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FINAL PRELIMINARY ASSESSMENT/ SITE INVESTIGATION REPORT NIKE FORT STORY VA

1/1/1992

MONTGOMERY WATSON

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0155

Site 1: (Landfill 1)
(FTSTY-01)

Site 2: Landfill 2
(02)

Site 4: Fire Training Area
(04)

Site 5: JP-4 Fuel Tank farm
(05)

Site 6: LARC-60 Maintenance Area
(06)

Site 7: Former Auto Craft shop
(07)

Site 8: Drainage Outfall Line (NOT IRP Site)

Site 9: Nike Facility (NOT IRP Site)

U.S. Army Corps of Engineers
Missouri River Division
Omaha District

Final Site Investigation Report for the

Fort Story Preliminary Assessment/Site Investigation and Fort Story NIKE Preliminary Assessment/Site Investigation

Fort Story, Virginia
January 1992

JMM James M. Montgomery

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LIST OF ABBREVIATIONS AND ACRONYMS

A-E	Architect-Engineer
APHA	American Public Health Association
AR	Army Regulation
ARAR	Applicable or Relevant and Appropriate Regulations
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AWWA	American Water Works Association
BARC	barge amphibious resupply cargo
bls	below land surface
BNA	base, neutral and acid extractable compound
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
BTU	British Thermal Unit
CFR	Code of Federal Regulations
COC	chain of custody
DEH	Directorate of Engineering and Housing
DO	delivery order
DQCR	Daily Quality Control Report
DQO	Data Quality Objective
DSIR	Draft Site Investigation Report
ECD	electron capture detector
EM	Electromagnetic
EPA	Environmental Protection Agency
FID	Flame Ionization Detector
FTS SSDR	Preliminary Summary Site Data Report, Fort Story, Virginia
FTSDSIR	Fort Story Draft Site Investigation Report
FTSFARD	Fort Story Final Analytical Results Document
FTSGID	Fort Story Geotechnical Information Document
GC	gas chromatograph
GC/MS	Gas Chromatography/ Mass Spectrophotometry
gpd/ft	gallons per day per foot
gpm	gallons per minute
I/HW	Industrial/ Hazardous Waste
ID	inside diameter
IEC	Installation Environmental Coordinator
JMM	James M. Montgomery, Consulting Engineers, Inc.
LARC	lighter amphibious resupply cargo
MCL	Maximum Contaminant Level
mg/kg	milligram per kilogram
mg/l	milligrams per liter
MRD	USACE Missouri River Division Laboratory
MRL	Method Reporting Level
MS/MSD	Matrix Spike/ Matrix Spike Duplicate
NAPL	non-aqueous phase liquid
ND	Non Detect
NGVD	National Geodetic Vertical Datum of 1929
NIOSH	National Institute for Occupational Safety and Health
NTU	Nephlometric Turbidity Units
OD	outside diameter
OSHA	Occupational Safety and Health Administration
OSO	On-Site Safety Officer
OVM	Organic Vapor Meter

PA/SI	Preliminary Assessment/Site Investigation
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PID	Photoionization detector
PM	Project Manager
ppm	parts per million
psig	pounds per square inch gage
QA/QC	quality assurance/quality control
QCSP/FIP	final quality control and sampling plan/field investigation plan
QCSR	Quality Control Summary Report
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/ Feasibility Study
SHERP	Final Safety Health and Emergency Response Plan, Fort Story and Fort Eustis, Virginia
SPT	Standard Penetration Test
TCA	1,1,1 trichloroethane
TCE	trichloroethene
TFH-H	total fuel hydrocarbons-heavy fraction
TFH-L	total fuel hydrocarbons-light fraction
TOC	top of casing
TOX	total organic halogens
USACE	U.S. Army Corps of Engineers
USAEHA	U.S. Army Environmental Health Agency
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
UST	underground storage tank
UV	Ultraviolet
VGWPL	Virginia Groundwater Protection Level
VOC	volatile organic compound
VWCB	Commonwealth of Virginia, State Water Control Board
WPCF	Water Pollution Control Federation

EXECUTIVE SUMMARY

JMM conducted a Preliminary Assessment/Site Investigation (PA/SI) at Fort Story, Virginia, to determine the presence of significant contamination at eight project sites.

- Site 1 (Landfill 1)
- Site 2 (Landfill 2)
- Site 4 (Firefighter Training Area)
- Site 5 (Underground Fuel Storage Tank Farm)
- Site 6 (LARC Maintenance Area)
- Site 7 (Autocraft Building)
- Site 8 (Drainage Outfall Line)
- Site 9 (NIKE Facility)

This program was intended to identify environmental levels of contaminants relative to regulatory standards, assess contaminant transport pathways at the site and define future investigations and/or actions that may be required.

The Scope of Services for this investigation included the conduct of several activities in conjunction with the site evaluation. These items included:

- Literature and Information Search. The activities associated with this phase of the project served to develop site histories of past operations and identify appropriate sampling and analytical procedures to properly investigate each site.

- Preparation of Plans. The development of a quality control and sampling plan and a health and safety plan addressing all field methods and safety procedures associated with the drilling and sampling activities.

- Field Investigation. The investigation consisted of the drilling and collection of soil samples from 48 soil borings and 26 well borings; installation and sampling of 26 groundwater monitoring wells; and collection of 29 sediment samples over a four-month period. Soil, groundwater, surface water, and sediment samples collected during the sampling activities were analyzed for selected contaminants based on site historical records.

- Preparation of Reports. Documents addressing the investigative techniques utilized during the field program and the validity and quality of the analytical data obtained were prepared following the conclusion of the field effort. The significance of analytical results was also discussed.

JMM evaluated contaminant concentration levels in soil and groundwater relative to statistically significant background levels or regulatory-based standards. Based upon this evaluation, recommendations were developed as to whether or not more investigative activities would be required. These recommendations are divided among three areas - No Further Action, Further Confirmatory Studies, or Remedial Investigation/Feasibility Study. A recommendation of No Further Action means that the results of the data evaluation indicate that past activities at the site do not show evidence of adverse environmental impacts. A recommendation for Further Confirmatory Studies means that additional information is needed to make a determination related to contamination of the site. A recommendation for a Remedial Investigation/Feasibility Study (RI/FS) means that there exists sufficient evidence to require a more extensive investigation, in which the site will be completely characterized from an environmental as well as exposure perspective.

For the eight sites investigated at Fort Story by JMM, three are recommended for no further action - Landfill 1 (Site 1), the Drainage Outfall Line (Site 8), and the NIKE Facility (Site 9). Further confirmatory investigation is recommended at one site, Landfill 2 (Site 2). A remedial investigation/feasibility study is recommended at the remaining four sites - the Firefighter Training Area (Site 4), the Underground Fuel Storage Tanks (Site 5), the LARC Area (Site 6), and the Autocraft Building (Site 7). Table E-1 summarizes these recommendations, and lists the contaminants of concern which directed the recommendation.

TABLE E-1

SUMMARY OF RECOMMENDATIONS FOR
PA/SI AND NIKE PROJECT SITES - FORT STORY, VIRGINIA

Site Identifier	Media	Contaminants of Concern[a]	Projected Future Activities
Site 1 - Landfill 1	Soil	None	No further action is needed at this site.
	Groundwater	None	
Site 2 - Landfill 2	Soil	Metals (>T)	Further Confirmatory Investigation is needed at this site.
	Groundwater	Metals (>T)	
Site 4 - Firefighter Training Area	Soil	TFH-L (>T) Metals (>T)	An RI/FS is recommended for this site.
	Groundwater	VOCs (>T) BNAs (>T) TFH-L (>T)	
Site 5 - Underground Fuel Storage Tanks	Soil	TFH-L (>T) Total Lead (>T)	An RI/FS is recommended for this site.
	Groundwater	BETX (>T)	
Site 6 - LARC Maintenance Area	Soil	VOCs (>T) TFH-H (>T) Metals (>T)	An RI/FS is recommended for this site.
	Groundwater	VOCs (>T) TFH-H (>T) Metals (>T)	
Site 7 - Auto Craft Building	Soil	TFH-H (>T) Metals (>T)	An RI/FS is recommended for this site.
	Groundwater	TFH-H (>T) Metals (>T)	

TABLE E-1
(Continued)

SUMMARY OF RECOMMENDATIONS FOR PA/SI AND NIKE PROJECT SITES - FORT STORY, VIRGINIA

Site Identifier	Media	Contaminants of Concern[a]	Projected Future Activities
Site 8 - Drainage Outfall Line	Soil	None	No further action is needed at this site.
	Sediment in Outfall Line	TFH-H (>T) Metals (>T)	
	Sediment at Outfall Discharge	None	
	Groundwater	None	
Site 9 - NIKE Facility	Soil	Zn >T	No further action is needed at this site.
	Groundwater	None	

(a) Contaminant concentrations are indicated as greater than the trigger (>T) level for that contaminant in a specific medium.
(b) Possible laboratory artifact.

RI/FS Remedial Investigation/Feasibility Study
T Trigger Level
TFH-H Total fuel hydrocarbons, heavy fraction
VOCs Volatile organic compounds
BNAs Base/neutral/acid extractable compounds

1.0 INTRODUCTION

James M. Montgomery, Consulting Engineers, Inc. (JMM) is the prime Architect-Engineer (A-E) contracted by the U.S. Army Corps of Engineers (USACE) Omaha District to perform environmental investigations of specific sites at the Fort Story Installation suspected to be contaminated with hazardous substances. Fort Story is located within the Hampton Roads region of southeastern Virginia.

JMM was retained by the USACE under Contract DACW45-89-D-0501 to perform investigations at Fort Eustis and Fort Story. Fort Story is a sub-installation of Fort Eustis. Figure 1-1 presents the locations with respect to the Hampton Roads region of the Fort Eustis and Fort Story Installations, as well as the former NIKE missile facilities affiliated with Fort Eustis. The work at these two Installations was divided into four separate projects (i.e., Delivery Orders 0001, 0002, 0004 and 0006):

1. Delivery Order 0001 - A Preliminary Assessment/Site Investigation (PA/SI) project for Fort Eustis and Fort Story covering eight sites at Fort Eustis and seven sites at Fort Story, as well as quarterly sampling of 24 wells at three additional sites.

2. Delivery Order 0002 - A Remedial Investigation/Feasibility Study (RI/FS) project for Fort Eustis and Fort Story covering four sites at Fort Eustis and two sites at Fort Story.

3. Delivery Order 0004 - A PA/SI project for two former NIKE missile facilities. One NIKE site is located at Fort Story, and one, although not located at Fort Eustis, is located in Hampton Roads and associated with the Fort Eustis Installation.

4. Delivery Order 0006 - A Site Investigation (SI) and Underground Storage Tank (UST) Removal Design project for Site 10, Block 600, at Fort Story.

Field investigations for all delivery orders were conducted concurrently. This *Final Site Investigation Report for the Fort Story Preliminary Assessment/Site Investigation and Fort Story NIKE Preliminary Assessment/Site Investigation (PA/SI)* specifically addresses only the PA/SI sites and NIKE PA/SI sites located at Fort Story. Work for these sites was performed under Delivery Orders 0001 and 0004. The PA/SI sites and NIKE PA/SI sites for Fort Eustis will be discussed in the separate *Final Site Investigation Report for the Fort Eustis Preliminary Assessment/Site Investigation and Fort Eustis NIKE Preliminary Assessment/Site Investigation* (JMM, 1992). The work associated with Delivery Order 0006 is presented in JMM's *Final Site Investigation Report - Initial Site Investigation and Design for Underground Storage Tank Removal, Block 600, Fort Story, VA,* (JMM, 1991a).

1.1 STUDY OBJECTIVES

A PA/SI is an initial analysis of existing information and preliminary contamination data intended to determine if a release or discharge of hazardous substances might be serious enough to warrant additional investigation or action. The PA is the first phase in the process of determining whether a site is releasing, or has the potential to release, hazardous substances, pollutants or contaminants into the environment and whether response action is necessary. The SI is the first phase in the process of characterizing the presence of hazardous substances in environmental media, via collection and analysis of multi-media samples.

The PA/SI attempts to establish whether the site has the potential to adversely affect the environment; however, it is not intended to determine the magnitude or extent of environmental contamination. These determinations are made during a Remedial Investigation/Feasibility Study

(RI/FS). Also, the PA/SI qualitatively assesses contaminant transport pathways in environmental media; however, it is not intended to quantify exposure concentrations or dosages or health/environmental risk levels. Exposure and risk levels associated with transport pathways and receptors are characterized during the RI/FS process.

JMM's objectives during the PA/SI and NIKE PA/SI studies are:

1. To confirm the presence or absence of significant contamination in site environmental media;

2. To identify environmental levels of contaminants relative to regulatory standards;

3. To qualitatively characterize basic pathways through which contaminants could migrate across the designated sites or off of site boundaries; and

4. To define future investigations or other appropriate actions required at the designated sites.

1.2 REPORT ORGANIZATION

Section 1, Introduction, summarizes the scope and extent of work performed for the PA/SI and NIKE PA/SI investigations associated with Fort Story. This section details the field procedures utilized and sampling techniques employed for different mediums. Decontamination and health and safety issues are also briefly summarized.

Section 2, Assessment of Contamination, contains an overview of the analytical program and identifies appropriate regulatory action levels. Investigation results are presented, including a summary of applicable previous investigations and base-wide findings at Fort Story. Site-specific investigation results are also presented. The site-specific analytical data are evaluated, and the nature and presence of contamination is discussed.

Section 3, Conclusions, summarizes the results of the field investigation and contamination assessment. Based on this information, recommendations for additional work at specific Fort Story project sites are presented.

Appendix A, References, lists the sources of information used by JMM during the development of this report. Appendix B, Sampling Locations Rationale, presents the rationale for each sampling location. Appendix C, Geotechnical Soil Classification Summary, presents a summary of geotechnical soil classifications associated with the PA/SI and NIKE PA/SI. Appendix D, Soil Gas Survey, presents the results of the shallow soil gas survey at Site 4.

The *Fort Story Final Analytical Results Document (FTSFARD)* (JMM, 1991b), a companion document to this report, summarizes the analytical results from the investigations of different media at Fort Story PA/SI and NIKE PA/SI sites. The *Fort Story Geotechnical Information Document (FTSGID)* (JMM, 1991c), a companion document to this report, contains information relating to drilling and monitoring well construction. In addition, soil gradation and classifications, development logs and associated final development water photographs, slug test results and well sampling logs are presented.

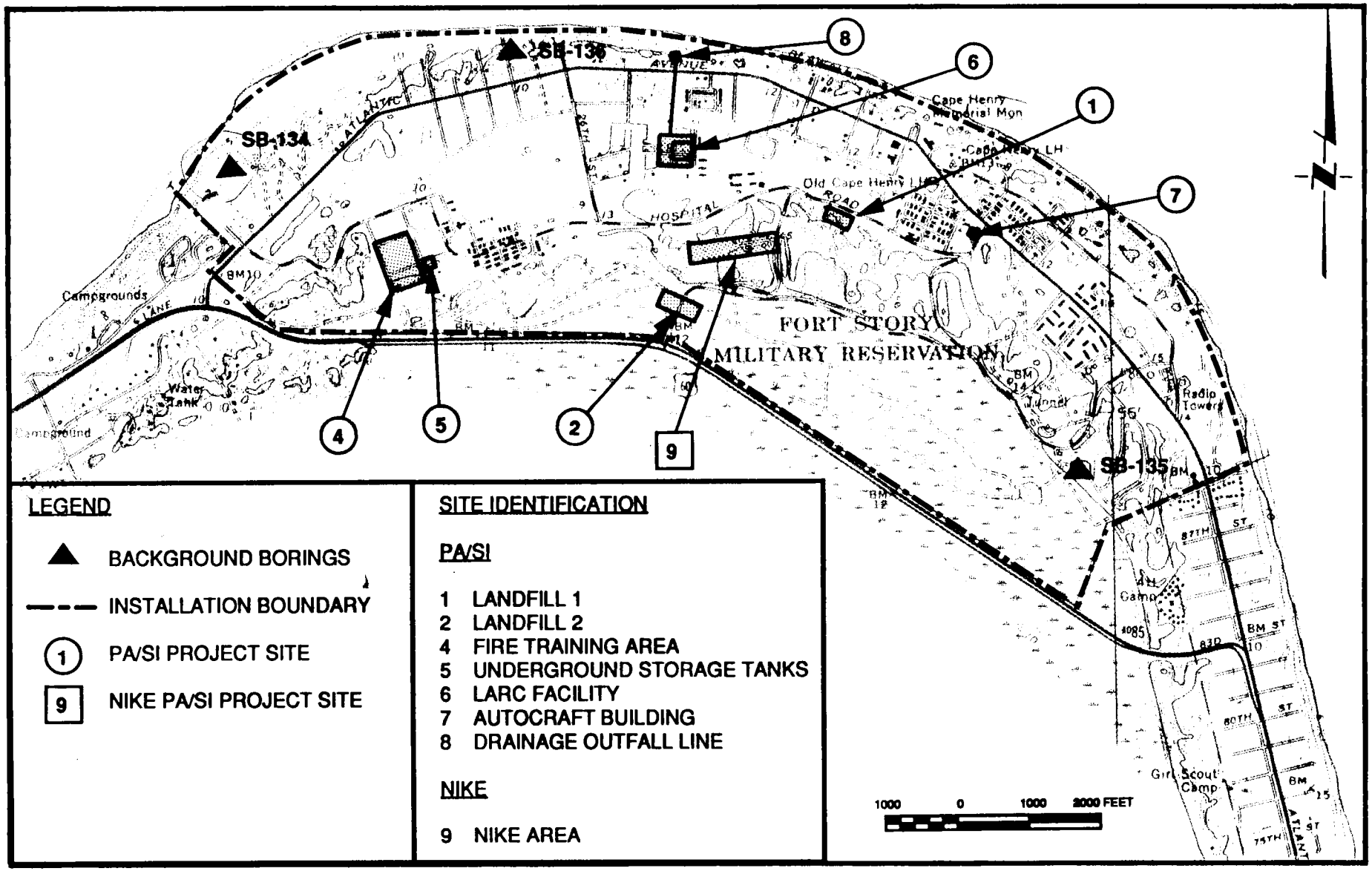
1.3 SCOPE OF SERVICES

The assessment of Fort Story involved field investigations performed at seven PA/SI sites and one NIKE missile facility PA/SI site (Table 1-1) (Figure 1-2). The media investigated for potential

TABLE 1-1

FORT STORY PROJECT SITES

Project Type	Delivery Order	Site No.	Site Name
PA/SI	0001	1	Landfill 1
		2	Landfill 2
		4	Firefighter Training Area
		5	Underground Fuel Storage Tank Farm
		6	LARC Maintenance Area
		7	Auto Craft Building
		8	Drainage Outfall Line
NIKE PA/SI	0004	9	Fort Story NIKE Facility



LEGEND

- ▲ BACKGROUND BORINGS
- — — — INSTALLATION BOUNDARY
- (1) PA/SI PROJECT SITE
- [9] NIKE PA/SI PROJECT SITE

SITE IDENTIFICATION

PA/SI

1 LANDFILL 1
2 LANDFILL 2
4 FIRE TRAINING AREA
5 UNDERGROUND STORAGE TANKS
6 LARC FACILITY
7 AUTOCRAFT BUILDING
8 DRAINAGE OUTFALL LINE

NIKE

9 NIKE AREA

JMM

Military Installation Project Site Locations
Ft. Story, VA

Figure 1-2

contamination at Fort Story included soil, groundwater and sediments. Among the seven PA/SI sites, the investigation exclusively focused on groundwater and soil at six of the sites:

- Site 1 (Landfill 1)
- Site 2 (Landfill 2)
- Site 4 (Firefighter Training Area)
- Site 5 (Underground Fuel Storage Tank Farm)
- Site 6 (LARC Maintenance Area)
- Site 7 (Auto Craft Building)

At the remaining PA/SI site, Site 8 (Drainage Outfall Line), the scope of the investigation included the collection of sediment samples in addition to soil and groundwater samples.

Groundwater and soils were investigated in the NIKE PA/SI Site (Site 9). Three background soil borings also were collected from isolated areas of Fort Story. The Scope of Services included the conduct of several activities in conjunction with the site evaluation. These activities are summarized later.

1.3.1 Literature and Information Search

General and site-specific information pertaining to the PA/SI at Fort Story were collected and reviewed, including applicable reports, topographic maps, and as-built specifications detailing regional, local and site-specific characteristics. Documents describing local hydrogeological conditions were also reviewed. The sites were toured and inspected for evidence of contamination to assist in the placement of soil borings and monitoring wells. Finally, informal interviews were conducted with installation personnel familiar with current or past operations at the site. Appendix A contains complete reference information for all documents reviewed and individuals contacted for this PA/SI.

1.3.2 Plan Preparation

Using the data and references acquired during the literature search, a *Final Quality Control Sampling Plan/Field Investigation Plan (QCSP/FIP)* (JMM, 1990a) was developed. The *QCSP/FIP* discussed the methods, equipment and procedures to be used during the field investigation. Soil boring and monitoring well locations were identified, as well as field and analytical procedures, to ensure quality control.

A *Final Safety, Health and Emergency Response Plan (SHERP)* (JMM, 1990b) was developed in addition to the *QCSP/FIP* to address any potential safety and chemical exposure hazards associated with performance of field work. The *SHERP* established the protocols necessary to protect on-site personnel, off-site receptors and the environment from potential hazards.

1.3.3 Field Investigation

The field investigation activities at Fort Story involved the assessment of potential contamination in soils and groundwater. Contamination assessments of these media were performed at eight sites. Soil and groundwater contamination were assessed at eight sites. Sediment sampling activities were performed at one site. The field investigation included the use of geophysical surveying to delineate the sub-areal extent of buried fill material at two landfills. In addition, soil-gas surveying was utilized at Site 4, the Firefighter Training Area, as a means to focus the study on areas of significant contamination. The assessment of Fort Story included collecting soil samples through the construction of soil borings and monitoring wells, collecting groundwater samples through the sampling of monitoring wells, measuring aquifer characteristics through in situ permeability testing, and collecting sediment samples.

The drilling and sampling activities were conducted starting in March 1990, with resampling events in August 1990. Section 1.3 provides a general summary of the field procedures. The *Fort Story-Preliminary Summary Site Data Report (FTS-SSDR)* (JMM, 1990c) provides a detailed discussion of the field effort.

1.3.4 Report Preparation

The *FTS-SSDR* briefly reviews investigative activities and lists the locations and quantities of contaminants found at Fort Story. A *Quality Control Summary Report (QCSR)* (JMM, 1991e) addresses the validity and quality of the data obtained during the field investigation. The document provided a concise summary of quality control practices used to meet the project data quality objectives (DQOs). The report described any deviations from planned protocols, summarized corrective actions implemented, and evaluated data quality in relation to DQOs. Quality control sample results were also summarized and interpreted.

Both *Preliminary Draft and a Draft of this Fort Story Preliminary Assessment/Site Investigation and Fort Story NIKE Preliminary Assessment/Site Investigation* (JMM, 1991e) was submitted to the USACE (JMM, 1991f) and the *Preliminary Draft for the Fort Story Final Analytical Results Document* (JMM, 1991g) present the analytical data for each of the sites included in the investigation. Site-specific summaries of field activities and analytical data were presented as well as laboratory analytical reports for all soil and water analyses. Additionally, an outline was proved for the Draft and Final reports.

1.4 GENERAL FIELD PROCEDURES

This section summarizes the field procedures used in acquiring the data required to meet the objectives of the PA/SI and NIKE PA/SI projects. These field investigation activities were completed at Fort Story: geophysical surveys to delineate the boundaries of two abandoned landfills; soil gas survey at PA/SI Site 4, soil and groundwater sampling at the seven PA/SI sites and one NIKE PA/SI site; sediment sampling from catch basins upstream of PA/SI Site 8; soil sampling from background boring locations; and in situ permeability testing.

1.4.1 Geophysical Survey

Geophysical surveying determined the areal boundaries of the Site 1 and Site 2 abandoned landfills. Results of the surveys aided in the selection of monitoring well locations. The geophysical surveying techniques utilized in the investigation included magnetics and electromagnetics.

Magnetic geophysical surveying is performed using a magnetometer. Magnetometers measure the intensity of the Earth's magnetic field at any given sampling point. Magnetic anomalies are variations in the local strength of the Earth's magnetic field. The presence of natural iron minerals or buried ferrous objects, such as landfilled metallic debris, cause magnetic anomalies. Generally, it is easy to detect magnetic anomalies from buried metal objects. Though several factors influence the response of a magnetometer, the most significant are the ferrous mass of the anomaly-producing object and the depth of the object. Site specific conditions, however, generally preclude an accurate determination of the object's precise location and depth.

Electromagnetic (EM) surveying is performed using an EM conductivity meter. The EM survey provides a means of measuring the bulk electrical conductivity of subsurface soil, sediment, rock and groundwater. Normally, the amount and type of pore fluids dominate the electrical conductivity measured by EM instruments. The soil matrix composition and thickness, together with its porosity and permeability, also significantly affect the EM response. The electrical

conductivity of objects expected to be buried in the abandoned landfills is often many orders of magnitude greater than the response measured for naturally occurring materials. The observed reading of an EM instrument is a bulk measurement of conductivity and represents the cumulative response of the subsurface materials from the surface to the effective depth of the instrument.

An EG&G GeoMetrics G-856 proton procession magnetometer was used for magnetic surveying, while a Geonics Limited EM-31 conductivity meter was used for EM surveying. The EM-31 device can investigate subsurface conditions to depths as great as 18 feet. As the G-856 magnetometer measures the Earth's magnetic field, the investigation depth of this instrument is unlimited.

Sufficient background data were available for a generalized delineation of the respective boundaries of the landfills. The two geophysical surveying techniques were implemented utilizing a semi-continuous profiling technique. North-south and east-west profiles were generated across the estimated area for each landfill by taking instrument readings at 10-foot intervals. Once a boundary position had been detected by either instrument and confirmed by the second instrument, the boundary location was staked. Using the results of the geophysical methods, estimates of each landfill boundary were completed.

1.4.2 Shallow Soil Gas Survey

A shallow soil gas survey was performed at Fort Story Site 4, the Firefighter Training Area. The purpose of the survey was to delineate possible areas of significant soil and groundwater contamination at the site. Shallow soil gas investigation usually involves pumping a small amount of soil gas from hollow probes driven into the ground and analyzing the gas for the presence of volatile organic compounds (VOCs). The presence of VOCs in shallow soil gas indicates that the observed compounds may either be in the vadose zone near the probe or in groundwater below the probe. Results of the investigation were used as an aid in siting the six soil borings and three monitoring wells installed at the site.

The shallow soil gas survey was performed utilizing a field van outfitted with required sampling tools and a gas chromatograph (GC). The sampling procedure involved advancing the soil gas sampling probes into the ground. The probes consisted of seven-foot lengths of three-quarter-inch diameter hollow steel pipe fitted with detachable drive tips. Once inserted into the ground, the above-ground end of the sampling probes were fitted with a steel reducer and a length of polyethylene tubing leading to a vacuum pump. A vacuum gauge monitored gas flow to maintain an adequate flow. The field van contained all equipment required to insert and withdraw the subsurface sampling probes. Gasoline-powered generators provided the electrical power required to operate the analytical instrumentation.

Prior to sampling, the volume of air within the probe and pumping system were purged using two to five liters of gas. During the soil gas evacuation, samples were collected in a glass syringe by inserting the syringe needle through a silicone rubber segment in the evacuation line and down into the steel probe. This procedure avoided contact between the sample analyzed and the silicone tubing. Each sampling event involved the collection of 10 milliliters of gas by the described means, followed immediately by analysis of the sample using the field van GC.

The GC is a two-staged instrument, incorporating a gas chromatograph column and detector device. The soil gas sample is introduced to the GC column through an injection port in the GC column. The temperature in the GC column is then slowly increased so that successively higher boiling point compounds are vaporized and carried into the detector device. Several detector devices exist, but one of the most commonly used for soil gas surveys is a flame ionization detector (FID) and an electron capture detector (ECD).

The FID was used for the analysis of gasoline-range hydrocarbons including benzene, toluene, ethylbenzene, xylenes, and total hydrocarbons. The ECD was used for the analysis of chlorinated organics including 1,1,1-trichloroethane (TCA), trichloroethene (TCE), and tetrachloroethene (PCE). The retention time in the GC column compared to known calibration standards identified compounds detected in soil gas samples. Instrument calibration checks were run periodically throughout the sampling period and system blanks were run at the beginning of the sampling period to check for contamination in the soil gas sampling equipment. Ambient air samples were also routinely analyzed to check for background levels of the analyzed compounds. Results of the Soil Gas Survey conducted by Tracer Research Corporation appear in Appendix D.

1.4.3 Soil Investigation

Forty-eight soil borings and 26 monitoring well borings were drilled to obtain soil samples for chemical and lithologic analyses at the seven PA/SI sites and one NIKE PA/SI site at Fort Story. Most of the borings were completed using the hollow-stem auger drilling technique. Hollow-stem augering involves construction of the borehole by simultaneously rotating and axially advancing the auger column into unconsolidated or poorly consolidated formations. The auger flights convey the cuttings produced by the lead auger upward to the surface. Augers having inside diameters (ID) and outside diameters (OD) of 4.25 and 8.25 inches, respectively, were used for drilling. When the borehole met a desired sampling depth, sampling tools were inserted through the axis of the hollow stem column. The formation sample was then obtained by driving a split-spoon sampler into the formation materials. Both two-inch and three-inch diameter split-spoon samplers, driven by a 140-pound hammer, were utilized in the soil investigation for this project. A hand auger was used to collect soil boring samples in areas where the terrain did not accommodate a drill rig.

Hollow-stem auger drilling in non-cohesive formation materials at depths greater than the water table may result in the movement of formation materials through the opening in the lead auger. The addition of water to the auger column during drilling is often used to mitigate this condition. During drilling of several soil borings at Fort Story, sandy formation material moved into the auger column. The addition of minor amounts of water to the auger column during drilling sufficiently controlled this condition. Water used for drilling purposes was available from the potable water distribution system at Fort Story.

The drill rig, all drill pipe and sampling equipment were steam cleaned prior to use at each site. All drilling and sampling tools were steam cleaned between individual holes, and the rig was routinely examined for hydraulic fluid leaks. During all drilling operations, air quality in and near the open borehole was continuously monitored to ensure personnel health and safety, using a photoionization detector (PID).

Most soil samples were collected in a stainless-steel split-spoon sampler. The split-spoon sampler was opened upon retrieval from the borehole. Following a brief visual inspection by the field geologist, the samples to be analyzed for VOCs were immediately placed in four-ounce sample containers. In addition, a portion of soil was transferred to a plastic bag. The contents of the plastic bag were shaken vigorously and allowed to sit for 15 minutes, at which point the headspace was sampled with a PID to determine the presence of VOCs. The remaining soil from the split-spoon sampler was transferred to a stainless-steel bowl, and the appropriate sample containers were filled as specified in the *QCSP/FIP*.

The soil sampling procedures utilized when constructing soil borings at Site 5, Underground Fuel Storage Tanks, were designed to address the sampling of the most visibly contaminated depth intervals at a given boring location, based on field observations and field PID readings. This sampling procedure was utilized for all soil borings constructed at Fort Story Site 5. Site 5 soil borings include: SB-110A, SB-110B, SB-110C, SB-111A, S5-111B, and SB-111C. Soil

samples from these soil borings were collected continuously to the total depths of the borings. VOC samples were immediately collected from each split-spoon and jarred as described earlier. The remaining portion of the samples from each spoon were then temporarily stored on aluminum foil. After field PID screening of the soil samples from all depth intervals, selections of samples for laboratory analysis were made based on the relative magnitudes of the PID readings. The two samples exhibiting the highest PID readings were then shipped for laboratory analysis.

The hand auger, which was utilized to collect soil samples where the drill rig could not, consisted of a one-foot stainless-steel auger bit and barrel, five-foot extensions, and an insulated T-handle. The lengths of the auger extensions provided a means to determine the depth of the auger bit below the ground surface. When the desired sampling depth was reached, the hand auger was removed, and the auger bit, sample barrel and extension rods were decontaminated. The hand auger equipment was then reinserted into the borehole, and a sample at the required depth was collected in the sample barrel.

Following the removal of the sample, the contents of the barrel were emptied into a stainless-steel bowl. The samples to be analyzed for VOCs were immediately placed in the four-ounce sample containers, and a portion of the soil was collected for PID screening. All information relevant to PID readings, geologic strata, sampling depths, and air monitoring conditions were recorded on the boring log forms.

During the drilling of all soil borings and monitoring well borings, the field geologist prepared a lithologic log for the borehole by examining the formation material from the split-spoon sampler and the cuttings generated while drilling. All soils were classified using the Unified Soil Classification System (USCS). The geologist recorded on the boring logs lithologic data, PID screening data, standard penetration test (SPT) blow counts, and depths to distinct strata. The geologist also recorded on the boring log comments describing PID instrumentation, sampling irregularities or difficulties encountered during drilling. Boring logs developed during the Fort Story PA/SI and NIKE PA/SI are presented in the *FTSGID*. When the hand auger drilling method was used, SPT blow counts could not be collected and drums were not used to contain the low volumes of soil cuttings generated. The spoil material was returned to the bore hole at the completion of drilling.

Additional soil samples were also collected for quality assurance (QA) and quality control (QC) purposes. Field duplicate samples were collected to monitor QC throughout the project. The field duplicate samples were collected at the same time and from the same source as the original sample but were submitted to the laboratory separately to assess the overall consistency of the sampling and analytical program. Field duplicate samples, with the exception of those designated for VOC analysis, were composited prior to submittal to the laboratory. Matrix spike (MS) and matrix spike duplicate (MSD) samples were collected to evaluate the effect of the matrix on precision and accuracy.

Upon arrival at the laboratory, the MS/MSD samples were spiked with appropriate analytes and analyzed according to the referenced method. The relative percent difference between samples was calculated and used to assess analytical precision. Split samples, or QA samples, were collected to assess the interlaboratory analytical consistency and accuracy. The split samples were sent to the USACE Missouri River Division (MRD) laboratory for analysis. These results were compared to the JMM laboratory's results by MRD.

Sample packaging, shipping and chain of custody (COC) procedures followed the guidelines listed in the *USACE Sample Handling Protocol for Low, Medium and High Concentration Samples of Hazardous Waste* (USACE, 1988), as well as those guidelines presented in the *QCSP/FIP*. The sample for VOCs was the first sample taken from the split-spoon. The soil was removed with stainless-steel implements and placed in sample jars sealed with Teflon-lined caps. Headspace in

the jars was kept to a minimum. The samples were placed on ice for transportation to the appropriate laboratory for analysis. The remaining soil for all other analyses was then placed in a stainless-steel bowl, homogenized, and put in glass sample jars sealed with Teflon-lined caps. Each jar was labeled with the date, site location and requisite analyses. The jars were then sealed in zip seal storage bags and refrigerated prior to shipping off-site. COC forms were completed for each sample and included in the shipment to the laboratory.

Following the subsurface sample collection activities, the borings drilled using the hollow-stem auger were backfilled with a cement-bentonite grout mixture. The grout slurry was tremied into place using the inner annulus of the augers. The borings were cemented to surface and allowed to set overnight. The borings were checked for settlement the following day and, if necessary, additional grout was added to fill any depressions. Where applicable, the asphalt was repaired following the drilling and sampling activities.

Backfilling procedures for the borings drilled with the hand auger varied from the procedures described earlier. The small borehole diameter prevented the use of a tremie pipe. Based on the site conditions, the borehole was expected to remain open, and grout was introduced from the surface. Like the hollow-stem auger borings, the hand auger borings were checked for settlement the following day and additional grout was added as necessary.

1.4.4 Monitoring Well Installation Procedures

Twenty-six monitoring wells were drilled and installed at the seven PA/SI and one NIKE PA/SI site. This section covers monitoring well drilling and soil sampling procedures, construction of wells and well development.

1.4.4.1 Drilling and Soil Sampling. Monitoring wells were constructed using the hollow-stem augering drilling technique as described in the *QCSP/FIP*. The procedure for the collection of analytical soil samples from monitoring well borings was identical to the soil boring analytical soil sampling procedures outlined in the *QCSP/FIP*. Soil samples from the 26 monitoring well borings were not collected below the water table. The drilling operations, however, continued to the depth required for placement of the bottom of the well casing. Lithologic logging was completed for each monitoring well boring for the entire boring depth.

1.4.4.2 Monitoring Well Construction Procedures. Monitoring wells were completed by emplacing the well assembly and well gravel pack material through the axis of the auger string. The well assembly consisted of nominal two-inch-ID, schedule 40, potable water grade PVC pipe and well screen. Factory-slotted screens were utilized in the construction of all wells for this project. In addition, flush-joint threaded couplings were utilized for joining the well screen and riser pipe. A closed shoe was fitted to the bottom of the well screen to prevent the entry of foreign material into the well. PVC glues were not used during well construction.

The well screen slot size and filter pack grading used in the wells varied depending on site conditions. Either 0.020-inch or 0.010-inch screen slot sizes were utilized depending on lithology. Gravel pack gradings utilized include No. 1 and No. 2 filter sand. The No. 1 and No. 2 gradings are 90 and 98 percent retained, respectively, on a 0.020-inch slot screen.

Well screen slot size selection in the construction of wells at Fort Story depended on the lithology encountered within the screened interval. Sandy lithologies with and without a fine-grained fraction were encountered at Fort Story. The 0.020-inch slot screen and No. 2 filter sand were generally chosen for locations characterized by sandy formation materials that lacked a significant fine-grained fraction. Wells completed at locations having sandy lithologies with a fine-grained fraction generally utilized the combination of 0.010-inch screen and No. 1 filter sand.

Gravel pack material was emplaced around the wells to a depth of 2 feet above the top of the well screen. A two-foot thickness of bentonite pellets was then installed in the borehole annular space above the gravel pack material. Cement grout having a maximum of three percent bentonite was then installed to seal the well to ground level. At locations having water tables too shallow to allow the specified thicknesses of gravel pack and bentonite pellets, the well design was altered to maximize the thickness of the cement grout seal. In addition, an alignment test was performed on each well. The test consisted of verifying that a 10-foot section of PVC pipe with O.D. one-quarter-inch less than the I.D. of the well casing, could freely pass through the total depth of the well. The *FTSGID* presents well construction summary sheets that describe drilling method, personnel, elevations, well design, and well materials for each well constructed.

During the construction of the wells, precautions were taken to prevent the entrance of foreign material into the wells. If an interruption in work on the well occurred (e.g., an overnight shutdown), well openings were covered with PVC pipe end caps. After completion of each well, a permanent locking vented cap was installed. All wells were tagged with a metal identification plate indicating the well number, elevation, total depth and screened interval.

Above-ground and flush-mount type surface completions were utilized for the monitoring wells constructed. The choice of the surface completion utilized was generally based on land use considerations, as stipulated by the Installation. The thickness of the grout seal installed also affected the surface completion type selected for a given well. This parameter is a function of the depth of the water table. Flush-mount completions were utilized for wells that were otherwise specified to have surface completions, if the grout seal thickness was less than 3 feet. This alteration was necessary to ensure the structural integrity of the surface completion construction.

Above-ground surface completion involved construction of a concrete pad (3 feet by 3 feet by 4 inches) around the well casing. The well casing was extended approximately 3 feet above ground and enclosed in a larger diameter protective steel casing. Three steel bollard posts were then installed through the concrete pad at evenly spaced positions around the protective steel casing. Flush-mount completions involved the construction of a concrete pad sloping in all directions away from the well casing to prevent standing water from entering the well. The well casing was truncated just below ground level and enclosed in a steel meter box equipped with a steel flush mounted manhole cover. Flush-mounted wells in remote areas were equipped with a single bollard post installed through the concrete pad to ensure visibility. Pads at Site 4, the Firefighter Training Area, were reinforced with steel and were deeper than standard size (3 feet by 3 feet by 1 foot) to withstand large vehicles passing over them.

1.4.4.3 Monitoring Well Development Procedures. Monitoring wells were developed by air surging and hand bailing to remove fine-grained materials adjacent to the screened interval of the wells. Water generated by well development activities was collected in properly labeled, DOT-approved, 55-gallon drums. Decisions regarding disposal of development water will be based on the presence or absence of contamination as determined by analysis of the groundwater samples collected from the wells. Monitoring well development was performed as a two-phase process consisting of the initial development phase and the final development phase.

Initial development of the wells was performed by the drilling subcontractor after at least 48 hours had elapsed from the placement of the grout seal. The purpose of the initial development procedure was to ensure that the contractor had provided a viable well capable of producing water in sufficient volume for sampling purposes. Initial development generally involved surging the wells with compressed air. The compressor was equipped with an air filter to prevent the introduction of compressor oil into the wells. For wells installed at locations having a shallow water table [e.g., generally less then 2 feet below land surface (bls)], initial development was performed by hand bailing instead of air surging to preclude possible damage to grout seals. Development by hand

bailing involved plunging a bailer, 2 feet in length and 1 inch in diameter, up and down within the screened interval.

Final development of wells, which involved pumping, bailing, or pumping with bailing, was performed by JMM personnel and included the periodic monitoring of development water temperature, pH, conductivity and a final turbidity reading. Temperature and pH were determined using an Orion SA 250 temperature/pH meter. A Yellow Springs Instruments Model 33 conductivity/temperature meter was utilized for conductivity measurements. Turbidity measurements were obtained using a La Motte Model 2008 turbidity meter. Pumping was performed using a low capacity [0.5-2 gallons per minute (gpm)], gasoline-powered centrifugal pump. Intermittent bailing during final development pumping provided a means for removal of any sediment that passed through the well screen during pumping.

Development of the monitoring wells installed at Fort Story for the project resulted in the removal of an average 14.8 well volumes per well. This quantity is partitioned between an average of 3.0 well volumes per well for initial development and an average of 11.8 well volumes per well for final development. The larger than expected volumes of water generated during development were necessary in order to satisfy the parameter stabilization criteria and to maximize development water clarity. Detailed development information can be found in the *FTSGID*.

A water sample was taken at the end of the development process and stored in a Mason jar as a permanent record of the clarity of the final development water. A photographic record was also made for all of these samples, which is presented in the *FTSGID*.

For each of the wells installed for this project, development water was contained in appropriately labeled, 55-gallon DOT-approved drums. Upon completion of sampling activities at each site, the water drums were transported to a temporary containment area on the Installation. Based on the analytical results from the groundwater samples obtained from each of the wells, the contents of the respective drums are scheduled to be either disposed of at the Installation or stored at the Installation for eventual off-site disposal at an approved facility.

1.4.5 Groundwater Level Measurement

A Marine Moisture Flexidip product/water level indicator was used to obtain static water level measurements from each of the monitoring wells installed for this project. Measurement of the static water levels was performed prior to purging for groundwater sample collection. In addition, the static water levels in all of the Fort Story wells installed were measured during a 24-hour period on June 11, 1990.

In addition to measuring the static water level in each of the monitoring wells, the product/water indicator was utilized to detect the presence of floating product. The measured static water levels and free product thicknesses were recorded on the appropriate log sheets. After obtaining measurements in each well, the indicator probe and tape were decontaminated in accordance with the procedures specified in the *QCSP/FIP*.

1.4.6 Monitoring Well Sampling

Twenty-six monitoring wells were sampled at PA/SI and NIKE PA/SI sites at Fort Story. All sampling was performed during the period May 30 through June 10, 1990. Monitoring wells were sampled by determining the volume of water contained in the well, purging the required number of well volumes, measuring the variation of field parameters during purging, and collecting the groundwater sample. The well volume for each monitoring well is defined as the volume of water contained in the well screen, casing and gravel pack material as constrained by the measured static water level and total depth of the well. The purge volume is defined as the number of well

volumes required to be pumped from a well prior to collecting the groundwater sample. The *QCSP/FIP* specifies that the purge volume from all monitoring wells sampled for the project be equivalent to three well volumes.

Well volumes were calculated as the product of a well volume factor and the length of submerged well footage. The well volume factor represents the quantity of water contained per linear foot of submerged well (including well screen, casing and gravel pack). Calculations based on an 8.25-inch diameter borehole, two-inch casing diameter, and an assumed porosity of 30 percent for the gravel pack material produce a value of 0.95 gallons per foot for the well volume factor utilized in well volume calculations for Fort Story wells installed by JMM. The three existing monitoring wells sampled at Landfill 3 were installed by the U.S. Army Environmental Hygiene Agency (USAEHA) (USAEHA, 1987a). Because of uncertainty regarding the borehole diameters constructed for these wells, the diameter was conservatively estimated as 12 inches. The well volume factor calculated using a 12-inch diameter borehole, two-inch casing diameter, and an assumed gravel pack porosity of 30 percent is 1.88 gallons per foot. A well volume factor of 1.88 gallons per foot was therefore utilized for calculating the well volumes of the USAEHA-installed wells.

Measurements of the static water level and total depth of each monitoring well were required for the calculation of the respective well volumes. Water level and total depth measurements were obtained using a Marine Moisture Flexidip product/water level indicator. This device was decontaminated between wells using the procedures specified in the *QCSP/FIP*. Through visual displays and audible signals, this instrument indicates the air/non-aqueous phase interface and the non-aqueous/aqueous phase interface. Depth to floating product (if present), depth to water, total well depth, and respective purge volume were recorded on the well sample log. Sampling logs were completed for each well for each sampling event.

Purging of the Fort Story monitoring wells was performed using a Teflon bailer, 1 inch in diameter and 3 feet in length. Sterile nylon cord was utilized for lowering and withdrawing the bailer from the wells. The nylon cord was discarded following the sampling of each well. A discharge rate of approximately 2.0 gpm was obtained using bailing.

During purging operations, periodic field measurements of purge water temperature, pH and conductivity were obtained. Temperature and pH were determined using an Orion SA 250 pH meter. A Yellow Springs Instruments Model 33 conductivity meter was utilized for measurement of purge water conductivity. A La Motte 2008 turbidity meter was utilized for measurement of water turbidity. The measurements were obtained at each well with the initiation of purging and periodically thereafter as each well volume was withdrawn. Each of the measurements obtained was recorded on the respective sampling log for the given well and sampling event. Purging of the Fort Story monitoring wells required between three and five rounds of measurements, including a final round of measurements at the conclusion of purging activities. Additionally, a PID scan of the final purge water sample was performed to assess the presence of VOCs.

Following the withdrawal of the specified purge volumes, groundwater samples were obtained from the wells. The Teflon bailer used for purging was also used for collecting groundwater samples. Dissolved metals samples involved filtering water in the field. The filtering procedure involved first collecting a sufficient sample volume in a decontaminated two-liter amber glass bottle. Utilizing a peristaltic pump and a length of polyethylene tubing, the sample was then transferred through the filter and into the appropriate sample containers. The filter utilized was rated as retaining all particulate matter in excess of 0.45 micron. The pump and Teflon bailer were decontaminated following the collection of each groundwater sample. The polyethylene tubing and filter used in sampling a given well, however, were discarded before proceeding to the next well.

For each of the wells installed for this project, purge water was contained in appropriately labeled, 55-gallon, DOT-approved drums. Upon completion of sampling activities at each site, the purge water drums were transported to a temporary containment area on the Installation. Based on the analytical results from the groundwater samples obtained from each of the wells, the contents of the respective drums are scheduled to be either disposed of at the Installation or stored at the Installation for eventual off-site disposal at an approved facility.

1.4.7 In Situ Permeability Testing

In situ permeability tests were performed in each of the wells installed for this project. Test results provide information regarding the general magnitude of the hydraulic conductivity of the aquifer materials at the sites investigated. A slug testing procedure was utilized that included use of a 5 pounds per square inch gage (psig) pressure transducer and Hermit data logger. Enclosed 1-inch diameter stainless-steel bars of three-foot and six-foot lengths were used to displace a known volume of water in the wells. The bars, with all measuring tapes, water level indicators, and transducer equipment used in the testing, were decontaminated between wells using the standard decontamination procedures outlined in the *QCSP/FIP*.

The slug testing procedure first involved determining the static depth to water and the total depth of the well. The pressure transducer was then inserted into the well and the data logger was configured for direct reading of the transducer. Based on the water column thickness in the well, either the three-foot or six-foot slug bar was selected and submerged within the well water column. After placement of the bar, the transducer water level was viewed continually to monitor the receding of the well water level to the observed static level. After the attainment of static conditions in the well with the slug bar in place, the bar was rapidly withdrawn. At the same instant, the data logger was configured to begin recording water level data. Data collection continued until the well had stabilized to the observed static water level. Slug test data collected using the above procedure were then compiled and analyzed using the Bouwer method (Bouwer, 1978) and (Bouwer, 1989), as described in Section 2.2.1.3. The method selected is valid for use in wells that partially penetrate an unconfined aquifer and are screened through the water table. These conditions are characteristic of the wells installed for this project. The analysis of the slug test data is presented in the *FTSGID*.

1.4.8 Sediment Sampling

Twenty-nine sediment samples were collected at the Drainage Outfall Line (Site 8) from the manhole and catch basin drainage structures in the LARC area storm drainage system. Prior to the collection of samples, structure coverings such as storm gratings and manhole covers were removed and the headspace air within the structure was monitored for hazardous conditions. Air monitoring was performed for combustible gases, oxygen deficiency and VOCs. Upon gaining access to a structure, a sediment sample was collected from the location in the structure having the greatest depth of sediment. A decontaminated stainless-steel spatula was used for the collection of the sediment samples. Sampling was initiated with the collection of a VOC grab sample. The collection of samples for the remaining analytes was then performed by compositing the collected sediment in a stainless-steel mixing bowl prior to transferring the sample to the appropriate sample jars. Sample packaging, shipping and COC procedures sediment samples followed the procedures outlined in the *QCSP/FIP*.

1.4.9 Surveying

The newly installed monitoring wells and soil borings were surveyed to establish horizontal and vertical locations. The horizontal coordinates were surveyed from permanent site features using the Commonwealth of Virginia State Plane Coordinate System. The horizontal control was established to the nearest 0.5 foot. Vertical control was established using differential and

trigonometric levelling to the nearest 0.1 foot and referenced to the National Geodetic Vertical Datum of 1929 (NGVD). The surveying of top of pipe elevations were also conducted, with vertical control within 0.01 foot. Differential leveling for elevation measurement was conducted using a surveying quality level and rod. Trigonometric elevations were obtained with an electronic theodolite total station. Tables 1-2 and 1-3 contain the surveying results.

1.4.10 Equipment Decontamination Procedures

Strict decontamination procedures were followed during drilling and sampling activities to prevent cross-contamination. Before use, all drilling and sampling equipment was decontaminated by steam cleaning or by an Alconox wash, a tap water rinse, a methanol rinse and a double distilled water rinse. The drill pipe and drill tools were steam cleaned prior to drilling each boring. A designated area for decontamination was not provided by base personnel, and decontamination activities were conducted at each site. Sampling equipment, including split-spoon samplers, hand augers, stainless-steel mixing bowls, and stainless-steel mixing utensils, was cleaned using the Alconox wash procedures. Decontamination water from the sampling equipment was containerized at each site and handled as discussed in Section 1.4.4.3.

A sample of the source water used for decontamination activities was originally not collected during the PA/SI and NIKE PA/SI sampling. The source water consists of distilled water obtained from Water and Health, Inc. and potable water that was available at the Installation. The results of the source water analyses can be used to determine if contamination was introduced through the sample collection procedures as a result of poor water quality. The same source water, however, was used during the PA/SI activities at the LACV-30 Wetlands Maintenance Facility, i.e., the distilled water was obtained from the same vendor and the potable water from the same location as for this project. Samples of potable water and distilled water were collected for this project and analyzed for VOCs, base/neutral/acid extractable organic compounds (BNAs), pesticides, polychlorinated biphenyls (PCBs), total metals and dissolved metals. Therefore, the results presented in the *Analytical Results Report for the Preliminary Assessment/Site Investigation LACV-30 Maintenance Facility Wetlands Area* and the *Site Investigation/Decision Plans and Specifications for Underground Storage Tank Removal Atlantic Street Gas Station, Fort Story, Virginia* (JMM, 1991h) for Installation water and distilled water samples should provide a general indication of the quality of the source water used for the earlier projects.

Table 1-4 contains a summary of the results from the source water samples. Chloroform and dichlorobromomethane were detected in the distilled and Installation water samples. These compounds are known chlorinated byproducts from the water treatment process. Zinc was detected in the total metals and dissolved metals analyses of tap water available from the Installation. The results for zinc show that the concentration of dissolved zinc was greater than for total zinc. This could have been due either to the samples being switched in the field or as a function of laboratory preparation and analysis methods. This may have contributed to the detection of zinc in the PA/SI and NIKE PA/SI water samples.

1.4.11 Health and Safety

As mentioned in Section 1.3.2, a *SHERP* was developed to provide guidelines and stipulate procedures for protecting site personnel and the environment during the investigation. The requirements outlined in the *SHERP* were followed by all personnel on the site during the field program.

An exclusion zone was established around all work areas. Traffic cones and construction ribbon were used to delineate the exclusion zone. All personnel working on site had fulfilled the training requirements specified in *Hazardous Waste Operations and Emergency Response*, 29 CFR 1910.120 (OSHA, 1989).

TABLE 1-2

SURVEYING RESULTS - MONITORING WELLS
FORT STORY, VIRGINIA

Site	Location	Ground Elevation (ft., NGVD)[c]	TOC[b] (ft., NGVD)	VSPCS[a] Northing	VSPCS[a] Easting
1	MW-101	21.9	24.44	224437.5720	2727239.0070
	MW-102	8.97	8.69	224682.3580	2726951.5810
	MW-103	28.3	30.53	224465.2600	2726979.4320
	MW-104	19.5	22.21	224659.8340	2727117.5340
2	MW-105	16.89	16.56	223866.4310	2724570.7300
	MW-106	9.75	9.52	223740.8530	2724355.4450
	MW-107	10.84	10.60	223368.2810	2724613.9660
	MW-108	9.29	8.98	223040.2080	2724645.2320
	MW-109	10.07	9.68	223184.1330	2725537.1600
4	MW-110	13.79	13.51	223776.7480	2720739.3130
	MW-111	14.03	13.83	223674.4830	2720726.1650
	MW-112	14.00	13.74	223835.8010	2721089.0720
5	MW-113A	16.02	15.78	223783.7250	2721238.5610
	MW-113B	13.46	13.25	223903.3780	2721066.5840
	MW-114A	16.46	19.59	223838.1320	2721181.3430
	MW-114B	17.83	17.56	223985.5030	2721279.7390
6	MW-115	10.00	9.36	225998.0990	2724411.0470
	MW-116	10.04	9.77	226023.0220	2724537.2700
	MW-117	13.97	16.00	225436.8720	2724496.3220
	MW-118	13.71	13.24	225250.7320	2724498.5080
7	MW-119	12.87	12.47	224825.0180	2728717.7190
	MW-120	15.59	15.21	224724.7010	2728729.2480
8	MW-121	7.06	9.92	226669.2050	2724327.2000
9	MW-401	49.24	48.91	224060.0240	2725156.7320
	MW-402	34.50	34.19	224407.6660	2725123.8060
	MW-403	48.78	48.49	224519.3820	2725592.1040

(a) Commonwealth of Virginia State Plane Coordinate System (VSPCS)
(b) TOC = top of casing
(c) National Geodetic Vertical Datum of 1929 (NGVD)

TABLE 1-3

SURVEYING RESULTS - SOIL BORINGS
FORT STORY, VIRGINIA

Site	Location	Ground Elevation (ft., NGVD)[b]	VSPCS[a] Northing	VSPCS[a] Easting
4	SB-101	10.25	224370.4610	2720870.9310
	SB-102	10.36	224142.1810	2720539.4150
	SB-103	10.25	224121.6960	2720756.8440
	SB-104	10.80	224193.8450	2720944.9210
	SB-105	11.64	223921.2440	2720525.4260
	SB-106	12.48	223971.8520	2720938.8380
	SB-107	13.58	223761.2680	2720690.1420
	SB-108	13.49	223736.9060	2720597.7290
	SB-109	13.67	223917.0180	2721048.6020
5	ESB-1	14.90	223916.4730	2721118.2570
	ESB-2	16.23	223923.9510	2721117.4830
	ESB-3	15.30	223895.3940	2721125.4700
	ESB-4	17.27	223898.2930	2721152.7130
	ESB-5	17.27	223975.3120	2721109.6600
	ESB-6	13.65	223893.0750	2721071.3990
	ESB-7	17.63	223991.8750	2721288.6950
6	SB-112	7.69	226178.1630	2724432.5590
	SB-113	8.98	226175.4130	2724560.6600
	SB-114	9.72	226161.5150	2724690.9860
	SB-115	9.01	226101.1650	2724446.0000
	SB-116	9.45	226092.5370	2724572.7700
	SB-117	11.05	226093.2350	2724730.8040
	SB-118	11.83	226030.0770	2724676.5230
	SB-119	12.14	226028.4520	2724757.9250
	SB-120	11.65	225950.5790	2724553.4800
	SB-121	11.96	225956.0300	2724590.9880
	SB-122	13.66	225403.4730	2724495.0220
	SB-123	14.29	225341.9750	2724503.3840
7	SB-124	13.61	224795.1880	2728692.3900
	SB-125	13.86	224790.3390	2728681.3040
	SB-126	14.14	224783.5790	2728687.8770
	SB-127	14.32	224777.7700	2728698.8420
	SB-128	15.40	224747.2620	2728666.7810
	SB-129	15.42	224733.4330	2728626.7790
	SB-130	15.71	224706.8960	2728648.7000
	SB-131	16.11	224645.4680	2728773.0080
8	SB-132	4.50	226655.3580	2724216.9800
	SB-133	4.60	226658.9730	2724055.4050

TABLE 1-3
(Continued)

SURVEYING RESULTS - SOIL BORINGS
FORT STORY, VIRGINIA

Site	Location	Ground Elevation (ft., NGVD)[b]	VSPCS[a] Northing	VSPCS[a] Easting
9	SB-401	48.38	224235.0560	2724902.2380
	SB-402	48.31	224257.4900	2725070.7790
	SB-403	51.80	224287.4270	2725491.5240
	SB-404	49.58	224270.1760	2725623.0030
	SB-405	49.58	224299.2010	2725687.0630
	SB-406	49.50	224352.7730	2725792.7690
	SB-407	49.50	224288.5250	2725884.1860
	SB-408	50.80	224431.4720	2725623.5480
BB[c]	SB-134	4.70	225533.3540	2718452.6460
	SB-135	58.15	221239.9020	2730431.4870
	SB-136	20.40	227047.7020	2722174.6230

(a) Commonwealth of Virginia State Plane Coordinate System (VSPCS)
(b) National Geodetic Vertical Datum of 1929 (NGVD)
(c) BB = Background Borings

TABLE 1-4

SOURCE WATER ANALYTICAL RESULTS

Type of Source Water	Analysis	Compound	Concentration
Distilled	VOC	Chloroform	68 µg/l
Distilled	VOC	Dichlorobromomethane	14 µg/l
Installation	VOC	Chloroform	74 µg/l
Installation	VOC	Dichlorobromomethane	13 µg/l
Installation	Total Metals	Zinc	0.66 mg/l
Installation	Dissolved Metals	Zinc	1.0 mg/l

A PID meter was used to monitor the presence of organic vapors potentially emanating from the soil samples, the borehole, and in the breathing zone of the workers. Hearing protection was always available. All personnel wore hardhats, steel-toed boots and nitrile gloves when handling any drill cuttings, soil samples or groundwater.

All intrusive activities at Fort Story were done with personnel donned in Level D protection. Although JMM was prepared to do work in Level C, PID readings taken during the work effort did not exceed the permissible levels for Level D as delineated in the *SHERP*.

2.0 ASSESSMENT OF CONTAMINATION

Work was performed at Fort Story as described in JMM's *Final Quality Control and Sampling Plan/Field Investigation Plan (QCSP/FIP)* (JMM, 1990a). This section evaluates the environmental contamination detected at each of the Fort Story Preliminary Assessment/Site Investigation (PA/SI) sites. Initially, analytical data from field samples are summarized and appropriate trigger levels for site media are presented. The investigatory activities performed at each of the sites are then discussed with a media-specific discussion of the significance of the contamination. The significance of environmental contamination is assessed based on a comparison of the analytical results with the defined trigger levels.

2.1 INTRODUCTION

The Fort Story investigation addressed seven PA/SI sites, one NIKE PA/SI site and three background soil boring sites involving the collection and analysis of groundwater, soil and sediment samples. Seventy-six soil borings, including 28 borings for monitoring well installations, were drilled and sampled. Boring depths ranged from 3 to 47 feet and averaged 16 feet. All wells and some borings were drilled using a hollow stem auger. Some borings were installed using a hand auger, as indicated in the text. With the exception of Site 5, the Underground Fuel Storage Tank Farm, lithologic sampling in all borings was conducted at regular five-foot intervals in addition to specific depths where analytical samples were collected. Collection of the five-foot interval samples provided lithologic control at each of the boring locations. Samples were collected continuously from six of the 10 soil borings installed at Site 5.

Table 2-1 presents a summary of the samples collected at each site. Sampling activities for all matrices, with the exception of groundwater, were performed during late March and early April 1990. Groundwater sampling was performed during the period May 30 through June 10, 1990. Appendix B presents the rationale used for selecting sampling locations.

2.1.1 Overview of the Analytical Program

Analytical samples were collected for soil, sediment and groundwater matrices during the Fort Story field effort. These samples were analyzed for a broad array of chemical compounds. Table 2-2 presents analytical methods used to analyze project samples. Table 2-3, Table 2-4, and Table 2-5 identify which general types of analyses were performed on the soil, groundwater and sediment samples, respectively, from each site. Laboratory analytical reports were included in the *Preliminary Summary Site Data Report , Fort Story, Virginia* (JMM, 1990c). Method Reporting Levels for all analytes discussed in this report can be found in the *Fort Story Final Analytical Results Document (FTSFARD)* (JMM, 1991c), a companion document to this report.

With the exception of the total fuel hydrocarbon (TFH) analysis, analytical methods are described in *Test Methods for Evaluating Solid Waste, EPA SW-846* [U.S. Environmental Protection Agency (EPA), 1986] or in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1989). The TFH method is a modified version of EPA Method 8015 and is described in the State of California document *Leaking Underground Fuel Tank Manual -- Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure* (CA LUFT) (State of California, 1989). Two distinct procedures were used to isolate a specific TFH analysis function: (1) a headspace procedure for measurement of short chain carbon compounds (generally compounds with 10 or fewer carbon atoms), which isolates the light TFH fraction, and (2) an extraction procedure for measurement of longer chain compounds (generally compounds between 10 and 30 carbon atoms), which isolates the heavy fraction. The analysis of the light or heavy TFH fraction is referenced as TFH-L and TFH-H, respectively.

TABLE 2-1

FORT STORY SAMPLES

Site No.	Site Name	Soil Matrix		Sediment Matrix		Groundwater Matrix	
		Samples	QC[a]	Samples	QC[a]	Samples	QC[b]
PA/SI Project:							
1	Landfill 1	12	1	0	0	4	1(3)
2	Landfill 2	10	1	0	0	5	1(3)
4	Firefighter Training Area	24	1	0	0	3	1(3)
5	Underground Fuel Storage Tank Farm	20	1	0	0	4	1(3)
6	LARC Maintenance Area	32	3	0	0	4	1(3)
7	Auto Craft Building	20	2	0	0	2	1(3)
8	Drainage Outfall Line	2	0	29	3	1	1(2)
	Background Borings	6	1	0	0	0	0
NIKE PA/SI Project:							
9	Fort Story NIKE Facility	16	2	0	0	3	1(3)
	TOTALS	142	12	29	3	26	8(23)

(a) QC samples designate field duplicate samples.
(b) QC samples designate field duplicate, rinsate blank or trip blank samples.
1(3) = 1 set of QC samples collected, comprised of a duplicate, a rinsate blank and a trip blank.

TABLE 2-2

ANALYTICAL METHOD REFERENCES FOR FORT STORY PA/SI SAMPLES

Analyte	Soil Matrix Method Number		Water Matrix Method Number		Product Matrix Method Number		Reference
	Digestion	Analysis	Digestion	Analysis	Digestion	Analysis	
VOCs[a]	—	8240	—	8240	—	—	SW-846[b]
BNAs[c]	3550	8270	3510	8270	—	—	SW-846
Pesticides	3550	8080	3510	8080	—	—	SW-846
PCBs	3550	8080	3510	8080	3510	8080	SW-846
Fuel Hydrocarbons	—	8015 (mod.)	—	8015 (mod.)	—	8015 (mod.)	CA LUFT[d]
Total Cyanide	—	9012	—	9012	—	—	SW-846
Total Solids	—	2540A[e]	—	—	—	—	Standard Methods[f]
Anions							
Fluoride	—	—	—	4500F	—	—	Standard Methods
Chloride	—	—	—	4110	—	—	Standard Methods
Sulfate	—	—	—	4110	—	—	Standard Methods
Nitrate	—	—	—	4110	—	—	Standard Methods
Nitrite	—	—	—	4110	—	—	Standard Methods
Total and Dissolved Metals							
Antimony	3050	6010	3005	6010	—	—	SW-846
Arsenic	3050	6070	3005	7060	3050	7060	SW-846
Barium	3050	6010	3005	6010	—	—	SW-846
Beryllium	3050	6010	3005	6010	—	—	SW-846
Cadmium	3050	6010	3005	6010	3050	6010	SW-846
Chromium, Total	3050	6010	3005	6010	3050	6010	SW-846
Copper	3050	6010	3005	6010	—	—	SW-846
Lead	3050	7421	3005	7421	3050	7421	SW-846
Mercury	—	7471	—	7470	—	—	SW-846
Nickel	3050	6010	3005	6010	—	—	SW-846
Selenium	3050	7740	3005	7740	—	—	SW-846
Silver	3050	6010	3005	6010	—	—	SW-846
Thallium	3050	7841	3005	7841	—	—	SW-846
Zinc	3050	6010	3005	6010	—	—	SW-846
EP Toxicity Metals							
Arsenic	1310	7060	—	—	—	—	SW-846
Barium	1310	6010	—	—	—	—	SW-846
Cadmium	1310	6010	—	—	—	—	SW-846
Lead	1310	6010	—	—	—	—	SW-846
Mercury	1310	7670	—	—	—	—	SW-846
Selenium	1310	7740	—	—	—	—	SW-846
Silver	1310	6010	—	—	—	—	SW-846

(a) EPA Method 8240 was modified to include a capillary column for analysis of all VOC compounds.
(b) EPA, 1986, *Test Methods for Evaluating Solid Waste SW-846. 3rd ed.*
(c)) EPA Method 8270 was used to analyze all BNA compounds. Sample cleanup was performed as necessary to obtain appropriate detection limits.
(d) State of California, 1989, *Leaking Underground Fuel Tank Manual.* Method 8015 (modified) includes TFH-L and TFH-H.
(e) Sample results were reported on an as-received basis with subsequent reporting of the total solids value.
(f) APHA, AWWA, and WPCF,1989, *Standard Methods for the Examination of Water and Wastewater.*

TABLE 2-3

FORT STORY ANALYSIS SUMMARY
SOIL SAMPLES

Site Number	Boring Number	Pesticides/ PCBs	VOCs	BNAs	Total Metals	EP Tox	TFH H	TFH L	BTEX	Cyanide	Total Solids
1	MW-101	X	X	X	X	X				X	X
	MW-102	X	X	X	X	X				X	X
	MW-103	X	X	X	X	X				X	X
	MW-104	X	X	X	X	X				X	X
2	MW-105	X	X	X	X	X				X	X
	MW-106	X	X	X	X	X				X	X
	MW-107	X	X	X	X	X				X	X
	MW-108	X	X	X	X	X				X	X
	MW-109	X	X	X	X	X				X	X
4	MW-110	X	X	X	X		X				X
	MW-111	X	X	X	X		X				X
	MW-112	X	X	X	X		X				X
	SB-101	X	X	X	X			X			X
	SB-102	X	X	X	X			X			X
	SB-103	X	X	X	X			X			X
	SB-104	X	X	X	X			X			X
	SB-105	X	X	X	X			X			X
	SB-106	X	X	X	X			X			X
	SB-107	X	X	X	X			X			X
	SB-108	X	X	X	X			X			X
	SB-109	X	X	X	X			X			X
5	MW-113				X		X	X	X		X
	MW-114				X			X	X		X
	SB-110A				X			X	X		X
	SB-110B				X			X	X		X
	SB-110C				X			X	X		X
	SB-111A				X			X	X		X
	SB-111B				X			X	X		X
	SB-11C				X			X	X		X
6	MW-115	X	X	X	X		X				X
	MW-116	X	X	X	X		X				X
	MW-117	X	X	X	X		X				X
	MW-118	X	X	X	X		X				X
	SB-112	X	X	X	X		X				X
	SB-113	X	X	X	X		X				X
	SB-114	X	X	X	X		X				X
	SB-115	X	X	X	X		X				X
	SB-116	X	X	X	X		X				X
	SB-117	X	X	X	X		X				X
	SB-118	X	X	X	X		X				X
	SB-119	X	X	X	X		X				X

TABLE 2-3 (Continued)

FORT STORY ANALYSIS SUMMARY
SOIL SAMPLES

Site Number	Boring Number	Pesticides/ PCBs	VOCs	BNAs	Total Metals	EP Tox	TFH H	TFH L	BTEX	Cyanide	Total Solids
6 (cont.)	SB-120	X	X	X	X		X				X
	SB-121	X	X	X	X		X				X
	SB-122	X	X	X	X		X				X
	SB-123	X	X	X	X		X				X
7	MW-119	X	X	X	X		X				X
	MW-120	X	X	X	X		X				X
	SB-124	X	X	X	X		X				X
	SB-125	X	X	X	X		X				X
	SB-126	X	X	X	X		X				X
	SB-127	X	X	X	X		X				X
	SB-128	X	X	X	X		X				X
	SB-129	X	X	X	X		X				X
	SB-130	X	X	X	X		X				X
	SB-131	X	X	X	X		X				X
8	SB-132	X	X	X	X		X				X
	SB-133	X	X	X	X		X				X
9	MW-401	X	X	X	X		X			X	X
	MW-402	X	X	X	X		X			X	X
	MW-403	X	X	X	X		X			X	X
	SB-401	X	X	X	X		X			X	X
	SB-402	X	X	X	X		X			X	X
	SB-403	X	X	X	X		X			X	X
	SB-404	X	X	X	X		X			X	X
	SB-405	X	X	X	X		X			X	X
	SB-406	X	X	X	X		X			X	X
	SB-407	X	X	X	X		X			X	X
	SB-408	X	X	X	X		X			X	X
Background Borings	SB-134	X	X	X	X						X
	SB-135	X	X	X	X						X
	SB-136	X	X	X	X						X

VOCs - volatile organic compounds
BNAs - base/neutral/acid extractables
TFH - total fuel hydrocarbons
BTEX - benzene, toluene, ethylbenzene and xylenes
PCBs - polychlorinated biphenyls

TABLE 2-4

FORT STORY ANALYSIS SUMMARY
GROUNDWATER SAMPLES

Site Number	Well ID	Pesticides/ PCBs	VOCs	BNAs	Total Metals	Dissolved Metals	TFH H	TFH L	BTEX	Cyanide	Anions
1	GW-101	X	X	X	X	X				X	X
	GW-102	X	X	X	X	X				X	X
	GW-103	X	X	X	X	X				X	X
	GW-104	X	X	X	X	X				X	X
2	GW-105	X	X	X	X	X				X	X
	GW-106	X	X	X	X	X				X	X
	GW-107	X	X	X	X	X				X	X
4	GW-110	X	X	X	X			X			
	GW-111	X	X	X	X			X			
	GW-112	X	X	X	X			X			
5	GW-113A				X	X		X	X		
	GW-113B				X	X		X	X		
	GW-114A				X	X		X	X		
	GW-114B				X	X		X	X		
6	GW-115	X	X	X	X	X	X				
	GW-116	X	X	X	X	X	X				
	GW-117	X	X	X	X	X	X				
	GW-118	X	X	X	X	X	X				
7	GW-119	X	X	X	X	X	X				
	GW-120	X	X	X	X	X	X				
8	GW-121	X	X	X	X	X	X				
9	GW-401	X	X	X	X	X	X				
	GW-402	X	X	X	X	X	X				
	GW-403	X	X	X	X	X	X				

VOCs - volatile organic compounds
BNAs - base/neutral/acid extractables
TFH - total fuel hydrocarbons
BTEX - benzene, toluene, ethylbenzene and xylenes
PCBs - polychlorinated biphenyls

TABLE 2-5

FORT STORY ANALYSIS SUMMARY
SEDIMENT SAMPLES

Site Number	Location	Pesticides/ PCBs	VOCs	BNAs	Total Metals	TFH H	TFH L	Total Solids
8	SD-102	X	X	X	X	X		X
	SD-103	X	X	X	X	X		X
	SD-104	X	X	X	X	X		X
	SD-105	X	X	X	X	X		X
	SD-106	X	X	X	X	X		X
	SD-107	X	X	X	X	X		X
	SD-108	X	X	X	X	X		X
	SD-109	X	X	X	X	X		X
	SD-110	X	X	X	X	X		X
	SD-111	X	X	X	X	X		X
	SD-112	X	X	X	X	X		X
	SD-113	X	X	X	X	X		X
	SD-114	X	X	X	X	X		X
	SD-115	X	X	X	X	X		X
	SD-117	X	X	X	X	X		X
	SD-118	X	X	X	X	X		X
	SD-119A	X	X	X	X	X		X
	SD-120	X	X	X	X	X		X
	SD-121	X	X	X	X	X		X
	SD-122	X	X	X	X	X		X
	SD-123	X	X	X	X	X		X
	SD-124	X	X	X	X	X		X
	SD-125	X	X	X	X	X		X
	SD-131	X	X	X	X	X		X
	SD-132	X	X	X	X	X		X
	SD-133	X	X	X	X	X		X
	SD-134	X	X	X	X	X		X
	SD-135	X	X	X	X	X		X

VOCs - volatile organic compounds
BNAs - base/neutral/acid extractables
TFH - total fuel hydrocarbons
PCBs - polychlorinated biphenyls

The project analytical program for soil samples was designed to identify a variety of chemical contaminants. The analytical parameters were selected based on contamination that was either known or suspected to be encountered at each site. With the exception of samples collected at Site 5, the Underground Fuel Storage Tank Farm, all soil samples were analyzed for volatile organic compounds (VOCs), base, neutral and acid extractable compound (BNA) compounds, pesticides and polychlorinated biphenyls (pesticides/PCBs), priority pollutant metals, and total solids. Samples at several sites were also analyzed for EP Toxicity (EP Tox), cyanide and TFH. Site 5 soil samples were analyzed for benzene, toluene, ethylbenzene and xylene (BTEX); TFH and total lead. All sediment samples were analyzed for standard parameters: total metals, BNAs, pesticides/PCBs, VOCs, TFH and total solids. All groundwater samples were analyzed for VOCs, BNAs, pesticides/PCBs, total and dissolved priority pollutant metals, total cyanide, and common anions.

JMM Laboratories performed most of the chemical analyses for the Fort Story PA/SI and NIKE PA/SI projects. In some cases, however, JMM Laboratories was unable to meet the sample holding times as specified in the *QCSP/FIP*. As a result, 41 of 1,050 analyses, representing approximately four percent of the total Fort Story analyses performed, were performed outside holding times. Because the analytical results for these 41 samples may underestimate the true values, all positive results and quantitation limits for non-detect results were considered estimated data for these samples. As a corrective action, 12 of the 41 samples analyzed outside holding times were recollected and analyzed within the holding times. The selection of the resampling locations was based on JMM's professional judgement after considering these factors:

- the results of the samples analyzed past the holding times
- analytical results for other samples collected at the site
- magnitude of the holding time delay
- the significance of the sample

The U.S. Army Corps of Engineers (USACE) approved JMM's proposed resampling locations. The resampling effort increased the number of valid sample analyses to a level that is considered acceptable.

A detailed review of the validity of project analytical data for the Fort Story field effort is provided in JMM's *Quality Control Summary Report (QCSR)* (JMM, 1991c). The *QCSR* includes the results of the data review procedures, documents laboratory nonconformance with respect to holding time problems and where field and laboratory quality control samples did not meet project Data Quality Objectives (DQO). It also provides an explanation for resampling at each site. JMM submitted the *QCSR* to the USACE on February 25, 1991. The USACE has approved the project data for use in site contamination assessments.

The *FTSFARD* provides analytical results obtained from the soil, groundwater and sediment samples collected at Fort Story for the PA/SI investigation. Only those compounds that were positively detected at one of the sampling points at a given site instead of the full range of analytes are presented in the *FTSFARD*. Soil samples are designated by the prefix of (SB) or (MW) in combination with a unique sequential corresponding to the appropriate soil boring (SB) or monitoring well (MW) boring, respectively, from which the soil sample was collected. In addition, soil sample identifiers are suffixed with a number enclosed in parentheses to indicate the depth of sample collection. Groundwater and sediment samples are designated using the prefixes (GW) and (SD), respectively, together with a unique sequential number. The GW sample number corresponds directly with the associated monitoring well (i.e., GW-104 was collected from MW-104). In addition, samples from all media are prefixed with an (S) to symbolize Fort Story

and the appropriate site number. For example, the generic designation for a soil sample collected from a monitoring well is as follows: S(site number)MW(associated number)(sample depth), e.g., S12MW104(0).

2.1.2 Identification of Trigger Levels

The analytical results from the Fort Story PA/SI sites and NIKE PA/SI field investigations were utilized to evaluate site specific contamination and the need for further investigations at the sites. To provide a basis for evaluating the data, media-specific trigger levels were developed for each of the analytes detected. The trigger levels are based on statistically-significant site background data and regulatory standards promulgated by the EPA or the Commonwealth of Virginia for the chemicals of concern.

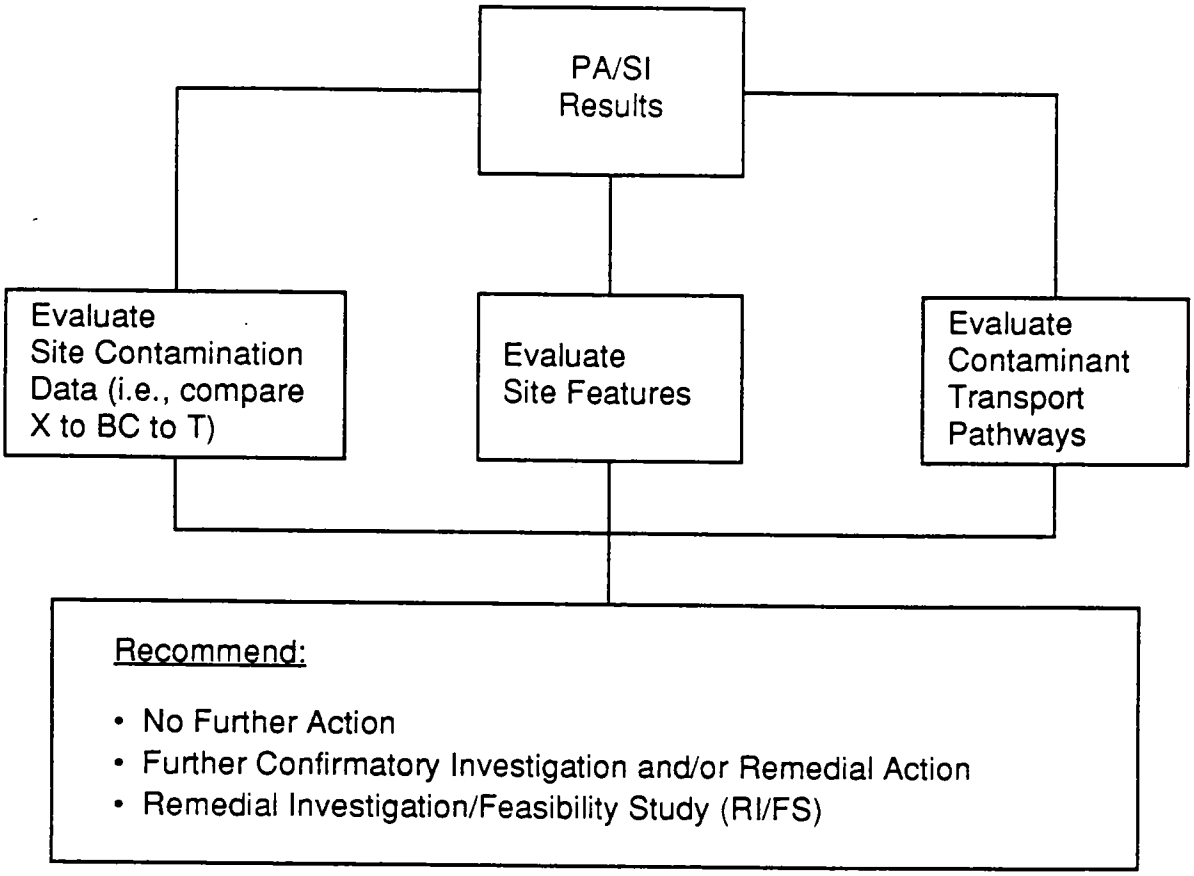
The selection of the type of further investigation that is appropriate for a given PA/SI or NIKE PA/SI site is based on comparison of analytical results to trigger levels for compounds of concern, evaluation of contaminant transport pathways for compounds of concern and consideration of pertinent site features. The assessment of site contamination data involved comparison of contaminant concentrations measured in site media to appropriate background concentrations and/or trigger levels. This interpretation is not strictly quantitative, however. For example, if one contaminant is detected at a level above the trigger level in the groundwater from an isolated monitoring well, this factor would not necessarily constitute recommending further investigative activity. However, if the presence of this contaminant in the groundwater was indicative of the presence of a plume or a source at the site, further study would be recommended. Other data, such as site features and contaminant transport pathways, are relevant for consideration in this context and in those instances where multiple site contaminants are present in site media at levels above background but below trigger levels. Figure 2-1 is a matrix showing the decision and recommendation process for PA/SI sites. The possible additional site activities presented in order of increasing levels of effort required are:

- **No Further Action**: This option may be recommended for a PA/SI site when analyte concentrations in site environmental media are below the background concentrations. In this instance, trace levels of environmental contamination imply that any potential contaminant transport at or near the site would be insignificant.

- **Further Confirmatory Investigation and/or Removal Action**: This option may be recommended for a PA/SI site when concentrations of a limited number of compounds of concern in site environmental media are above the trigger levels. Additional confirmatory investigation might focus on particular media, compounds of concern or site locations in an attempt to verify existing data. Removal action denotes mitigation of possibly contaminated material or media present at a PA/SI site to reduce or eliminate potential contaminant transport.

- **Remedial Investigation/Feasibility Study (RI/FS)**: This option may be recommended for a PA/SI site when concentrations of many compounds of concern in site environmental media are above the corresponding trigger levels or when data possibly indicate the presence of a contaminated groundwater plume. An RI/FS involves focused additional investigation at a site to confirm source areas and delineate the nature and extent of environmental contamination. An RI/FS provides additional data necessary for estimating exposure concentrations and dosages and predicting health or environmental risks associated with exposure.

The trigger levels represent a mechanism to screen each of the sites for the purpose of determining whether there is sufficient cause to warrant further inquiry into site conditions. As such, they are generally not intended to be action levels in a regulatory sense.



X = Detected Concentration of Analyte
BC = Background Concentration of Analyte
T = Trigger Level Concentration of Analyte

JMM

Site Evaluation and Recommendation Decision Matrix

Figure 2-1

The following sections discuss how the trigger levels are developed.

2.1.2.1 Soil. To date, regulatory standards have not been promulgated by federal or state authorities for most of the soil contaminants detected at Fort Story. As such, TFH and PCBs represent the only analytes that have regulatory-based trigger levels. The trigger levels for metals in soil were derived from a statistical analysis of the background boring results. No trigger level has been set for VOCs, BNAs or cyanide. DDT, DDD, DDE and Chlordane, while not having any set regulatory levels for soil, represent particular analytes that were widely used throughout the Installation in the past and warrant special consideration, as discussed below.

Total Fuel Hydrocarbons (TFH). Contaminant-specific guidelines for hydrocarbons in soil are provided in *Underground Storage Tanks; Technical Standards and Corrective Action Requirements VR-680-13-02* (Commonwealth of Virginia, 1989). Based on these regulations, any contaminated soil exhibiting a total fuel hydrocarbon level in excess of 100 parts per million (ppm) or 100 milligrams per kilogram (mg/kg) must be disposed of in accordance with state and federal guidelines. Although this criterion is disposal related, this concentration level (100 mg/kg) was adopted for this evaluation as a regulatory-based trigger level for TFH in soil.

Polychlorinated Biphenyls (PCBs). The EPA regulates PCBs under the Toxic Substance Control Act (TSCA). No regulatory requirements exist for PCB cleanup with the exception of the requirement for timely cleanup. However, EPA has published a nationwide TSCA PCB spill clean-up policy stipulating clean-up levels for PCB discharges to the environment (40 CFR Part 761) (EPA, 1987).

Since the sites at Fort Story are not considered by the Commonwealth of Virginia Department of Waste Management to be restricted access areas, the relevant section of the policy serves as the basis for the trigger level for PCBs. The TSCA policy for defining "clean fill" is less than 1 ppm by weight. JMM has adopted this standard as the appropriate trigger level for PCBs in soil at Fort Story PA/SI and NIKE PA/SI sites.

DDT, DDD, DDE and Chlordane. Review of previous investigations at Fort Story suggests that these compounds were used widely throughout the Installation in the past. They have been detected at low levels at numerous locations (USAEHA, 1987; ESE, 1988). JMM also determined through contacts with Commonwealth of Virginia employees associated with Virginia Polytechnic Institute and State University and Consolidated Laboratory Services, Pesticide Lab, respectively, that the levels of DDT and its metabolites, DDD and DDE along with Chlordane present at the sampling sites at Fort Story were not unusual compared to other areas in Virginia, given the extensive use of DDT and Chlordane at the installation in the past. Both contacts considered JMM's detected values to be within a reasonable range for concentrations of DDT and its metabolites, as well as Chlordane, within the soils in the area of the project sites (Personal Communication, Young, Chase, 1991). Subsequently, no trigger level has been set for DDT and its metabolites, along with Chlordane, as all concentrations are considered to be within expected background ranges (Personal Communication, Young, Chase, 1991).

Cyanide. Cyanide was detected in the analysis of soil at one site at Fort Story. Because of the highly toxic nature of this compound, further investigation into the nature of this compound was conducted.

Cyanide compounds all share the common ^{-}CN group. The simplest form of cyanide is HCN. The ^{-}CN group can also form simple salts with such cations such as potassium and sodium. More complex organic forms include the cyanates ^{-}OCN, and the thiocyanates ^{-}SCN. Metal cyanide complexes, ferricyanides, and ferrocyanides are also common.

Hydrogen cyanide and the simple salt forms (free cyanide) are highly toxic. In contrast, the complexed cyanide compounds appear to exhibit low toxicity. Toxicity of ferrocyanide complexes is related to the degree to which dissociation occurs and free cyanide is available. There is no evidence of cyanide accumulation in mammals or aquatic organisms.

A related problem in assessing the toxicity of cyanide at these sites concerns the methods by which the chemicals are analyzed. There are a number of methods available. However, there is considerable uncertainty concerning the form or species of cyanide that is actually being measured. Because different forms of cyanide differ in toxicity, there is a need to define better the methods used. When a priority pollutant analysis is done, only total cyanide analysis is required. This is the case at Fort Story.

Iron cyanide complexes are generated in the manufactured gas and coal industry through the process by which the produced gas is cleaned. Cyanide is commonly present in areas where coal is stored, and used to be a common ingredient in rodenticides. Cyanide was found in the soil at Site 2, Landfill 2, at a concentration of 2 mg/kg in a surface soil sample. It is possible that the cyanide found in the soil sample was from either of these sources if they were dumped in the landfill.

Cyanide has also been found in uncontaminated soils in some areas throughout the United States - levels for cyanide reported as indicative of uncontaminated conditions are (Kelly, 1979):

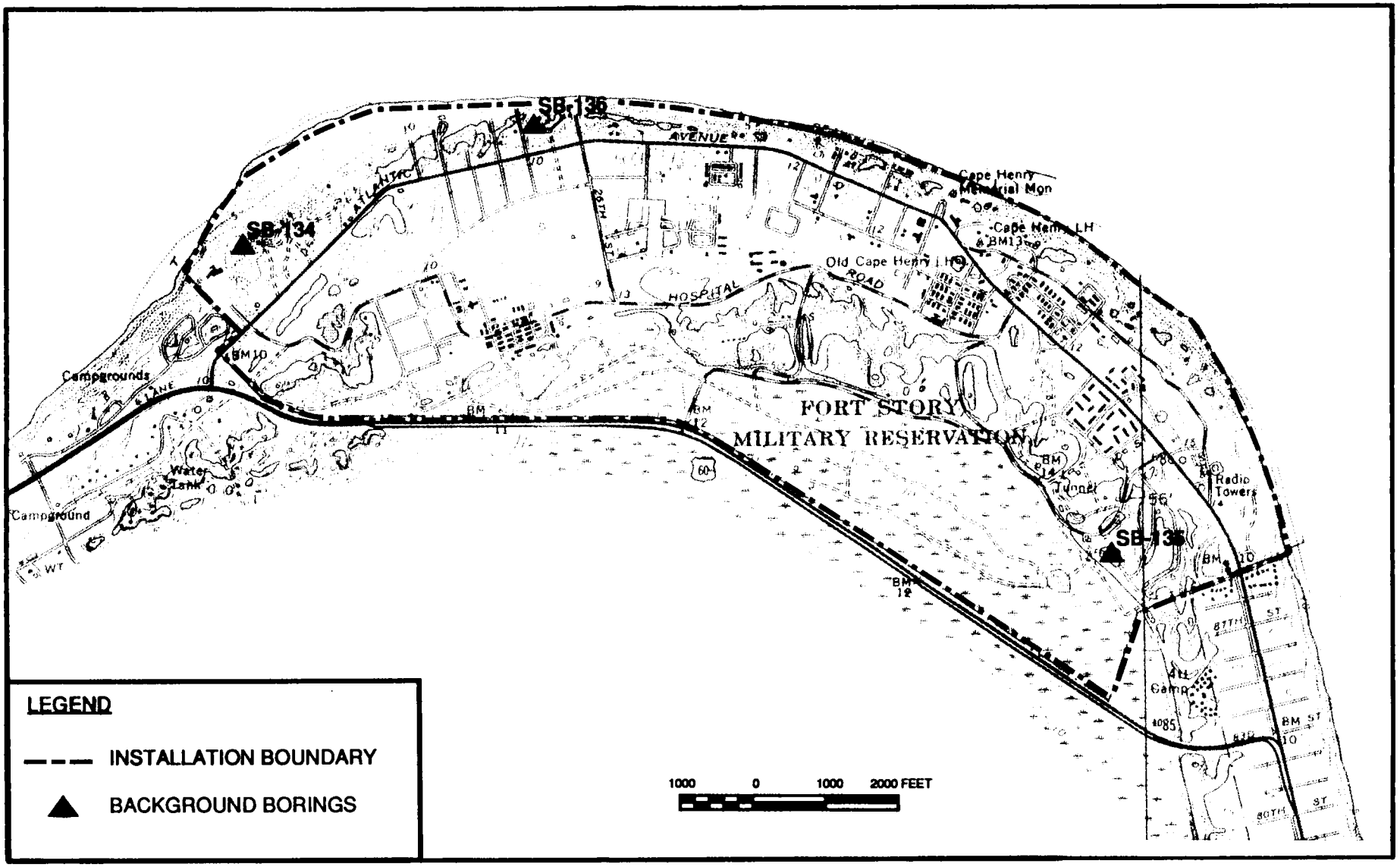
- Free cyanide, 0 - 1 mg/kg
- Total cyanide, 0 - 5 mg/kg
- Ferricyanide, 0 - 100 mg/kg
- Thiocyanide, 0 - 10 mg/kg

Several countries have developed guidelines for assessment and/or clean-up of contaminated soil. These guidelines consider background for total cyanide to be equal to or less than 1 mg/kg for total free cyanide and equal to or less than 5 mg/kg for total complex cyanide [(Moen, J.E.T., J.P. Cornet and C.W.A. Evers, 1985) (Quebec, Ministry of the Environment of, 1986) (Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL), 1983a.) (Guidance on the Assessment and Redevelopment of Contaminated Land, ICRCL 59/83.) (CDEP/EPTS, Romney House, 43 Marsham Street, London, SWIP 3PY, UK, CDEP/EPTS, 1983b.); Notes on the Redevelopment of Gas Works Sites, ICRCL 18/79, 1983c.)].

The exact form of cyanide at Site 2 is unknown. It is possible that the cyanide is in a metal complex form and therefore less toxic than free cyanide. Despite the unknown form, the concentrations of cyanide found are within the range of total cyanide considered representative of uncontaminated soils. The concentrations identified on-site are sufficiently low to not be a human health concern. Regardless of the source, cyanide at the site does not require further evaluation.

Background Borings. Background borings were drilled and sampled during the project to determine the background levels of analytes at Fort Story. Figure 2-2 shows the location of background borings sampled for the Fort Story investigation. These include borings SB-134, SB-135 and SB-136. Soil boring SB-134 was located near the eastern perimeter of Fort Story and is representative of conditions in the sand flat area. Soil boring SB-135 was located adjacent to the western boundary of Fort Story and is representative of conditions in the central sand ridge area. Located in the north-central perimeter of Fort Story, SB-136 is representative of conditions in the coastal dune complex.

Two soil samples were collected from each background boring for analytical characterization. Seven analytical samples, including one field duplicate sample, were collected from the



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Background Boring Locations
Ft. Story, VA

Figure 2-2

background borings. The analytical soil samples were collected from the ground surface and at the total depth of each boring. Table 2-6 summarizes the soil sampling depths for the samples collected from the three background borings. The laboratory analyses performed on each of the analytical soil samples collected included pesticides/PCBs, VOCs, BNAs, total metals, EP Toxicity metals and total solids. Results of these analyses are presented in the *FTSFARD*.

Statistical Evaluation of Background Soil Analytical Data. A statistical evaluation was performed on the analytical data for metals obtained from the Fort Story background boring analytical data. The purpose of the evaluation was to develop a single background concentration for each of the metal analytes found in native Fort Story area soils, i.e., areas where anthropogenic activities were not expected to have occurred. These single background concentration values were set equal to the upper one-sided 95 percent confidence limit of the mean concentration of each metal, using a standard statistical procedure described in a standard engineering statistics textbook (Devore, 1982).

This statistical method is based on the assumption that the metals concentrations are distributed according to the T-distribution, which is a distribution for a limited number of sample sizes, such as the background boring metals concentrations for Fort Story. The method involves estimating the upper limit of the range within which the true mean soil concentration of a metal at Fort Story lies, based upon the characteristics of data from background borings and a confidence criterion. In this case, that upper limit is called the upper one-sided (1-α) percent confidence limit ($\mu_{u,\alpha}$) where α represents the confidence criterion. For this analysis, α is set equal to 0.05 for a 95 percent confidence limit.

The value of the upper one-sided confidence limit of the mean is given by:

$$\mu_{u\alpha} = \bar{x} + t_{\alpha/2},\ df \left(\frac{S}{\sqrt{n}}\right) \qquad (1)$$

where: $\bar{x}$ is the computed mean concentration in soil background samples; the quantity ($t_{\alpha/2}$,df) is the "t value" (obtained from standard statistics tables) for a given confidence criterion (α) and number of degrees of freedom (df), which is defined as the sample size (n) minus one; and S is the standard deviation of the set of concentration data.

At Fort Story, seven background soil samples were analyzed for metals. Therefore, for a 95 percent confidence limit ($\alpha = 0.05$) and seven data points (n = 7, d.f. = 6), Equation (1) becomes:

$$\mu_{u,\,0.05} = \bar{x} + 2.447 \left(\frac{S}{\sqrt{7}}\right), \text{ or}$$

$$\mu_{u,\,0.05} = \bar{x} + 0.9249\ (S) \qquad (2)$$

Thus, the upper confidence limit values for metals at Fort Story were calculated using Equation (2) and the mean (x) and standard deviation (S) of the set of concentrations obtained for each metal. In order to calculate the mean and standard deviation for each metal, a value had to be assigned to samples that had no detectable concentration (ND) to include their occurrence in the statistical evaluation. One method is to assign ND concentrations a value equal to the detection limit (DL) divided by two (DL/2). This method assumes that the data below the detection limit are uniformly distributed; i.e., every value between zero and the detection limit has an equal probability of occurrence. Hornung and Reed of the National Institute for Occupational Safety and Health (NIOSH) present another approach to estimating ND values in which they assume that the ND

TABLE 2-6

BACKGROUND BORINGS
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
SB-134	15	4	2	0,4,9,13
SB-135	42	9	2	0,5,10,15,20,25,30,35,40
SB-136	22	6	2	0,4,9,13,15,20

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

values are distributed lognormally between the detection limit and zero. This assumption is probably more accurate than the assumption that the ND values are distributed normally because it weights the distribution of the ND values toward the detection limit. If all the data (above and below the detection limit) is distributed normally, such as in the T-distribution in this case, then the ND values would also be weighted toward the detection limit. By using a value equal to the detection limit divided by the square root of two ($DL/\sqrt{2}$), a more accurate representation of lognormal values below the detection limit can be achieved (Hornung and Reed, 1990). This technique ($DL/\sqrt{2}$) has been used in this *PA/SI*.

Of the parameters analyzed for the Fort Story PA/SI, five metals (chromium, copper, zinc, arsenic and lead) and the pesticide DDT were detected in background soil boring samples. Table 2-7 shows the results of the statistical analysis for these metals. The remaining seven metals (barium, beryllium, cadmium, mercury, nickel, selenium and silver), as well as pesticides (other than DDT), PCBs, VOCs and BNAs were not detected in background borings from Fort Story.

Although DDT was found in two of the seven background soil samples, the use of the statistics developed herein is not recommended because the information provided by Commonwealth of Virginia employees has provided more focused guidance, as discussed at the beginning of this section. The ubiquitous nature of DDT, and its associated metabolites (DDD and DDE), is due to the extensive use of the pesticide in the past to control mosquito population (Personal Communication, Young, Chase, 1991) and is illustrated by the fact that it was found in the surface soil sample collected from a background boring as well as numerous other sampling locations throughout Fort Story.

As a result of this analysis, identification of any particular metal analyte at concentrations greater than the 95 percent confidence interval concentration should not automatically result in a recommendation for further investigation at the given Fort Story PA/SI site. A trigger level has been established for soils that realistically reflects a situation at any given site where anthropogenic activities have most likely resulted in contamination that requires further investigation. As a result of these considerations, the evaluation of the reported metals concentrations is based on the assumption that additional investigation is warranted when any metal analyte exceeds the 95 percent confidence interval for background concentration by an order of magnitude (10 times background) (EPA, 1988a). The EPA's Department of Site Assessment concurred with the use of 10 times background upon discussion with JMM and indicated that this was the best approach to take, given the lack of regulatory guidance (Personal Communication, Grubbs, 1991). This value, therefore, is utilized as the specified trigger level for the given analyte.

Analytes not Detected in Background Samples. The background soil samples were analyzed for pesticides/PCBs, VOCs, BNAs, total metals and EP Toxicity metals. Only DDT, arsenic, chromium, copper, lead and zinc were found in concentrations greater than the Method Reporting Level (MRL). Many analytes not found in the background samples were found in the site samples. Identification of any analyte greater than the MRL should not automatically result in recommendation for further action at any given site. Subsequently, evaluation of these will be based upon a site specific evaluation of all media sampled.

Because some trace metals were not detected in background soil borings, and in order to provide some supporting information to complement background boring analytical data, JMM attempted to determine the native concentrations of trace metals in the area of Fort Story.

Although it is clear that soils are derived from parent geologic materials as a result of physical, chemical and biological weathering processes, the range of natural or background metal

TABLE 2-7

BACKGROUND BORING DATA STATISTICS[a]
PRELIMINARY ASSESSMENT/SITE INVESTIGATION
FORT STORY, VIRGINIA

Analyte	Number of Samples Collected	Samples Above Detection Limit	Detection Limit	Assigned ND[b] Value	Mean	Standard Deviation	Upper 95% Confidence Limit Value
Arsenic	7	1	2.5	1.8	1.9	0.26	2.1
Chromium	7	7	1	0.71	2.2	0.69	2.8
Copper	7	3	1	0.71	1.0	0.46	1.4
Lead	7	6	1	0.71	3.6	3.8	7.1
Zinc	7	4	2	1.4	3.2	2.7	5.7
DDT	7	2	0.004	0.0028	0.0034	0.0011	0.0044

(a) All values given in (mg/kg).
(b) ND = Not detected.

concentrations is extremely large, with the composition of the parent material being the principal factor influencing the concentrations of metals in pristine soils. It was found that while there is some published information about typical ranges of concentrations for the United States as a whole (Shacklett and Boerngen, 1984, Kabata-Pendias and Pendias, 1984), no specific information was found that would help to determine native concentrations. JMM contacted representatives of the United States and Commonwealth of Virginia Departments of Agriculture (Personal Communication, Wenthouse, 1991) and the United States Geological Survey (Personal Communication, McNeil, 1991), along with professors from the Department of Crop and Environmental Sciences, Virginia Polytechnic Institute (Personal Communication, Daniels, Martins, 1991). No specific information was acquired from these contacts. JMM determined that while the background metal concentration levels were within the typical ranges for U.S. soils, a more specific determination could not be made for the Fort Story area.

Recommended Trigger Levels. Table 2-8 presents the MRL, background 95 percent confidence interval concentration levels, and the trigger level for each analyte detected in Fort Story soil samples. The trigger levels, as herein defined, provide conservative guidance for determination of whether further investigative activity is required at a given site.

The trigger levels determined for compounds of concern found at PA/SI and NIKE PA/SI sites are intended as a quantitative indicator whether further investigatory action may be appropriate for the site. The trigger levels are derived based on statistically-significant background concentrations of compounds of concern, or regulatory standards as may be appropriate. The trigger levels do not necessarily constitute applicable or relevant and appropriate requirements (ARARs). ARARs are developed while a project site is undergoing an RI/FS evaluation and the magnitude and extent of environmental contamination is being assessed. ARARs then serve as potential clean-up standards for contaminated site media.

2.1.2.2 Groundwater Trigger Levels. Regulatory maximum contaminant levels (MCLs), along with Commonwealth of Virginia groundwater protection levels (VGWPLs), have been established for most of the analytes present in the water samples analyzed for the PA/SI. MCLs are enforceable standards, promulgated under the Safe Drinking Water Act of 1986 (EPA, 1991 40 CFR Parts 141, 142 and 143) and regulated by the Commonwealth of Virginia State Department of Health, which has primary responsibility for enforcing compliance with all drinking water standards. MCLs are set at levels that are determined to be protective of human health and are as close as feasible to the Maximum Contaminant Level Goals (MCLGs). In addition, MCLs address the use of the best available water treatment technology, treatment cost and other considerations.

The VGWPLs are health-based standards derived from Federal Resource Conservation and Recovery Act (RCRA) groundwater protection standards (EPA, 1990) and Commonwealth of Virginia State Water Control Board Regulations VR 680-21-00 (Commonwealth of Virginia, 1990). The water quality standards are health-based in nature and were developed in the 1970s as standards to protect groundwater quality. They are not considered appropriate as clean-up standards (Personal Communication, Barron, August 1991) and consequently have not been integrated into this report. The VGWPLs are most appropriate as guidelines for groundwater protection associated with existing solid waste management units, such as surface impoundments, landfills or waste piles.

Generally, MCLs are considered relevant and appropriate for groundwater that is a current or potential source of drinking water. The presence of wetlands adjacent to a site, the possibility that a nonpotable aquifer could be used for supplying drinking water in the future, or significant interaction of groundwater with surface waters could prompt MCLs to be used as site clean-up goals. Therefore, based on the nature of the PA/SI and NIKE PA/SI project sites and consideration of these regulatory preferences, JMM considers the MCLs to be more relevant and

TABLE 2-8

SOIL TRIGGER LEVELS
PRELIMINARY ASSESSMENT/SITE INVESTIGATION
FORT STORY, VA

Parameter	Method Reporting Level[a] (mg/kg)	Background 95% Confidence Interval[b] (mg/kg)	Trigger Level[c] (mg/kg)
Pesticides/PCBs			
Chlordane	0.04	ND	-
p,p'DDD	0.02	ND	(d)
p,p'DDE	0.02	ND	(d)
p,p'DDT	0.02	0.0041	(d)
Arochlor 1254	0.02	ND	1[e]
Arochlor 1260	0.02	ND	1[e]
VOCs			
Carbon Disulfide	0.01	ND	-
Chloroform	0.01	ND	-
1,2-Dichlorobenzene	0.01	ND	-
1,3-Dichlorobenzene	0.01	ND	-
1,1-Dichloroethane	0.01	ND	-
1,2-Dichloroethane	0.01	ND	-
1,1-Dichloroethene	0.01	ND	-
cis-1,2-Dichloroethene	0.01	ND	-
Ethylbenzene	0.01	ND	-
Methylene Chloride	0.1	ND	-
Tetrachloroethene	0.01	ND	-
Toluene	0.01	ND	-
1,1,1-Trichloroethane	0.01	ND	-
Vinyl Chloride	0.025	ND	-
m,p-Xylenes	0.01	ND	-
o-Xylene	0.01	ND	-
Total Xylenes	0.01	ND	-
BNAs			
Benzoic Acid	10	ND	-
Di-n-butylphthalate	2	ND	-
Fluorene	1	ND	-
2-Methylnaphthalene	1	ND	-
Naphthalene	1	ND	-
Phenanthrene	1	ND	-
Phenol	1	ND	-
Pyrene	1	ND	-
			-
TFH-L	0.20	ND	100[f]
TFH-H	10	ND	100[f]

TABLE 2-8 (Continued)

SOIL TRIGGER LEVELS
PRELIMINARY ASSESSMENT/SITE INVESTIGATION
FORT STORY, VA

Parameter	Method Reporting Level[a] (mg/kg)	Background 95% Confidence Interval[b] (mg/kg)	Trigger Level[c] (mg/kg)
Inorganics			
Arsenic	2.5	2.1	21
Barium	10	ND	-
Cadmium	0.5	ND	-
Chromium	1.0	2.8	28
Copper	1.0	1.4	14
Cyanide	0.1	ND	-
Lead	1.0	7.1	71
Mercury	0.02	ND	-
Nickel	4.0	ND	-
Zinc	7.0	5.7	57

(a) Method Reporting Level (MRL) represents the minimum concentration of an analyte that can be reported with a known confidence level.
(b) Upper bound of the 95 percent confidence interval on the population mean concentrations for background soil borings at Fort Story.
(c) For metal analytes detected in the background borings, the trigger levels are set at 10 times the 95 percent confidence interval.
(d) All DDT, DDE and DDD levels detected at Fort Story are within the expected background range (Personal Communication, Young, Chase, 1991).
(e) EPA, 1987, *Toxic Substances Control Act (TSCA) PCB Spill Cleanup Policy 40 CFR Section 761 Subpart G.*
(f) Commonwealth of Virginia, State Water Control Board, 1989 VR-680-13-02

ND = Not Detected in the background borings.

appropriate than VGWPLs for use as trigger levels for this project. Therefore, for a compound of concern that has an MCL and a VGWPL, the MCL will be used as a trigger level.

Table 2-9 presents a summary of the analytes identified in the water samples with their associated trigger levels. Use of the water table (Columbia) aquifer as a source of potable water is presently limited by the Commonwealth of Virginia State Department of Health, the MCLs and VGWPLs serve as a conservative rationale for developing groundwater contamination trigger levels. These values, along with the soil values presented in Section 2.1.2.1 and the hydrogeology of the site, were used to evaluate the results for each Fort Story PA/SI site.

MCLs and VGWPL values are for chemical contaminants dissolved in water. When a groundwater sample is collected from a well, a fraction of the sample mass is associated with fine particles suspended within the water sample. These particles are usually colloidal in nature, and the relative mass amount present is reflected in the turbidity measured - the higher the turbidity, the higher the colloidal content. The problem with analyzing groundwater that contains colloids is that colloids, which are normally negatively charged, will have positively charged contaminants (usually metals) adsorbed to their surface. Subsequently, the sample needs to be filtered to remove the colloids to have a better understanding of what is truly dissolved in the groundwater. Currently accepted EPA protocol is to utilize a 0.45 micron filter, as was stated in the *QCSP/FIP*. Based upon this understanding, the dissolved metal results, as opposed to total metal results, will be assessed against the MCLs or VGWPLs.

2.1.3 Contaminant Pathways

Three basic pathways exist through which contaminants could migrate within a Fort Story PA/SI project site or beyond site boundaries. Contaminants resulting from spills or other releases of hazardous substances could migrate via atmospheric, surface or subsurface transport pathways. These contaminant pathways are discussed later.

2.1.3.1 Atmospheric Transport. Any release of hazardous substances from a contaminant source at a Fort Story PA/SI project site could result in release of contaminants to ambient air. Compounds released into ambient air could include contaminated dust particles or volatile organic vapors. Site sources could include landfilled material, underground storage tanks, above-ground tanks, miscellaneous spills or discharges associated with waste management systems and practices, contaminated soil, or groundwater.

The direction of transport and degree of dispersion of contaminants would depend on local meteorological conditions and the type of compound and or contaminant transport medium (e.g., soil, dust). The climate of the Fort Story area, as discussed in detail in Section 2.2.1.2, is a humid sub-tropical climate (influenced by the Atlantic Ocean and Chesapeake Bay), which is characterized by an average annual temperature of 60 degrees Fahrenheit (60° F). Winters are typically mild, while summers are relatively cool. Most precipitation is received during the months of April through September. Moderate (0 to 87 inches) snowfall is received during the winter months. Convective thunderstorm activity significantly contributes to precipitation received during the summer months. Annual precipitation is occasionally augmented by the local passage of these storms. Winds in the Fort Story area are usually light to moderate but on occasion may be gusty, which would result in greater migration of any airborne chemical vapors or particulates.

2.1.3.2 Subsurface Transport. Any spills or other releases of hazardous substances from sources at the Fort Story PA/SI project sites could negatively impact soil, surface water/sediments and groundwater. Compounds discharged to the subsurface could migrate downward and reach the water table. This potential migration, however, would potentially be limited to some extent by adsorption and dispersion processes in the unsaturated zone. The degree of this attenuation would depend on site-specific hydrogeologic conditions.

TABLE 2-9

GROUNDWATER TRIGGER LEVELS
PRELIMINARY ASSESSMENT/SITE INVESTIGATION
FORT STORY, VA

Parameter	Method Reporting Level[a]	Virginia GW Protection Standards[b]	Maximum Contaminant Level[c]	Trigger Level
VOCs (µg/l)				
Benzene	0.2	5	5	5
Carbon Disulfide	0.5	1,000	-	1,000
Chloroform	0.5	5	-	5
1,1-Dichloroethane	0.5	-	-	-
1,2-Dichloroethane	0.5	5	5	5
1,1 Dichloroethene	0.5	7	7	7
Ethylbenzene	0.5	-	700	700
Methylene Chloride	0.5	600	-	600
1, 1, 1-Trichloroethane	0.5	200	200	200
Tetrachloroethene	0.5	7	5	5
Toluene	0.5	1,000	1,000	1,000
Vinyl Chloride	1	2	2	2
m,p-Xylenes	0.5	-	-	-
o-Xylene	0.5	-	-	-
Total Xylenes	0.5	-	10,000	10,000
BNAs (µg/l)				
Anthracene	5	-	-	-
Benzoic Acid	50	-	-	-
bis(2-Ethylhexyl)phthalate	20	-	-	-
Dibenzofuran	5	-	-	-
2-Methylnaphthalene	5	-	-	-
Naphthalene	5	-	-	-
Phenanthrene	5	-	-	-
Phenol	5	1	-	1
Pyrene	5	-	-	-
TFH-L (mg/l)	0.05	1	-	1
TFH-H (mg/l)	0.1	1	-	1
Dissolved Metals (mg/l)				
Arsenic	0.005	0.05	0.05	0.05
Barium	0.1	1	1	1
Cadmium	0.005	0.0004	0.005	0.005
Lead	0.002	0.05	0.015[d]	0.015
Zinc	0.02	0.05	5	5

(a) Method Reporting Level (MRL) represents the minimum concentration of an analyte that can be reported with a known confidence level. The listed values were in effect for the PA/SI project.
(b) Commonwealth of Virginia, Department of Waste Management, 1988, *Solid Waste Management Regulations VR 672-20-10*
(c) EPA, 1991, *National Primary Drinking Water Regulations, 40 CFR Parts 141, 142, and 143*
(d) Takes effect December 1992.

As discussed in detail in Section 2.2.1.3, the subsurface at Fort Story PA/SI project sites generally consists of unconsolidated, interbedded sands and clays with minor occurrences of gravel and shell fragments. The hydrogeologic framework within the Fort Story vicinity consists of a system of seven aquifer units separated by intervening semi-confining units.

The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. Potable water is reportedly obtained from groundwater sources only to a minor extent. Groundwater use at Fort Story is restricted to withdrawals from a single well located at Site 6, LARC Maintenance Area. Water obtained from this well is used for nonpotable applications only.

The water table below Fort Story PA/SI project sites is encountered at relatively shallow depths ranging from approximately 10 feet in low-lying areas to approximately 40 feet (bls) in high ridge areas. In coastal sand ridges to the north, however, groundwater levels decline to approximately 3 feet NGVD. Water table contours within the Fort Story area are generally characterized by the presence of a localized groundwater divide in the vicinity of the central sand ridge complex. Ambient groundwater flow directions are generally northward toward the coastline and southward toward the wooded wetland, respectively, from the central sand ridge area. Therefore, contaminants released to the subsurface could migrate through the unconsolidated overburden material into the groundwater. Subsequently, contaminants could discharge into the wetland areas or the Chesapeake Bay.

2.1.3.3 Surface Transport. The sandy surface soils characteristic of the Fort Story area promote efficient infiltration of precipitation received at the Installation. Overland surface runoff is collected in ponds or wetland areas or is routed through Fort Story's storm sewer system to one of three outfalls discharging to either the Atlantic Ocean or Chesapeake Bay. Contaminants adsorbed to affected soils at the PA/SI project sites could be carried by surface water runoff and discharged into ponds, wetland areas or the storm sewer system. Subsequently, contaminants could potentially be discharged into the ocean or bay.

2.2 RESULTS OF INVESTIGATIONS

Eight sites were investigated during the Fort Story PA/SI project. These include seven sites for the PA/SI project (under Delivery Order 0001) and one site for the NIKE PA/SI project (under Delivery Order 0004). No previous field investigation activities had been conducted at any of these sites.

Section 2.2.1 provides a discussion of the installation physical characteristics obtained during the literature search and associated fieldwork. Section 2.2.2 provides a site specific discussion for the seven PA/SI sites. For each medium investigated, the significance of site contamination is evaluated through a comparison of the analytical data to the identified trigger levels as defined in Section 2.1.2. Data of concern from each of the investigated media are summarized on the site figures presented in Sections 2.2.1 and 2.2.2.

2.2.1 Installation Physical Characteristics

Fort Story is located in Virginia Beach, Virginia. Virginia Beach is located in the Hampton Roads region of southeastern Virginia, which is included in the coastal tidewater portion of the Atlantic Coastal Plain physiographic province. Occupying an area of approximately 1,450 acres, Fort Story is situated on Cape Henry, which roughly divides the waters of the Chesapeake Bay to the north from those of the Atlantic Ocean to the east.

2.2.1.1 Topography. Land features encountered at Fort Story consist of linear sand ridges, sand flats and wetland areas. The topography is dominated by a series of prominent linear, well-

drained sand ridges that roughly bisect the Fort Story area. The central ridges trend parallel to the coastline and are characterized by maximum elevations in excess of 85 feet, National Geodetic Vertical Datum of 1929 (NGVD). A second series of sand ridges located on Fort Story are comprised of an active dune complex located adjacent to the coastline. The coastal sand ridges attain maximum elevations in excess of 25 feet NGVD. Broad, poorly drained sand flats are located adjacent to the sand ridge areas. Land surface elevations in the sand flat areas typically range between 5 and 10 feet, NGVD. Wetland areas, which are common features of the sand flats, occur locally in closed depressions. South of the central sand ridges, the Fort Story topography consists of an extensive, wooded, wetland area, formerly a back-bay, lagoonal feature. Most of the Installation's facilities and operations are confined to the sand ridge and sand flat areas.

2.2.1.2 Climate. The climate of the Fort Story area is a maritime-type climate characterized by an average annual temperature of 60° F. Winters are typically mild, with temperatures averaging 42° F. During the summer months, temperatures average 77° F while the maximum daily temperature averages 85° F. The average total annual precipitation is 45 inches. Of this, 25 inches is received during the months of April through September. Snowfall in the region averages 7.3 inches per year. A significant component of precipitation received during the summer months results from convective thunderstorm activity. Though the region lies north of the typical hurricane and tropical storm track, annual precipitation is occasionally augmented by the local passage of these storm events [Environmental Science and Engineering (ESE), 1988].

2.2.1.3 Hydrogeology. The Virginia Coastal Plain sediments consist of an eastward thickening wedge of generally unconsolidated, interbedded sands and clays with minor occurrences of gravel and shell fragments. Within the Fort Story area, the sediments are in excess of 3,500 feet thick and are underlain by crystalline basement rocks (Lloyd, et al., 1985). Utilizing well data from the region, Meng and Harsh (1988) determined the distribution of the principal aquifer units within these sediments. Their analyses indicated that the hydrogeologic framework of the coastal plain sediments within the Fort Story vicinity consists of a system of six aquifer units separated by intervening semi-confining units. In order of increasing depth from ground surface, these aquifers include (Meng and Harsh, 1988):

- The Columbia Aquifer, which is the water table aquifer, comprised of undifferentiated Holocene age sediments;
- The Yorktown-Eastover Aquifer, which occurs within the Yorktown and Eastover formations of Pliocene and Miocene Age, respectively;
- The Chickahominy - Piney Point Aquifer, which occurs within the Chickahominy and Piney Point formations of Eocene Age and the Old Church Formation of Oligocene Age, where present ; and
- The Upper, Middle, and Lower Potomac aquifers, which occur within the Potomac Group of Cretaceous age.

The Columbia, Yorktown - Eastover, and Chickahominy - Piney Point aquifers and intervening semi-confining units comprise roughly the upper one-quarter of the total thickness of the coastal plain sediments in the Fort Story area. The remaining sediment thickness, in turn, consists of the Upper, Middle and Lower aquifers and intervening semi-confining units that comprise the Potomac Group. Groundwater chloride concentrations exceed 5,000 milligrams per liter (mg/l) at a depth of approximately 900 feet below land surface (bls) in the Fort Story vicinity (Lloyd et al., 1985). The shallower aquifers, including the Columbia, Yorktown - Eastover, Chickahominy - Piney Point, Aquia and Upper Potomac aquifers, are characterized by transmissivities of less than 50,000 gallons per day per foot (gpd/ft). Transmissivities in the range of 50,000 to 100,000 gpd/ft are estimated for the Middle and Lower Potomac aquifers (Lloyd et al., 1985).

Meng and Harsh (1988) indicate that the thickness of the Columbia Aquifer in the Fort Story area is approximately 120 feet and separated from the underlying Yorktown - Eastover Aquifer by the Yorktown semi-confining layer which has an approximate thickness of 40 feet. The lithology of the Columbia Aquifer is characterized primarily as Holocene beach sand and nearshore marine sand, which commonly contains pebbles, shell fragments and blocks of coquinite (Johnson, 1972). JMM has estimated hydraulic conductivity values for the sediments comprising the Columbia Aquifer in the Fort Story area by performing slug tests on 28 wells installed for this project. Based on the results of these tests, hydraulic conductivity values for the sediments comprising the upper portion of the Columbia Aquifer in the Fort Story area average approximately 190 gallons per day per foot squared (gpd/ft.^{2}) [8.2 centimeters per second (cm/sec)]. The underlying Yorktown semi-confining unit is comprised of the upper portion of the Yorktown formation and described as marine silt with occasional interbeds of fine sand and coquina (Johnson, 1972).

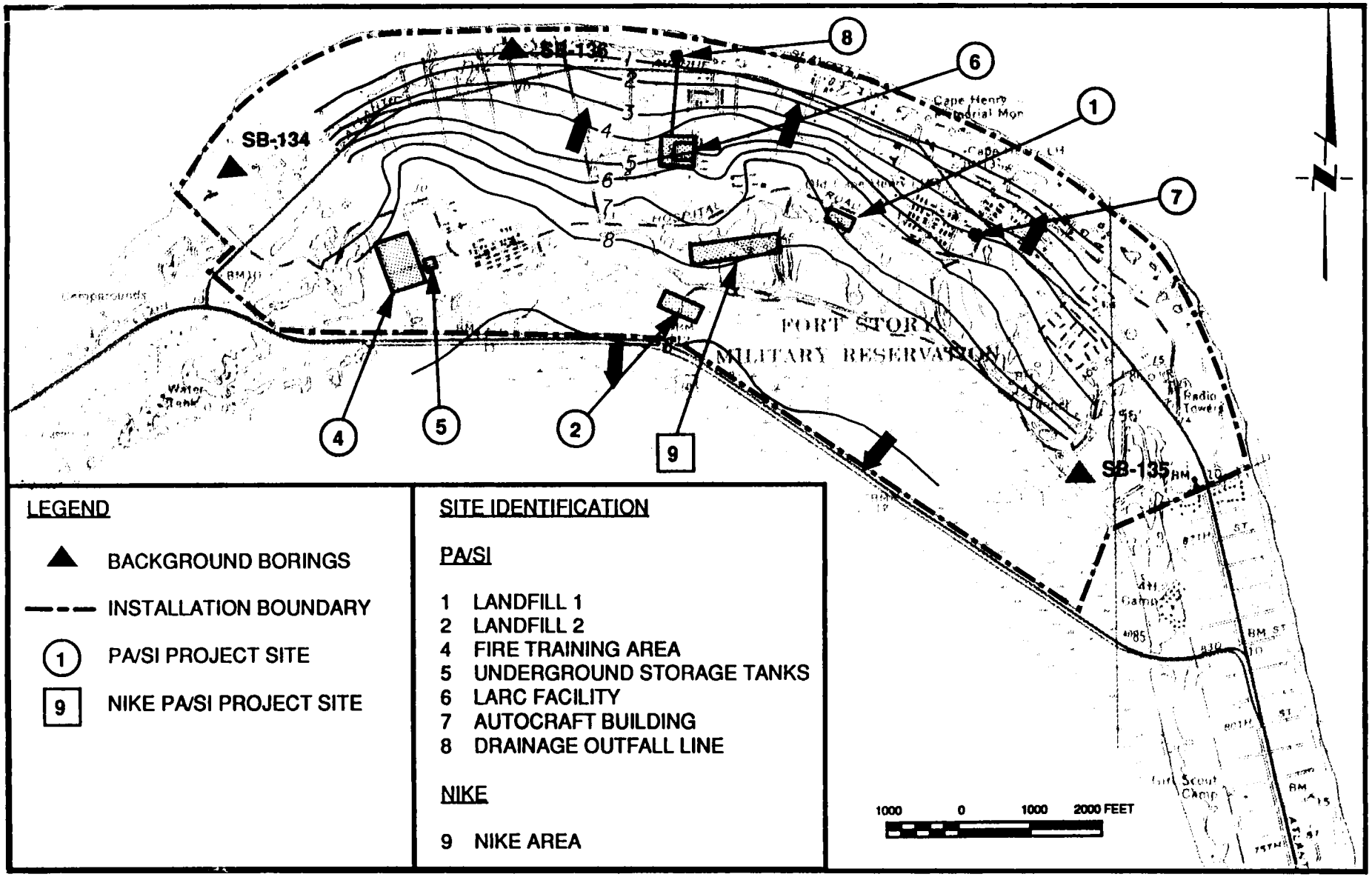
The Yorktown - Eastover Aquifer underlies the Yorktown confining unit and is encountered between the depths of approximately 160 and 440 feet (bls). The depths to the tops of the Chickahominy - Piney Point Aquifer and the Upper Potomac Aquifer are approximately 810 and 1,130 feet (bls), respectively. The respective thicknesses of these aquifers in the Fort Story area are 140 and 220 feet. Meng and Harsh (1988) indicate that insufficient data are available in the Fort Story vicinity for direct characterization of the thicknesses of the Middle and Lower Potomac aquifers from well data.

The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. To a minor extent, potable water is obtained from groundwater sources. The Yorktown - Eastover Aquifer, occurring between the depths of 160 and 440 feet (bls), is the most significant groundwater source for potable supply [Sirrine Environmental Consultants (Sirrine), 1988]. Groundwater use at Fort Story is restricted to withdrawals from a single well located at Site 6, LARC Maintenance Area. The unavailability of construction data for this well precludes a determination of which aquifer unit provides the groundwater withdrawn from this well. Water is obtained from the well for nonpotable uses only.

The Commonwealth of Virginia State Department of Health regulates wells in the region. Information obtained by JMM indicates that groundwater use is discouraged because of poor quality and withdrawal restrictions. High dissolved iron and manganese and total solids characterize the groundwater in the upper aquifers (Personal Communication, Mohsenin, Newton, August 1991). The Yorktown-Eastover aquifer is the most significant groundwater source for potable supply (Sirrine, 1989).

Based on depth to water measurements obtained from the 28 monitoring wells that JMM installed for this study and the other three studies, the water table is encountered at an average depth of 10 feet within the Fort Story area. The depth to the water table may exceed 40 feet (bls) in the higher ridge areas. Generalized water table contours within the Fort Story area, depicted in Figure 2-3, are characterized by the presence of a localized groundwater divide in the vicinity of the central sand ridge complex. Groundwater elevations in excess of 10 feet NGVD are encountered in this area. Groundwater levels decline to approximately 3 feet NGVD in coastal sand ridges to the north. South of the central sand ridge complex, groundwater levels decline to approximately 8 feet NGVD in the vicinity of the wetland area. Based on these data, the general ambient groundwater flow directions are northward toward the coastline and southward toward the wooded wetland, respectively, from the central sand ridge area.

The distribution of groundwater elevations at each of the Fort Story sites was evaluated using the SURFER contouring software package (Golden Software, 1990). Data used to evaluate water table elevations at each site were collected during the PA/SI, NIKE PA/SI field efforts, mostly over a 24-hour period on June 11, 1990, and are considered generally representative of Spring 1990



LEGEND

- ▲ BACKGROUND BORINGS
- — - — INSTALLATION BOUNDARY
- (1) PA/SI PROJECT SITE
- [9] NIKE PA/SI PROJECT SITE

SITE IDENTIFICATION

PA/SI

1 LANDFILL 1
2 LANDFILL 2
4 FIRE TRAINING AREA
5 UNDERGROUND STORAGE TANKS
6 LARC FACILITY
7 AUTOCRAFT BUILDING
8 DRAINAGE OUTFALL LINE

NIKE

9 NIKE AREA

JMM

Generalized Water Table Elevations,
Ft. Story, VA

Figure 2-3

conditions. These data were supplemented by water level data compiled from on-going and previously conducted Fort Story studies. In addition, topographic maps were utilized for the general evaluation of the effects of coastal and inland wetland features. The resulting information was used to determine, to the extent possible, the general groundwater flow directions at each of the Fort Story sites as indicated on the respective figures.

Estimated hydraulic properties of the aquifer systems at each of the Fort Story sites were determined through the analysis of data collected during in situ permeability testing or "slug testing" of monitoring wells as described by Bouwer (1978) and Bouwer (1989). The tests consisted of submersing a slug bar of known volume into each well and monitoring receding water level changes until measurements indicated that the static water level had been achieved. The slug bar was then removed from each well and recovery (rising head) water levels were monitored until the static water level was again achieved. Changes in water levels over time were monitored using a pressure transducer in conjunction with a Hermit data logger.

The slug test data were analyzed to determine aquifer properties using SLUG (Jones, 1984), a computer program designed to perform initial data reductions, tabulate data and perform preliminary calculations for aquifer intrinsic permeability (Ki) and storage coefficient. The program plots the ratio (L_o/L) of the water level immediately after slug bar removal (L_o) and the water level at any time thereafter (L) against elapsed time. The program then employs linear regression techniques to calculate values for hydraulic conductivity (K). Hydraulic conductivity is a coefficient of proportionality that describes the rate at which groundwater flows through aquifer material and is often expressed in units of length per unit time (e.g., centimeters per second). As a function of the aquifer material and groundwater, hydraulic conductivity is also defined as the quantity of water that will flow through a unit cross sectional area of the aquifer material per unit of time under a hydraulic gradient of 1.00 and at an assumed temperature of 60° F (e.g., gallons per day per square foot) (Sevee, 1991) (Fetto, 1980). Due to the very limited amount of draw down produced by slug testing, values of hydraulic conductivity determined from individual well testing are qualitative indicators of the aquifer characteristics in the immediate vicinity of the well only. Therefore, each individual value does not necessarily reflect area-wide aquifer properties. SLUG develops numerical values for hydraulic conductivity by using the methods of Bouwer (1978); Hvorsley (1951); Cooper, Bredehoeft and Papadapulos (1967); Jones, (1984). The Bouwer (1978) method was selected for use as it is valid for slug tests performed in partically penetrating wells in unconfined aquifers (Jones, 1984).

The aquifer property values presented herein represent estimates of in situ, site-specific hydraulic conductivity (K) of the formation materials and fluid adjacent to the screened interval at each well location. Table 2-10 presents a summary of hydraulic conductivity values for individual wells and average hydraulic conductivity values for each PA/SI site. Data from Site 3, Landfill 3, a Fort Story RI/FS site, was used to evaluate Installation-wide hydraulic conductivity. Although Site 3 is not discussed in this report, data from the site are included to show the complete hydraulic conductivity data set. As presented in Table 2-10, hydraulic conductivity values range from 1.74×10^{-4} to 2.02×10^{-2} cm/sec (4 to 428 gal/day/ft^2) have been determined for wells screened in the water table aquifer, with an average value of 8.21×10^{-3} cm/sec (174 gal/day/ft^2). The lowest average site hydraulic conductivity was measured at Site 3 at 9.61×10^{-3} cm/sec. This low value is likely due to the well's proximity to both the landfill area and the marshy area to the south. The highest average site hydraulic conductivity was measured at Site 8 at 1.12×10^{-2} cm/sec. These values are consistent with ranges estimated for typical unconsolidated sediments comprised of well-sorted sands, silty sands and fine sands to silts and clayey silts (Sevee, 1991; Kruseman and De Fidder, 1983; Fetto, 1980).

The information used to develop Table 2-10, including raw data, graphs and calculations, is located in the *Fort Story Geotechnical Information Document (FTSGID)*. Appendix C includes a

TABLE 2 -10
IN SITU PERMEABILITY TEST RESULTS
FORT STORY, VA

SITE NUMBER	WELL NUMBER	HYDRAULIC CONDUCTIVITY (cm/sec) (a)	HYDRAULIC CONDUCTIVITY (gal/day/sq ft) (b)
1	MW101	1.71 E-3	36
1	MW102	5.45 E-3	116
1	MW103	2.04 E-3	43
1	MW104	6.52 E-3	138
2	MW105	5.13 E-3	109
2	MW106	1.79 E-2	379
2	MW107	1.74 E-4	4
2	MW108	2.08 E-3	44
2	MW109	6.51 E-3	138
3	MW201	4.61 E-3	98
3	MW202	1.46 E-2	310
4	MW110	1.18 E-2	250
4	MW111	1.17 E-2	248
4	MW112	1.37 E-2	290
5	MW113A	8.27 E-3	175
5	MW113B	1.39 E-2	295
5	MW114A	6.20 E-3	131
5	MW114B	2.02 E-2	428
6	MW115	6.16 E-3	131
6	MW116	1.99 E-3	42
6	MW117	3.13 E-3	66
6	MW118	1.84 E-2	390
7	MW119	3.23 E-3	68
7	MW120	7.11 E-3	151
8	MW121	1.12 E-2	237
9	MW401	9.78 E-3	207
9	MW402	1.08 E-2	229
9	MW403	5.61 E-3	119

Site-Specific Hydraulic Conductivity

		(cm/sec)	(gal/day/sq ft)
Installation-Wide			
	Highest Value K	2.02 E-2	428
	Lowest Value K	1.74 E-4	4
	Average Value K	8.21 E-3	174
	Standard Deviation	5.48 E-3	116
Site 1	Average Value K	3.93 E-3	83
Site 2	Average Value K	6.36 E-3	135
Site 3	Average Value K	9.61 E-3	204
Site 4	Average Value K	1.24 E-2	263
Site 5	Average Value K	1.21 E-2	257
Site 6	Average Value K	7.42 E-3	157
Site 7	Average Value K	5.17 E-3	110
Site 8	Average Value K	1.12 E-2	237
Site 9	Average Value K	8.73 E-3	185

(a) cm/sec = centimeters per second (E = x10)
(b) gal/day sq ft = gallons per day per square foot

Results derived from calculations utilized by SLUG (Jones,1984) as based upon Bouwer (1978).

summary of geotechnical soil classification results from the screened interval of each monitoring well. The *FTSGID* presents the actual grain size distribution plots are presented in the *FTSGID*.

2.2.2 PA/SI Sites

The draft findings for the seven Fort Story PA/SI site investigations are presented in Sections 2.2.2.1 through 2.2.2.7.

Specific analytical results for each of the environmental media investigated at each site are presented in the *FTSFARD*. The following conventions apply to the presentation of the data of concern in the *FTSFARD*. For all analytical data, any value that exceeds the trigger level of the analyte is signified by underlined bold-face type, e.g. **25**. The trigger level is presented as a bracketed number, e.g. (5). Concentrations of an analyte in excess of its trigger level indicate that further investigation may be warranted at the site, based upon review of all of the data of concern.

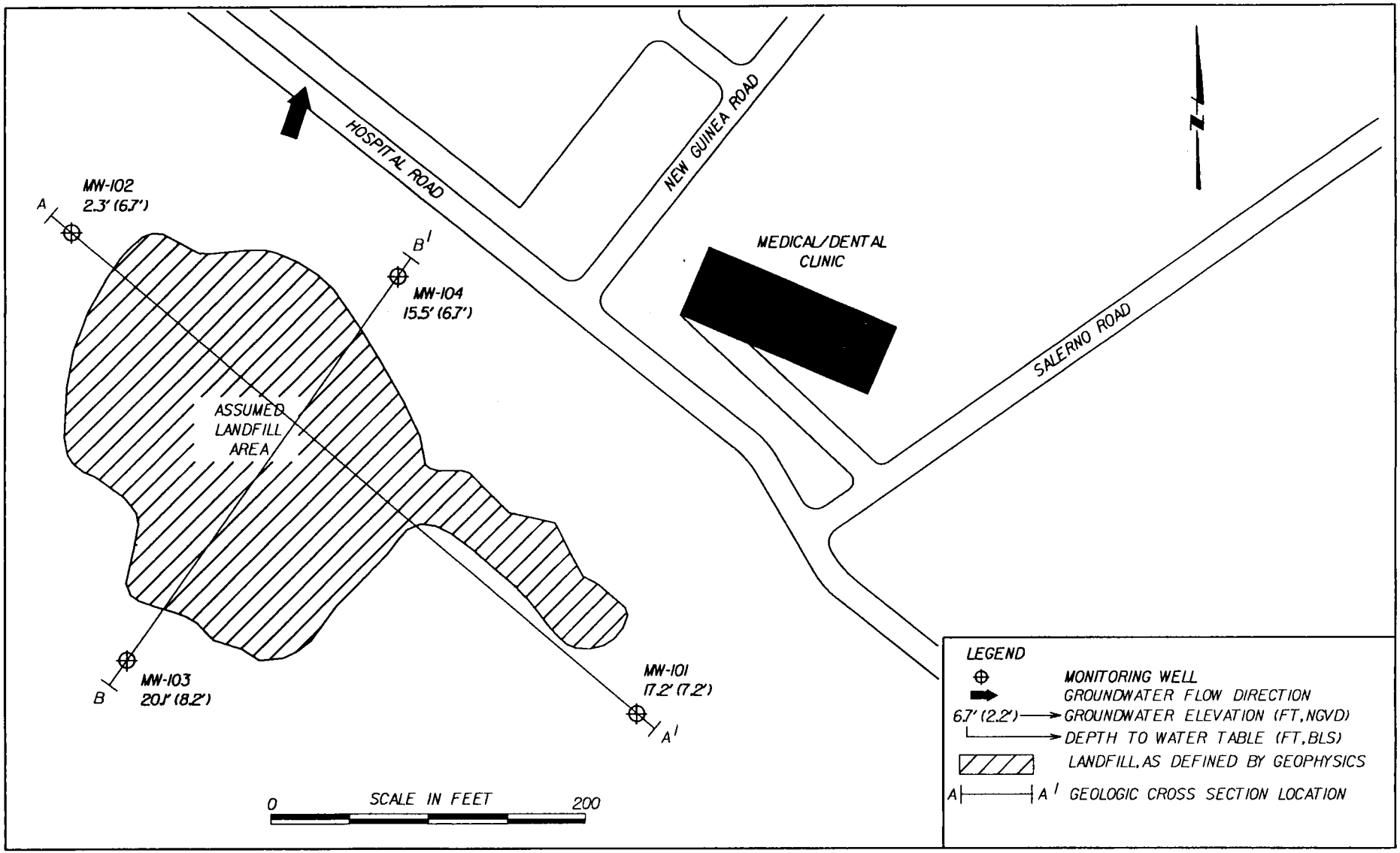
2.2.2.1 Site 1, Landfill 1. Site 1, Landfill 1, is located on the northern flank of the central sand ridge area near the junction of Desert Road and Hospital Road, south of the present dental clinic. The purpose of the investigation of Site 1, Landfill 1, was to determine the boundary of the landfill and the presence of soil and groundwater contamination associated with the landfill.

Landfill 1 was operated from 1946 to 1952. All types of solid wastes generated on the Installation are believed to have been disposed of at this site (ESE, 1988). During a 1989 field visit, JMM identified small amounts of debris along the eastern edges of the landfill. Trench and fill techniques may have been employed at this landfill during its period of active operation. In 1985, a preconstruction subsurface investigation was conducted by the Installation to screen potential construction sites for a proposed dental clinic. This investigation identified large amounts of landfill debris. As a result, the proposed dental clinic was relocated to Hospital Road located opposite the landfill site (Personal Communication, Fort Story Personnel, 1989).

Groundwater and soil matrices were investigated at the site through the installation of four monitoring wells. The landfill boundary was delineated and locations for the monitoring wells, shown in Figure 2-4, were selected on the basis of geophysical surveying performed to locate the extent of the fill area. The monitoring wells were installed in positions that collectively encircle the fill area. The site is underlain predominantly by Holocene age sand deposits. The sand is typically described as medium to fine grained, subrounded to subangular, and well graded. A thin clay unit characterizes the surficial sediments in the low-lying area adjacent to the western flank of the fill area. Site 1 is also characterized by considerable spatial variation in land surface elevations. Figure 2-5 presents two cross sections based on soil boring data that illustrate the general stratigraphy of Site 1. The locations of the cross sections are shown on Figure 2-4.

Groundwater is encountered at a depth of 20.07 feet bls in MW-103 as compared to a depth of only 2.26 feet bls in MW-102. Depths to groundwater in wells MW-101 and MW-104 were 14.66 and 12.79 feet bls, respectively, in June 1990. The water table elevation ranges from in excess of 8 feet NGVD south of the site in an upgradient direction to approximately 6.5 feet NGVD immediately downgradient of the fill area (Table 2-11). Groundwater flow is directed generally to the northeast across the site (Figure 2-4). Hydraulic conductivity values calculated for Site 1 range from 1.71×10^{-3} to 6.52×10^{-3} cm/sec (36 to 138 gal/day/ft^2), with an average value of 3.93×10^{-3} cm/sec (83 gal/day/ft^2).

Table 2-12 summarizes the soil sampling depths for the well borings. Three analytical samples were collected from each monitoring well boring. Analytical soil samples were collected at ground surface, at the approximate middle of the unsaturated zone, and at the soil-groundwater interface.



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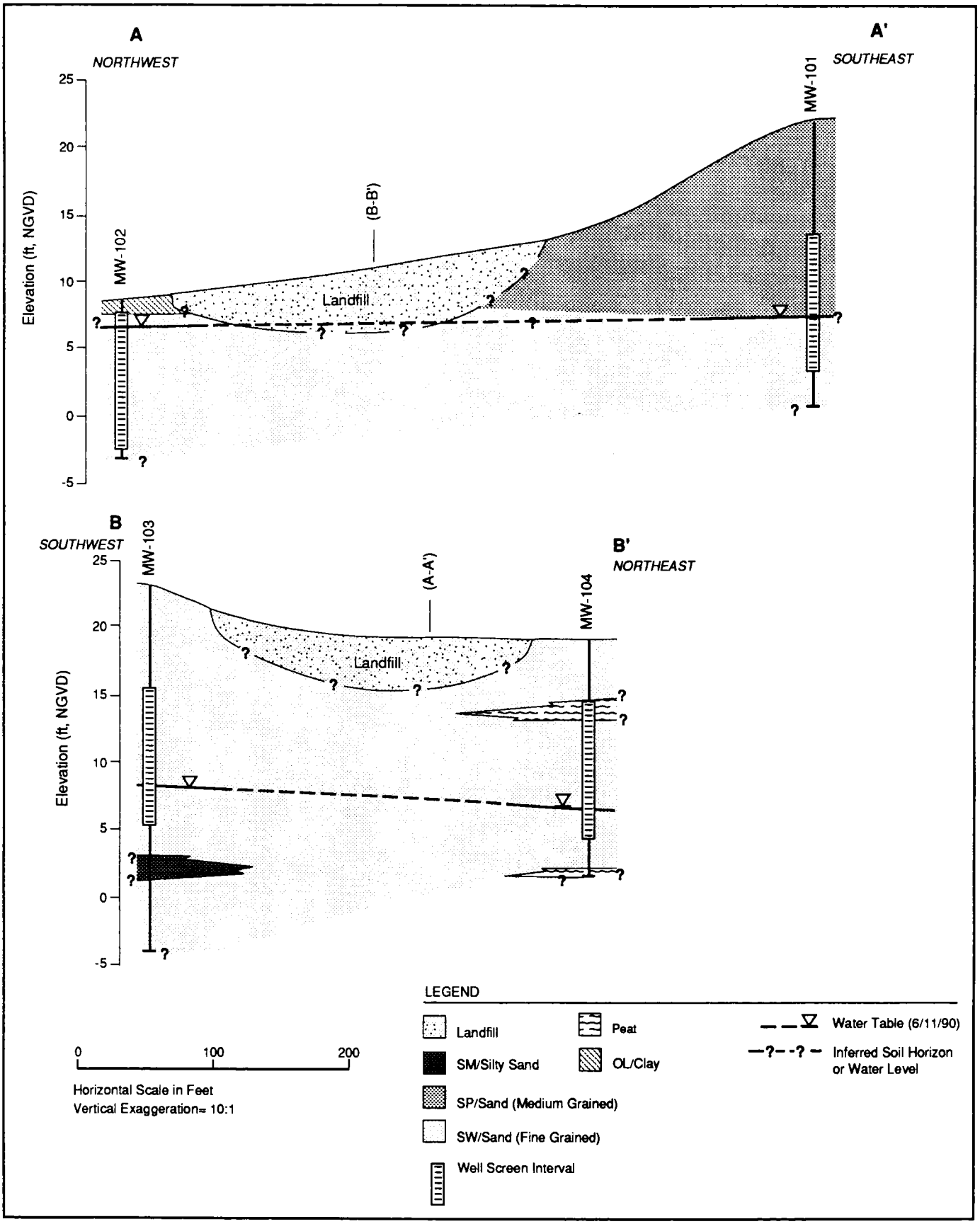
Sampling Locations and Geologic Cross Section Locations,
Site 1, Landfill 1
Ft. Story, VA

Figure 2-4



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Cross Sections A-A' and B-B' at Site 1, Landfill 1
Ft. Story, VA

Figure 2-5

TABLE 2-11

SITE 1, LANDFILL 1
WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-101	24.44	21.00	13.44	3.44	21.90	14.66	7.24	06/11/90
MW-102	8.69	11.25	7.44	-2.56	8.79	2.26	6.71	06/11/90
MW-103	30.53	25.00	15.53	5.53	28.30	20.07	8.23	06/11/90
MW-104	22.21	17.50	14.71	4.71	19.50	12.79	6.71	06/11/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to ground surface.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-12

SITE 1, LANDFILL 1
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
MW-101	21	7	3	0,4,8,10,12, 14, 19
MW-102	11.5	4	3	0,1,2,4,9
MW-103	27	6	3	0,4,10,15,20,25
MW-104	17.5	4	3	0,4,10,15

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

Samples submitted for chemical analysis were analyzed for pesticides/PCBs, VOCs, BNAs, total metals, EP Tox metals, cyanide, and total solids. The original VOC analyses for soil, samples S1MW101(0) and S1MW104(0), were not analyzed within holding times. These two locations were resampled and analyzed within holding times. The analytical results obtained from the soil samples, as well as the resampling data, are presented in the *FTSFARD*. Groundwater samples were analyzed for pesticides/PCBs, VOCs, BNAs, dissolved metals, total metals, cyanide and inorganics. The analytical results obtained from the groundwater samples collected from the Site 1 wells are presented in the *FTSFARD*.

Soil Analytical Results. The analytical results of soil analysis at Site 1 can be found in Table 1-SS of *FTSFARD*. Figure 2-4 shows the sampling locations. None of the parameters selected to characterize Site 1 were detected above their respective trigger levels in any of the soil samples collected.

The soil sample collected at a depth of 10 feet from MW-103 contained trace levels of DDT, DDD and DDE which were detected above method reporting level (MRL). As has been discussed, DDT and its metabolites are ubiquitous throughout the area.

Groundwater Analytical Results. Analytical groundwater results for Site 1 can be found in Table 1-GW of the *FTSFARD*. Figure 2-4 shows the sampling locations. No analytes in the groundwater were detected above the trigger levels.

Some compounds were found below the trigger level. Groundwater samples MW-101, MW-101 D, MW-102, MW-103, MW-104 contained carbon disulfide at concentrations of 25 µg/l, 10 µg/l, 15 µg/l, 5.7 µg/l and 0.6 µg/l respectively. While carbon disulfide is a common laboratory artifact, it is also possibly a result of biological reductive breakdown associated with a landfill. The concentrations are well below the trigger level for carbon disulfide (1,000 µg/l) and are subsequently of little consequence. Also, inorganic compounds such as fluoride, chloride and sulfate were detected in groundwater samples at levels below their respective trigger levels. MW-101 contained trace levels of benzoic acid in a duplicate sample, although the associated initial sample did not contain benzoic acid. MW-104 also contained trace levels of benzoic acid in the groundwater. Benzoic acid is a common constituent of leachate associated with landfills and is a by-product of natural organic degradation in a reducing environment.

Recommendations. The concentrations of pesticides/PCBs, VOCs, BNAs, total metals, EP Tox metals, and cyanide in soil samples are below the appropriate trigger levels. Pesticides/PCBs, VOCs, BNAs, total metals, dissolved metals, and cyanide in the groundwater samples are also all below the appropriate trigger levels. Therefore, JMM recommends no further action for Site 1, Landfill 1.

2.2.2.2 Site 2, Landfill 2. Site 2, Landfill 2, is located within the wetland area along the southern margin of Fort Story, immediately adjacent to the southern flank of the central sand ridge area near the junction of Coast Artillery Road and U.S. Route 60. The purpose of the investigation of Site 2, Landfill 2, was to determine the boundary of the landfill and the presence of soil and groundwater contamination associated with the landfill.

The landfill was in operation from 1956 to 1962 (ESE, 1988). During the 1960s, a group of wooden buildings may have been demolished and buried at this site, but no documentation is available to confirm this action (Personal Communication, Fort Story Personnel, 1990). JMM's recent field observations did not indicate any surface debris or evidence of buried debris.

Groundwater and soil matrices were investigated at Site 2 through the installation of five monitoring wells. Figures 2-6 and 2-7 show sampling locations. Locations for the monitoring wells, which were installed in positions that collectively encircle the fill area, were selected on the

basis of geophysical surveying performed to locate the extent of the fill area. The geophysical survey at Landfill 2 did not clearly define its boundaries as clearly as for Landfill 1. This may be due to a lack of sufficient ferrous materials for the instruments (magnetic conductivity and magnetometer) to detect the transition between fill and native soil.

Well to poorly graded Holocene-age sand deposits underlie the site. The sand is generally characterized as medium to medium-fine grained and subangular to subrounded. At some locations, thin discontinuous peat lenses are interbedded with the sand. From ground surface to relatively shallow depths, the sand locally includes significant quantities of silt. Figure 2-8 presents cross sections based on soil boring data that illustrate the general stratigraphy of Site 2. The locations of the cross sections are shown on Figure 2-6.

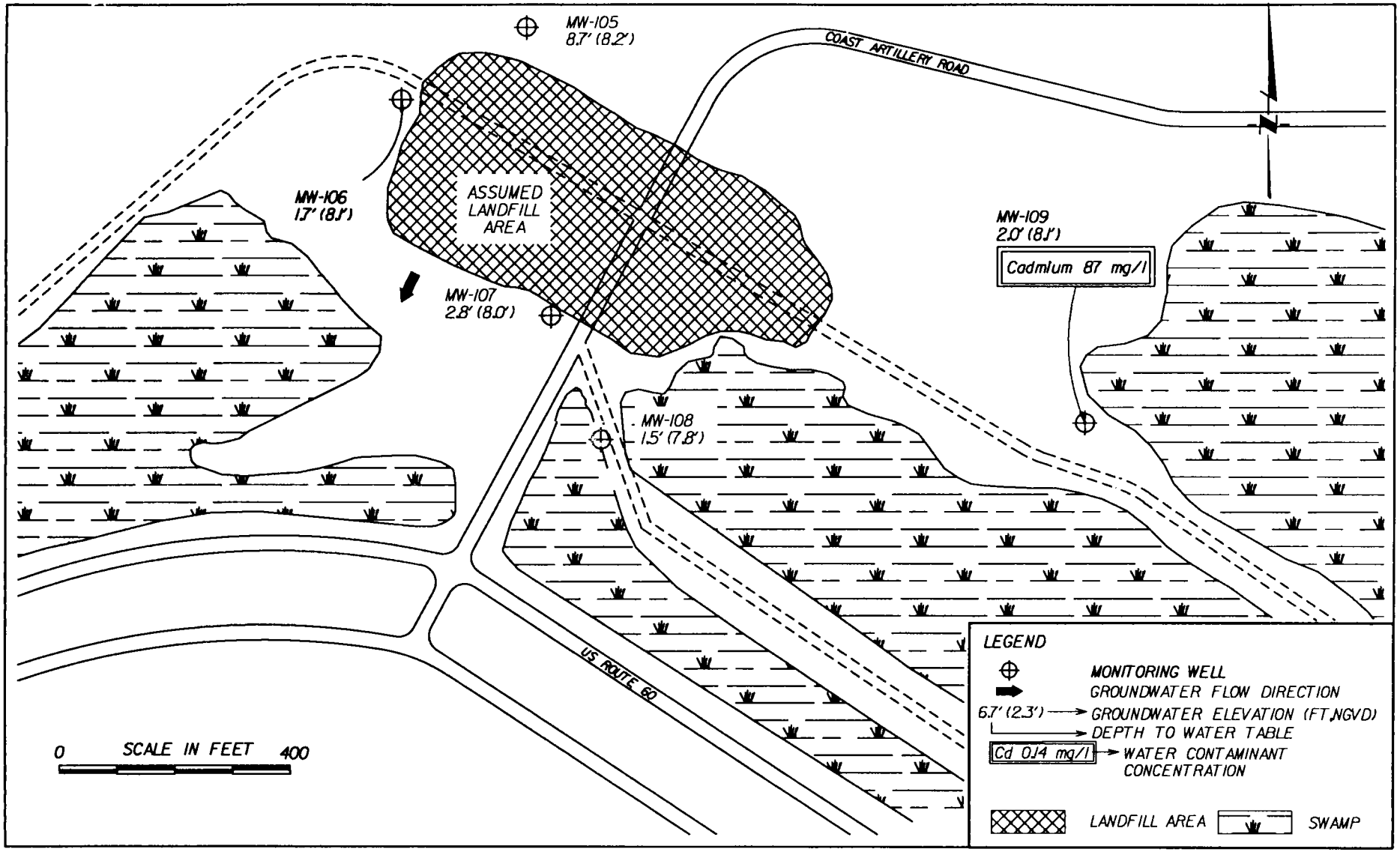
Groundwater is encountered at relatively shallow depths in the Site 2 area. Monitoring wells MW-106 through MW-109 were installed in the immediate vicinity of the fill area. Based on water level data from the wells installed in the low lying area adjacent to the landfill, the water table was measured at an average depth of 2 feet bls. Water level data and well construction data for each of the Site 2 monitoring wells are presented in Table 2-13. Well MW-105 is located in an upgradient position, on the southern flank of the central sand ridge area. The water table occurs at a depth of 8.73 feet bls in this well. Measured groundwater elevations ranged from 8.16 feet NGVD in MW-105 to 7.78 feet NGVD in MW-108. Based on these data, the hydraulic gradient across the site is directed toward the southwest. Hydraulic conductivity values calculated for Site 2, Landfill 2, range from 1.74×10^{-4} to 1.79×10^{-2} cm/sec (4 to 379 gal/da/ft^2),.with an average value of 6.36×10^{-3} cm/sec (135 gal/da/ft^2).

Table 2-14 indicates the depths at which soil samples were collected from the Site 2 monitoring well borings. Analytical soil samples were collected at ground surface and at the depth corresponding to the soil-groundwater interface. The analyses performed on the samples collected included pesticides/PCBs, VOCs, BNAs, total metals, EP Tox metals, cyanide and total solids. Holding times were exceeded for these VOC soil samples: S2MW105(10), S2MW107(0), S2MW107(2), S2MW108(0), S2MW108(0)D and S2MW108(2). These three soil samples were recollected and sent to the laboratory for analysis: S2MW107(0), S2MW108(0), and S2MW108(0)D. The analytical results from the Site 2 soil samples and the resampling effort are presented in Table 2-SS of the *FTSFARD*. The groundwater samples collected from the Site 2 monitoring wells were analyzed for pesticides/PCBs, VOCs, BNAs, dissolved metals, total metals, cyanide and inorganics. The analytical results for these analyses are presented in Table 2-GW in the *FTSFARD*.

Soil Analytical Results. The results of soil analyses at Site 2 are presented in Table 2-SS of the *FTSFARD*. Figure 2-6 shows the sampling locations and the soil analytes detected above trigger levels. The only analyte detected above trigger level that could warrant further investigation in the soil was copper, at 19 mg/kg and 17 mg/kg, which was detected in the surface soil and two-foot samples collected from MW-107, located downgradient of the landfill. This slightly exceeds the trigger level of 14 mg/kg for copper. Although 2 mg/kg of cyanide was found in the sample collected from the surface at MW-107, it is considered to be within acceptable range for background, as discussed in Section 2.1.2.1.

Groundwater Analytical Results. The analytical results of groundwater analyses of samples from Site 2 are presented in Table 2-GW of the *FTSFARD*. Figure 2-7 shows the sampling locations, with the groundwater analytes detected above trigger levels. Cadmium was found in concentrations greater than its trigger level in the sample from one well, MW-109, at a concentration of 87 µg/l, which is over 10 times the trigger level of 5 µg/l.

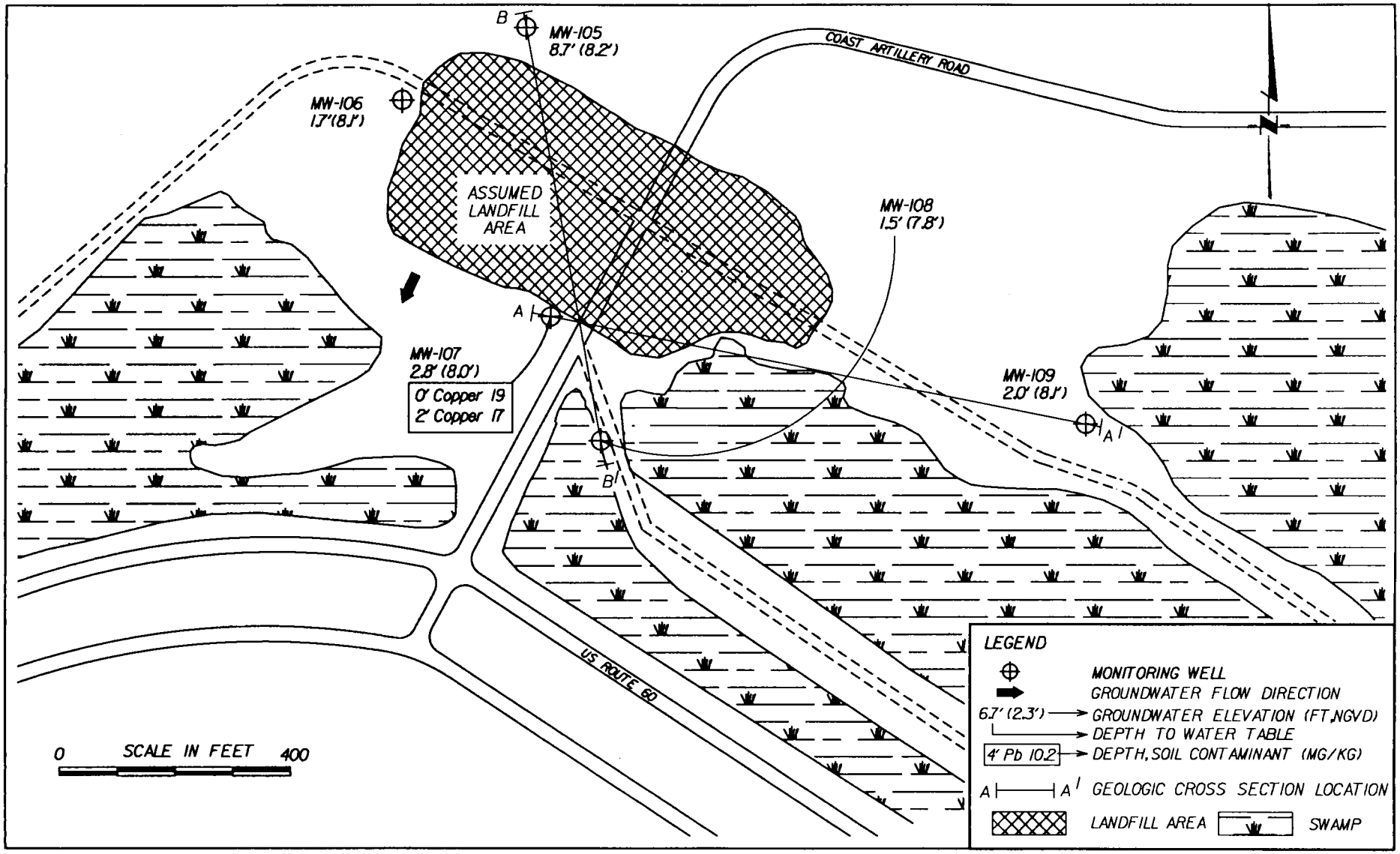
Numerous analytes were detected in concentrations below trigger levels. Carbon disulfide was detected in all monitoring well groundwater samples collected at this site. The highest



JMM

Groundwater Chemistry Concentrations,
Site 2, Landfill 2
Ft. Story, VA

Figure 2-7



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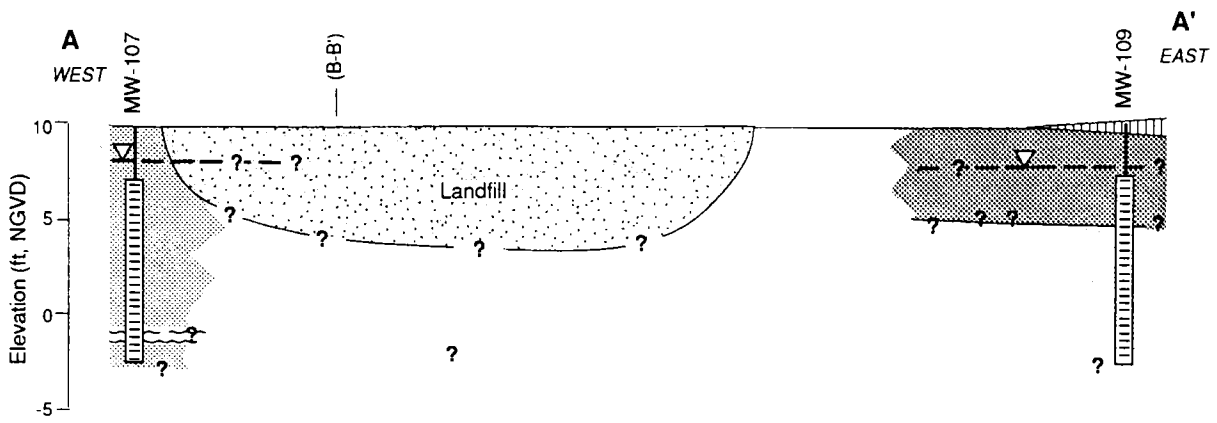
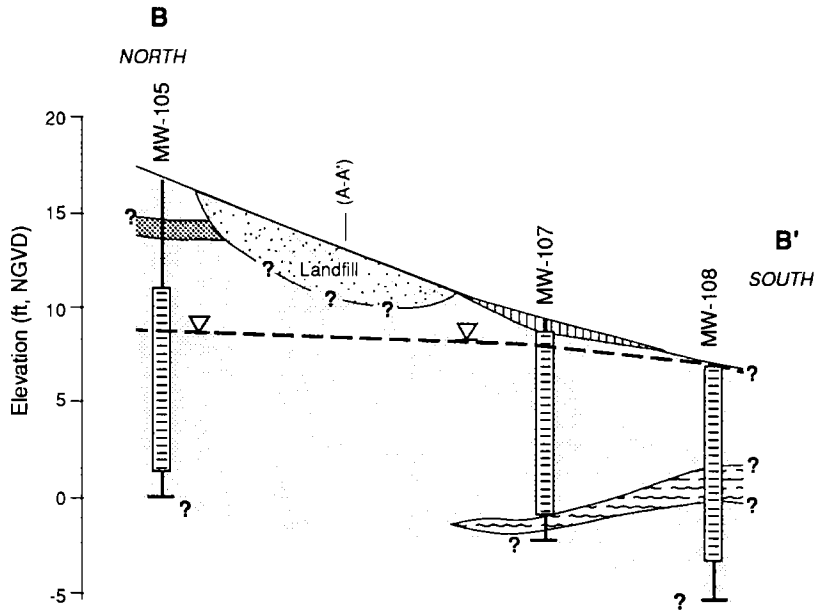
Soil Chemistry Concentrations and Geologic Cross Section Locations,
Site 2, Landfill 2
Ft. Story, VA

Figure 2-6





LEGEND

- Landfill
- SM/Silty Sand
- SP/Sand (well sorted)
- SW/Sand (fine grained)
- ML/Silt
- Peat
- Water Table (6/11/90)
- Inferred Soil Horizon or Water Level
- Well Screen Interval
- Soil Boring

0 200 400

Horizontal Scale in Feet
Vertical Exaggeration= 27:1

JMM

Cross Sections A-A' and B-B' at Site 2, Landfill 2
Ft. Story, VA

Figure 2-8

TABLE 2-13

SITE 2, LANDFILL 2
WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-105	16.56	15.00	11.56	1.56	16.89	8.73	8.16	06/11/90
MW-106	9.52	11.75	7.77	-2.23	9.75	1.73	8.02	06/11/90
MW-107	10.60	11.50	9.10	-0.90	10.84	2.84	8.00	06/11/90
MW-108	8.98	12.00	6.98	-3.02	9.29	1.51	7.78	06/11/90
MW-109	9.68	10.07	7.93	-2.07	10.07	1.99	8.08	06/11/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to ground surface.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-14

SITE 2, LANDFILL 2
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
MW-105	17.5	6	2	0,2,4,6,8,14
MW-106	12	4	2	0,2,4,10
MW-107	13	4	2	0,2,5,10
MW-108	14	4	2	0,2,5,10
MW-109	12	4	2	0,2,4,10

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

concentrations were 18 µg/l and 25 µg/l, found at MW-108 and MW-109. Toluene was detected at 1.3 µg/l in MW-109. Benzoic acid, at 120 µg/l, was found in MW-108. Both carbon disulfide and benzoic acid are commonly found in landfill leachate and are products of naturally occurring reductive degradation of detritus.

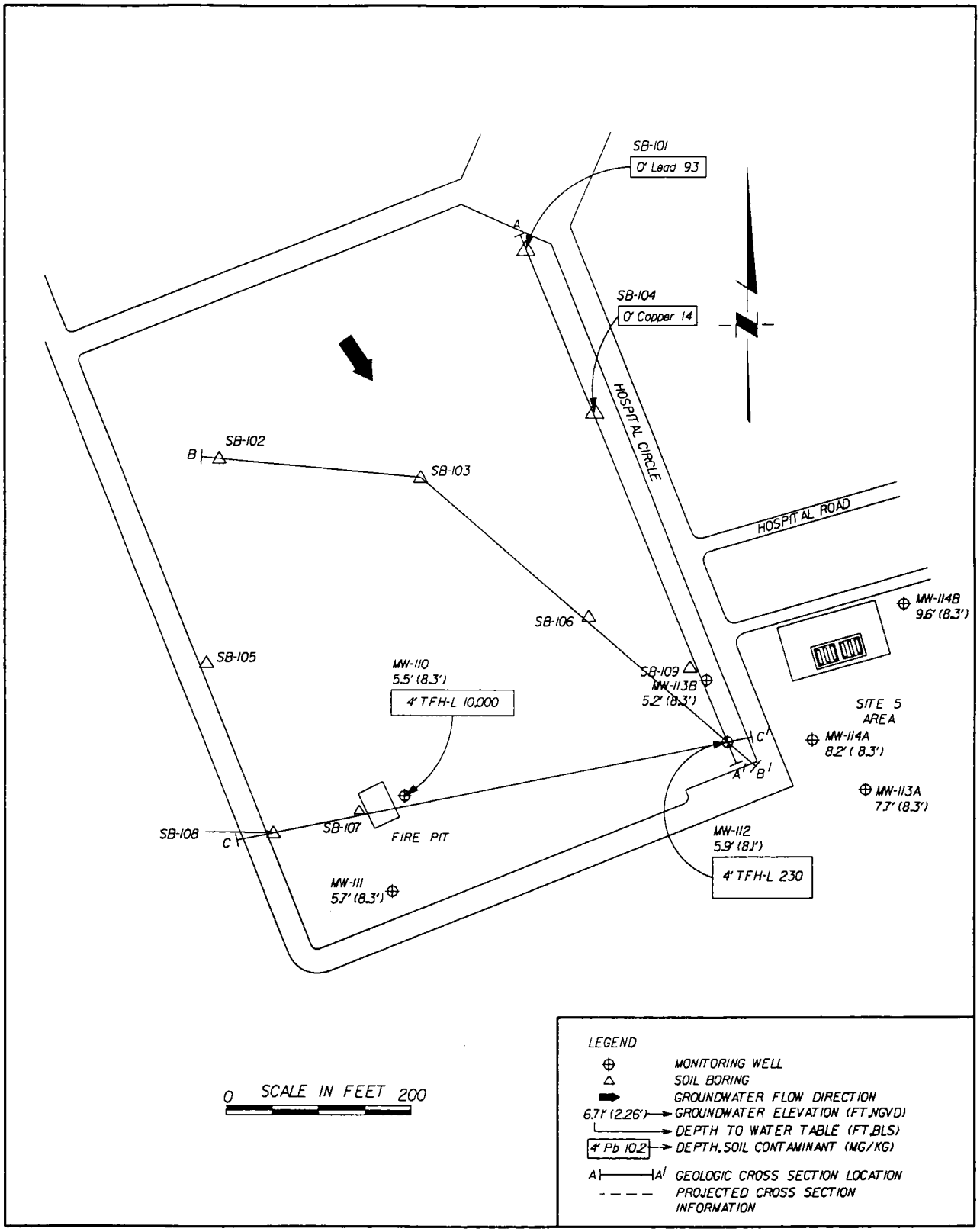
Recommendations. The presence of cadmium in the groundwater beneath Site 2, Landfill 2, warrants further investigation. The elevated levels of copper found in soil collected from MW-107 have apparently not affected the groundwater, although infiltration could occur. The discontinuous random distribution of the constituents of concern (Figures 2-6 and 2-7) indicate that the source of the cadmium may not be associated with the landfill, based on JMM's interpretation of the site's hydrogeological features. Therefore, JMM recommends that further confirmatory investigation involving additional groundwater, surface water and sediment sampling be performed to help determine the source of the cadmium. Additional fixed interval monitoring of contaminant levels in groundwater is also recommended.

2.2.2.3 Site 4, Firefighter Training Area. Site 4, Firefighter Training Area, is located in a sandy flat area situated adjacent to the northern flank of the central sand ridge in the southwestern section of Fort Story, along Hospital Road adjacent to the fuel farm. The purpose of the investigation of Site 4, Firefighter Training Area, was to determine the presence of soil and groundwater contamination associated with previous activities at this site.

A temporary hospital facility formerly located on this site was relocated in 1960, and the old structure demolished. From 1960 through 1978, the area adjacent to the southern boundary along U.S. Route 60 was used as a wildlife game preserve (Personal Communication, Fort Story Personnel, 1989). The site was cleared and used for fire training exercises in the latter part of 1978. Prior to 1980, these exercises consisted of extinguishing JP-4 aviation fuel, which was released and ignited directly on the surface soils of the site. The releases were reportedly extinguished by a mixture of fire-fighting foam and water (Personal Communication, Fort Story Personnel, 1989).

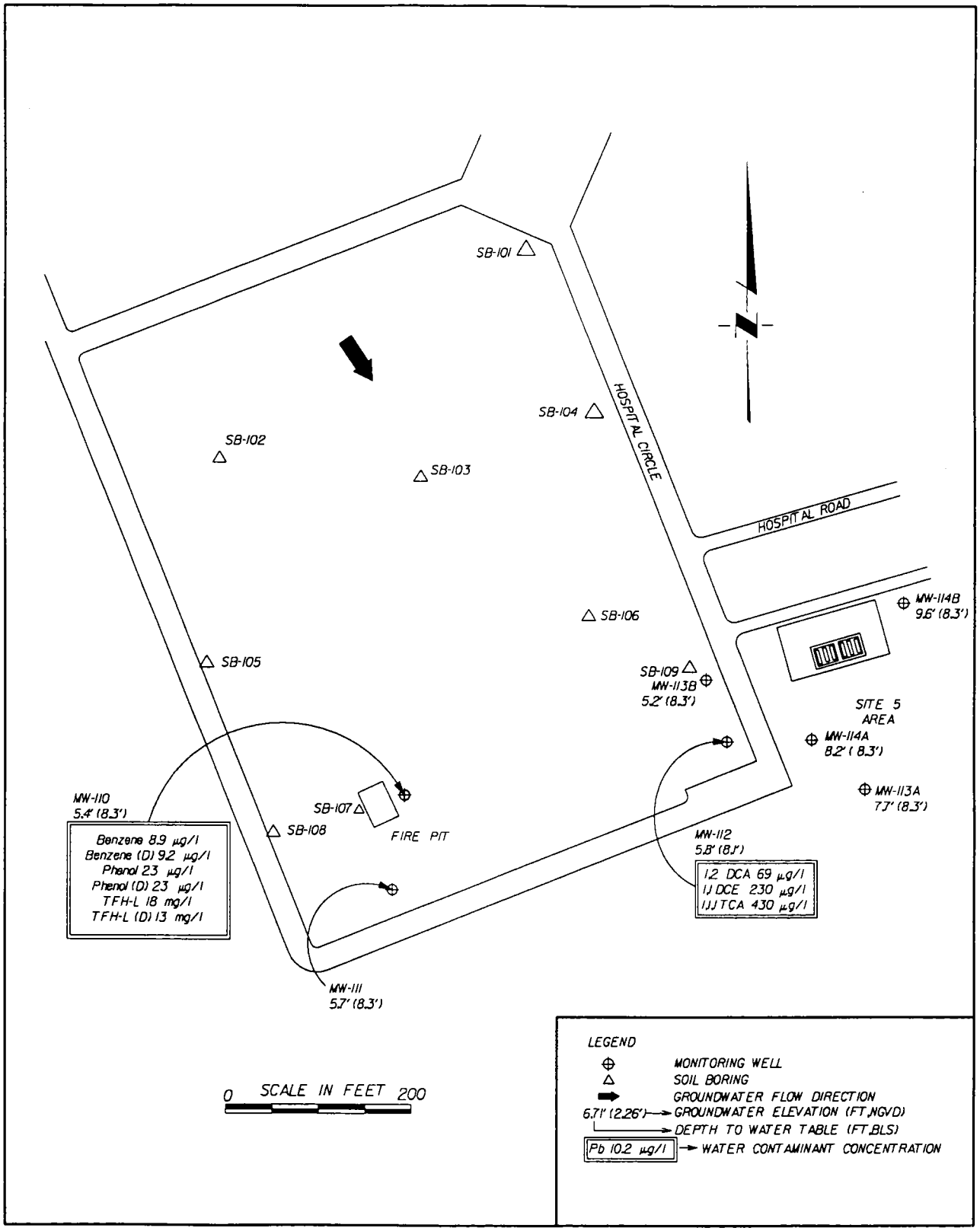
A concrete fire pit was constructed in 1980 and used for fire-fighter training exercises. The 100 foot square by 2 foot deep pit was used on a monthly basis and involved this procedure: The pit was first filled with several inches of water and 75 to 400 gallons of fuel (JP-4 fuel, contaminated fuels and hydraulic fluid). The mixture was then ignited and allowed to burn. During the exercise, three to four firefighters performed extinguishing exercises using 50 to 150 gallons of fire-fighting foam. Once the fire was extinguished, the residues of the fuel and extinguishing mixtures were left to evaporate naturally. Additionally, during 1980 through 1986, many installation personnel reportedly used the firefighting training area as an unauthorized dumping site. The site is currently free of any surface debris or evidence of buried debris. In June 1988, firefighting training activities were discontinued at this site (Personal Communication, Fort Story Personnel, 1989).

Groundwater and soil matrices were investigated at the site with the installation of three monitoring wells and nine soil borings. Figures 2-9 and 2-10 show sampling locations. The locations for the three monitoring wells and nine soil borings installed at the site were selected based on the results of a soil gas survey conducted during the field investigation. Soil gas samples were collected at the intersections of a 100-foot by 100-foot grid having seven rows and six columns (Figure 2-11). The extracted soil gas samples were analyzed for 1,1,1-trichloroethane (TCA), trichloroethene (TCE), tetrachloroethene (PCE), benzene, toluene, ethylbenzene, xylenes and total hydrocarbons. Results of the survey indicate that potentially contaminated areas of the site include the north central site location, as indicated by detectable levels of benzene, and the extreme southeastern corner of the site, as suggested by elevated levels of benzene, TCA and total hydrocarbons. Figures 2-12, 2-13 and 2-14 presented the soil gas contour plots for benzene, trichlorethane (TCA) and total hydrocarbons, respectively. The soil gas survey results are presented in Appendix D.



Soil Chemistry Concentrations and Geologic Cross Section Locations,
Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-9



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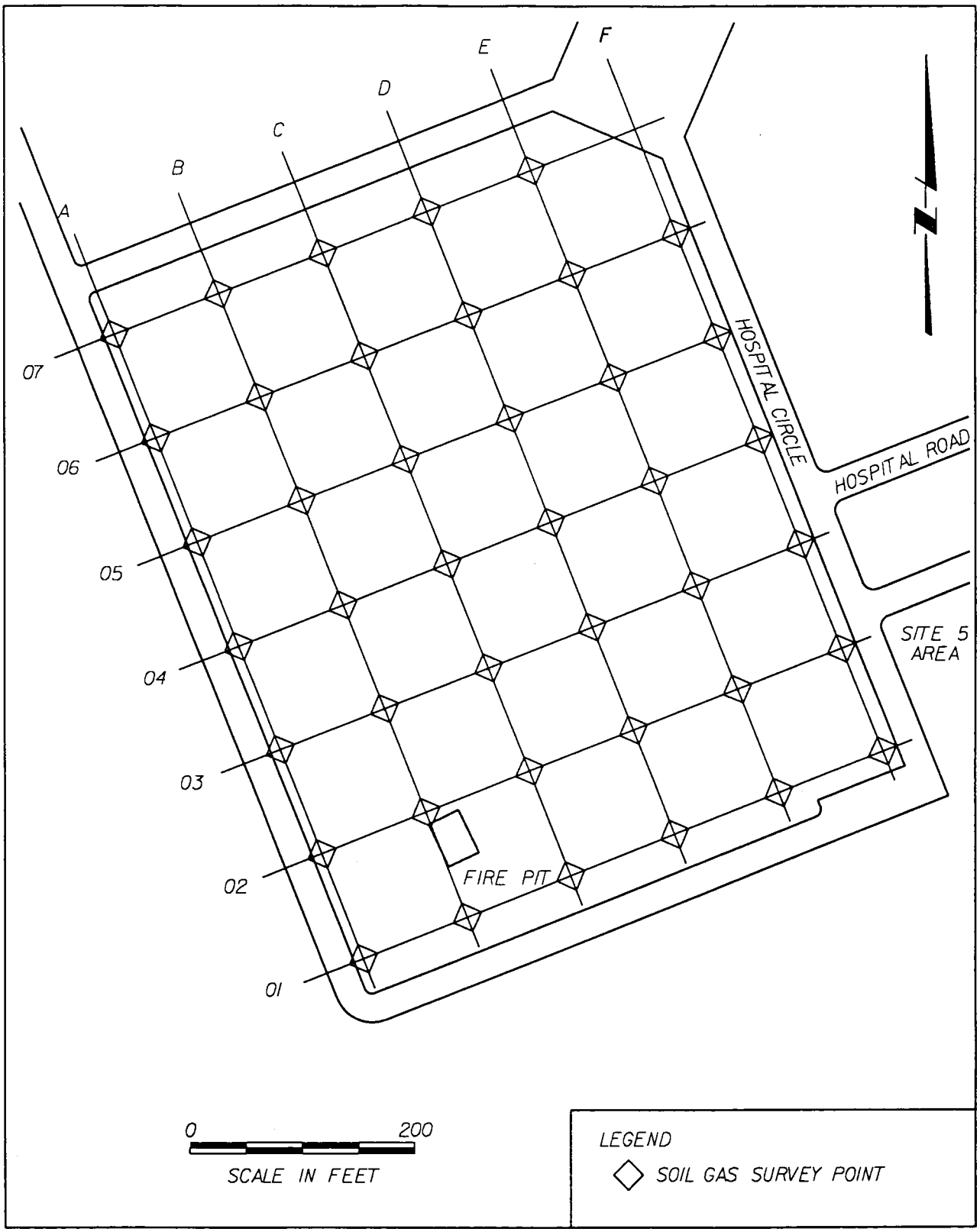
Groundwater Chemistry Concentrations,
Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-10



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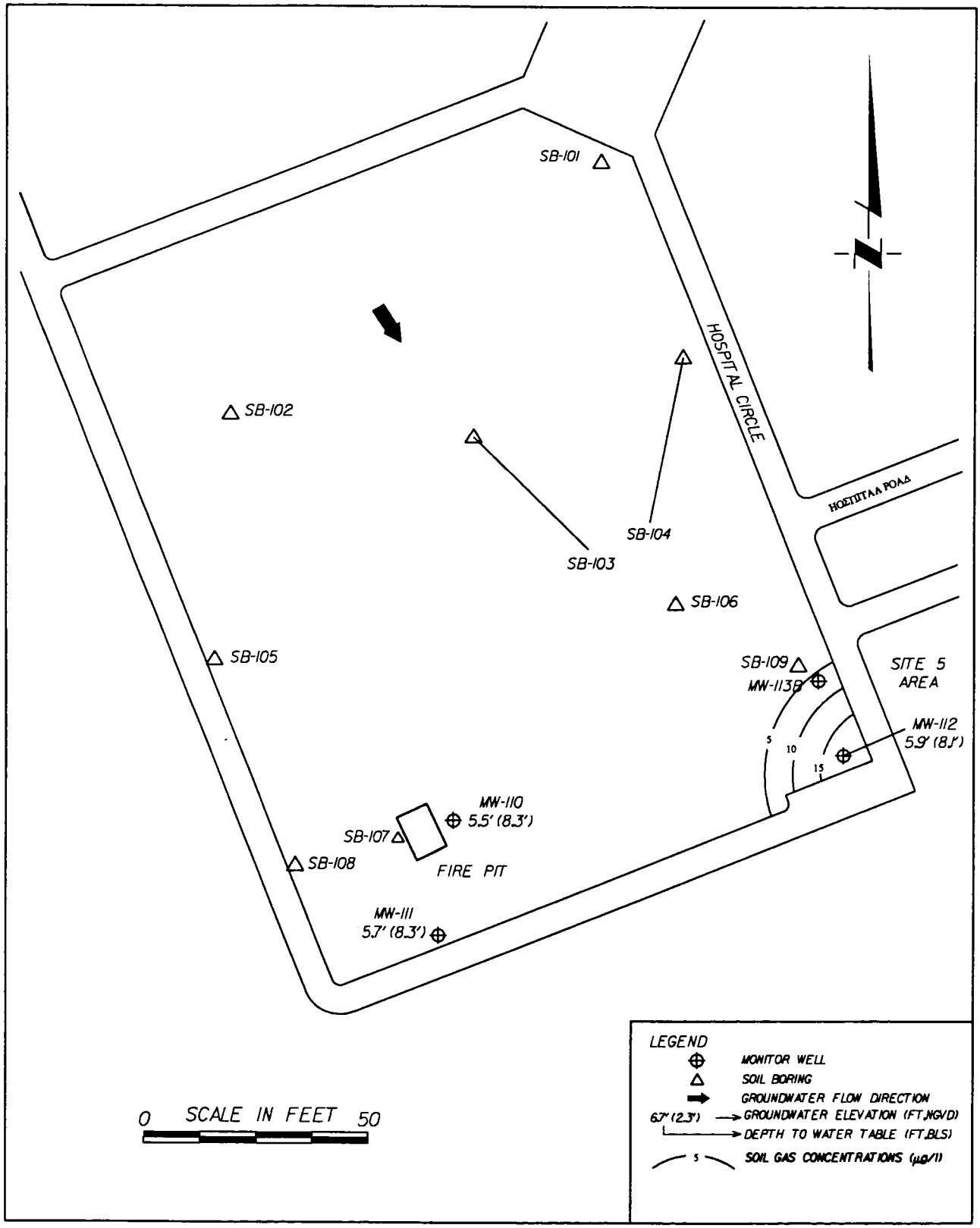
Soil Gas Survey Grid,
Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-11



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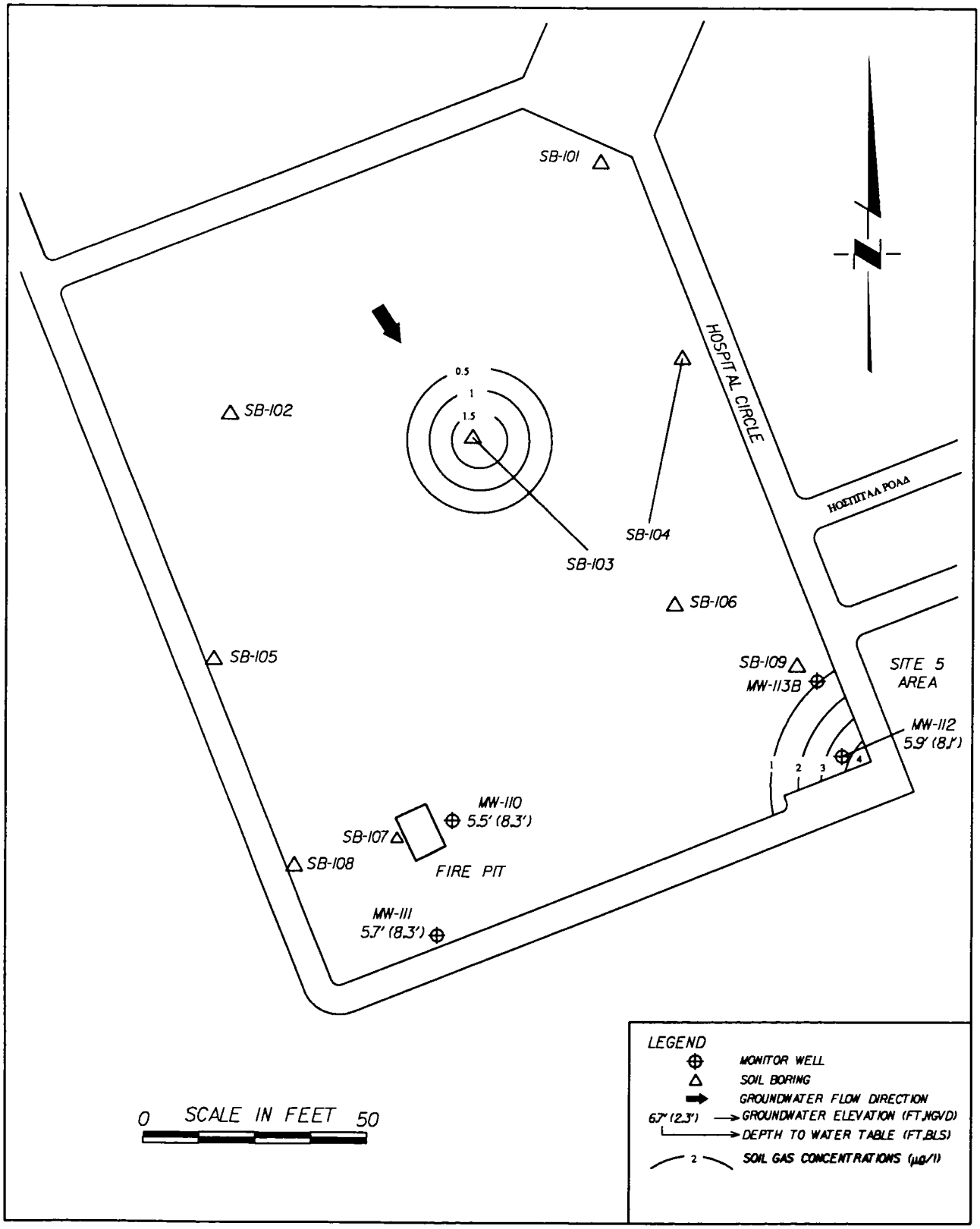
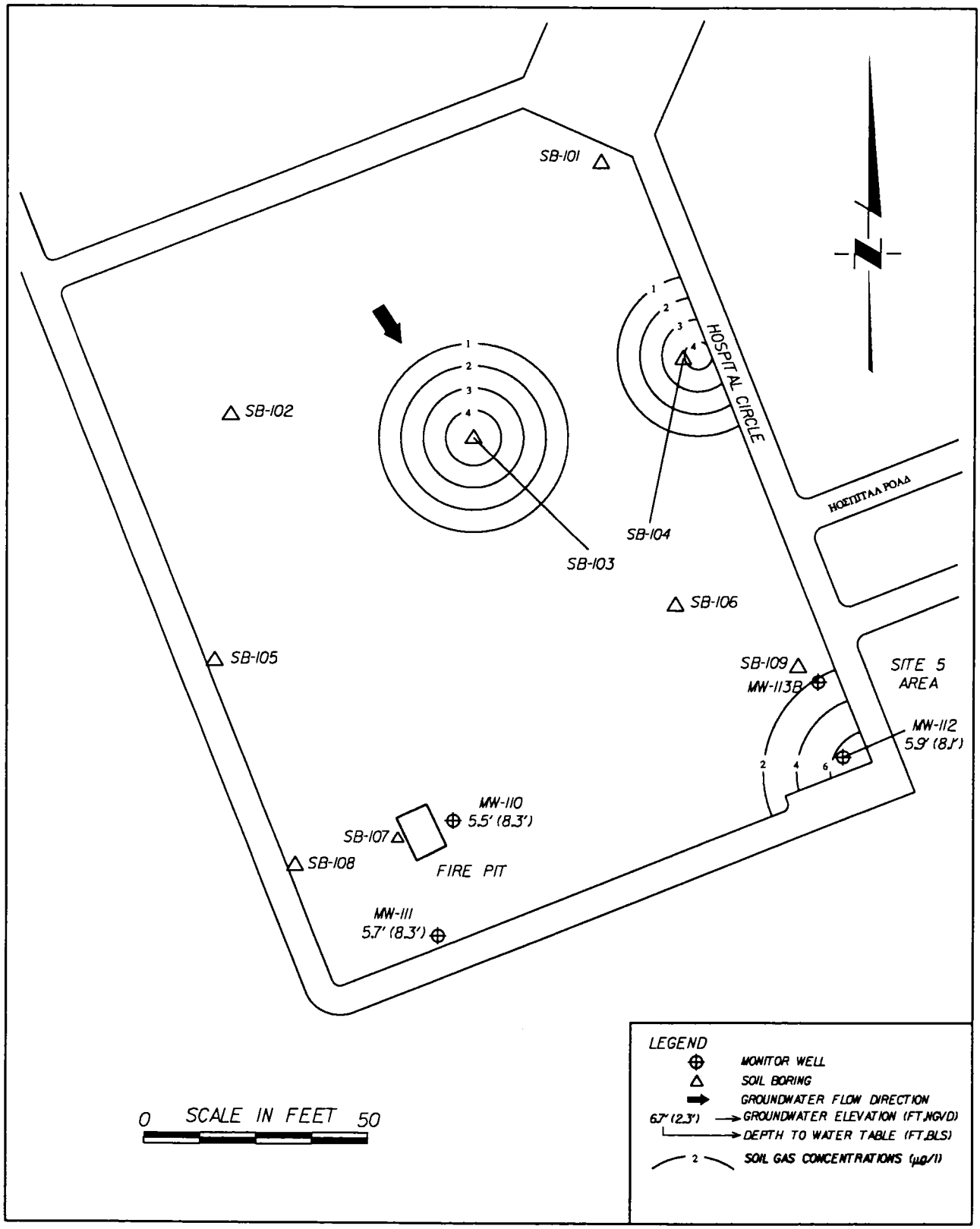
Benzene Concentrations in Soil Gas at Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-12



TCA Concentrations in Soil Gas at Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-13



Total Hydrocarbon Concentrations in Soil Gas at Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-14

The site is underlain by Holocene Age sand deposits. The sand is typically subrounded to subangular, usually poorly graded and medium to coarse grained. The coarse grained facies is generally restricted to depths in excess of 4 feet. Silty sand is present to a depth of 2 to 4 feet in the eastern area of the site. Figures 2-15 and 2-16 present three cross sections based on soil boring data that illustrate the general stratigraphy of Site 4. The locations of the cross sections are presented on Figure 2-9.

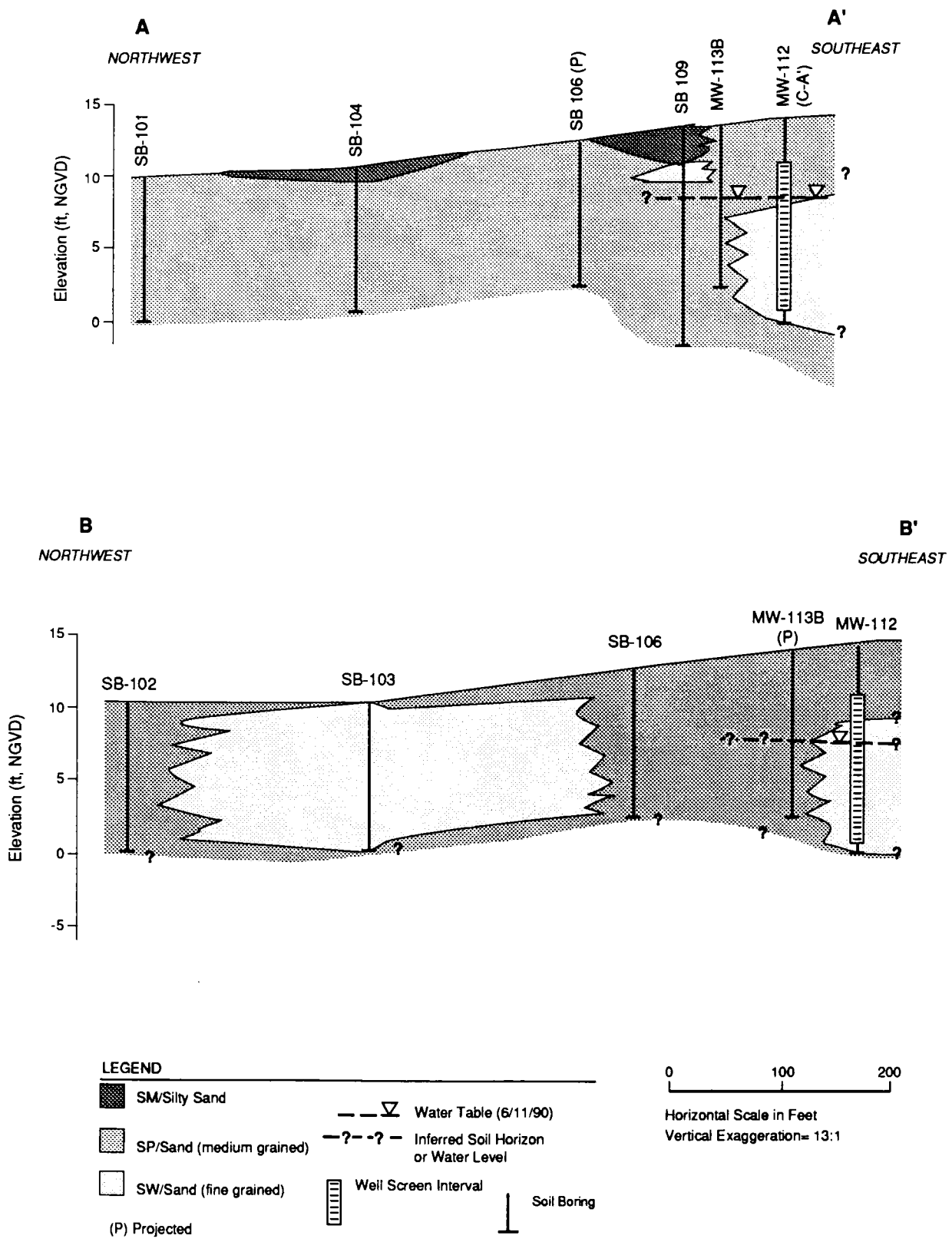
The three monitoring wells installed at the site provide data regarding the depth to groundwater in the southern portion of the site. The measured depth to the water table in this area ranged from 5.20 feet bls in MW-110 to 5.60 feet bls in MW-112. Table 2-15 presents water level data and construction characteristics for the installed monitoring wells. Based on the groundwater elevation data from the wells installed at the site, together with other water level data from the Fort Story area, water table elevations range from 8.5 feet NGVD in the northern portion of the site to less then 8.3 feet NGVD in vicinity of the southern portion. Water table elevations measured in the installed monitoring wells range from 8.33 feet NGVD in MW-111 to 8.14 feet NGVD in MW-112. Groundwater flow is directed from the northwest across the site to the south and east. Hydraulic conductivity values calculated for Site 4 range from 1.17×10^{-2} to 1.37×10^{-2} cm/sec.(248 to 290 gal/day/ft^2), with an average value of 1.24×10^{-2} cm/sec (263 gal/day/ft^2).

The construction of the wells and soil borings at Site 4 included soil sampling at regular intervals (Table 2-16). Analytical soil samples from borings were collected at ground surface and at the terminus of the soil borings. Analytical soil samples from well borings were collected during the construction of the monitoring wells from the ground surface and from the depth corresponding to the soil-groundwater interface. The analyses performed on the samples included pesticides/PCBs, VOCs, BNAs, TFH-L, total metals and total solids. Analytical results obtained from the soil samples collected at Site 4 are presented in the Table 4-SS of the *FTSFARD*. Static water level measurement activities at well MW-110 indicated the presence of 8 inches of floating non-aqueous phase liquid (NAPL) on May 27, 1990. The groundwater samples collected were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-L, dissolved metals and total metals.

Soil Analytical Results. The analytical results of soil analyses from samples from Site 4 are presented in Table 4-SS of the *FTSFARD*. Figure 2-9 shows the sampling locations, along with the soil analytes detected above trigger levels that warrant further investigation.

Several analytes were detected at levels above the trigger level in the soil at Site 4. The largest concentration was associated with areas adjacent to the existing fire pit, as well as an area located in the southeast corner of the site. The sample collected 4 feet below grade from MW-110, located adjacent to the fire pit, contained 10,000 mg/kg of TFH-L. Copper, at 14 mg/kg, was found at the trigger level in the surface sample of boring SB-104; and 93 mg/kg of lead was found in the surface sample collected from SB-101, which is a concentration exceeding lead's trigger level of 71 mg/kg. The four-foot soil sample collected from MW-112, located in the southeast corner of the site, contained 230 mg/kg of TFH-L. Although the analytical results for TFH-L found in soils from MW-110 and MW-112 are considered estimated, because of the laboratory problems discussed in the *QCSR*, the relative magnitude of TFH-L detected, when compared to the trigger level of 100 mg/kg, still indicates that the soil is contaminated.

Numerous analytes without trigger levels were found in concentrations above MRL at several locations where soil samples were collected. At MW-110, VOCs (m,p-xylenes, o-xylene) and BNAs, associated with the large TFH-L detection, were detected in the four-foot sample.



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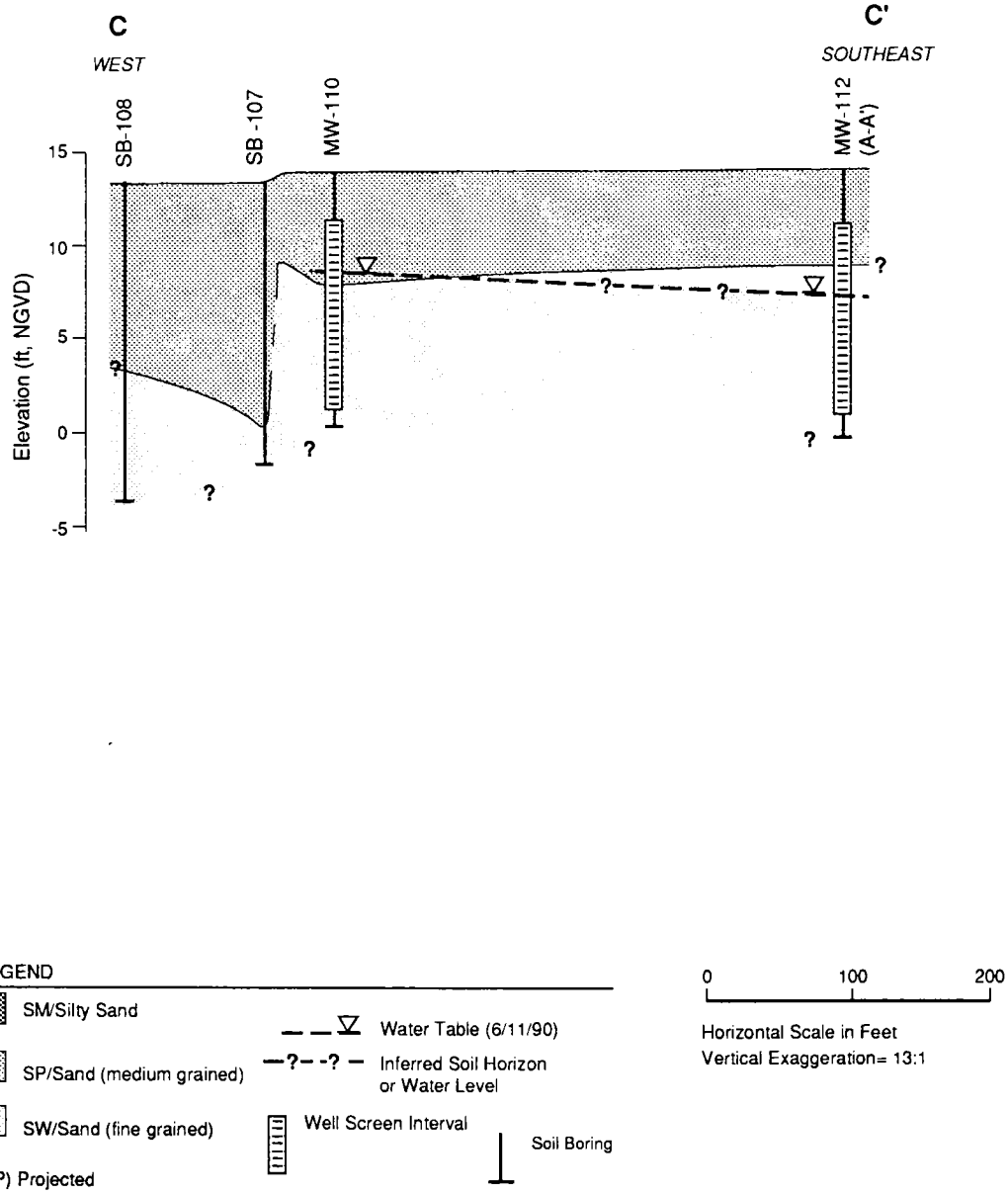
Cross Sections A-A' and B-B' at Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-15



Cross Sections C-C' at Site 4, Firefighter Training Area
Ft. Story, VA

Figure 2-16

TABLE 2-15

SITE 4, FIREFIGHTER TRAINING AREA
WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-110	13.51	13.50	10.51	0.51	13.79	5.20	8.31	06/11/90
MW-111	13.83	13.50	10.83	0.83	14.03	5.50	8.33	06/11/90
MW-112	13.74	14.00	10.74	0.74	14.00	5.60	8.14	06/11/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to TOC.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-16

SITE 4, FIREFIGHTER TRAINING AREA
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
SB-101	10	3	2	0,5,8
SB-102	10	3	2	0,4,8
SB-103	10	3	2	0,4,8
SB-104	10	3	2	0,5,8
SB-105	10	3	2	0,5,8
SB-106	10	3	2	0,5,8
SB-107	13	3	2	0,4,9,13
SB-108	17	3	2	0,5,10,15
SB-109	15	3	2	0,5,10,13,15
MW-110	13.5	4	2	0,2,4,10
MW-111	13.5	4	2	0,2,4,10
MW-112	14	4	2	0,2,4,10

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

Groundwater Analytical Results. The analytical results of water analysis at Site 4 are presented in Table 4-GW of the *FTSFARD*. Figure 2-10 shows the sampling locations, along with the groundwater analytes detected above trigger levels.

As with soil samples, numerous analytes were detected above trigger levels, with the major areas of contamination associated with the existing fire pit as well as the southeast corner of the site. The groundwater sample and associated duplicate sample collected from MW-110 contained 8.9 µg/l and 9.2 µg/l of benzene, which exceeds the trigger level of 5 µg/l. The presence of these analytes is not unreasonable due to the high TFH-L concentration detected in the soil as well as the groundwater, which contained 18 mg/l of TFH-L in the initial sample and 13 mg/l of TFH-L in the associated duplicate samples, both exceeding the TFH-L trigger level of 1 mg/l. The same sets of samples also contained 23 mg/l of phenol, which has a trigger level of 1 µg/l. The groundwater sample collected from MW-112 contained 69 µg/l of 1,2-dichloroethane (trigger level 5 µg/l), 430 µg/l of 1,1,1-trichloroethane (trigger level 200 µg/l) and 230 µg/l of 1,1-dichloroethene (trigger level 7 µg/l). Numerous analytes were detected in concentrations below the trigger levels, as shown in the *FTSFARD*.

Recommendations. Environmental contamination problems associated with Site 4 appear to be associated with two main sources: the fire pit area and the area located in the southeastern corner of Site 4, as well as the general area north of the pit. TFH compounds in site soil appears to have already infiltrated the site groundwater, based on JMM's interpretation of the existing data.

Although the soil gas survey identified the possible location of a former burn pit at SB-103, soil analysis at that location reveals no residual environmental contamination associated with the site. However, the high TFH-L as well as organic and metal values associated with soil samples collected from MW-110 and MW-112 warrant further investigation of the fire pit area, and the region at the southeast corner of the site. JMM recommends that an RI/FS be performed at the site to delineate the extent of soil and groundwater contamination in the site area adjacent to the pit and in the site area located in the far southeastern corner of the site. Attention needs to be focused toward the groundwater divide issue in the RI/FS.

2.2.2.4 Site 5, Underground Fuel Storage Tank Farm. Site 5, the Underground Fuel Storage Tank Farm, is located in a sand flat area situated adjacent to the northern flank of Fort Story's central sand ridge. This fuel farm consists of six 10,000-gallon capacity USTs for storage of JP-4 fuel and is located adjacent to the eastern boundary of Site 4, Firefighter Training Area. The purpose of the investigation of Site 5, Underground Fuel Storage Tank Farm, was to determine the presence of soil and groundwater contamination associated with the USTs at this site.

The first three 10,000-gallon tanks were installed in 1980. The remaining three tanks were installed in 1985. No spills were reported during the past operation of this facility. The tanks are configured in a parallel line, two sets of three (see Figure 2-17). Leak-testing of the tanks in November 1989 detected evidence of tank vapor leakage from tanks 2, 4 and 6 (Tracer Research Corporation, 1990). All three tanks were removed from service in December 1989 and the contents removed in January 1990. This information was reported to the Commonwealth of Virginia State Water Control Board (VWCB) by the Installation (Personal Communication, VanDervort, 1991). The assessment of the fuel storage area, therefore, focused on determining the nature and extent of petroleum hydrocarbon contamination in the soil and groundwater at the site.

The investigation of Site 5 involved the installation of four monitoring wells, six soil borings and seven exploratory soil borings (Figures 2-17 and 2-18). Selections of the locations for most of the wells and borings installed were guided by preliminary assessments of subsurface conditions at the site through the installation of seven exploratory borings (Figure 2-17). Exploratory boring soil samples were obtained from the drilling rig auger flights at two-foot depth intervals. The samples

were then field screened utilizing a PID according to procedures outlined in the *QCSP/FIP*. No analytical soil samples were collected from the exploratory borings.

Holocene Age sand deposits underlie the Site 5 area. Typically, the sand is characterized as subrounded to subangular, medium to coarse grained and generally poorly graded. Figure 2-19 presents cross sections based on soil boring data that illustrate the general stratigraphy at Site 5. The locations of the cross sections are shown on Figure 2-17.

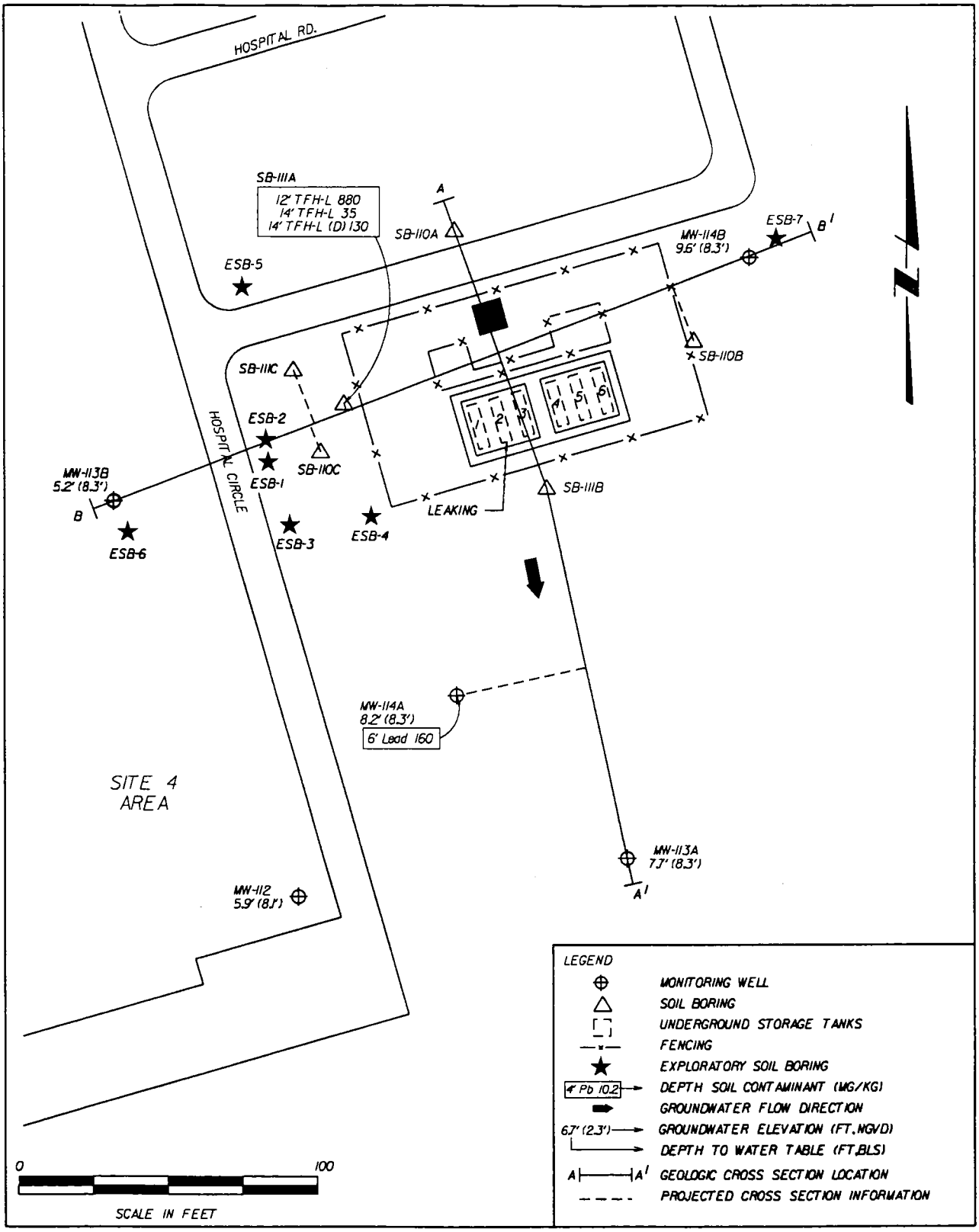
Well MW-113B is located in the Site 4 area adjacent to the Site 4 - Site 5 boundary. Well MW-114B is located in the eastern portion of the Site 5 area, which is at a slightly higher topographic elevation relative to the Site 4 area. The measured depth to the water table in the four monitoring wells installed at Site 5 ranged from 7.74 feet bls in MW-113A to 12.21 feet bls in well MW-113B (Table 2-17). Water table elevations at Site 5 ranged from 8.3 feet NGVD in MW-114A to 8.25 feet NGVD in MW-113B. Though at a slightly higher topographic elevation then MW-114A, the water table elevation in MW-114B was 8.26 feet NGVD, 0.04 feet less then that measured in MW-114A. The water table elevation measured in MW-113A was 8.28 feet NGVD. Water level data from the Site 5 monitoring wells, together with the anticipated boundary influences of the ocean and wetland areas adjacent to Site 5 and water level data from Site 4, the Fire Training Area, indicate that a possible divergent groundwater divide exists within the Site 5 area. Groundwater flow appears to be to the south from the tank area (Figure 2-17). Hydraulic conductivity values calculated for Site 5 range from 6.2×10^{-3} to 2.02×10^{-2} cm/sec (131 to 428 gal/day/ft^2), with an average of 1.21×10^{-2} cm/sec (215 gal/day/ft^2).

Analytical soil samples collected from six soil borings and four monitoring wells installed at the site were used to assess the nature and extent of soil contamination. Four of the soil borings were installed adjacent to the four sides of the fenced area containing the USTs (Figure 2-17). Locations of the remaining two soil borings and the four monitoring wells were selected based on the exploratory borings. Soil borings at Site 5 were drilled uniformly to depths of 20 feet. The monitoring wells were constructed to depths ranging from 12 to 16 feet and averaging 14.5 feet.

The soil sampling procedure utilized in the investigation of Site 5 permitted sampling of the most visibly contaminated depth intervals at a given boring location, based on field observations and field PID readings. Split-spoon samples from the soil borings were continuously collected from ground surface throughout the total depths of the borings. VOC samples were immediately collected from each split-spoon and placed in jars, in accordance with the specifications in the *QCSP/FIP*. The remaining portion of the sample from each interval was then temporarily stored on aluminum foil. After field PID screening of the soil samples from all depth intervals, samples were selected for laboratory analysis based on the relative magnitudes of the PID readings. The two samples exhibiting the highest PID readings were selected for shipment to the laboratory. Soil sampling during monitoring well construction at Site 5 involved collecting samples from ground surface and from the depth corresponding to the soil-groundwater interface.

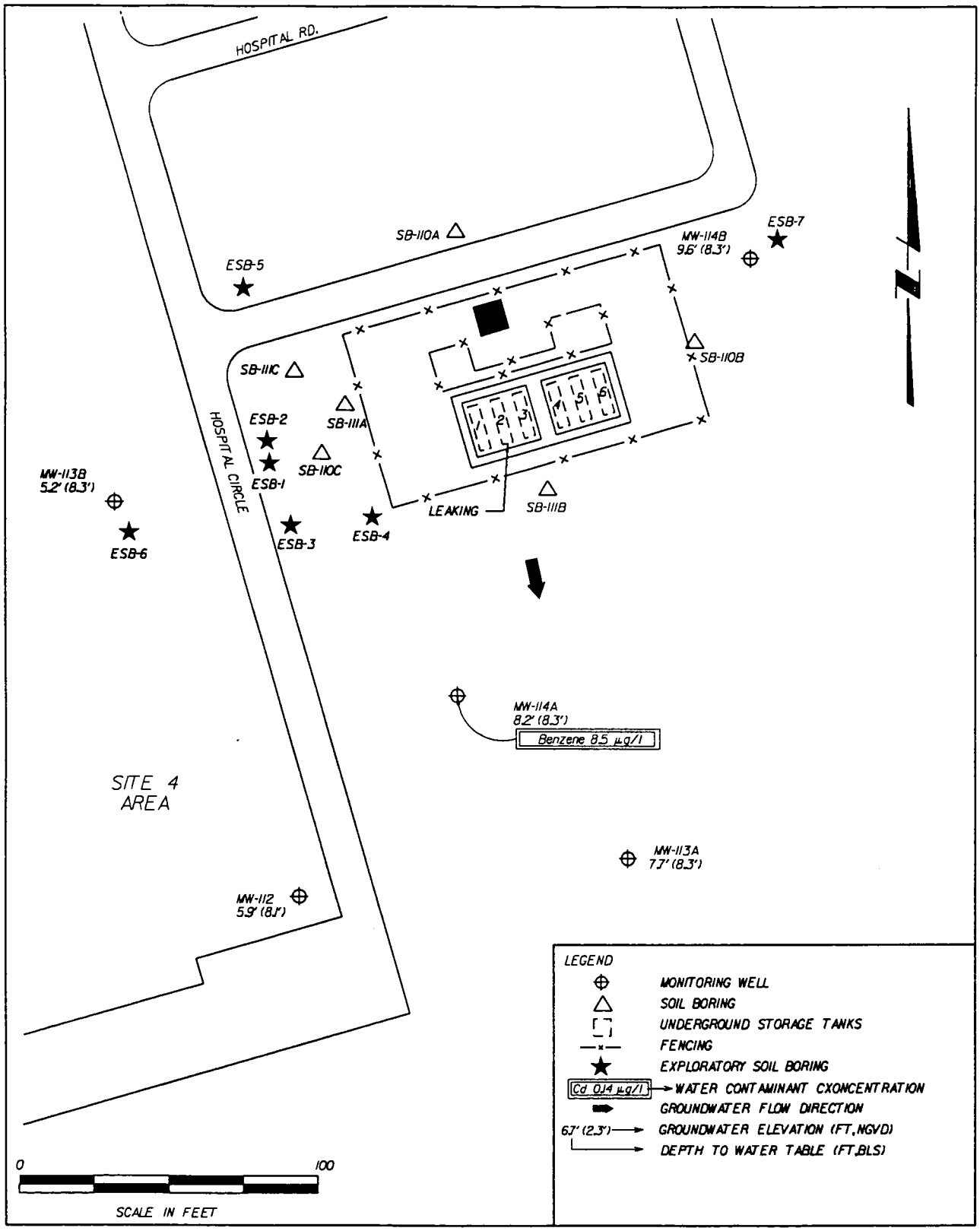
Table 2-18 summarizes the soil sampling intervals for each of the soil and well borings constructed at Site 5. Analytical soil samples were analyzed for BTEX, TFH-L, lead and total solids. Results of these analyses are presented in Table 5-SS of the *FTSFARD*. Groundwater samples collected from the Site 5 monitoring wells were analyzed for BTEX, TFH-L, dissolved lead and total lead. Table 5-GW in the *FTSFARD* presents the analytical results obtained from these analyses. Figure 2-17 shows the sampling locations.

Subsequent to JMM's field effort, the Installation hired Froehling & Robertson, Inc. (F&R) to perform a preliminary site assessment, exposure evaluation, and remediation assessment for Site 5, Underground Fuel Storage Tank Farm, during the latter quarter of 1990. The components and results of F&R's assessment are described in F&R's report *Site, Risk, and Remediation Assessment JP-4 Tank Farm* dated December 19, 1990 (F&R, 1990).



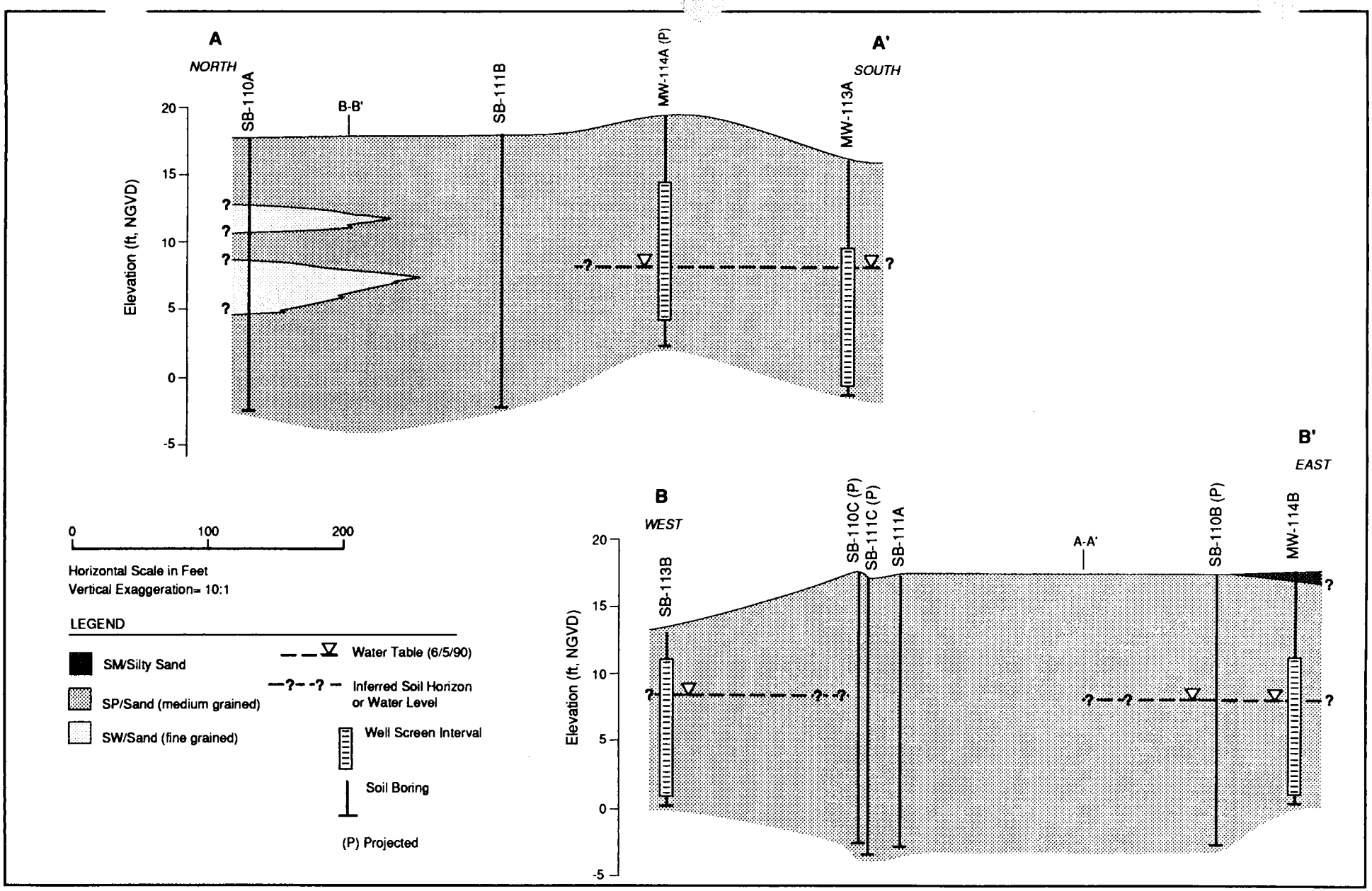
Soil Chemistry Concentrations and Geologic Cross Section Locations,
Site 5, Underground Storage Tank Farm
Ft. Story, VA

Figure 2-17



Groundwater Chemistry Concentrations,
Site 5, Underground Fuel Storage Tank Farm
Ft. Story, VA

Figure 2-18



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Cross Sections A-A' and B-B' at Site 5, Underground Fuel Storage Tank Farm
Ft. Story, VA

Figure 2-19

TABLE 2-17

SITE 5, UNDERGROUND FUEL STORAGE TANK FARM WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-113A	15.78	15.00	10.78	0.78	16.02	7.74	8.28	06/05/90
MW-113B	13.25	12.00	11.25	1.25	13.46	12.21	8.25	06/05/90
MW-114A	19.59	15.00	14.50	4.50	16.46	8.16	8.30	06/05/90
MW-114B	17.56	16.00	11.56	1.56	17.83	9.57	8.26	06/05/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to ground surface.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-18

SITE 5, UNDERGROUND FUEL STORAGE TANK FARM
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
SB-110A	20	10	2	0,2,4,6,8,10,12,14,16,18
SB-110B	20	10	2	0,2,4,6,8,10,12,14,16,18
SB-110C	20	10	2	0,2,4,6,8,10,12,14,16,18
SB-111A	20	10	2	0,2,4,6,8,10,12,14,16,18
SB-111B	20	10	2	0,2,4,6,8,10,12,14,16,18
SB-111C	20	10	2	0,2,4,6,8,10,12,14,16,18
MW-113A	17	4	2	0,5,10,15
MW-113B	12	4	2	0,2,4,10
MW-114A	17	5	2	0,4,6,10,15
MW-114B	17	5	2	0,4,6,8,15

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

F&R's study was intended to help define the nature and extent of subsurface petroleum contamination at the site. This contamination is suspected to have emanated from a UST, designated as JP4-2, located in the westernmost pad at Site 5, or from surface spillage during site operations. This particular UST contained JP-4 fuel and has been identified as a leaking UST based on recent tank integrity tests sanctioned by the Fort Story installation (F&R, 1990).

F&R constructed six soil borings to the water table (which was encountered approximately 10 feet below ground surface) using a hand auger. Five of these borings were located inside the fence line that traverses the periphery of the tank pads. The remaining soil boring was located outside the fence line, west of the JP4-1,2, and 3 tank pad. Headspace within the borings was monitored with a PID instrument during drilling. Soil samples were collected at five-foot intervals from the borings and analyzed for Total Petroleum Hydrocarbons (TPH). F&R also installed one monitoring well at the site. Groundwater samples were collected from five existing monitoring wells installed by JMM and the newly-installed well. Groundwater samples were analyzed for TPH and BTEX (F&R, 1990).

Following completion of field investigation, F&R used site features information and assessment data to complete a preliminary exposure assessment, in which exposure pathways and potential receptors were characterized.

F&R's findings indicate that soil in and around the tank basin is contaminated with TPH at levels ranging from 287 to 16,913 ppm. Soil in and around the easternmost tank basin, which contains tanks 4, 5, and 6, contained nondetectable quantities of TPH. In addition, F&R determined that site groundwater upgradient and downgradient of the tank farm contained nondetectable quantities of TPH and BTEX. F&R then suggested that soil in and around the 1, 2, and 3 tank basin could be successfully remediated by performing either in situ bioremediation, or soil excavation followed by bioremediation of excavated soil (to be performed on an adjacent property).

Soil Analytical Results. The analytical results of soil analysis at Site 5 can be found in Table 5-SS of the *FTSFARD*. Figure 2-17 shows the sampling locations, along with the soil analytes detected above trigger levels.

Several analytes were detected above trigger levels during the soil sampling at Site 5. The soil sample collected 12 feet below grade at SB-111A, located west of the tank area, contained 880 mg/kg of TFH-L, exceeding the TFH-L trigger level of 100 mg/kg. The sample collected 14 feet below grade from SB-111A contained 35 mg/kg of TFH-L, while the duplicate collected from the same location contained 130 mg/kg. The sample collected 6 feet below grade at MW-114A, located south of the tank area, contained 160 mg/kg of total lead, which exceeds lead's trigger level of 71 mg/kg.

Several compounds were found above MRL levels at Site 5, as shown in the *FTSFARD*. Total lead was found in at least one set of soil samples collected from each of the wells and borings. Several low concentrations of VOCs were also detected.

Groundwater Analytical Results. The analytical results of water analyses at Site 5 can be found in Table 5-GW of the *FTSFARD*. Figure 2-18 shows the groundwater sampling locations, along with the groundwater analytes detected above trigger levels.

Benzene was detected at 8.5 µg/l in one of the four wells (MW-114A), and was the only VOC detected from water samples collected from wells directly dedicated to Site 5. This concentration exceeds the trigger level for benzene of 5 µg/l.

Recommendations. The high concentration of TFH-L and lead found in the soil (from SB-111A and MW-114A borings), benzene concentrations greater than MCL in groundwater from

MW-114A, along with information from JMM's exploratory borings indicate that further investigative activities are warranted at Site 5.

The presence of TFH-L and lead in site soil and groundwater may be affiliated with leakage and/or spillage of fuels associated with the USTs at Site 5. JMM recommends that an RI/FS be performed at Site 5 to delineate the extent of soil and groundwater contamination in areas adjacent to the tanks. Analyses should include TFH-H as well as TFH-L, with associated fuel identification. Groundwater samples should also be analyzed for VOCs, since VOCs detected in site groundwater are possible precursors to regulated VOCs other than BTEX. Much of the information presented in F&R's contamination assessment results for Site 5, Underground Fuel Storage Tank Farm, could be utilized during the RI/FS and subsequent remedial design under the Installation Restoration Program. However, the quality assurance/quality control results associated with F&R's data must prove to be acceptable within the context of USACE's data quality objectives established for the PA/SI project. In addition, F&R's findings must be found acceptable by the Commonwealth of Virginia's governing regulatory agencies.

2.2.2.5 Site 6, LARC Maintenance Area. Site 6, the LARC Maintenance Area, which is the maintenance and wash rack area for lighter amphibious resupply cargo (LARC) vehicles is located in the sand flat area that lies between the coastal dune complex to the north and the central sand ridge to the south. Located along Atlantic Avenue and Lingayan Gulf Road, Site 6 includes Buildings 1081, 1082, 1083 and 1084. The purpose of the investigation of Site 6, LARC Maintenance Area, was to determine the presence of soil and groundwater contamination associated with the washrack area and the underground waste oil storage tank.

During the 1950s, the wash rack area was first used as the barge amphibious resupply cargo (BARC) motor pool and maintenance facility. In 1964, the BARC vehicle was phased out and the lighter amphibious resupply cargo (LARC) vehicle was prototyped. Presently, this is the only facility on the East Coast available to the Army Transportation Corps for amphibious training.

In 1982, the LARC facility was modified with the construction of a concrete wash rack pad. Prior to construction, 2 feet of soil were removed to obtain proper drainage. The concrete wash rack pad is 12 inches thick with 16-inch reinforced curbs to allow fully loaded LARC vehicles access without damaging the surface area. The wash rack area has 39 catch basins associated with drainage outfall system 001 to help control runoff and rainwater, as well as an oil/water separator (Personal Communication, Fort Story Personnel, 1989). These catch basins associated with drainage outfall system 001 were given a separate site number (Site 8) and are discussed in Section 2.2.2.7. In 1987, the U.S. Army Environmental Hygiene Agency (USAEHA) conducted a study at Site 6 and concluded that the soil north of the wash rack area was contaminated with grease, oil, lead and chromium. However, USAEHA determined that this contaminated material did not pose a significant health hazard (USAEHA, 1987).

The underground storage tank area is located approximately 600 feet south of the wash rack area. A 10,000-gallon UST is located at the north gate of the LARC vehicle motor pool. This tank was installed in 1983. Although JMM's April 1990 field visits to this area identified soil-stained zones around the UST, no reports of the tank failing or leaking have been documented. These soil-stained areas may have been caused by overfilling or spillage during use. In 1987, the USAEHA sampled the UST and found it contained oil, water, 1,1,1-trichloroethane and chromium (USAEHA, 1987). This UST is not presently being used.

Soil and groundwater were investigated at Site 6 with the installation of four monitoring wells and 12 soil sampling borings. Figures 2-20 and 2-21 show the locations at Site 6. Location of the Site 6 soil borings and monitoring wells were selected based on consideration of current and previous site activities suspected to have potentially resulted in the contamination of environmental media at the site. Soil borings SB-112 through SB-119 were installed in the wash rack area. Located in the

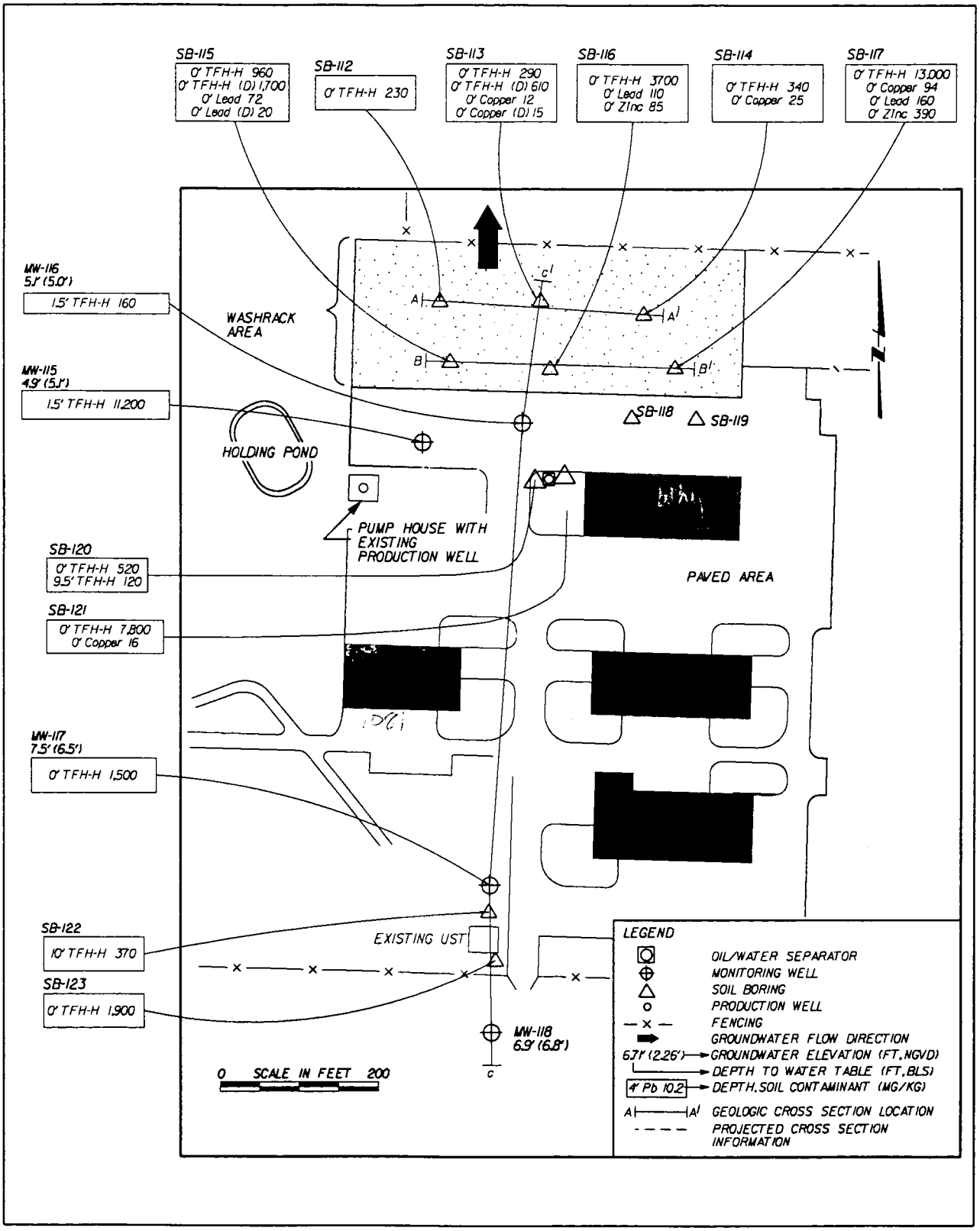
close proximity to the LARC maintenance buildings, borings SB-118 and SB-119 with wells MW-115 and MW-116 were installed through the concrete apron portion of the wash rack. The presence of contaminated soils in the vicinity of the wash rack oil/water separator was investigated through the installation of soil borings SB-120 and SB-121. Borings SB-120 and SB-121 were constructed using a hand auger due to accessibility problems. At the location of a waste oil storage tank south of the wash rack area, soil borings SB-122 and SB-123 and monitoring well MW-117 were installed. Well MW-118 was installed as an upgradient well south of the waste oil storage tank.

The Site 6 area is underlain by Holocene age sand deposits. The sand is typically described as fine to medium grained, poorly graded, subrounded, and occasionally slightly silty. At one location (SB-119) within the site area, a peat lense less than 1 foot in thickness was encountered at relatively shallow depths bls. Figure 2-22 presents three cross sections that illustrate the general stratigraphy of Site 6. The locations of the cross sections are shown on Figure 2-20.

The measured depth to groundwater in the Site 6 area ranged from 7.47 feet bls in MW-117 to 5.07 feet bls in MW-116. The water table was encountered at 5.94 and 6.87 feet bls in wells MW-115 and MW-118, respectively. Measured groundwater elevations in the Site 6 wells ranged from 6.5 feet NGVD in MW-117 to 4.97 feet NGVD in MW-116. Groundwater was encountered at elevations of 6.84 and 5.06 feet NGVD, respectively, in MW-118 and MW-115. Table 2-19 presents water level and construction data for the four monitoring wells installed at the site. Based on data collected from these wells and water level data from nearby off-site wells, the water table elevation ranges from approximately 8 feet NGVD in the southern portion of the site to less then 5 feet NGVD in the unpaved, wash rack area. Additionally, the water level data at the LARC Maintenance Area and surroundings suggest the possible existence of a cone of depression in the vicinity of the washrack supply well located at the southwestern corner of the wash rack area (Figure 2-24). The minimum groundwater level elevation within the cone of depression is approximately 4 feet NGVD. Though locally variable in magnitude and direction, the prevailing hydraulic gradient for the Site 6 area is directed in a northward direction toward the coastline. Hydraulic conductivity values calculated for Site 6 range from 1.99×10^{-3} to 1.84×10^{-2} cm/sec (42 to 390 gal/day/ft^2), with an average value of 7.42×10^{-3} cm/sec (157 gal/day/ft^2).

Table 2-20 indicates the depths at which soil samples were collected from the Site 6 soil borings and monitoring well borings. With the exception of soil boring SB-123, all soil borings were drilled to the depth of 10 feet. Soil boring SB-123 was drilled to a depth of 14 feet because of inadequate sample volumes obtained from the sample intervals at 8 to 10 feet and 10 to 12 feet. The specified sampling intervals for the soil borings were the ground surface and bottom of boring intervals. Analytical soil samples were collected from the monitoring well borings at ground surface and at the depth corresponding to the soil-groundwater interface. The analyses performed on the samples collected included pesticides/PCBs, VOCs, BNAs, TFH-H, total metals and total solids. The *FTSFARD* presents the results of these analyses.

Potential groundwater contamination at Site 6 was assessed through the collection of groundwater samples from each of the monitoring wells installed for the project. In addition, the wash rack supply well was scheduled for sampling. The Installation's construction activities at the site in which the holding pond shown in Figure 2-20 was being constructed, however, resulted in the interruption of electric power to the well. The pond was constructed as part of the upgrade to the storm drainage system. Fort Story was unable to restore power to the well during the field effort and obtaining a groundwater sample from the well through a means other than the pump installed in the well was too difficult. JMM (with the USACE Project Manager's approval) abandoned efforts to sample this well. The groundwater samples collected from the Site 6 wells were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-H, dissolved metals, and total metals. QC problems associated with the detection of TFH-H in associated groundwater blank samples collected from this site resulted in resampling. The sample identification numbers for the



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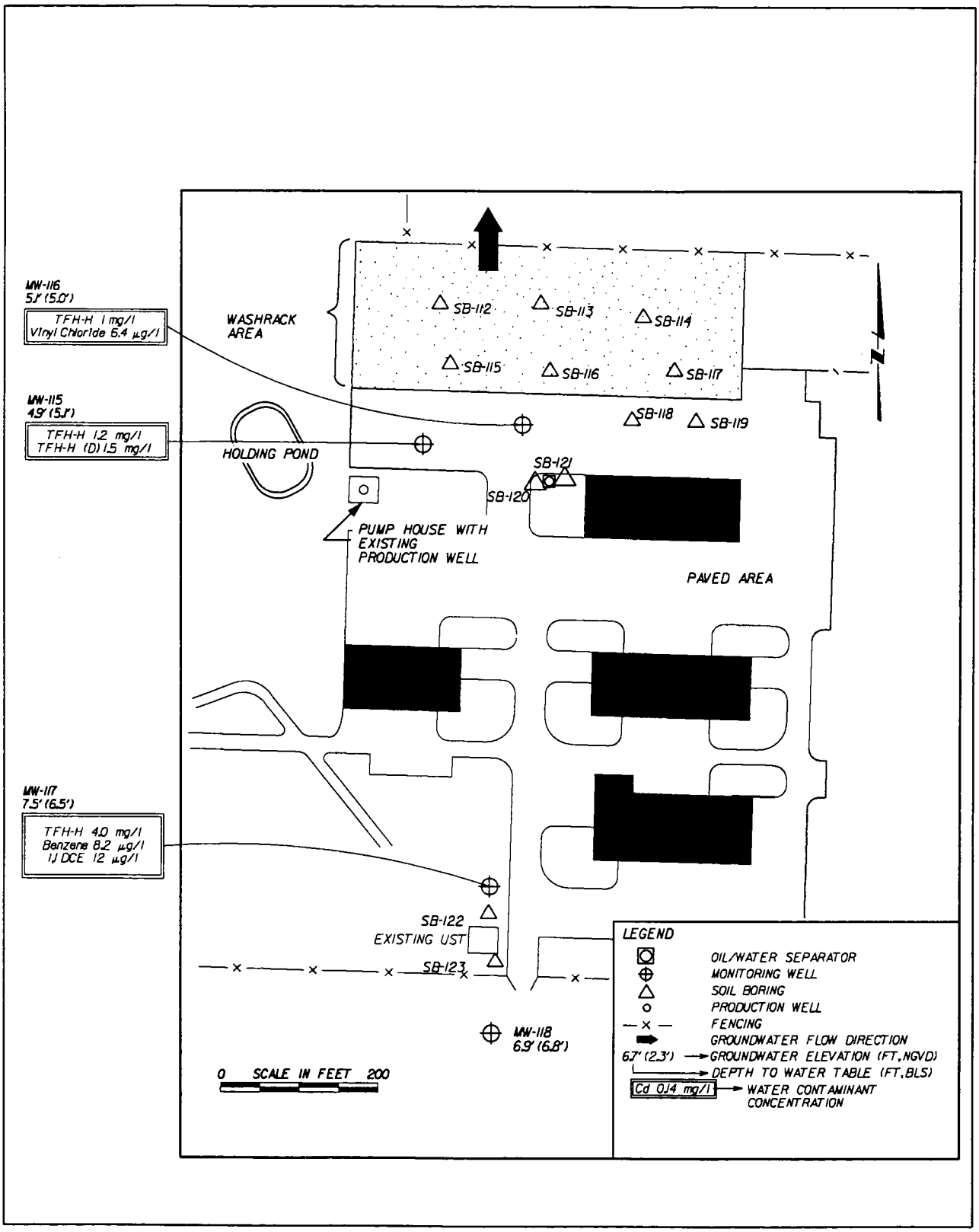
Soil Chemistry Concentration and Geologic Cross Section Locations,
Site 6, LARC Maintenance Area
Ft. Story, VA

Figure 2-20



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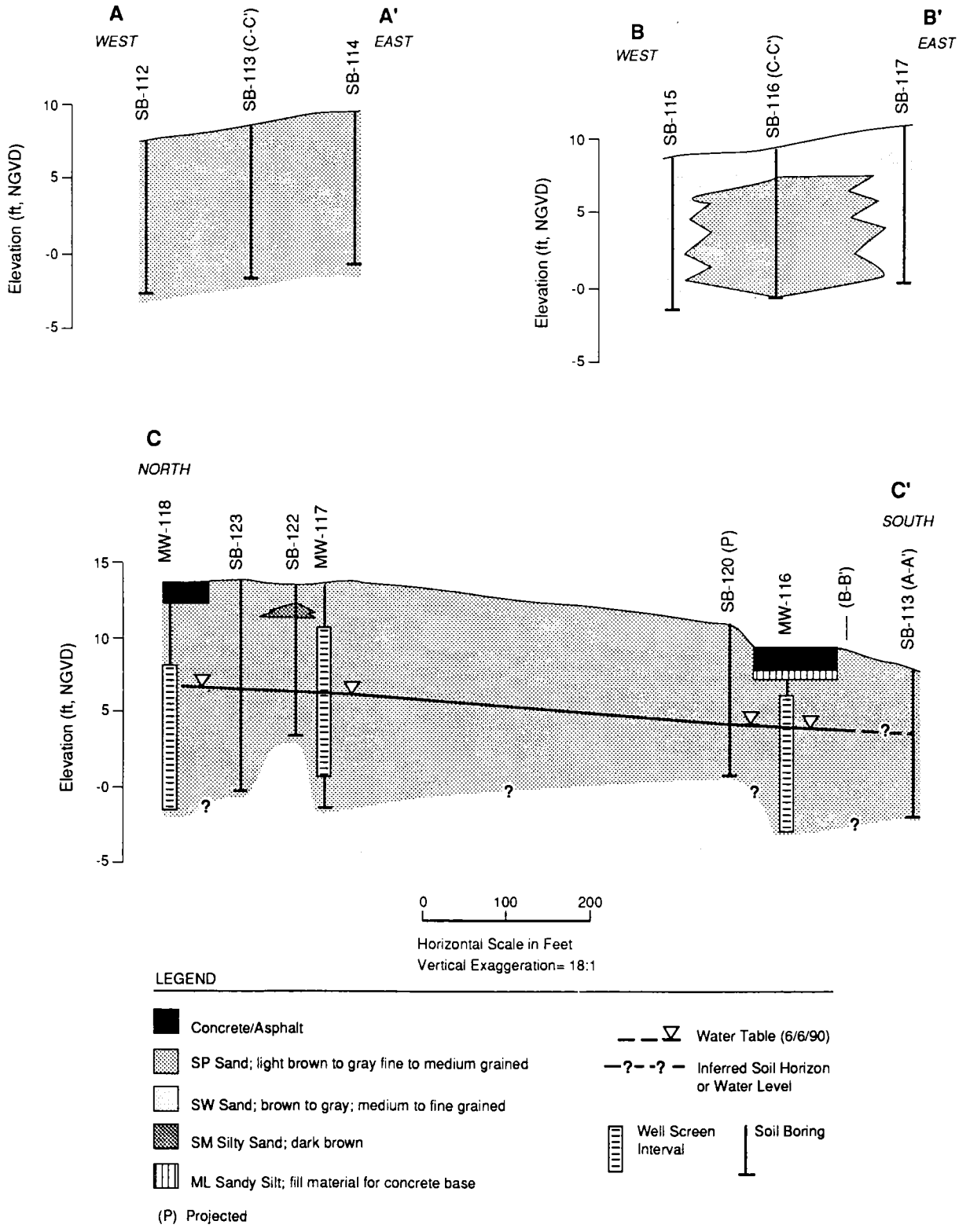
Groundwater Chemistry Concentrations,
Site 6, LARC Maintenance Area
Ft. Story, VA

Figure 2-21



Cross Sections A-A', B-B' and C-C' at Site 6, LARC Maintenance Area
Ft. Story, VA

Figure 2-22

TABLE 2-19

SITE 6, LARC MAINTENANCE AREA
WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-115	9.36	12.50	6.86	-3.14	10.00	5.94	5.06	06/06/90
MW-116	9.77	12.50	7.27	-2.73	10.04	5.07	4.97	06/06/90
MW-117	16.00	14.00	12.00	2.00	13.97	7.47	6.50	06/06/90
MW-118	13.24	15.00	8.24	-1.76	13.71	6.87	6.84	06/06/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to ground surface.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-20

SITE 6, LARC MAINTENANCE AREA
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
SB-112	10	4	2	0,2,4,8,
SB-113	10	3	2	0,4,8
SB-114	10	3	2	0,4,8
SB-115	10	3	2	0,4,8
SB-116	10	3	2	0,4,8
SB-117	10	3	2	0,4,8
SB-118	10	3	2	1.5,5,8
SB-119	10	3	2	0,4,8
SB-120	10	3	2	0,4.5,9.5
SB-121	10	3	2	0,4.5,9.5
SB-122	10	5	2	0,2,4,6,8,10
SB-123	14	6	2	0,4,6,8,10,12
MW-115	12.5	3	2	1.5,3.5,10
MW-116	12	4	2	1.5,3.5,5.5,10
MW-117	15	3	2	0.5,10
MW-118	15	5	2	1.5,6,8,10,13

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

recollected samples are: S6GW115(R), S6GW116(R) and S6GW117(R). The *FTSFARD* presents the analytical results for the sampling and resampling efforts.

Soil Analytical Results. The analytical results of soil analyses at Site 6 are presented in Table 6-SS of the *FTSFARD*. Figure 2-20 shows the soil sampling locations, along with the soil analytes detected above trigger levels.

The LARC Maintenance Area has two main areas of possible environmental concern: the wash rack area where the LARCs are parked, which has an oil/water separator, and the existing UST (located at the southern perimeter of the site). Approximately 80 percent of the soil samples contained at least one analyte detected above trigger levels.

Soil borings SB-112 through SB-119, and monitoring wells MW-115 and MW-116 were installed in the wash rack area. TFH-H was found in levels ranging between 160 mg/kg and 13,000 mg/kg in soil samples from six of eight borings, and in both wells, as depicted in Figure 2-24, all exceeding the TFH-H trigger level of 100 mg/kg. Lead, at 72 mg/kg, 110 mg/kg and 160 mg/kg, was found in the surface soil samples at SB-115, SB-116 and SB-117, respectively, exceeding the trigger level of 71 mg/kg. The sample associated with the lead analysis for the surface sample collected from SB-115 is considered an estimate, as discussed in the *QCSR*. The duplicate surface soil sample collected from the surface at SB-115 contained 20 mg/kg lead and 1,700 mg/kg TFH-H. Several other metals (e.g., copper, lead and zinc) were found at levels greater than the trigger in SB-113, SB-116, SB-114 and SB-117, as shown in Figure 2-24. All appear to be relatively proportional to the TFH-H concentration.

Soil borings SB-120 and SB-121 were installed adjacent to the oil/water separator. TFH-H, at 520 mg/kg and 120 mg/kg, was found in the surface and 9.5-foot soil samples of SB-120. The surface sample from SB-121 contained 7,800 mg/kg of TFH-H, but the deeper sample (9.5 feet) was below the trigger level of 100 mg/kg.

Soil borings SB-122 and SB-123, along with monitoring well MW-117, were installed in the vicinity of the UST. All three locations showed evidence of TFH-H contamination. TFH-H, at 1,500 mg/kg and 370 mg/kg, was found in the downgradient soil samples collected at the surface of MW-117 and 10 feet below grade at SB-122, respectively. The surface soil sample collected from the slightly upgradient boring, SB-123, contained 1,900 mg/kg of TFH-H. The areal extent of contamination upgradient is not known, although no contamination was detected in soil samples collected at MW-118, located approximately 100 feet upgradient (south) of the UST.

Groundwater Analytical Results. The analytical results of groundwater analyses at Site 6 can be found in Table 6-GW of the *FTSFARD*. Figure 2-21 shows the groundwater sampling locations, with the groundwater analytes detected above trigger levels that warrant further investigation.

In the washrack area, the sample collected from MW-115 contained 1.2 mg/l of TFH-H (1.5 mg/l in the duplicate sample) and 4 µg/l of lead (3 µg/l in the duplicate). Note that since the TFH-H was resampled, the original analysis was disregarded. The groundwater sample collected from MW-116 contained 1 mg/l of TFH-H and 6.4 µg/l of vinyl chloride. Note that although the reported detection limit for vinyl chloride was increased due to sample dilution, the resultant amount found is still valid.

In the UST area, 8.2 µg/l of benzene was found in the MW-117 groundwater sample. This value exceeds the current MCL value of 5 µg/l. In addition, 12 µg/l of 1,1-dichloroethene and 4 mg/l of TFH-H were found at concentrations greater than their respective trigger levels (7 µg/l and 1 mg/l) in the groundwater sample collected from MW-117. The concentration of vinyl chloride in the GW-116 sample, 6.4 µg/l, also exceeded the trigger level of 2 µg/l. Vinyl chloride is a degradation product of dichloroethane, dichloroethylene and other chlorinated hydrocarbons.

Subsequently, it is not suspected to be a primary contaminant at this site. As shown in the *FTSFARD* and reported in the *QCSR*, benzene and TFH-H were found in the associated trip blanks sent with these samples, which causes these results to be suspect.

Recommendations. The existence of high levels of TFH-H in the soil and associated VOCs and BNAs in the groundwater around the wash rack, oil/water separator and UST warrant further investigation. JMM recommends an RI/FS at Site 6, LARC Maintenance Area to determine the sources, magnitudes, and extent of the soil and groundwater contamination.

2.2.2.6 Site 7, Auto Craft Building. Site 7, the Auto Craft Building, is located in the sand flat area south of the coastal dune complex at the junction of Atlantic Avenue and Cebu Road. The purpose of the investigation of Site 7, Auto Craft Building, was to determine the presence of soil and groundwater contamination associated with former waste oil disposal practices at the site.

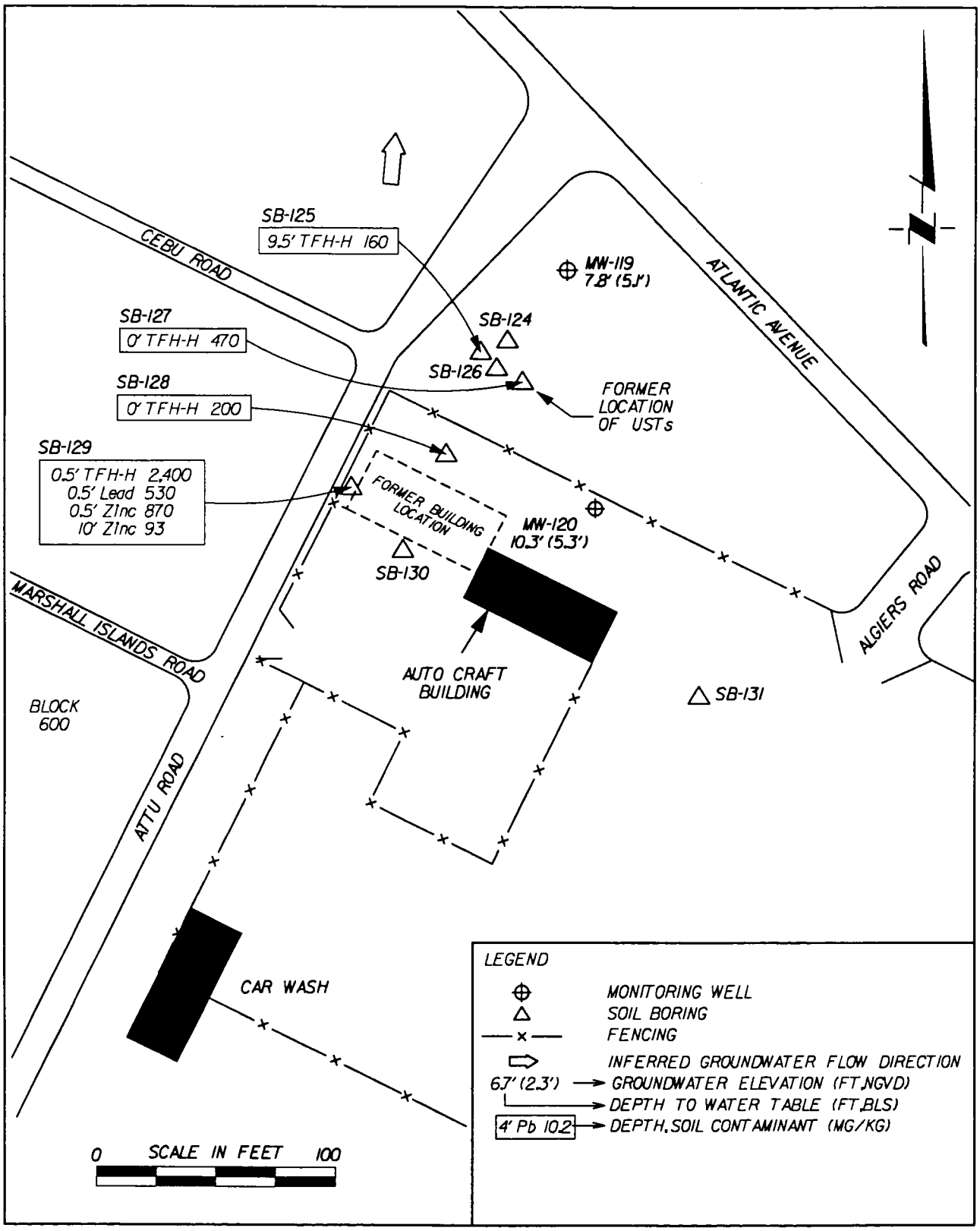
Two solvent dip tanks were used for the storage of spent degreasing solvents and waste oils when the Autocraft building was in use. Previously, waste oil generated at the site was piped out of the building and into an adjacent UST. At the time of JMM's field investigation in the Spring of 1990, the UST had been removed. All waste solvents generated at the site are currently removed and disposed of through the Defense Reutilization & Marketing Office (DRMO) (ESE, 1988).

Prior to its use as the Auto Craft Building, the site was used as a motor pool for wheeled vehicles. During the winter of 1989-1990, a portion of the Auto Craft Building was destroyed by fire. A portion of the building's concrete foundation and some debris remained in the area following the fire (Personal Communication, Fort Story Personnel, 1989). A previous investigation indicated that waste solvents (PD 680, Type II) were poured directly on the ground to control weed growth along the fence surrounding the site (ESE, 1988). A visual inspection during April 1990 by JMM personnel verified the presence of an apparent petroleum-based product around the area and a distinctive petroleum odor at this site.

The investigation of Site 7 involved the installation of eight soil borings and two monitoring wells. The locations of the sampling locations are shown in Figures 2-23 and 2-24. The locations of the soil borings and monitoring wells installed at Site 7 were selected based on knowledge of previous site activities that were suspected to have potentially resulted in the contamination of environmental media. Four of the soil borings were installed near the former locations of two USTs. These borings, which include borings SB-124 through SB-127, were drilled using a hand auger. The remaining four soil borings, SB-128 through SB-131, were drilled along the perimeter of the Auto Craft Building using a hollow stem auger. Each of the soil borings were completed to a depth of 10 feet. The monitoring wells installed at the site are located adjacent to the former USTs and downgradient from the Auto Craft Building.

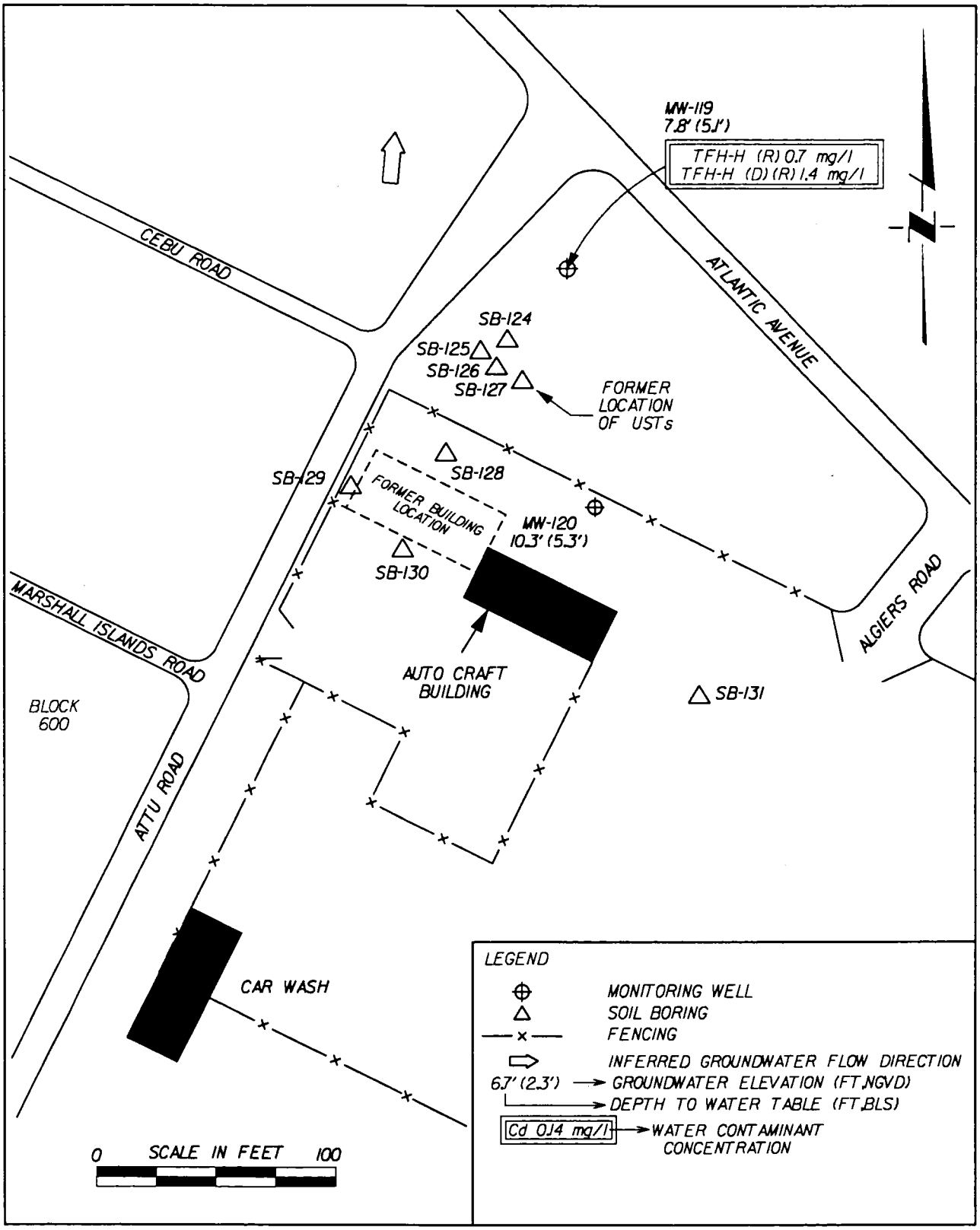
Site 7 is underlain by Holocene age sand deposits. The sand is typically characterized as fine to medium grained, subrounded, and poorly graded. Discontinuous units of clay and silt are located in the north area of the site at depths of up to 5 feet and thicknesses up to 2 feet. A one- to two-foot thick silty sand unit was encountered at a depth of approximately 15 feet in MW-120. Figure 2-25 presents two cross sections based on soil boring data that illustrate the general stratigraphy at Site 7. The locations of the cross sections are presented on Figure 2-23.

Depths to groundwater at the site vary from 7.80 feet bls in MW-119 to 10.25 feet bls in MW-120 (Table 2-21). Based on the water level data from the Site 7 wells in conjunction with water level data from adjacent Fort Story sites, water table elevations at the site ranged from 5.3 feet NGVD near the Auto Craft Building to 5.07 feet NGVD in the vicinity of MW-119 and MW-120. Based on the water level data obtained from the Site 7 monitoring wells, the lateral hydraulic gradient at



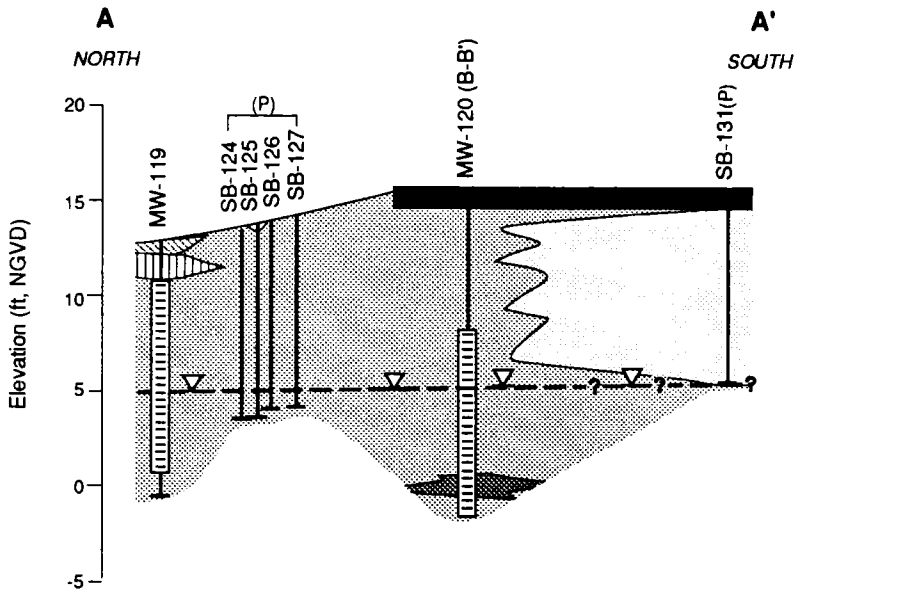
Soil Chemistry Concentrations and Geologic Cross Section Locations,
Site 7, Auto Craft Building
Ft. Story, VA

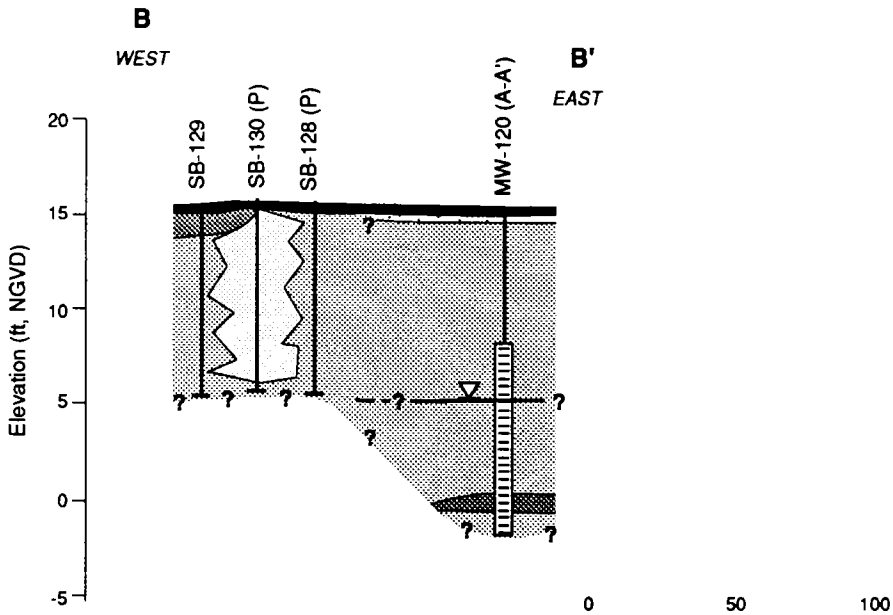
Figure 2-23



Groundwater Chemistry Concentrations,
Site 7, Auto Craft Building
Ft. Story, VA

Figure 2-24





0 50 100

Horizontal Scale in Feet
Vertical Exaggeration= 7:1

LEGEND

- Asphalt/Concrete
- SM/Silty Sand
- SP/Sand (Medium Grained)
- SW/Sand (Fine Grained)
- SC/ Sandy Clay, fill
- ML/Silt
- OL/Clay
- Water Table (4/14/90)
- Inferred Soil Horizon or Water Level
- (P) Projected
- Well Screen Interval
- Soil Boring

JMM

Cross Sections A-A' and B-B' at Site 7, Auto Craft Building
Ft. Story, VA

Figure 2-25

TABLE 2-21

SITE 7, AUTO CRAFT BUILDING
WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-119	12.47	13.00	9.97	-0.53	12.87	7.80	5.07	04/24/90
MW-120	15.21	20.00	8.21	-1.79	15.59	10.25	5.34	04/14/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to TOC.
(d) NGVD - National Geodetic Vertical Datum of 1929.

the site is directed to the northeast. Based upon a limited number of wells, hydraulic conductivity values for Site 7 range from 3.23×10^{-3} to 7.11×10^{-3} cm/sec (68 to 151 gal/day/ft^2), with an average value of 5.17×10^{-3} cm/sec (110 gal/day/ft^2).

Analytical soil samples were collected from soil borings at ground surface and from the total depths of the borings (Table 2-22). Soil samples were collected from the monitoring well borings at ground surface and at the depth below ground surface that corresponded to the soil-groundwater interface. The laboratory analyses performed on the soil included pesticides/PCBs, VOCs, BNAs, TFH-H, total metals and total solids. Three soil samples from Site 7 were resampled due to holding time expirations. These samples were S7SB124(0), S7SB125(0) and S7SB126(0). Results of these analyses as well as those from the initial sampling are presented in the *FTSFARD*. Groundwater samples were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-H, dissolved metals and total solids. QC problems were associated with the detection of TFH-H in the associated blank samples of sample S7GW119. This sample was a duplicate sample, so the original and the duplicate were resampled and analyzed for TFH-H. The *FTSFARD* presents the results of these analyses.

Soil Analytical Results. The analytical results of soil analysis at Site 7 can be found in Table 7-SS of the *FTSFARD*. Figure 2-23 shows the soil sampling locations, along with the soil analytes detected above trigger levels.

TFH-H and metals detected in some of the soil samples from the site are present at levels higher than the trigger levels. The 9.5-foot and surface samples collected from SB-125 and SB-127 contained 160 mg/kg and 470 mg/kg of TFH-H, respectively, exceeding the TFH-H soil trigger level of 100 mg/kg. These borings, along with SB-124, were located adjacent to the former location of two USTs, which had been recently removed.

Soil boring SB-128, located approximately 50 feet upgradient of the former UST site, had 200 mg/kg of TFH-H in the surface soil sample. The 0.5-foot soil sample collected from SB-129, located on the western edge of the former building, adjacent to Attu Road contained 2,400 mg/kg of TFH-H . The 0.5-foot sample at SB-129 contained 530 mg/kg of lead, exceeding the trigger level of 71 mg/kg for lead. The sample collected at 0.5 feet and 10 feet below grade from SB-129 also contained 870 mg/kg and 93 mg/kg of zinc, respectively, exceeding the trigger level of 57 mg/kg.

DDT, DDD, DDE, several metals, as well as methylene chloride and chloroform, were detected in several of the soil samples in amounts below trigger levels or above MRLs. Methylene chloride is a common laboratory artifact (EPA, 1988b). Chloroform was found during the analysis of the distilled water (JMM, 1991h), used in decontamination activities, which may account for the low levels of chloroform found in the soil.

Groundwater Analytical Results. The analytical results of groundwater analysis at Site 7 can be found in Table 7-GW of the *FTSFARD*. Figure 2-24 shows the groundwater sampling locations, with the groundwater analytes detected above trigger levels.

Groundwater collected from the downgradient well, MW-119, during the resampling round contained 0.7 mg/l and 1.4 mg/l of TFH-H in the initial and associated duplicate sample. Note that the original TFH-H values of 3.6 mg/l and 1.4 mg/l are not valid, thus the reason for resampling. Given the trigger level of 1 mg/l, the higher concentration shown is of concern. Note that only analytical results from the resampling event are used in this determination, as the original samples were deemed invalid. No other analytes detected in groundwater samples from MW-119 and MW-120 exceeded trigger levels.

TABLE 2-22

SITE 7, AUTO CRAFT BUILDING AREA
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
SB-124	10	2	2	0,9.5
SB-125	10	2	2	0,9.5
SB-126	10	2	2	0,9.5
SB-127	10	2	2	0,9.5
SB-128	10	3	2	0,5,8
SB-129	10	3	2	0.5,5,10
SB-130	10	3	2	0.5,5,8
SB-131	10	3	2	0.5,5,8
MW-119	12	4	2	0.2,5,7
MW-120	17	5	2	0.5,5,7,9,15

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

Recommendations. The elevated levels of TFH-H found in soil adjacent to the former building and former USTs and the TFH-H levels found in the groundwater collected downgradient in MW-119 warrant further investigation. JMM recommends that an RI/FS be performed at Site 7, Auto Craft Building, to help define the magnitude and extent of soil and groundwater contamination.

2.2.2.7 Site 8, Drainage Outfall Line. The Drainage Outfall Line diverts storm runoff from the LARC Maintenance Area (Site 6) into the Chesapeake Bay. The Site 8 area extends from the LARC Maintenance Area northward to the coastline. The purpose of the investigation of Site 8, Drainage Outfall Line, was to determine the presence of contamination within the Drainage Outfall Line as well as within the soil, sediment and groundwater adjacent to the drainage outfall line that transports wash water and storm water runoff from the LARC Maintenance Area.

The outfall line, designated 001 by the Installation in their National Pollution Discharge Elimination System (NPDES) permit, discharges to the beach area north of the LARC area (Site 6) (ESE, 1988). According to the Installation, the LARC Maintenance Area storm drainage system consists of 39 catch basins to collect wash water and surface water runoff. The system includes an oil/water separator to aid in the abatement of accidental spills entering the storm drain system. After a severe storm in 1984, the storm drain system became clogged. As a result, the Installation commissioned a vacuum truck to clean out the portion of the storm drain system extending from Building 1081 to the outfall (Personal Communication, Fort Story Personnel, 1990).

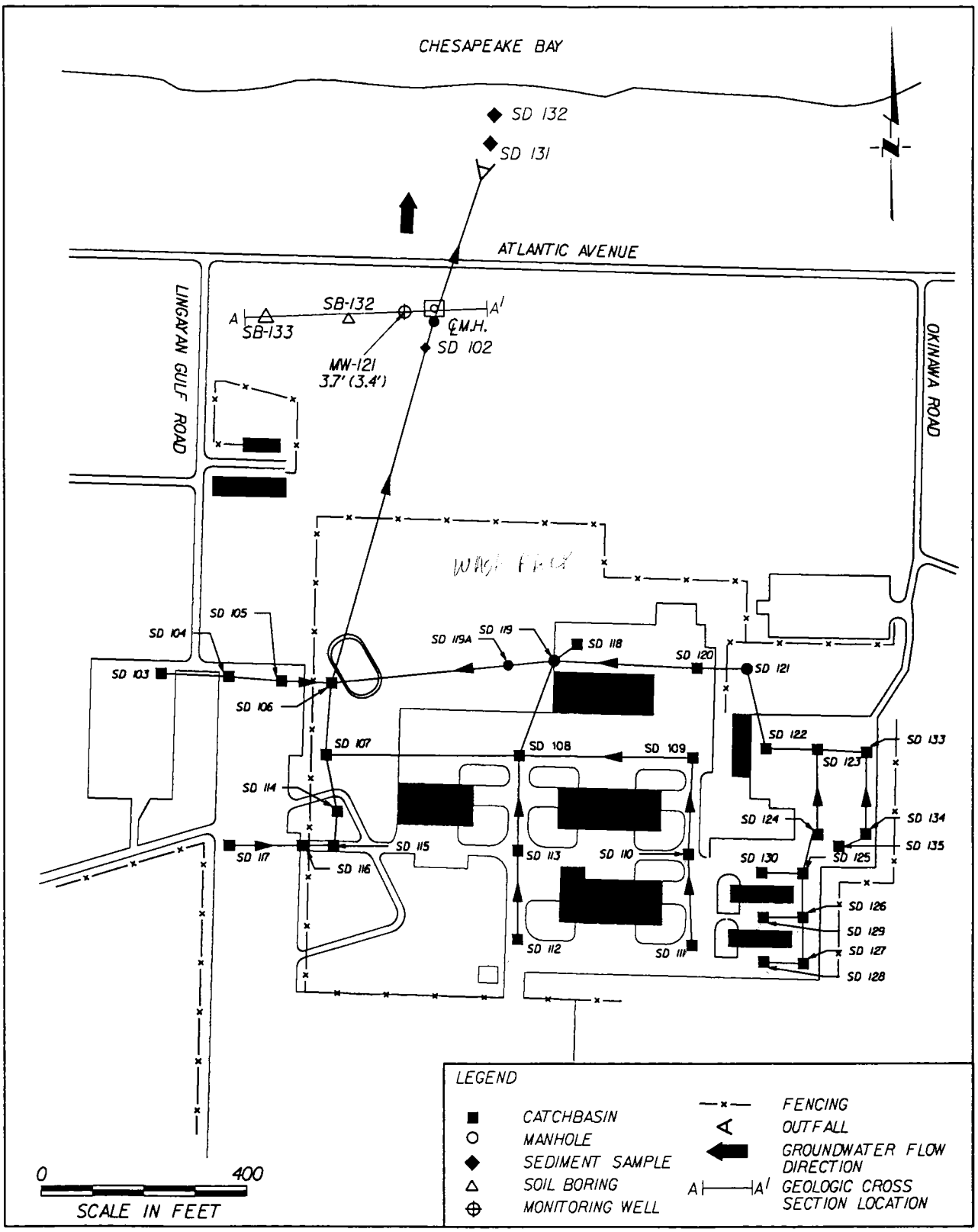
In 1980, the Virginia Water Control Board (VWCB) recorded five NPDES locations at Fort Story, including System 001. In 1986, however, Fort Story was authorized to reduce this number to the three existing outfalls. Inspection of the outfall system in 1986 indicated that the Site 8, Drainage Outfall Line, was in violation of the NPDES standards for discharging oil and waste products (ESE, 1988).

Fort Story is subject to an Administrative Order on Consent with VWCB and must upgrade the existing Site 8, Drainage Outfall Line. Construction activity to upgrade this outfall has been completed. As part of this upgrade, Manhole E-2 has been demolished and a new junction box has been constructed as a replacement. In addition, a large holding pond was constructed as part of the project. The NPDES permit for Fort Story Outfall 001 expired in June 1990 but has subsequently been renewed (Personal Communication, VanDervort, 1991).

Maintenance of Outfall 001 by Fort Story requires periodic sampling for the detection of oil residues. Booms are installed when necessary to aid in catching residues before passing discharge through the outfall to the ocean. JMM's field observations in April 1990 indicated stained soil at the drainage outfall line.

The investigation of the Drainage Outfall Line included the installation of one monitoring well and two soil borings, with the collection of 29 catch basin sediment samples (Figure 2-26). In addition, three field duplicate sediment samples were collected. The Installation storm drainage system map for the LARC Maintenance area identifies 39 manholes or drainage basins. Field inspection of the site, however, confirmed the existence of 36 such structures. It appears that three were either covered by sand or asphalt. Though an attempt was made to sample each of the identified structures, sediment samples were collected at only 30 points within the drainage system.

The 30 sediment samples collected from the Drainage Outfall Line include two samples, SD-131 and SD-132, collected from the ocean beach area at the outfall line terminus. The absence of an adequate quantity of sediment for sampling or the inaccessibility of some of the drainage structure sampling points prohibited the sampling of six identified sampling points. Structure inaccessibility resulted from conditions such as the partial covering of gratings with asphalt or gratings that were corrosion-locked. During the field sampling event, the sampling team observed that the sediment deposits within the drainage outfall line were very thin (from one-eighth inch to one-half inch



Sampling Locations and Geololgic Cross Section Information,
Site 8, Drainage Outfall Line
Ft. Story, VA

Figure 2-26

thick). The sediment appeared to consist of oily sand. Subsequently, the sample collection process required the team to scrape a sufficient volume of sediment off of the catch basin bottom to fill the associated sample jar. The total mass amount of contaminated sediment is expected to be relatively small, assuming that distribution throughout the system is similar to that found in the vicinity of the catch basins.

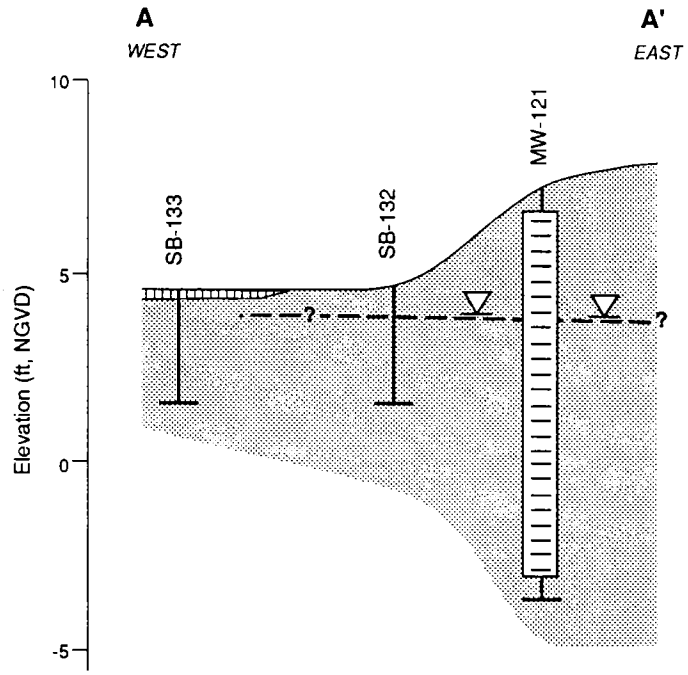
Holocene age sand deposits underlie the Site 8 area. The sand is described as fine to medium grained, subrounded to subangular, and poorly graded. Figure 2-27 presents one cross section based on soil boring data that illustrates the general stratigraphy of Site 8. The cross section location can be found in Figure 2-26.

Measured depths to groundwater in the Site 8 area ranged from 3.66 feet bls in MW-121 located adjacent to the coastline to 7.47 feet bls in MW-117 located in the southern portion of Site 6, LARC Maintenance Area. Table 2-23 presents construction and water level data for MW-121. Table 2-19 provides water level data and construction information for MW-115 through MW-118. Based on data from the Site 8 area, in conjunction with water level data from adjacent Fort Story areas, water table elevations across the Site 8 area range from in excess of 7 feet NGVD within the eastern portion of the LARC Maintenance Area to less then 1 foot NGVD in the vicinity of the coastline. Measured groundwater elevations at the site range from 3.4 feet NGVD in MW-121 to 6.84 feet NGVD in MW-118. The prevailing direction of groundwater flow at the site area is toward the north, as shown in Figure 2-26. Based upon limited data, the hydraulic conductivity value calculated for Site 8 is 1.12×10^{-2} cm/sec (237 gal/day/ft^2).

Groundwater and soil sampling was performed at Site 8 in the vicinity of Manhole E2, located near the coastal terminus of the Drainage Outfall Line. Soil borings SB-132 and SB-133 and monitoring well MW-121 were installed adjacent to this structure. The soil borings were constructed using a hand auger. Table 2-24 summarizes the depths where analytical soil samples were collected during the Site 8 drilling program. Analyses performed on soils included pesticides/PCBs, VOCs, BNAs, TFH-H, total metals, and total solids. Results of these analyses are presented in the *FTSFARD*. Sediment samples collected were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-H, total metals, and total solids. Results of these analyses are presented in the *FTSFARD*. Potential groundwater contamination in the vicinity of Manhole E2 was evaluated through the collection of groundwater samples from MW-121. Groundwater samples obtained from the well were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-H, dissolved metal and total metals. The *FTSFARD* presents the results of these analyses.

Soil/Sediment Analytical Results. The analytical results of soil analysis at Site 8, Drainage Outfall Line, can be found in Table 8-SS of the *FTSFARD*. Figure 2-26 shows the sampling locations. The purpose of this investigation was to determine the presence of contamination within the drainage outfall line and within the soil and groundwater in the vicinity of the line. JMM has assumed that the soil trigger levels can be utilized to analyze contamination in the sediments at Site 8.

SD-102 through SD-115, SD-117 through SD-125, and SD-133 through SD-135 were collected from within the drainage outfall line. TFH-H was detected in concentrations greater than the trigger level of 100 mg/kg in 73 percent of these samples. Elevated levels of VOCs were detected whenever high levels of TFH-H were observed, as shown in the *FTSFARD*. Because 73 percent of the sediment sampling points showed evidence of contamination, the presence of TFH-H compounds in the sediment is considered to be ubiquitous within the drainage system. Subsequently, a separate map showing sediment contamination at specific locations has not been included.



LEGEND

- SP/Sand
- ML/Silt
- Water Table (6/7/90)
- Well Screen Interval
- Soil Boring

0 100 200

Horizontal Scale in Feet
Vertical Exaggeration= 27:1

JMM

Cross Section A-A' at Site 8, Drainage Outfall Line
Ft. Story, VA

Figure 2-27

TABLE 2-23

SITE 8, DRAINAGE OUTFALL WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-121	9.92	11.50	8.42	-1.58	7.06	3.66	3.40	06/07/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to ground surface.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-24

SITE 8, DRAINAGE OUTFALL LINE
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed	Depth of Soil Samples[b] (ft.)
SB-132	3	1	1	2.5
SB-133	3	1	1	2.5
MW-121	11.5	3	0	0,4,8

(a) Total depth relative to ground surface.
(b) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.

Soil borings SB-132 and SB-133 and sediment samples SD-131 and SD-132 were constructed to identify the presence of soil and sediment contamination in areas adjacent to the drainage system, as shown in Figure 2-26. No analytes were detected above trigger levels.

Groundwater Analytical Results. The analytical results of groundwater analysis at Site 8 can be found in Table 8-GW of the *FTSFARD*. Figure 2-26 shows the sampling locations.

No analytes analyzed from MW-121 groundwater samples exceeded trigger levels. Methylene chloride was detected in the duplicate sample, but this is suspected to be a laboratory artifact.

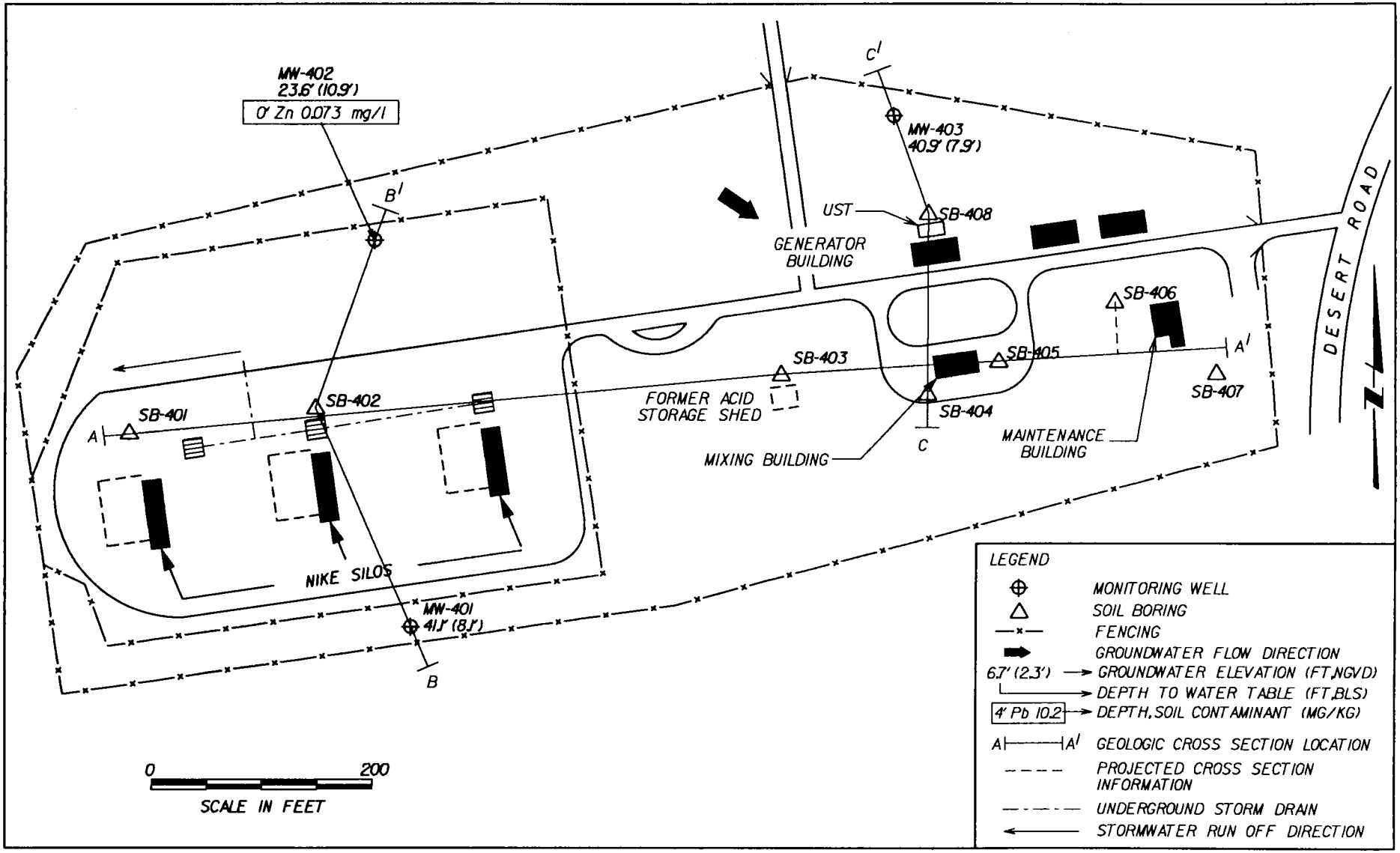
Recommendations. The elevated levels of TFH-H and other contaminants (e.g., metals) found in the sediment samples collected from within the drainage outfall line have clearly established the presence of contamination within the system, as it existed at the time of sampling. Data collected for soil and groundwater located outside of the drainage line indicate that contamination is limited to within the drainage outfall line. Additional sampling of this system is not warranted because JMM has verified and defined the petroleum-derived contamination within the system. Subsequently, JMM recommends that no further investigation activities be performed at this site. The current construction upgrade of the system, which has been completed, should eliminate the possibility of discharge of contaminants to the Chesapeake Bay.

2.2.3 NIKE Facility PA/SI Site

Site 9, the Fort Story NIKE Facility, is located on the crest of the central sand ridge in the approximate geographic center of Fort Story. The NIKE missile defense system was developed for deployment throughout the continental United States to protect major metropolitan areas during the 1950s through the 1970s (ESE, 1988). The NIKE system consists of three separate operating areas: the integrated fire control (IFC) area, the radar area and the launch area (ESE, 1984).

Site 9 is located along Desert Road and is a former NIKE missile launch area. Most of the key structures for the launch area are still intact. This site is no longer used for its initial purpose and is presently used as a storage facility by the 599th Quartermaster Battalion. Presently, all three missile silos contain bladder hoses and water pumps, and do not show evidence of groundwater or surface water infiltration or impoundment. The launch site consists of a maintenance building, diesel fuel and heating oil USTs, a mixing building, a warhead fueling building and several missile silos (ESE, 1984). Previous investigations had indicated potential sources of contamination from NIKE bases (Law Engineering and Testing Company, 1986).

The purpose of the investigation of Site 9, NIKE Facility PA/SI Site, was to determine the presence of soil and groundwater contamination associated with previous uses of the site. Locations for the soil borings and monitoring wells installed at the site were selected on the basis of knowledge of previous activities conducted at the site that were suspected to have potentially resulted in the contamination of environmental media. The investigation of Site 9 involved the installation of eight soil borings and three monitoring wells (Figure 2-28). Two soil borings (SB-401 and SB-402) were installed in the silo area. Soil boring SB-403 was installed adjacent to the former acid storage shed. Soil borings SB-404 and SB-405 were constructed for assessing contamination in the vicinity of the mixing building, while soil borings SB-406 and SB-407 provided a means for assessing contamination at the maintenance building site. Boring SB-408 was installed adjacent to an UST located north of the generator building. With the exception of SB-405, soil boring completion depths were to a depth of 20 feet below ground surface. Soil boring SB-405 was constructed at 42 feet, the depth at which the water table was encountered. The installation of monitoring wells MW-401 and MW-402 enabled the assessment of groundwater quality and water table elevations within the vicinity of the silos. Well MW-403 provided groundwater quality data immediately downgradient of the support area buildings.



JMM

Soil Chemistry Concentrations and Geologic Cross Section Locations,
Site 9, NIKE Facility
Ft. Story, VA

Figure 2-28

The site is underlain by Holocene Age sand deposits. The sand is characterized as medium to medium-fine grained, subrounded to subangular, and poorly graded. A sandy clay unit approximately 1 foot thick is located at the surface in the eastern portion of the site. A silty sand unit approximately 1 foot thick is located in the western portion of the site. Figures 2-29 and 2-30 present three cross sections based on soil boring data that illustrate the general stratigraphy at Site 9. The locations of the cross sections are shown in Figure 2-28.

As a result of the high topographic elevations of Site 9 with regard to the surrounding areas, together with sandy lithologic materials that underlie the site, groundwater encountered at the site is considerably deeper than is typical for the Fort Story area. The measured depths to groundwater in the three installed monitoring wells ranged from 41.13 feet bls in MW-401 to 23.61 feet bls in MW-402. Groundwater was encountered at a depth of 40.89 feet bls in MW-403. Table 2-25 presents well construction and water level data for each of the monitoring wells installed at the site.

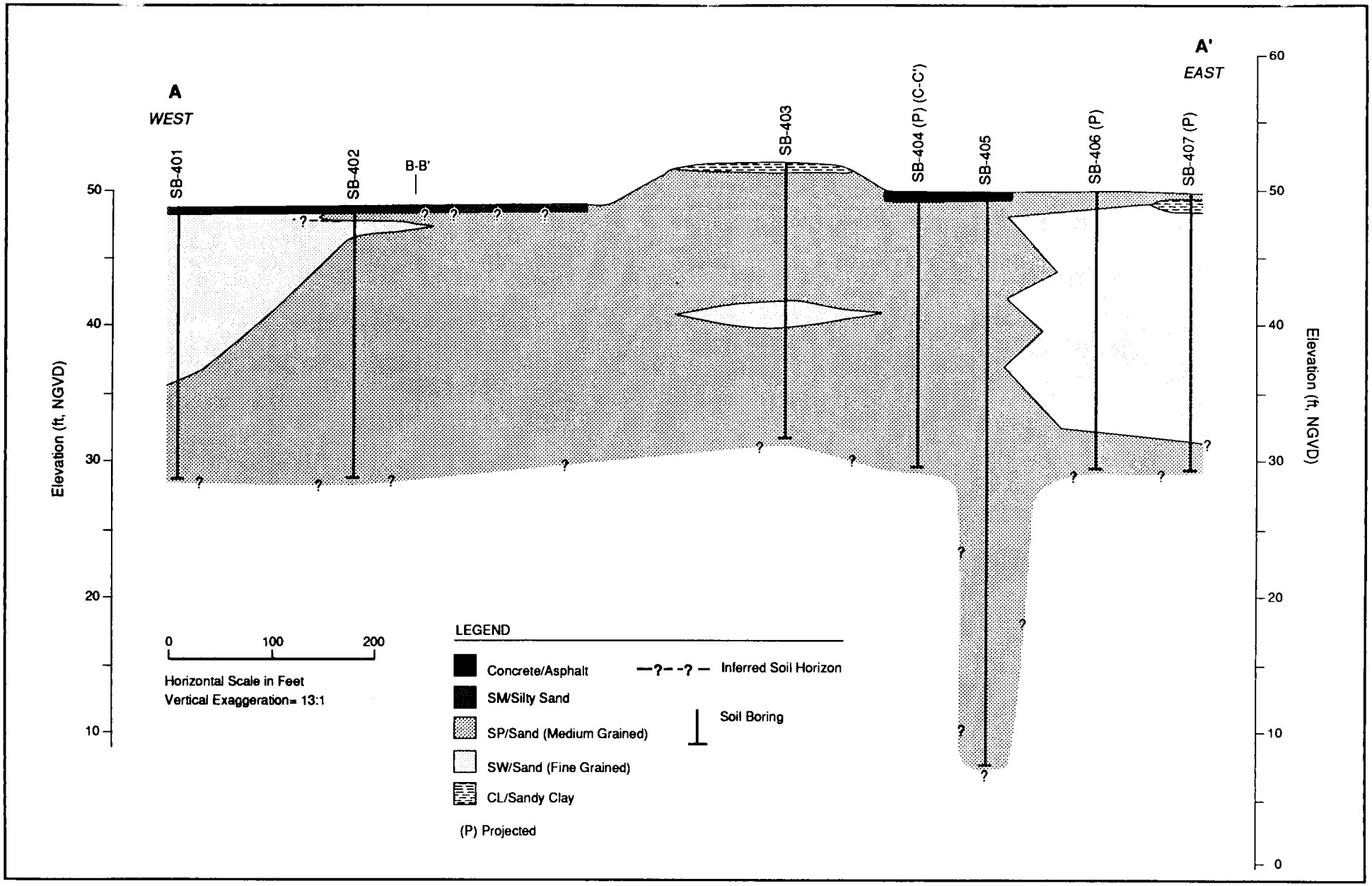
Water table elevations from Site 9 and the adjacent Fort Story area indicate that Site 9 may be located within or adjacent to a groundwater divide (Figures 2-3 and 2-28). From the maximum measured water table elevation of 10.89 feet NGVD measured in MW-402, groundwater elevations decline to less then 8 feet NGVD in the wooded wetland area located along the southern margin of Fort Story and decline to mean sea level datum to the north in the direction of the coastline. Water table elevations of 8.11 feet NGVD and 7.89 feet NGVD were measured in wells MW-401 and MW-403, respectively. Because of the occurrence of the groundwater divide within the Site 9 vicinity, the direction and magnitude of the hydraulic gradient appears varies considerably with location. In the silo area, the gradient is directed toward the southeast at a magnitude of approximately 0.006 and to the northwest at a magnitude of approximately 0.003. The hydraulic gradient across the adjacent support building area is directed toward the east with a magnitude of approximately 0.005. Data are insufficient to characterize the magnitude and direction of the hydraulic gradient in a western orientation from the silo area. Hydraulic conductivity values calculated for Site 9 range from 5.61×10^{-3} to 1.08×10^{-2} cm/sec (119 to 229 gal/day/ft^2), with an average value of 8.73×10^{-3} cm/sec (185 gal/day/ft^2).

Analytical soil samples were collected from the soil borings at ground surface, 10 feet below ground surface, and at the total depth of the boring. Table 2-26 summarizes the soil sampling depths for all well and soil borings constructed at Site 9. The sampling procedure for VOCs for each soil boring first involved collecting a grab sample from each of the analytical samples collected. PID screening of the grab samples was then utilized to select the most highly contaminated sample. The VOC sample corresponding to the highest PID reading was submitted for analysis. Equal volumes of all the analytical samples collected from the boring were then composited and submitted for analysis of the remainder of the required parameters. Analytical soil samples were collected in the construction of the well borings at ground surface, the depth corresponding to the estimated middle of the unsaturated zone, and from the soil-groundwater interface. Analytical soil sampling procedures were in accordance with the *QCSP/FIP*.

The laboratory analyses performed on each of the analytical soil samples collected include pesticides/PCBs, VOCs, BNAs, TFH-H, metals, and total solids. Results of these analyses are presented in *FTSFARD*. Groundwater samples collected from the Site 9 monitoring wells were analyzed for pesticides/PCBs, VOCs, BNAs, TFH-H, dissolved metals, and total metals. The *FTSFARD* presents the results of these analyses.

Soil Analytical Results. The analytical results of soil analysis at Site 9 can be found in Table 9-SS of the *FTSFARD*. Figure 2-28 shows the soil sampling locations, along with the soil analytes detected above trigger levels.

The surface soil sample collected at MW-402, which is located upgradient on the northern portion of the site, contained 73 mg/kg of zinc, which exceeds the associated trigger level of 57 mg/kg.



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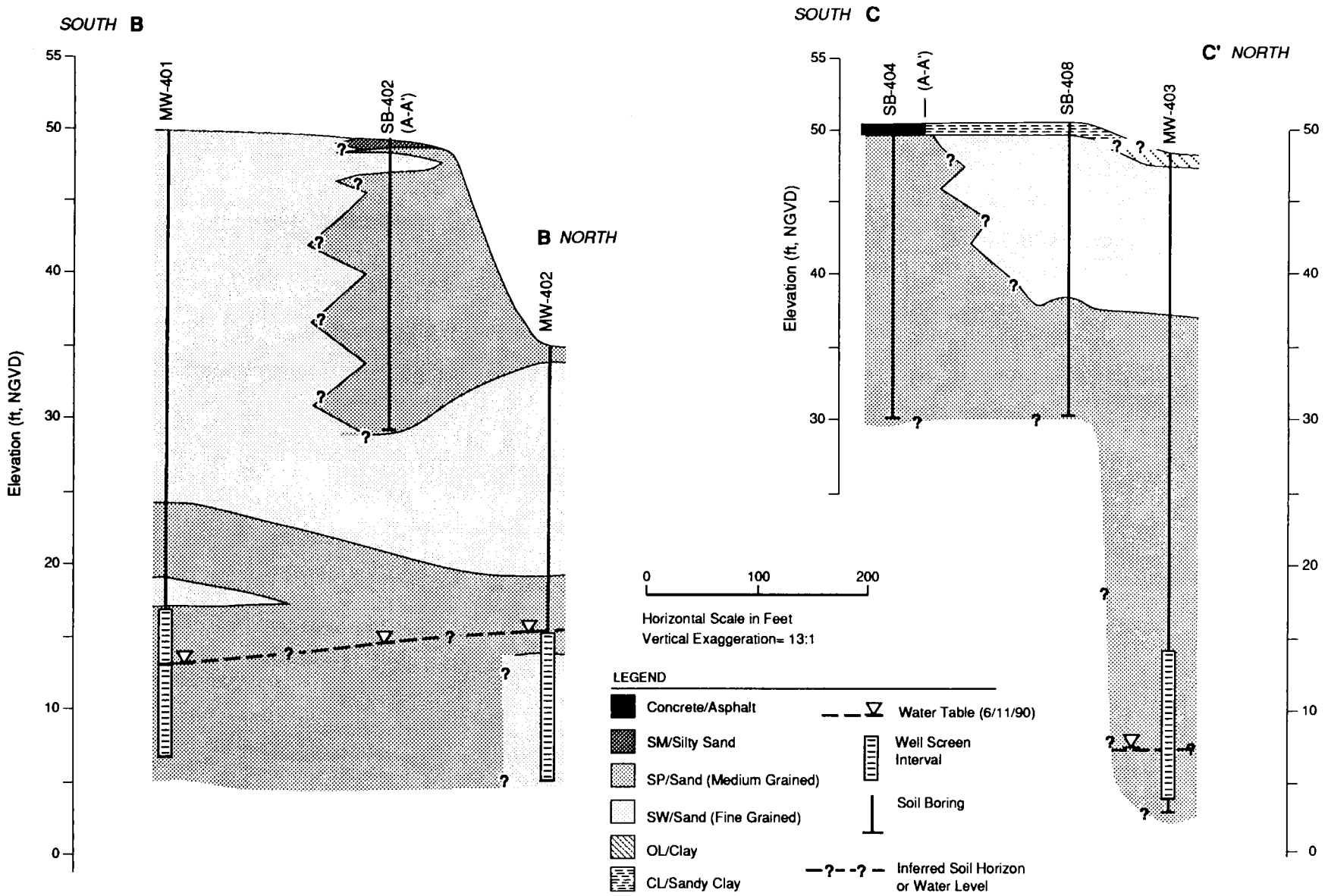
Cross Sections A-A' at Site 9, NIKE Facility
Ft. Story, VA

Figure 2-29



JMM

Cross Sections B-B' and C-C' at Site 9, NIKE Facility
Ft. Story, VA

Figure 2-30

TABLE 2-25

SITE 9, NIKE MISSILE BASE
WELL CONSTRUCTION SUMMARY

Well No.	TOC[a] Elevation (ft., NGVD[d])	Total Depth[b] (ft.)	Elevation Top Screen (ft., NGVD)	Elevation Bottom Screen (ft., NGVD)	Ground Elevation (ft., NGVD)	Depth to Water[c] (ft.)	Water Level (ft., NGVD)	Date Water Level Measured
MW-401	48.91	47.00	11.91	1.91	49.24	41.13	8.11	06/11/90
MW-402	34.19	34.00	10.19	0.19	34.50	23.61	10.89	06/11/90
MW-403	48.49	44.00	14.49	4.49	48.78	40.89	7.89	06/11/90

(a) TOC - top of casing.
(b) Total depth relative to ground surface.
(c) Relative to ground surface.
(d) NGVD - National Geodetic Vertical Datum of 1929.

TABLE 2-26

SITE 9, NIKE MISSILE BASE
SUMMARY OF SOIL SAMPLING DEPTHS

Boring Number	Total Depth[a] (ft.)	Samples Logged	Samples Analyzed[b]	Depth of Soil Samples[c] (ft.)
SB-401	20	5	1	0[d],5,10,15,20
SB-402	22	5	1	0[d],5,10,15,20
SB-403	22	5	1	0,5,10[d],15,18
SB-404	20	5	1	0,5,10[d],15,18
SB-405	42	9	1	0[d],5,10,15,20,25,30,35,40
SB-406	22	5	1	0[d],5,10,15,20
SB-407	22	5	1	0[d],5,10,15,20
SB-408	22	5	1	0[d],5,10,15,20
MW-401	47	10	1	0[d],5,10,15,20[d],25,30,35,40[d],45
MW-402	34	6	1	0[d],5,10,15[d],20.25[d]
MW-403	45	10	1	0[d],5,10,15,20,25,30,35[d],40,43

(a) Total depth relative to ground surface.
(b) Samples were composited for chemical analysis.
(c) An underlined number (e.g., 0) indicates depth at which an analytical sample was collected. Lithologic samples were collected at all depths shown.
(d) VOC grab sample.

This was the only analyte detected above trigger levels from soil collected from the three wells and eight soil borings installed at the site.

Groundwater Analytical Results. The analytical results for groundwater at Site 9 can be found in Table 9-GW of the *FTSFARD*. Figure 2-28 shows the sampling locations. No analytes were detected in concentrations that exceeded trigger levels.

Recommendations. The identification of zinc at 73 mg/kg in the upgradient soil is the only soil or water contaminant detected above the trigger level. No other contaminants of concern were detected in any other site media collected. Therefore, JMM recommends no further action for Site 9, NIKE Missile Base.

3.0 CONCLUSIONS

The Preliminary Assessment/Site Investigation (PA/SI) effort has been successfully implemented for the seven PA/SI sites and one NIKE site located at Fort Story. The purpose of this work effort was to confirm the presence of contamination at the eight potential hazardous waste sites. This document summarizes and evaluates the findings of the field investigation and recommends appropriate future investigatory or response activities.

In conjunction with this site evaluation effort, several other activities were performed. A literature and information search was completed to gain a better understanding of past and current site activities. Prior to the field investigation, a *Final Quality Control Sampling Plan/Field Investigation Plan (QCSP/FIP)* (JMM, 1990a) and a *Final Safety, Health and Emergency Response Plan (SHERP)* (JMM, 1990b) were prepared. These plans provided procedures for conducting field activities. The plans were implemented through the collection of soil, groundwater and tank samples during the field effort. The analytical results were utilized to provide an initial evaluation of the extent of contamination at the various sites. Finally, documents were prepared to summarize the drilling and sampling activities, data quality control issues and the analytical results.

This investigation has identified isolated areas at the Fort Story project sites where elevated levels of soil and/or groundwater contamination have been detected. A number of recommendations for further work have been developed, based on comparison of these findings with regulatory-based action levels or background data from unaffected areas at Fort Story. Recommendations were presented at the end of each site-specific investigatory discussion in Sections 2.2.2 and 2.2.3. A summary of these recommendations for the PA/SI and NIKE PA/SI sites at Fort Story is presented in Tables 3-1 and 3-2, respectively. These tables outline the recommended action, if any, for soil and groundwater at each site. Additionally, the analytes of concern at the PA/SI sites are listed, should further investigations be conducted.

The recommended actions fall under three categories:

- No Further Action
- Further Confirmatory Investigation and/or Removal Action
- Remedial Investigation/Feasibility Study (RI/FS)

"No Further Action" may be appropriate for a PA/SI site when analyte concentrations in site environmental media were measured below the background concentrations. In this instance, trace levels of environmental contamination imply that any potential transport pathways at or near the site to compounds of concern would be insignificant.

"Further Confirmatory Investigation and/or Removal Action" may be appropriate for a PA/SI site when concentrations of a limited number of compounds of concern in site environmental media were measured above the trigger level and viable transport pathways exist for those compounds of concern.

"Remedial Investigation/Feasibility Study (RI/FS)" may be appropriate for a PA/SI site when concentrations of compounds of concern in site environmental media were measured above the corresponding trigger levels, or when data possibly indicate the presence of a plume in site groundwater.

TABLE 3-1

SUMMARY OF RECOMMENDATIONS FOR PA/SI PROJECT SITES - FORT STORY, VIRGINIA

Site Identifier	Media	Contaminants of Concern[a]	Projected Future Activities
Site 1 - Landfill 1	Soil	None	No further action is needed at this site.
	Groundwater	None	
Site 2 - Landfill 2	Soil	Metals (>T)	Further Confirmatory Investigation is needed at this site.
	Groundwater	Metals (>T)	
Site 4 - Firefighter Training Area	Soil	TFH-L (>T) Metals (>T)	An RI/FS is recommended for this site.
	Groundwater	VOCs (>T) BNAs (>T) TFH-L (>T)	
Site 5 - Underground Fuel Storage Tanks	Soil	TFH-L (>T) Total Lead (>T)	An RI/FS is recommended for this site.
	Groundwater	BETX (>T)	
Site 6 - LARC Maintenance Area	Soil	VOCs (>T) TFH-H (>T) Metals (>T)	An RI/FS is recommended for this site.
	Groundwater	VOCs (>T) TFH-H (>T) Metals (>T)	
Site 7 - Auto Craft Building	Soil	TFH-H (>T) Metals (>T)	An RI/FS is recommended for this site.
	Groundwater	TFH-H (>T) Metals (>T)	

TABLE 3-1 (Continued)

SUMMARY OF RECOMMENDATIONS FOR
PA/SI PROJECT SITES - FORT STORY, VIRGINIA

Site Identifier	Media	Contaminants of Concern[a]	Projected Future Activities
Site 8 - Drainage Outfall Line	Soil	None	No further action is needed at this site.
	Sediment in Outfall Line	TFH-H (>T) Metals (>T)	
	Sediment at Outfall Discharge	None	
	Groundwater	None	

(a) Contaminant concentrations are indicated as greater than the trigger (>T) level for that contaminant in a specific medium.
(b) Possible laboratory artifact.

RI/FS Remedial Investigation/Feasibility Study
T Trigger Level

TABLE 3-2

SUMMARY OF RECOMMENDATIONS FOR NIKE PROJECTS - FORT STORY, VIRGINIA

Site Identifier	Media	Contaminants of Concern[a]	Projected Future Activities
Site 9 - NIKE Facility	Soil	Zn >T	No further action is needed at this site.
	Groundwater	None	

(a) Contaminant concentrations are indicated as greater than the trigger (>T) level for that contaminant in a specific medium.

APPENDIX A

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APPENDIX B

SOIL BORING AND MONITORING WELL LOCATION RATIONALE FORT STORY, VIRGINIA

SOIL BORING AND MONITORING WELL LOCATION RATIONALE
FORT STORY, VIRGINIA

Site Number	Boring Number	Rationale for Sampling Location
1	MW-101	Southeast boundary of landfill
	MW-102	Northwest boundary of landfill
	MW-103	Southern boundary of landfill
	MW-104	Northern boundary of landfill
2	MW-105	Northern boundary of landfill
	MW-106	Western boundary of landfill
	MW-107	Southern boundary of landfill
	MW-108	South of landfill
	MW-109	Southeast of landfill
4	MW-110	Based on soil gas survey
	MW-111	Based on soil gas survey
	MW-112	Based on soil gas survey
	SB-101	Based on soil gas survey
	SB-102	Based on soil gas survey
	SB-103	Based on soil gas survey
	SB-104	Based on soil gas survey
	SB-105	Based on soil gas survey
	SB-106	Based on soil gas survey
	SB-107	Based on soil gas survey
	SB-108	Based on soil gas survey
	SB-109	Based on soil gas survey
5	MW-113A	Based on exploratory soil borings. South of UST farm
	MW-113B	Based on exploratory soil borings. West of UST farm
	MW-114A	Based on exploratory soil borings. South of UST farm
	MW-114B	Based on exploratory soil borings. East of UST farm
	SB-110A	Based on exploratory soil borings. North of UST farm
	SB-110B	Based on exploratory soil borings. Eastern boundary of UST farm
	SB-110C	Based on exploratory soil borings. West of UST farm
	SB-111A	Based on exploratory soil borings. Western boundary of UST farm
	SB-111B	Based on exploratory soil borings. Southern boundary of UST farm
	SB-111C	Based on exploratory soil borings. West of UST farm
6	MW-115	Determination of soil contamination associated with the wash rack
	MW-116	Determination of soil contamination associated with the wash rack
	MW-117	Downgradient of waste oil storage tank
	MW-118	Upgradient of waste oil storage tank
	SB-112	Determination of soil contamination associated with the wash rack
	SB-113	Determination of soil contamination associated with the wash rack
	SB-114	Determination of soil contamination associated with the wash rack
	SB-115	Determination of soil contamination associated with the wash rack
	SB-116	Determination of soil contamination associated with the wash rack
	SB-117	Determination of soil contamination associated with the wash rack
	SB-118	Determination of soil contamination associated with the wash rack
	SB-119	Determination of soil contamination associated with the wash rack
	SB-120	Determination or soil contamination associated with
	SB-121	the washrack and oil/water separator
	SB-122	Determination of soil contamination associated with
	SB-123	the waste oil storage tank

SOIL BORING AND MONITORING WELL LOCATION RATIONALE
FORT STORY, VIRGINIA
(Continued)

Site Number	Boring Number	Rationale for Sampling Location
7	MW-119	Downgradient from the two former USTs
	MW-120	Downgradient from the Autocraft Building
	SB-124	Determination of soil contamination from two former USTs
	SB-125	Determination of soil contamination from two former USTs
	SB-126	Determination of soil contamination from two former USTs
	SB-127	Determination of soil contamination from two former USTs
	SB-128	Northern perimeter of former building
	SB-129	Western perimeter of former building
	SB-130	Southern perimeter of former building
	SB-131	Eastern perimeter of Autocraft building
8	MW-121	Determination of contamination adjacent to Drainage Outfall Line
	SB-132	Determination of soil contamination adjacent to Drainage Outfall Line
	SB-133	Determination of soil contamination adjacent to Drainage Outfall Line
	SD-102	Determination of contamination within the Drainage Outfall Line
	SD-103	Determination of contamination within the Drainage Outfall Line
	SD-104	Determination of contamination within the Drainage Outfall Line
	SD-105	Determination of contamination within the Drainage Outfall Line
	SD-106	Determination of contamination within the Drainage Outfall Line
	SD-107	Determination of contamination within the Drainage Outfall Line
	SD-108	Determination of contamination within the Drainage Outfall Line
	SD-109	Determination of contamination within the Drainage Outfall Line
	SD-110	Determination of contamination within the Drainage Outfall Line
	SD-111	Determination of contamination within the Drainage Outfall Line
	SD-112	Determination of contamination within the Drainage Outfall Line
	SD-113	Determination of contamination within the Drainage Outfall Line
	SD-114	Determination of contamination within the Drainage Outfall Line
	SD-115	Determination of contamination within the Drainage Outfall Line
	SD-117	Determination of contamination within the Drainage Outfall Line
	SD-118	Determination of contamination within the Drainage Outfall Line
	SD-119A	Determination of contamination within the Drainage Outfall Line
	SD-120	Determination of contamination within the Drainage Outfall Line
	SD-121	Determination of contamination within the Drainage Outfall Line
	SD-122	Determination of contamination within the Drainage Outfall Line
	SD-123	Determination of contamination within the Drainage Outfall Line
	SD-124	Determination of contamination within the Drainage Outfall Line
	SD-125	Determination of contamination within the Drainage Outfall Line
	SD-131	Determination of sediment contamination adjacent to Drainage Outfall
	SD-132	Determination of sediment contamination adjacent to Drainage Outfall
	SD-133	Determination of contamination within the Drainage Outfall Line
	SD-134	Determination of contamination within the Drainage Outfall Line
	SD-135	Determination of contamination within the Drainage Outfall Line
9	MW-401	Adjacent to silos
	MW-402	Adjacent to silos
	MW-403	Downgradient of support area building
	SB-401	In former silo area
	SB-402	In former silo area
	SB-403	Adjacent to former acid storage shed
	SB-404	Assessing soil contamination in the vicinity
	SB-405	of former mixing building

SOIL BORING AND MONITORING WELL LOCATION RATIONALE
FORT STORY, VIRGINIA
(Continued)

Site Number	Boring Number	Rationale for Sampling Location
	SB-406	Assessing soil contamination at former maintenance building
	SB-407	Assessing soil contamination at former maintenance building
	SB-408	Located adjacent an UST, N of Generator Building
Background Borings	SB-134	Representative of eastern sand flat area
	SB-135	Representative of central sand ridge area
	SB-136	Representative of coastal dune complex

APPENDIX C

GEOTECHNICAL SOIL CLASSIFICATION SUMMARY
FORT STORY, VIRGINIA

GEOTECHNICAL SOIL CLASSIFICATION SUMMARY
FORT STORY, VIRGINIA

Site	Well No.	Depth in Feet	Classification
1	MW-101	16	SP - Tan Sand
1	MW-102	6	SP - Tan Sand
1	MW-103	22	SP - Tan Sand
1	MW-104	12	SP - Tan Sand
2	MW-105	10	SP - Tan Sand
2	MW-106	4	SP - Tan Sand
2	MW-107	3	SP - Tan Sand
2	MW-108	3	SP - Tan Sand
2	MW-109	6	SP - Tan Sand
4	MW-110	6	SP - Tan Sand
4	MW-111	6	SP - Tan Sand
4	MW-112	6	SP - Tan Sand
5	MW-1113A	10	SM - Brown Silty Sand
5	MW-1113B	4	SM - Brown Silty Sand
5	MW-1114A	10	SM - Brown Silty Sand
5	MW-1114B	15	SM - Brown Silty Sand
6	MW-115	6	SP - Tan Sand
6	MW-116	4	SP-SM - Tan Slightly Silty Sand with Some Grain
6	MW-117	5	SP-SM - Tan Slightly Silty Sand
6	MW-118	10	SP - Tan Sand
7	MW-119	4	SP - Tan Sand
7	MW-120	10	SP - Tan Sand
8	MW-121	10	SP - Tan Sand
9	MW-401	40	SP - Tan Sand
9	SB-402	20	SP - Tan Sand
9	MW-402	25	SP - Tan Sand
9	MW-403	36	SP - Tan Sand
9	MW-403	40	ML - Brown Sandy Silt
9	SB-407	0	SP - Tan Sand
9	SB-408	10	SM - Tan Slightly Silty Sand

APPENDIX D

SHALLOW SOIL GAS INVESTIGATION, FORT STORY SITE 4

Tracer Research Corporation

PREPARED FOR:

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SHALLOW SOIL GAS INVESTIGATION
FORT STORY SITE 4
VIRGINIA BEACH, VIRGINIA

MARCH 1990

SUBMITTED BY:

Karen L. Suess

Tracer Research Corporation

JMMFTSTRY.MSG
1-90-259-S

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INTRODUCTION

A shallow soil gas investigation was performed by Tracer Research Corporation (TRC) at Fort Story Site 4, located in Virginia Beach, Virginia. The investigation was conducted on March 20-22, 1990 under contract to JM Montgomery. The purpose of the investigation was to determine the presence, areal extent, and concentration levels of volatile organics in the groundwater and/or vadose zone. The results were used to determine the location of six soil borings and monitoring well locations.

During this survey, a total of forty-three soil gas samples were collected and analyzed. Samples were analyzed for volatile compounds from the following suite:

benzene
toluene
ethylbenzene
xylenes
total hydrocarbons (THC)
1,1,1-trichloroethane (TCA)
trichloroethene (TCE)
tetrachloroethene (PCE)

Xylenes are reported as the total of the three xylene isomers and total hydrocarbons are reported as gasoline range compounds consisting of approximately C_4-C_9 aliphatic, alicyclic and aromatic compounds.

The compounds in this suite were chosen as target compounds because of their suspected presence in the subsurface and amenability to soil gas technology. Soil gas samples were screened on a gas chromatograph equipped with a flame ionization detector (FID) and and electron capture detector (ECD).

SHALLOW SOIL GAS INVESTIGATION - METHODOLOGY

Shallow soil gas investigation refers to a method developed by TRC for investigating underground contamination from volatile organic chemicals (VOCs) such as industrial solvents, cleaning fluids and petroleum products by looking for their vapors in the shallow soil gas. The method involves pumping a small amount of soil gas out of the ground through a hollow probe driven into the ground and analyzing the gas for the presence of volatile contaminants. The presence of VOCs in shallow soil gas indicates the observed compounds may either be in the vadose zone near the probe or in groundwater below the probe. The soil gas technology is most effective in mapping low molecular weight halogenated solvent chemicals and petroleum hydrocarbons possessing high vapor pressures and low aqueous solubilities. These compounds readily partition out of the groundwater and into the soil gas as a result of their high gas/liquid partitioning coefficients. Once in the soil gas, VOCs diffuse vertically and horizontally through the soil to the ground surface where they dissipate into the atmosphere. The contamination acts as a source and the above ground atmosphere acts as a sink, and typically a concentration gradient develops between the two. The concentration gradient in soil gas between the source and ground surface may be locally distorted by hydrologic and geologic anomalies (e.g. clays, perched water); however, soil gas mapping generally remains effective because distribution of the contamination is usually broader in areal extent than the local geologic barriers and is defined using a large data base. The presence of geologic obstructions on a small scale tends to create anomalies in the soil gas-groundwater correlation, but generally does not obscure the broader areal picture of the contaminant distribution.

Soil gas contaminant mapping helps to reduce the time and cost required to delineate underground contamination by volatile contaminants. The soil gas investigation does this by outlining the general areal extent of contamination. Conventional bore holes or observation wells are used to verify both the presence and extent of the subsurface contamination as indicated in the soil gas survey. In this manner, soil gas contaminant mapping can assist in determining the placement of monitoring wells. Thus, the likelihood

of drilling unnecessary monitoring wells is reduced. The soil gas survey is not intended to be a substitute for conventional methodology, but rather to enable conventional methods to be used efficiently.

EQUIPMENT

Tracer Research Corporation utilized a one ton Ford analytical field van that was equipped with one gas chromatograph and two Spectra Physics computing integrators. In addition, the van has two built-in gasoline powered generators that provide the electrical power (110 volts AC) to operate all of the gas chromatographic instruments and field equipment. A specialized hydraulic mechanism consisting of two cylinders and a set of jaws was used to drive and withdraw the sampling probes. A hydraulic hammer was used to assist in driving probes past cobbles and through unusually hard soil.

SAMPLING PROCEDURES

Sampling probes consist of 7 foot lengths of 3/4 inch diameter hollow steel pipe that are fitted with detachable drive tips. Soil gas probes were advanced to 1-5 feet below grade. Once inserted into the ground, the above-ground end of the sampling probes were fitted with a steel reducer and a length of polyethylene tubing leading to a vacuum pump. Gas flow is monitored by a vacuum gauge to insure that an adequate flow is obtained.

To adequately purge the volume of air within the probe, 2 to 5 liters of gas is evacuated with a vacuum pump. During the soil gas evacuation, samples are collected in a glass syringe by inserting a syringe needle through a silicone rubber segment in the evacuation line and down into the steel probe. Ten milliliters of gas are collected for immediate analysis in the TRC analytical field van. Soil gas is subsampled (duplicate injections) in volumes ranging from 1 uL to 2 mL, depending on the VOC concentration at any particular location.

Sample probe vacuum pressures measured with a vacuum gauge ranged from one to five inches Hg. Maximum vacuum pump pressure was measured at twenty-six inches Hg.

ANALYTICAL PROCEDURES

A Varian 3300 gas chromatograph, equipped with a flame ionization detector (FID), and and electron capture detector were used for the soil gas analyses. The FID was used for the analysis of gasoline range hydrocarbons including benzene, toluene, ethylbenzene, xylenes, and total hydrocarbons. The ECD was used for the analysis of TCA, TCE, and PCE. Compounds were separated on a 3' or 6' by 1/8" OD packed column with OV-101 as the stationary phase in a temperature controlled oven at 55°C. Nitrogen was used as the carrier gas.

Hydrocarbon and halocarbon compounds detected in soil gas were identified by chromatographic retention time. Quantification of compounds was achieved by comparison of the detector response of the sample with the response measured for calibration standards (external standardization). Instrument calibration checks were run periodically throughout the day and system blanks were run at the beginning of the day to check for contamination in the soil gas sampling equipment. Air samples were also routinely analyzed to check for background levels in the atmosphere.

Detection limits for the compounds of interest are a function of the injection volume as well as the detector sensitivity for individual compounds. Thus, the detection limit varies with the sample size. Generally, the larger the injection size the greater the sensitivity. However, peaks for compounds of interest must be kept within the linear range of the analytical equipment. If any compound has a high concentration, it is necessary to use small injections, and in some cases to dilute the sample to keep it within linear range. This may cause decreased detection limits for other compounds in the analyses.

The detection limits for the selected compounds were approximately 0.03 ug/L for hydrocarbons and 0.0002 ug/L for halocarbons, depending on the conditions of the measurement, in particular, the sample size. If any component being analyzed is not detected, the detection limit for that compound in that analysis is given as a "less than" value (e.g. <0.1 ug/L). Detection limits obtained from GC analyses are calculated from the

current response factor, the sample size, and the estimated minimum peak size (area) that would have been visible under the conditions of the measurement.

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

Tracer Research Corporation's normal quality assurance procedures were followed in order to prevent any cross-contamination of soil gas samples.

- Steel probes are used only once during the day and then washed with high pressure soap and hot water spray or steam-cleaned to eliminate the possibility of cross-contamination. Enough probes are carried on each van to avoid the need to reuse any during the day.
- Probe adaptors (TRC's patented design) are used to connect the sample probe to the vacuum pump. The adaptor is designed to eliminate the possibility of exposing the sample stream to any part of the adaptor. Associated tubing connecting the adaptor to the vacuum pump is replaced periodically as needed during the job to insure cleanliness and good fit. At the end of each day the adaptor is cleaned with soap and water and baked in the GC oven.
- Silicone tubing (which acts as a septum for the syringe needle) is replaced as needed to insure proper sealing around the syringe needle. This tubing does not directly contact soil gas samples.
- Glass syringes are usually used for only one sample per day and are washed and baked out at night. If they must be used twice, they are purged with carrier gas (nitrogen) and baked out between probe samplings.
- Injector port septa through which soil gas samples are injected into the chromatograph are replaced on a daily basis to prevent possible gas leaks from the chromatographic column.

- Analytical instruments are calibrated each day by analytical standards from Chem Service, Inc. Calibration checks are also run after approximately every five soil gas sampling locations.
- Subsampling syringes are checked for contamination prior to sampling each day by injecting nitrogen carrier gas into the gas chromatograph.
- Prior to sampling each day, system blanks are run to check the sampling apparatus (probe, adaptor, 10 cc syringe) for contamination by drawing ambient air from above ground through the system and comparing the analysis to a concurrently sampled ambient air analysis.
- All sampling and subsampling syringes are decontaminated each day and no such equipment is reused before being decontaminated. Microliter size subsampling syringes are reused only after a nitrogen carrier gas blank is run to insure it is not contaminated by the previous sample.
- Soil gas pumping is monitored by a vacuum gauge to insure that an adequate gas flow from the vadose zone is maintained. A reliable gas sample can be obtained if the negative pressure reading on the vacuum gauge is at least 2 inches Hg less than the maximum pressure of the pump.

APPENDIX A: CONDENSED DATA

JM MONTGOMERY/FORT STORY, VIRGINIA BEACH, VIRGINIA JOB#1-90-259-S
03-20-90
CONDENSED DATA

SAMPLE	TCA ug/l	TCE ug/l	PCE ug/l	BENZENE ug/l	TOLUENE ug/l	ETHYL BENZENE ug/l	XYLENES ug/l	THC ug/l
AIR	<0.00009	<0.0002	<0.00005	<0.02	<0.02	<0.02	<0.02	<0.02
A-1-3'	<0.0002	<0.0005	0.001	1	<0.04	<0.04	<0.04	1
A-2-3'	0.04	<0.0005	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
A-3-3'	0.02	<0.0005	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
A-4-3'	0.0004	<0.0005	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
A-5-2'	<0.0002	<0.0005	0.0006	<0.04	<0.04	<0.04	<0.04	<0.04
A-6-3'	<0.0002	<0.0005	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
A-7-3'	0.001	<0.0005	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
AIR	<0.00009	<0.0002	<0.0005	<0.02	<0.02	<0.02	<0.02	<0.02
3-21-90								
AIR	<0.0002	<0.0004	<0.00008	<0.02	<0.02	<0.03	<0.02	<0.02
A-1-4'	1	<0.002	<0.0004	0.6	<0.04	<0.06	<0.05	0.8
B-1-4.5'	0.06	<0.002	<0.0004	<0.03	<0.04	<0.06	<0.05	<0.04
B-2-3'	<0.0003	<0.0008	0.004	<0.03	<0.04	<0.06	<0.05	<0.04
B-3-3'	<0.0003	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
B-4-3'	0.0008	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
B-5-3'	0.0008	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
B-6-1'	0.004	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
B-7-1.5'	0.004	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
C-1-3'	0.01	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
C-2-3'	3	<0.0008	0.001	0.7	<0.04	<0.06	<0.05	0.9
C-3-3'	0.0008	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
C-4-2'	<0.0003	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
C-5-1'	0.0008	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
C-6-1'	0.0009	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
C-7-1'	0.0006	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
D-1-4.5'	0.001	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
D-3-3'	0.0008	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
D-4-3'	0.0006	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
D-5-3'	0.0008	<0.0008	<0.0002	2	0.2	<0.03	<0.02	5
D-6-.75'	0.0009	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
D-7-1'	0.0004	<0.0008	<0.0002	<0.03	<0.04	<0.06	<0.05	<0.04
E-1-4'	3	<0.0008	<0.0002	0.8	<0.04	<0.06	<0.05	0.9
AIR	<0.0002	<0.0004	0.0004	<0.02	<0.02	<0.03	<0.02	1

Analyzed by: T. Carey
Checked by: M. Field
Proofed by: L. Laplander

Tracer Research Corporation

JM MONTGOMERY/FORT STORY/VIRGINIA BEACH, VIRGINIA JOB#1-90-259-S
03-22-90
CONDENSED DATA

SAMPLE	TCA ug/l	TCE ug/l	PCE ug/l	BENZENE ug/l	TOLUENE ug/l	ETHYL BENZENE ug/l	XYLENES ug/l	THC ug/l
AIR	<0.0001	<0.0003	0.0005	<0.02	<0.02	<0.02	<0.02	<0.02
E-3-3'	<0.0002	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
E-2-4'	0.0006	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
E-4-1'	0.0006	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
E-5-1'	0.0006	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
E-6-1'	0.0008	<0.0007	0.0008	<0.04	<0.04	<0.04	<0.04	<0.04
E-7-1'	0.0006	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
F-1-4'	17	<0.0003	<0.0006	5	<0.04	<0.04	<0.04	6
D-2-4'	0.03	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
F-2-4'	0.002	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
F-3-3'	0.0003	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
F-4-2.5'	0.002	0.002	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
F-5-1.5'	1	<0.003	<0.0006	0.2	<0.04	<0.04	1	4
F-6-1.5'	0.004	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
F-7-.75'	0.004	<0.0007	<0.0001	<0.04	<0.04	<0.04	<0.04	<0.04
AIR	<0.0001	<0.0003	<0.00006	<0.02	<0.02	0.02	<0.02	<0.02

Analyzed by: T. Carey
Checked by: M. Field
Proofed by: L. Laplander

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