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IRP PHASE II - C/Q STAGE I DOVER AFB VOL. I

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Installation Restoration Program
Phase II — Confirmation/Quantification
Stage 1

Dover Air Force Base
Dover, Delaware 19901

Science Applications International Corporation
8400 Westpark Drive, McLean, VA 22102

June 1986

Final Report 9/84 to 6/86
Volume 1 — Technical Report

Prepared for
Headquarters Military Airlift Command
Command Surgeon's Office, (HQ MAC/SGPB)
Bioenvironmental Engineering Division
Scott Air Force Base, IL 62225

United States Air Force
Occupational and Environmental Health Laboratory (USAFOEHL)
Brooks Air Force Base, TX 78235-5501

INSTALLATION RESTORATION PROGRAM
PHASE II - CONFIRMATION/QUANTIFICATION
STAGE 1

FINAL REPORT

FOR

DOVER AIR FORCE BASE
DOVER, DELAWARE 19901

HEADQUARTERS MILITARY AIRLIFT COMMAND
COMMAND SURGEON'S OFFICE (HQ MAC/SGPB)
BIOENVIRONMENTAL ENGINEERING DIVISION
SCOTT AIR FORCE BASE, ILLINOIS 62225

JUNE, 1986

PREPARED BY

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
8400 WESTPARK DRIVE
MCLEAN, VA 22102

USAF CONTRACT NO F33615-80-D-4002 DELIVERY ORDER NO. 56

CONTRACTOR CONTRACT NO. 2-827-06-182 DELIVERY ORDER NO. 56

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Copies of this report may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS N/A
2a SECURITY CLASSIFICATION AUTHORITY N/A	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for Public Release; Distribution is Unlimited
2b DECLASSIFICATION / DOWNGRADING SCHEDULE N/A	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) N/A	5 MONITORING ORGANIZATION REPORT NUMBER(S) N/A
6a NAME OF PERFORMING ORGANIZATION Science Applications International Corporation 6b OFFICE SYMBOL (If applicable) N/A	7a NAME OF MONITORING ORGANIZATION USAFOEHL/TS
6c ADDRESS (City, State, and ZIP Code) 8400 Westpark Drive McLean, VA 22102	7b ADDRESS (City, State, and ZIP Code) Brooks AFB, TX 78235-5501
8a NAME OF FUNDING / SPONSORING ORGANIZATION USAFOEHL/TS 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Contract No. F33615-80-D-4002 Delivery Order No. 56
8c ADDRESS (City, State, and ZIP Code) Brooks AFB, TX 78235-5501	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)

IRP Phase II, Stage 1, Dover AFB, DE

12 PERSONAL AUTHOR(S)
Tokarski, E., J. Bramlett, R. Eades, A. Lapins, and E. Repa

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final	FROM 9/84 TO 6/86	1986, June 10	281

16 SUPPLEMENTARY NOTATION

Volume 1 contains the technical report, Volume 2 contains appendices.

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	IRP, Groundwater, Contaminant Migration

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

See Attached

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL Cpt. Maria R. LaMagna	22b TELEPHONE (Include Area Code) 512-536-2158 / 22c OFFICE SYMBOL USAFOEHL/TS

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete.

ABSTRACT

Twelve sites at Dover Air Force Base (DAFB) were investigated during the Installation Restoration Program (IRP) Phase II Stage 1 Study. These sites included four landfills (D-10, D-4, D-5, D-2), three fire training areas (FT-1, FT-2, FT-3), two fuel spill areas (XYZ, SP-4), one surface impoundment area (T-1), one hazardous waste storage area (S-1), and one drainage ditch (DD-1). Interviews conducted prior to the start of field activities indicated that one fire training site (FT-2) did not have the potential to contaminate the environment because fire training activities probably did not take place at the site, and because the site is now covered by a parking lot.

During Stage 1 field activities, 32 new monitoring wells were installed and 35 monitoring wells, 15 surface water and 26 soil or sediment locations were sampled. Analyses were performed on 187 groundwater samples, 76 surface water samples, 134 soil or sediment samples, and 131 field quality control/ quality assurance samples. Analyses were conducted to determine the concentrations of volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), oil and grease (O&G), phenols, cyanide, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, zinc, total organic carbon (TOC), and total organic halogens (TOX).

The concentrations of VOCs in groundwater at Sites T-1, D-4, D-5, and S-1 exceeded published health criteria. The concentrations of metals in groundwater at Sites T-1, D-10, D-5, FT-3, FT-1, and S-1 exceeded Delaware drinking water standards or published health criteria. The concentrations of metals in surface waters at Sites T-1, DD-1, and FT-3 exceeded standards or health criteria. VOCs were detected in soils or sediments at Sites T-1 and S-1. The concentrations of arsenic and metals at Sites T-1, DD-1, FT-3, S-1, and D-2 exceeded background values reported for Maryland and Delaware coastal plain soils or U.S. averages.

The Stage 1 study did not fully pinpoint contaminant sources or characterize the rate or extent of substance migration from the sites. The

recommended Stage 2 program consists of three steps. Step 1 involves sampling at all sites to confirm and fully characterize the types of compounds present and conducting soil gas analysis to help locate new monitoring wells. Step 2 includes installing 86 new monitoring wells, sampling 130 wells, collecting and analyzing surface water samples at 24 locations, sediment samples at 27 locations, and soil samples at 34 locations, and conducting four aquifer pump tests. Step 3 involves sampling 15 wells at three depths within each well to characterize the vertical distribution of substances in groundwater. The Stage 2 program is estimated to require 24 months.

PREFACE

This report describes activities, results, findings, and recommendations associated with the Installation Restoration Program (IRP) Phase II Stage 1 - Confirmation/Quantification study undertaken at Dover Air Force Base, Delaware by Science Applications International Corporation (SAIC). Groundwater, surface water, soils, and sediment samples were collected and analyzed at eleven sites. The purpose of the investigation was to confirm the absence or presence of contamination at the study sites.

SAIC personnel began work in May 1984. Stage 1 field activities began in October 1984 and were completed in February 1985. Analysis results were available by March 1985. SAIC was responsible for project management and technical performance of the study. Subcontractors provided well installation, surveying, and analysis services. On-base support was provided by the Bioenvironmental Engineering and Civil Engineering Offices.

Edward Tokarski was the SAIC Project Manager. SAIC personnel who participated in field efforts included Richard Eades, Kurt Kruger, Andris Lapins, Chris Manikas, and Ellen Scopino. Senior technical supervision and report review was provided by Dr. Edward Repa, Dr. Zubair Saleem, John Meade, and Dr. Richard Berry. The draft report was prepared by Edward Tokarski, Richard Eades, Andris Lapins, Jennifer Bramlett, Dr. Edward Repa, and Dr. Richard Berry.

This study could not have been conducted without the assistance, guidance, and advice of: Capt. Lindsey Waterhouse, 1Lt. Lee Braithewaite, 1Lt. Michael Ducharme, and Mr. Don Witmer, Dover AFB; Kevin Burdette, Delmarva Drilling Company, and his staff; Claudia Wiegand, SAIC Environmental Chemistry Laboratory, and her staff; Tom Donovan, Donovan Associates, and his staff; and Tom Cullen, ERG, and his staff. Their efforts are very much appreciated. 1Lt. Maria R. Lamagna, Technical Services Division, USAF Occupational and Environmental Health Laboratory (USAFOEHL), was the Technical Monitor.

Approved:

John P. Meade

John P. Meade
Contract Program Manager

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EXECUTIVE SUMMARY

Twelve sites at Dover Air Force Base (DAFB) were investigated during the Installation Restoration Program (IRP) Phase II Stage 1 Study (Figure ES-1). Site FT-2 was not monitored because fire training activities reportedly did not occur at the site. During Stage 1, 32 new monitoring wells were installed. Thirty-five monitoring well, 15 surface water, and 26 soil or sediment locations were sampled. Analyses were performed on 187 groundwater samples, 76 surface water samples, 134 soil or sediment samples, and 131 field quality control/quality assurance samples. Analyses were conducted to determine the concentrations of volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), oil and grease (O&G), phenols, cyanide, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, zinc, total organic carbon (TOC), and total organic halogens (TOX). Tables ES-1, ES-2, and ES-3 summarize the analytical results. Table ES-4 identifies the source for each published health standard and criterion provided on Tables ES-1 and ES-2.

The concentrations of VOCs in groundwater at Sites T-1, D-4, D-5, and S-1 exceeded published health criteria. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. The concentrations of metals in groundwater at Sites T-1, D-10, D-5, FT-3, FT-1, and S-1 exceeded Delaware drinking water standards or published health criteria. The concentrations of metals in surface waters at Sites T-1, DD-1, and FT-3 exceeded standards or health criteria. VOCs were detected in soils or sediments at Sites T-1 and S-1. The concentrations of arsenic and metals at Sites T-1, DD-1, FT-3, S-1, and D-2 exceeded background values reported for Maryland and Delaware coastal plain soils or U.S. averages.

Stage 1 results indicated that Site FT-1 had not affected environmental quality. Sites T-1, DD-1, D-10, D-4, S-1, XYZ, and D-2 were potentially identified as sources of concentrations of contaminants found in the environment. Other unidentified sources appeared to be contributing to contaminant concentrations found around Sites T-1, DD-1, D-10, and S-1. Sources of the

contaminant concentrations found around Sites D-5, FT-3, and SP-4 are not identifiable at this time. Stage 1 findings are summarized in Table ES-5.

The rate and complete extent of substance migration was not determined during Stage 1. Recommendations for additional investigations under Phase II Stage 2 are summarized in Tables ES-6, ES-7, and ES-8.

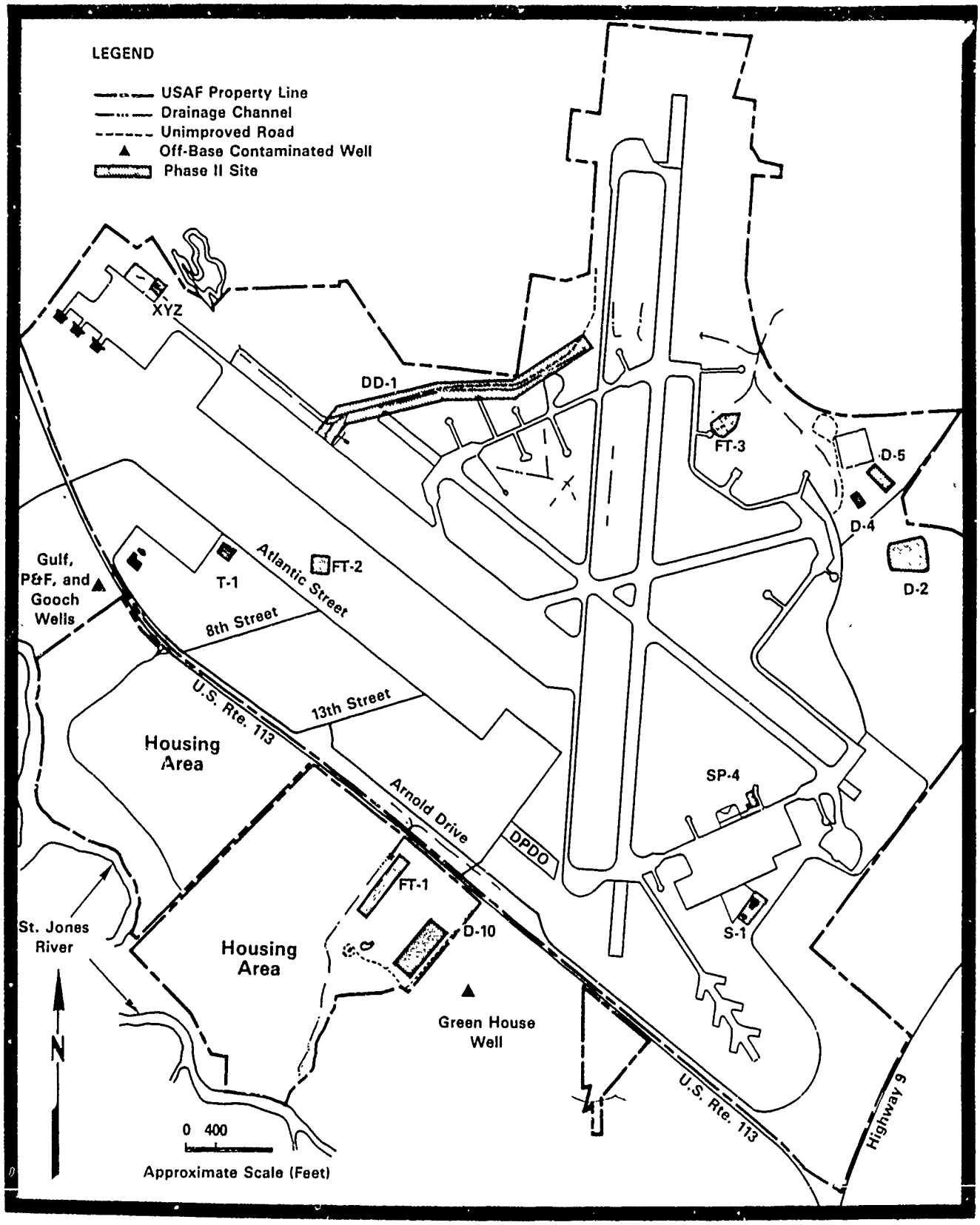


Figure ES-1. Locations of Sites Studied at Dover Air Force Base During Phase II, Stage 1

Table ES-1

CONCENTRATION RANGES FOR STAGE 1 PARAMETERS IN GROUNDWATER SAMPLES, DOVER AFB PHASE II STAGE 1

Stage 1 Parameter	Local or Regional Maximum	USAFOEHL Reporting Limit	Health Standards or Criteria	T-1, IW Basins	D-10, Landfill	D-4, Liquid Waste Site	FT-1, Fire Training Area 1
			(Results in ppb)				
Laboratory[a]							
Dichloroethane, 1,1-				ND-720		ND	
Dichloroethane, 1,2-			0.50	ND-57		ND-62	
Dichloroethylene, 1,1-			0.24	ND-830		ND-0.67	
Dichloroethylene, trans-1,2-			270.0	ND-4400		1.2-700	
Methylene chloride			0.19	ND-450		ND	
Tetrachloroethylene			1.0	0.49-1500		ND-2700	
Trichloroethane, 1,1,1-			21.7	ND-7700		ND	
Trichloroethylene			1.8	0.14-240		ND-2100	
Vinyl chloride			0.15	ND-100[b]		ND-9[b]	
Benzene			0.67	ND-8.0		9.1-83	
Ethylbenzene			1400.0	ND-97		ND-570	
Toluene			14300.0	ND-220		1.7-56	
PCBs			7.9×10^{-5}				
Silver		10	50	ND-L	ND-L	ND-L	ND
Arsenic	20	10	50	ND	ND	ND	ND
Cadmium	3	10	10	L	L	L	L
Chromium	11	50	50	L-460	L-84	L	L
Copper	60	20	1000	L-180	L-53	L-24	L
Iron	30,000	100	300	L-170	L	L	L
Mercury	<10	1	2	L	L	L	L
Nickel		13.4	13.4	L-280	L-53	L	ND-16
Lead	10	20	50	L-230	L-63	L	L
Zinc	210	50	5000	L-470	L-130	ND-L	L
			(Results in ppm)				
Oil and Grease	1	0.1		ND-0.82	ND-0.26	ND-1.3	ND
Cyanide			0.2	ND	ND-0.009	ND-0.008	
Phenols			3.5	ND-6.3	ND	ND-0.011	
TOX	0.02			0.26-7.5	0.065-0.12	0.016-0.093	0.045-0.073
TOC	3.2			2.5-74	2.7-23	2.3-24	1.6-16
Field							
Temperature (°C)				12-28	14-15	8.1-13	12-13
Conductivity (umhos/cm)	290			140-1300	145-380	80-2600	55-450
pH (std. units)	6.8			4.5-6.3	3.8-5.0	5.3-6.0	4.5-5.4

(continued)

NOTE: Blank space under Local or Regional Maximum, USAFOEHL Reporting Limit, and Health Standards or Criteria columns indicates data not available. Blank space under sites indicates analysis not conducted
ppb = ug/l; ppm = mg/l; ND = Not detected, indicates parameter not present above detection limit
L = Detected at level less than USAFOEHL reporting limit. The reporting limits are equal to or less than drinking water standards

[a] The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b] Chromatographs of samples showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-columr gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak may be an interference from the sample matrix

Table ES-1 (Continued)

CONCENTRATION RANGES FOR STAGE 1 PARAMETERS IN GROUNDWATER SAMPLES,
DOVER AFB PHASE II STAGE 1

Stage 1 Parameter	Local or Regional Maximum	USAFOEHL Reporting Limit	Health Standards or Criteria	FT-3, Fire Training Area 3	SP-4, JP-4 Pipeline Leak	D-5, Landfill	S-1, Hazardous Waste Storage	XYZ, Fuel Pump Station
Laboratory[a]			(Results in ppb)					
Dichloroethane, 1,1-			0.05			ND	ND	
Dichloroethane, 1,2-			0.50			ND	ND	
Dichloroethylene, 1,1-			0.24			ND	ND-1.5	
Dichloroethylene, trans,-1,2-			270.0			ND-5.8	0.1-790	
Methylene chloride			0.19			ND	ND	
Tetrachloroethylene			1.0			1.1-1.8	0.50-1400	
Trichloroethane, 1,1,1-			21.7			ND	ND	
Trichloroethylene			1.8			0.48-1.7	0.23-300	
Vinyl chloride			0.15			ND	ND-10[b]	
Benzene			0.67			ND	ND-5.5	
Ethylbenzene			1400.0			ND-2.1	0.34-4.0	
Toluene			14300.0			ND	ND-0.29	
PCBs			7.9×10^{-6}				ND	
Silver		10	50	ND		ND-L	L	
Arsenic	20	10	50	ND		ND	ND	
Cadmium	3	10	10	L		L	L	
Chromium	11	50	50	L		L-64	53-230	
Copper	60	20	1000	L		L-25	28-91	
Iron	30,000	100	300	L		L	L	
Mercury	<10	1	2	ND-L		L	L	
Nickel		13.4	13.4	ND-55		L-21	28-100	
Lead	10	20	50	L		L-25	L-110	
Zinc	210	50	5000	L		L-64	74-240	
			(Results in ppm)					
Oil and Grease		0.1		ND-0.14	0.12-0.43	ND-0.15	ND-0.49	ND-2.0
Cyanide			0.2			ND-0.009	ND-0.006	
Phenols			3.5			ND	ND	
TOX	0.02			0.12-0.13		ND-0.10	0.10-8.2	
TOC	3.2			1.3-8.9	2.1-32	2.4-5.4	1.9-4.7	3.3-20
Field								
Temperature (°C)				14	16-18	8.5-15	12-16	
Conductivity (umhos/cm)	290			120-200	160-250	90-180	100-480	
pH (std. units)	6.8			5.3-5.6	5.9-6.7	5.1-5.7	5.3-6.4	

NOTE: Blank space under Local or Regional Maximum, USAFOEHL Reporting Limit, and Health Standards or Criteria columns indicates data not available. Blank space under sites indicates analysis not conducted

ppb = ug/l; ppm = mg/l; ND = Not detected, indicates parameter not present above detection limit

L = Detected at level less than USAFOEHL reporting limit. The reporting limits are equal to or less than drinking water standards

[a] The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b] Chromatographs of samples showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak ma be an interference from the sample matrix

Table ES-2

CONCENTRATION RANGES FOR STAGE 1 PARAMETERS IN SURFACE WATER SAMPLES,
DOVER AFB PHASE II STAGE 1

Stage 1 Parameter	Local or Regional Maximum	USAFOEHL Reporting Limit	Health Standards or Criteria	T-1, IW Basins	DD-1, North Ditch	FT-1, Fire Training Area 1	FT-3, Fire Training Area 3	XYZ, Fuel Pump Station
Laboratory[a]			(Results in ppb)					
Dichloroethane, 1,1-				23-100				
Dichloroethane, 1,2-			0.50	0.5-2.0				
Dichloroethylene, 1,1-			0.24	2.0-19				
Dichloroethylene, trans-1,2-			270.0	7.1-130				
Methylene chloride			0.19	ND-23000				
Tetrachloroethylene			1.0	6.1-100				
Trichloroethane, 1,1,1-			21.7	390-900				
Trichloroethylene			1.8	4.4-10				
Vinyl chloride			0.15	ND				
Benzene			0.67	19-70				
Ethylbenzene			1400.0	ND-36				
Toluene			14300.0	480-620				
Silver		10	50	L	ND-L	ND-L	ND	
Arsenic		10	50	ND	ND	ND	ND	
Cadmium	1.8	10	10	120-140	L	L	L	
Chromium		50	50	780-2500	L	L	L	
Copper	90	20	1000	45-100	L	L	L	
Iron		100	300	L	L	L	L	
Mercury	1.32	1	2	ND-L	L	ND	ND-L	
Nickel		13.4	13.4	16-55	L-32	ND	ND	
Lead	14.5	20	50	51-130	L	L	L	
Zinc		50	5000	270-500	130-280	L	L-260	
			(Results in ppm)					
Oil and Grease	1	0.1		17-93	ND-0.25	[illegible]	ND-0.34	ND
Cyanide			0.2	0.010-0.013	ND			
Phenols			3.5	0.026-34	ND			
TOX	0.02			1.2-1.5	0.06-2.6	0.066-0.094		
TOC				110-300	4.5-16	2.5-18	4.1-5.3	29
Field								
Temperature (°C)				9.2-11	1.6-7.5	13	8.5-9.4	
Conductivity (umhos/cm)				620-720	110-220	180-300	80-140	
pH (std. units)				7.8-8.3	6.2-6.7	6.5-6.9	6.4-6.9	

NOTE: Blank space under Local or Regional Maximum, USAFOEHL Reporting Limit, Health Standards or Criteria columns indicates data not available.
Blank space under sites indicates analysis not conducted
ND = Not detected; indicates parameter not present above detection limits
ppb = ug/l; ppm = mg/l.
L = Detected at level less than USAFOEHL reporting limit. The reporting limits are equal to or less than drinking water standards
[a]The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

Table ES-3

CONCENTRATION RANGES FOR STAGE 1 PARAMETERS IN SOIL/SEDIMENT SAMPLES,
DOVER AFB PHASE II STAGE 1

Stage 1 Parameter	Local or Regional Maximum	USAFOEHL Reporting Limit	T-1, IW Basin	DD-1, North Ditch	FT-3, Fire Training Area 3	S-1, Hazardous Waste Storage	XYZ, Fuel Pump Station	D-2, Rubble Area
Laboratory[b]			(Results in ppb)					
Dichloropropane, 1,2-			ND-0.6			ND		
Dichloroethane, 1,1-			ND-200			ND		
Dichloroethane, 1,2-			ND-1.1			ND		
Dichloroethylene, 1,1-			ND-8.2			ND		
Dichloroethylene, trans-1,2-			ND-230			ND		
Methylene chloride			ND-46			ND-100		
Tetrachloroethylene			4.5-100			0.6-19		
Trichloroethane, 1,1,1-			2.9-12			0.9-3.7		
Trichloroethylene			2.4-66			1.3-2.3		
Vinyl chloride			ND			ND		
Benzene			ND-41			ND		
Chlorobenzene			ND-1.8			ND		
Ethylbenzene			ND			ND		
Toluene			ND-660			ND		
Dichlorobenzene, 1,2-			1.2-270			ND		
Dichlorobenzene, 1,3-			ND-34			ND		
Dichlorobenzene, 1,4-			ND-0.6			ND		
PCBs						ND-240[a]		
			(Results in ppm, except as noted)					
Silver			0.050-0.25	0.020-2.42	0.039-0.13	0.020-0.08		0.031-0.089
Arsenic	2.7		4.0-43	6.6-48	11-78	26-45		27-48
Cadmium	0.3		2.7-15	0.67-48	0.67-9.0	0.22-3.9		0.060-0.30
Chromium	50	5	68-380	9.0-280	10-27	14-30		7.6-12
Copper	7		6.6-17	0.68-1100	6.7-20	9.9-270		3.9-6.4
Iron (%)	1		0.22-0.47	0.032-4.9	0.52-1.8	0.56-0.83		0.27-1.1
Mercury (ppb)	140		0.013-0.055	0.0013-0.72	0.018-0.056	0.020-0.065		0.023-0.081
Nickel	7		4.8-5.8	0.69-750	5.4-26	9.2-14		4.8-10
Lead	20	2	24-100	5.1-740	29-170	22-180		13-176
Zinc	29		23-67	44-3800	18-76	38-220		19-120
Oil and Grease	10		1100-7000	76-2800	ND-230	24-630	3.5-65	7.6-78
Cyanide			0.2	0.1-1.1		0.1-0.4		
Phenols			ND-3.2	ND-0.5		ND-0.9		
TOX			0.12-16	ND-1.8	0.59-3.1	0.26-2.9		0.24-1.1
TOC (%)			ND-3.2	ND-4.4	0.3-2.3	0.3-1.4	0.2-0.9	1.3-4.8

Note: Blank space under Local or Regional Maximum, USAFOEHL Reporting Limit, Health Standards or Criteria columns indicates data not available. Blank space under sites indicates analysis not conducted

[a] Analytical results are for Arochlor 1260, which was the only PCB detected and is one of the PCBs listed as a priority pollutant

[b] The positive identities of VOCs were not confirmed by either second column gas chromatographic analysis or by mass spectroscopy

ppm = ug/gm; ppb = ug/kg; 1% = 10,000 ppm; soils in dry weight

ND = Not detected; indicates parameter not present above detection limits

Table ES-4

SUMMARY OF STANDARDS AND CRITERIA FOR
PHASE II STAGE 1 ANALYSIS PARAMETERS

Parameter	Standard	Criteria	Reference
		(Concentrations in ppb)	
Chloroform	<100		a, f
Chlorobenzene		488	d
Bromodichloromethane	<100		a, f
Dibromochloromethane	<100		a, f
Dichlorobenzene, 1,2-		400	d
Dichlorobenzene, 1,3-		400	d
Dichlorobenzene, 1,4-		400	d
Dichloroethane, 1,2-		0.50	c
Dichloroethylene, 1,1-		0.24	c
Dichloroethylene, trans-1,2-		270.0	e
Methylene chloride		0.19	d
Tetrachloroethylene		1.0	c
Trichloroethane, 1,1,1-		21.7	c
Trichloroethylene		1.8	c
Vinyl chloride		0.15	c
Benzene		0.67	c
Ethylbenzene		1400.0	d
Toluene		14300.0	d
PCBs		7.9×10^{-5}	d
Silver	50		a
Arsenic	50		a
Cadmium	10		a
Chromium	50		a
Copper	1000		b
Iron	300		a
Mercury	2		a
Nickel		13.4	d
Lead	50		a
Zinc	5000		b
Cyanide		200	d
Phenols		3500	d

a = Safe Drinking Water Act maximum contaminant levels (adopted by Delaware)
b = State of Delaware Drinking Water Standard
c = EPA Carcinogen Assessment Group Cancer Risk Estimate. Carcinogenic substance values correspond to a carcinogenic risk level of 10^{-6}
d = Clean Water Act Water Quality Criteria for Human Health
e = Suggested No Adverse Response Levels (SNARLS) -- Safe Drinking Water Act Health Advisory
f = The sum concentration of chloroform, bromodichloromethane, and dibromochloromethane must be less than 100 ppb

Table ES-5

SUMMARY OF FINDINGS, PHASE II STAGE 1, DOVER AFB

Sites	Groundwater	Surface Water	Soils/Sediments
T-1, IW Basins	• Levels above health standards/ criteria - VOCs, phenols - Chromium, nickel, lead • Levels above background maximum - Chromium, copper, lead, zinc - TOC, TOX	• Levels above health standards/ criteria - VOCs, phenols - Cadmium, chromium, nickel, lead • Levels above background maximum - Cadmium, copper, lead - TOX, TOC, oil and grease, pH, specific conductance	• Levels above background maximum - Arsenic, cadmium, chromium, copper, lead, zinc, oil and grease • VOCs, cyanide, phenols present
DD-1, North Ditch	• Not investigated	• Levels above health standards/ criteria - Nickel • Levels above background maximum - TOX, TOC	• Levels above background maximum - Arsenic, cadmium, chromium, copper, iron, nickel, lead, zinc, mercury • Oil and grease, cyanide, phenols present
D-10, Landfill	• Levels above health standards/ criteria - Chromium, nickel, lead • Levels above background maximum - Chromium, lead - TOX, TOC, pH, specific conductance	• Not investigated	• Not investigated

(continued)

Table ES-5 (continued)

SUMMARY OF FINDINGS, PHASE II STAGE 1, DOVER AFB

Sites	Groundwater	Surface Water	Soils/Sediments
FT-1, Fire Training Area 1	• Levels above health standards/ criteria - Nickel • Levels above background maximum - TOX, TOC, pH, specific conductance	• Levels above background maximum - TOX	• Not investigated
D-4, Liquid Waste Site	• Levels above health standards/ criteria - VOCs • Levels above background maximum - TOX, TOC	• Not investigated	• Not investigated
D-5, Landfill	• Levels above health standards/ criteria - Chromium, nickel • Levels above background maximum - Chromium, lead - TOC, oil and grease	• Not investigated	• Not investigated
FT-3, Fire Training Area 3	• Levels above health standards/ criteria - Nickel • Levels above background maximum - Nickel - TOC, TOX	• Levels above background maximum - Zinc - TOC	• Levels above background maximum - Arsenic, cadmium, copper, iron, nickel, lead, zinc - Oil and grease

(continued)

Table ES-5 (continued)

SUMMARY OF FINDINGS, PHASE II STAGE 1, DOVER AFB

Sites	Groundwater	Surface Water	Soils/Sediments
SP-4, JP-4 Pipeline Leak	• Levels above background maximum - TOC	• Not investigated	• Not investigated
S-1, Hazardous Waste Storage	• Levels above health standards/ criteria - VOCs - Chromium, nickel, lead • Levels above background maximum - Chromium, copper, lead, zinc - TOX, TOC	• Not investigated	• Levels above background maximum - Arsenic, cadmium, copper, nickel, lead, zinc - Oil and grease • VOCs, cyanide, phenols, PCBs (Arochlor 1260) present
XYZ, Fuel Pump Station	• Levels above background maximum - TOC, oil and grease		• Levels above background maximum - Oil and grease
D-2, Rubble Area	• Not investigated	• Not investigated	• Levels above background maximum - Arsenic, iron, nickel, lead, zinc - Oil and grease

Table ES-6

SUMMARY OF STEP 1 OF RECOMMENDED STAGE 2 MONITORING PROGRAM

Site	Soil Gas Transects	Groundwater Sampling	Surface Water Sampling	Sediment Sampling	Soil Sampling
T-1	175 Points	4 Wells - P.P. Org. - P. Hcrbns.	-	-	-
S-1	125 Points	2 Wells - P.P. Org.	1 Sample - P.P. Org.	1 Sample - P.P. Org.	1 Sample - P.P. Org.
D-4, D-5	100 Points	2 Wells - P.P. Org.	-	-	-
D-10	135 Points	2 Wells - P.P. Org.	-	-	-
DD-1	90 Points	-	3 Samples - P.P. Org. - P. Hcrbns.	3 Samples - P.P. Org. - P. Hcrbns.	-
XYZ	60 Points	2 Wells - P. Hcrbns.	-	-	-
D-2	30 Points	-	-	-	2 Samples - P.P. Org.
FT-3	30 Points	2 Wells - P.P. Org. - P. Hcrbns.	2 Samples - P.P. Org. - P. Hcrbns.	-	2 Samples - P.P. Org. - P. Hcrbns.
SP-4	40 Points	2 Wells - P. Hcrbns.	-	-	-
Runway	-	-	4 Samples - P.P. Org. - P. Hcrbns.	4 Samples - P.P. Org. - P. Hcrbns.	4 Samples - P.P. Org. - P. Hcrbns.

P.P. Org. = Priority pollutant organics analysis
P. Hcrbns. = Petroleum hydrocarbon analysis

Table ES-7

SUMMARY OF STEP 2 OF RECOMMENDED STAGE 2 MONITORING PROGRAM

Site	Monitoring Well Installation	Aquifer Testing	Groundwater Sampling[a]	Surface Water Sampling[a]	Sediment Sampling[a]	Soil Sampling[a]
T-1	18 C Wells 4 F Wells	1 C Well 1 F Well	37 Wells - VOCs, P. Hcrbns., As, Metals, Phenols	-	-	-
S-1	11 C Wells 1 F Well	1 C Well	15 Wells - VOCs, PCBs, O&G, Cn, Phenols, As, Metals	2 Samples 2 S.W. Elevation Pts.	2 Samples	23 Samples
D-4, D-5	11 C Wells 1 F Well	1 C Well	19 Wells - VOCs, O&G, Metals	2 Samples	2 Samples	-
D-10	11 C Wells	-	20 Wells - VOCs, Metals	5 Samples 4 S.W. Elevation Pts.	5 Samples	-
DD-1	9 C Wells	-	9 Wells - VOCs, P. Hcrbns., O&G, Cn, Phenols, As, Metals	6 Samples 3 S.W. Elevation Pts.	15 Samples	-
XYZ	4 Hanging C Wells	-	7 Wells - P. Hcrbns., VAs	-	-	-
D-2	7 C Wells	-	6 Wells - VOCs, O&G, As, Metals	-	-	13 Samples
FT-3	2 C Wells	-	5 Wells - VOCs, P. Hcrbns., O&G, As, Metals	5 Samples 1 S.W. Elevation Pt.	17 Samples	10 Samples
SP-4	4 Hanging C Wells	-	7 Wells - P. Hcrbns., VAs	-	-	-
Runway	3 Hanging C Wells	-	3 Wells - VOCs, P. Hcrbns., Phenols, O&G, As, Metals	4 Samples	-	4 Samples

[a]Analysis parameters listed under groundwater sampling apply to all media. Recommended analysis may be modified depending on Step 1 results

VOCs = Volatile organic compounds; O&G = Oil and Grease; Cn = Cyanide; P. Hcrbns. = Petroleum Hydrocarbons; VAs = Volatile Aromatics; S.W. Elevation Pts. = Surface water elevation points; C Well = Well installed in the Columbia aquifer; F Well = Well installed in Frederica aquifer

Table ES-8

SUMMARY OF STEP 3 OF RECOMMENDED STAGE 2 MONITORING PROGRAM

Site	Stratified Groundwater Sampling[a]
T-1	5 wells with 3 samples per well - VOCs.
S-1	3 wells with 3 samples per well - VOCs.
D-4, D-5	4 wells with 3 samples per well - VOCs.
D-10	3 wells with 3 samples per well - VOCs.
DD-1	Program not planned.
XYZ	Program not planned.
D-2	Program not planned.
FT-3	Program not planned.
SP-4	Program not planned.
Runway	Program not planned.

[a]Analysis parameters may be modified depending on Step 2 results
VOCs = Volatile organic compound analysis with second-column gas chromatographic analysis and mass spectroscopy to positively confirm the identities of VOCs.

1.0 INTRODUCTION

This report describes activities, results, findings and recommendations associated with the Installation Restoration Program (IRP) Phase II Stage 1 study conducted at Dover AFB (DAFB). The Stage 1 investigation at DAFB was designed to confirm the presence or absence of contamination at 12 sites that were identified during IRP Phase I and Phase II Presurvey studies as having the potential to contaminate the environment. These sites are identified on Figure 1-1. Important findings from the activities conducted to date are summarized below:

1. Hazardous waste has been generated at and disposed of on DAFB since the base began operations in 1941. Studies (U.S. HEW, 1965; Jordan, McNee, Parnum and Yule, 1967; USEPA, 1972; Engineering-Science, 1983) have characterized portions of this waste as containing waste fuels, oils, solvents, hydraulic fluids, paints, lubricants, paint and rust removers, muriatic acid, nitric acid, caustic soda, cyanide, phenols, cadmium, chromium, copper, nickel, lead, and zinc.

2. The IRP Phase I Report (Engineering-Science, 1983) identified 11 sites that had the potential to contaminate the environment. These included:

   - Three landfills (Sites D-4, D-5, and D-10)
   - Three fire training areas (Sites FT-1, FT-2, and FT-3)
   - Two fuels spills or leaks (Sites SP-3 and SP-4)
   - The Wastewater Treatment Basins (Site T-1), the Hazardous Waste Storage Area (Site S-1), and the North Drainage Ditch (Site DD-1).

3. Additional information obtained during the Phase II Presurvey indicated that Site SP-3 did not have the potential to contaminate the environment because the spill probably was contained and cleaned-up immediately after its occurrence. However, Phase II Presurvey information indicated that two additional sites - a fuel leak or spill around Building 950 (Site XYZ) and the existing Rubble Landfill (Site D-2) - did have the potential to contaminate the environment. Ten Phase I sites (all but Site SP-3) plus the two other sites identified during the Phase II Presurvey were investigated during Phase II Stage I.

4. Volatile organic compounds (VOCs) were detected in 1982 in groundwater around Site T-1.

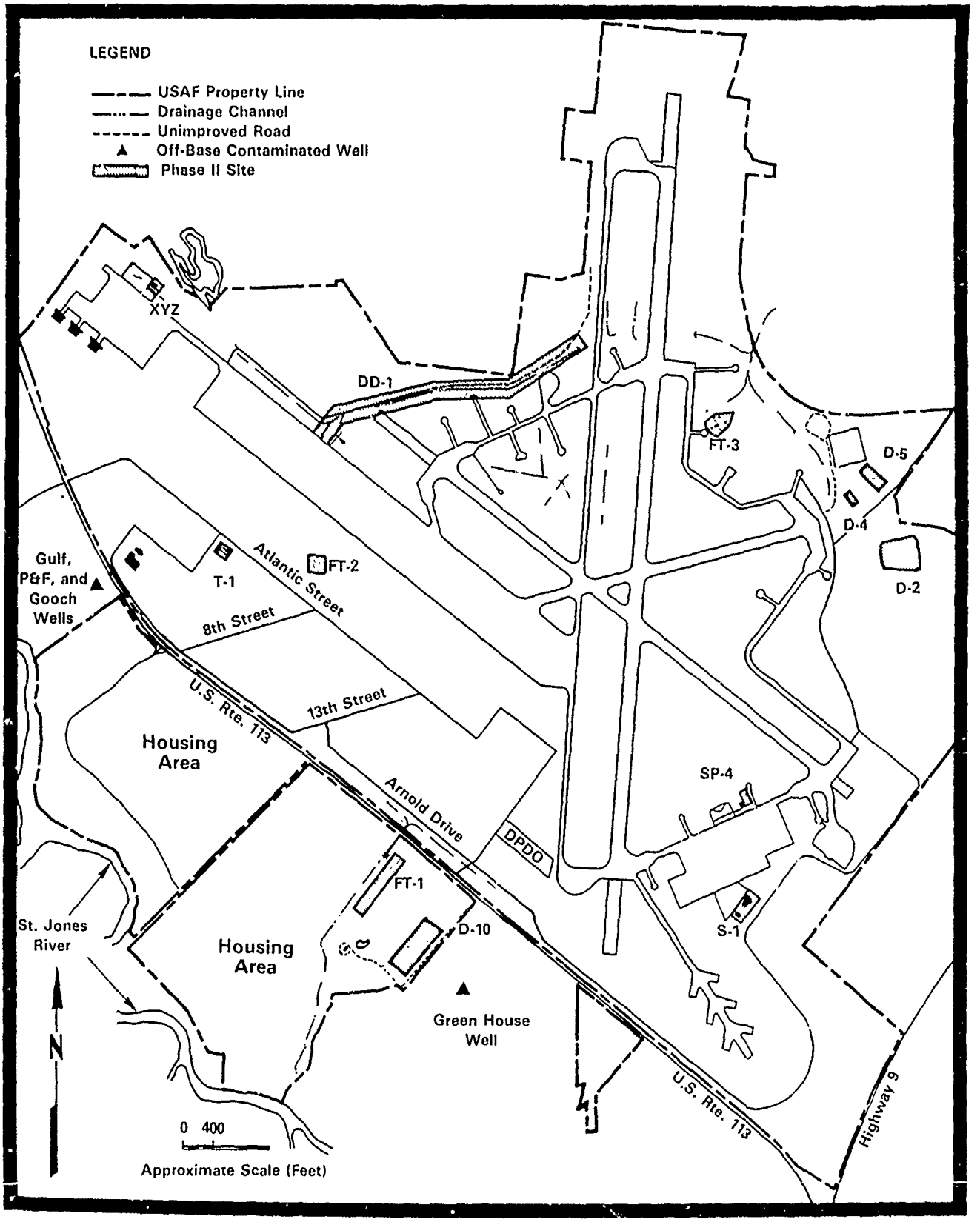


Figure 1-1. Locations of Sites Studied at Dover Air Force Base During Phase II, Stage 1

5. Phase II Stage 1 activities confirmed concentrations of Stage 1 parameters at levels above health standards, health criteria or background maximums in sediment, soil, surface water, or groundwater at ten Stage 1 sites. Seven of the Stage 1 sites (T-1, DD-1, D-10, D-4, S-1, XYZ, and D-2) were potentially identified as sources of concentrations of contaminants found in the environment. Stage 1 activities did not identify the sources of the contaminant concentrations found in the environment at or around three Stage 1 sites (D-5, FT-3, and SP-4) for the following reasons:

   - The direction of groundwater flow in the immediate vicinity of Site D-5 could not be identified because water levels in wells around this site were not significantly different and the slope of the water table could not be determined. The VOCs found in monitoring wells at D-5 may be migrating from the adjacent Site D-4, at which groundwater was found to contain VOCs at an order of magnitude higher than found at D-5. The metals found at levels above health standards or background levels at D-5 could not be completely attributed to D-5 because of the uncertain flow direction.

   - Sediments in the streams and wetland areas around Site FT-3 contained levels of oil and grease and metals above published background levels; however, groundwater downgradient of the site did not contain higher concentrations of these parameters and evidence was not found that runoff flowed from the fire training pit into the streams. Thus, a migration path from FT-3 to the sediments was not identified. In addition, the highest concentration of zinc in surface waters at this site was detected in a sample collected upstream of Site FT-3, indicating a possible site upstream of FT-3. Other sites have not been identified in the area, so the source or sources of the elevated concentrations could not be identified, nor could the elevated concentrations be attributed to Site FT-3.

   - The direction of groundwater flow around Site SP-4 could not be identified because water levels in wells changed over short time periods, which indicated that the direction of groundwater flow was changing. SP-4 is located near the estimated position of the groundwater divide thought to exist in the area, so changes in flow direction can be expected. However, because of the changing flow direction, the levels of TOC above the regional background level found at SP-4 could not be attributed to the site.

   Additional data gathering activities are recommended at the ten sites where concentrations of contaminants were confirmed to identify the sources of substances found and determine their direction and rate of migration.

6. Samples from potential background monitoring locations indicated that other unidentified sites possibly are sources of concentrations of substances detected at Sites T-1, DD-1, D-10, and S-1. Background samples were collected from locations which were thought to not have been affected by substances migrating from the sites, e.g.,

from wells which were upgradient of the site based on groundwater flow directions and from surface water located upstream from a site. The background samples were preserved and stored in the same kind of containers and analyzed for the same parameters of concern as samples collected from potentially downgradient or downstream from sites. Other sources of contaminants were suspected based on comparisons between reported naturally occurring regional or local levels or of the background sample results with the downgradient or downstream results. Specifically, other sites are suspected sources of substances detected at Sites T-1, DD-1, D-10, and S-1 for the following reasons:

- A potential background groundwater sample for Site T-1, IW Basins was collected from well 01j. VOCs were detected in the sample, including tetrachloroethylene at a level higher than any level found in the downgradient wells. Well 01j is located upgradient of Site T-1 based on regional groundwater flow direction; however, infiltration from the basin has affected local groundwater flow patterns, so the source of the VOCs in well 01j may be from an unidentified upgradient source or actually may be from the IW Basins.

- Sampling point w-d03 at Site DD-1, North Ditch was located on a surface water diversion channel north of the reported point of wastewater discharge to the ditch. This sampling point potentially qualified as the background sample and as a means to identify if any sources north of DD-1 were contributing to levels found at DD-1. The TOC and TOX results for w03 indicated that a source (or sources) west of DD-1 may have contributed halogenated and non-halogenated organic compounds to those found in the North Ditch. Other sources upstream of w-d03 may also be contributing to oil and grease concentrations found in the ditch.

- Two wells, 05j and 14, were potentially located upgradient from the Golf Course Sites D-10 and FT-1. The TOX and TOC levels above reported or estimated regional background levels found in both wells may not have been caused by Site D-10 or Site FT-1. Therefore, another source upgradient of those sites is suspected.

- Well 24 is located northeast of Site S-1 and is not downgradient of the site because the groundwater flow direction appears to be toward the south or southwest. The metal concentrations above health standards or published background levels found in well 24 may not be attributed to Site S-1. Therefore, another source east to north of the site is suspected.

7. Data gathered during Phase II Stage 1 indicated that Site FT-2, Fire Training Area 2 did not have the potential to contaminate the environment because fire training activities did not likely take place at this location. Consequently, the Stage 1 monitoring progam for this site was not implemented.

8. Results of analysis conducted on samples collected during Stage 1 confirmed that Site FT-1, Fire Training Area 1 was not affecting groundwater or surface water quality.

9. The Delaware Department of Natural Resources and Environmental Control (DNREC) has identified two areas of contaminated groundwater off-base, the trailer park area wells and the Green House well. The sources of the off-base contamination have not been determined.

10. A fuel leak at the DAFB Motor Pool (436 Transportation Squadron) was discovered and fixed in October 1984. The Motor Pool leak is upgradient of DNREC monitoring wells and is a potential source for benzene, toluene, and xylene found in these wells.

The following sections provide background information on the IRP, the history of DAFB, base waste management practices, previous studies, off-base contamination incidents, and Phase II Stage 1 activities. Sections 2 through 6 will present the results, findings, and conclusions of Stage 1.

1.1 INSTALLATION RESTORATION PROGRAM REVIEW

Evidence that natural resources were being contaminated and public health threatened by substances migrating from hazardous waste sites located across the U.S. accumulated during the 1970s. Because the Department of Defense (DOD) conducts operations that require the use and disposal of hazardous materials, and in response to the growing national problem, DOD instituted a program to identify past disposal locations at its facilities including United States Air Force (USAF) installations. In 1980, Federal laws were passed that were designed to control hazardous waste disposal and to identify and clean-up those sites causing contamination. These laws were the Resource Conservation and Recovery Act of 1976 (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund). DOD responded to these new laws by issuing the Environmental Quality Program Policy Memorandum 81-5 establishing the Installation Restoration Program (IRP). The IRP is the framework under which CERCLA-mandated activities are conducted at DOD installations.

The IRP requires the following:

1. The identification and evaluation of hazardous material sites on DOD property.

2. The control of contaminant migration.

3. The control or removal of hazards to public health or the environment from past DOD activities.

The USAF IRP consists of four phases, each with separate and distinct tasks and outputs. These phases are:

- Phase I - Installation Assessment (Records Search)
- Phase II - Confirmation/Characterization
- Phase III - Technology Base Development
- Phase IV - Operations/Remedial Actions.

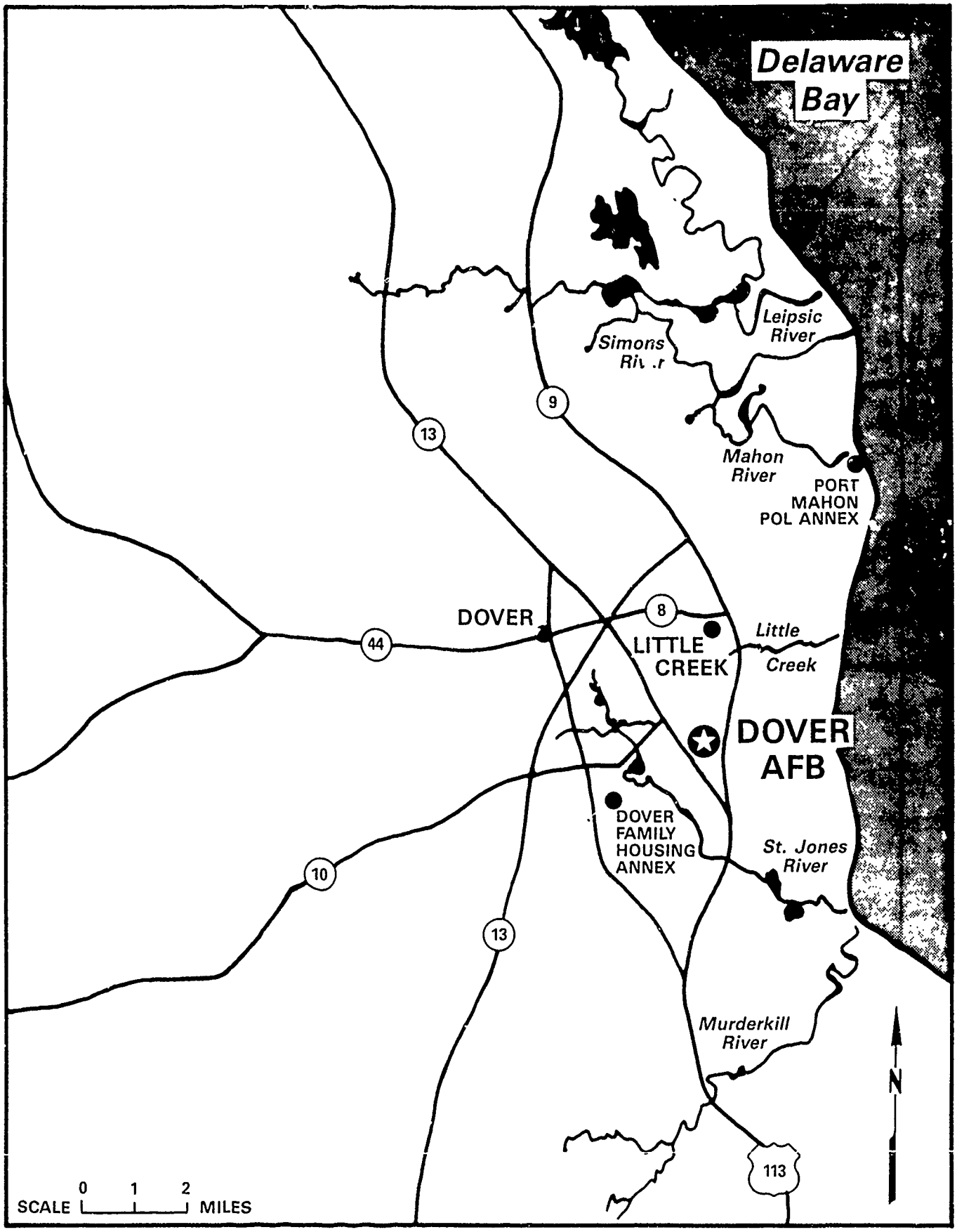
Phases I, III, and IV are administered through the Air Force Engineering and Services Center (AFESC), Tyndall AFB, Florida. Phase II is administered through the U.S. Air Force Occupational and Environmental Health Laboratory (USAFOEHL), Brooks AFB, TX.

Phase I was completed at DAFB in October 1983. Phase II at DAFB began with the presurvey site visit in May 1984. Monitoring well installation and environmental sampling (Phase II Stage 1) began in October 1984.

1.2 DOVER AFB ORGANIZATION AND MISSION

DAFB is located in Kent County, Delaware, approximately 3.5 miles southeast of the center of Dover, Delaware (Figure 1-2). Including annexes, easements, and leased property, DAFB encompasses 3,734 acres. A Military Airlift Command (MAC) base, DAFB is the home of the 436th Military Airlift Wing equipped with C-5 Galaxies which provide strategic airlift capability. The primary mission of the Wing is to provide immediate airlift of troops, cargo, and military equipment, and to participate in airland or airdrop operations. The 436th Air Base Group provides support for assigned and attached units at DAFB.

Activities at the Dover Army Airfield began in December 1941 and continued until the airfield was deactivated in September 1946. During this time, the base supported patrol and training operations in addition to serving as the site for development of air-launched rockets. From 1946 until July 1950, the Air National Guard periodically conducted training exercises on the airfield. Dover Air Force Base was activated in July 1950. In March 1952, with a transfer of command to the Military Air Transport Service (now MAC), the base mission switched from air and land defense to cargo operations.



Source: ES, 1983

Figure 1-2. Area Location of Dover Air Force Base

Except for supporting a Strategic Air Command (SAC) detachment from 1960 to 1965, base operations have consisted primarily of cargo operations.

1.3 DOVER AFB HAZARDOUS WASTE MANAGEMENT ACTIVITIES

The generation and disposal of hazardous or potentially hazardous wastes at DAFB was investigated during IRP Phase I. In Phase I, hazardous wastes were defined as those identified as hazardous by CERCLA, and potentially hazardous wastes were defined as those suspected of being hazardous, although insufficient data were available to fully characterize the wastes. During Phase I, little information regarding waste generation and disposal practices for the period from 1941 to the mid-1950s was discovered.

Most hazardous wastes generated at DAFB resulted from industrial operations, fuels management, and pesticide utilization. Hazardous wastes generated at DAFB included: waste fuels, oils and solvents; empty pesticide containers; transformers containing polychlorinated biphenyls (PCBs); excess paints; and wastewaters from industrial shops. Tables containing breakdowns of waste generated at DAFB are provided in Appendix J.

Prior to 1963, waste oils, fuels, solvents and paint were disposed of in landfills or pits located along the base perimeter, or were taken to fire training areas and burned during training exercises. During this period, industrial wastewaters were generated primarily by the engine build-up shop, aircraft wash racks and plating shops. Wastewaters contained paint and rust removers, methylene chloride, caustic soda, muriatic acid, sodium cyanide, and nitric acid, and were discharged to a storm drainage ditch (Site DD-1, North Ditch) that drained to a tributary of the Little River.

In 1963, the Industrial Wastewater Basins (Site T-1, IW Basins) were completed and began to accept wastewater from the engine build-up shop. The IW Basins consisted of two concrete accepting basins, two oil water separators, and two unlined settling lagoons. Wastewaters entering the accepting basins flowed through the oil water separators before entering the unlined lagoons. Discharge from the basins was routed back to the North Ditch, but other industrial wastewater continued to be discharged directly to the North Ditch. In 1968, plating shop wastewater was routed to the IW basins prior to discharge to the North Ditch.

Discharge from the IW Basins to the North Ditch was stopped in 1969. From 1969 to 1975, basin effluent was routed to the base sanitary treatment facility prior to discharge. Since 1975, effluent has been discharged to the regional (Kent County) sanitary treatment facility.

From 1963 to 1975, waste oils, solvents, and fuels were collected and separated for recycling or for use in fire training exercises. JP-4 has been used for fire training since 1975.

1.4 SUMMARY OF PREVIOUS INVESTIGATIONS

In addition to IRP-sponsored investigations, other studies conducted at or near DAFB were concerned with waste management or environmental quality. Previous investigations are summarized below.

1.4.1 Early Investigations: Pre-1982

Prior to 1982 there were three studies that concerned treatment or disposal of waste at DAFB:

1. Waste Disposal Studies. Dover Air Force Base, Dover, Delaware. July and October 1964. U.S. Dept. of Health, Education and Welfare. Robert A. Taft Sanitary Engineering Center. Cincinnati, OH. June 1965.

2. Twenty-percent Concept for Industrial Waste Treatment: Metal Plating Shop, Engine Build-up Shop, Washracks. Dover AFB, Dover, Delaware. Jordan, McNee, Parnum and Yule, Architects and Engineers, Philadelphia, PA. No date (possibly 1967).

3. Report on Waste Disposal Practices at Dover AFB, Dover, Delaware. U.S. Environmental Protection Agency, Region III. Philadelphia, PA. 19101. September 1972.

Information provided in these reports is summarized below:

1. In 1964 and 1965 the North Ditch was receiving wastewater containing solvents, cyanide, phenols, oil and greases, cadmium, chromium, copper, nickel and zinc. The engine build-up shop generated the majority of this waste. Spent PS-661 solution (aliphatic naphtha saturated aliphatic hydrocarbon similar to kerosene; flammab , insoluble in water) was being hauled to and spread over an unidentified land disposal area. This area was located such that large amounts of the waste were carried to the North Ditch during rainfall events. The location of this land spreading area has not been confirmed.

2. Wastes from the Plating Shop were discharged directly to the North Ditch. Wastes contained cadmium, cyanide, iron, copper, nickel, lead, and zinc.

3. In 1964, the North Ditch was characterized as devoid of bottom organisms because of the presence of a black, oily, sludge covering the bottom of the ditch.

4. A major spill occurred in February 1972 in the JP-4 pipeline from Port Mahon. The location of the leak has not been identified.

5. Mercury was used on-base for laboratory purposes and in trickling seals.

Except for the area where spent SP-661 solution was being spread, landfill or land disposal sites were not mentioned in any of these reports.

1.4.2 EPA Field Investigation Team (FIT) Report: August 1982

In March 1980, EPA initiated a study at DAFB because of the existence of an on-site landfill (Site D-2) used for construction debris and rubble. In May 1981, DAFB notified EPA Region III of the existence of thirteen disposal sites on the base that had been used to dispose of various industrial wastes. Based on this information, EPA's FIT contractor for Region III was tasked to investigate the base.

An on-site inspection and sampling trip was conducted on 12 April 1982. Results summarized in the FIT report (USEPA, 1982a) included the following:

1. Trichloroethylene (TCE) and tetrachloroethylene (PCE) were detected in surface water samples taken at the Golf Course.

2. Arsenic was detected in base well "D" at the method detection limit of 10 ug/l.

3. Recommendations were not made other than to resample the base drinking water wells to confirm the absence or presence of arsenic.

Information in the FIT report contradicts other reports, including the Phase I report. Specifically, the FIT's descriptions of Site #2 (Site FT-3) and Site #8 (Site D-6) indicated that these sites contained liquid industrial wastes. In addition, site locations did not correspond with known or estimated locations as described by DAFB personnel, although this may have been caused by the FIT using dated topographic maps for reference.

Three samples collected since the FIT study detected arsenic in base drinking water wells at levels which were lower than the Safe Drinking Water Act maximum contaminant level of sample. Sample results and collection dates are as follows: 26 ppb (21 February 1983); 49 ppb (3 November 1983); and 25 ppb (7 July 1985).

1.4.3 Groundwater Analysis and Sampling Report - IW Basins: October 1982

In 1982, Roy F. Weston Designers and Engineers were tasked by USAFOEHL to investigate groundwater contamination at the IW Basins. Weston's report (Weston, 1982) stated that although up to eight monitoring wells were planned, the number ultimately installed was reduced to three after discussion with DNREC personnel. Three wells (Wells 101, 102, and 103) were installed, one each immediately NE, SE, SW of the basins (Figure 1-3). Volatile organic compounds (VOCs) found in samples collected from the wells are identified on Table 1-1.

1.4.4 IRP Phase I, Records Search - October 1983

Phase I activities at DAFB included record searches, personnel interviews, and site inspections. Little information was discovered regarding waste disposal practices for the period from 1941 to the mid-1950s. Known methods of disposal of wastes, generated primarily from aircraft and vehicle maintenance and repair, included on- and off-site landfills; discharge, both with and without pretreatment to surface waters; discharge to treatment plants; and burning during fire training exercises. Wastes generated at DAFB included waste fuels, oils, solvents, pesticides, empty containers, PCB transformers, plating wastes, and excess paint.

The Phase I report (Engineering Science, 1983) identified eleven sites considered to have the potential to cause environmental contamination, and evaluated the sites using the USAF Hazard Assessment Rating Methodology (HARM). Based on the HARM scores, monitoring programs were recommended for seven sites.

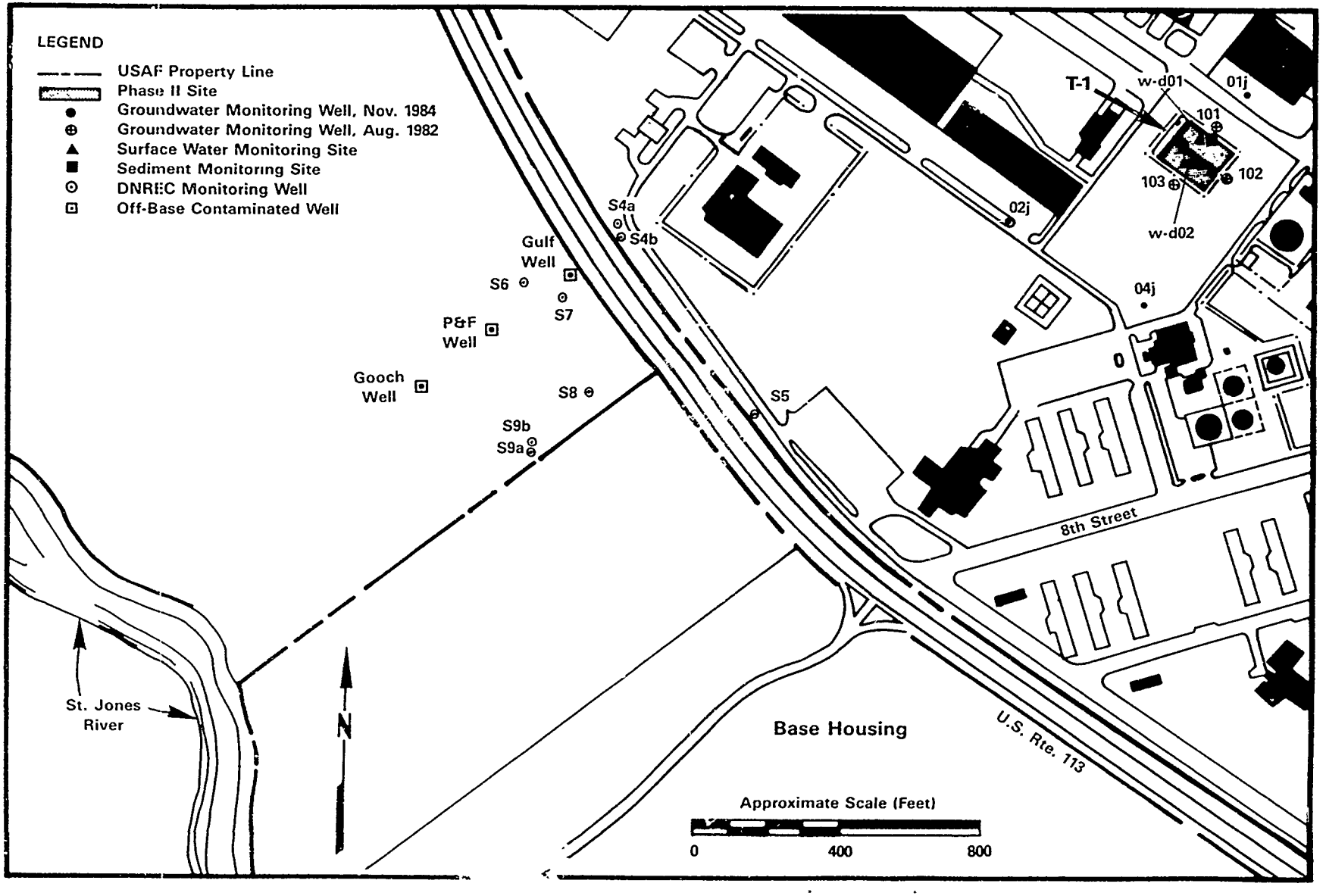


Figure 1-3. Locations of DNREC Wells in Vicinity of Motor Pool Area and Site T-1, IW Basins

Table 1-1

SUMMARY OF IW BASIN AREA CONTAMINATION
AUGUST 1982 TO JUNE 1984

Parameter	Groundwater		Surface Water[b]	Sediments[c]
	1982[a]	1984[c]		
	(Results in ppb)			
Tetrachloroethylene	TR-11	12-2300	ND	NA
1,1,1-Trichloroethane	ND-12	9.8-4250	268-280	NA
Trichloroethylene	24-42	38-2250	TR	NA
trans-1,2-Dichloroethylene	ND-12	NA	TR-13	NA
Vinyl chloride	ND-35	ND	ND	NA
Carbon tetrachloride	ND-TR	ND	58-59	NA
1,1-Dichloroethane	ND-TR	0.6-205	12-16	NA
1,1-Dichloroethylene	ND-TR	ND	ND	NA
Methylene chloride	ND-TR	ND-101	400-630	NA
Benzene	ND	NA	10-12	NA
Chlorobenzene	ND	ND-127	TR	NA
Toluene	ND	NA	200-210	NA
Phenols	NA	NA	0.01-284	NA
Cadmium	NA	NA	<10-550	1900
Chromium	NA	NA	<50-6500	33000
Copper	NA	NA	<20-320	993
Iron	NA	NA	<100-5270	11000
Mercury	NA	NA	<5-20	NA
Lead	NA	NA	NA	8200
Silver	NA	NA	NA	15.9
Zinc	NA	NA	NA	4300

[a]Source: Weston (1982).
[b]Sources: Organics data from Weston (1982); and metals data from USAFOEHL Monitoring Data (1984).
[c]Source: USAFOEHL Monitoring Data (1984).
ppb = ug/l for water; ug/kg dry weight for sediments.
TR = Trace (between 1 and 10 ppb).
ND = Not detected.
NA = Data not provided or analysis not performed.

1.4.5 IRP Phase II, Presurvey - June 1984

In March 1984, the USAFOEHL directed SAIC to develop technical approaches and costs to investigate the eleven sites that were rated using the HARM during Phase I. SAIC conducted a presurvey site visit in May 1984, and obtained information and collected samples. Information gathered during this visit indicated that Site SP-3, a fuel spill, was contained and cleaned up immediately after its occurrence and thus did not have the potential to contaminate the environment. Therefore, Site SP-3 was eliminated from the program. Other information identified two other sites, an unidentified fuel release or spill near Building 950 (Site XYZ) and the existing Rubble Area (Site D-2) as having the potential to contaminate the environment. Site XYZ was added to the program because DAFB personnel reported during the presurvey site visit that a fuel layer was noticed while pumping rainwater from manholes in the area. Also, a major spill of "TC-94" apparently occurred in this area. The environmental concern was that spilled fuels may have formed a layer of fuel floating on groundwater. The inclusion of Site D-2 in the program was requested because of the site's long history of use for disposal, even though the only known disposal materials are construction debris and general refuse. Possible surface water and groundwater contamination was the environmental concern at Site D-2. Monitoring programs for ten Phase I sites (all but SP-3) and the two additional sites were described in the Phase II presurvey report (JRB, 1984). Information available on the 12 sites is summarized in Table 1-2.

The results of analysis conducted on samples collected during the presurvey visit are provided in Appendix H. Sampling confirmed elevated levels for TOX (16 ppm) and TOC (15 ppm) in monitoring wells surrounding Site T-1, IW Basins. Sample results also indicated that all DAFB drinking water wells, which are screened in deeper aquifers, were not contaminated. The absence of detailed, base-specific, hydrogeologic information was confirmed during this visit.

As part of the Phase II presurvey, a coordination meeting was held on 17 May 1984. Phase II objectives, activities and schedules were discussed during this meeting. Representatives from SAIC, USAF, and DNREC attended the meeting.

Table 1-2

SUMMARY OF TWELVE SITES PROPOSED FOR STUDY
AT DOVER AIR FORCE BASE DURING PHASE II STAGE 1

Site Identity[a]		Time Period	Waste Type
D-2	Rubble Area	1960s-present	General refuse, construction rubble
D-4	Liquid Waste Site	1950s (late)	Waste oil, hydraulic fluids, waste solvents
D-5	Landfill	1960s	General refuse
D-10	Landfill	1950s (mid)	General refuse, shop liquid waste drums, waste solvents
FT-1	Fire Training Area 1	1951-1962	Contaminated fuels, solvents, paints, misc. liquid wastes
FT-2	Fire Training Area 2	1956-1958	Contaminated fuels, solvents, paints, misc. liquid wastes
FT-3	Fire Training Area 3	1962-present	Contaminated fuels, solvents, paints, misc. liquid wastes
SP-4	JP-4 Pipeline Leak	1975	Unknown quantity of JP-4
XYZ	Fuel Pump Station, Fuel Spill[b]	Unknown	Unknown quantity of JP-4
S-1	Hazardous Waste Storage (Bldgs. 1306 and 1305)	? - present	Oils, fuels, PCB-containing material
T-1	IW Basins	1963-present	Industrial wastewater (metals and solvents)
DD-1	North Ditch	1950s-1969	Industrial wastewater (metals and solvents)

[a]Figure 1-1 illustrates the locations of all sites.
[b]Site identified after Phase I.

A Phase II presurvey report was developed and submitted to OEHL on 15 June 1984. This report contained a discussion of Phase I findings and recommendations and presented SAIC's recommendations and estimated cost for conducting Phase II Stage 1 investigations at the 12 study sites.

1.4.6 Preliminary Hydrogeologic Investigation at Gooch's Trailer Park, Dover, Delaware - 1984

In June 1984, DNREC became concerned about the effects of the IW Basins on groundwater in the area after reviewing groundwater monitoring data. DNREC's Division of Public Health sampled water supply wells west of Route 113. Results (provided in Table 1-3) indicated that the public supply well at Gooch's Trailer Park (Gooch well) was contaminated with the industrial solvents trichloroethylene (TCE) and tetrachloroethylene (PCE), and dissolved hydrocarbons. Wells belonging to Paul Moore (P&F well) and Paradee's Gulf Station and Restaurant (Gulf well) also were found contaminated by industrial solvents. DNREC issued a no-drinking order and DAFB supplied an emergency water truck to supply emergency drinking water. In July 1984, DNREC installed eight wells at six locations (well pairs were installed at two locations) along Route 113 (Figure 1-3). These and the three existing IW Basin wells were sampled during August 1984. DNREC (Weber et al., 1984) concluded that:

1. Groundwater flows from the IW Basin area towards the contaminated wells.

2. The Miocene clay layer at the base of the Columbia (water-table) aquifer dips to the northwest. This may represent the edge of an ancient stream channel that has incised the top of the clay layer.

3. The centerline of this ancient stream channel trends northeast/southwest, and is located northwest of DNREC wells 6 and 7 (S6 and S7).

4. A contaminant plume is migrating from the Basins and moving northwest of S6 and S7 and the Gooch well. The absence of contaminants in S8, S9A, and S9B is because the plume is north of these wells. The absence of contaminants in well S5 is probably because it is screened below the confining Miocene clay layer and in the Frederica aquifer.

5. The distribution of hydrocarbon contaminants indicates that the DAFB Motor Pool gasoline storage tanks are one of the possible sources.

Table 1-3

GROUNDWATER CHEMISTRY DATA - DNREC WELLS, 22 AUGUST 1984

Compound	Well Identification[a]													
	Gooch	Gulf	P&F	S4a	S4b	S5	S6	S7	S8	S9a	S9b	101	102	103
	(Results in ppb)													
Trichloroethylene (TCE)	ND	3.6	8.3	ND	62	ND	ND	ND	ND	ND	ND	38	140	2250
Benzene	175	ND	ND	320	ND	ND	ND	ND	ND	ND	ND	2	7.8	265
Tetrachloroethylene (PCE)	235	ND	ND	ND	19	ND	ND	ND	ND	ND	ND	36	12	2300
Toluene	ND	ND	ND	4300	ND	ND	ND	ND	ND	ND	ND	ND	3	1.75

[a]Well locations shown on Figure 1-3.
ppb = ug/l.
ND = Not detected; indicates compound not present above detection limit.

6. The differences between the contaminants found immediately adjacent to the IW Basins and the contaminants found in the contaminated wells is probably a result of transport velocities and physical/chemical changes taking place over the four to ten years estimated transport time for water seeping from the basins to reach the contaminated wells.

7. The contamination in the Gooch well is because the well draws water from the edge of the plume and from a slightly deeper zone.

In December 1984, DAFB provided a permanent water line that hooked into the trailer park distribution system and the other two systems, and now provides a contaminant-free supply of water. DAFB installed this line because the base could complete the task faster and easier than other water suppliers in the area, and not because DAFB acknowledged responsibility for causing the contamination.

1.5 IRP PHASE II STAGE 1: CONFIRMATION/CHARACTERIZATION, OCTOBER 1984 - MAY 1985.

Phase II Stage 1 field activities at DAFB began on 15 October 1984. The Stage 1 objectives were to:

1. Confirm the absence or presence of environmental contamination at the twelve study sites. The locations of these sites were shown in Figure 1-1. Detailed descriptions are provided in Section 2.0 of this report. Site-specific maps of each site are provided as Figures 1-3 through 1-9. Site-specific maps are also provided in Section 2.0 as Figures 2-10, 2-12, 2-13, 2-15, 2-18, 2-20, and 2-21. These maps also show Phase II Stage 1 monitoring locations.

2. Collect sufficient data so that additional investigation activities (Phase II Stage 2) could proceed at those sites where Phase II Stage 1 results confirmed contamination.

The Scope of Work for Phase II Stage 1 is provided in Appendix B.

Reconnaissance activities to locate sites and collect information prior to drilling began on 16 October 1984. Information gathered indicated that Site FT-2, Fire Training Area 2 was not used as a fire training area and that fire training activities between 1956 and 1958 were conducted at FT-1. The Phase II Stage 1 monitoring program planned for FT-2 was cancelled because the site did not have the potential to contaminate the environment.

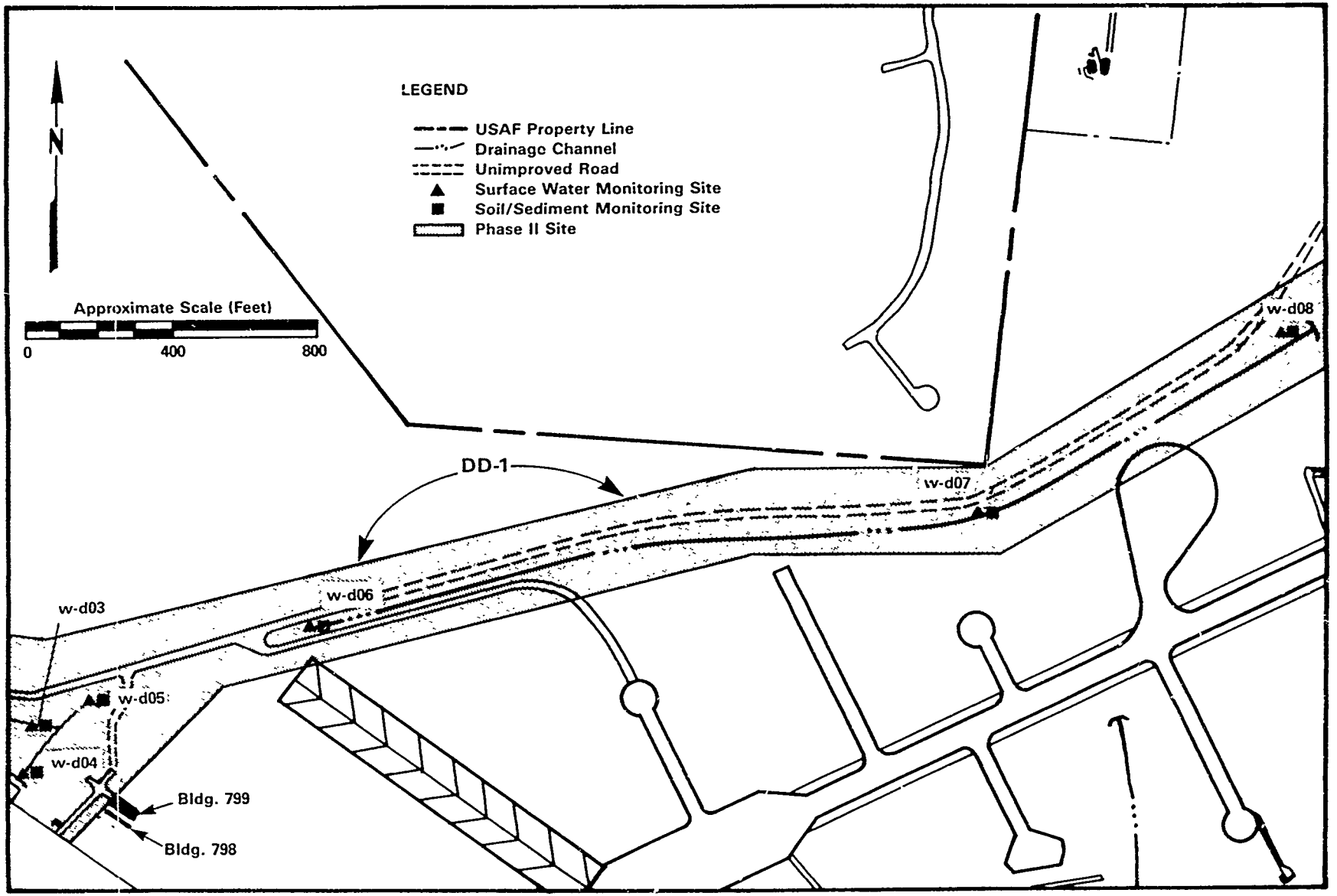


Figure 1-4. Site DD-1, North Ditch

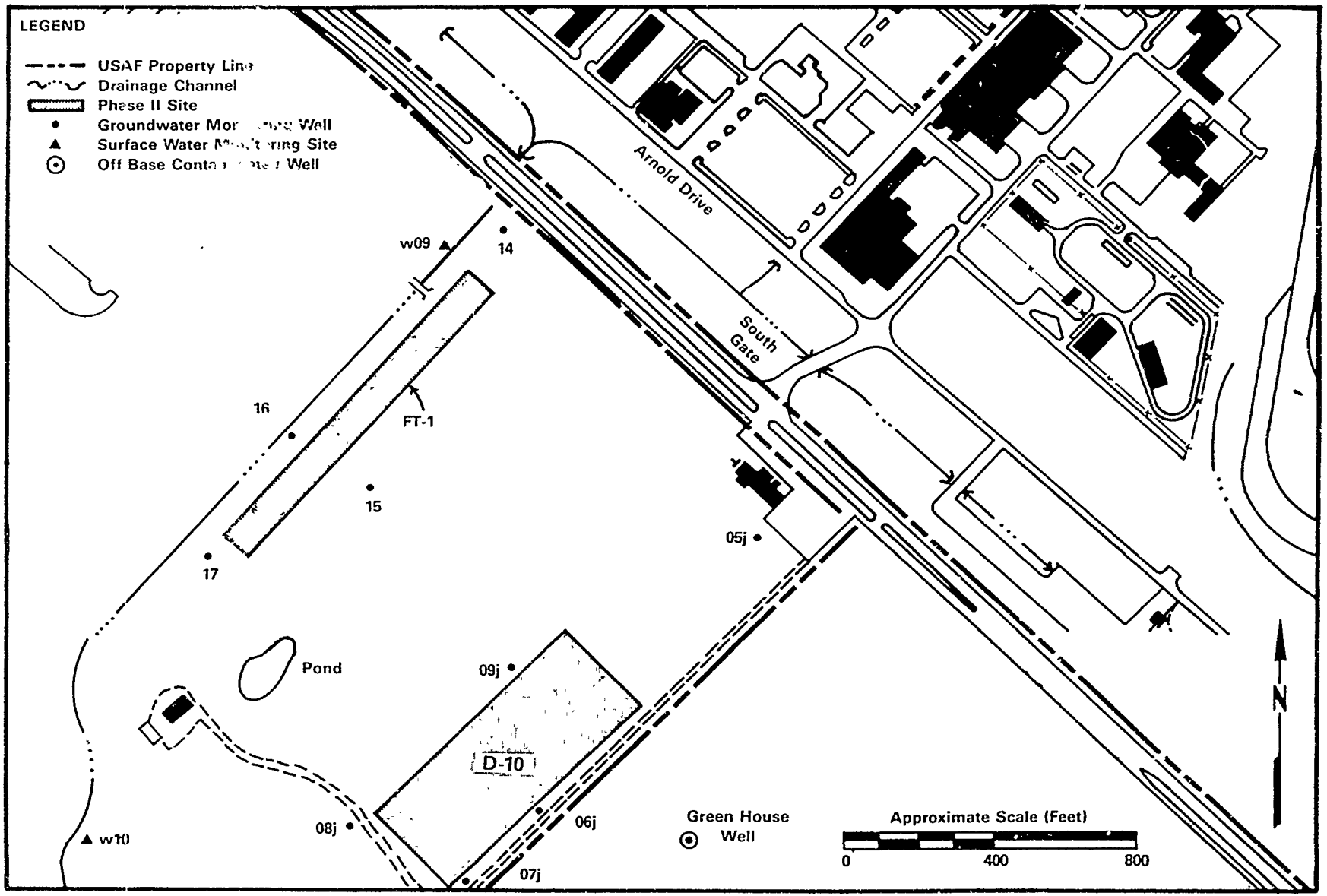


Figure 1-5. Site D-10, Landfill and Site FT-1, Fire Training Area 1 (Golf Course Sites)

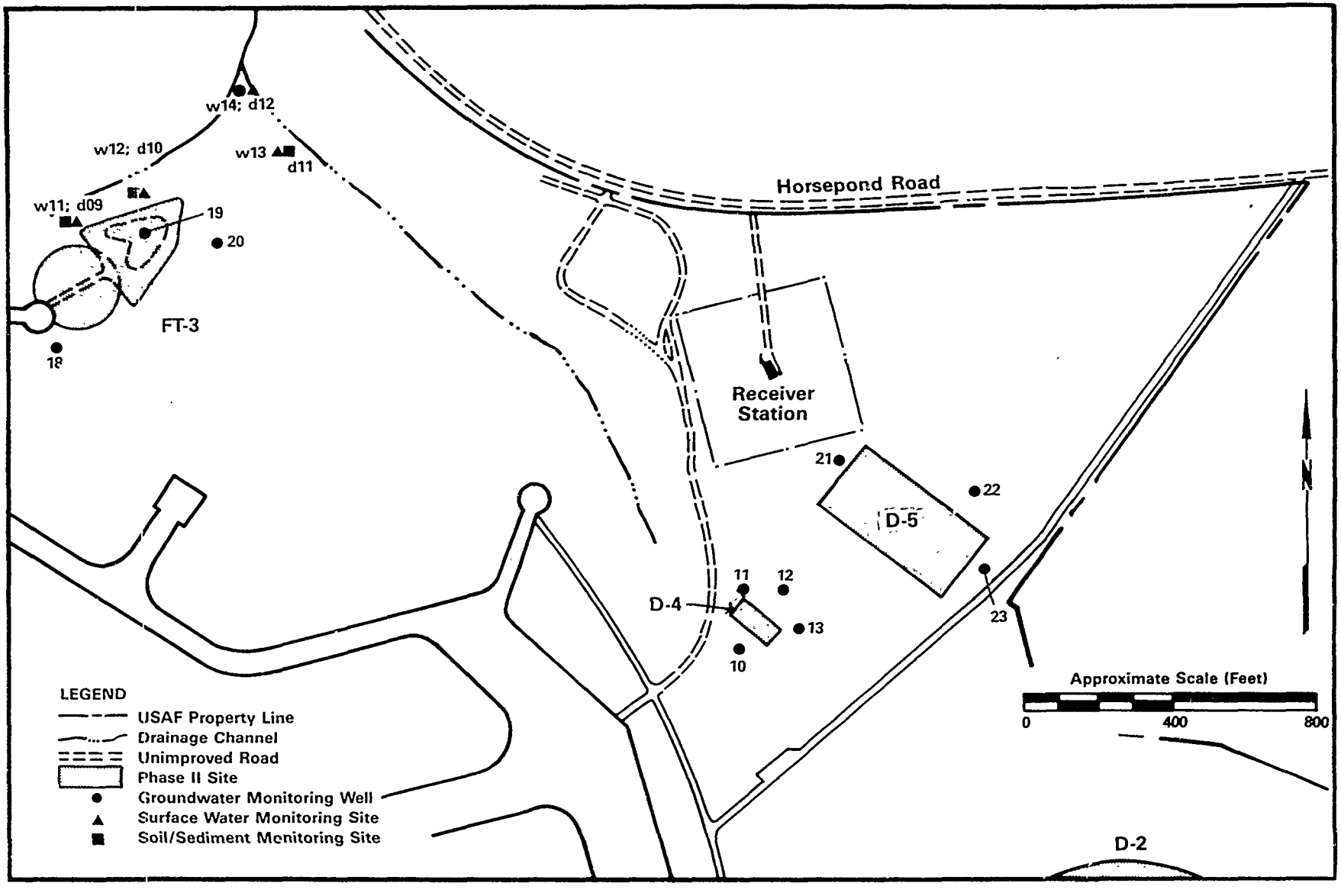


Figure 1-6. Sites D-4, Liquid Waste Site and D-5, Landfill (Receiver Station Sites), and Site FT-3, Fire Training Area 3

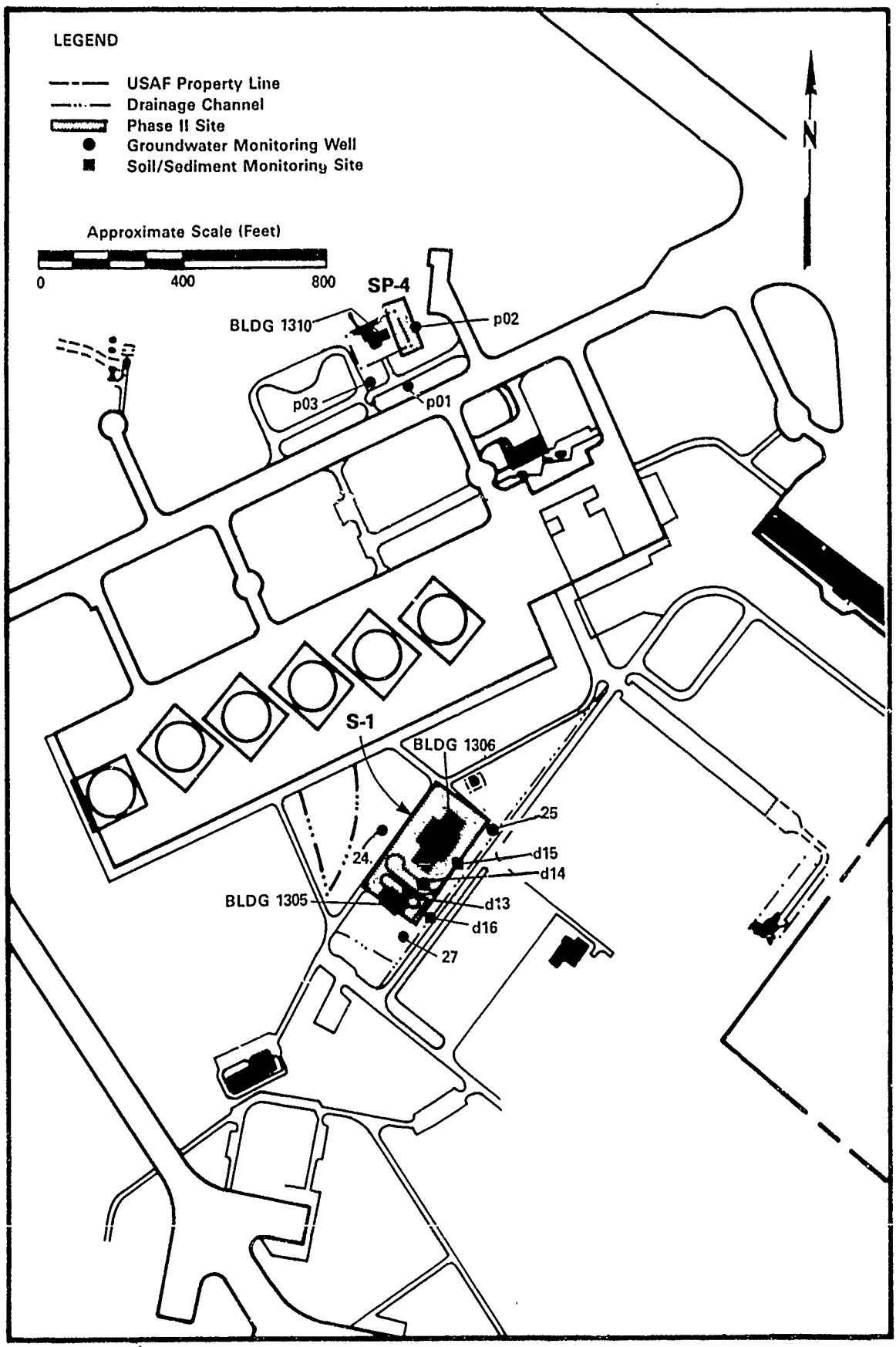


Figure 1-7. Site SP-4, JP-4 Pipeline Leak and Site S-1, Hazardous Waste Storage

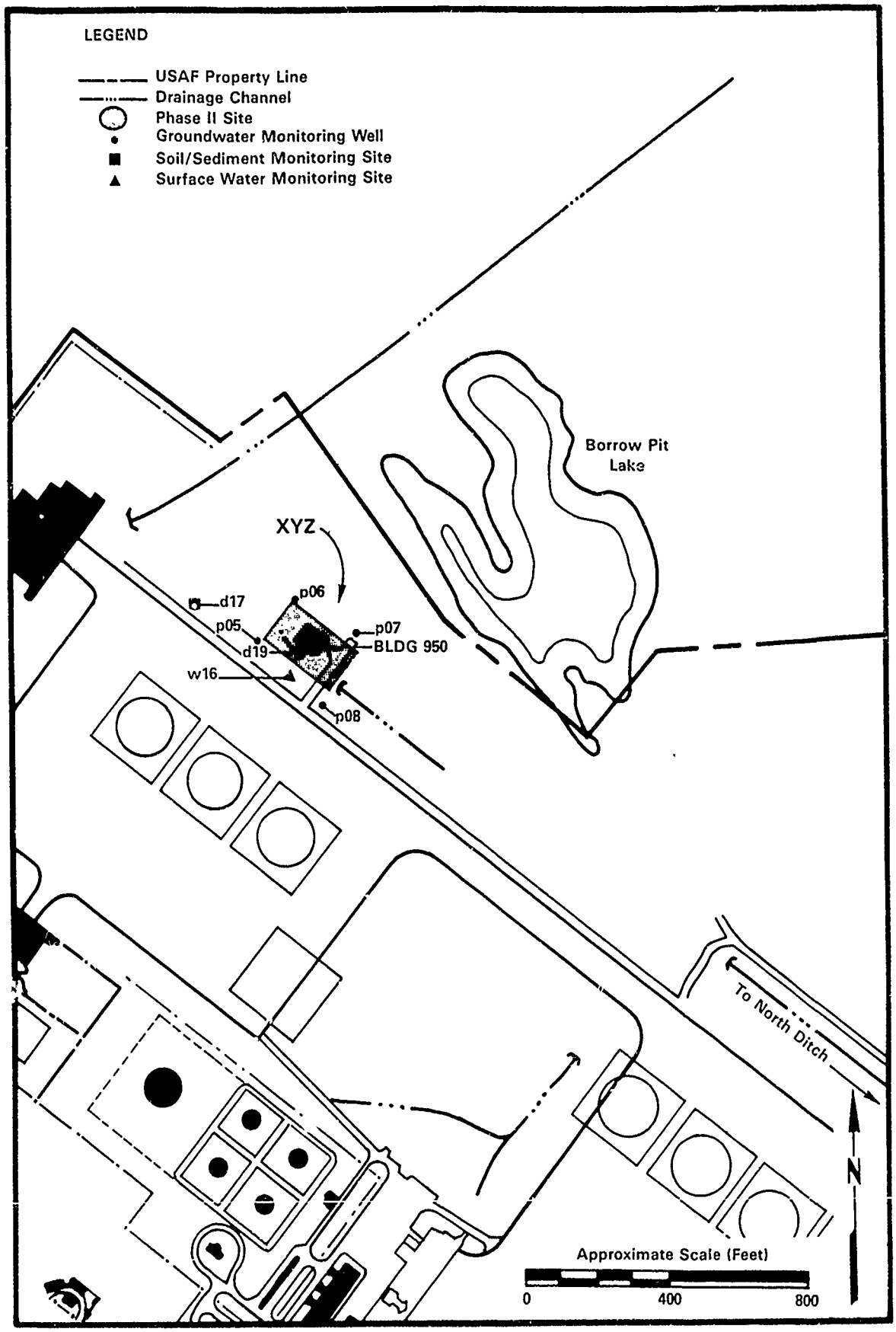


Figure 1-8. Site XYZ, Fuel Pump Station

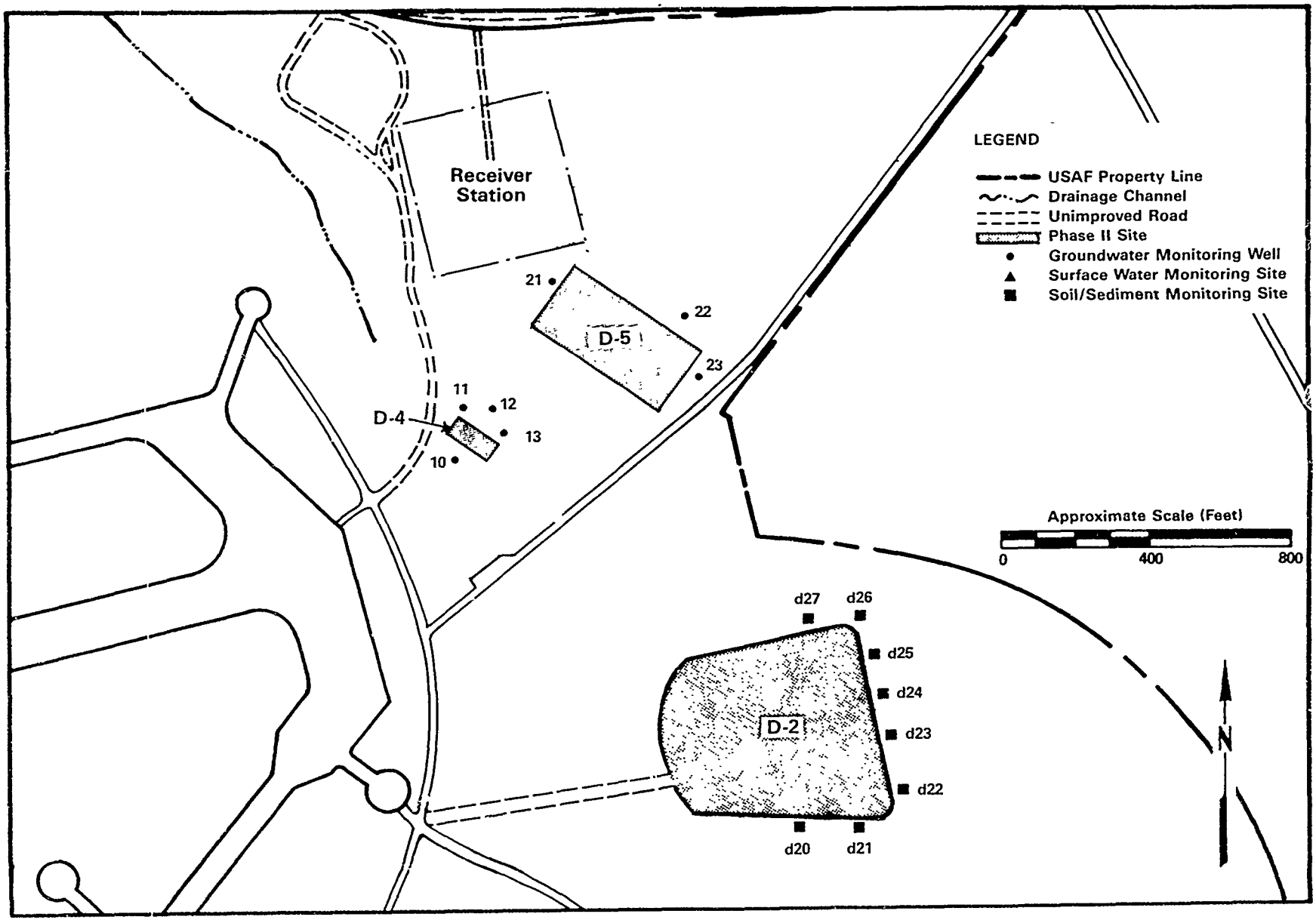


Figure 1-9. Site D-2, Rubble Area

Drilling operations began on 23 October 1984 and were completed on 26 November 1984. Twenty-five monitoring wells that are screened throughout the Columbia aquifer to the top of the Kirkwood (Miocene) silty-clay and seven monitoring well points that partially penetrate the aquifer were installed. A complete discussion of the drilling program is presented in Section 3.0. Well logs and as-built drawings for Stage 1 wells are provided in Appendix D.

Groundwater, surface water, soil and sediment sampling began on 28 November 1984 and the majority of samples were collected by 14 December 1984. Two samples of drilling cuttings were collected in January 1985 to determine compliance with EP toxicity and ignitability criterion. Surface water and groundwater samples for VOC analysis were collected in February 1985. The analysis results were reviewed by laboratory QA/QC Officers, and the results were available by 11 March 1985. Complete analysis data were transmitted to USAFOEHL in an Informal Technical Report on 29 March 1985. Results are presented in Appendix H.

Table 1-4 summarizes the analyses performed on samples collected at each site. Participants in the Phase II Stage 1 study are identified in Table 1-5. The results, findings, conclusions, and recommendations of this study are provided in other sections of this report.

1.6 RECENT DEVELOPMENTS

There have been several recent developments which affect Phase II activities. First, DAFB is in the process of removing the IW Basins from service. Industrial wastewater will be routed around the basins and the basins will be closed according to a plan developed to comply with the closure requirements under RCRA. The plans to bypass the basins are complete and contracts are being negotiated to complete the work. Successful implementation of this plan will remove a source of groundwater contamination in the basin area.

In October 1984, a fuel leak at the DAFB Motor Pool (436th Transportation Squadron) was discovered and fixed. The leak was located upgradient of the DNREC monitoring wells and the contaminated trailer park wells. The fuel leak is a potential source of benzene, toluene, and xylene found in the DNREC

Table 1-4

SUMMARY OF DAFB PHASE II STAGE 1 CHEMICAL ANALYSIS

Site	Media	Parameters						
		Volatile Organics[a]	Oil and Grease	Cyanide and Phenols	Metals[b]	TOX	TOC	PCBs
1. T-1, IW Basins	GW/SW/SED	X	X	X	X	X	X	
2. DD-1, North Ditch	SW/SED		X	X	X	X	X	
3. D-10, Landfill	GW		X	X	X	X	X	
4. D-4, Liquid Waste Site	GW	X	X	X	X	X	X	
5. FT-1, Fire Training Area 1	GW/SW		X		X	X	X	
6. FT-3, Fire Training Area 3	GW/SW/SED		X		X	X	X	
7. SP-4, JP-4 Pipeline Leak	GW		X				X	
8. D-5, Landfill	GW	X	X	X	X	X	X	
9. S-1, Hazardous Waste Storage	GW/SL	X	X	X	X	X	X	X
10. XYZ, Fuel Pump Station	GW/SW/SED		X				X	
11. D-2, Rubble Area	SL		X		X	X	X	

[a]Laboratory analyses by EPA Methods 601 and 602 for waters and SW 846 Methods 8010 and 8020 for sediments and soils.
[b]Arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc.
GW = Groundwater, SED = Sediment, SL = Soil, SW = Surface water.

Table 1-5

ADDRESSES AND RESPONSIBILITIES OF PHASE II STAGE 1 PARTICIPANTS

Organization	Responsibility
SAIC Waste Management Department - Applied Technologies Group 8400 Westpark Drive McLean, VA 22102 703/821-4600	• Project management • Subcontractor management • Technical direction • Drilling supervision • Sampling • Data evaluation • Report preparation
Delmarva Drilling Co., Inc. Bridgeville, DE 19933 302/337-8254	• Drilling program implementation • Installation and development of wells
Gerald A. Donovan Associates, Inc. 439 S. Governors Avenue Dover, DE 19901 302/674-2903	• Project surveyor • Establishment of horizontal and vertical control for all wells
Dr. Richard H. Berry, P.G. (DE #249) 5203 Richardson Drive Fairfax, VA 22032 703/323-5211	• Project professional geologist • Technical review • Hydrogeologic data evaluation • Report review and technical approval
SAIC Laboratories 476 Prospect Street La Jolla, CA 92038	• Laboratory coordination • Sample analysis - Metals - Oil and grease - Polychlorinated biphenyls (PCBs)
Laucks Testing Laboratories, Inc. 940 South Harvey Street Seattle, WA 98108	• Sample analysis - Cyanide - Phenols - Total organic halogens (TOX) - Total organic carbon (TOC) - EP Toxicity
Environmental Research Group, Inc. 117 N. First Street Ann Arbor, MI 48104	• Sample analysis - Volatile organic compounds (VOCs)

wells. However, the leak cannot be a source of the solvents found in the Trailer Park Area drinking water wells.

In late 1984, DNREC sampled a private well (the Green House well, Figures 1-1 and 1-5) south of Route 113 across from DAFB. TCE was found in excess of 600 ug/l in the well. On 25 January 1985, DAFB also sampled Stage 1 monitoring wells 06j and 07j, which are adjacent to the Green House well. TCE was not detected in the sample from well 06j; and was detected at 180 ug/l in the sample from well 07j.

The remainder of this report focuses on the Phase II Stage 1 study at DAFB. Information provided in this introduction is referred to in the following sections:

- Section 2.0: Environmental Setting - Information regarding physical geography, geology, historic groundwater problems, and study sites are provided in this section.
- Section 3.0: Field Program - Field activities conducted during Phase II Stage 1 are described in this section.
- Section 4.0: Discussion of Results and Significance of Findings - The results of the field program and discussions of findings are provided in this section.
- Section 5.0: Alternative Measures - This section contains discussions of possible monitoring programs.
- Section 6.0: Recommendations - The conclusions made as a result of data gathered during Phase II Stage 1 are provided in this section.

2.0 ENVIRONMENTAL SETTING

The environmental setting at DAFB must be understood to evaluate data obtained and recommendations made as part of this Phase II Stage 1. Dover AFB (DAFB) is located in an area of little relief (+30 feet MSL to +10 feet MSL). The base lies along a topographic high that creates a natural drainage divide; consequently, surface waters flow off base to the north, northeast, and southwest. Near this divide, surface waters may not have eroded their channels to depths below the water table, and may be recharging groundwater via infiltration. However, most area streams receive up to 75 percent of their base flow from groundwater discharging from the Columbia aquifer, which is the water table aquifer under DAFB (Johnston, 1971 and 1973). The Columbia consists of coarse to fine sands with lenses of silt and clay. Hydraulic gradients within the Columbia range from 0.09% to 0.45% under DAFB, with resultant groundwater flow rates ranging from 0.41 ft/day to 2.03 ft/day. The Columbia is underlain by a dense, gray-black, silty clay of Miocene Age identified as part of the Kirkwood Formation (Rasmussen et al., 1958). The low hydraulic conductivity of this silty clay, i.e., a calculated high value of 1×10^{-7} cm/sec (Leahy, 1982), will reduce the rate of groundwater flow to the underlying Frederica aquifer. The Frederica, which is not used to supply water in the DAFB area, overlies the Cheswold and Piney Point aquifers, which supply approximately 80 percent of the total municipal and industrial water pumped in Kent County, Delaware (Leahy, 1982).

This section contains a summary of the physical geography, regional and local geology, and hydrogeology of the DAFB area. The history of and the geologic and hydrogeologic conditions found at each Stage 1 site are also discussed.

2.1 PHYSICAL GEOGRAPHY

DAFB is located on a broad, low plain about 1 mile west of Delaware Bay and approximately 3.5 miles southeast of the center of the City of Dover, Kent

County, Delaware. The base lies on the portion of the Atlantic Coastal Plain Physiographic Province known as the Delmarva Peninsula, which is characterized by broad sandy plains that have been infrequently dissected by moderately to highly sinuous streams and rivers. The low relief of the area can be seen on the recently revised topographic map shown in Figure 2-1. Surface elevations range from about +10 feet MSL along the St. Jones River southeast of the base to +30 feet MSL along the base's western boundary. The SE-NW runway has an elevation of +28 ft MSL, which is higher than most of the surrounding area.

The higher elevations along the SE-NW runway mark the location of a drainage divide. Surface waters flow downslope away from this divide (Figure 2-2). On-base runoff and nonprocess waters are discharged to several surface water diversions (e.g., the North Ditch). Close to the divide, the depth of the water table is estimated to be 15 feet and surface waters in the diversion ditches may not have eroded their channels below the water table level. Consequently, surface waters may infiltrate and recharge groundwater. Downslope from the drainage divide, the diversions and streams cut below the water table level and groundwater discharge apparently occurs. In Delaware, small streams may receive up to 75 percent of base flow from groundwater (Johnston, 1971 and 1973).

Because of the drainage divide, surface waters on the northern portion of the base flow northeast through Morgan and Pipe Elm Branches to the Little River and the southern portion drains southwest to the St. Jones River. Both the Little and St. Jones rivers flow to the Delaware Bay. Wetlands exist along the St. Jones River south of base housing and the golf course and northeast of the existing fire training area along a small stream that flows into Pipe Elm Branch.

Temperature, precipitation, and snowfall data recorded at DAFB over a 39-year period are provided in Table 2-1. July and August are the wettest months of the year, each averaging over 4 inches of precipitation. The mean annual precipitation is 41.7 inches, with a calculated net precipitation of 6.3 inches. This amount is available to recharge groundwater.

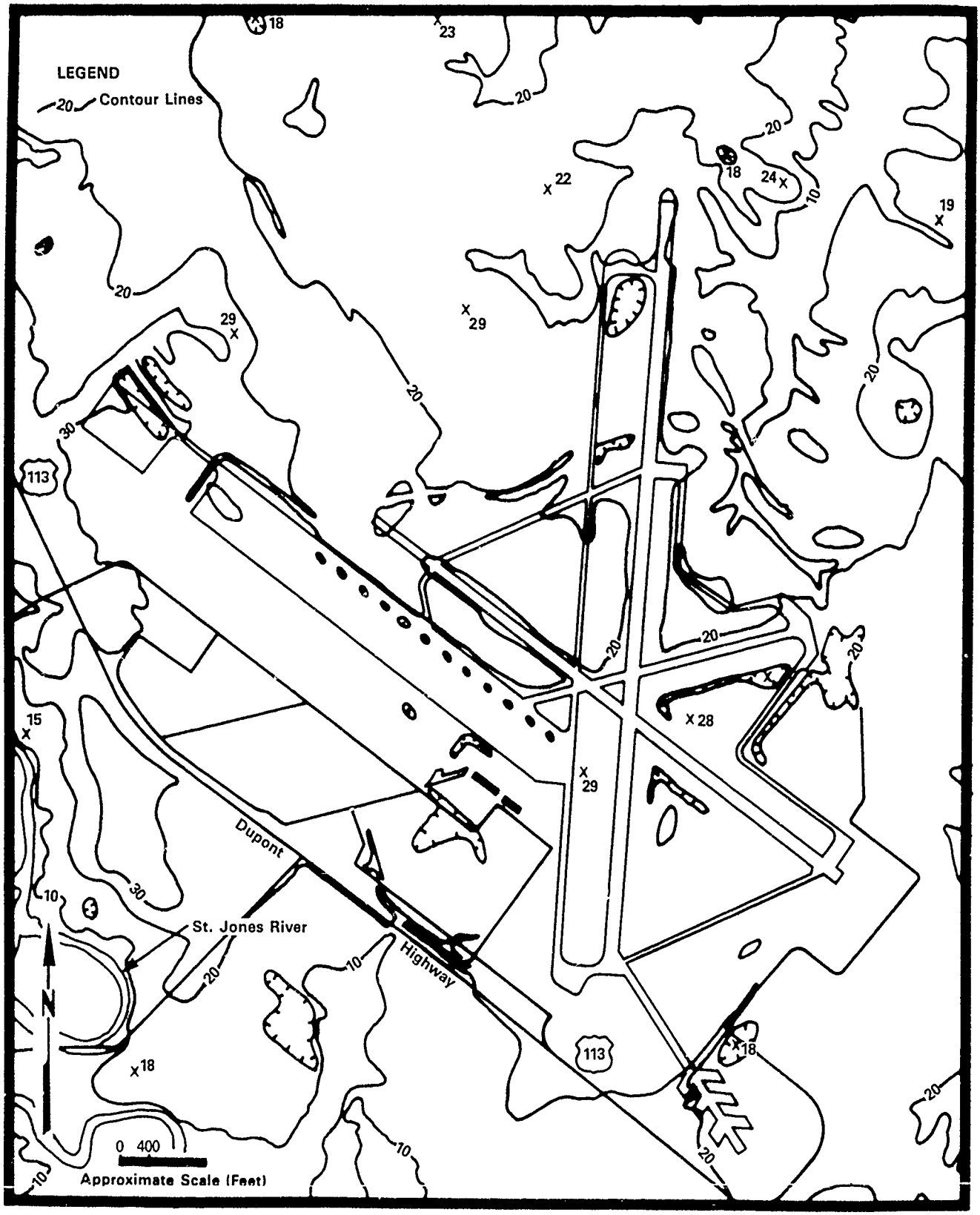


Figure 2-1. Topographic Map, Dover AFB Area

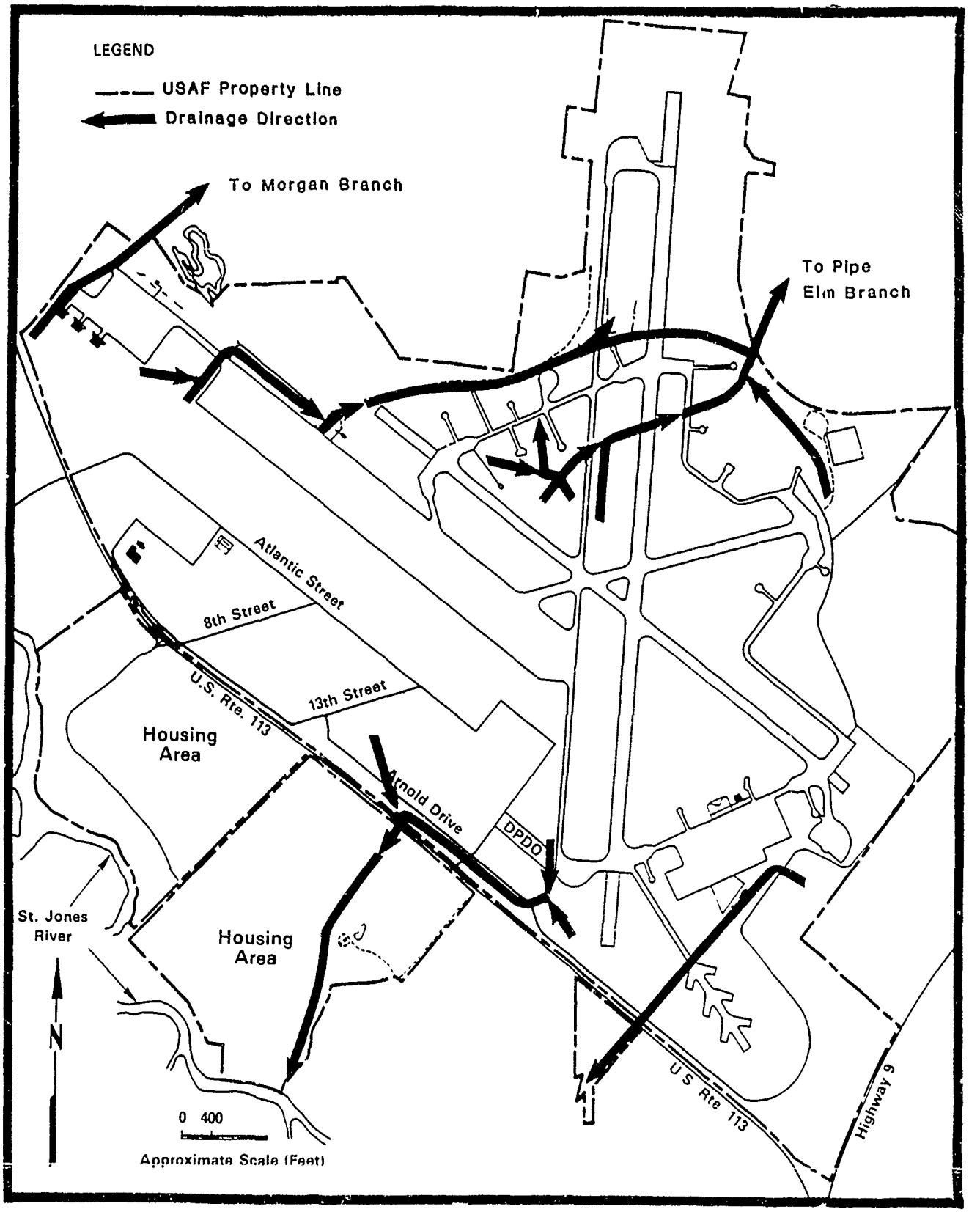


Figure 2-2. Installation Drainage, Dover AFB

Table 2-1

SUMMARY OF METEROLOGIC DATA - DOVER AFB

MONTH	Temperature (°F)					Precipitation (In)				Snowfall (In)		
	Mean			Extreme		Monthly				Monthly		
	Daily		Monthly						Max			Max
	Max	Min		Max	Min	Mean	Max	Min	24 Hrs	Mean	Max	24 Hrs
Jan	40	26	33	72	-3	3.1	8.2	#	2.2	5	22	7
Feb	43	27	35	76	0	3.0	7.5	#	2.7	7	34	18
Mar	52	35	43	87	9	3.7	7.2	#	2.0	3	20	8
Apr	62	44	53	89	21	3.1	7.9	#	2.6	#	2	2
May	72	54	63	97	33	3.3	7.7	#	2.5	#	#	#
Jun	81	63	72	100	43	3.1	6.6	.7	2.8	0	0	0
Jul	85	68	76	101	52	4.3	12.6	.8	5.4	0	0	0
Aug	83	66	75	100	48	4.5	16.6	#	9.0	0	0	0
Sep	77	60	69	97	39	3.4	7.7	.4	3.5	0	0	0
Oct	66	48	57	91	24	3.1	6.9	#	4.1	#	#	#
Nov	55	38	47	83	14	3.5	8.6	.5	5.7	1	9	9
Dec	45	29	37	74	-4	3.6	8.1	.0	2.7	2	11	9
Annual	63	47	55	101	-4	41.7	16.6	.0	9.0	18	34	18

#: Trace

Source: Engineering Science, 1983.

2.2 REGIONAL HYDROGEOLOGY

The Columbia aquifer is the water table aquifer beneath DAFB and, therefore, is most likely to be affected by land disposal or waste management activities. Below the Columbia is the Kirkwood Formation, which consists of silty-clay of Miocene Age (12 to 26 million years old). The integrity, thickness, and permeability of the Kirkwood (Miocene) silty-clay layer controls the flow of groundwater moving from the Columbia to the deeper aquifers. The hydrogeologic conditions existing in the Frederica aquifer which underlies the Kirkwood (Miocene) will also impact vertical groundwater flow. Beneath the Frederica are the principal water supply aquifers in the area, the Cheswold and Piney Point. Pumping in these aquifers has increased the flow rate of water moving downward from the Columbia aquifer based on information provided by Leahy (1982).

Geologic and hydrogeologic information about these formations is provided below. Geochemical information on the Columbia is also provided so that the environmental chemistry results obtained during this study can be evaluated in comparison to naturally occurring concentrations.

2.2.1 Regional Geology

DAFB is located in the Atlantic Coastal Plain Province. According to Foster (1950), the Coastal Plain is a wide belt of sedimentary deposits of gravel, sand, clay, shale, limestone, chalk, and marl that dip towards the southeast. The western boundary of the Province is called the Fall Line, which is a broad zone of waterfalls and rapids caused by abrupt gradient changes as streams flow eastward from areas underlain by crystalline rocks to areas of unconsolidated sediments. Crystalline rocks lie at or near the surface at the Fall Line, but are found at progressively greater depths eastward towards the coast. Because of the slight southeasterly dip, successively younger formations outcrop closer to the coast. Water enters the formations where they outcrop and then moves downdip (southeast) towards the coast. Groundwater occurs in the permeable sands, gravels, and limestones, while the low permeability clays and shales are confining layers.

The Coastal Plain stratigraphy of Delaware is summarized on Table 2-2. The stratigraphic relationship and seaward dipping trend of the formations is shown in the north-south cross section developed by Leahy (1979) (Figure 2-3). From this figure, the layer-cake stratigraphy of the Coastal Plain is evident. The stratigraphic sequence under DAFB includes the Columbia Formation at the surface, the Kirkwood (Miocene) Formation underneath, and the Frederica, Cheswold, and Piney Point aquifers (with intervening confining layers) found at successively greater depths.

Johnston (1977) described the Columbia as a broad sheet of Pleistocene age fluvial sediments that cover most of Kent County. According to Jordan (1964), these sediments were deposited by streams which originated in glacial areas, entered Delaware from the northeast, and spread south and southeast. North of DAFB in southern New Castle County, the streams coalesced into a system of braided channels (Spoljavic, 1967). From the Kent-New Castle County line south, the Columbia deposits consist of a sheet of sand which thickens southward across Kent and Sussex Counties. The color of these sands ranges from reddish brown and purplish black through shades of brown to tan, yellow, or light gray, depending on the amount of iron present. In general, dark brown sands contain greater than 4 percent ferric iron, whereas the yellow and light gray sands contain less than 1 percent ferric iron (Johnston, 1973). In extreme southern Delaware, these deposits were probably reworked by transgressing and regressing seas, as indicated by the beach, dune, estuarine, offshore bar, and lagoonal deposits that are found in the area (Jordan, 1964).

The Columbia's diverse depositional setting probably caused its undulating base (Figure 2-4). The base of the Columbia becomes less well defined in southern Delaware as underlying deposits become more sandy. However, in central Delaware and the DAFB area Columbia deposits are distinguishable from underlying gray-black Kirkwood (Miocene) silty clays. Variability in the elevation of the Columbia-Kirkwood contact in the DAFB area is greater than 50 feet. Locally, this pronounced relief may impact groundwater flow directions.

Table 2-2

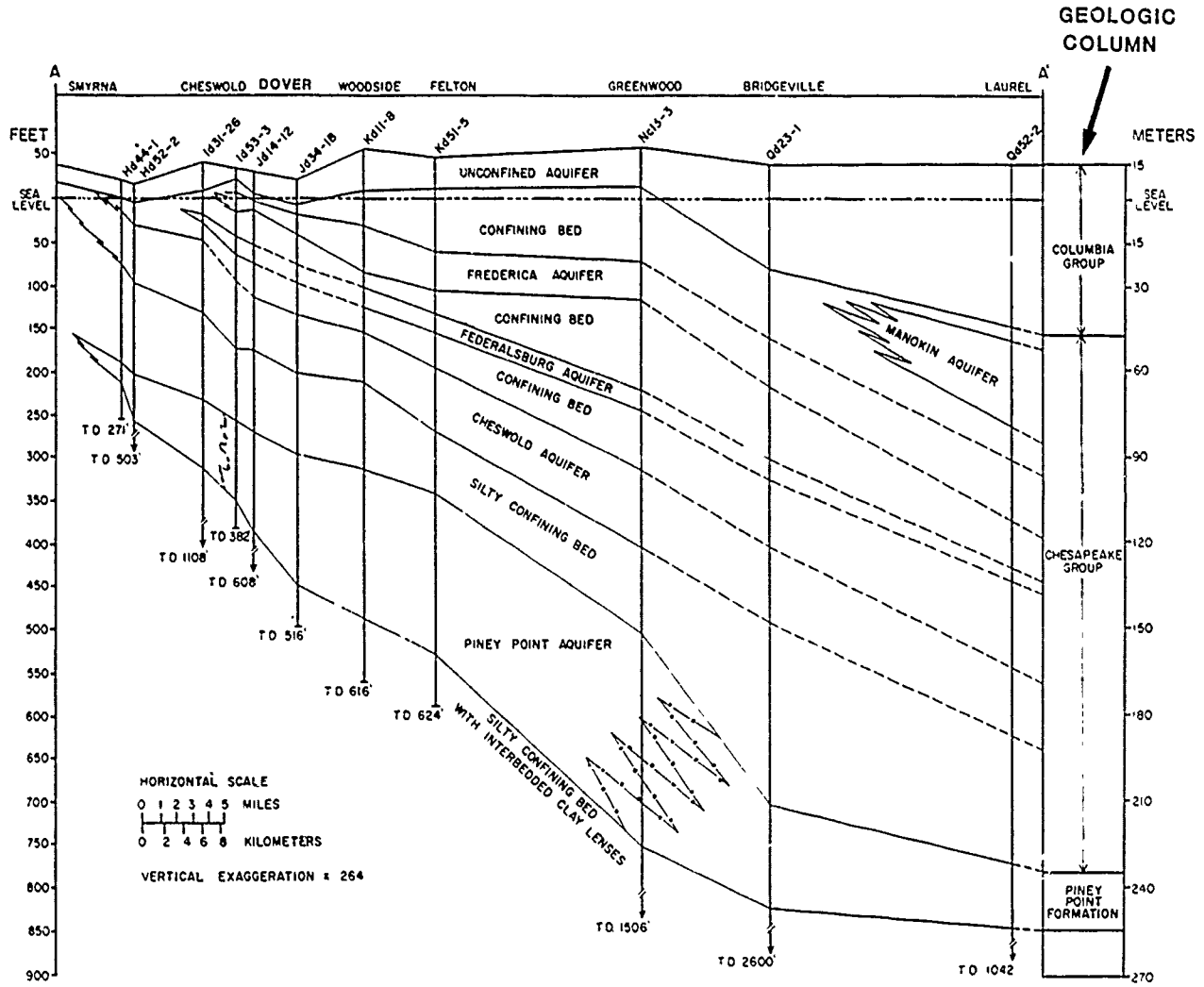
STRATIGRAPHIC UNITS AND MAJOR AQUIFERS UNDERLYING THE COASTAL PLAIN OF DELAWARE AND MARYLAND

System	Series	Stratigraphic Units: Maryland	Stratigraphic Units: Delaware	Aquifers in the Coastal Plain	Aquifers and confining beds in Kent County study area as used in this report
Quaternary	Holocene	--------	--------	Unconfined aquifer	Unconfined aquifer
	Pleistocene	Columbia Group undivided	Columbia Group undivided		
Tertiary	Miocene	Brandywine Formation	--------	Pocomoke aquifer	Sandy confining bed
		Chesapeake Group: St. Marys Formation, Choptank Formation, Calvert Formation	Chesapeake Group undivided	Manokin aquifer; Frederica aquifer; Federalsburg aquifer	
				Cheswold aquifer	Cheswold aquifer
					Silty confining bed
	Oligocene				
	Eocene	Piney Point Formation, Nanjemoy Formation	Piney Point Formation, Nanjemoy Formation	Piney Point aquifer	Piney Point aquifer
	Paleocene	Aquia Formation, Brightseat Formation	Rancocas Group: Vincentown Formation, Hornerstown Formation	Rancocas aquifer	Clayey confining bed
Cretaceous	Upper Cretaceous	Monmouth Formation, Matawan Formation, Magothy Formation, Raritan Formation	Mount Laurel Formation; Matawan Group: Marshalltown Formation, Englishtown Formation, Merchantville Formation; Magothy Formation	Magothy aquifer	Magothy aquifer
	Lower Cretaceous	Potomac Group: Patapsco Formation, Arundel Formation, Patuxent Formation	Potomac Formation	Nonmarine Cretaceous aquifer	

Explanation: Section not present.

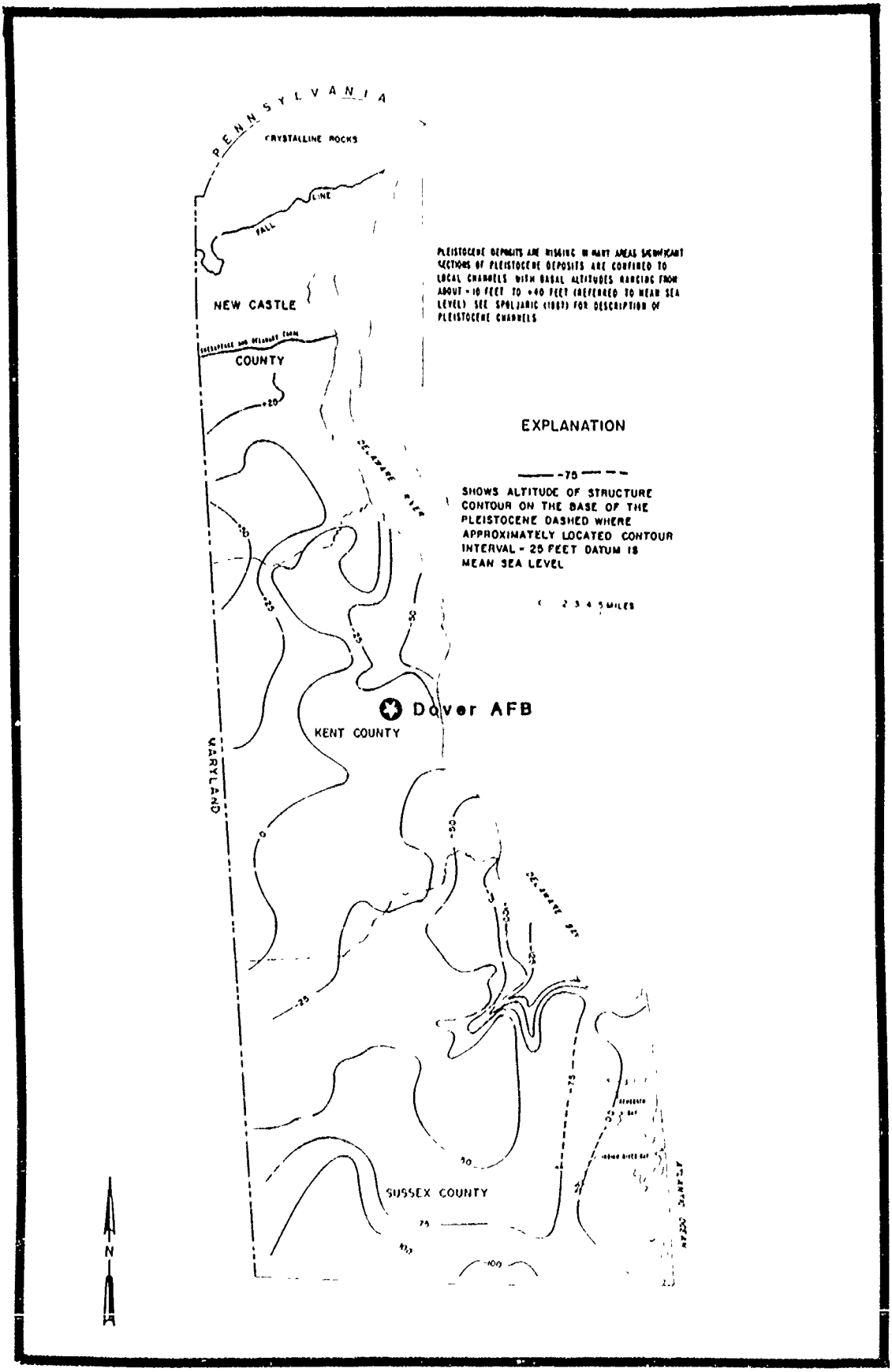
The stratigraphic nomenclature used is that of the Delaware Geological Survey and Maryland Geological Survey and does not necessarily follow the usage of the U. S. Geological Survey.

Source: Leahy, 1982



Source: Modified from Leahy, 1979

Figure 2-3. Generalized Geologic Section, Dover AFB



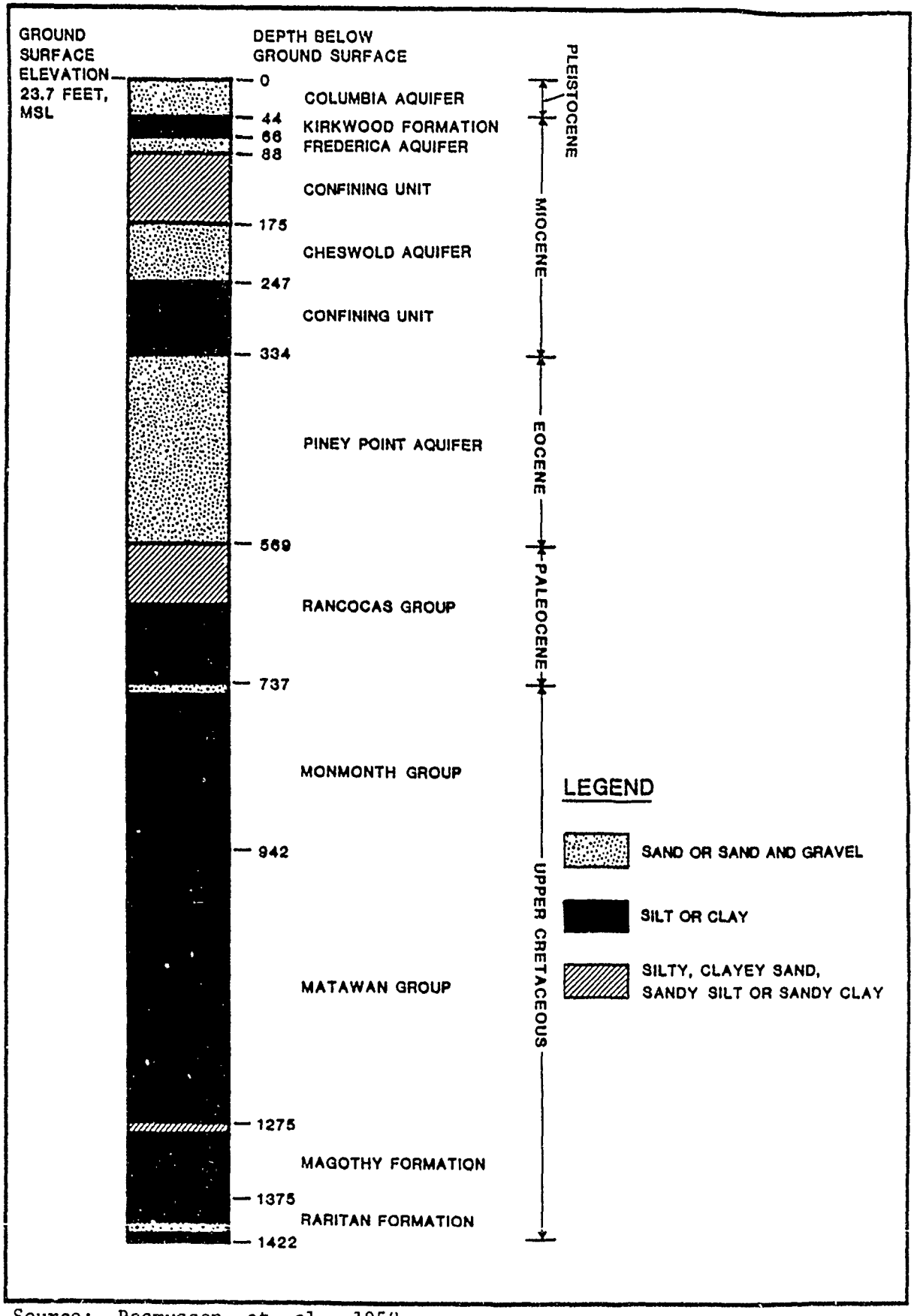
Source: Johnston, 1973

Figure 2 4. Structure Contour Map of the Base of the Columbia (Pleistocene) Deposits

Published information on the lithology of either the Kirkwood (Miocene) silty clay unit or the Frederica aquifer is limited. Leahy (1982) groups both units with other members of the Chesapeake Group and describes them as containing gray and bluish-gray silt with beds of light gray, fine to medium sand. During the Phase II Stage 1 drilling program, the Kirkwood (Miocene) Formation immediately below its contact with the Columbia was found to consist of firm, dense, very dark gray (Munsell 5Y 4/1) silty clay containing traces of very fine sand with light to dark gray (2.5Y 4/0) very fine sand and silt laminations. The top of the formation was found between -8.4 feet MSL and -43 feet MSL at all locations, but was between -20 feet MSL and -43 feet MSL in all but one borehole. Stage 1 wells did not penetrate the Kirkwood (Miocene), and information on the thickness of the Kirkwood or the lithology of the Frederica aquifer below are not available.

Underlying the Frederica are the Cheswold and Piney Point aquifers, which are the primary water supply aquifers in the Dover area. Figure 2-5 shows the depths to and thicknesses of these aquifers as found in a USGS test well located on DAFB.

According to Leahy (1982), the Cheswold is composed of fine to coarse sand with shells. Aquifer thickness ranges from zero at its updip limit to more than 150 feet downdip and is 50 to 75 feet thick in the Dover area. The elevation of the top of the Cheswold ranges from about sea level in the Smyrna-Clayton area 9 miles north of DAFB to about -360 feet MSL near Milford 17 miles south of DAFB (Sundstrom and Pickett, 1968). The reported dip of the aquifer is about 11 feet per mile (0.21%) between Smyrna and Dover. A thick, silty sand unit underlying the Cheswold acts as a confining bed separating the Cheswold from the Piney Point aquifer. The Piney Point contains green, fine to medium glauconitic sands. The green-colored glauconite marks the contact between the Piney Point formation and the overlying non-glauconitic sediments. The maximum thickness of the Piney Point is 251 feet and thickness decreases to zero both updip and downdip and to the northeast and southwest along strike, creating an elongated, lenticular shape. The Piney Point strikes



Source: Rasmussen, et. al., 1958

Figure 2-5. Log of USGS High-capacity Test Well No. JE 32-4 at Dover AFB

between N30°E and N47°E, with a reported dip between 15 and 31 feet per mile (0.28% and 0.59%) (Talley, 1975).

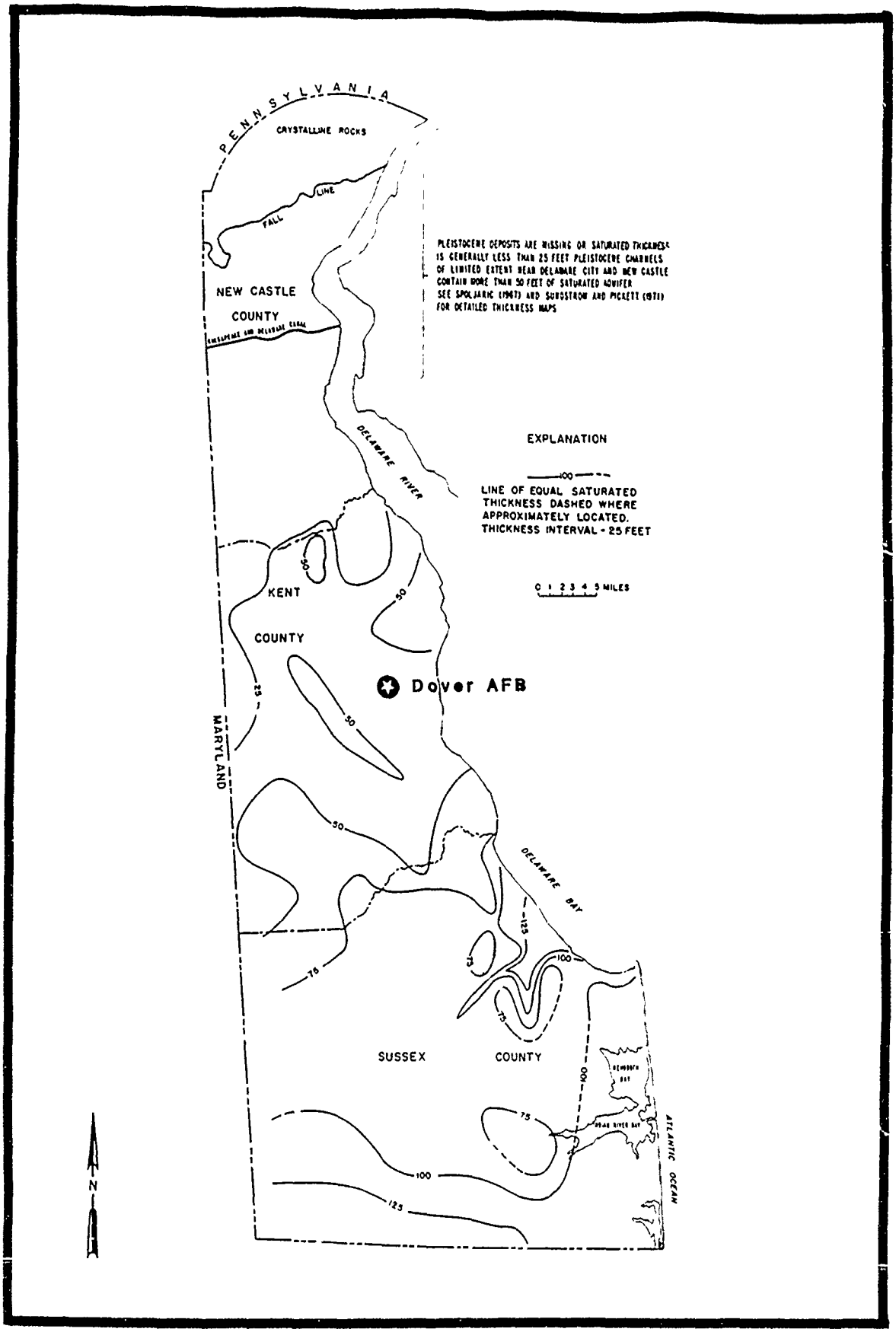
Because the Columbia occurs at the surface, it is vulnerable to the affects of land disposal or waste management activities. The silty clay underlying the Columbia will slow the rate of groundwater moving towards lower aquifers. Contaminanted groundwater migrating towards the drinking water aquifers--the Cheswold and Piney Point--would be detected in the Frederica aquifer, which is not used to supply drinking water, before being found in the deeper aquifers.

2.2.2 Regional Hydrogeology

The principal water-bearing units in the DAFB area are the Columbia, Frederica, Cheswcld, and Piney Point aquifers. The Cheswold and Piney Point provide approximately 80 percent of the total municipal and industrial water pumped in Kent County (Leahy, 1982). By contrast, pumping from the Columbia aquifer is minor (Johnston, 1977) and the water is used primarily for irrigation and domestic supply. However, because the Columbia is easily accessible and can provide large quantities of water, it is among the most important statewide groundwater resources. The Frederica is not used to supply water in the DAFB area.

The saturated thickness of the Columbia aquifer ranges from a few feet in many parts of northern Delaware to more than 180 feet in southern Delaware (Figure 2-6). The increase in saturated thickness corresponds to the southward thickening wedge of deposits (Figure 2-3). Throughout 1,500 square miles of central and southern Delaware (75% of the State's area), the saturated thickness ranges from 25 to 180 feet and the Columbia deposits comprise all or nearly all of the water-table aquifer (Johnston, 1973).

Johnston (1973) conducted the most definitive study of the Columbia aquifer in Kent County and stated that the aquifer is generally a medium to coarse sand. However, aquifer transmissivity varies greatly because of local changes in both lithology (from fine sand to coarse sand and gravel) and



Source: Johnston, 1973

Figure 2-6. Saturated Thickness Map of the Columbia (Pleistocene) Deposits in Delaware

saturated thickness. Average transmissivity in central and southern Delaware is about 7,000 ft^2/day (53,000 gpd/ft) with an average hydraulic conductivity of 90 ft/day (3.1×10^{-3} cm/sec). Six areas have been identified in central and southern Delaware where transmissivity ranges from 10,000 ft^2/day (75,000 gpd/ft) to 22,000 ft^2/day (170,000 gpd/ft). These areas occur where troughs in the base of the Columbia increase the aquifer's saturated thickness. The highest transmissivities are found where these thicker saturated zones contain primarily clean, coarse sand and interbedded gravel. A specific yield of 0.15 is considered representative for the aquifer.

Streamflow hydrographs indicate that average groundwater discharge from the Columbia is about 800 mgd. Average recharge to the aquifer, as computed from runoff values during the nongrowing season, is approximately 1 billion gallons per day. Present pumpage (33 mgd) is small compared to the aquifer's natural discharge (800 mgd). The specific capacity of large diameter wells in the Columbia ranges from about 5 to 100 gpm/ft (gallons per minute per foot of drawdown) and averages 28 gpm/ft. Throughout most of central and southern Delaware, the Columbia is capable of producing 500 gpm or more for short periods of time.

The hydrogeologic properties of the Kirkwood (Miocene) silty clay unit underlying the Columbia in the study area are not known. However, Leahy (1982) makes several assumptions and estimates the hydraulic conductivity at between 8.0×10^{-5} and 4.0×10^{-4} ft/day (2.7×10^{-8} to 1×10^{-7} cm/sec).

The hydrogeologic properties of the Frederica aquifer are not known. Groundwater in the formation presumably moves downdip (southeast) in the absence of pumping. The Frederica does not outcrop in Delaware, so recharge takes place in the subcrop area north of DAFB, or occurs as water moves downward through the Kirkwood (Miocene) unit.

According to Leahy (1982), transmissivities of the Cheswold aquifer range from 7,400 ft^2/day at Dover to 350 ft^2/day at Magnolia, approximately 5 miles south of the base. Transmissivities of the underlying Piney Point aquifer range from 7,350 ft^2/day near Lebanon, approximately 2.5 miles southwest of

DAFB, to 26 ft^2/day near Magnolia. Storage coefficients for the Cheswold range from 1.4×10^{-4} to 3.1×10^{-4}, and for the Piney Point range from 3.6 to 10^{-4} to 1.9×10^{-4}. The Cheswold is recharged from the Columbia at its subcrop area north of Dover and by vertical leakage through the Kirkwood (Miocene) unit. The Piney Point has neither an outcrop, nor a subcrop; therefore, recharge to the aquifer is by vertical leakage from the Cheswold.

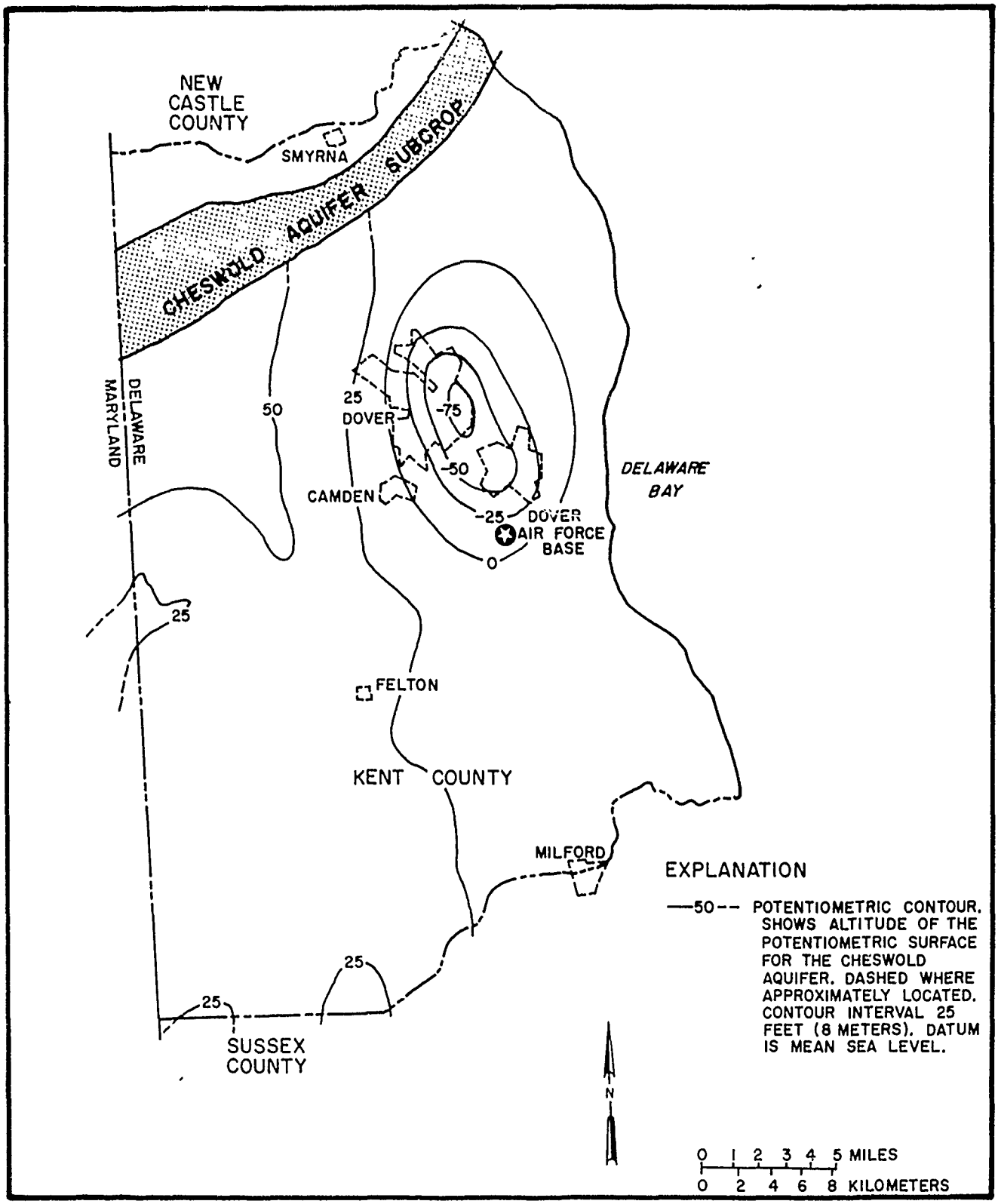
Flow within the Cheswold and Piney Point in the absence of pumping (prior to 1893) was probably downdip (southeast). However, pumping has drastically altered natural groundwater flow conditions in both aquifers. The Cheswold has been pumped at Dover since 1893 and development of the Piney Point began in 1952. Leahy (1982) estimated that heads (i.e., water levels) in the Cheswold declined over 100 feet from prepumping levels by 1977, with 60 percent of this decline occurring between 1952 and 1977. Leahy also estimated that levels in the Piney Point declined as much as 110 feet between 1952 and 1977. Potentiometric surface maps of both aquifers (Figures 2-7 and 2-8) show the extent of the cones of depression caused by pumping in the Dover area.

One result of the decline in head levels is an increase in the rate of groundwater flow from the Columbia through the confining layers to the Cheswold and Piney Point. This increased downward flow rate has decreased the time required for groundwater from the Columbia to reach the lower aquifers. This time interval depends in part on the rate groundwater flows through the Kirkwood (Miocene) unit. Groundwater flow rates are calculated using Darcy's Law, but because of the limited information available, several assumptions must be made in order to calculate flow rates through the Kirkwood (Miocene) unit under DAFB. These assumptions are:

1. The vertical hydraulic conductivity of the Kirkwood (Miocene) silty clay is equal to the highest value of horizontal hydraulic conductivity calculated by Leahy (1982), which is 4×10^{-4} ft/day.

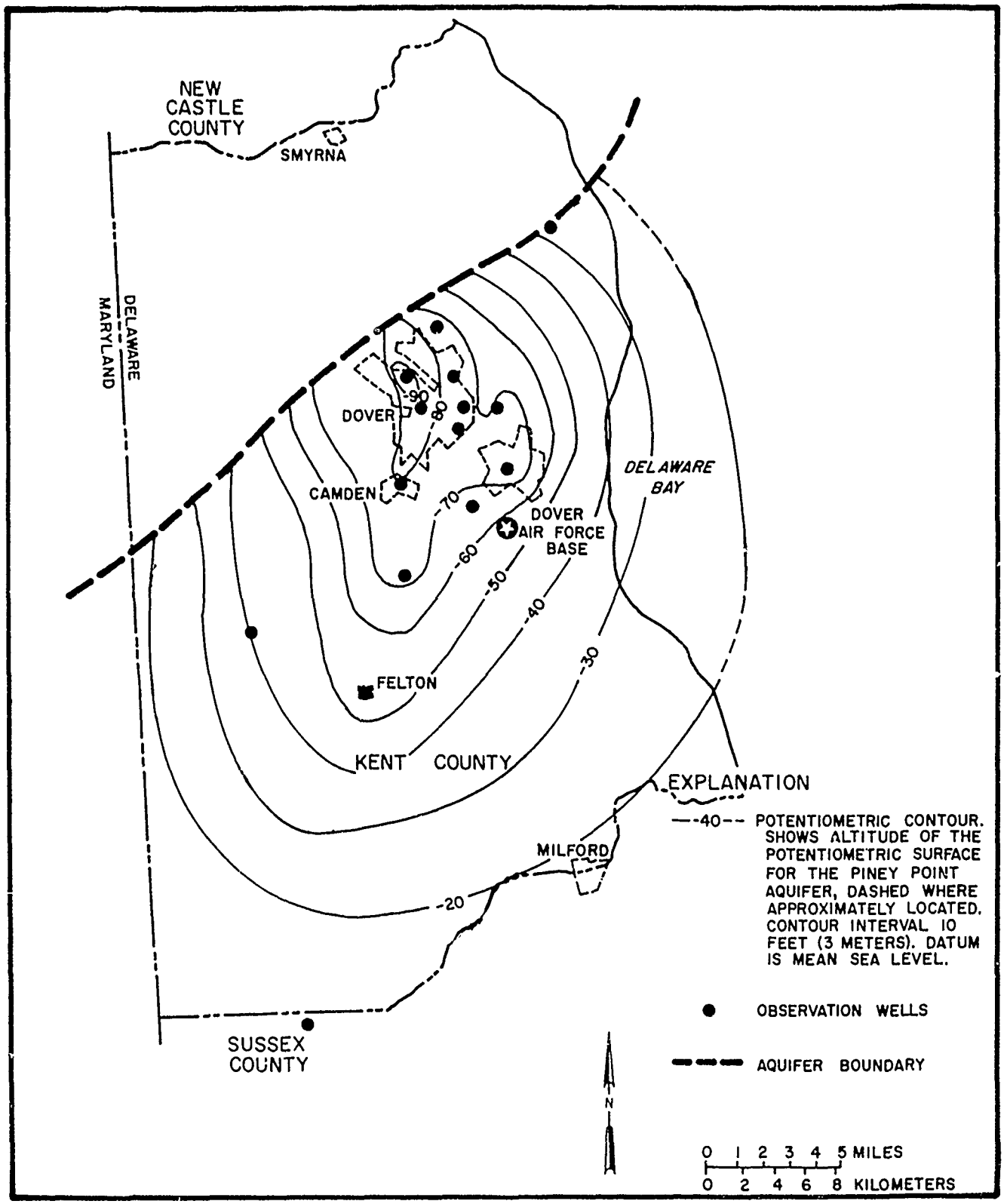
2. The effective porosity of the Kirkwood (Miocene) is 0.4.

3. The hydraulic gradient within the Kirkwood (Miocene) is the same as that between the Columbia and the Cheswold. This gradient is 0.4, based on the 125-foot vertical distance between the Columbia and the Cheswold, and the assumed potentiometric surfaces in the Columbia and



Source: Leahy, 1979

Figure 2-7. Potentiometric Surface of the Cheswold Aquifer, Kent County, Delaware.



Source: Leahy, 1979

Figure 2-8. Potentiometric Surface of the Piney Point Aquifer, Kent County, Delaware.

Cheswold of +15 feet MSL and -35 feet MSL respectively. The potentiometric surface for the Columbia was based on Phase II Stage 1 information, and the value for the Cheswold was estimated from Figure 2-7, assuming that pumping has lowered the water level in the Cheswold by 10 feet since 1979.

Using these values and Darcy's Law, the rate at which water moves through the Kirkwood (Miocene) can be calculated as follows:

$$\text{Velocity} = Ki/n$$

where: K = hydraulic conductivity (ft/day)
i = hydraulic gradient (dimensionless)
n = effective porosity (dimensionless)

Flow through the Kirkwood (Miocene) is calculated as follows:

$$V = Ki/n = (4 \times 10^{-4} \text{ ft/day})\ (0.4)/(0.4)$$
$$= 4 \times 10^{-4} \text{ft/day}.$$

Groundwater moving at this rate would require approximately 150 years to penetrate the 22 feet of Kirkwood (Miocene) silty clay known to exist under DAFB. That is, groundwater will take 150 years to move from the Columbia to the next lower aquifer, the Frederica, and would require a longer time period to move from the Frederica through the intervening sandy confining layers to the major water supply aquifers.

The hydrogeologic data summarized above support the following conclusions:

1. Because of local surface exposure, high hydraulic conductivity, and the lack of internal, laterally continuous, low conductivity zones, the Columbia aquifer appears to be highly prone to being affected by land disposal sites or waste management activities.

2. Because the base flow of many streams consists of groundwater from the Columbia, surface waters downgradient of sites that have affected groundwater also may be affected. However, in certain areas (e.g., the North Ditch) where water runoff and other nonindustrial water is discharged to surface water diversions that have not eroded to below

the water table, groundwater will be recharged by the surface waters. Chemical constituents in surface waters may enter groundwater in these areas.

3. Because of the low hydraulic conductivity and apparent lateral continuity of the Kirkwood (Miocene) unit, it will slow the vertical migration of groundwater to lower aquifers.

4. Contaminants moving towards the lower aquifers would first be detected in the Frederica aquifer, which is above the major supply aquifers in the area.

2.2.3 Regional Geochemistry

There is not a large amount of data available on the geochemistry of soils, surface water, and groundwater in the DAFB area. Information on the occurrence of VOCs in the area was not found, however, these compounds are not known to naturally occur in the environment. Limited information was found on selected metals and several other parameters measured during Stage 1. This information is summarized in Table 2-3.

Groundwater in the Columbia is generally soft, slightly acidic, and contains low dissolved solids. In some areas, high iron content and low pH may require treatment. Based on samples from 12 Columbia aquifer wells located in Kent County (Table 2-3), groundwater is acidic to slightly acidic (pH from 4.8 to 6.8), has a low specific conductance (67 umhos to 290 umhos) and, except for iron (up to 30,000 ug/l), contains low concentrations of dissolved metals. The total organic content (TOC) of the groundwater ranged from 1.1 mg/l to 3.2 mg/l.

Little information on surface water quality in the area was found. Information provided in Table 2-3 was obtained from one study conducted in 1973 by the University of Delaware. This study found low concentrations (less than 15 ug/l) of the metals cadmium, lead, and mercury and higher concentrations (up to 90 ug/l) of copper in streams. The study also found concentrations of these metals in rainwater, which may have affected the concentrations found in the streams.

Table 2-3

DAFB PHASE II STAGE 1. REGIONAL GEOCHEMISTRY INFORMATION

Media	No. of Samples	pH (Std. Units)	Sp. Cond. (umhos/cm)	As	Cd	Cr	Cu
				(Results in ppb, except as noted)			
Columbia Aquifer Groundwater[a]	12 wells	4.8-6.8	67-290	-	<1-3	-	<10-60
Surface Waters[b]	2 streams multiple samples	-	-	-	0.6-1.8	-	0.3-90
Rainfall[b]	2 points	-	-	-	0.6-13.6	-	0.9-34
				(Results in ppm, except as noted)			
Soils-Delaware[c]	2 samples	-	-	<1-2.7	-	10-50	3-7
Maryland[c]	3 samples	-	-	1.1-1.7	-	15	5-7

(continued)

[a]Source: USGS (1983). Samples collected during 1983 from 12 wells in Kent County, Delaware
[b]Source: University of Delaware (1973). Multiple samples collected during 1972 and 1973 at streams 5 miles north of Smyrna and 15 miles south of Dover
[c]Source: USGS (1981). Delaware samples collected 2 miles north of Smyrna and 2 miles southwest of Midway. Maryland samples collected from Queen Annes, Talbot and Worcester Counties
"-" = Data not reported

Table 2-3 (continued)

DAFB PHASE II STAGE 1. REGIONAL GEOCHEMISTRY INFORMATION

Media	Fe	Hg	Ni	Pb	Zn	TOC
			(Results in ppb, except as noted)			
Columbia Aquifer Groundwater[a]	7-30,000	-	-	<10-10	3-210	1.1-3.2 mg/l
Surface Waters[b]	-	ND-1.32	-	1.7-14.5	-	-
Rainfall[b]	-	ND-0.33	-	0.8-38.0	-	-
			(Results in ppm, except as noted)			
Soils-Delaware[c]	0.5-1%	0.03-0.05	<5-7	10-20	17-29	-
Soils-Maryland[c]	0.5-1%	0.04-0.14	<5-5	15	8-25	-

[a]Source: USGS (1983). Samples collected during 1983 from 12 wells in Kent County, Delaware
[b]Source: University of Delaware (1973). Multiple samples collected during 1972-1973 at streams 5 miles north of Smyrna and 15 miles south of Dover
[c]Source: USGS (1981). Delaware samples collected 2 miles north of Smyrna and 2 miles southwest of Midway. Maryland samples collected from Queen Annes, Talbot and Worcester Counties
"-" = Data not reported

Limited information on the chemistry of soils in the area was found. Data from two soil samples collected by the USGS in Delaware (near Smyrna and Midway) and three samples of Maryland Eastern Shore coastal plain sediments are presented in Table 2-3.

2.3 SITE DISCUSSIONS: HISTORY, GEOLOGY, AND HYDROGEOLOGY

Hydrogeologic conditions found during Phase II Stage 1 were consistent with the regional setting. The Columbia aquifer consisted of sands with thin discontinuous beds of silty clays and gravel. The upper portion of the aquifer at several sites contained silty clay lenses, including a 13-foot thick layer in well 02j, 1400 feet southwest of Site T-1, IW Basins. The Kirkwood (Miocene) unit was found at all sites at depths between 33 feet and 63 feet BLS. The Kirkwood (Miocene) was easily identified because of its distinctive lithology (silty clay with fine sand laminations) and color (dark gray to black). In some areas, the top few feet (less than 5 feet) of the Kirkwood (Miocene) was stained a rust-red before grading downward to its characteristic dark gray color.

A potentiometric surface map for the Columbia aquifer under DAFB (Figure 2-9) was developed based on water levels in monitoring wells. Groundwater southwest of the estimated position of the groundwater divide flows toward the St. Jones River, but groundwater northeast of the divide flows toward Morgan or Pipe Elm Branch. Infiltration from Site T-1, IW Basins has caused a localized rise in the water table elevation around the basins. The water table gradient at several sites is slight. Across large areas of the base (e.g., along Site DD-1, North Ditch), the water table elevations shown in Figure 2-9 are estimated. Groundwater elevation measurements recorded during Stage 1 are provided in Appendix E.

The history of each Phase II Stage 1 site and the hydrogeologic conditions found at each site during this study are discussed below. In two cases, sites are located close to each other and are discussed together: Sites D-4, Liquid Waste Site and D-5, Landfill are discussed as the Receiver Station Sites; and Sites D-10, Landfill and FT-1, Fire Training Area 1 are

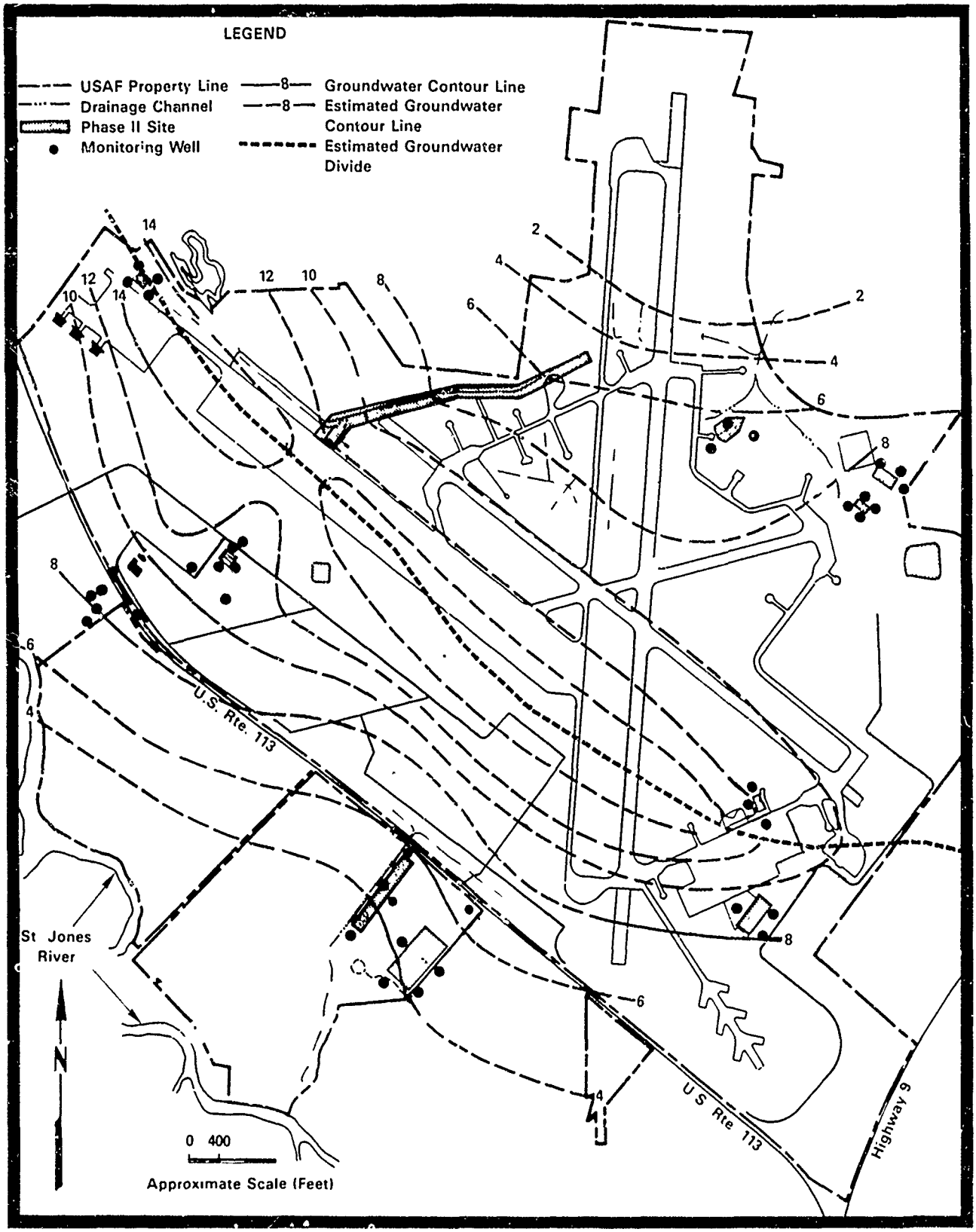


Figure 2-9. Water Table Elevation, Columbia Aquifer, 9 January 1985, at Dover Air Force Base

discussed as the Golf Course Sites. Subsurface cross sections were developed from data obtained during the Stage 1 drilling program. These cross sections illustrate the thickness of the Columbia aquifer, the elevation of the contact between the Columbia and the Kirkwood (Miocene) silty clay, the screened interval for each well, and the thickness and extent of clay layers where they occur in the Columbia. Well logs used to develop these cross sections are provided in Appendix D. Calculations of hydrogeologic parameters are provided in Appendix K. Field procedures for obtaining these data are discussed in Section 3.0.

2.3.1 Site T-1, IW Basins

The IW Basins cover approximately 19,200 square feet (Figure 2-10). They were constructed in 1963 to receive wastes from the engine build-up shop. Wastes passed through an oil/water separator and two separation basins before being discharged to the North Ditch. In 1968, the system was expanded to include plating shop and wash rack wastes. In 1969, effluent from the IW Basins was routed to the base sanitary treatment facility. Beginning in 1975, the base was connected to the Kent County Regional Wastewater Treatment Plant.

The IW Basins are currently receiving wastewaters from base operations, but there are plans to bypass the basins. A black sludge that contains metals and organic compounds has built up on the sides and bottom of the basins. In 1982, a USAFOEHL sponsored study found VOCs in groundwater at the basins (Section 1.4.3).

Three Columbia aquifer wells approximately 3,000 feet southwest of the IW Basins supplied drinking water to two commercial establishments and a trailer park. DNREC found TCE, PCE, and hydrocarbons in these wells in July 1984. DNREC conducted an investigation in this area (Section 1.4.6) and suggested that the IW Basins and DAFB Motor Pool were likely sources (DNREC, 1984). In October 1984, a leak was discovered and plugged at the Motor Pool gas station located approximately 1500 feet west of the basins.

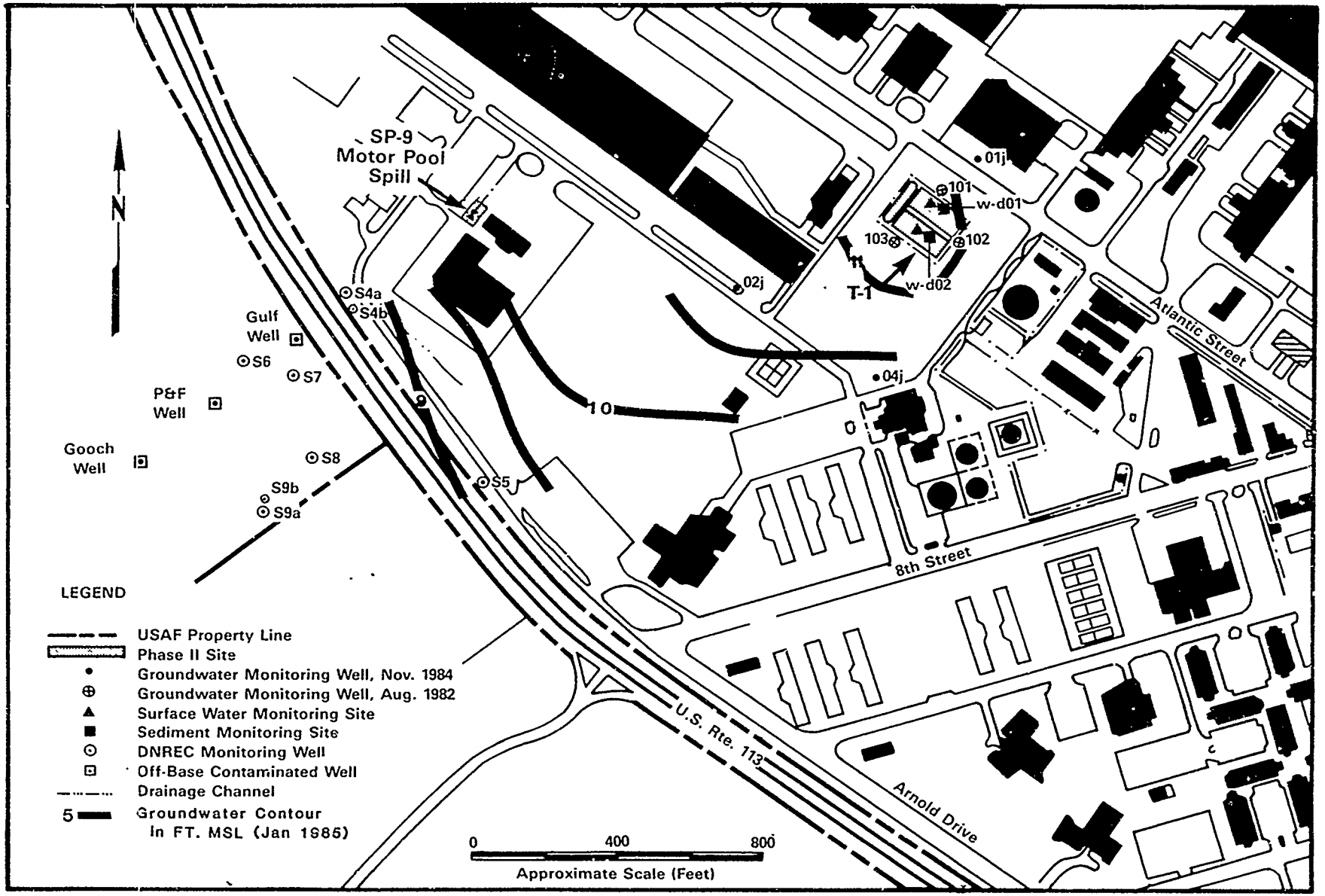


Figure 2-10. Site T-1, IW Basins

There are 14 moni' ring wells in the basin area. Two principal geologic features are noticeable in cross section (Figure 2-11). One is a 13-foot thick silty clay layer found at well 02j, which thins to the southwest to five feet at DNREC Well S4b and pinches out toward the northeast at well 01j where it was not found. The other is the northeast dip of the Columbia-Kirkwood (Miocene) contact between wells 01j and 02j which contrasts with the southeast regional dip. This dip reversal is not considered significant because the base of the Columbia is known to undulate. The occurrence of the discontinuous silty clay layer is also not surprising since such layers are known to occur elsewhere in the Columbia.

In the IW Basin area, fine sand and silt occur primarily in the upper portion of the aquifer, with a coarsening downward sequence noted in all fully-penetrating wells. The Columbia-Kirkwood (Miocene) contact is very distinct with the Kirkwood (Miocene) appearing as a finely laminated, dense, dark gray silty clay.

Groundwater elevations in the area (Figure 2-10) show the effect of recharge from the IW Basins. An apparent recharge mound under the basins has caused a reversal in groundwater flow direction northeast of the site. As a result, groundwater flows radially away from the basins before moving towards the St. Jones River. The estimated hydraulic gradient is 0.16 percent based on the potentiometric surface of 9 January 1985. Groundwater flow velocity was 0.72 ft/day calculated according to the method described in Section 2.2.2. Using this velocity, travel time for groundwater flowing from the IW Basins to Route 113 was calculated as 1805 days or 4.9 years. Calculations are provided in Appendix K.

In a worst case analysis, any compound entering groundwater from the IW Basins moves at a rate similar to groundwater. However, compounds should move at a slower rate because of various attenuation processes (e.g., sorption, degradation). Compounds entering groundwater from the IW Basins will migrate radially until the influence of the mound under the basins does not have an effect, at which time they will flow southwest towards the St. Jones River.

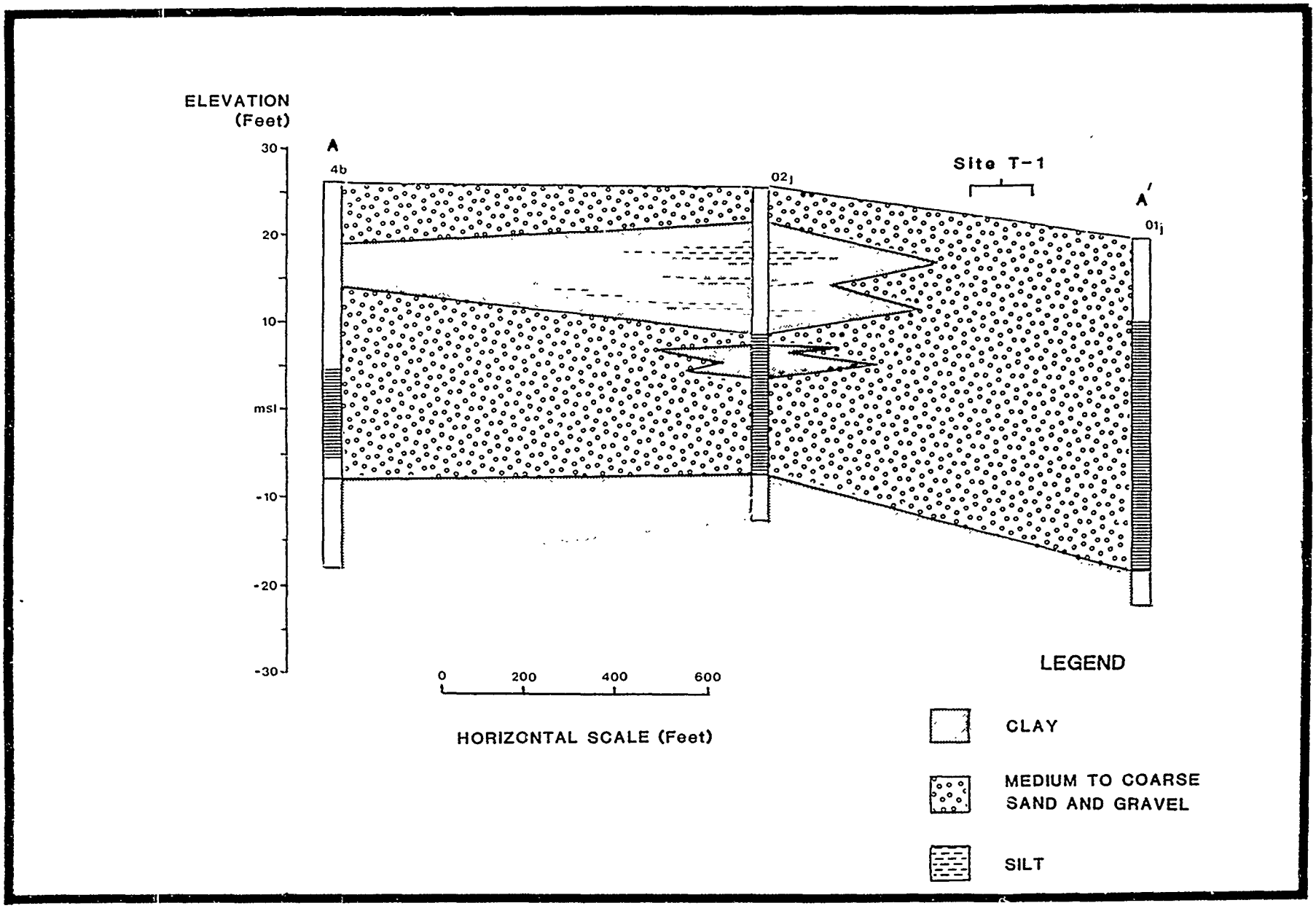


Figure 2-11. Geologic Cross-section at Site T-1, IW Basins

The cross section developed to illustrate the geology at Site T-1, IW Basins did not take into account DNREC well S5. The well log for S5 shows the Kirkwood (Miocene) silty clay at 5 feet BLS; however, the occurrence of the clay at this level contradicts the majority of data collected during Stage 1. At all other locations the Kirkwood (Miocene) was found at least 33 feet BLS. Variations known to exist in the elevation of the base of the Columbia could account for the apparent anomaly found at well S5. As an alternative explanation, the unit found in S5 may be a discontinuous silty clay unit as found in well 02j. The water levels in S5 are consistent with wells screened in the Columbia aquifer (e.g., +9.08 ft MSL in S4B to +8.71 ft MSL in S5). A well screened in a lower, confined aquifer which is not known to be pumped would be expected to have a water level that neither agrees with nor behaves as water levels in wells screened in the water table aquifer. For these reasons, the well log for S5 was not used in developing cross sections for this site.

2.3.2 Site DD-1, North Ditch

The North Ditch is located in the northern portion of DAFB and extends for approximately 3000 feet from an area adjacent to the northwest overrun to just below the N-S runway (Figure 2-12). The ditch is approximately 40 feet wide and 15 feet deep. Weeds, tall grasses, and several small trees are growing along the bottom of the ditch.

All DAFB industrial wastewater including those from the engine build-up shop, the wash racks, and the plating shops discharged to the North Ditch prior to 1963. In 1963, wastewater from the engine build-up shop was routed to the IW Basins and, in 1968, plating shop wastes were also routed to the basins. Basin effluents were discharged to the North Ditch until 1969.

The difficulties with investigating this site were:

1. The site extends for a great distance, but contaminants may be localized to areas adjacent to the point where wastewater discharged to the ditch (near w-d04). Because the discharge point is close to

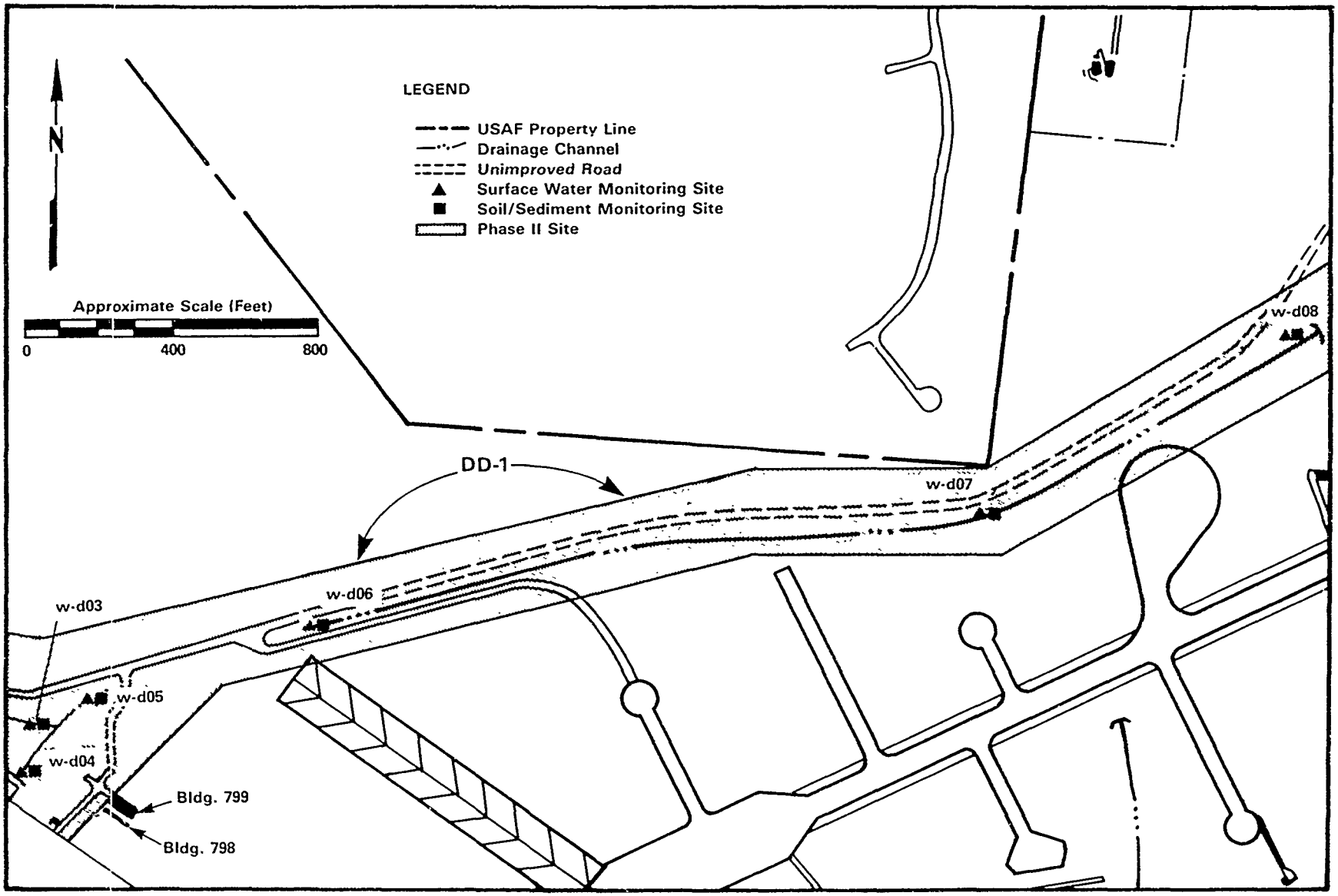


Figure 2-12. Site DD-1, the North Ditch

the groundwater divide, waters from the North Ditch may recharge groundwater.

2. Geophysical techniques such as resistivity surveys which rapidly cover large areas may not be suitable for indicating areas of contamination at this site. The metals and VOCs that were possible contaminants may not be detected by resistivity surveys and naturally occurring levels of other ions (e.g., iron) may obscure areas of contamination. DNREC doubted the effectiveness of geophysical surveys recommended in the IRP Phase I Study (DNREC, 1984, provided in Appendix I).

3. The site has not received industrial wastewater for at least 14 years. Therefore, compounds which degrade in the environment may no longer be present. Stormwater flow through the ditch may have swept contaminated sediments from the ditch or may have buried contaminated material. Also, groundwater flow may have diluted a contaminant plume and may have spread low levels of contaminants over a wide area.

4. DAFB Civil Engineering personnel report that heavy equipment is periodically used to clear the ditch of sediment and debris, so contaminated sediments may have been removed.

Groundwater monitoring wells were not installed at this site during Stage 1. Groundwater is thought to flow to the northeast based on topography and the location of the nearest wetlands.

2.3.3 Golf Course Sites: D-10, Landfill and FT-1, Fire Training Area 1

Site D-10, Landfill is located beneath the golf course on the southwest portion of DAFB (Figure 2-13). The site was used during the 1950s for the disposal of general base refuse, spent chemicals, and industrial shop wastes. Trenches were excavated to a depth of approximately 15 feet, probably close to or into groundwater. At present, uneven ground settling possibly caused by differential subsidence of waste or drum collapse is noticeable in this area.

Southeast of the site off U.S. Government property is an area that is apparently a junkyard. Broken and rusting machinery, automobiles, heavy equipment and construction rubble are scattered across a large area. Between this area and Route 113 is a domestic well, the Green House well, that was recently found to contain VOCs (Section 1.6).

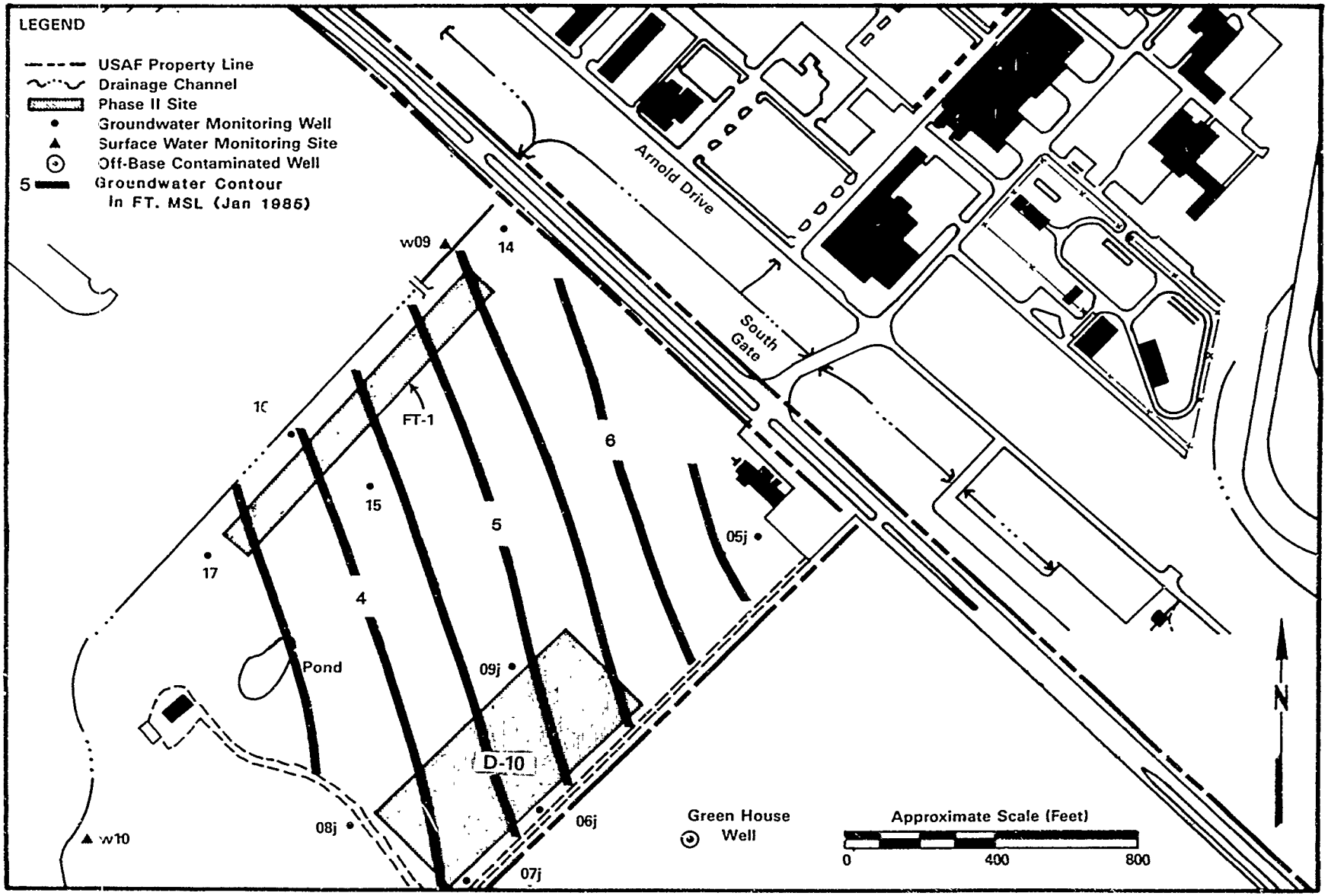


Figure 2-13. Golf Course Sites, D-10 and FT-1

Site FT-1, Fire Training Area 1 covers an area of approximately 900 feet by 50 feet on the golf course east of the drainage ditch. Drums of contaminated waste oils, solvents, paint thinners, and contaminated fuels were reportedly stored on site prior to burning, plus reports indicated residual fuels and wastes remained on the ground after each training exercise. These conditions indicate a high potential for contamination. Operations at the site consisted of spreading at least 1000 gallons of waste fuels and liquids on a water saturated area, igniting the material, and using protein foams to extinguish the flames. These exercises reportedly were conducted twice per week from 1951 through 1962; however, a review of aerial photos indicated fire training operations may have ceased prior to 1959 when construction of the golf course began. At present, evidence of environmental degradation or contaminant release is not visible.

Several areas reportedly were used for training exercises within the 900 foot x 50 foot area of FT-1. Exact locations of these areas could not be determined because excavation and grading during construction of the golf course may have buried the areas under several feet of uncontaminated material or may have mixed contaminated soils with uncontaminated materials, thus spreading low levels of contaminants over a much larger area than outlined as FT-1.

Three cross sections were constructed to show subsurface conditions at the Golf Course Sites (Figure 2-14). Cross sections B-B′ and C-C′ trend northeast to southwest and extend approximately 1240 feet and 1200 feet, respectively. Cross section D-D′ extends approximately 1250 feet from southeast to northwest between the two sites.

Beneath Site D-10, the Columbia is principally composed of medium to coarse sand and gravel. At wells 05j and 06j, the portion of the Columbia above the water table contains discontinuous lenses of silty sands. Thin (less than 1 foot) gravel layers were common throughout the Columbia in well 07j, less common in well 05j, and absent in well 06j. Consequently these gravel layers were considered to have minimal lateral extent. Overall, the Columbia coarsens downward to a sharp contact with the underlying Kirkwood

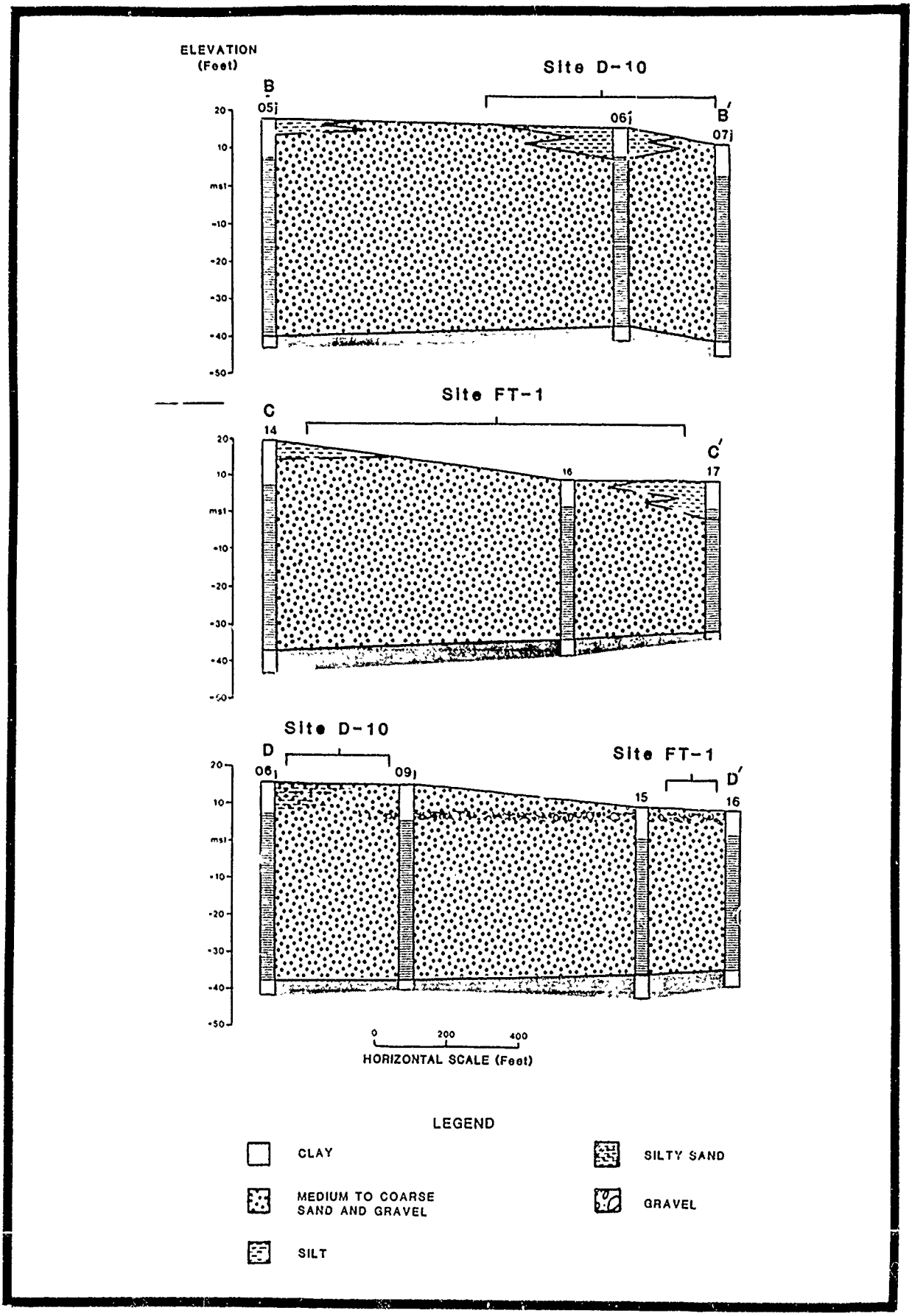


Figure 2-14. Geologic Cross-section at Sites D-10 and FT-1, Golf Course Sites

(Miocene) unit, which is consistently identifiable as a dense, finely laminated, dark gray, silty clay. Total relief of the contact is approximately two feet along section B-B' indicating a very flat lying bed.

The Columbia is homogeneous beneath FT-1 (cross section C-C'). Thin silty sand lenses, similar to those of section B-B', occur in the uppermost portion of the Columbia. However, the thin gravel beds found under D-10 are not present under FT-1. The aquifer's lithology, best described as poorly sorted, medium to coarse sand, with some gravel, is essentially the same as that described in the literature. The contact between the Columbia and underlying Kirkwood (Miocene) dips to the northeast at approximately one foot vertically for every 600 feet horizontally (0.167%).

Cross section D-D' illustrates the subsurface conditions between sites D-10 and FT-1. The Columbia is primarily composed of medium to coarse sand, with a thin gravel layer occurring between three and six feet BLS. Reworking or regrading of the area may be the source for this thin gravel bed rather than Pleistocene deposition. The Kirkwood (Miocene) again appeared as a dark gray, well compacted, finely laminated, silty clay, dipping very slightly (2 feet over a distance of 1250 feet, or 0.16%) to the southeast.

Groundwater flow is southwest towards the St. Jones River (Figure 2-13). Water table gradient at the golf course is approximately 0.24 percent. Groundwater flow velocity beneath the golf course is approximately 1.08 ft/day. Travel time to the DAFB boundary along the St. Jones River is 10.4 years. Calculations are provided in Appendix K.

2.3.4 Receiver Station Sites: D-4, Liquid Waste Site and D-5, Landfill

Site D-4, Liquid Waste Site is located in the northeast section of the base near the Receiver Station (Figure 2-15). Liquid industrial wastes and waste oils were disposed during the late 1950s in a single trench approximately 15 feet wide, 100 feet long, and 10 feet deep. At present, the area shows evidence of waste disposal activity, but this evidence (e.g., disturbed ground, subsidence, and dead vegetation in strips approximately 15 feet wide by 75 feet long) cannot be attributed only to D-4 because two other disposal

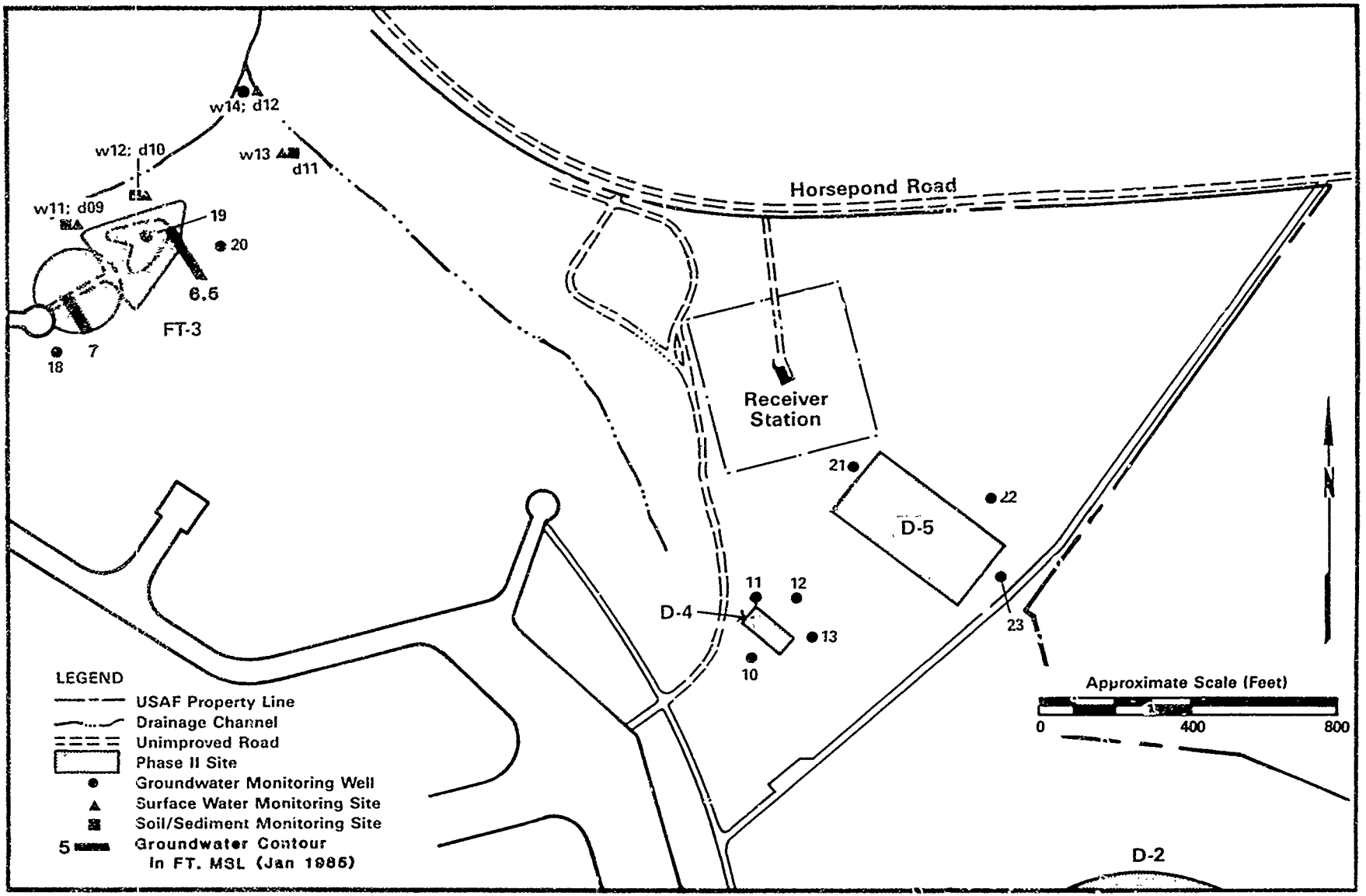


Figure 2-15. Receiver Station Sites, D-4 and D-5 and Site FT-3, Fire Training Area 3

sites, Site D-5, Landfill and Site SD-1, Sludge Disposal area are located in the same general area. The location of D-4 was delineated by a heavy equipment operator who excavated the trenches at the site.

Site D-5 is located in the same general area as D-4 (Figure 2-15). The site was reported to be less than 0.5 acres and used in the 1960s, although personnel familiar with the site described it as much larger. The area method of filling was used and wastes were placed to a depth of 8 feet.

A total of seven monitoring wells were installed in this area. Cross sections E-E' and F-F' (Figure 2-16) extend approximately 600 and 700 feet respectively northwest and southeast of the sites. The Columbia deposits found beneath the Receiver Station Sites show much greater heterogeneity than at any other Stage 1 site. A silty clay layer occurs from 4 to 14 feet BLS and appears to be laterally continuous beneath both sites. This upper unit varies in thickness from 2 to 10 feet and is marginally thicker northwest of the sites. The unit appears to have a larger percentage of clay size materials in wells 21 and 23 at the northeast extremities of the two cross sections than found in well 10.

Beneath the upper silty clay, the Columbia aquifer gradually coarsens downward with the exception of discontinuous gravel lenses at 28 feet BLS (well 10) and 30 feet BLS (well 23). The mildly undulating contact between the Columbia and Kirkwood (Miocene) silty clay dips up to 2 degrees without preferential orientation. The Kirkwood appears as a finely laminated, dark gray, silty clay.

Groundwater elevations showed little variability between wells in the area, ranging from +8.79 ft MSL to +8.94 ft MSL. Consequently, direction of flow is not known and gradients cannot be calculated. Based on the DAFB area potentiometric surface map (Figure 2-9), groundwater is moving northwest towards the wetlands area along Pipe Elm Branch.

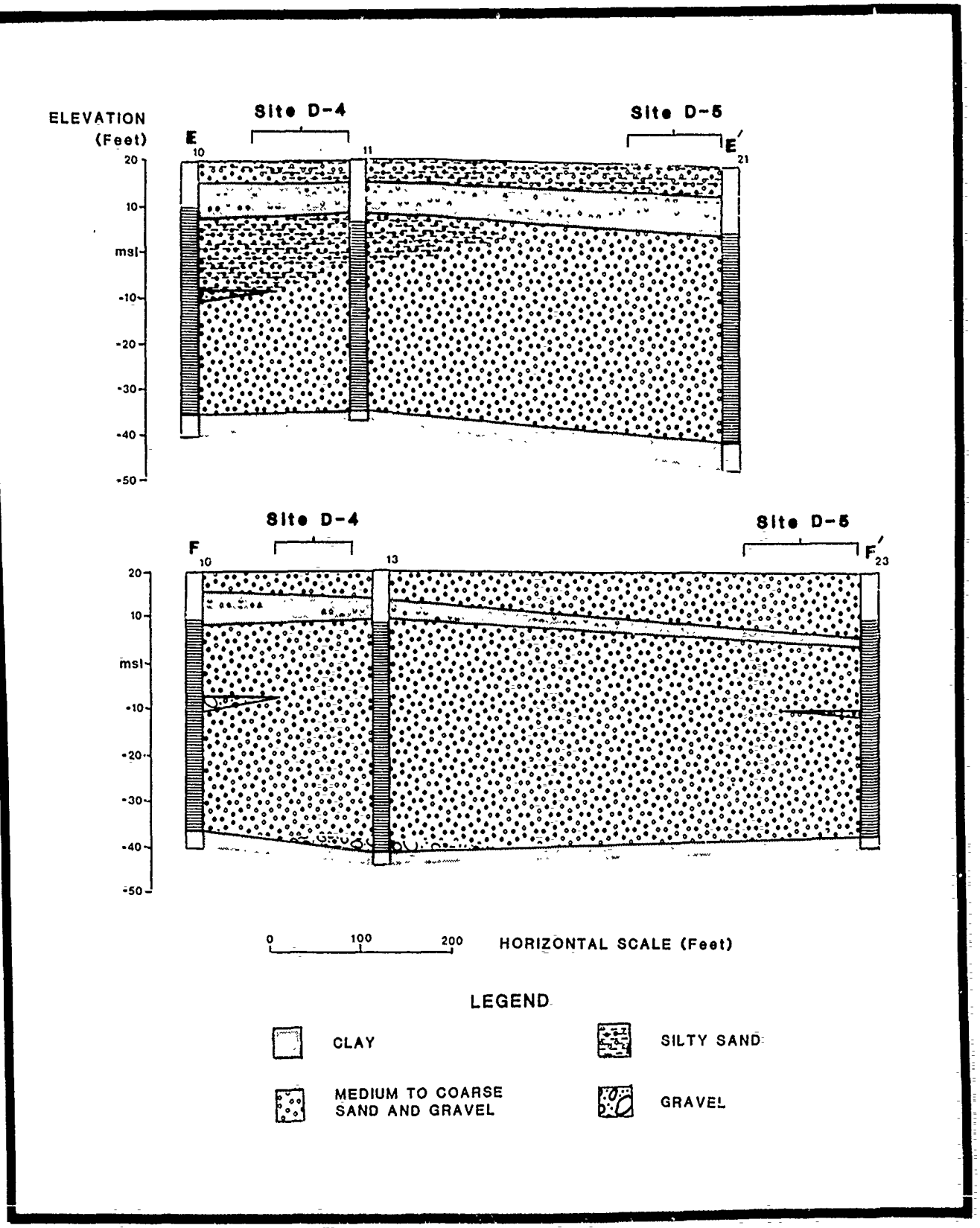


Figure 2-16. Geologic Cross-section at Sites D-4 and D-5

2.3.5 Site FT-3, Fire Training Area 3

Site FT-3, Fire Training Area 3 is located in the northeast section of DAFB, east of the N-S runway and west of the Receiver Station and sites D-4 and D-5 (Figure 2-15). The site has served as the fire training area since 1962 and initially was located closer to the wetland area (old Fire Training Area 3). The old FT-3 has been described as a pit used to dispose of oils, paints, and other liquid industrial wastes. In the 1960s and early 1970s, training exercises using at least 1000 gallons of contaminated waste oil and fuel reportedly were conducted at the site twice per week. Drums of waste oil and fuel were delivered to the site and stored until used. Current training operations (existing Fire Training Area 3) are conducted four times per year and use approximately 200 to 700 gallons of JP-4. Unconsumed fuel, foam, and water are drained to an oil/water separator.

Lithologic data from the three wells at the site were used to construct cross section G-G' (Figure 2-17). In general, the Columbia coarsens downward to a very flat contact with the underlying Kirkwood (Miocene) silty clay. A silty sand horizon from 8 to 24 feet BLS in well 18 apparently correlates with a thinner layer with a higher percentage of clay in wells 19 and 20. Beneath this horizon lies an apparently continuous 2 foot thick gravel layer at depths from 26 feet BLS in well 18 to 10 feet BLS in well 20. Underlying the gravel and at wells 18 and 20 are silty sand lenses. These lenses appear to have little lateral continuity and grade downward to medium to coarse sand and gravel through the remaining portions of the Columbia.

Groundwater flow is northeast towards the nearby Pipe Elm Branch. The maximum gradient is approximately 0.14 percent. Groundwater flow velocity was calculated to be 0.63 ft/day. Travel time to the base boundary was estimated at 6.1 years. Calculations are provided in Appendix K.

2.3.6 Site SP-4, JP-4 Pipeline Leak (Building 1310)

Site SP-4, JP-4 Pipeline Leak northeast of Building 1310, (Figure 2-18) was identified as a potential site primarily because of the size of the spill that occurred in 1975 and the extent of cleanup could not be determined.

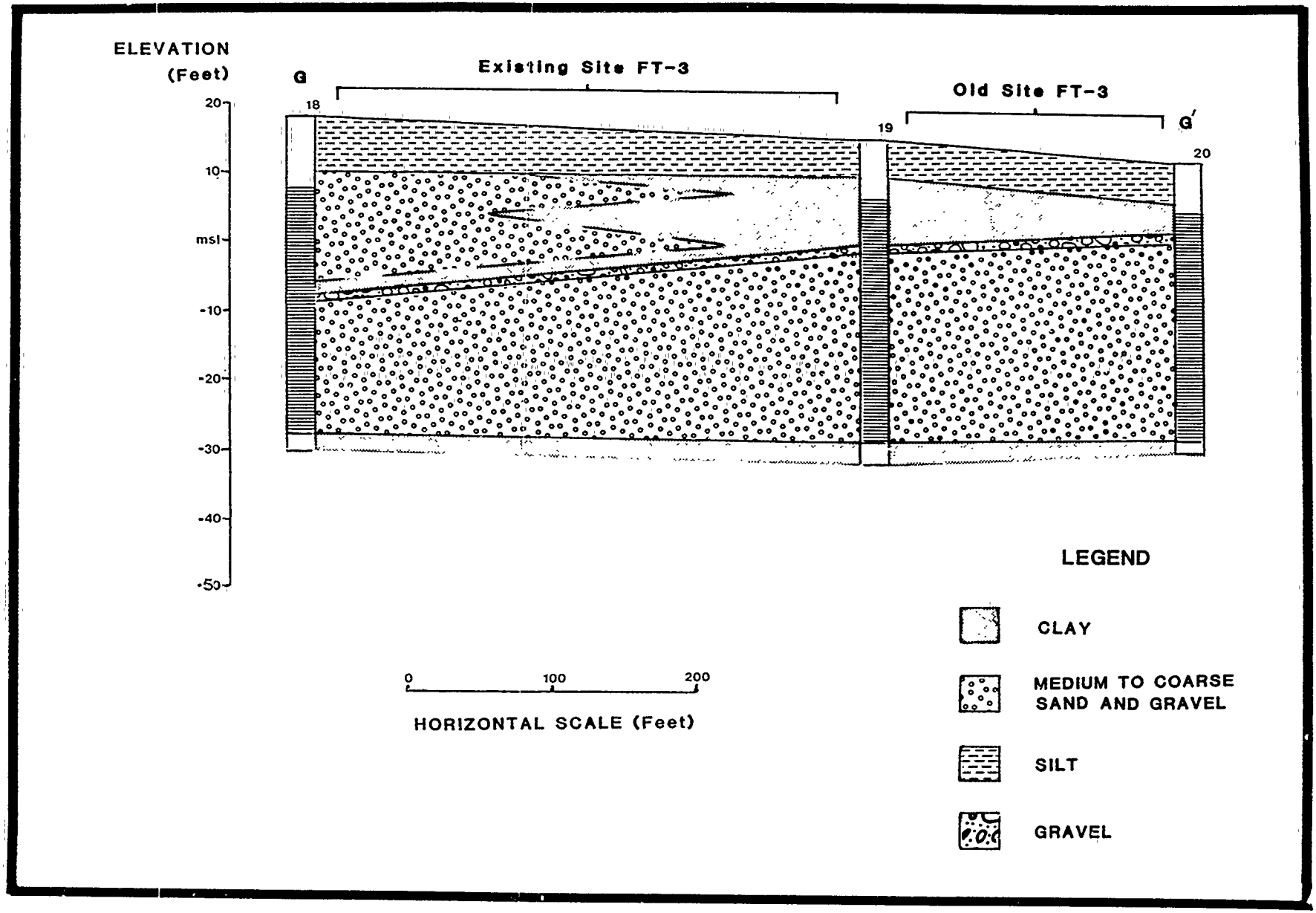


Figure 2-17. Geologic Cross-section at Site FT-3

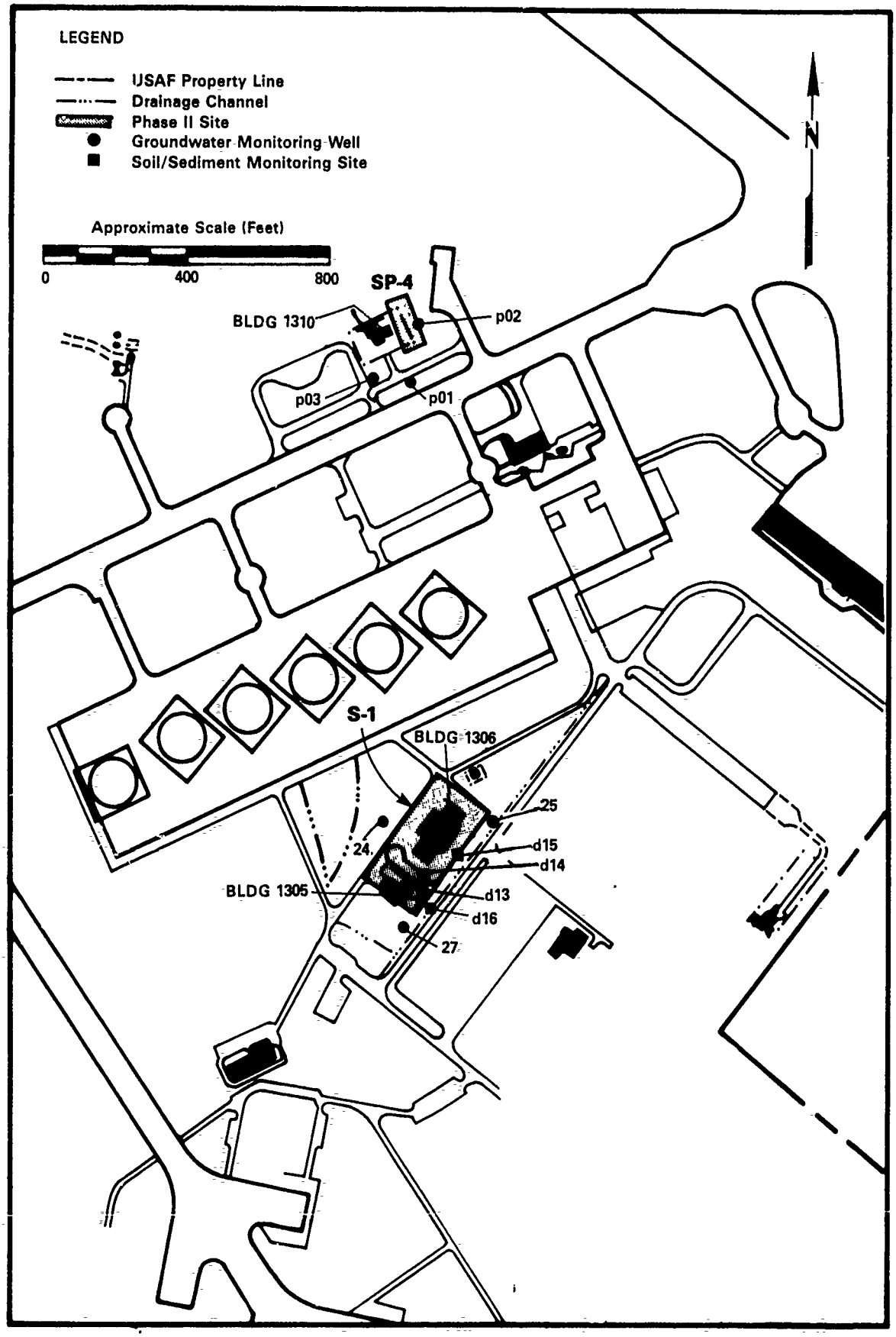


Figure 2-18. Site SP-4, JP-4 Pipeline Leak and Site S-1, Hazardous Waste Storage

The problems associated with investigating this site were:

1. The extent of the spill was unknown and could be quite small. In addition, any residual contamination may have migrated from the site, been diluted below detection limits, or been degraded below detection limits.

2. The spill site was located close to a groundwater divide. Consequently, residual contaminants may be moving away from the spill site in more than one direction.

Geologic data from three well points, installed to depths up to 20 feet BLS, indicated that the Columbia beneath Site SP-4 is composed of thin interbeds of clays and silty, fine to medium sands. Distinctive beds of any significant thickness do not occur in the area. Although the coarse sands and gravels common to the Columbia were not found, the sequence generally became less clayey and coarsened with depth.

Water levels in the well points showed a large variation over time. For example, water levels for p01, p02, and p03 were +13.43 ft MSL, +10.16 ft MSL, and +12.69 ft MSL on 16 November 1984, respectively. Almost 1 month later on 10 December 1984, water levels for the same well points were +12.70 ft MSL, +11.07 ft MSL, and +12.73 ft MSL. On 9 January 1985, water levels were +15.04 ft MSL, +10.01 ft MSL, and +12.92 ft MSL. The water level in p01 fell then rose between measurements, in p02 rose then fell, and in p03 rose slightly. Examination of well logs and as-built drawings indicated that these well points were screened in a silty clay; therefore, water levels may not be indicative of groundwater levels in the sands of the Columbia aquifer.

2.3.7 Site S-1, Hazardous Waste Storage Area

Site S-1 is located at Buildings 1306 and 1305 in the southeastern section of the base (Figure 2-18). Drummed waste from industrial shops are stored in these areas until contracts are arranged for off-base disposal. The yard is lined with an asphalt pavement. Visual evidence of contamination was not found during the Phase II presurvey site visit.

Geologic data from the three well locations at Site S-1 were used to construct a fence diagram (Figure 2-19). Well locations are shown on Figure 2-18. The wells ranged in depth from 57 to 66 feet BLS and represent the greatest depth to the Kirkwood (Miocene) encountered during the Stage 1 drilling program.

Generally the composition of the Columbia coarsens downward. The upper portion consists of a sequence of silts and silty clays ranging in thickness from 9 feet in well 27 to 15 feet in well 25, which grade laterally to silty sands with a thin clay interbed in the upper 24 feet of well 24. Below this horizon the Columbia is principally medium to coarse sand and gravel. The contact between the Columbia and the underlying Kirkwood (Miocene) is sharp and was found at an elevation 11 feet higher in well 25 than in well 27. This represents the greatest relief identified during Stage 1. The apparent dip of the Kirkwood is slightly greater than 3 percent in a southwest direction.

Groundwater levels at Site S-1 did not differ significantly (e.g., +8.69 to +8.46 ft MSL). However, direction of flow appears to be southward towards the St. Jones River. With a gradient of approximately 0.09 percent, the flow rate was computed to be 0.41 ft/day. Travel time to the base boundary along Route 113 was estimated to be 18.8 years. Calculations are provided in Appendix K.

2.3.8 Site XYZ, Fuel Pump Station (Building 950)

This site was identified during the Phase II presurvey site visit. DAFB personnel reported that rainwater in manholes along the hardstand in the area of Building 950 (Figure 2-20) contained a distinct fuel layer on top of the water. DAFB personnel recalled a spill of fuel in this area. Alternately, the fuel could be the result of residual fuels from the hardstand being carried into the manholes by runoff or could be the result of spilled fuel floating on top of the groundwater and entering the manholes when the water table rose.

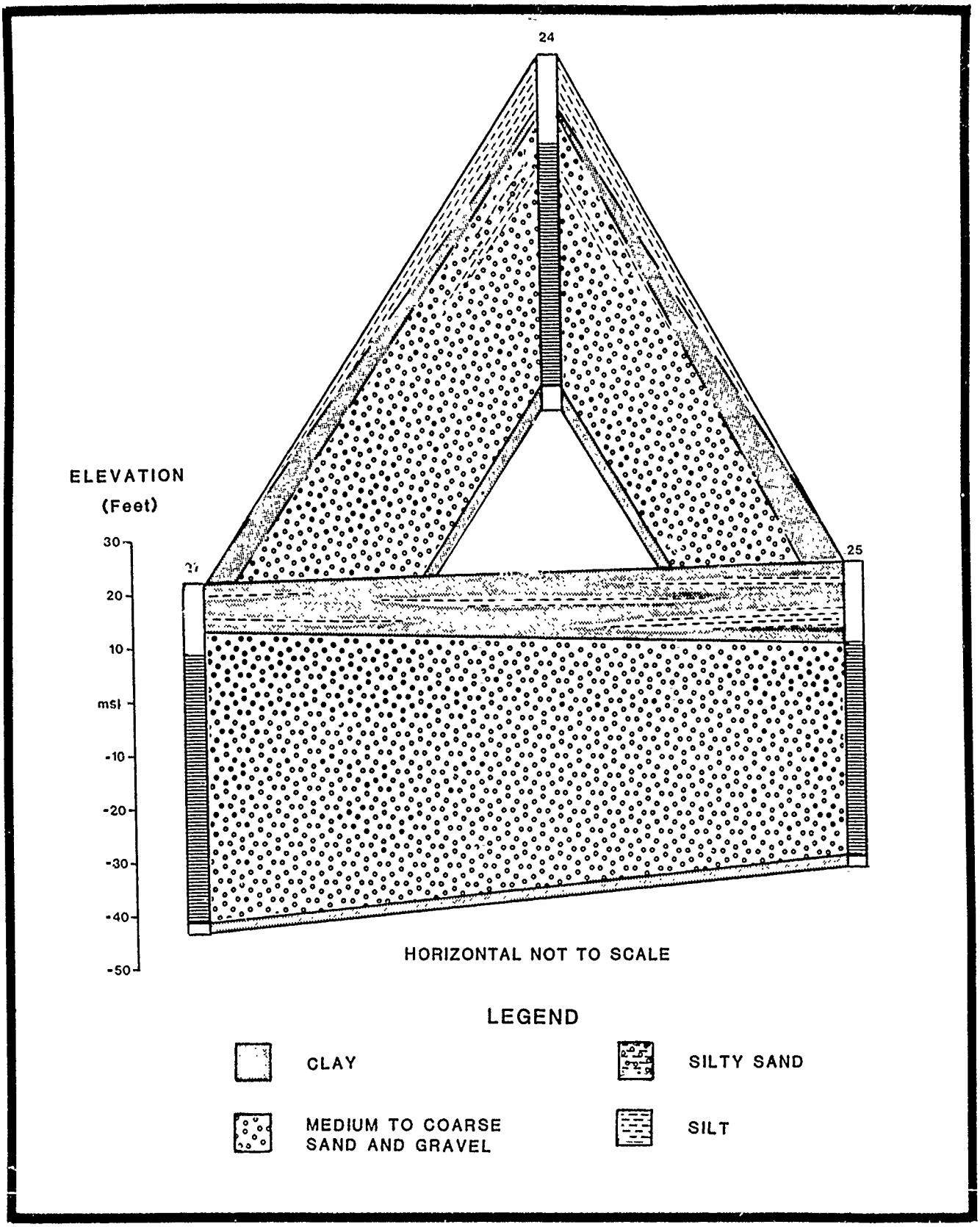


Figure 2-19. Fence Diagram for Site S-1

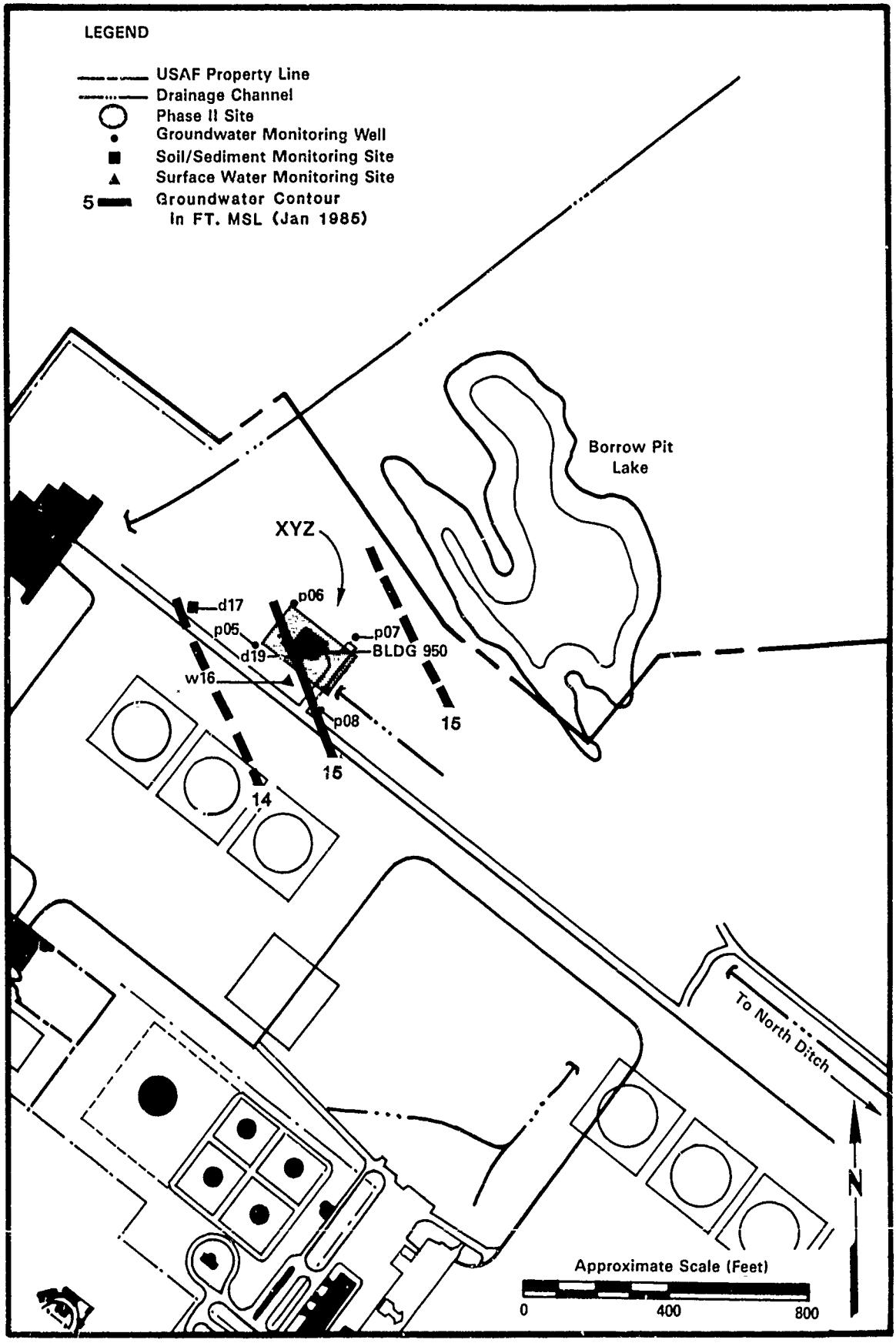


Figure 2-20. Site XYZ, Fuel Pump Station

Cuttings obtained during the installation of four well points showed Site XYZ to be underlain by poorly sorted materials ranging in grain size from clay to gravel, but principally consisting of fine to coarse sands. Depth of the well points ranged from 15.0 to 20.5 feet BLS, with the entire interval best described as silty sand with a trace of clay, grading downward to medium to coarse sand with some gravel. Groundwater flow is southwest towards the St. Jones River (Figure 2-20) and apparently not towards the Borrow Pit Lake northeast of the site. Maximum hydraulic gradient in the area is approximately 0.45 percent. Groundwater velocity was calculated to be 2.0 feet/day, and travel time to the base boundary was estimated to be 3.55 years. Calculations are provided in Appendix K.

2.3.9 Site D-2, Rubble Area

Site D-2, Rubble Area is the largest disposal site on base and currently is being used for the disposal of construction debris and rubble. The site is located in the eastern portion of the base (Figure 2-21) and the surface is covered with concrete, lumber, cans, metal scraps, and other debris. The eastern edge of the site is a level area which abruptly ends in a 20-foot [illegible] that consists of concrete and debris. The low area extends from the fill's toe to a treeline close to the base boundary. This low area is also covered with debris and rubble.

The environmental concern at this site is the possible contamination of surface water and groundwater. Groundwater monitoring was not conducted at this site during Phase II Stage 1 because of access problems and the primary route of migration was considered to be by surface runoff. Groundwater flow is probably northwest towards Pipe Elm Branch.

2.4 SUMMARY OF ENVIRONMENTAL SETTING

A summary of important environmental information is provided in Table 2-4. Flow times to the base boundary assumed groundwater flow at a steady rate to the nearest boundary along the line of maximum hydraulic gradient. Calculations are provided in Appendix K.

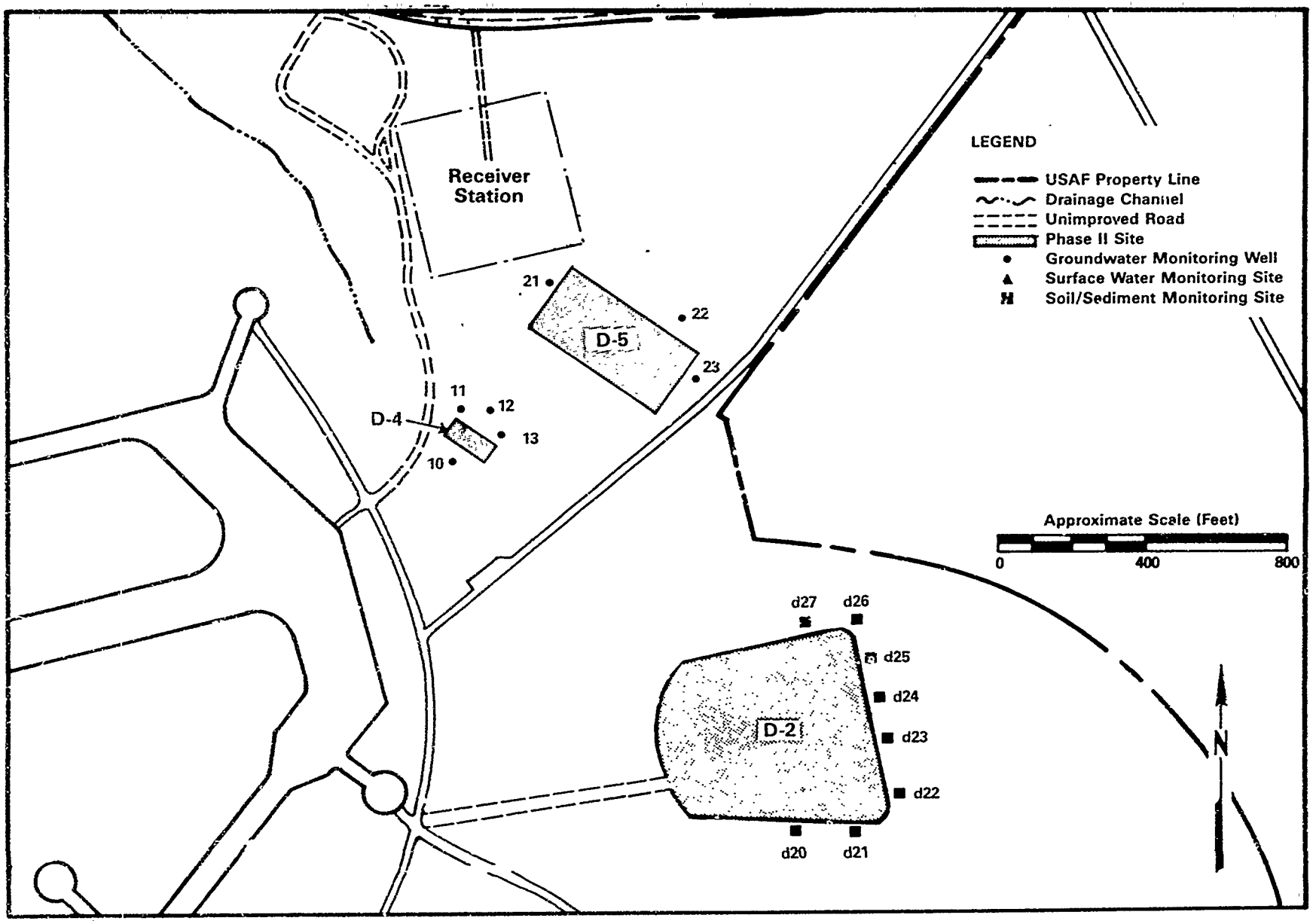


Figure 2-21. Site D-2, Rubble Area

Table 2-4

DAFB PHASE II STAGE 1. SUMMARY OF ENVIRONMENTAL SETTING INFORMATION

Site	Groundwater Flow Direction	Flow Rate (ft/day)[a]	Hydraulic Gradient	Depth to Groundwater (ft BLS)	Elevation of Groundwater (ft MSL)	Groundwater Flow Time to Base Boundary (Years)[b]
T-1, IW Basins	SW	0.72	0.0016	9.5-15	9.9-11.3	4.9 (to Route 113)
DD-1, North Ditch	(est. NE)	ND	ND	ND	ND	ND
Golf Course Sites (D-10, FT-1)	SW	1.08	0.0024	4.5-13	3.2-6.81	10.4
Receiver Station Sites (D-4, D-5)	(est. N)	ND	ND	7-12	8.8-8.9	ND
FT-3, Fire Training Area 3	NE	0.63	0.0014	4.0-12.5	6.2-7.0	6.1
SP-4, JP-4 Pipeline Leak	(est. N)	ND	ND	14.0-17.0	12.5-15)	ND
S-1, Hazardous Waste Storage	(est. S to SW)	0.41	0.0009	14-16	8.5-8.7	18.8
XYZ, Fuel Pump Station	SW	2.03	0.0045	8.5-10.5	14.3-15.6	3.55
D-2, Rubble Area	(est. N)	ND	ND	ND	ND	ND

(continued)

[a]Flow rate = (hydraulic conductivity)(hydraulic gradient)/effective porosity.
[b]Flow time = distance to boundary/flow rate.
ND = Data not available; BLS = Below land surface; MSL = Mean sea level.
est. = estimated.

Table 2-4 (continued)

DAFB PHASE II STAGE 1. SUMMARY OF ENVIRONMENTAL SETTING INFORMATION

Site	Depth to Kirkwood (ft BLS)	Elevation of Kirkwood (ft MSL)	Surface Water Drainage
T-1, IW Basins	34-46	-8.4--22.6	NA
DD-1, North Ditch	ND	ND	To Pipe Elm Branch
Golf Course Sites (D-10, FT-1)	40-59	-31.9--41.63	To St. Jones River
Receiver Station Sites (D-4, D-5)	55-60	-35.2--43.9	To Pipe Elm Branch
FT-3, Fire Training Area 3	40-49	-29.5--30.9	To Pipe Elm Branch
SP-4, JP-4 Pipeline Leak	ND	ND	NA
S-1, Hazardous Waste Storage	56-63.5	-31.5--41.3	NA
XYZ, Fuel Pump Station	ND	ND	To Morgan Branch
D-2, Rubble Area	ND	ND	To Pipe Elm Branch

BLS = Below land surface.
MSL = Mean sea level.
NA = Not applicable.
ND = Data not available.

The environmental setting at DAFB can be summarized as follows:

1. Surface waters flow to Pipe Elm Branch and the St. Jones River with a man-made diversion to Morgan Branch on the far northwest corner of the base. These streams may act as shallow drains in the aquifer and receive up to 75 percent of baseflow from groundwater. An exception to this is where process and nonprocess waters are discharged to surface water diversions close to the groundwater divide. In these cases, the surface waters may be recharging groundwater.

2. Groundwater flow off base is primarily in two directions: northeast towards Pipe Elm and southwest towards the St. Jones River.

3. Groundwater flow rates in the Columbia ranged from 0.135 to 2.02 ft/day. Hydraulic gradients ranged from 0.09 percent to 0.45 percent. Hydraulic conductivity of the Columbia was reported to average 90 ft/day (Johnston, 1973).

4. The Kirkwood (Miocene) silty clay beneath the Columbia was found in all wells fully penetrating the Columbia aquifer and is continuous beneath DAFB. Elevations at the top of this unit ranged from -8.4 ft MSL to -43.9 ft MSL with 25 of 26 of the boreholes encountering the unit between -22 ft MSL and -43.9 ft MSL. Hydraulic conductivity of the Kirkwood was reported to be 8.0×10^{-5} to 4.0×10^{-4} ft/day (Leahy, 1982).

5. Groundwater flow times from study sites to the DAFB boundary, assuming straight line flow along maximum hydraulic gradient at a steady rate, ranged from 3.55 years to 18.8 years. Calculated rate of groundwater flow through the Kirkwood (Miocene) using published data to provide values for hydraulic conductivity, gradient, and effective porosity was 4×10^{-4} ft/day. At this rate, groundwater from the Columbia would require 155 years to penetrate 22 feet of Kirkwood silty clay.

6. Contaminants from sites can potentially migrate to the water table because of the absence of low permeability zones between land surface and the water table.

3.0 FIELD PROGRAM

This section describes the procedures followed during the Phase II Stage 1 field program at Dover AFB (DAFB). A brief summary of this section is as follows:

1. The monitoring plan for this stage was developed in June 1984 and was based primarily on information provided in the Phase I report (Section 1.4.4).

2. Actual thickness of the Columbia aquifer resulted in monitoring wells being drilled deeper than expected. Subsequently, two wells in the Columbia aquifer and three in the Frederica aquifer were not installed. These wells were proposed for installation during Phase II Stage 2.

3. Field conditions encountered and information collected during Phase II Stage 1 resulted in the elimination of eight surface water sampling locations and four soil or sediment samples. In addition, deep soil samples were changed to surface soil samples to provide greater area coverage.

4. The groundwater monitoring program consisted of installing 32 wells at nine study sites, including 7 well points and 25 Columbia aquifer wells. These plus the existing three wells at the IW Basins were sampled. Groundwater monitoring well locations are shown on Figure 3-1.

5. The surface water monitoring program consisted of collecting samples at 15 locations to determine surface water quality at 5 sites. Surface water monitoring locations are shown on Figure 3-2.

6. The soil or sediment monitoring program consisted of collecting samples at 26 locations to determine soil or sediment quality at 6 sites. Soil and sediment monitoring locations are shown on Figure 3-3.

7. Examination of QA/QC results and chain-of-custody forms by the Laboratory QA/QC Officers and USAFOEHL representatives indicated that sample analysis results were valid.

The development of the monitoring program is described in Section 3.1. The implementation of the program is discussed in Section 3.2.

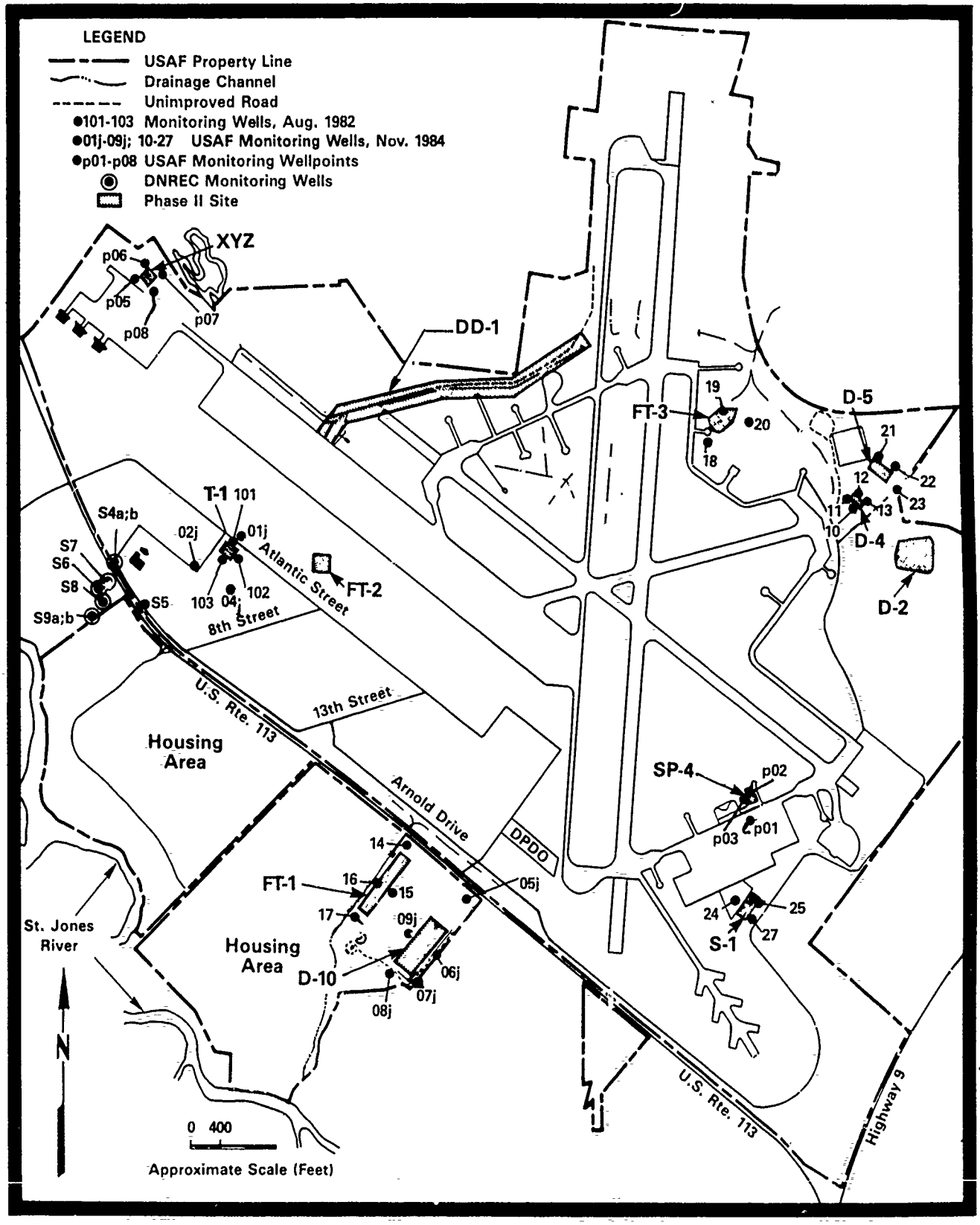


Figure 3-1. Locations of Groundwater Monitoring Wells at Dover Air Force Base, December 1984

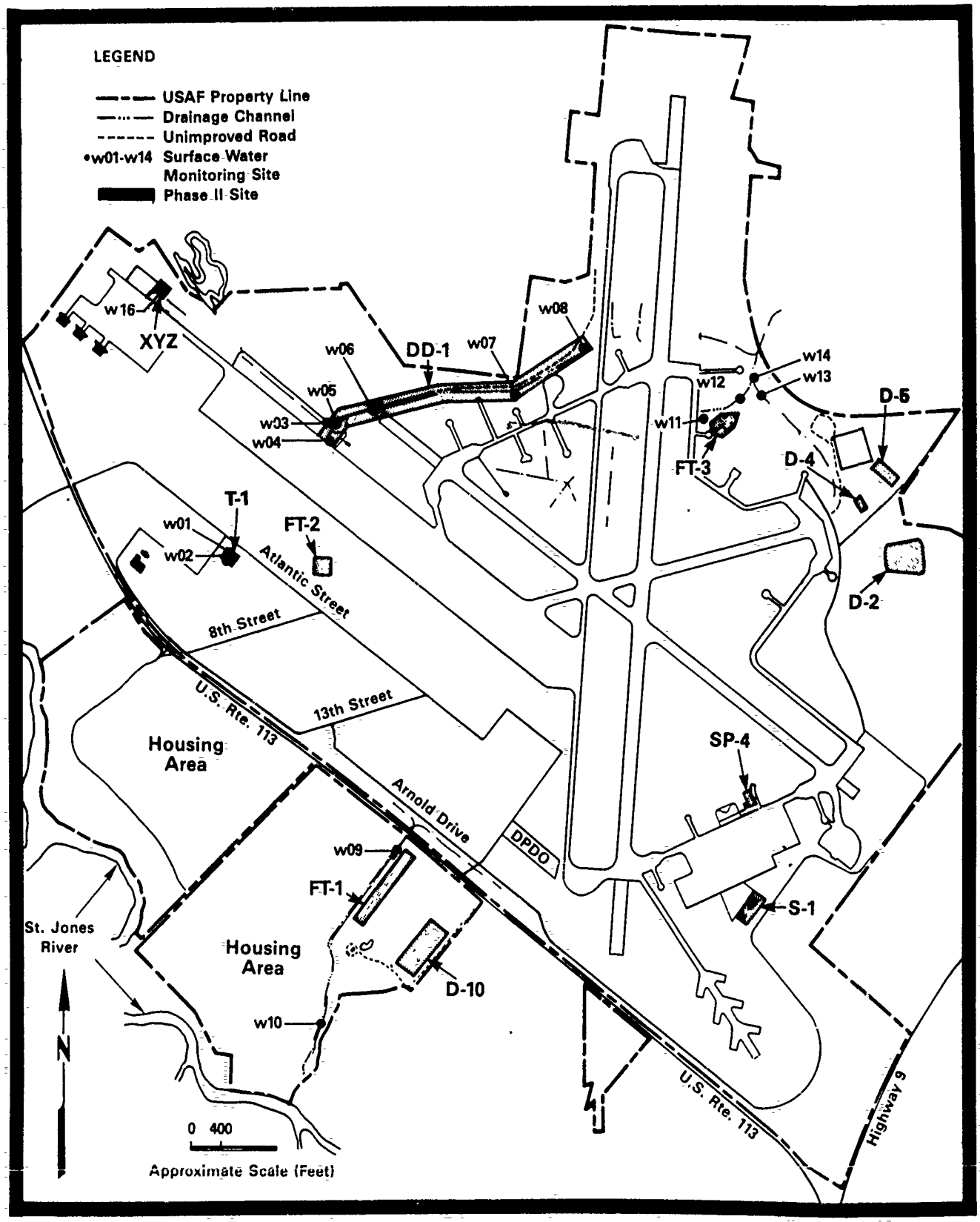


Figure 3-2. Locations of Surface Water Monitoring at Dover Air Force Base, December 1984

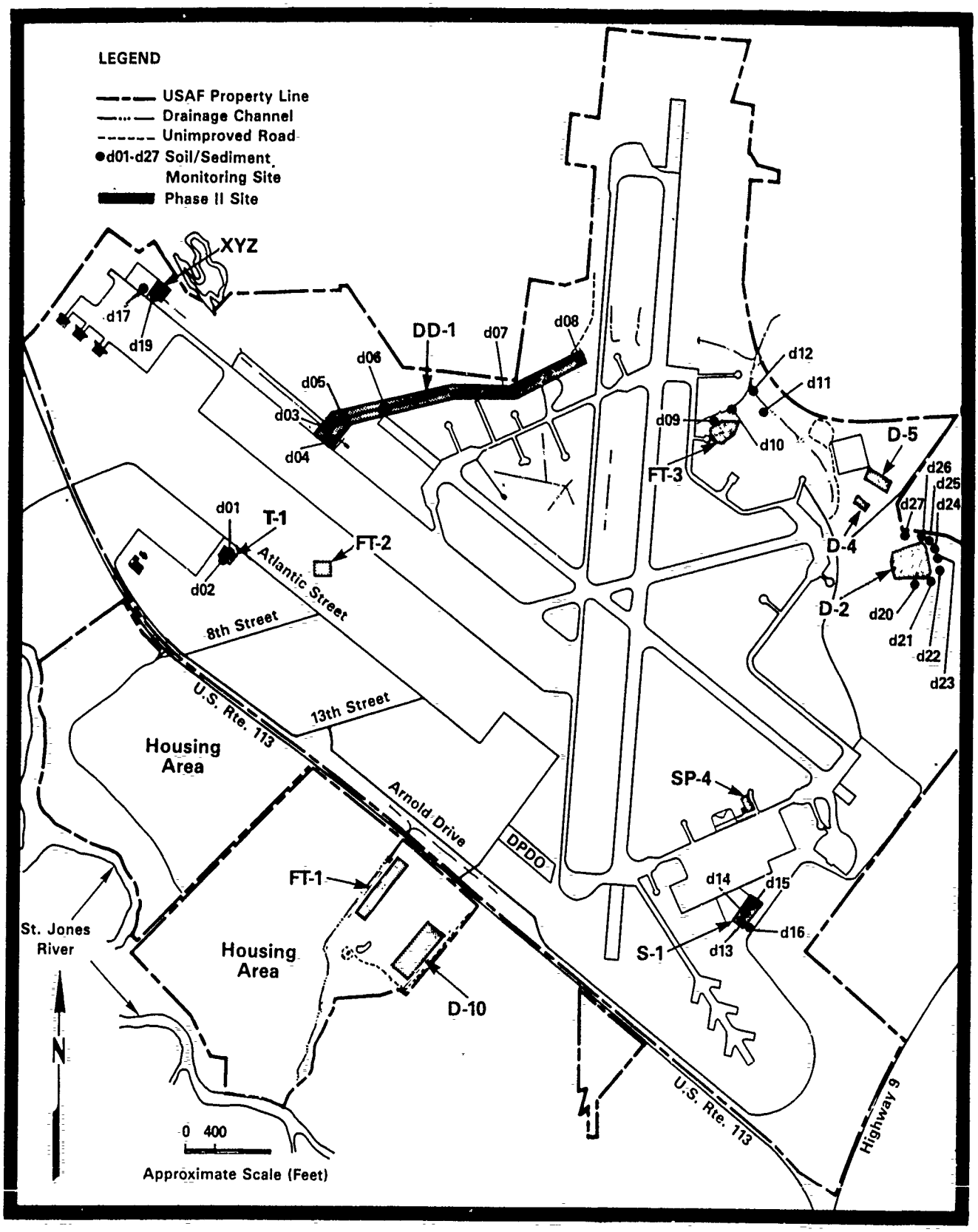


Figure 3-3. Locations of Soil/Sediment Monitoring at Dover Air Force Base, December 1984

3.1 MONITORING PROGRAM DEVELOPMENT

The Phase II Stage 1 monitoring program was designed to confirm the absence or presence of environmental contamination at study sites such that each site could be classified as:

1. Not of environmental concern (Category 1 Site)
2. Requiring additional study to characterize the extent and magnitude of confirmed contamination (Category 2 Site)
3. Sufficiently characterized as to the extent and magnitude of contamination such that IRP Phases III or IV may commence (Category 3 Site).

The Phase I report (Section 1.4.4) and the Phase II presurvey site visit provided the information used to develop the monitoring program. A draft monitoring plan was part of the Phase II presurvey report submitted to USAFOEHL on 15 June 1984. With minor modifications, this plan became the formal scope of work (SOW) for Phase II Stage 1. The SOW is provided in Appendix B.

The SOW was modified during the field program based on new information and because of unexpected field conditions. The original SOW, the implemented program, and the reasons for modifying the SOW are summarized on Table 3-1.

3.1.1 Selection of Groundwater Monitoring Locations and Well Design

Groundwater monitoring was conducted at nine study sites because the types of waste disposed, the permeable subsurface materials, and the shallow water table created a potential for groundwater contamination. Groundwater monitoring was not conducted at two sites during Stage 1 for the following reasons:

1. At Site DD-1, North Ditch, the configuration of the site (i.e., 6000 ft x 80 ft) presented difficulties in determining well placement. Instead, the Stage 1 program proposed for the site was

Table 3-1

DAFB PHASE II STAGE 1. SUMMARY OF PROPOSED AND IMPLEMENTED MONITORING PROGRAMS

Site	Program Proposed	Program as Implemented	Reason for Program Modification
1. T-1, IW Basins	• 4 Columbia aq. wells • 3 Frederica aq. wells • 2 Surface water/sediment samples.	• 3 Columbia aq. wells • No Frederica aq. wells • 2 Surface water/sediment samples	• Unexpected well completion depths required rescheduling four wells until Stage 2.
2. DD-1, North Ditch	• 8 Surface water/sediment samples • 3 Soil borings to 5 ft. BLS (2 samples/boring)	• 6 Surface water/sediment samples	• Interviews indicated a single point of wastewater discharge to site; samples scheduled at discharge points were eliminated. Soil borings were rescheduled until after contaminated areas are confirmed.
3. D-10, Landfill	• 5 Columbia aq. wells	• Implemented as proposed	
4. D-4, Liquid Waste Site	• 4 Columbia aq. wells	• Implemented as proposed	
5. FT-1, Fire Training Area 1	• 4 Columbia aq. wells • 2 Surface water samples	• Implemented as proposed	
6. FT-3, Fire Training Area 3	• 3 Columbia aq. wells • 4 Surface water/sediment samples	• Implemented as proposed	

(continued)

BLS = Below land surface.
aq. = Aquifer.

Table 3-1 (continued)

DAFB PHASE II STAGE 1. SUMMARY OF PROPOSED AND IMPLEMENTED MONITORING PROGRAMS

Site	Program Proposed	Program as Implemented	Reason for Program Modification
SP-4, JP-4 Pipeline Leak	• 3 Well points (Columbia aq.)	• Implemented as proposed	
D-5, Landfill	• 3 Columbia aq. wells	• Implemented as proposed	
FT-2, Fire Training Area 2	• 1 Well point (Columbia aq.)	• Program not implemented	• Information indicated FT-2 did not exist as described, and did not have the potential to contaminate the environment.
S-1, Hazardous Waste Storage	• 4 Columbia aq. wells • 2 Soil borings to 5 ft BLS (2 samples/boring)	• 3 Columbia aq. wells • 4 Surface soil samples	• Well completion depths beyond those expected required rescheduling one well to Stage 2. Surface soil samples provided greater areal coverage of site than soil borings.
Site XYZ, Fuel Pump Station	• 4 Well points • 3 Surface water/sediment samples from manholes	• 4 Well points • 1 Surface water sample • 2 Sediment samples	• Two manholes did not contain water, one manhole contained water but did not contain sediment.
Site D-2, Rubble Area	• 4 Surface water/sediment samples • 4 Soil samples at 5 ft BLS	• 8 Soil samples	• Surface waters were not present during field program. Surface soil samples provided greater areal coverage than deep soil borings.

BLS = Below land surface.
aq. = Aquifer.

designed to confirm contamination and identify zones of high contamination within the ditch through surface water and sediment sampling. Monitoring wells would then be installed during Stage 2 to target these identified areas.

2. At Site D-2, Rubble Area, available data indicated that the site was not used for subsurface burial. Therefore, the proposed Stage 1 program consisted of sampling surface water and soils around the area because the primary route of contaminant migration was thought to be by surface runoff.

Groundwater monitoring wells were potentially located to determine water quality upgradient and downgradient of sites. In the absence of site-specific data on groundwater flow direction, well locations were selected based on the estimated direction of groundwater flow provided in the Phase I report, the surface topography, and the location of surface water bodies. Wells were located close to study sites so that leaks from the source would be detected.

The selection of monitoring well locations was complicated at Sites XYZ, SP-4, D-10, and FT-1. At Sites XYZ and SP-4, the direction of flow could not be estimated because the sites are located near a presumed groundwater divide; therefore, wells were located surrounding each of these sites. Wells were located surrounding Sites D-10 and FT-1 (Golf Course Sites) because the effects of seasonal spray irrigation on groundwater flow patterns under the golf course could not be determined. Groundwater recharge from golf course irrigation could increase the elevation of the water table beneath Sites FT-1 and D-10. This temporary rise could alter groundwater flow patterns causing radial flow away from the irrigated areas to occur. Monitoring wells surrounding the sites would identify contaminants entering groundwater from the sites regardless of the effects on groundwater flow patterns caused by the seasonal irrigation.

The number of groundwater monitoring wells installed at each site was based on several factors:

1. The size of the site: large sites (e.g., FT-1, D-10) required more wells to provide sufficient coverage.

2. The type of waste: more wells were located near sites where liquid wastes were thought to be disposed (e.g., D-4, D-10) because of the higher potential for contaminant migration.

3. The confidence in the estimated flow direction: sites where multiple flow directions were possible (e.g., SP-4, XYZ area) required more wells.

4. A minimum monitoring configuration of three wells: one upgradient and two downgradient wells, so that groundwater flow directions and rates could be determined.

5. Downgradient of Site T-1 wells were located farther from the site to attempt to establish the extent and flow direction of the confirmed groundwater contamination (Section 1.4.3).

Columbia aquifer wells (C wells) were designed to allow sampling of the entire saturated thickness of the Columbia aquifer. C well construction can be summarized as follows:

1. Well construction consisted of 2 inch inside diameter PVC riser and screen.

2. The entire saturated interval of the aquifer was screened (screens extended from the base of the Columbia to the water table).

3. Screens were 0.01 inch slot size as suggested by the drillers for the formation. Screens were manufactured, not hand-slotted.

4. Gravel pack was added to above the top of the screen.

5. The annular space above the gravel pack was sealed with bentonite and grout.

6. Protective steel casings with locking caps were installed to protect each well.

Well drilling and installation procedures are described in Section 3.2.1.

3.1.2 Selection of Surface Water Monitoring Locations

Fifteen surface water samples were collected at five Stage 1 sites (Figure 3-2). Analysis of IW Basin liquids was proposed to identify the types of constituents present. Sampling locations at the other sites were selected to identify contaminants entering surface waters as runoff from sites or in groundwater contaminated by sites. At Sites DD-1, FT-1, and FT-3, upstream samples were collected to identify background water quality. Surface water sampling procedures are described in Section 3.2.2.

3.1.3 Selection of Sediment or Soil Monitoring Locations

Twenty-six sediment or soil samples were collected at six Stage 1 sites (Figure 3-3). Grab samples of sediments were collected at all but two surface water monitoring locations (w09 and w10 at site FT-1). The long-term quality of surface waters can be estimated using the concentrations of contaminants that have entered sediments from surface waters because substances such as VOCs, metals, and oil and grease in surface waters can concentrate in sediments through a variety of mechanisms including precipitation (of metals) and adsorption (of VOCs on organic carbon and metals on clays). Sediments can also provide information on the quality of groundwater discharging to streams because the same mechanisms that act to concentrate contaminants from surface waters also act on substances in groundwater entering streams.

Surface soil samples were collected from possible spill locations and from areas that would indicate if surface runoff was being contaminated by sites. Two samples were collected at areas around Site S-1, Hazardous Waste Storage where oil stains in soils indicated possible spills. The remaining soil samples were collected from runoff swales or other downslope areas at sites where surface runoff may have transported waste material. Sediment and soil sampling procedures are described in Section 3.2.2.

3.1.4 Selection of Analysis Parameters

Table 3-2 identifies the parameters analyzed at each Stage 1 study site. These parameters were selected based on the types of compounds or wastes potentially present at each site. The types of compounds or wastes possibly present were identified in the Phase I report.

3.2 MONITORING PROGRAM IMPLEMENTATION

Phase II Stage 1 field activities began in October 1984. The monitoring program is summarized as follows:

- 25 C wells were installed and sampled
- Seven well points were installed and sampled
- Three existing wells were sampled
- 15 surface water locations were sampled

Table 3-2

SUMMARY OF DAFB PHASE II STAGE 1 CHEMICAL ANALYSIS

Site	Media	Parameters						
		Volatile Organics[a]	Oil and Grease	Cyanide and Phenols	Metals[b]	TOX	TOC	PCBs
1. T-1, IW Basins	GW/SW/SED	X	X	X	X	X	X	
2. DD-1, North Ditch	SW/SED		X	X	X	X	X	
3. D-10, Landfill	GW		X	X	X	X	X	
4. D-4, Liquid Waste Site	GW	X	X	X	X	X	X	
5. FT-1, Fire Training Area 1	GW/SW		X		X	X	X	
6. FT-3, Fire Training Area 3	GW/SW/SED		X		X	X	X	
7. SP-4, JP-4 Pipeline Leak	GW		X				X	
8. D-5, Landfill	GW	X	X	X	X	X	X	
9. S-1, Hazardous Waste Storage	GW/SL	X	X	X	X	X	X	X
10. XYZ, Fuel Pump Station	GW/SW/SED		X				X	
11. D-2, Rubble Area	SL		X		X	X	X	

[a]Laboratory analyses by EPA Methods 601 and 602 for waters and SW 846 Methods 8010 and 8020 for sediments and soils. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

[b]Arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc.

GW = Groundwater, SED = Sediment, SL = Soil, SW = Surface water.

- 26 soil or sediment locations were sampled
- 187 groundwater samples were collected for analysis
- 76 surface water samples were collected for analysis
- 134 soil/sediment samples were collected for analysis
- 131 QA/QC samples were prepared in the field for analysis
- 105 measurements of physical parameters (pH, specific conductance, and temperature) were made.

Implementation of specific elements of the field program are discussed in the following sections.

3.2.1 Installation of Monitoring Wells and Well Points

On 23 October 1984, SAIC began drilling and installing well points and monitoring wells at DAFB. All well sites were staked by SAIC geologists and checked for subsurface utilities by DAFB personnel. The drilling and installation of wells and well points was conducted by Delmarva Drilling Co., Inc., of Bridgeville, Delaware, and was supervised by SAIC personnel. A total of 25 C wells and seven well points were installed utilizing both hydraulic rotary and auger drilling methods. A summary of well construction data is provided in Table 3-3.

3.2.1.1 Columbia Aquifer Monitoring Wells (C wells)

Each C well was installed to the top of the confining Kirkwood (Miocene) silty clay to an average depth of 52 feet BLS (depths ranged from 33 ft to 63.5 ft BLS). Wells were screened throughout the entire saturated thickness of the aquifer. All wells were constructed of 2-inch inside diameter schedule 40 slip-joint PVC riser and screen which were fastened together with 3/8-inch stainless steel screws. Glue or adhesives were not used. Screen specifications were five slots per inch at 0.01 inch per slot. Well risers extended to approximately 2 feet above land surface (ALS) and were fitted with a vented PVC slip cap and a steel eye-bolt to facilitate cap removal. A 6-inch diameter steel surface casing complete with locking cap and drainage vent was installed over each well to prevent unauthorized access. As an added protective measure, three 2-inch diameter steel guard posts were placed radially around each well (except at the golf course). Both the steel protective casing and guard posts measured 5 feet in length and were installed approximately 2.5 feet ALS and BLS (Figure 3-4).

Table 3-3

MONITORING WELL AND WELL POINT CONSTRUCTION SUMMARY

Well Identification	Estimated Location[a]	Date Installed (Month/Day in 1984)	Drilling Method	Elevation Base of Aquifer		Screened Interval		Static Water Level (1/9/85)	
				BLS	MSL	BLS	MSL	BTC	MSL
01j[b]	200 ft NE Site T-1	10/31	Rotary	40	-20.56	9-38	10.44-⁻18.56	11.51	9.88
02j	500 ft W T-1	11/14	Auger	34	- 8.44	18-33.5	7.56-⁻7.94	16.89	10.67
04j	400 ft S T-1	11/09	Rotary	45.8	-22.6	10.8-44.8	12.4-⁻21.6	14.96	10.44
05j	800 ft NE Site D-10	11/13	Auger	59	-41.03	13-58.5	4.97-⁻40.53	13.26	6.81
06j	20 ft SE D-10	11/2	Rotary	55	-39.65	8-53	7.35-⁻37.53	12.86	4.54
07j	20 ft SW D-10	11/1	Auger	52	-41.63	8-52	2.37-⁻41.63	8.48	4.09
08j	40 ft SW D-10	11/7	Rotary	52	-39.50	10-51	2.50-⁻38.5	10.59	3.61
09j	20 ft NW D-10	11/2	Auger	52	-37.37	10-52	4.63-⁻37.37	11.61	4.74
10	20 ft WSW Site D-4	10/25	Auger	59	-39.60	10-56	9.4-⁻36.60	13.44	8.94
11	30 ft N D-4	10/26	Rotary	55	-35.25	11-55	8.75-⁻35.25	12.92	8.84
12	40 ft NE D-4	10/29	Auger	55	-35.26	11-55	8.74-⁻35.26	12.98	8.83
13	30 ft E D-4	10/26	Auger	63	-42.64	11.5-61.5	8.86-⁻41.14	14.10	8.87
14	30 ft NE Site FT-1	11/1	Rotary	57	-37.88	13-56	6.12-⁻36.88	15.33	5.83
15	20 ft SE FT-1	11/5	Auger	45	-35.79	8-48	1.21-⁻38.79	6.79	4.32
16	10 ft NW FT-1	11/5	Rotary	45	-36.51	6-42.5	2.49-⁻34.01	6.53	4.04
17	20 ft SW FT-1	11/13	Rotary	40.3	-31.90	7-40	1.40-⁻31.60	7.07	3.20
18	50 ft S Site FT-3	10/24	Auger	49	-30.87	10.5-48.5	7.63-⁻30.37	12.70	7.03
19	100 ft NNE FT-3	10/24	Rotery	44	-29.58	9-44	5.42-⁻29.58	9.66	6.66

(continued)

[a]Surveyed locations are provided in Appendix D.

[b]The suffix "j" on wells 01 through 09 was added to differentiate the wells installed by SAIC during Stage 1 from the wells installed by DNREC (S4 through S9, refer to Section 1.4.6) in July-August 1984.

[c]Wells 101, 102, and 103 were installed in 1982 by a USAFOEHL contractor (refer to Section 1.4.3).

BLS = Below land surface.
MSL = Mean sea level.
BTC = Below top of casing.

Table 3-3 (continued)

MONITORING WELL AND WELL POINT CONSTRUCTION SUMMARY

Well Identification	Estimated Location[a]	Date Installed (Month/Day in 1984)	Drilling Method	Elevation Base of Aquifer		Screened Interval		Static Water Level (1/9/85)	
				BLS	MSL	BLS	MSL	BTC	MSL
20	250 ft E FT-3	10/25	Rotary	40	-29.61	7-40	3.39-⁻29.61	6.10	6.24
21	20 ft N Site D-5	10/29	Rotary	60	-43.94	10-60	6.06-⁻43.94	9.24	8.79
22	20 ft NE D-5	10/30	Rotary	60	-41.77	10-60	8.23-⁻41.77	11.35	8.84
23	20 ft SE D-5	10/30	Auger	58.2	-38.76	10-57	9.44-⁻37.56	12.45	8.94
24	50 ft NW Site S-1	10/31	Auger	61.5	-37.82	15-60	8.68-⁻37.82	16.99	8.62
25	10 ft SE S-1	11/8	Auger	56	-31.48	18-55	6.52-⁻30.48	18.13	8.69
27	10 ft SE S-1	11/9	Auger	63.5	-41.29	13-63	9.21-⁻40.79	15.75	8.46
p01	100 ft SE Site SP-4	11/6	Auger			13.5-16.5	12.42-9.42	13.98	15.04
p02	20 ft NE SP-4	11/6	Auger			13.5-16.5	11.85-8.85	17.34	10.01
p03	200 ft SW SP-4	11/6	Auger/Rotary			14-17	11.79-8.79	14.07	12.92
p05	50 ft WNW Site XYZ	11/7	Auger			11.5-14.5	11.37-8.37	10.60	14.27
p06	50 ft NW XYZ	11/7	Auger			17-20	9.87-6.87	13.53	15.34
p07	50 ft ENE XYZ	11/7	Rotary			14-17	9.58-7.34	10.55	15.63
p08	50 ft SE XYZ	11/7	Auger			14.5-17.5	10.34-7.34	11.83	15.01
101[c]	10 ft NE Site T-1							13.75	11.26
102	10 ft SE T-1							13.40	11.11
103	10 ft SW T-1							13.45	11.17

Note: Blank space indicates data not available.
[a]Surveyed locations are provided in Appendix D.
[b]The suffix "j" on wells 01 through 09 was added to differentiate the wells installed by SAIC during Stage 1 from the wells installed by DNREC (S4 through S9, refer to Section 1.4.6) in July-August 1984.
[c]Wells 101, 102, and 103 were installed in 1982 by a USAFOEHL contractor (refer to Section 1.4.3).

BLS = Below land surface.
MSL = Mean sea level.
BTC = Below top of casing.

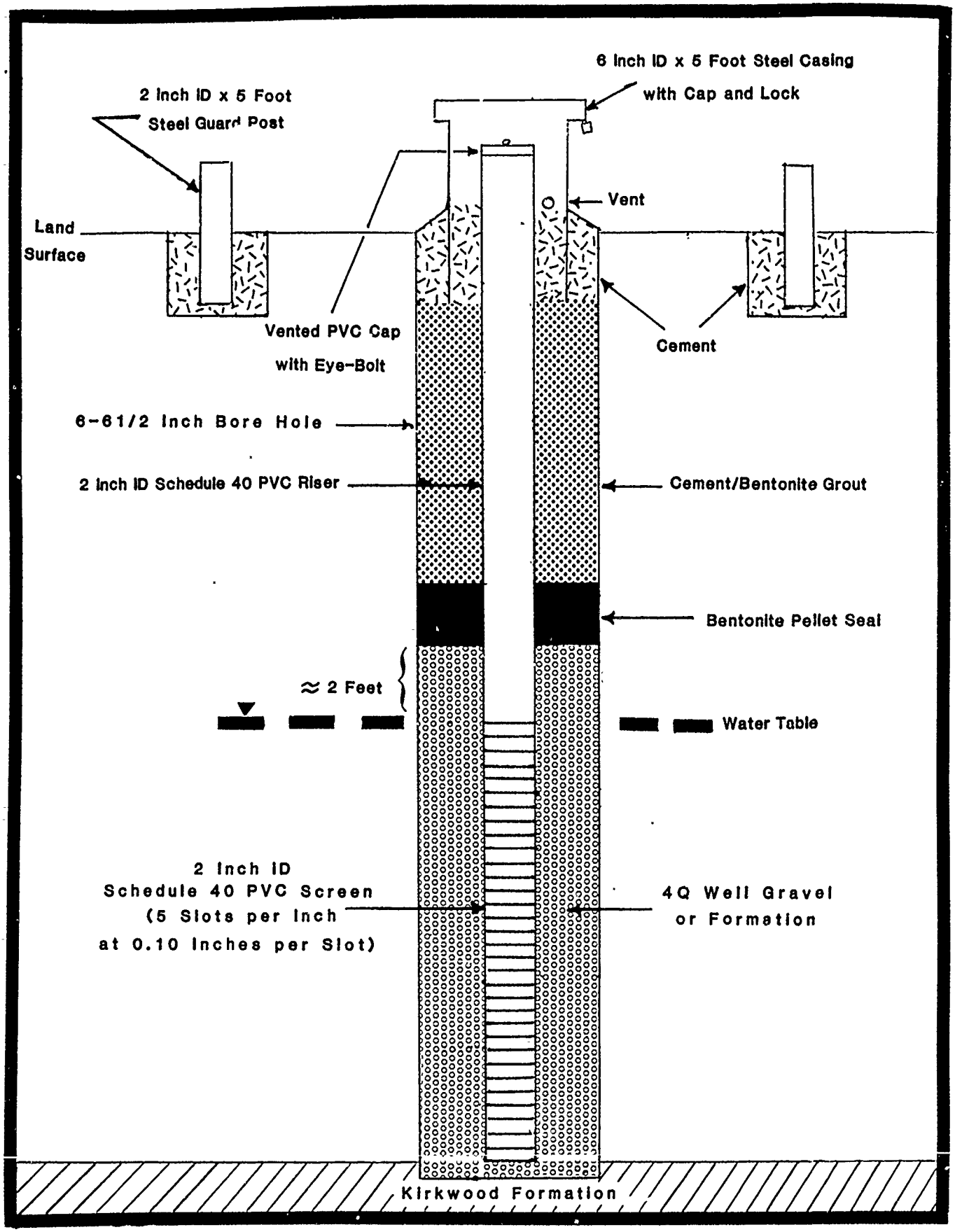


Figure 3-4. Diagram of a Typical Monitoring Well

Well boreholes were drilled using either an auger drill rig equipped with 6-inch outside diameter (o.d.), 3 1/4-inch inside diameter, (i.d.) hollow stem augers or a hydraulic rotary rig equipped with a 6 1/2-inch diameter drag bit. Drilling began by advancing the borehole 4 to 5 feet BLS. At this point, and at 5-foot intervals thereafter, a 1.5-foot split spoon sample was taken in accordance with ASTM Standard 2586 for lithologic and pedologic description. Sample descriptions recorded by the SAIC supervisory geologist consisted of the following:

- Sample interval
- Blow count per 6-inch sample interval
- Amount of recovery
- Sample color (based on Munsell color charts)
- Sample texture
- Sample moisture content
- Unusual or distinguishing characteristics.

The drilling and sampling cycle was repeated until the top of the Kirkwood (Miocene) unit was encountered. Ambient air monitoring was performed during drilling using an organic vapor analyzer (h·nu Photo-ionizer Model 101).

Once the top of the Kirkwood (Miocene) was reached, proper lengths of screen and riser pipe were fastened together and lowered within the in-place hollow stem augers or open borehole. For wells drilled with a hydraulic rotary rig, 4Q sand was poured down the annulus between the well and borehole. The depth to the top of the sand pack was measured until it extended 2 feet above the screen. After confirming the depth of the sand pack, a 2 to 3 foot bentonite pellet seal was added over the sand pack and allowed to hydrate. For wells installed through in-place hollow stem augers, sand pack could not be installed through the auger flights because of running and heaving sands. Instead, the augers were removed slowly over the well allowing the formation to collapse around the screen. Once the augers had been completely removed, the depth to the top of the collapsed formation material was measured and 4Q sand was added until it extended to 2 feet above the well screen. A 2 to 3 foot bentonite pellet seal was then added and allowed to hydrate.

Once the bentonite seal was in place (regardless of drilling method), a cement/bentonite grout mixture (approximately 5 lbs of Quick-Gel bentonite to 94 lbs of Type 1 Portland cement) was added until it extended to approximately 2.5 feet BLS. The grout mixture was allowed to set-up for at least 24 hours. The protective steel casing was then cemented in place over the well. A schematic diagram of a typical well is shown in Figure 3-4. Boring logs and well construction summaries for each of the wells installed during Stage 1 are provided in Appendix D.

3.2.1.2 Well Points

A total of seven well points were installed at Sites XYZ and SP-4. Each well point consisted of a 3 foot section of 2-inch inside diameter Johnson™ stainless steel well screen (10 slots per inch at 0.01 inches per slot) screwed onto a threaded 2-inch inside diameter steel riser, which extended to approximately 2 feet ALS. The top of the riser was threaded and a screw-type (threaded) vented steel cap was placed at the top of each riser.

An initial attempt was made to install the well points by jet-washing them to the required depth, but the presence of gravel within the surficial deposits beneath each of the sites prohibited use of this method. Consequently, boreholes were drilled with an auger drill rig equipped with 6-inch o.d. by 3 1/2-inch i.d. hollow stem augers and a hydraulic rotary rig using a 6 1/2-inch diameter drag bit. The well points were installed through the in-place hollow stem augers or down an open borehole in the same manner as previously described.

Drilling began by advancing the borehole to the water table. Then the borehole was advanced an additional 5 feet. Drill cuttings were described and logged by the supervisory geologist and ambient air monitoring was performed with an organic vapor analyzer. Once the borehole was at least 5 feet below the water table, the proper riser length was selected, a well screen was attached, and the well point assembly was lowered down the in-place hollow stem augers or open borehole. Well points were then completed using the same procedures as C wells described above. Boring logs and well construction summaries for each of the well points installed are provided in Appendix D.

3.2.1.3 Well Development and Surveying

After wells had been in place for at least 24 hours, each well or well point was developed by first air surging for a period of at least 2 hours to loosen fines from the screen and sandpack and then pumping at least 5 casing volumes of water. In most cases, wells were pumped for at least 2 hours at approximately 10 gallons per minute. Because of the slow rate of recovery and small volume of standing water within the well points, five casing volumes of water were removed from each well point by hand bailing with a teflon bailer. Also, the rate of groundwater recovery within well 02j was insufficient for use of a centrifugal pump and was developed by hand bailing.

At the completion of drilling operations, horizontal and vertical locations of all wells were surveyed by Gerald A. Donovan and Associates of Dover, Delaware. Horizontal locations were established by EDM (Electronic Distance Meter) measurements from known landmarks. Vertical control was established to the well top (PVC riser) by running levels from a known bench mark. Surveyed horizontal locations are provided in Appendix D. Table 3-3 lists the elevations of each well taken at the top of casing and at land surface.

3.2.1.4 Decontamination Procedures

Before drilling each well, all equipment (e.g., augers, drill steel, bits, samplers, wrenches, and other equipment) that contacted potentially contaminated soil or water were laid out and sprayed with clean water from the base's domestic water source to remove caked-on mud and dirt. These items were then washed with a high pressure steam sprayer to remove residual contaminants and then rinsed. Drill rigs also were washed between each well with the high pressure steam sprayer to remove mud and contaminants from the drill platform and adjacent work areas.

3.2.2 Sampling Procedures

3.2.2.1 Groundwater Sampling

Water levels were measured at each well using the wetted tape method (USGS, 1980). For this method, a weighted graduated tape is marked with a

water soluble marker and lowered to just below the groundwater level. The total distance from the top of the casing was recorded and the tape extracted. Once removed, the length of the mark removed by the water is recorded. This length is then subtracted from the total length to obtain depth to groundwater.

Prior to collecting groundwater quality samples, each well or well point was purged by pumping or bailing at least five casing volumes to ensure that a representative sample of the aquifer was collected. A centrifugal pump or teflon bailer was used in purging depending on well yield. The pump and hosing or bailer were decontaminated between each well by scrubbing with a low residue laboratory grade detergent and then rinsing with distilled water (deVera et al., 1980). Sample collection took place within 24 hours after purging. Water quality samples were collected by lowering a cleaned, point-source, teflon bailer into the well. Samples were collected at the top of the well screen (i.e., top of the surficial aquifer) because most wells are located adjacent to study sites, and the highest concentrations should be found close to the water table. The bailer was cleaned between well samples with a low residue laboratory grade detergent and rinsed with distilled water. Water quality samples were extracted from the bailer with a teflon bottom emptying device to minimize sample agitation.

Samples were analyzed in the laboratory for various parameters depending on the site, including TOX, TOC, oil and grease, phenols, cyanide, PCBs, purgeable hydrocarbons and aromatics, and metals. Table 3-2 lists the type of analyses performed at each study site. Samples were preserved and stored in containers according to methods prescribed by EPA (1979) in "Methods for Chemical Analysis of Water and Wastes" and by SAIC Laboratories. Table 3-4 lists the preservation method and sample container type used during Stage 1.

During the sampling operations, collected samples were stored in ice chests to maintain a temperature of 4°C. At the end of a sampling day, collected samples were packaged in ice chests with "blue ice" or regular ice to maintain the 4°C temperature and shipped via overnight carrier to the laboratory. This ensured delivery of the samples to the laboratory within 24 hours of sample collection.

Table 3-4

DAFB PHASE II STAGE 1. SUMMARY OF SAMPLE PRESERVATION AND STORAGE PROCEDURES

Media	Parameter	Container	Preservative[a]	Special Instructions
Water	Oil and Grease	1 liter glass	1-2 ml of HCl	Fill container 90% full
	TOC	120 ml amber glass	1 ml H_2SO_4	No air space
	TOX	120 ml amber glass	5 drops 1M Na_2SO_3 1 ml HNO_3	No air space
	Phenols	1 liter amber glass	2 ml H_3PO_4 1 g $CuSO_4$ powder	Fill container greater than 3/4 full
	Metals[b]	1 liter plastic (LPE)	2 ml of HNO_3	Fill container 3/4 full
	Volatile Organics[c]	4-40 ml clear VOA vials with teflon septa		No air space
	Cyanide	1 liter plastic (LPE)	2 ml NaOH	Fill container greater than 3/4 full
	PCBs	1 gallon amber with teflon liners	None	Fill container 90% full
Solids	TOX	40 ml clear VOA vials	None	Fill 2 vials with homogenous sediment sample
	Volatile Organics[d]	40 ml clear VOA vials	None	
	Oil and Grease	32 oz. glass widemouth	None	Fill container as full as possible, pour off excess water
	TOC	32 oz. widemouth	None	Fill container as full as possible, pour off excess water
	Phenols	32 oz. widemouth	None	Fill container as full as possible, pour off excess water
	Metals	32 oz. widemouth	None	Fill container as full as possible, pour off excess water
	Cyanide	32 oz. widemouth	None	Fill container as full as possible, pour off excess water
	PCBs	32 oz. widemouth	None	Fill container as full as possible, pour off excess water

[a]All samples placed in ice chests and cooled to 4°C.
[b]Arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, and zinc.
[c]Purgeable Hydrocarbons and Aromatics (EPA Methods 601 and 602).
[d]Purgeable Hydrocarbons and Aromatics (SW-846 Methods 8020 and 8010).

3.2.2.2 Surface Water, Sediments, and Soil Sampling

When possible, both surface water and sediment samples were taken at the same location on a stream. Table 3-2 lists the parameters that were analyzed at each location.

Surface water quality samples were obtained using grab sampling techniques (USGS, 1977). A Nalgene scoop was used to collect the sample, which was then transferred to appropriate containers. The Nalgene scoop was decontaminated between each sampling location by scrubbing with a low residue laboratory grade detergent and then rinsing with distilled water. Care was taken not to disturb bottom sediments and incorporate them into the water sample. This was achieved by sampling the point furthest downstream first and working upstream. When wading into the stream was necessary, samples were collected upstream from any disturbance.

Surface water quality samples were obtained only at those points where water was flowing. Stagnant water was not sampled because this water may not be representative of contaminant concentrations migrating from a site.

Sediment and soil samples were collected from the top three inches of soil with a plastic or stainless steel scoop and deposited directly into sample containers. The scoop was thoroughly cleaned between samplings by scrubbing with an Alconox solution and rinsing with distilled water to prevent cross contamination between samples.

3.2.2.3 Field QA/QC Sample Collection

During the field sampling of groundwater, surface water, and sediments, numerous QA/QC procedures were enacted to ensure the quality and integrity of the effort. These procedures included the following:

- Maintenance of chain-of-custody forms for all samples.
- Daily collection of the following QA samples:
  - One field blank was collected prior to the start of sampling. This sample consisted of pouring distilled water into sample containers and carrying these samples through the day's field sampling activities.

- One bailer wash was collected prior to the start of sampling after the bailer had been decontaminated. This sample consisted of filling the bailer with distilled water and pouring the water into sample containers. Bailer washes are utilized to evaluate field decontamination procedures.

- Field duplicate samples that consisted of two samples collected from the same location for every 10 environmental samples. Field duplicates were collected in the same manner as normal samples. Results of field duplicate samples are used as an indication of the reproducability of sampling procedures. They also provide an indication of the precision of the sampling and analysis procedures.

- Cleaning of all sampling implements (i.e., hoses, bailers, spades) between each sample point by washing with a low residue, biodegradable detergent and rinsing with clean water. This method was utilized to ensure that contaminants were not transferred between monitoring points (EPA, 1977).

Copies of the results of the field QA samples are given in Appendix H and discussed in Section 4.1.1.

4.0 DISCUSSION OF RESULTS AND SIGNIFICANCE OF FINDINGS

Environmental monitoring was performed at 11 sites at Dover AFB (DAFB) during Phase II Stage 1. Samples of groundwater at nine sites, surface water at five sites, and soils or sediments at six sites were collected for analysis. Section 3 discussed the types and numbers of samples collected and analyses performed. The analytical methodologies and complete laboratory reports are provided in Appendix H.

Results presented in this section's tables are as detected and reported by the laboratory except for metals and arsenic in water. Values reported by the laboratory for metals and arsenic which were less than the USAFOEHL reporting limits are reported in the tables as less than the reporting limits (L). The USAFOEHL reporting limits are at or below drinking water standards and the USAFOEHL uses these limits as cutoff levels for analysis purposes only. Levels below laboratory detection limits are reported in the tables as not detected (ND).

Findings based on sample analysis results include the following:

1. Field blank and bailer wash results indicated that sample collection and handling procedures did not introduce into samples levels of VOCs, cyanides, phenols, metals, or arsenic that would affect data interpretation. Field decontamination procedures were effective in preventing cross-contamination between samples. Field blank and bailer wash samples contained several VOCs at 1.1 ppb or less and several metals at levels less than the USAFOEHL reporting limits. One field blank and one bailer wash, collected on the same day, contained chloroform (25 ppb and 25 ppb, respectively) and 1,2-dichloropropane (25 ppb and 20 ppb, respectively), but data interpretation was not affected because these compounds were not detected in environmental samples.

2. Field blanks and bailer wash results for TOX, TOC, and oil and grease indicated that sampling or analytical procedures may have affected the detected levels of these parameters in the environmental samples. Therefore, the levels of these parameters in the environmental samples were compared with the respective levels detected in the QA/QC samples collected on the same day.

3. The results of field duplicate sample pairs indicated that sample collection and handling procedures did not affect the reproducibility of samples. Agreement between field duplicate pairs for all parameters except VOCs was good. With respect to VOCs, the laboratory detected the same VOC in 81 percent of the analysis pairs. In 70 percent of these cases, detected concentrations were within one order of magnitude of each other. In most other cases (i.e., where VOC concentrations in field duplicate pairs were not similar), detected concentrations were close to detection limits and differences may have been caused by inaccuracies inherent in analytical methods at these levels.

4. VOCs were detected in:

   - Groundwater, surface water, and sediments at Site T-1, IW Basins.
   - Groundwater and soils at Site S-1, Hazardous Waste Storage.
   - Groundwater at Sites D-4, Liquid Waste Site and D-5, Landfill.

   The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

5. Concentrations of metals above criteria and standards or background levels were detected in groundwater at Sites T-1, D-10, FT-1, FT-3, D-5, and S-1.

6. The concentrations of metals in surface waters (excluding wastewater in Site T-1, IW Basins) were above background levels at Site FT-3 (zinc) and were above criteria and standards at Site DD-1 (nickel).

7. The concentrations of metals and arsenic in soils and sediments at Sites T-1, DD-1, FT-3, S-1, and D-2 were above background levels.

8. At least one indicator parameter (oil and grease, cyanide, phenol, TOX, TOC) in at least one media at each site was above background levels.

Sample results and findings based on the Phase II Stage 1 program are presented in the following sections. Section 4.1 contains the results of field and laboratory QA/QC samples. Section 4.2 describes the procedures used in evaluating sample results. The section also provides regional geochemical data used to identify naturally occurring concentrations and the water quality criteria and standards used to indicate potential health or environmental hazards. Section 4.3 includes the results of samples collected at study sites and the findings based on these results.

4.1 QUALITY ASSURANCE/QUALITY CONTROL DATA

QA/QC samples analyzed during Stage 1 were:

1. Field QA/QC samples to identify whether field or laboratory procedures could have introduced contaminants to environmental samples and to check the overall precision of sampling and analysis procedures. These QA/QC samples included field blanks, bailer washes, and field duplicate pairs.

2. Laboratory QA/QC samples to measure the accuracy and precision of laboratory procedures. These included spiked samples and laboratory replicates.

Sections 4.1.1 and 4.1.2 respectively discuss the analytical results of field and laboratory QA/QC samples.

4.1.1 Field QA/QC Sample Results

Ten field blanks and seven bailer washes were collected and analyzed during Phase II Stage 1. Eight field blanks and five bailer washes were analyzed for metals and indicator parameters and two field blanks and two bailer washes were analyzed for VOCs. Tables 4-1 and 4-2 summarize the results of field blank and bailer wash analyses. As discussed in Section 3.2.2.3, field blanks were prepared by pouring distilled water into sample bottles at the start of the day. These samples were carried through the field during sampling activities and shipped with the environmental samples to the laboratory for analysis. Parameters detected in field blanks may be the result of improper sample handling, cross-contamination during sample shipment, or inherent contamination in the distilled water.

Bailer washes were prepared by pouring distilled water into a clean bailer and then into sample bottles. Bailer washes were shipped with the environmental samples for analysis. Because the distilled water only contacts the clean bailer, the bailer wash analysis is used to indicate if bailer decontamination was complete and has prevented sample cross-contamination (i.e., the introduction of contaminants from a contaminated well into an uncontaminated or less contaminated well via a bailer which was not properly decontaminated).

Table 4-1

ANALYSIS RESULTS FOR PURGEABLE HALOCARBON AND AROMATIC COMPOUNDS
IN FIELD QA/QC SAMPLES

Compound	QA Sample Types	
	Field Blanks QA1b and QA4b	Bailer Washes QA2b and QA5b
EPA Method 601	(Results in ppb)	
Bromoform	ND	ND
Bromodichloromethane	ND	ND
Bromomethane	ND	ND
Carbon tetrachloride	ND	ND
Chlorobenzene	ND	ND
Chloroethane	ND	ND
Chloroethyl vinyl ether, 2-	ND	ND
Chloroform	ND and 25	ND and 20
Chloromethane	ND	ND
Dibromochloromethane	ND	ND
Dichlorobenzene, 1,2-	ND	ND
Dichlorobenzene, 1,3-	ND	ND
Dichlorobenzene, 1,4-	ND	ND
Dichlorodifluoromethane	ND	ND
Dichloroethane, 1,1-	ND	ND
Dichloroethane, 1,2-	ND	ND
Dichloroethylene, 1,1-	ND	ND
Dichloroethylene, trans-1,2-	ND	ND
Dichloropropane, 1,2-	ND and 25	ND and 25
Dichloropropene, cis-1,3-	ND	ND
Dichloropropene, trans-1,3-	ND	ND
Methylene chloride	ND	ND
Tetrachloroethane, 1,1,2,2-	ND	ND
Tetrachloroethylene	0.68 and 0.35	0.48 and 0.2
Trichloroethane, 1,1,1-	ND	ND
Trichloroethane, 1,1,2-	ND	ND
Trichloroethylene	0.2 and ND	0.18 and ND
Trichlorofluoromethane	ND	ND
Vinyl chloride	ND	ND
EPA Method 602		
Benzene	ND	ND
Chlorobenzene	ND	ND
Dichlorobenzene, 1,2-	ND	ND
Dichlorobenzene, 1,3-	ND	ND
Dichlorobenzene, 1,4-	ND	ND
Ethylbenzene	ND	ND
Toluene	1.1 and 0.84	0.54 and 0.76

Note: The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy
ND = Not detected; indicates compound not present above detection limit
ppb = ug/l

Table 4-2

CONCENTRATION RANGES OF METALS AND INDICATOR COMPOUNDS IN FIELD QA/QC SAMPLES

Parameter	Groundwater		Surface Water
	Field Blanks	Bailer Wash	Field Blanks
	(Results in ppb)		
Silver	ND	ND-0.50	ND
Arsenic	ND	ND	ND
Cadmium	ND-0.21	ND-0.12	ND-0.56
Chromium	ND-0.72	ND-0.90	0.32-0.49
Copper	1.3-3.6	1.2-3.1	1.1-1.4
Iron	ND-32	ND-0.017	ND
Mercury	ND-0.33	ND-0.044	ND
Nickel	ND-7.4	ND-6.6	ND-6.5
Lead	ND-7.0	ND-2.1	0.97-4.9
Zinc	ND-8.7	1.4-12	3.2-5.9
	(Results in ppm)		
Oil and Grease	ND-0.28	ND-0.11	ND-2.3
Cyanide	ND-0.007	ND-0.010	ND
Phenols	ND	ND-0.006	ND
TOX	ND-0.068	0.035-75	0.066-1.0
TOC	0.4-4.7	0.7-6.8	0.6-12
PCBs[a]	ND	ND	

Note: Blank space indicates analysis was not conducted
[a]Analysis for PCBs was conducted on one field blank and one bailer wash, which were collected during the sampling of Site S-1, Hazardous Waste Storage
ppb = ug/l; ppm = mg/l
ND = Not detected; indicates parameter not present above detection limit

The results of field blanks and bailer washes are summarized as follows:

1. Five VOCs were detected in analyzed QA samples. The same five compounds appeared in both field blanks and bailer washes at nearly the same concentrations. Toluene, trichloroethylene, and tetrachloroethylene were detected at levels between 0.54 and 1.1 ppb, ND and 0.2 ppb, and 0.2 and 0.68 ppb, respectively. Chloroform and 1,2-dichloropropane were both detected at levels of between ND and 25 ppb, but were not detected in any environmental sample. Therefore, their presence was not a result of cross-contamination. The positive identities of the VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

2. The concentrations of metals and arsenic detected in field blanks and bailer washes prepared on the same day were similar.

3. Oil and grease concentrations ranged from ND to 2.3 ppm in field blanks and ND to 0.11 ppm in bailer washes.

4. Cyanide was detected at 0.01 ppm or less in field blanks and bailer washes. Phenol was detected at 0.006 ppm or less in bailer washes.

5. TOX levels were detected in all but 1 of 13 field QA/QC samples. All of the detected results were higher than the maximum TOX estimated to occur naturally (0.02 ppm). In some cases, TOX levels in these samples were higher than those found in environmental samples.

6. TOC values ranged from 0.4 to 12 ppm in field blanks, and 0.7 to 6.8 ppm in bailer washes. TOC levels in 62 percent of the field blanks and 60 percent of the bailer washes were higher than 2.0 ppm.

7. PCBs were not detected in field blanks or bailer washes.

The sources for the compounds detected in field blanks and bailer washes were not identified. Distilled water purchased off the shelf appears to be the source of the VOCs and metals because the VOCs and metals were detected in similar concentrations in both field blanks and bailer washes prepared on the same day. Agitation of the sample inherent to preparing a bailer wash would strip VOCs from the distilled waters but would not have any affect on the metals. This could explain the slightly lower VOC concentrations in bailer washes than in field blanks versus the similar metal concentrations detected in both field blanks and bailer washes prepared on the same day. The levels of cyanide and phenol detected in field blanks and bailer washes were only slightly above laboratory detection limits and may have been a result of inaccuracies in laboratory methods or residuals in the distilled water. The sources of the compounds responsible for the levels of oil and grease, TOX,

and TOC were not identified, but the levels may have been caused by interferences introduced during sampling (e.g., from distilled water, from unclean glassware or less than pure reagents or preservatives, or by laboratory error). Elevated TOX concentrations could be caused by low-grade reagents, unsealed glassware, impure or contaminated activated carbon, halogenated organic vapors present in the laboratory, or long storage periods above temperatures of 4°C (USEPA, 1982c). TOC levels also could be caused by plasticizers or phthalates leaching from plastic distilled water containers.

Field blank and bailer wash results indicated that sample collection, handling, and analysis procedures did not introduce levels of VOCs, cyanides, phenols, metals, or arsenic that would affect the levels of these parameters detected in the environmental samples. However, the concentrations of TOX, TOC, and oil and grease detected in several field blanks and bailer washes do indicate that unidentified sources may have been introduced which might affect the concentrations of the respective parameters detected in the environmental samples. In such situations, the levels detected in the environmental samples were compared with the levels in the field blank and bailer wash collected on the same day as the environmental samples. Levels in the environmental samples above those in the field blank or bailer wash were accepted as concentrations actually present in the environmental samples (Section 4.2).

Tables 4-3, 4-4, and 4-5 provide the analytical results for field duplicate sample pairs. These sample pairs were collected from the same location at the same time. However, they are not split samples because the sampled media was not initially mixed and subsequently halved to create two homogeneous samples. Samples were not mixed so as to minimize any agitation that could strip VOCs or other volatile components from the samples. Field duplicate sample pairs check the overall precision of sampling and analysis procedures. A total of 11 field duplicate pairs were collected and analyzed during Stage 1.

Table 4-3

CONCENTRATIONS OF PURGEABLE HALOCARBON AND AROMATIC COMPOUNDS
IN FIELD DUPLICATES

Compound	Field Duplicate Pairs							
	MW 103	QA 6b	SW 01	QA 7b	SD 02	QA 17a	MW 13	QA 3b
EPA Method 601[a]	(Results in ppb)							
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethyl vinyl ether, 2-	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene, 1,4-	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroethane, 1,1-	350	720	23	41	ND	3.6	ND	ND
Dichloroethane, 1,2-	20	57	0.5	0.81	ND	ND	ND	ND
Dichloroethylene, 1,1-	240	830	2.0	19	ND	ND	ND	ND
Dichloroethylene, trans-1,2-	3900	4400	7.1	130	ND	ND	620	640
Dichloropropane, 1,2-	ND	ND	ND	ND	ND	ND	ND	ND
Dichloropropene, cis-1,3-	ND	ND	ND	ND	ND	ND	ND	ND
Dichloropropene, trans-1,3-	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	ND	450	9000	23000	ND	ND	ND	ND
Tetrachloroethane, 1,1,2,2-	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethylene	13	30	6.1	7.1	4.5	4.5	15	3.0
Trichloroethane, 1,1,1-	7700	5700	390	880	2.9	3.2	ND	ND
Trichloroethane, 1,1,2-	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethylene	80	240	4.4	8.0	2.4	2.9	2.8	0.53
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	25[b]	100[b]	ND	ND	ND	ND	ND	ND

(continued)

[a]The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b]Chromatographs of samples MW 103 and field duplicate QA6b showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak may be an interference from the sample matrix

ND = Not detected; indicates compound not present above detection limit
ppb = ug/l for water; ug/kg for solids
MW = Groundwater sample; SW = Surface water sample; SD = Sediment/solids sample;
QA = Field duplicate sample

Table 4-3 (continued)

CONCENTRATIONS OF PURGEABLE HALOCARBON AND AROMATIC COMPOUNDS
IN FIELD DUPLICATES

Compound	Field Duplicate Pairs							
	MW 103	QA 6b	SW 01	QA 7b	SD 02	QA 17a	MW 13	QA 3b
EPA Method 602[a]								
Benzene	ND	1.7	22	19	ND	1.5	24	23
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene, 1,2-	ND	ND	ND	ND	1.2	13	ND	ND
Dichlorobenzene, 1,3-	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene, 1,4-	ND	ND	ND	ND	0.6	ND	ND	ND
Ethylbenzene	97	4.3	14	ND	ND	ND	360	570
Toluene	42	78	610	620	ND	55	24	56

[a]The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b]Chromatographs of samples MW 103 and field duplicate QA6b showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak may be an interference from the sample matrix

ND = Not detected; indicates compound not present above detection limit
ppb = ug/l for water; ug/kg for solids
MW = Groundwater sample; SW = Surface water sample; SD = Sediment/solids sample;
QA = Field duplicate sample

Table 4-4

CONCENTRATIONS OF METAL AND INDICATOR COMPOUNDS
IN FIELD DUPLICATES (WATER)

Parameter	Field Duplicate Pairs					
	MW 102	Dup. 102	MW 04j	QA 10a	SW 02	QA 16a
	(Results in ppb)					
Silver	0.11	0.089	ND	ND	0.80	0.93
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	0.53	0.54	0.45	0.19	120	130
Chromium	71	89	14	9.8	780	780
Copper	44	42	9.3	5.0	45	47
Iron	69	73	12	7.3	1.8	1.9
Mercury	0.47	0.11	0.059	0.021	ND	0.046
Nickel	75	94	13	9.0	16	16
Lead	56	60	9.95	6.7	51	53
Zinc	76	80	49	31	270	280
	(Results in ppm)					
Oil and Grease	ND		ND	ND	26	17
Cyanide	ND		ND	ND	0.013	0.013
Phenols	0.016		ND	ND	0.026	0.056
TOX	0.46		0.26	0.23	1.2	1.5
TOC	11		2.5	1.8	110	120

(continued)

Note: Blank space indicates analysis not conducted
ppb = ug/l; ppm = mg/l
ND = Not detected; indicates parameter not present above detection limit
MW = Groundwater sample; SW = Surface water sample;
Dup. or QA = Field duplicate sample

Table 4-4 (continued)

CONCENTRATIONS OF METAL AND INDICATOR COMPOUNDS
IN FIELD DUPLICATES (WATER)

Parameter	Field Duplicate Pairs					
	SW 10	QA 19a	MW 12	QA 2a	MW 27	QA 14a
	(Results in ppb)					
Silver	ND	0.056	0.05	ND	0.12	0.14
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	0.37	0.39	0.081	0.12	0.51	0.63
Chromium	0.66	0.72	18	17	56	53
Copper	1.4	1.5	8.3	7.5	28	31
Iron	0.22	0.23	6.3	6.5	15	18
Mercury	ND	ND	0.016	0.033	0.14	0.10
Nickel	ND	ND	12	10	33	28
Lead	4.5	4.8	7.3	12	45	68
Zinc	42	41	11	27	88	100
	(Results in ppm)					
Oil and Grease	ND	ND	ND	0.19	ND	0.49
Cyanide			ND	ND	0.006	0.006
Phenols			ND	ND	ND	ND
TOX	0.066	0.094	0.016	0.068	1.4	8.2
TOC	2.5	18	2.3	20	3.8	4.7

Note: Blank space indicates analysis not conducted
ppb = ug/l; ppm = mg/l
ND = Not detected; indicates parameter not present above detection limit
MW = Groundwater sample; SW = Surface water sample;
Dup. or QA = Field duplicate sample

Table 4-5

CONCENTRATIONS OF METAL AND INDICATOR COMPOUNDS
IN FIELD DUPLICATES (SOLIDS)

Parameter	Field Duplicate Pairs			
	SD 02	QA 17a	SD 20	QA 20a
	(Results in ppm, except as noted)			
Silver	0.050	0.048	0.070	0.071
Arsenic	37	43	27	27
Cadmium	2.7	3.1	0.16	0.22
Chromium	68	76	7.6	7.8
Copper	6.6	7.2	5.2	5.8
Iron	0.46	0.47	0.40	0.38
Mercury	0.020	0.013	0.062	0.57
Nickel	5.8	4.8	7.4	6.5
Lead	24	27	34	31
Zinc	23	26	72	59
Oil and Grease	1100	1200	78	64
Cyanide	0.2	0.2		
Phenols	0.1	ND		
TOX	0.12	0.18	1.1	0.96
TOC (%)	1.2	ND	2.3	4.1

Note: Blank space indicates analysis not conducted
SD = Sediment/solid sample; QA = Field duplicate sample
ND = Not detected; indicates parameter not present above detection limit
ppm = ug/gm

The results of the field duplicate sample pairs are summarized as follows:

1. Four duplicate sample pairs were analyzed for VOCs. In 81 percent of the cases where VOC detection occurred among pairs, the compound was detected in both duplicate sample pairs (e.g., toluene at 610 ppb in SW-1 and 620 ppb in QA7b). In the cases of VOC detection in only one sample of the pair, the levels were very close to the laboratory detection level (e.g., benzene at ND in MW103 and 1.7 ppb in QA6b). In 70 percent of all cases of VOC detection in both samples, concentration levels were within one order of magnitude of each other (e.g., toluene at 24 ppb in MW13 and 56 ppb in QA3b).

2. Eight duplicate sample pairs were analyzed for metals and the indicator parameters. In 94 percent of the cases, a particular metal was detected in both samples. In the three instances of metal detection in only one sample of the pair, concentrations were detected at less than 1 ppb. There was excellent agreement in concentrations detected between pairs; most results for duplicate pairs were within several parts per billion of each other. The remaining indicator parameters (oil and grease, cyanide, phenols, TOX, and TOC) were detected in both samples of a duplicate sample pair in all but four cases. Concentration levels were within one order of magnitude in 81 percent of the cases.

Generally, the field duplicate pairs indicated that sampling procedures did not adversely affect the samples obtained and that the overall precision of the sampling and analysis procedures was acceptable. However, results for VOCs indicated a possibility that at low concentrations false negatives or positives may have occurred. Variations in VOC concentrations were expected since the samples were not completely homogeneous. The overall precision of sampling and analysis procedures for VOCs was acceptable given that duplicate sample pairs were not split samples, that the potential for false positives or negatives to occur was low, and that 70 percent of duplicate analysis values agreed within one order of magnitude.

4.1.2 Laboratory QA/QC Sample Results

Laboratory QA/QC samples document the accuracy and precision of the analytical methods. These QA/QC samples included spiked and replicate samples. Laboratory spiked samples were prepared by adding a known concentration of a compound (the spike) to a sample that had been analyzed. This spiked sample was analyzed and a recovery value obtained by comparing the

result to the calculated known concentration. A 100 percent recovery value represents complete agreement between the actual analysis result and the calculated result. Laboratory spiked samples check the accuracy of the analytical methods.

Laboratory replicate samples were prepared by splitting environmental samples. Routine analysis was performed and either the relative standard deviations (more than one replicate) or the relative percentage differences (two replicate samples) was calculated. Relative standard deviations are calculated by taking the sample set's standard deviation and dividing by the set's mean. The equation for relative percent differences is: (Replicate 1 - Replicate 2)/[(Replicate 1 + Replicate 2)/2], wherein absolute values are used. The results are multiplied by 100 to get a percentage. A zero percent difference or standard deviation indicates complete agreement between replicate results. Laboratory replicate samples check the precision of the analytical methods.

Laboratory QA/QC reports are provided in Appendix H. The results are summarized as follows:

1. Percent recovery for metals and arsenic in spiked samples ranged from 77% to 149%, with 82% of the recovery values between 90% and 115%. Percent recovery for TOC, cyanide, and phenols ranged from 98% to 110%.

2. A laboratory spike analysis for TOX was performed on one sample with a result of 44% recovery. Spiked sample analysis of TOX performed on the same day on samples from other laboratory projects yielded recoveries ranging from 0% to 76%. Low TOX recovery values are acceptable because the samples initially contained low levels (e.g., 0.026 ppm) and were spiked with low levels (e.g., less than 0.050 ppm). High percentage recovery is difficult to achieve at these low levels because a loss of a very small concentration has a relatively large impact. For example, a loss of 0.03 ppm TOX represents 60% of a spike of 0.05 ppm and a recovery of 40%. Yet this same loss represents only 6% of a spike of 0.5 ppm, which results in a recovery of 94%. Because of the low concentrations used for the spiked samples, the recovery values obtained for TOX are considered acceptable.

3. Percent recovery levels for VOCs were between 91% and 140% with 12 out of 16 recovery levels between 91% and 120%. The positive identities of the VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

4. Relative standard deviations for metals in laboratory replicate analyses ranged from 0% to 40%. Relative percent differences for TOC for the most part ranged from 0% to 14% with 1 value out of 13 at 21%. The percent differences for TOX ranged from 0% to 11%; for cyanide, from 0% to 7%, with 1 value out of 6 at 40%; and for phenols ranged from 0% to 2%, with 1 value out of 6 at 22%.

5. Relative percent differences for VOCs in laboratory replicates ranged from 0% to 10%, with one relative percent difference of 71% for toluene and another of 25% for vinyl chloride.

Evaluation of laboratory spike samples and replicate analyses indicated the following:

1. Laboratory accuracy for all parameters was high. Low recovery levels obtained for TOX were within acceptable standards and reflected the inaccuracy inherent in this nonspecific test.

2. Replicate analysis results agreed very closely for all parameters, indicating acceptable laboratory precision.

Generally, the field and laboratory QA/QC data indicated that results reported were valid and reliable indicators of environmental conditions. Sample procedures did not cause false positive or negative values to occur and laboratory methods were accurate and precise. However, since field blanks and bailer washes did contain concentrations of certain compounds, environmental sample results were compared to the field blank and bailer wash results to identify any concentrations that may have been caused by interferences.

4.2 INTERPRETATION OF ANALYSIS RESULTS

Results of analyses conducted on environmental samples were evaluated as follows:

1. Results were compared to field blank and bailer wash results (Section 4.1.1). Concentrations in environmental samples below the field blank and bailer wash results may not be representative of the environmental quality at the site.

2. Environmental concentrations were compared to published background levels to identify elevated concentrations possibly not attributable to a site. Regional or U.S. average data, where available, provided background levels for sites. At these sites, parameters with concentration levels greater than regional or U.S. average background levels were identified as elevated and possibly attributable to the sites.

3. Concentration levels at a site were compared to available standards and criteria to identify potential environmental or health hazards.

Field blank and bailer wash results were discussed in Section 4.1.1. Background levels and standards and criteria are discussed below.

4.2.1 Background Levels

Background contaminant levels are concentrations observed in environmental media in the absence of identified sources of contamination. Frequently, samples from upgradient monitoring stations are shown to be free of contaminants of site-specific origin and are used to obtain background levels which can be compared to samples from other monitoring stations. Because contaminants existed at both upgradient and downgradient stations at most sites at Dover AFB and groundwater flow in the surficial aquifer appears to originate from the base, this approach was not considered viable for the base. Instead, published background levels for this region of the United States were obtained and used to identify concentration ranges.

Background levels were obtained for groundwater, surface water and soils and are summarized in Table 4-6. Published background levels were not available for VOCs, PCBs, silver, oil and grease, cyanide, phenols, and TOX.

In addition to the published information and with respect to oil and grease and TOX, the following were estimated as background concentrations based on past experience and judgment in similar circumstances:

- Oil and grease = 1 mg/l for water
  10 mg/l for soil/sediments
- TOX = 0.02 mg/l for water

Because site-specific background levels could not be determined during Stage 1a, recommendation of this study is that Stage 2 activities include obtaining complete and reliable background concentration information for all parameters. This data will be necessary in order to fully define the extent and magnitude of substance migration from the study sites and to identify any unidentified sources (Section 6.3.1.10).

Table 4-6

SUMMARY OF REGIONAL BACKGROUND LEVELS FOR PHASE II STAGE 1 ANALYSIS PARAMETERS

Media	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Zinc
Groundwater				(Results in ppb)					
Columbia Aquifer[a]	-	<1-3	-	<10-60	7-30,000	<10-10	-	-	3-210
U.S. Drinking Water[b]	<10-20	<0.1-9	0.1-11	<0.4-170	-	<0.1-100	<0.5-<10	-	<10-3000
Estimate[e]	-	-	-	-	-	-	-	-	-
Surface Water									
Kent County, Delaware[c]	-	0.6-1.8	-	0.3-90	-	1.7-14.5	ND-1.32	-	-
U.S. Surface Waters[b]	10-100	10-130	-	-	-	1-80	0.1-20	-	-
Estimate[e]	-	-	-	-	-	-	-	-	-
				(Results in ppm, except as noted)					
Soils									
Maryland-Delaware Coastal Plain[d]	<1-2.7	-	10-50	3-7	0.5-1%	10-20	0.03-0.14	<5-7	8-29
U.S. Soils[b]	5	0.3	5-1000	0.1-200	-	15	0.071	-	10-300
Estimate[e]	-	-	-	-	-	-	-	-	-

(continued)

Note: Information was not available for silver, PCBs, cyanide, phenols, or volatile organics
"-" = Data not reported
[a]Source: USGS (1983). Samples collected during 1983 from 12 wells in Kent County, Delaware
[b]Source: U.S. EPA (1982b)
[c]Source: University of Delaware (1973). Multiple samples collected during 1972 and 1973 at streams 5 miles north of Smyrna and 15 miles south of Dover
[d]Source: USGS (1981). Delaware samples collected 2 miles north of Smyrna and 2 miles southwest of Midway and Maryland samples collected from Queen Annes, Talbot and Worcester Counties
[e]Source: Estimated based on past experience and judgement

Table 4-6 (continued)

SUMMARY OF REGIONAL BACKGROUND LEVELS FOR PHASE II STAGE 1 ANALYSIS PARAMETERS

Media	pH (Std. Units)	Sp. Cond. (umhos/cm)	TOX (ppm)	TOC (ppm)	Oil & Grease (ppm)
Groundwater					
Columbia Aquifer[a]	4.8-6.8	67-290	-	1.1-3.2	-
U.S. Drinking Water[b]	-	-	-	-	-
Estimate[e]	-	-	0.02	-	1
Surface Water					
Kent County, Delaware[c]	-	-	-	-	-
U.S. Surface Waters[b]	-	-	-	-	-
Estimate[e]	-	-	0.02	-	1
Soils					
Maryland-Delaware Coastal Plain[d]	-	-	-	-	-
U.S. Soils[b]	-	-	-	-	-
Estimate[e]	-	-	-	-	10

Note: Information was not available for silver, PCBs, cyanide, phenols, or volatile organics
"-" = Data not reported
[a]Source: USGS (1983). Samples collected during 1983 from 12 wells in Kent County, Delaware
[b]Source: U.S. EPA (1982b)
[c]Source: University of Delaware (1973). Multiple samples collected during 1972 and 1973 at streams 5 miles north of Smyrna and 15 miles south of Dover
[d]Source: USGS (1981). Delaware samples collected 2 miles north of Smyrna and 2 miles southwest of Midway and Maryland samples collected from Queen Annes, Talbot and Worcester Counties
[e]Source: Estimated based on past experience and judgement

4.2.2 Standards and Criteria

Standards and criteria used to identify concentrations of substances in water which pose a possible health or environmental hazard are presented in Table 4-7. These standards and criteria include the following:

1. Safe Drinking Water Act Maximum Contaminant Levels (MCLs). These standards are the only enforceable drinking water standards set by Federal law and they have been adopted by Delaware. MCLs represent a calculated lifetime exposure level for a 154-pound adult consuming 0.5 gallons of water per day. MCLs also reflect the technologic and economic feasibility of removing the contaminant from water supplies, and so are not based solely on health effects.

2. USEPA Carcinogen Assessment Group (CAG) Cancer Risk Estimates for VOCs; Projected Upper Limit Lifetime Cancer Risk. USEPA's CAG has developed cancer risk estimates for trichloroethylene, tetrachloroethylene, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethylene, benzene, 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, and 1,1,1-trichloroethane in drinking water. Although any exposure to a carcinogen carries some risk, concentrations corresponding to the 10^{-6} risk level were chosen by the USAFOEHL as levels to be used in evaluating data.

3. Clean Water Act Water Quality Criteria (CWA-WQC) for Human Health. The Federal water quality criteria propose estimates of pollutant concentrations in aquatic organisms and surface water which will not result in adverse health effects in humans. These levels are based on toxicity or other health effects and on cancer risk estimates for suspected or proven carcinogens. A 10^{-6} risk level was used for evaluating data.

4. Safe Drinking Water Act, Suggested No Adverse Response Limits (SNARLs) Health Advisories. SNARLs are guidelines developed by EPA which recommend maximum contaminant levels that can be ingested by a 10-kg child over a given exposure period.

Concentrations of substances in waters above the standards and criteria levels specified on Table 4-7 were assumed to represent potential health or environmental hazards. Standards and criteria levels are not available for all of the parameters detected in groundwaters and surface waters at DAFB. Criteria and standards are also not available for soils and sediments.

4.3 RESULTS AND FINDINGS OF PHASE II STAGE 1

This section presents the analytical results for samples collected at DAFB during Phase II Stage 1 and findings based on these results. Results and

Table 4-7

SUMMARY OF STANDARDS AND CRITERIA FOR
PHASE II STAGE 1 ANALYSIS PARAMETERS

Parameter	Standard	Criteria	Reference
		(Concentrations in ppb)	
Chloroform	<100		a, f
Chlorobenzene		488	d
Bromodichloromethane	<100		a, f
Dibromochloromethane	<100		a, f
Dichlorobenzene, 1,2-		400	d
Dichlorobenzene, 1,3-		400	d
Dichlorobenzene, 1,4-		400	d
Dichloroethane, 1,2-		0.50	c
Dichloroethylene, 1,1-		0.24	c
Dichloroethylene, trans-1,2-		270.0	e
Methylene chloride		0.19	d
Tetrachloroethylene		1.0	c
Trichloroethane, 1,1,1-		21.7	c
Trichloroethylene		1.8	c
Vinyl chloride		0.15	c
Benzene		0.67	c
Ethylbenzene		1400.0	d
Toluene		14300.0	d
PCBs		7.9×10^{-5}	d
Silver	50		a
Arsenic	50		a
Cadmium	10		a
Chromium	50		a
Copper	1000		b
Iron	300		a
Mercury	2		a
Nickel		13.4	d
Lead	50		a
Zinc	5000		b
Cyanide		200	d
Phenols		3500	d

a = Safe Drinking Water Act maximum contaminant levels (adopted by Delaware)
b = State of Delaware Drinking Water Standard
c = EPA Carcinogen Assessment Group Cancer Risk Estimate. Carcinogenic substance values correspond to a carcinogenic risk level of 10^{-6}
d = Clean Water Act Water Quality Criteria for Human Health
e = Suggested No Adverse Response Levels (SNARLS) -- Safe Drinking Water Act Health Advisory
f = The sum concentration of chloroform, bromodichloromethane, and dibromochloromethane must be less than 100 ppb

findings are presented for each site, with sites being discussed in order of decreasing HARM rating. Sites FT-1 and D-10 and Sites D-4 and D-5 are discussed as the Golf Course Sites and the Receiver Station Sites, respectively, because the sites within each pair are located adjacent to one another and data obtained can be considered reflective of the entire area.

Results are presented by media (i.e., groundwater, surface water, soils or sediments) and analysis parameter (e.g., VOCs, metals). Groundwater samples are identified by well number. Surface water ("w" prefix) and sediment or soil ("d" prefix) samples are identified by the sampling location numbers. Groundwater, surface water, sediment and soil sampling locations are shown on site maps that accompany the sample results.

Field blank and bailer wash results are provided on the results tables for the environmental samples to facilitate comparison (Section 4.1.1). Environmental sample results are not blank subtracted (i.e., concentrations found in field blanks have not been subtracted from the environmental sample results). Results presented for all parameters except metals and arsenic are as reported by the laboratory (i.e., rounded to two significant figures). Values for metals and arsenic detected by the laboratory below the USAFOEHL reporting limits are reported in the tables as "L". Laboratory reports are presented in Appendix H. Second column confirmation was not performed during analysis for VOCs (Methods 601 and 602), therefore, positive identities were not confirmed.

4.3.1 Site T-1, IW Basins

Groundwater samples were collected from the six wells at Site T-1, as shown in Figure 4-1. Wells 101, 102, and 103 were installed in 1982 and are located next to the lagoons. These wells do not fully penetrate the Columbia aquifer. Well 01j was installed during Stage 1 as the upgradient well for the site. Wells 02j and 04j were also installed during Stage 1 to determine groundwater quality downgradient of the basin along suspected migration paths. Well 02j was located in a direct line between the basins and the contaminated wells across Route 113 from DAFB.

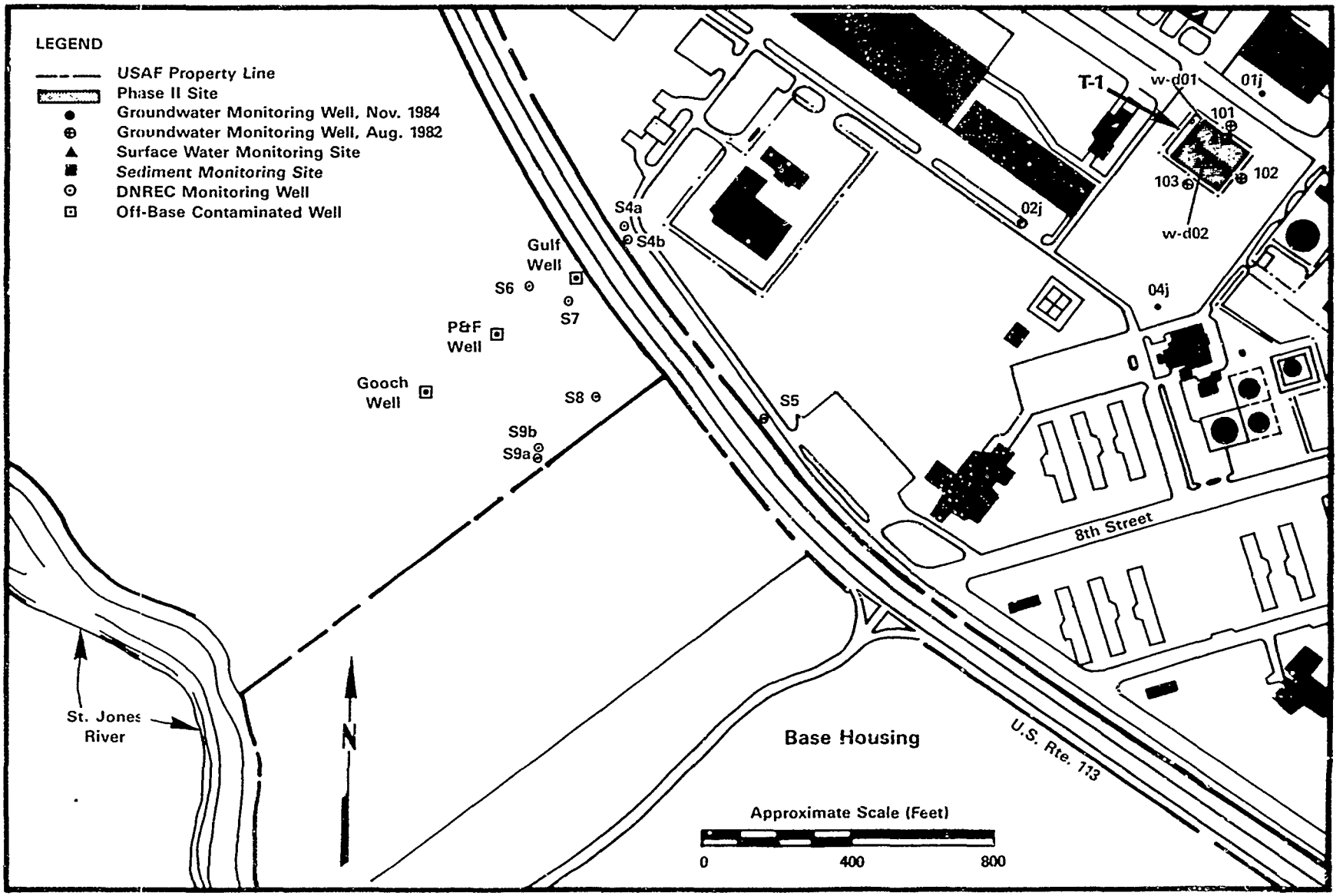


Figure 4-1. Monitoring Locations: Site T-1, IW Basins

One surface water and one sediment sample were collected from each basin. Surface water samples were collected from the liquids in the basins. Samples were collected from the oil-water separator outfall side of the basin, at about half the distance between the outfall and the discharge point (near well 102). Sediment sample d01 was collected from the top 6 inches of sediment in the northeast basin and d02 was collected from 4 to 5 feet below the sediment-liquid level in the southwest basin to identify the concentrations of substances beneath the sludge layer.

The direction of groundwater flow at the basins is towards the south and southwest (Section 2.3.1). Recharge from the basins has apparently caused a localized rise in the elevation of the water table around the basins. The extent of this mound outside the immediate vicinity of the basins (beyond wells 101, 102, and 103) is not known.

4.3.1.1 Groundwater Analysis Results

Results of analyses performed on groundwater samples collected at the site are as follows (Table 4-8):

1. VOCs were detected in all wells sampled. Of the 12 compounds detected in environmental samples, 9 (75%) of the VOCs were detected at their highest concentration in downgradient well 103. Other VOCs were at highest concentration in wells 101 (toluene, 220 ppb), 102 (benzene, 8.0 ppb), and 01j (tetrachloroethylene, 1500 ppb). The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

2. VOCs were detected in groundwater samples from wells 01j; 101, 102, and 103 at concentrations that exceeded health criteria. Wells 02j and 04j did not contain VOCs above health criteria standards. Ethylbenzene and toluene, when present, were at levels below health criteria.

3. High concentrations of total VOCs were found in the wells near the site: 103 (12611.0 ppb total VOCs), 01j (1735.58 ppb), 101 (244.41 ppb), and 102 (96.74 ppb). Low concentrations were detected in wells downgradient of the site: 02j (1.61 ppb) and 04j (0.63 ppb).

4. Well 103 contained the highest concentrations of metals detected in groundwater at the site. Levels of chromium in wells 103 (460 ppb), 02j (120 ppb), 102 (89 ppb), and 101 (63 ppb); and levels of lead in wells 103 (230 ppb), 102 (60 ppb), and 02j (55 ppb) exceeded drinking water standards. Levels of nickel in wells 103 (280 ppb), 02j (100 ppb), 102 (94 ppb), and 101 (44 ppb) exceeded the CWA-WQC (13.4 ppb).

Table 4-8

SITE T-1, IW BASINS ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number						Dup. 103	FB	BW
	01j	02j	04j	101	102	103	QA6b	QA4b	QA5b
VOCs[a]	(Results in ppb)								
Benzene	ND	ND	ND	ND	8.0	ND	1.7	ND	ND
Ethylbenzene	ND	0.4	ND	1.3	ND	97	4.3	ND	ND
Toluene	ND	ND	ND	220	10	42	78	0.84	0.76
Vinyl chloride	ND	ND	ND	ND	ND	25[b]	100[b]	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	450	ND	ND
Dichloroethylene, 1,1-	45	ND	ND	ND	0.74	240	830	ND	ND
Dichloroethane, 1,1-	ND	ND	ND	ND	48	350	720	ND	ND
Dichloroethylene, trans-1,2-	20	ND	ND	1.2	4.0	3900	4400	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	25	20
Dichloroethane, 1,2-	0.58	ND	ND	ND	3.8	20	57	ND	ND
Trichloroethane, 1,1,1-	ND	ND	ND	0.51	4.7	7700	5700	ND	ND
Dichloropropane, 1,2-	ND	ND	ND	ND	ND	ND	ND	25	25
Trichloroethylene	170	0.21	0.14	20	14	80	240	ND	ND
Tetrachloroethylene	1500	1.0	0.49	1.4	3.5	13	30	0.35	0.2
Field									
Temperature (°C)	20	15	13	12	12	12			
Conductivity (umhos/cm)	160	140	480	220	470	260			
pH (std. units)	4.7	6.0	4.8	4.9	5.7	5.3			

(continued)

[a]Laboratory analysis by EPA Methods 601 and 602. Only results for compounds present above detection limits are included in this table. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b]Chromatographs of samples from monitoring well 103 showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak may be an interference from the sample matrix

ppb = ug/l

Dup. = Field duplicate; BW = Bailer wash; FB = Field blank

ND = Not detected; indicates compound not present above detection limit

Table 4-8 (continued)

SITE T-1, IW BASINS ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number					
	01j	02j	04j	101	102	103
Metals			(Results in ppb)			
Silver	ND	L	ND	L	L	L
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	L	L	L	L	L	L
Chromium	L	120[a]	L	63[a]	71[a]	460[a]
Copper	L	56	L	39	44	180
Iron	L	140	L	L	L	170
Mercury	L	L	L	L	L	L
Nickel	L	100	L	44	75	280
Lead	L	55[a]	L	46	56[a]	230[a]
Zinc	L	210	L	83	76	470
Indicators			(Results in ppm)			
Oil & Grease	ND	ND	ND	ND	ND	0.82
Cyanide	ND	ND	ND	ND	ND	ND
Phenols	ND	ND	ND	ND	0.016	6.3
TOX	0.33	0.26	0.26	0.32	0.46	7.5
TOC	3.0	3.7	2.5	3.4	11	74
Field						
Temperature (°C)	28	16	15	15	15	12
Conductivity (umhos/cm)	160	280	500	200	400	1300
pH (std. units)	4.5	6.3	5.2	4.8	5.3	5.7

(continued)

[a]Exceeds Delaware State and Federal drinking water standards
L = Detected at level less than USAFOEHL reporting limit
ND = Not detected; indicates parameter not present above detection limit
ppb = ug/l; ppm = mg/l

Table 4-8 (continued)

SITE T-1, IW BASINS ANALYSIS RESULTS
GROUNDWATER

Parameter	Dup. 102	FB QA8a	BW QA9a	Dup. 04j QA10a
Metals		(Results in ppb)		
Silver	L	ND	ND	ND
Arsenic	ND	ND	ND	ND
Cadmium	L	0.084	ND	L
Chromium	89[a]	ND	ND	L
Copper	42	1.9	2.4	L
Iron	L	ND	ND	L
Mercury	L	0.33	0.029	L
Nickel	94	ND	ND	L
Lead	60[a]	7.0	0.87	L
Zinc	80	ND	4.0	L
Indicators		(Results in ppm)		
Oil & Grease		ND	ND	ND
Cyanide		ND	ND	ND
Phenols		ND	ND	ND
TOX		0.33	0.23	0.23
TOC		2.4	1.2	1.8

(continued)

Note: Blank space indicates analysis not conducted
[a]Exceeds Delaware State and Federal drinking water standards
L = Detected at level less than USAFOEHL reporting limit
ND = Not detected; indicates parameter not present above detection limit
Dup. = Field duplicate sample; FB = Field blank; BW = Bailer wash
ppb = ug/l; ppm = mg/l

Table 4-8 (continued)

SITE T-1, IW BASINS ANALYSIS RESULTS
SURFACE WATER AND SEDIMENT

Parameter	Surface Water Monitoring Point			Sediments Monitoring Point		
	w01	Dup. w01 QA7b	w02	d01	d02	Dup. d02 QA17a
VOCs[a]	(Results in ppb)					
Benzene	22	19	70	41	ND	1.5
Chlorobenzene	ND	ND	ND	1.8	ND	ND
Ethylbenzene	14	ND	36	ND	ND	ND
Toluene	610	620	480	660	ND	55
Methylene chloride	9000	23000	ND	46	ND	ND
Dichloroethylene, 1,1-	2.0	19	3.2	8.2	ND	ND
Dichloroethane, 1,1-	23	41	100	200	ND	3.6
Dichloroethylene, trans-1,2-	7.1	130	48	230	ND	ND
Dichloroethane, 1,2-	0.5	0.81	2.0	1.1	ND	ND
Trichloroethane, 1,1,1-	390	880	900	12	2.9	3.2
Trichloroethylene	4.4	8.0	10	66	2.4	2.9
Tetrachloroethylene	6.1	7.1	100	100	4.5	4.5
Dichlorobenzene, 1,2-	ND	ND	ND	270	1.2	13
Dichlorobenzene, 1,3-	ND	ND	ND	34	ND	ND
Dichlorobenzene, 1,4-	ND	ND	ND	ND	0.6	ND
Dichloropropane, 1,2-	ND	ND	ND	0.6	ND	ND

(continued)

[a]Laboratory analysis by EPA Methods 601 and 602 (surface water) and 8010 and 8020 (sediments). Only results for compounds present above detection limits are included in this table. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

ppb = ug/l for water; ug/kg for sediments

Dup. = Field duplicate

ND = Not detected; indicates compound not present above detection limits

Table 4-8 (continued)

SITE T-1, IW BASINS ANALYSIS RESULTS
SURFACE WATER

Parameter	Monitoring Point w01	Monitoring Point w02	Dup. w02 QA16a	FB QA15a
Metals		(Results in ppb)		
Silver	L	L	L	ND
Arsenic	ND	ND	ND	ND
Cadmium	140	120	130	ND
Chromium	2500	780	780	0.49
Copper	100	45	47	1.3
Iron	L	L	L	ND
Mercury	L	ND	L	ND
Nickel	55	16	16	6.5
Lead	130	51	53	1.1
Zinc	500	270	280	5.9
Indicators		(Results in ppm)		
Oil & Grease	93	26	17	2.3
Cyanide	0.010	0.013	0.013	ND
Phenols	34	0.026	0.056	ND
TOX	1.2	1.2	1.5	1.0
TOC	300	110	120	3.2
Field				
Temperature (°C)	11	9.2		
Conductivity (umhos/cm)	620	720		
pH (std. units)	8.3	7.8		

(continued)

Note: Blank space indicates analysis not conducted
FB = Field blank; Dup. = Field duplicate; ND = Not detected; indicates parameter not present above detection limit; ppb = ug/l; ppm = mg/l
L = Detected at level less than USAFOEHL reporting limit

Table 4-8 (continued)

SITE T-1, IW BASIN ANALYSIS RESULTS
SEDIMENT

Parameter	Montoring Point d01	Montoring Point d02	Dup. d02 QA17a
Metals	(Results in ppm, except as noted)		
Silver	0.25	0.050	0.048
Arsenic	4.0	37	43
Cadmium	15	2.7	3.1
Chromium	380	68	76
Copper	17	6.6	7.2
Iron (%)	0.22	0.46	0.47
Mercury (ppb)	0.055	0.020	0.013
Nickel	5.1	5.8	4.8
Lead	100	24	27
Zinc	67	23	26
Indicators			
Oil & Grease	7000	1100	1200
Cyanide	0.2	0.2	0.2
Phenols	3.2	0.1	ND
TOX	16	0.12	0.18
TOC (%)	3.2	1.2	ND

Note: All soils data reported in dry weight
Dup. = Field duplicate
ND = Not detected; indicates parameter not present above detection limit
ppm = ug/g or mg/kg dry weight; 1% = 10,000 ppm

5. The concentrations of chromium and lead in wells 02j, 101, 102, and 103 and zinc in well 103 exceeded background levels.

6. Well 103 was the only well that contained detectable levels of oil and grease (0.82 ppm).

7. Phenols were detected in wells 103 (6.3 ppm) and 102 (0.016 ppm), and the level in well 103 was above the health criteria of 3.5 ppm.

8. TOX levels in wells exceeded the expected background level (0.02 ppm) by an order of magnitude in wells 01j, 02j, 04j, 102 and 102, and by two orders of magnitude in well 103 (7.5 ppm). However, field blanks and bailer washes had TOX levels at or near the same levels detected in wells 01j, 02j, 04j, 101 and 102. Therefore, these levels may not be representative.

9. TOC levels (3.4 to 74 ppm) in all wells except 04j (2.5 ppm) and 01j (3.0 ppm) exceeded the highest level reported (3.2 ppm) for Columbia aquifer groundwater in Kent County, Delaware. Field blank and bailer wash values for TOC were as high as 2.4 ppm. Therefore, the presence of TOC in samples 01j (3.0 ppm), 02j (3.7 ppm), 04j (2.5 ppm), and 101 (3.4 ppm) may not be representative of groundwater conditions.

10. Groundwater temperature was high (28°C) in well 01j. DAFB personnel had reported a leak in a hot water/steam line in the area of the well. This leak was probably responsible for the increased temperature of groundwater.

11. Specific conductance exceeded maximum background levels (290 umho/cm in wells 102 (400 umho/cm) and 103 (1300 umho/cm).

12. The pH of groundwater fell within the background level range (4.8 to 6.8), except at well 01j where the pH was slightly lower (4.5 to 4.7).

4.3.1.2 Surface Water Analysis Results

Two surface water samples were collected from the basins. Sample w01 was collected from the northeast basin and sample w02 was taken from the southwest basin. At the time of sample collection, the northeast basin was receiving wastewater. Sample results are summarized as follows:

1. Total measured VOC concentrations in the northeast basin waters were 24724.91 ppb and in the southwest basin were 1749.2 ppb. All VOCs present in groundwater were also found in the basin waters with the exception of vinyl chloride, which was not found in basin waters. Chromatographs of samples from monitoring well 103 and duplicate QA6b showed a peak matching the retention time of vinyl chloride. The positive identify of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

Therefore, it cannot be definitely stated that vinyl chloride is present. The peak may be an interference from the sample matrix.

2. Methylene chloride was detected at high concentrations (23000 ppb) at w01 but was not detected at w02. In addition, toluene, 1,1-dichloroethylene, and trans-1,2-dichloroethylene were higher in sample w01.

3. Health criteria for VOCs were exceeded in both basins for benzene (19-70 ppb), ethylbenzene (14-36 ppb), 1,1-dichloroethylene (2.0-19 ppb), 1,1,1-trichloroethane (390-990 ppb), trichloroethylene (4.4-10 ppb) and tetrachloroethylene (6.1-100 ppb). Methylene chloride in w01 (9000-23000 ppb) and 1,2-dichloroethane in w02 exceeded health criteria.

4. Basin waters contained high levels of cadmium (140 ppb), chromium (2500 ppb), copper (100 ppb), nickel (55 ppb), lead (130 ppb), and zinc (2500 ppb). Metal concentrations were higher in northeast basin waters than in the southwest basin waters.

5. Concentrations of copper, iron, and nickel in basin waters were less than those found in groundwater. All other metals were detected at higher concentrations in basin waters than in groundwaters.

6. Metal concentrations of chromium, cadmium, nickel and lead in both basins exceeded health criteria. Cadmium and nickel in both basins and copper in w01 exceeded background levels.

7. Oil and grease levels were higher (93 ppm) in the northeast basin, which was receiving wastewater at the time of sampling. Oil and grease levels in both basins exceeded background levels.

8. Cyanide concentrations (0.01 and 0.013 ppm) were only slightly above the laboratory detection limit (0.005 ppm) and were below health criteria.

9. Phenols were higher in northeast basin waters (34 ppm) than in the southwest (0.026 and 0.056 ppm). Phenol levels in the northeast basin exceeded health criteria levels.

10. TOX concentrations in both samples exceeded background levels by two orders of magnitude. TOX concentrations in both samples (1.2 to 1.5 ppm) were only slightly higher than that in the field blank (1.0 ppm) and, therefore, may not be representative of actual conditions.

11. TOC levels were higher in northeast basin waters (300 ppm) than in the southwest basin (110 and 120 ppm) and exceeded background levels.

12. Basin waters exhibited high specific conductance (620 and 720 umhos/cm) and pH (7.8 and 8.3).

4.3.1.3 Sediment Analysis Results

Sediment samples were collected at the same locations as the two surface water samples. Sample d01 was collected from the top 6 inches of sediment in

the northeast basin at. d02 was collected from 4.0 ft to 5.0 ft below the top of the sediment layer in the southwest basin. Sample results are summarized as follows:

1. VOCs were detected in both samples; however, the total levels in the sediments lining the basins were greater (1670.7 ppb) than those in the sample collected at 4.0 to 5.0 feet below the base of the lagoons (83.7 ppb).

2. The concentrations of VOCs in sediments were greater than those found in surface waters for chlorobenzene, toluene, 1,1-dichloroethane, trans-1,2-dichloroethylene, trichloroethylene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and 1,2-dichloropropane.

3. Chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and 1,2-dichoropropane were detected in sediments, but were not found in surface waters or groundwaters. Ethylbenzene was not detected in sediments, but was found in basin waters and groundwaters. Chromotographs of samples from monitoring well 103 and duplicate QA6b showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. The peak may be an interference from the sample matrix.

4. Levels of arsenic (43 ppm), cadmium (15 ppm), chromium (380 ppm), copper (17 ppm), lead (100 ppm), and zinc (67 ppm) in sediments exceeded the highest values reported for Maryland and Delaware Coastal Plain soils. Levels of silver, mercury, and arsenic in sediments were greater than those detected in groundwater and surface waters. Except for iron, arsenic, and nickel, all metals were detected at higher concentrations in the shallow sediment sample than in the 4.0- to 5.0-foot deep sample.

5. Levels of oil and grease, phenols, TOX, and TOC were higher in d01 than d02. Cyanide levels (0.2 ppm) were the same for both samples. Oil and grease exceeded background levels (10 ppm) by two orders of magnitude.

4.3.1.4 Findings

Findings for Site T-1 based on the study results are summarized as follows:

1. Site T-1 is probably the source of VOCs detected in the wells surrounding the basins because the VOCs found in groundwater were also found in surface waters and sediments. Site T-1 cannot be positively identified as the source of VOCs found across Route 113

because VOCs were not detected in appreciable concentrations outside the immediate vicinity of the basins and were detected at only low levels in well 02j, which is on a direct line between the basins and the contaminated trailer park wells. Site T-1 cannot be positively identified as the source of the VOCs in well 01j because of the variations in the types and concentrations of VOCs found between well 01j and well 101 (e.g., tetrachloroethylene in 01j at 1500 ppb and in well 101 at 1.4 ppb) and between the basins and well 01j.

2. A plume exists containing chromium, copper, iron, nickel, lead, and zinc and extends from the basins to at least well 02j. VOCs and metals do not appear to be following the same migration paths or moving at the same rates based on the variations in levels of metals and VOCs in wells 02j (high metals, low VOCs) and 103 (high metals, high VOCs).

3. Oil and grease and phenols in groundwater were limited to the immediate area around the basins. Cyanide and arsenic were not present in groundwaters and the low levels of silver, cadmium, and mercury immediately adjacent to the basins indicated they were not migrating from lagoon to groundwater in appreciable amounts.

4. The principal direction of affected groundwater movement appeared to be south to southwest (from well 103 towards well 02j) based on the metal concentrations found and on the potentiometric surface map for the basin area (Section 2.3.1). The localized rise in the water table under the basins indicated that basin waters were recharging groundwater. Flow of groundwater is probably radially away from the site until out of the influence of the recharge mound and then south to southwest (normal flow direction). Well 04j apparently was not in the area of affected groundwater based on VOC and metal results.

5. Using the assumption that substances dissolved in groundwater move at the same rate as groundwater (i.e., no adsorption, degradation, or diffusion), substances entering groundwater at the basins and flowing with groundwater should reach Route 113 in approximately 4.9 years.

6. Except for ethylbenzene and toluene, concentrations of VOCs in groundwater at the basins exceeded the criteria (Table 4-7) used to indicate a potential health hazard. Chromium and lead levels in groundwater exceeded Delaware drinking water standards and nickel levels exceeded the CWA-WQC criterion. Levels of phenols in groundwater exceeded health criteria.

7. Waters in the basins contained levels of VOCs, metals, oil and grease, and phenols that exceeded health criteria or standards, or background levels. Cyanide was detected at levels slightly above detection limits. Contaminants have migrated with infiltrating water and have affected soils to a depth of at least five feet below the base of the lagoons. Infiltrating waters have also introduced VOCs, metals, phenols, and oil and grease into groundwater around the basins.

8. The sediments lining the basins contained VOCs, metals, oil and greases, cyanide, and phenols. Except for arsenic, nickel, and iron, concentrations of these substances were greater in the top 6-inch sediment layer lining the basins than at the 4.0 to 5.0 foot depth. VOC concentrations in sediments may have been caused by sorption of VOCs onto fine grained organic materials. Cation exchange, sorption, or precipitation because of high pH could explain high concentrations of metals in the basins.

9. The VOCs found in surface waters, sediments, soils, and groundwater were characteristic of fuels (benzene, ethylbenzene, toluene), and solvents (toluene, methylene chloride, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene) and their degradation products (tetrachloroethylene to trichloroethylene to trans-1,2-dichloroethylene to 1,1-dichloroethylene to vinyl chloride; 1,1,1-trichloroethane to 1,2-dichloroethane to 1,1-dichloroethane). The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

10. VOCs, metals, and other substances will continue to enter groundwater as long as wastewater is discharged into the lagoon and allowed to infiltrate. If wastewater discharge is halted, contaminated soils and sediments will continue to provide a source of contaminants as substances will leach from soils and sediments and move with infiltrating precipitation to groundwater.

4.3.2 Site DD-1, North Ditch

Surface water and sediment samples were collected at six locations along the ditch. Locations are shown in Figure 4-2 and were selected as follows:

1. w-d03 was sited to identify impacts on water and sediment quality in the North Ditch from sites adjacent to the surface water diversion that empties to the North Ditch at w-d03 (e.g., Site XYZ).

2. w-d04 was sited at the point of wastewater discharge to the ditch.

3. w-d05 was sited at the confluence of the North Ditch and the surface water diversion mentioned in number 1 above.

4. w-d06 was sited at an outfall draining a rubble dump area north of the North Ditch.

5. w-d07 was sited at an outfall draining the runway areas.

6. w-d08 was sited at the point where the ditch narrows and flows into a large diameter concrete pipe which passes under the runway.

Samples were analyzed to determine levels of arsenic, metals, oil and grease, cyanide, phenols, TOX, and TOC. Metal analysis results for w04 are

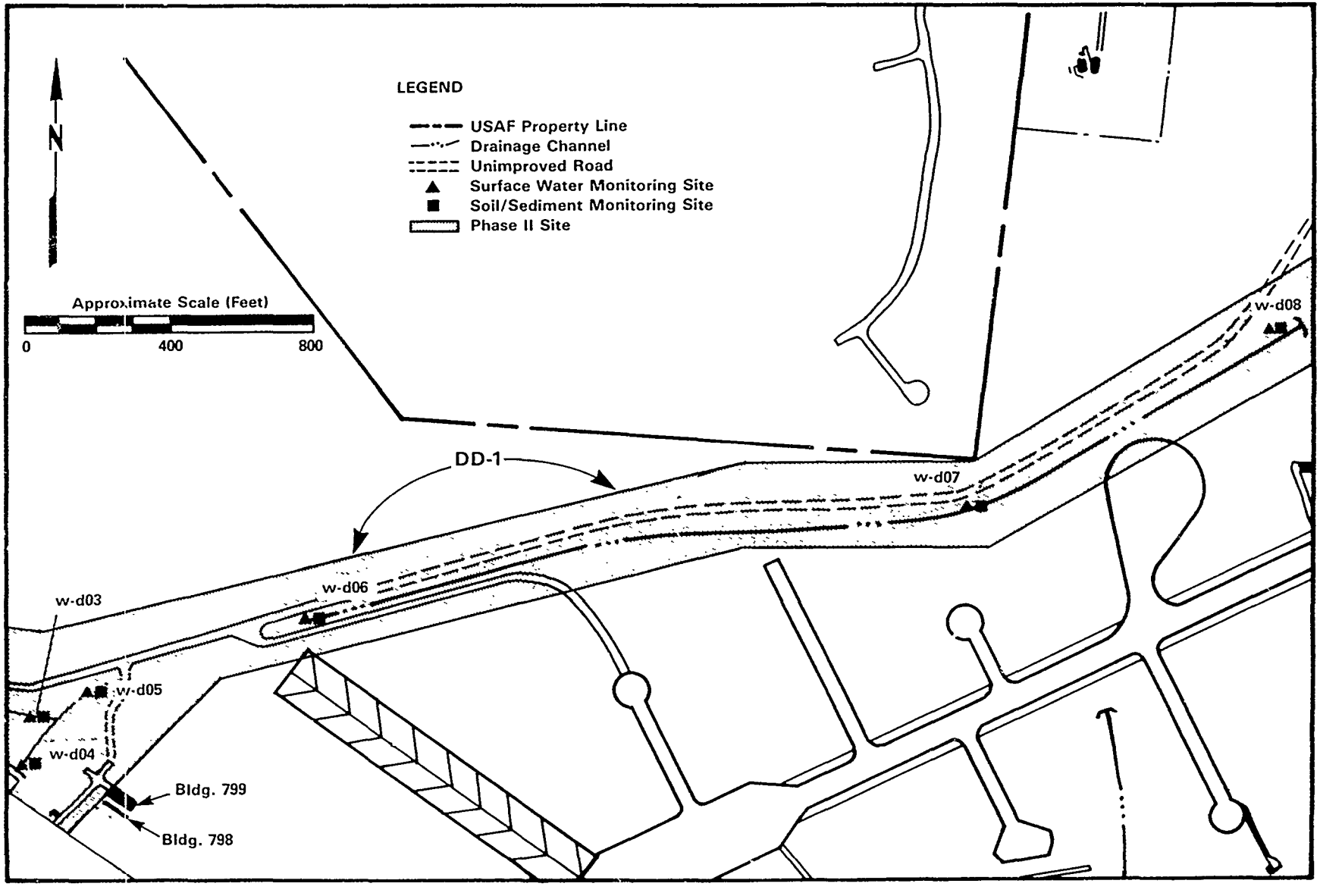


Figure 4-2. Monitoring Locations: Site DD-1, North Ditch

not available because the sample was not logged into the Laboratory's QA/QC system and resampling did not take place.

4.3.2.1 Surface Water Analysis Results

Surface water sample results are presented in Table 4-9 and are summarized as follows:

1. Nickel was present in sample w05 (32 ppb) above the CWA-WQC (13.4 ppb). Zinc (130 to 280 ppb) was detected in all samples, but the concentrations found were substantially less than the water quality criterion (5000 ppb). All other metals were detected at levels below health criteria or standards. Arsenic was not detected in samples.

2. Oil and grease was found at low levels in four samples: w03 (0.25 ppm), w04 (0.18 ppm), w05 (0.25 ppm), and w08 (0.16 ppm). These levels are below background limits.

3. Cyanides and phenols were not detected in samples.

4. TOX levels above background values were found in all samples (0.06 to 2.6 ppm). Only the concentrations found in w03 were appreciably above the field blank (w03 = 2.6 ppm; FB = 0.08 ppm). The TOX levels detected at the other five sites may not be representative of actual conditions.

5. TOC values ranged from 4.5 to 16 ppm and TOC was present in all samples. TOC steadily decreased downstream from w03 (16 ppm) towards w08 (4.5 ppm).

6. Surface water temperatures ranged from 1.6 to 7.5°C, specific conductances from 110 to 220 umhos/cm, and pH from 6.2 to 6.7 std. units.

4.3.2.2 Sediment Analysis Results

Sediment sample results are provided on Table 4-9 and are summarized as follows:

1. Except for chromium, metals were present in the North Ditch at concentrations higher than those at all other Stage 1 sites. Except for silver and mercury, levels of all metals were greater than the highest levels reported as background. For the most part, the concentrations in d03 and d04 were below those in the other samples collected at this site.

2. Arsenic was present in all samples (6.6 to 48 ppm) at concentrations above those reported as background (up to 2.7 ppm). Arsenic was lowest in d03 (6.6 ppm) and highest in d08 (48 ppm).

Table 4-9

SITE DD-1, NORTH DITCH ANALYSIS RESULTS
SURFACE WATER

Parameter	Monitoring Point						FB
	w03	w04	w05	w06	w07	w08	QA11a
Metals			(Results in ppb)				
Silver	ND	a	L	ND	ND	L	ND
Arsenic	ND	a	ND	ND	ND	ND	ND
Cadmium	L	a	L	L	L	L	0.20
Chromium	L	a	L	L	L	L	0.32
Copper	L	a	L	L	L	L	1.4
Iron	L	a	L	L	L	L	ND
Mercury	L	a	L	L	L	L	ND
Nickel	L	a	32	L	L	L	ND
Lead	L	a	L	L	L	L	4.8
Zinc	200	a	280	140	130	190	3.2
Indicators			(Results in ppm)				
Oil & Grease	0.25	0.18	0.25	ND	ND	0.16	a
Cyanide	ND	ND	ND	ND	ND	ND	ND
Phenols	ND	ND	ND	ND	ND	ND	ND
TOX	2.6	0.11	0.06	0.09	0.06	0.09	0.08
TOC	16	11	8.9	7.7	5.8	4.5	0.6
Field							
Temperature (°C)	4	7.5	3.8	7	4	1.6	
Conductivity (umhos/cm)	110	150	220	160	130	120	
pH (std. units)	6.4	6.2	6.7	6.6	6.4	6.6	

(continued)

[a]Data not available
FB = Field blank
ND = Not detected; indicates parameter not present above detection limit
ppb = ug/l; ppm = mg/l
L = Detected at level less than USAFOEHL reporting limit

Table 4-9 (continued)

SITE DD-1, NORTH DITCH ANALYSIS RESULTS
SEDIMENT

Parameter	Monitoring Point					
	d03	d04	d05	d06	d07	d08
Metals	(Results in ppm, except as noted)					
Silver	0.020	0.69	0.45	2.4	0.43	2.4
Arsenic	6.6	36	20	19	10	48
Cadmium	0.67	2.2	2.5	16	4.1	48
Chromium	9.0	150	90	130	17	280
Copper	0.68	1100	450	74	3.0	77
Iron (%)	0.14	4.9	1.9	0.66	0.032	3.0
Mercury (ppb)	0.0013	0.072	0.030	0.14	0.018	0.72
Nickel	0.69	750	310	30	1.4	43
Lead	5.1	740	340	360	30	530
Zinc	44	3800	1600	390	57	890
Indicators						
Oil & Grease	76	390	330	2800	140	1400
Cyanide	0.2	0.7	0.2	0.8	0.1	1.1
Phenols	0.3	ND	ND	0.1	ND	0.5
TOX	0.15	ND	0.31	0.20	0.27	1.8
TOC (%)	0.3	0.9	0.1	2.2	ND	4.4

Note: All soils data reported in dry weight
ND = Not detected; indicates parameter not present above detection limit
ppm = ug/g or mg/kg dry weight; ppb = ng/g; 1% = 10,000 ppm

3. d04 contained the highest concentrations of copper, iron, nickel, lead, and zinc, and d08 contained the highest concentrations of cadmium, chromium, and mercury.

4. Oil and grease levels in samples d04 to d08 (140 to 2800 ppm) were elevated when compared against sample d03 (76 ppm). The highest level was found in d06. All oil and grease levels exceeded background values (10 ppm).

5. Cyanide was present in all samples at levels ranging from 0.1 ppm (d07) to 1.1 ppm (d08). Phenols were detected in half the samples at levels ranging from 0.1 ppm (d06) to 0.5 ppm (d08).

6. The TOX levels ranged from 0.15 ppm (d03) to 1.8 ppm (d08). The TOX level in d04 was below laboratory detection limits.

7. TOC levels for all samples ranged from not detected (d07) to 4.4 percent (d08).

4.3.2.3 Findings

Findings based on the results of the Phase II Stage 1 program at Site DD-1 are as follows:

1. Surface waters in the North Ditch contained nickel above the health criteria and TOX and oil and grease above background levels. The sources are not known. TOC and TOX levels at w03 indicated that Site XYZ or some other source west of the North Ditch may be a source of halogenated and non-halogenated organic compounds. TOX and TOC levels in w04 indicated a source of halogenated and non-halogenated compounds discharging to the North Ditch at w04.

2. Sediments in the North Ditch contained elevated concentrations of arsenic, metals, cyanide, phenols, and oil and grease. Values for arsenic, cadmium, chromium, copper, iron, nickel, lead, and zinc were above the highest reported background values.

3. Values for TOX and TOC indicated that halogenated and non-halogenated organic compounds were present in sediments.

4. Based on the distribution of metals, arsenic, and oil and grease, the primary source of metals in the North Ditch sediments appears to be the discharge to the ditch at w-d04.

5. Elevated concentrations of arsenic (48 ppm), metals, cyanide (1.1 ppm), phenol (0.5 ppm), and oil and grease (2800 ppm) in sediments have not affected surface water quality, as indicated by the low levels for these parameters found in surface waters.

4.3.3 Golf Course Sites: D-10, Landfill and FT-1, Fire Training Area 1

Groundwater samples were collected from five wells around Site D-10 and from four wells around FT-1. Figure 4-3 provides the locations of these wells. Wells 05j and 14 were potentially located to provide data on background water quality. Wells 06j through 09j were located around the estimated boundary of Site D-10 and wells 15, 16, and 17 were located around the estimated boundary of FT-1. Surface waters were sampled adjacent to FT-1 (w09) and downstream of FT-1 (w10). Samples from the surface waters and wells 14 through 17 were analyzed for arsenic, metals, oil and grease, TOX, and TOC; samples from wells 05j through 09j were analyzed for these same parameters plus cyanide and phenols.

4.3.3.1 Groundwater Analysis Results

Groundwater results are provided in Table 4-10 and summarized as follows:

1. Well 09j contained chromium (84 ppb) and lead (63 ppb) at levels above drinking water standards (50 ppb) and nickel (53 ppb) above the CWA-WQC (13.4 ppb). Copper (53 ppb) and zinc (130 ppb) were also found in well 09j. The levels of these metals in 09j were between two and eight times as large as the concentrations found in the other wells on the golf course.

2. Wells 06j and 14 contained nickel (17 ppb and 16 ppb, respectively) slightly above the CWA-WQC (13.4 ppb). Metals detected in other wells were below the health standards or criteria.

3. The levels of chromium (84 ppb) and lead (63 ppb) at well 09; exceeded maximum background levels.

4. Oil and grease was detected in only one well: 08j at 0.26 ppm.

5. TOX levels in all wells exceeded background levels (0.02 ppm) and ranged from 0.045 ppm at well 14 to 0.12 ppm at well 05j. Bailer wash and field blank samples contained TOX levels of 0.075 and 0.068 ppm, respectively. Because these levels are close to those found in environmental samples, the presence of TOX may not be representative of actual groundwater.

6. TOC levels in 05j (23 ppm) and 14 (16 ppm) were elevated when compared to concentrations detected in other golf course wells (1.6 to 6.6 ppm). TOC levels in these wells and wells 07j (6.6 ppm), 08j (5.3 ppm), and 15 (3.4 ppm) were greater than the highest TOC value reported (3.2 ppm) for the Columbia aquifer in Kent County, Delaware. Field blank and bailer levels were 1.8 ppm and 5.3 ppm, respectively. Therefore, the values present in all environmental samples except 05j and 14 may not be indicative of actual TOC contamination.

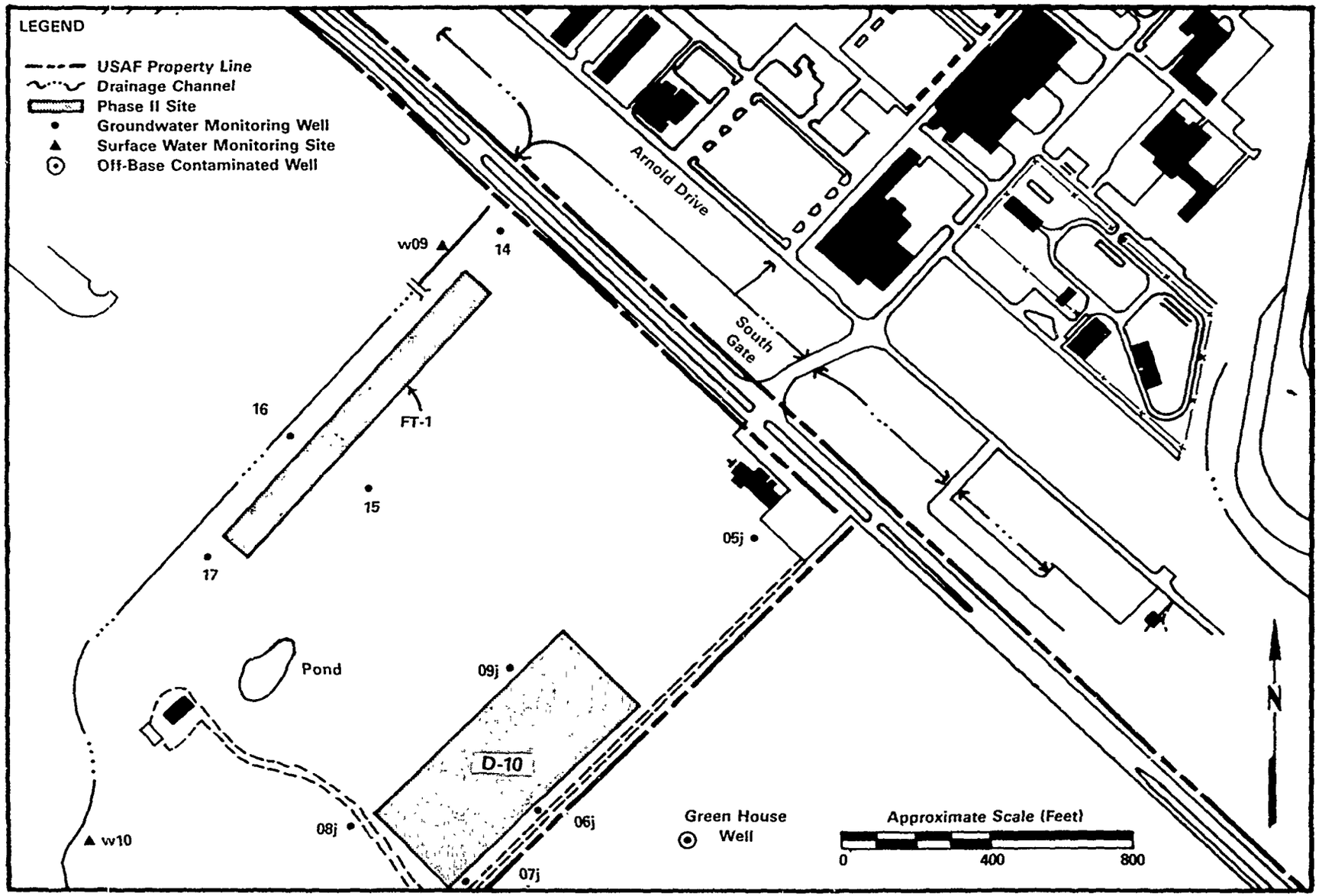


Figure 4-3. Monitoring Locations: Site D-10, Landfill and Site FT-1, Fire Training Area 1 (Golf Course Sites)

Table 4-10

GOLF COURSE SITES: SITE D-10, LANDFILL AND SITE FT-1, FIRE TRAINING AREA 1 ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number									FB	BW
	05j	06j	07j	08j	09j	14	15	16	17	QA6a	QA7a
Metals					(Results in ppb)						
Silver	L	ND	ND	ND	L	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	L	L	L	L	L	L	L	L	L	0.063	0.090
Chromium	L	L	L	L	84[a]	L	L	L	L	0.62	0.59
Copper	L	L	L	L	53	L	L	L	L	1.3	1.6
Iron	L	L	L	L	L	L	L	L	L	ND	ND
Mercury	L	L	L	L	L	L	L	L	L	0.022	0.044
Nickel	L	17	L	L	53	16	L	L	ND	7.4	6.6
Lead	L	L	L	L	63[a]	L	L	L	L	1.7	2.1
Zinc	L	L	L	L	130	L	L	L	L	1.4	1.4
Indicators					(Results in ppm)						
Oil & Grease	ND	ND	ND	0.26	ND	ND	ND	ND	ND	ND	ND
Cyanide	0.009	ND	ND	ND	ND					ND	ND
Phenols	ND	ND	ND	ND	ND					ND	ND
TOX	0.12	0.075	0.073	0.095	0.065	0.045	0.073	0.045	0.073	0.068	0.075
TOC	23	2.8	6.6	5.3	2.7	16	3.4	1.6	2.6	1.8	5.3
Field											
Temperature (°C)	15	14	14	14	15	13	13	12	13		
Conductivity (umhos/cm)	140	250	200	380	200	55	450	65	140		
pH (std. units)	4.6	3.8	5.0	5.0	4.3	4.8	5.4	4.6	4.5		

(continued)

Note: Blank space indicates that analysis was not conducted
[a]Exceeds Delaware State and Federal drinking water standards
FB = Field blank; BW = Bailer wash; ND = Not detected, indicates parameter not present above detection limit
ppb = ug/l; ppm = mg/l
L = Detected at level less than USAFOEHL reporting limit

Table 4-10 (continued)

GOLF COURSE SITES: SITE FT-1, FIRE TRAINING AREA 1 ANALYSIS RESULTS
SURFACE WATER

Parameter	Monitoring Point w09	Monitoring Point w10	Dup. w10 QA19a	FB QA18a
Metals		(Results in ppb)		
Silver	L	ND	L	ND
Arsenic	ND	ND	ND	ND
Cadmium	L	L	L	0.56
Chromium	L	L	L	0.48
Copper	L	L	L	1.1
Iron	L	L	L	ND
Mercury	ND	ND	ND	ND
Nickel	ND	ND	ND	ND
Lead	L	L	L	0.97
Zinc	L	L	L	3.7
Indicators		(Results in ppm)		
Oil & Grease	ND	ND	ND	ND
TOX	0.094	0.066	0.094	0.066
TOC	3.0	2.5	18	12
Field				
Temperature (°C)	13	13		
Conductivity (umhos/cm)	300	180		
pH (std. units)	6.9	6.5		

Note: Blank space indicates analysis not conducted
Dup. = Field duplicate; FB = Field blank
ND = Not detected; indicates parameter not present above detection limit
ppb = ug/l; ppm = mg/l
L = Detected at level less than USAFOEHL reporting limit

7. The pHs of groundwater in wells 05j, 06j, 09j, 16, and 17 (3.8 to 4.6) were outside the background range for pH.

8. The specific conductance in wells 08j (380 umhos/cm) and 15 (450 umhos/cm) exceeded the highest reported background value (290 umhos/cm).

4.3.3.2 Surface Water Analysis Results

Surface water results are presented in Table 4-10 and are summarized as follows:

1. Surface waters did not contain metals exceeding health criteria or standards, and did not contain oil and grease above background values.

2. TOX levels (0.094 and 0.066 ppm) exceeded background levels indicating that halogenated organic compounds may be present in surface waters. However, field blank results for TOX were 0.066 ppm and may negate the presence of TOX in environmental samples.

3. pHs of 6.5 and 6.9 agree with pH values for other natural surface waters collected at DAFB.

4.3.3.3 Findings

Findings for the Golf Course Sites based on the results are as follows:

1. Site FT-1 does not appear to have affected groundwater or surface water quality.

2. Elevated concentrations of chromium, lead, nickel, copper, iron, and zinc in well 09j compared with levels in upgradient well 05j indicated that Site D-10 is probably the source of these metals.

3. The anomalous TOC level in well 14 and the anomalous TOX and TOC levels in well 05j may not have been caused by Sites D-10 or FT-1 because the wells are upgradient of the sites. The TOC levels in wells 07j (6.6 ppm) and 08j (5.3 ppm) may be caused by Site D-10. The slightly elevated TOX level in well 08j (0.095 ppm) indicated that halogenated organic compounds were present in groundwater, and point to D-10 as a possible source.

4. Assuming that dissolved constituents in groundwater move at the same rate as groundwater (i.e., no adsorption, degradation, or diffusion), compounds in well 08j should reach the St. Jones River in 10 years, unless they discharge to the drainage stream between well 08j and the river.

5. Based on the direction of groundwater flow under the golf course (Section 2.3.3), which is northeast to southwest, Site D-10 could not be the source of the VOCs discovered in the Green House well east of the site.

4.3.4 Receiver Station Sites: D-4, Liquid Waste Disposal and D-5, Landfill

Groundwater samples were collected from four wells (10, 11, 12, and 13) around Site D-4 and from three wells (21, 22, and 23) around Site D-5 (Figure 4-4). Well 10 was potentially located to provide data on background water quality and the other wells were positioned to surround the estimated extent of the disposal sites. The approximate extent of the sites were identified by a civilian employee who operated heavy equipment to dig trenches and bury wastes at these sites. All samples were analyzed for VOCs, arsenic, metals, oil and grease, cyanide, phenols, TOX, and TOC.

The direction of groundwater flow in this area could not be determined because of the slight variation between water levels (+8.79 to +8.94 ft MSL) in the wells (Section 2.3.4). However, based on regional information, flow should be north or northwest towards the wetland areas around Pipe Elm Branch.

4.3.4.1 Groundwater Analysis Results

Groundwater results are presented in Table 4-11 and summarized as follows:

1. Groundwater at Site D-4 contained VOCs with the highest total VOC concentrations found in wells 11 (5648 ppb), well 13 (1292 ppb), and well 12 (330 ppb). Wells around Site D-5 contained low levels (0.48 to 5.8 ppb) of VOCs. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

2. Except for ethylbenzene and toluene, VOC concentrations in groundwater exceeded health criteria at both sites. Seven of the nine detected VOCs at Site D-4 exceeded health criteria while only one VOC of the four detected at Site D-5 exceeded health criteria.

3. VOCs were detected at low levels (less than 1.1 ppb) in the field blanks and bailer washes. The same VOCs were detected in both samples, but levels in the bailer wash were slightly less than the field blank.

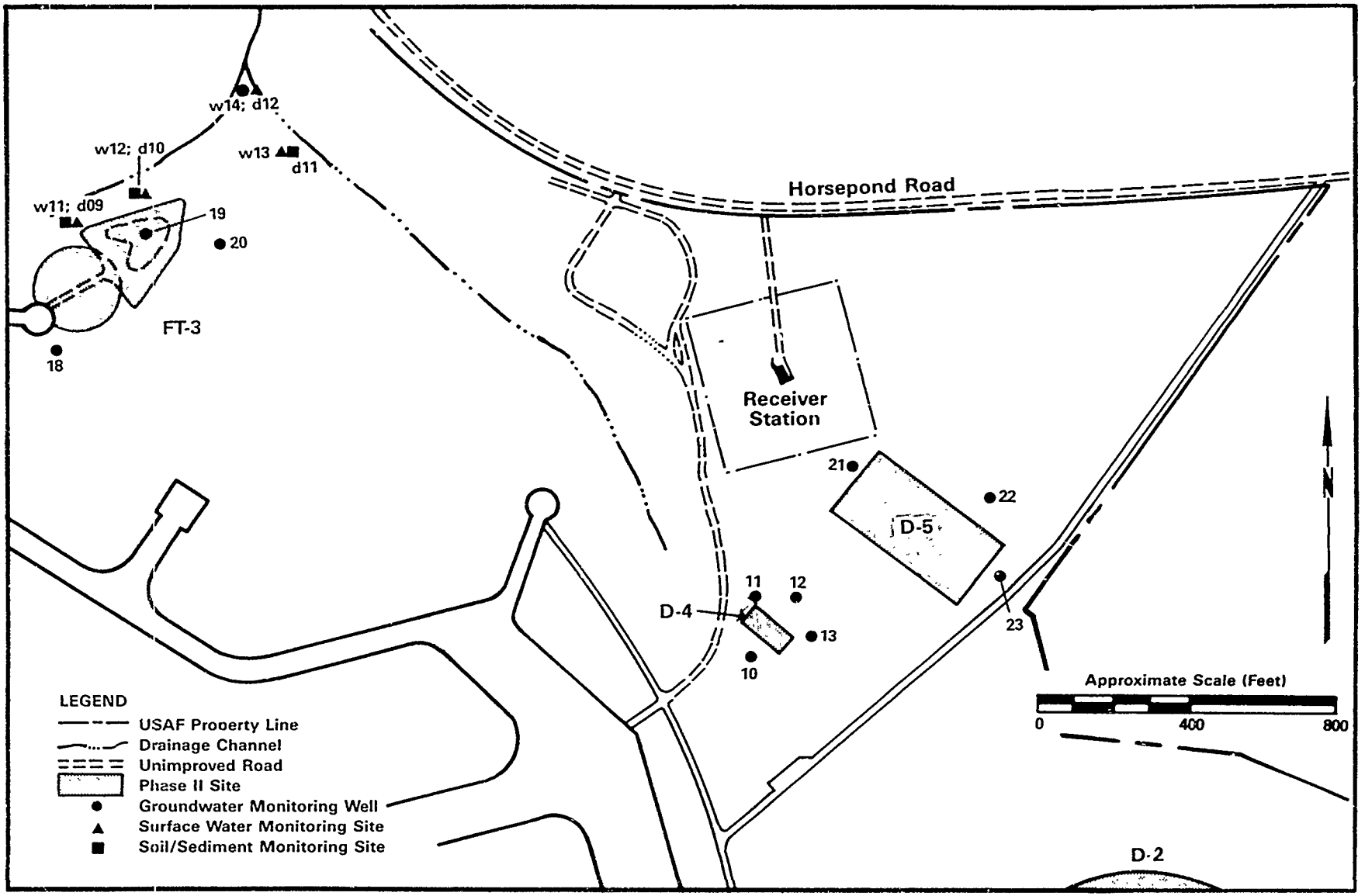


Figure 4-4. Monitoring Locations: Sites D-4, Liquid Waste Site and Site D-5, Landfill (Receiver Station Sites); and Site FT-3, Fire Training Area 3

Table 4-11

RECEIVER STATION SITES: SITE D-4, LIQUID WASTE SITE AND SITE D-5, LANDFILL ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number				Dup. 13	Well Number			FB	BW
	10	11	12	13	QA3b	21	22	23	QA1b	QA2b
VOCs[a]					(Results in ppb)					
Benzene	9.1	83	12	24	23	ND	ND	ND	ND	ND
Ethylbenzene	ND	11	ND	360	570	1.4	2.1	ND	ND	ND
Toluene	1.7	8.8	3.1	24	56	ND	ND	ND	1.1	0.54
Vinyl chloride	ND	6[b]	9[b]	ND	ND	ND	ND	ND	ND	ND
Dichloroethylene, 1,1-	ND	0.67	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroethylene, trans-1,2-	1.2	700	220	620	640	5.8	0.1	ND	ND	ND
Dichloroethane, 1,2-	ND	39	62	ND	ND	ND	ND	ND	ND	ND
Trichloroethylene	ND	2100	18	2.8	0.53	1.7	0.48	0.68	0.2	0.18
Tetrachloroethylene	ND	2700	6.3	15	3.0	1.8	1.4	1.1	0.68	0.48
Field										
Temperature (°C)	8.1	9.0	9.9	9.9		8.5	9.8	9.5		
Conductivity (umhos/cm)	160	160	130	2600		150	140	180		
pH (std. units)	5.6	5.8	5.4	6.0		5.7	5.4	5.2		

(continued)

Note: Blank space indicates analysis not conducted

[a]Laboratory analysis by EPA Methods 601 and 602 for volatile organics. Only results for compounds present above detection limit are included in this table. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b]Chromatographs of samples from monitoring wells 11 and 12 showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak may be an interference from the sample matrix

ppb = ug/l

ND = Not detected; indicates parameter not present above detection limit

Dup. = Field duplicate; BW = Bailer wash; FB = Field blank

Table 4-11 (continued)

RECEIVER STATION SITES: SITE D-4, LIQUID WASTE SITE AND SITE D-5, LANDFILL ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number 10	11	12	Dup. 12 QA2a	BW QA1a	FB QA3a
Metals			(Results in ppb)			
Silver	L	L	L	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	L	L	L	L	ND	ND
Chromium	L	L	L	L	0.90	0.020
Copper	L	L	L	L	2.7	1.7
Iron	L	L	L	L	ND	32
Mercury	L	L	L	L	0.028	ND
Nickel	L	L	L	L	3.9	ND
Lead	L	L	L	L	ND	6.5
Zinc	L	ND	L	L	9.0	1.8
Indicators			(Results in ppm)			
Oil & Grease	0.44	0.45	ND	0.19	0.11	ND
Cyanide	ND	0.007	ND	ND	ND	0.007
Phenols	ND		ND	ND	ND	ND
TOX	0.045	0.08	0.016	0.068	75	ND
TOC	8.9	4.5	2.3	20	2.5	2.9
Field						
Temperature (°C)	13	13	12			
Conductivity (umhos/cm)	120	110	80			
pH (std. units)	5.3	5.7	5.4			

(continued)

Note: Blank space indicates analysis not conducted
L = ected at level less than USAFOEHL reporting limit
ND = ot detected; indicates parameter not present above detection limit
Dup.= Field licate; BW = Bailer wash; FB = Field blank
ppb = ug/l, a = mg/l

Table 4-11 (continued)

RECEIVER STATION SITES: SITE D-4, LIQUID WASTE SITE AND SITE D-5, LANDFILL ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Numbers 13	21	22	23	FB QA4a	BW QA5a
Metals			(Results in ppb)			
Silver	ND	ND	ND	L	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	L	L	L	L	0.066	0.12
Chromium	L	L	L	64[a]	0.72	0.57
Copper	24	L	L	25	3.6	3.1
Iron	L	L	L	L	0.022	0.017
Mercury	L	L	L	L	0.011	ND
Nickel	L	21	L	20	ND	6.6
Lead	L	L	L	25	ND	0.56
Zinc	L	58	L	64	8.7	12
Indicators			(Results in ppm)			
Oil & Grease	1.3	ND	0.15	0.12	0.28	ND
Cyanide	0.008	0.009	0.006	ND	ND	ND
Phenols	0.011	ND	ND	ND	ND	ND
TOX	0.093	0.065	0.10	ND	0.064	0.035
TOC	24	2.8	2.4	5.4	4.7	6.8
Field						
Temperature (°C)	13	15	15	15		
Conductivity (umhos/cm)	250	150	90	160		
pH (std. units)	6.2	5.6	5.5	5.1		

Note: Blank space indicates analysis not conducted
[a]Exceeds Delaware State and Federal drinking water standards
L = Detected at level less than USAFOEHL reporting limit
ND = Not detected; indicates parameter not present above detection limit
FB = Field b' ; BW = Bailer wash
ppb = ug/l, = mg/l

4. Metals at Site D-4 were detected at levels below published health standards. The highest concentration detected was for copper at 24 ppb.

5. Two metals at Site D-5 were detected at levels above health standards; chromium (64 ppb) in well 23 and nickel in well 23 (20 ppb) and well 21 (21 ppb).

6. Oil and grease was detected in all groundwater samples except well 21 and ranged from 0.12 to 1.3 ppm. Only oil and grease in well 13 (1.3 ppm) exceeded background levels.

7. Cyanide at levels slightly above detection limits was detected in wells 11 (0.007 ppm), 13 (0.008 ppm), 21 (0.009 ppm), and 22 (0.006 ppm). The level of cyanide did not exceed health criteria.

8. TOC levels above the highest background value (3.2 ppm) were detected in wells 10 (8.9 ppm), 11 (4.5 ppm), 12 (20 ppm in QA2a), 13 (24 ppm) at Site D-4, and well 23 (5.4 ppm) at Site D-5. TOC levels ranged from 2.5 to 6.8 ppm in QA/QC samples.

9. The TOX value in QA1a (75.0 ppm) was very high and could not be explained. TOX were detected in all wells except well 23 and values ranged from 0.016 to 0.10 ppm.

10. The pH and specific conductance values for this area were within background levels except for specific conductance in well 13 of 2600 umhos/cm. This reading is almost one order of magnitude greater than one taken at well 13 on a different day and the cause of this high value is unknown.

4.3.4.2 Findings

Findings for Sites D-4 and D-5 based on the data results are as follows:

1. Site D-4 appears to be the source of the high levels of VOCs found in groundwater from wells surrounding the site. Site D-5 may be a source of low levels of VOCs found in its surrounding wells, however, the VOCs found in wells around D-5 may have originated in D-4. Levels of VOCs exceeded health criteria at both sites.

2. Site D-5 appeared to be a source of metals above health standards in surrounding wells, however, these elevated levels were not found in any other well at the receiver station area.

3. Site D-4 may be a source of oil and grease in groundwater at the receiver station.

4. The VOCs found at the receiver station are characteristic of fuels (benzene, ethylbenzene, toluene) and solvents (tetrachloroethylene, trichloroethylene) and their degradation products (tetrachloroethylene to trichloroethylene to trans-1,2-dichloroethylene to

1,1-dichloroethylene to vinyl chloride). The positive identities of VOCs were not confirmed by ither second-column gas chromatographic analysis or by mass spectr copy.

5. Assuming that substances dissolved in groundwater move at the same rate as groundwater (i.e., without adsorption, degradation, or diffusion), substances at well 11 should reach the base boundary north of the receiver station in 20 years. However, the stated assumptions maximize migration rates.

4.3.5 Site FT-3, Fire Training Area 3

Groundwater samples were collected from three wells (18, 19, and 20) around Site FT-3 (Figure 4-4). Well 18 is located upgradient of the site, well 19 is located between the site and a small stream north of the site, and well 20 is located between the site and a small stream northeast of the site. The direction of groundwater flow in this area is towards the northeast.

Surface water and sediment samples were collected from the two streams north and northeast of the site. The positions of the four sampling points were selected as follows:

1. w11 and d09 were located at the point where the north stream discharges from beneath the runway.
2. w12 and d10 were located in the north stream downstream from the site.
3. w13 and d11 were located in the northeast stream at a location where groundwater flowing under the site was estimated to discharge into the stream.
4. w14 and d12 were located at the confluence of the north and northwest streams.

All samples were analyzed to determine the concentrations of arsenic, metals, oil and grease, TOX, and TOC.

4.3.5.1 Groundwater Analysis Results

Groundwater results are presented in Table 4-12 and summarized as follows:

1. Nickel was detected in wells 18 (55 ppb) and 20 (14 ppb) at concentrations above the CWA-WQC. The upgradient well (18) typically

contained higher concentrations of metals than the downgradient wells (19 and 20).

2. Oil and grease in wells 18 (0.14 ppm) and 19 (0.11 ppm) were detected at concentrations less than the estimated background level of 1 ppm.

3. TOX levels in all three wells exceeded background levels (0.02 ppm) and ranged from 0.12 to 0.13 ppm. Field blank and bailer wash TOX levels were at 0.10 ppm; therefore, the level of TOX in environmental samples may not be representative.

4. The TOC concentration (8.9 ppm) in well 20 was elevated above background levels for the Columbia aquifer in Kent County, Delaware.

4.3.5.2 Surface Water Analysis Results

Four surface water samples were collected around Site FT-3. Results of analyses conducted on these samples are presented in Table 4-12 and summarized as follows:

1. Zinc was detected in sample w11 (260 ppb) at a level greater than the reported background level (210 ppb), but less than the State of Delaware drinking standard (5000 ppb). This sample was collected at a location upgradient from Site FT-3.

2. Oil and grease was detected in samples w11 (0.34 ppm) and w13 (0.21 ppm) at levels less than the estimated background level (1 ppm).

3. TOC levels (4.1 to 5.3 ppm) in samples were slightly elevated. There was only a slight increase between TOC levels in w11 (4.4 ppm) upstream from the site and w12 (4.9 ppm) and w14 (5.3 ppm) downstream from the site. The TOC level in the field blank was 3.2 ppm.

4.3.5.3 Sediment Analysis Results

Four sediment samples were collected around Site FT-3. Results of analyses conducted on these samples are summarized as follows:

1. Sediments contained detectable levels of arsenic, metals, and oil and grease. There was a noticeable increase in contaminant concentrations between the upstream sample d09 and the downstream samples (d10, d11) closest to the site: arsenic (11 to 78 ppm), cadmium (0.67 to 9.0 ppm), chromium (10 to 27 ppm), copper (6.7 to 20 ppm), iron (0.52 to 1.8%), nickel (5.4 to 26 ppm), lead (47 to 170 ppm), zinc (18 to 76 ppm), oil and grease (120 to 230 ppm), and TOC (0.3 to 2.3%). Levels in d12 were generally less than those in d10 and d11, but still greater than those in d09 with the exception of oil and grease and TOX.

Table 4-12

SITE FT-3, FIRE TRAINING AREA 3 ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number 18	19	20	FB QA12a	BW QA13a
Metals		(Results in ppb)			
Silver	ND	ND	ND	ND	0.50
Arsenic	ND	ND	ND	ND	ND
Cadmium	L	L	L	0.21	ND
Chromium	L	L	L	ND	ND
Copper	L	L	L	1.3	1.2
Iron	L	L	L	ND	ND
Mercury	L	L	ND	ND	0.011
Nickel	55	ND	14	ND	ND
Lead	L	L	L	1.2	ND
Zinc	L	L	L	6.7	5.5
Indicators		(Results in ppm)			
Oil & Grease	0.14	0.11	ND	ND	ND
TOX	0.12	0.13	0.12	0.10	0.10
TOC	1.6	1.3	8.9	0.4	0.7
Field					
Temperature (°C)	14	14	14		
Conductivity (umhos/cm)	130	120	200		
pH (std. units)	5.3	5.6	5.6		

(continued)

Note: Blank space indicates analysis not conducted
ND = Not detected; indicates parameter not present above detection limit
BW = Bailer wash; FB = Field blank
ppb = ug/l; ppm = mg/l
L = Detected at level less than USAFOEHL reporting limit

Table 4-12 (continued)

SITE FT-3, FIRE TRAINING AREA 3 ANALYSIS RESULTS
SURFACE WATER

Parameter	Monitoring Point				FB
	w11	w12	w13	w14	QA15a
Metals			(Results in ppb)		
Silver	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND
Cadmium	L	L	L	L	ND
Chromium	L	L	L	L	0.50
Copper	L	L	L	L	1.3
Iron	L	L	L	L	ND
Mercury	L	ND	L	ND	ND
Nickel	ND	ND	ND	ND	6.5
Lead	L	L	L	L	1.1
Zinc	260	L	L	L	5.9
Indicators			(Results in ppm)		
Oil & Grease	0.34	ND	0.21	ND	2.3
TOX	a	a	a	a	1.0
TOC	4.4	4.9	4.1	5.3	3.2

(continued)

Note: Blank space indicates analysis not conducted
[a]Data not available
ND = Not detected; indicates parameter not present above detection limit
BW = Bailer wash; FB = Field blank
ppb = ug/l; ppm = mg/l
L = Detected at level less than USAFOEHL reporting limit

Table 4-12 (continued)

SITE FT-3, FIRE TRAINING AREA 3 ANALYSIS RESULTS
SEDIMENT

Parameter	Monitoring Point			
	d09	d10	d11	d12
Metals	(Results in ppm, except as noted)			
Silver	0.039	0.13	0.063	0.058
Arsenic	11	23	78	41
Cadmium	0.67	9.0	1.6	0.76
Chromium	10	27	24	16
Copper	6.7	20	14	12
Iron (%)	0.52	1.0	1.8	1.1
Mercury (ppb)	0.018	0.056	0.054	0.050
Nickel	5.4	13	26	14
Lead	47	170	29	56
Zinc	18	76	48	47
Indicators				
Oil & Grease	120	110	230	ND
TOX	2.1	3.1	0.89	0.59
TOC (%)	0.3	1.8	2.3	1.3

ND = Not detected; indicates parameter not present above detection limit
ppb = ng/g; or ug/kg dry weight
ppm = ug/g; or mg/kg dry weight
1% = 10,000 ppm

2. Levels of arsenic, cadmium, copper, iron, nickel, lead, and zinc detected in sediments exceeded values for Maryland and Delaware Coastal Plain soils or U.S. average soils.

3. Oil and grease levels detected in samples d09 (120 ppm), d10 (110 ppm), and d11 (230 ppm) were higher than an estimated background level of 10 ppm.

4.3.5.4 Findings

Findings for Site FT-3 based on the data results are as follows:

1. Site FT-3 is probably not the source of metals and oil and grease found in groundwater based on the greater concentrations present in the upgradient well.

2. Site FT-3 may have caused an increase in the TOC levels in groundwater based on the elevated levels found in well 20.

3. Site FT-3 is probably not the source of the zinc found in surface waters, but may be a source of the slightly increased levels of TOC in surface waters downstream of the site.

4. FT-3 may be a source of the elevated concentrations of metals, arsenic, oil and grease, TOX, and TOC found in sediments downstream of the site. There appears to be an other source of metals, arsenic, oil and grease, and TOX upstream of the site (above d09) based on the contaminant levels detected in d09.

5. The elevated concentrations of contaminants detected in the sediments do not correlate with the low levels detected in groundwater and surface water. The mechanism of transport of substances from FT-3 to the sediments was not determined. Sediments apparently are not affecting the quality of surface waters, because elevated levels of arsenic, metals (with the exception of zinc), and oil and grease were not detected in surface waters.

4.3.6 Site SP-4, JP-4 Pipeline Leak, Building 1310

Groundwater samples were collected from three well points (p01, p02, and p03) around Building 1310 (Figure 4-5). Groundwater flow directions for this site could not be determined from the Stage 1 results because water levels in the well points fluctuated widely (e.g., water levels in p01 increased to +15.04 ft MSL from +12.7 ft MSL over 1 month, while the water levels in the other two well points decreased over the same time period). The site is located close to the estimated position of the groundwater divide, therefore, flow could be towards the north or south (Section 2.3.6).

Groundwater samples were analyzed for oil and grease and TOC.

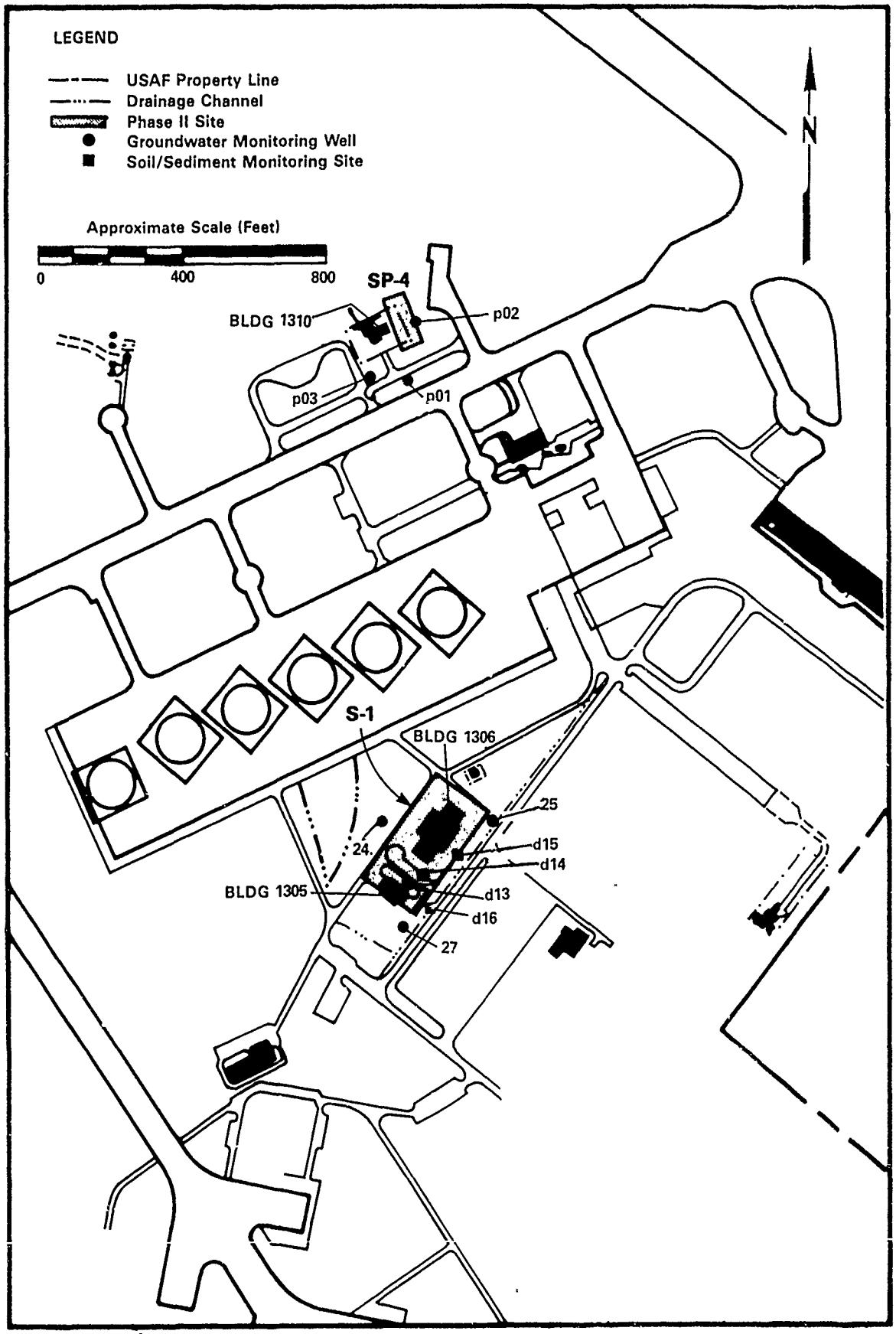


Figure 4-5. Monitoring Locations: Site SP-4, JP-4 Pipeline Leak and Site S-1, Hazardous Waste Storage

4.3.6.1 Groundwater Analysis Results

Groundwater results are presented in Table 4-13 and summarized as follows:

1. Oil and grease levels in all samples were below the background level of 1.0 ppm. Oil and grease levels ranged from 0.12 ppm in well p01 to 0.43 ppm in well p02.

2. TOC levels detected in wells p02 (4.9 ppm) and p03 (32 ppm) exceeded the background level (3.2 ppm) for the Columbia aquifer.

4.3.6.2 Findings

Findings for Site SP-4, based on the results of data collected during Phase II Stage 1, are as follows:

1. Groundwater at Site SP-4 possibly contains fuels or other organics, based on the levels of TOC detected in samples.

2. Site SP-4 cannot be positively identified as a source of the TOC levels in groundwater samples because of the lack of an upgradient sample and the proximity of the site to runway areas that may contribute substances that would affect TOC levels.

4.3.7 Site S-1, Hazardous Waste Storage Area, Buildings 1305 and 1306

Groundwater samples were collected from three wells (24, 25, and 27) around Site S-1 (Figure 4-5). Groundwater elevations differed slightly between these wells (+10.1 to +9.76 ft MSL). Direction of flow based on regional data appears to be south towards the St. Jones River (Section 2.3.7). Well 24 is located northeast of the basins and is not downgradient of the site, so this well provides background water quality information. Wells 25 and 27 were located next to the storage pads outside of Buildings 1305 and 1306 and well 25 is upgradient of well 27.

Four soil samples were collected from suspected spill and runoff areas around the site. The positions of the samples were selected as follows:

1. d13 was collected from a runoff swale alongside Building 1305.

2. d14 and d15 were collected from stained (black, oily discolorations) areas adjacent to the asphalt storage pad around Building 1306.

Table 4-13

SITE SP-4, JP-4 PIPELINE LEAK ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Point Number			FB	BW
	p01	p02	p03	QA12a	QA13a
Indicators			(Results in ppm)		
Oil & Grease	0.12	0.43[a]	0.24	ND	ND
TOC	2.1	4.9	32	0.4	0.7
Field					
Temperature (°C)	17	16	18		
Conductivity (umhos/cm)	250	160	200		
pH (std. units)	6.7	5.9	6.4		

Note: Blank space indicates analysis not conducted
[a]Approximately 10% of sample lost in analysis
ND = Not detected; indicates parameter not present above detection limit
FB = Field blank; BW = Bailer wash
ppm = mg/l

3. d1C was collected from the surface water runoff ditch downstream from the other soil samples.

All samples were analyzed to determine the concentrations of VOCs, arsenic, metals, oil and grease, cyanide, phenols, TOX, and TOC.

4.3.7.1 Groundwater Analysis Results

Groundwater results are presented in Table 4-14 and summarized as follows:

1. Groundwater contained detectable levels of eight VOCs. The highest total VOC concentrations were found in wells 25 (1524 ppb) and 27 (2042 ppb), while well 24 contained the lowest level (1.84 ppb). Several of the VOCs found in wells 24 (toluene, tetrachloroethylene) and 27 (toluene) were found at equivalent or higher concentrations in the field blank. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

2. Well 27 contained the highest levels of 1,1-dichloroethylene (1.5 ppb); trans-1,2-dichloroethylene (790 ppb); and trichloroethylene (300 ppb). The chromatographs of a sample from well 27 also showed a peak matching the retention time of vinyl chloride at 10 ppb. The identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. The peak may be an interference from the sample matrix. Well 25 contained the highest levels of benzene (5.5 ppb), ethylbenzene (4.0 ppb), and tetrachloroethylene (1400 ppb).

3. Except for ethylbenzene and toluene, VOCs detected in groundwater in wells 25 and 27 were present at levels greater than health criteria. VOCs were not detected at levels above health criteria in well 24.

4. Chromium was detected in all three wells at levels (53 to 230 ppb) exceeding the drinking water standard (50 ppb). Lead levels in wells 25 (110 ppb) and 27 (68 ppb in QA14a) exceeded the drinking water standard (50 ppb). Nickel levels in all wells (28 to 100 ppb) exceeded the CWA-WQC (13.4 ppb). These metals were also detected in one or more wells at levels above the respective reported background levels. Zinc was also detected in well 25 at a level (240 ppb) above the reported background maximum of 210 ppb.

5. Well 25 contained the highest concentrations of all metals. Well 24 and 27 had similar concentrations of metals except for lead which was higher in well 27.

Table 4-14

SITE S-1, HAZARDOUS WASTE STORAGE ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number 24	25	27	FB QA1b	BW QA2b
VOCs[a]	(Results in ppb)				
Benzene	ND	5.5	ND	ND	ND
Ethylbenzene	0.72	4.0	0.34	ND	ND
Toluene	0.29	ND	0.27	1.1	0.54
Vinyl chloride	ND	ND	10[b]	ND	ND
Dichloroethylene, 1,1-	ND	ND	1.5	ND	ND
Dichloroethylene, trans-1,2-	0.1	60	790	ND	ND
Trichloroethylene	0.23	55	300	0.2	0.18
Tetrachloroethylene	0.50	1400	940	0.68	0.48
Field					
Temperature (°C)	12	12	12		
Conductivity (umhos/cm)	480	180	170		
pH (std. units)	5.8	5.7	5.3		

(continued)

Note: Blank space indicates analysis not conducted

[a]Laboratory analysis by EPA Methods 601 and 602. Only results for compounds present above detection limits are included in this table. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

[b]Chromatograph of sample from monitoring well 27 showed a peak matching the retention time of vinyl chloride. The positive identity of this peak was not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy. Therefore, it cannot be definitely stated that vinyl chloride is present. This peak may be an interference from the sample matrix

ppb = ug/l

ND = Not detected; indicates compound not present above detection limit

FB = Field blank; BW = Bailer wash

Table 4-14 (continued)

SITE S-1, HAZARDOUS WASTE STORAGE ANALYSIS RESULTS
GROUNDWATER

Parameter	Well Number 24	25	27	Dup. 27 QA14a	FB QA12a	BW QA13a
Metals			(Results in ppb)			
Silver	L	L	L	L	ND	0.50
Arsenic	ND	ND	ND	ND	ND	ND
Cadmium	L	L	L	L	0.21	ND
Chromium	89[a]	230[a]	56[a]	53[a]	ND	ND
Copper	55	91	28	31	1.3	1.2
Iron	L	L	L	L	ND	ND
Mercury	L	L	L	L	ND	0.011
Nickel	43	100	33	28	ND	ND
Lead	L	110[a]	45	68[a]	1.2	ND
Zinc	74	240	88	100	6.7	5.5
Indicators			(Results in ppm, except as noted)			
Oil & Grease	0.11	ND	ND	0.49	ND	ND
Cyanide	0.006	ND	0.006	0.006	0.006	0.010
Phenols	ND	ND	ND	ND	ND	0.006
TOX	0.10	1.0	1.4	8.2	0.10	0.10
TOC	3.0	1.9	3.8	4.7	0.4	0.7
PCBs (ppb)	ND	ND	ND	ND	ND	ND
Field						
Temperature (°C)	16	16	16			
Conductivity (umhos/cm)	170	100	120			
pH (std. units)	6.4	5.7	5.7			

(continued)

Note: Blank space indicates analysis not conducted
[a]Exceeds Delaware State and Federal drinking water standards
ND = Not detected; indicates parameter not present above detection limit
ppb = mg/l; ppm = mg/l
FB = Field blank; BW = Bailer wash
L = Detected at level less than USAFOEHL reporting limit

Table 4-14 (continued)

SITE S-1, HAZARDOUS WASTE STORAGE ANALYSIS RESULTS
SOIL

Parameter	Monitoring Point			
	d13	d14	d15	d16
Metals	(Results in ppm, except as noted)			
Silver	0.047	0.034	0.081	0.020
Arsenic	32	26	35	45
Cadmium	1.1	3.9	1.7	0.22
Chromium	15	14	30	14
Copper	9.9	13	270	10
Iron (%)	0.83	0.72	0.70	0.56
Mercury (ppb)	0.036	0.035	0.065	0.020
Nickel	14	10	13	9.2
Lead	44	47	180	22
Zinc	57	53	220	38
Indicators				
Oil & Grease	71	630	290	24
Cyanide	0.3	0.4	0.4	0.1
Phenols	ND	ND	0.9	0.8
TOX	2.9	1.8	1.1	0.26
TOC (%)	0.3	1.1	1.4	0.3
PCBs (ppb)	240[a]	ND	ND	ND

(continued)

Note: Blank space indicates analysis not conducted. All soils data reported in dry weight

[a]Analytical results are for the detection of Arochlor 1260, which was the only PCB detected and is one of the PCBs listed as a priority pollutant

ND = Not detected; indicates parameter not present above detection limit

ppm = ug/g or mg/kg dry weight; 1% = 10,000 ppm

Table 4-14 (continued)

SITE S-1, HAZARDOUS WASTE STORAGE ANALYSIS RESULTS
SOIL

Parameter	Monitoring Point			
	d13	d14	d15	d16
VOCs[a]	(Results in ppb)			
Methylene chloride	ND	ND	ND	100
Tetrachloroethene	19	0.6	5.2	2.0
Trichloroethane, 1,1,1-	2.4	2.3	3.7	0.9
Trichloroethylene	1.9	1.3	2.3	1.5

[a]Laboratory analysis by EPA Methods 8010 and 8020. Only results for compounds present above detection limits are included in this table. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy

ppb = ug/kg for soils

ND = Not detected; indicates compound not present above detection limit

6. Cyanide was not detected at levels below health criteria in groundwater, however, the levels present were similar to those in the field blank. Phenols were not detected in groundwater.

7. Oil and grease levels in wells 24 (0.11 ppm) and 27 (0.49 ppm in QA14a) did not exceed background levels.

8. TOX levels exceeded background levels by an order of magnitude in wells 24 and 25, and two orders of magnitude in well 27. TOX levels in the field blank and bailer wash were identical to levels in wells 27 and 25. Therefore, environmental sample results may not be representative.

9. TOC levels in all wells (1.9 to 4.7 ppm) exceeded the highest value reported (3.2 ppm) for Columbia aquifer groundwater in Kent County, Delaware.

10. pH and specific conductance levels were within background ranges for groundwater.

4.3.7.2 Soil Analysis Results

Soil analysis results are presented in Table 4-14 and summarized as follows:

1. VOCs were detected in all soil samples. Tetrachloroethylene (0.6 to 19 ppb), 1,1,1-trichloroethane (0.9 to 3.7 ppb) and trichloroethylene (1.3 to 2.3 ppb) was detected in all soils. Additionally, methylene chloride (100 ppb) was detected in soil sample d16. Two of the VOCs, tetrachloroethylene and trichloroethylene, were also present in groundwaters at the site. The positive identities of VOCs were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

2. Sample d13 contained 240 ppb of the PCB Arochlor 1260.

3. The concentrations of arsenic (26 to 45 ppm), copper (9.9 to 270 ppm), nickel (9.2 to 14 ppm), lead (22 to 180 ppm), and zinc (38 to 220 ppm) in all samples exceeded the maximum values reported for metals in Maryland and Delaware Coastal Plain soils. Sample d15 contained higher concentrations of several metals compared to all other samples: copper (270), lead (180 ppb), and zinc (220). Sample d16 for the most part contained lower levels of metals than the other samples. Cadmium levels (1.1 to 3.9 ppm) in all samples except d16 were higher than background levels (0.3 ppm).

4. Oil and grease levels in d14 (630 ppm) and d15 (290 ppm) were greater than those found in d13 (71 ppm) and d16 (24 ppm).

5. Phenols were detected in two samples; d15 (0.9 ppm) at a spill near Building 1306 and d16 (0.8 ppm) in the drainage ditch. Cyanide was also detected (0.1 to 0.4 ppm) at all sites.

6. TOX was detected at all sites, with the highest level in sample d13 (2.9 ppm) and lowest level in sample d16 (0.26 ppm).

7. TOC was detected at all sites, with the highest levels in sample d15 (1.4%) and the lowest level in samples d13 and d16 (0.3%).

4.3.7.3 Findings

Findings for Site S-1 based on the data results are as follows:

1. Site S-1 is the probable source of VOCs in groundwater at the site, based on the VOC levels detected in wells at the site and on the presence of VOCs in soils at the site.

2. The VOCs detected in groundwater at Site S-1 are characteristic of fuels (benzene and ethylbenzene), and the solvents (tetrachloroethylene and trichloroethylene) and their degradation products (tetrachloroethylene to trichloroethylene to trans-1,2-dichloroethylene to 1,1-dichloroethylene to vinyl chloride). The positive identities of VOCS were not confirmed by either second-column gas chromatographic analysis or by mass spectroscopy.

3. Site S-1 may be a source of chromium, copper, nickel, lead, and zinc detected in groundwater at the site based on the concentrations found in well 25 and the metals detected in soils at S-1. However, the source of metals detected in well 24, which is not downgradient of Site S-1, was not identified.

4. Oil and grease in soils at S-1 may be a source of oil and grease in groundwater at S-1; however, the oil and grease in well 24 cannot be attributed to Site S-1.

5. The PCB found at d13 is likely associated with a spill area because PCBs were not detected in any other sample at S-1. The PCB Arochlor 1260 was detected in sample d13 at a level of 240 ppb. This level is two orders of magnitude less than a level of 97,400 ppb, which is that soil level calculated as corresponding to a carcinogenic risk level of 10^{-6}. The soil level was calculated by SAIC based on information from the U.S. Department of Health, Education, and Welfare publication entitled "Air Quality Criteria for Particulate Matter" (1969) and the U.S. EPA publication (600/8-84-031) entitled "Risk Analysis of TCDD-contaminated Soil" (1984).

6. Soils around S-1 contain VOCs, oil and grease, and metals. Five metals at the site exceeded background levels for the region. However, the presence of these metals could not be directly linked to the site.

7. Cyanides and phenols were present in soils and appear not to be migrating to groundwater.

8. The concentrations of oil and grease, metals, and arsenic present in soils adjacent to the site indicate a potential for these substances to enter surface waters.

9. Assuming that substances dissolved in groundwater move at the same rate as groundwater (i.e., without adsorption, degradation, or diffusion), substances in groundwater at well 27 will reach the base boundary at Route 113 in 18 years.

4.3.8 Site XYZ, Fuel Pump Station, Building 950

Groundwater samples were collected from four well points (p05, p06, p07, and p08) around Building 950 (Figure 4-6). The site is located along the groundwater divide, so groundwater flows away from the site towards the southwest and northeast (Section 2.3.8). One surface water sample (w16) was collected from a manhole southwest of Building 950. Sediment samples (d17 and d19) were collected from two manholes between the hardstand and Building 950. All samples were analyzed for oil and grease and TOC.

4.3.8.1 Groundwater Analysis Results

Groundwater results are presented in Table 4-15 and summarized as follows:

1. Oil and grease levels in p07 (2.0 ppm) and p08 (1.4 ppm), located east and south of Building 950, were higher than the background level of 1 ppm. Oil and grease was not detected in p05 and p06.

2. TOC levels in p07 (20 ppm) and p08 (11 ppm) were higher than the highest background level reported for the Columbia aquifer and were greater than levels in p05 (5.0 ppm) and p06 (3.3 ppm).

4.3.8.2 Surface Water Analysis Results

The results for the single surface water sample collected at this site are as follows:

1. Oil and grease was not detected.

2. A TOC level of 29 ppm was detected in the water sample.

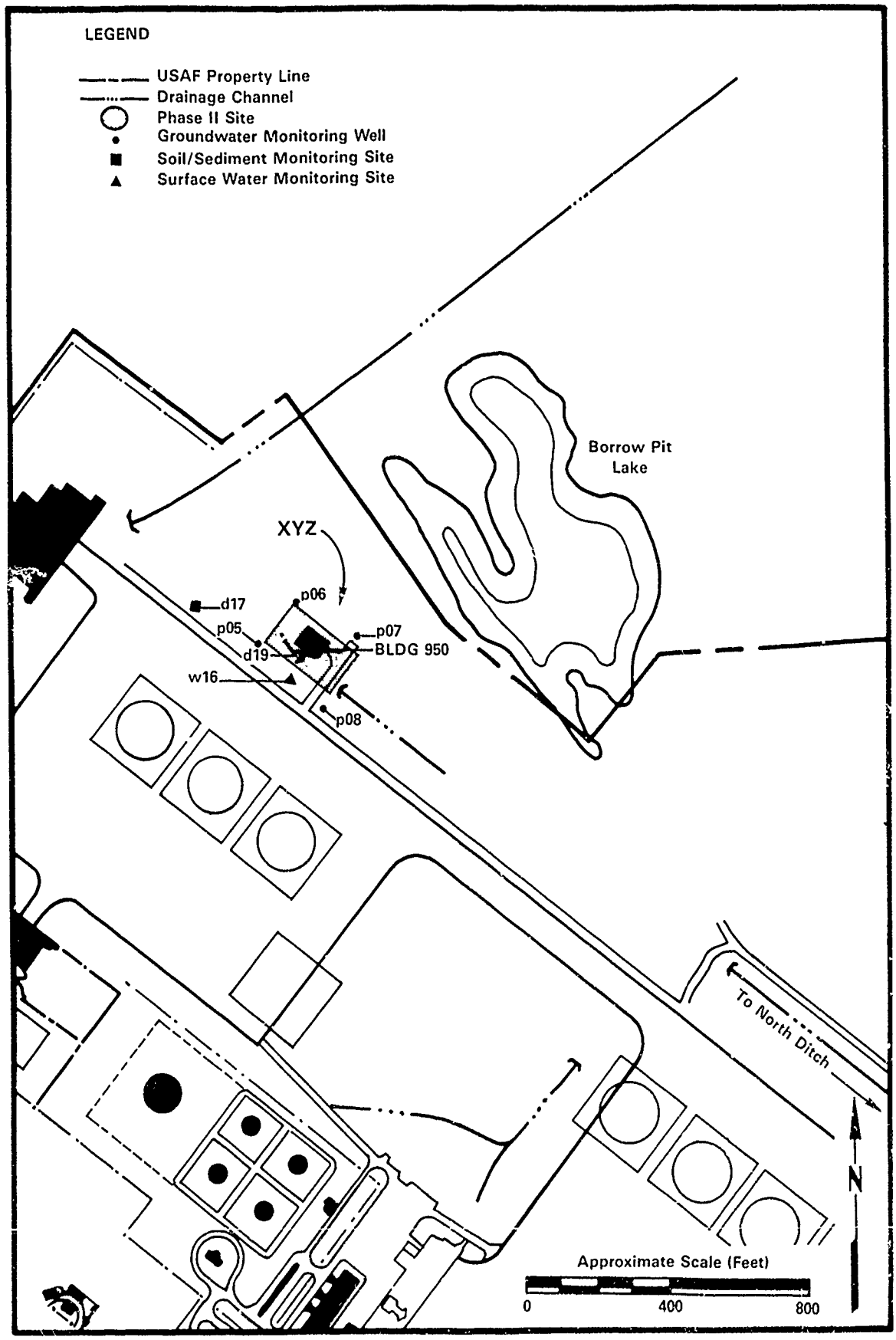


Figure 4-6. Monitoring Locations: Site XYZ, Fuel Pump Station

Table 4-15

SITE XYZ, FUEL PUMP STATION ANALYSIS RESULTS
GROUNDWATER, SURFACE WATER AND SEDIMENT

Parameter	Groundwater						Surface Water		Sediments	
	Well Point Number				FB	BW		FB		
	p05	p06	p07	p08	QA8a	QA9a	w16	QA18a	d17	d19
Indicators	(Results in ppm, except as noted)									
Oil & Grease	ND	ND	2.0	1.4	ND	ND	ND	ND	3.5	65
TOC	5.0	3.3	20	11	2.4	1.2	29	12	0.2%	0.9%

Note: Blank space indicates analysis not conducted
ND = Not detected; indicates parameter not present above detection limit
FB = Field blank; BW = Bailer wash
ppm = mg/l for water; ug/gm dry weight for soils; 1% = 10,000 ppm

4.3.8.3 Sediment Analysis Results

Sediment results are summarized as follows:

1. Sample d19, collected from a manhole adjacent to Building 950, contained higher levels (65 ppm) of oil and grease than that detected in d17 (3.5 ppm) and was higher than an estimated background level of 10 ppm.

2. The TOC level in d19 (0.9%) was higher than that detected in d17 (0.2%).

4.3.8.4 Findings

Findings for Site XYZ based on the results are as follows:

1. Groundwater and sediments around Building 950 contain levels of oil and grease and TOC above background levels. The type of compounds present are not known, but they may be the result of the fuel spill.

2. The levels of oil and grease and TOC in p07 and p08 may indicate that fuels in groundwater are migrating towards the east and south.

3. Groundwater at the site flows in a southwest and northeast direction because the site lies on the groundwater divide. However, compounds indicating groundwater contains fuels were found only east and south of the site.

4.3.9 Site D-2, Rubble Area

Eight soil samples were collected from around the toe of the landfill where runoff would be expected. Locations of sampling stations are shown in Figure 4-7. Soil samples were analyzed for arsenic, metals, oil and grease, TOX and TOC.

4.3.9.1 Soil Analysis Results

Soil results are presented in Table 4-16 and summarized as follows:

1. Metals were detected in all soil samples, with chromium, copper, mercury and cadmium being detected at levels less than background values.

2. Levels of arsenic (27 to 48 ppm) in all samples exceeded the highest background levels (2.7 ppm) reported for the Maryland and Delaware Coastal Plain.

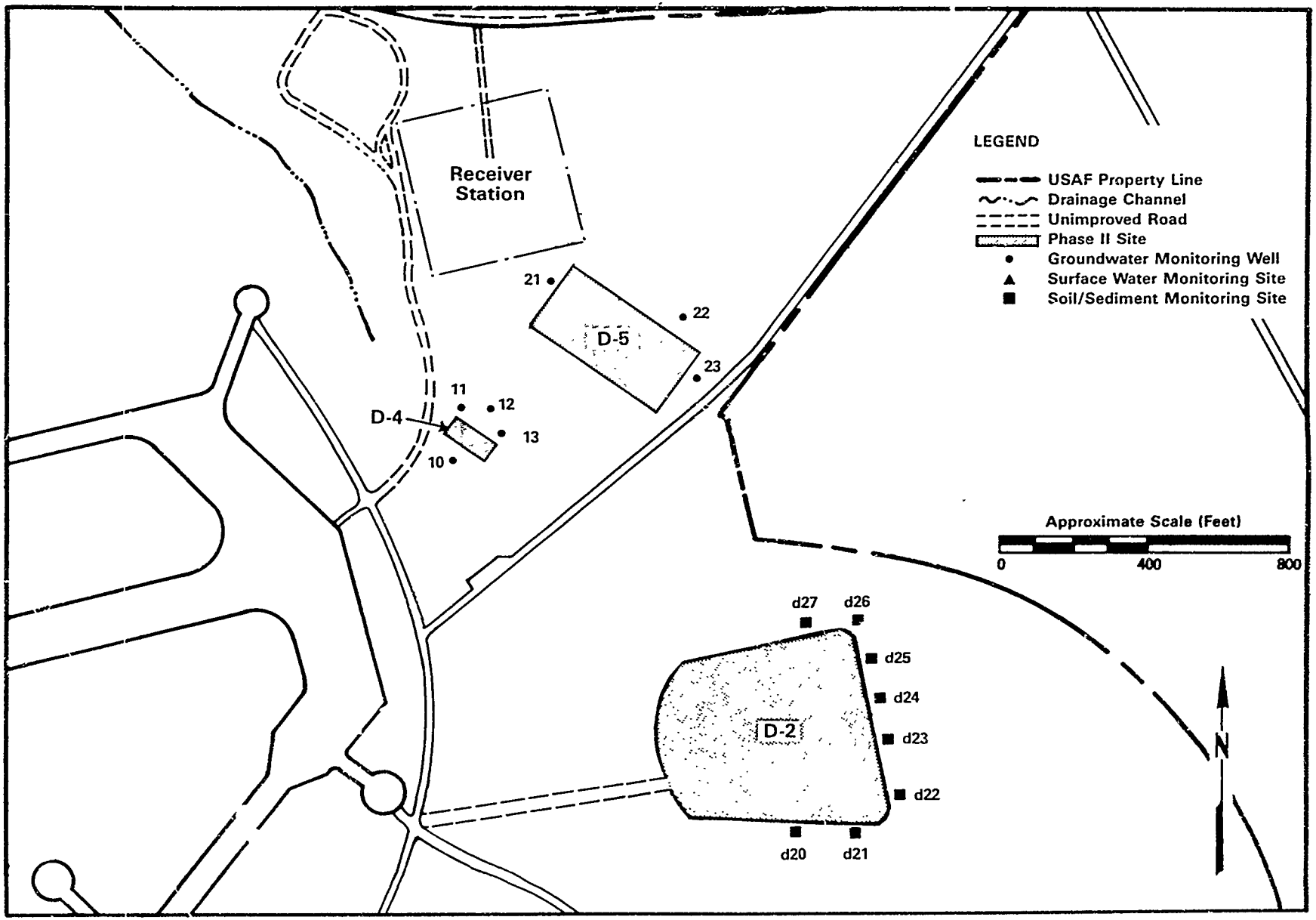


Figure 4-7. Monitoring Locations: Site D-2, Rubble Area

Table 4-16

SITE D-2, RUBBLE AREA ANALYSIS RESULTS
SOIL

Parameter	Monitoring Point								Dup. d20
	d20	d21	d22	d23	d24	d25	d26	d27	QA20a
Metals	(Results in ppm, except as noted)								
Silver	0.070	0.084	0.089	0.050	0.050	0.040	0.031	0.034	0.071
Arsenic	27	30	34	27	32	32	48	46	27
Cadmium	0.16	0.25	0.30	0.068	0.11	0.094	0.060	0.060	0.22
Chromium	7.6	8.0	11	8.6	8.5	8.6	12	11	7.8
Copper	5.2	6.4	6.0	5.1	4.7	4.2	3.9	5.0	5.8
Iron (%)	0.40	0.27	0.35	0.80	0.46	0.60	1.9	1.1	0.38
Mercury	0.062	0.061	0.081	0.078	0.056	0.023	0.024	0.031	0.057
Nickel	7.4	4.8	4.9	5.4	5.2	5.9	8.6	10	6.5
Lead	34	28	40	29	31	17	13	15	31
Zinc	72	120	29	19	21	23	23	26	59
Indicators									
Oil & Grease	78	46	71	65	53	7.6	17	12	64
TOX	1.1	0.98	0.97	0.63	0.89	0.65	0.53	0.24	0.96
TOC (%)	2.3	4.8	2.4	4.2	3.4	4.6	1.3	1.5	4.1

Dup. = Field duplicate
ppm = ug/g, or mg/kg dry weight; 1% = 10,000 ppm

3. The level of iron in d27 (1.1%) was slightly greater than the highest background level reported (1%) for Maryland and Delaware Coastal Plain soils.

4. Levels of nickel in d20 (7.4 ppm), d26 (8.6 ppm), and d27 (10 ppm); lead in d20 (34 ppm), d21 (28 ppm), d22 (40 ppm), d23 (29 ppm), d24 (31 ppm), and d25 (176 ppm); and zinc in d20 (72 and 59 ppm), d21 (120 ppm), and d22 (29 ppm) exceeded the highest background values reported for these metals in Maryland and Delaware Coastal Plain soils.

5. Oil and grease levels east to southeast of the landfill (d20 to d24) were higher (46 ppm to 78 ppm) than those (7.6 to 17 ppm) to the north (d25 to d27). All levels except that of d25 (7.6 ppm) were greater than the background level of 10 ppm.

6. TOX and TOC were detected in all soil samples from the site. TOX levels ranged from 0.24 ppm to 1.1 ppm and TOC levels ranged from 1.3 to 4.8%.

4.3.9.2 Findings

Based on these results, runoff from D-2 may be a source of the oil and grease, arsenic, iron, nickel, lead, and zinc found in soil. Halogenated organic compounds may also be present based on indicator parameters.

4.4 SUMMARY OF FINDINGS

Table 4-17 summarizes the findings presented in this section.

Additional activities are required at DAFB to identify the extent and magnitude of contamination. Chapter 5 presents options for additional monitoring at each site. Recommendations are presented in Chapter 6.

Table 4-17

SUMMARY OF FINDINGS, PHASE II STAGE 1, DOVER AFB

Sites	Groundwater	Surface Water	Soils/Sediments
T-1, IW Basins	• Levels above health standards/ criteria - VOCs, phenols - Chromium, nickel, lead • Levels above background maximum - Chromium, copper, lead, zinc - TOC, TOX	• Levels above health standards/ criteria - VOCs, phenols - Cadmium, chromium, nickel, lead • Levels above background maximum - Cadmium, copper, lead - TOX, TOC, oil and grease, pH, specific conductance	• Levels above background maximum - Arsenic, cadmium, chromium, copper, lead, zinc, oil and grease • VOCs, cyanide, phenols present
DD-1, North Ditch	• Not investigated	• Levels above health standards/ criteria - Nickel • Levels above background maximum - TOX, TOC	• Levels above background maximum - Arsenic, cadmium, chromium, copper, iron, nickel, lead, zinc, mercury • Oil and grease, cyanide, phenols present
D-10, Landfill	• Levels above health standards/ criteria - Chromium, nickel, lead • Levels above background maximum - Chromium, lead - TOX, TOC, pH, specific conductance	• Not investigated	• Not investigated

(continued)

Table 4-17 (continued)

SUMMARY OF FINDINGS, PHASE II STAGE 1, DOVER AFB

Sites	Groundwater	Surface Water	Soils/Sediments
FT-1, Fire Training Area 1	• Levels above health standards/ criteria - Nickel • Levels above background maximum - TOX, TOC, pH, specific conductance	• Levels above background maximum - TOX	• Not investigated
D-4, Liquid Waste Site	• Levels above health standards/ criteria - VOCs • Levels above background maximum - TOX, TOC	• Not investigated	• Not investigated
D-5, Landfill	• Levels above health standards/ criteria - Chromium, nickel • Levels above background maximum - Chromium, lead - TOC, oil and grease	• Not investigated	• Not investigated
FT-3, Fire Training Area 3	• Levels above health standards/ criteria - Nickel • Levels above background maximum - Nickel - TOC, TOX	• Levels above background maximum - Zinc - TOC	• Levels above background maximum - Arsenic, cadmium, copper, iron, nickel, lead, zinc - Oil and grease

(continued)

Table 4-17 (continued)

SUMMARY OF FINDINGS, PHASE II STAGE 1, DOVER AFB

Sites	Groundwater	Surface Water	Soils/Sediments
SP-4, JP-4 Pipeline Leak	• Levels above background maximum - TOC	• Not investigated	• Not investigated
S-1, Hazardous Waste Storage	• Levels above health standards/ criteria - VOCs - Chromium, nickel, lead • Levels above background maximum - Chromium, copper, lead, zinc - TOX, TOC	• Not investigated	• Levels above background maximum - Arsenic, cadmium, copper, nickel, lead, zinc - Oil and grease • VOCs, cyanide, phenols, PCBs (Arochlor 1260) present
XYZ, Fuel Pump Station	• Levels above background maximum - TOC, oil and grease		• Levels above background maximum - Oil and grease
D-2, Rubble Area	• Not investigated	• Not investigated	• Levels above background maximum - Arsenic, iron, nickel, lead, zinc - Oil and grease

5.0 ALTERNATIVE MEASURES

Findings of Phase II Stage 1, summarized in Section 4, indicate the need for additional investigations at DAFB sites because:

1. Concentrations of Stage 1 parameters were detected above applicable health standards or criteria at 8 sites.

2. Seven sites were potentially identified as sources of the concentrations of contaminants found in the environment. These sites are: T-1, DD-1, D-10, D-4, S-1, XYZ, and D-2.

3. Other unidentified sources appeared to be contributing to contaminant concentrations found in the environment at or around sites T-1, DD-1, D-10, and S-1.

4. Sources for the contaminant concentrations found in the environment at or around sites D-5, FT-3, and SP-4 are not identifiable at this time.

This section discusses options for obtaining data necessary to characterize the extent, magnitude, migration rates and pathways of substances detected in the environment at DAFB. Various suboptions (e.g., aquifer testing and deep aquifer monitoring) and alternatives (e.g., using either indicator parameters or priority pollutant scans during analysis) are also evaluated. Suboptions applicable to more than a single site are discussed in Section 5.1. Site-specific monitoring options are discussed in Section 5.2. Recommendations for additional activities at each site are presented in Section 6.

5.1 SUBOPTIONS APPLICABLE TO MORE THAN A SINGLE STUDY SITE

This section discusses suboptions that apply to more than one site or that can be implemented at selected sites and the data used to evaluate other sites. For example, the advantages and disadvantages of using soil gas analysis investigations are discussed in this section because the technology is applicable to numerous sites and a discussion of monitoring approaches to the Frederica aquifer is provided because monitoring of the Frederica at selected sites would provide data that could be applied at all DAFB sites.

Suboptions evaluated for use at DAFB include:

1. Using soil gas analysis to identify areas of elevated VOC concentrations, which will help place wells, identify sources and delineate plumes.

2. Installing Frederica aquifer wells to determine flow rates and direction and the presence of contaminants.

3. Using geophysical techniques to characterize subsurface conditions.

4. Conducting aquifer tests to determine aquifer properties.

5. Using soil or sediment composite samples to provide information about larger areas with fewer samples.

6. Collecting samples from various depths in wells to identify variations in VOC concentrations with depth in the aquifer.

7. Conducting several rounds of sampling, using the first round to identify target analysis parameters to be used during later studies. An initial round of samples would be analyzed for a large number of compounds and substances and would identify the range of substances present at a site. The target parameters would be selected from among all the substances identified at a location.

The advantages and disadvantages of each suboption are presented below. The applicability of each suboption to site conditions is evaluated in Section 5.2.

5.1.1 Soil Gas Analysis Investigation

Soil gas investigations detect the presence of volatile chemicals such as solvents, cleaning fluids, and hydrocarbons in the soil pores. The presence of VOCs in soil gas has been shown to correlate with the concentrations of VOCs in soils or groundwater. Mapping areas likely to contain VOCs using this method can save time and costs by reducing the number of samples required to delineate a contaminated area.

5.1.1.1 Alternatives

The alternatives for conducting soil gas investigations at DAFB sites include:

1. Not using the technology and relying on estimated groundwater flow patterns and the locations of potential sources to place future monitoring wells.

2. Conducting soil gas analysis at all sites where VOCs were detected in groundwater.

3. Conducting soil gas analysis at all sites where Stage 1 analysis confirmed contamination or where substances in soils or sediments are suspected of migrating to groundwater.

5.1.1.2 Alternatives Evaluation

The potential cost savings, ease of use, and ability to conduct soil gas investigations in areas close to runways where drilling may not be permitted because of flight operations are the major reasons for conducting soil gas investigations at DAFB sites. Arguments against using the technique are two-fold. First, interferences from VOCs in soil could indicate higher concentrations of VOCs than are actually present in groundwater and result in less than optimum well placement. Second, the technique will not map metals or nonvolatile organics. However, soil interferences and data interpretation problems have been successfully handled during other soil gas investigations. In addition, the hydrogeologic conditions at DAFB are well-suited to soil gas investigations because of the shallow water table and lack of a continuous, low permeability zone between the land surface and the water table, which favors the migration of VOCs from the water table through the unsaturated zone.

Soil gas investigations could be conducted either at sites where only VOCs have been detected or at all sites where any contaminants have been detected. Using the technique at sites with confirmed VOCs in groundwater would help locate wells by identifying potential plume limits. Using the technique at sites where sampling for VOCs has not been conducted would indicate if soil gas contained VOCs and, therefore, if VOCs might be present in groundwater.

Because of the presence of VOCs in groundwater at all sites where samples were analyzed for VOCs, soil gas investigations are recommended for all sites selected for study during Stage 2.

5.1.2 Frederica Aquifer Monitoring

The Frederica aquifer is a minor water producing zone between the Columbia aquifer and the deeper Cheswold and Piney Point aquifers. Substances

migrating from the Columbia will be observed in the Frederica before detection in the deeper, water-producing aquifers (Section 2.2.2).

5.1.2.1 Alternatives

The various alternatives for monitoring the Frederica aquifer at DAFB include:

1. Not monitoring the Frederica aquifer at any study site.
2. Monitoring only at sites where the highest concentrations of substances likely to migrate from the Columbia to lower aquifers have been detected and using the results to indicate if migration to the Frederica could occur at other sites. Monitoring of the Frederica at other sites where groundwater in the Columbia aquifer has been affected would be implemented if substances are detected in the Frederica aquifer at the highest likelihood sites.
3. Monitoring at all locations where Columbia aquifer groundwater has been affected.

5.1.2.2 Alternatives Evaluation

The low hydraulic conductivity of the Kirkwood (Miocene) confining layer and the apparent long groundwater travel times to the Frederica aquifer from the Columbia (approximately 150 years) makes Frederica aquifer contamination by DAFB activities unlikely, thus supporting the no-action alternative. However, the Kirkwood (Miocene) may not be continuous throughout the area and calculated flow times may not be accurate because they are based on estimates of hydraulic conductivity and not actual data from monitoring of the Frederica.

Alternative 2, if implemented, would indicate if substances are moving through the confining layer in areas where substances are present at high concentrations (i.e., at Site T-1). The thickness and hydrogeologic properties of the Kirkwood (Miocene) and Frederica units also would be determined. This alternative could be implemented at Site T-1 using a staged approach as follows:

1. Initial installation of three Frederica aquifer wells in a triangular pattern around Site T-1.

2. Based on calculated flow directions determined from the three initial wells, installation of a fourth well directly downgradient from areas of highest concentrations of substances in Columbia aquifer groundwater.

3. Installation of two or three Frederica aquifer wells at selected sites (e.g., D-4 and S-1) sufficiently removed from Site T-1 and each other to determine groundwater flow direction. Each well would be located downgradient (as identified in number 2 above) from sites where substances were detected in Columbia aquifer.

This approach assumes that the possibility of substances migrating to the Frederica would be greatest in the Site T-1 area because of the high concentrations of substances detected in the Columbia aquifer and the basin's proximity to the Dover area groundwater pumping centers where the vertical gradient between the Columbia and the lower aquifers is greatest.

Alternative 3 would provide detailed hydrogeologic information on the Kirkwood (Miocene) and Frederica units from a large number of sites and would increase the confidence in estimates of aquifer characteristics. In addition, because monitoring would be conducted at all sites where substances could migrate to the Frederica aquifer, contamination of the Frederica would be confirmed or denied at all sites. Alternative 3 would be more costly to implement than alternative 2 because an estimated 30 double-cased wells, assuming 3 wells per site, would probably be required.

Because substances can possibly migrate to lower aquifers, implementation of a Frederica aquifer monitoring plan should be considered. Alternative 2 is recommended to obtain site-specific information on the Kirkwood (Miocene) confining unit and the Frederica aquifer. Additional Frederica wells would be installed if information gathered during Stage 2 indicated that substances were migrating to the Frederica aquifer.

Any Frederica aquifer monitoring well should be drilled using outer steel casings to isolate the borehole from the Columbia aquifer before the borehole penetrates the Kirkwood (Miocene) confining unit (i.e., double cased wells).

5.1.3 Geophysical Survey Investigations

Geophysical survey techniques such as resistivity, seismic, and ground-penetrating radar surveys can provide data that indicates the extent of

affected groundwater and possible migration paths. Their use may not be appropriate at DAFB because the types of substances present (VOCs) may not be mappable using available geophysical techniques. Geophysics may be most useful in identifying the boundaries of land disposal sites or hydrogeologic controls on groundwater movement. Geophysical investigations are probably not required at this time, but could be used during later studies to map buried waste or to characterize the thickness of the Columbia aquifer.

5.1.4 Aquifer Testing

Aquifer tests provide data on aquifer properties that affect groundwater flow. Long-term (over 48 hours) pump tests are usually required in areas of high transmissivity, like the Dover area, to provide accurate data for calculating aquifer properties.

5.1.4.1 Alternatives

The various alternatives for conducting aquifer testing at DAFB include:

1. The no-action alternative, which would require the use of published reports to provide data on aquifer characteristics.
2. Aquifer tests at several selected sites across the base and application of the data to the other sites.
3. Aquifer tests at all sites.

5.1.4.2 Alternatives Evaluation

Published data for the Columbia aquifer indicates that aquifer characteristics are highly variable. Predictions of groundwater flow using published reports as data sources may vary from actual conditions by several orders of magnitude. Therefore, the no-action alternative (alternative 1) limits the ability to best predict the extent of affected groundwater.

An advantage associated with alternative 2 is that site-specific aquifer properties could be identified for less cost than alternative 3. However, under alternative 3, aquifer properties at each site would be more precisely determined. Once monitoring wells are installed, testing could be conducted on any well as data needs are identified.

An aquifer testing program should be considered because of the lack of hydrogeologic data specific to DAFB. If implemented, alternative 2 would include a pump test on both a Columbia aquifer well and a Frederica aquifer well in the Site T-1 area; a pump test on a Columbia aquifer well at Site D-4, which is located on the other side of the groundwater divide from T-1; and a pump test at Site S-1. Results would indicate aquifer variability and would provide site-specific data to help calculate groundwater flow rates.

5.1.5 Composite Soil Sampling

Composite soil sampling involves collecting samples from several locations within a study area and combining them for analysis. Composite samples indicate the average chemical quality of soils in the sampled area.

5.1.5.1. Alternatives

Soil composite sampling alternatives vary according to site-specific conditions and study objectives, therefore, all possible alternatives cannot be listed. However, the basic alternative options are composite sample or grab sample collection. The advantages and disadvantages of composite sampling are discussed below and the various alternatives for composite sampling at specific sites are discussed in Section 5.2.

5.1.5.2. Alternatives Evaluation

The problems associated with composite sampling include:

1. The method could mask the presence of low levels of substances concentrated in a small area.
2. Elevated concentrations could be reduced because of compositing materials with lower concentrations.
3. The chances of picking up a "hot spot" in a normally uncontaminated area are increased because the sample is made up of material from a larger number of locations. However, because contaminated and uncontaminated soil may be mixed to form the composite, concentrations will likely be less than the maximum in the area.

The advantage of composite sampling is that the technique provides coverage from a larger area at less cost than individual grab samples. Composite samples also identify average chemical concentrations in the sampled areas.

5.1.6 Stratified Groundwater Sampling

The VOCs identified at DAFB have specific gravities that may cause them to move more rapidly vertically within the aquifer. Collecting samples at various depths within a well will identify any stratification of contaminants within the aquifer.

5.1.6.1 Alternatives

Alternatives for collecting stratified groundwater samples at DAFB include:

1. Collecting all samples from a single point in the water column, assuming stratification is minimal.
2. Collecting stratified samples only at selected wells and use this data to predict the extent of stratification occurring throughout the aquifer.
3. Collecting stratified samples at all wells.

5.1.6.2 Alternatives Evaluation

The VOCs identified at DAFB are sufficiently soluble to spread throughout the water column. However, they may concentrate within a certain aquifer zone because of specific gravity differences and aquifer heterogeneities. Samples taken from a single depth in a well would possibly delineate the contaminated area, but not the concentration variations within the water column. Under alternative 2, the areal extent of contaminated groundwater would be determined at each site and then stratified samples would be taken from wells within the major or most highly concentrated zones. Thus, the vertical and horizontal extent of substances could be determined. Alternative 3 is probably not required because stratification sampling at all wells would duplicate alternative 2 at a higher cost.

Collecting stratified groundwater samples from wells with high concentrations should be conducted to identify the vertical extent of affected groundwater.

5.1.7 Sample Analysis Parameter Selection

Both compound specific (e.g., EPA Method 601 for purgeable halocarbons) and indicator parameter (e.g., TOX and TOC) tests were conducted on environmental samples during Stage 1. In many cases, evaluation of test results indicated the possibility that compounds other than those specifically identified may be present at study sites. If additional monitoring is conducted, the parameters selected for analysis should cost-effectively identify the range of substances present at a site. The same set of analyses should be performed on all samples collected at a site regardless of media so that the movement of substances between media can be evaluated and the sources identified.

5.1.7.1 Alternatives

The alternatives for selecting Stage 2 analysis parameters include:

1. Selecting a limited number of target parameters based on the Stage 1 results.
2. Reusing the Stage 1 parameters.
3. Selecting target parameters based on both the Stage 1 findings and results from a small number of new samples which are analyzed for a comprehensive set of compounds.
4. Analyzing all samples using a comprehensive set of analysis parameters (e.g., a priority pollutant scan).

5.1.7.2 Alternatives Evaluation

Stage 2 parameters could be selected based on the Stage 1 results. For example, at a site where groundwater contains VOCs and the metals chromium and lead, these could be analyzed for in new wells during Stage 2. At many sites, however, results from nonspecific tests such as oil and grease, TOC, and TOX indicates that compounds may be present for which analysis was not conducted during Stage 1. A program implemented with parameters selected according to either alternative 1 or 2 would potentially characterize the extent and magnitude of only a limited set of substances (i.e., at the most, all of the Stage 1 parameters) without identifying any other specific compounds.

Under alternative 3, target parameters would be selected based on results from both Stage 1 and from new samples collected at a few locations. New samples would be collected at locations of greatest concentration based on Stage 1 results. Results of comprehensive analyses conducted on these samples and the results of Stage 1 would be used to identify the target compounds. The assumption associated with alternative 3 is that all of the substances at a site are present at locations with the greatest concentrations of Stage 1 parameters. This assumption is not associated with alternative 4, which would be more expensive to implement than alternative 3.

5.2 SITE-SPECIFIC MONITORING OPTIONS

Site-specific monitoring options are presented for each site by media of concern, although not all media are addressed at each site. In addition, options for Stage 2 analyses parameters are discussed. Sites are discussed in order of decreasing HARM score. Media at a site is described as containing elevated concentrations of particular parameters if the Stage 1 analytical results for the parameters were above health standards, health criteria, or background maximum levels. Table 4-17, located in Section 4.0, summarized these findings by media and site.

5.2.1 Site T-1, IW Basins

Media sampled at Site T-1 contained elevated concentrations of VOCs, arsenic, cadmium, chromium, copper, nickel, lead, zinc, oil and grease, and phenols. Based on Stage 1 results and findings, the following information should be obtained to fully characterize the extent and magnitude of substances in the environment at Site T-1:

1. Identification of the source of the anomalous groundwater chemistry results at well 01j.
2. Determination of the extent of substances in groundwater.
3. Identification of the source(s) of benzene, toluene, xylene, tetrachloroethylene, and trichloroethylene in DNREC wells.
4. Characterization of aquifer properties, including hydraulic conductivities and the areal extent of the recharge mound under the basins.

5. Determination of the potential for groundwater to migrate to deeper aquifers.

6. Identification of all VOCs in groundwater.

7. Characterization of the structure (topography, vertical extent) of the Kirkwood (Miocene) silty clay unit.

Monitoring options discussed below are evaluated as to their suitability for collecting this information.

5.2.1.1 Groundwater Monitoring Options

Groundwater at Site T-1 contained elevated concentrations of VOCs, chromium, copper, nickel, lead, zinc, oil and grease, phenols, TOC, and TOX. Options for investigating groundwater at Site T-1 include:

1. Not conducting additional groundwater monitoring.

2. Monitoring groundwater using existing USAF wells.

3. Monitoring groundwater using existing USAF and DNREC wells.

4. Monitoring groundwater using both newly installed wells and existing wells.

The extent and magnitude of substances in groundwater would not be determined under option 1. A program implemented under option 2 would duplicate Stage 1 and would not identify the presence of upgradient sources, characterize the extent of the recharge mound under the basins, or identify the extent of groundwater contamination in the motor pool area. Implementation of option 3 would provide more information on groundwater quality southwest of the basins, but would have the same shortcomings as option 2. Stage 2 objectives would probably not be met under options 1, 2, or 3.

Option 4 appears to be the best monitoring alternative for obtaining the required information on the basin area. Fully screened, fully penetrating monitoring wells would be sited based on the results from the soil gas analysis and Stage 1 results. Wells probably would be required around the basin and motor pool, and possibly along the base boundary at Route 113, to characterize groundwater quality between the basins and the contaminated

drinking water wells. The inclusion of the DNREC wells in the monitoring program would reduce the number of new wells required. Depending on Stage 2 findings, new off-base monitoring wells may be required.

5.2.1.2 Surface Water Monitoring Options

Surface waters in the basin contained elevated concentrations of VOCs, oil and grease, cadmium, chromium, copper, nickel, lead, phenols, TOX, TOC, pH, and specific conductance. The surface waters are not natural waters, rather they are industrial wastewaters discharged to the basins.

Options for sampling the basin waters at Site T-1 include:

1. Not conducting additional monitoring.
2. Monitoring for the same parameters selected for groundwater monitoring.

Historical monitoring at Site T-1 should provide sufficient data on the migration of substances from the basins to soils and groundwater. The DAFB Bioenvironmental Engineering Office has taken numerous samples from the basin waters, therefore, sufficient data to characterize the waters may be available. Selection of option 2 would be required if additional substances are found in groundwater. Option 2 also may be required to obtain a complete picture of the problem.

5.2.1.3 Sediment Monitoring Options

Sediments under the basins contain elevated concentrations of oil and grease, arsenic, cadmium, chromium, copper, lead, and zinc. Cyanide, phenols and VOCs are also present, although regional or national background levels are not available for these parameters in soils or sediments. Results indicated that the basin sediments are acting as a sink in which substances are being concentrated.

Options for monitoring the basin sediments include:

1. Not conducting additional monitoring.

2. Collecting additional surface sediment samples.
3. Collecting additional sediment samples at the surface and at depth.

Under option 1, the existing information on the basin sediments would be used to estimate the concentrations and quantities of substances in the sediments. DAFB has analysis of sediment samples which could be used along with Stage 1 results to characterize substances in sediments.

Option 2 and 3 would be implemented if available data is insufficient to characterize the substances present (e.g., if additional parameters are found at elevated concentrations in the groundwater). Composite samples taken from a number of surface locations in the basins could be used to characterize surface sediment quality.

Option 3 would be implemented to determine the depth of substance migration within the unsaturated zone beneath the basins. Stage 1 results indicate that substances in general are decreasing with depth below the sediment-surface water interface, but are still present at five feet below the interface. However, this finding is based on only one sample collected at a depth of 5 feet below the basins.

DAFB has developed a plan to remove surface sediments and cap the lagoons with impermeable barriers to prevent the contact of infiltrating precipitation with basin substances. This plan would minimize the leaching of substances from soils into the groundwater under the basins. Because surface sediments would be removed, option 2 may not be required. The collection of additional sediment samples under option 2 may be needed if additional substances are found during groundwater sampling or a complete picture of the situation is desired. Option 3 could be implemented before cleanup to characterize the depth of affected soil. The extent and amount of substances remaining in the soils could be used to determine the potential for long-term migration of substances from soils to groundwater.

The collection of deep soil samples is probably not required for Phase II Stage 2. Once cleanup is implemented, the migration of substances from the unsaturated zone to the saturated zone will approach zero because water

flow through the unsaturated zone will be minimized. Deep soil samples can be collected easier, faster, and without interference from basin waters if collection is implemented after the liquids are drained from the lagoons.

5.2.1.4 Sample Analysis Options

Chemical analyses to be conducted during any additional monitoring at Site T-1 include the following:

1. Analyzing for Stage 1 parameters found at elevated levels, these include VOCs, phenols, arsenic, and heavy metals; plus analyzing for petroleum hydrocarbons.

2. Analyzing for all of the Stage 1 parameters, these include VOCs, arsenic, cyanide, phenols, heavy metals, TOX, TOC, and oil and grease.

3. Analyzing samples from those wells with the most elevated concentrations for priority pollutant organics. Compounds found would be added to those listed in option 1 above to determine the analysis suite for additional monitoring during Stage 2.

4. Conducting complete priority pollutant scans on all samples.

Additional monitoring using the option 1 or 2 parameters would not identify or characterize other organics that may be present in groundwater. Under option 3, the priority pollutant scans conducted on selected wells (e.g., 01j, 103, S4a, and S4b) would be used to characterize the potential range of organic compounds in groundwater. These plus the Stage 1 parameters confirmed in groundwater (i.e., option 1 parameters) would be used to select the target parameters for analysis as part of any additional monitoring. The assumption associated with this option is that the range of organic compounds present can be characterized with analysis from a small number of samples. A complete priority pollutant scan conducted on all additional samples would provide a full characterization of organics in groundwater, but at a greater cost than option 3.

5.2.2 Site DD-1, North Ditch

Sediments in the ditch contained elevated concentrations of arsenic and all Stage 1 metals, except silver. Oil and grease, cyanide, and phenols were also present. Surface waters contained elevated concentrations of nickel,

TOX, and TOC. Groundwater monitoring was not conducted and analysis for VOCs was not performed during Stage 1.

Based on Stage 1 results and findings, the following information should be obtained to characterize the extent and magnitude of substances at Site DD-1.

1. Determination of any effect sediment contamimants may have on groundwater quality.
2. Identification of the depth of affected sediments and the variations in concentrations throughout the ditch.
3. Characterization of the sources of the substances.
4. Identification of any continued discharge to North Ditch surface waters.
5. Characterization of the movement of substances between sediments, surface water, and groundwater.

Monitoring options discussed below are evaluated as to their suitability for obtaining the required information.

5.2.2.1 Groundwater Monitoring Options

Groundwater at Site DD-1 was not monitored during Stage 1. Options for investigating groundwater at Site DD-1 during Stage 2 include:

1. Not monitoring groundwater.
2. Monitoring groundwater at selected areas of elevated concentrations (e.g., around w-d04).
3. Monitoring groundwater along the entire ditch.

The assumption associated with option 1 is that substances in sediments have not migrated to groundwater, but have been immobilized in the sediments. However, migration to groundwater may be occurring because of the elevated concentrations present and the possibility that ditch waters are recharging groundwater.

Under option 2, groundwater monitoring would be implemented at the areas of highest concentrations based on Stage 1 data, assuming that the potential for migration to groundwater is highest in these areas. If substances are confirmed in groundwater, additional monitoring would be required along the entire ditch area. Under option 3, infiltration is assumed to have occurred along the entire length of the ditch and, therefore, migration is possible throughout the area. More wells would probably be required for option 3 than for option 2, but a better characterization of the hydrogeology and groundwater quality would be obtained under option 3.

Conducting a soil gas investigation would be a viable option at this site because the ditch received the same wastewaters prior to 1964 as the IW Basins. Therefore, VOCs found at the basins may be also present in groundwater at the North Ditch.

5.2.2.2 Surface Water Monitoring Options

Surface waters at Site DD-1 contained elevated levels of nickel, TOC, and TOX. Options for investigating surface waters at Site DD-1 include:

1. Not monitoring surface waters.
2. Collecting samples at Stage 1 locations.
3. Collecting samples at selected Stage 1 and new locations.

Ditch surface waters contained low concentrations of most Stage 1 parameters; therefore, continued surface water sampling may not be required. However, TOX levels indicate the presence of halogenated organic compounds in surface waters. Because compound-specific scans were not carried out during Stage 1, the presence of VOCs cannot be ruled out. In addition, samples indicated a source of TOX and oil and grease from the XYZ area. The possible presence of VOCs, the elevated level of nickel, and the need to more adequately characterize any source still discharging to the ditch argue against option 1.

Option 2 would not adequately characterize any source from the XYZ area and would not provide any additional data unless VOCs are included in the analysis.

Collecting additional surface water samples around the runway area near the point of discharge and along the portion of the ditch leading to the XYZ area would potentially provide the data necessary to determine if sources are continuing to discharge to the North Ditch. Samples could be collected from several points parallel to the runway between Site XYZ and the ditch, and along the ditch.

5.2.2.3 Sediment Monitoring Options

Sediments at Site DD-1 contained elevated concentrations of all of the Stage 1 metals, except silver for which a regional background level is not available. The sediments also contained elevated concentrations of arsenic, cyanide, phenols, TOX, and TOC. Oil and grease, cyanide, and phenols were also present. Options for investigating sediments at Site DD-1 include:

1. Not conducting additional monitoring.
2. Collecting additional near-surface sediment samples.
3. Collecting soil samples from various depths at selected Stage 1 sediment monitoring locations.
4. Implementing both options 2 and 3.

The elevated concentrations detected in the sediments argue against option 1 because the extent and magnitude of affected sediments would not be determined.

Under option 2, the distribution of substances at the surface water/ sediment interface could be more precisely defined, although samples from Stage 1 have already located several areas with elevated concentrations. Characterization of concentrations between d05 and d06 and between d07 and d08 could further characterize substance distribution within the ditch.

Under option 3, the depth of substance migration could potentially be identified. This information could be used to evaluate remedial actions and to help characterize compound movement between sediments, surface water, and groundwater. An alternative under option 3 would be to limit samples to those

locations sampled in Stage 1 which had the highest concentrations of substances in sediments, assuming that the depth of migration would be greatest in these areas.

The entire ditch contains elevated concentrations of substances based on Stage 1 findings. Option 4 would provide a more complete characterization of substances at the surface, as well as an indication of the depth of substance migration.

5.2.2.4 Sample Analysis Options

Alternatives for analysis parameters to be used during additional investigations at Site DD-1 include the following:

1. Analyzing for certain parameters detected during Stage 1, these include arsenic, heavy metals, oil and grease, cyanide, and phenols; plus VOCs.

2. Conducting analysis for all of the Stage 1 parameters including those listed in option 1, plus TOX and TOC.

3. Analyzing several grab sediment samples at locations of elevated concentrations (e.g., at Stage 1 monitoring points d03, d04, and d08) for priority pollutant organics and petroleum hydrocarbons. Compounds found in these samples and samples collected at Site T-1 would be added to those listed in option 1 above to determine the analysis parameter suite for additional monitoring under Stage 2.

4. Analyzing all samples for all priority pollutants, plus oil and grease and fuels.

A monitoring program implemented using the analysis under options 1 or 2 would not identify any VOCs that may be present based on site history. In addition, fuels could not be identified under option 1 and could only be evaluated through the use of indicator parameters under option 2. Options 3 and 4 would identify and characterize the substances confirmed as present, plus any fuels and any other priority pollutant organics that may be present. Option 3 would be less expensive than 4, but includes the assumption that the presence of other priority pollutant organics could be determined from samples collected at a select few locations with elevated concentrations of Stage 1 parameters.

The purpose of the initial sampling for priority pollutant organics under option 3 is to indicate if organics are present in surface waters and sediments. These results, plus the results of any priority pollutant scans conducted on groundwater samples from the Site T-1 area, would be used to determine the suite of analysis for the additional monitoring program.

5.2.3 Golf Course Sites: D-10, Landfill and FT-1, Fire Training Area 1

Groundwater at Site D-10 contained elevated levels of lead, nickel, chromium, TOX, TOC, pH, and specific conductance. Halogenated and nonhalogenated organic compounds may be the cause of the elevated levels of TOX and TOC. VOCs were found in samples collected by the USAF from well 07j. Elevated TOC levels in upgradient wells indicated that a source or sources upgradient of the sites may exist. Surface waters and sediments downgradient of D-10 were not sampled during Stage 1. Groundwater at Site FT-1 contained elevated levels of nickel, TOX, TOC, pH, and specific conductance. Surface waters contained elevated levels of TOX. However, Stage 2 monitoring is not specifically recommended for Site FT-1 because the elevated levels were found at upgradient monitoring locations.

Based on Stage 1 findings, the following information should be obtained to characterize the extent and magnitude of substance contamination at the golf course:

1. Identification of the source of anomalous TOX and TOC levels.
2. Confirmation of the existence and location of upgradient sources.
3. Determination of the extent of affected groundwater downgradient of D-10.
4. Determination of the potential for substance migration to surface waters and sediments downgradient of D-10 (i.e., into the wetlands at D-10 and the golf course pond).

Monitoring options discussed below are evaluated as to their suitability for obtaining this information.

5.2.3.1 Groundwater Monitoring Options

Groundwater at Site D-10 contained elevated levels of chromium, nickel, lead, TOX, and TOC. Alternatives for investigating groundwater at the golf course include:

1. Not monitoring groundwater.
2. Monitoring groundwater using existing wells at D-10 only.
3. Monitoring groundwater using all existing wells at the golf course.
4. Monitoring groundwater using all existing wells and newly installed wells.

Option 1 would not determine the extent or magnitude of substances confirmed as present in groundwater. Options 2 and 3 would not provide any additional information about the substances, unless VOCs are included in the analyses. Option 2 would not provide data on groundwater quality between Site D-10 and the St. Jones River or upgradient of the site. Neither option 2 nor 3 would characterize substance migration towards the St. Jones River.

The installation of additional wells is probably necessary because an upgradient source is suspected and any movement of substances in groundwater from Site D-10 towards the St. Jones River has not been characterized. Additional upgradient wells would be located across Route 113 opposite the golf course and upgradient of the Green House well. Wells would also be installed between the sites and the St. Jones River to confirm migration routes. Implementation of option 4 would generate data necessary to characterize the upgradient sources and the downgradient extent of affected groundwater.

5.2.3.2 Surface Water Monitoring Options

Surface water in the small drainage ditch at the golf course contained slightly elevated levels of TOX. Samples did not contain elevated levels of metals or oil and grease. Analysis for VOCs was not performed. The golf course pond and the wetland area downgradient from D-10 were not sampled

during Stage 1. Options for investigating surface waters at the golf course include:

1. Not conducting additional monitoring.
2. Monitoring at Stage 1 monitoring locations.
3. Monitoring at the Stage 1 monitoring locations, plus the golf course pond and the D-10 wetland area.

Option 1 would not characterize any VOCs which might be migrating to surface waters, because specific analysis for VOCs has not been performed to date. The surface waters near D-10 have not been sampled and could be contaminated if affected groundwater is discharging to surface waters.

Option 2 would duplicate Stage 1 efforts without determining water quality at the locations most likely to receive affected groundwater, which includes the pond and wetland area around D-10.

Option 3 would identify if substances are migrating to surface waters. Surface water sites would be sampled for the same parameters as groundwater because surface waters near Site D-10 could be affected by the discharge of groundwater. Samples would probably be required from two or three points along the stream and from one or two points in both the D-10 wetland area and the golf course pond.

5.2.3.3 Sediment Monitoring Options

Sediments at the golf course were not sampled during Stage 1 activities. Options for investigating sediments at the golf course include:

1. Not collecting sediment samples.
2. Collecting samples from sediments at Site D-10 where substances were detected in groundwater.
3. Collecting samples at all of the same golf course monitoring locations for surface waters.

Sediment samples would not be collected under option 1; therefore, additional data would not be generated. Option 1 is not recommended because

substances have been confirmed as present in groundwater and the potential for migration to sediments and surface waters exists.

Option 2 would potentially identify if substances are migrating from groundwater to surface waters from Site D-10. Because the water table lies close to the land surface, groundwater may discharge to the golf course pond and the small wetland area. Samples at these locations would confirm if affected groundwater is being discharged to surface waters. If substances were detected at these locations, additional sampling of the St. Jones River and of tributaries feeding the St. Jones River from the golf course may be required.

Option 3 would confirm the presence or absence of substances in sediments at all surface water monitoring stations on the golf course. Sediments have not been sampled at the golf course, so the chemical content of this media has not been characterized. The difference between options 2 and 3 is that the stream adjacent to Site FT-1 would be sampled under option 3, but would not be sampled under option 2. Collecting composite samples is feasible under either option 2 or 3 to characterize average sediment chemical quality.

5.2.3.4 Sample Analysis Options

Alternatives for analysis to be conducted during additional investigations at the golf course include the following:

1. Analyzing for certain parameters found at elevated levels during Stage 1, these include the heavy metals; plus analyzing for VOCs.
2. Analyzing for all of the Stage 1 parameters, these include heavy metals, oil and grease, cyanide, phenols, TOX, and TOC; plus VOCs.
3. Analyzing for a set of target parameters. Samples collected from wells found to contain VOCs would undergo initial analysis for priority pollutant organics. Compounds found, plus chromium, nickel, and lead would complete the analysis suite for the Stage 2 monitoring program.
4. Analyzing for all priority pollutants.

Options 1 or 2 would not identify additional organics that may be present, although the extent of VOCs and the metals would be characterized.

Options 3 and 4 would identify and characterize both the substances known to be present, as well as any additional organics that may be present. Option 3 would be less expensive than 4, but the assumption associated with option 3 is that the presence of other priority pollutant organics could be determined from a select few samples taken at wells where VOCs have been found. If additional sources were located, priority pollutant organic scans may be required to characterize the range of organics present at these monitoring locations.

5.2.4 Receiver Station Sites: D-4, Liquid Waste Site and D-5, Landfill

Groundwater at the Receiver Station sites contained elevated levels of VOCs, oil and grease, chromium, lead, TOX, and TOC. Cyanide and phenols were present at low levels. Metals found in well 23 indicated a possible additional source located south to southeast of the area. Surface waters and sediments in the small drainage ditch west of Site D-4 were not sampled during Stage 1. Migration of substances to ditch waters and sediments is possible if affected groundwater is discharging to the ditch.

Based on the Stage 1 findings, the following information should be obtained to characterize the extent and magnitude of substances in the environment in the area of the Receiver Station Sites:

1. Characterization of the extent and magnitude of VOCs and metals in groundwater around the area.
2. Determination of the contribution by other sites to the elevated concentrations found in groundwater.
3. Identification of the potential for migration of substances to surface waters and sediments in the drainage ditch west of Site D-4.
4. Determination of the thickness of the Kirkwood (Miocene) confining layer and the hydrogeologic properties and water quality in the Frederica aquifer so as to characterize the potential for migration to the lower aquifers.

The monitoring options discussed below are evaluated as to their suitability for obtaining this information.

5.2.4.1 Groundwater Monitoring Options

As stated above, groundwater at the Receiver Station Sites contained elevated levels of VOCs, oil and grease, chromium, lead, TOX, and TOC. Options for investigating groundwater in this area include:

1. Not conducting additional groundwater monitoring.
2. Monitoring using existing wells.
3. Monitoring using existing and newly installed monitoring wells.

The extent and magnitude of substances in groundwater in this area has not been completely characterized. A program implemented under option 1 would require using published data on aquifer properties and gradient information to calculate the maximum extent of affected groundwater. However, predictions based on published information may not be as accurate as those made based on site-specific information.

Under an option 2 program, priority pollutant scans performed on existing wells at Site D-4 would identify the compounds in groundwater, but this option would not characterize the horizontal extent of affected groundwater or substance migration to surface waters or sediments.

Under option 3, additional wells south, east, and north of the sites would characterize groundwater flow conditions over a larger area, identify additional sources, and confirm the extent and magnitude of substances in groundwater. Wells would be installed near the base boundary. Off-base investigations would not be required at this stage.

5.2.4.2 Surface Water Monitoring Options

Surface water samples were not collected during Stage 1 from the small drainage ditch west of Site D-4. Surface waters in the ditch may be affected by groundwater discharging to the ditch. Options for investigating surface waters west of the Receiver Station Sites include:

1. Not conducting additional monitoring.
2. Monitoring at selected locations in the ditch.

Under option 1, samples would not be collected from the drainage ditch. Without this data, identifying the affect of groundwater discharge to the ditch would not be possible. The potential for migration of substances to surface waters exists, therefore, samples should be collected.

Option 2 would confirm if substances are entering surface waters. Results would be combined with groundwater monitoring data to characterize groundwater discharge to surface waters. Because the route of migration to surface water is via groundwater, surface water samples should be analyzed for the same parameters as groundwater.

5.2.4.3 Sediment Monitoring Options

Sediments at the Receiver Station Sites were not sampled during Stage 1. Sediments may be affected by groundwater discharging to the ditch. Options for investigating sediments include:

1. Not collecting sediment samples.
2. Collecting sediment samples at the surface water sampling locations in the drainage ditch.

Samples would not be collected under an option 1 program, so determining the effects on sedments of groundwater discharging to the stream would not be possible.

Under option 2, sediment samples would be collected at surface water sampling locations in the drainage ditch to characterize sediment chemical quality. Because of the possible route of substance migration, sediment samples collected under option 2 would be analyzed for the same substances found in groundwater.

5.2.4.4 Sample Analysis Options

Alternatives for analyses to be conducted during Stage 2 at the Receiver Station Sites include the following:

1. Analyzing for certain Stage 1 parameters found at elevated concentrations during Stage 1, these include VOCs, oil and grease, and heavy metals.

2. Analyzing for all Stage 1 parameters, these include VOCs, cyanides, phenols, oil and grease, arsenic, heavy metals, TOX, and TOC.

3. Analyzing wells with the highest VOC concentrations for priority pollutant organics. Compounds detected would be added to those listed in option 1 above to determine the analysis suite for the Stage 2 monitoring program.

4. Conducting analysis for all priority pollutants, plus oil and grease.

Additional monitoring using the analysis sets in options 1 and 2 would not identify or characterize other organics that may be present. Under option 3, the range of organics would potentially be characterized so that all organics present at D-4 could be included in the analysis suite. Complete characterization of organics and metals in the environment at the Receiver Station Sites would be obtained using option 4 analyses.

5.2.5 Site FT-3, Fire Training Area 3

Groundwater upgradient and downgradient of Site FT-3 contained elevated levels of nickel and TOX. Only groundwater downgradient of the site contained elevated levels of TOC. Surface waters upstream contained elevated levels of zinc and TOC. Surface waters downstream contained elevated levels of only TOC. Sediments contained elevated concentrations of arsenic, cadmium, copper, iron, nickel, lead, zinc, and oil and grease. Sediments downstream of FT-3 generally contained greater concentrations than those found in the upstream sample. Based on the Stage 1 findings, the following information should be obtained to fully characterize the extent and magnitude of substances in the environment at Site FT-3.

1. Characterization of the types of substances in groundwater.

2. Identification of the sources of the substances found in sediments.

3. Identification and characterization of other sources (e.g., runway runoff).

4. Determination of the presence or absence of VOCs or fuels at the site.

Monitoring options presented below are evaluated to determine suitability for obtaining the required information.

5.2.5.1 Groundwater Monitoring Options

Groundwater at Site FT-3 contained elevated levels of nickel, TOC, and TOX. Organic compounds may be present based on the elevated indicator parameters. VOCs were not included in Stage 1 analysis. Options for investigating groundwater at Site FT-3 include:

1. Not conducting additional monitoring.
2. Monitoring for additional compounds using the existing wells.
3. Monitoring using existing and newly installed wells.

Levels of TOC found at the site cannot be solely attributed to activities at Site FT-3. The levels present in upgradient wells suggest that runway runoff may be a source. This conclusion supports the no further monitoring option. However, the absence of VOC data and the elevated TOC levels downgradient of Site FT-3 argue against option 1.

Option 2 would be implemented using compound-specific scans for VOCs or fuels in samples taken from the existing wells. Results may indicate that JP-4 or fire-fighting agents used in fire training are present in groundwater. Because compound-specific scans are more sensitive than indicator parameters like oil and grease, TOX, and TOC, concentration variations between wells 18, 19, and 20 would potentially indicate if FT-3 is the source of substances in groundwater. Implementation of option 2 would help identify the type and sources of substances at Site FT-3.

Under option 3, additional wells would be located upgradient and downgradient of Site FT-3 to identify other sources. The advantage of option 3 over option 2 is that new wells could be selectively placed to confirm runway runoff or fire training activities as sources.

5.2.5.2 Surface Water Monitoring

Surface waters at Site FT-3 contained elevated levels of zinc and TOC. VOCs were not included in the Stage 1 analysis. Options for investigating surface waters at Site FT 3 include:

1. Not conducting additional monitoring.

2. Monitoring at selected locations in the wetlands adjacent to the site.

The Stage 1 results did not identify the source of the TOC or zinc in surface waters. Because VOCs were not included in the Stage 1 analysis, the sources of zinc and TOC and the presence of any VOCs cannot be characterized. Fuel may be present in surface waters, but such a determination cannot be made until compound-specific analyses are conducted. An expanded monitoring program could confirm the presence or absence of VOCs in surface waters and this data could be used to identify sources. In addition, surface water monitoring in conjunction with groundwater monitoring could assist in characterizing the movement of substances between surface water and groundwater.

5.2.5.3 Sediment/Soil Monitoring Options

Sediments in the streams adjacent to Site FT-3 contained elevated levels of oil and grease, arsenic, cadmium, copper, iron, nickel, lead, and zinc. TOX concentrations indicated the presence of halogenated organic compounds. Samples were not collected from the soils within the burn area. The sources of the elevated concentrations in sediments have not been determined, but the generally higher levels downstream of FT-3 indicate that FT-3 may be a source. Options for investigating sediments at FT-3 include:

1. Not conducting additional monitoring.
2. Collecting composite surface or deep sediment samples or both to indicate average sediment quality.
3. Collecting composite surface or deep soil samples or both from the burn pit area.
4. Both options 3 and 4 above.

Under option 1, the existing data would be used to estimate the extent of substances in sediments, but the sources would not be identified. Additional monitoring may not be necessary at Site FT-3 because surface waters did not contain as many elevated concentrations as the sediments, indicating that compounds are tied up in sediments and not migrating from the site. However, migration is possible during periods of high flow when stream capacity and competence increase and sediments move as suspended solids.

Option 2 may be necessary to characterize the depth of the affected sediments and identify the sources of the substances. Option 2 results would be used to calculate the quantities of substances present and the extent of any remediation activities required. Composite samples could be collected from the stream at several locations in both branches to indicate average surface sediment quality. Samples at several depths could be collected at several Stage 1 locations to indicate the concentrations of substances at depth.

The burn pit at Site FT-3 is probably contaminated based on physical observation. Identification of the chemical quality of the soils would aid in characterizing the affect of FT-3 on groundwater and sediment quality. Composite samples taken from the burn pit during Stage 2 would characterize substances present in the soils that could enter groundwater, surface waters, and sediments.

5.2.5.4 Sample Analysis Options

Alternatives for analysis to be conducted during additional investigations at Site FT-3 include the following:

1. Analyzing for certain parameters found at elevated levels during Stage 1, these include oil and grease, arsenic, and heavy metals; plus analyzing for VOCs.

2. Analyzing for all of the Stage 1 parameters, these include those listed in option 1 above, plus TOX and TOC.

3. Analyzing samples collected from several wells and at surface water and sediment monitoring stations for priority pollutant organics plus petroleum hydrocarbons. Compounds found would be added to those listed in option 1 above to determine the analysis suite for the Stage 2 monitoring program.

4. Analyzing for all priority pollutants and oil and grease.

The presence of VOCs or fuels would not be determined with either options 1 or 2, although oil and grease could be used as an indication of fuels. Monitoring using options 3 and 4 would identify and characterize substances known to be present and determine if organics are present. Option 3 would be less expensive than 4 because the assumption of 3 is that the presence of

fuels and other organics can be determined from a few selected samples. If option 3 is selected, initial samples should be collected from wells 18 and 20, at surface water and sediment points w12/d10, and w13/d11, and at two locations in the burn pit.

5.2.6 Site SP-4, JP-4 Pipeline Leak

Groundwater at Site SP-4 contained elevated levels of TOC, indicating the possible presence of fuels. The site is near the estimated position of a groundwater divide.

5.2.6.1 Groundwater Monitoring Options

Options for investigating groundwater at Site SP-4 include:

1. Not conducting additional monitoring.
2. Monitoring using existing wells.
3. Monitoring using additional and existing wells.

Fuel operations or the pipeline leak are suspected of being the source of the elevated concentrations of TOC. Option 1 would not identify either the organic compounds present in groundwater or the extent of fuels in groundwater. The option 2 program might not generate the required data, because the existing well points may not be installed directly downgradient of SP-4 and may not be screened at the optimum level. Option 3 is probably required because it would best characterize any fuels in groundwater in the area.

5.2.6.2 Sample Analysis Options

Fuels are the only suspected substances at the site. The alternatives for analysis to be conducted during additional monitoring at this site are as follows:

1. Analyzing for Stage 1 indicator parameters.
2. Analyzing for specific compounds to identify the petroleum hydrocarbons in groundwater.
3. Analyzing with priority pollutant scans on all samples to completely characterize groundwater quality.

Because indicator parameters have high detection limits and are not compound specific, low levels of fuels may not be detected using only the Stage 1 parameters. Compound-specific scans might detect specific components of petroleum hydrocarbons at lower concentrations. However, these analyses are usually more expensive than analyses for only indicator parameters. Full priority pollutant scans are probably not warranted because fuels are the only suspected contaminant.

5.2.7 Site S-1, Hazardous Waste Storage Area

Groundwater at Site S-1 contained elevated concentrations of VOCs, chromium, copper, nickel, lead, zinc, TOX, and TOC. All wells in the area contained VOCs and elevated concentrations of metals. Soils at the site contained elevated levels of oil and grease, arsenic, cadmium, copper, nickel, lead, zinc. Soils also contained VOCs, cyanide, phenols, and the PCB Arochlor 1260 (in one sample). Surface waters were not sampled during Stage 1, but possibly may be affected by runoff from the S-1 area.

Based on Stage 1 findings, the following information should be obtained to characterize the extent and magnitude of substances in the environment at Site S-1.

1. Characterization of the extent of affected groundwater around the site.
2. Determination of the effect on groundwater by other sources.
3. Identification of effects on surface water.
4. Characterization of the extent and magnitude of substances in soils.

The monitoring options discussed below are evaluated as to their suitability for obtaining required data.

5.2.7.1 Groundwater Monitoring Options

Groundwater at this site contained elevated concentrations of VOCs, chromium, copper, nickel, lead, zinc, TOX, and TOC. A second source east to

north of the site is suspected. Options for investigating groundwater at Site S-1 include:

1. Not conducting additional monitoring.
2. Monitoring using existing wells.
3. Monitoring using the existing wells plus newly installed wells.

The extent and magnitude of substances in groundwater would not be determined under either options 1 or 2. The results to date and any additional analysis results from the same locations would only provide information on the area immediately around the site. Calculations would be required to estimate the extent of affected groundwater and assumptions associated with the calculations would make the conclusions little more than rough estimates. The locations of any additional sources would also not be determined under options 1 or 2. Option 3 would potentially identify sources around Site S-1 and could indicate if VOCs present in groundwater at Site S-1 are the source of VOCs in the Green House well south of Site S-1. Under option 3, additional wells should be installed north, east and southeast to southwest of the site.

5.2.7.2 Surface Water Monitoring Options

Samples were not collected during Stage 1 from the surface water drainage ditch adjacent to the site on the southwest. Surface waters could be affected by runoff from Site S-1 or discharge of affected groundwater. Options for investigating surface waters at Site S-1 include:

1. Not conducting additional monitoring.
2. Monitoring at selected locations.

An investigation may not be required because any substances migrating from Site S-1 to surface waters by overland flow or discharge of groundwater may be diluted below detection limits. A few select samples collected from the surface waters would potentially confirm if substances are present and if they are attributable to Site S-1. If option 2 is implemented, two samples from the drainage ditch southeast of Site S-1 should be sufficient to characterize surface water quality.

5.2.7.3 Soil/Sediment Monitoring Options

Soils around Site S-1 contained elevated concentrations of arsenic, cadmium, copper, nickel, lead, zinc, and oil and grease. Soils also contained VOCs, cyanide, phenols and the PCB Arochlor 1260 (in one sample). Soils were probably affected by spills from Site S-1, while sediments in the drainage ditch may have been affected by runoff from Site S-1 and other sources or via groundwater discharge to the ditch. Compared to the other soil samples, the one sample of sediments from the ditch (i.e., d16) showed lower levels for 11 of the 16 Stage 1 compounds. Options for investigating soils at Site S-1 include:

1. Not conducting additional monitoring.
2. Monitoring only at locations where spills are visually evident.
3. Monitoring using a grid (triangular) pattern, compositing samples to indicate average soil and sediment chemistry and collecting samples at depth to characterize the downward migration of substances.

The presence of metals, VOCs, and a PCB in the soils indicates contamination by spills or runoff at Site S-1. The extent of these substances in soil, especially in the case of PCBs, should be identified to determine if remedial measures should be taken. Option 1 would not provide the additional information necessary to determine if affected soils are widespread or if substances are migrating toward the water table.

Option 2 would potentially characterize the effects of spills, while option 3 would potentially characterize average soil and sediment quality. A combination of options 2 and 3 would characterize both average soil and sediment quality and also the concentrations of substances at spill sites.

As an alternative to option 2, visually identified spill areas could be removed and drummed for disposal. The cost of removal and disposal may be less than the cost to sample the spills. However, analysis would still be required to characterize the excavated soils prior to acceptance for disposal and to determine if all contaminated soils at the site have been removed.

5.2.7.4 Sample Analysis Options

Alternatives for analysis to be conducted during additional monitoring at this site include the following:

1. Analyzing for certain parameters detected during Stage 1, these include VOCs, oil and grease, cyanide, phenols, PCBs, arsenic, and heavy metals.

2. Analyzing for all of the Stage 1 parameters, these include those listed in option 1 above plus TOX and TOC.

3. Analyzing samples from wells 25 and 27 and from several surface water and sediment locations for priority pollutant organics. Compounds found would be added to those listed in option 1 to determine the analysis suite for the monitoring program.

4. Analyzing for all priority pollutants on all samples.

A monitoring program implemented using the analysis described under options 1 and 2 would not sufficiently identify or characterize other organic compounds that may be present. Under option 3, the priority pollutant organic scans might characterize the range of organic compounds in groundwater, surface waters, soils, and sediments. These, plus the Stage 1 parameters already confirmed as present, would make up the suite of analyses for use during additional monitoring. The assumption associated with option 3 is that the range of compounds present can be determined from a few samples. The assumption does not apply to option 4, but option 4 would cost more than option 3.

5.2.8 Site XYZ, Fuel Pump Station

Groundwater at the site to contained elevated concentrations of oil and grease and TOC, indicating the presence of fuels. Samples of soils in manholes in the area contained oil and grease. A surface water sample taken from a manhole in the area did not contain oil and grease and was apparently free of contamination.

Site XYZ is located along an assumed groundwater divide. Based on Stage 1 data, groundwater flow directions appear to be toward the southwest. Wells northeast of the site had the highest levels of compounds, possibly indicating

substance migration to the northeast. This could occur if groundwater flow directions shift across this area as recharge conditions change. The hydraulic connection between the borrow pit lake and groundwater is also not known. Groundwater may be discharging to the lake, to the small drainage ditch parallel to the runway and flowing towards Site DD-1, or flowing towards the St. Jones River.

Based on Stage 1 findings, the following information should be obtained to characterize the extent and magnitude of fuels in groundwater at Site XYZ:

1. Determination of the extent and magnitude of affected groundwater, and the direction and rate of groundwater flow.
2. Characterization of the effect of th borrow pit lake on groundwater flow patterns.
3. Evaluation of the impact of affected groundwater on surface waters and sediments.

Monitoring options presented below are evaluated to determine suitability for obtaining the required information.

5.2.8.1 Groundwater Monitoring Options

Options for investigating groundwater at XYZ include:

1. Not conducting additional monitoring.
2. Monitoring using existing wells.
3. Monitoring using existing and newly installed wells.

Option 1 would not characterize the direction of groundwater flow, the location and behavior of the groundwater divide, or the extent of affected groundwater in the area. Option 2 would potentially characterize the type and concentration of fuels in groundwater, but would not generate data on direction of flow and extent of substances. Under option 3, additional monitoring wells surrounding the site would help characterize the direction of groundwater flow, identify the location of the groundwater divide, and confirm the extent of affected groundwater.

5.2.8.2 Surface Water Monitoring Options

Surface waters at the site include the borrow pit lake, waters in the small drainage ditch parallel to the aircraft parking area, and waters within the manholes at the site. Options for investigating surface waters at the XYZ site include:

1. Not conducting additional monitoring at any location.
2. Monitoring of the borrow pit lake.
3. Monitoring of the drainage ditch.
4. Monitoring of the manholes.

Under option 1, samples would not be collected at any surface water site. Additional sampling may not be necessary because: 1) waters in the manhole were tested during Stage 1 and found to be free of contamination, 2) DAFB has sampled the borrow pit lake and not found any contamination, and 3) the small drainage ditch only contains water during periods of rainfall, which would be representative of runoff from the runways. Sampling of this drainage ditch could possibly be conducted as part of Stage 2 activities at Site DD-1.

Options 2, 3, and 4 could confirm whether fuels are present in surface waters. Results from surface water samples could be compared with groundwater results to evaluate substance migration between the two media.

5.2.8.3 Soil/Sediment Monitoring Options

Sediment samples were collected during Stage 1 from two manholes. Reports indicated that fuels in groundwater periodically appear in the manholes. Sediment sampling results indicated elevated levels of oil and grease, indicating the presence of fuels, but the source of these elevated levels could be runoff from aircraft parking areas. Sediments in the borrow pit lake and the small drainage ditch were not sampled during Stage 1. Options for investigating sediments at Site XYZ include:

1. Not conducting additional monitoring.
2. Monitoring sediment quality at the location of any surface water sampling point.

The route of substance migration to sediments is via surface waters or by groundwater discharge. DAFB has already sampled the surface waters in the borrow pit and not detected fuels. This data could be used to conclude that substances are not migrating via the surface water route because surface waters are free of substances. However, this may not be true based on the elevated levels of oil and grease found during Stage 1 at Site DD-1. If surface water sampling is conducted, sediment samples should also be collected at the same locations to provide data that could be used to characterize the migration of substances between groundwater, surface water, and sediments.

5.2.8.4 Sample Analysis Options

Fuels are the only suspected contaminants at the site. Alternatives for analysis to be conducted during additional monitoring at this site are as follows:

1. Analyzing for the Stage 1 indicator parameters.
2. Analyzing for petroleum hydrocarbons and volatile aromatics to identify fuels in samples.
3. Analyzing with priority pollutant scans on all samples.

Low levels of fuels may not be detected when analyzing indicator parameters because of the higher detection limits for these tests. Analyzing for petroleum hydrocarbons and volatile aromatics should detect lower concentrations of fuels because of the lower detection limits and identify specific compounds. However, compound-specific tests are more expensive than tests for only indicator parameters. Full priority pollutant scans are probably not warranted because fuels are the only suspected contaminants.

5.2.9 Site D-2, Rubble Area

Soils around Site D-2 contained elevated concentrations of oil and grease, arsenic, iron, nickel, lead, and zinc. TOX levels indicated the presence of halogenated organic compounds. Analysis for VOCs was not performed and groundwater was not monitored during Stage 1. Streams, wetlands, and drainage ditches are not located adjacent to this site. Substances in soils are likely the result of runoff from the rubble area. Precipitation

percolating through the waste could transport substances to groundwater. Based on Stage 1 findings, the following information should be obtained to characterize the extent and magnitude of substances in the environment at Site D-2:

1. Determination of the impact of the site on groundwater quality.
2. Characterization of the extent and magnitude of substances in soil around the landfill.

Monitoring options presented below are evaluated to determine suitability for obtaining the required information.

5.2.9.1 Groundwater Monitoring Options

There are two groundwater monitoring options available at this site:

1. Not conducting a groundwater investigation.
2. Installing and sampling monitoring wells around the site.

If an investigation is not conducted, oil and greases and metals in the soils are assumed to be immobile, and wastes containing VOCs or other organics are assumed not to be present at this site. Stage 1 results at other sites indicate that substances are being concentrated in soils, but have migrated through soils to groundwater. TOX values in soils indicated that halogenated organic compounds might be present at Site D-2. The effect of this sit on groundwater would not be determined under option 1, but groundwater quality would be characterized under option 2. Therefore, option 2 is probably required.

If groundwater monitoring is implemented at this site, wells should surround the site because the actual direction of groundwater flow in this area is not known but assumed to correspond with local trends.

5.2.9.2 Soil Monitoring Options

Soils around the north and southeastern perimeter of Site D-2 contained elevated concentrations of oil and grease, arsenic, iron, nickel, lead, zinc,

and possibly halogenated organic compounds. Options for Stage 2 monitoring include:

1. Not conducting additional monitoring.
2. Collecting additional surface soil samples to characterize soil chemistry.
3. Collecting soil samples at various depths at selected locations to determine the depth of substance migration.

The eight soil samples collected during Stage 1 were mainly located on the eastern boundary of the site, therefore, characterization of soil quality north and west of the site could better identify the types of substances present. Option 1 would not provide data on soil quality north and west of this site.

Under options 2 and 3, samples would be collected north and west of the site and would help characterize the extent of substances in soils. Soil sample collection at various depths would characterize the depth and rate of substance migration through the soils. Composite samples could also be collected north and west of the site. If option 3 is implemented, locations for sample collection could be selected based on Stage 1 results.

5.2.9.3 Sample Analysis Options

Alternatives for analysis to be conducted during additional monitoring at this site are as follows:

1. Analyzing for those Stage 1 parameters found at elevated concentrations, these include oil and grease, arsenic, and heavy metals.
2. Analyzing for all of the Stage 1 parameters, these include those listed in option 1 above plus TOX and TOC.
3. Analyzing samples from selected locations for priority pollutant organics. Compounds found would be added to those listed in option 1 above to determine the analysis suite for the monitoring program. Analysis for VOCs would also be included.
4. Analyzing for all priority pollutants.

A monitoring program using the analysis described in options 1 and 2 would not identify or characterize other organic compounds that may be present. Organics are not known to have been disposed of at this site, but were found at the four locations on base where sampling for organics was conducted and TOX levels indicated that halogenated organic compounds may be present. Under option 3, priority pollutant organic scans conducted on selected soil samples would help characterize the type of organic compounds that are present. The initial sampling under option 3 would indicate if any other organics need to be added to the VOC scans that would be conducted. The assumption associated with option 3 is that the range of organics present at this site can be determined from a select few soil samples. This assumption is not associated with option 4 and option 4 would be more expensive than option 3.

If option 3 is implemented, VOCs should probably be included in analysis even if organics are not initially found in soils. If VOCs are found in groundwater, priority pollutant organic scans of selected samples may be necessary to fully characterize the range of organics present in groundwater.

6.0 RECOMMENDATIONS

The objective of the Phase II Stage 1 study at DAFB was to identify environmental contamination resulting from waste disposal practices, fuel spills, or fire training activities. Phase II Stage 1 results indicated that concentrations of Stage 1 analytical parameters above health standards or criteria or background levels were present at all 11 sites.

These findings, which were discussed in detail in Section 4, indicate the need for additional investigations. Various alternative study approaches were discussed in Section 5. This section recommended an approach for Phase II Stage 2 investigations at DAFB.

Section 6 is organized as follows:

1. Section 6.1 categorizes sites according to those not requiring any additional work (Category 1) and those requiring additional investigations (Category 2). Sites at DAFB cannot be classified in Category 3, remedial measures, although steps that can be taken to mitigate the possible environmental impacts at each site are identified.

2. Section 6.2 provides site-specific recommendations for additional investigations.

3. Section 6.3 integrates the site-specific approaches into a Stage 2 investigation program.

Important points discussed in this section include the following:

1. Immediate remedial measures can be implemented at Sites T-1, S-1, FT-3, and D-2 to limit the migration of substances.

2. The recommended approach for Stage 2 consists of three discrete steps.

   - Step 1, will be to conduct soil gas investigations to estimate the extent of VOCs in groundwater. Samples also will be collected at selected wells, surface water, and soil and sediment points to indicate the range of organic compounds that are present in groundwater, surface waters, soils, and sediments.

- Step 2 will be the installtion of additional monitoring wells and sampling of both new and old wells to provide an estimate of the areal extent of substances in groundwater. In addition, comprehensive sampling programs will be implemented to identify the extent and magnitude of substances in surface waters, sediments, and soils. Aquifer tests will be conducted to characterize the Columbia and Frederica aquifers.

- Step 3 will be to collect samples from discrete intervals in the aquifer at wells with high concentrations of VOCs to identify vertical variations in water quality.

3. As part of Step 2, groundwater, soil and surface water samples from the area between the runways will be collected to characterize the impact of runway and aircraft operations on the levels of VOCs, petroleum hydrocarbons, cyanides, phenols, oil and grease, and metals. In addition, surface water elevation measuring points will be established to help identify the surface water/groundwater relationship at several sites.

4. The estimated duration of Stage 2, from the commencement of Step 1 to the submittal of the draft report, is approximately 66 weeks (16 months).

6.1 SITE CATEGORIZATION AND PRIORITIZATION

The categorization and prioritization of the Stage 1 study sites provided below are based on Stage 1 results and findings.

6.1.1 Categorization

Phase II Stage 1 study sites fall into either Category 1 (i.e., no additional monitoring or remedial action required) or Category 2 (i.e., additional investigation activities warranted). Sufficient information is not available to classify any site as Category 3 (i.e., ready for remedial actions), although remedial activities to partially mitigate environmental impacts can be recommended.

There are two sites at DAFB that fall into Category 1. These are:

1. Site FT-1, Fire Training Area 1. Groundwater and surface waters downgradient of this site were found not to be contaminated.

2. Site FT-2, Fire Training Area 2. This site was reportedly used for a very short period of time in the late 1950s. The area is now covered by a parking lot and buildings. Personnel who worked in the area during the 1950s stated that fire training did not occur in the area. The short time period during which the site may have been in operation, the types of operations conducted, and the existing conditions that minimize infiltration of precipitation rule out unacceptable health or environmental risks (Section 1.5).

Additional action is not required at either of these sites.

There are 10 sites at DAFB that fall into Category 2. These are (in order of priority as will be discussed in Section 6.1.2):

1. The IW Basin Area Sites: Site T-1, IW Basins and SP-9, Motor Pool Spill. Sampled media at Site T-1 contained VOCs, metals, oil and grease, and phenols, with TOC and TOX levels above background. The motor pool area was determined to be a possible source of the VOCs detected in off-base wells.

2. Site S-1, Hazardous Waste Storage. Groundwater contained VOCs and metals, with TOC and TOX levels above background. Soils contained VOCs, metals, and the PCB Arochlor 1260 (in one sample).

3. The Receiver Station Sites: Site D-4, Liquid Waste Disposal and Site D-5, Landfill. Groundwater contained VOCs, metals, and oil and grease, with TOC and TOX levels above background. Local groundwater hydraulic gradients are slight, but regional flow is towards the Pipe Elm Branch wetland areas.

4. Site D-10, Landfill. Groundwater contained metals, with TOC and TOX levels above background and DAFB personnel reported finding VOCs in wells. Groundwater is moving towards the St. Jones River. The site does not appear to be the cause of the Green House well problem. An upgradient source affecting groundwater quality in this area is possible.

5. Site DD-1, North Ditch. Sediments at this site contained metals, oil and grease, cyanide, and phenols. The surface waters also contained nickel, with TOC and TOX levels above background. Migration to groundwater is possible.

6. Site XYZ, Fuel Pump Station. Groundwater probably contains fuels, based on the levels of TOC and oil and grease found in the media. The direction of groundwater flow in the area is uncertain.

7. Site D-2, Rubble Area. Soils contained metals and oil and grease. Migration to groundwater is possible at this site.

8. Site FT-3, Fire Training Area 3. Groundwater at FT-3 contained nickel, with levels of TOC and TOX above background. Surface waters contained zinc, with levels of TOC above background. Sediments contained metals and oil and grease. Substances in groundwater may be from a source upgradient of FT-3, which is suggested by concentrations found in the upgradient sample.

9. Site SP-4, JP-4 Pipeline Leak. Groundwater at SP-4 contained oil and grease, and TOC levels above background. This may indicate the presence of fuels in groundwater. However, results were not conclusive and the sources have not been identified.

6.1.2 Site Prioritization

Based on Phase II Stage 1 findings, the sites have been prioritized as follows:

1. Site T-1 appears to have affected groundwater and both Sites T-1 and SP-9, the motor pool spill, are suspected sources of VOCs in the drinking water wells off-base. For these reasons, this area was ranked as the highest priority.

2. Site S-1 was given a high priority because of the VOCs, PCBs, and metals present. The site may be upgradient of the Green House well.

3. Receiver Station Sites (D-4 and D-5) were rated as a high priority because of VOCs present in groundwater.

4. Site D-10 was given a high priority because of the size of the site, the metals found in groundwater, and the reports that VOCs were found in groundwater.

5. Site DD-1 was given a high priority because of the concentrations of metals and oil and grease in sediments, the potential for migration to groundwater, and the size of the site.

6. Site XYZ was given a moderate priority because fuels are thought to be present in groundwater, based on oil and grease concentrations.

7. Site D-2 was given a moderate priority because of the size of the site, the concentrations of metals and oil and grease found in soils, and the potential for migration to groundwater.

8. Site FT-3 was assigned a low priority because groundwater contained only nickel, with TOC and TOX levels above background. VOCs were not confirmed in groundwater. Surface waters contained only zinc, with TOC levels above background. The substances found in sediments at the site may be immobilized.

9. Site SP-4 received the lowest priority ranking because of the nature of the site (i.e., a leak that has been stopped), the length of time

since the incident (i.e., 9 years), and the relatively low levels of indicator parameters found, which could be caused by runway runoff. The large distance between the site and any receptor reduces the potential for risk to human health or the environment.

Even though Sites FT-3 and SP-4 are the lowest priorities, additional investigations at these sites are recommended because the source of metals and oil and grease in sediments at FT-3 is not known and the possibility that well points at Site SP-4 may not be screened in the most appropriate zone.

6.2 RECOMMENDATIONS FOR REMEDIAL ACTIONS (PARTIAL IRP PHASE IV)

The complete extent and magnitude of contamination has not been determined for any of the Stage 1 sites; thus no complete site can be recommended for Phase IV remedial activities. However, sufficient evidence is available to recommend partial remedial actions at several sites. These actions should limit the continued migration of substances to the environment, reducing or halting the ongoing escalation of the contaminant problems and ultimate clean-up requirements at these sites. The recommended measures include:

1. Implementing the IW Basin bypass and closure plan to reduce continued migration of substances to groundwater.

2. Installing a berm around the storage pads at Site S-1 and improving drainage. Runoff can be directed into an oil and water separator to reduce the amount of oil and grease flowing to surface waters and soils.

3. Sealing the pads at Site S-1 with a low permeability top coat to reduce infiltration of spilled substances to groundwater.

4. As an alternative to #2 and #3 above, storing drums inside the storage buildings at S-1 so that spills can be contained and runoff does not carry substances to surface waters or soils.

5. Constructing a low permeability pad under Site FT-3 to minimize the possible migration of fuels to groundwater. A concrete pad covered by several inches of gravel, constructed to promote drainage to a central drain, would prevent migration of residual fuels to groundwater. The drain would channel residuals through an oil and water separator before discharge to surface waters. The gravel layer would protect the pipes used to spray the JP-4 during fire training and would provide a firm footing for personnel entering the pit during exercises.

6. Covering the rubble area at Site D-2 with clean fill, graded and compacted, to promote runoff and reduce infiltration. A new area could be set aside for the disposal of construction debris at this site.

These activities can be implemented without affecting the recommended Stage 2 investigations and will minimize further migration of substances to the environment.

6.3 SUMMARY OF RECOMMENDED STAGE 2 MONITORING PROGRAM

The recommended Stage 2 monitoring program is structured to obtain data necessary to define the extent and magnitude of substances migrating from study sites. The approach will also provide data on the rate and direction of substance migration.

The Stage 2 program is designed to be implemented in three steps:

1. Step 1 will include:
   - Implementing a soil gas analysis investigation at all sites
   - Sampling selected Stage 1 wells to positively confirm the identity of organic compounds and fuels present in groundwater
   - Sampling soils, sediments, or surface waters at selected points to identify organic compounds and fuels present
   - Evaluating data to finalize Step 2.
2. Step 2 will include:
   - Installing 86 new monitoring wells
   - Sampling all 130 monitoring wells
   - Surveying wells and surface water elevation measuring points
   - Collecting soil, sediment, and surface water samples
   - Conducting tests to determine the hydrogeologic properties of the Columbia and Frederica aquifers
   - Evaluating data to determine the extent and magnitude of substances detected in groundwater, surface waters, soils, and sediments.

3. Step 3 will include:

   - Collecting samples at various depths in selected wells to define vertical variations in VOC concentrations.
   - If needed, installing and sampling any additional monitoring wells.
   - If needed, sampling soils, sediments or surface waters at selected points to positively confirm the identity of organic compounds.

Descriptions of the activities to be conducted at each site under this program are provided in Section 6.3.1. Summaries of the specific activities to be conducted in each step are provided in Section 6.3.2. An estimated schedule for the Stage 2 program is provided in Section 6.3.3.

6.3.1 Site-Specific Monitoring Approaches

Alternatives for site-specific monitoring approaches have been discussed in Section 5. Details of recommended approaches are provided below.

6.3.1.1 The IW Basin Area Sites: Site T-1 and Motor Pool Area

Figure 6-1 illustrates recommended Stage 2 monitoring well and soil gas transect locations at the IW Basin Area Sites. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 175 sampling points) throughout the area and extending across Route 113 into the trailer park area.
2. Sampling wells 103, 01j and DNREC wells S4a and S4b to positively confirm the identities of priority pollutant organics and petroleum hydrocarbons.

Information resulting from these activities will be used to place monitoring wells and to select parameters for analysis during Step 2. This step will include the following activities:

1. Installing 18 Columbia aquifer wells (C wells) around the area. Wells will be 4 inches in diameter, schedule 40, threaded, flush joint PVC, and will be completed to the Kirkwood (Miocene) silty-clay. Stage 1 installation procedures will be followed (Section 3). Well locations shown on Figure 6-1 are approximate. The exact positions and number of wells will be selected based on soil gas investigation results.

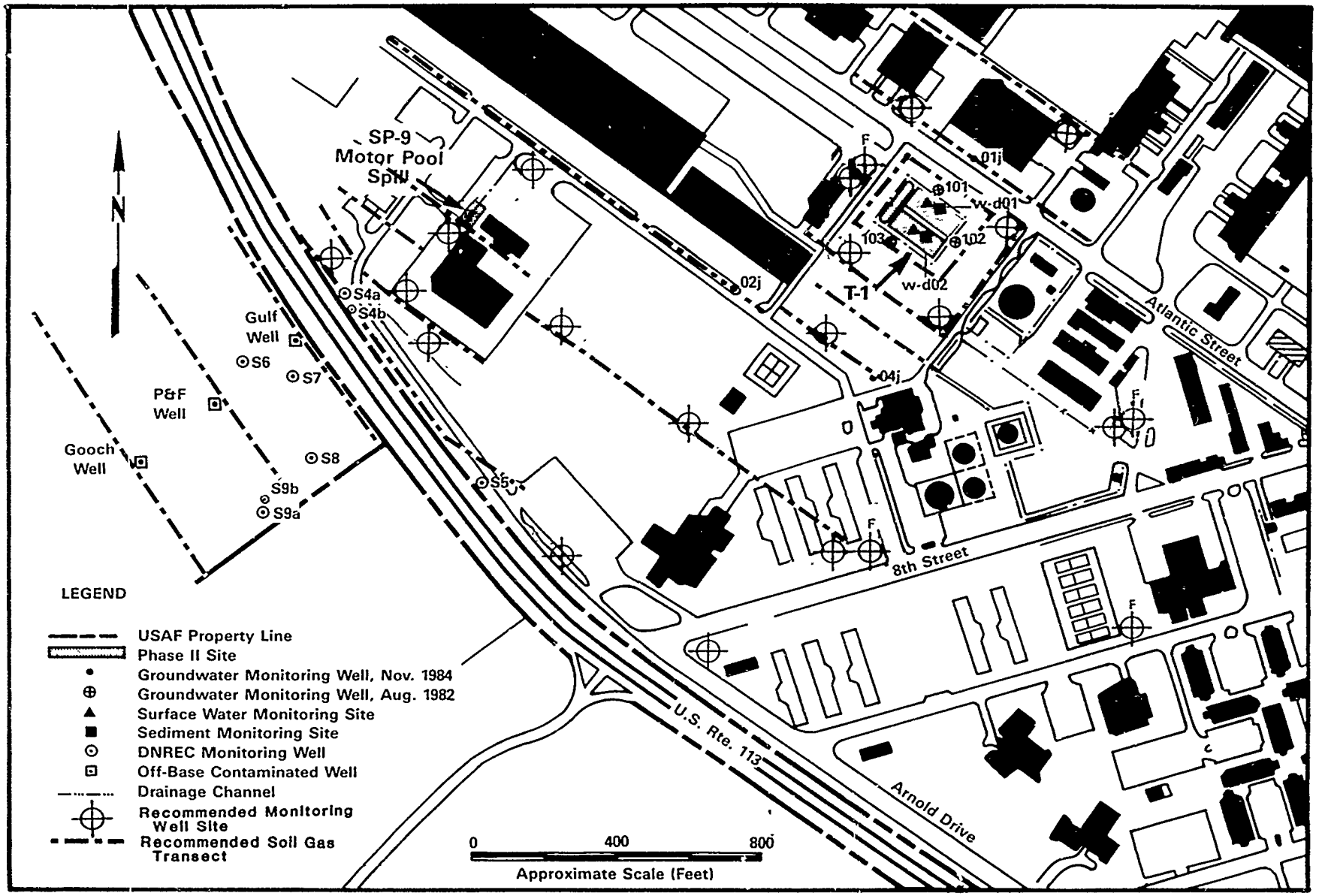


Figure 6-1. Recommended Monitoring Well and Soil Gas Transect Locations, Site T-1 Area

2. Installing four Frederica aquifer wells (F wells) around the basin, with three installed and surveyed to indicate direction of flow in the Frederica and a fourth installed downgradient of the basins.

3. Sampling all wells (including DNREC wells) for phenols, VOCs, petroleum hydrocarbons, arsenic, and heavy metals. Tests for other organics may be required depending on the results from Step 1.

4. Surveying all wells (including DNREC wells) to establish vertical and horizontal control.

5. Conducting pump tests on a selected F well and C well.

The Step 2 program should confirm the areal extent of affected groundwater.

Step 3 will include sampling at three depths within the Columbia aquifer at an estimated five wells (15 discrete samples) to identify vertical variations in VOC concentrations. Analysis may include other parameters based on Step results.

The recommended Stage 2 program should identify:

1. The source (i.e., the IW Basins or some upgradient source not identified) of VOCs in well 01j.

2. The vertical and horizontal extent of groundwater containing VOCs and elevated concentrations of metals.

3. The effects on groundwater quality caused by activities conducted in the Motor Pool area.

4. The DAFB contribution to the VOCs found in the off-base wells.

5. Columbia and Frederica aquifer properties that affect groundwater movement.

6.3.1.2 Site S-1, Hazardous Waste Storage Area

Figure 6-2 illustrates the recommended Stage 2 monitoring well and soil gas transect locations at Site S-1. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 125 sampling points) around the site.

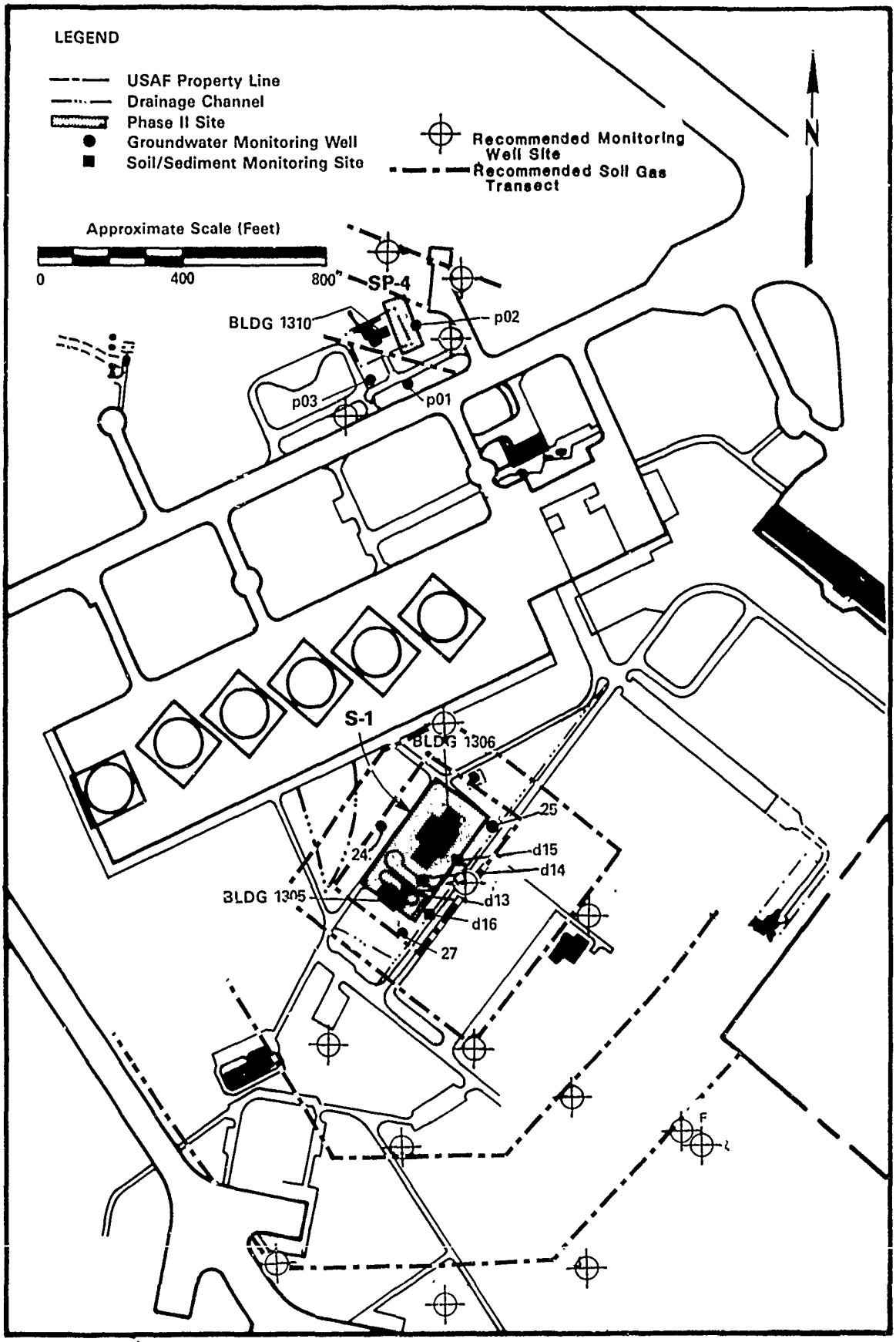


Figure 6-2. Recommended Monitoring Well and Soil Gas Transect Locations, Site S-1 Area

2. Sampling wells 25 and 27 to positively confirm the identities of priority pollutant organics.

3. Collecting one surface water sample, one sediment sample, and one soil sample for priority pollutant organics analysis.

Information resulting from this step will be used to place monitoring wells and select parameters for analysis during Step 2.

Step 2 at this site will include:

1. Installing 11 C wells. Well locations shown in Figure 6-2 are approximate. The exact positions and number of wells will be selected based on soil gas investigation results.

2. Installing an F well southeast of the site.

3. Sampling all wells (14 C wells, 1 F well).

4. Collecting composite soil samples using a grid system to select subsample locations. Ten composite samples will probably be needed to cover soils around this site.

5. Sampling spill locations (estimated as four).

6. Collecting deep soil samples (i.e., 1-2 ft, 4-5 ft, 7-8 ft BLS) at three Stage 1 locations: d13, d14, and d15.

7. Collecting two surface water samples.

8. Collecting two grab sediment samples.

9. Analyzing all samples for VOCs, PCBs, oil and grease, cyanide, phenols, arsenic, and heavy metals. Tests for other organics may be required depending on Step 1 results.

10. Surveying the new wells and two surface water sampling points. The surface water elevations will help characterize the groundwater/surface water relationship.

11. Conducting a pump test on a selected C well.

The Step 2 program should confirm the extent of substances in the environment.

Step 3 will include sampling at three depths in the Columbia aquifer at an estimated three wells (nine discrete samples) to identify vertical variations in VOC concentrations.

This recommended Stage 2 program should identify:

1. The vertical and horizontal extent of VOCs and metals in groundwater.
2. The extent and concentration of substances in soils, sediments, and surface waters.
3. Columbia aquifer properties that affect groundwater movement.

6.3.1.3 The Receiver Station Sites: D-4, Liquid Waste Site and D-5, Landfill

Figure 6-3 illustrates the recommended Stage 2 monitoring well and soil gas transect locations at Site D-4 and D-5. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 100 sampling points).
2. Sampling wells 11 and 13 to positively confirm the identities of priority pollutant organics.

Information resulting from this step will be used to finalize monitoring well locations and select parameters for analysis during Step 2.

Activities recommended for Step 2 at this site include:

1. Installing 11 C wells. Well locations shown on Figure 6-3 are approximate. The exact positions will be selected based on soil gas investigation results.
2. Installing an F well southeast of the site.
3. Sampling all wells (18 C wells, 1 F well).
4. Sampling sediments in the drainage ditch northwest of the sites. An estimated two samples are needed.
5. Sampling surface waters at two locations.
6. Analyzing all samples for VOCs, oil and grease, and heavy metals. Testing for any additional organics identified during Step 1 may be required.
7. Surveying the new wells to establish vertical and horizontal control.

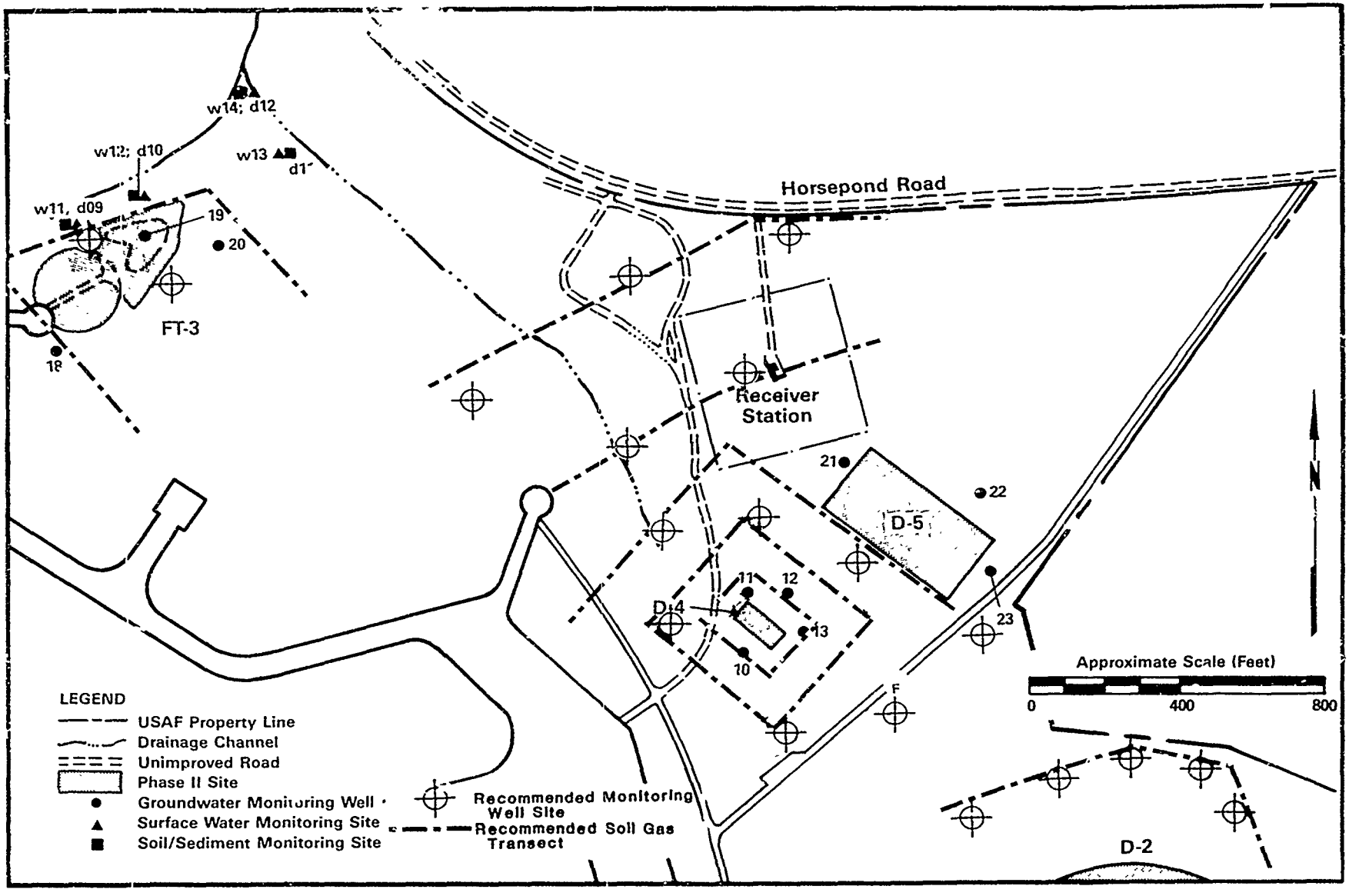


Figure 6-3. Recom[illegible]nded Monitoring Well and Soil Gas Transect Locations, Receiver Station Area

8. Conducting a pump test on a selected C well.

The Step 2 program should confirm the extent of substances in groundwater, surface waters, and sediments.

Step 3 should include sampling for VOCs at three depths within the Columbia aquifer at an estimated four wells (12 discrete samples) to identify variations in VOC concentration with depth in the aquifer.

This Stage 2 program should identify:

1. The vertical and horizontal extent of affected groundwater.
2. The presence, extent, and magnitude of substances in sediments and surface waters.
3. Columbia aquifer properties that affect groundwater movement.
4. The source (i.e., D-4, D-5, or some upgradient source not yet identified) of the concentrations of metals found in well 23.

6.3.1.4 Site D-10, Landfill

Figure 6-4 illustrates the recommended Stage 2 monitoring well and soil gas transect locations at Site D-10. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (135 sampling points) throughout the area.
2. Sampling two wells in the area for priority pollutant organics. Wells will be selected based on the DAFB VOC analysis results for this area.

Information from Step 1 will be used to identify possible upgradient sources and select analysis parameters.

Activities recommended for Step 2 at this site include:

1. Installing 11 C wells. Well locations shown on Figure 6-4 are approximate. The exact positions will be selected based on the soil gas investigation results.

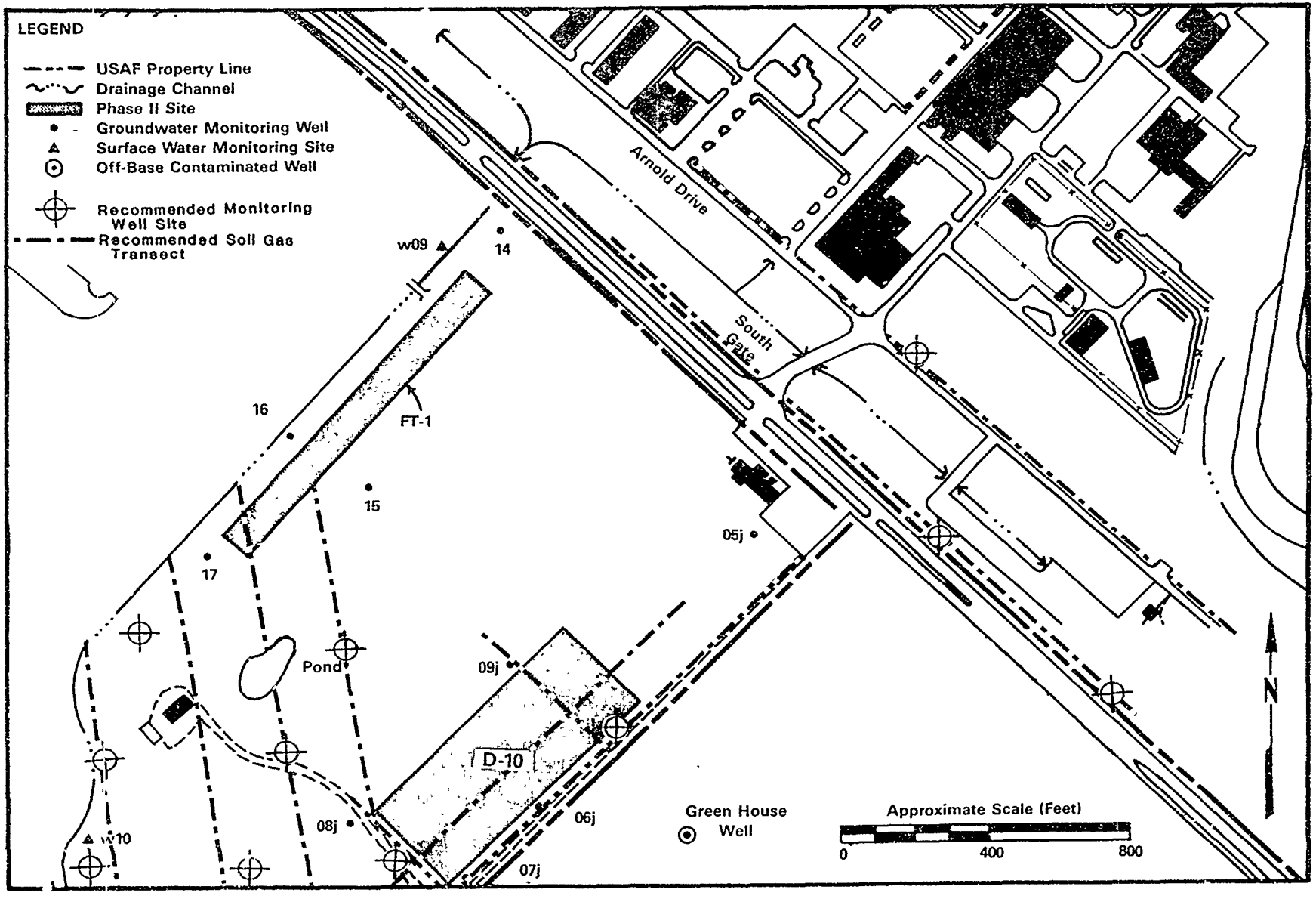


Figure 6-4. Recommended Monitoring Well and Soil Gas Transect Locations, Site D-10 Area

2. Sampling all wells on the golf course (20 C wells).

3. Collecting composite sediment samples in the stream, the pond, and the wetland area southwest of D-10. Five samples are estimated to be required.

4. Sampling surface waters at the five sediment sampling locations.

5. Analyzing all samples for VOCs and heavy metals. Testing for any additional organics found during Step 1 may be required.

6. Surveying the new wells and two surface water level measuring points. The surface water elevations will help characterize the groundwater/surface water relationship.

Additional wells and samples will be necessary if affected groundwater is identified beneath the drainage channel southwest of D-10 or off-base.

Step 3 will include sampling for VOCs at three depths within the Columbia aquifer at an estimated three wells (nine samples) to determine vertical variations in VOC concentrations.

This Stage 2 program should identify:

1. The vertical and horizontal extent of affected groundwater.

2. The presence, extent, and magnitude of substances in surface waters and sediments.

3. The presence of any VOCs in groundwater upgradient from the contaminated Green House well to identify the source.

6.3.1.5 Site DD-1, The North Ditch

Figures 6-5 and 6-6 illustrate the recommended Stage 2 monitoring well and soil gas transect locations at Site DD-1. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 90 sampling points) throughout the area.

2. Collecting three surface water and three sediment samples (i.e., at locations w-d03, w-d04, and w-d08) and analyzing them for priority pollutant organics and fuels.

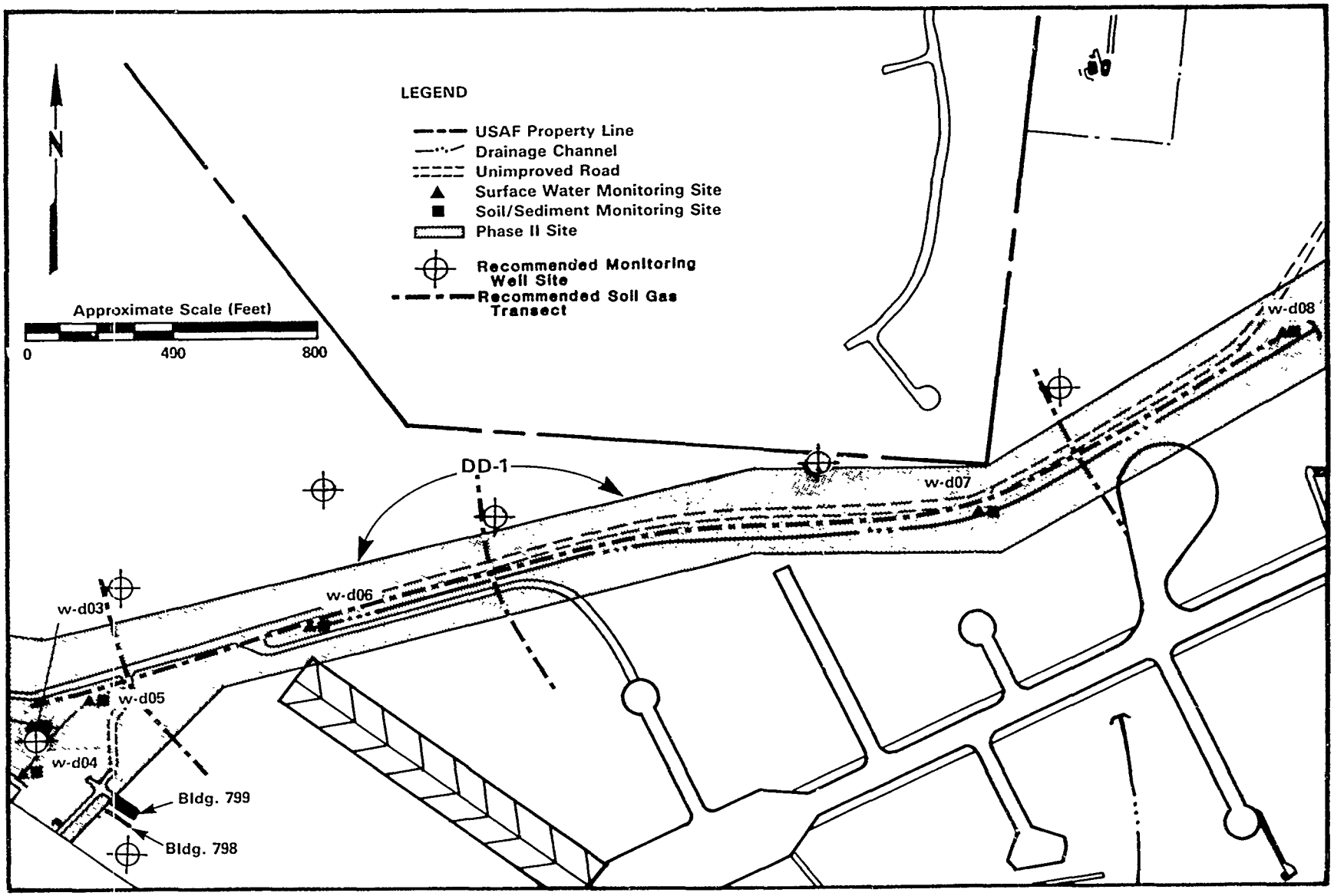


Figure 6-5. Recommended Monitoring Well and Soil Gas Transect Locations, Site DD-1

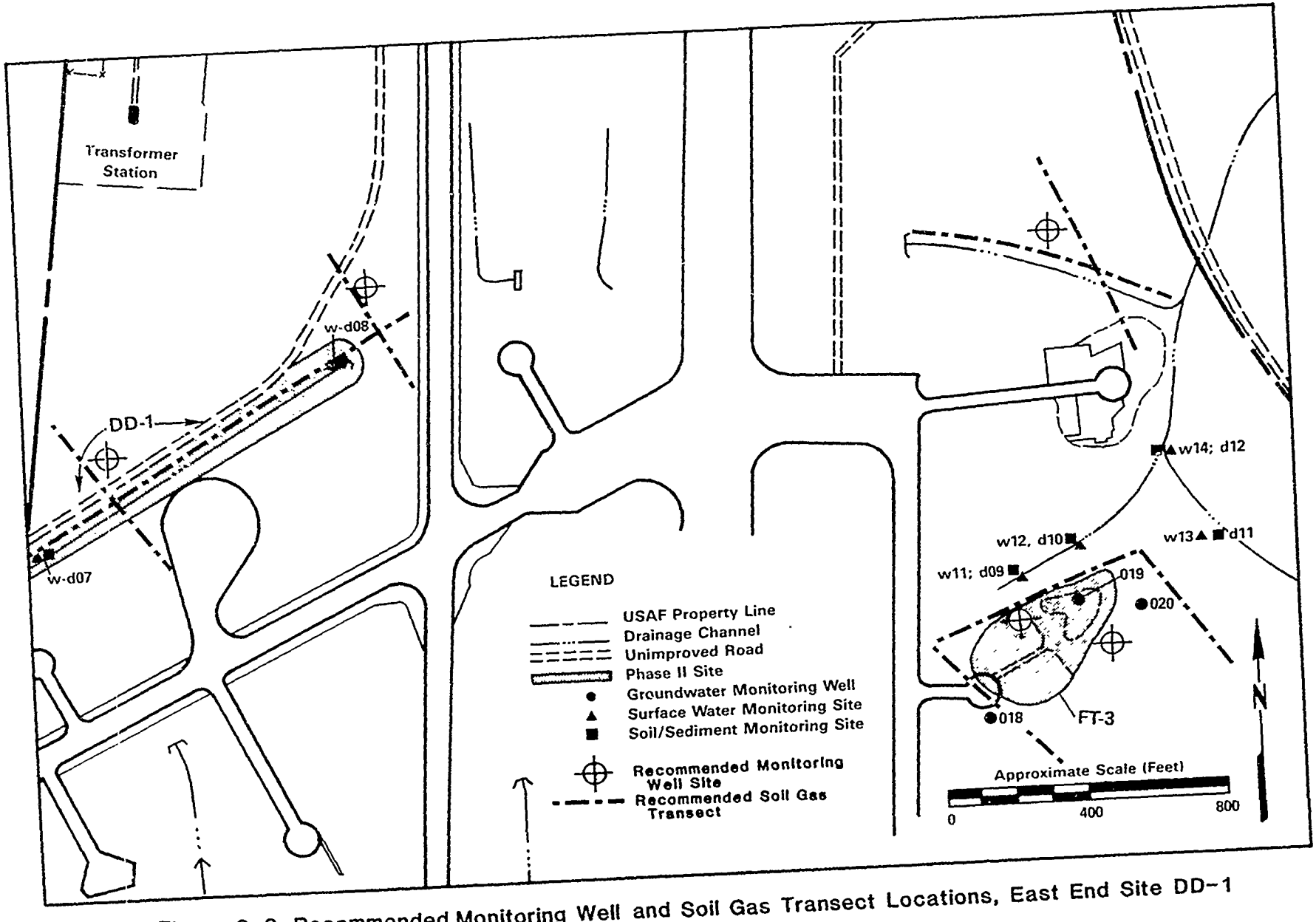


Figure 6-6. Recommended Monitoring Well and Soil Gas Transect Locations, East End Site DD-1

Information from Step 1 will indicate whether tests for additional organics should be included in the analyses and whether VOCs are present in soil gas. Wells will be located based on soil gas results.

Activities recommended for Step 2 include:

1. Installing nine C wells. Well locations shown on Figures 6-5 and 6-6 are approximate. The exact locations will be selected based on soil gas investigation results.

2. Collecting composite sediment samples for six areas in the ditch (i.e., two northwest of d03, between d04 and d05, between d06 and d07, between d07 and d08. and across the runway where the ditch empties into Pipe Elm Branch).

3. Collecting deep sediment samples at d04, d05, and d08. Samples will be collected from depths of 1-2 ft, 4-5 ft, and 7-8 ft BLS.

4. Collecting six surface water samples in the same areas as the sediment samples.

5. Analyzing all samples for VOCs, oil and grease, petroleum hydrocarbons, cyanide, phenols, arsenic, and heavy metals. Testing for any additional parameters identified during Step 1 may be required.

6. Surveying wells and three surface water sampling points. Surface water elevations will help characterize the groundwater/ surface water relationship.

The Stage 2 program should:

1. Identify any ongoing discharge to the ditch.

2. Characterize the vertical and horizontal extent of substances in sediments.

3. Determine whether groundwater has been affected.

6.3.1.6 Site XYZ, Fuel Pump Station

Figure 6-7 illustrates the recommended monitoring well and soil gas transect locations for Stage 2 at Site XYZ. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 60 sampling points) throughout the area.

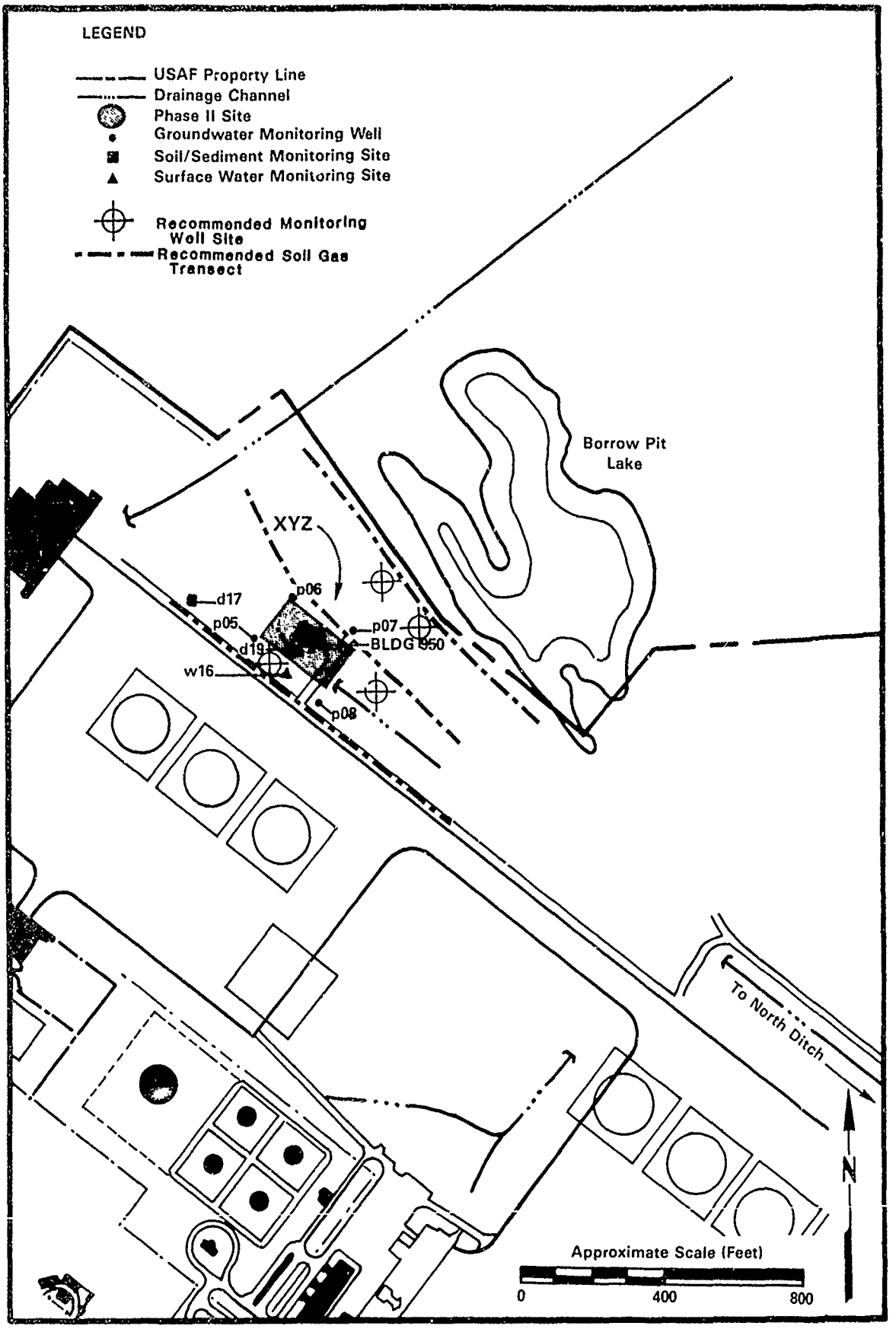


Figure 6-7. Recommended Monitoring Well and Soil Gas Transect Locations, XYZ Area

2. Sampling well points p07 and p08 to determine the specific fuel components present in groundwater.

Results of Step 1 will be used to select new well locations and analysis parameters for Step 2.

Recommended Step 2 activities include:

1. Installing 4 hanging C wells (i.e., installed in a manner similar to other C wells but completed 15 feet below the water table).
2. Sampling all wells (total of 8) for petroleum hydrocarbons.
3. Surveying all wells to establish vertical and horizontal control.

This Stage 2 program should identify:

1. The extent and magnitude of fuels in groundwater.
2. The source of fuels in groundwater.
3. The direction of groundwater flow.

6.3.1.7 Site D-2, Rubble Area

Figure 6-8 illustrates the recommended monitoring well and gas transect locations for Stage 2 at Site D-2. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 30 sampling points) around the site.
2. Collecting two soil samples for priority pollutant organics analysis.

Step 1 information will determine whether other organics need to be analyzed during Step 2 and will be used to locate Step 2 monitoring wells.

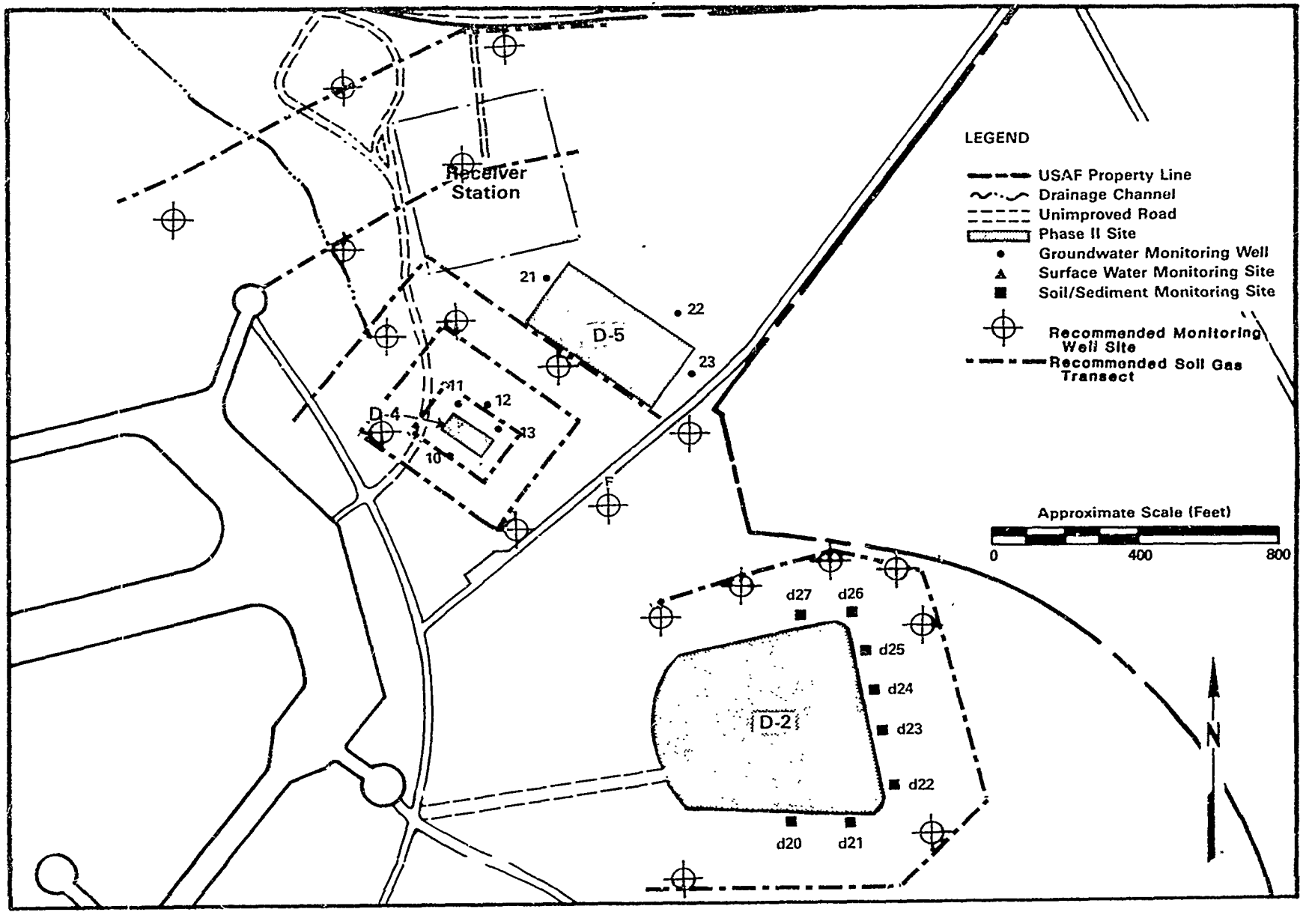


Figure 6-8. Recommended Monitoring Well and Soil Gas Transect Locations, Site D-2

Activities recommended for Step 2 include:

1. Installing seven C wells. Well locations shown on Figure 6-8 are approximate. Exact locations will be determined based on soil gas investigation results.
2. Collecting composite soil samples. An estimated four composite samples may be required.
3. Collecting deep soil samples (i.e., 1-2 ft, 4-5 ft, 7-8 ft BLS) at locations d20, d22, d24.
4. Analyzing all samples for VOCs, oil and grease, cyanide, phenols, arsenic, and heavy metals. Tests for any additional organics identified during Step 1 may be required.
5. Surveying wells to establish vertical and horizontal control.

This Stage 2 program should:

1. Characterize the extent and magnitude of substances in soils.
2. Determine whether groundwater has been affected by Site D-2.

6.3.1.8 Site FT-3, Fire Training Area 3

Figure 6-9 illustrates the recommended monitoring well and soil gas transect locations for Stage 2 at Site FT-3. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 30 samples) around the area.
2. Collecting samples from two existing wells and at two surface water and sediment monitoring points to determine the presence of priority pollutant organics and petroleum hydrocarbons.

Information from Step 1 will be used to determine those organics which need to be added to Step 2 analyses and to locate additional monitoring wells.

Activities recommended for Step 2 at this site include:

1. Installing two C wells with locations based on the soil gas investigation results. The locations shown on Figure 6-9 are approximate.

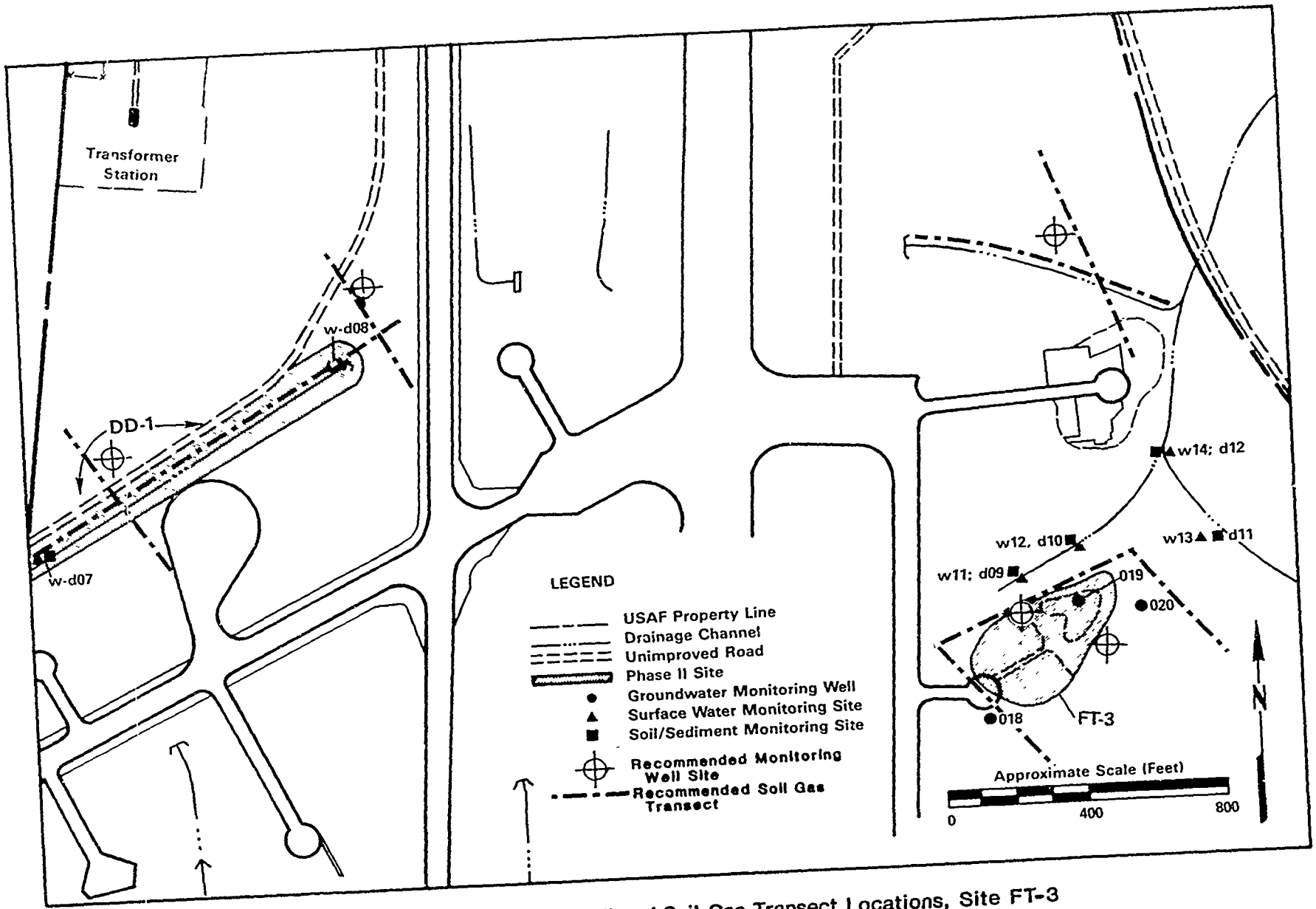


Figure 6-9. Recommended Monitoring Well and Soil Gas Transect Locations, Site FT-3

2. Sampling all wells.

3. Collecting composite sediment samples. An estimated five composite samples are required, including one from upstream of d09.

4. Sampling sediments at various depths (i.e., 1-2 ft., 4-5 ft., and 7-8 ft. BLS) at four locations.

5. Collecting composite soil samples in the fire training pit. Four composite samples are estimated.

6. Collecting soil samples at various depths in the pit (i.e., 1-2 ft., 4-5 ft., and 7-8 ft. BLS). Two deep samples are estimated.

7. Collecting five surface water samples.

8. Analyzing all samples for VOCs, petroleum hydrocarbons, oil and grease, arsenic, and heavy metals. Tests for any additional organics found in Step 1 may be required.

9. Surveying all wells for vertical and horizontal control and establishing one surface water level measuring point.

The Stage 2 program for this site should:

1. Confirm the absence or presence of VOCs or fuels in groundwater.

2. Identify the extent and magnitude of substances in surface waters, soils, and sediments.

3. Identify the source of the substances found in sediments.

6.3.1.9 Site SP-4, JP-4 Pipline Leak

Figure 6-10 illustrates the recommended monitoring well and soil gas transect locations for Stage 2 at Site SP-4. The following activities are recommended for Step 1 of Stage 2:

1. Sampling soil gas (approximately 40 sample points) around the area.

2. Sampling well points p02 and p03 to determine the specific components of fuels present in groundwater.

The Step 1 results will be used to locate new wells and select analysis parameters for Step 2.

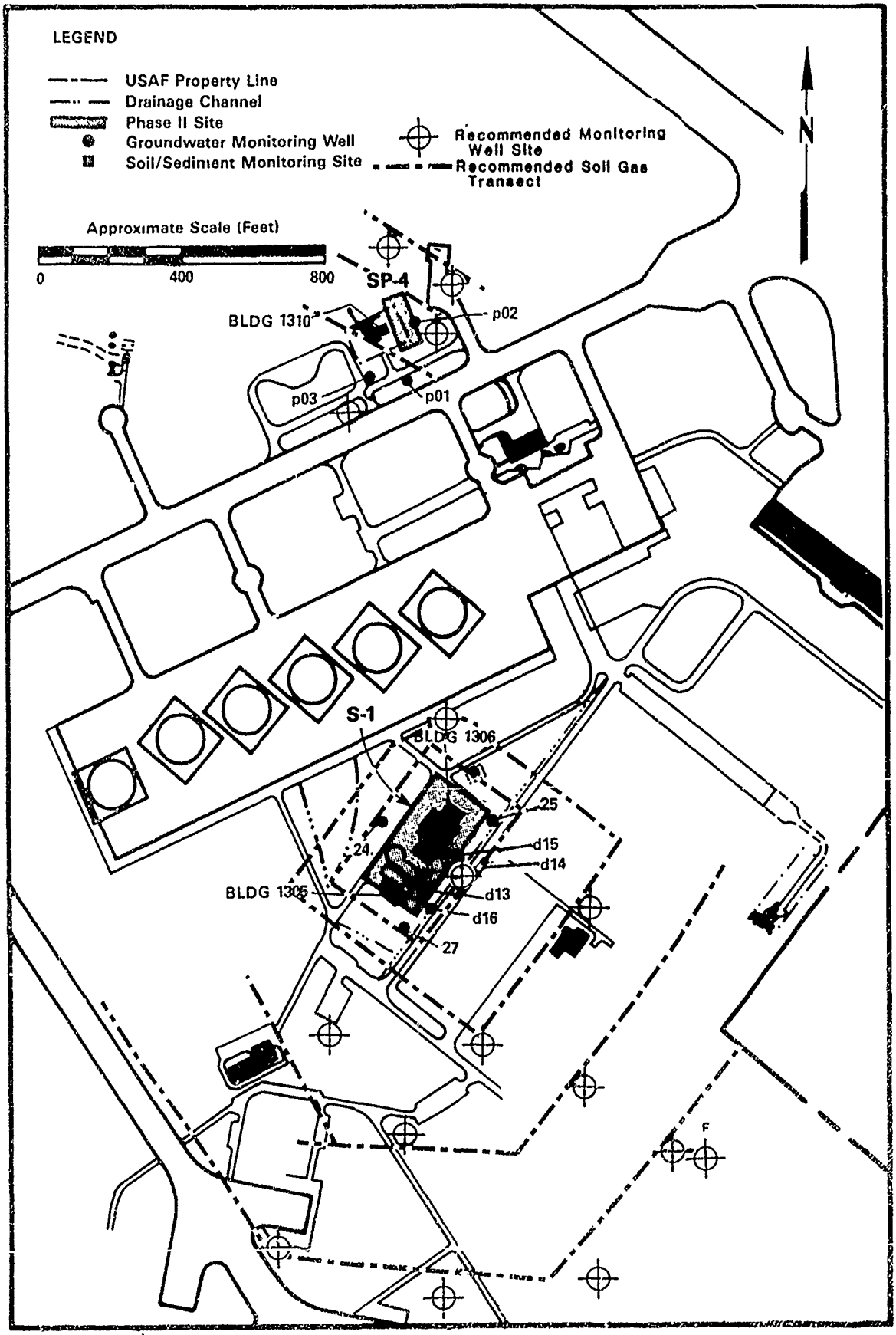


Figure 6-10. Recommended Monitoring Well and Soil Gas Transect Locations, Site SP-4

Step 2 activities will consist of:

1. Installing 4 hanging C wells (installed similarly to other C wells but only completed to 15 feet below the water table)
2. Sampling all wells for petroleum hydrocarbons.
3. Surveying the new wells to establish vertical and horizontal control.

This Stage 1 plan should characterize the source and extent of fuels in groundwater.

6.3.1.10 Runway Area Investigation

Aircraft operations may be contributing to the elevated levels of certain parameters (e.g., VOCs, TOC, oil and grease). Determination of the impact of these operations will assist in evaluating data from Stage 2 and in identifying potential sources. The following activities are recommended during Step 1:

1. Collecting four composite soil samples and four surface water and sediment samples from between the runways.
2. Analyzing samples for priority pollutant organics and petroleum hydrocarbons.

Step 2 activities will consist of:

1. Installing three hanging wells between the two runways. Groundwater samples will be collected.
2. Collecting composite soil samples at four locations between the runways.
3. Collecting four surface water runoff samples from locations between the runways.
4. Analyzing all samples for VOCs, petroleum hydrocarbons, oil and grease, cyanide, phenols, arsenic, and heavy metals. Testing for additional organics may be necessary based on the results of Step 1.

6.3.2 Summary of DAFB Stage 2 Program

The site-specific monitoring approaches for the 10 sites recommended for additional study under Phase II Stage 2 at DAFB can be implemented in three steps. Activities to be undertaken during each step are summarized below:

6.3.2.1 Step 1

Step 1 will involve conducting soil gas investigations and identifying the presence of organics at select wells or surface water/sediment sampling stations. Table 6-1 summarizes the recommended Step 1 activities by site. Specific tasks to be conducted include the following:

1. Soil Gas Analysis Investigation. Includes transects requiring almost 800 planned sampling points.
2. Groundwater Sampling - Existing Wells. Includes sampling of 16 existing wells.
3. Surface Water Sampling. Includes collecting samples at 10 locations.
4. Soil and Sediment Sampling. Includes collecting samples at 17 locations.

Results from Step 1 should:

1. Characterize the fuels and volatile and nonvolatile organics in groundwater, surface waters, soils, and sediments.
2. Map VOCs in soil gas to assist in finalizing locations for monitoring wells.

6.3.2.2 Step 2

Step 2 will involve installing new monitoring wells and collecting groundwater, surface water, soil, and sediment samples to establish the extent and magnitude of substances in the environment. Table 6-2 summarizes the

Table 6-1

SUMMARY OF STEP 1 OF RECOMMENDED STAGE 2 MONITORING PROGRAM

Site	Soil Gas Transects	Groundwater Sampling	Surface Water Sampling	Sediment Sampling	Soil Sampling
T-1	175 Points	4 Wells - P.P. Org. - P. Hcrbns.	-	-	-
S-1	125 Points	2 Wells - P.P. Org.	1 Sample - P.P. Org.	1 Sample - P.P. Org.	1 Sample - P.P.Org.
D-4, D-5	100 Points	2 Wells - P.P. Org.	-	-	-
D-10	135 Points	2 Wells - P.P. Org.	-	-	-
DD-1	90 Points	-	3 Samples - P.P. Org. - P. Hcrbns.	3 Samples - P.P. Org. - P. Hcrbns.	-
XYZ	60 Points	2 Wells - P. Hcrbns.	-	-	-
D-2	30 Points	-	-	-	2 Samples - P.P. Org.
FT-3	30 Points	2 Wells - P.P. Org. - P. Hcrbns.	2 Samples - P.P. Org. - P. Hcrbns.	-	2 Samples - P.P. Org. - P. Hcrbns.
SP-4	40 Points	2 wells - P. Hcrbns.	-	-	-
Runway	-	-	4 Samples - P.P. Org. - P. Hcrbns.	4 Samples - P.P. Org. - P. Hcrbns.	4 Samples - P.P. Org. - P. Hcrbns.

P.P. Org. = Priority pollutant organics analysis
P. Hcrbns. = Petroleum hydrocarbon analysis

Table 6-2

SUMMARY OF STEP 2 OF RECOMMENDED STAGE 2 MONITORING PROGRAM

Site	Monitoring Well Installation	Aquifer Testing	Groundwater Sampling[a]	Surface Water Sampling[a]	Sediment Sampling[a]	Soil Sampling[a]
T-1	18 C Wells 4 F Wells	1 C Well 1 F Well	37 Wells - VOCs, P. Hcrbns., As, Metals, Phenols	-	-	-
S-1	11 C Wells 1 F Well	1 C Well	15 Wells - VOCs, PCBs, O&G, Cn, Phenols, As, Metals	2 Samples 2 S.W. Elevation Pts.	2 Samples	23 Samples
D-4, D-5	11 C Wells 1 F Well	1 C Well	19 Wells - VOCs, O&G, Metals	2 Samples	2 Samples	-
D-10	11 C Wells	-	20 Wells - VOCs, Metals	5 Samples 4 S.W. Elevation Pts.	5 Samples	-
DD-1	9 C Wells	-	9 Wells - VOCs, P. Hcrbns., O&G, Cn, Phenols, As, Metals	6 Samples 3 S.W. Elevation Pts.	15 Samples	-
XYZ	4 Hanging C Wells	-	8 Wells - P. Hcrbns., VAs	-	-	-
D-2	7 C Wells	-	7 Wells - VOCs, O&G, As, Metals	-	-	13 Samples
FT-3	2 C Wells	-	5 Wells - VOCs, P. Hcrbns., O&G, As, Metals	5 Samples 1 S.W. Elevation Pt.	17 Samples	10 Samples
SP-4	4 Hanging C Wells	-	7 Wells - P. Hcrbns., VAs	-	-	-
Runway	3 Hanging C Wells	-	3 Wells - VOCs, P. Hcrbns., Phenols, O&G, Cn, As, Metals	4 Samples	-	4 Samples

[a]Analysis parameters listed under groundwater sampling apply to all media. Recommended analysis may be modified depending on Step 1 results

VOCs = Volatile organic compounds; O&G = Oil and Grease; Cn = Cyanide; P. Hcrbns. = Petroleum Hydrocarbons; VAs = Volatile Aromatics; S.W. Elevation Pts. = Surface water elevation points; C Well = Well installed in the Columbia aquifer; F Well = Well installed in Frederica aquifer

recommended Step 2 activities by site. Specific tasks to be conducted include the following:

1. Monitoring Well Installation. Includes the installation of 69 fully penetrating Columbia aquifer wells, 11 hanging wells completed to 15 feet below the water table, and 6 Frederica aquifer wells.

2. Groundwater Sampling. Involves collecting samples from 130 wells.

3. Surface Water Level Measurement. Includes establishing 10 points from which surface water levels can be measured.

4. Surface Water Sampling. Involves collecting samples at 24 locations.

5. Sediment Sampling. Involves collecting samples at 27 locations.

6. Soil Sampling. Involves collecting samples at 34 locations.

7. Aquifer Testing. Includes conducting pump tests on three C wells and one F well.

Results from Step 2 should:

1. Estimate the extent and magnitude of contamination.

2. Confirm the presence or absence of groundwater contamination at two sites.

3. Identify the source(s) of contamination at all sites.

6.3.2.3 Step 3

Step 3 as planned will involve collecting samples at various depths within the Columbia aquifer at selected wells to identify the vertical distribution of VOCs. Table 6-3 summarizes the Step 3 activities by site. Depending on Step 2 findings, additional wells or samples may be necessary. Step 3 will consist of stratified groundwater sampling to involve collecting samples for VOC analysis at three depths within the Columbia aquifer at 15 wells. Step 3 activities are not presently planned at five sites but such activities may be necessary depending on the results of Step 2.

Table 6-3

SUMMARY OF STEP 3 OF RECOMMENDED STAGE 2 MONITORING PROGRAM

Site	Stratified Groundwater Sampling[a]
T-1	5 wells with 3 samples per well - VOCs.
S-1	3 wells with 3 samples per well - VOCs.
D-4, D-5	4 wells with 3 samples per well - VOCs.
D-10	3 wells with 3 samples per well - VOCs.
DD-1	Program not planned.
XYZ	Program not planned.
D-2	Program not planned.
FT-3	Program not planned.
SP-4	Program not planned.
Runway	Program not planned.

[a]Analysis parameters may be modified depending on Step 2 results
VOCs = Volatile organic compound analysis with second-column gas chromatographic analysis and mass spectroscopy to positively confirm the identities of VOCs.

6.3.3 Stage 2 Program Schedule

The Stage 2 study outlined in the previous sections will take 96 weeks (approximately 24 months), from the start of Step 1 to the submittal of a final report (66 weeks or 16 months to submittal of the draft report). The estimated duration of various tasks are shown in Table 6-4. The schedule will need to be adjusted if step activities are modified.

Table 6-4

ESTIMATED SCHEDULE FOR RECOMMENDED STAGE 2 MONITORING PROGRAM

Step		Activity	Duration (Weeks)	Start-Up	End
STEP 1	1.	Preparation	3	Week 1	Week 4
	2.	Soil Gas Investigation and Reporting	15	Week 5	Week 20
	3.	Sample Collection	2	Week 5	Week 7
	4.	Sample Analysis	5	Week 7	Week 12
	5.	Soil Gas Data Evaluation and Well Location Selection	16	Week 9	Week 25
	6.	Preparation For Drilling	11	Week 18	Week 29
STEP 2	1.	Monitoring Well Installation	9	Week 25	Week 34
	2.	Sample Collection	7	Week 29	Week 36
	3.	Sample Analysis	11	Week 30	Week 41
	4.	Aquifer Testing and Reporting	6	Week 36	Week 42
	5.	Surveying and Reporting	6	Week 32	Week 38
	6.	Data Evaluation	14	Week 36	Week 50
	7.	Informal Technical Report Preparation	4	Week 41	Week 45
STEP 3	1.	Preparation for Sampling	1	Week 43	Week 44
	2.	Stratified Groundwater Sampling	2	Week 45	Week 47
	3.	Sample Analysis	6	Week 47	Week 53
	4.	Data Evaluation	2	Week 53	Week 57
	5.	Informal Technical Report Preparation	3	Week 57	Week 60
	6.	Draft Report Preparation	9	Week 57	Week 66
REPORT REVIEW	1.	USAF Review	10	Week 66	Week 76
	2.	Draft Final Report Preparation	6	Week 76	Week 82
	3.	Draft Final Report Review	10	Week 82	Week 92
	4.	Final Report Preparation	4	Week 92	Week 96