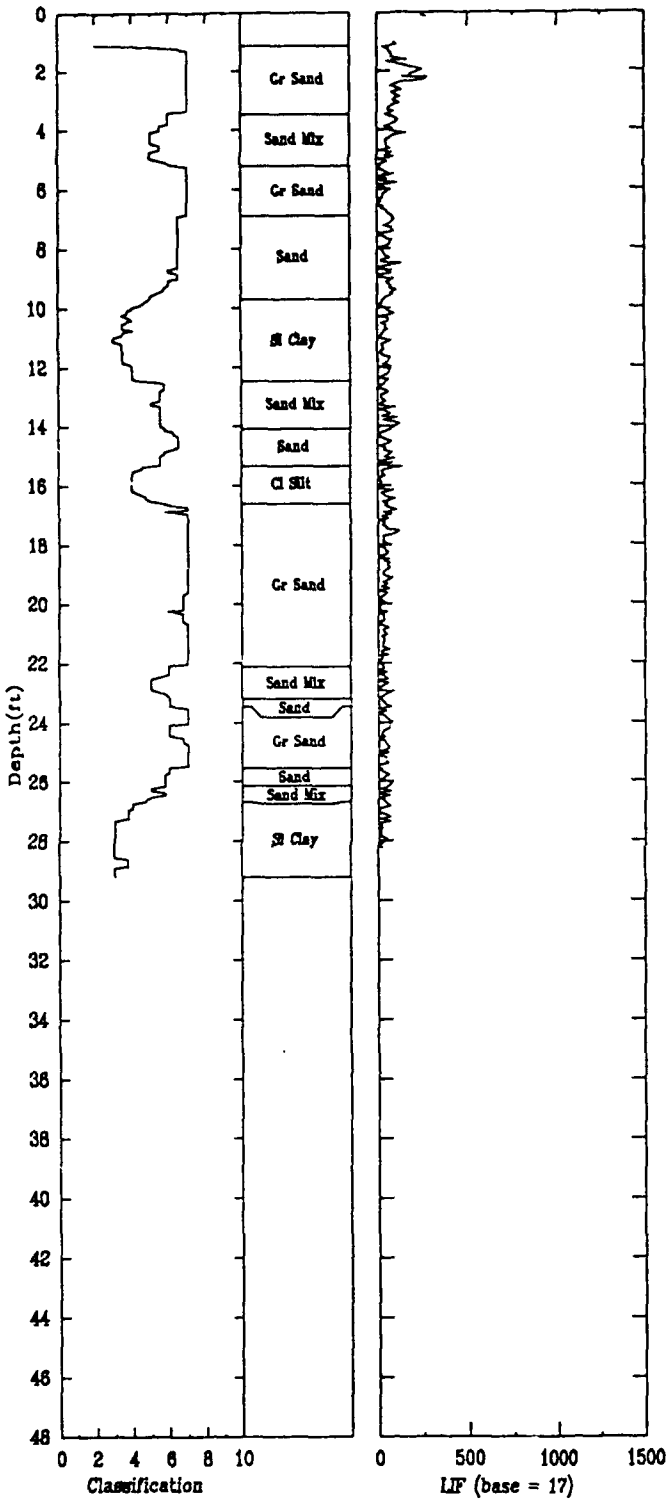
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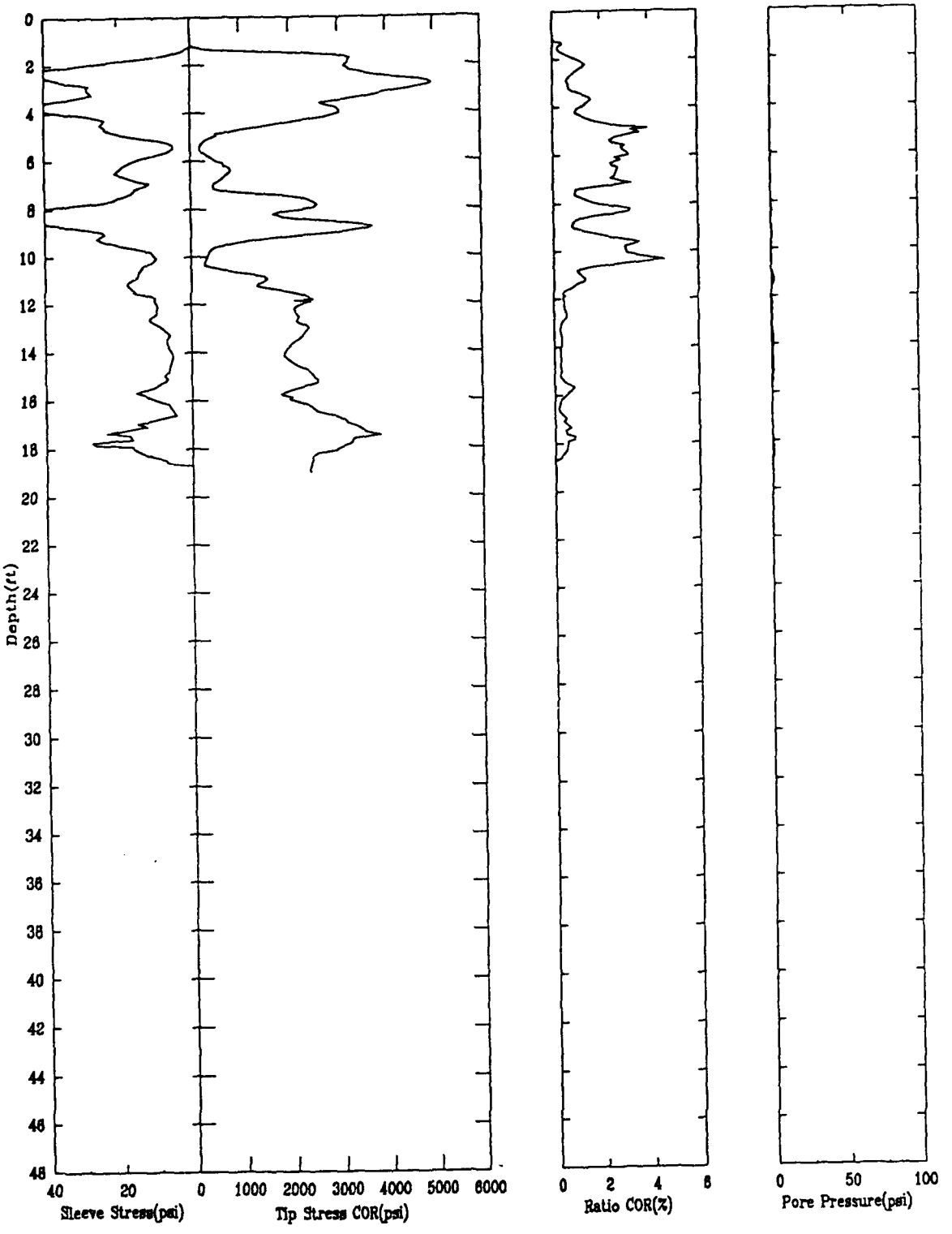
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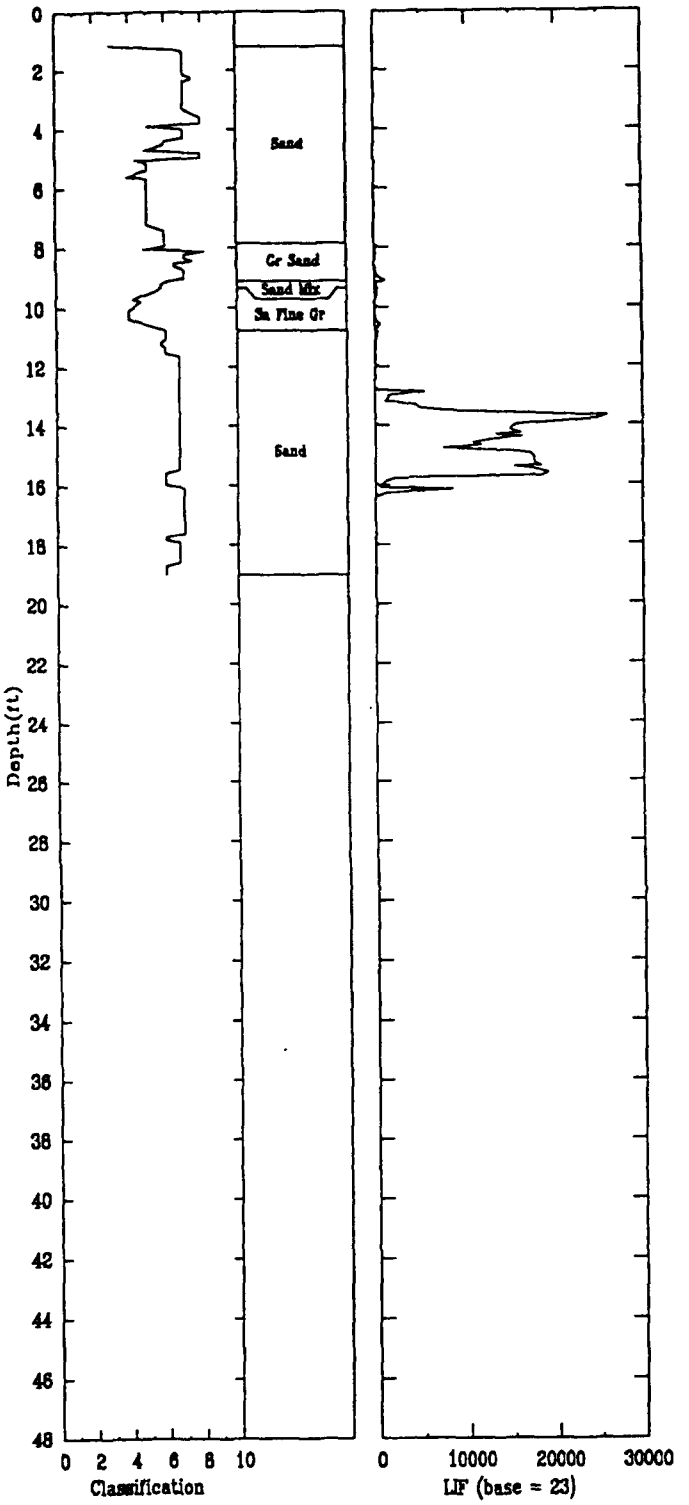
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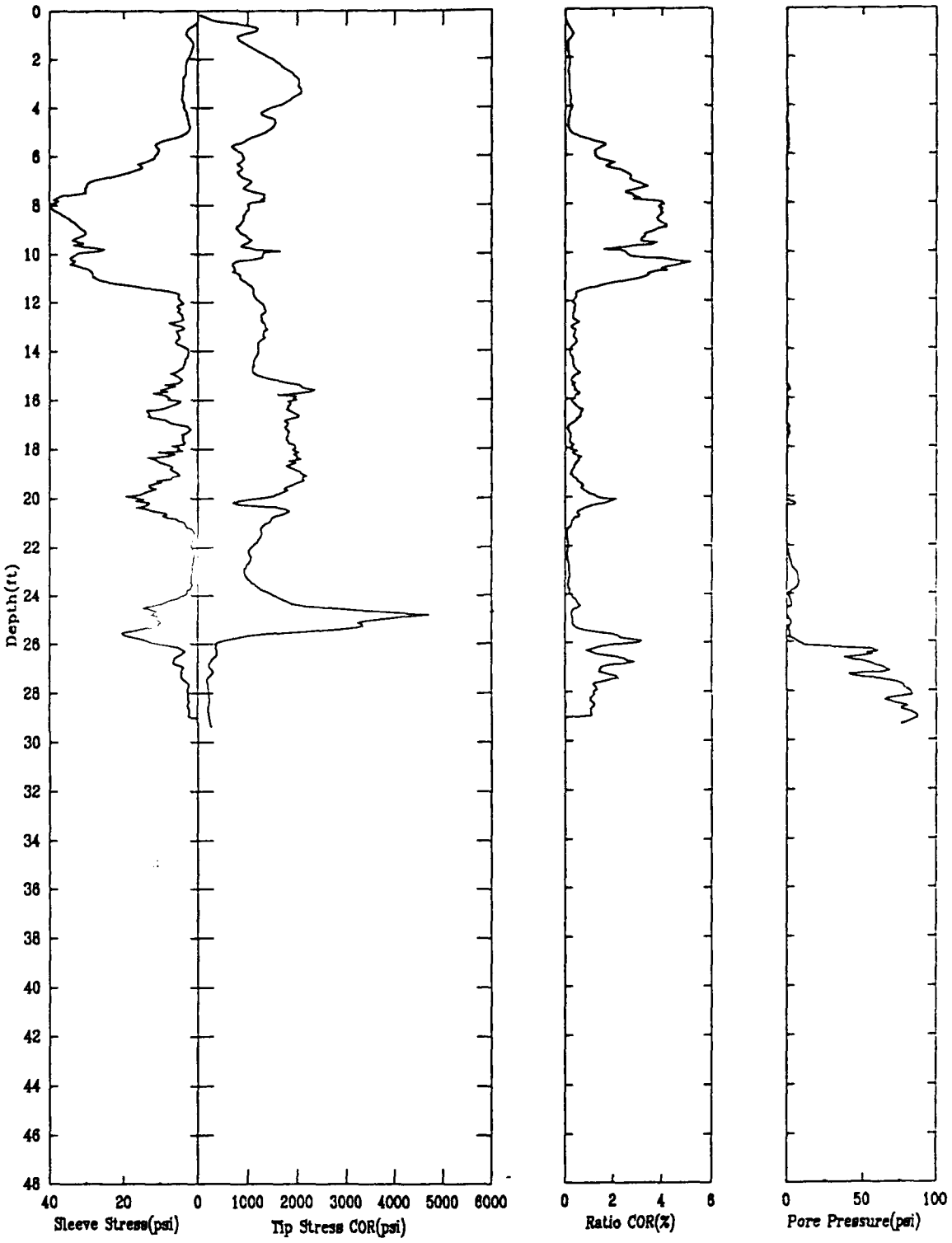
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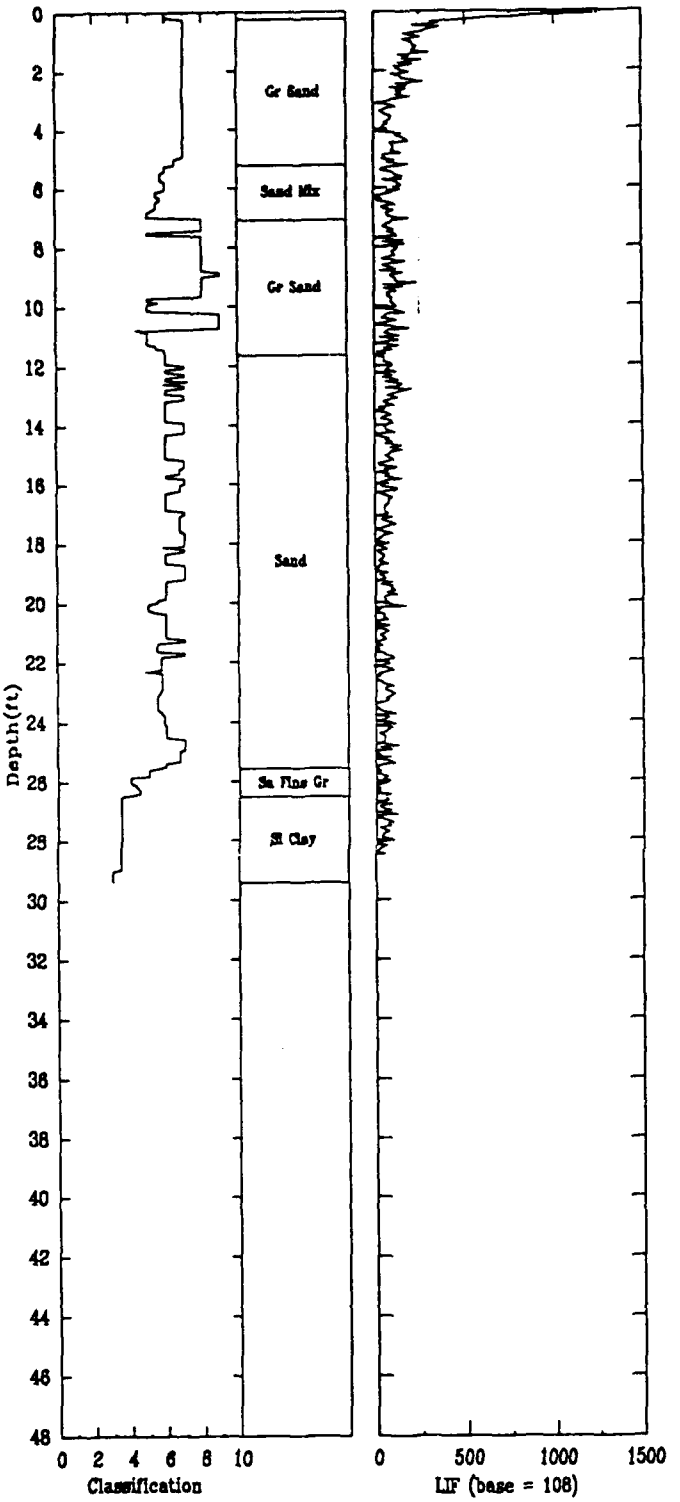
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Dover Air Force Base



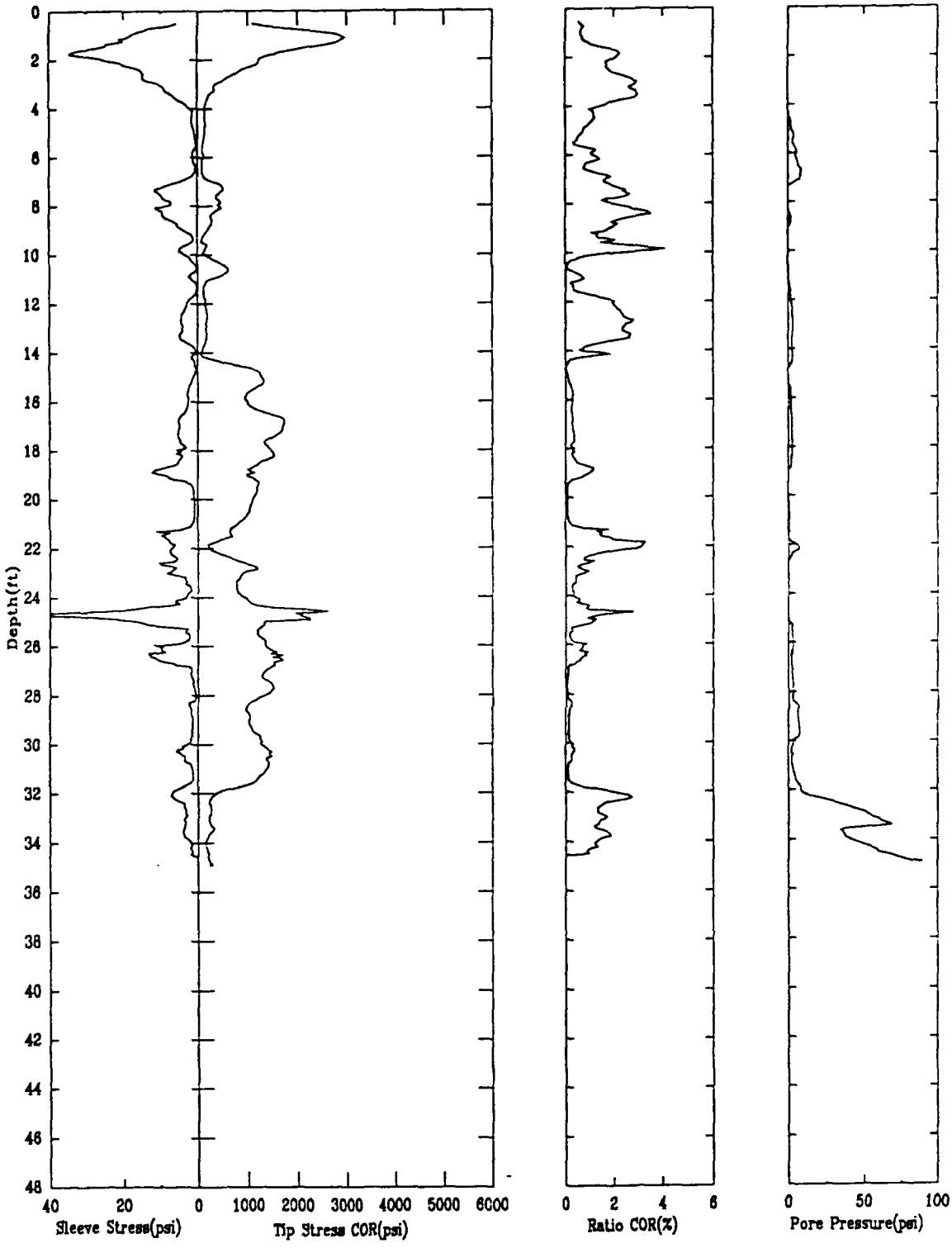
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Dover Air Force Base



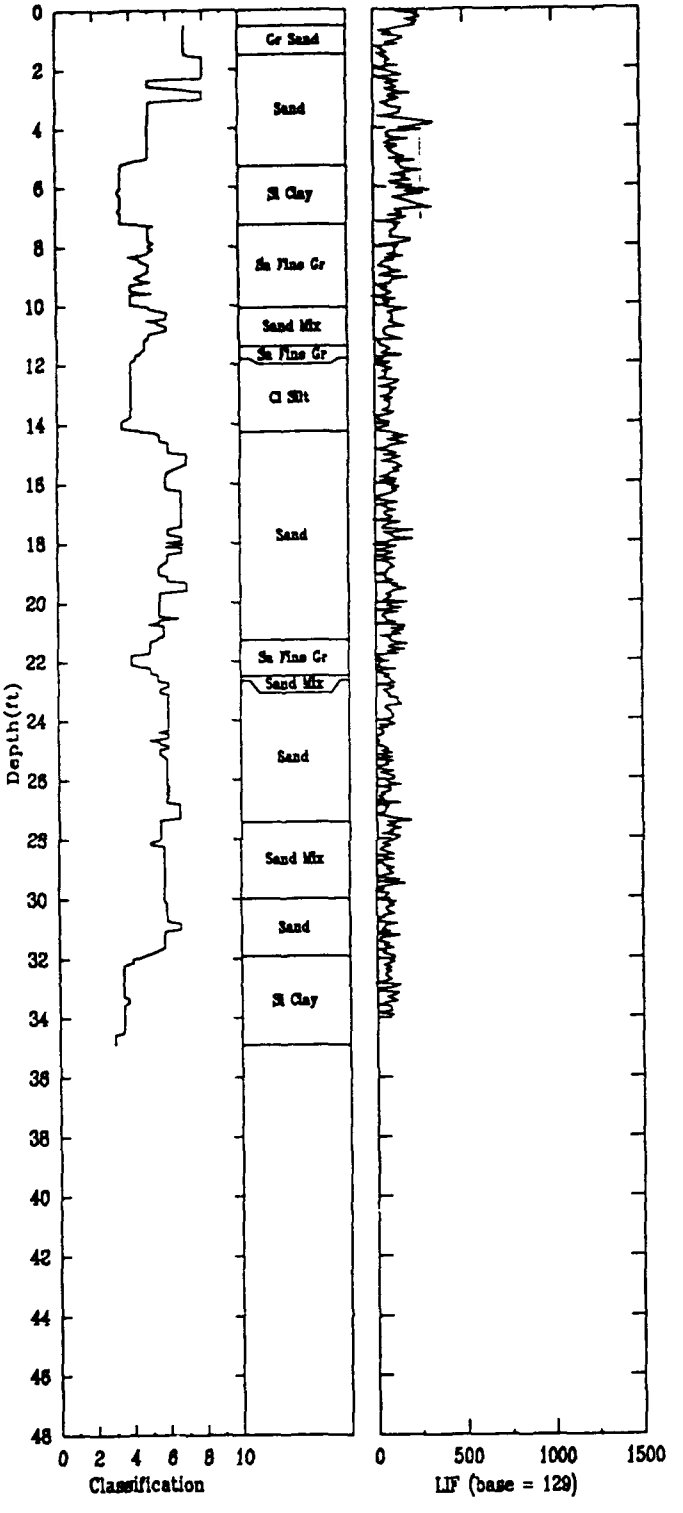
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Dover Air Force Base



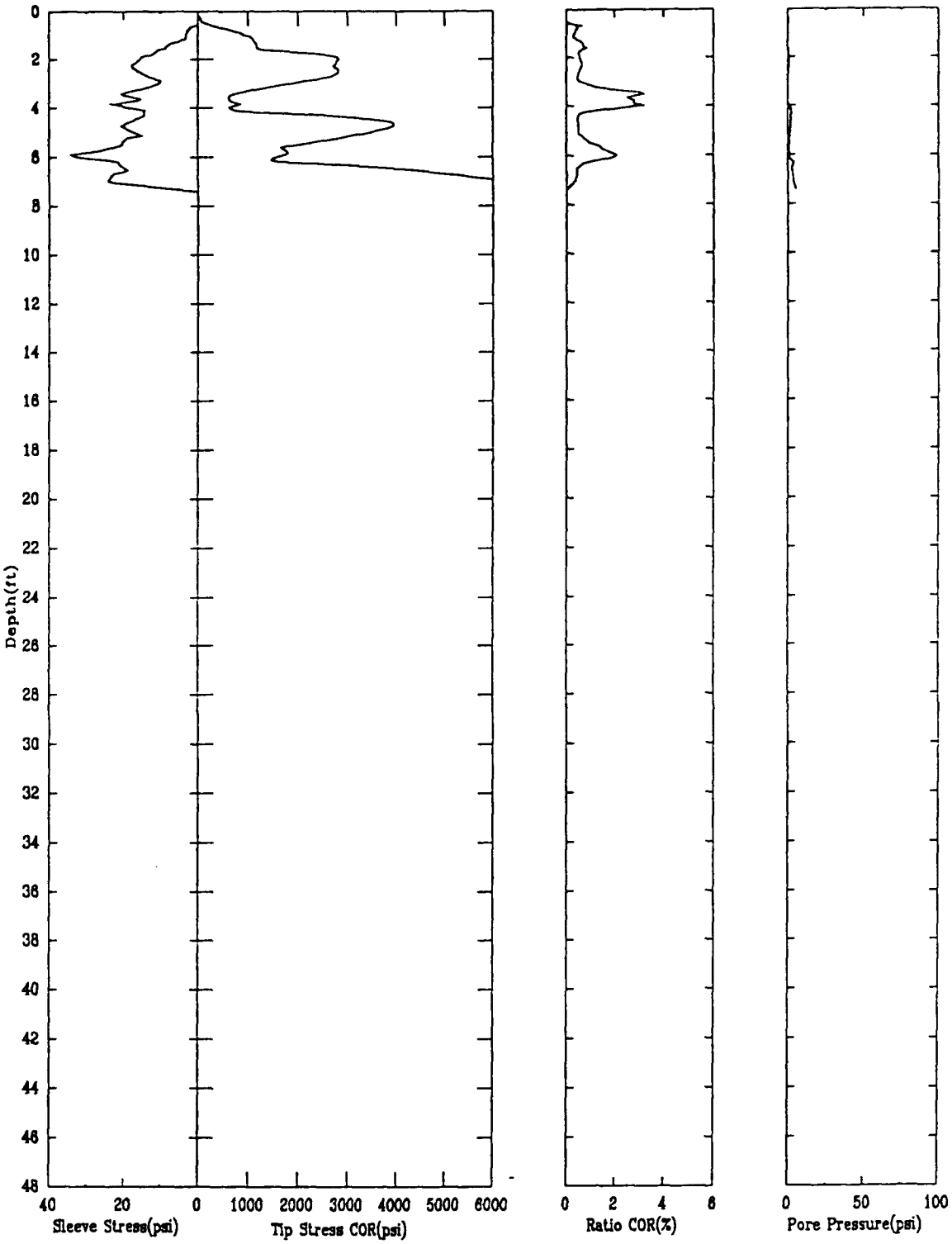
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Dover Air Force Base



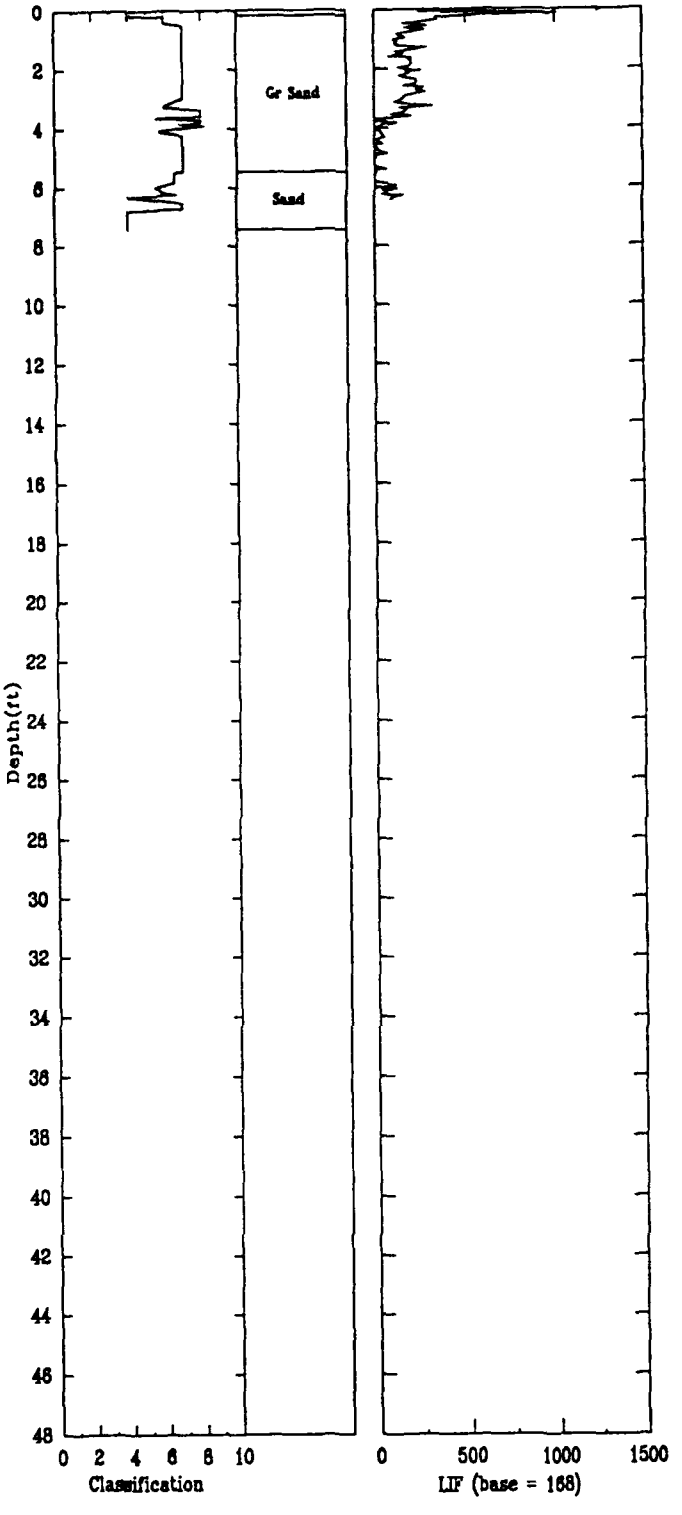
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Dover Air Force Base



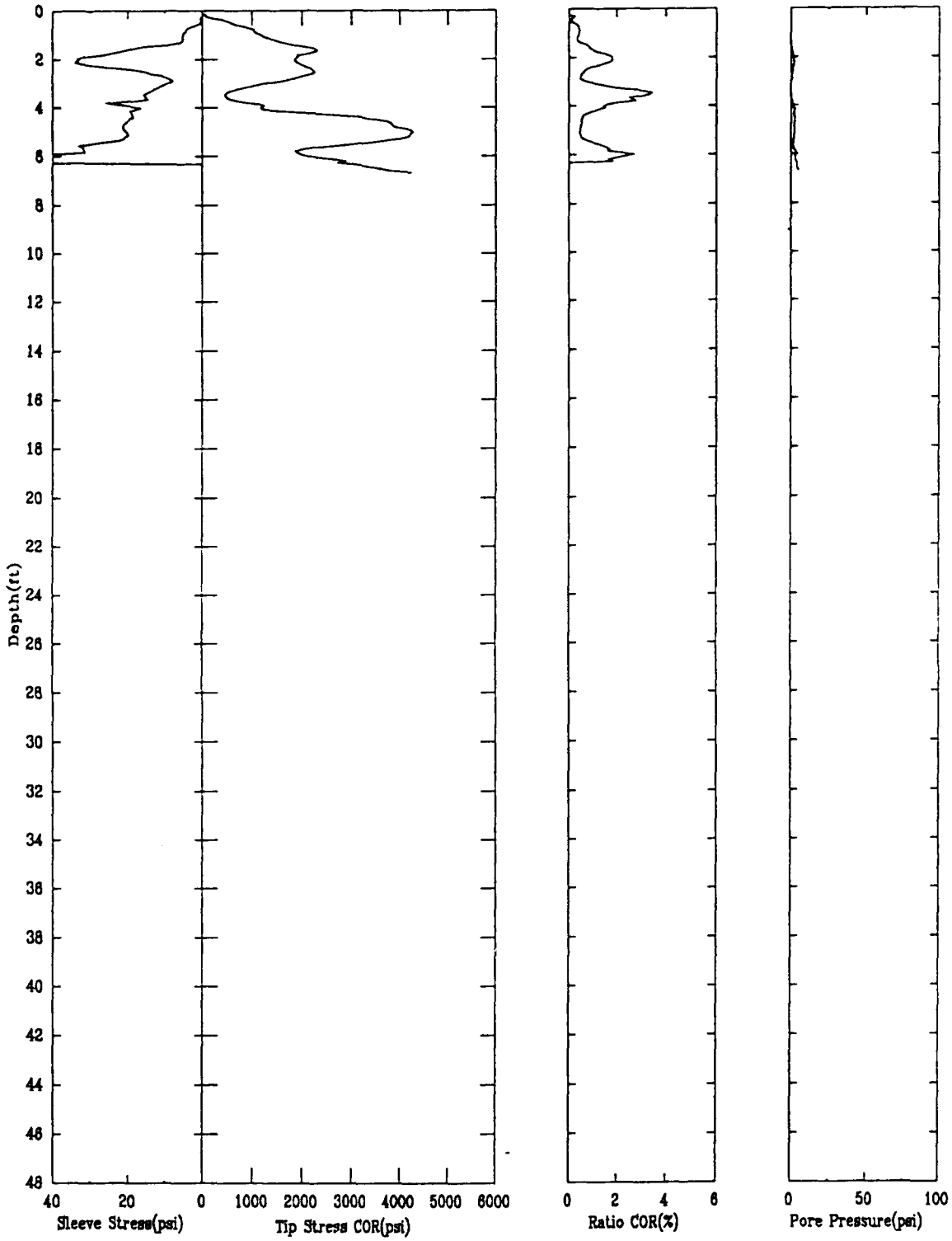
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Dover Air Force Base



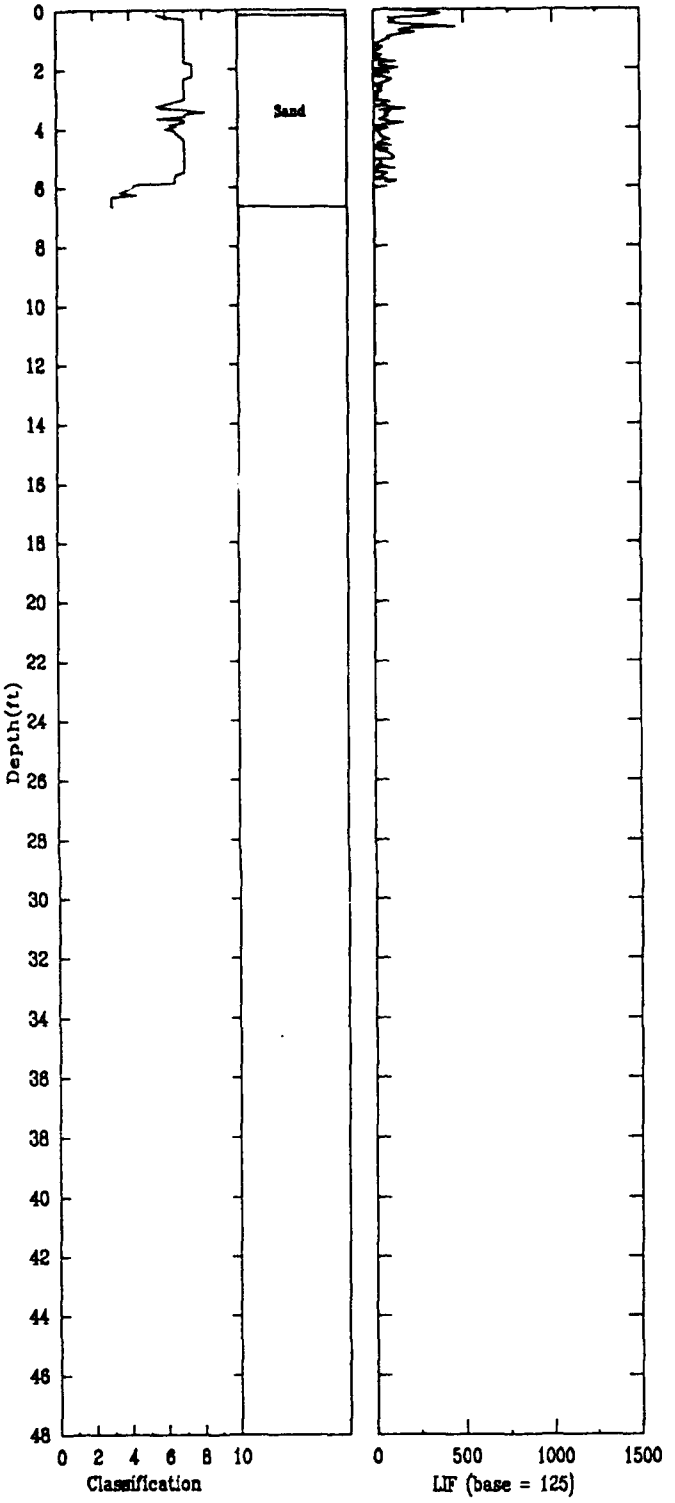
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Dover Air Force Base



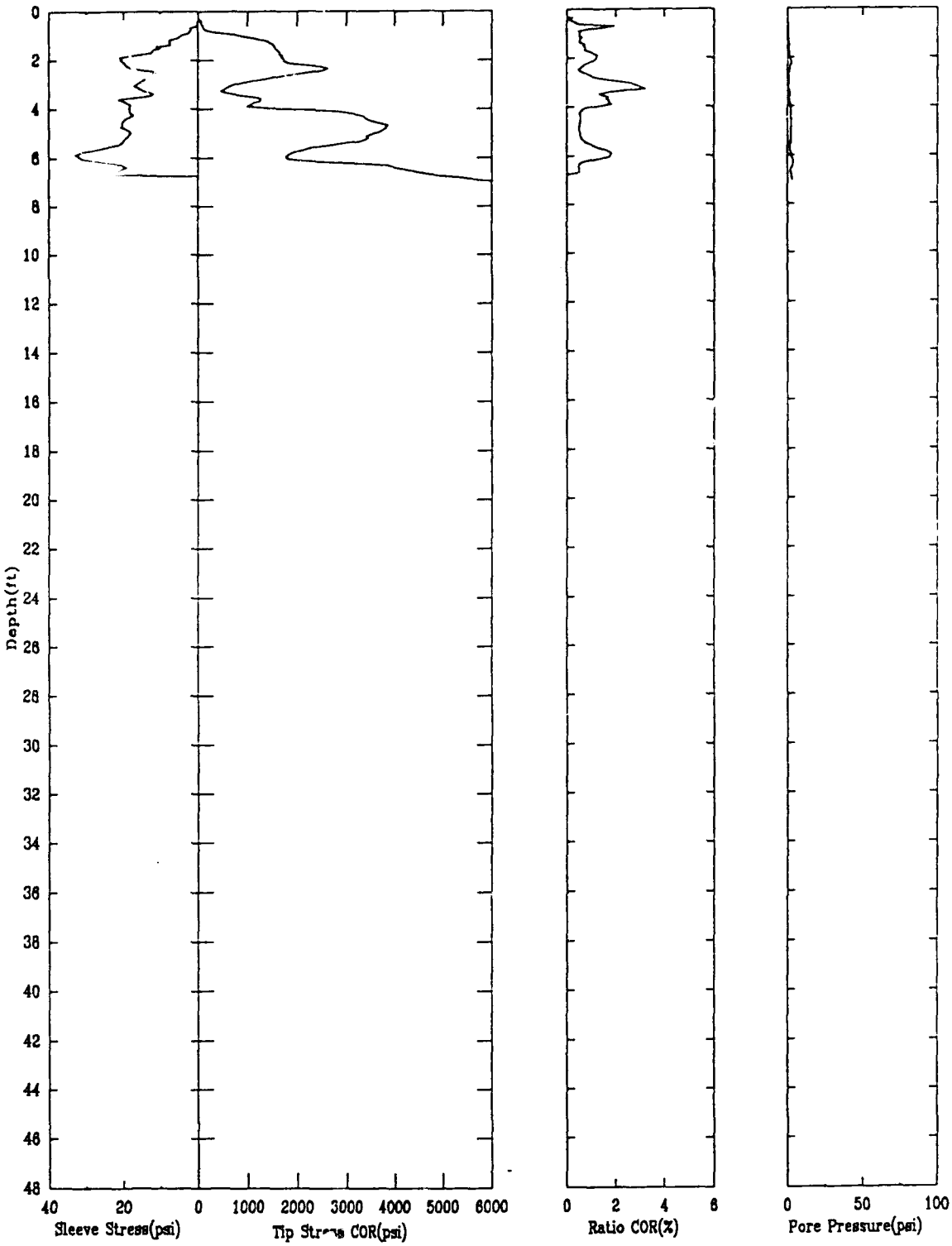
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Dover Air Force Base



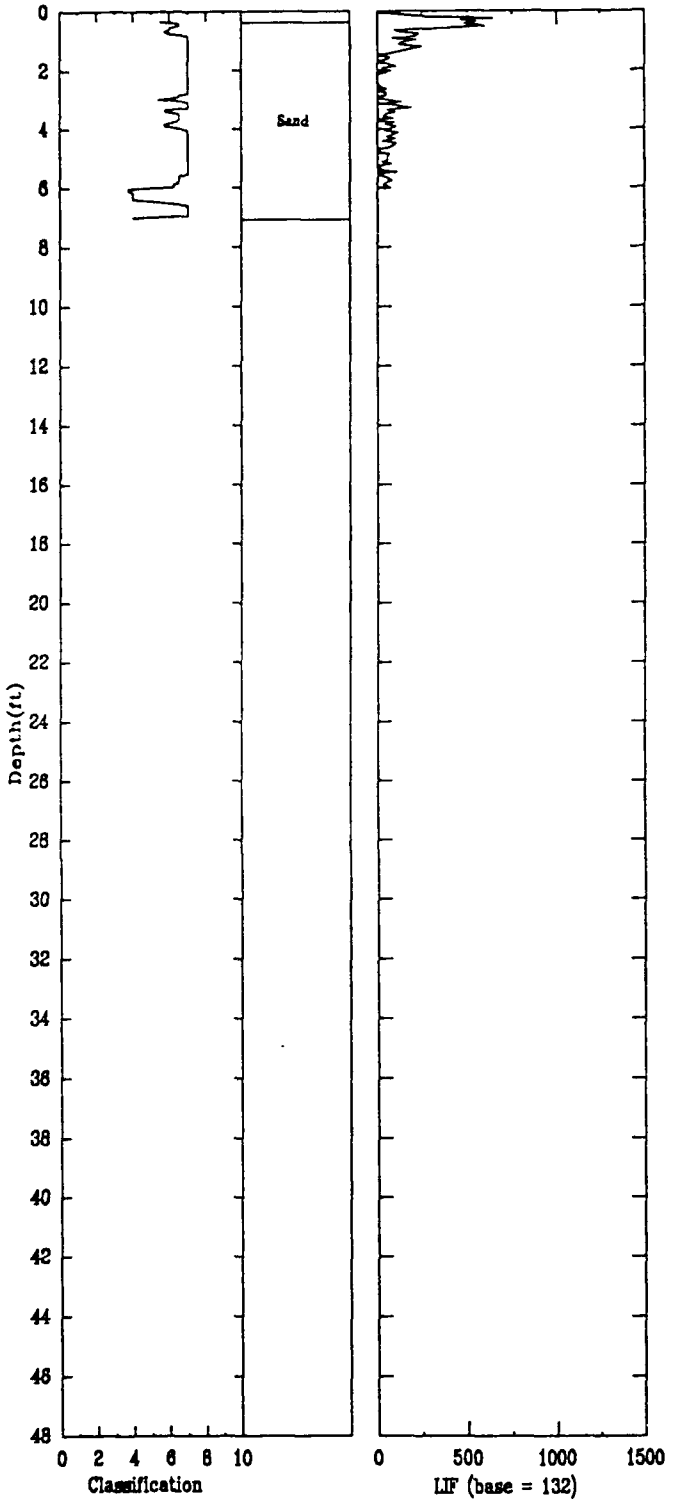
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Dover Air Force Base



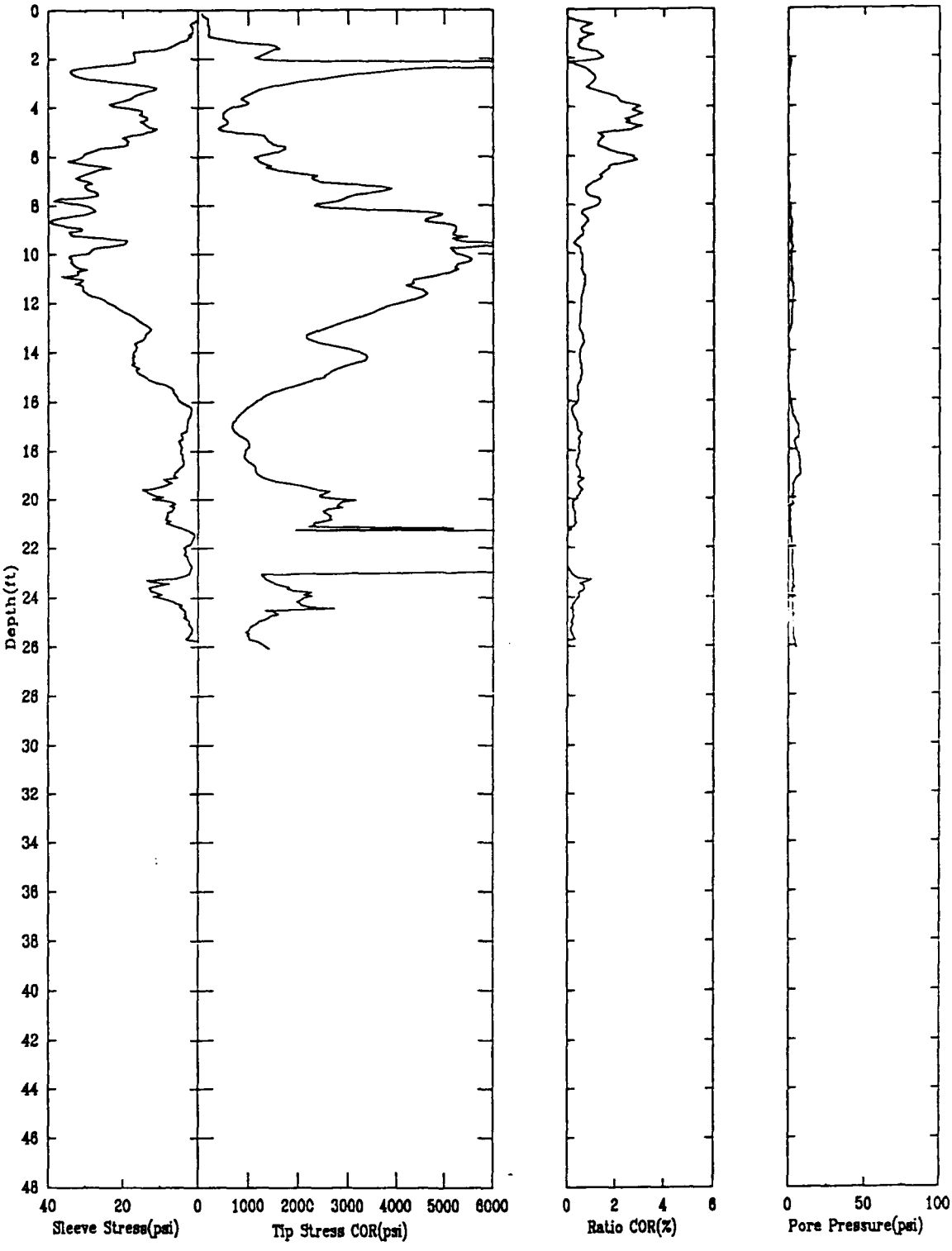
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Dover Air Force Base



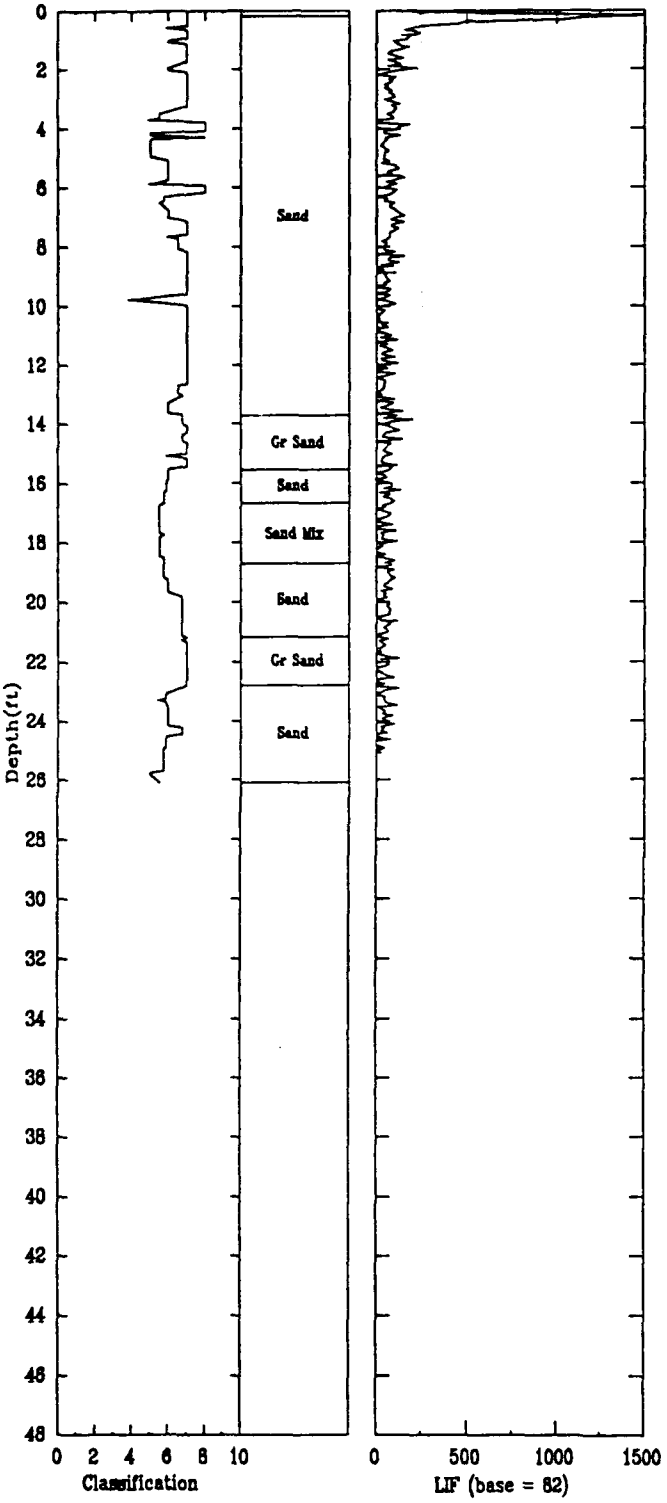
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Dover Air Force Base



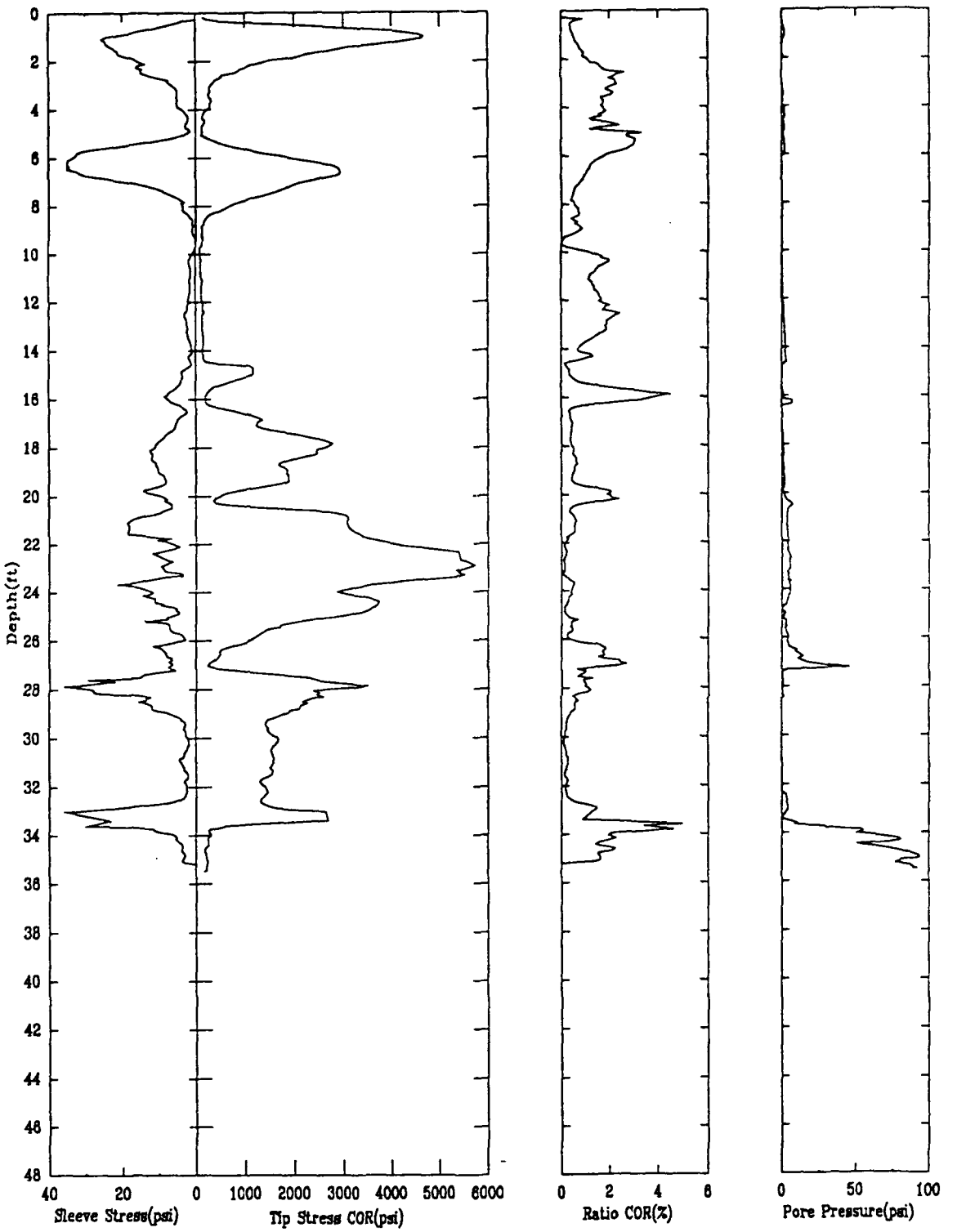
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Dover Air Force Base



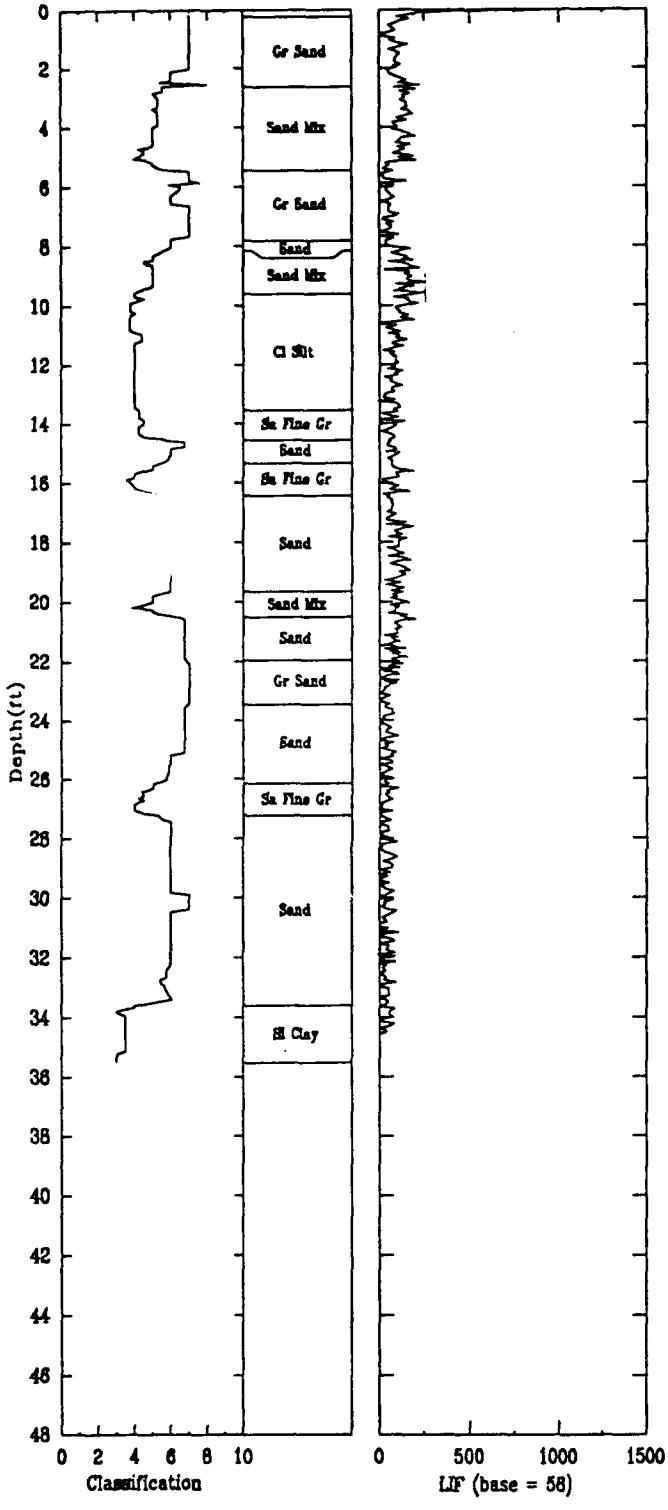
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Dover Air Force Base



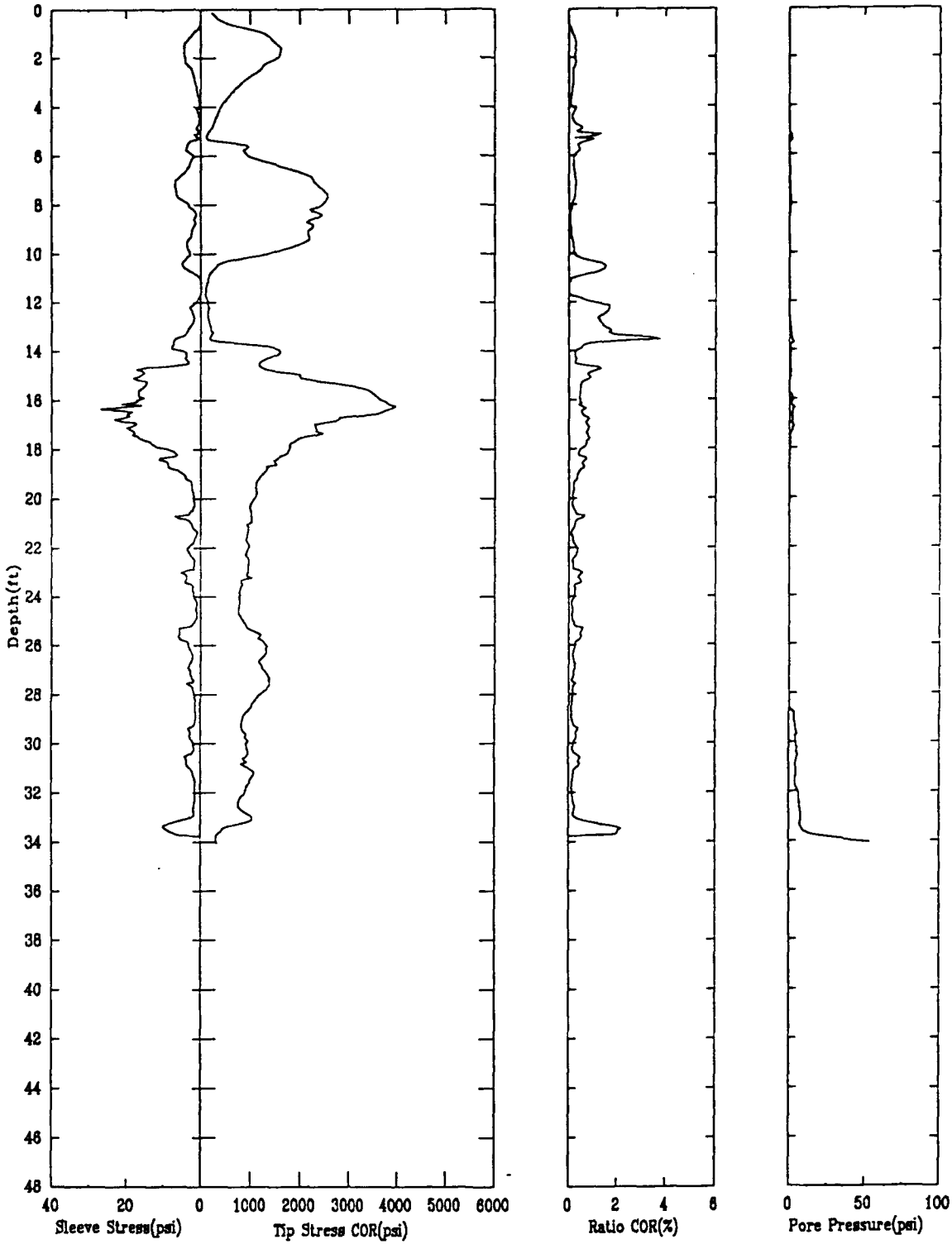
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Dover Air Force Base



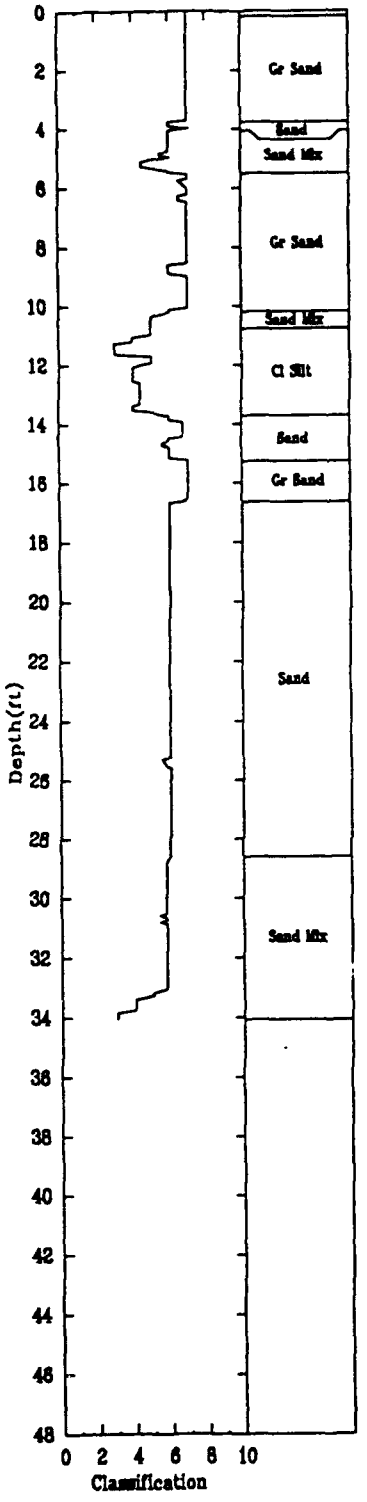
XYZ-CPT-27 APPLIED RESEARCH ASSOCIATES, INC. 04/18/94

Dover Air Force Base



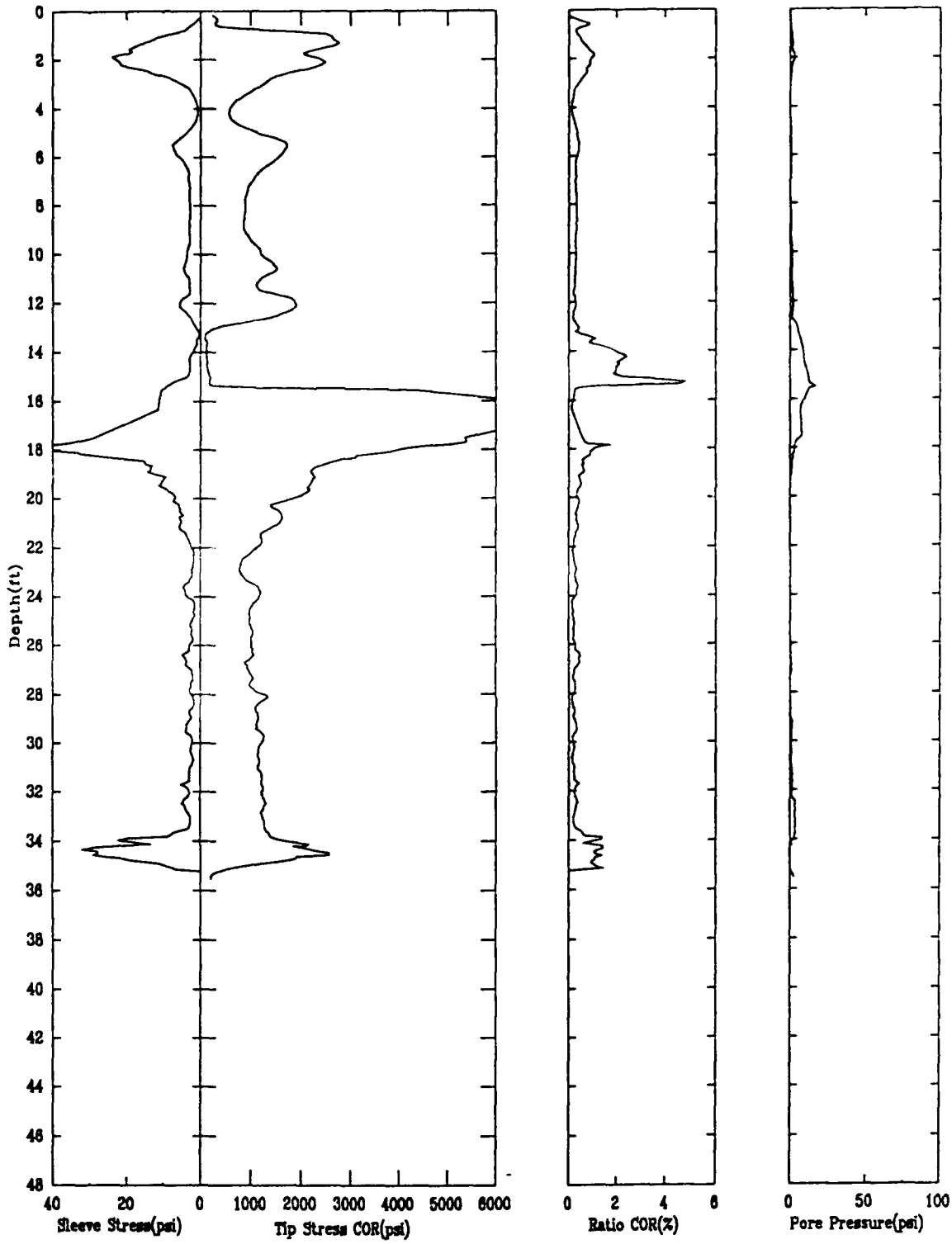
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Dover Air Force Base



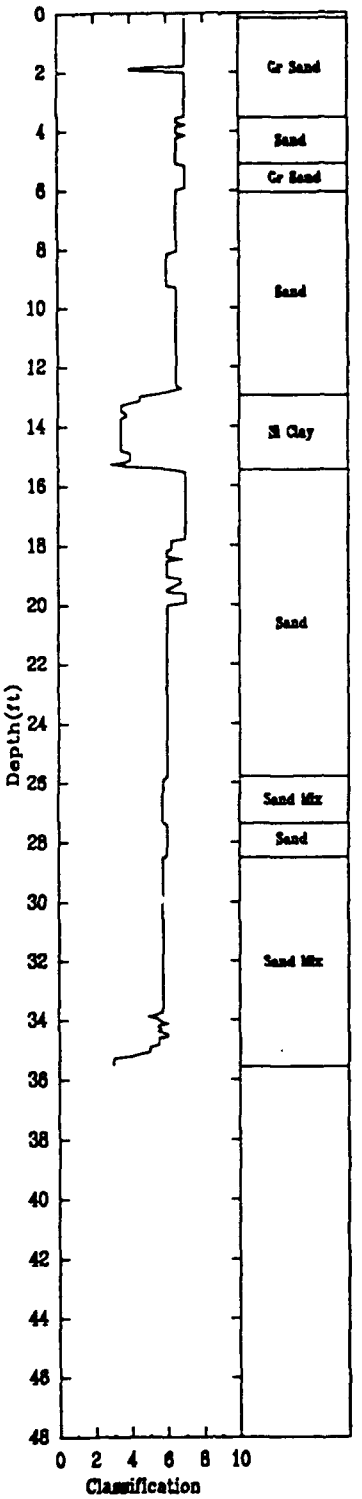
XYZ-CPT-28 APPLIED RESEARCH ASSOCIATES, INC. 04/18/94

Dover Air Force Base



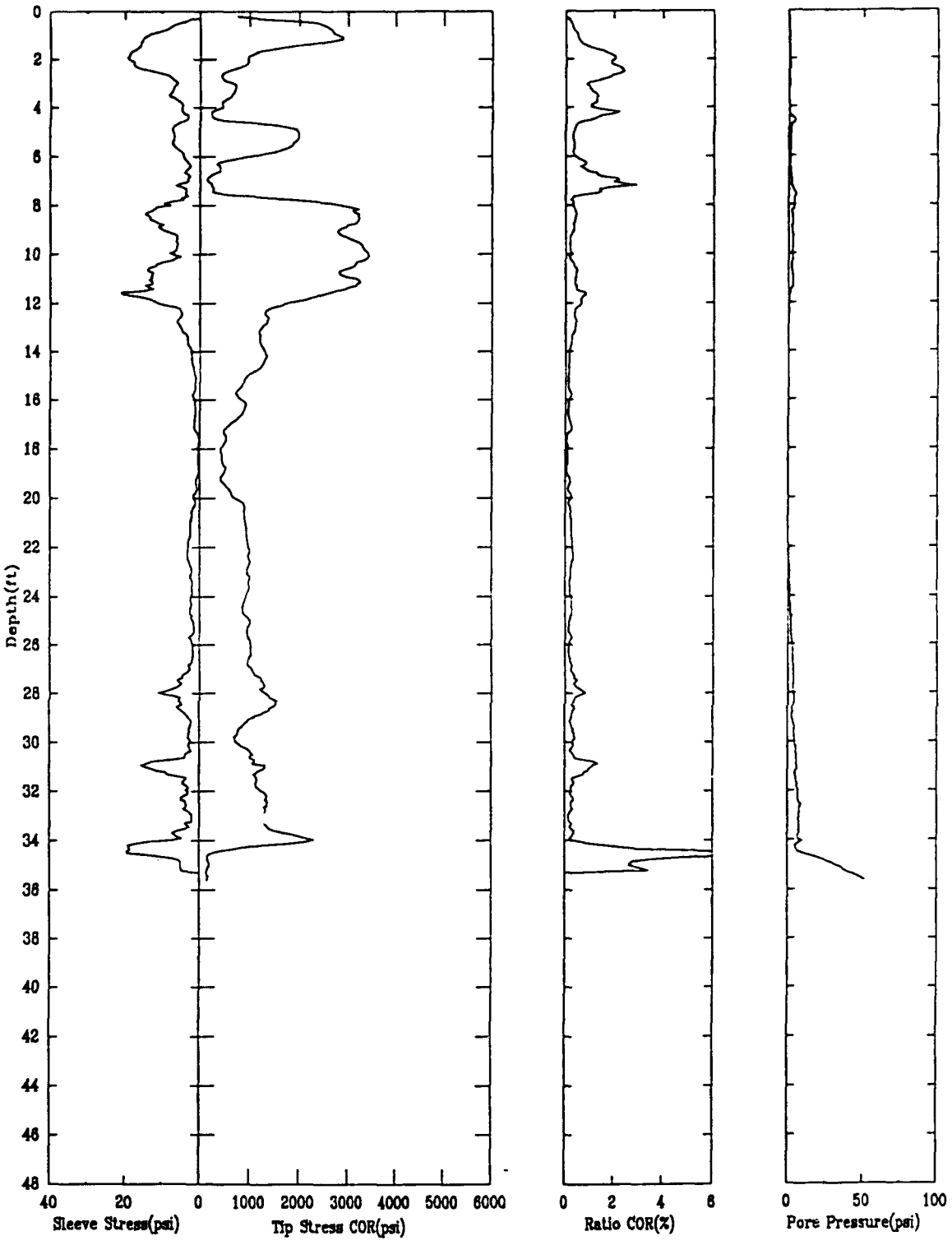
XYZ-CPT-28 APPLIED RESEARCH ASSOCIATES, INC. 04/18/94

Dover Air Force Base



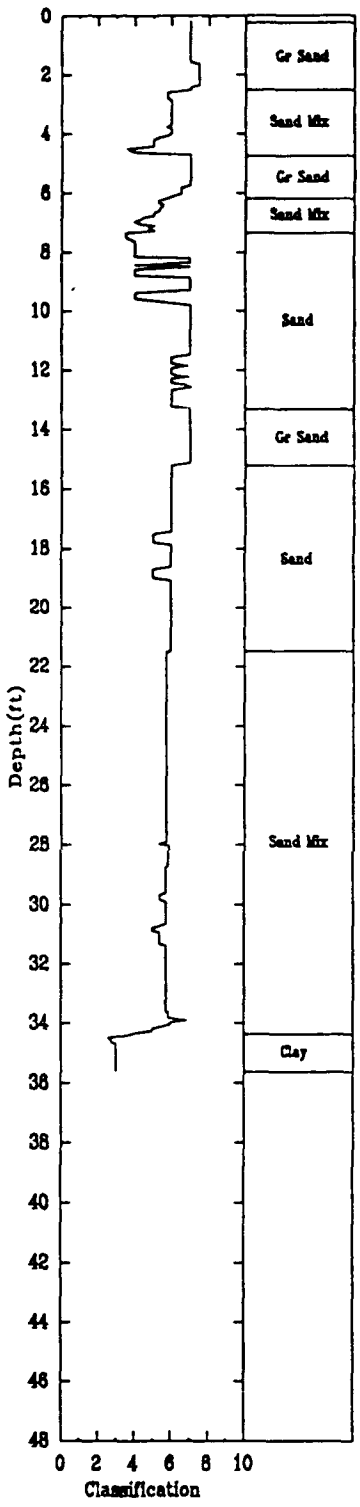
XYZ-CPT-29 APPLIED RESEARCH ASSOCIATES, INC. 04/19/94

Dover Air Force Base



XYZ-CPT-29 APPLIED RESEARCH ASSOCIATES, INC. 04/19/94

Dover Air Force Base



MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT013-L

JOB NUMBER 722450.06 — INSTALLATION DATE 4/12/94 — LOCATION SS27

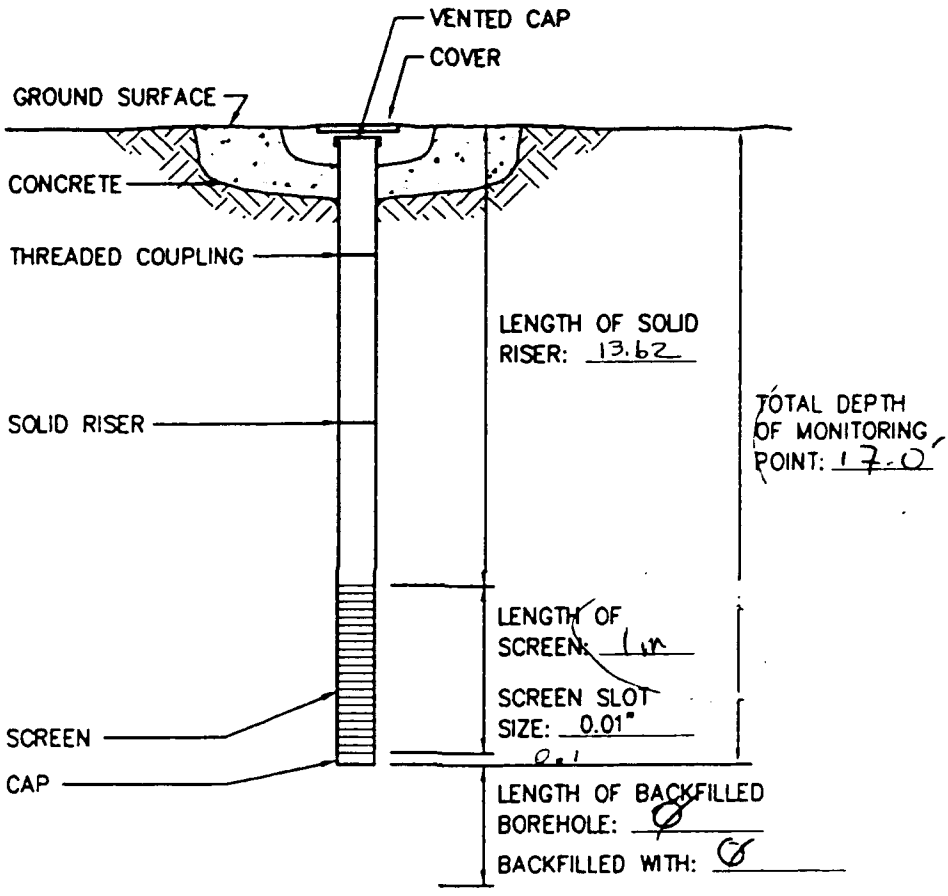
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL 9.38' FEET BELOW DATUM. BTOC

TOTAL MONITORING POINT DEPTH 16.74+.24' FEET BELOW DATUM. BTOC

GROUND SURFACE 0.14' FEET ATOC

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER X42-CPT025

JOB NUMBER 722450.06 INSTALLATION DATE 4-12-94 LOCATION

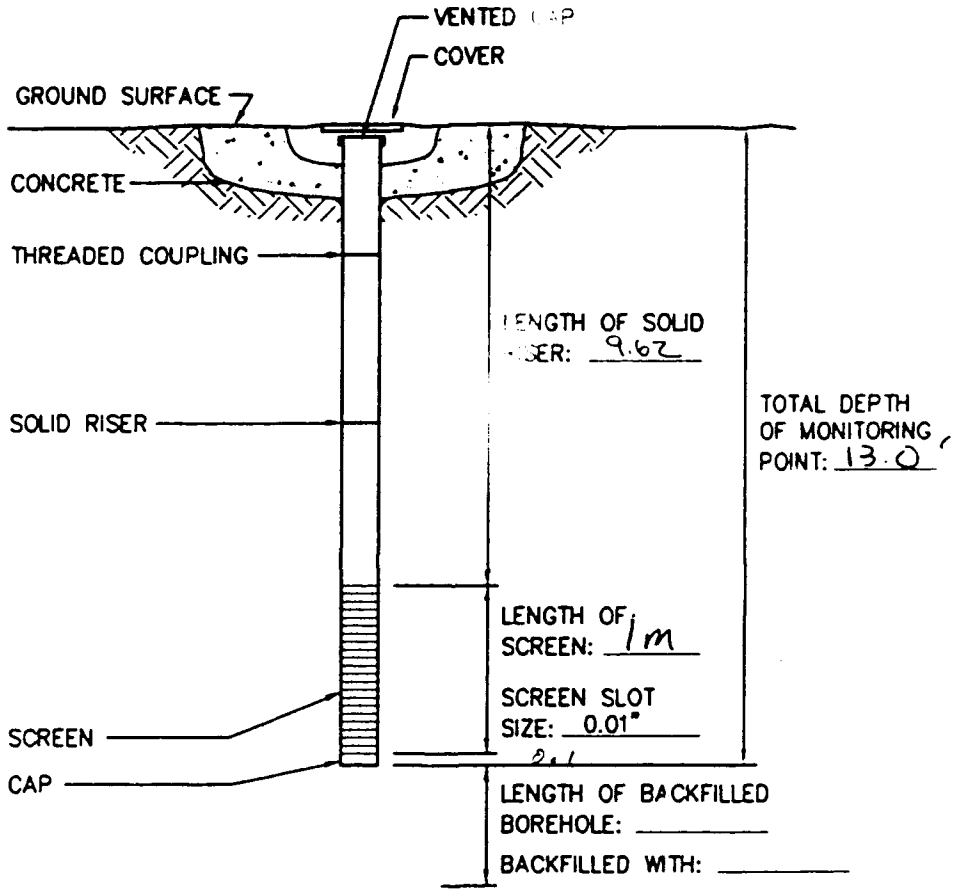
DATUM ELEVATION GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL ½" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL ½" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL 7.43' FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 13.06+.09' FEET BELOW DATUM.

GROUND SURFACE FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

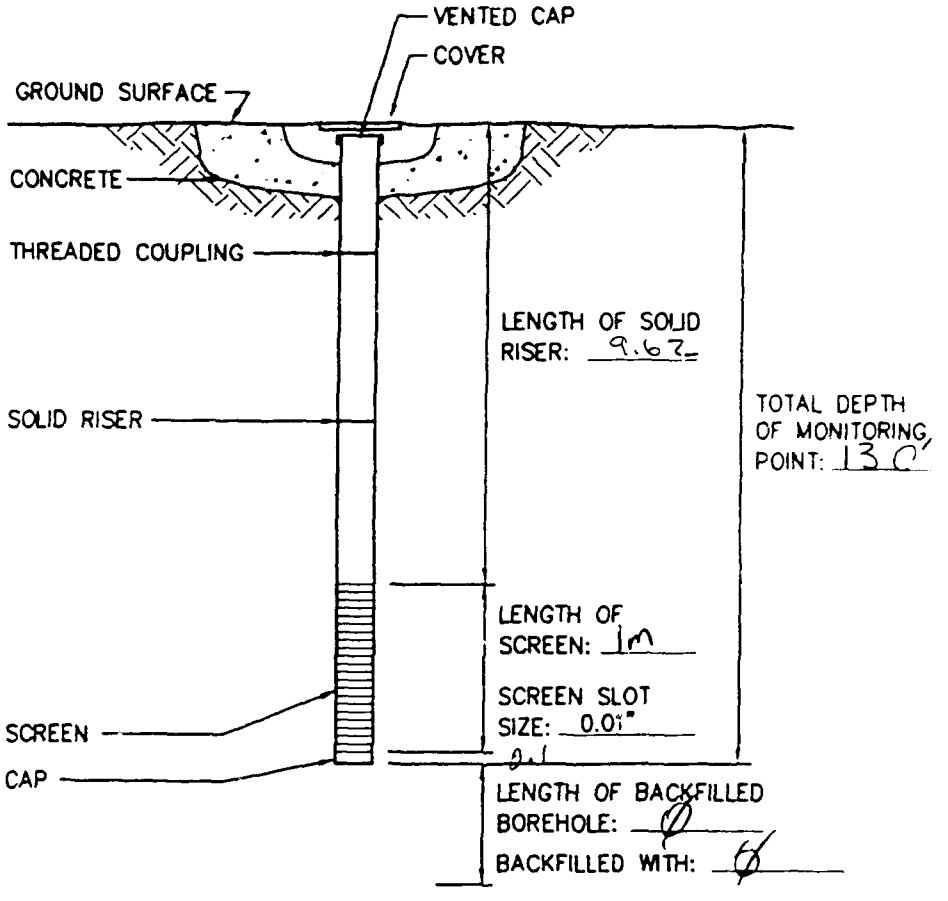
Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB
MONITORING POINT NUMBER XY2-CPT03
JOB NUMBER 722450.06
INSTALLATION DATE 3/2/94
LOCATION SD29
DATUM ELEVATION
GROUND SURFACE ELEVATION
DATUM FOR WATER LEVEL MEASUREMENT TOC
SCREEN DIAMETER & MATERIAL 1/2" ID PVC
SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 1/2" ID PVC
BOREHOLE DIAMETER 1.75"
CONE PENETROMETER CONTRACTOR ARA, INC
ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL 5.35' FEET BELOW DATUM.
TOTAL MONITORING POINT DEPTH 12.73' + .29' STICK FEET BELOW DATUM.
GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

940N0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XY2-CITCW521F

JOB NUMBER 722450.06 — INSTALLATION DATE 4/12/97 — LOCATION SS2

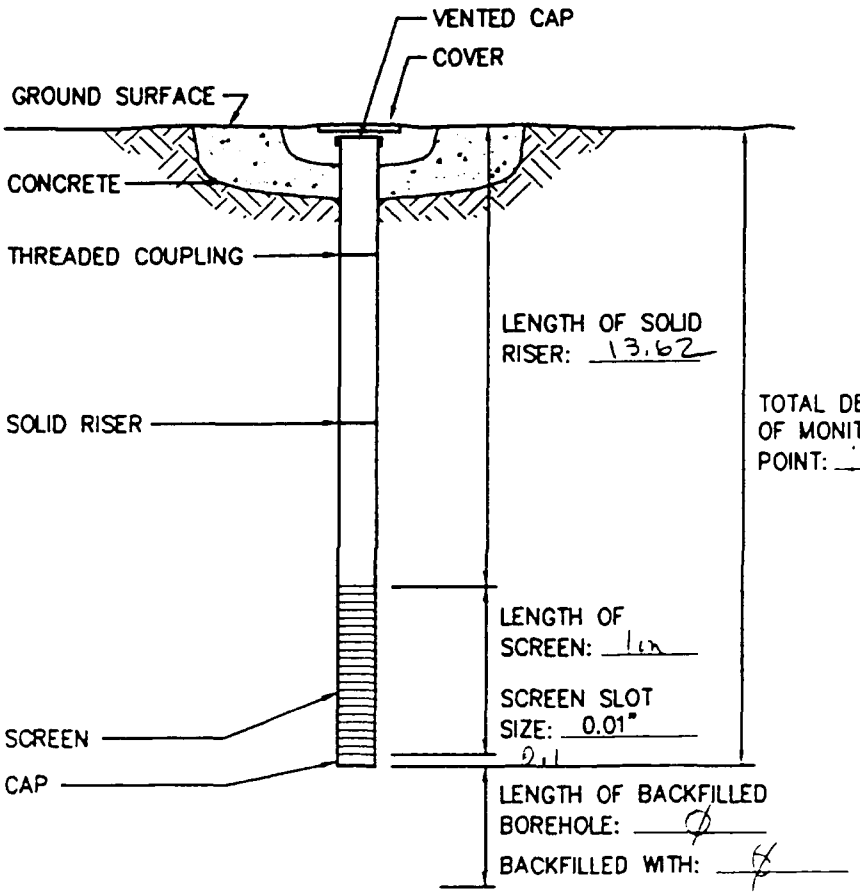
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1½" ID PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1½" ID PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL 8.57' FEET, BTOC BELOW DATUM.

TOTAL MONITORING POINT DEPTH 16.55' FEET BTOC BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

940N0363, C4/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-MPT06

JOB NUMBER 722450.06 — INSTALLATION DATE 4/12/94* — LOCATION

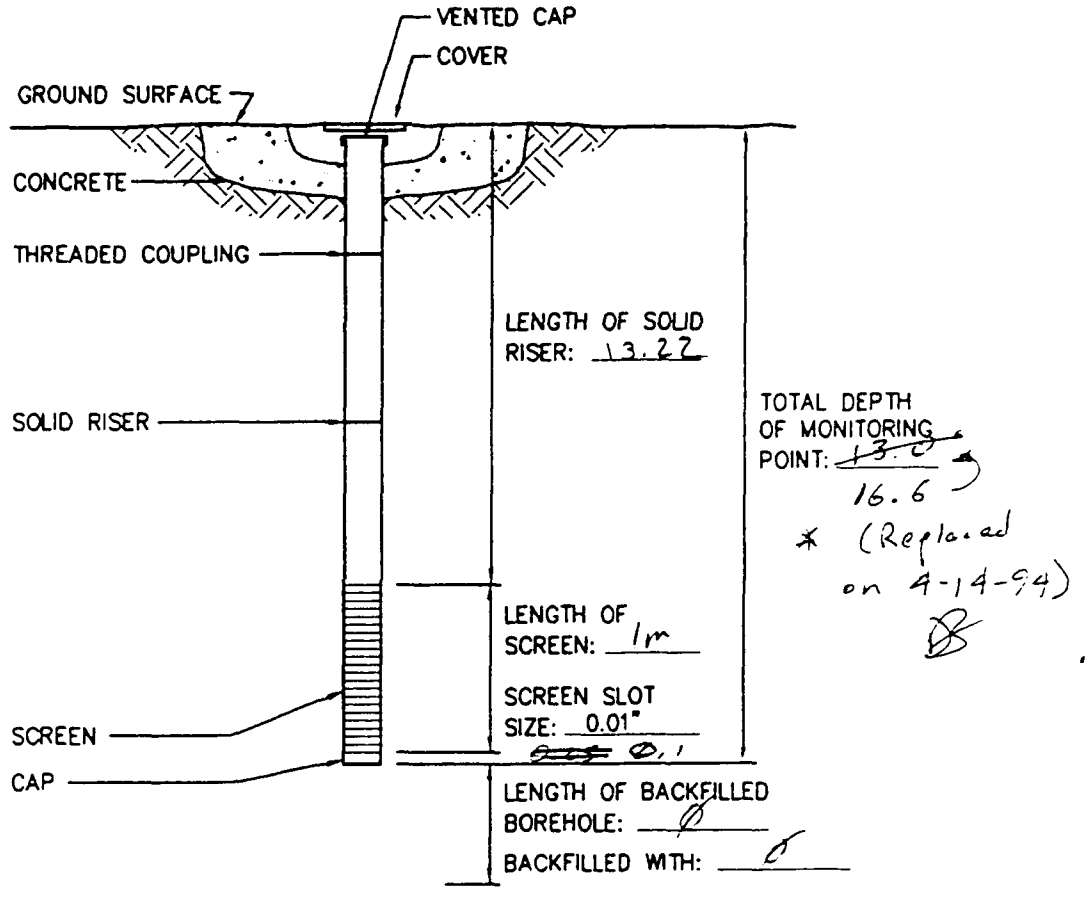
DATUM ELEVATION — GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL 7.52' FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 12.41' BTOC. FEET BELOW DATUM. +c. 29

GROUND SURFACE ~.20' FEET ATLL

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT6D-LIF

JOB NUMBER 722450.06 — INSTALLATION DATE 4/14/94 — LOCATION SS27

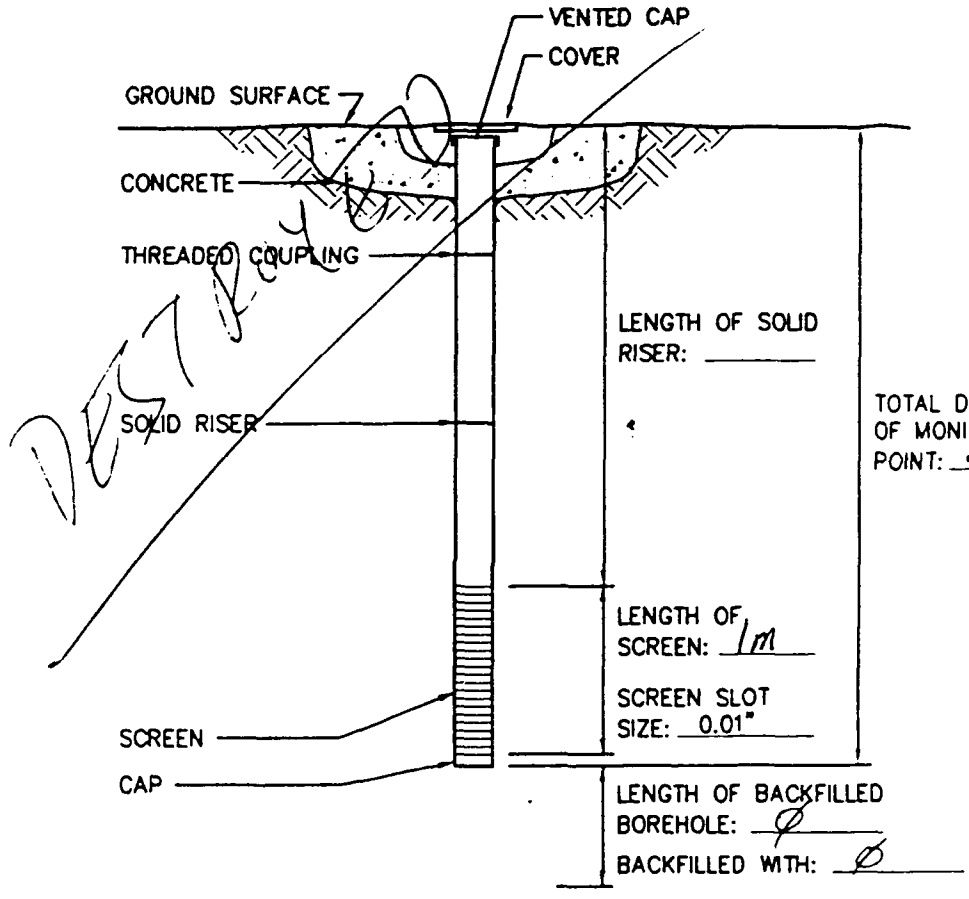
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER SW2 - CPT-SC11F

JOB NUMBER 722450.06 — INSTALLATION DATE 4/13/94 — LOCATION SS27

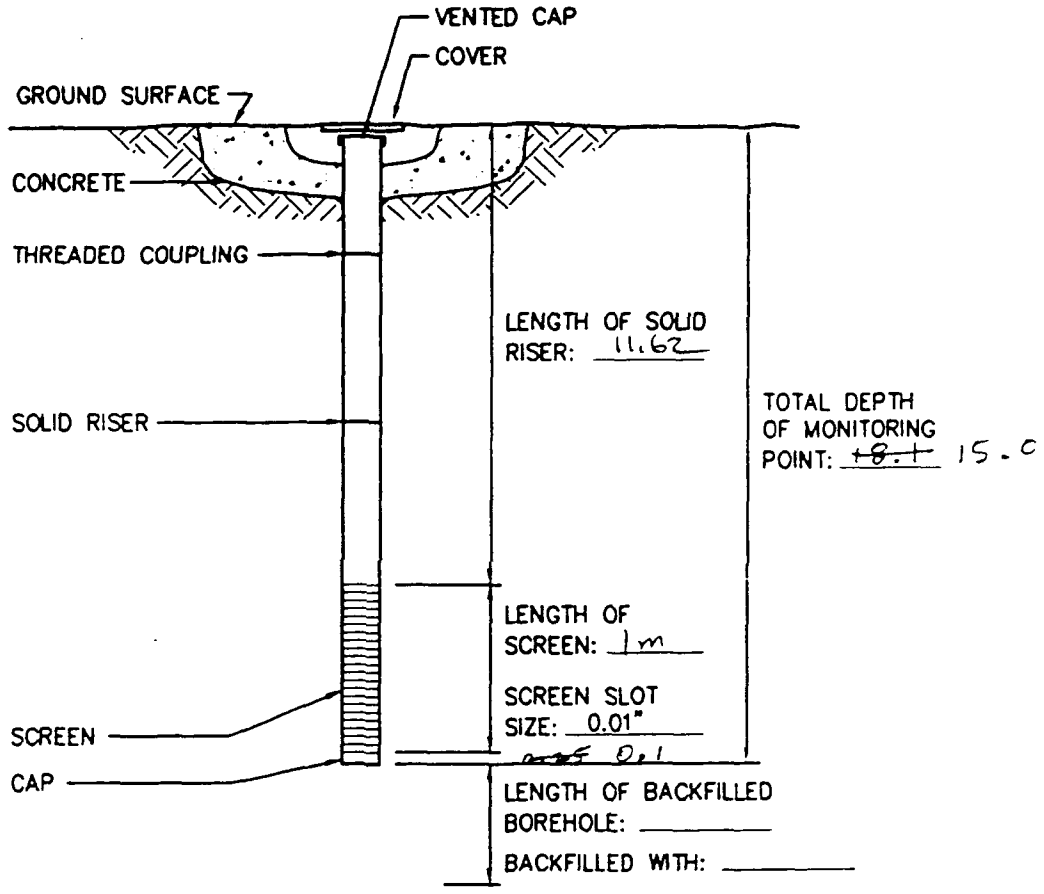
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" ID PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" ID PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

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JOB NUMBER 722450.06 — INSTALLATION DATE 4/13/94 — LOCATION SS27

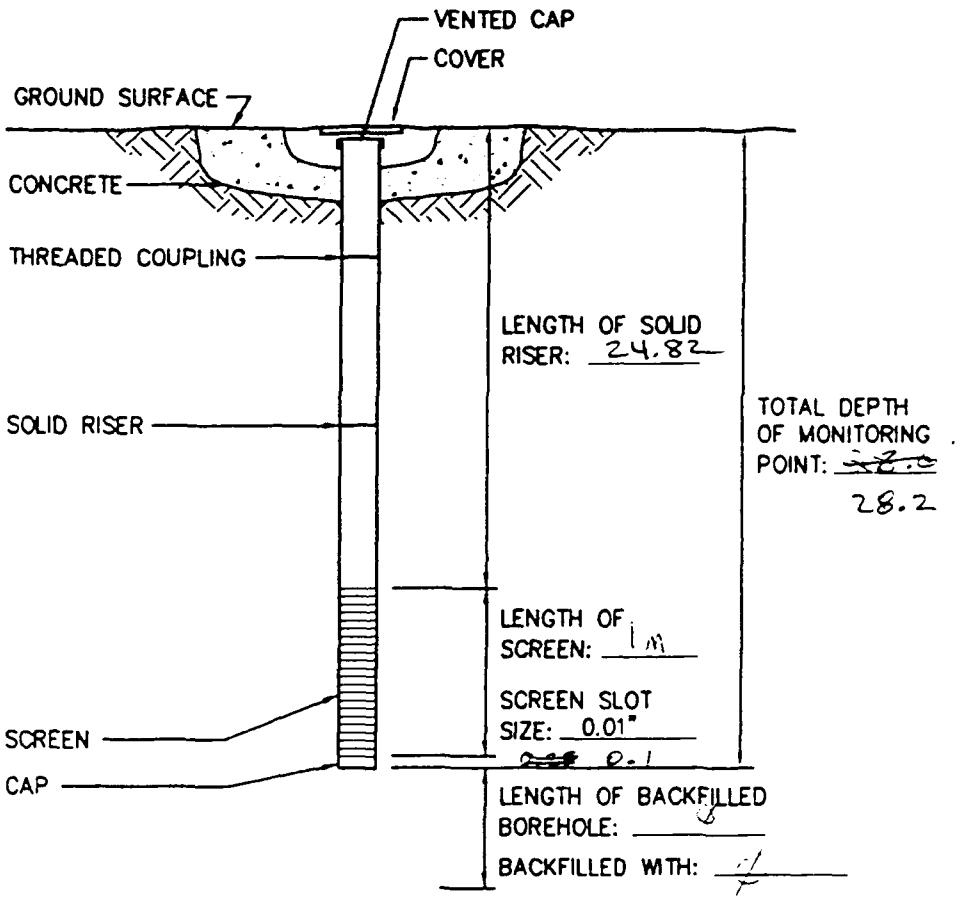
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" ID PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" ID PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER MW2-PT28P

JOB NUMBER 722450.06 — INSTALLATION DATE 4-15-94 — LOCATION SS27

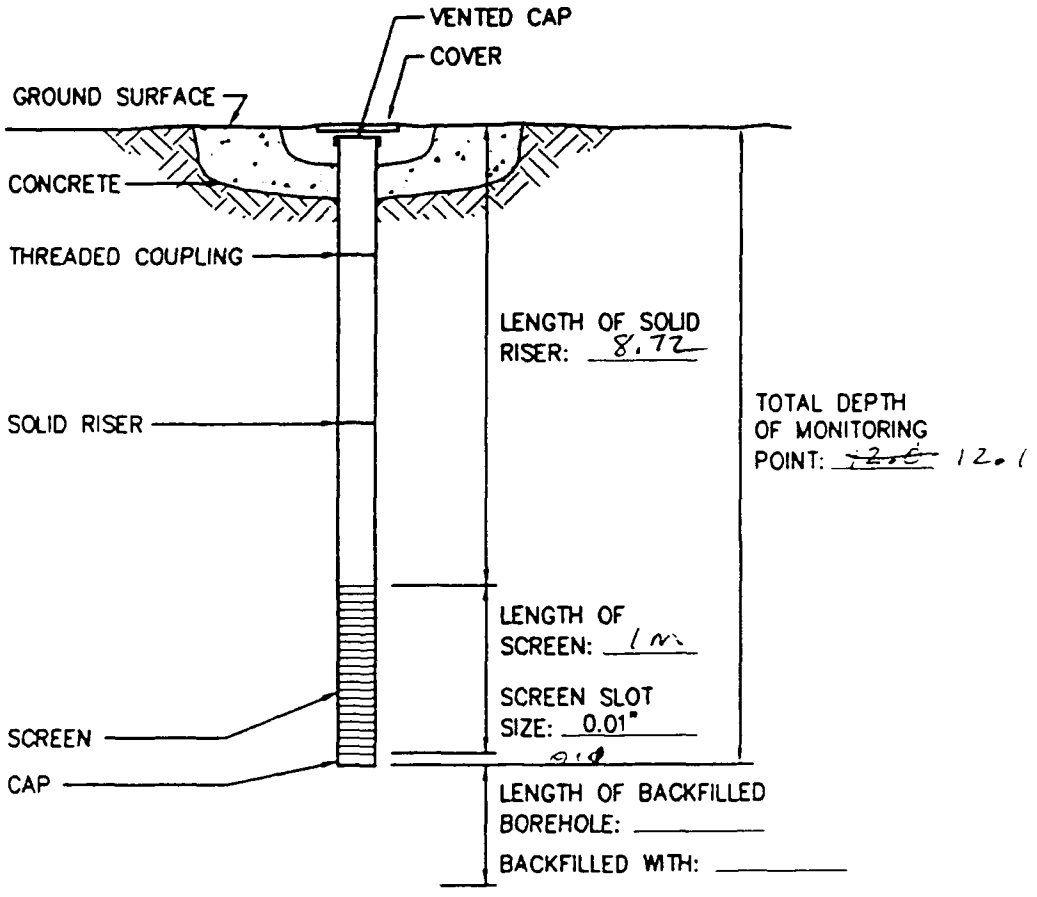
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363. 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XYZ-CPT085

JOB NUMBER 722450.06 INSTALLATION DATE 4-13-94 LOCATION 5527

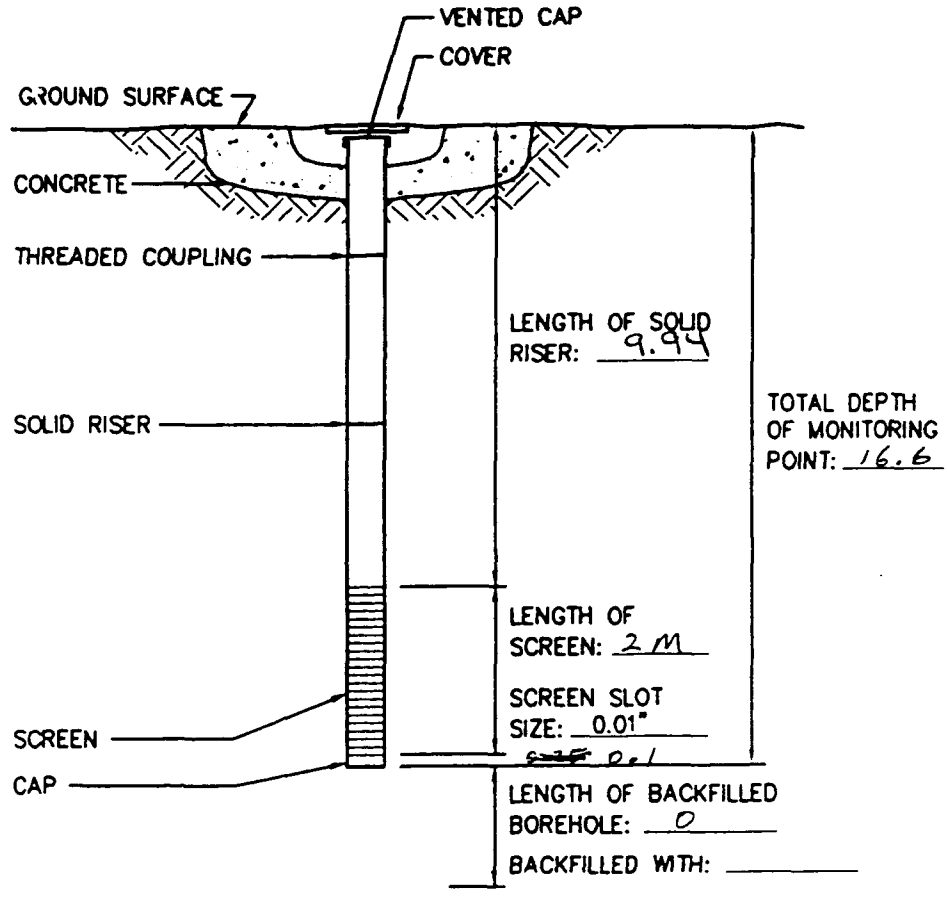
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" ID PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" ID PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE ~~KC/TH~~ DB Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

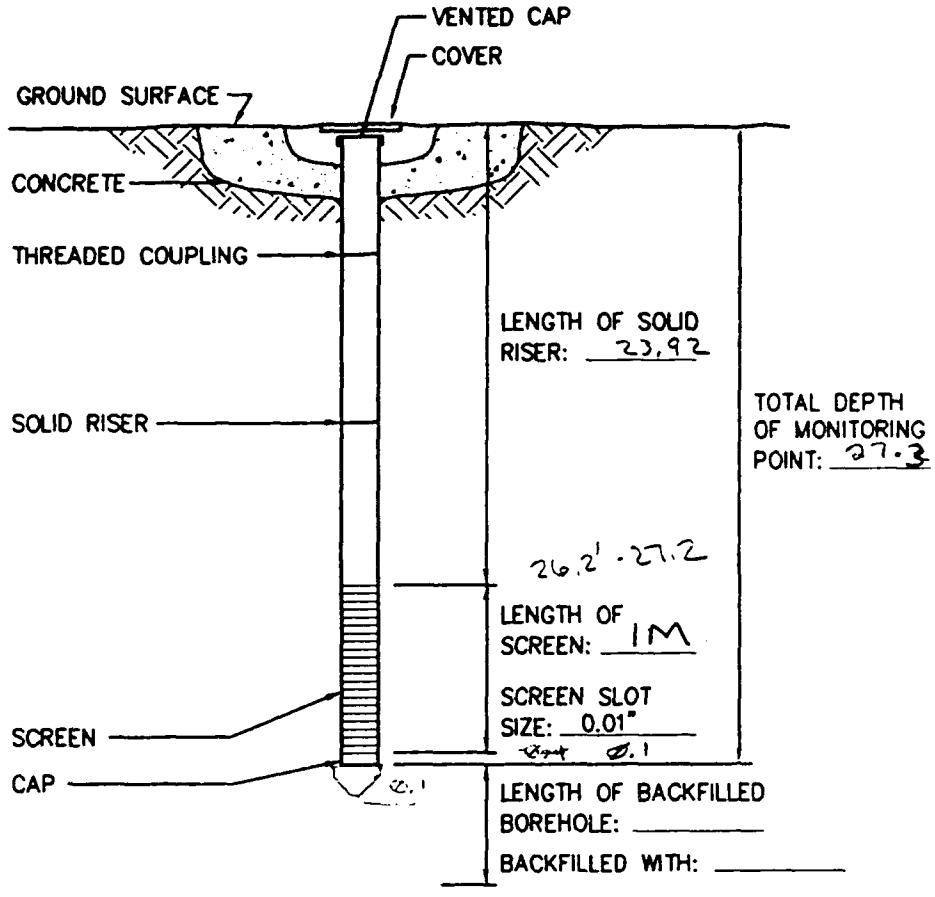
Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ (per 08 D)
JOB NUMBER 722450.06 — INSTALLATION DATE 4-18-94 — LOCATION SS27
DATUM ELEVATION ____ — GROUND SURFACE ELEVATION ____
DATUM FOR WATER LEVEL MEASUREMENT TOC
SCREEN DIAMETER & MATERIAL 1½" PVC — SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 1½" PVC — BOREHOLE DIAMETER 1.75"
CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL ____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH ____ FEET BELOW DATUM.

GROUND SURFACE ____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XYZ-CPT095

JOB NUMBER 722450.06 INSTALLATION DATE 4-13-94 LOCATION SS27

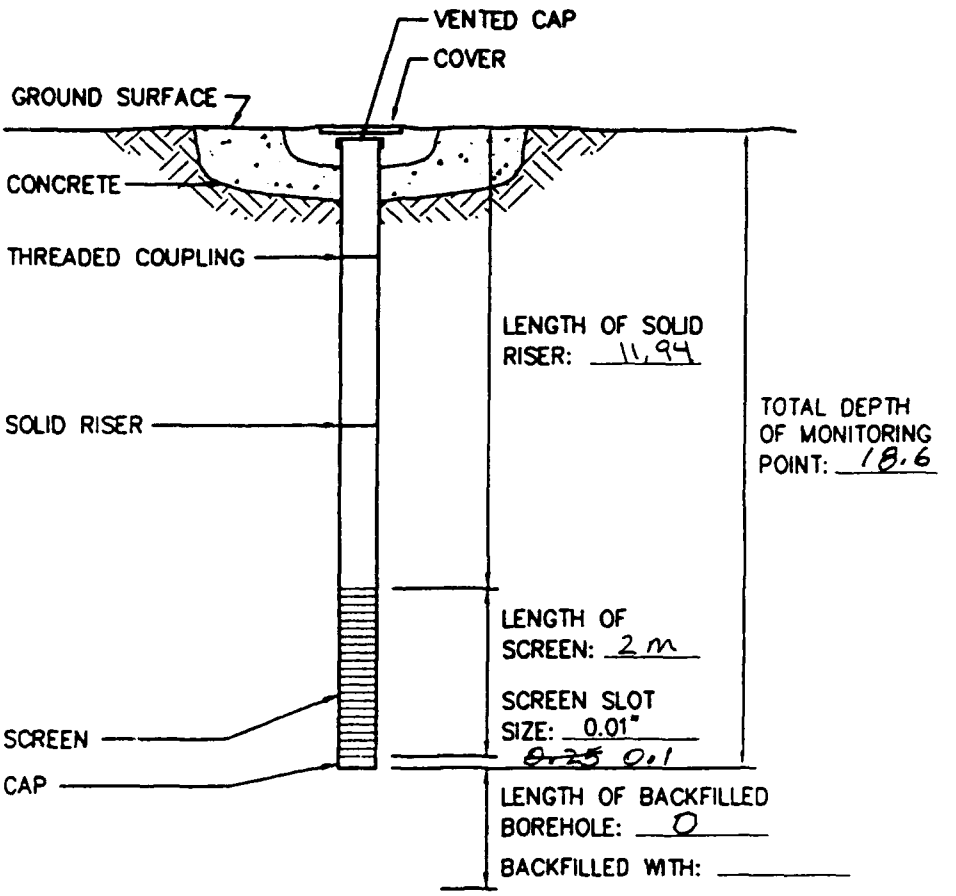
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE ~~KC/TH~~ D.C.B.



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

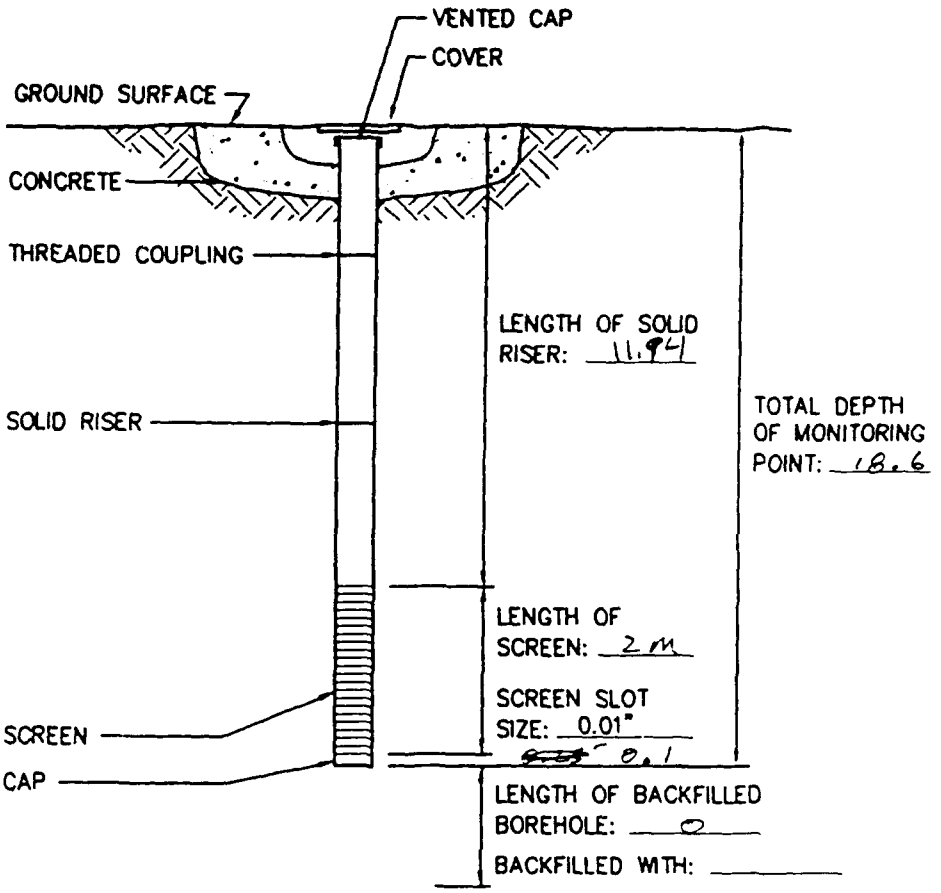
Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT10S
JOB NUMBER 722450.06 — INSTALLATION DATE 4-13-94 — LOCATION
DATUM ELEVATION — GROUND SURFACE ELEVATION
DATUM FOR WATER LEVEL MEASUREMENT TOC
SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"
CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE ~~KC/TH~~ Don Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XYZ-CPT11P

JOB NUMBER 722450.06 INSTALLATION DATE 4-13-94 LOCATION SS27

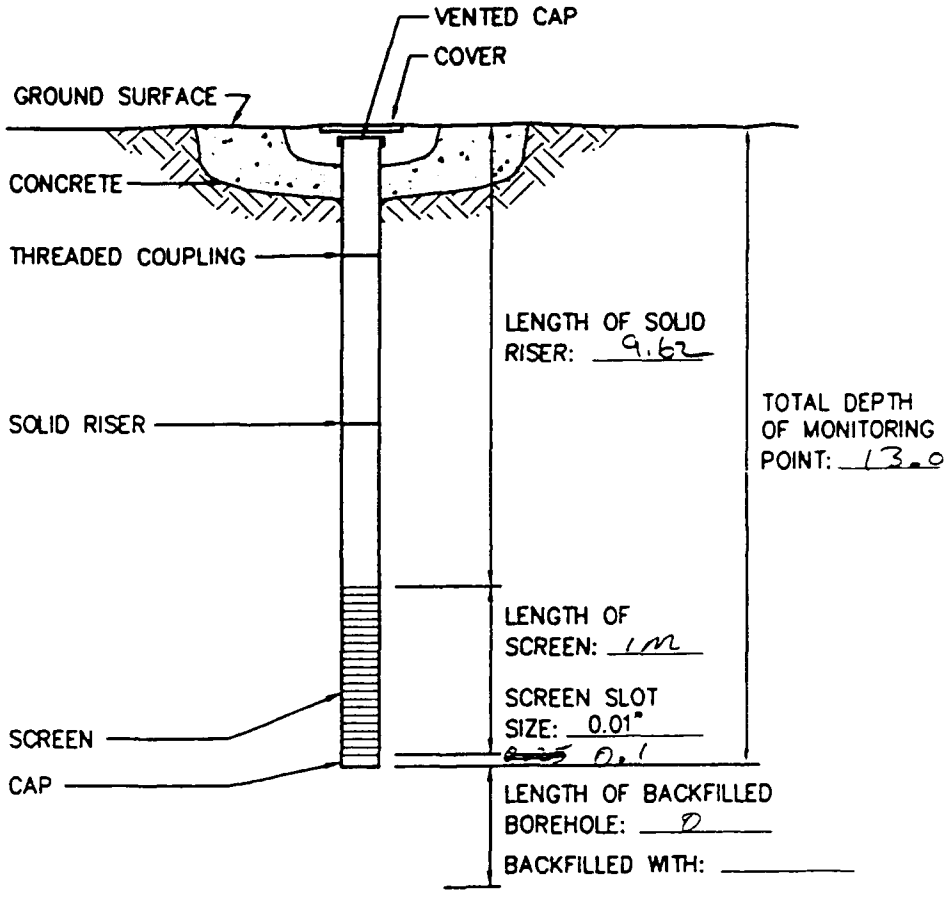
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE ~~KC/TH~~ D. Bangle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT15

JOB NUMBER 722450.06 — INSTALLATION DATE 4-13-94 — LOCATION SS27

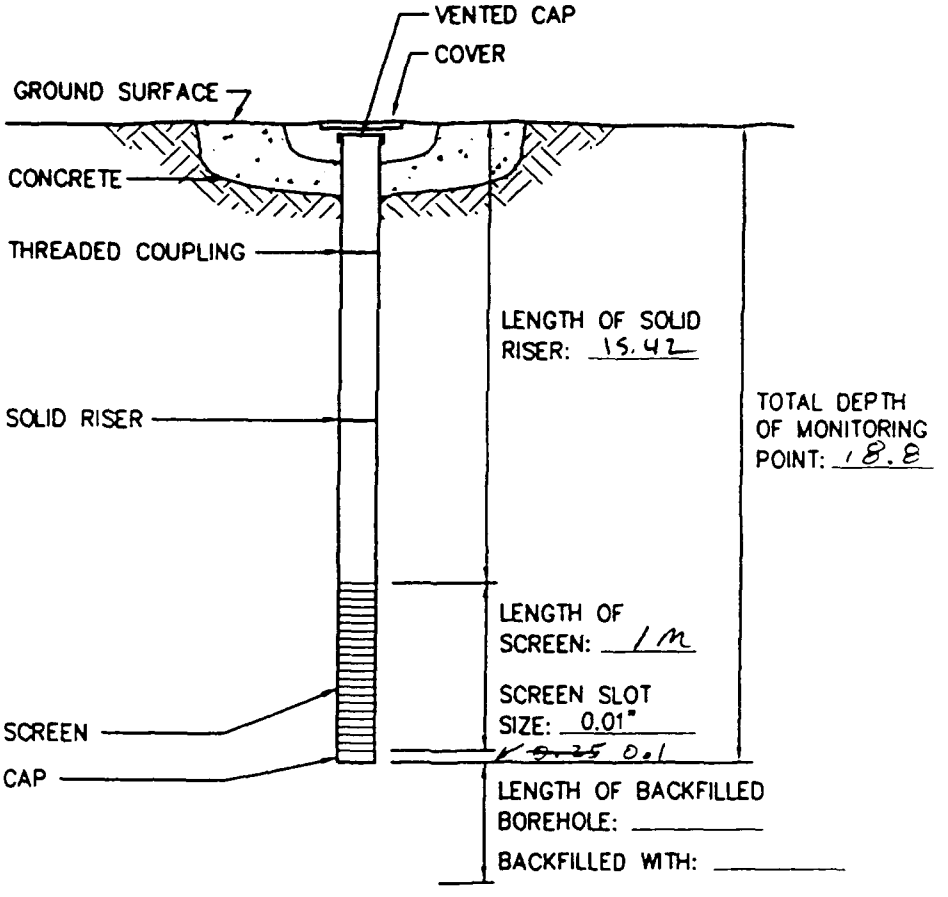
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT12P

JOB NUMBER 722450.06 — INSTALLATION DATE 4-14-94 — LOCATION SSZ

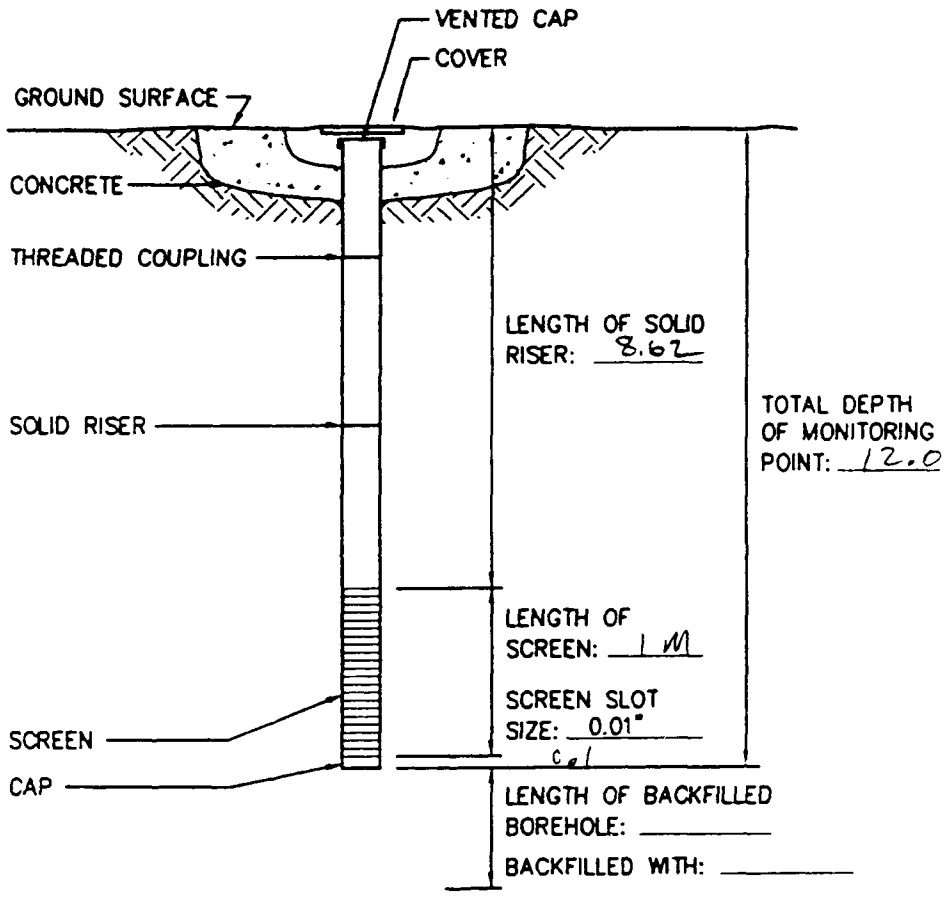
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D. Bayle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CP-125

JOB NUMBER 722450.06 — INSTALLATION DATE 4-14-94 — LOCATION SSZ7

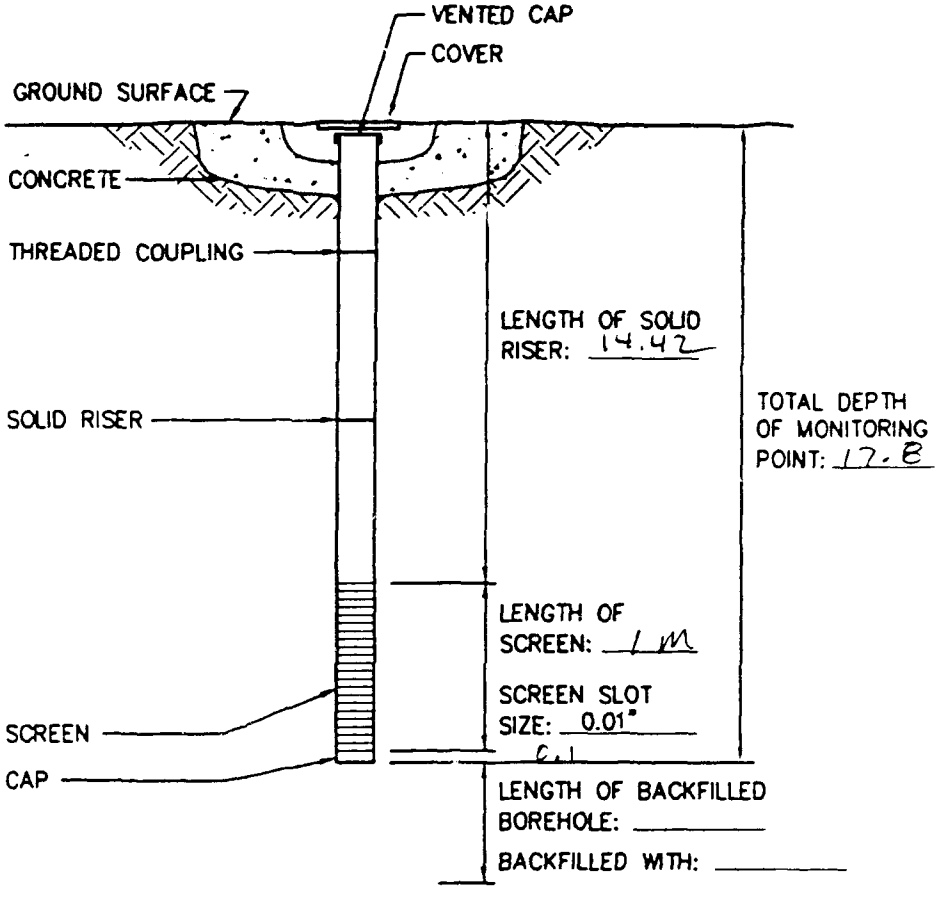
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE ~~KC/TH~~ D. Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT12D

JOB NUMBER 722450.06 — INSTALLATION DATE 4/18/94 — LOCATION

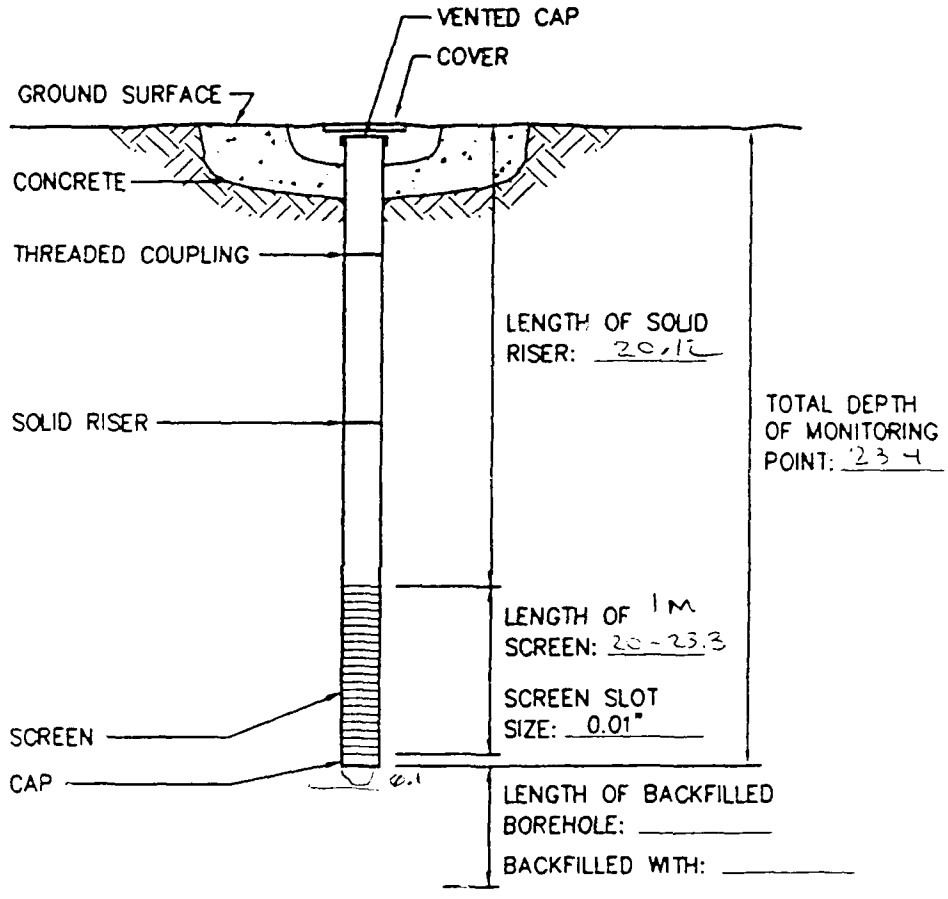
DATUM ELEVATION — GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" ϕ PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" ϕ PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

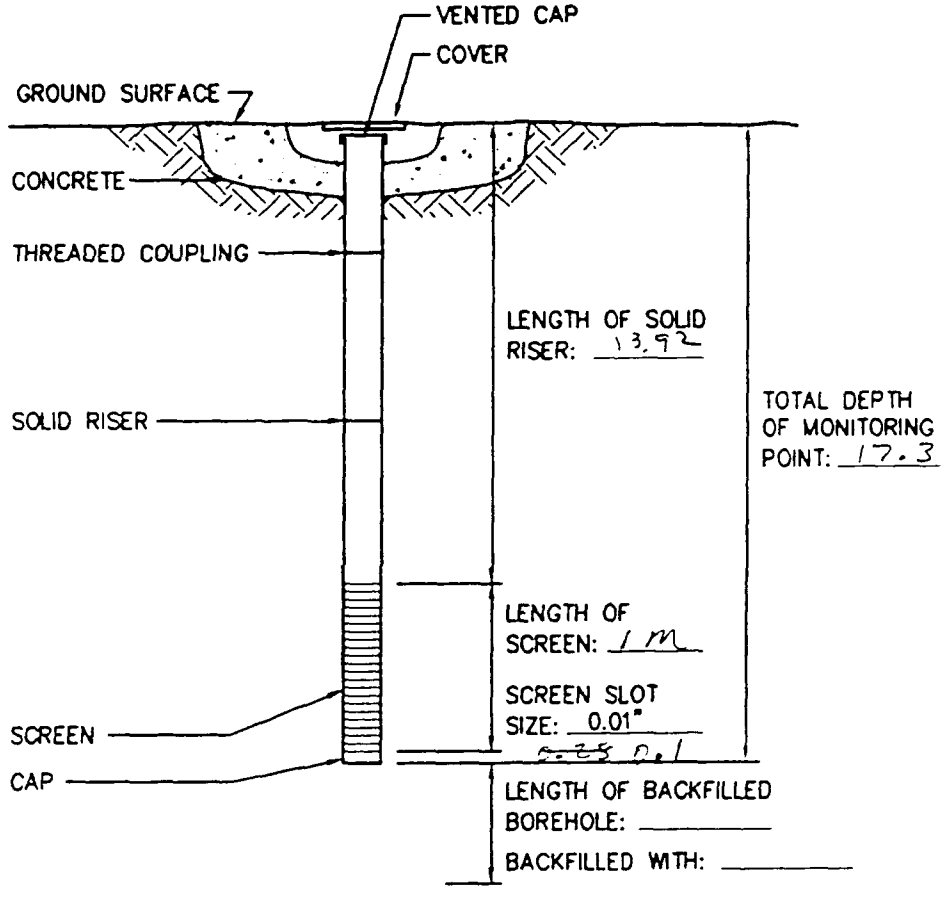
Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT13S
JOB NUMBER 722450.06 — INSTALLATION DATE 4-14-94 — LOCATION SSZ7
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____
DATUM FOR WATER LEVEL MEASUREMENT TOC
SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"
CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D.Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT14P

JOB NUMBER 722450.06 — INSTALLATION DATE 9-15-94 — LOCATION SS27

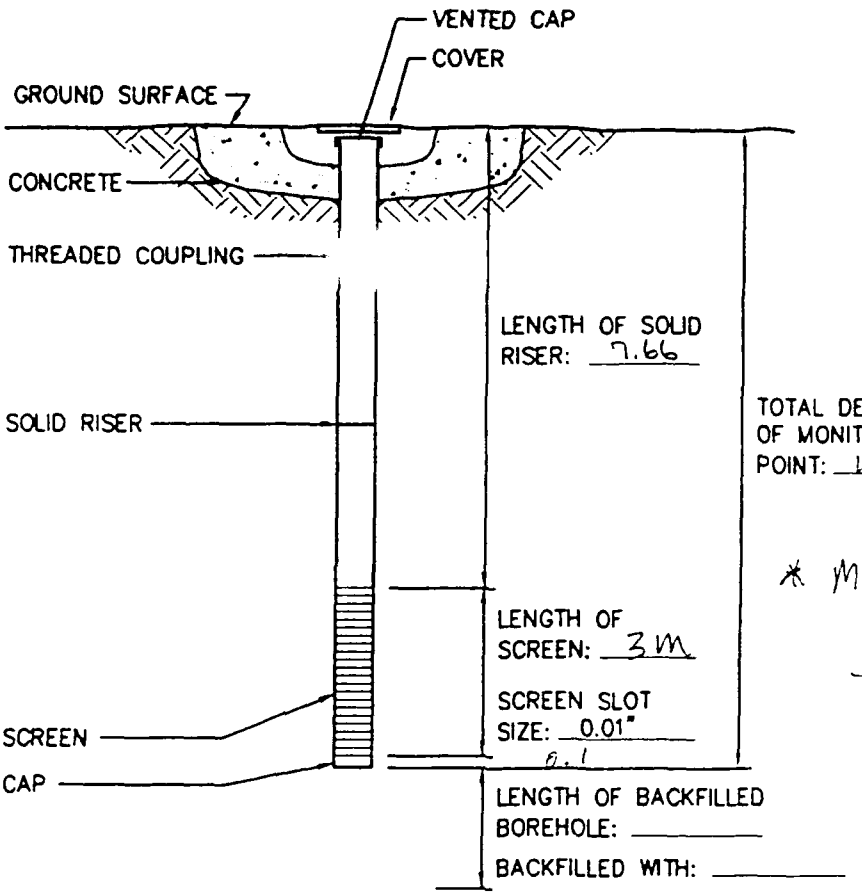
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D. Bergen



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ - CPT145

JOB NUMBER 722450.06 — INSTALLATION DATE [illegible] — LOCATION SS27

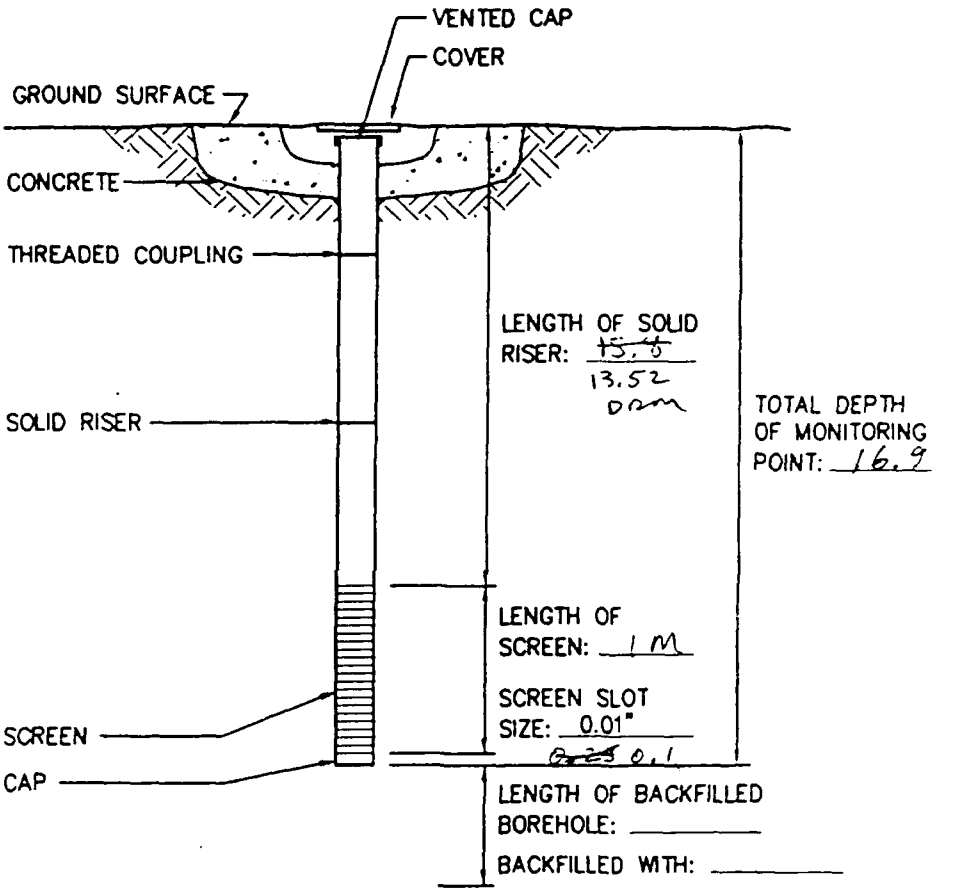
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D. Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT155

JOB NUMBER 722450.06 — INSTALLATION DATE 4-14-94 — LOCATION SS27

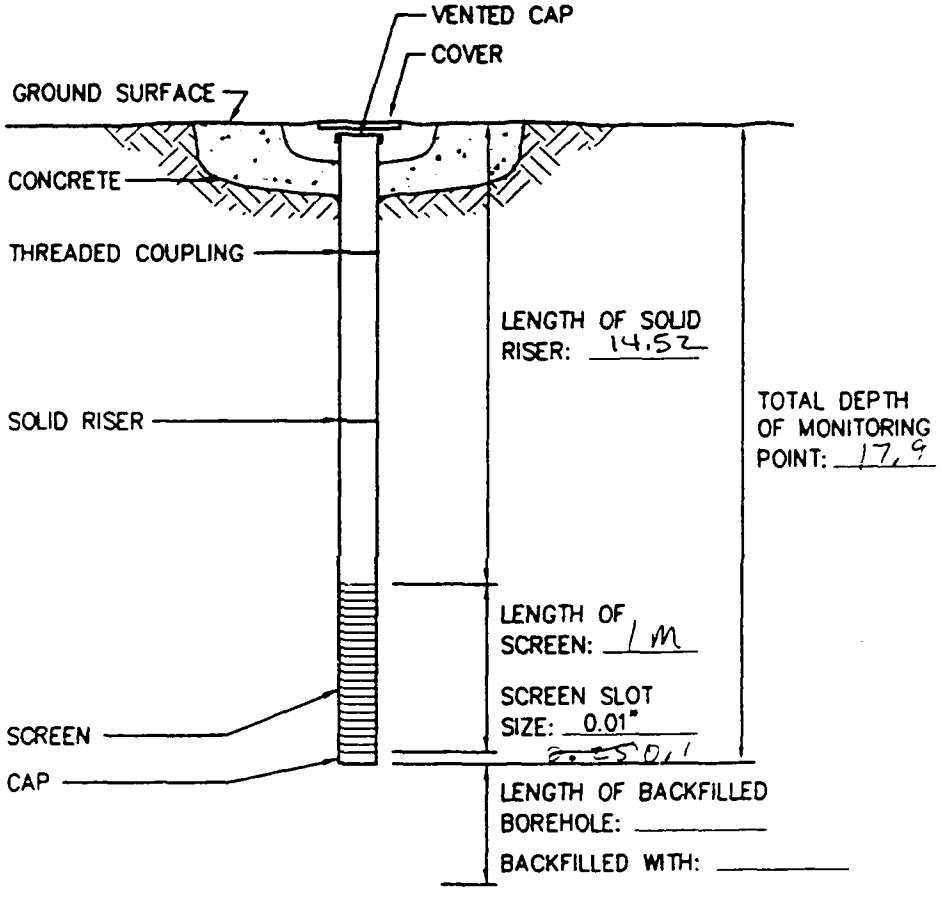
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D. Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER SVE-27-05

JOB NUMBER 722450.06 INSTALLATION DATE 4/18/94 LOCATION

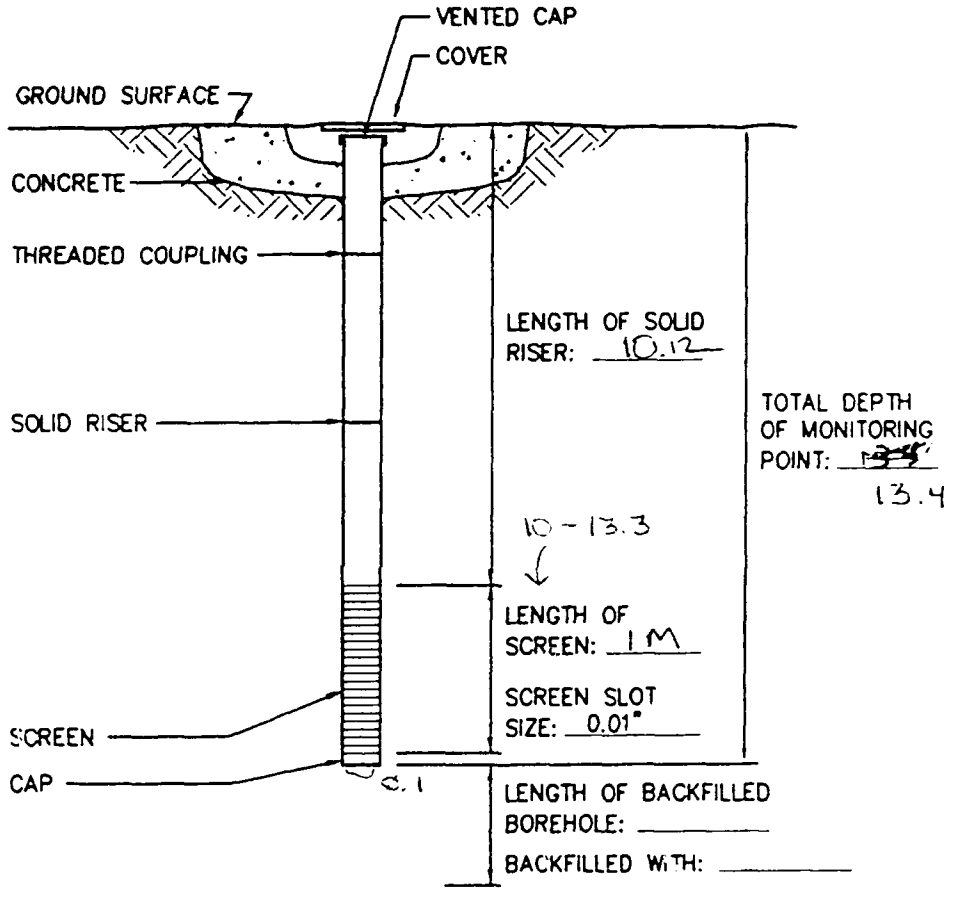
DATUM ELEVATION GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT16D

JOB NUMBER 722450.06 — INSTALLATION DATE 4-18-94 — LOCATION

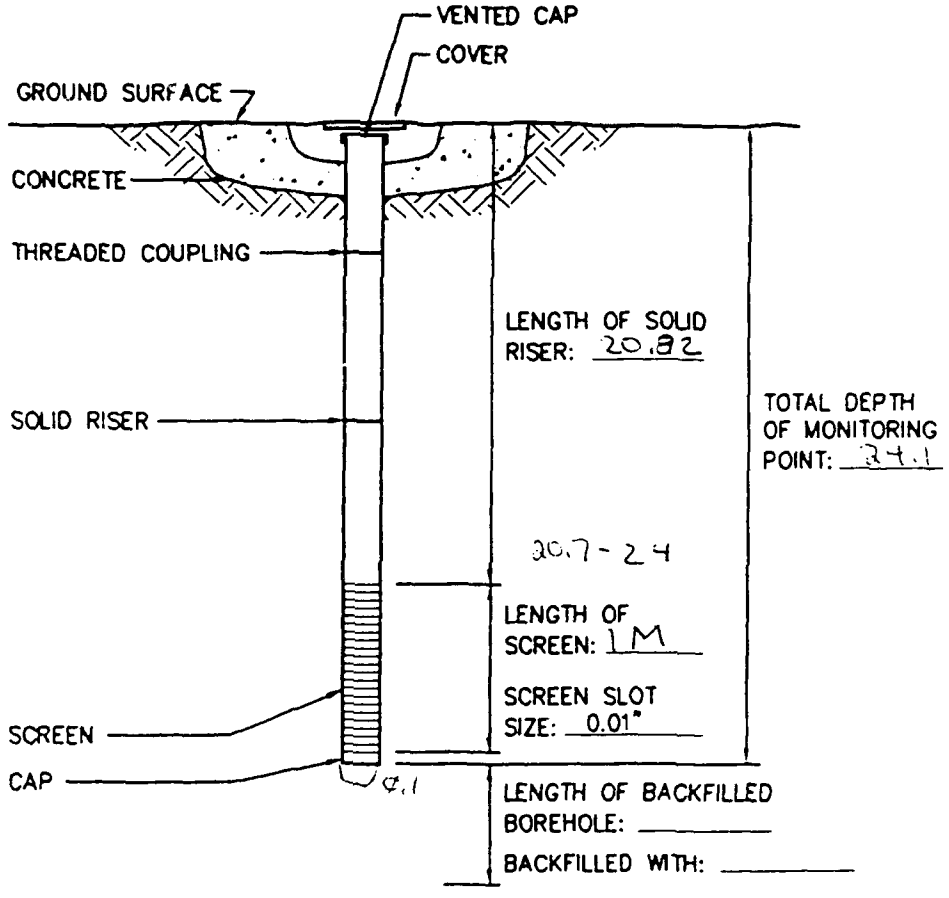
DATUM ELEVATION — GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

940N0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT-75

JOB NUMBER 722450.06 — INSTALLATION DATE 4-14-94 — LOCATION SS27

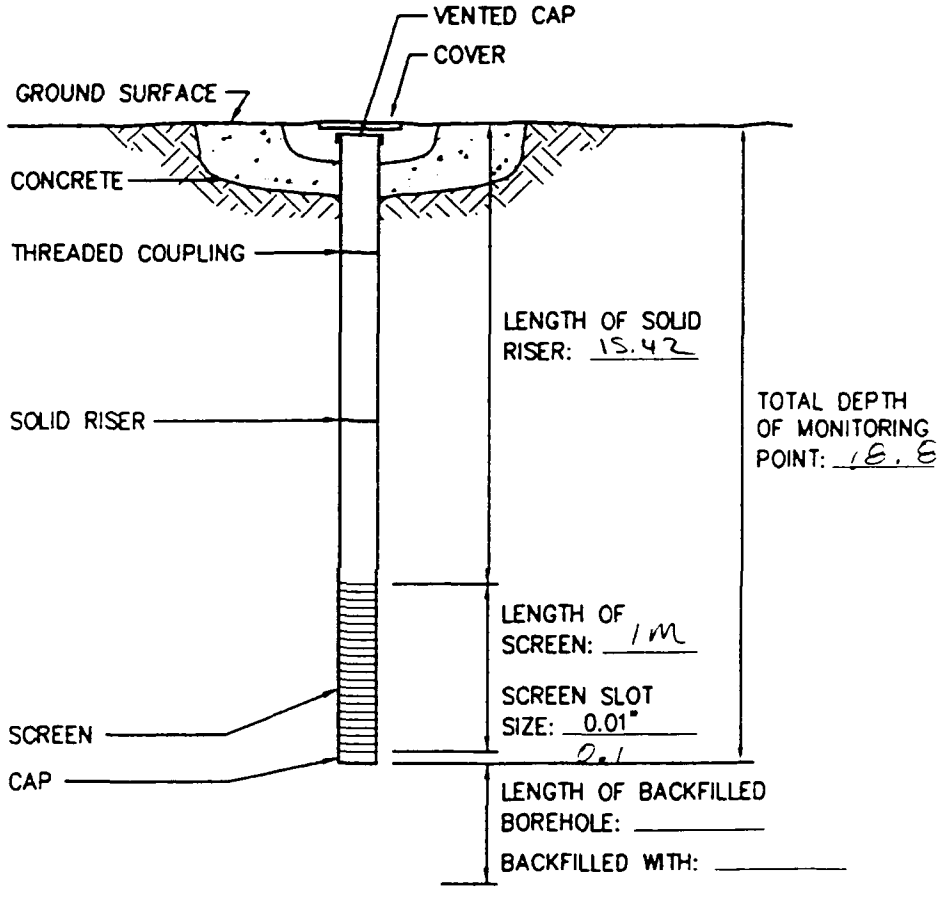
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D. Scott



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT1ES

JOB NUMBER 722450.06 — INSTALLATION DATE 4-15-94 — LOCATION SS27

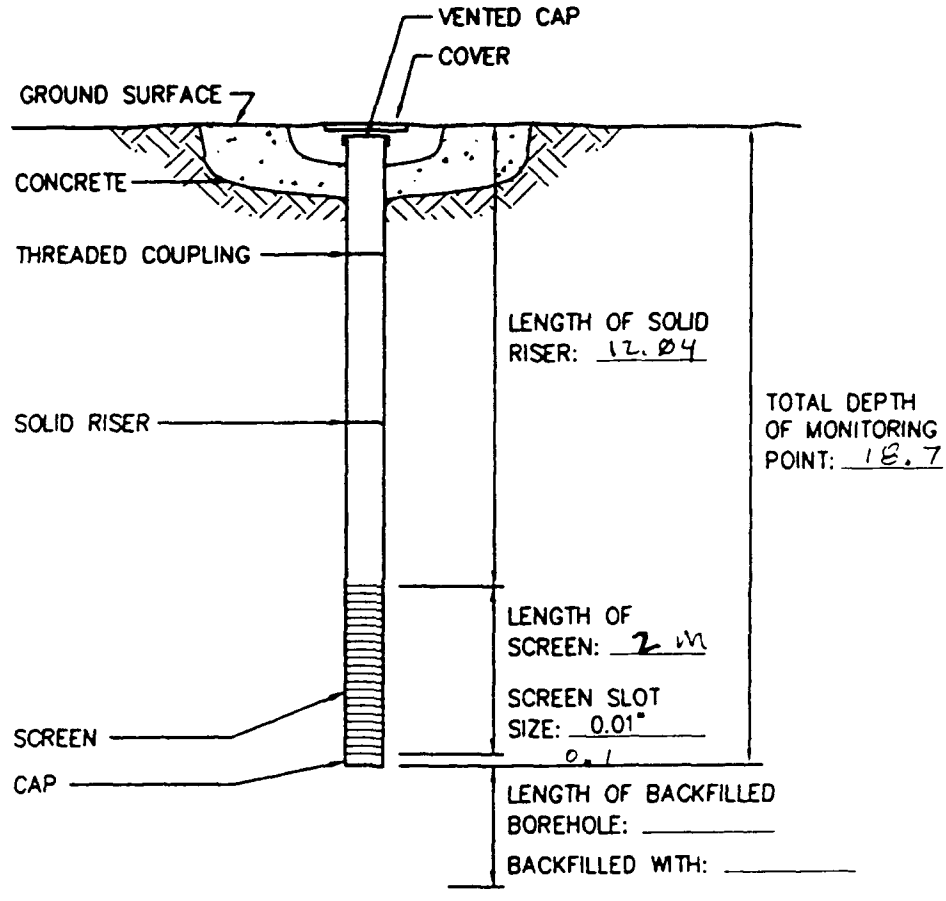
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH & Bayc



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.

Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XX22(2-??

JOB NUMBER 722450.06 INSTALLATION DATE 4-15-94 LOCATION SS27

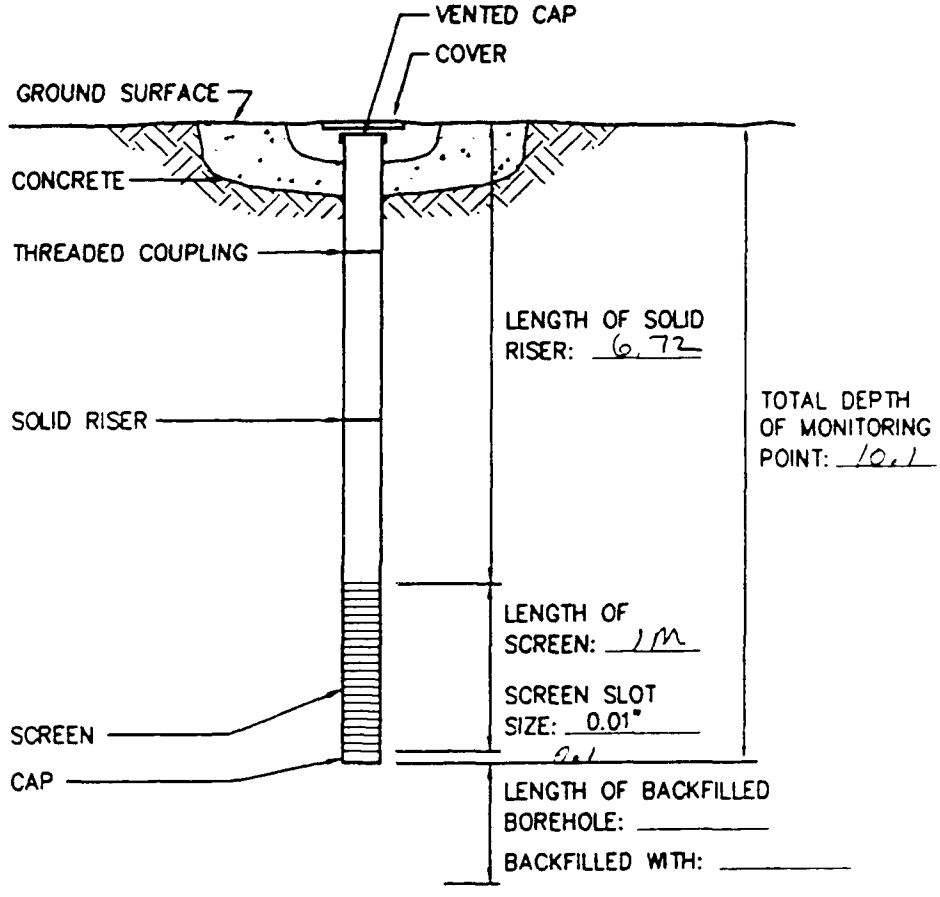
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1½" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1½" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH D. Boyce



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZCP-19S

JOB NUMBER 722450.06 — INSTALLATION DATE A-15-94 — LOCATION SSZ7

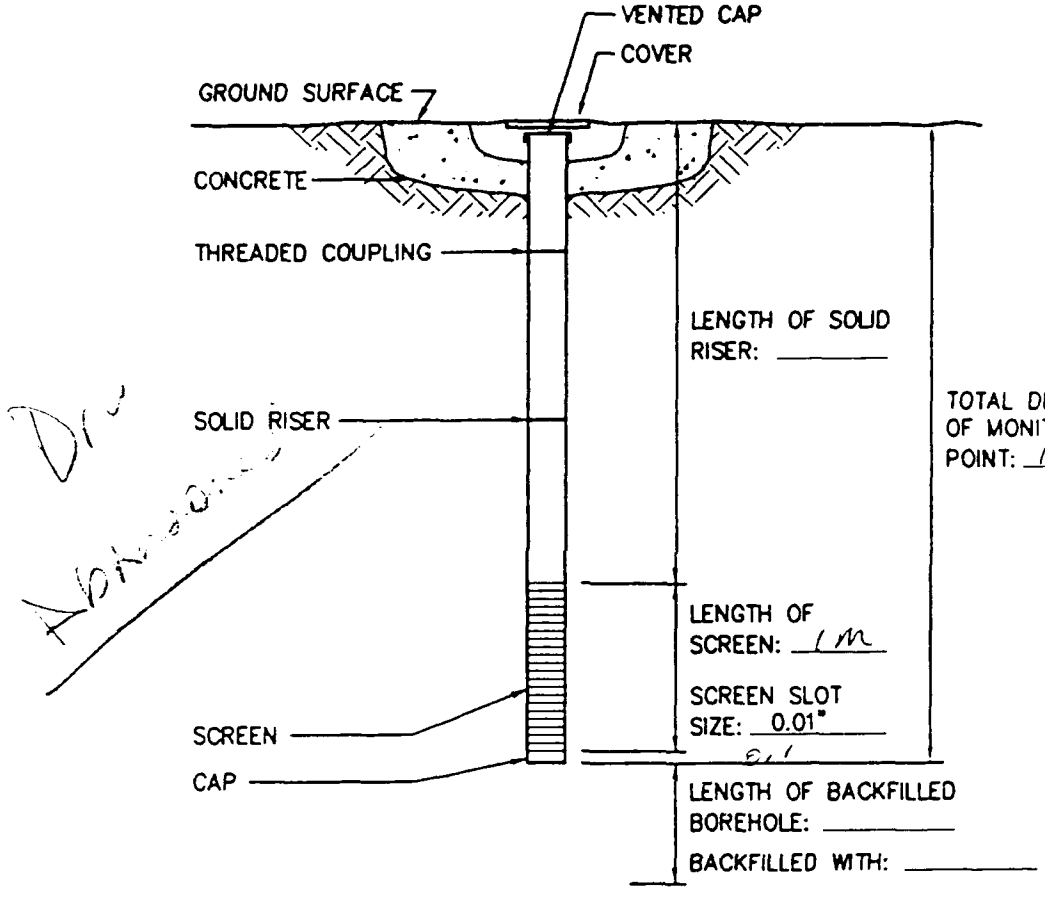
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1½" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1½" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D. Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

940N0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XVZCPT16D

JOB NUMBER 722450.06 — INSTALLATION DATE _____ — LOCATION _____

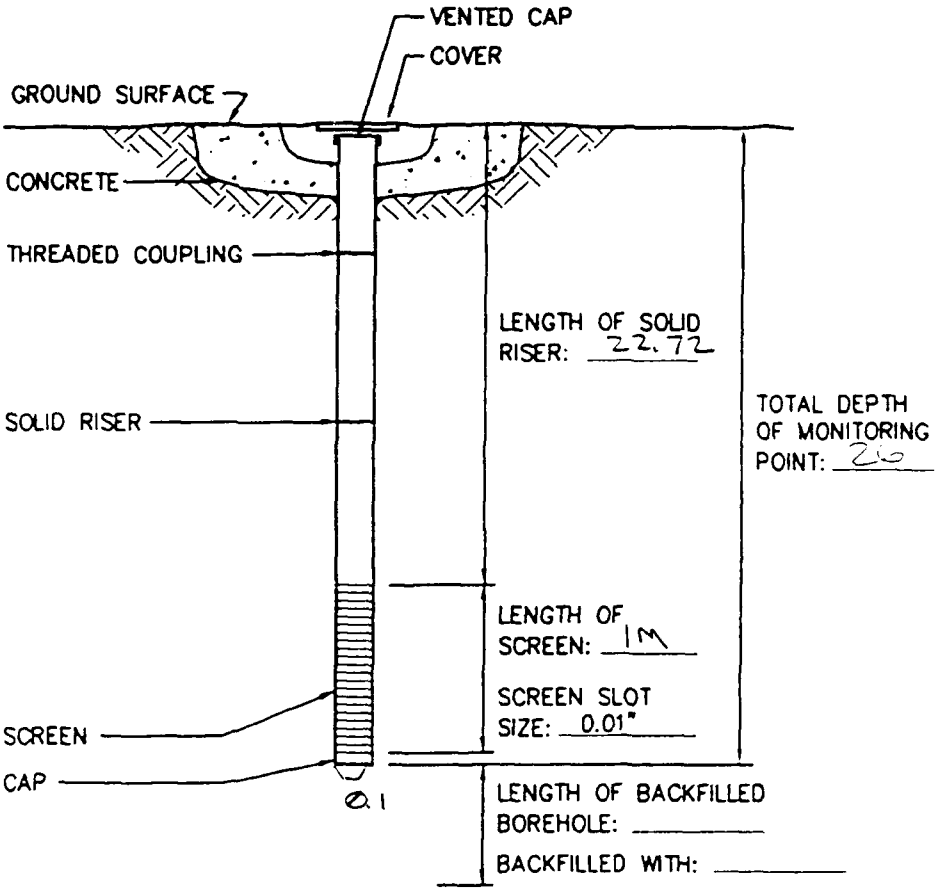
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XVEC2-205

JOB NUMBER 722450.06 — INSTALLATION DATE 4-15-94 — LOCATION SSE7

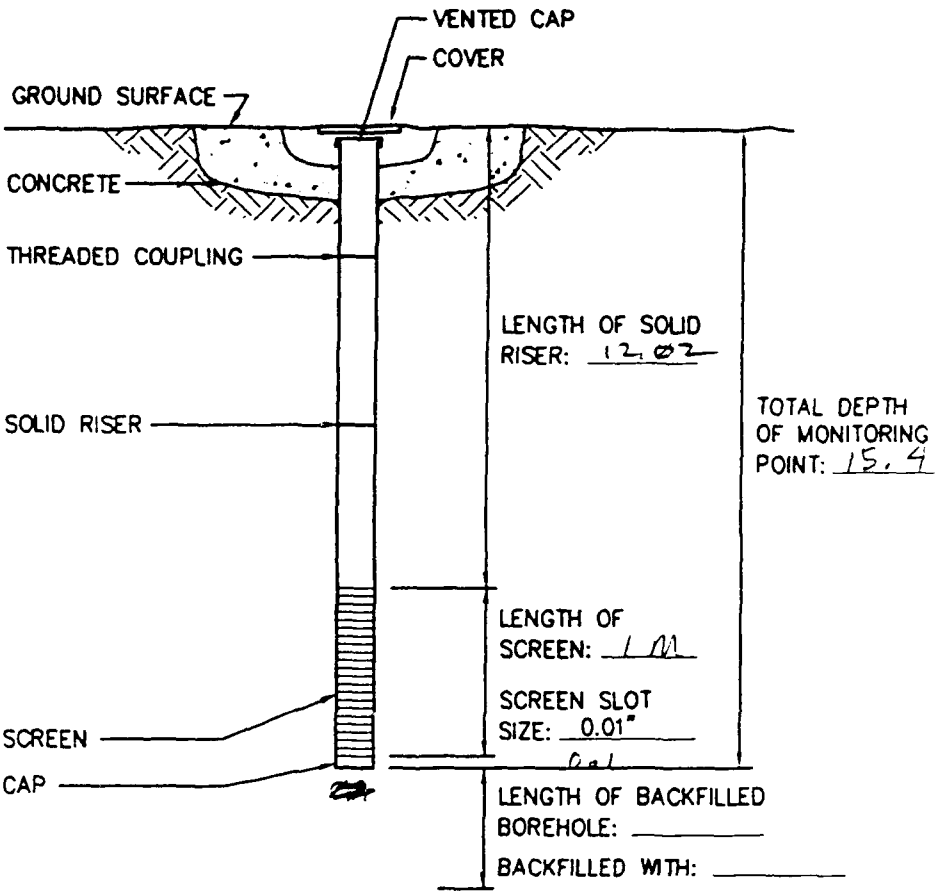
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D.Bagley



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER MW62-215

JOB NUMBER 722450.06 — INSTALLATION DATE 4-16-94 — LOCATION SS27

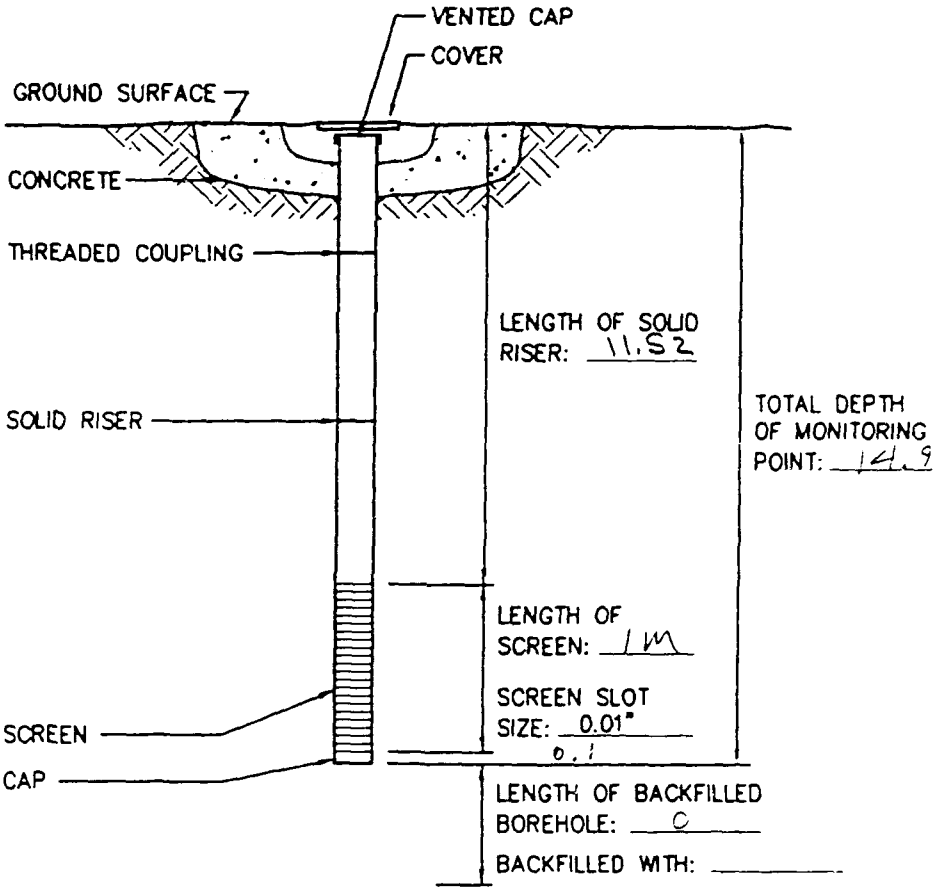
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH P.B.M.



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B 4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER MW-225

JOB NUMBER 722450.06 INSTALLATION DATE 4-16-94 LOCATION SS27

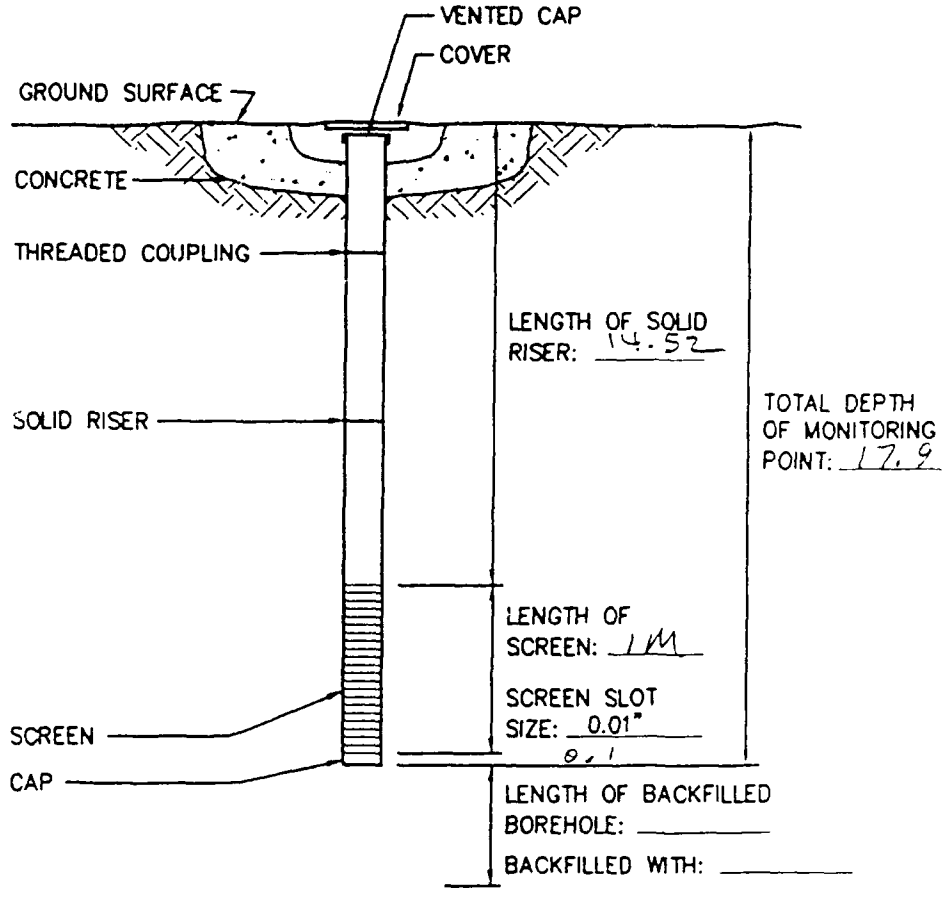
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH D.Sanik



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZCPT22D

JOB NUMBER 722450.06 — INSTALLATION DATE 4-16-94 — LOCATION SS27

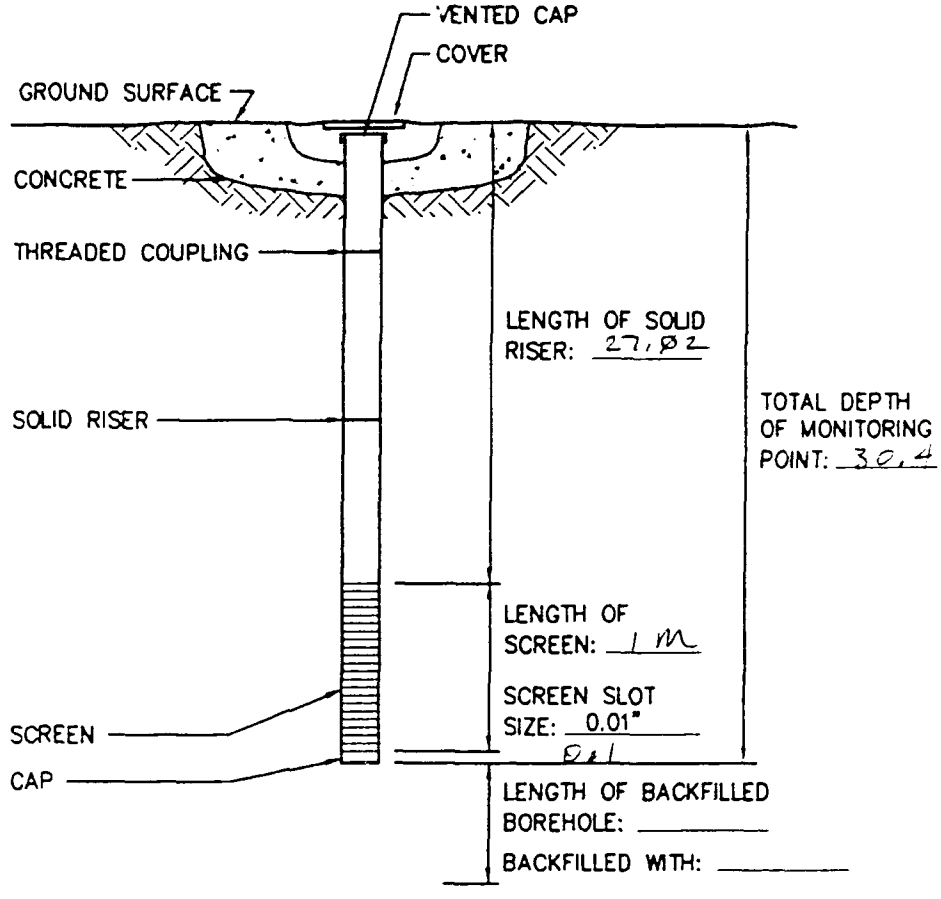
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D.Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZLPT24S

JOB NUMBER 722450.06 — INSTALLATION DATE 4-16-94 — LOCATION SS27

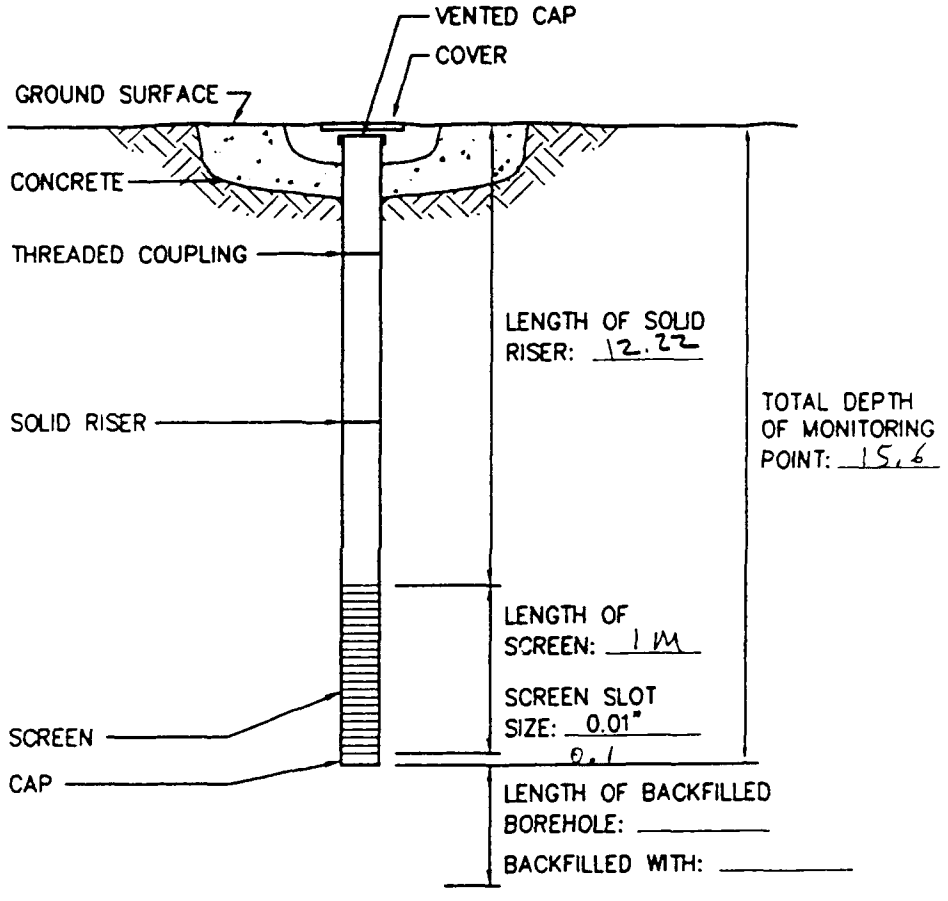
DATUM ELEVATION _____ — GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH D.Boyce



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:27

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XYZ CPT25S

JOB NUMBER 722450.06 INSTALLATION DATE 9-16-94 LOCATION SS27

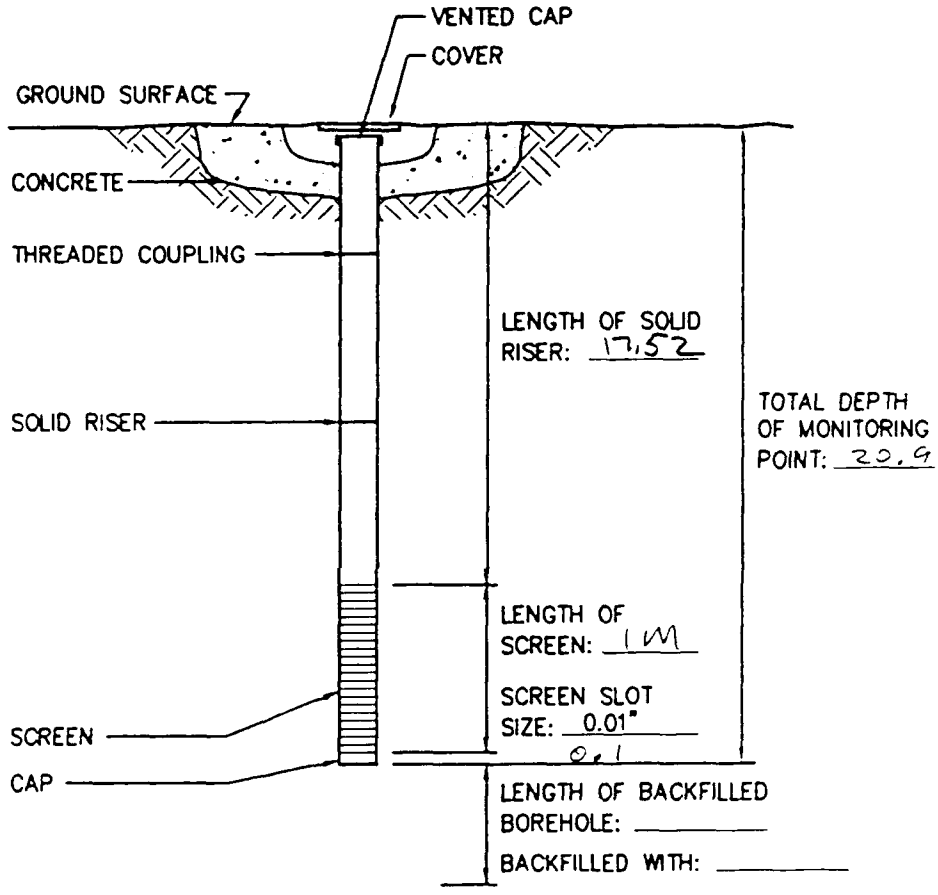
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH D Boyle



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/'94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XYZCPT26S

JOB NUMBER 722450.06 INSTALLATION DATE 4-16-94 LOCATION SS27

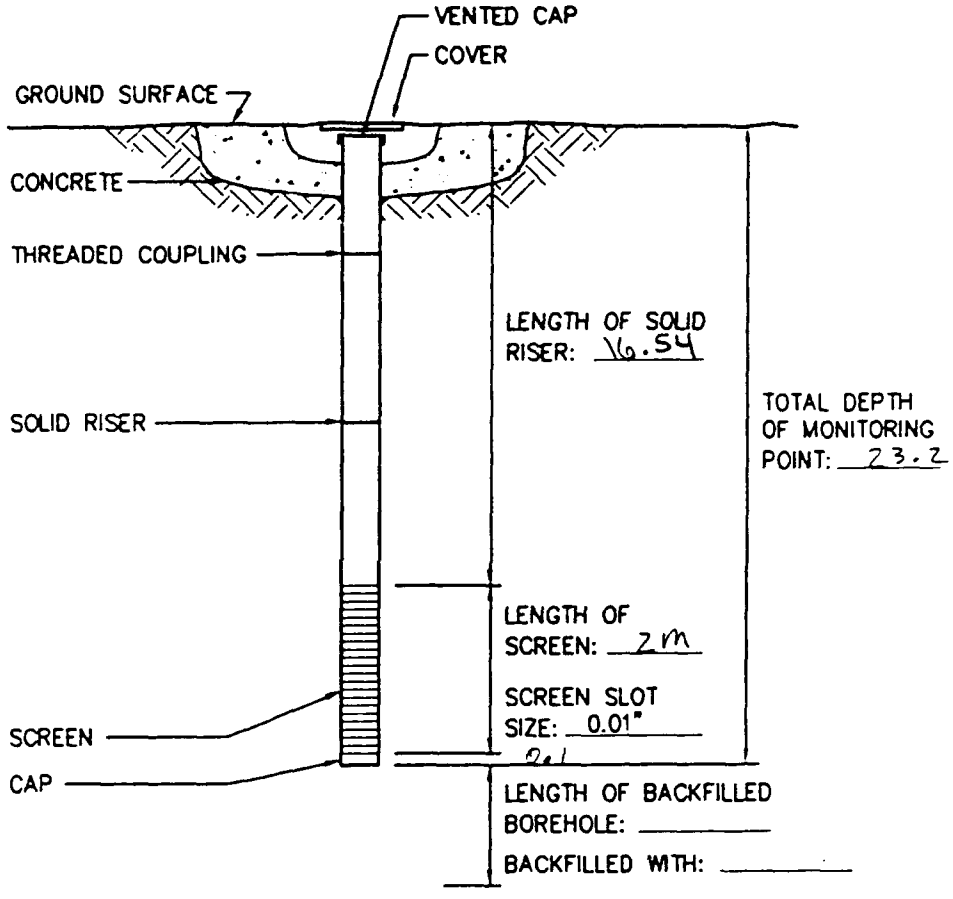
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZCPT27S

JOB NUMBER 722450.06 — INSTALLATION DATE 4-18-94 — LOCATION

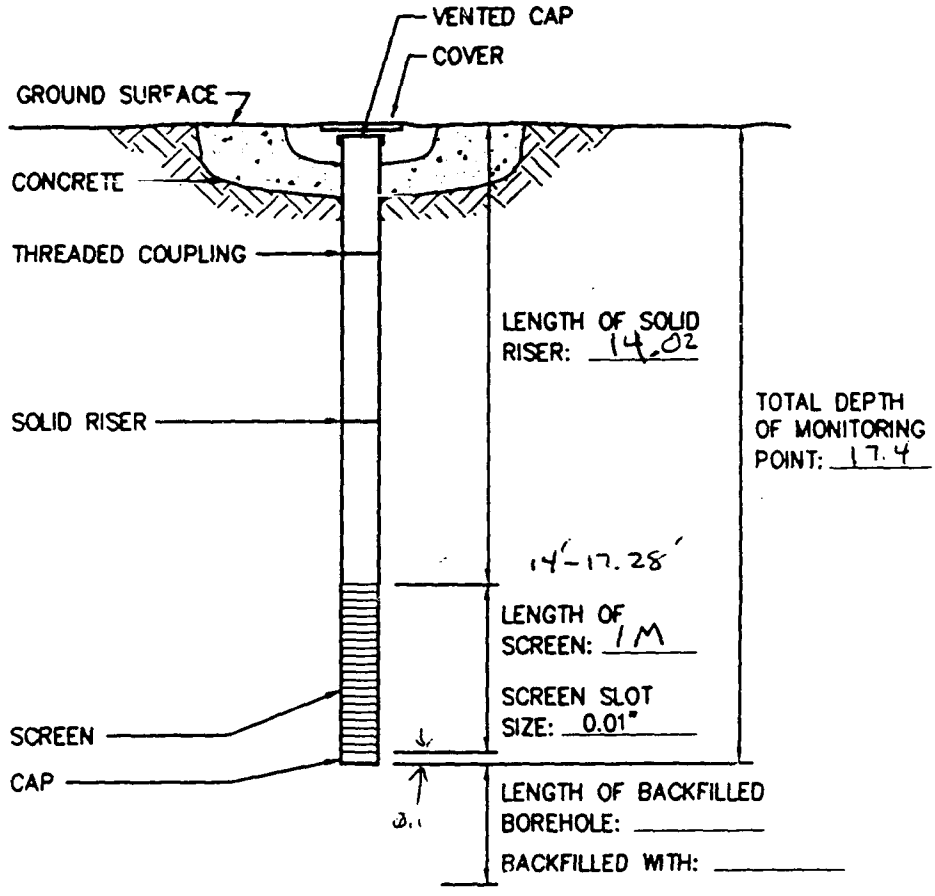
DATUM ELEVATION TOC — GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT

SCREEN DIAMETER & MATERIAL 1/2" PVC — SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" PVC — BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

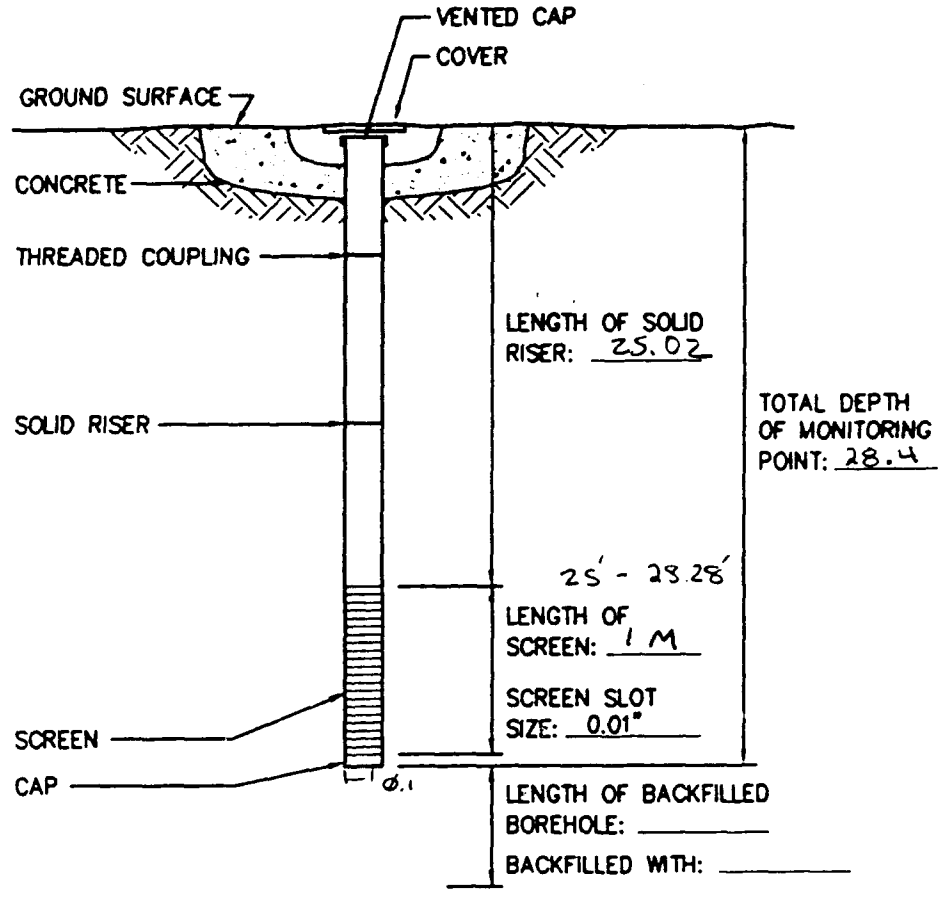
Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB — MONITORING POINT NUMBER XYZ-CPT 27 D
JOB NUMBER 722450.06 — INSTALLATION DATE 4/18/94 — LOCATION
DATUM ELEVATION — GROUND SURFACE ELEVATION
DATUM FOR WATER LEVEL MEASUREMENT TOC
SCREEN DIAMETER & MATERIAL 1/2" Ø PVC — SLOT SIZE 0.01"
RISER DIAMETER & MATERIAL 1/2" Ø PVC — BOREHOLE DIAMETER 1.75"
CONE PENETROMETER CONTRACTOR ARA, INC — ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

94DN0363, 04/05/94 at 15:22

MONITORING POINT INSTALLATION RECORD

JOB NAME DOVER AFB MONITORING POINT NUMBER XYZ CPT 285

JOB NUMBER 722450.06 INSTALLATION DATE 4-18-94 LOCATION

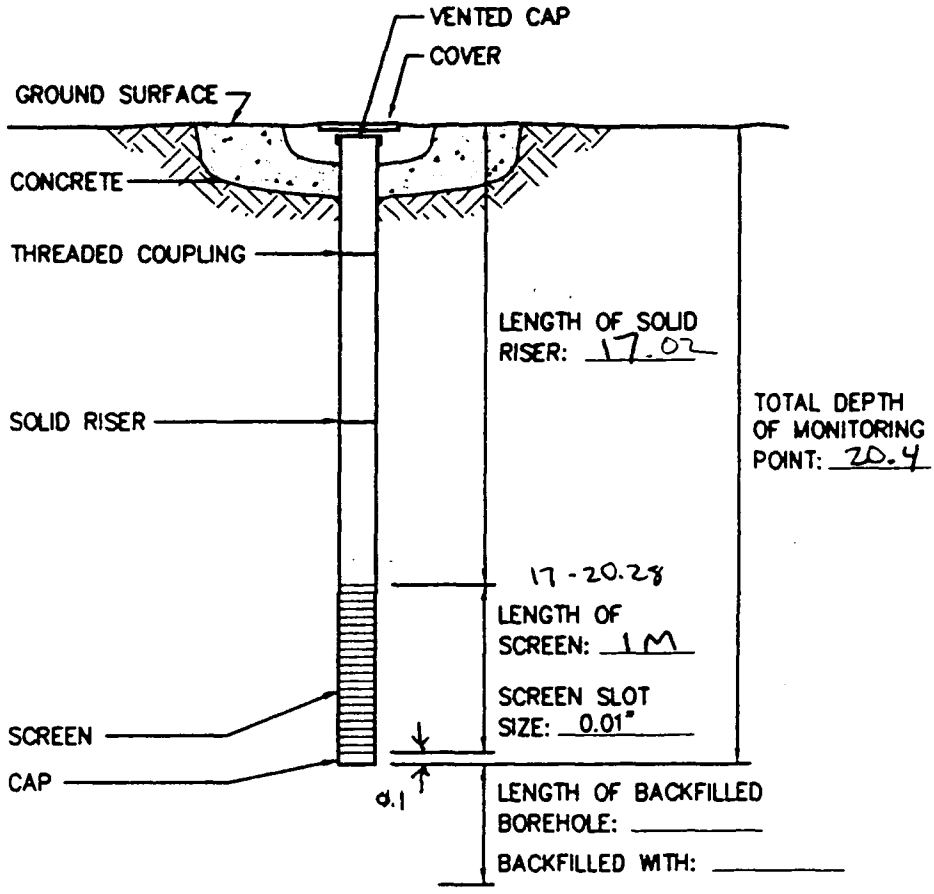
DATUM ELEVATION GROUND SURFACE ELEVATION

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL 1/2" Ø PVC SLOT SIZE 0.01"

RISER DIAMETER & MATERIAL 1/2" Ø PVC BOREHOLE DIAMETER 1.75"

CONE PENETROMETER CONTRACTOR ARA, INC ES REPRESENTATIVE KC/TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH _____ FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE B.4.5

EXAMPLE OF MONITORING POINT INSTALLATION RECORD

Intrinsic Remediation Demonstration
Dover Air Force Base, Delaware

ENGINEERING-SCIENCE, INC.
Denver, Colorado

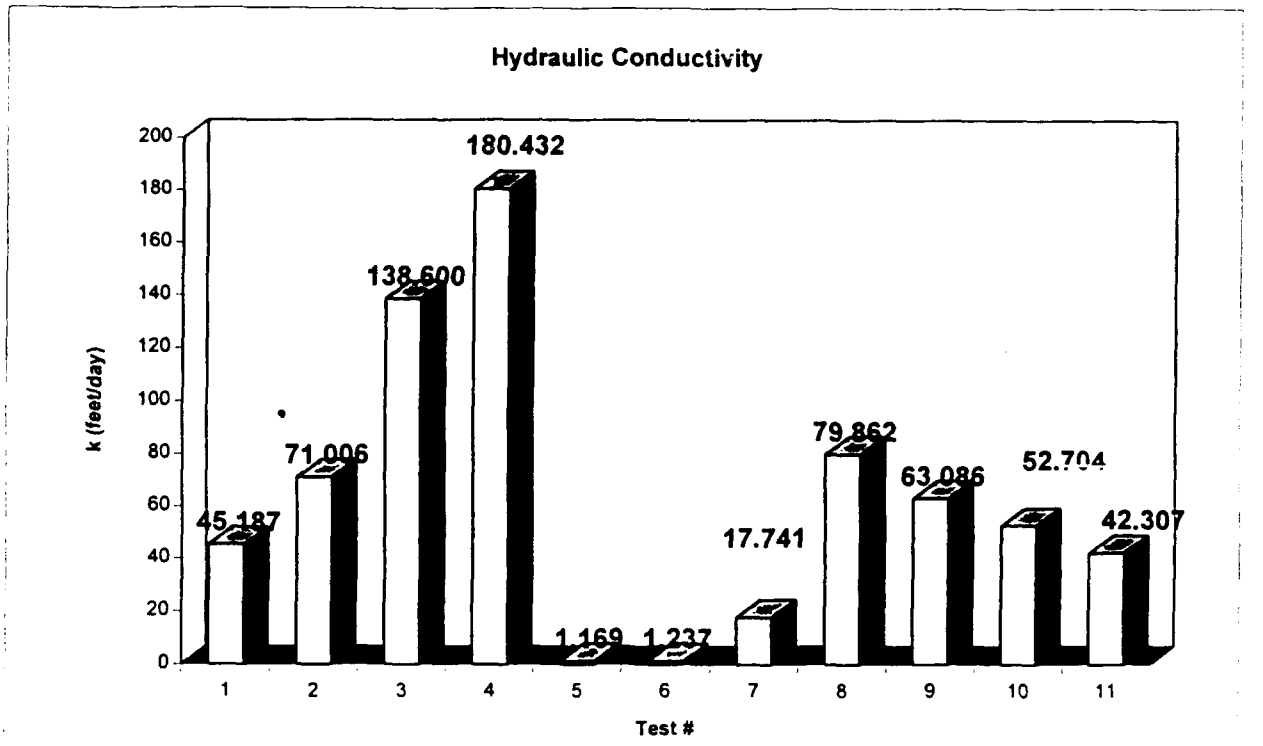
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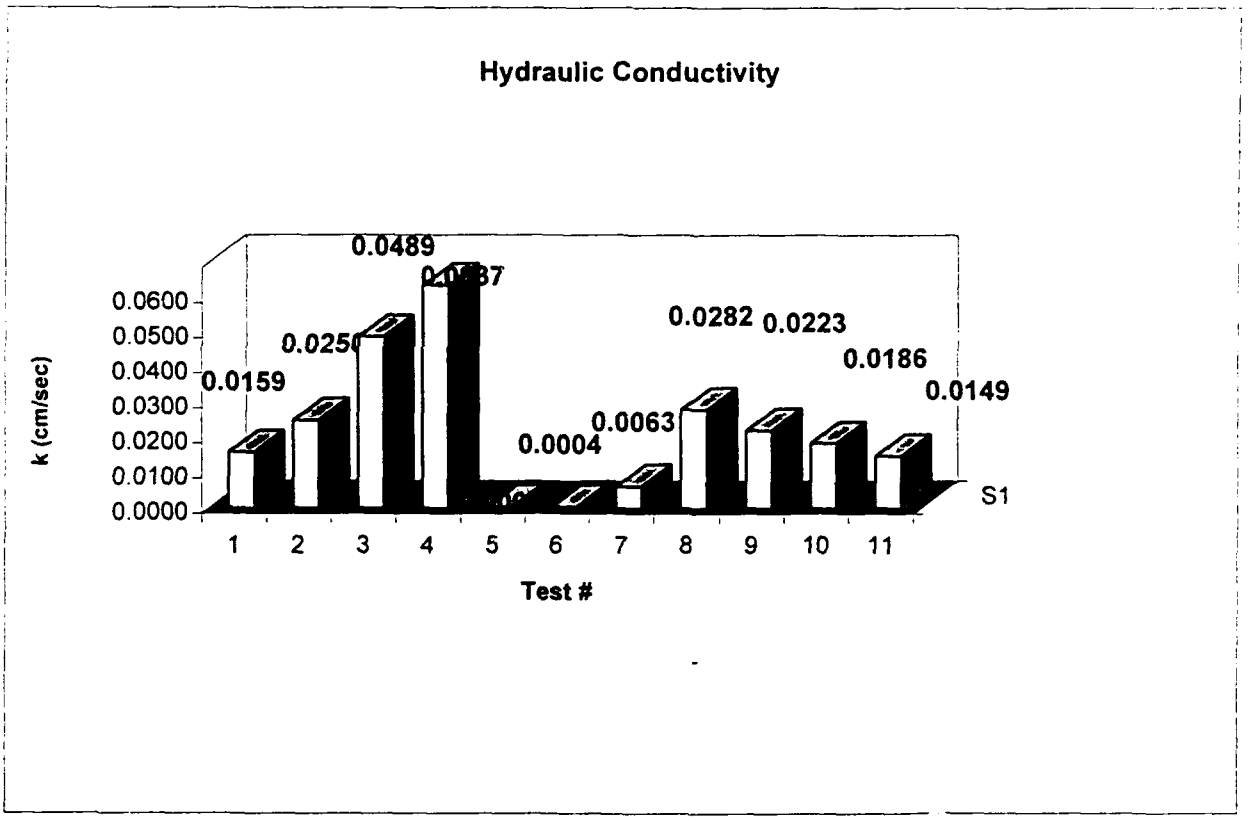
AQUIFER TEST RESULTS
DOVER AIR FORCE BASE

Slug Test Number	Well Identification	Hydraulic Conductivity (feet/min)	Hydraulic Conductivity (feet/day)	Hydraulic Conductivity (cm/sec)	Yo (feet)	Well Depth (feet bgs)
1	DM341SR1	0.031380	45.187	0.0159	0.3151	18.56
2	DM341SR2	0.049310	71.006	0.0250	0.3773	18.56
3	DM341DR1	0.096250	138.600	0.0489	0.6310	28.11
4	DM341DR2	0.125300	180.432	0.0637	0.9741	28.11
5	DM343SR1	0.000812	1.169	0.0004	1.0740	*
6	DM343SR2	0.000859	1.237	0.0004	1.0390	*
7	DM343DR2	0.012320	17.741	0.0063	0.8873	*
8	DM345SR1	0.055460	79.862	0.0282	0.4715	*
9	DM345SR2	0.043810	63.086	0.0223	0.5441	*
10	DM349SR2	0.036600	52.704	0.0186	0.1722	*
11	DM349SR3	0.029380	42.307	0.0149	0.1497	*
	Average	0.043771	63.030	0.0222		

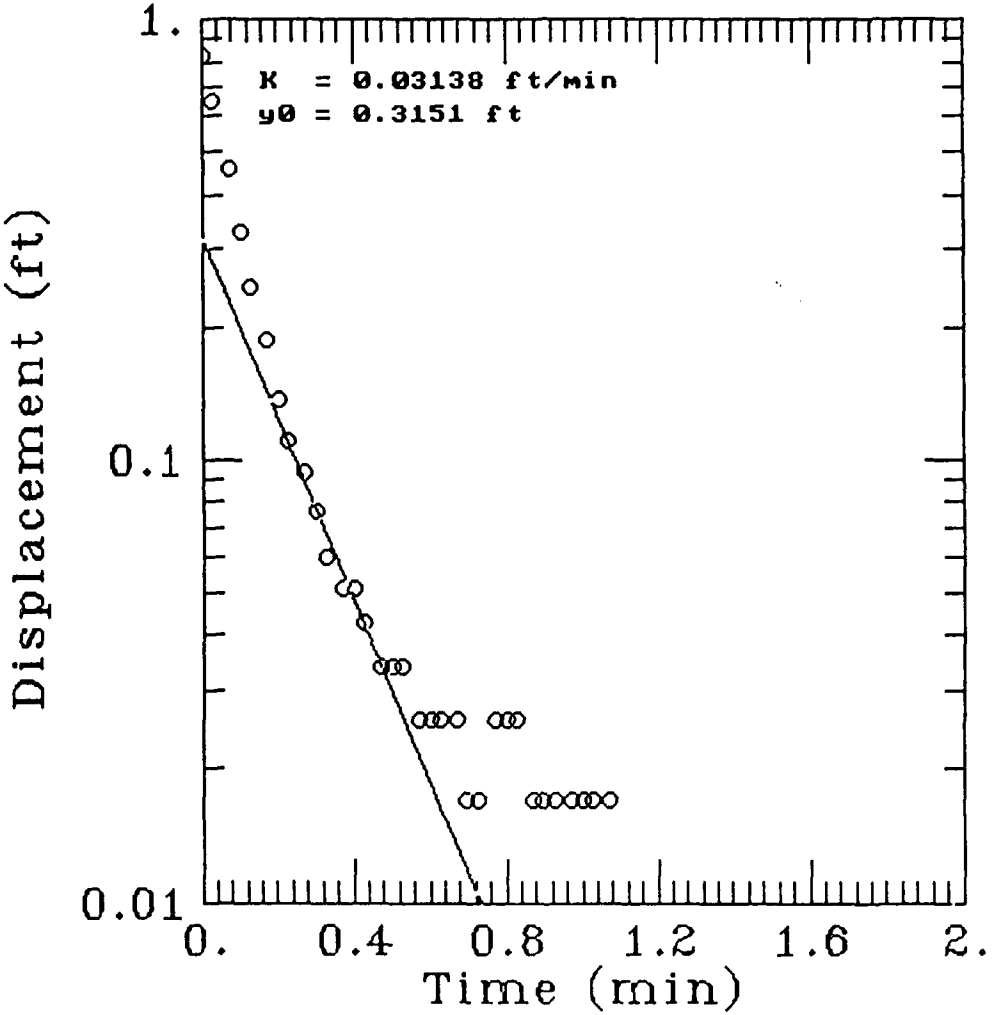
* - Information Not Available at this time
Hydraulic Conductivity and Yo calculated using AQTESOLV

Aquifer Test Data Table





DM341SR1

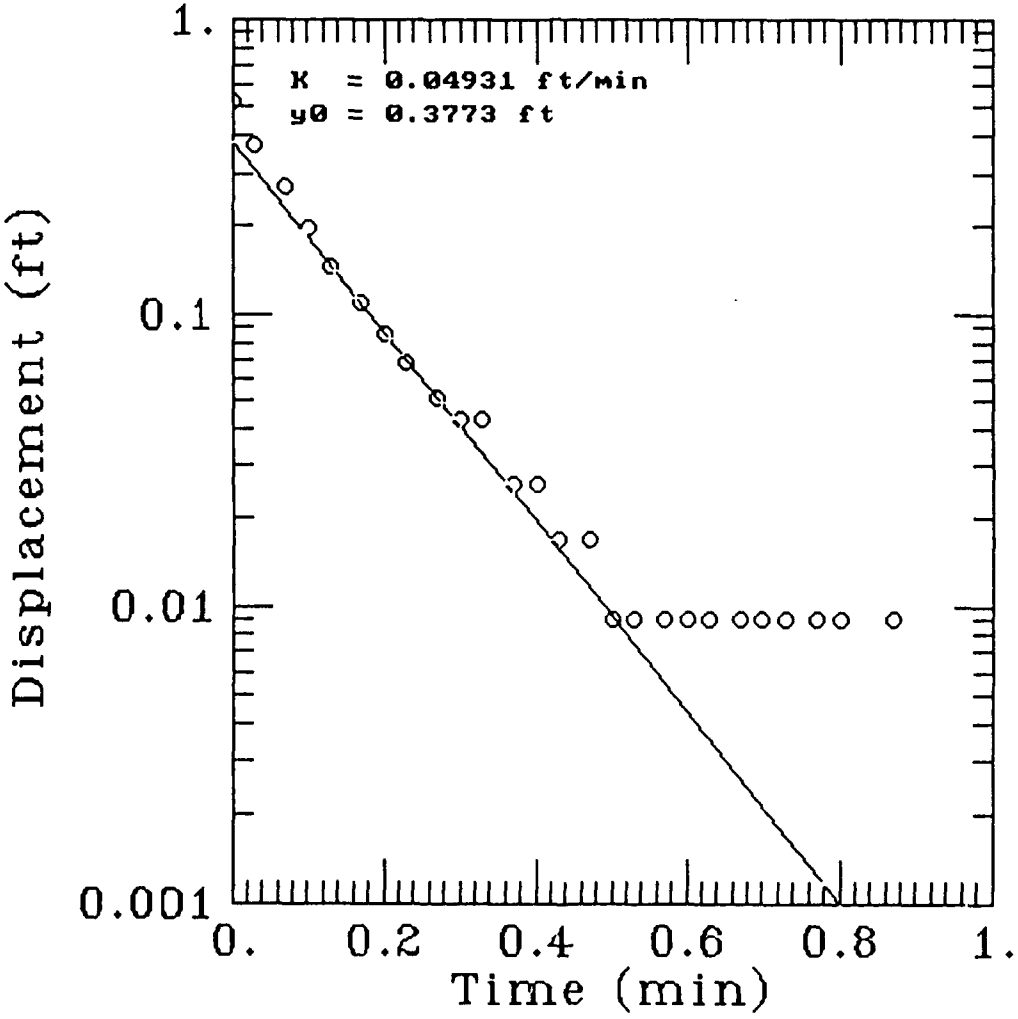


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

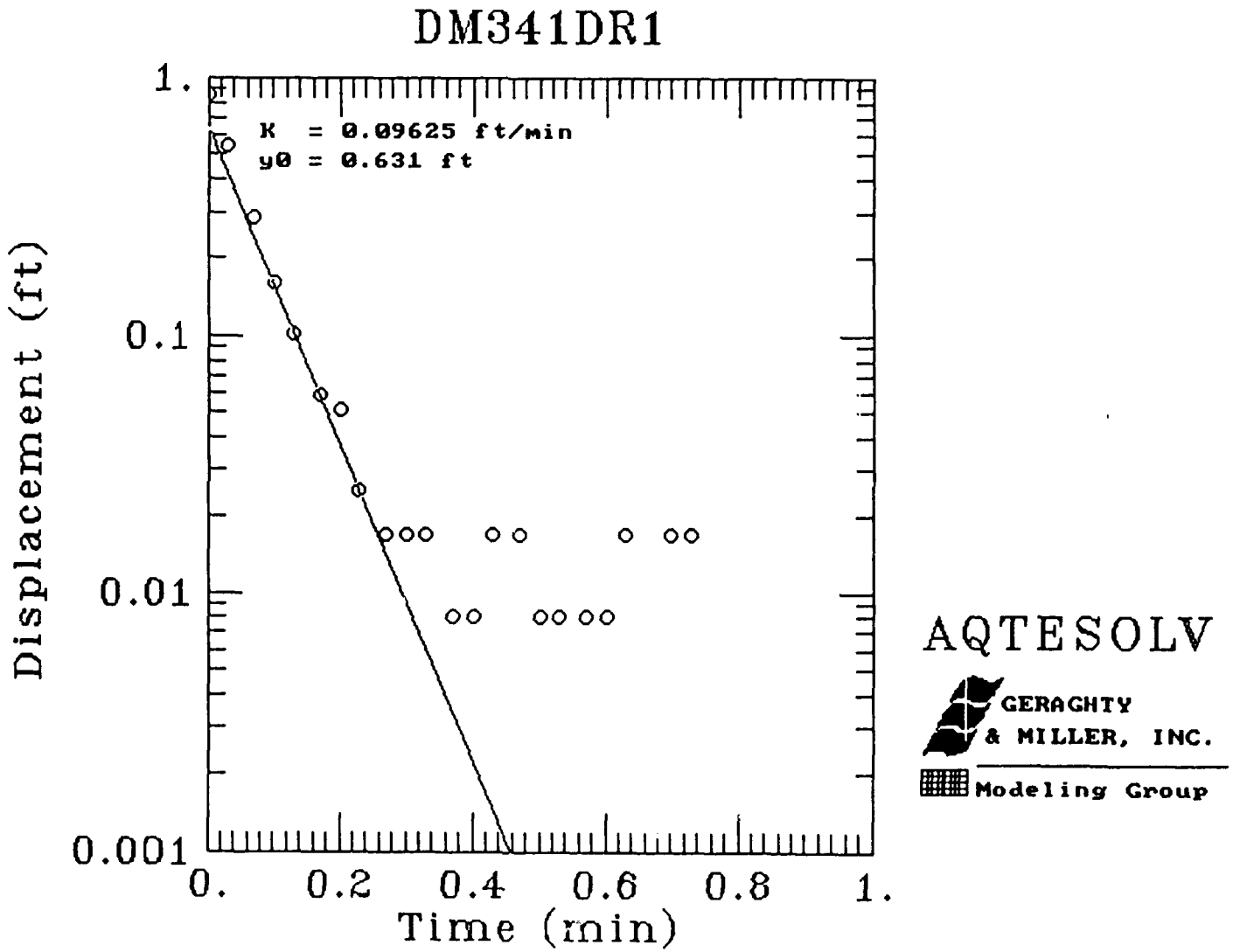
DM341SR2



AQTESOLV

GERAGHTY & MILLER, INC.

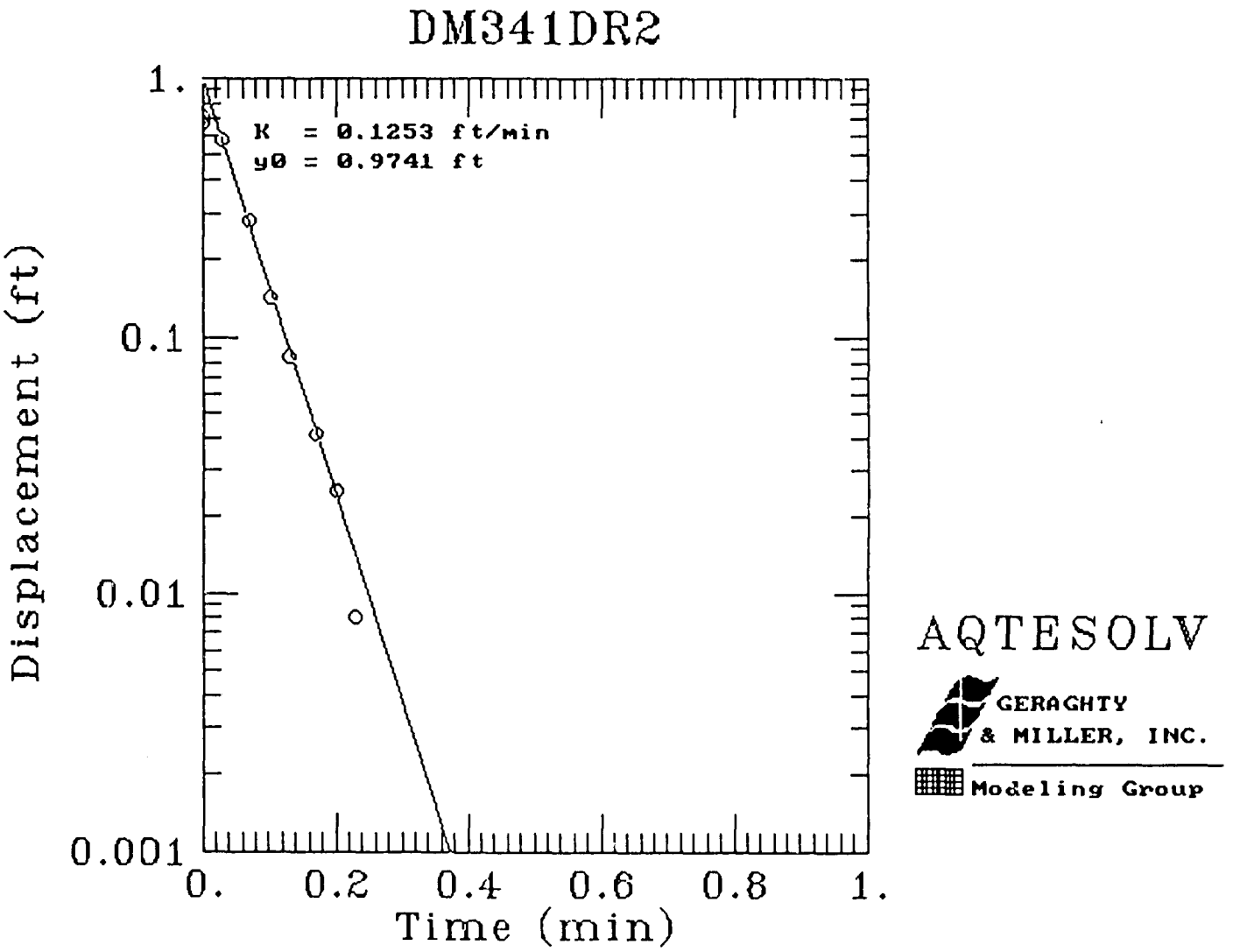
Modeling Group

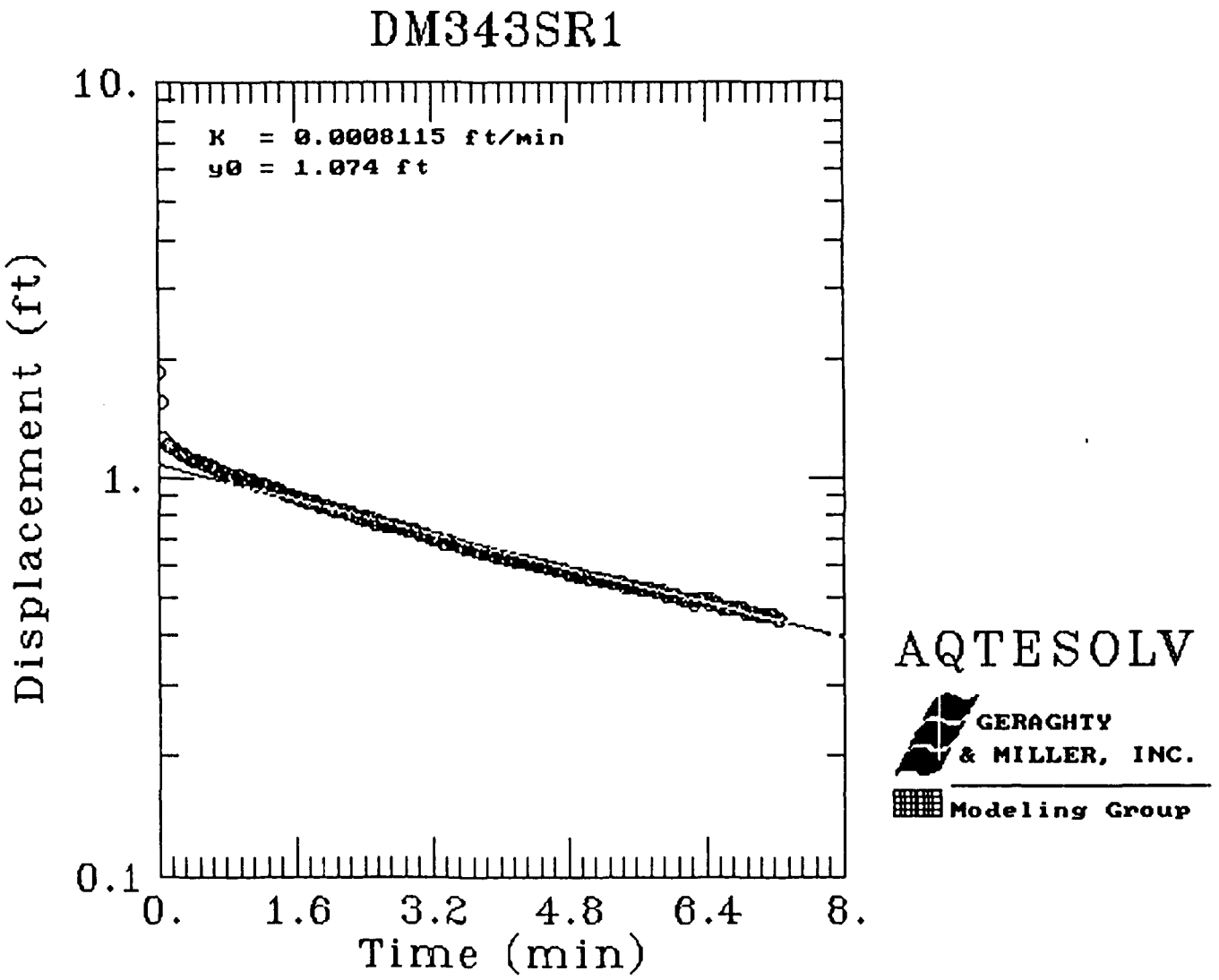


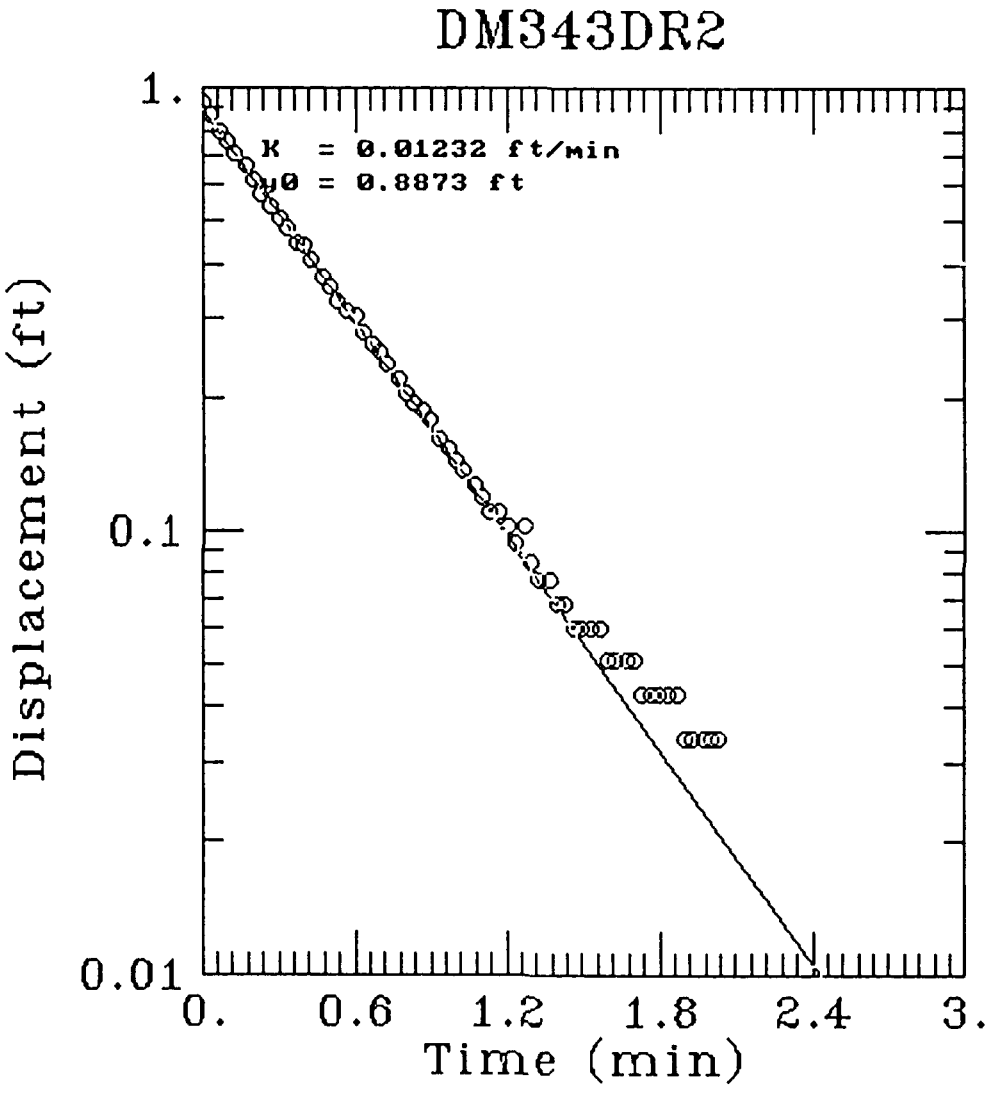
AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group


DM341DR2
K = 0.1253 ft/min
y0 = 0.9741 ft
Displacement (ft)
1.
0.1
0.01
0.001
0.
0.2
0.4
0.6
0.8
1.
Time (min)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group

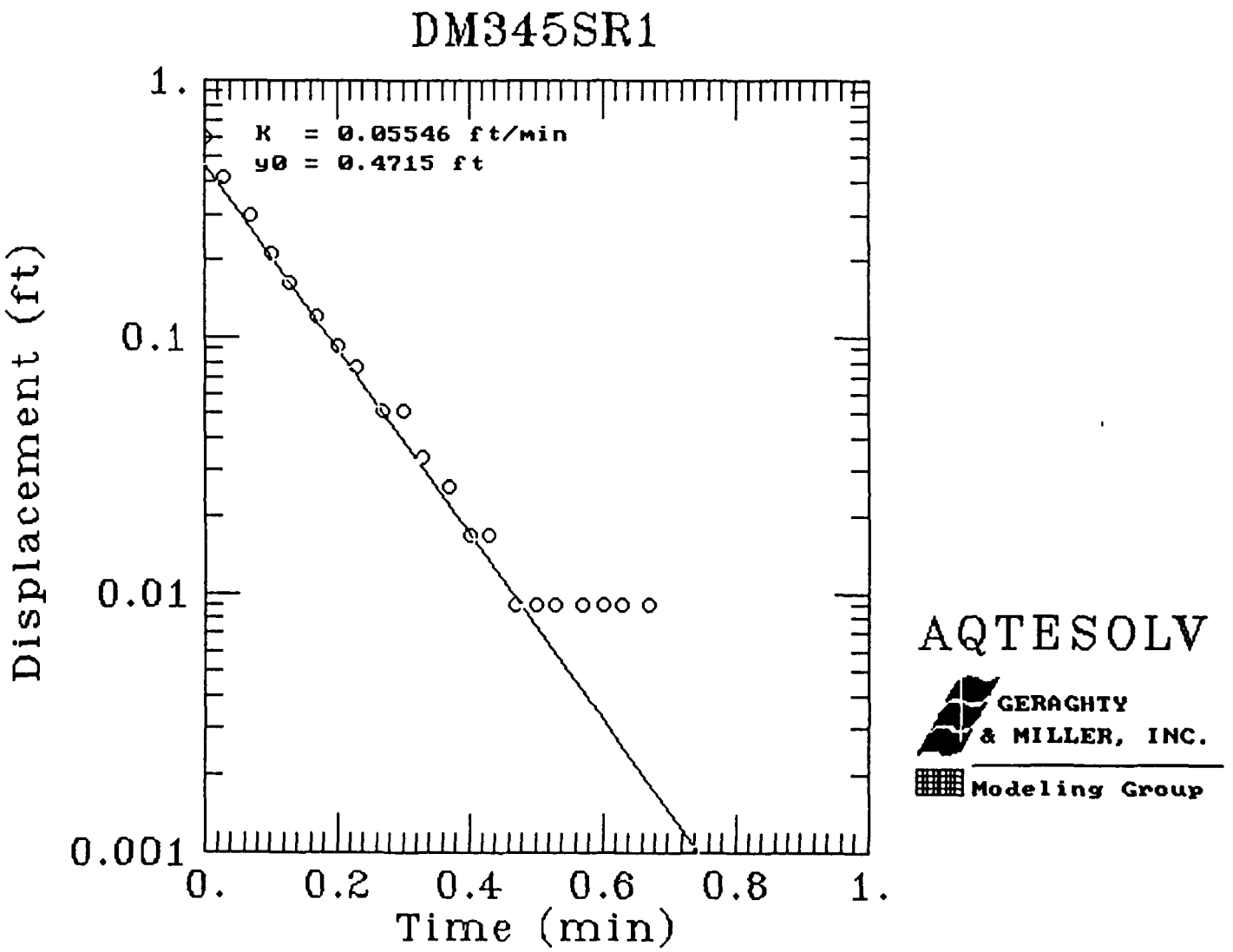

DM343SR1
K = 0.0008115 ft/min
y0 = 1.074 ft
10.
1.
0.1
Displacement (ft)
0.
1.6
3.2
4.8
6.4
8.
Time (min)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group

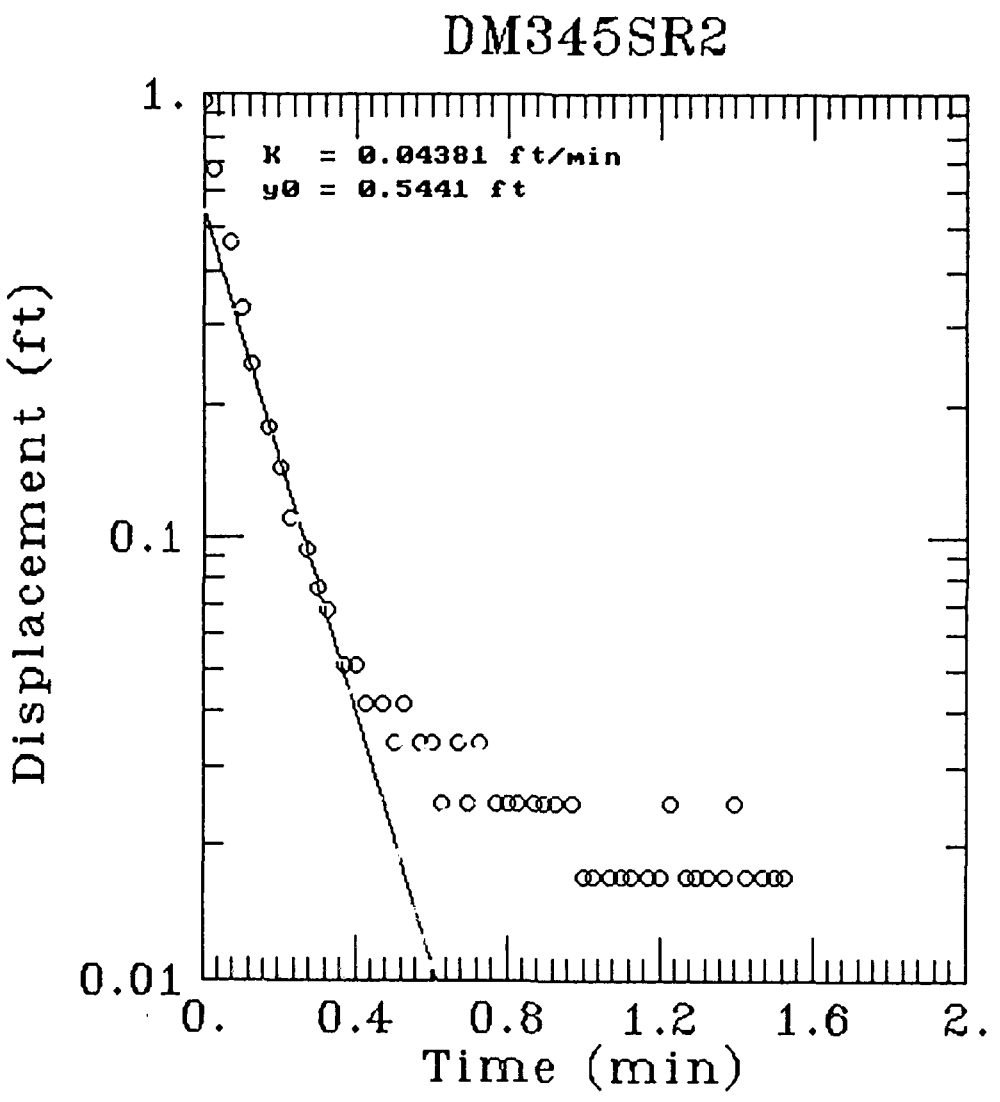


AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

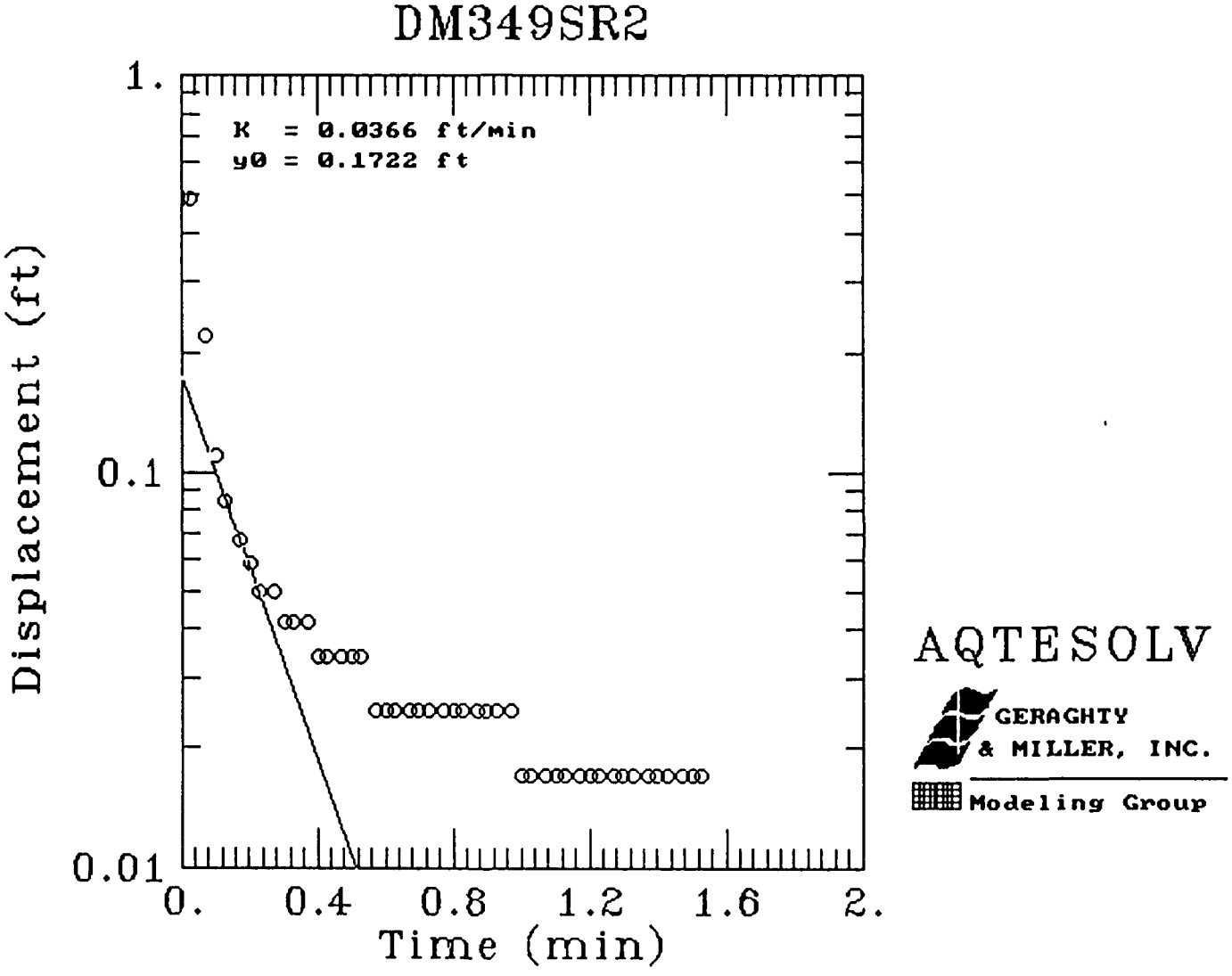

DM345SR1
K = 0.05546 ft/min
y0 = 0.4715 ft
Displacement (ft)
1.
0.1
0.01
0.001
0.
0.2
0.4
0.6
0.8
1.
Time (min)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group

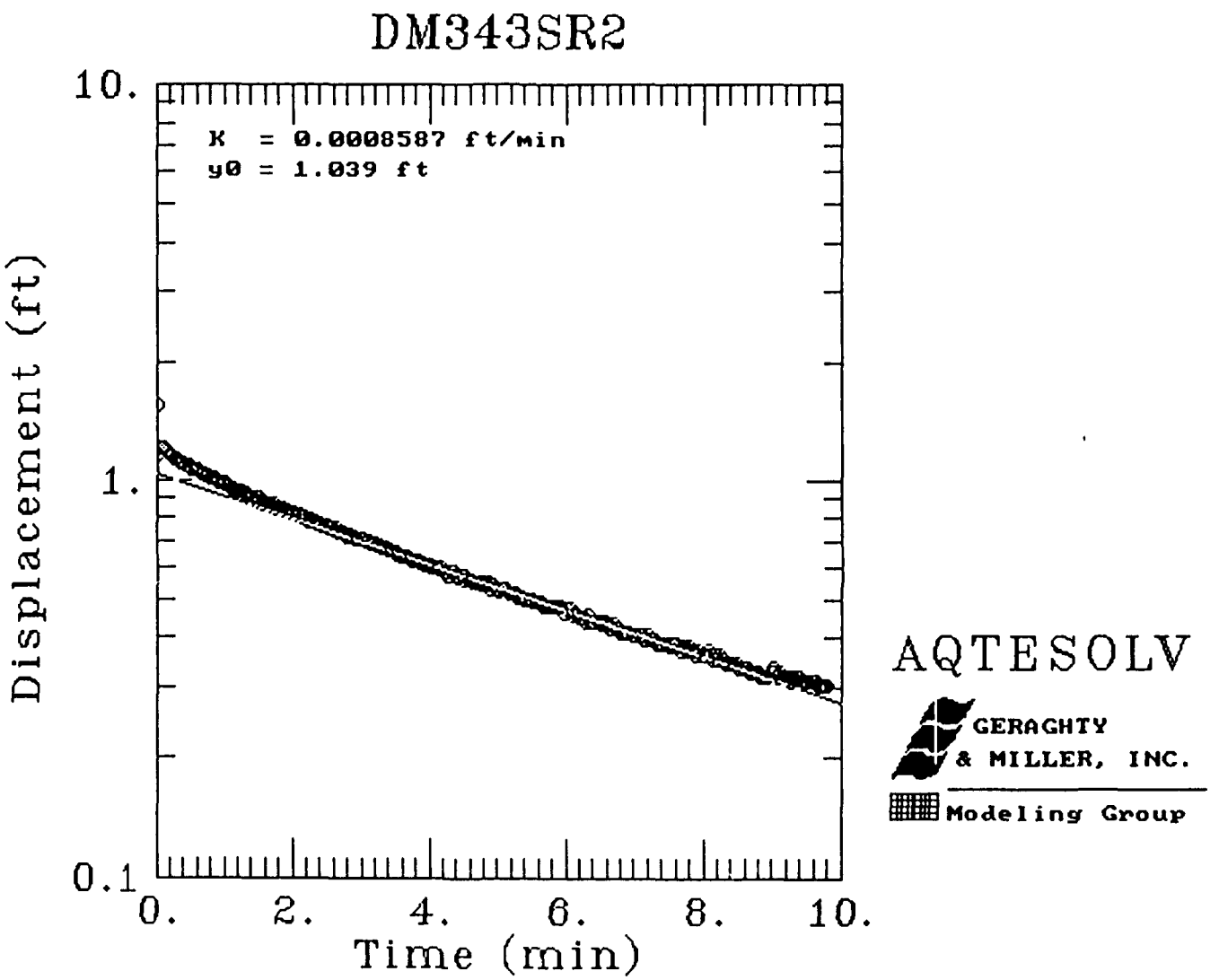


AQTESOLV

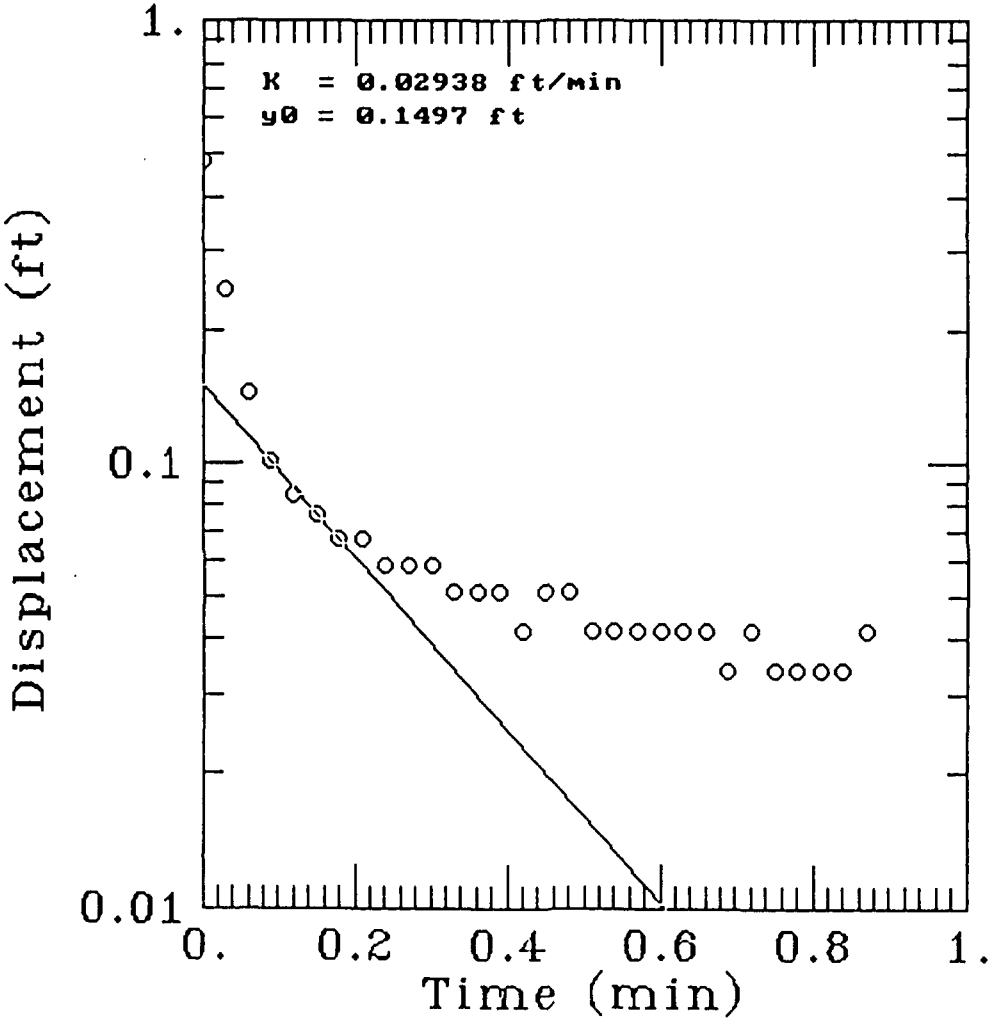
GERAGHTY & MILLER, INC.

Modeling Group


DM349SR2
K = 0.0366 ft/min
y0 = 0.1722 ft
Displacement (ft)
1.
0.1
0.01
0.
0.4
0.8
1.2
1.6
2.
Time (min)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group


DM343SR2
K = 0.0008587 ft/min
y0 = 1.039 ft
10.
1.
0.1
Displacement (ft)
0.
2.
4.
6.
8.
10.
Time (min)
AQTESOLV
GERAGHTY
& MILLER, INC.
Modeling Group

DM349SR3



AQTESOLV

GERAGHTY & MILLER, INC.

Modeling Group

APPENDIX B

WATER LEVEL ELEVATION DATA FROM MONITORING POINTS
APRIL 21, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DE

Sample Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Ground Elevation (ft msl)	Total Depth (ft bls)[d]	LNAPL Observed[e] (Y/N)	Water Depth (ft)	Inner Well Diameter (inches)	Screen Length (ft)	Depth to Screen		Potentiometric Surface Elevation (ft msl)
										Top (ft bls)	Base (ft bls)	
Monitoring Points												
CPT-15S	414104	479746	25.44	25.65	17.90	Y	8.45	0.50	3.28	5.17	8.45	16.99
CPT-16S	414307	479748	NM	24.97	13.40	N	5.65	0.50	3.28	2.37	5.65	NM
CPT-16D	414307	479748	NM	24.97	24.10	N	6.06	0.50	3.28	2.78	6.06	NM
CPT-17S	413912	479430	26.98	27.06	18.80	N	9.35	0.50	3.28	6.07	9.35	17.63
CPT-18S	413813	479294	26.11	26.34	18.70	Y	12.10	0.50	6.56	5.54	12.10	14.01
CPT-19P	413733	479484	NA	26.56	10.10	N	NA	1.50	3.28	7.80	11.08	NA
CPT-19S	413733	479484	NM	26.56	15.90	N	8.96	1.50	3.28	-3.28	NM	NM
CPT-19D	413733	479484	NM	26.56	26.00	N	8.85	0.50	3.28	-3.28	0.00	NM
CPT-20S	413842	479557	26.74	27.00	15.40	N	9.13	0.50	3.28	-3.28	0.00	17.61
CPT-21S	414447	480032	24.42	24.05	14.90	N	4.36	0.50	3.28	-3.28	0.00	20.06
CPT-22S	414388	480694	25.92	26.11	17.90	N	6.31	0.50	3.28	-3.28	0.00	19.61
CPT-22D	414388	480694	NM	26.11	30.40	N	9.33	0.50	3.28	-3.28	0.00	NM
CPT-23S	NM	NM	NA	NM	NA	N	NA	NA	NA	NA	NA	NA
CPT-24S	NM	NM	NA	NM	15.60	N	DRY	0.50	3.28	-3.28	0.00	NA
CPT-25S	414674	480669	26.59	26.63	20.90	N	9.00	0.50	3.28	-3.28	0.00	17.59
CPT-26S	414382	481072	24.88	25.07	23.20	N	9.16	0.50	6.56	-6.56	0.00	15.72
CPT-27S	413518	478754	26.04	26.29	17.40	N	9.83	0.50	3.28	-3.28	0.00	16.21
CPT-27D	413518	478754	NA	26.29	28.40	N	NA	0.50	3.28	-3.28	0.00	NA
CPT-28S	413685	478465	27.47	27.04	20.40	N	11.08	0.50	3.28	-3.28	0.00	16.39
CPT-29S	NM	NM	NM	NM	16.30	N	NM	0.50	3.28	13.09	16.30	NM

[a] See Figure 3.1 for sample locations
[b] Datum is top of casing
[c] ft msl = feet above mean sea level
[d] ft bls = feet below land surface
[e] Emulsification was observed in monitoring point during sampling
[f] NM = Not measured
[g] NA = Not available

APPENDIX B

WATER LEVEL ELEVATION DATA FROM MONITORING POINTS
APRIL 21, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DE

Sample Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Ground Elevation (ft msl)	Total Depth (ft bls)[d]	LNAPL Observed[e] (Y/N)	Water Depth (ft)	Inner Well Diameter (inches)	Screen Length (ft)	Depth to Screen		Potentiometric Surface Elevation (ft msl)
										Top (ft bls)	Base (ft bls)	
Monitoring Points												
CPT-01S	413590	480024	26.48	26.50	17.00	N	9.22	0.50	3.28	5.94	9.22	17.26
CPT-02S	413721	480113	25.51	25.89	13.00	N	7.18	0.50	3.28	3.90	7.18	18.33
CPT-03S	413754	479968	25.64	26.16	13.00	N	8.04	0.50	3.28	4.76	8.04	17.60
CPT-04S	413863	479748	26.31	26.44	17.00	N	8.50	0.50	3.28	5.22	8.50	17.81
CPT-05S	NM[f]	NM	NA[g]	NM	NA	N	NM	NA	NA	NA	NA	NA
CPT-06S	413657	480522	24.10	24.95	16.60	N	6.60	0.50	3.28	3.32	6.60	17.50
CPT-07S	415476	479293	25.85	25.18	15.00	N	6.92	0.50	3.28	3.64	6.92	18.93
CPT-07D	415475	479294	25.83	25.18	28.20	N	7.02	0.50	3.28	3.74	7.02	18.81
CPT-08P	NM	NM	NA	NM	12.10	N	DRY	0.50	3.28	-3.28	DRY	NA
CPT-08S	414102	479416	26.18	26.45	16.6	N	8.42	0.50	6.56	1.86	8.42	17.76
CPT-08D	NM	NM	NM	NM	27.30	N	8.52	0.50	3.28	5.24	8.52	NA
CPT-09S	414644	479271	23.98	24.16	18.60	N	6.04	0.50	6.56	-0.52	6.04	17.94
CPT-10S	414410	479107	NM	25.79	18.60	N	7.85	0.50	6.56	1.29	7.85	NM
CPT-11P	NM	NM	NM	NM	13.00	N	6.15	0.50	3.28	2.87	6.15	NM
CPT-11S	NM	NM	NM	NM	18.80	N	8.70	0.50	3.28	5.42	8.70	NM
CPT-12P	NM	NM	NA	NM	5.10	N	DRY	0.50	3.28	-3.28	DRY	NA
CPT-12S	413955	479095	26.24	26.36	17.80	N	8.76	0.50	3.28	5.48	8.76	17.48
CPT-12D	413955	479103	26.23	26.36	23.40	N	8.83	0.50	3.28	5.55	8.83	17.40
CPT-13S	414106	479154	27.03	27.16	17.30	N	9.18	0.50	3.28	5.90	9.18	17.85
CPT-14S	413951	479626	NM	26.46	17.60	N	NM	1.50	3.28	-3.28	NM	NM

[a] See Figure 3.1 for sample locations

[b] Datum is top of casing

[c] ft msl = feet above mean sea level

[d] ft bls = feet below land surface

[e] Emulsification was observed in monitoring point during sampling

[f] NM = Not measured

[g] NA = Not available

APPENDIX B

WATER LEVEL ELEVATION DATA FROM MONITORING POINTS
APRIL 21, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DE

Sample Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Ground Elevation (ft msl)	Total Depth (ft bls)[d]	LNAPL Observed[e] (Y/N)	Water Depth (ft)	Inner Well Diameter (inches)	Screen Length (ft)	Depth to Screen		Potentiometric Surface Elevation (ft msl)
										Top (ft bls)	Base (ft bls)	
Monitoring Points												
CPT-15S	414104	479746	25.44	25.65	17.90	Y	8.45	0.50	3.28	5.17	8.45	16.99
CPT-16S	414307	479748	NM	24.97	13.40	N	5.65	0.50	3.28	2.37	5.65	NM
CPT-16D	414307	479748	NM	24.97	24.10	N	6.06	0.50	3.28	2.78	6.06	NM
CPT-17S	413912	479430	26.98	27.06	18.80	N	9.35	0.50	3.28	6.07	9.35	17.62
CPT-18S	413813	479294	26.11	26.34	18.70	Y	12.10	0.50	6.56	5.54	12.10	14.01
CPT-19P	413733	479484	NA	26.56	10.10	N	NA	1.50	3.28	7.80	11.08	NA
CPT-19S	413733	479484	NM	26.56	15.90	N	8.96	1.50	3.28	-3.28	NM	NM
CPT-19D	413733	479484	NM	26.56	26.00	N	8.85	0.50	3.28	-3.28	0.00	NM
CPT-20S	413842	479557	26.74	27.00	15.40	N	9.13	0.50	3.28	-3.28	0.00	17.61
CPT-21S	414447	480032	24.42	24.05	14.90	N	4.36	0.50	3.28	-3.28	0.00	20.06
CPT-22S	414388	480694	25.92	26.11	17.90	N	6.31	0.50	3.28	-3.28	0.00	19.61
CPT-22D	414388	480694	NM	26.11	30.40	N	9.33	0.50	3.28	-3.28	0.00	NM
CPT-23S	NM	NM	NA	NM	NA	N	NA	NA	NA	NA	NA	NA
CPT-24S	NM	NM	NA	NM	15.60	N	DRY	0.50	3.28	-3.28	0.00	NA
CPT-25S	414674	480669	26.59	26.63	20.90	N	9.00	0.50	3.28	-3.28	0.00	17.59
CPT-26S	414382	481072	24.88	25.07	23.20	N	9.16	0.50	6.56	-6.56	0.00	15.72
CPT-27S	413518	478754	26.04	26.29	17.40	N	9.83	0.50	3.28	-3.28	0.00	16.21
CPT-27D	413518	478754	NA	26.29	28.40	N	NA	0.50	3.28	-3.28	0.00	NA
CPT-28S	413685	478465	27.47	27.04	20.40	N	11.08	0.50	3.28	-3.28	0.00	16.39
CPT-29S	NM	NM	NM	NM	16.30	N	NM	0.50	3.28	13.09	16.30	NM

[a] See Figure 3.1 for sample locations
[b] Datum is top of casing
[c] ft msl = feet above mean sea level
[d] ft bls = feet below land surface
[e] Emulsification was observed in monitoring point during sampling
[f] NM = Not measured
[g] NA = Not available

APPENDIX C

SOIL AND GROUNDWATER ANALYTICAL DATA

Evergreen

May 3, 1994

MR TODD WIEDEMEIER/MR TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY SUITE 900
DENVER CO 80290

Data Report : 94-1374
Client Project : Dover AFB

Dear Mr. Wiedemeier/Mr. Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice President of Quality Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

C H. Barney/cmt

Jack Barney
President

JJ

Evergreen Analytical Sample Log Sheet

Project # 94-1374

Date(s) Sampled: 04/20/94 COC

Date Due: 04/26/94-UST
05/05/94-Others

e Received: 04/21/94 1015 **Holding Time(s):** 04/22-NO_2,NO_3 as N,04/27-BTEX

Client Project I.D. DOVER AFB **Rush** STANDARD

Client: ENGINEERING SCIENCE **Shipping Charges** 5.00

Address: 1700 BROADWAY SUITE 900 **E.A. Cooler #** N/A

DENVER, CO 80290 **Airbill #** FEDEX 1968905385

TODD WIEDEMEIER/TODD HERRINGTON

Contact: DENVER CONTACT/FIELD CONTACT

Custody Seal Intact? Y
Cooler X Bottles X

Client P.O. 722450.06020 **COC Present** Y

Sample Tags Present? Y

Phone #831-8100 **Fax #**WILL CALL **Sample Tags Listed?** Y

Sample(s) Sealed? Y

Special Invoicing/Billing

Special Instructions **SEE ATTACHED FOR METHODS AND LIMITS.**

Lab ID #	Client ID#	Analysis	Mtx	Btl	Loc
X86375A/B	XYZ-22D	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86379A/B	XYZCPT-29	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86380A/B	XYZCPT-55?	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86375C-F	XYZ-22D	METHANE	W	40V	2
X86379C-F	XYZCPT-29	"	W	40V	2
X86375G	XYZ-22D	ALKALINITY,NO_2,NO_3 AS N, CHLORIDE,SO_4	W	500P	C5
X86376A	XYZ-22S	"	W	500P	"
X86377A	XYZ-25S	"	W	500P	"
X86378A	XYZ-26S	"	W	500P	"
X86379G	XYZCPT-29	"	W	500P	"

R=Sample to be returned
Route GC/MS __ GC 4 Metals __ Gen Chem 2 SxPrep __ Acctg 1

SxRec C Adm C QA/QC C Sales C File Orig

Page 1 of 1 Page(s)

Custodian/Date: LAB 4/21/94

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

Page 1 of 1

COMPANY Engineering Science
ADDRESS 1700 Broadway, Ste 900
CITY Denver STATE CO ZIP 80270
PHONE # 831 8100 FAX # _____ FAX RESULTS Y / N

COMPANY CONTACT (print) Todd Herrington
PROJECT I D Denver AFB
P.O. # 72245.0600
TURNAROUND REQUIRED* Normal
*expedited turnaround subject to additional fee

Sampler Name:
(signature) [signature]
(print) Kyle Cannon

Evergreen Analytical Cooler No. 307

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	Soil / Solid (circle)	Sludge/Slurry (circle)	Oil/Organic Liquid (circle)	Multiphase (identify phase to be analyzed)	ANALYSIS REQUESTED: TCLP VOA/BNA/Pest/Herb/Metals (circle)	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608/508 (circle)	Herbicides 8150/515 (cicle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle) MTBE (circle)	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	MeHalide	Alkalinity / Anions				Notes
XYZ-22D	4-20-94	0930	7												X						X	X					
XYZ-22S	4-20-94	0945	1																			X					
XYZ-25S	4-20-94	1015	1																			X					
XYZ-26S	4-20-94	1045	1																			X					
XYZ CPT-29	4-20-94	1500	7												X						X	X					
XYZ CPT-55	4-20-94	1500	2												X												

Instructions:

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
[signature]	4-20-94 1800	T. Smith	4/21/94 10:15				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZCPT-29	Client Project No.	: Dover AFB
Lab Sample Number	: X86379	Lab Project No.	: 94-1374
Date Sampled	: 4/20/94	Dilution Factor	: 1.00
Date Received	: 4/21/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042221
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	22	B	4
Ethyl Benzene	100-41-4	0.5	J	4
Total Xylene (m/p + o)	1330-20-7	2.2	BJ	4
1,3,5-Trimethylbenzene	108-67-8	0.5	J	4
1,2,4-Trimethylbenzene	95-63-6	0.8	J	4
1,2,3-Trimethylbenzene	526-73-8	0.5	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 111%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-22D	Client Project No.	: Dover AFB
Lab Sample Number	: X86375	Lab Project No.	: 94-1374
Date Sampled	: 4/20/94	Dilution Factor	: 1.00
Date Received	: 4/21/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042231
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	1.1	J	4
Toluene	108-88-3	14	B	4
Ethyl Benzene	100-41-4	0.7	J	4
Total Xylene (m/p + o)	1330-20-7	3	BJ	4
1,3,5-Trimethylbenzene	108-67-8	0.9	J	4
1,2,4-Trimethylbenzene	95-63-6	1.3	J	4
1,2,3-Trimethylbenzene	526-73-8	0.6	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 92%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

APPENDIX D

GRIDDED MODEL INPUT AND CALIBRATION RESULTS

FOR BIOPLUME II MODEL

APPENDIX D1

POTENTIOMETRIC HEADS AT MODEL BOUNDARIES

X-axis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	0	19.2	19.4	19.6	20.1	20.3	20.3	20	19.7	19.3	19	18.8	18.5	18.2	17.8	17.7	17.6	17.5	17.4	0	2
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15 Y-axis
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
29	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	29
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Units are shown in feet above mean sea level

Each cell is 120 feet (x-axis) by 120 feet (y-axis)

APPENDIX D2

TOTAL BTEX PLUME MAP AT TIME=0

X-axis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	0	10	10	10	10	10	90	200	1000	10000	1000	100	10	0	0	0	0	0	0	0	1
2	0	20	20	20	50	100	20	500	1000	20000	10000	100	10	0	0	0	0	0	0	0	2
3	0	30	40	80	100	150	200	800	10000	30000	10000	800	80	30	10	10	10	0	0	0	3
4	0	20	20	20	40	70	80	100	1000	15000	15000	1000	200	100	90	50	20	20	10	0	4
5	0	0	5	10	10	20	50	90	300	10000	15000	1000	800	400	150	100	90	40	20	0	5
6	0	0	0	0	0	10	40	70	200	8000	10000	800	100	50	50	50	40	20	20	0	6
7	0	0	0	0	0	10	40	80	100	5000	9000	100	10	10	10	10	10	10	10	0	7
8	0	0	0	0	0	10	40	60	100	5000	7000	100	10	0	0	0	0	0	0	0	8
9	0	0	0	0	0	10	40	70	100	5000	2000	90	0	0	0	0	0	0	0	0	9
10	0	0	0	0	0	20	30	60	100	1000	1000	80	0	0	0	0	0	0	0	0	10
11	0	0	0	0	10	20	50	100	200	800	200	40	0	0	0	0	0	0	0	0	11
12	0	0	0	0	0	10	50	100	200	400	100	10	0	0	0	0	0	0	0	0	12
13	0	0	0	0	0	10	50	100	200	300	100	10	0	0	0	0	0	0	0	0	13
14	0	0	0	0	0	0	10	90	150	100	80	10	0	0	0	0	0	0	0	0	14
15	0	0	0	0	0	0	5	20	60	50	40	10	0	0	0	0	0	0	0	0	15 Y-axis
16	0	0	0	0	0	0	0	5	30	20	10	0	0	0	0	0	0	0	0	0	16
17	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	0	0	0	17
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Units are shown in ug/L

Each cell is 120 feet (x-axis) by 120 feet (y-axis)

Appendix D3

Dissolved Oxygen Grid

X-axis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1
2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2
3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3
4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6
7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	7
8	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	8
9	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	9
10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10
11	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	11
12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	12
13	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	13
14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	14
15	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	15 Y-axis
16	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	16
17	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	17
18	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	18
19	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	19
20	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	20
21	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	21
22	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	22
23	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	23
24	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	24
25	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25
26	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	26
27	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	27
28	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	28
29	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	29
30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Units are shown in mg/l

Each cell is 120 feet (x-axis) by 120 feet (y-axis)

Appendix D4

Dissolved Nitrate (as N) Grid

X-axis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1
2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	2
3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3
4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6
7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	7
8	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	8
9	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	9
10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10
11	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	11
12	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	12
13	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	13
14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	14
15	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	15 Y-axis
16	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	16
17	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	17
18	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	18
19	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	19
20	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	20
21	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	21
22	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	22
23	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	23
24	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	24
25	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25
26	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	26
27	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	27
28	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	28
29	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	29
30	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Units are shown in mg/l

Each cell is 120 feet (x-axis) by 120 feet (y-axis)

Appendix D6

Dissolved Nitrate (as O_2 Equivalents) Grid

X-axis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	1
2	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	2
3	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	3
4	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	4
5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	5
6	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	6
7	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	7
8	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	8
9	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	9
10	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	10
11	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	11
12	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	12
13	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	13
14	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14
15	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	15 Y-axis
16	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	16
17	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	17
18	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	18
19	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	19
20	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	20
21	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	2
22	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	22
23	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	23
24	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	24
25	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	25
26	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	26
27	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	27
28	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	28
29	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	29
30	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Units are shown in mg/l

Each cell is 120 feet (x-axis) by 120 feet (y-axis)

Appendix D6

Dissolved Oxygen and Nitrate (as O2 Equivalents) Grid

X-axis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	1
2	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	2
3	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19 5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	3
4	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	4
5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	5
6	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	6
7	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	7
8	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	8
9	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	9
10	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	10
11	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	11
12	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	12
13	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	13
14	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	14
15	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	15 Y-axis
16	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	16
17	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	17
18	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	18
19	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19
20	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	20
21	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	21
22	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	22
23	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	23
24	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	24
25	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	25
26	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	26
27	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	27
28	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	28
29	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	29
30	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

Units are shown in mg/l

Each cell is 120 feet (x-axis) by 120 feet (y-axis)

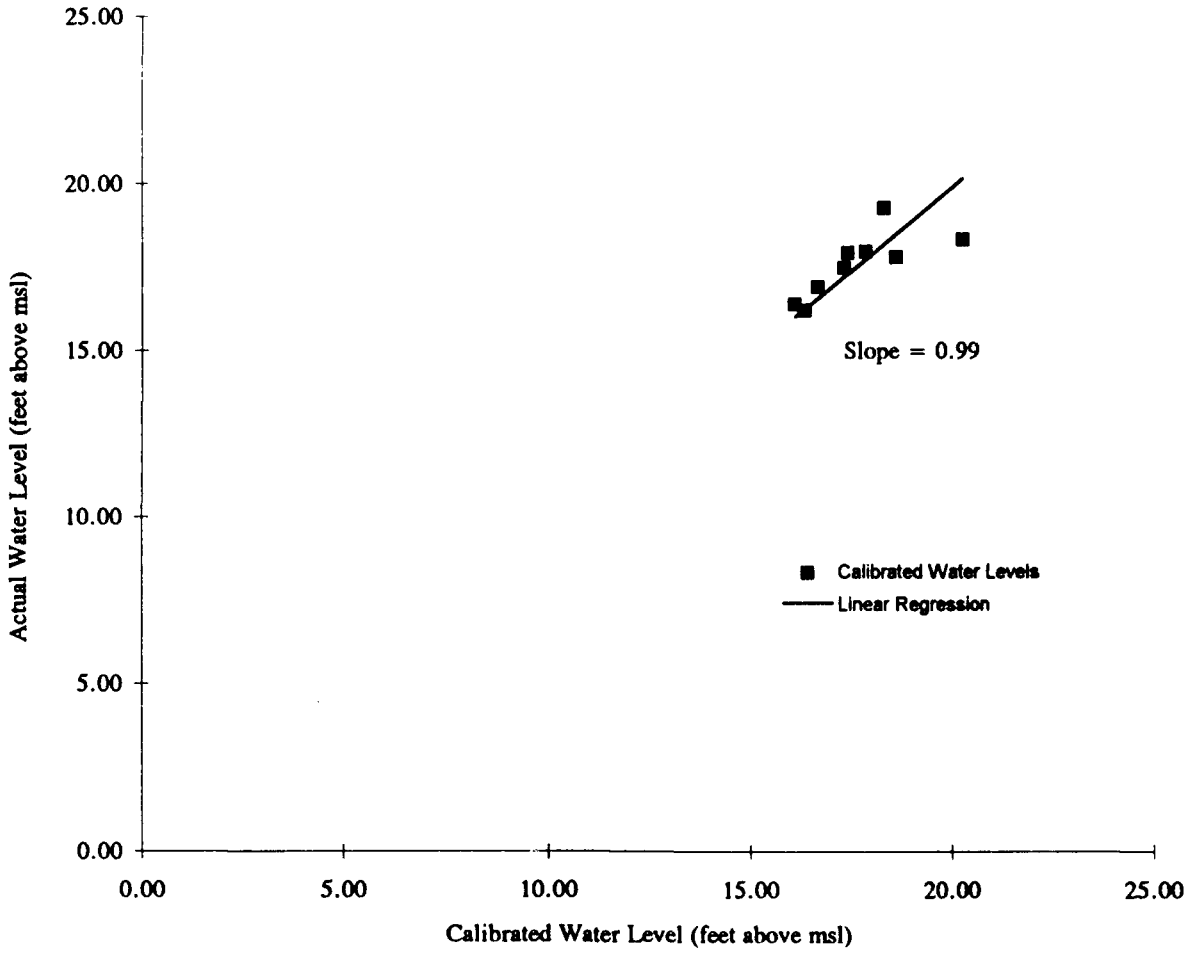
Appendix D

Groundwater Model Calibration Error

Location	Actual Water Level	Calibrated Water Level	Deviation from Mean		
			h_m-h_s	abs(h_m-h_s)	(h_m-h_s)^2
CPT-2S	18.33	20.30	1.97	1.97	3.88
DM345S	19.28	18.33	-0.95	0.95	0.90
CPT-4S	17.81	18.63	0.82	0.82	0.67
CPT-9S	17.94	17.43	-0.51	0.51	0.26
DM343S	17.97	17.87	-0.10	0.10	0.01
CPT-12	17.48	17.35	-0.13	0.13	0.02
75S	16.91	16.68	-0.23	0.23	0.05
CPT-27	16.21	16.37	0.16	0.16	0.03
CPT-28	16.39	16.12	-0.27	0.27	0.07
		Totals:	0.76	5.1	5.9
			n=	9	
			ME=	0.084	
			MAE=	0.57	
			RMS=	0.81	

hm = Calibrated Water Level
hs = Actual Water Level
n = Number of Observations
ME = $1/n * \Sigma(h_m-h_s)$
MAE = $1/n * \Sigma|(h_m-h_s)|$
RMS = $(1/n * \Sigma(h_m-h_s)^2)^{0.5}$

Groundwater Model Water Table Calibration



APPENDIX D
ESTIMATION OF LONGITUDINAL DISPERSIVITY

Assumptions: A. Plume migration is sufficiently aligned along the longitudinal axis of the grid to calculate a longitudinal moment.

B. Longitudinal dispersivity is 1/10 of the distance from the contamination source to the center of contamination.

From Appendix D2, an estimate for the center of mass along the plume center line will be taken by calculating the longitudinal moment around cell (10,1) along column 10, which is near the source of contamination.

Row	Mass (ug/l)	Distance From Cell (10,1) (ft)	Mass x Distance (ug-ft/L)
1	12,450	0	0
2	31,840	120	3,820,800
3	52,340	240	12,561,600
4	32,840	360	11,822,400
5	28,085	480	13,480,800
6	19,450	600	11,670,000
7	14,400	720	10,368,000
8	12,320	840	10,348,800
9	7,310	960	7,017,600
10	2,290	1,080	2,473,200
11	1,420	1,200	1,704,000
12	870	1,320	1,148,400
13	770	1,440	1,108,800
14	440	1,560	686,400
15	185	1,680	310,800
16	65	1,800	117,000
17	20	1,920	38,400
18	0	2,040	0
19	0	2,160	0
20	0	2,280	0
21	0	2,400	0
22	0	2,520	0
23	0	2,640	0
24	0	2,760	0
25	0	2,880	0
26	0	3,000	0
27	0	3,120	0
28	0	3,240	0
29	0	3,360	0
Totals:	204,645		88,677,000

Now, estimate the longintudinal centroid of the plume:

Σ(mass x distance)/Σ(mass) in feet: 430

Estimated distance from the source cell (10,1) to the centroid in feet: 430

Estimated Longitudinal Dispersivity (Dist. x 0.1) in feet: 43

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

COMPANY Engineering Science
ADDRESS 1700 Broadway, Ste 900
CITY Denver STATE CO ZIP 80290
PHONE # 831-8100 FAX # _____ FAX RESULTS Y (N)

COMPANY CONTACT (print) Todd Herrington
PROJECT I.D. Dover AFB
P.O. # 72245J0.6020
TURNAROUND REQUIRED* Normal
*expedited turnaround subject to additional fee

Sampler Name:
(signature) [signature]
(print) Kyle L. Cannon

Evergreen Analytical Cooler No. 173-~~207~~

~~* Custody Seal~~

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	Soil / Solid (circle)	Sludge/Slurry (circle)	Oil/Organic Liquid (circle)	Multiphase (identify phase to be analyzed)	TCLP VOA/BNA/Pest/Herb/Metals (circle)	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608/508 (circle)	Herbicides 8150/515 (circle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle) MTBE	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	Methane	Alkalinity / Anion	TOC	Phosphate	Dissolved Organic Carbon	Notes
~~XYZ-22S~~	4-16-94	1445	~~10~~ 9				X								2		2	1			4						
XYZ-25S	4-16-94	1400	9				X								2		2	1			4						
XYZ-26S	4-16-94	1800	~~06~~				X								2						4						
XYZCPT22-13'-15'	4-16-94	1810	4		X										2		1						1				
XYZ-19S	4-18-94	1100	12				X								2		2	1			4	1		1	1		
XYZ-19D	4-18-94	~~1100~~ 1200	10				X								2		2	1			4	1					
XYZ-14S	4-18-94	1330	~~10~~				X								2		2	1			4	1					
XYZ-15S	4-18-94	1430	7				X								2			~~1~~			4	1					
XYZ-08D	4-18-94	1530	10				X								2		2	1			4	1					
XYZ-12D	4-18-94	1630	10				X								2		2	1			4	1					

Instructions: XYZ CPT 16 LIF (7'-9') 4-18-94 1100, (TVH & BTEX) 3 jars; XYZ CPT 16 LIF (11'-13'), 4-18-94, 1130, 3 jars, TVH & BTEX; XYZ CPT 08 LIF (8'-10') 4-18-94, 0924, 3 jars, TVH & BTEX; XYZ CPT 12-LIF (13.7-15.7), 4-18-94 0935, 3 jars, BTEX & TVH; XYZ CPT 12-LIF (14'-16'), 4-18-94, 1013, 3 jars, TVH & BTEX; XYZ CPT 07-LIF (16'-18') 4-18-94 1342 TOC

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
[signature]	1800 4-18-94	Joe Mac	4-19-94 1100				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

Evergreen Analytical Sample Receipt/Check-in Record

Date & Time Rec'd: 4-19-94 1100 Shipped Via: H.D.
(Airbill # if applicable)

Client : Engineering Science

Client Project ID(s): Dover AFB

EAL Project #(s): 94- 1329 EAL Cooler(s): (Y) N

Cooler#	173								
Ice packs	(Y)	N	Y	N	Y	N	Y	N	Y	N
Temperature °C	4.0°C								

	Y	N	N/A
1. Custody seal(s) present:	X		
Seals on cooler intact	X		
Seals on bottle intact		X	
2. Chain of Custody present:	X		
3 Containers broken or leaking: (Comment on COC if Y)		X	
4. Containers labeled:	X		
5. COC agrees w/ bottles received: (Comment on COC if N)	X		
6. COC agrees w/ labels: (Comment on COC if N)	X		
7. Headspace in VOA vials-waters only (comment on COC if Y)		X	
8. VOA samples preserved:		X	
9. pH measured on metals, cyanide or phenolics*:			X
List discrepancies			
*Non-EAL provided containers only, water samples only.			
10. Dissolved metals samples present:		X	
To be preserved:			X
To be filtered:			X
11. Short holding times:	X		
Specify parameters NO_2, NO_3			
12. Multi-phase sample(s) present:		X	
13. COC signed w/ date/time:	X		

Comments:

(Additional comments on back)
Custodian Signature/Date: Joe Mas 4-19-94

Eng. Science Precontract parameter
Dover AFB

TABLE A.3

SUMMARY OF AQUEOUS ANALYTICAL METHODS

INQUIRY 722450-SC001

Parameter	Analytical Method	Reporting Units	Maximum Analyses	Unit Price
Total Phosphate	E365 2	mg/L[a/]	5	$____EA
Sulfate Anions	E300	mg/L	30	$____EA
Purgeable Aromatic (BTEX + trimethylbenzene isomers)	SW8020	µg/L	30	$____EA
Alkalinity	A403	mg/L	30	$____EA
Dissolved Organic Carbon*	A5310C	mg/L	5	$____EA
Nitrogen, NO_3/NO_2 Nitrate	E300	mg/L	30	$____EA
Chloride (Anion)	E300	mg/L	30	$____EA
Methane	**RSKSOP-147	mg/L	30	$____EA
Total Hydrocarbons (Volatile & Extractable)	SW8015 Modified Gasoline Range	mg/L	20	$____EA

a/ mg/L = milligrams per liter.
b/ µg/L = micrograms per liter.

* Optional, may not be required. See page A-8 para. 3.1.
** Standard Operating Procedure Attached (12 pages).

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-22S	Client Project No.	: Dover AFB
Lab Sample Number	: X86231	Lab Project No.	: 94-1329
Date Sampled	: 4/16/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042308
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	6.7		4
Toluene	108-88-3	45	B	4
Ethyl Benzene	100-41-4	7		4
Total Xylene (m/p + o)	1330-20-7	48	B	4
1,3,5-Trimethylbenzene	108-67-8	4.6		4
1,2,4-Trimethylbenzene	95-63-6	17		4
1,2,3-Trimethylbenzene	526-73-8	4.6		4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 101%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

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(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-25S	Client Project No.	: Dover AFB
Lab Sample Number	: X86232	Lab Project No.	: 94-1329
Date Sampled	: 4/16/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Water
Date Analyzed	: 4/24/94	Lab File No.	: BX2042310
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	1.2	J	4
Toluene	108-88-3	13	B	4
Ethyl Benzene	100-41-4	2.1	J	4
Total Xylene (m/p + o)	1330-20-7	8.9	B	4
1,3,5-Trimethylbenzene	108-67-8	1.7	J	4
1,2,4-Trimethylbenzene	95-63-6	4.7		4
1,2,3-Trimethylbenzene	526-73-8	1.7	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 101%
QC Reporting Limits	: 77%-116%

QUALIFIERS:

E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available

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(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-26S	Client Project No.	: Dover AFB
Lab Sample Number	: X86233	Lab Project No.	: 94-1329
Date Sampled	: 4/16/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Water
Date Analyzed	: 4/24/94	Lab File No.	: BX2042311
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	0.9	J	4
Toluene	108-88-3	6.1	B	4
Ethyl Benzene	100-41-4	1.5	J	4
Total Xylene (m/p + o)	1330-20-7	6.6	B	4
1,3,5-Trimethylbenzene	108-67-8	1.5	J	4
1,2,4-Trimethylbenzene	95-63-6	3.6	J	4
1,2,3-Trimethylbenzene	526-73-8	1.4	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 101%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-19S	Client Project No.	: Dover AFB
Lab Sample Number	: X86235	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042212
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	2.8	BJ	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	1.4	BJ	4
1,3,5-Trimethylbenzene	108-67-8	0.7	J	4
1,2,4-Trimethylbenzene	95-63-6	1	J	4
1,2,3-Trimethylbenzene	526-73-8	0.6	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 106%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-19D	Client Project No.	: Dover AFB
Lab Sample Number	: X86236	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/22/94	Lab File No.	: BX2042214
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	22		4
Toluene	108-88-3	49	B	4
Ethyl Benzene	100-41-4	12		4
Total Xylene (m/p + o)	1330-20-7	53	B	4
1,3,5-Trimethylbenzene	108-67-8	4.2		4
1,2,4-Trimethylbenzene	95-63-6	14		4
1,2,3-Trimethylbenzene	526-73-8	3.7	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 116%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-14S	Client Project No.	: Dover AFB
Lab Sample Number	: X86237	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 10.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Water
Date Analyzed	: 4/24/94	Lab File No.	: BX2042314
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	920		40
Toluene	108-88-3	430	B	40
Ethyl Benzene	100-41-4	210		40
Total Xylene (m/p + o)	1330-20-7	790	B	40
1,3,5-Trimethylbenzene	108-67-8	82		40
1,2,4-Trimethylbenzene	95-63-6	310		40
1,2,3-Trimethylbenzene	526-73-8	63		40

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 100%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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BTEX Data Report

Client Sample Number	: XYZ-51S	Client Project No.	: Dover AFB
Lab Sample Number	: X86238	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Water
Date Analyzed	: 4/24/94	Lab File No.	: BX2042316
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	960		40
Toluene	108-88-3	460	B	40
Ethyl Benzene	100-41-4	240		40
Total Xylene (m/p + o)	1330-20-7	940	B	40
1,3,5-Trimethylbenzene	108-67-8	160		40
1,2,4-Trimethylbenzene	95-63-6	490		40
1,2,3-Trimethylbenzene	526-73-8	94		40

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 99%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZ-08D	Client Project No.	: Dover AFB
Lab Sample Number	: X86239	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042229
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	7.7		4
Toluene	108-88-3	19	B	4
Ethyl Benzene	100-41-4	2.6	J	4
Total Xylene (m/p + o)	1330-20-7	7.5	B	4
1,3,5-Trimethylbenzene	108-67-8	2.1	J	4
1,2,4-Trimethylbenzene	95-63-6	3.8	J	4
1,2,3-Trimethylbenzene	26-73-8	1.7	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 105%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZ-12D	Client Project No.	: Dover AFB
Lab Sample Number	: X86240	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042230
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	1.7	J	4
Toluene	108-88-3	8.3	B	4
Ethyl Benzene	100-41-4	1.1	J	4
Total Xylene (m/p + o)	1330-20-7	3.6	BJ	4
1,3,5-Trimethylbenzene	108-67-8	0.8	J	4
1,2,4-Trimethylbenzene	95-63-6	1.3	J	4
1,2,3-Trimethylbenzene	526-73-8	0.7	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 103%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report
Method Blank Report

Method Blank Number	: MEB042294	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/22/94	Lab Project No.	: 94-1329
Date Analyzed	: 4/23/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042225

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	1.1	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.6	J	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 112%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report
Method Blank Report

Method Blank Number	: MB042394	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/23/94	Lab Project No.	: 94-1329
Date Analyzed	: 4/23/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042303

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	0.6	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.9	J	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 110%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZCPT 22-13'-15'	Client Project No.	: Dover AFB
Lab Sample Number	: X86234	Lab Project No.	: 94-1329
Date Sampled	: 4/16/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Lab File No.	: BX1042105
Methanol Extract?	: No	Method Blank No.	: MEB042194

Compound Name	Cas Number	Sample Concentration ug/kg		PQL ug/kg
Benzene	71-43-2		U	4
Toluene	108-88-3	0.6	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 96%
QC Reporting Limits : 55%-127%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZCPT 16LIF(7'-9')	Client Project No.	: Dover AFB
Lab Sample Number	: X86241	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 125.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Lab File No.	: BX1042106
Methanol Extract?	: Yes	Method Blank No.	: MEB042194

Compound Name	Cas Number	Sample Concentration ug/kg		PQL ug/kg
Benzene	71-43-2	8800		500
Toluene	108-88-3	36000	E	500
Ethyl Benzene	100-41-4	33000	E	500
Total Xylene (m/p + o)	1330-20-7	34000		500

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 362% Co-eluting peaks.
QC Reporting Limits : 55%-127%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZCPT 16LIF(11'-13')	Client Project No.	: Dover AFB
Lab Sample Number	: X86242	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Lab File No.	: BX1042107
Methanol Extract?	: No	Method Blank No.	: MEB042194

Compound Name	Cas Number	Sample Concentration ug/kg		PQL ug/kg
Benzene	71-43-2		U	4
Toluene	108-88-3		U	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.5	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 110%
QC Reporting Limits : 55%-127%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZCPT 08-LIF(8'-10')	Client Project No.	: Dover AFB
Lab Sample Number	: X86243	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 5.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Lab File No.	: BX1042110
Methanol Extract?	: No	Method Blank No.	: MEB042194

Compound Name	Cas Number	Sample Concentration ug/kg	PQL ug/kg
Benzene	71-43-2	U	20
Toluene	108-88-3	U	20
Ethyl Benzene	100-41-4	U	20
Total Xylene (m/p + o)	1330-20-7	U	20

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 113%
QC Reporting Limits : 55%-127%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZCPT12(or8)-LIF(13.7-15.7')		
		Client Project No.	: Dover AFB
Lab Sample Number	: X86244	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 5.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Lab File No.	: BX1042111
Methanol Extract?	: No	Method Blank No.	: MEB042194

Compound Name	Cas Number	Sample Concentration ug/kg	PQL ug/kg
Benzene	71-43-2	U	20
Toluene	108-88-3	U	20
Ethyl Benzene	100-41-4	U	20
Total Xylene (m/p + o)	1330-20-7	U	20

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 108%
QC Reporting Limits : 55%-127%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report

Client Sample Number	: XYZCPT 12LIF(14'-16')	Client Project No.	: Dover AFB
Lab Sample Number	: X86245	Lab Project No.	: 94-1329
Date Sampled	: 4/18/94	Dilution Factor	: 1.00
Date Received	: 4/19/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Lab File No.	: BX1042112
Methanol Extract?	: No	Method Blank No.	: MEB042194

Compound Name	Cas Number	Sample Concentration ug/kg	PQL ug/kg
Benzene	71-43-2	U	4
Toluene	108-88-3	U	4
Ethyl Benzene	100-41-4	U	4
Total Xylene (m/p + o)	1330-20-7	U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 108%
QC Reporting Limits	: 55%-127%

QUALIFIERS:

E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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BTEX Data Report
Method Blank Report

Method Blank Number	: MEB042194	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/21/94	Lab Project No.	: 94-1329
Date Analyzed	: 4/21/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX1042109

Compound Name	Cas Number	Sample Concentration ug/L	PQL ug/L
Benzene	71-43-2	U	4
Toluene	108-88-3	U	4
Ethyl Benzene	100-41-4	U	4
Total Xylene (m/p + o)	1330-20-7	U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 111%
QC Reporting Limits	: 77%-116%

QUALIFIERS:

E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/16,18/94	Client Project Number	: Dover AFB
Date Received	: 4/19/94	Lab Project Number	: 94-1329
Date Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/L	MDL mg/L
X86231	XYZ-22S	94%	0.5	0.1
X86232	XYZ-25S	101%	U	0.1
X86235	XYZ-19S	107%	U	0.1
X86236	XYZ-19D	101%	0.4	0.1
X86237	XYZ-14S	97%	14	0.1
X86239	XYZ-08D	101%	0.4	0.1
X86240	XYZ-12D	101%	U	0.1
X86240-DUP	XYZ-12D	100%	U	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

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TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/16,18/94	Client Project Number	: Dover AFB
Date Received	: 4/19/94	Lab Project Number	: 94-1329
Date Prepared	: 4/21/94	Matrix	: Soil
Date Analyzed	: 4/21/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/Kg	MDL mg/Kg
X86234C	XYZCPT22-13'-15'	93%	U	0.1
X86241C	XYZCPT16LIF(7'-9')	71%	360	0.5
X86242C	XYZCPT16LIF(11'-13')	96%	0.4	0.1
X86243C	XYZCPT08-LIF(8'-10')	107%	U	0.1
X86244C	XYZCPT112(or 8)-LIF (13.7-15.7')	107%	U	0.1
X86245C	XYZCPT12LIF(14'-16')	107%	U	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

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TOTAL EXTRACTABLE HYDROCARBONS (TEH)
C11-C28 Boiling Range

Date Sampled	: 4/16,18/94	Client Project Number	: Dover AFB
Date Received	: 4/19/94	Lab Project Number	: 94-1329
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/21/94	Method Number	: 3500/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TEH mg/L	MDL mg/L
WB042094		71%	U	0.5
DI Matrix Spike		77%	58% Diesel Spike Recovery	
X86231I	XYZ-22S	71%	U	0.5
X86232I	XYZ-25S	67%	U	0.5
X86235J	XYZ-19S	64%	U	0.5
X86236J	XYZ-19D	65%	U	0.5
X86237J	XYZ-14S	[1]	5.9	0.5
X86239J	XYZ-08D	71%	U	0.5
X86240J	XYZ-12D	71%	U	0.5

QUALIFIERS
U = TEH analyzed for but not detected.
B = TEH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit
[1] = Unable to separate surrogate from analyte.

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Methane Data Report

Client Project No.: Dover AFB
Date Sampled : 04/16,18/94
Lab Project No. : 94-1329
Date Received : 04/19/94
Dilution Factor : see below
Date Prepared : 04/22/94
Method : FID
Date Analyzed : 04/22/94
Matrix : Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042294	Method Blank	Water	U	10 (DF=1)
x86231	XYZ-22S	Water	U	10 (DF=1)
x86232	XYZ-25S	Water	120	50 (DF=5)
x86233	XYZ-26S	Water	58	10 (DF=1)
x86235	XYZ-19S	Water	650	100 (DF=10)
x86236	XYZ-19D	Water	36	10 (DF=1)
x86237	XYZ-14S	Water	970	100 (DF=10)
x86238	XYZ-51S	Water	960	100 (DF=10)
x86239	XYZ-08D	Water	550	100 (DF=10)
x86240	XYZ-12D	Water	160	100 (DF=5)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

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Miscellaneous Analyses

Date Sampled	: 4/18/94	Client Project ID.	: Dover AFB
Date Received	: 4/19/94	Lab Project No.	: 94-1329
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method	: EPA 310.1

Evergreen Sample #	Client Sample ID	Total Alkalinity($mgCaCO_3/L$)
X86235	XYZ-19S	163
X86236	XYZ-19D	13.5
X86237	XYZ-14S	195
X86238	XYZ-51S	200
X86239	XYZ-08D	15.3
X86240	XYZ-12D	12.6

Analyst

Approved

1329tm.4

EVERGREEN ANALYTICAL, INC.
4036 Youngfield Street Wheat Ridge, CO 80033
(303) 425-6021

Anions

Date Sampled : 4/18/94
Date Received : 4/19/94
Date Prepared : 4/20/94
Date Analyzed : 4/20/94

Client Project ID : Dover AFB
Lab Project No. : 94-1329
Method : EPA Method 300.0

Client Sample ID	XYZ-19S	XYZ-19D	XYZ-14S	XYZ-51S	XYZ-08D	XYZ-12D
Evergreen Sample #	X86235	X86236	X86237	X86238	X86239	X86240
Matrix	Water	Water	Water	Water	Water	Water
Chloride (mg/L)	4.64	7.11	6.72	6.56	6.95	6.26
Nitrite-N (mg/L)	<0.076	<0.076	<0.076	<0.076	<0.076	<0.076
Nitrate-N (mg/L)	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056
Sulfate (mg/L)	54.1	24.7	7.54	7.37	44.8	54.7

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield Street Wheat Ridge, CO 80033
(303) 425-6021

Anions

Date Sampled : 4/18/94
Date Received : 4/19/94
Date Prepared : 4/20/94
Date Analyzed : 4/20/94

Client Project ID : Dover AFB
Lab Project No. : 94-1329
Method : EPA Method 300.0

Client Sample ID	XYZ-19S	XYZ-19D	XYZ-14S	XYZ-51S	XYZ-08D	XYZ-12D
Evergreen Sample #	X86235	X86236	X86237	X86238	X86239	X86240
Matrix	Water	Water	Water	Water	Water	Water
Chloride (mg/L)	4.64	7.11	6.72	6.56	6.95	6.26
Nitrite-N (mg/L)	<0.076	<0.076	<0.076	<0.076	<0.076	<0.076
Nitrate-N (mg/L)	<0.056	<0.056	<0.056	<0.056	<0.056	<0.056
Sulfate (mg/L)	54.1	24.7	7.54	7.37	44.8	54.7

Analyst

Approved

1329tn.24

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/18/94	Client Project ID.	: Dover AFB
Date Received	: 4/19/94	Lab Project No.	: 94-1329
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method	: EPA 365.2

Evergreen Sample #	Client Sample ID	Total Phosphate (mg/L)
X86235	XYZ-19S	<0.01

Analyst

Approved

1329tm.4

HUFFMAN
LABORATORIES, INC.
Quality Analytical Services Since 1936
4630 Indiana Street • Golden, CO 80403
Phone: (303) 278-4455 • FAX: (303) 278-7012

CUSTOMER #:
02602

DATE 5/6/94
LAB# 172994
P.O. 10496
RECD 04/21/94

ANALYSIS REPORT

CARL SMITS
EVERGREEN ANALYTICAL
4036 YOUNGFIELD
WHEAT RIDGE CO 80033

PROJ. # 94-1291, 1309, 1329 AND 1357

SEQUENCE/ SAMPLE NUMBER	ANALYSIS CARBONATE C---%	TOTAL CARBON--%	ORGANIC C-----%	DOC--------MG/
01/XYZCPT-07 LIF-	<0.02	<0.05	<0.05	←
02/XYZCPT-14 13-15-	<0.02	0.17	0.17	
03/XYZCPT-19 9-11-	<0.02	0.08	0.08	
04/XYZCPT-22 13-15-	<0.02	0.55	0.55	←
05/XYZ-07S				0.75
06/XYZ-08S				3.02
07/XYZ-12S				<0.05
08/XYZ-19S				3.70 ←
09/XYZ-27S				<0.05

DOC VALUES WERE DETERMINED BY AMPOULE COMBUSTION ON FILTERED SAMPLES. ALTHOUGH FILTER BLANKS WERE CONSISTENT, SOME APPARENT VARIABILITY IN FILTERED VALUES WAS OBSERVED. TOC VALUES ON THE SAMPLES AS DETERMINED BY UV-PERSULFATE OXIDATION AND MEMBRANE-CONDUCTIVITY DETECTION ARE AS FOLLOWS:

SAMPLE	TOC--------MG/L
05/XYZ-07S	2.77
06/XYZ-08S	4.09
07/XYZ-12S	1.56
08/XYZ-19S	4.87 ←
09/XYZ-27S	0.91

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ANALYSIS REPORT

CARL SMITS
EVERGREEN ANALYTICAL
4036 YOUNGFIELD
WHEAT RIDGE CO 80033

PROJ. # 94-1291, 1309, 1329, AND 1357

SEQUENCE/ SAMPLE NUMBER	ANALYSIS CARBONATE C---%	TOTAL CARBON--%	ORGANIC C-----%	DOC--------MG/L
01/XYZCPT-07 LIF-	<0.02	<0.05	<0.05	
02/XYZCPT-14 13-15-	<0.02	0.17	0.17	
03/XYZCPT-19 9-11-	<0.02	0.08	0.08	
04/XYZCPT-22 13-15-	<0.02	0.55	0.55	
05/XYZ-07S-				0.75
06/XYZ-08S-				3.02
07/XYZ-12S-				<0.05
08/XYZ-19S-				3.70
09/XYZ-27S-				<0.05

DOC VALUES WERE DETERMINED BY AMPOULE COMBUSTION ON FILTERED SAMPLES. ALTHOUGH FILTER BLANKS WERE CONSISTENT, SOME APPARENT VARIABILITY IN FILTERED VALUES WAS OBSERVED. TOC VALUES ON THE SAMPLES AS DETERMINED BY UV-PERSULFATE OXIDATION AND MEMBRANE-CONDUCTIVITY DETECTION ARE AS FOLLOWS:

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05/XYZ-07S	2.77
06/XYZ-08S	4.09
07/XYZ-12S	1.56
08/XYZ-19S	4.87
09/XYZ-27S	0.91

Evergreen

P.O. # 10496

OUTSIDE CONTRACTOR ANALYSIS REQUEST & CHAIN-OF-CUSTODY

Analytical Lab: Huffman Laboratories, Inc

Address: 4630 Indiana Street, Golden, CO 80403

Phone: 278-4455

Contact: Sue Zeller

Results Required By: Standard

Please analyze the following samples as described below:

No. of Samples Shipped: 9

Project No.	Client Sample No.	Date/Time Sampled	Matrix	Analysis Requested
94-1291	XYZ-12S	4/14/94	water	DOC 5310D Method #
94-1310	XYZ-07S	4/15/94	water	↓
94-1310	XYZ-08S	4/15/94	water	↓
94-1309	XYZ-CPT 14-13-15	4/15/94	soil	SW 9060 TOC MODIFIED
94-1309	XYZCPT 19-9-11	4/15/94	↓	↓

RUSH SERVICES (FOR EXTRA FEE): YES ____ NO ____

IF ANY QUESTIONS OR PROBLEMS CONTACT: Shon Greiner

PLEASE FAX THE RESULTS TO: CARL SMITS

PLEASE MAIL WRITTEN RESULTS TO: CARL SMITS

SAMPLES RELINQUISHED BY: ____

METHOD OF SHIPMENT: ____ DATE:/TIME ____

SAMPLES RECEIVED BY: Mary Dunlap DATE:/TIME 4/20/94 3:45

CUSTODY SEAL INTACT: YES ____ NO ____

Note Run DOC by ampule method.
Please report using Client Sample No.

coc.frm

Evergreen

P.O. # 10496

OUTSIDE CONTRACTOR ANALYSIS REQUEST & CHAIN-OF-CUSTODY

Analytical Lab: Huffman

Address: 4630 Indiana ST
Golden, CO 80403

Phone: 2784455

Contact: Sue Zeller

Results Required By: ~~Rush~~ Standard

Please analyze the following samples as described below:

No. of Samples Shipped: _____

Project No.	Client Sample No.	Date/Time Sampled	Matrix	Analysis Requested
94-1329	XYZ-17S	4/18/94	WATER	DOC 53 >
↓	XYZ CPT 07 LIF 16'-18'	4/18/94	SOIL	TOC Mod. 9060
↓	XYZ CPT 22 13'-15'	4/16/94	↓	TOC Mod. 9060
94-1357	XYZ 27S	4/19/94	WATER	DOC 5310D

RUSH SERVICES (FOR EXTRA FEE): YES_____ NO_____

IF ANY QUESTIONS OR PROBLEMS CONTACT: Shea Gremillion

PLEASE FAX THE RESULTS TO: ~~Shea~~ Carl Smith

PLEASE MAIL WRITTEN RESULTS TO: Carl Smith

SAMPLES RELINQUISHED BY: _____

METHOD OF SHIPMENT: _____ **DATE:/TIME** _____

SAMPLES RECEIVED BY: Mary Dunlap **DATE:/TIME** 4/20/94 3:45

CUSTODY SEAL INTACT: YES _____ NO _____

Note: 1 Run DOC by ampule method
Please report using Client sample No,

coc.frm

Soil/Sediment Analytes/Methods													
Method:	SW8020												
Sample ID	Benzene (µg/kg)	Benzene flag	Toluene (µg/kg)	Toluene flag	Ethyl Benzene (µg/kg)	Ethyl Benzene flag	M&P-xylene (µg/kg)	M&P-xylene flag	O-xylene (µg/kg)	O-xylene flag	Total Xylenes (µg/kg)	Total Xylenes flag	Total BTEX (µg/kg)
XYZCPT 14-13-15	75	J	590		590		3100		900		4000		5255
XYZCPT 19-9-11	2	<	2	<	2	<	2	<	2	<	2	<	2
XYZCPT 19-15-17	0.6	J	1.4	J	0.4	<	0.5	J	0.4	<	0.5	J	2.5
XYZCPT 22-13-15	0.4	<	0.6	J	0.4	<	0.4	<	0.4	<	0.4	<	0.6
XYZCPT 16 LIF (7-9)	8800		36000	E	33000	E	18,000		16,000		34,000		111800
XYZCPT 16 LIF (11-13)	0.4	<	0.4	<	0.4	<	0.5	J	0.4	<	0.5	J	0.5
XYZCPT 08 LIF (8-10)	2	<	2	<	2	<	2	<	2	<	2	<	2
XYZCPT 8 LIF (13.7-15.7)	2	<	2	<	2	<	2	<	2	<	2	<	2
XYZCPT 12 LIF (14-16)	2	<	2	<	2	<	2	<	2	<	2	<	2
XYZCPT 07 LIF (16-18)													

	Soil/Sediment Analytes/Methods (continued)					
	418.1		SW5030/SW8015M		A5310C	
	Total Petroleum Hydro-carbons (mg/kg)	TPH flag	Total Volatile Hydro-carbons (µg/kg)	TVH flag	Total Organic Carbon (mg/kg)	Total Organic Carbon flag
Total BTEX flag						
			1100		1700	
<			0.2		800	
			0.1	<		
			0.1	<	0.55	
			360			
			0.4			
<			0.1	<		
<			0.1	<		
<			0.1	<		
					0.05	<

Aqueous Analytes/Methods													
Method:	SW8020												
					Ethyl	Ethyl					Total	Total	Total
Sample	Benzene	enzen	Toluene	oluen	Benzene	enzen	M&P-xylene	M&P-xylene	O-xylene	-xyle	Xylenes	ylene	BTEX
ID	(µg/L)	flag	(µg/L)	flag	(µg/L)	flag	(µg/L)	flag	(µg/L)	flag	(µg/L)	flag	(µg/L)
XYZ-2S	0.4	J	2.3	J	0.4	<	0.8	J	0.4	<	0.8	BJ	3.5
XYZ-06S	0.4	<	7.4		0.4	<	0.9	BJ	0.4	<	0.9	BJ	8.3
XYZ-11P	0.4	<	6.5		0.4	<	0.9	BJ	0.4	<	0.9	BJ	7.4
XYZ-11S	0.4	<	8.8		0.5	J	1.3	BJ	0.4	J	1.4	BJ	11
XYZ-12S	0.4	J	3.7	J	0.4	<	0.6	BJ	0.4	<	0.6	BJ	4.7
XYZ-07S	0.4	<	15	B	0.4	J	1.5	BJ	0.4	J	1.9	BJ	17.3
XYZ-09S	2.2	J	2.6	J	0.4	<	1.3	BJ	0.4	<	1.3	BJ	6.1
XYZ-10S	0.4	<	3.9	J	0.4	<	0.4	BJ	0.4	<	0.4	BJ	4.3
XYZ-60S	0.9	J	6.5		0.4	J	0.9	BJ	0.4	J	1.3	BJ	9.1
XYZ-08S	0.9	J	7.4		0.4	J	1	BJ	0.5	J	1.5	BJ	10.2
XYZ-18S	6500		13,000	B	820		1600	B	1000		2600	B	22,920
XYZ-13S	0.9	J	5.6		0.8	J	1.9	BJ	1.1	J	3	BJ	10.3
XYZ-21S	55		150		30		99	B	44		143		378
XYZ-22S	6.7		45	B	7		32	B	16		48	B	106.7
XYZ-25S	1.2	J	13	B	2.1	J	5.5	B	3.4	J	8.9	B	25.2
XYZ-26S	0.9	J	6.1	B	1.5	J	3.9	BJ	2.7	J	6.6	B	15.1
XYZ-19S	0.4	<	2.8	J	0.4	<	0.9	BJ	0.5	J	1.4	BJ	4.2
XYZ-19D	22		49	B	12		38	B	15		53	B	136
XYZ-14S	920		430	B	210		600	B	190		790	B	2350
XYZ-51S	960		460	B	240		730	B	210		940	B	2600
XYZ-08D	7.7		19	B	2.6	J	5.1	B	2.4	J	7.5	B	36.8
XYZ-12D	1.7	J	8.3	B	1.1	J	2.5	B	1.1	J	3.6	B	14.7
XYZ-15S	970,000	E	2,500,000	BE	1,600,000	E	4,200,000	BE	2,000,000	E	6,200,000	BE	11,270
XYZ-16S	14		34	B	54		44	B	11		55	B	157
XYZ-16D	350	E	64	B	28		24	B	14		38	B	480
XYZ-27S	0.7	J	6	B	1.5	J	4.6	B	1.7	J	6.3	B	14.5
XYZ-27D	5.4		18	B	1.7	J	3.7	BJ	2.5	J	6.2	B	31.3
XYZ-28S	5		54	B	5		19	B	6		25	B	89
XYZ-22D	1.1	J	14	B	0.7	J		BJ	0.9	J	3	BJ	18.8
XYZCPT-29	0.4	<	22	B	0.5	J	1.6	BJ	0.6	J	2.2	BJ	24.7
XYZCPT-55	0.4	<	21	B	0.6	J	1.7	BJ	0.9	J	2.6	BJ	24.2
XYZ-22S													
XYZ-25S													
XYZ-26S													
3/10/95													

	Aqueous Analytes/Methods (continued)														
	SW8020 cont.						SW8015 modified		Field tests				E300		
Total BTEX flag	1,3,5-Trimethylbenzene (µg/L)	1,3,5-TMB flag	1,2,4-Trimethylbenzene (µg/L)	1,2,4-TMB flag	1,2,3-Trimethylbenzene (µg/L)	1,2,3-TMB flag	Total Hydrocarbons (TVH/TEH) (mg/L)	TVH/TEH flag	pH (units) (field)	Conductivity (umhos/cm) (field)	Dissolved Oxygen (mg/L) (field)	Redox Potential (millivolts) (field)	Nitrogen Nitrate + Nitrite (mg/L)	Nitrogen Nitrate + Nitrite flag	Sulfate (anion) (mg/L)
	0.4	<	0.4	<	0.4	<	0.2/0.5	/<					0.08	<	17.6
	0.4	<	0.4	<	0.4	<	0.2/0.5	/<					0.11		51.1
	0.4	<	0.4	<	0.4	<	0.2/0.5	/<					12.5		6.42
	0.4	<	0.4	<	0.4	<	0.2/0.5	/<					15.3		8.4
	0.4	<	0.4	<	0.4	<	0.2/0.5	/<					1.67		7.1
	0.4	<	0.4	<	0.4	<	0.2/0.5	/<					3.16		11.2
	0.6	J	0.4	<	0.4	<	0.2/0.5	/<					0.08	<	36.9
	0.4	<	0.4	<	0.4	<	0.1/0.5	</<					2.05		18.1
	0.4	<	0.5	J	0.6	J	0.2/0.7						0.08	<	23.4
	0.4	<	0.4	J	0.5	J	0.2/0.7						0.08	<	22.9
	220	J	560	J	200	J							0.08	<	3.46
	0.4	<	0.8	J	0.4	<	NR						0.45		23.3
	32		94		31		1.4/0.8						0.24		10.1
	4.6		17		4.6		0.5/0.5	/<							
	1.7	J	4.7		1.7	J	0.1/0.5	</<							
	1.5	J	3.6	J	1.4	J									
	0.7	J	1.0	J	0.6	J	0.1/0.5	</<					0.08	<	54.1
	4.2		14		3.7	J	0.4/0.5	/<					0.08	<	24.7
	82		310		63		14/5.9						0.08	<	7.54
	160		490		94								0.08	<	7.37
	2.1	J	3.8	J	1.7	J	0.4/0.5	/<					0.08	<	44.8
	0.8	J	1.3	J	0.7	J	0.1/0.5	</<					0.08	<	54.7
mg/L	2,700,000	BE	5,500,000	BE	3,400,000	E									
	33		88		59		1.1/2.5						0.08	<	3.50
	3.1	J	11		47								0.08	<	2.46
	1.8	J	3.5	J	1.6	J	0.2/0.5	/<					1.66		33.9
	0.5	J	0.9	J	0.6	J							0.09		32.6
	2	J	4.2		2.5	J							1.88		41.5
	0.9	J	1.3	J	0.6	J							0.08	<	31.7
	0.5	J	0.8	J	0.5	J							0.08	<	23.2
	0.6	J	0.9	J	0.5	J							NR		NR
													7.7		30.8
													0.08	<	267
													0.08	<	74.2

	Aqueous Analytes/Methods (continued)													
	E300 cont.		SW7380 or SW6010		SW6010/SW7460		E365.4		RSKSOP-147		A5310C		A403	
Sulfate (anion) flag	Chloride (anion) (mg/L)	Chloride (anion) flag	Total Iron (mg/L)	Total Iron flag	Total Manganese (µg/L)	Total Manganese flag	Total Phosphate (mg/L)	Total Phosphate flag	Methane (mg/L)	Methane flag	Dissolved Organic Carbon (mg/L)	Dissolved Organic Carbon flag	Total Alkalinity (mg/L)	Total Alkalinity flag
	4.52								10	<			110	
	6.69								40				38	
	4.17								40	<			9.22	
	3.57						0.01	<	15				11.8	
	9.93						0.01	<	670		0.05	<	23.6	
	12.4						0.01	<	10	<	0.75		21.8	
	5.03								1100				102	
	3.36								40				40.6	
	14.6								1300				37	
	14.2						0.01	<	1200		3.02		36.6	
	6.92								640				155	
	7.2								810				21.8	
	4.65								18				23.1	
									10	<				
									120					
									58					
	4.64						0.01	<	650		3.70		163	
	7.11								36				13.5	
	6.72								970				195	
	6.56								960				200	
	6.95								550				15.3	
	6.26								160				12.6	
	14.3								340	E			122	
	5.56								430				195	
	16.6						0.01	<	10	<	0.05	<	5.00	<
	11.8								75				8.50	
	15.9								34				52.6	
	6.26								43					
	11.2								140					
	NR													
	5.89													
	7.37													
	10.0													

Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Semivolatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27			SS27			SS27			SS27			SS27			SS27			SS27			SS27		
Loc ID:	XYZ			XYZ			XYZ			XYZ			XYZ			XYZ			XYZ			XYZ		
Sample ID:	DM341D			DM341S			DM343D			DM343S			DM344D			DM344S			DM344SDL					
SDG:	1732L			1732L			1841L			1841L			1732L			00005			00005					
Sample Date:	04/01/94			04/01/94			03/31/94			03/31/94			04/01/94			04/29/94			04/29/94					
Depth:	0.0			0.0			0.0			0.0			0.0			0.0			0.0					
Matrix:	CGW			CGW			CGW			CGW			CGW			CGW			CGW					
Unit of Measure:	UG/L			UG/L			UG/L			UG/L			UG/L			UG/KG			UG/KG					
		L	V		L	V		L	V		L	V		L	V		L	V		L	V			
1,2,4-TRICHLOROBENZENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
1,2-DICHLOROBENZENE	NT			NT			NT			NT			NT			200000	U		300000	U				
1,3-DICHLOROBENZENE	NT			NT			NT			NT			NT			200000	U		300000	U				
1,4-DICHLOROBENZENE	NT			NT			NT			NT			NT			200000	U		300000	U				
2,4,5-TRICHLOROPHENOL	20	U		20	U		20	U		20	U		20	U		500000	U		750000	U				
2,4,6-TRICHLOROPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2,4-DICHLOROPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2,4-DIMETHYLPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2,4-DINITROPHENOL	20	U	UJ	20	U	UJ	20	U		20	U	UJ	20	U	UJ	500000	U		750000	U				
2,4-DINITROTOLUENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2,6-DINITROTOLUENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2-CHLORONAPHTHALENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2-CHLOROPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2-METHYLNAPHTHALENE	5	U		5	U		5	U		5	U		7			1700000	E		1600000	D				
2-METHYLPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
2-NITROANILINE	20	U	UJ	20	U	UJ	20	U		20	U		20	U	UJ	500000	U		750000	U				
2-NITROPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
3,3'-DICHLOROBENZIDINE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
3-NITROANILINE	20	U		20	U		20	U		20	U		20	U		500000	U		750000	U				
4,6-DINITRO-O-CRESOL	20	U	UJ	20	U	UJ	20	U		20	U	UJ	20	U	UJ	500000	U		750000	U				
4-BROMOPHENYL PHENYL E	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
4-CHLORO-3-METHYLPHENO	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
4-CHLOROANILINE	5	U	UJ	5	U	UJ	5	U	UJ	5	U	UJ	5	U	UJ	200000	U		300000	U	UJ			
4-CHLOROPHENYL PHENYLE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
4-METHYLPHENOL	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
4-NITROANILINE	20	U		20	U		20	U		20	U		20	U		500000	U		750000	U				
4-NITROPHENOL	20	U		20	U		20	U		20	U		20	U		500000	U		750000	U				
ACENAPHTHENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
ACENAPHTHYLENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
ANTHRACENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
BENZO[A]ANTHRACENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
BENZO[A]PYRENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
BENZO[B]FLUORANTHENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
BENZO[G,H,I]PERYLENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
BENZO[K]FLUORANTHENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				
BIS(2-CHLOROETHOXY) ME	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U				

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Semivolatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27	SS27	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
Sample ID:	DM341D	DM341S	DM343D	DM343S	DM344D	DM344S	DM344SDL
SDG:	1732L	1732L	1841L	1841L	1732L	00005	00005
Sample Date:	04/01/94	04/01/94	03/31/94	03/31/94	04/01/94	04/29/94	04/29/94
Depth:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Matrix:	CGW	CGW	CGW	CGW	CGW	CGW	CGW
Unit of Measure:	UG/L	UG/L	UG/L	UG/L	UG/L	UG/KG	UG/KG

		L	V		L	V		L	V		L	V		L	V		L	V		L	V
BIS(2-CHLOROETHYL) ETH	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
BIS(2-CHLOROISOPROPYL)	5	U	UJ	5	U	UJ	5	U		5	U	UJ	5	U	UJ	200000	U		300000	U	
BIS(2-ETHYLHEXYL)PHTHA	2	J		2	J		3	BJ	U	3	J		5	J		200000	U		300000	U	
BUTYL BENZYL PHTHALATE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
CARBAZOLE	NT			NT			NT			NT			NT			200000	U		300000	U	
CHRYSENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
DI-N-BUTYL PHTHALATE	5	U		5	U		0.9	J		5	U		5	U		200000	U		300000	U	
DI-N-OCTYL PHTHALATE	5	U		5	U		5	U	UJ	5	U		5	U		200000	U		300000	U	
DIBENZOFURAN	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
DIBENZ[A,H]ANTHRACENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
DIETHYL PHTHALATE	5	U		5	U		0.5	J		5	U		5	U		200000	U		300000	U	
DIMETHYL PHTHALATE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
FLUORANTHENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
FLUORENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
HEXACHLOROBENZENE	5	U		5	U		5	U		5	U		5	U		23000	J		300000	U	
HEXACHLOROBUTADIENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
HEXACHLOROCYCLOPENTADI	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
HEXACHLOROETHANE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
INDENO(1,2,3-CD)PYRENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
ISOPHORONE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
N-NITROSODIPHENYLAMINE	5	U	UJ	5	U	UJ	5	U		5	U	UJ	5	U	UJ	200000	U		300000	U	
N-NITROSODIPROPYLAMINE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
NAPHTHALENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
NITROBENZENE	5	U		5	U		5	U		5	U		17			970000			960000	D	
PENTACHLOROPHENOL	20	U		20	U		20	U		20	U		20	U		500000	U		750000	U	
PHENANTHRENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	
PHENOL	0.8	BJ	U	0.8	BJ	U	5	U		5	U		5	B	U	200000	U		300000	U	
PYRENE	5	U		5	U		5	U		5	U		5	U		200000	U		300000	U	

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Semivolatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27			SS27			SS27			SS27					
Loc ID:	XYZ			XYZ			XYZ			XYZ					
Sample ID:	MW59S			MW60D			MW60S			MWCOE					
SDG:	00002			2073L			1841L			1841L					
Sample Date:	04/29/94			04/12/94			03/31/94			03/30/94					
Depth:	0.0			0.0			0.0			0.0					
Matrix:	CGW			CGW			CGW			CGW					
Unit of Measure:	UG/L			UG/L			UG/L			UG/L					
		L	V		L	V		L	V		L	V			
1,2,4-TRICHLOROBENZENE	300	U		5	U		5	U		5	U				
1,2-DICHLOROBENZENE	300	U		NT			NT			NT					
1,3-DICHLOROBENZENE	300	U		NT			NT			NT					
1,4-DICHLOROBENZENE	300	U		NT			NT			NT					
2,4,5-TRICHLOROPHENOL	750	U		20	U		20	U		20	U				
2,4,6-TRICHLOROPHENOL	300	U		5	U		5	U		5	U				
2,4-DICHLOROPHENOL	300	U		5	U		5	U		5	U				
2,4-DIMETHYLPHENOL	280	J		5	U		5	U		5	U				
2,4-DINITROPHENOL	750	U		20	U		20	U		20	U	UJ			
2,4-DINITROTOLUENE	300	U		5	U		5	U		5	U				
2,6-DINITROTOLUENE	300	U		5	U		5	U		5	U				
2-CHLORONAPHTHALENE	300	U		5	U		5	U		5	U				
2-CHLOROPHENOL	300	U		5	U		5	U		5	U				
2-METHYLNAPHTHALENE	1000			5	U		5	U		5	U				
2-METHYLPHENOL	110	J		5	U		5	U		5	U				
2-NITROANILINE	750	U		20	U		20	U		20	U				
2-NITROPHENOL	300	U		5	U		5	U		5	U				
3,3'-DICHLOROBENZIDINE	300	U		5	U		5	U		5	U				
3-NITROANILINE	750	U		20	U		20	U		20	U				
4,6-DINITRO-O-CRESOL	750	U	UJ	20	U		20	U		20	U	UJ			
4-BROMOPHENYL PHENYL E	300	U		5	U		5	U		5	U				
4-CHLORO-3-METHYLPHENO	300	U		5	U		5	U		5	U				
4-CHLOROANILINE	300	U	UJ	5	U	UJ	5	U	UJ	5	U	UJ			
4-CHLOROPHENYL PHENYLE	300	U		5	U		5	U		5	U				
4-METHYLPHENOL	120	J		5	U		5	U		5	U				
4-NITROANILINE	750	U		20	U		20	U		20	U				
4-NITROPHENOL	750	U		20	U		20	U		20	U				
ACENAPHTHENE	300	U		5	U		5	U		5	U				
ACENAPHTHYLENE	300	U		5	U		5	U		5	U				
ANTHRACENE	300	U		5	U		5	U		5	U				
BENZO[A]ANTHRACENE	300	U		5	U		5	U		5	U				
BENZO[A]PYRENE	300	U		5	U		5	U		5	U				
BENZO[B]FLUORANTHENE	300	U		5	U		5	U		5	U				
BENZO[G,H,I]PERYLENE	300	U		5	U	UJ	5	U		5	U				
BENZO[K]FLUORANTHENE	300	U		5	U	UJ	5	U		5	U				
BIS(2-CHLOROETHOXY) ME	300	U		5	U		5	U		5	U				

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Data Summary Report for Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Semivolatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27		SS27		SS27		SS27	
Loc ID:	XYZ		XYZ		XYZ		XYZ	
Sample ID:	MA59S		MA60D		MA60S		MA60E	
SDG:	00002		2073L		1841L		1841L	
Sample Date:	04/29/94		04/12/94		03/31/94		03/30/94	
Depth:	0.0		0.0		0.0		0.0	
Matrix:	CGW		CGW		CGW		CGW	
Unit of Measure:	UG/L		UG/L		UG/L		UG/L	
		L V		L V		L V		L V
BIS(2-CHLOROETHYL) ETH	300	U	5	U	5	U	5	U
BIS(2-CHLOROISOPROPYL)	300	U UJ	5	U	5	U	5	U UJ
BIS(2-ETHYLHEXYL)PHTHA	38	BJ U	4	BJ U	10	B U	5	U
BUTYL BENZYL PHTHALATE	300	U	5	U UJ	5	U	5	U
CARBAZOLE	300	U	NT		NT		NT	
CHRYSENE	300	U	5	U	5	U	5	U
DI-N-BUTYL PHTHALATE	300	U	5	U	5	U	5	U
DI-N-OCTYL PHTHALATE	NT		2	J J	14	J	5	U
DIBENZOFURAN	300	U	5	U	5	U	5	U
DIBENZ[A,H]ANTHRACENE	300	U	5	U UJ	5	U	5	U
DIETHYL PHTHALATE	300	U	0.6	J	5	U	5	U
DIMETHYL PHTHALATE	300	U	5	U	5	U	5	U
FLUORANTHENE	300	U	5	U	5	U	5	U
FLUORENE	300	U	5	U	5	U	5	U
HEXACHLOROBENZENE	300	U	5	U	5	U	5	U
HEXACHLOROBUTADIENE	300	U	5	U	5	U	5	U
HEXACHLOROCYCLOPENTADI	300	U	5	U	5	U	5	U
HEXACHLOROETHANE	300	U	2	J	5	U	5	U
INDENO(1,2,3-CD)PYRENE	300	U	5	U UJ	5	U	5	U
ISOPHORONE	300	U	5	U	5	U	5	U
N-NITROSODIPHENYLAMINE	300	U	5	U	5	U	5	U
N-NITROSODIPROPYLAMINE	300	U	5	U	5	U	5	U
NAPHTHALENE	810		5	U	5	U	5	U
NITROBENZENE	300	U	5	U	5	U	5	U
PENTACHLOROPHENOL	750	U	20	U	20	U	20	U
PHENANTHRENE	300	U	5	U	5	U	5	U
PHENOL	300	U	0.6	BJ U	2	J	5	U
PYRENE	300	U	5	U	5	U	5	U

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(10)

Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
SVOC Tentatively Identified Compnd. - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27	SS27	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
Sample ID:	DM341D	DM341S	DM343D	DM343S	DM344D	DM344S	DM344SDL
SDG:	1732L	1732L	1841L	1841L	1732L	00005	00005
Sample Date:	04/01/94	04/01/94	03/31/94	03/31/94	04/01/94	04/29/94	04/29/94
Depth:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Matrix:	GW	GW	GW	GW	GW	GW	GW
Unit of Measure:	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L

		L	V		L	V		L	V		L	V		L	V		L	V		L	V
+TOTAL TICS	0			0			0			0			0			22			22		
DIETHYLBENZENE	NT			NT			NT			NT			NT			2600000		J	NT		
ETHYL METHYL BENZENE	NT			NT			NT			NT			NT			3200000		J	2900000		J
ETHYLDIMETHYLBENZENE	NT			NT			NT			NT			NT			5600000		J	NT		
METHYLPROPYLBENZENE	NT			NT			NT			NT			NT			5400000		J	NT		
TRIMETHYLBENZENE	NT			NT			NT			NT			NT			1900000		J	2800000		J

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
SVOC Tentatively Identified Compnd. - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ	XYZ
Sample ID:	MW59S	MW60D	MW60S	MWCOE
SDG:	00002	2073L	1841L	1841L
Sample Date:	04/29/94	04/12/94	03/31/94	03/30/94
Depth:	0.0	0.0	0.0	0.0
Matrix:	GW	GW	GW	GW
Unit of Measure:	UG/L	UG/L	UG/L	UG/L

		L	V		L	V		L	V		L	V
+TOTAL TICS	22			0			0			0		
DIETHYLBENZENE	NT			NT			NT			NT		
ETHYL METHYL BENZENE	1400		J	NT			NT			NT		
ETHYLDIMETHYLBENZENE	NT			NT			NT			NT		
METHYLPROPYLBENZENE	NT			NT			NT			NT		
TRIMETHYLBENZENE	2500		J	NT			NT			NT		

(12)

SEP 07 '94 13:08 DAMES & MOORE P.13

Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Volatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27	SS27	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
Sample ID:	DM341D	DM341DD	DM341S	DM342D	DM342S	DM343D	DM343S
SDG:	953-L	953-L	953-L	936-L	936-L	953-L	936-L
Sample Date:	04/01/94	04/01/94	04/01/94	03/30/94	03/30/94	03/31/94	03/31/94
Depth:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Matrix:	CGW	CGW	CGW	CGW	CGW	CGW	CGW
Unit of Measure:	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L

		L	V		L	V		L	V		L	V		L	V		L	V		L	V		L	V
1,1,1-TRICHLOROETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,1,2,2-TETRACHLOROETH	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,1,2-TRICHLOROETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,1-DICHLOROETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,1-DICHLOROETHENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,2-DIBROMO-3-CHLOROPR	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,2-DIBROMOETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,2-DICHLOROBENZENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,2-DICHLOROETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,2-DICHLOROETHENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,2-DICHLOROPROPANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,3-DICHLOROBENZENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
1,4-DICHLOROBENZENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
2-BUTANONE	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R
2-HEXANONE	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R
4-METHYL-2-PENTANONE	5	U		5	U		5	U		5	U		5	U		5	U		5	U		5	U	
ACETONE	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R	5	U	R
BENZENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
BROMOCHLOROMETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
BROMODICHLOROMETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
BROMOFORM	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
BROMOMETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CARBON DISULFIDE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CARBON TETRACHLORIDE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CHLOROBENZENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CHLOROETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CHLOROFORM	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CHLOROMETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
CIS-1,3-DICHLOROPROPEN	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
DIBROMOCHLOROMETHANE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
ETHYLBENZENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
METHYLENE CHLORIDE	0.9	J	U	1	J	U	1	J	U	6		U	7		U	2		U	4		U	1		U
STYRENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
TETRACHLOROETHENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
TOLUENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	
TRANS-1,2-DICHLOROETHE	1	U		1	U		1	U		1	U		1	U		1	U		1	U		1	U	

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Volatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27	SS27	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
Sample ID:	DW341D	DW341DD	DW341S	DW342D	DW342S	DW343D	DW343S
SDG:	953-L	953-L	953-L	956-L	956-L	953-L	956-L
Sample Date:	04/01/94	04/01/94	04/01/94	03/30/94	03/30/94	03/31/94	03/31/94
Depth:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Matrix:	CGW	CGW	CGW	CGW	CGW	CGW	CGW
Unit of Measure:	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L

		L	V		L	V		L	V		L	V		L	V		L	V		L	V
TRANS-1,3-DICHLOROPROP	1	U		1	U		1	U		1	U		1	U		1	U		1	U	
TRICHLOROETHENE	1	U		1	U		1	U		1	U		1	U		1	U		1	U	
VINYL CHLORIDE	1	U		1	U		1	U		1	U		1	U		1	U		1	U	
XYLENE (TOTAL)	1	U		1	U		1	U		1	U		1	U		1	U		1	U	

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Volatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27	SS27	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ	XYZ
Sample ID:	DM344D	DM344S	DM345S	DM345SD	MW59S	MW60D	MW60S
SDG:	00028	00005	953-L	953-L	00002	102-L	00028
Sample Date:	04/01/94	04/29/94	04/01/94	04/01/94	04/29/94	04/12/94	04/12/94
Depth:	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Matrix:	CGW	CGW	CGW	CGW	CGW	CGW	CGW
Unit of Measure:	UG/L	UG/KG	UG/L	UG/L	UG/L	UG/L	UG/L

		L V		L V		L V		L V		L V		L V		L V
1,1,1-TRICHLOROETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,1,2,2-TETRACHLOROETH	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,1,2-TRICHLOROETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,1-DICHLOROETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,1-DICHLOROETHENE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,2-DIBROMO-3-CHLOROPR	NT	NT	1	U	1	U	330	U	1	U	10	U
1,2-DIBROMOETHANE	NT	NT	1	U	1	U	NT	1	U UJ	NT
1,2-DICHLOROBENZENE	NT	NT	1	U	1	U	NT	1	U	NT
1,2-DICHLOROETHANE	42	U	120000	U R	1	U	1	U	NT	1	U	NT
1,2-DICHLOROETHENE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,2-DICHLOROPROPANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
1,3-DICHLOROBENZENE	NT	NT	1	U	1	U	330	U	1	U	10	U
1,4-DICHLOROBENZENE	NT	NT	1	U	1	U	NT	1	U	NT
2-BUTANONE	42	U	120000	U R	5	U R	5	U R	NT	1	U	NT
2-HEXANONE	42	U	120000	U R	5	U R	5	U R	330	U	5	U R	10	U
4-METHYL-2-PENTANONE	42	U	120000	U R	5	U	5	U R	330	U	5	U R	10	U
ACETONE	42	U	120000	U R	5	U R	5	U	330	U	5	U	10	U
BENZENE	560	26000	J J	8	8	330	U	5	U	10	U
BROMOCHLOROMETHANE	NT	NT	1	U	1	U	2400	J	1	U	21	1	U R	10	U
BROMODICHLOROMETHANE	42	U	120000	U R	1	U	1	U	NT	1	U UJ	NT
BROMOFORM	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
BROMOMETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
CARBON DISULFIDE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
CARBON TETRACHLORIDE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
CHLOROBENZENE	42	U	56000	J J	1	U	1	U	330	U	1	U	10	U
CHLOROETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
CHLOROFORM	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
CHLOROMETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
CIS-1,3-DICHLOROPROPEN	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U UJ
DIBROMOCHLOROMETHANE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
ETHYLBENZENE	82	66000	J J	16	16	1100	1	U UJ	10	U
METHYLENE CHLORIDE	15	BJ U	120000	U R	0.8	J U	0.9	J U	230	BJ U	1	BJ U	5	BJ U
STYRENE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
TETRACHLOROETHENE	42	U	120000	U R	1	U	1	U	330	U	1	U	10	U
TOLUENE	42	U	49000	J J	0.8	J U	0.8	J U	4700	J	1	U	10	U
TRANS-1,2-DICHLOROETHE	NT	NT	1	U	1	U	NT	1	U	NT

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Volatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27			SS27			SS27			SS27			SS27			SS27			SS27			SS27		
Loc ID:	XYZ			XYZ			XYZ			XYZ			XYZ			XYZ			XYZ			XYZ		
Sample ID:	DM344D			DM344S			DM345S			DM345SD			MW59S			MW60D			MW60S					
SDG:	00828			00005			953-L			953-L			00002			102-L			00828					
Sample Date:	04/01/94			04/29/94			04/01/94			04/01/94			04/29/94			04/12/94			04/12/94					
Depth:	0.0			0.0			0.0			0.0			0.0			0.0			0.0					
Matrix:	CGW			CGW			CGW			CGW			CGW			CGW			CGW					
Unit of Measure:	UG/L			UG/KG			UG/L			UG/L			UG/L			UG/L			UG/L					
		L	V		L	V		L	V		L	V		L	V		L	V		L	V			
TRANS-1,3-DICHLOROPROP	42	U		120000	U	R	1	U		1	U		330	U		1	U		10	U				
TRICHLOROETHENE	42	U		120000	U	R	1	U		1	U		330	U		1	U		10	U				
VINYL CHLORIDE	42	U		120000	U	R	1	U		1	U		330	U		1	U		10	U				
XYLENE (TOTAL)	5	J		270000		J	13			14			6700	E		1	U		6	J				

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Data Summary Report For Dover Air Force Base Remedial Investigation
Chemical Analysis Data
Volatile Organic Compounds - Groundwater
Criteria: Site - SS27

Site ID:	SS27	SS27	SS27
Loc ID:	XYZ	XYZ	XYZ
Sample ID:	MWC0E	P05	P07
SDG:	195LB	953-L	00828
Sample Date:	03/30/94	04/01/94	04/01/94
Depth:	0.0	0.0	0.0
Matrix:	CGW	CGW	CGW
Unit of Measure:	UG/L	UG/L	UG/L

		L	V		L	V		L	V
1,1,1-TRICHLOROETHANE	1	U		1	U		10	U	
1,1,2,2-TETRACHLOROETH	1	U		1	U		10	U	
1,1,2-TRICHLOROETHANE	1	U		1	U		10	U	
1,1-DICHLOROETHANE	1	U		1	U		10	U	
1,1-DICHLOROETHENE	1	U		1	U		10	U	
1,2-DIBROMO-3-CHLOROPR	1	U		1	U		NT		
1,2-DIBROMOETHANE	1	U		1	U		NT		
1,2-DICHLOROBENZENE	1	U		1	U		NT		
1,2-DICHLOROETHANE	1	U		1	U		10	U	
1,2-DICHLOROETHENE	1	U		1	U		10	U	
1,2-DICHLOROPROPANE	1	U		1	U		10	U	
1,3-DICHLOROBENZENE	1	U		1	U		NT		
1,4-DICHLOROBENZENE	1	U		1	U		NT		
2-BUTANONE	5	U	R	5	U	R	10	U	
2-HEXANONE	5	U	R	5	U	R	10	U	
4-METHYL-2-PENTANONE	5	U		5	U		10	U	
ACETONE	5	U	R	5	U	R	130		U
BENZENE	1	U		1	U		10	U	
BROMOCHLOROMETHANE	1	U		1	U		NT		
BROMODICHLOROMETHANE	1	U		1	U		10	U	
BROMOFORM	1	U		1	U		10	U	
BROMOMETHANE	1	U		1	U		10	U	
CARBON DISULFIDE	1	U		1	U		10	U	
CARBON TETRACHLORIDE	1	U		1	U		10	U	
CHLOROBENZENE	1	U		1	U		10	U	
CHLOROETHANE	1	U		1	U		10	U	
CHLOROFORM	1	U		1	U		10	U	
CHLOROMETHANE	1	U		1	U		10	U	UJ
CIS-1,3-DICHLOROPROPEN	1	U		1	U		10	U	
DIBROMOCHLOROMETHANE	1	U		1	U		10	U	
ETHYLBENZENE	1	U		1			61		
METHYLENE CHLORIDE	10		J	0.9	J	U	5	BJ	U
STYRENE	1	U		1	U		10	U	
TETRACHLOROETHENE	1	U		1	U		10	U	
TOLUENE	1	U		1	U		10	U	
TRANS-1,2-DICHLOROETHE	1	U		1	U		NT		

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TABLE OF BTEX CONSTITUENTS FOR SELECTED DAFB WELLS (µg/L)

Well ID	BENZENE	ETHYLBENZENE	TOLUENE	XYLENE
DM 336S	-	-	-	-
DM 336D	-	-	-	-
DM 338S	-	-	-	-
DM 338D	-	1	-	-
DM 339S	-	27	10	73
DM 339D	-	4	1	9
DM 340S	-	-	-	-
DM 346S	-	-	-	-
DM 346D	-	-	-	-
DM 348S	-	-	-	-
DM 348D	-	-	-	-
DM 349S	-	-	-	-
DM 349D	-	-	-	-
MW 75S	-	-	-	-
MW 75D	1.4	-	-	-
MW 76S	39	-	-	-
MW 76D	10	-	-	-
MW 77S	15	17	0.2	5
MW 77D	6	-	-	-
MW 78S	2	-	0.6	-
MW 78D	0.2	-	-	-

Received from Dames AFB 2/14/95

APPENDIX E

BIOPLUME II MODEL INPUT AND OUTPUT FILES

APPENDIX F

ANALYTICAL MODELS

First-Order Rate Constant Calculation
Calculated Along the Primary Southwestern Flow Path
Utilizing the Overall Gradient and Average Velocity (300 feet/year) to the St. Jones River
Site SS27/XYZ Intrinsic Remediation EE/CA
Dover AFB, Delaware

Compound	CPT Well Location							
	CPT-15 Measured Concentration (µg/L)	CPT-15 Equilibrium Concentration[a] (µg/L)	CPT-18 Measured Concentration (µg/L)	CPT-18 Corrected Concentration[b] (µg/L)	First Order Rate Constant Between B and C[c,d] (week^{-1})	CPT-28 Measured Concentration (µg/L)	CPT-28 Corrected Concentration (µg/L)	First Order Rate Constant Between C and D (week^{-1})
benzene	970,000	9,820	6,500	5,770	0.0056	5.0	563	0.0166
toluene	2,500,000	8,490	13,000	11,541	-0.0032	54	6083	0.0052
ethylbenzene	1,600,000	670	820	728	-0.0009	5.0	563	0.0026
m- and p-xylene	4,200,000	2,459	1,600	1,420	0.0058	19	2140	-0.0020
o-xylene	2,000,000	1,171	1,000	888	0.0029	6.0	676	0.0027
Total BTEX	11,270,000	22,610	22,920	20,347	0.0011	89	10025	0.0056
trimethylbenzene	11,600,000	870	980	870		8.7	980	
							Overall Maximum	0.0166
							Overall Minimum	-0.0032
							Overall Average	0.0035

[a] Accounted for emulsified LNAPL in sample by methods in Wiedemeier *et al.* (1995).

[b] See text for calculation of corrected concentration.

[c] See text for calculation of first order rate constant.

[d] Trimethylbenzenes are non-conservative at the locations which result in a negative first-order rate constant.

First-Order Rate Constant Calculation
Calculated Along the Primary Southwestern Flow Path
Utilizing the Local Average Gradient and Average Velocity (150 feet/year) on the Site
Site SS27/XYZ Intrinsic Remediation EE/CA
Dover AFB, Delaware

Compound	CPT Well Location							
	CPT-15 Measured Concentration (µg/L)	CPT-15 Equilibrium Concentration[a] (µg/L)	CPT-18 Measured Concentration (µg/L)	CPT-18 Corrected Concentration[b] (µg/L)	First Order Rate Constant Between B and C[c,d] (week^{-1})	CPT-28 Measured Concentration (µg/L)	CPT-28 Corrected Concentration (µg/L)	First Order Rate Constant Between C and D (week^{-1})
benzene	970,000	9,820	6,500	5,770	0.0028	5.0	563	0.0083
toluene	2,500,000	8,490	13,000	11,541	-0.0016	54	6,083	0.0026
ethylbenzene	1,600,000	670	820	728	-0.0004	5.0	563	0.0013
m- and p-xylene	4,200,000	2,459	1,600	1,420	0.0029	19	2,140	-0.0010
o-xylene	2,000,000	1,171	1,000	888	0.0015	6.0	676	0.0013
Total BTEX	11,270,000	22,610	22,920	20,347	0.0006	89	10,025	0.0028
trimethylbenzene	11,600,000	870	980	870		8.7	980	
							Overall Maximum	0.0083
							Overall Minimum	-0.0016
							Overall Average	0.0017

[a] Accounted for emulsified LNAPL in sample by methods in Wiedemeier *et al.* (1995).

[b] See text for calculation of corrected concentration.

[c] See text for calculation of first order rate constant.

[d] Trimethylbenzenes are non-conservative at the locations which result in a negative first-order rate constant.

Appendix F

First-Order Rate Constant Calculation
Calculated Along the Northwestern Flow Path
Utilizing the Overall Average Velocity of 130 feet/year
Site SS27/XYZ Intrinsic Remediation EE/CA
Dover AFB, Delaware

Compound	CPT Well Location							
	CPT-15 Measured Concentration (µg/L)	CPT-15 Equilibrium Concentration[a] (µg/L)	CPT-16D Measured Concentration (µg/L)	CPT-16D Corrected Concentration[b] (µg/L)	First Order Rate Constant Between B and C[c] ($week^{-1}$)	CPT-07 Measured Concentration (µg/L)	CPT-07 Corrected Concentration (µg/L)	First Order Rate Constant Between C and D[d] ($week^{-1}$)
benzene	970,000	9,820	350	4,992	0.0081	0.4	122	0.0020
toluene	2,500,000	8,490	64	913	0.0265	15	4575	-0.0082
ethylbenzene	1,600,000	670	28	399	0.0062	0.4	122	-0.0028
m- and p-xylene	4,200,000	2,459	24	342	0.0235	2	458	-0.0057
o-xylene	2,000,000	1,171	14	200	0.0210	0.4	122	-0.0042
Total BTEX	11,270,000	22,610	480	6,846	0.0142	18	5399	-0.0047
trimethylbenzene	11,600,000	870	61	870		0.2	61	
							Overall Maximum	0.0265
							Overall Minimum	-0.0082
							Overall Average	0.0063

[a] Accounted for emulsified LNAPL in sample by methods in Wiedemeier *et al.* (1995).

[b] See text for calculation of corrected concentration.

[c] See text for calculation of first order rate constant.

[d] Trimethylbenzenes are non-conservative at the locations which result in a negative first-order rate constant.

Appendix F

First-Order Rate Constant Calculation
Calculated Along the Northeastern Flow Path
Utilizing the Overall Average Velocity of 310 feet/year
Site SS27/XYZ Intrinsic Remediation EE/CA
Dover AFB, Delaware

Compound	CPT Well Location							
	DM 344S Measured Concentration (µg/L)	DM 344S Equilibrium Concentration[a] (µg/L)	CPT-22S Measured Concentration (µg/L)	CPT-22S Corrected Concentration[b] (µg/L)	First Order Rate Constant Between A and B[c] ($week^{-1}$)	CPT-26S Measured Concentration (µg/L)	CPT-26S Corrected Concentration (µg/L)	First Order Rate Constant Between B and C[d] ($week^{-1}$)
benzene	26,000	9,820	7	224	0.0504	0.9	117	-0.0447
toluene	49,000	8,490	45	1,506	0.0231	6	793	-0.0448
ethylbenzene	66,000	670	7	234	0.0140	1.5	195	-0.0520
total xylenes	270,000	2,459	48	1,606	0.0057	7	858	-0.0451
Total BTEX	411,000	21,439	107	3,570	0.0239	15	1963	-0.0455
trimethylbenzene	1,900,000	870	26	870		0.2	26	
							Overall Maximum	0.0504
							Overall Minimum	-0.0520
							Overall Average	-0.0115

[a] *Accounted for emulsified LNAPL in sample by methods in* Wiedemeier *et al.* (1995).

[b] See text for calculation of corrected concentration.

[c] See text for calculation of first order rate constant.

[d] Trimethylbenzenes are non-conservative at the locations which result in a negative first-order rate constant.

APPENDIX F

STEADY-STATE SOLUTION TO THE ADVECTIVE-DISPERSIVE EQUATION ONE DIMENSIONAL FLOW, TYPE ONE BOUNDARY CONDITION (CONSTANT SOURCE WITH 0.0018 DAY^{-1} FIRST-ORDER DECAY) PRIMARY SOUTHWESTERN FLOW PATH FOR COMPARISON TO BIOPLUME II (MODEL CAL) RESULTS

Hydrogeologic Data

Hydraulic conductivtiy $K := 6.92 \cdot 10^{-4} \cdot \frac{ft}{sec}$ $K = 59.789 \cdot \frac{ft}{day}$

Hydraulic gradient $I := 0.0021 \cdot \frac{ft}{ft}$

Effective porosity (Baker, 1994) $n_e := 0.30$

Total porosity $n := 0.30$

Longitudinal dispersivity (Parsons ES, 1985) $\alpha_x := 25 \cdot ft$

Retardation Coefficient Calculation

Maximum Contaminant Concentration $C_o := 21.4 \cdot \frac{mg}{liter}$

Contaminant Decay Rate $\lambda := .001800 \cdot \frac{1}{day}$

Minimum soil sorption coefficient (Wiedemeier et al., 1994) $K_{oc} := 79 \cdot \frac{mL}{gm}$

Particle mass density (Freeze and Cherry, 1979) $\rho_s := 2.28 \cdot \frac{gm}{cm^3}$

Bulk density (Freeze and Cherry, 1979) $\rho_b := \rho_s \cdot (1 - n)$ $\rho_b = 1.596 \cdot \frac{gm}{cm^3}$

Minimum organic carbon content $f_{oc} := 0.027 \cdot \%$

Retardation coefficient $R := 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water) $v_x := \frac{K \cdot I}{n_e}$ $v_x = 152.862 \cdot \frac{ft}{yr}$

Contaminant velocity $v_c := \frac{v_x}{R}$ $v_c = 137.283 \cdot \frac{ft}{yr}$

Longitudinal dispersion coefficient $D_x := \alpha_x \cdot v_x$ $D_x = 10.463 \cdot \frac{ft^2}{day}$

The measured distance from CPT-15 (the center of the source area) to CPT-28 (the most downgradient extent) is approximately 1,380 feet. This analytical solution is used to confirm the Bioplume II predicted concentrations and calibrate first-order decay.

c:\protocol\append-d\equations\FORMPLUM.MCD

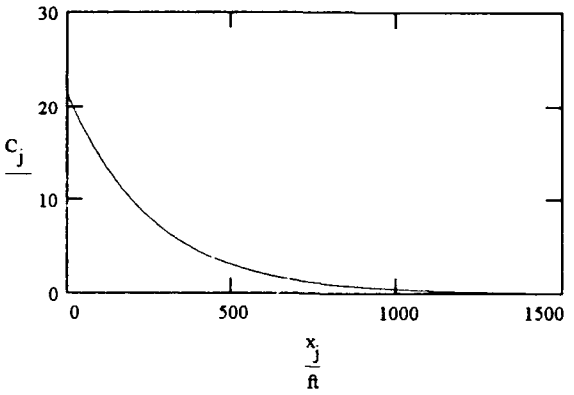
$j := 0..1400$

$\Delta x := 1 \cdot ft$

$x_j := \Delta x \cdot j$

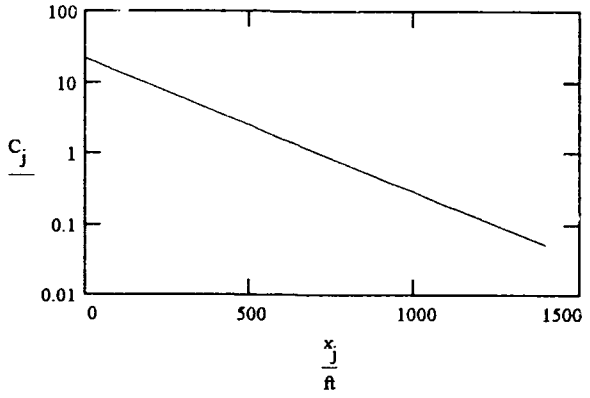
For Unretarded Flow with Biodegradation (Bear, 1979, p. 642, Domenico and Schwartz, 1990)

$$C_j := (C_o) \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \alpha_x} \cdot \left[1 - \sqrt{1 + \left[\frac{4 \cdot \lambda \cdot \alpha_x}{(v_x)}\right]}\right]\right] \text{ in mg/L.}$$



For Retarded Flow with Biodegradation (Wexler, 1992 p. 20, eq. 62)

$$C_j := C_o \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \frac{D_x}{R}} \cdot \left[\frac{v_x}{R} - \sqrt{\left(\frac{v_x}{R}\right)^2 + 4 \cdot \lambda \cdot \frac{D_x}{R}}\right]\right] \text{ in mg/L.}$$



APPENDIX F

STEADY-STATE SOLUTION TO THE ADVECTIVE-DISPERSIVE EQUATION ONE DIMENSIONAL FLOW, TYPE ONE BOUNDARY CONDITION (CONSTANT SOURCE WITH 0.0018 DAY^{-1} FIRST-ORDER DECAY) PRIMARY SOUTHWESTERN FLOW PATH TO ESTIMATE POTENTIAL EFFECTS TO THE ST. JONES RIVER

Hydrogeologic Data

Hydraulic conductivtiy	$K := 6.92 \cdot 10^{-4} \cdot \frac{ft}{sec}$	$K = 59.789 \cdot \frac{ft}{day}$
Hydraulic gradient	$I := 0.0041 \cdot \frac{ft}{ft}$	
Effective porosity (Baker, 1994)	$n_e := 0.30$	
Total porosity	$n := 0.30$	
Longitudinal dispersivity (Parsons ES, 1985)	$\alpha_x := 25 \cdot ft$	

Retardation Coefficient Calculation

Maximum Contaminant Concentration	$C_o := 21.4 \cdot \frac{mg}{liter}$	
Contaminant Decay Rate	$\lambda := .001800 \cdot \frac{1}{day}$	
Minimum soil sorption coefficient (Wiedemeier et al., 1994)	$K_{oc} := 79 \cdot \frac{mL}{gm}$	
Particle mass density (Freeze and Cherry, 1979)	$\rho_s := 2.28 \cdot \frac{gm}{cm^3}$	
Bulk density (Freeze and Cherry, 1979)	$\rho_b := \rho_s \cdot (1 - n)$	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Minimum organic carbon content	$f_{oc} := 0.027 \cdot \%$	
Retardation coefficient	$R := 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$	$R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x := \frac{K \cdot I}{n_e}$	$v_x = 298.444 \cdot \frac{ft}{yr}$
Contaminant velocity	$v_c := \frac{v_x}{R}$	$v_c = 268.03 \cdot \frac{ft}{yr}$
Longitudinal dispersion coefficient	$D_x := \alpha_x \cdot v_x$	$D_x = 20.428 \cdot \frac{ft^2}{day}$

The measured distance from CPT-15 (the center of the source area) to the St. Jones River is 3,800 feet. This analytical solution is used to confirm Bioplume II predicted concentrations.

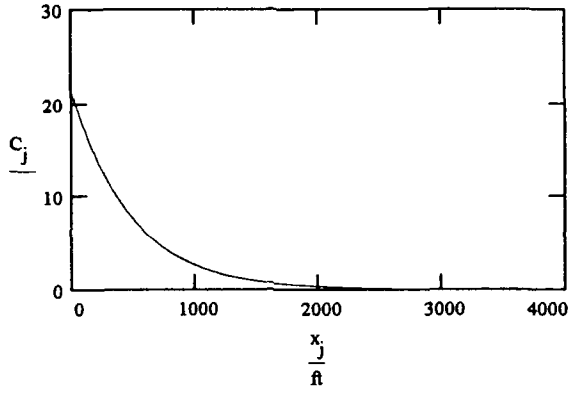
$j := 0..3800$

$\Delta x := 1 \cdot ft$

$x_j := \Delta x \cdot j$

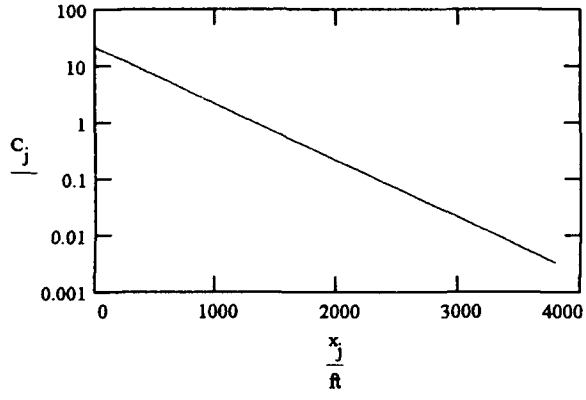
For Unretarded Flow with Biodegradation (Bear, 1979, p. 642, Domenico and Schwartz, 1990)

$$C_j := (C_o) \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \alpha_x}\left[1 - \sqrt{1 + \left[\frac{4 \cdot \lambda \cdot \alpha_x}{(v_x)}\right]}\right]\right] \text{ in mg/L.}$$



For Retarded Flow with Biodegradation (Wexler, 1992 p. 20, eq. 62)

$$C_j := C_o \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \frac{D_x}{R}}\left[\frac{v_x}{R} - \sqrt{\left(\frac{v_x}{R}\right)^2 + 4 \cdot \lambda \cdot \frac{D_x}{R}}\right]\right] \text{ in mg/L.}$$



APPENDIX F
STEADY-STATE SOLUTION TO THE ADVECTIVE-DISPERSIVE EQUATION ONE DIMENSIONAL FLOW, TYPE ONE BOUNDARY CONDITION (CONSTANT SOURCE WITH 0.0019 DAY^{-1} FIRST-ORDER DECAY) SECONDARY NORTHWESTERN FLOW PATH TO ESTIMATE POTENTIAL EFFECTS NEAR CPT-07

Hydrogeologic Data

Hydraulic conductivtiy	$K := 6.92 \cdot 10^{-4} \cdot \frac{ft}{sec}$	$K = 59.789 \cdot \frac{ft}{day}$
Hydraulic gradient	$I := 0.0018 \cdot \frac{ft}{ft}$	
Effective porosity (Baker, 1994)	$n_e := 0.30$	
Total porosity	$n := 0.30$	
Longitudinal dispersivity (Parsons ES, 1985)	$\alpha_x := 25 \cdot ft$	

Retardation Coefficient Calculation

Maximum Contaminant Concentration	$C_o := 21.4 \cdot \frac{mg}{liter}$	
Contaminant Decay Rate	$\lambda := .0019 \cdot \frac{1}{day}$	
Minimum soil sorption coefficient (Wiedemeier et al., 1994)	$K_{oc} := 79 \cdot \frac{mL}{gm}$	
Particle mass density (Freeze and Cherry, 1979)	$\rho_s := 2.28 \cdot \frac{gm}{cm^3}$	
Bulk density (Freeze and Cherry, 1979)	$\rho_b := \rho_s \cdot (1 - n)$	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Minimum organic carbon content	$f_{oc} := 0.027 \cdot \%$	
Retardation coefficient	$R := 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$	$R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x := \frac{K \cdot I}{n_e}$	$v_x = 131.024 \cdot \frac{ft}{yr}$
Contaminant velocity	$v_c := \frac{v_x}{R}$	$v_c = 117.672 \cdot \frac{ft}{yr}$
Longitudinal dispersion coefficient	$D_x := \alpha_x \cdot v_x$	$D_x = 8.968 \cdot \frac{ft^2}{day}$

The measured distance from CPT-15 (the center of the source area) to CPT-07 is 1,500 feet. This analytical solution is used to confirm the observed concentrations and calibrate first-order decay.

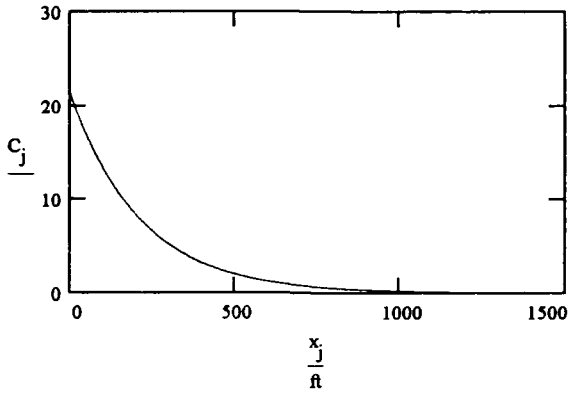
$j := 0 .. 1500$

$\Delta x = 1 \cdot ft$

$x_j = \Delta x \cdot j$

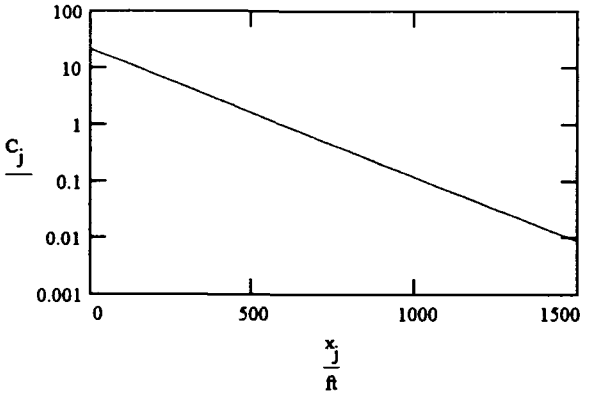
For Unretarded Flow with Biodegradation (Bear, 1979, p. 642, Domenico and Schwartz, 1990)

$$C_j := (C_o) \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \alpha_x} \cdot \left[1 - \sqrt{1 + \left[\frac{4 \cdot \lambda \cdot \alpha_x}{(v_x)}\right]}\right]\right] \text{ in mg/L.}$$



For Retarded Flow with Biodegradation (Wexler, 1992 p. 20, eq. 62)

$$C_j := C_o \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \frac{D_x}{R}} \cdot \left[\frac{v_x}{R} - \sqrt{\left(\frac{v_x}{R}\right)^2 + 4 \cdot \lambda \cdot \frac{D_x}{R}}\right]\right] \text{ in mg/L.}$$



APPENDIX F

STEADY-STATE SOLUTION TO THE ADVECTIVE-DISPERSIVE EQUATION ONE DIMENSIONAL FLOW, TYPE ONE BOUNDARY CONDITION (CONSTANT SOURCE WITH 0.0072 DAY^{-1} FIRST-ORDER DECAY) SECONDARY NORTHEASTERN FLOW PATH TO ESTIMATE POTENTIAL EFFECTS NEAR CPT-26

Hydrogeologic Data

Hydraulic conductivtiy	$K := 6.92 \cdot 10^{-4} \cdot \frac{ft}{sec}$	$K = 59.789 \cdot \frac{ft}{day}$
Hydraulic gradient	$I := 0.0043 \cdot \frac{ft}{ft}$	
Effective porosity (Baker, 1994)	$n_e := 0.30$	
Total porosity	$n := 0.30$	
Longitudinal dispersivity (Parsons ES, 1985)	$\alpha_x := 25 \cdot ft$	

Retardation Coefficient Calculation

Maximum Contaminant Concentration	$C_o := 21.4 \cdot \frac{mg}{liter}$	
Contaminant Decay Rate	$\lambda := .0072 \cdot \frac{1}{day}$	
Minimum soil sorption coefficient (Wiedemeier et al., 1994)	$K_{oc} := 79 \cdot \frac{mL}{gm}$	
Particle mass density (Freeze and Cherry, 1979)	$\rho_s := 2.28 \cdot \frac{gm}{cm^3}$	
Bulk density (Freeze and Cherry, 1979)	$\rho_b := \rho_s \cdot (1 - n)$	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Minimum organic carbon content	$f_{oc} := 0.027 \cdot \%$	
Retardation coefficient	$R := 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$	$R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x := \frac{K \cdot I}{n_e}$	$v_x = 313.003 \cdot \frac{ft}{yr}$
Contaminant velocity	$v_c := \frac{v_x}{R}$	$v_c = 281.104 \cdot \frac{ft}{yr}$
Longitudinal dispersion coefficient	$D_x := \alpha_x \cdot v_x$	$D_x = 21.424 \cdot \frac{ft^2}{day}$

The measured distance from well DM 344 (the upgradient center of the source area) to CPT-26 is 830 feet. This analytical solution is used to confirm the observed BTEX concentrations and calibrate first-order decay.

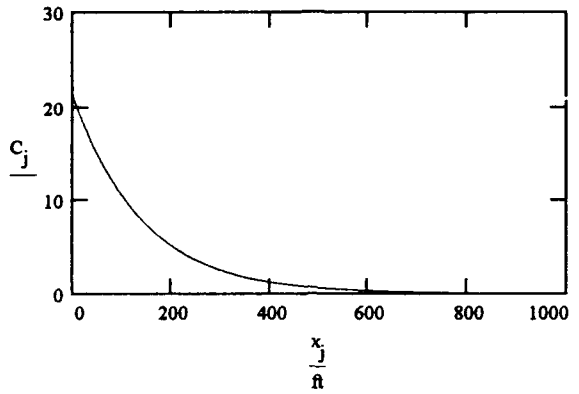
$j := 0..830$

$\Delta x := 1 \cdot ft$

$x_j := \Delta x \cdot j$

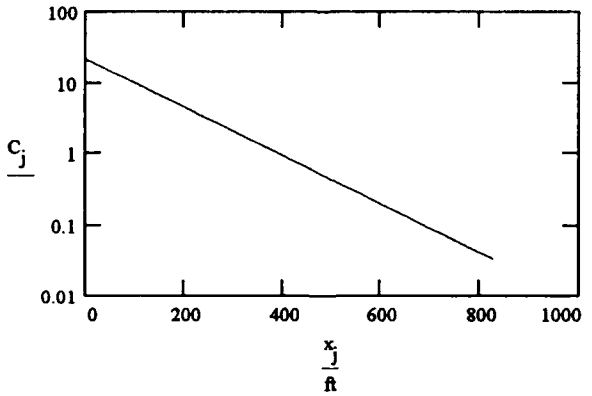
For Unretarded Flow with Biodegradation (Bear, 1979, p. 642, Domenico and Schwartz, 1990)

$$C_j := (C_o) \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \alpha_x} \cdot \left[1 - \sqrt{1 + \left[\frac{4 \cdot \lambda \cdot \alpha_x}{(v_x)}\right]}\right]\right] \text{ in mg/L.}$$



For Retarded Flow with Biodegradation (Wexler, 1992 p. 20, eq. 62)

$$C_j := C_o \cdot 1000 \cdot \exp\left[\frac{x_j}{2 \cdot \frac{D_x}{R}} \cdot \left[\frac{v_x}{R} - \sqrt{\left(\frac{v_x}{R}\right)^2 + 4 \cdot \lambda \cdot \frac{D_x}{R}}\right]\right] \quad \text{in mg/L.}$$



ES ENGINEER-SCIENCE, INC.

Client Denver AFB
Subject First - Order Long Term Rel
ITRC Source

Job No. [illegible]
By TCH
Checked DR Malone

Sheet [illegible]
Date 2/[illegible]
Rev. -

$$\frac{C}{C_o} = e^{-\alpha t}$$

Assume $\frac{C}{C_o} = 0.95$

Time: 6 yr source remediation = 2190 days
6 yr source remediation = 2920 days

$0.95 = e^{-\alpha (2190\ days)}$

$-0.05 = -\alpha (2190\ days)$

$\alpha = 0.0000234\ day^{-1}$
(SR6)

$0.95 = e^{-\alpha (2920\ days)}$

$-0.05 = -\alpha (2920\ days)$

$\alpha = 0.0000176\ day^{-1}$
(SR8)

APPENDIX F

Transient Solution to the Advective-Dispersive Equation for One-Dimensional Flow, Type Three Boundary Condition (Decaying Source, Constant Location, Variable Time, Solution of van Genuchten and Alves, 1982) - Checked against Solute ONE3-D by THW 1/5/95 Primary Southwestern Flow Path to CPT-28

Hydrogeologic Data

Hydraulic conductivity	$K = 60 \cdot \frac{ft}{day}$
Hydraulic gradient	$I = 0.0021 \cdot \frac{ft}{ft}$
Effective porosity	$n_e = 0.3$
Total porosity	$n = 0.3$
Longitudinal dispersivity (EPRI, 1985)	$\alpha_x = 25 \cdot ft$
Concentration of Injected Contaminant	$C_s = 21.4 \cdot \frac{mg}{liter}$
Initial Dissolved Contaminant Concentration	$C_o = 0 \cdot \frac{mg}{liter}$

Retardation Coefficient Calculation

Solute Decay Rate	$\lambda = 0.0018 \cdot \frac{1}{day}$
Source Decay Rate	$\gamma = 0.0000176 \cdot \frac{1}{day}$
Soil sorption coefficient (EPA, 1990)	$K_{oc} = 79 \cdot \frac{mL}{gm}$
Bulk density (Freeze and Cherry, 1979)	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Organic carbon content	$f_{oc} = 0.027 \cdot \%$
Retardation coefficient	$R = 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x = \frac{K \cdot I}{n_e}$	$v_x = 0.42 \cdot \frac{ft}{day}$
Contaminant velocity	$v_c = \frac{v_x}{R}$	$v_c = 0.377 \cdot \frac{ft}{day}$
Longitudinal dispersion coefficient	$D_x = \alpha_x \cdot v_x$	$D_x = 10.5 \cdot \frac{ft^2}{day}$

Initial Plume Distribution Calculation

$year = 365 \cdot day$ $i = 1..100$ $x = 1380 \cdot ft$

$\Delta t = 1 \cdot year$ $ug = \frac{mg}{1000}$

$t_i = \Delta t \cdot i$

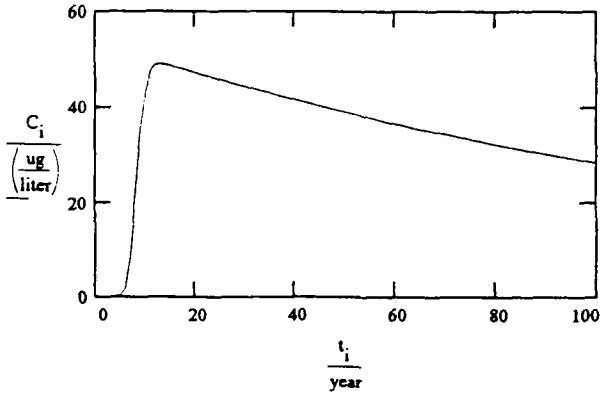
For Retarded Flow with Biodegradation and a Decaying Source (van Genuchten and Alves, 1982)

$$C_i = C_o \cdot \exp\left(-\lambda \cdot t_i\right) \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x - v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) - \left(\frac{v_x^2 \cdot t_i}{\pi \cdot D_x \cdot R} \right) \cdot \exp\left[- \frac{(R \cdot x - v_x \cdot t_i)^2}{4 \cdot D_x \cdot R \cdot t_i} \right] + \frac{1}{2} \cdot \left(1 + \frac{v_x \cdot x}{D_x} + \frac{v_x^2 \cdot t_i}{D_x \cdot R} \right) \cdot \exp\left(\frac{v_x \cdot x}{D_x} \right) \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$

$$+ C_s \cdot \exp\left(-\gamma \cdot t_i\right) \cdot \left[\left[\frac{v_x}{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x - t_i \cdot \left[v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right]}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \dots \right.$$

$$+ \left[\frac{v_x}{v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x + t_i \cdot v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \dots$$

$$\left. + \left[\frac{v_x^2}{2 \cdot D_x \cdot R \cdot (\lambda - \gamma)} \right] \cdot \exp\left[\frac{v_x \cdot x}{D_x} - (\lambda - \gamma) \cdot t_i \right] \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$



APPENDIX F

Transient Solution to the Advective-Dispersive Equation for One-Dimensional Flow, Type Three Boundary Condition (Decaying Source, Constant Location, Variable Time, Solution of van Genuchten and Alves, 1982) - Checked against Solute ONE3-D by THW 1/5/95 Primary Southwestern Flow Path to Property Boundary

Hydrogeologic Data

Hydraulic conductivtiy	$K = 60 \cdot \frac{ft}{day}$
Hydraulic gradient	$I = 0.0021 \cdot \frac{ft}{ft}$
Effective porosity	$n_e = 0.3$
Total porosity	$n = 0.3$
Longitudinal dispersivity (EPRI, 1985)	$\alpha_x = 25 \cdot ft$
Concentration of Injected Contaminant	$C_a = 21.4 \cdot \frac{mg}{liter}$
Initial Dissolved Contaminant Concentration	$C_o = 0 \cdot \frac{mg}{liter}$

Retardation Coefficient Calculation

Solute Decay Rate	$\lambda = 0.0018 \cdot \frac{1}{day}$
Source Decay Rate	$\gamma = 0.0000176 \cdot \frac{1}{day}$
Soil sorption coefficient (EPA, 1990)	$K_{oc} = 79 \cdot \frac{mL}{gm}$
Bulk density (Freeze and Cherry, 1979)	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Organic carbon content	$f_{oc} = 0.027 \cdot \%$
Retardation coefficient	$R = 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x = \frac{K \cdot I}{n_e}$	$v_x = 0.42 \cdot \frac{ft}{day}$
Contaminant velocity	$v_c = \frac{v_x}{R}$	$v_c = 0.377 \cdot \frac{ft}{day}$
Longitudinal dispersion coefficient	$D_x = \alpha_x \cdot v_x$	$D_x = 10.5 \cdot \frac{ft^2}{day}$

Initial Plume Distribution Calculation

year := 365·day i := 1..50 x := 0·ft

Δt := 1·year μg := mg/1000

$t_i := \Delta t \cdot i$

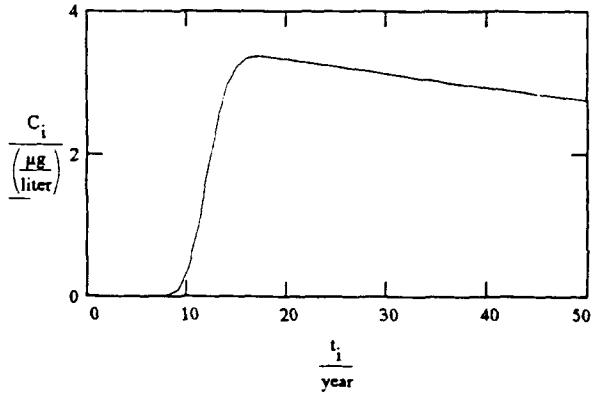
For Retarded Flow with Biodegradation and a Decaying Source (van Genuchten and Alves, 1982)

$$C_i = C_o \cdot \exp(-\lambda \cdot t_i) \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x - v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) - \left(\frac{v_x^2 \cdot t_i}{\pi \cdot D_x \cdot R} \right) \cdot \exp\left[- \frac{(R \cdot x - v_x \cdot t_i)^2}{4 \cdot D_x \cdot R \cdot t_i} \right] + \frac{1}{2} \cdot \left(1 + \frac{v_x \cdot x}{D_x} + \frac{v_x^2 \cdot t_i}{D_x \cdot R} \right) \cdot \exp\left(\frac{v_x \cdot x}{D_x} \right) \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right] \dots$$

$$+ C_s \cdot \exp(-\gamma \cdot t_i) \cdot \left[\left[\frac{v_x}{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x - t_i \cdot \left[v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right]}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \dots \right.$$

$$+ \left[\frac{v_x}{v_x - v_x \cdot \sqrt{1 - \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x + t_i \cdot v_x \cdot \sqrt{1 - \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \dots$$

$$\left. + \left[\frac{v_x^2}{2 \cdot D_x \cdot R \cdot (\lambda - \gamma)} \right] \cdot \exp\left[\frac{v_x \cdot x}{D_x} - (\lambda - \gamma) \cdot t_i \right] \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$



APPENDIX F

Transient Solution to the Advective-Dispersive Equation for One-Dimensional Flow, Type Three Boundary Condition (Decaying Source, Constant Location, Variable Time, Solution of van Genuchten and Alves, 1982) - Checked against Solute ONE3-D by THW 1/5/95 Northwestern Flow Path to CPT-07

Hydrogeologic Data

Hydraulic conductivity	$K = 60 \cdot \frac{ft}{day}$
Hydraulic gradient	$I = 0.0018 \cdot \frac{ft}{ft}$
Effective porosity	$n_e = 0.3$
Total porosity	$n = 0.3$
Longitudinal dispersivity (EPRI, 1985)	$\alpha_x = 25 \cdot ft$
Concentration of Injected Contaminant	$C_s = 21.4 \cdot \frac{mg}{liter}$
Initial Dissolved Contaminant Concentration	$C_o = 0 \cdot \frac{mg}{liter}$

Retardation Coefficient Calculation

Solute Decay Rate	$\lambda = 0.0019 \cdot \frac{1}{day}$
Source Decay Rate	$\gamma = 0.0000176 \cdot \frac{1}{day}$
Soil sorption coefficient (EPA, 1990)	$K_{oc} = 79 \cdot \frac{mL}{gm}$
Bulk density (Freeze and Cherry, 1979)	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Organic carbon content	$f_{oc} = 0.027 \cdot \%$
Retardation coefficient	$R = 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $\quad R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x = \frac{K \cdot I}{n_e}$	$v_x = 0.36 \cdot \frac{ft}{day}$
Contaminant velocity	$v_c = \frac{v_x}{R}$	$v_c = 0.323 \cdot \frac{ft}{day}$
Longitudinal dispersion coefficient	$D_x = \alpha_x \cdot v_x$	$D_x = 9 \cdot \frac{ft^2}{day}$

Initial Plume Distribution Calculation

$year = 365 \cdot day$ $i = 1..50$ $x = 1500 \cdot ft$

$\Delta t = 1 \cdot year$ $\mu g = \frac{mg}{1000}$

$t_i = \Delta t \cdot i$

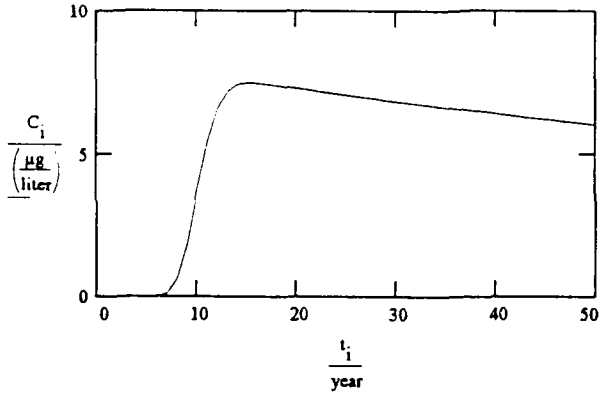
For Retarded Flow with Biodegradation and a Decaying Source (van Genuchten and Alves, 1982)

$$C_i = C_o \cdot \exp\left(-\lambda \cdot t_i\right) \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x - v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) - \left(\frac{v_x^2 \cdot t_i}{\pi \cdot D_x \cdot R} \right) \cdot \exp\left[- \frac{(R \cdot x - v_x \cdot t_i)^2}{4 \cdot D_x \cdot R \cdot t_i} \right] + \frac{1}{2} \cdot \left(1 + \frac{v_x \cdot x}{D_x} + \frac{v_x^2 \cdot t_i}{D_x \cdot R} \right) \cdot \exp\left(\frac{v_x \cdot x}{D_x} \right) \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right] \ldots$$

$$+ C_s \cdot \exp\left(-\gamma \cdot t_i\right) \cdot \left[\left[\frac{v_x}{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot D_x} \cdot x \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x - t_i \cdot v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \ldots \right.$$

$$+ \left[\frac{v_x}{v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot D_x} \cdot x \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x + t_i \cdot v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \ldots$$

$$\left. + \left[\frac{v_x^2}{2 \cdot D_x \cdot R \cdot (\lambda - \gamma)} \right] \cdot \exp\left[\frac{v_x \cdot x}{D_x} - (\lambda - \gamma) \cdot t_i \right] \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$



APPENDIX F

Transient Solution to the Advective-Dispersive Equation for One-Dimensional Flow, Type Three Boundary Condition (Decaying Source, Constant Location, Variable Time, Solution of van Genuchten and Alves, 1982) - Checked against Solute ONE3-D by THW 1/5/95 Northwestern Flow Path to Property Boundary

Hydrogeologic Data

Hydraulic conductivity	$K := 60 \cdot \frac{ft}{day}$
Hydraulic gradient	$I := 0.0018 \cdot \frac{ft}{ft}$
Effective porosity	$n_e := 0.3$
Total porosity	$n := 0.3$
Longitudinal dispersivity (EPRI, 1985)	$\alpha_x := 25 \cdot ft$
Concentration of Injected Contaminant	$C_s := 21.4 \cdot \frac{mg}{liter}$
Initial Dissolved Contaminant Concentration	$C_o := 0 \cdot \frac{mg}{liter}$

Retardation Coefficient Calculation

Solute Decay Rate	$\lambda := 0.0019 \cdot \frac{1}{day}$
Source Decay Rate	$\gamma := 0.0000176 \cdot \frac{1}{day}$
Soil sorption coefficient (EPA, 1990)	$K_{oc} := 79 \cdot \frac{mL}{gm}$
Bulk density (Freeze and Cherry, 1979)	$\rho_b := 1.596 \cdot \frac{gm}{cm^3}$
Organic carbon content	$f_{oc} := 0.027 \cdot \%$
Retardation coefficient	$R := 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x := \frac{K \cdot I}{n_e}$	$v_x = 0.36 \cdot \frac{ft}{day}$
Contaminant velocity	$v_c := \frac{v_x}{R}$	$v_c = 0.323 \cdot \frac{ft}{day}$
Longitudinal dispersion coefficient	$D_x := \alpha_x \cdot v_x$	$D_x = 9 \cdot \frac{ft^2}{day}$

Initial Plume Distribution Calculation

$year := 365 \cdot day \quad i := 1..50 \quad x := 1700 \cdot ft$

$\Delta t := 1 \cdot year \quad \mu g := \frac{mg}{1000}$

$t_i := \Delta t \cdot i$

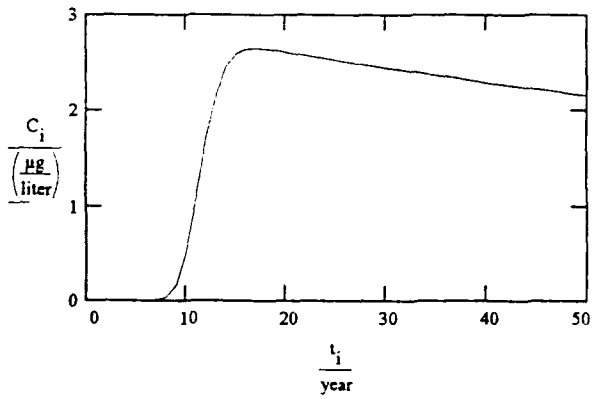
For Retarded Flow with Biodegradation and a Decaying Source (van Genuchten and Alves, 1982)

$$C_i = C_o \cdot \exp\left(-\lambda \cdot t_i\right) \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x - v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) - \left(\frac{v_x^2 \cdot t_i}{\pi \cdot D_x \cdot R} \right) \cdot \exp\left[- \frac{\left(R \cdot x - v_x \cdot t_i \right)^2}{4 \cdot D_x \cdot R \cdot t_i} \right] + \frac{1}{2} \cdot \left(1 + \frac{v_x \cdot x}{D_x} + \frac{v_x^2 \cdot t_i}{D_x \cdot R} \right) \cdot \exp\left(\frac{v_x \cdot x}{D_x} \right) \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right] \ldots$$

$$+ C_s \cdot \exp\left(-\gamma \cdot t_i\right) \cdot \left[\left[\frac{v_x}{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x - t_i \cdot \left[v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right]}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \ldots \right.$$

$$+ \left[\frac{v_x}{v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x + t_i \cdot v_x \cdot \sqrt{1 - \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \ldots$$

$$\left. + \left[\frac{v_x^2}{2 \cdot D_x \cdot R \cdot (\lambda - \gamma)} \right] \cdot \exp\left[\frac{v_x \cdot x}{D_x} - (\lambda - \gamma) \cdot t_i \right] \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$



APPENDIX F

Transient Solution to the Advective-Dispersive Equation for One-Dimensional Flow, Type Three Boundary Condition (Decaying Source, Constant Location, Variable Time, Solution of van Genuchten and Alves, 1982) - Checked against Solute ONE3-D by THW 1/5/95 Northeastern Flow Path to CPT-26

Hydrogeologic Data

Hydraulic conductivity	$K := 60 \cdot \frac{ft}{day}$
Hydraulic gradient	$I := 0.0043 \cdot \frac{ft}{ft}$
Effective porosity	$n_e := 0.3$
Total porosity	$n := 0.3$
Longitudinal dispersivity (EPRI, 1985)	$\alpha_x := 25 \cdot ft$
Concentration of Injected Contaminant	$C_s := 21.4 \cdot \frac{mg}{liter}$
Initial Dissolved Contaminant Concentration	$C_o := 0. \cdot \frac{mg}{liter}$

Retardation Coefficient Calculation

Solute Decay Rate	$\lambda := 0.0072 \cdot \frac{1}{day}$
Source Decay Rate	$\gamma := 0.0000176 \cdot \frac{1}{day}$
Soil sorption coefficient (EPA, 1990)	$K_{oc} := 79 \cdot \frac{mL}{gm}$
Bulk density (Freeze and Cherry, 1979)	$\rho_b := 1.596 \cdot \frac{gm}{cm^3}$
Organic carbon content	$f_{oc} := 0.027 \cdot \%$
Retardation coefficient	$R := 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x := \frac{K \cdot I}{n_e}$	$v_x = 0.86 \cdot \frac{ft}{day}$
Contaminant velocity	$v_c := \frac{v_x}{R}$	$v_c = 0.772 \cdot \frac{ft}{day}$
Longitudinal dispersion coefficient	$D_x := \alpha_x \cdot v_x$	$D_x = 21.5 \cdot \frac{ft^2}{day}$

Initial Plume Distribution Calculation

year := 365·day i := 1..50 x := 830·ft

Δt := 1·year μg := mg/1000

$t_i := \Delta t \cdot i$

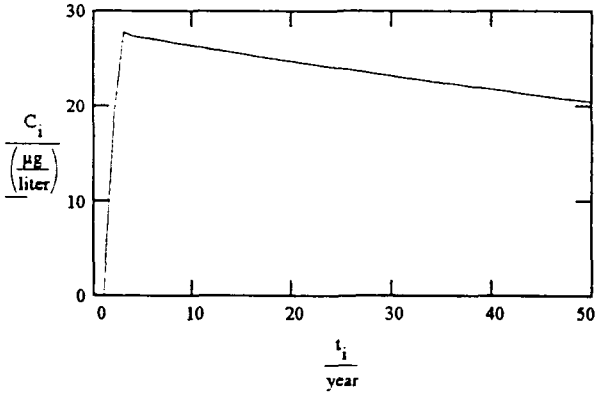
For Retarded Flow with Biodegradation ar... ...aying Source (van Genuchten and Alves, 1982)

$$C_i = C_0 \cdot \exp(-\lambda \cdot t_i) \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x - v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) - \left(\frac{v_x^2 \cdot t_i}{\pi \cdot D_x \cdot R} \right) \cdot \exp\left[- \frac{(R \cdot x - v_x \cdot t_i)^2}{4 \cdot D_x \cdot R \cdot t_i} \right] + \frac{1}{2} \cdot \left(1 + \frac{v_x \cdot x}{D_x} + \frac{v_x^2 \cdot t_i}{D_x \cdot R} \right) \cdot \exp\left(\frac{v_x \cdot x}{D_x} \right) \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$

$$+ C_s \cdot \exp(-\gamma \cdot t_i) \cdot \left[\left[\frac{v_x}{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x - t_i \cdot \left[v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right]}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \right.$$

$$+ \left[\frac{v_x}{v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x + t_i \cdot v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \right.$$

$$\left. + \left[\frac{v_x^2}{2 \cdot D_x \cdot R \cdot (\lambda - \gamma)} \right] \cdot \exp\left[\frac{v_x \cdot x}{D_x} - (\lambda - \gamma) \cdot t_i \right] \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$



APPENDIX F

Transient Solution to the Advective-Dispersive Equation for One-Dimensional Flow, Type Three Boundary Condition (Decaying Source, Constant Location, Variable Time, Solution of van Genuchten and Alves, 1982) - Checked against Solute ONE3-D by THW 1/5/95 Northeastern Flow Path to Property Boundary

Hydrogeologic Data

Hydraulic conductivity	$K = 60 \frac{ft}{day}$
Hydraulic gradient	$I = 0.0043 \frac{ft}{ft}$
Effective porosity	$n_e = 0.3$
Total porosity	$n = 0.3$
Longitudinal dispersivity (EPRI, 1985)	$\alpha_x = 25 \cdot ft$
Concentration of Injected Contaminant	$C_s = 21.4 \frac{mg}{liter}$
Initial Dissolved Contaminant Concentration	$C_o = 0. \frac{mg}{liter}$

Retardation Coefficient Calculation

Solute Decay Rate	$\lambda = 0.0072 \cdot \frac{1}{day}$
Source Decay Rate	$\gamma = 0.0000176 \cdot \frac{1}{day}$
Soil sorption coefficient (EPA, 1990)	$K_{oc} = 79. \frac{mL}{gm}$
Bulk density (Freeze and Cherry, 1979)	$\rho_b = 1.596 \cdot \frac{gm}{cm^3}$
Organic carbon content	$f_{oc} = 0.027 \cdot \%$
Retardation coefficient	$R = 1 + \frac{\rho_b \cdot K_{oc} \cdot f_{oc}}{n}$ $R = 1.113$

Groundwater Hydraulics Calculations

Groundwater velocity (pore-water)	$v_x = \frac{K \cdot I}{n_e}$	$v_x = 0.86 \cdot \frac{ft}{day}$
Contaminant velocity	$v_c = \frac{v_x}{R}$	$v_c = 0.772 \cdot \frac{ft}{day}$
Longitudinal dispersion coefficient	$D_x = \alpha_x \cdot v_x$	$D_x = 21.5 \cdot \frac{ft^2}{day}$

Initial Plume Distribution Calculation

year $:= 365 \cdot day$ $\quad i := 1..50$ $\quad x := 2500 \cdot ft$

$\Delta t := 1 \cdot year$ $\quad \mu g := \frac{mg}{1000}$

$t_i := \Delta t \cdot i$

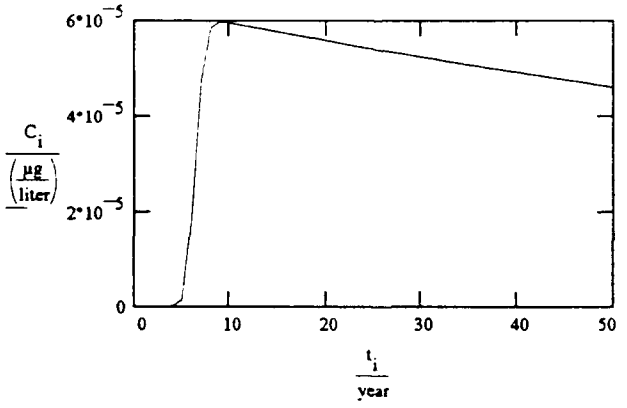
For Retarded Flow with Biodegradation and a Decaying Source (van Genuchten and Alves, 1982)

$$C_i := C_0 \cdot \exp\left(-\lambda \cdot t_i\right) \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x - v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) - \left(\frac{v_x^2 \cdot t_i}{\pi \cdot D_x \cdot R} \right) \cdot \exp\left[- \frac{(R \cdot x - v_x \cdot t_i)^2}{4 \cdot D_x \cdot R \cdot t_i} \right] + \frac{1}{2} \cdot \left(1 + \frac{v_x \cdot x}{D_x} + \frac{v_x^2 \cdot t_i}{D_x \cdot R} \right) \cdot \exp\left(\frac{v_x \cdot x}{D_x} \right) \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$

$$+ C_s \cdot \exp\left(-\gamma \cdot t_i\right) \cdot \left[\left[\frac{v_x}{v_x + v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x - t_i \cdot v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \right.$$

$$+ \left[\frac{v_x}{v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}} \right] \cdot \exp\left[\frac{\left[v_x - v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)} \right] \cdot x}{2 \cdot D_x} \right] \cdot \left[1 - \operatorname{erf}\left[\frac{R \cdot x + t_i \cdot v_x \cdot \sqrt{1 + \frac{4 \cdot D_x \cdot R}{v_x^2} \cdot (\lambda - \gamma)}}{2 \sqrt{D_x \cdot R \cdot t_i}} \right] \right] \cdots$$

$$\left. + \left[\frac{v_x^2}{2 \cdot D_x \cdot R \cdot (\lambda - \gamma)} \right] \cdot \exp\left[\frac{v_x \cdot x}{D_x} - (\lambda - \gamma) \cdot t_i \right] \cdot \left(1 - \operatorname{erf}\left(\frac{R \cdot x + v_x \cdot t_i}{2 \cdot \sqrt{D_x \cdot R \cdot t_i}} \right) \right) \right]$$



EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZCPT-55	Client Project No.	: Dover AFB
Lab Sample Number	: X86380	Lab Project No.	: 94-1374
Date Sampled	: 4/20/94	Dilution Factor	: 1.00
Date Received	: 4/21/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042222
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	21	B	4
Ethyl Benzene	100-41-4	0.6	J	4
Total Xylene (m/p + o)	1330-20-7	2.6	BJ	4
1,3,5-Trimethylbenzene	108-67-8	0.6	J	4
1,2,4-Trimethylbenzene	95-63-6	0.9	J	4
1,2,3-Trimethylbenzene	526-73-8	0.5	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 107%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report
Method Blank Report

Method Blank Number	: MEB042294	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/22/94	Lab Project No.	: 94-1374
Date Analyzed	: 4/23/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042225

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	1.1	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.6	J	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 112%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

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Methane Data Report

		Client Project No.	: Dover AFB
Date Sampled	: 04/20/94	Lab Project No.	: 94-1374
Date Received	: 04/21/94	Dilution Factor	: see below
Date Prepared	: 04/24/94	Method	: FID
Date Analyzed	: 04/24/94	Matrix	: Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042494	Method Blank	Water	U	10 (DF=1)
x86375	XYZ-22D	Water	43	10 (DF=1)
x86379	XYZCPT-29	Water	140	100 (DF=10)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

Analyst

Approved

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(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/20/94	Client Project ID.	: Dover AFB
Date Received	: 4/21/94	Lab Project No.	: 94-1374
Date Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Method	: EPA 310.1

Evergreen Sample #	Client Sample ID	Total Alkalinity ($mgCaCO_3/L$)
X86375	XYZ-22D	12.0
X86376	XYZ-22S	65.6
X86377	XYZ-25S	19.8
X86378	XYZ-26S	27.0
X86379	XYZCPT-29	23.1

Analyst

Approved

1374tm.4

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4036 Youngfield Street Wheat Ridge, CO 80033
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Anions

Date Sampled : 4/20/94
Date Received : 4/21/94
Date Prepared : 4/22/94
Date Analyzed : 4/22/94

Client Project ID : Dover AFB
Lab Project No. : 94-1374
Method : EPA Method 300.0

Client Sample ID	XYZ-22D	XYZ-22S	XYA-25S	XYZ-26S	XYZCPT-29	
Evergreen Sample #	X86375	X86376	X86377	X86378	X86379	
Matrix	Water	Water	Water	Water	Water	
Chloride (mg/L)	6.26	5.89	7.37	10.0	11.2	
Nitrite-N (mg/L)	<0.076	<0.076	<0.076	<0.076	<0.076	
Nitrate-N (mg/L)	<0.056	7.67	<0.056	<0.056	<0.056	
Sulfate (mg/L)	31.7	30.8	267	74.2	23.2	

Analyst

Approved

1374tm.24

Evergreen

May 2, 1994

MR TODD WIEDEMEIER/MR TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY SUITE 900
DENVER CO 80290

Data Report : 94-1312
Client Project : Dover AFB

Dear Mr. Wiedemeier/Mr. Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice President of Quality Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

J. H. Barney /mr

Jack Barney
President

JJ

Evergreen Analytical Sample Log Sheet REVISION 4/18/94 Project # 94-1312

Date(s) Sampled: 4/16/94 COC **Date Due:** 4/21/94-UST
5/2/94-OTHER

Date Received: 4/18/94 1000 **Holding Time(s):** 4/18/94-NO3,NO2
4/23/94BTEX,TVH,TEH,METHANE

Client Project I.D. Dover AFB **Rush** STANDARD

Client: Engineering Science **Shipping Charges** N/A

Address: 1700 Broadway, Suite 900 **E.A. Cooler #** 302

Denver, CO 80290 **Airbill #** FEDEX

Contact: Todd ~~Wediemler~~ / Todd Herrington
Denver contact / field contact
Wiedemeier

Client P.O. 722450.06020

Phone #831-8100 **Fax #**

Custody Seal Intact? Y
Cooler X Bottles
COC Present Y
Sample Tags Present? Y
Sample Tags Listed? Y
Sample(s) Sealed? Y

Special Instructions * ANALYZE AND REPORT NITRATE AND NITRITE SEPARATELY

Lab #	Client ID#	Analysis	Mtx	Btl	Loc
X86180A/B	XYZ-13S	8020 BTEX + (Trimmethylbenzene Isomers)	W	40ML	2
X86181A/B	XYZ-21S	"	"	"	"
X86181C/D	XYZ-21S	TVH 8015	"	"	"
X86181E	XYZ-21S	TEH 8015	"	1LA	C2
X86180C	XYZ-13S	ALKALINITY,SULFATE, CHLORIDE,*NO2/NO3 (As N)	"	500P	"
X86181F	XYZ-21S	" " "	"	"	"
X86180D-G	XYZ-13S	METHANE		40ML	2
X86181G-J	XYZ-21S	"	"	"	"

R=Sample to be returned
Route To GC/MS GC 5 Metals Gen Chem 2 SxPrep 1 Acctg 1
SxRec C Adm C QA/QC C Sales C File Orig

Page 1 of 1 Page(s) **Custodian/Date:** JM 4/18/94

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

COMPANY Engineering Science
ADDRESS 1700 Broadway, Ste 900
CITY Denver STATE CO ZIP 80290
PHONE # 831-8100 FAX # will call FAX RESULTS (Y) / N

COMPANY CONTACT (print) Todd Herrington
PROJECT I D Dover AFB 5327
P.O. # 722450.06020
TURNAROUND REQUIRED* Normal
*expedited turnaround subject to additional fee

Sampler Name:
(signature) Kyle L. Cannon
(print) Kyle L. Cannon

Evergreen Analytical Cooler No. 302

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	MATRIX: Soil / Solid (circle)	MATRIX: Sludge/Slurry (circle)	MATRIX: Oil/Organic Liquid (circle)	MATRIX: Multiphase (identify phase to be analyzed)	ANALYSIS REQUESTED: TCLP VOA/BNA/Pest/Herb/Metals	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608/508 (circle)	Herbicides 8150/515 (cicle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle)	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	Alkanity / Anions	Methane				Notes
XYZ-13S	4-16-94	0930	7												2							1	4				
XYZ-21BS	4-16-94	1030	10												2		2	1				1	4				

Instructions:

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
[illegible]	12:00 4/16/94	Tracy Dreiseitl	4/18/94 0:[illegible]				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

Eng. Science Precontract parameters
Dover AFB

TABLE A.3

SUMMARY OF AQUEOUS ANALYTICAL METHODS

INQUIRY 722450-SC001

Parameter	Analytical Method	Reporting Units	Maximum Analyses	Unit Price
Total Phosphate	E365 2/4	mg/L[a/]	5	$____EA
Sulfate Anions	E300	mg/L	30	$____EA
Purgeable Aromatic (BTEX + trimethylbenzene isomers)	SW8020	µg/L	30	$____EA
Alkalinity	A403	mg/L	30	$____EA
Dissolved Organic Carbon*	A5310C	mg/L	5	$____EA
Nitrogen, NO_3/NO_2 Nitrate	E300	mg/L	30	$____EA
Chloride (Anion)	E300	mg/L	30	$____EA
Methane	**RSKSOP-147	mg/L	30	$____EA
Total Hydrocarbons (Volatile & Extractable)	SW8015 Modified Gasoline Range	mg/L	20	$____EA

a/ mg/L = milligrams per liter.
b/ µg/L = micrograms per liter.

* Optional, may not be required. See page A-8 para. 3.1.
** Standard Operating Procedure Attached (12 pages).

Evergreen Analytical Sample Receipt/Check-in Record

Date & Time Rec'd: 4/18/94 10:00 Shipped Via: FedX 196890537
(Airbill # if applicable)

Client : Engineering Science

Client Project ID(s): Dover AFB 5527

EAL Project #(s): 94-1312 EAL Cooler(s): Y (N)

Cooler#	302								
Ice packs	(Y)	(N)	Y	N	Y	N	Y	N	Y	N
Temperature °C	20.2								

	Y	N	N/A
1. Custody seal(s) present:	X		
Seals on cooler intact	X		
Seals on bottle intact			X
2. Chain of Custody present:	X		
3. Containers broken or leaking: (Comment on COC if Y)		X	
4. Containers labeled:	X		
5. COC agrees w/ bottles received: (Comment on COC if N)		X	
6. COC agrees w/ labels: (Comment on COC if N)		X	
7. Headspace in VOA vials-waters only (comment on COC if Y)			X
8. VOA samples preserved:			X
9. pH measured on metals, cyanide or phenolics*:			X
List discrepancies			
*Non-EAL provided containers only, water samples only.			
10. Dissolved metals samples present:			
To be preserved:			X
To be filtered:			X
11. Short holding times:			
Specify parameters			
12. Multi-phase sample(s) present:		X	
13. COC signed w/ date/time:	X		

Comments:

(Additional comments on back)
Custodian Signature/Date: J Smith 4/18/94

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-13S	Client Project No.	: Dover AFB
Lab Sample Number	: X86180	Lab Project No.	: 94-1312
Date Sampled	: 4/16/94	Dilution Factor	: 1.00
Date Received	: 4/18/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042113
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	0.9	J	4
Toluene	108-88-3	5.6		4
Ethyl Benzene	100-41-4	0.8	J	4
Total Xylene (m/p + o)	1330-20-7	3	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6	0.8	J	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 99%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-21S	Client Project No.	: Dover AFB
Lab Sample Number	: X86181	Lab Project No.	: 94-1312
Date Sampled	: 4/16/94	Dilution Factor	: 1.00
Date Received	: 4/18/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042114
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	55		4
Toluene	108-88-3	150		4
Ethyl Benzene	100-41-4	30		4
Total Xylene (m/p + o)	1330-20-7	140	B	4
1,3,5-Trimethylbenzene	108-67-8	32		4
1,2,4-Trimethylbenzene	95-63-6	94		4
1,2,3-Trimethylbenzene	526-73-8	31		4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 99%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report
Method Blank Report

Method Blank Number	: MB042194	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/21/94	Lab Project No.	: 94-1312
Date Analyzed	: 4/21/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042103

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3		U	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.6	J	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: *Total Xylene consist of three isomers, two of which co-elute.*
The Xylene PQL is for a single peak.
Note: High surrogate recovery due to increased sensitivity of initial runs.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 124%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = *Extrapolated value*
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/16/94	Client Project Number	: Dover AFB
Date Received	: 4/18/94	Lab Project Number	: 94-1312
Date Prepared	: 4/19/94	Matrix	: Water
Date Analyzed	: 4/19/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/L	MDL mg/L
X86181	XYZ-21S	107%	1.4	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL EXTRACTABLE HYDROCARBONS (TEH)
C11-C28 Boiling Range

Date Sampled	: 4/16/94	Client Project Number	: Dover AFB
Date Received	: 4/18/94	Lab Project Number	: 94-1312
Date Prepared	: 4/19/94	Matrix	: Water
Date Analyzed	: 4/19/94	Method Number	: 3500/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TEH mg/L	MDL mg/L
WB041994		71%	U	0.5
DI Matrix Spike		95%	69% Diesel Spike Recovery	
X86181E	XYZ-21S	116%	0.8	0.5

QUALIFIERS
U = TEH analyzed for but not detected.
B = TEH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/16/94	Client Project ID.	: Dover AFB 5327
Date Received	: 4/18/94	Lab Project No.	: 94-1312
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method	: EPA 310.1

Evergreen Sample	Client Sample ID	Total Alkalinity ($mgCaCO_3/L$)
X861..	XYZ-13S	21.8
X86181	XYZ-21S	23.1

Analyst

Approved

1312tm.4

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Anions

Date Sampled	: 4/16/94	Client Project ID.	: Dover AFB 5327
Date Received	: 4/16/94	Lab Project No.	: 94-1312
Client Sample ID.	: XYZ-13S	Matrix	: Water
Lab Sample No.	: X86180	Method	: EPA 300.0

Analyte	Result (mg/L)	Date Prepared	Date Analyzed
Chloride	7.20	4/18/94	4/18/94
Nitrite-N	<0.076	4/18/94	4/18/94
Nitrate-N	0.45	4/18/94	4/18/94
Sulfate	23.3	4/18/94	4/18/94

Analyst

Approved

1312tm.31

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Anions

Date Sampled	: 4/16/94	Client Project ID.	: Dover AFB 5327
Date Received	: 4/16/94	Lab Project No.	: 94-1312
Client Sample ID.	: XYZ-21S	Matrix	: Water
Lab Sample No.	: X86181	Method	: EPA 300.0

Analyte	Result (mg/L)	Date Prepared	Date Analyzed
Chloride	4.65	4/18/94	4/18/94
Nitrite-N	<0.076	4/18/94	4/18/94
Nitrate-N	0.24	4/18/94	4/18/94
Sulfate	10.1	4/18/94	4/18/94

Analyst

Approved

1312tm.31

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303)425-6021

Methane Data Report

		Client Project No.	: Dover AFB
Date Sampled	: 04/16/94	Lab Project No.	: 94-1312
Date Received	: 04/18/94	Dilution Factor	: see below
Date Prepared	: 04/20,21/94	Method	: FID
Date Analyzed	: 04/20,21/94	Matrix	: Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042094	Method Blank	Water	U	10 (DF=1)
x86181	XYZ-21S	Water	18	10 (DF=1)
MB042194	Method Blank	Water	U	10 (DF=1)
x86180	XYZ-13S	Water	810	100 (DF=10)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

Analyst

Approved

Evergreen

May 6, 1994

MR TODD WIEDEMEIER/TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY SUITE 900
DENVER CO 80290

Data Report : 94-1291
Client Project : Dover AFB

Dear Mr. Wiedemeier/Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice President of Quality Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

J H Barney/cpy

Jack Barney
President

™

Evergreen Analytical Sample Log Sheet

Project # 94-1291

Date(s) Sampled: 4/14/94 COC

Date Due: 4/20/94-UST
4/29/94-OTHER

Date Received: 4/15/94 1000

Holding Time(s): 4/16/94-NO3,NO2
4/21/94BTEX,TVH,TEH,METHANE

Client Project I.D. Dover AFB

Rush STANDARD

Client: Engineering Science

Address: 1700 Broadway, Suite 900

Denver, CO 80290

Contact: Todd Wediemier / Todd Herrington
Denver contact / field contact

Client P.O. 722450.06020

Phone #831-8100 **Fax #**

Shipping Charges N/A

E.A. Cooler # 314

Airbill # FEDEX

Custody Seal Intact? Y
Cooler X Bottles
COC Present Y
Sample Tags Present? Y
Sample Tags Listed? Y
Sample(s) Sealed? Y

Special Instructions * ANALYZE AND REPORT NITRATE AND NITRITE SEPARTELY
** PHOSPHATE BY NON AUTOMATED METHOD EPA 365.2

Lab #	Client ID#	Analysis	Mtx	Btl	Loc
X86110A/B	XYZ-2S	8020 BTEX + Trimethylbenzene Isomers	W	40ML	2
X86111A/B	XYZ-06S	"	"	"	"
X86112A/B	XYZ-11P	"	"	"	"
X86113A/B	XYZ-11S	"	"	"	"
X86114A/B	XYZ-12S	"	"	"	"
X86110C/D	XYZ-2S	TVH 8015	"	"	"
X86111C/D	XYZ-06S	"	"	"	"
X86112C/D	XYZ-11P	"	"	"	"
X86113C/D	XYZ-11S	"	"	"	"
X86114C/D	XYZ-12S	"	"	"	"
X86110E-H	XYZ-2S	METHANE	"	"	"
X86111E-H	XYZ-06S	"	"	"	"
X86112E-H	XYZ-11P	"	"	"	"

R=Sample to be returned
Route To: GC/MS __ GC 5 Metals __ Gen Chem 2 SxPrep 1 Acctg 1
SxRec C Adm C QA/QC C Sales C File Orig

Custodian/Date: JM 4/15/94

Lab ID #	Client ID#	Analysis	Mtx	Btl	Loc
X86113E-H	XYZ-11S	METHANE	W	40ML	2
X86114E-H	XYZ-12S	"	"	"	"
X86110I	XYZ-2S	ALKALINITY,SULFATE, CHLORIDE,*NO2/NO3 (as N)	"	250P	C1
X86111I	XYZ-06S	"	"	"	"
X86112I	XYZ-11P	"	"	"	"
X86113I	XYZ-11S	"	"	"	"
X86114I	XYZ-12S	"	"	"	"
X86110J	XYZ-2S	TEH 8015	"	"	"
X86111J	XYZ-06S	"	"	"	"
X86112J	XYZ-11P	"	"	"	"
X86113J	XYZ-11S	"	"	"	"
X86114J	XYZ-12S	"	"	"	"
X86113I	XYZ-11S	**TOTAL PHOSPHATE	"	USE ANIONS BOTTLE	"
X86114K	XYZ-12S	** "	"	250P	"
X86114L	XYZ-12S	DOC	"	125A	OUT

Project # 94-1291

R=Sample to be returned

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

COMPANY Engineering - Science
ADDRESS 1700 Broadway, Ste 900
CITY Denver STATE CO ZIP 80290
PHONE # 831 - 8100 FAX # ~~(303) 831~~ Will Call

FAX RESULTS (Y) / N

COMPANY CONTACT (print) Todd Herrington
PROJECT I.D Dover AFB
P.O. # 722450.06020
TURNAROUND REQUIRED* 3 Days
*expedited turnaround subject to additional fee

Sampler Name:
(signature) Kyle L Cannon
(print) Kyle L. Cannon

Evergreen Analytical Cooler No. 314

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	MATRIX: Soil / Solid (circle)	MATRIX: Sludge/Slurry (circle)	MATRIX: Oil/Organic Liquid (circle)	MATRIX: Multiphase (identify phase to be analyzed)	TCLP VOA/BNA/Pest/Herb/Metals (circle)	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608/508 (circle)	Herbicides 8150/515 (cicle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle) MTBE (circle)	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	Methane	Alkalinity / Anions	Total Organic Carbon	Phosphate	Nitrate	Notes
XYZ-2S	4/14/94	0800	10												2		2	1				4	1				
XYZ-06S	4/14/94	1000	10												2		2	1				4	1				
XYZ-11P	4/14/94	1200	10												2		2	1				4	1				
XYZ-11S	4/14/94	1400	10												2		2	1				4	1	1	1		
~~XYZ-12P~~	~~4/14/94~~	~~1530~~	~~12~~												~~2~~		~~2~~	~~1~~				~~4~~	~~1~~	~~1~~	~~1~~		
~~XYZ-12P~~	~~4/14/94~~																										
XYZ-12S	4/14/94	1550	12												2		2	1				4	1	1	1		

Instructions: No phosphate, NP TOC bottle received for XYZ-11S 4-15-94 JMoss

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
Kyle L Cannon	4/14/94 1800	Joe Moss	4-15-94 1050				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

Dover AFB project
Engineering Science

PROJECT SPECIAL INSTRUCTIONS 94-

Date: 4/15/94 EAL Contact: Skea Client Contact: Todd Wedlemier (Denver)
Todd Herrington in Dallas

INSTRUCTIONS:

3 day TA (we need a std for the trimethylbenzenes as they know that this will make the BTEX late)
BTEX 8020 + Trimethylbenzene isomers
TVH & TEH

Other analyses are Std. 10 day T.A.

TOC should be Dissolved Organic Carbon Send to Huffman + their method # is 5310D (not 5310C as on Tables)

Phosphate by non automated method
See M. Mosher for # EPA 365.2

Nitrate & Nitrite separately

TABLE A.3

SUMMARY OF AQUEOUS ANALYTICAL METHODS

INQUIRY 722450-SC001

Parameter	Analytical Method	Reporting Units	Maximum Analyses	Unit Price
Total Phosphate	E365.4 2	mg/L[a/]	5	$_____EA
Sulfate Anions	E300	mg/L	30	$_____EA
Purgeable Aromatic (BTEX + trimethylbenzene isomers)	SW8020	µg/L	30	$_____EA
Alkalinity	A403	mg/L	30	$_____EA
Dissolved Organic Carbon*	A5310C	mg/L	5	$_____EA
Nitrogen, NO_3/NO_2 Nitrate	E300	mg/L	30	$_____EA
Chloride (Anion)	E300	mg/L	30	$_____EA
Methane	**RSKSOP-147	mg/L	30	$_____EA
Total Hydrocarbons (Volatile & Extractable)	SW8015 Modified Gasoline Range	mg/L	20	$_____EA

a/ mg/L = milligrams per liter.
b/ µg/L = micrograms per liter.

* Optional, may not be required. See page A-8 para. 3.1.
** Standard Operating Procedure Attached (12 pages).

TABLE A.4

SUMMARY OF SOIL/SEDIMENT ANALYTICAL METHODS

SUBCONTRACT NO. 722450-SC001

Parameter	Analytical Method	Reporting Units	Maximum Analyses	Unit Price
Total Organic Carbon (TOC)	SW9060 Modified	mg/kg [a/]	-5	$____EA
Total Volatile Hydrocarbons (gasoline)	SW5030/SW8015M	µg/kg	-10	$____EA
Purgeable Aromatics (BTEX)[c/]	SW8020	µg/kg[d/]	-10	$____EA

a/ mg/kg = milligrams per kilogram.
b/ TRPH = Total recoverable petroleum hydrocarbons.
c/ BTEX = benzene, toluene, ethylbenzene, xylenes.
d/ µg/kg = micrograms per kilogram.

Evergreen Analytical Sample Receipt/Check-in Record

Date & Time Rec'd: 4-15-99 · 1000 Shipped Via: FEDEX 1541419740
(Airbill # if applicable)

Client : Engineering Science

Client Project ID(s): Dover AFB

EAL Project #(s): 94- 1291 EAL Cooler(s): (Y) N

Cooler#	314								
Ice packs	(Y)	N	Y	N	Y	N	Y	N	Y	N
Temperature °C	7.1°								

	Y	N	N/A
1. Custody seal(s) present:	X		
Seals on cooler intact	X		
Seals on bottle intact		X	
2. Chain of Custody present:	X		
3. Containers broken or leaking: (Comment on COC if Y)		X	
4. Containers labeled:	X		
5. COC agrees w/ bottles received: (Comment on COC if N)	X	X	
6. COC agrees w/ labels: (Comment on COC if N)	X		
7. Headspace in VOA vials-waters only (comment on COC if Y)		X	
8. VOA samples preserved:		X	
9. pH measured on metals, cyanide or phenolics*:			X
List discrepancies			
*Non-EAL provided containers only, water samples only.			
10. Dissolved metals samples present:		X	X
To be preserved:			
To be filtered:			X
11. Short holding times:	X		
Specify parameters NO3 + NO2			
12. Multi-phase sample(s) present:		X	
13. COC signed w/ date/time:	X		

Comments:

(Additional comments on back)
Custodian Signature/Date: Jon Mas 4-15-99

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-2S	Client Project No.	: Dover AFB
Lab Sample Number	: X86110	Lab Project No.	: 94-1291
Date Sampled	: 4/14/94	Dilution Factor	: 1.00
Date Received	: 4/15/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042107
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	0.4	J	4
Toluene	108-88-3	2.3		4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.8	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 115%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-06S	Client Project No.	: Dover AFB
Lab Sample Number	: X86111	Lab Project No.	: 94-1291
Date Sampled	: 4/14/94	Dilution Factor	: 1.00
Date Received	: 4/15/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042108
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	7.4		4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.9	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 109%
QC Reporting Limits	: 77%-116%

QUALIFIERS:

E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. *Compare blank and sample data.*
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-11P	Client Project No.	: Dover AFB
Lab Sample Number	: X86112	Lab Project No.	: 94-1291
Date Sampled	: 4/14/94	Dilution Factor	: 1.00
Date Received	: 4/15/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042109
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	6.5		4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.9	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 104%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-11S	Client Project No.	: Dover AFB
Lab Sample Number	: X86113	Lab Project No.	: 94-1291
Date Sampled	: 4/14/94	Dilution Factor	: 1.00
Date Received	: 4/15/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042111
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	8.8		4
Ethyl Benzene	100-41-4	0.5	J	4
Total Xylene (m/p + o)	1330-20-7	1.7	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 103%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-12S	Client Project No.	: Dover AFB
Lab Sample Number	: X86114	Lab Project No.	: 94-1291
Date Sampled	: 4/14/94	Dilution Factor	: 1.00
Date Received	: 4/15/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042112
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	0.4	J	4
Toluene	108-88-3	3.7	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.6	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 82%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report
Method Blank Report

Method Blank Number	: MB042194	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/21/94	Lab Project No.	: 94-1291
Date Analyzed	: 4/21/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042103

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3		U	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.6	J	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.
Note: High surrogate recovery due to increased sensitivity of initial runs.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 124%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/14/94	Client Project Number	: Dover AFB
Date Received	: 4/15/94	Lab Project Number	: 94-1291
Date Prepared	: 4/19/94	Matrix	: Water
Date Analyzed	: 4/19/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/L	MDL mg/L
X86110	XYZ-2S	98%	0.2	0.1
X86111	XYZ-06S	106%	0.2	0.1
X86112	XYZ-11P	112%	0.2	0.1
X86113	XYZ-11S	112%	0.2	0.1
X86114	XYZ-12S	107%	0.2	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

Analyst

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4036 Youngfield, Wheat Ridge, CO 80033
(303)425-6021

Methane Data Report

Client Project No.: Dover AFB
Date Sampled : 04/14/94
Lab Project No. : 94-1291
Date Received : 04/15/94
Dilution Factor : 1.00
Date Prepared : 04/20/94
Method : FID
Date Analyzed : 04/20/94
Matrix : Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042094	Method Blank	Water	U	10
x86110	XYZ-2S	Water	U	10
x86111	XYZ-06S	Water	40	10
x86112	XYZ-11P	Water	U	10
x86113	XYZ-11S	Water	15	10
x86114	XYZ-12S	Water	670	100 (DF=10)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

Analyst

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4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/14/94	Client Project ID.	: Dover AFB
Date Received	: 4/15/94	Lab Project No.	: 94-1291
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method	: EPA 310.1

Evergreen Sample #	Client Sample ID	Total Alkalinity ($mgCaCO_3/L$)
X86110	XYZ-2S	110
X86111	XYZ-06S	38.0
X86112	XYZ-11P	9.22
X86113	XYZ-11S	11.8
X86114	XYZ-12S	23.5

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1291tm.4

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Anions

Date Sampled : 4/14/94
Date Received : 4/15/94
Date Prepared : 4/15/94
Date Analyzed : 4/15/94

Client Project ID. : Dover AFB
Lab Project No. : 94-1291
Method : EPA 300.0

Evergreen Sample #	Client Sample ID	Matrix	Chloride (mg/L)	Sulfate (mg/L)
X86110	XYZ-2S	Water	4.52	17.8
X86111	XYZ-06S	Water	6.69	51.1
X86112	XYZ-11P	Water	4.17	6.42
X86113	XYZ-11S	Water	3.57	8.40
X86114	XYZ-12S	Water	9.93	7.10

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1291tm.25

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Anions

Date Sampled : 4/14/94
Date Received : 4/15/94
Date Prepared : 4/15/94
Date Analyzed : 4/15/94

Client Project ID. : Dover AFB
Lab Project No. : 94-1291
Method : EPA 300.0

Evergreen Sample #	Client Sample ID	Matrix	Nitrite-N(mg/L)	Nitrate-N (mg/L)
X86110	XYZ-2S	Water	<0.076	<0.056
X86111	XYZ-06S	Water	<0.076	0.11
X86112	XYZ-11P	Water	<0.076	12.5
X86113	XYZ-11S	Water	<0.076	15.3
X86114	XYZ-12S	Water	<0.076	1.67

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL EXTRACTABLE HYDROCARBONS (TEH)
C11-C28 Boiling Range

Date Sampled	: 4/14/94	Client Project Number	: Dover AFB
Date Received	: 4/15/94	Lab Project Number	: 94-1291
Date Prepared	: 4/18/94	Matrix	: Water
Date Analyzed	: 4/18/94	Method Number	: 3500/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TEH mg/L	MDL mg/L
WB01894		78%	U	0.5
DI Matrix Spike		84%	75% Diesel Spike Recovery	
X86110J	XYZ-2S	64%	U	0.5
X86111J	XYZ-06S	70%	U	0.5
X86112J	XYZ-11P	71%	U	0.5
X86113J	XYZ-11S	73%	U	0.5
X86114J	XYZ-12S	73%	U	0.5

QUALIFIERS
U = TEH analyzed for but not detected.
B = TEH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

Analyst

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4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/14/94	Client Project ID.	: Dover AFB
Date Received	: 4/15/94	Lab Project No.	: 94-1291
Date Prepared	: 4/15,20/94	Matrix	: Water
Date Analyzed	: 4/15,20/94	Method	: EPA 365.2

Evergreen Sample #	Client Sample ID	Total Phosphate-P (mg/L)
X86113	XYZ-11S	<0.01
X86114	XYZ-12S	<0.01

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1291tm.4

HUFFMAN
LABORATORIES, INC.
Quality Analytical Services Since 1936
4630 Indiana Street • Golden, CO 80403
Phone: (303) 278-4455 • FAX: (303) 278-7012

JSTOMER #:
02602

DATE 5/6/94
LAB# 172994
P.O. 10496
RECD 04/21/94

ANALYSIS REPORT

CARL SMITS
EVERGREEN ANALYTICAL
4036 YOUNGFIELD
WHEAT RIDGE CO 80033

PROJ. # 94-1291, 1309, 1329, AND 1357

SEQUENCE/ SAMPLE NUMBER	ANALYSIS CARBONATE C---%	TOTAL CARBON--%	ORGANIC C-----%	DOC--------MG/	
01/XYZCPT-07 LIF- - -	<0.02	<0.05	<0.05		
02/XYZCPT-14 13-15- -	<0.02	0.17	0.17		
3/XYZCPT-19 9-11- -	<0.02	0.08	0.08		
04/XYZCPT-22 13-15- -	<0.02	0.55	0.55		
05/XYZ-07S- - - - - -				0.75	
06/XYZ-08S- - - - - -				3.02	
07/XYZ-12S- - - - - -				<0.05	←
08/XYZ-19S- - - - - -				3.70	
09/XYZ-27S- - - - - -				<0.05	

DOC VALUES WERE DETERMINED BY AMPOULE COMBUSTION ON FILTERED SAMPLES. ALTHOUGH FILTER BLANKS WERE CONSISTENT, SOME APPARENT VARIABILITY IN FILTERED VALUES WAS OBSERVED. TOC VALUES ON THE SAMPLES AS DETERMINED BY UV-PERSULFATE OXIDATION AND MEMBRANE-CONDUCTIVITY DETECTION ARE AS FOLLOWS:

SAMPLE	TOC--------MG/L	
05/XYZ-07S	2.77	
06/XYZ-08S	4.09	
07/XYZ-12S	1.56	←
08/XYZ-19S	4.87	
09/XYZ-27S	0.91	

Evergreen

May 6, 1994

MR TODD WIEDEMEIER/TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY SUITE 900
DENVER CO 80290

Data Report : 94-1309
Client Project : Dover AFB
SS27

Dear Mr. Wiedemeier/Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice President of lity Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

J. M. Barney /cpp

Jack Barney
President

™

Evergreen Analytical, Inc. 4036 Youngfield St. Wheat Ridge, CO 80033-3862 (303) 425-6021 FAX (303) 425-6854

Evergreen Analytical Sample Log Sheet

Project # 94-1309

Date(s) Sampled: 04-15-94 COC

Date Due: 04-21-94-UST
05-02-94-TOC

Date Received: 04-16-94 1140

Holding Time(s): 04-29-94

Client Project I.D. DOVER AFB SS27

Rush Standard

Client: ENGINEERING SCIENCE, INC

Shipping Charges N/A

Address: 1700 BROADWAY SUITE 900

E.A. Cooler # 345

DENVER, CO 80290

Airbill # FED EX 1968964082

Contact: Todd Wiedemeier /Todd Herrington
Denver contact/ Field contact

Custody Seal Intact? N
Cooler ___ Bottles ___

Client P.O. 722450.06020

COC Present Y

Sample Tags Present? Y

Phone #831-8100 **Fax #**Will Call

Sample Tags Listed? Y

Sample(s) Sealed? Y

Special Invoicing/Billing

Special Instructions **See attached for methods & reporting limits.**

ID #	Client ID#	Analysis	Mtx	Btl	Loc
X86170A/B	XYZCPT 14-13-15	BTEX	S	4WM	2
X86171A/B	XYZCPT 19-9-11	"	"	"	"
X86172A/B	XYZCPT 19-15-17	"	"	"	"
X86170C	XYZCPT 14-13-15	TVH	"	"	"
X86171C	XYZCPT 19-9-11	"	"	"	"
X86172C	XYZCPT 19-15-17	"	"	"	"
X86170D	XYZCPT 14-13-15	TOC	"	"	OUT
X86171D	XYZCPT 19-9-11	"	"	"	"

R=Sample to be returned

Route GC/MS ___ GC 3 Metals ___ Gen Chem ___ SxPrep ___ Acctg 1

SxRec C Adm C QA/QC C Sales C File Orig

Page 1 of 1 Page(s)

Custodian/Date: SS 4/16/94

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

COMPANY Engineering-Science, Inc.
ADDRESS
CITY Denver STATE CO ZIP
PHONE # 303 831 8100 FAX # Will Call FAX RESULTS Y / N

COMPANY CONTACT (print) Todd Harrington
PROJECT I.D Dover AFB 5527
P.O. # 722450.06020
TURNAROUND REQUIRED* 3-DAY
*expedited turnaround subject to additional fee

Sampler Name:
(signature)
(print) Donald B. Boyle

Evergreen Analytical Cooler No. 307

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	MATRIX: Soil / Solid (circle)	MATRIX: Sludge/Slurry (circle)	MATRIX: Oil/Organic Liquid (circle)	MATRIX: Multiphase (identify phase to be analyzed)	TCLP VOA/BNA/Pest/Herb/Metals (circle)	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608/508 (circle)	Herbicides 8150/515 (cicle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle) MTBE (circle)	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	TDC	Notes
~~CA~~																							
XYZCPT14-13-15	4-15-94	1635			X										X		X					X	
XYZCPT-19-9-11'	4-15-94	1705			X										X		X					X	
XYZCPT-19-15-17'	4-15-94	1725			X										X		X						

Instructions:

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
[signature]	4-15-94 1900	Stacy Smith	4/16/94 11:00				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

Eng Science Pre contract Parameters
Dover AFB

TABLE A.4

SUMMARY OF SOIL/SEDIMENT ANALYTICAL METHODS

SUBCONTRACT NO. 722450-SC001

Parameter	Analytical Method	Reporting Units	Maximum Analyses	Unit Price
Total Organic Carbon (TOC)	SW9060 Modified	mg/kg [a/]	-5	$____EA
Total Volatile Hydrocarbons (gasoline)	SW5030/SW8015M	µg/kg	-10	$____EA
Purgeable Aromatics (BTEX)[c/]	SW8020	µg/kg[d/]	-10	$____EA

a/ mg/kg = milligrams per kilogram.
b/ TRPH = Total recoverable petroleum hydrocarbons.
c/ BTEX = benzene, toluene, ethylbenzene, xylenes.
d/ µg/kg = micrograms per kilogram.

Evergreen Analytical Sample Receipt/Check-in Record

Date & Time Rec'd: 4/16/94 11:40 Shipped Via: FedX 1968964082
(Airbill # if applicable)

Client : Engineering Science

Client Project ID(s): Dover AFB 5527

EAL Project #(s): 94-1309 EAL Cooler(s): (Y) N

Cooler#	345								
Ice packs	(Y)	N	Y	N	Y	N	Y	N	Y	N
Temperature °C	11.5								

	Y	N	N/A
1. Custody seal(s) present:		X	
Seals on cooler intact			X
Seals on bottle intact			
2. Chain of Custody present:	X		
3. Containers broken or leaking: (Comment on COC if Y)		X	
4. Containers labeled:	X		
5. COC agrees w/ bottles received: (Comment on COC if N)	X		
6. COC agrees w/ labels: (Comment on COC if N)	X		
7. Headspace in VOA vials-waters only (comment on COC if Y)			X
8. VOA samples preserved:			X
9. pH measured on metals, cyanide or phenolics*:			X
List discrepancies			
*Non-EAL provided containers only, water samples only.			
10. Dissolved metals samples present:			X
To be preserved:			X
To be filtered:			X
11. Short holding times:			
Specify parameters			
12. Multi-phase sample(s) present:		X	
13. COC signed w/ date/time:	X		

Comments:

(Additional comments on back)
Custodian Signature/Date: A Smith 4/16/94

Pg 1 of 2

Evergreen

P.O. # 10496

OUTSIDE CONTRACTOR ANALYSIS REQUEST
&
CHAIN-OF-CUSTODY

Analytical Lab: Huffman Laboratories, Inc

Address: 4630 Indiana Street
Golden, Co 80403

Phone: 278-4455

Contact: Sue Zeller

Results Required By: Standard

Please analyze the following samples as described below:

No. of Samples Shipped: 9

Project No.	Client Sample No.	Date/Time Sampled	Matrix	Analysis Requested
94-1291	XYZ-125	4/14/94	water	DOC 5310D (Method #)
94-1310	XYZ-075	4/15/94	water	↓
94-1310	XYZ-085	4/15/94	water	↓
94-1309	XYZ-CPT 14-13-15	4/15/94	soil	SW 9060 TOC MODIFIED
94-1309	XYZCPT 19-9-11	4/15/94	↓	↓

RUSH SERVICES (FOR EXTRA FEE): YES ✓ NO _____

IF ANY QUESTIONS OR PROBLEMS CONTACT: Sheri Greiner

PLEASE FAX THE RESULTS TO: CARL SMITS

PLEASE MAIL WRITTEN RESULTS TO: CARL SMITS

SAMPLES RELINQUISHED BY: _____

METHOD OF SHIPMENT: _____ DATE:/TIME _____

SAMPLES RECEIVED BY: Mary Dunlap DATE:/TIME 4/20/94 3:45

CUSTODY SEAL INTACT: YES _____ NO _____

Run DOC by ampule method.
Please report using Client Sample No.

coc.frm

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZCPT 14-13-15	Client Project No.	: Dover AFB SS27
Lab Sample Number	: X86170	Lab Project No.	: 94-1309
Date Sampled	: 4/15/94	Dilution Factor	: 125.00
Date Received	: 4/16/94	Method	: 8020
Date Extracted/Prepared	: 4/20/94	Matrix	: Soil
Date Analyzed	: 4/20/94	Lab File No.	: BX2042006
Methanol Extract?	: Yes	Method Blank No.	: MEB042094

Compound Name	Cas Number	Sample Concentration ug/kg		PQL ug/kg
Benzene	71-43-2	75	J	500
Toluene	108-88-3	590		500
Ethyl Benzene	100-41-4	590		500
Total Xylene (m/p + o)	1330-20-7	4000		500

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 115%
QC Reporting Limits	: 55%-127%

QUALIFIERS:

E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZCPT 19-9-11	**Client Project No.**	: Dover AFB SS27
Lab Sample Number	: X86171	**Lab Project No.**	: 94-1309
Date Sampled	: 4/15/94	**Dilution Factor**	: 5.00
Date Received	: 4/16/94	**Method**	: 8020
Date Extracted/Prepared	: 4/20/94	**Matrix**	: Soil
Date Analyzed	: 4/20/94	**Lab File No.**	: BX2042007
Methanol Extract?	: No	**Method Blank No.**	: MEB042094

Compound Name	Cas Number	Sample Concentration ug/kg	PQL ug/kg
Benzene	71-43-2	U	20
Toluene	108-88-3	U	20
Ethyl Benzene	100-41-4	U	20
Total Xylene (m/p + o)	1330-20-7	U	20

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 111%
QC Reporting Limits : 55%-127%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZCPT 19-15-17	Client Project No.	: Dover AFB SS27
Lab Sample Number	: X86172	Lab Project No.	: 94-1309
Date Sampled	: 4/15/94	Dilution Factor	: 1.00
Date Received	: 4/16/94	Method	: 8020
Date Extracted/Prepared	: 4/20/94	Matrix	: Soil
Date Analyzed	: 4/20/94	Lab File No.	: BX2042008
Methanol Extract?	: No	Method Blank No.	: MEB042094

Compound Name	Cas Number	Sample Concentration ug/kg		PQL ug/kg
Benzene	71-43-2	0.6	J	4
Toluene	108-88-3	1.4	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.5	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 82%
QC Reporting Limits	: 55%-127%

QUALIFIERS:

E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report
Method Blank Report

Method Blank Number	: MEB042094	Client Project No.	: Dover AFB SS27
Date Extracted/Prepared	: 4/20/94	Lab Project No.	: 94-1309
Date Analyzed	: 4/20/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042011

Compound Name	Cas Number	Sample Concentration ug/L	PQL ug/L
Benzene	71-43-2	U	4
Toluene	108-88-3	U	4
Ethyl Benzene	100-41-4	U	4
Total Xylene (m/p + o)	1330-20-7	U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:

a,a,a,-Trifluorotoluene	: 103%
QC Reporting Limits	: 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

Evergreen Analytical, Inc.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

BTEX Matrix Spike/Matrix Spike Duplicate Data Report

Client Sample No.	: XYZCPT 19-15-17	Client Project No.	: Dover AFB SS27
Lab Sample No.	: X86172	Lab Project No.	: 94-1309
Date Sampled	: 4/15/94	EPA Method No.	: 8020
Date Received	: 4/16/94	Matrix	: Soil
Date Prepared	: 4/20/94	Lab File Number(s)	: BX2042022,23
Date Analyzed	: 4/21/94	Method Blank	: MEB042094

Compound	Spike Added (ug/L)	Sample Concentration (ug/L)	MS Concentration (ug/L)	MS %REC	QC Limits %REC
Benzene	20	0.6	18.8	91	39-150
Toluene	20	1.4	18.2	84	46-148
Ethyl Benzene	20	0	14.9	74.5	32-160
m/p-Xylene	20	0.5	14.9	72	32-160
o-Xylene	20	0	14.2	71	32-160

Compound	Spike Added (ug/L)	MSD Concentration (ug/L)	MS %REC	RPD	QC Limits RPD	QC Limits %REC
Benzene	20	17.9	86.5	5.1	21	39-150
Toluene	20	16.5	75.5	10.7	21	46-148
Ethyl Benzene	20	13.5	67.5	9.9	21	32-160
m/p-Xylene	20	13.4	64.5	11.0	21	32-160
o-Xylene	20	13.1	65.5	8.1	21	32-160

* = Values outside of QC limits.

RPD: 0 out of (5) outside limits.

Spike Recovery: 0 out of (10) outside limits.

Comments: CJC

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/15/94	Client Project Number	: DOVER AFB SS27
Date Received	: 4/16/94	Lab Project Number	: 94-1309
Date Prepared	: 4/19/94	Matrix	: Soil
Date Analyzed	: 4/20/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/Kg	MDL mg/Kg
X86170C	XYZCPT 14-13-15	55% *	1,100	1
X86171C	XYZCPT 19-9-11	95%	0.2	0.1
X86172C	XYZCPT 19-15-17	94%	U	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit
* = Low surrogate recovery due to analyte interference.

Analyst

Approved

HUFFMAN
LABORATORIES, INC.
Quality Analytical Services Since 1936
4630 Indiana Street • Golden, CO 80403
Phone: (303) 278-4455 • FAX: (303) 278-7012

CUSTOMER #:
02602

DATE 5/6/
LAB# 17299
P.O. 10496
RECD 04/21/94

ANALYSIS REPORT

CARL SMITS
EVERGREEN ANALYTICAL
4036 YOUNGFIELD
WHEAT RIDGE CO 80033

PROJ. # 94-1291, 1309, 1329, AND 1357

SEQUENCE/ SAMPLE NUMBER	ANALYSIS CARBONATE C---%	TOTAL CARBON--%	ORGANIC C-----%	DOC--------MG/L
01/XYZCPT-07 LIF	<0.02	<0.05	<0.05	
02/XYZCPT-14 13-15	<0.02	0.17	0.17	←
03/XYZCPT-19 9-11	<0.02	0.08	0.08	←
04/XYZCPT-22 13-15	<0.02	0.55	0.55	
05/XYZ-07S				0.75
06/XYZ-08S				3.02
07/XYZ-12S				<0.05
08/XYZ-19S				3.70
09/XYZ-27S				<0.05

DOC VALUES WERE DETERMINED BY AMPOULE COMBUSTION ON FILTERED SAMPLES. ALTHOUGH FILTER BLANKS WERE CONSISTENT, SOME APPARENT VARIABILITY IN FILTERED VALUES WAS OBSERVED. TOC VALUES ON THE SAMPLES AS DETERMINED BY UV-PERSULFATE OXIDATION AND MEMBRANE-CONDUCTIVITY DETECTION ARE AS FOLLOWS:

SAMPLE	TOC--------MG/L
05/XYZ-07S	2.77
06/XYZ-08S	4.09
07/XYZ-12S	1.56
08/XYZ-19S	4.87
09/XYZ-27S	0.91

Evergreen

May 9, 1994

MR TODD WIEDEMEIER/TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY SUITE 900
DENVER CO 80290

Data Report : 94-1310
Client : Dover AFB
SS27

Dear Mr. Wiedemeier/Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice President of Quality Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

J. H. Barney Jr

Jack Barney
President

™

Evergreen Analytical Sample Log Sheet

Project # 94-1310

Date(s) Sampled: 4/15/94 COC

Date Due: 4/21/94-UST
5/02/94-OTHER

Date Received: 4/16/94 1140

Holding Time(s): 4/17/94-NO3,NO2
4/22/94BTEX,TVH,TEH,METHANE

Client Project I.D. Dover AFB SS27

Rush STANDARD

Client: Engineering Science

Address: 1700 Broadway, Suite 900

Denver, CO 80290

Contact: Todd Wiedemeier/ Todd Herrington
Denver contact / field contact

Client P.O. 722450.06020

Phone #831-8100 **Fax #**Will Call

Shipping Charges N/A

E.A. Cooler # 345

Airbill # FEDEX

Custody Seal Intact? Y
Cooler X Bottles ___
COC Present Y
Sample Tags Present? Y
Sample Tags Listed? Y
Sample(s) Sealed? Y

Special Instructions ***ANALYZE AND REPORT NITRATE AND NITRITE SEPARATELY.**
****PHOSPHATE BY NON AUTOMATED METHOD EPA 365.2. SEE ATTACHED FOR METHODS & LIMITS**

Lab ID #	Client ID#	Analysis	Mtx	Btl	Loc
X86173A/B	XYZ-07S	8020 BTEX + Trimethylbenzene Isomers	W	40V	2
X86174A/B	XYZ-09S	"	"	"	"
X86175A/B	XYZ-10S	"	"	"	"
X86176A/B	XYZ-50S	"	"	"	"
X86177A/B	XYZ-08S	"	"	"	"
X86178A/B	XYZ-18S	"	"	"	"
X86173C/D	XYZ-07S	TVH 8015	"	"	"
X86174C/D	XYZ-09S	"	"	"	"
X86175C/D	XYZ-10S	"	"	"	"
X86176C/D	XYZ-50S	"	"	"	"
X86177C/D	XYZ-08S	"	"	"	"
X86173E-H	XYZ-07S	METHANE	W	40V	2
X86174E-H	XYZ-09S	"	"	"	"

R=Sample to be returned
Route To GC/MS ___ GC 5 Metals ___ Gen Chem 2 SxPrep 1 Acctg 1
SxRec C Adm C QA/QC C Sales C File Orig

Custodian/Date: CLD 4/16/94

MJM

Lab ID #	Client ID#	Analysis	Mtx	Btl	Loc
X86175E-H	XYZ-10S	METHANE	W	40V	2
X86176E-H	XYZ-50S	"	"	"	"
X86177E-H	XYZ-08S	"	"	"	"
X86178E-H	XYZ-18S	"	"	"	"
X86173L	XYZ-07S	TEH 8015	"	1LA	C2
X86174J	XYZ-09S	"	"	"	"
X86175J	XYZ-10S	"	"	"	"
X86176J	XYZ-50S	"	"	"	"
X86177L	XYZ-08S	"	"	"	"
X86173I	XYZ-07S	DISSOLVED ORGANIC CARBON	W	125A	OUT
X86177I	XYZ-08S	"	"	"	"
X86173J	XYZ-07S	PHOSPHATE	W	125P	C2
X86177J	XYZ-08S	"	"	"	"
X86173K	XYZ-07S	ALKALINITY, SULFATE, CHLORIDE, *NO_2, NO_3 (AS N)	W	500P	C2
X86174I	XYZ-09S	"	"	"	"
X86175I	XYZ-10S	"	"	"	"
X86176I	XYZ-50S	"	"	"	"
X86177K	XYZ-08S	"	"	"	"
X86178G	XYZ-18S	"	"	"	"

Project # 94-1310

R=Sample to be returned

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

COMPANY Engineering-Science Inc.
ADDRESS 1700 Broadway, Ste 900
CITY Denver STATE CO ZIP 80290
PHONE # 303 831 8100 FAX # Will Call FAX RESULTS (Y) / N

COMPANY CONTACT (print) Todd Herrington
PROJECT I D Dover AFB SS27
P.O. # 722450.06020
TURNAROUND REQUIRED* 3 days
*expedited turnaround subject to additional fee

Sampler Name:
(signature) Kyle L Cannon
(print) Kyle L. Cannon

Evergreen Analytical Cooler No. 345

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	MATRIX: Soil / Solid (circle)	MATRIX: Sludge/Slurry (circle)	MATRIX: Oil/Organic Liquid (circle)	MATRIX: Multiphase (identify phase to be analyzed)	ANALYSIS REQUESTED: TCLP VOA/BNA/Pest/Herb/Metals (circle)	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608 (circle)	Herbicides 8150/515 (circle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle)	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	Alkalinity / Anions	Methane	Dissolved Organic Carbon	Phosphates		Notes
XYZ-07S	4/15/94	0930	12												2		2	1			1	4	1	1		
XYZ-09S	4/15/94	1200	10												2		2	1			1	4				
XYZ-10S	4/15/94	1300	10												2		2	1			1	4				
XYZ-50S	4/15/94	1230	10												2		2	1			1	4				
~~XYZ-08D~~	~~4/15/94~~	~~1430~~																								
XYZ-08S	4/15/94	1500	12												2		2	1			1	4	1	1		
XYZ-18S	4/15/94	1730	17												2						1	4				
TOTAL			61												12		10	5			6	24	2	2		

Instructions:

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
Kyle L Cannon	4/15/94 1800	J Smith	4/16/94 1117				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

Eng. Science Precontract parameters
Dover AFB

TABLE A.3

SUMMARY OF AQUEOUS ANALYTICAL METHODS

INQUIRY 722450-SC001

Parameter	Analytical Method	Reporting Units	Maximum Analyses	Unit Price
Total Phosphate	E365 2	mg/L[a/]	5	$____EA
Sulfate Anions	E300	mg/L	30	$____EA
Purgeable Aromatic (BTEX + trimethylbenzene isomers)	SW8020	µg/L	30	$____EA
Alkalinity	A403	mg/L	30	$____EA
Dissolved Organic Carbon*	A5310C	mg/L	5	$____EA
Nitrogen, NO_3/NO_2 Nitrate	E300	mg/L	30	$____EA
Chloride (Anion)	E300	mg/L	30	$____EA
Methane	**RSKSOP-147	mg/L	30	$____EA
Total Hydrocarbons (Volatile & Extractable)	SW8015 Modified Gasoline Range	mg/L	20	$____EA

a/ mg/L = milligrams per liter.
b/ µg/L = micrograms per liter.

* Optional, may not be required. See page A-8 para. 3.1.
** Standard Operating Procedure Attached (12 pages).

Dover AFB project
Engineering Science

PROJECT SPECIAL INSTRUCTIONS 94-

Date: 4/15/94 EAL Contact: Shea Client Contact: (Todd Wedlemier) Todd Herrington in Dover

INSTRUCTIONS:

3 day TA { BTEX 8020 + Trimethyl benzene isomers
TVH & TEH

(we need a std for the trimethylbenzenes & they know that this will make the BTEX late)

Other analyses are std. 10 day TA.

TCC should be Dissolved Organic Carbon Send to Huffman - their method # is 5310D (not 5310C as on Tables)

Phosphate by non automated method See M. Mosher for # EPA 365.2

Nitrate & Nitrite separately

Evergreen Analytical Sample Receipt/Check-in Record

Date & Time Rec'd: 4/16/94 1140 Shipped Via: Fed Ex
(Airbill # if applicable)

Client : Engineering- Science

Client Project ID(s): Dover AFB

EAL Project #(s): 94-1310 EAL Cooler(s): (Y) N

Cooler#	345								
Ice packs	(Y)	N	Y	N	Y	N	Y	N	Y	N
Temperature °C	11.5								

	Y	N	N/A
1. Custody seal(s) present:		X	
Seals on cooler intact			X
Seals on bottle intact			(X)
2. Chain of Custody present:	X		
3. Containers broken or leaking: (Comment on COC if Y)		X	
4. Containers labeled:	X		
5. COC agrees w/ bottles received: (Comment on COC if N)	X		
6. COC agrees w/ labels: (Comment on COC if N)	X		
7. Headspace in VOA vials-waters only (comment on COC if Y)			X
8. VOA samples preserved:			X
9. pH measured on metals, cyanide or phenolics*:			X
List discrepancies			
*Non-EAL provided containers only, water samples only.			
10. Dissolved metals samples present:		X	Y
To be preserved:			
To be filtered:			(Y)
11. Short holding times:	X		
Specify parameters			
12. Multi-phase sample(s) present:		X	
13. COC signed w/ date/time:	X		

Comments:

(Additional comments on back)
Custodian Signature/Date: CLD 4/16/94

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-07S	**Client Project No.**	: Dover AFB SS27
Lab Sample Number	: X86173	**Lab Project No.**	: 94-1310
Date Sampled	: 4/15/94	**Dilution Factor**	: 1.00
Date Received	: 4/16/94	**Method**	: 8020
Date Extracted/Prepared	: 4/23/94	**Matrix**	: Water
Date Analyzed	: 4/23/94	**Lab File No.**	: BX2042306
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	15	B	4
Ethyl Benzene	100-41-4	0.4	J	4
Total Xylene (m/p + o)	1330-20-7	1.9	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 103%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-09S	Client Project No.	: Dover AFB SS27
Lab Sample Number	: X86174	Lab Project No.	: 94-1310
Date Sampled	: 4/15/94	Dilution Factor	: 1.00
Date Received	: 4/16/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042118
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	2.2	J	4
Toluene	108-88-3	2.6	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	1.3	BJ	4
1,3,5-Trimethylbenzene	108-67-8	0.6	J	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 93%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-10S	Client Project No.	: Dover AFB SS27
Lab Sample Number	: X86175	Lab Project No.	: 94-1310
Date Sampled	: 4/15/94	Dilution Factor	: 1.00
Date Received	: 4/16/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/21/94	Lab File No.	: BX2042119
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	3.9	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.4	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 89%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-50S	Client Project No.	: Dover AFB SS27
Lab Sample Number	: X86176	Lab Project No.	: 94-1310
Date Sampled	: 4/15/94	Dilution Factor	: 1.00
Date Received	: 4/16/94	Method	: 8020
Date Extracted/Prepared	: 4/21/94	Matrix	: Water
Date Analyzed	: 4/22/94	Lab File No.	: BX2042122
		Method Blank No.	: MB042194

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	0.9	J	4
Toluene	108-88-3	6.5		4
Ethyl Benzene	100-41-4	0.4	J	4
Total Xylene (m/p + o)	1330-20-7	1.3	BJ	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6	0.5	J	4
1,2,3-Trimethylbenzene	526-73-8	0.6	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 86%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-18S	Client Project No.	: Dover AFB SS27
Lab Sample Number	: X86178	Lab Project No.	: 94-1310
Date Sampled	: 4/15/94	Dilution Factor	: 200.00
Date Received	: 4/16/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042307
		Method Blank No.	: MB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	6500		800
Toluene	108-88-3	13000	B	800
Ethyl Benzene	100-41-4	820		800
Total Xylene (m/p + o)	1330-20-7	2600	B	800
1,3,5-Trimethylbenzene	108-67-8	220	J	800
1,2,4-Trimethylbenzene	95-63-6	560	J	800
1,2,3-Trimethylbenzene	526-73-8	200	J	800

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 105%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

Evergreen Analytical, Inc.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

BTEX Matrix Spike/Matrix Spike Duplicate Data Report

Client Sample No.	: XYZ-08S	Client Project No.	: Dover AFB SS27
Lab Sample No.	: X86177	Lab Project No.	: 94-1310
Date Sampled	: 4/15/94	EPA Method No.	: 8020
Date Received	: 4/16/94	Matrix	: Water
Date Prepared	: 4/21/94	Lab File Number(s)	: BX2042124,25
Date Analyzed	: 4/22/94	Method Blank	: MB042194

Compound	Spike Added (ug/L)	Sample Concentration (ug/L)	MS Concentration (ug/L)	MS %REC	QC Limits %REC
Benzene	20	0.9	18.5	88	39-150
Toluene	20	7.4	26.8	97	46-148
Ethyl Benzene	20	0.4	17.5	85.5	32-160
m/p-Xylene	20	1	17.9	84.5	32-160
o-Xylene	20	0.5	18	87.5	32-160

Compound	Spike Added (ug/L)	MSD Concentration (ug/L)	MS %REC	RPD	QC Limits RPD	QC Limits %REC
Benzene	20	17.6	83.5	5.2	21	39-150
Toluene	20	25.6	91	6.4	21	46-148
Ethyl Benzene	20	16.6	81	5.4	21	32-160
m/p-Xylene	20	17	80	5.5	21	32-160
o-Xylene	20	16.8	81.5	7.1	21	32-160

* = Values outside of QC limits.

RPD: 0 out of (5) outside limits.

Spike Recovery: 0 out of (10) outside limits.

Comments: CJC

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303)425-6021

Methane Data Report

Date Sampled : 04/15/94
Date Received : 04/16/94
Date Prepared : 04/21/94
Date Analyzed : 04/21/94

Client Project No.: Dover AFB SS27
Lab Project No. : 94-1310
Dilution Factor : see below
Method : FID
Matrix : Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042194	Method Blank	Water	U	10 (DF=1)
x86173	XYZ-07S	Water	U	10 (DF=1)
x86174	XYZ-09S	Water	1100	100 (DF=10)
x86175	XYZ-10S	Water	40	10 (DF=1)
x86176	XYZ-50S	Water	1300	100 (DF=10)
x86177	XYZ-08S	Water	1200	100 (DF=10)
x86178	XYZ-18S	Water	640	100 (DF=10)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

Analyst

Approved

Pg 1 of 1

Evergreen

P.O. # 10496

OUTSIDE CONTRACTOR ANALYSIS REQUEST
&
CHAIN-OF-CUSTODY

Analytical Lab: Huffman Laboratories, INC

Address: 4630 Indiana Street
Golden, CO 80403

Phone: 278-4455

Contact: Sue Zeller

Results Required By: Standard

Please analyze the following samples as described below:

No. of Samples Shipped: 9

Project No.	Client Sample No.	Date/Time Sampled	Matrix	Analysis Requested (Method #)
94-1291	XYZ-12S	4/14/94	water	DOC 5310D
94-1310	XYZ-075	4/15/94	water	↓
94-1310	XYZ-085	4/15/94	water	↓
94-1309	XYZ-CPT 14-13-15	4/15/94	soil	SW 9060 TOC MODIFIED
94-1309	XYZCPT 19-9-11	4/15/94	↓	↓

RUSH SERVICES (FOR EXTRA FEE): YES ____ NO ____

IF ANY QUESTIONS OR PROBLEMS CONTACT: Sher Greiner

PLEASE FAX THE RESULTS TO: CARL SMITS

PLEASE MAIL WRITTEN RESULTS TO: CARL SMITS

SAMPLES RELINQUISHED BY: _____

METHOD OF SHIPMENT: _____ DATE:/TIME _____

SAMPLES RECEIVED BY: Mary Dunlap DATE:/TIME 4/20/94 3:45

CUSTODY SEAL INTACT: YES _____ NO _____

Note Run DOC by ampule method.
Please report using Client Sample No.

coc.frm

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/15/94	Client Project ID.	: Dover AFB SS27
Date Received	: 4/16/94	Lab Project No.	: 94-1310
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method	: EPA 310.1

Evergreen Sample #	Client Sample ID	Total Alkalinity ($mgCaCO_3/L$)
X86173	XYZ-07S	21.8
X86174	XYZ-09S	102
X86175	XYZ-10S	40.5
X86176	XYZ-50S	37.0
X86177	XYZ-08S	36.6
X86178	XYZ-18S	155

Analyst

Approved

1310tm.4

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/15/94	Client Project Number	: Dover AFB SS27
Date Received	: 4/16/94	Lab Project Number	: 94-1310
Date Prepared	: 4/19/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/L	MDL mg/L
X86173	XYZ-07S	101%	0.2	0.1
X86174	XYZ-09S	106%	0.2	0.1
X86175	XYZ-10S	106%	U	0.1
X86176	XYZ-50S	101%	0.2	0.1
X86177	XYZ-08S	101%	0.2	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared)..
E = Extrapolated value.
MDL = Method Detection Limit

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303)425-6021

Methane Data Report

Client Project No.: Dover AFB SS27
Date Sampled : 04/15/94
Lab Project No. : 94-1310
Date Received : 04/16/94
Dilution Factor : see below
Date Prepared : 04/21/94
Method : FID
Date Analyzed : 04/21/94
Matrix : Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042194	Method Blank	Water	U	10 (DF=1)
x86173	XYZ-07S	Water	U	10 (DF=1)
x86174	XYZ-09S	Water	1100	100 (DF=10)
x86175	XYZ-10S	Water	40	10 (DF=1)
x86176	XYZ-50S	Water	1300	100 (DF=10)
x86177	XYZ-08S	Water	1200	100 (DF=10)
x86178	XYZ-18S	Water	640	100 (DF=10)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

Analyst

Approved

Pg 1 of 1

Evergreen

P.O. # 10496

OUTSIDE CONTRACTOR ANALYSIS REQUEST
&
CHAIN-OF-CUSTODY

Analytical Lab: HUFFMAN Laboratories, INC

Address: 4630 Indiana Street Phone: 278-4455

Golden, CO 80403 Contact: Sue Zeller

Results Required By: Standard

Please analyze the following samples as described below:

No. of Samples Shipped: 9

Project No.	Client Sample No.	Date/Time Sampled	Matrix	Analysis Requested
94-1291	XYZ-12S	4/14/94	water	DOC 5310D Method #
94-1310	XYZ-075	4/15/94	water	↓
94-1310	XYZ-085	4/15/94	water	↓
94-1309	XYZ-CPT 14-13-15	4/15/94	soil	SW 9060 TOC MODIFIED
94-1309	XYZCPT 19-9-11	4/15/94	↓	↓

RUSH SERVICES (FOR EXTRA FEE): YES ____ NO ____

IF ANY QUESTIONS OR PROBLEMS CONTACT: Shea Greiner

PLEASE FAX THE RESULTS TO: CARL SMITS

PLEASE MAIL WRITTEN RESULTS TO: CARL SMITS

SAMPLES RELINQUISHED BY: ____

METHOD OF SHIPMENT: ____ DATE:/TIME ____

SAMPLES RECEIVED BY: Mary Dunlap DATE:/TIME 4/20/94 3:45

CUSTODY SEAL INTACT: YES ____ NO ____

Note Run DOC by ampule method.
Please report using Client Sample No.

coc.frm

CUSTOMER #:
02602

HUFFMAN
LABORATORIES, INC.
Quality Analytical Services Since 1936
4630 Indiana Street • Golden, CO 80403
Phone: (303) 278-4455 • FAX: (303) 278-7012

DATE 5/6/94
LAB# 172994
P.O. 10496
RECD 04/21/94

ANALYSIS REPORT

CARL SMITS
EVERGREEN ANALYTICAL
4036 YOUNGFIELD
WHEAT RIDGE CO 80033

PROJ. # 94-1291, 1309, 1329, AND 1357, 1310

SEQUENCE/ SAMPLE NUMBER	ANALYSIS CARBONATE C---%	TOTAL CARBON--%	ORGANIC C-----%	DOC--------MG/L
01/XYZCPT-07 LIF-	<0.02	<0.05	<0.05	
02/XYZCPT-14 13-15-	<0.02	0.17	0.17	
03/XYZCPT-19 9-11-	<0.02	0.08	0.08	
04/XYZCPT-22 13-15-	<0.02	0.55	0.55	
05/XYZ-07S-				0.75 ←
06/XYZ-08S-				3.02 ←
07/XYZ-12S-				<0.05
08/XYZ-19S-				3.70
09/XYZ-27S-				<0.05

TOC VALUES WERE DETERMINED BY AMPOULE COMBUSTION ON FILTERED SAMPLES. ALTHOUGH FILTER BLANKS WERE CONSISTENT, SOME APPARENT VARIABILITY IN FILTERED VALUES WAS OBSERVED. TOC VALUES ON THE SAMPLES AS DETERMINED BY UV-PERSULFATE OXIDATION AND MEMBRANE-CONDUCTIVITY DETECTION ARE AS FOLLOWS:

SAMPLE	TOC--------MG/L
05/XYZ-07S	2.77 ←
06/XYZ-08S	4.09 ←
07/XYZ-12S	1.56
08/XYZ-19S	4.87
09/XYZ-27S	0.91

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/15/94	Client Project ID.	: Dover AFB SS27
Date Received	: 4/16/94	Lab Project No.	: 94-1310
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/20/94	Method	: EPA 310.1

Evergreen Sample #	Client Sample ID	Total Alkalinity ($mgCaCO_3/L$)
X86173	XYZ-07S	21.8
X86174	XYZ-09S	102
X86175	XYZ-10S	40.5
X86176	XYZ-50S	37.0
X86177	XYZ-08S	36.6
X86178	XYZ-18S	155

Analyst

Approved

1310tm.4

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Anions

Date Sampled : 4/15/94
Date Received : 4/16/94
Date Prepared : 4/16/94
Date Analyzed : 4/16/94

Client Project ID. : Dover AFB SS27
Lab Project No. : 94-1310
Method : EPA 300.0

Evergreen Sample #	Client Sample ID	Matrix	Nitrite-N (mg/L)	Nitrate-N (mg/L)
X86173	XYZ-07S	Water	<0.076	3.16
X86174	XYZ-09S	Water	<0.076	<0.056
X86175	XYZ-10S	Water	<0.076	2.05
X86176	XYZ-50S	Water	<0.076	<0.056
X86177	XYZ-08S	Water	<0.076	<0.056
X86178	XYZ-18S	Water	<0.076	<0.056

Analyst

Approved

1310tm.25

Evergreen

May 10, 1994

MR TODD WIEDEMEIER/TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY STE 900
DENVER CO 80290

Data Report : 94-1351
Client Project : Dover AFB

Dear Mr. Wiedemeier/Mr. Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice President of Quality Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

J. H Barney /cmr

Jack Barney
President

JJ

Evergreen Analytical, Inc. 4036 Youngfield St. Wheat Ridge, CO 80033-3862 (303) 425-6021 FAX (303) 425-6854

Evergreen Analytical Sample Log Sheet

Project # 94-1351

Date(s) Sampled: 04/19/94 COC

Date Due: 04/25/94-UST
05/04/94-Others

Date Received: 04/20/94 1115 **Holding Time(s):** 04/21-NO_2, NO_3, PO_4, 04/26-BTEX, TVH, TEH, METHANE

Client Project I.D. DOVER AFB **Rush** STANDARD

Client: ENGINEERING SCIENCE

Address: 1700 BROADWAY SUITE 900

DENVER, CO 80290

Contact: TODD WIEDEMEIER/TODD HERRINGTON
Denver contact/Field contact

Client P.O. 722450.06020

Phone #831-8100 **Fax #**WILL CALL

Shipping Charges 5.00

E.A. Cooler # N/A

Airbill # FEDEX 1968905396

Custody Seal Intact? Y
Cooler ___ Bottles X
COC Present Y
Sample Tags Present? Y
Sample Tags Listed? Y
Sample(s) Sealed? Y

Special Invoicing/Billing

Special Instructions **SEE ATTACHED FOR METHODS & LIMITS.**

Lab ID #	Client ID#	Analysis	Mtx	Btl	Loc
X86322A/B	XYZ-15S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	Oil	40V	2
X86323A/B	XYZ-16S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86324A/B	XYZ-16D	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86325A/B	XYZ-27S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86326A/B	XYZ-27D	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86327A/B	XYZ-28S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86328A/B	TRIP BLANK	HOLD	W	40V	2
X86323C/D	XYZ-16S	TVH	W	40V	2
X86325C/D	XYZ-27S	TVH	W	40V	2
X86323I	XYZ-16S	TEH	W	1LA	C4
X86325K	XYZ-27S	TEH	W	1LA	C4

R=Sample to be returned
Route To GC/MS ___ GC 5 Metals ___ Gen Chem 2 SxPrep 1 Acctg 1
SxRec C Adm C QA/QC C Sales C File Orig

Custodian/Date: 4/20/94

CHAIN OF CUSTODY RECORD / ANALYTICAL SERVICES REQUEST

Evergreen Analytical Inc.

4036 Youngfield
Wheat Ridge, Colorado 80033
(303) 425-6021
FAX (303) 425-6854

Page 1 of 1

COMPANY Engineering Science
ADDRESS 1700 Broadway, Ste 900
CITY Denver STATE CO ZIP 80290
PHONE # 831 8100 FAX # _____ FAX RESULTS Y / N

COMPANY CONTACT (print) Todd Herrington
PROJECT I.D ~~EE~~ Dover AFB
P.O. # 722450.06020
TURNAROUND REQUIRED* Normal
*expedited turnaround subject to additional fee

Sampler Name:
(signature) Kyle Cannon
(print) Kyle Cannon

~~Evergreen Analytical~~ Cooler No. # 100
Engineering Science

SAMPLE IDENTIFICATION	DATE SAMPLED	TIME	No. of Containers	MATRIX: Water - Drinking/Discharge/Ground (circle)	Soil / Solid (circle)	Sludge/Slurry (circle)	Oil/Organic Liquid (circle)	Multiphase (identify phase to be analyzed)	TCLP VOA/BNA/Pest/Herb/Metals (circle)	VOA 8260/624/524.2 (circle)	BNA 8270/625 (circle)	Pesticides 8080/608 (circle)	Pest/PCBs 8080/608/508 (circle)	Herbicides 8150/515 (cicle)	PCB 8080/PCB Screen (circle)	BTEX 8020/602 (circle) /MTBE (circle)	TRPH 418.1/Oil & Grease 413.1 (circle)	TVH 8015mod. (Gasoline)	TEH 8015mod. (Diesel)	Total Metals-DW / NPDES / SW846 (circle & list metals below)	Dissolved Metals - DW / SW846 (circle & list metals below)	Alkalinity / Anions	Methane	DOC	Phosphates			Notes
X42-15S	4-19-94	0800	2				X								X													
X42-16S	4-19-94	0930	10	X											X		X	X				X	X					
X42-16D	4-19-94	1030	7	X											X		~~X~~					X	X					
X42-27S	4-19-94	1130	12	X											X		X	X				X	X	X	X			
X42-27D	4-19-94	1215	7	X											X							X	X					
X42-28S	4-19-94	1300	7	X											X							X	X					
Trip Blank	4-19-94	1500	1	X																								

Instructions:

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time
Kyle Cannon	4-19-94 1800	Stacy Small	4/20/94 11:15				
Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time	Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Date/Time

Evergreen Analytical Sample Receipt/Check-in Record

Date & Time Rec'd: 4/20/94 11:15 Shipped Via: FedX 1968905396
(Airbill # if applicable)

Client: Engineering Science

Client Project ID(s): Dover AFB

EAL Project #(s): 94-1351 EAL Cooler(s): (Y) N

Cooler#	Client								
Ice packs	(Y)	N	Y	N	Y	N	Y	N	Y	N
Temperature °C	11.7								

	Y	N	N/A
1. Custody seal(s) present:	X		
Seals on cooler intact		X	
Seals on bottle intact	X		
2. Chain of Custody present:	X		
3. Containers broken or leaking: (Comment on COC if Y)		X	
4. Containers labeled:	X		
5. COC agrees w/ bottles received: (Comment on COC if N)	X		
6. COC agrees w/ labels: (Comment on COC if N)	X		
7. Headspace in VOA vials-waters only (comment on COC if Y)			X
8. VOA samples preserved:			X
9. pH measured on metals, cyanide or phenolics*:			X
10. Dissolved metals samples present:			
To be preserved:			X
To be filtered:			X
11. Short holding times:			
12. Multi-phase sample(s) present:		X	
13. COC signed w/ date/time:	X		

List discrepancies

*Non-EAL provided containers only, water samples only.

Specify parameters

Comments:

(Additional comments on back)
Custodian Signature/Date: Tracy Smith 4/20/94

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-15S	Client Project No.	: Dover AFB
Lab Sample Number	: X86322	Lab Project No.	: 94-1351
Date Sampled	: 4/19/94	Dilution Factor	: 5000.00
Date Received	: 4/20/94	Method	: 8020
Date Extracted/Prepared	: 4/23/94	Matrix	: Oil
Date Analyzed	: 4/24/94	Lab File No.	: BX2042321
		Method Blank No.	: MEB042394

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	970000	E	20000
Toluene	108-88-3	2500000	BE	20000
Ethyl Benzene	100-41-4	1600000	E	20000
Total Xylene (m/p + o)	1330-20-7	6200000	BE	20000
1,3,5-Trimethylbenzene	108-67-8	2700000	BE	20000
1,2,4-Trimethylbenzene	95-63-6	5500000	BE	20000
1,2,3-Trimethylbenzene	526-73-8	3400000	E	20000

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 230% Co-eluting peaks.
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-16S	Client Project No.	: Dover AFB
Lab Sample Number	: X86323	Lab Project No.	: 94-1351
Date Sampled	: 4/19/94	Dilution Factor	: 1.00
Date Received	: 4/20/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042226
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	14		4
Toluene	108-88-3	34	B	4
Ethyl Benzene	100-41-4	54		4
Total Xylene (m/p + o)	1330-20-7	55	B	4
1,3,5-Trimethylbenzene	108-67-8	33		4
1,2,4-Trimethylbenzene	95-63-6	88		4
1,2,3-Trimethylbenzene	526-73-8	59		4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 106%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-16D	Client Project No.	: Dover AFB
Lab Sample Number	: X86324	Lab Project No.	: 94-1351
Date Sampled	: 4/19/94	Dilution Factor	: 1.00
Date Received	: 4/20/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042227
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	350	E	4
Toluene	108-88-3	64	B	4
Ethyl Benzene	100-41-4	28		4
Total Xylene (m/p + o)	1330-20-7	38	B	4
1,3,5-Trimethylbenzene	108-67-8	3.1	J	4
1,2,4-Trimethylbenzene	95-63-6	11		4
1,2,3-Trimethylbenzene	526-73-8	47		4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 111%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-27S	Client Project No.	: Dover AFB
Lab Sample Number	: X86325	Lab Project No.	: 94-1351
Date Sampled	: 4/19/94	Dilution Factor	: 1.00
Date Received	: 4/20/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042228
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	0.7	J	4
Toluene	108-88-3	6	B	4
Ethyl Benzene	100-41-4	1.5	J	4
Total Xylene (m/p + o)	1330-20-7	6.3	B	4
1,3,5-Trimethylbenzene	108-67-8	1.8	J	4
1,2,4-Trimethylbenzene	95-63-6	3.5	J	4
1,2,3-Trimethylbenzene	526-73-8	1.6	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 98%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-27D	Client Project No.	: Dover AFB
Lab Sample Number	: X86326	Lab Project No.	: 94-1351
Date Sampled	: 4/19/94	Dilution Factor	: 1.00
Date Received	: 4/20/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042234
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	5.4		4
Toluene	108-88-3	18	B	4
Ethyl Benzene	100-41-4	1.7	J	4
Total Xylene (m/p + o)	1330-20-7	6.2	B	4
1,3,5-Trimethylbenzene	108-67-8	0.5	J	4
1,2,4-Trimethylbenzene	95-63-6	0.9	J	4
1,2,3-Trimethylbenzene	526-73-8	0.6	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 101%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report

Client Sample Number	: XYZ-28S	Client Project No.	: Dover AFB
Lab Sample Number	: X86327	Lab Project No.	: 94-1351
Date Sampled	: 4/19/94	Dilution Factor	: 1.00
Date Received	: 4/20/94	Method	: 8020
Date Extracted/Prepared	: 4/22/94	Matrix	: Water
Date Analyzed	: 4/23/94	Lab File No.	: BX2042235
		Method Blank No.	: MEB042294

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2	5		4
Toluene	108-88-3	54	B	4
Ethyl Benzene	100-41-4	5		4
Total Xylene (m/p + o)	1330-20-7	25	B	4
1,3,5-Trimethylbenzene	108-67-8	2	J	4
1,2,4-Trimethylbenzene	95-63-6	4.2		4
1,2,3-Trimethylbenzene	526-73-8	2.5	J	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 98%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

Approved

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report
Method Blank Report

Method Blank Number	: MEB042294	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/22/94	Lab Project No.	: 94-1351
Date Analyzed	: 4/23/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042225

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	1.1	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.6	J	4
1,3,5-Trimethylbenzene	108-67-8		U	4
1,2,4-Trimethylbenzene	95-63-6		U	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 112%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

BTEX Data Report
Method Blank Report

Method Blank Number	: MEB042394	Client Project No.	: Dover AFB
Date Extracted/Prepared	: 4/23/94	Lab Project No.	: 94-1351
Date Analyzed	: 4/24/94	Dilution Factor	: 1.00
		Method	: 8020
		Matrix	: Water
		Lab File No.	: BX2042320

Compound Name	Cas Number	Sample Concentration ug/L		PQL ug/L
Benzene	71-43-2		U	4
Toluene	108-88-3	0.5	J	4
Ethyl Benzene	100-41-4		U	4
Total Xylene (m/p + o)	1330-20-7	0.8	J	4
1,3,5-Trimethylbenzene	108-67-8	0.5	J	4
1,2,4-Trimethylbenzene	95-63-6	1.2	J	4
1,2,3-Trimethylbenzene	526-73-8		U	4

Note: Total Xylene consist of three isomers, two of which co-elute.
The Xylene PQL is for a single peak.

Surrogate Recovery:
a,a,a,-Trifluorotoluene : 93%
QC Reporting Limits : 77%-116%

QUALIFIERS:
E = Extrapolated value
U = Compound analyzed for, but not detected.
B = Compound found in blank and sample. Compare blank and sample data.
J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit (PQL).
PQL = Practical Quantitation Limit. The PQL is equal to the dilution factor multiplied by ten times the Method Detection Limit as determined by EPA SW846, Vol. 1B, Part II, pa. 8000-14.
NA = Not available.

Analyst

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL VOLATILE HYDROCARBONS (TVH)

Date Sampled	: 4/19/94	Client Project Number	: Dover AFB
Date Received	: 4/20/94	Lab Project Number	: 94-1351
Date Prepared	: 4/25/94	Matrix	: Water
Date Analyzed	: 4/25/94	Method Number	: 5030/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TVH mg/L	MDL mg/L
X86323	XYZ-16S	94%	1.1	0.1
X86325	XYZ-27S	92%	0.2	0.1

QUALIFIERS
U = TVH analyzed for but not detected.
B = TVH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303) 425-6021

TOTAL EXTRACTABLE HYDROCARBONS (TEH)
C11-C28 Boiling Range

Date Sampled	: 4/19/94	Client Project Number	: Dover AFB
Date Received	: 4/20/94	Lab Project Number	: 94-1351
Date Prepared	: 4/20/94	Matrix	: Water
Date Analyzed	: 4/21,22/94	Method Number	: 3500/Mod.8015

Evergreen Sample #	Client Sample #	Surrogate Recovery	TEH mg/L	MDL mg/L
WB042094		71%	U	0.5
DI Matrix Spike		77%	58% Diesel Spike Recovery	
X86323I	XYZ-16S	125%	2.5	0.5
X86325K	XYZ-27S	72%	U	0.5

QUALIFIERS
U = TEH analyzed for but not detected.
B = TEH found in blank as well as sample (blank data should be compared).
E = Extrapolated value.
MDL = Method Detection Limit

Analyst

Approved

EVERGREEN ANALYTICAL, INC.
4036 Youngfield, Wheat Ridge, CO 80033
(303)425-6021

Methane Data Report

		Client Project No.	: Dover AFB
Date Sampled	: 04/19/94	Lab Project No.	: 94-1351
Date Received	: 04/20/94	Dilution Factor	: see below
Date Prepared	: 04/24/94	Method	: FID
Date Analyzed	: 04/24/94	Matrix	: Water

Evergreen Sample #	Client Sample #	Matrix	Concentration mg/L	EDL* mg/L
MB042494	Method Blank	Water	U	10 (DF=1)
x86323	XYZ-16S	Water	340 E	10 (DF=1)
x86324	XYZ-16D	Water	430	100 (DF=10)
x86325	XYZ-27S	Water	U	10 (DF=1)
x86326	XYZ-27D	Water	75	10 (DF=1)
x86327	XYZ-28S	Water	34	10 (DF=1)

QUALIFIERS:

U = Compound analyzed for, but not detected above the Estimated Detection Limit.
B = Compound also found in the blank, blank data should be compared.
* = Indicates the Estimated Detection Limit.
E = Extrapolated value.

Analyst

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EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

MISCELLANEOUS ANALYSES

Date Sampled : 4/19/94
Date Received : 4/20/94
Date Prepared : 4/21/94
Date Analyzed : 4/21/94

Client Project ID: Dover AFB
Lab Project No. : 94-1351
Method : EPA 305.1
Matrix : Water

Evergreen Sample #	X86323	X86324	X86325	X86326	X86327	
Client Sample ID	XYZ-16S	XYZ-16D	XYZ-27S	XYZ-27D	XYZ-28S	
Total Alkalinity ($mgCaCO_3/L$)	122	195	< 5.00	8.50	52.6	

Analyst

Approved

1351tm.16

EVERGREEN ANALYTICAL, INC.
4036 Youngfield Street Wheat Ridge, CO 80033
(303) 425-6021

Anions

Date Sampled : 4/19/94
Date Received : 4/20/94
Date Prepared : 4/20/94
Date Analyzed : 4/20/94

Client Project ID : Dover AFB
Lab Project No. : 94-1351
Method : EPA Method 300.0

Client Sample ID	XYZ-16S	XYZ-16D	XYZ-27S	XYZ-27D	XYZ-28S	
Evergreen Sample #	X86323	X86324	X86325	X86326	X83627	
Matrix	Water	Water	Water	Water	Water	
Chloride (mg/L)	14.3	5.56	16.6	11.8	15.9	
Nitrite-N (mg/L)	<0.076	<0.076	<0.076	<0.076	,0.076	
Nitrate-N (mg/L)	<0.056	<0.056	1.66	0.091	1.88	
Sulfate (mg/L)	3.50	2.46	33.9	32.6	41.5	

Analyst

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1351tm.24

EVERGREEN ANALYTICAL, INC.
4036 Youngfield St. Wheat Ridge, CO 80033
(303)425-6021

Miscellaneous Analyses

Date Sampled	: 4/19/94	Client Project ID.	: Dover AFB
Date Received	: 4/20/94	Lab Project No.	: 94-1351
Client Sample ID.	: XYZ-27S	Matrix	: Water
Lab Sample No.	: X86325		

Analysis	Result	Date Prepared	Date Analyzed	Method
Total Phosphate-P (mg/L)	<0.01	4/20/94	4/20/94	EPA 365.2

Analyst

Approved

1351tm.16

HUFFMAN
LABORATORIES, INC.
Quality Analytical Services Since 1936
4630 Indiana Street • Golden, CO 80403
Phone: (303) 278-4455 • FAX: (303) 278-7012

CUSTOMER #:
02602

DATE 5/6/94
LAB# 172994
P.O. 10496
RECD 04/21/94

ANALYSIS REPORT

CARL SMITS
EVERGREEN ANALYTICAL
4036 YOUNGFIELD
WHEAT RIDGE CO 80033

PROJ. # 94-1291, 1309, 1329, AND 1357 (1357)

SEQUENCE/ SAMPLE NUMBER	ANALYSIS CARBONATE C---%	TOTAL CARBON--%	ORGANIC C-----%	DOC--------MG/L
01/XYZCPT-07 LIF-	<0.02	<0.05	<0.05	
02/XYZCPT-14 13-15-	<0.02	0.17	0.17	
03/XYZCPT-19 9-11-	<0.02	0.08	0.08	
04/XYZCPT-22 13-15-	<0.02	0.55	0.55	
05/XYZ-07S				0.75
06/XYZ-08S				3.02
07/XYZ-12S				<0.05
08/XYZ-19S				3.70
09/XYZ-27S				<0.05 ←

DOC VALUES WERE DETERMINED BY AMPOULE COMBUSTION ON FILTERED SAMPLES. ALTHOUGH FILTER BLANKS WERE CONSISTENT, SOME APPARENT VARIABILITY IN FILTERED VALUES WAS OBSERVED. TOC VALUES ON THE SAMPLES AS DETERMINED BY UV-PERSULFATE OXIDATION AND MEMBRANE-CONDUCTIVITY DETECTION ARE AS FOLLOWS:

SAMPLE	TOC--------MG/L
05/XYZ-07S	2.77
06/XYZ-08S	4.09
07/XYZ-12S	1.56
08/XYZ-19S	4.87
09/XYZ-27S	0.91

Evergreen

May 13, 1994

MR TODD WIEDEMEIER/TODD HERRINGTON
ENGINEERING SCIENCE
1700 BROADWAY SUITE 900
DENVER CO 80290

Data Report : 94-1329
Client Project : Dover AFB

Dear Mr. Wiedemeier/Mr. Herrington:

Enclosed are the analytical results for the samples shown in the Sample Log Sheet. The enclosed data have been reviewed for quality assurance. If you have any questions concerning the reported information, please contact Carl Smits, Vice Pre-ident of Quality Assurance, or me.

Please Note: Samples marked for return on the Sample Log Sheet are considered hazardous, unsuitable for municipal disposal or were placed on hold at your request. Samples considered hazardous or unsuitable for municipal disposal will be returned to you immediately. Samples placed on hold will be returned and samples not considered hazardous will be disposed of one (1) month from the date of this letter.

The invoice for this work will be mailed to your Accounts Payable department shortly.

Thank you for using the services of Evergreen Analytical.

Sincerely,

J H Barney/cpz

Jack Barney
President

JJ

Evergreen Analytical, Inc. 4036 Youngfield St. Wheat Ridge, CO 80033-3862 (303) 425-6021 FAX (303) 425-6854

Evergreen Analytical Sample Log Sheet

Project # 94-1329

Date(s) Sampled: 04/16,18/94 COC

Date Due: 04/22/94-UST
05/03/94-Others

Date Received: 04/19/94 1100 **Holding Time(s):** 04/20-PO_4, NO_3, NO_2, 4/23,25 BTEX,TVH, TEH,Methane-Waters,4/30,5/02-BTEX,TVH,TEH,Methane-Soils

Client Project I.D. Dover AFB **Rush** STANDARD

Client: Engineering Science

Address: 1700 Broadway, Suite 900

Denver, CO 80290

Contact: Todd Wiedemeier/Todd Herrington
Denver contact/Field contact

Client P.O. 722450.6020

Phone #831-8100 **Fax #**Will Call

Shipping Charges N/A

E.A. Cooler # 173

Airbill # FEDEX 1968905341

Custody Seal Intact? Y
Cooler X Bottles ___
COC Present Y
Sample Tags Present? Y
Sample Tags Listed? Y
Sample(s) Sealed? Y/N

Special Invoicing/Billing

Special Instructions Analyze NO_3 & NO_2 separately. See attached for methods & limits. †Per Todd to Shea use sample I.D. not COC.

LD #	Client ID#	Analysis	Mtx	Btl	Loc
X86231A/B	XYZ-22S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86232A/B	XYZ-25S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86233A/B	XYZ-26S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86235A/B	XYZ-19S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86236A/B	XYZ-19D	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86237A/B	XYZ-14S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86238A/B	XYZ-51S	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86239A/B	XYZ-08D	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86240A/B	XYZ-12D	BTEX 8020 + TRIMETHYLBENZENE ISOMERS	W	40V	2
X86234A/B	XYZCPT22-13'-15'	BTEX	S	2WM	2
X86241A/B	XYZCPT16LIF(7'-9')	BTEX	S	2WM	2
X86242A/B	XYZCPT16LIF(11'-13')	BTEX	S	2WM	2
X86243A/B	XYZCPT08-LIF(8'-10')	BTEX	S	2WM	2

R=Sample to be returned

Route GC/MS ___ GC 4 Metals ___ Gen Chem 2 SxPrep 1 Acctg 1

SxRec C Adm C QA/QC C Sales C File Orig

Custodian/Date: 4/19/94

ab D #	Client ID#	Analysis	Mtx	Btl	Loc
36244A/B	†XYZCPT8-LIF(13.7-15.7')	BTEX	S	2WM	2
36245A/B	XYZCPT12LIF(14'-16')	BTEX	S	2WM	2
36231C/D	XYZ-22S	TVH	W	40V	2
36232C/D	XYZ-25S	"	W	40V	2
36235C/D	XYZ-19S	"	W	40V	2
36236C/D	XYZ-19D	"	W	40V	2
36237C/D	XYZ-14S	"	W	40V	2
36239C/D	XYZ-08D	"	W	40V	2
36240C/D	XYZ-12D	"	W	40V	2
36234C	XYZCPT22-13'-15'	"	S	2WM	2
36241C	XYZCPT16LIF(7'-9')	"	S	2WM	2
36242C	XYZCPT16LIF(11'-13')	"	S	2WM	2
36243C	XYZCPT08-LIF(8'-10')	"	S	2WM	2
36244C	†XYZCPT8-LIF(13.7-15.7')	TVH	S	2WM	2
36245C	XYZCPT12LIF(14'-16')	TVH	S	2WM	2
36231I	XYZ-22S	TEH	W	40V	2
36232I	XYZ-25S	"	W	40V	2
36235J	XYZ-19S	"	W	40V	2
36236J	XYZ-19D	"	W	40V	2
36237J	XYZ-14S	"	W	40V	2
36239J	XYZ-08D	"	W	40V	2
36240J	XYZ-12D	"	W	40V	2
36231E-H	XYZ-22S	METHANE	W	40V	2
36232E-H	XYZ-25S	"	W	40V	2
36233E-H	XYZ-26S	"	W	40V	2
36235E-H	XYZ-19S	"	W	40V	2
36236E-H	XYZ-19D	"	W	40V	2
36237E-H	XYZ-14S	"	W	40V	2
36238E-H	XYZ-51S	"	W	40V	2
36239E-H	XYZ-08D	"	W	40V	2
36240E-H	XYZ-12D	"	W	40V	2

Project # 94-1329

=Sample to be returned

APPENDIX G

COSTING WORKSHEETS AND PRESENT WORTH CALCULATIONS

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 1

Present Worth Analysis Annual Discount Factor = 5%

Alternative 1: Intrinsic Remediation, Mobile LNAPL Recovery, and Institutional Controls with Long-Term Groundwater Monitoring	years	Present Worth ($)	Cost ($) at Year Indicated: Year: 1	2	3	4	5	6	7	8	9	10	11
LNAPL Recovery													
Monthly Site Work	6	$56,000	$11,025	$11,025	$11,025	$11,025	$11,025	$11,025	$0	$0	$0	$0	$0
Subtotal Present Worth ($)		$56,000											
Maintain Institutional Controls	30	$76,900	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Long-term Monitoring													
Install New LTM/POC Wells	1	$16,200	$17,055	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Sampling	30	$56,900	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704
Annual Reporting	30	$60,100	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910
Project Management	30	$15,000	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975
Subtotal Present Worth ($)		$225,100											

Total Present Worth Cost ($): $281,100

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 1

Cost ($) at Year Indicated																		
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704
$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910
$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 2

Present Worth Analysis Annual Discount Factor = 5%

Alternative 2: Intrinsic Remediation, LNAPL Recovery, a Hydraulic Barrier, and Institutional Controls and Long-Term Groundwater Monitoring	years	Present Worth ($)	Cost ($) at Year Indicated Year: 1	2	3	4	5	6	7	8	9	10	11
LNAPL Recovery													
Monthly Site Work	6	$56,000	$11,025	$11,025	$11,025	$11,025	$11,025	$11,025	$0	$0	$0	$0	$0
Subtotal Present Worth ($)		$56,000											
Hydraulic Barrier System Design, Installation, and Operation													
Develop Work Plan	1	$3,500	$3,627	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Install Test Wells, Conduct Pilot Stud	1	$7,000	$7,350	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design System	1	$8,600	$9,039	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Prepare Bid Package	1	$2,300	$2,447	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Install System	1	$82,600	$86,698	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Project Management	30	$10,000	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650
Operational Costs	30	$332,200	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609
Subtotal Present Worth ($)		$446,200											
Maintain Institutional Controls	30	$76,900	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Long-term Monitoring													
Install New LTM/Sentry Wells	1	$16,200	$17,055	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Sampling	30	$56,900	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704
Annual Reporting	30	$60,100	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910
Project Management	30	$15,000	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975
Subtotal Present Worth ($)		$225,100											

Total Present Worth Cost ($): $727,300

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 2

Cost ($) at Year Indicated																		
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650	$650
$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609	$21,609
$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704
$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910
$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 3

Present Worth Analysis Annual Discount Factor = 5%

Alternative 3: Intrinsic Remediation with Bioslurping and Bioventing in the Source Area, Oil/Water Separation, Off-gas Treatment, and Institutional Controls with Long-Term Groundwater Monitoring	years	Present Worth ($)	Cost ($) at Year Indicated Year: 1	2	3	4	5	6	7	8	9	10	11
Bioslurping, Bioventing System Design, Installation, and Operation													
Develop Work Plan	1	$4,300	$4,482	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Install Test Wells, Conduct Pilot Stud	1	$12,100	$12,670	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design System	1	$9,300	$9,809	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Prepare Bid Package	1	$1,800	$1,840	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Install System	1	$171,800	$180,404	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Project Management	8	$21,000	$3,250	$3,250	$3,250	$3,250	$3,250	$3,250	$3,250	$3,250	$0	$0	$0
Operational/Reporting Costs	8	$142,300	$22,019	$22,019	$22,019	$22,019	$22,019	$22,019	$22,019	$22,019	$0	$0	$0
		$362,600											
Maintain Institutional Controls	24	$69,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Long-term Monitoring													
Install New LTM/POC Wells	1	$16,200	$17,055	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Sampling	24	$51,100	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704
Annual Reporting	24	$54,000	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910
Project Management	24	$13,500	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975
Subtotal Present Worth ($)		$203,800											

Total Present Worth Cost ($): $566,400

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 3

Cost ($) at Year Indicated																		
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$0	$0	$0	$0	$0	$0
$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$0	$0	$0	$0	$0	$0
$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$0	$0	$0	$0	$0	$0

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 4

Present Worth Analysis Annual Discount Factor = 5%

Alternative 4: Continued Mobile LNAPL Removal, Pump and Treat Groundwater, and Institutional Controls with LTM	years	Present Worth ($)	Cost ($) at Year Indicated Year: 1	2	3	4	5	6	7	8	9	10	11
LNAPL Recovery													
LNAPL Recovery System Installation	1	$103,700	$108,867	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Monthly Site Work	6	$74,700	$14,722	$14,722	$14,722	$14,722	$14,722	$14,722	$0	$0	$0	$0	$0
Annual Reporting	6	$8,300	$1,637	$1,637	$1,637	$1,637	$1,637	$1,637	$0	$0	$0	$0	$0
Subtotal Present Worth ($)		$186,700											
Vapor Extraction/Bioventing/Biosparging System Design, Installation, and Operation													
Develop Work Plan	1	$4,300	$4,482	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Install Test Wells, Conduct Pump Test	1	$13,100	$13,790	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design System	1	$9,300	$9,809	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Prepare Bid Package	1	$1,800	$1,840	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Install System	1	$200,500	$210,508	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Project Management	6	$16,500	$3,250	$3,250	$3,250	$3,250	$3,250	$3,250	$0	$0	$0	$0	$0
Operational/Reporting Costs	6	$116,700	$22,993	$22,993	$22,993	$22,993	$22,993	$22,993	$0	$0	$0	$0	$0
		$362,200											
Maintain Institutional Controls	24	$69,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Long-term Monitoring													
Install New LTM/POC Wells	1	$16,200	$17,055	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual Sampling	24	$51,100	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704
Annual Reporting	24	$54,000	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910
Project Management	24	$13,500	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975
Subtotal Present Worth ($)		$203,800											
Total Present Worth Cost ($):		$752,700											

APPENDIX G

PRESENT WORTH ANALYSIS
SITE SS27/XYZ INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

ALTERNATIVE 4

Cost ($) at Year Indicated																		
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5	00	$0	$0	$0	$0	$0	$0
$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$3,704	$0	$0	$0	$0	$0	$0
$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$3,910	$0	$0	$0	$0	$0	$0
$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$975	$0	$0	$0	$0	$0	$0

Alternatives 1, 2, 3, and 4: Long-Term Monitoring and Institutional Controls

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	*Install New* LTM/POC Wells ($)	Task 2 (hrs)	Annual Sampling ($)	Task 3 (hrs)	Annual Reporting and PM ($)
Word Processor 88/(15)	$30	0	$0	0	$0	6	$180
CADD Operator 58/(25)	$47	0	$0	0	$0	10	$470
Technician 42/(50)	$40	5	$200	12	$480	5	$200
Staff Level 16/(65)	$57	50	$2,850	12	$684	30	$1,710
Project Level 12/(70)	$65	2	$130	4	$260	15	$975
Senior Level 10/(80)	$85	1	$85	0	$0	2	$170
Principal 02/(85)	$97	0	$0	0	$0	0	$0
Total Labor (hrs|$)		58	$3,265	28	$1,424	68	$3,705
ODCs							
Phone			$10		$0		$40
Photocopy			$10		$0		$40
Mail			$20		$50		$50
Computer			$0		$0		$400
CAD			$0		$0		$450
WP			$0		$0		$200
Travel			$540		$180		$0
Eqpt. & Supplies			$300		$100		$0
Total ODCs			$880		$330		$1,180
Outside Services							
LTM/POC Well Installation Costs(1 LTM, 6 POC)			$12,525		$0		$0
Laboratory Fees (BTEX/TVH), $150ea, 1 sets/yr	soil		$385	5 LTM, 6 POC, 2qa/	$1,950		$0
Other: Maintain Institutional Controls			$0		$0		$5,000
Total Outside Services			$12,910		$1,950		$5,000

Proposal Estimate	Task 1	Task 2	Task 3
Labor	$3,265	$1,424	$3,705
ODC's	$880	$330	$1,180
Outside Services	$12,910	$1,950	$5,000
Total by Task	$17,055	$3,704	$9,885

Total Labor	$8,394
Total ODCs	$2,390
Total Outside Services	$19,860
Total Project	$30,644

Task 1: Install New LTM/POC Wells
Task 2: Semiannual Sampling
Task 3: Semiannual Reporting and PM

Alternatives 1 and 2: LNAPL Recovery

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Monthly Site Work ($)
Word Processor 88/(15)	$30	0	$0
CADD Operator 58/(25)	$47	0	$0
Technician 42/(50)	$40	144	$5,760
Staff Level 16/(65)	$57	0	$0
Project Level 12/(70)	$65	12	$780
Senior Level 10/(80)	$85	0	$0
Principal 02/(85)	$97	0	$0
Total Labor (hrs | $)		156	$6,540
ODCs			
Phone			$60
Photocopy			$0
Mail			$0
Computer			$0
CAD			$0
WP			$0
Travel			$600
Eqpt. & Supplies			$500
Total ODCs			$1,160
Outside Services			
Well Installation			$0
Recovery System Installation			$0
Equipment Costs			$0
Product Hauling/Disposal			$3,125
Electrical Costs			$200
Laboratory Fees			$0
Other			$0
Total Outside Services			$3,325

Proposal Estimate	Task 2
Labor	$6,540
ODC's	$1,160
Outside Services	$3,325
Total by Task	$11,025

Task 1: Monthly Site Time and Travel Costs (per year)

Alternative 2: Hydraulic Barrier System Design and Installation

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1	Work Plan ($)	Task 2	Pump Tests ($)	Task 3	Design ($)	Task 4	Bid ($)	Task 5	Installation ($)	Task 6	Annual Operation and Reporting ($)
Word Processor 88/(15)	$30	20	$600	0	$0	10	$300	15	$450	5	$150	10	$300
CADD Operator 58/(25)	$47	10	$470	0	$0	20	$940	0	$0	0	$0	8	$376
Technician 42/(50)	$40	0	$0	30	$1,200	0	$0	0	$0	0	$0	120	$4,800
Staff Level 16/(65)	$57	25	$1,425	0	$0	60	$3,420	20	$1,140	56	$3,192	30	$1,710
Project Level 12/(70)	$65	6	$390	40	$2,600	40	$2,600	0	$0	10	$650	10	$650
Senior Level 10/(80)	$85	0	$0	4	$340	5	$425	4	$340	2	$170	2	$170
Principal 02/(85)	$97	1	$97	0	$0	2	$194	1	$97	0	$0	2	$194
Total Labor (hrs)($)		62	$2,982	74	$4,140	137	$7,879	40	$2,027	73	$4,162	182	$8,200
ODCs													
Phone			$20		$20		$30		$20		$40		$80
Photocopy			$30		$0		$100		$100		$0		$100
Mail			$45		$0		$30		$0		$0		$75
Computer			$200		$0		$500		$200		$0		$400
CAD			$150		$0		$300		$0		$0		$450
WP			$200		$0		$200		$100		$0		$300
Travel			$0		$540		$0		$0		$630		$600
Eqpt. & Supplies			$0		$1,000		$0		$0		$200		$300
Total ODCs			$645		$1,560		$1,160		$420		$870		$2,285
Outside Services													
Well Installation Costs			$0		$0		$0		$0		$15,875		$0
Equipment Costs			$0		$0		$0		$0		$28,550		$0
Electrical Costs			$0		$0		$0		$0		$0		$4,574
Carbon Regeneration			$0		$0		$0		$0		$0		$4,500
Laboratory Fees			$0		$150		$0		$0		$1,350		$2,700
Construction Costs			$0		$1,500		$0		$0		$35,891		$0
Total Outside Services			$0		$1,650		$0		$0		$81,666		$11,774

Proposal Estimate	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Labor	$2,982	$4,140	$7,879	$2,027	$4,162	$8,200
ODC's	$645	$1,560	$1,160	$420	$870	$2,285
Outside Services	$0	$1,650	$0	$0	$81,666	$11,774
Total by Task	$3,627	$7,350	$9,039	$2,447	$86,698	$22,259

Total Labor	$29,390
Total ODCs	$6,940
Total Outside Services	$95,091
Total Project	$131,421

Task 1: Work Plan Development
Task 2: Vapor Extraction/Bioventing/Air Sparging Pilot Study
Task 3: Design
Task 4: Prepare and Solicit Bids
Task 5: System Installation
Task 6: System Operation, Maintenance, Semiannual Monitoring, and Project Management

Alternative 3: Bioslurping and Bioventing System Design and Installation

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1	Work Plan ($)	Task 2	Pilot Study ($)	Task 3	Design ($)	Task 4	Bid ($)	Task 5	Installation ($)	Task 6	Annual Operation Report ($)
Word Processor 88/(15)	30	20	$600	0	$0	20	$600	5	$150	5	$150	30	$900
CADD Operator 58/(25)	47	10	$470	0	$0	30	$1,410	0	$0	0	$0	10	$470
Technician 42/(50)	40	0	$0	40	$1,600	0	$0	0	$0	0	$0	48	$1,920
Staff Level 16/(65)	57	40	$2,280	0	$0	60	$3,420	20	$1,140	96	$5,472	60	$3,420
Project Level 12/(70)	65	6	$390	60	$3,900	40	$2,600	2	$130	40	$2,600	50	$3,250
Senior Level 10/(80)	85	0	$0	4	$340	5	$425	0	$0	4	$340	4	$340
Principal 02/(85)	97	1	$97	0	$0	2	$194	0	$0	2	$194	2	$194
Total Labor (hrs/$)		77	$3,837	104	$5,840	157	$8,649	27	$1,420	147	$8,756	204	$10,494
ODCs													
Phone			$20		$20		$30		$20		$40		$60
Photocopy			$30		$0		$100		$100		$0		$100
Mail			$45		$0		$30		$0		$0		$75
Computer			$200		$0		$500		$200		$0		$400
CAD			$150		$0		$300		$0		$0		$450
WP			$200		$0		$200		$100		$0		$300
Travel			$0		$900		$0		$0		$1,440		$540
Eqpt. & Supplies			$0		$2,000		$0		$0		$200		$300
Total ODCs			$645		$2,920		$1,160		$420		$1,680		$2,225
Outside Services													
Well Installation			$0		$3,210		$0		$0		$20,865		$0
Electrical Costs			$0		$0		$0		$0		$0		$1,300
LNAPL Recovery Costs			$0		$0		$0		$0		$0		$6,250
Laboratory Fees			$0		$700		$0		$0		$1,250		$5,000
Equipment Costs			$0		$0		$0		$0		$96,000		$0
Construction Costs			$0		$0		$0		$0		$51,853		$0
Total Outside Services			$0		$3,910		$0		$0		$169,968		$12,550

Proposal Estimate	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Labor	$3,837	$5,840	$8,649	$1,420	$8,756	$10,494
ODC's	$645	$2,920	$1,160	$420	$1,680	$2,225
Outside Services	$0	$3,910	$0	$0	$169,968	$12,550
Total by Task	$4,482	$12,670	$9,809	$1,840	$180,404	$25,269

Total Labor	$38,996
Total ODCs	$9,050
Total Outside Services	$186,428
Total Project	$234,474

Task 1: Work Plan Development
Task 2: Bioventing Pilot Study
Task 3: Design
Task 4: Prepare and Solicit Bids
Task 5: System Installation
Task 6: System Operation, Maintenance, Semiannual Monitoring, and Project Management

Alternative 4: Vapor Extraction/Bioventing/Biosparging System Design and Installation

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1	Work Plan ($)	Task 2	Pilot Studies ($)	Task 3	Design ($)	Task 4	Bid ($)	Task 5	Installation ($)	Task 6	Operation and 2 Reports Annual ($)
Word Processor 88/(15)	$30	20	$600	0	$0	20	$600	5	$150	5	$150	30	$900
CADD Operator 58/(25)	$47	10	$470	0	$0	30	$1,410	0	$0	0	$0	30	$1,410
Technician 42/(50)	$40	0	$0	40	$1,600	0	$0	0	$0	0	$0	48	$1,920
Staff Level 16/(65)	$57	40	$2,280	0	$0	60	$3,420	20	$1,140	144	$8,208	60	$3,420
Project Level 12/(70)	$65	6	$390	60	$3,900	40	$2,600	2	$130	40	$2,600	50	$3,250
Senior Level 10/(80)	$85	0	$0	4	$340	5	$425	0	$0	4	$340	8	$680
Principal 02/(85)	$97	1	$97	0	$0	2	$194	0	$0	2	$194	4	$388
Total Labor (hrs)($)		77	$3,837	104	$5,840	157	$8,649	27	$1,420	195	$11,492	230	$11,968
ODCs													
Phone			$20		$20		$30		$20		$40		$60
Photocopy			$30		$0		$100		$100		$0		$100
Mail			$45		$0		$30		$0		$0		$75
Computer			$200		$0		$500		$200		$0		$400
CAD			$150		$0		$300		$0		$0		$450
WP			$200		$0		$200		$100		$0		$300
Travel			$0		$1,440		$0		$0		$2,070		$540
Eqpt. & Supplies			$0		$2,000		$0		$0		$200		$300
Total ODCs			$645		$3,460		$1,160		$420		$2,310		$2,225
Outside Services													
Well Installation			$0		$3,390		$0		$0		$22,035		$0
Electrical Costs			$0		$0		$0		$0		$0		$4,550
Natural Gas Costs			$0		$0		$0		$0		$0		$2,500
Laboratory Fees			$0		$1,100		$0		$0		$1,250		$5,000
Equipment Costs			$0		$0		$0		$0		$110,000		$0
Construction Costs			$0		$0		$0		$0		$63,421		$0
Total Outside Services			$0		$4,490		$0		$0		$196,706		$12,050

Proposal Estimate	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Labor	$3,837	$5,840	$8,649	$1,420	$11,492	$11,968
ODC's	$645	$3,460	$1,160	$420	$2,310	$2,225
Outside Services	$0	$4,490	$0	$0	$196,706	$12,050
Total by Task	$4,482	$13,790	$9,809	$1,840	$210,508	$26,243

Total Labor	$43,206
Total ODCs	$10,220
Total Outside Services	$213,246
Total Project	$266,672

Task 1: Work Plan Development
Task 2: Vapor Extraction/Bioventing/Air Sparging Pilot Study
Task 3: Design
Task 4: Prepare and Solicit Bids
Task 5: System Installation
Task 6: System Operation, Maintenance, Semiannual Monitoring, and Project Management

Alternative 4: LNAPL Recovery

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Design & Install Recovery System ($)	Task 2 (hrs)	Monthly Site Work ($)	Task 3 (hrs)	Annual Reporting ($)
Word Processor 88/(15)	$30	4	$120	0	$0	4	$120
CADD Operator 58/(25)	$47	20	$940	0	$0	4	$188
Technician 42/(50)	$40	0	$0	144	$5,760	0	$0
Staff Level 16/(65)	$57	40	$2,280	0	$0	16	$912
Project Level 12/(70)	$65	20	$1,300	12	$780	2	$130
Senior Level 10/(80)	$85	2	$170	0	$0	0	$0
Principal 02/(85)	$97	1	$97	0	$0	1	$97
Total Labor (hrs|$)		87	$4,907	156	$6,540	27	$1,447
ODCs							
Phone			$60		$60		$10
Photocopy			$20		$0		$20
Mail			$20		$0		$20
Computer			$50		$0		$40
CAD			$120		$0		$60
WP			$20		$0		$40
Travel			$0		$600		$0
Eqpt. & Supplies			$0		$500		$0
Total ODCs			$290		$1,160		$190
Outside Services							
Well Installation			$8,050		$0		$0
Recovery System Installation			$78,895		$0		$0
Equipment Costs			$16,725		$0		$0
Product Hauling/Disposal			$0		$6,250		$0
Electrical Costs			$0		$572		$0
Laboratory Fees			$0		$200		$0
Other			$0		$0		$0
Total Outside Services			$103,670		$7,022		$0

Proposal Estimate	Task 1	Task 2	Task 3
Labor	$4,907	$6,540	$1,447
ODC's	$290	$1,160	$190
Outside Services	$103,670	$7,022	$0
Total by Task	$108,867	$14,722	$1,637

Total Labor	$12,894
Total ODCs	$1,640
Total Outside Services	$110,692
Total Project	$125,226

Task 1: LNAPL Recovery System Design and Construction
Task 2: Monthly Site Time and Travel Costs (per year)
Task 3: Report Preparation and Product Disposal

Dover AFB Backup Calculations

Alternatives 1, 2, 3, and 4: Long-term Monitoring

Misc calculations

Number of LTM wells:		
Number of wells:	7	
Depth each:	35	ft

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Well Installation					$ 12,525	
Mobilization	ea	1	$ 1,000	$ 1,000		
Well Installation	ln ft	245	$ 45	$11,025		
Soil Disposal	drum	5	$ 100	$ 500		

Alternatives 1 and 2: LNAPL Recovery and Disposal

Misc calculations

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Product Disposal	gallon	2,500	$ 1.25	$ 3,125	$ 3,125	

Alternatives 3 and 4: LNAPL Recovery and Disposal

Misc calculations

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Product Disposal	gallon	5,000	$ 1.25	$ 6,250	$ 6,250	

Dover AFB Backup Calculations

Alternatives 4: LNAPL Recovery System

Misc calculations

Number of LNAPL recovery wells:		
Number of wells:	10	
Depth each:	15	ft
Trench Volume/Area		
Width:	12	in
Depth:	3	ft
Length:	1,000	ft
Volume:	3,000	cf
	111	cy
Surface Area:	1,000	sf
	111	sy
Concrete Volume/Area		
Length:	1,000	lf
Width:	14	in
Thickness:	12	in
Volume:	1167	cf
	43	cy
Area:	1,167	sf
	130	sy

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Well Installation					$ 8,050	
Mobilization	ea	1	$ 1,000	$ 1,000		
Well Installation	ln ft	150	$ 45	$ 6,750		
Soil Disposal	drum	3	$ 100	$ 300		
Equipment Costs					$ 16,725	
Skimmers	ea	10	$ 500	$ 5,000		
Compressors	ea	2	$ 3,000	$ 6,000		Similar Projects
Storage Tank	ea	1	$ 5,725	$ 5,725		Means 132 151 5540
System Installation					$ 78,895	
Mob/Demob	ea	1	$ 1,000	$ 1,000		
Concrete Cutting	ln ft	2,000	$ 18.80	$37,600		Means 020 728 0420
Trenching	cy	111	$ 5.05	$ 561		Means 022 254 0050
Pipe laying	ln ft	1,200	$ 13.05	$15,660		Means 151 701 0550/026 686 2800
Backfill	cy	111	$ 17.20	$ 1,909		Means 022 204 0600
Compaction	cy	111	$ 5.10	$ 566		Means 022 204 0600
Pavement Base	sy	111	$ 5.25	$ 583		Means 022 308 0100
Concrete repair	cy	43	$ 97.00	$ 4,171		Means 033 130 4700
Reseeding	sy	20	$ 1.91	$ 38		Means 029 304 0310
Piping	lf	250	$ 9.30	$ 2,325		Means 151 551 1880
Mechanical	man hr	80	$ 38.83	$ 3,106		Means Q-1 crew
Electrical	ls	1	$ 2,500	$ 2,500		
Slab	cy	2	$ 97.00	$ 194		Means 033 130 4700
Building	ea	1	$ 4,925	$ 4,925		Means 131 221 0010
Contingency	%	5%	$75,138	$ 3,757		

Dover AFB Backup Calculations

Alternative 2: Hydraulic Barrier

Misc calculations

Groundwater wells (6 RWs and 3 Sentry Wells)		
Number:	9	
Depth:	35	ft
Trench Volume/Area		
Width:	12	in
Depth:	4	ft
Length:	1,000	ft
Volume:	4,000	cf
	148	cy
Surface Area:	1,000	sf
	111	sy

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Well Installation					$ 15,875	
Mobilization	ea	1	$ 1,000	$ 1,000		
Well Installation	ln ft	315	$ 45	$14,175		
Soil Disposal	drum	7	$ 100	$ 700		
Equipment					$ 28,550	
Pumps	ea	9	$ 700	$ 6,300		Means 026 704 1600
Air Stripper	ea	1	$20,000	$20,000		Similar Projects
Vapor Phase Carbon Units	ea	3	$ 750	$ 2,250		Similar Projects
Trenching/Piping Installation					$ 35,891	
Mob/Demob	ea	1	$ 1,000	$ 1,000		
Trenching	cy	148	$ 5.05	$ 747		Means 022 254 0050
Pipe laying	ln ft	1,200	$ 13.05	$15,660		Means 026 686 2800
Backfill	cy	148	$ 17.20	$ 2,546		Means 022 204 0600
Compaction	cy	148	$ 5.10	$ 755		Means 022 204 0600
Reseeding	sy	222	$ 1.91	$ 424		Means 029 304 0310
Piping	lf	250	$ 9.30	$ 2,325		Means 151 551 1880
Mechanical	man hr	80	$ 38.83	$ 3,106		Means Q-1 crew
Electrical	ls	1	$ 2,500	$ 2,500		
Slab	cy	2	$ 97.00	$ 194		Means 033 130 4700
Building	ea	1	$ 4,925	$ 4,925		Means 131 221 0010
Contingency	%	0	$34,182	$ 1,709		

Dover AFB Backup Calculations

Alternative 3: Bioslurping/Bioventing System

Misc calculations

Wells/Monitoring Points		
Number of Wells:	15	
Number of MPs:	8	
Depth:	25	ft
Trench Volume/Area		
Width:	12	in
Depth:	2	ft
Length:	1,000	ft
Volume:	2,000	cf
	74	cy
Surface Area:	1,000	sf
	111	sy
Concrete Volume/Area		
Length:	750	lf
Width:	14	in
Thickness:	10	in
Volume:	729	cf
	27	cy
Area:	875	sf
	97	sy

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Well Installation					$ 24,075	
Mobilization	ea	1	$ 1,000	$ 1,000		
Well Installation	ln ft	375	$ 45	$16,875		
MP Installation	ln ft	200	$ 25	$ 5,000		
Soil Disposal	drum	12	$ 100	$ 1,200		
Equipment Costs					$ 96,000	
Bioventing Blower	ea	1	$ 5,000	$ 5,000		
Bioslurping Blower	ea	1	$ 8,000	$ 8,000		
Oil/Water Separator	ea	1	$ 8,000	$ 8,000		
Internal Combustion Engine for Emission Control	ea	1	$60,000	$60,000		
Air Stripper	ea	1	$15,000	$15,000		
System Installation					$ 51,853	
Mob/Demob	ea	1	$ 1,000	$ 1,000		
Concrete Cutting	ln ft	1,000	$ 18.80	$18,800		Means 020 728 0420
Trenching	cy	111	$ 5.05	$ 561		Means 022 254 0050
Pipe laying	ln ft	1,200	$ 13.05	$15,660		Means 151 701 0550/026 686 2800
Backfill	cy	111	$ 17.20	$ 1,909		Means 022 204 0600
Compaction	cy	111	$ 5.10	$ 566		Means 022 204 0600
Pavement Base	sy	111	$ 5.25	$ 583		Means 022 308 0100
Concrete repair	cy	27	$ 97.00	$ 2,619		Means 033 130 4700
Reseeding	sy	28	$ 1.91	$ 53		Means 029 304 0310
Piping	lf	100	$ 9.30	$ 930		Means 151 551 1880
Mechanical	man hr	40	$ 38.83	$ 1,553		Means Q-1 crew
Electrical	ls	1	$ 2,500	$ 2,500		
Slab	cy	2	$ 97.00	$ 194		Means 033 130 4700
Building	ea	1	$ 4,925	$ 4,925		Means 131 221 0010

Dover AFB Backup Calculations

Alternative 4: Vapor Extraction (Internal Combustion Engine)/Bioventing/Biosparging

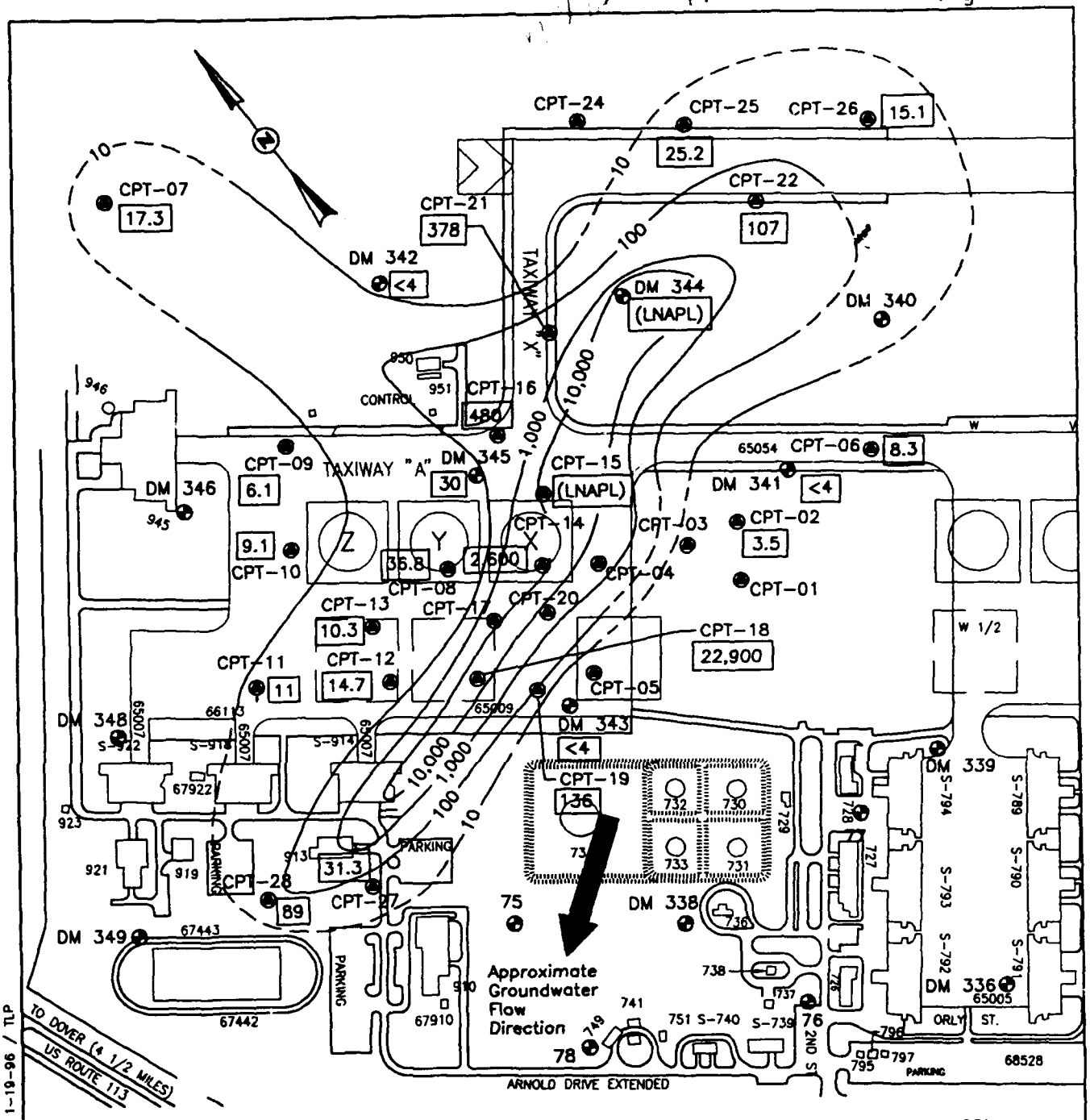
Misc calculations

Wells/Monitoring Points		
Number of Wells:	15	
Number of MPs:	10	
Depth:	25	ft
Trench Volume/Area		
Width:	12	in
Depth:	2	ft
Length:	1500	ft
Volume:	3000	cf
	111	cy
Surface Area:	1500	sf
	167	sy
Concrete Volume/Area		
Length:	1000	lf
Width:	14	in
Thickness:	10	in
Volume:	972	cf
	36	cy
Area:	1167	sf
	130	sy

Cost calculations

Description	Unit	Quantity	Unit Pric	Subtotal	Total	Source (If applicable)
Well Installation					$ 25,425	
Mobilization	ea	1	$ 1,000	$ 1,000		
Well Installation	ln ft	375	$ 45	$16,875		
MP Installation	ln ft	250	$ 25	$ 6,250		
Soil Disposal	drum	13	$ 100	$ 1,300		
Equipment Costs					$ 110,000	
Blowers	ea	2	$ 5,000	$10,000		
Internal Combustion Engine	ea	1	######	######		
System Installation					$ 63,421	
Mob/Demob	ea	1	$ 1,000	$ 1,000		
Concrete Cutting	ln ft	1,000	$ 18.80	$18,800		Means 020 728 0420
Trenching	cy	111	$ 5.05	$ 561		Means 022 254 0050
Pipe laying	ln ft	1,800	$ 13.05	$23,490		Means 151 701 0550/026 686 2800
Backfill	cy	111	$ 17.20	$ 1,909		Means 022 204 0600
Compaction	cy	111	$ 5.10	$ 566		Means 022 204 0600
Pavement Base	sy	167	$ 5.25	$ 877		Means 022 308 0100
Concrete repair	cy	36	$ 97.00	$ 3,492		Means 033 130 4700
Reseeding	sy	74	$ 1.91	$ 141		Means 029 304 0310
Piping	lf	200	$ 9.30	$ 1,860		Means 151 551 1880
Mechanical	man hr	80	$ 38.83	$ 3,106		Means Q-1 crew
Electrical	ls	1	$ 2,500	$ 2,500		
Slab	cy	2	$ 97.00	$ 194		Means 033 130 4700
Building	ea	1	$ 4,925	$ 4,925		Means 131 221 0010

Figure 4.3



LEGEND

DM 341	Monitoring well.
CPT-01	Monitoring point and CPT test location installed by CPT rig.
89	Total benzene, toluene, ethylbenzene and xylenes (BTEX) concentration (µg/L).
—10—	Total BTEX concentration (µg/L) contour, dashed where inferred.
(LNAPL)	LNAPL emulsified in sample.
	Former C-10 fueling pad.

400' 200' 0 400'

Approximate Scale in Feet

Total Dissolved BTEX Isopleth Map
April 1994

Site SS27/XYZ
Intrinsic Remediation EE/CA
Dover AFB, Delaware

722450G0.dwg + 722450X1.dwg / ps:1=1 / 1-19-96 / TLP

PARSONS ENGINEERING SCIENCE, INC.

TABLE 3.1

WATER LEVEL ELEVATION DATA FROM MONITORING POINTS
APRIL 21, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Measurement Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Total Depth (ft bls)[d]	LNAPL Observed (Y/N)	Water Depth (ft)	Water Level Elevation (ft msl)
Monitoring Points							
CPT-01S	413590	480024	26.48	17.00	N	9.22	17.26
CPT-02S	413721	480113	25.51	13.00	N	7.18	18.33
CPT-03S	413754	479968	25.64	13.00	N	8.04	17.60
CPT-04S	413863	479748	26.31	17.00	N	8.50	17.81
CPT-05S	NM[e]	NM	NA[f]	NA	N	NM	NA
CPT-06S	413657	480522	24.10	16.60	N	6.60	17.50
CPT-07S	413476	479293	25.85	15.00	N	6.92	18.93
CPT-07D	413475	479294	25.83	28.20	N	7.02	18.81
CPT-08P	NM	NM	NA	12.10	N	DRY	NA
CPT-08S	414102	479416	26.18	16.6	N	8.42	17.76
CPT-08D	NM	NM	NM	27.30	N	8.52	NA
CPT-09S	414644	479271	23.98	18.60	N	6.04	17.94
CPT-10S	414410	479107	NM	18.60	N	7.85	NM
CPT-11P	NM	NM	NM	13.00	N	6.15	NM
CPT-11S	NM	NM	NM	18.80	N	8.70	NM
CPT-12P	NM	NM	NA	5.10	N	DRY	NA
CPT-12S	413955	479095	26.24	17.80	N	8.76	17.48
CPT-12D	413955	479103	26.23	23.40	N	8.83	17.40
CPT-13S	414106	479154	27.03	17.30	N	9.18	17.85
CPT-14S	413951	479626	NM	17.60	N	NM	NM
CPT-15S	414104	479746	25.44	17.90	Y[g]	8.45	16.99
CPT-16S	414307	479748	NM	13.40	N	5.65	NM
CPT-16D	414307	479748	NM	24.10	N	6.06	NM
CPT-17S	413912	479430	26.98	18.80	N	9.35	17.63
CPT-18S	413813	479294	26.11	18.70	Y[g]	12.10	14.01
CPT-19P	413733	479484	NA	10.10	N	NA	NA
CPT-19S	413733	479484	NM	15.90	N	8.96	NM
CPT-19D	413733	479484	NM	26.00	N	8.85	NM
CPT-20S	413842	479557	26.74	15.40	N	9.13	17.61
CPT-21S	414447	480032	24.42	14.90	N	4.36	20.06
CPT-22S	414388	480694	25.92	17.90	N	6.31	19.61
CPT-22D	414388	480694	NM	30.40	N	9.33	NM
CPT-23S	NM	NM	NA	NA	N	NA	NA
CPT-24S	NM	NM	NA	15.60	N	DRY	NA
CPT-25S	414674	480669	26.59	20.90	N	9.00	17.59
CPT-26S	414382	481072	24.88	23.20	N	9.16	15.72
CPT-27S	413518	478754	26.04	17.40	N	9.83	16.21
CPT-27D	413518	478754	NA	28.40	N	NA	NA
CPT-28S	413685	478465	27.47	20.40	N	11.08	16.39
CPT-29S	NM	NM	NM	16.30	N	NM	NM

[a] See Figure 3.1 for measurement locations.
[b] Datum is top of casing.
[c] ft msl = feet above mean sea level.
[d] ft bls = feet below land surface.
[e] NM = Not measured.
[f] NA = Not available.
[g] Emulsification was observed in monitoring point during sampling.

TABLE 3.2

WATER LEVEL ELEVATION DATA FROM MONITORING WELLS
APRIL 19, 1994
SITE SS27/XYZ
INTRINSIC REMEDIATION EE/CA
DOVER AFB, DELAWARE

Measurement Location[a]	Northing (ft)	Easting (ft)	Datum Elevation[b] (ft msl)[c]	Ground Elevation (ft msl)	Total Depth[d] (ft)	Product Thickness Observed on April 19, 1994 (ft)	Water Depth[e] (ft)	Water Level Elevation (ft msl)
Monitoring Wells								
75S	413225	478969	27.18	25.43	27.66	0.00	10.27	16.91
75D	413236	478978	27.10	25.36	35.86	0.00	10.41	16.69
76S	412555	479452	30.90	28.76	29.60	0.00	14.58	16.32
76D	412549	479447	30.88	28.68	37.42	0.00	14.56	16.32
77S	412880	479886	23.97	24.68	18.23	0.00	NM[f]	NM
77D	412889	479894	23.49	24.02	22.64	0.00	NM	NM
78S	412821	478908	29.66	28.18	30.68	0.00	13.22	16.44
78D	412827	478900	29.95	28.40	37.71	0.00	13.52	16.43
DM 204S	415508	480856	24.91	22.24	16.00	0.00	6.87	18.04
DM 204D	415504	480861	24.76	22.28	34.00	0.00	6.73	18.03
DM 336S	412263	479909	24.37	24.61	16.00	0.00	7.93	16.44
DM 336D	412262	479912	24.38	24.66	36.00	0.00	8.53	15.85
DM 338S	412932	479324	28.68	26.24	20.00	0.00	NM	NM
DM 338D	412935	479321	28.83	26.17	39.00	0.00	NM	NM
DM 339S	412894	480158	24.81	25.13	14.50	0.00	NM	NM
DM 339D	412891	480157	24.74	25.13	28.00	0.00	NM	NM
DM 340S	413925	480765	22.16	22.29	18.50	0.00	4.79	17.37
DM 341S	413750	480309	25.42	26.06	19.00	0.00	NM	NM
DM 341D	413755	480303	25.60	26.05	28.00	0.00	NM	NM
DM 342S	414840	479750	24.94	25.19	19.00	0.00	4.61	20.33
DM 342D	414838	479748	25.09	25.02	28.00	0.00	4.72	20.37
DM 343S	413597	479448	26.62	26.93	18.00	0.00	8.65	17.97
DM 343D	413603	479439	26.62	26.93	30.00	0.00	8.60	18.02
DM 344S	414415	480259	23.44	23.36	18.00	2.70 (6.88[g])	9.67	13.77
DM 344D	414408	480263	23.49	23.37	30.00		4.36	19.13
DM 345S	414255	479634	25.60	26.03	19.00	0.00	6.32	19.28
DM 346S	414670	478942	29.62	26.82	22.00	0.00	10.34	19.28
DM 346D	414674	478945	29.56	26.84	45.00	0.00	10.28	19.28
DM 347S	NA[h]	NA	NA	NA	NA	0.00	9.48	NA
DM 347D	NA	NA	NA	NA	NA	0.00	9.50	NA
DM 348S	414290	478418	29.27	26.15	20.00	0.00	10.02	19.25
DM 348D	414295	478421	29.13	26.09	34.00	0.00	11.26	17.87
DM 349S	413817	478125	32.43	29.72	28.00	0.00	19.75	12.68
DM 349D	413821	478130	32.00	29.40	35.00	0.00	19.34	12.66

[a] See Figure 3.1 for measurement locations.
[b] Datum elevation refers to top of casing.
[c] ft msl = feet above mean sea level.
[d] Total depth of well measured from the top of casing.
[e] Measured from the top of casing.
[f] NM = not measured.
[g] Maximum product thickness observed on April 14, 1994.
[h] NA = not available.