Final

Feasibility Study

Camp Allen Landfill
Norfolk Naval Base
Norfolk, Virginia

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Department of the Navy
Atlantic Division
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Engineering Command
Norfolk, Virginia

Under the

LANTDIV CLEAN Program

Comprehensive Long-Term
Environmental Action Navy

Baker
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CONTRACT TASK ORDER 0084

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DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
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Prepared by:

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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
AWQC	ambient water quality criteria
BDAT	best demonstrated available technology
bgs	below ground surface
BOD	biological oxygen demand
BTEX	benzene, toluene, ethylbenzene, xylenes
CASY	Camp Allen Salvage Yard
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COD	chemical oxygen demand
COMNAVBASE	Commander, Naval Base
COPCs	contaminants of potential concern
CWA	Clean Water Act
DCA	dichloroethane
DCE	dichloroethene
DON	Department of the Navy
DPVE	dual phase vapor extraction
EE/CA	Engineering Evaluation/Cost Analysis
FS	Feasibility Study
GAC	granular activated carbon
gpd/ft	gallons per day per foot
gpm	gallons per minute
HI	hazard index
HRSD	Hampton Roads Sanitation District
ICRs	incremental cancer risks
IWTP	industrial wastewater treatment plant
LANTDIV	Atlantic Division Naval Facilities Engineering Command
LDR	land disposal restriction
LTTS	low temperature thermal stripping
MCLGs	maximum contaminant level goals
MCLs	maximum contaminant levels
mg/kg	milligrams per kilogram
μg/L	micrograms per liter
MGD	million gallons per day
NAS	Naval Air Station
NCP	National Contingency Plan
NEESA	Naval Energy and Environmental Support Activity
NOB	Naval Operating Base
NPW	net present worth

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

O&M	operation and maintenance
PA/SI	Preliminary Assessment/Site Investigation
PAH	polyaromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
POTW	publicly owned treatment works
ppm	parts per million
PRAP	Proposed Remedial Action Plan
RAOs	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SPNC	Sewell's Point Naval Complex
SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
TBC	to be considered
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TMV	toxicity, mobility, or volume
TOC	total organic carbon
TOX	total organic halogens
TPH	total petroleum hydrocarbons
TRC	Technical Review Committee
USEPA	United States Environmental Protection Agency
USMC	United States Marine Corps
UV	ultraviolet
VLDPE	very low density polyethylene
VOCs	volatile organic compounds
VR	Virginia Regulations

SECTION 1 - INTRODUCTION AND PURPOSE

1.0 INTRODUCTION AND PURPOSE

This report presents the Feasibility Study (FS) for Areas A and B of the Camp Allen Landfill Site, Norfolk Naval Base. This FS has been prepared by Baker Environmental, Inc. (Baker) under contract to the Atlantic Division Naval Facilities Engineering Command (LANTDIV), Contract Number N62470-89-D-4814. The development of this report is based on the scope of work for Contract Task Order Number 0084.

This FS has been conducted according to the basic methodology outlined in the National Contingency Plan (NCP) for interim remedial actions (40 CFR 300.430). These NCP regulations were promulgated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), commonly referred to as Superfund, and amended by the Superfund Amendments and Reauthorization Act (SARA) signed into law on October 17, 1986. The EPA document Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988b) was used as a guidance document for preparing this report.

The FS has been based on existing data collected during various studies conducted at Norfolk Naval Base by the Department of the Navy (DON), other DON consultants, and during a Remedial Investigation (RI) conducted by Baker personnel. Site-specific information for this report was obtained from the following documents:

- Final Remedial Investigation Report, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia, Baker Environmental, July 1994.

- Final Baseline Risk Assessment, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia, Baker Environmental, November 1994.

- Final Remedial Design Work Plan, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia, Baker Environmental, May 1994.

- Final Industrial Wastewater Treatment Plant Engineering Analysis Report, Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia, Baker Environmental, January 1994.

- Final Engineering Evaluation/Cost Analysis, Camp Allen Landfill - Area B, Norfolk Naval Base, Norfolk, Virginia, August 1993.

Based on site information, contamination associated with the Camp Allen Landfill (Area A and Area B) generally consists of volatile organic compounds (VOCs) (e.g., vinyl chloride, toluene) resulting from releases of solvent-and fuel-laden wastes disposed at the site. In addition, other organic and inorganic contaminants were detected; however, the VOCs represent the majority of the risk-based contaminants of potential concern. The Camp Allen Landfill Site (Areas A and B) and the surrounding areas are illustrated in Figure 1-1.

The results of the RI and risk assessment indicate that there are potential risks to human health or the environment associated with certain media at the Camp Allen Landfill Site. Additional information on RI results and the risk assessment is presented in Sections 1.2, 1.4, 1.5, and 1.6.

Based on the RI findings, an Engineering Evaluation/Cost Analysis (EE/CA) for a non-time-critical removal action (Baker, 1993a) in Area B was performed to develop and evaluate alternatives for removal and disposal of contaminated subsurface soil and debris identified in former waste burial trenches at this location. The selected removal action alternative included:

- Temporary dewatering of the removal areas to lower the water table;
- Collection of extracted groundwater, pre-treatment of the water to comply with applicable federal, state, and local pretreatment standards, and transportation to the Hampton Roads Sanitation District (HRSD) wastewater treatment facility for treatment and disposal;
- Excavation of the soil and debris from the trenches plus over-excavation of visibly-contaminated soil from the side walls and floor of the excavation;
- Confirmation soil sampling and analysis, and additional excavation of material contaminated in excess of the removal action endpoints;
- Transportation to and disposal of excavated soil and debris at a RCRA-permitted hazardous waste landfill; and
- Site restoration.

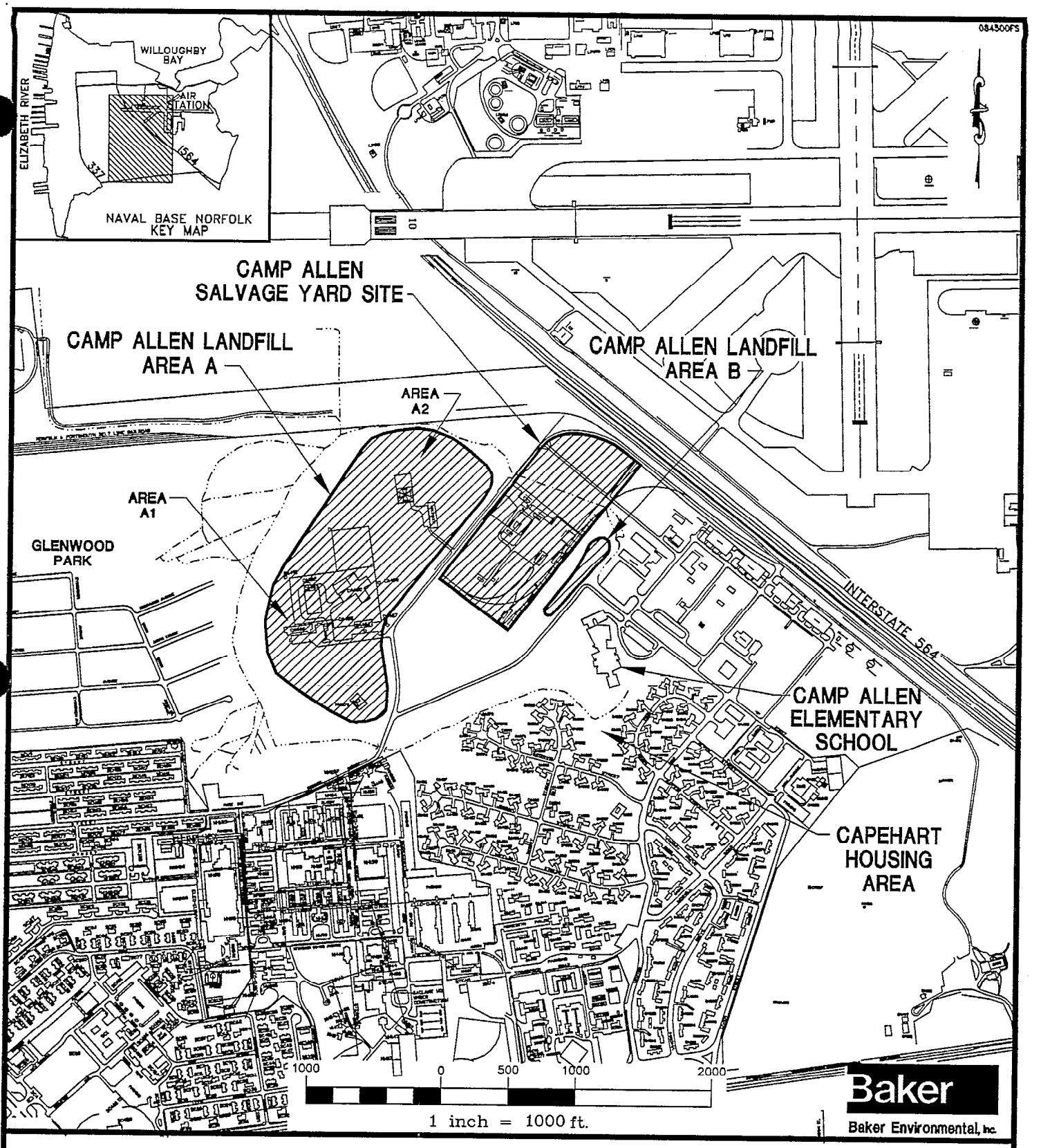


FIGURE 1-1
SITE LOCATION MAP
CAMP ALLEN LANDFILL

NAVAL BASE NORFOLK
NORFOLK, VIRGINIA

SOURCE: LANTDIV, OCTOBER 1991

The Area B removal action was initiated in the summer of 1994 and is near completion. At the completion of these activities, the primary sources of contamination at Area B will be eliminated. The objective of the removal action is to remove the sources of groundwater contamination within the Area B Landfill so that no further remedial actions are required for the soils and debris associated with the Area B Landfill. Confirmation soil sampling and analysis will be performed to verify that the soil cleanup levels, included in the Final EE/CA Report, have been met.

This FS addresses the following contaminated media at the Camp Allen Landfill Site:

- Area A: Potential VOC-contaminated subsurface soil, potential inorganic-contaminated surface water and sediment, and VOC-contaminated groundwater.

- Area B: Potential VOC-contaminated subsurface soil, potential VOC-and inorganic-contaminated surface water and sediment, and VOC-contaminated groundwater.

As noted in the RI Report, there are several additional areas in the immediate vicinity of the Camp Allen Landfill Area with documented or potential contamination of environmental media. A Preliminary Assessment/Site Inspection (PA/SI) was performed at the Camp Allen Salvage Yard Site (CASY) and the and the results were documented in the Final PA/SI Report (Baker, 1994f). In general, CASY activities have included storage and management of waste oils and chemicals, used chemicals, and scrap industrial/commercial equipment. Potential site contamination at the CASY will be addressed during an RI/FS for this site, which is scheduled for 1995.

Based on historical information, the Capehart Housing Area, located south of Area B and the Camp Allen Elementary School, was the site of soil borrow activities during the 1930s and 1940s. During the Camp Allen Landfill RI, potential contamination was identified in this vicinity. Currently, the Navy is further evaluating historical information related to this area in an effort to develop a scope of work for future environmental assessment of the site.

It should be noted that the CASY and Capehart areas, and any other potential contamination sources or contaminated media, were not considered or addressed in this FS.

The purpose of this FS is to evaluate a range of remedial alternatives that will protect the public health, welfare, and the environment from potential risks associated with contaminated media at the Camp Allen Landfill Site.

1.1 Base/Site History

1.1.1 Naval Base Norfolk History

On June 28, 1917, 474 acres of land were acquired by Presidential Proclamation to establish the Sewell's Point Naval Complex (SPNC) to support the war effort. Construction of facilities began on July 4, 1917. On October 12, 1917, the naval facilities were officially commissioned as the Hampton Roads Naval Operating Base (NOB). In order to fulfill the NOB mission, bulkheads were built from 1917 to 1918 in the waters along the coast to extend available land. After dredge and fill operations, the total land under Navy control was increased from 474 to 792 acres. An additional 143 acres were acquired in 1918 and officially commissioned for the Naval Air Station (NAS).

The post-World War I period was one of decreased naval operations and of economic depression. Few physical changes to the facility occurred between 1920 and 1935. From 1936 to 1940, improvements to the piers and expansion of supplies and materials handling facilities were completed. During this time, the area of the Naval Base expanded to over 2,100 acres because of the involvement of the United States in World War II.

After World War II, naval operations again declined; many ships were decommissioned and crews were discharged. Administrative reorganization of the Navy according to peacetime needs resulted in the establishment of Naval Base Norfolk. Naval Base Norfolk comprised several major components of the former NOB and other Hampton Roads facilities.

The evolution of naval hardware has necessitated many changes since 1960. Facilities to provide support and maintenance for the primary tools of naval operation including aircraft carriers, guided-missile cruisers, and helicopters were the main projects. Rehabilitation of hangars, taxiways, runways, and air traffic control facilities, as well as waterfront construction of several piers, also increased the capability to fulfill the Commander, Naval Base (COMNAVBASE) mission. The mission of COMNAVBASE is to provide fleet support and readiness for the Atlantic Fleet. The mission is four-fold: to command assigned naval shore activities; to coordinate support to afloat units, their air arm, and other naval activities on the naval base complex; to act as regional area coordinator; and to act as senior officer present afloat for administration in the Hampton Roads area.

During its history, Naval Base Norfolk has expanded to become the world's largest naval installation, with 105 ships homeported in Norfolk. The base currently has 15 piers handling 3,100 ship movements annually. COMNAVBASE supports 20 tenant commands located on the Atlantic Fleet compound.

1.1.2 Site History

The Camp Allen Landfill Site is located approximately one mile east of Hampton Boulevard and one mile south of Willoughby Bay. Prior to 1940, this area was primarily occupied by surface water features related to Bousch Creek, which flows north into Willoughby Bay. Development of residential, commercial, and military related structures was limited to adjacent topographically high areas during this time period. In the late 1930s, these high portions of the Camp Allen area were reportedly used as soil borrow areas for development of other portions of Naval Base Norfolk. During the early 1940s, landfill operations commenced in the Camp Allen area (Camp Allen Landfill). Disposal activities continued until 1975.

The Camp Allen Landfill Site today is comprised of two distinct areas (Area A and Area B), as shown in Figure 1-1. Area A is a 45-acre site that was used primarily for the disposal of miscellaneous debris, metal plating and parts cleaning sludge, and various organic solvent related residues. In the mid-1940s, an incinerator was constructed in the southern portion of the Camp Allen area to burn combustible wastes. This incinerator operated until the mid-1960s. Materials too bulky for the incinerator were burned in Area A. Additionally, ash from the incineration of solid wastes, as well as fly and bottom ash from the Naval Base power plant, were disposed in Area A. For purposes of the FS and for future Remedial Design/Remedial Action (RD/RA) activities, Area A has been divided into two portions: Area A1 located west of the Brig Facility; and Area A2 located in the northern section of the Area A Landfill.

The eastern portion of the Camp Allen Landfill (Area B) received wastes from a 1971 Salvage Yard fire. The Camp Allen Salvage Yard, which is still in operation, is located between Camp Allen Landfill Areas A and B. In general, Salvage Yard activities have included storage and management of waste oils and chemicals, over-age chemicals, and scrap industrial/ commercial equipment. Also, miscellaneous incineration was a past practice and various recycling activities currently are performed at the facility. The residue and debris remaining after the 1971 Salvage Yard fire were buried in an adjacent area (Area B) via trench and fill operations. Located south of Area B is the Camp Allen Elementary School and the Capehart Housing Area.

At present, the majority of Area A and Area B are soil covered and revegetated to minimize surface erosion. Area A incorporates the Navy Brig Facility and a heliport built over a portion of the landfill in

the mid-1970s. Glenwood Park (an off-base residential area) is located to the west of Area A and Camp Allen Elementary School is located to the south of Area B. The Capehart Military Housing Area is located south of the Camp Allen Elementary School. Various military activities, including USMC Camp Elmore operations, are conducted throughout the Camp Allen area.

1.1.3 Previous Investigations

Previous investigations of hazardous waste sites at the Norfolk Naval Base (including the Camp Allen Landfill) have been conducted under an Initial Assessment Study, Site Suitability Assessment Study, Confirmation Study, an Interim Remedial Investigation Report of the Installation Restoration Program, and an Interim Remedial Investigation of the Camp Allen Landfill Site. The following summarizes previous investigations and their findings as they pertain to the Camp Allen Landfill Site:

- Initial Assessment Study (Malcolm Pirnie, Inc., February 1983): Based on review of historical records and general site reconnaissance, the Camp Allen Landfill was among the sites at the Norfolk Naval Base recommended for further study.

- Site Suitability Assessment (Malcolm Pirnie, Inc., June 1984): Assessment activities for a proposed Brig Expansion. Magnetometer survey results indicated extensive areas of buried metallic objects throughout the middle and southern regions of Area A. Shallow groundwater sample analysis for Priority Pollutants from 11 wells identified the area west of the Brig Facility as having organic pollutants (i.e., trichloroethylene, benzene, and toluene) in concentrations that exceeded USEPA water quality criteria. Additionally, groundwater from several well locations exceeded USEPA water quality criteria for various total metal constituents (i.e., arsenic, cadmium, lead, and zinc). Gas monitoring at nine stations identified methane concentrations significantly less than 220 parts per million (ppm) in all but one location. An existing pumping station was possibly the cause of the one high reading.

- Confirmation Study (Malcolm Pirnie, Inc., June 1983): Confirmation Study activities were aimed at confirming the existence of contaminants potentially detrimental to human health and the environment at Camp Allen Areas A and B. The study included four separate sampling events. Analysis of organic compounds in water table aquifer groundwater samples from two general locations (Area A [west of Brig] - 3 wells; Area B [northeast portion] - 3 wells) identified elevated concentrations (exceeding

applicable water quality criteria/standards) of several VOCs (i.e., vinyl chloride, trichloroethylene, toluene). Analysis of organic compounds in Yorktown Aquifer groundwater samples from two locations (0.75 miles northwest of Area A and directly southeast of Area B) indicated that no organic compounds were present at or above analytical method detection limits. Surface water sample results indicated that leaching of organic compounds (i.e., vinyl chloride, trichloroethylene) had occurred directly east of Area B into the drainage and ponded surface waters. Analysis of inorganic compounds in unfiltered groundwater and surface water indicated that concentrations of cadmium, chromium, lead, and zinc exceeded applicable water quality criteria.

- Interim Remedial Investigation Report (Malcolm Pirnie, Inc., March 1988): This interim report only summarized Confirmation Study results for the Camp Allen Landfill. Additional field activities were not performed.

- Interim Remedial Investigation (CH_2M Hill, 1990-1991): CH_2M Hill continued the Interim Remedial Investigation activities at the Camp Allen Landfill. In general, investigation results were as follows:

  - Shallow groundwater in the water table aquifer appeared to flow radially away from the landfill at Area A and southeast from Area B. Deep groundwater in the Yorktown Aquifer appeared to flow primarily to the northwest.

  - The confining clay unit which separates the water table and Yorktown Aquifers, appeared to be absent in various locations, allowing for potential downward migration of contaminants from the landfill.

  - Analytical results for one round of groundwater samples collected from a total of 27 shallow wells at Areas A and B identified organic compounds in the shallow groundwater from two general locations (Area A - west of Brig and southeast of Area B) as having elevated concentrations (exceeding applicable water quality criteria/standards) of several VOCs including vinyl chloride, trichloroethene, and 1,2-dichloroethene.

  - Analytical results for two rounds of groundwater samples collected from a total of nine deep wells at Areas A and B identified organic compounds in the deep

groundwater samples from three general locations (Area A - west and north of Brig and southeast of Area B) as having elevated concentrations (exceeding applicable water quality criteria/standards) of several VOCs again including vinyl chloride, trichloroethene, and 1,2-dichloroethene.

- Analytical results for eight surface water and sediment sample locations collected from Areas A and B indicated that leaching of organic compounds (i.e., vinyl chloride, trichloroethene, 1,2-dichloroethene) had occurred directly east of Area B into the drainage ditch sediments and ponded surface waters.

- Analysis of inorganic compounds in sediment samples indicated elevated concentrations (exceeding applicable sediment quality criteria) of various metals including arsenic, cadmium, chromium, lead, and zinc, primarily in the northern region of Area A.

- A soil gas survey conducted at Area B preliminarily identified three primary source areas of VOCs (aromatic hydrocarbons, tetrachloroethane, and cycloalkanes/alkenes).

- Analytical results for groundwater samples collected from 55 residential wells (non-potable wells installed in the water table aquifer) in Glenwood Park indicated that VOCs in the water table aquifer did not appear to be migrating past the drainage ditch west of Area A.

Previous investigation results preliminarily identified areas of contamination, as well as important geologic/hydrogeologic considerations within Area A and Area B of the Camp Allen Landfill. In part, these results guided LANTDIV in the preparation of the scope of work for the Remedial Investigation. The composite information generated from the previous investigations noted above has been incorporated into this study's interpretation, as appropriate.

1.2 Remedial Investigation Field Activities and Results

The primary objectives of the RI at the Camp Allen Landfill Site were to identify and evaluate the physical and chemical characteristics of the Camp Allen area. Field activities performed in and around the Camp Allen Landfill were designed to adequately describe site topography, subsurface geology, hydrogeologic

features, primary waste characteristics, and the nature and extent of constituent migration resulting from past disposal practices at the Camp Allen Landfill.

Field activities were conducted at the Camp Allen Landfill Site as three separate events (designated as Rounds 1, 2, and 3). Round 1 primarily consisted of field verification sampling designed to help select/finalize various proposed sampling locations (i.e., monitoring well locations). Round 2 consisted of a comprehensive round of sampling of subsurface soil, surface soil, sediment, surface water, and groundwater. In general, Round 3 was performed to fill additional data needs identified from a preliminary evaluation of Round 2 data. Additionally, Round 3 activities included an air sampling program.

RI activities were performed in accordance with the following LANTDIV/Activity-approved Project Plans:

- Work Plan (WP)
- Sampling and Analysis Plan (SAP)
- Quality Assurance Project Plan (QAPP)
- Health and Safety Plan (HASP)
- Round 3 Project Plan Addendum
- Air Sampling Program Project Plan Addendum (WP/SAP/QAPP/HASP inclusive)

Final Project Plans were submitted to LANTDIV in April 1992, and the Final Round 3 Project Plan Addendum and Air Sampling Program Project Plan Addendum were submitted in December 1992.

1.2.1 Overview of RI Activities

Field activities conducted at Area A included:

- Geophysical survey (electromagnetometer/resistivity sounding/downhole gamma logging)

- Monitoring well installation (ten installed in the Yorktown Aquifer/one installed in the water table aquifer/one, 4-inch pumping well and one, 2-inch piezometer installed in the Yorktown Aquifer)

- Surface soil sampling (five locations)

- Source characterization (eight subsurface soil sample locations)

- Surface water and sediment sampling (11 surface water and 31 sediment sample locations)
- Geologic borings (11 locations)
- Residential well groundwater sampling - two locations to complement previous sampling by CH_2M Hill at 55 locations.
- Groundwater sampling (three separate rounds)
- Aquifer testing (pumping test from the pumping well and slug tests at 10 locations)
- Air sampling (12 locations in the Brig Facility and five ambient air locations)
- Land surveying (investigative points and primary surface features)

Field activities conducted at Area B included:

- Geophysical survey (electromagnetometer and ground penetrating radar)
- Geoprobe investigation (in-situ groundwater sampling [water table aquifer])
- Monitoring well installation (four installed in the Yorktown Aquifer and eight installed in the water table aquifer)
- Surface soil sampling (eight locations)
- Source characterization (ten subsurface soil sample locations)
- Surface water and sediment sampling (five surface water and eight sediment sample locations)
- Groundwater sampling (three separate rounds)
- Aquifer testing (slug tests at nine locations)

- Air sampling (five locations at the Camp Allen Elementary School)

- Land surveying (investigative points and primary surface features)

The various media sampled at the Camp Allen Landfill were selectively analyzed for VOCs, semivolatile organic compounds (SVOCs), pesticides/PCBs, and inorganic compounds including total and dissolved fractions, as appropriate. Select samples/media were also analyzed for indicator parameters such as alkalinity, total suspended solids, and total organic content. Analyses were performed under Naval Energy and Environmental Support Activity (NEESA) and Contract Laboratory Program (CLP) Protocol. In addition, NEESA Level D quality assurance was followed. The only exception was that of air sample analysis; as VOCs were the primary constituents of concern, EPA Compendium Method TO-14 was used. Analytical reports from the NEESA/CLP approved laboratory were submitted to an independent data validator to evaluate the usability of the analytical data. Based on information contained in the Data Validation Reports, the analytical results for the samples collected at the Camp Allen Landfill are considered representative of site conditions with the assurance that no inadvertent contamination has taken place. In general, all data are acceptable for use as part of this study and are presented as such.

1.2.2 Remedial Investigation Results

Information from the previous investigations of the Camp Allen Landfill Site, in conjunction with the data generated during the current Remedial Investigation, have been carefully evaluated/interpreted to fulfill the original goals of the RI: (1) characterization of the geologic/hydrogeologic conditions in Areas A and B as they relate to the potential for migration of contaminants; and, (2) characterization of the nature and extent of contamination and its potential impact on human health and the environment. RI findings with regard to these two goals are summarized in the following sections.

1.2.2.1 Geology/Hydrogeology

Two physical characteristics of the Camp Allen area must be clearly understood prior to summarizing analytical results. These include site lithology and hydrogeologic characteristics. Site lithology, in general, consists of three primary separate strata: 1) silts, clays, and sands of the Columbia Group ranging from 0 to 27 feet below ground surface (bgs) or deeper; 2) a confining clay layer at the base of the Columbia Group (locally absent in places) ranging from 25 to approximately 40 feet bgs; and/or, 3) a silt/sand/shell hash unit (Yorktown Formation) ranging from about 40 to 130 feet bgs, where it abruptly contacts the St. Mary's "blue bed" of the Calvert Formation.

Two aquifer systems are impacted by the Camp Allen Landfill: the water table aquifer (Columbia Group) and Yorktown Aquifer (Yorktown Formation). The water table (shallow groundwater) is an unconfined aquifer with a water level ranging from approximately 4 to 6 feet bgs. Flow direction within this water table aquifer typically mirrors the topography of the area with an average flow velocity of 0.6 to 1.2 feet per day. The Yorktown Aquifer (deep groundwater), which exists within the Yorktown Formation, is separated from the water table aquifer by the confining clay unit noted above and has been determined to be under semiconfined (leaky) conditions. This is primarily due to the presence of a breach and/or ineffective (poorly developed) portions of the confining clay unit at the base of the Columbia Group. The breached or ineffective portions allow for the downward migration of constituents from the Camp Allen Landfill. Groundwater flow in the Yorktown Aquifer in Area A is primarily to the northwest, and groundwater flow in Area B in the Yorktown Aquifer is generally towards the southeast. Average groundwater flow velocities in the Yorktown Aquifer range from approximately 0.001 to 0.08 feet/day.

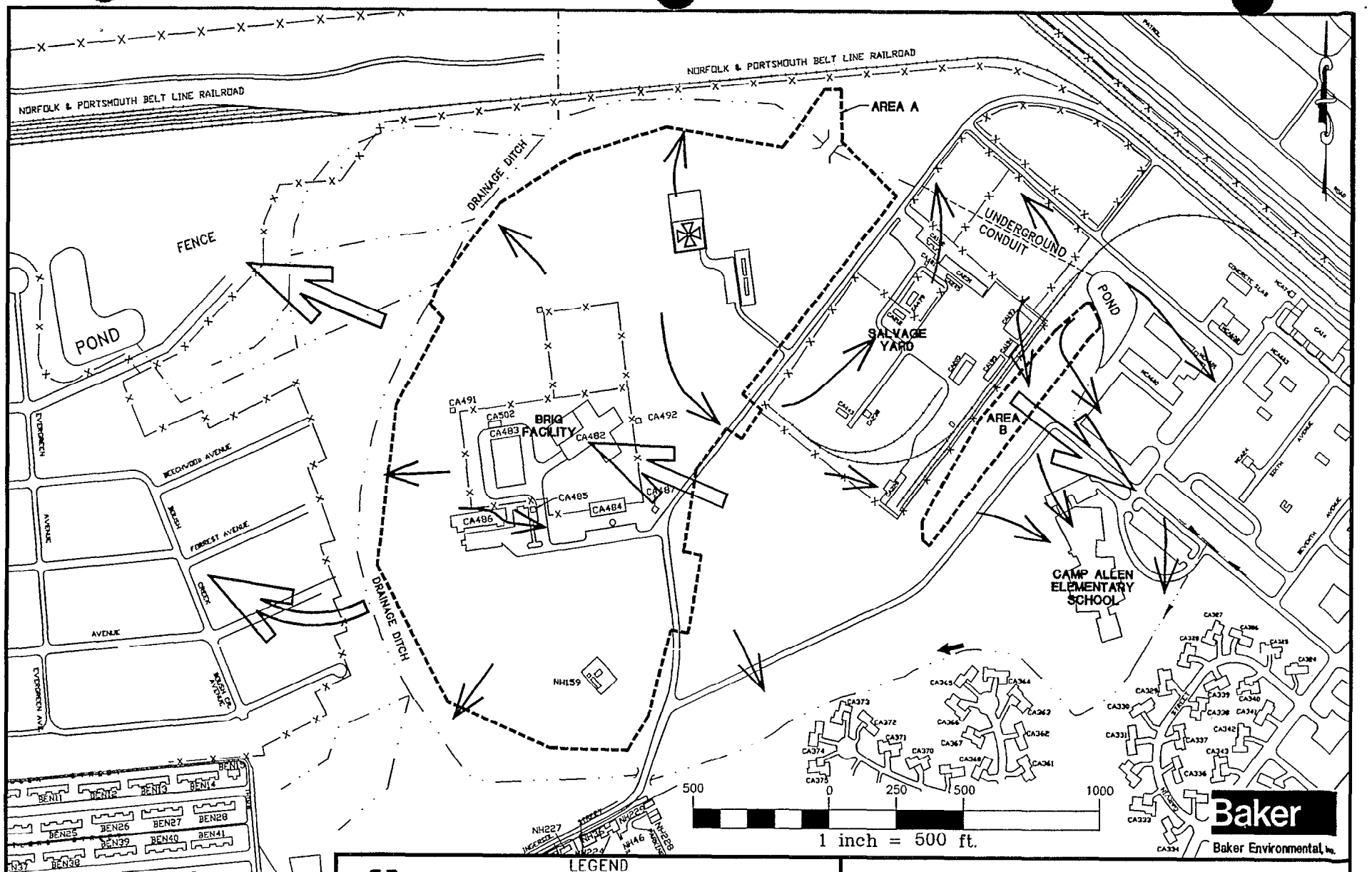
In order to help visualize overall site conditions, two generalized site depictions have been developed. Figure 1-2 presents generalized groundwater flow patterns for both the Columbia and Yorktown Aquifer systems. Figure 1-3 presents a conceptualized geologic cross-section indicating generalized contaminant migration within and from the Camp Allen Landfill.

1.2.2.2 Analytical Results

Detected constituents in site media are detailed in the RI Report. For purposes of the FS, a series of tables were developed to present the range of constituent concentrations (minimum to maximum) detected in site media. Selected contaminants that are primary contributors to potential human health and environmental risks are identified for each site area (Area A and Area B) and media (soil, sediment, surface water, and groundwater) in Tables 1-1 through 1-8. Tables 1-1 through 1-4 summarize the Area A RI Report findings, and Tables 1-5 through 1-8 summarize the Area B RI Report findings.

1.3 Pre-Design Investigation Activities and Results

In order to obtain additional information concerning the extent of soil and groundwater contamination associated with the Camp Allen Landfill, a pre-design field investigation was performed in Areas A and B from October 1993 through December 1993. Data collected during the pre-design investigation helped to expedite subsequent Remedial Design/Remedial Action (RD/RA) efforts. The scope of work and the analytical results of the pre-design investigation are summarized in the following sections. A more detailed discussion of the pre-design investigation is included in Appendix A.



LEGEND

ASSUMED LANDFILL BOUNDARY

GENERAL DEEP GROUNDWATER FLOW DIRECTION (YORKTOWN AQUIFER)

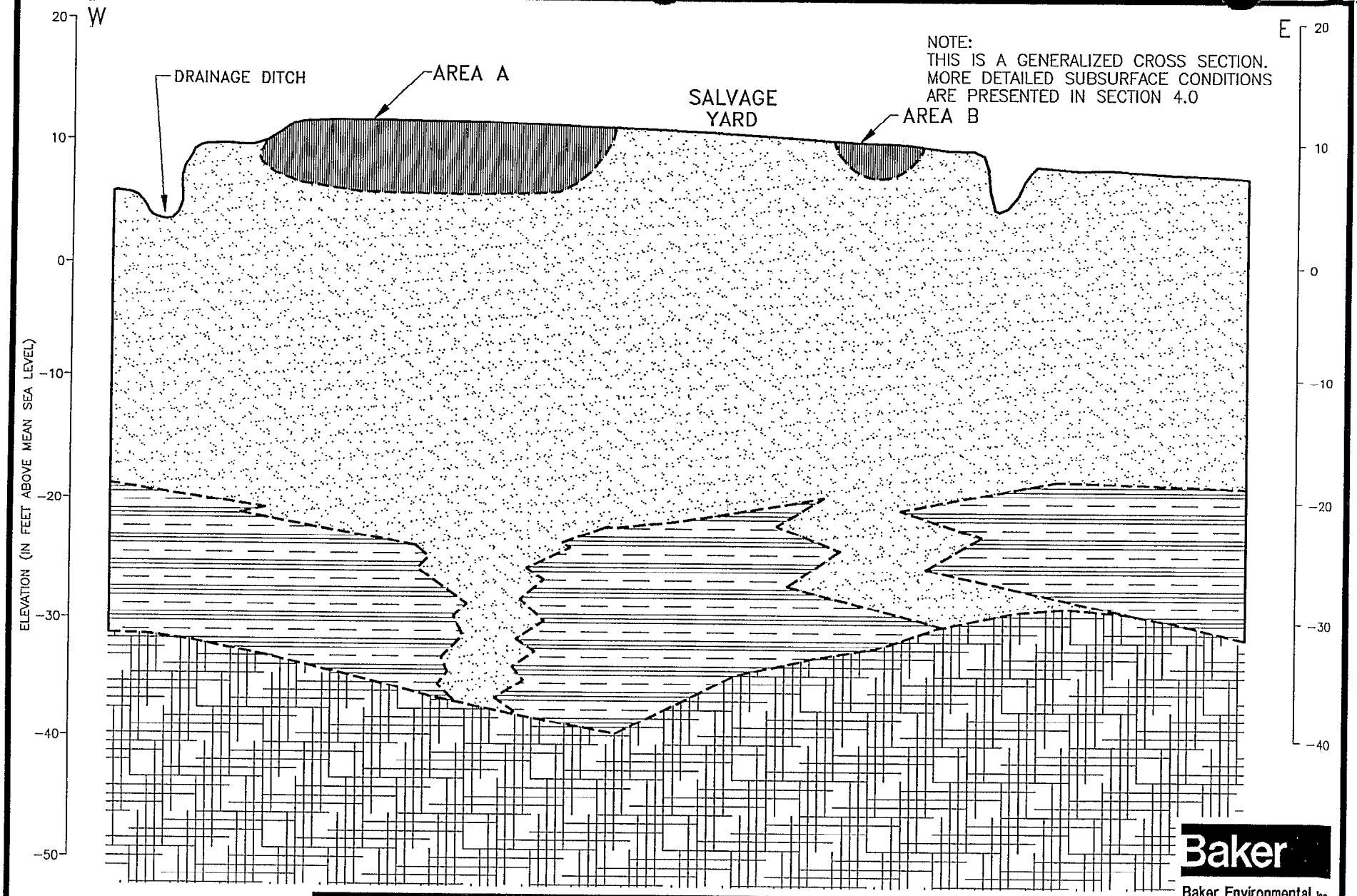
GENERAL SHALLOW GROUNDWATER FLOW DIRECTION (WATER TABLE AQUIFER)

NOTE: INFORMATION DEPICTED ON THIS FIGURE IS GENERALIZED AND DOES NOT INDICATE ACTUAL DEFINED PATTERNS.

SOURCE: LANTDIV, OCTOBER 1991

FIGURE 1-2
GENERAL GROUNDWATER FLOW PATTERNS
CAMP ALLEN LANDFILL AREAS A & B

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



300 0 150 300

1 inch = 300 ft.
HORIZONTAL SCALE

VERTICAL EXAGGERATION ±20x

084501FS

LEGEND

- FILL
- SILTY AND CLAYEY SANDS (COLUMBIA GROUP)
- CLAY WITH LITTLE SILT, SAND (YORKTOWN CONFINING UNIT: BREACHED AT PLACES)
- SILTY SANDS WITH SHELLS (YORKTOWN FORMATION)

FIGURE 1-3
GENERALIZED GEOLOGIC CROSS-SECTION
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

TABLE 1-1

SOIL RI ANALYTICAL DATA SUMMARY
AREA A
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	SURFACE SOIL CONCENTRATIONS[1] (mg/Kg)		SUBSURFACE SOIL CONCENTRATIONS[2] (mg/Kg)	
	Minimum	Maximum	Minimum	Maximum
Arsenic	1.9	70	--	--
Benzene	--	--	--	--
Cadmium	22	89	--	--
Chromium	8.9	121	--	--
Dichloroethylene, 1, 2-	--	--	--	0.384
Dichloroethane, 1, 2-	--	--	--	--
Tetrachloroethylene	--	--	--	--
Trichloroethylene	--	--	--	--
Toluene	--	--	0.015	3,000
Vinyl chloride	--	--	--	--
Xylene (total)	--	--	0.030	340

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
[1] Round 3 sample results.
[2] Round 2 sample results.

TABLE 1-2

SEDIMENT RI ANALYTICAL DATA SUMMARY
AREA A
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	SEDIMENT CONCENTRATIONS[1] (mg/Kg)	
	Minimum	Maximum
Arsenic	5.1	590
Benzene	--	--
Cadmium	6	160
Chromium	38	3000
Dichloroethylene, 1, 2-	--	--
Dichloroethane, 1, 2-	--	--
Tetrachloroethylene	--	--
Trichloroethylene	--	--
Toluene	--	--
Vinyl chloride	--	--
Xylene (total)	--	--

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
[1] Concentrations represent minimum and maximum values detected during Rounds 2 and 3.

TABLE 1-3

SURFACE WATER RI ANALYTICAL DATA SUMMARY
AREA A
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	SURFACE WATER CONCENTRATIONS[1] (μg/L)	
	Minimum	Maximum
Arsenic (total)	20	64
Benzene	--	--
Cadmium (total)	--	--
Chromium (total)	12	104
Dichloroethylene, 1, 2-	3	4
Dichloroethane, 1, 2-	--	--
Tetrachloroethylene	--	--
Trichloroethylene	2	3
Toluene	--	--
Vinyl chloride	--	--
Xylene (total)	--	3

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
[1] Round 2 sample results.

TABLE 1-4

GROUNDWATER RI ANALYTICAL DATA SUMMARY
AREA A
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	WATER TABLE AQUIFER CONCENTRATIONS[1] (μg/L)		YORKTOWN AQUIFER CONCENTRATIONS[1] (μg/L)	
	Minimum	Maximum	Minimum	Maximum
Arsenic (total)	3.8	309	1.4	64
Benzene	--	310	--	3
Cadmium (total)	9.3	46	--	6.5
Chromium (total)	16	353	7.2	166
Dichloroethylene, 1, 2-	3	6100	2	540
Dichloroethane, 1, 2-	--	3	15	38
Tetrachloroethylene	4	620	--	4
Trichloroethylene	18	1800	2.5	100
Toluene	1200	5400	--	1
Vinyl chloride	2	3300	13.5	100
Xylene (total)	130	250	--	1

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
(1) Concentrations represent minimum and maximum values detected during Rounds 2 and 3.

TABLE 1-5

SOIL RI ANALYTICAL DATA SUMMARY
AREA B
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	SURFACE SOIL CONCENTRATIONS[1] (mg/Kg)		SUBSURFACE SOIL CONCENTRATIONS[2] (mg/Kg)	
	Minimum	Maximum	Minimum	Maximum
Arsenic	2.5	25	0.7	61
Benzene	--	--	26	250
Cadmium	1.5	31	0.7	1.3
Chromium	7.9	869	5.9	25
Dichloroethylene, 1, 2-	--	--	0.004	4.3
Dichloroethane, 1, 2-	--	--	--	0.025
Tetrachloroethylene	--	--	--	--
Trichloroethylene	--	--	0.027	3.1
Toluene	--	--	0.014	16
Vinyl chloride	--	--	--	0.016
Xylene (total)	--	--	0.004	200

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
(1) Concentrations represent the minimum and maximum values detected during Rounds 2 and 3.
(2) Round 2 sample results.

TABLE 1-6

SURFACE WATER RI ANALYTICAL DATA SUMMARY
AREA B
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	SURFACE WATER CONCENTRATIONS[1] (μg/L)	
	Minimum	Maximum
Arsenic (total)	4.1	12
Benzene	3	12
Cadmium (total)	--	--
Chromium (total)	--	--
Dichloroethylene, 1, 2-	15	46
Dichloroethane, 1, 2-	3	8
Tetrachloroethylene	--	6
Trichloroethylene	20	45
Toluene	--	--
Vinyl chloride	6	22
Xylene (total)	--	--

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
[1] Round 2 sample results.

TABLE 1-7

SEDIMENT RI ANALYTICAL DATA SUMMARY
AREA B
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	SEDIMENT CONCENTRATIONS[1] (mg/Kg)	
	Minimum	Maximum
Arsenic	3.2	52
Benzene	14	62
Cadmium	1.5	42
Chromium	3	225
Dichloroethylene, 1, 2-	0.011	0.345
Dichloroethane, 1, 2-	--	0.020
Tetrachloroethylene	--	0.081
Trichloroethylene	0.003	0.520
Toluene	--	--
Vinyl chloride	0.044	0.060
Xylene (total)	--	0.004

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
[1] Round 2 sample results.

TABLE 1-8

GROUNDWATER RI ANALYTICAL DATA SUMMARY
AREA B
CAMP ALLEN LANDFILL SITE
NORFOLK NAVAL BASE, NORFOLK, VIRGINIA

PARAMETER	WATER TABLE AQUIFER CONCENTRATIONS[1] (μg/L)		YORKTOWN AQUIFER CONCENTRATIONS[1] (μg/L)	
	Minimum	Maximum	Minimum	Maximum
Arsenic (total)	7.6	94	2.7	194
Benzene	20	410	12	12
Cadmium (total)	2.3	18	27	31
Chromium (total)	33	775	17	542
Dichloroethylene, 1, 2-	418	1,600	3	16
Dichloroethane, 1, 2-	2	180	2	450
Tetrachloroethylene	8	10	--	--
Trichloroethylene	3	520	4	18
Toluene	--	--	1	1
Vinyl chloride	2	940	2	3
Xylene (total)	115	140	2	3

Notes: Minimum concentrations represent minimum positive detection values.
-- = Not detected
[1] Concentrations represent the minimum and maximum values detected during Rounds 2 and 3.

1.3.1 Overview of Pre-Design Investigation Activities

The pre-design activities are described in the following sections. The results of the pre-design investigation are summarized in Section 1.3.2.

1.3.1.1 In-Situ Groundwater Sampling

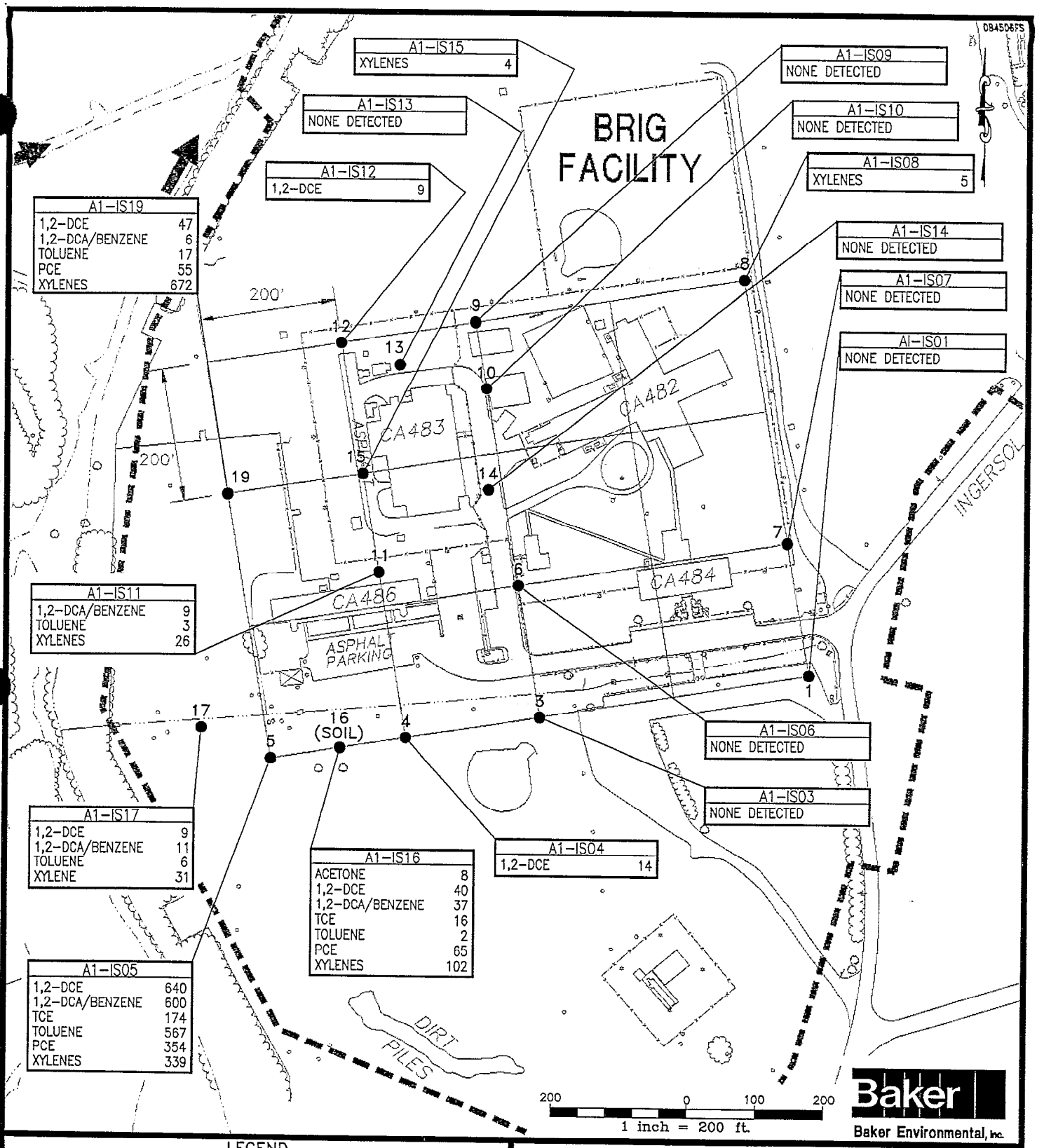
Initial pre-design activities at Area A consisted of installation and in situ sampling of hydraulic drive points (Geoprobe sampling points) to further delineate the extent of shallow groundwater contamination in Areas A1 and A2 and to help locate potential source areas. In situ groundwater sampling results were used to confirm/modify proposed test pit and temporary monitoring well locations. Shallow groundwater samples were collected from the upper portion of the water table aquifer. Samples were analyzed on site using a portable gas chromatograph unit for selected primary VOCs of concern.

Sample locations were based primarily on 600 foot by 800 foot grids with 200-foot intervals superimposed onto each suspected source area (Area A1 and Area A2). In situ groundwater sampling began in known areas of groundwater contamination and continued following the 200-foot sampling interval. Sampling nodes within the 600 foot by 800 foot grid were selectively chosen based on the results from the ongoing on-site analysis of in situ groundwater samples. Each of the established grids was extended or modified (e.g., sampling intervals reduced to 100 feet in some areas), as required based on the nature and extent of VOC contamination observed from the sampling results. A total of 47 in situ samples were collected from Areas A1 and A2. In situ sampling locations for Areas A1 and A2 are depicted in Figures 1-4 and 1-5, respectively.

1.3.1.2 Source Characterization Activities

Baker performed source characterization activities, which included installation and sampling of test pits in the suspected source areas to delineate potential source areas in Areas A1 and A2.

Based on in situ groundwater sampling results, potential source areas were identified in Areas A1 and A2. Test pit activities were concentrated in these areas where shallow groundwater was found to contain the highest levels of VOCs. Test pit locations were based on subdividing the grid used for in situ groundwater sampling activities into 50-foot intervals in the potential "hot spot" areas. In some areas, grid spacing was reduced to 25-foot intervals, as required.



LEGEND

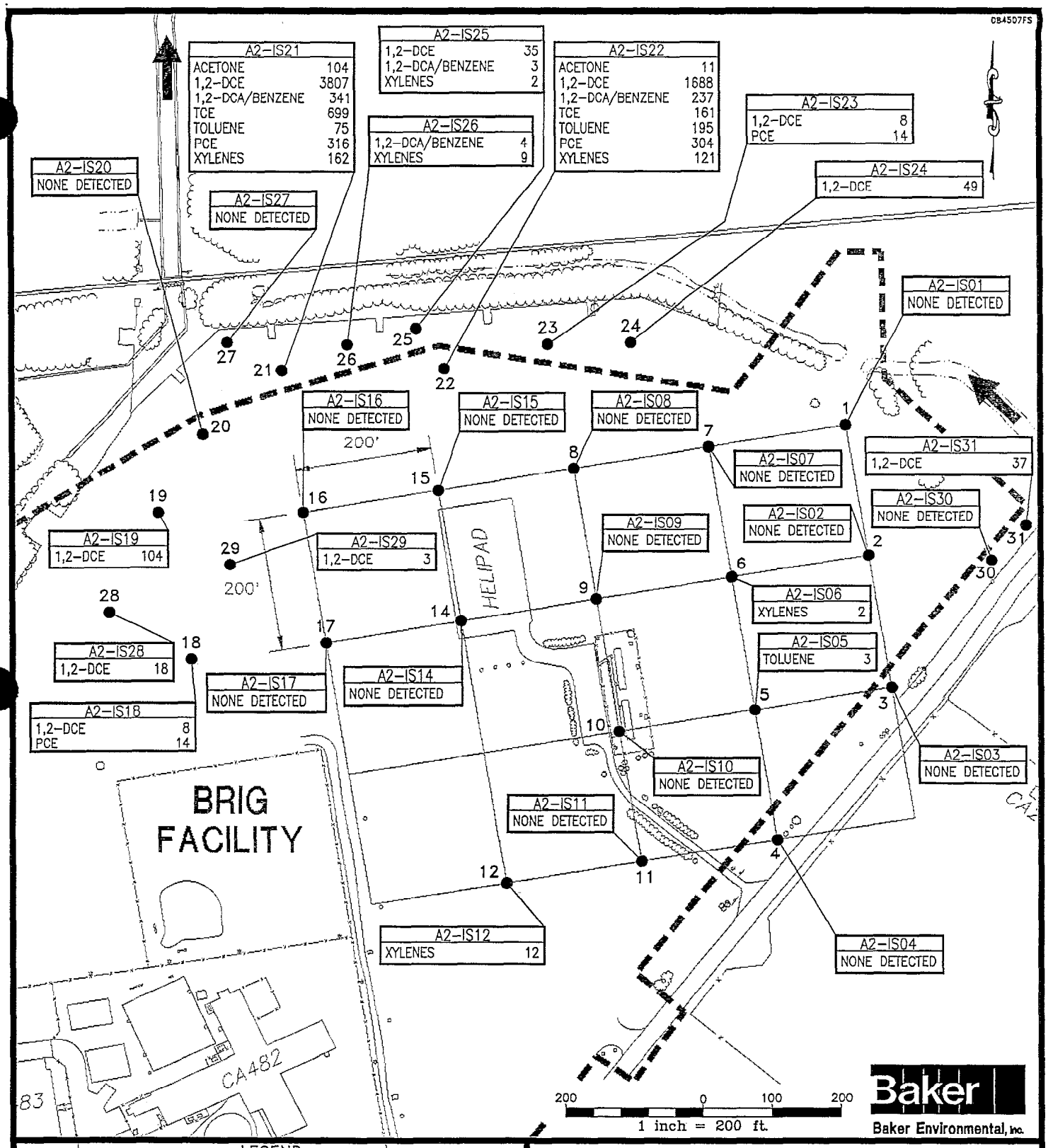
LIMIT OF AREA A LANDFILL

1 IN SITU SAMPLING POINTS

STREAM FLOW DIRECTION

NOTE: ALL CONCENTRATIONS IN ug/L

FIGURE 1-4
AREA A1 IN SITU GROUNDWATER SAMPLE LOCATIONS AND VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

— — LIMIT OF AREA A LANDFILL

12 ● IN SITU SAMPLING POINTS

STREAM FLOW DIRECTION

NOTE: ALL CONCENTRATIONS IN ug/L

FIGURE 1-5
AREA A2 IN SITU GROUNDWATER SAMPLE LOCATIONS AND VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

A total of 12 test pits were excavated in Area A1, as shown in Figure 1-6. An additional 12 test pits were located in Area A2, as shown in Figure 1-7. Soil samples were analyzed for Target Compound List (TCL) VOCs and SVOCs, and a limited number of samples were also analyzed for Target Characteristic Leaching Procedure (TCLP) parameters, total organic carbon (TOC), and total petroleum hydrocarbons (TPH).

1.3.1.3 Temporary Well Installation and Sampling

Temporary shallow and deep monitoring/observation wells were installed to further delineate the extent of shallow and deep groundwater contamination and to provide additional aquifer characteristics in Areas A1, A2, and B. The temporary monitoring wells, similar in construction to the existing on-site monitoring wells, are referred to as "temporary" because they are not intended to serve as permanent, long-term monitoring wells. Long-term monitoring wells will be selected later during development of the operations and maintenance plan for the site. In general, temporary well locations were selected based on previous investigation results and in situ groundwater sampling results. The following temporary wells were installed in each area:

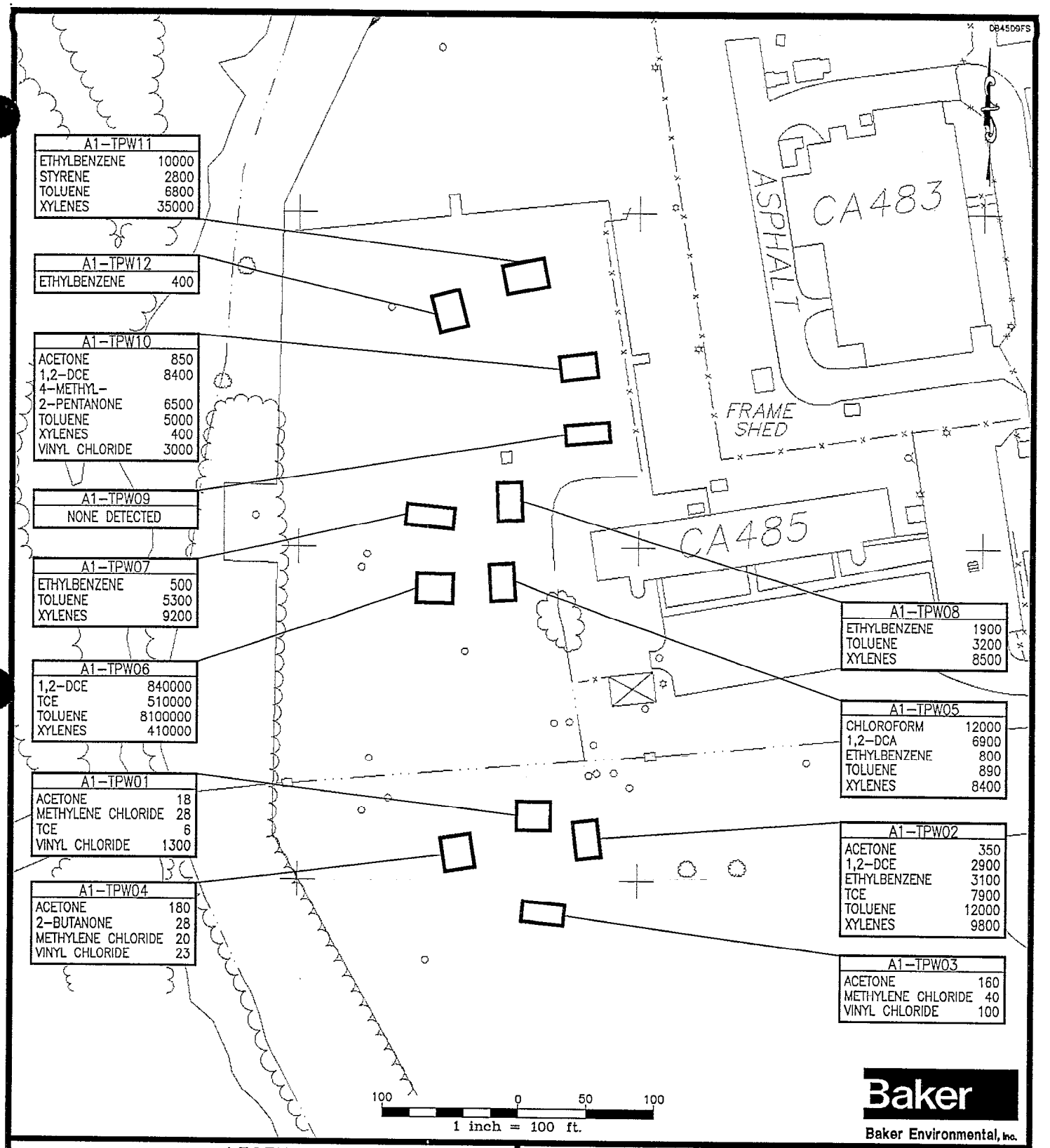
- Area A1 - Four (4) shallow and four (4) deep temporary wells
- Area A2 - Two (2) deep temporary wells
- Area B - Six (6) shallow and four (4) deep temporary wells

In addition to the temporary monitoring/observation wells, a total of three (3) pumping/pilot test extraction wells also were installed in Area A1 and Area B as follows:

- Area A1 - One (1) deep extraction well
- Area B - One (1) shallow and one (1) deep extraction well

Existing and newly installed well locations for Areas A1 and A2 are presented in Figures 2-7 and 2-8 in Appendix A for shallow and deep wells, respectively. Existing and newly installed well locations for Area B are presented in Figures 2-9 and 2-10 in Appendix A for shallow and deep wells, respectively.

Shallow wells were constructed as Type II wells (unconfined water table) with depths ranging from 15 to 29 feet below ground surface (bgs). Deep wells were constructed as Type III wells (with surface casing) in order to "case off" the water table aquifer prior to advancing the boring into the upper portion of the Yorktown Aquifer. Deep wells extend into the upper portion of the Yorktown Aquifer (depths range from 64 to 65 feet bgs).



LEGEND

TEST PIT

NOTE: ALL CONCENTRATIONS IN ug/kg.

FIGURE 1-6
AREA A1 TEST PIT LOCATIONS
AND VOLATILES RESULTS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

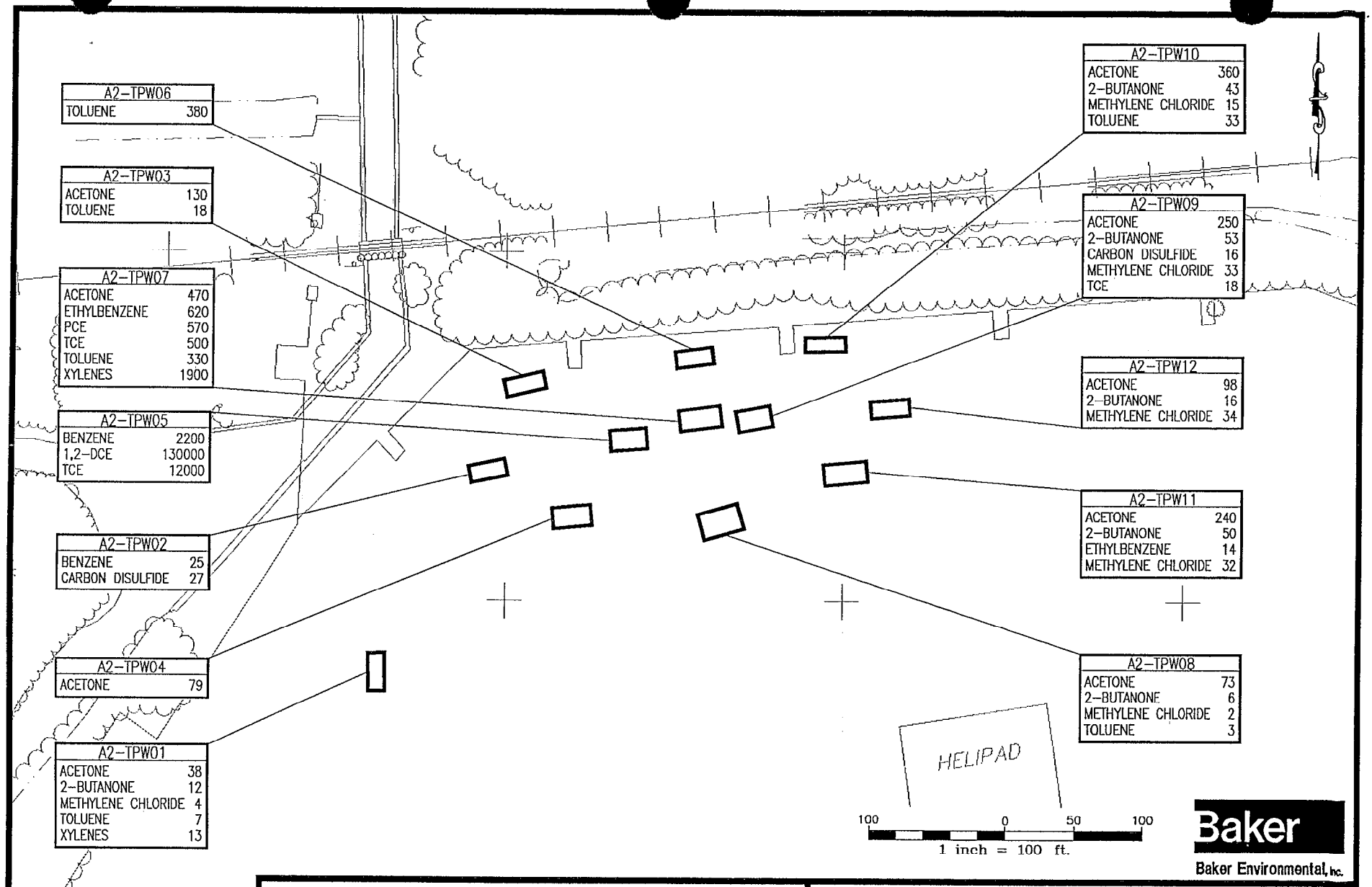


FIGURE 1-7
AREA A2 TEST PIT LOCATIONS
AND VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Following well installation and development activities, groundwater from selected new and existing shallow and deep wells in/near the areas of contamination was sampled to help confirm the extent of groundwater contamination in each area. Groundwater samples were analyzed for VOCs using EPA Methods 601 and 602.

1.3.1.4 Pumping/Pilot Tests

The on-site pumping/pilot pre-design tests were conducted to achieve the following objectives:

- Aquifer hydraulic characterization to develop groundwater extraction system parameters (e.g., pumping rates, well spacings, screen intervals, shallow/deep aquifer interactions).

- Aquifer chemical characterization to enable a more accurate prediction of the actual groundwater influent characteristics under pumping conditions, which will facilitate design of the most optimum, cost-effective treatment system.

Thus, the pumping/pilot tests were conducted to better characterize the hydraulic and chemical properties of the aquifers. In addition, information to evaluate the performance of the pilot-scale treatment system was gathered during the tests. Four 3-day (approximately 75 hour) constant rate pumping/pilot tests were originally scheduled to be performed. However, the shallow aquifer test for Area A1 was cancelled because all of the shallow wells in this area (B-20WSS, A1-MW20, and A1-MW21) were bailed dry during development and would not sustain a continuous pumping rate. In addition to this change, the Yorktown Aquifer test was shortened to a 1-day (approximately 30 hours) test. This change was a result of a pump failure at pumping station CA-487, to which treated groundwater was discharged. Also, a generator, which was used to power the treatment system, malfunctioned, causing the test to be shortened to a one-day test. (See Section 2.5.2 in Appendix A for treatment system description.) In summary, the following tests were conducted in the sequence shown:

- Area B - One 72-hour water table (shallow aquifer) test
- Area B - One 72-hour upper Yorktown test
- Area A1 - One 30-hour upper Yorktown test

1.3.2 Pre-Design Investigation Results

The results of the pre-design investigation are summarized in the following sections.

1.3.2.1 In Situ Groundwater Sampling Results

In situ sampling locations and VOC results for Areas A1 and A2 are depicted in Figures 1-4 and 1-5. Sampling results show the greatest levels of contamination in the southwest portion of Area A1 and the north-northwestern portion of Area A2. The following compounds were detected in several groundwater samples:

- 1,2-DCE
- 1,2-DCA/benzene
- TCE
- toluene
- PCE
- xylenes
- acetone

In both areas, the primary contaminant was 1,2-DCE, which was found at 640 μg/L at sampling point A1-IS05, at 3,807 μg/L at in situ sampling point A2-IS21, and at 1,688 μg/L at in situ sampling point A2-IS22.

As shown in Figure 1-4 and Table 2-1 in Appendix A, test pits numbers A1-TPW01, A1-TP02, A1-TP03, A1-TP05, A1-TP06, and A1-TP10 contained the highest concentrations of chlorinated VOCs (e.g., TCE, vinyl chloride, 1,2-DCE) in Area A1. Toluene, ethylbenzene, and/or xylenes were detected in many of the test pits, with pits A1-TPW02, A1-TP05, A1-TP06, A1-TP07, A1-TP08, and A1-TP11 exhibiting the highest concentrations of these constituents.

As shown in Table 2-2 in Appendix A, a number of SVOCs were detected in the Area A1 test pits including naphthalene, 2-methylnaphthalene, and several phenolic compounds. As previously discussed, SVOCs were infrequently detected in the groundwater. Therefore, the SVOCs in soil do not appear to pose a risk to groundwater (i.e., through leaching) and are not considered as contaminants of concern for this FS.

A black, powder-like ash material was observed in all test pits in Area A1 at depths ranging from 1 to 10 feet bgs. Based on the sampling results shown in Table 2-1 in Appendix A, there appears to be no correlation between contaminant concentrations detected in the test pit samples and the ash material. Therefore, it is possible that the organic contamination originated from other waste materials that were combined with the ash during disposal rather than from the ash itself. In addition to the ash, the following materials were observed:

- A1-TP04: a 30-gallon crushed drum at 1-2 feet bgs.
- A1-TP05, A1-TP07, A1-TP08: fill material containing bricks, cinder blocks, and concrete rubble at 1-3 feet bgs.
- A1-TP06: paper debris at 6-6.5 feet bgs.
- A1-TP08: paint cans and dried paint wastes.

Soils located above the ash material (1 to 3 feet bgs) consisted mainly of medium-grained sands and fill material, and soils beneath the ash (7 to 12 feet bgs) consisted mostly of clay.

Results for the TCLP analyses (Table 2-5 in Appendix A) suggest that the soils in Area A1 are not classified as a characteristic hazardous waste under the Resource Conservation and Recovery Act (RCRA), but that the ash material may be considered hazardous since sample A1-TPW08-05 slightly exceeded the TCLP standard for lead. Also, as shown in Table 2-5 in Appendix A, the ash material observed in Area A1 contains a significant amount of total petroleum hydrocarbons (TPH), the majority of which are SVOCs.

As shown in Figure 1-5 and Table 2-3 in Appendix A, test pits numbers A2-TPW05 and A2-TPW07 contain the highest concentrations of chlorinated VOCs (e.g., TCE, 1,2-DCE, PCE) in Area A2. These test pits were located in the vicinity of in situ sampling points A2-IS21 and A2-IS22, which contained the highest concentrations of 1,2-DCE. In addition, test pit 5 contains benzene at 2,000 μg/kg. Fill material containing extensive debris (e.g., metal pipes, steel cable, glass, wood, paper, and miscellaneous scrap metal) and construction debris (e.g., concrete rubble and brick) were observed in many of the test pits in Area A2 at depths ranging from 2 to 9 feet bgs. Soil types consisted mainly of medium-grained sands, although clay lenses were observed in test pits A2-TPW01 and A2-TPW02 ranging from 5 to 7 feet in thickness.

As shown in Table 2-4 in Appendix A, a variety of SVOCs were detected in the Area A2 test pits including several polyaromatic hydrocarbons (PAHs). As previously discussed, SVOCs were infrequently detected in the groundwater. Therefore, the SVOCs in soil do not appear to pose a risk to groundwater and are not considered as contaminants of concern for this FS.

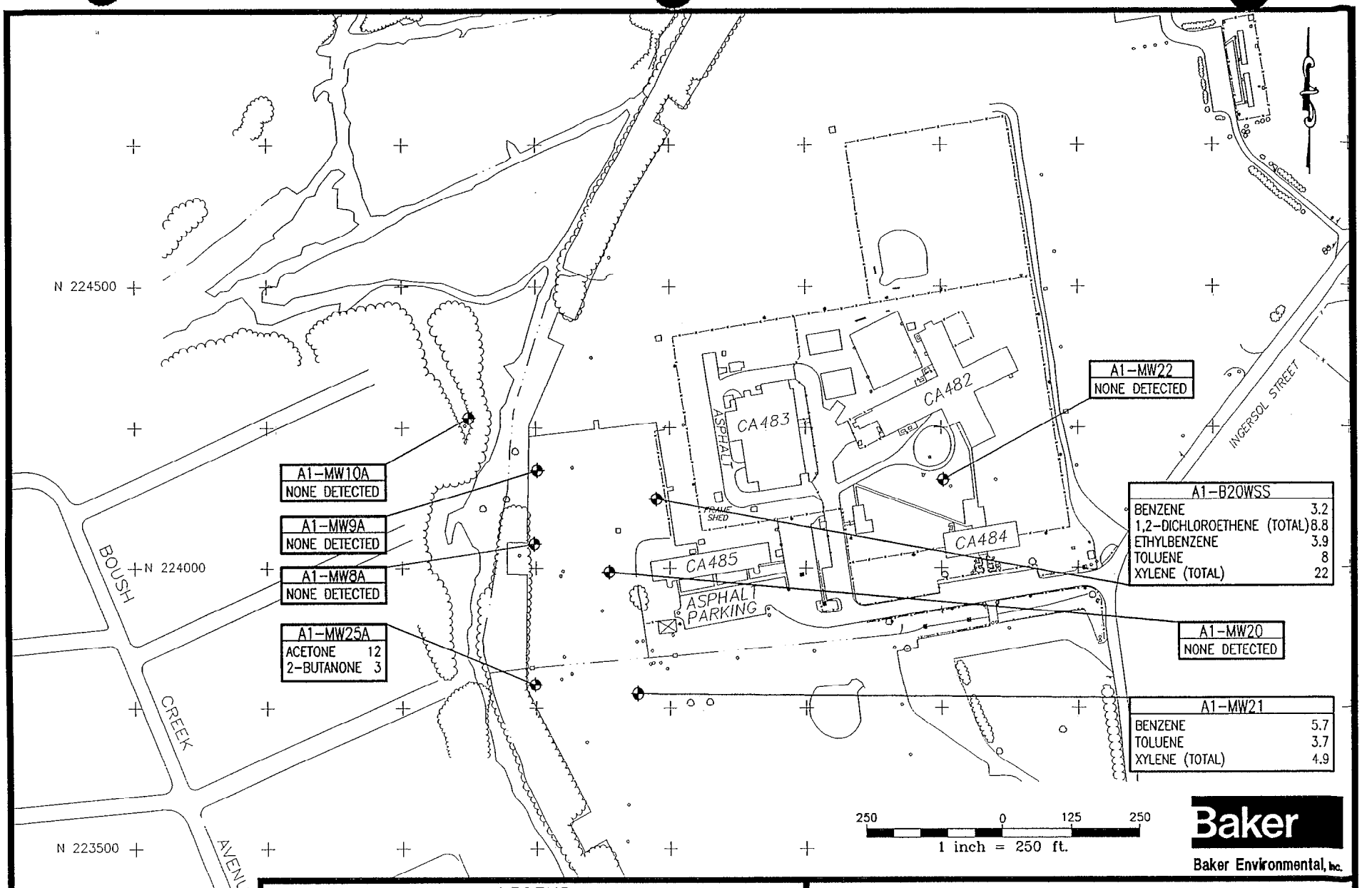
Results for the TCLP analysis (Table 2-5 in Appendix A) indicate that the soils in Area A2 are not classified as a characteristic hazardous waste under RCRA. Also, as shown in Table 2-5, the soils in Area A2 appear to contain a much lower amount of TPH than those in Area A1.

1.3.2.2 Groundwater Sampling Results

A summary of groundwater sampling locations is contained in Table 2-6 in Appendix A. Groundwater sampling points are presented by area (A1/A2/B), as well as by existing and proposed well locations. Analytical results (VOCs only) are presented in Tables 2-7 through 2-12 in Appendix A. These results are also depicted on the tag maps presented as Figures 1-8 through 1-13. In addition, samples from monitoring wells A1-MW20 and A1-MW21 were analyzed for SVOCs, inorganics (total and dissolved metals), and other engineering parameters; these results are presented in Tables 2-13 and 2-14 in Appendix A.

In previous sampling rounds (Rounds 2 and 3), SVOCs were detected very infrequently and in low concentrations in the water table and Yorktown Aquifers in Areas A1, A2, and B. The highest levels of SVOCs detected in the groundwater in the previous sampling rounds were in the shallow aquifer in Area A1. As shown in Table 2-13 in Appendix A, only phenol and/or bis(2-ethylhexyl)phthalate were detected in groundwater samples collected from wells A1-MW20 and A1-MW21 and were present at very low concentrations.

VOC concentrations detected in the shallow groundwater in Area A1 during the pre-design investigation (Figure 1-8) were much lower than those observed in sampling round 2 (based on well A1-B20WSS results). Similarly to Round 2 results, no VOCs were detected in wells A1-MW8A, A1-MW9A, and A1-MW10A, suggesting that shallow contaminated groundwater is not discharging to the creek or migrating beneath it. Based on the in situ and monitoring well sampling results, groundwater contamination in the vicinity of the Brig (near A1-B20WSS, A1-MW20, and A1-MW-21) appears to be present as small, isolated areas, or "pockets," of contamination rather than as one continuous contaminant plume.



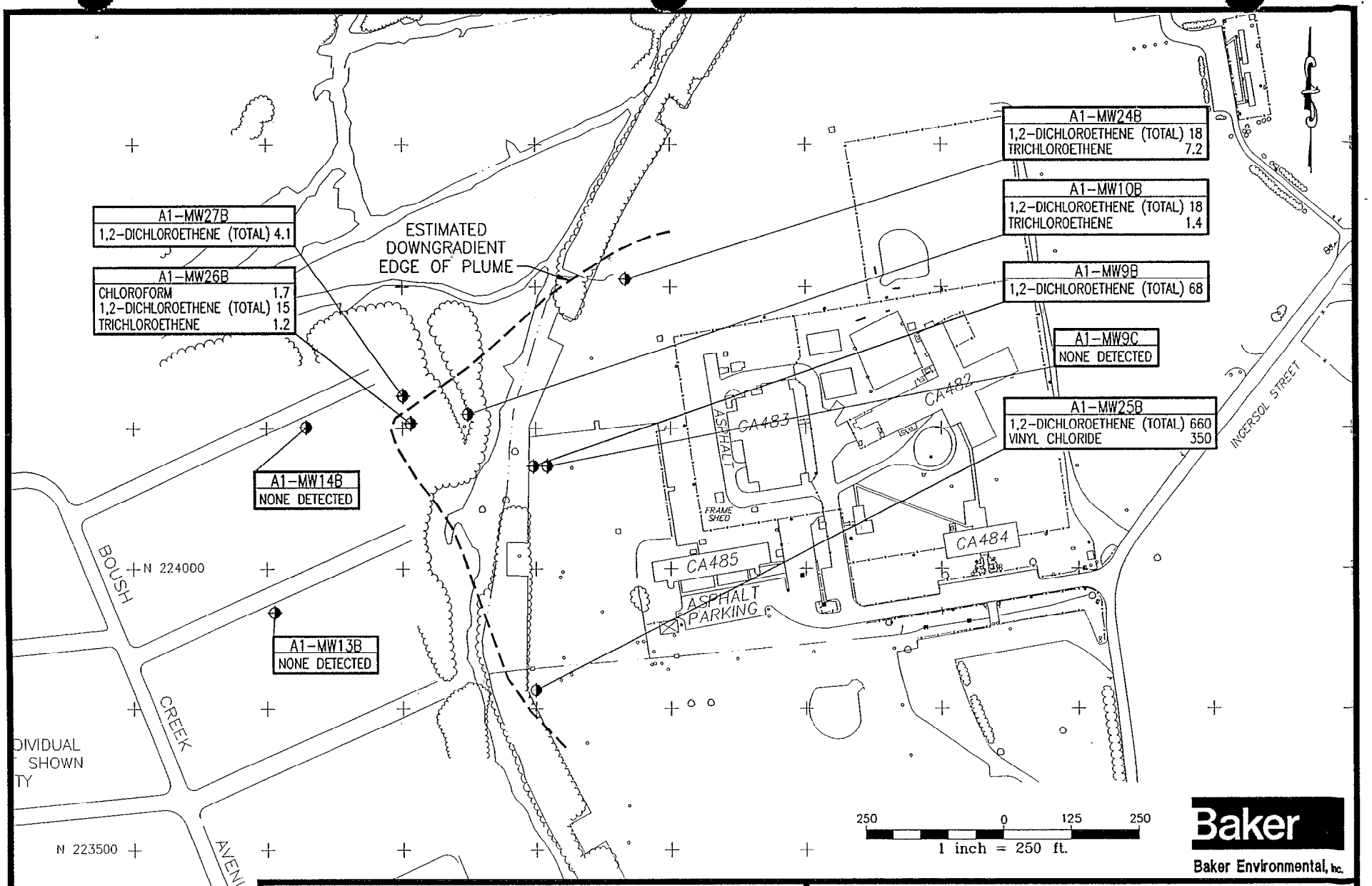
LEGEND

◆ SHALLOW MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.

SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 1-8
AREA A1 SHALLOW GROUNDWATER VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



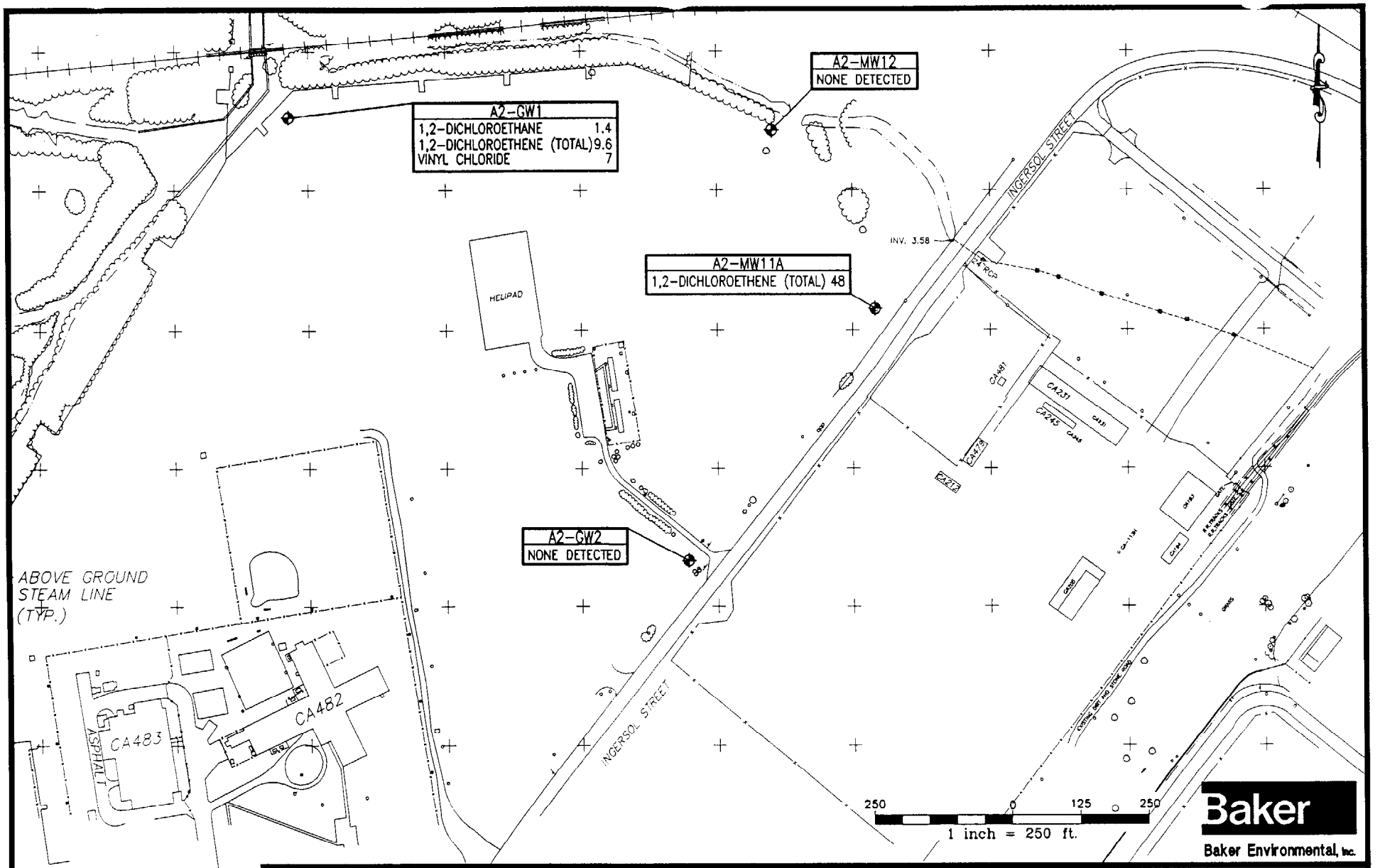
LEGEND

DEEP MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

084511FS

FIGURE 1-9
AREA A1 DEEP GROUNDWATER VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



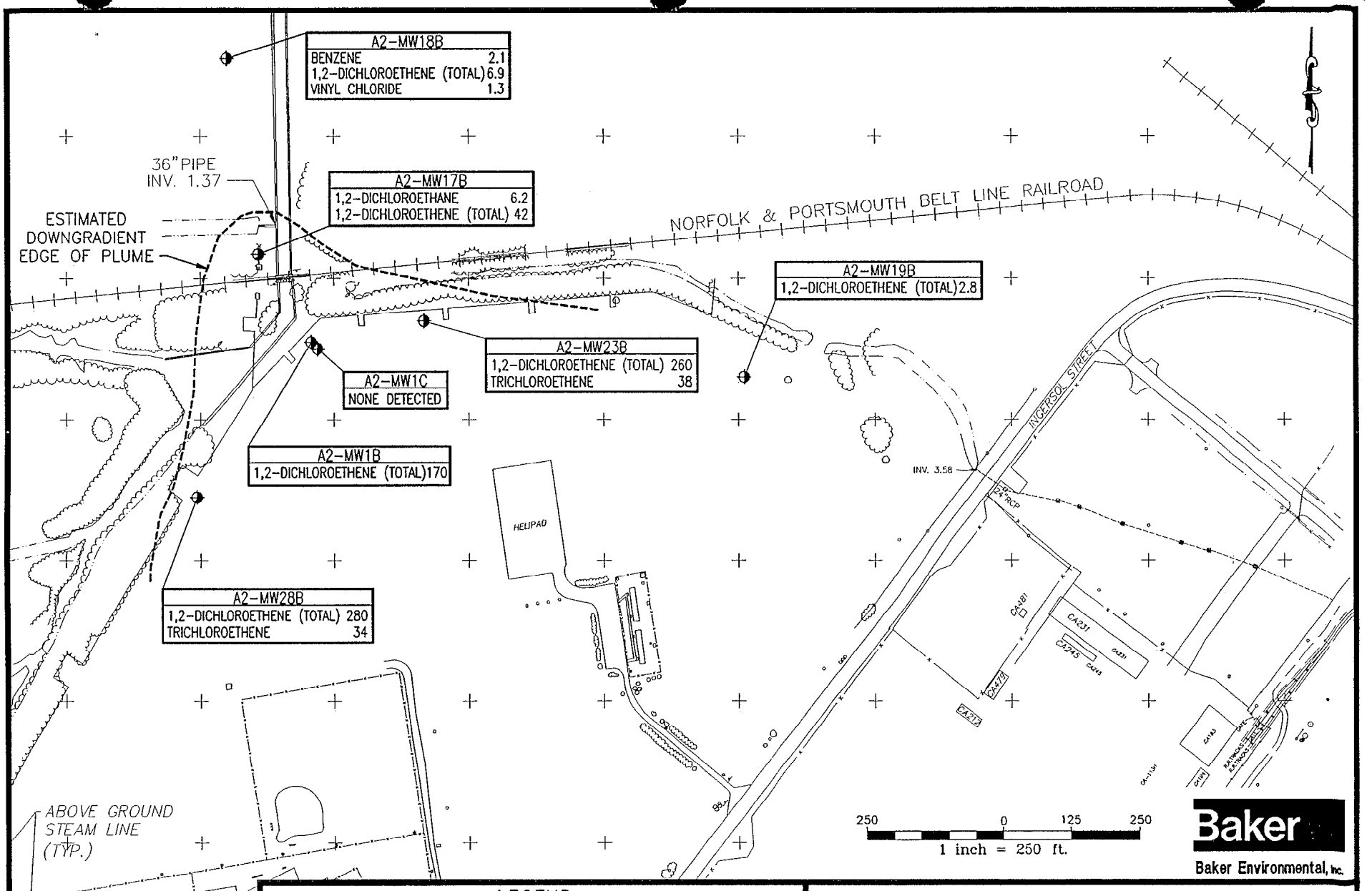
LEGEND

SHALLOW MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

084512FS

FIGURE 1-10
AREA A2 SHALLOW GROUNDWATER VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



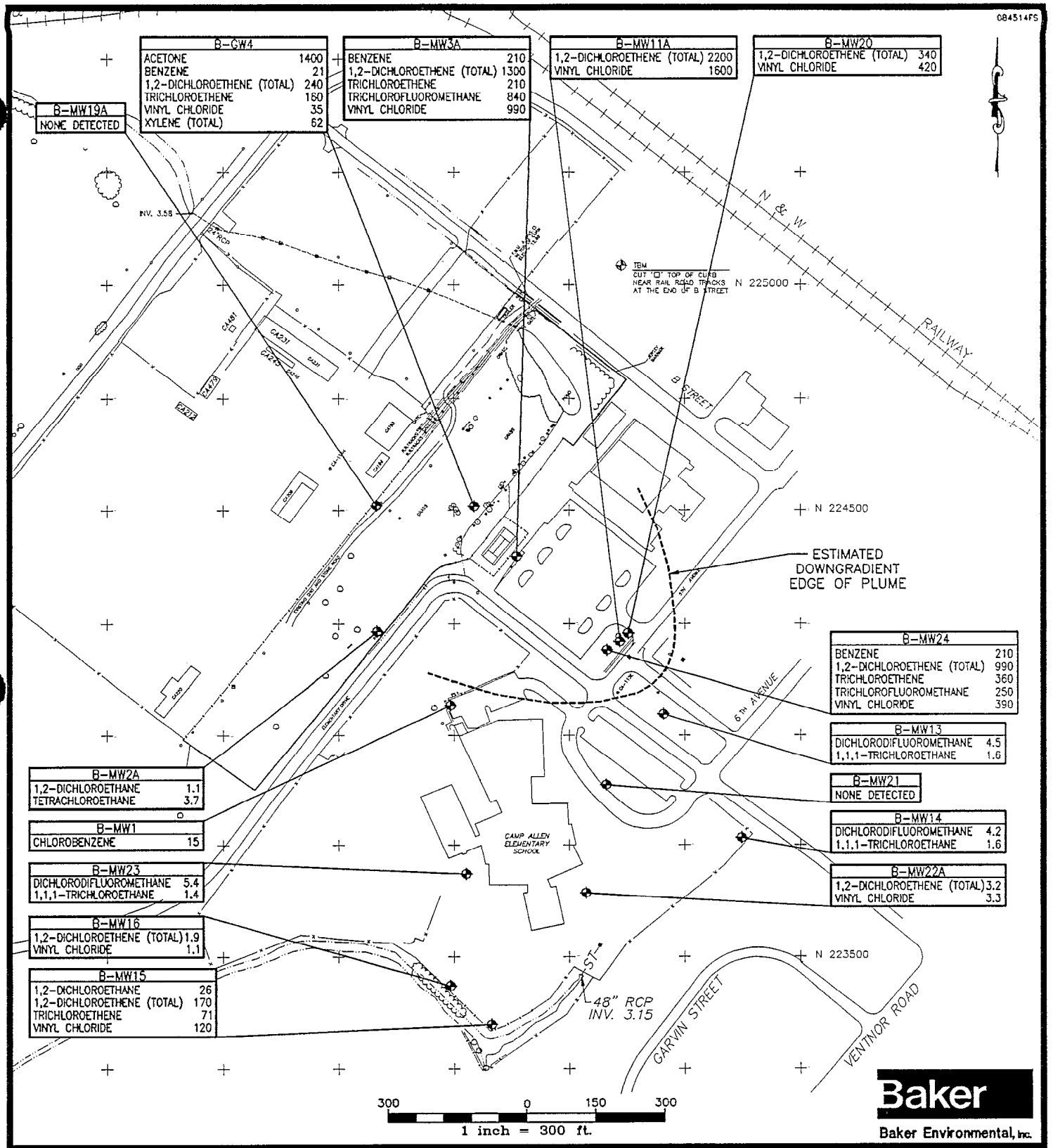
LEGEND

DEEP MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.

SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 1-11
AREA A2 DEEP GROUNDWATER VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



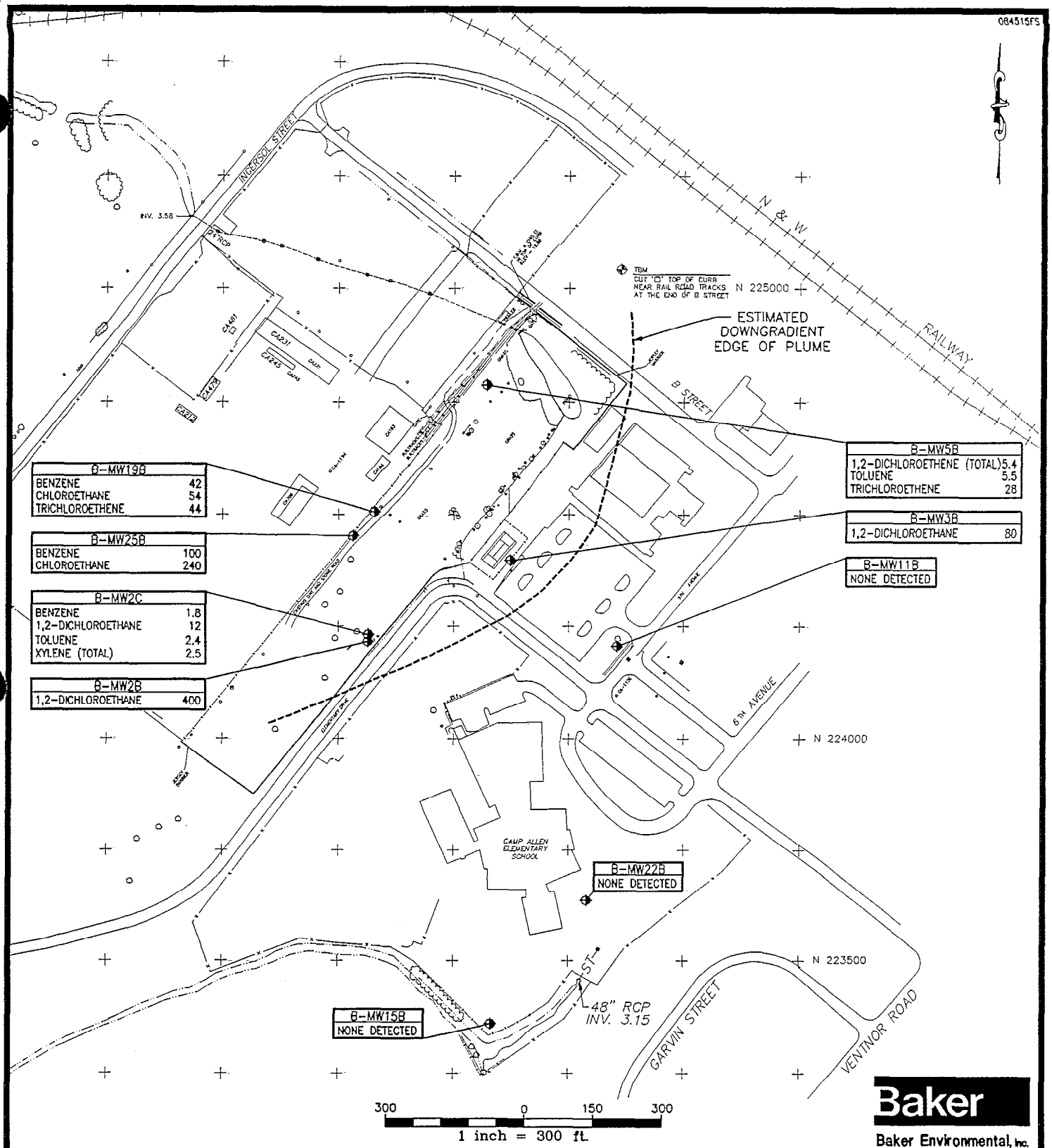
LEGEND

◆ SHALLOW MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 1-12
AREA B SHALLOW GROUNDWATER
VOLATILES RESULTS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

⊕ DEEP MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 1-13
AREA B DEEP GROUNDWATER
VOLATILES RESULTS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

With the exception of new monitoring well A1-MW25B, VOC concentrations detected in the upper Yorktown Aquifer in Area A1 during the pre-design investigation (Figure 1-9) were lower than those observed in sampling rounds 2 and 3.

With respect to Area A2, VOC concentrations detected in the water table and upper Yorktown Aquifers during the pre-design investigation (Figures 1-10 and 1-11) were similar to or lower than those observed in sampling rounds 2 and 3. The area of highest shallow groundwater contamination appears to be in the northern section of Area A2 near test pits A2-TPW05 and A2-TPW07 (see Figure 1-7).

Concentrations of VOCs detected in the water table and upper Yorktown Aquifers in Area B during the pre-design investigation (Figures 1-12 and 1-13) were also similar to or lower than those observed in sampling rounds 2 and 3. The highest levels of VOCs detected in the shallow aquifer were centered around wells B-GW4, B-MW3A, and B-MW11A and also south of the elementary school in well B-MW15. Analytical results for the wells located along the east and west sides of the school showed sporadic VOC levels in the low part per billion (ppb) range with no clearly defined east/west boundaries of the contaminant plume. Therefore, the contamination detected in well B-MW15 is suspected to be associated with the Capehart Housing Area and not the Area B Landfill. As shown in Figure 1-13, contamination was not detected in wells B-MW15B and B-MW22B located south of the elementary school.

1.3.2.3 Pumping/Pilot Tests

Based on the data collected during the three pilot/pumping tests, aquifer hydraulic parameters were calculated for the water table and Yorktown Aquifers. The procedures for these calculations included: identifying responding wells; estimating the available drawdown remaining in the production well; and calculating the test trends by variations of the Jacob, Boulton and Hantush methods used in the parametric analysis of aquifer characteristics. The calculated aquifer parameters are presented in Table 1-9. Pumping test results and aquifer parameter calculations are provided in the Final Basis of Design Report (Baker, 1994e).

1.4 Nature and Extent of Contamination

Based on site history, previous investigations, RI findings, and pre-design investigation results, contamination from prior disposal practices at Area A and Area B of the Camp Allen Landfill has impacted subsurface soils, surface soils, sediment, surface water, and groundwater (water table and Yorktown

TABLE 1-9

AQUIFER PARAMETERS
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Area/Aquifer	Transmissivity (gpd/ft)	Storativity	Regional Gradient
Area B Water Table	1,540	2.3E-03	3.0E-03
Area A1 Upper Yorktown	45,100	3.6E-04	8.3E-04
Area A2 Upper Yorktown	45,100	3.6E-04	8.3E-04
Area B Upper Yorktown	12,000	1.8E-04	2.3E-04

Aquifer systems). In general, the primary COPCs are VOCs and several inorganic constituents. Following is a general description of findings at the Camp Allen Landfill Site:

Area A

- Source characterization: VOCs were the predominant contaminants detected in the subsurface soils at Area A. In general, two primary source locations were indicated. The first area appears to be located in the western vicinity of the Brig facility. The second potential area appears to be located towards the northern/northeastern region of Area A.

- Surface soil: Analytical results indicate surficial soil to be nominally impacted by disposal activities.

- Surface water: Results indicate isolated areas of various inorganic constituent concentrations, some exceeding applicable standards/criteria.

- Sediment: Results indicate isolated, sporadic areas of various inorganic constituent concentrations.

- Groundwater: Two primary areas of VOC contamination were identified at Area A (A1 and A2). Area A1 is located towards the western portion of the Brig facility and Area A2 is located along the north portion of the site. Both shallow and deep groundwater contamination is present within these areas. Identified contaminants appear to correspond to source areas mentioned above.

- Residential well groundwater sampling: Analytical results indicate that site-related contaminants have not impacted the shallow (water table) groundwater in the Glenwood Park area. VOCs were detected in four out of 55 residential wells sampled in Glenwood Park. However, the detections appear to be isolated occurrences that are unrelated to disposal activities at Area A. Although 1,2-dichloroethane, a constituent of concern at Area A, was detected in residential well 55, no VOCs have been detected in monitoring wells A-MW8A, A-MW9A, and A-MW10A (located between Area A and residential well 55). These results do not indicate a connection between site contamination and the 1,2-dichloroethane detected in well 55. Furthermore, for the water table aquifer, the

drainage ditch located between Area A and Glenwood Park serves as a hydrogeologic boundary between these areas.

- Air sampling: No significant site-specific volatile air contaminants were detected.

Area B

- Source characterization: VOCs were the predominant contaminants detected in the subsurface soils at Area B. In general, the primary source area is located in the middle portion of the site within the landfill.

- Surface soil: Analytical results indicate surficial soil to be nominally impacted by disposal activities.

- Surface water: Results indicate areas of various VOC and inorganic constituent concentrations exceeding applicable standards/criteria primarily in the eastern and northern portion of the ponded area.

- Sediment: Results indicate isolated areas of various VOC and inorganic constituent concentrations. Contamination could be present in areas of the ponded drainage area northeast of the site.

- Groundwater: One primary area of VOC contamination was identified at Area B. This area is located in the vicinity of the landfill. Both shallow and deep groundwater contamination is present within this area. Identified contaminants correspond to the source area within the Area B landfill mentioned above. The contamination detected in Well B-MW15, located near the southern border of the site (directly south of the Camp Allen Elementary School) is suspected to be associated with the Capehart Housing Area and not the Area B landfill.

- Residential wells: No residential wells are located in the vicinity of Area B.

- Air sampling: No significant site-specific volatile air contaminants were detected.

It must be noted that various total inorganic constituents (e.g., arsenic, chromium) were detected in groundwater samples collected from the shallow (water table) and deep (Yorktown) aquifer at concentrations exceeding state and federal drinking water standards throughout the site. However, based on comparisons of total verses dissolved metal concentrations and linear regression correlations between naturally occurring elements (i.e., iron and aluminum) and constituents of potential concern (e.g., arsenic, chromium), the inorganic contaminants detected in the groundwater are believed to be associated with total suspended solids (turbidity) present in the wells and not representative of actual groundwater contamination.

1.5 Summary of Site Risks to Human Health

The public health risks associated with exposure to contaminated media within Areas A and B of the Camp Allen Landfill Site were evaluated. An ecological evaluation was also performed (see Section 1.6). This baseline assessment evaluates and assesses the potential risks which might result under current use and potential future use scenarios. The public health risks and ecological risks associated with the site are presented in detail in the Final Baseline Risk Assessment (Baker, 1994b).

Incremental cancer risks (ICRs) and the potential to experience non-carcinogenic adverse effects (i.e., central nervous system effects, kidney effects, etc.), as measured by a hazard index (HI), were evaluated in this assessment. Estimated incremental cancer risks were compared to the target risk range of 10^{-4} to 10^{-6}, which the USEPA considers to be safe and protective of public health (USEPA, 1989). The calculated HI was compared to a threshold value of one; below this level, there is minimal potential to experience noncarcinogenic adverse health effects. In addition, potential ecological effects were evaluated qualitatively.

The risk assessment has shown that past practices at the Camp Allen Landfill Site have contaminated certain media to the extent that they pose a potential threat to human health under current use and potential future residential use scenarios. Although future residential use scenarios are unlikely at the site, they have been incorporated into the baseline comparisons. Table 1-10 summarizes potential health risk values associated with soil, surface water, and sediment under current use and potential future (residential) use scenarios. Table 1-11 summarizes potential health risk values associated with groundwater under current use (nonpotable) and potential future use (potable) scenarios. Risk values presented for soil, sediment, surface water, shallow groundwater, and deep groundwater are considered to be "worst case," as they were derived by selecting those sampling locations with the most primary constituents of potential concern (COPCs). Sample locations were also selected so as to not underestimate the resulting potential human health risks. More detailed risk assessment summary tables are presented in Appendix F.

TABLE 1-10

SUMMARY TABLE OF MAXIMUM INCREMENTAL CANCER RISKS (ICR) AND HAZARD INDICES (HI) FOR MEDIA OF INTEREST, AREAS A AND B CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

	Area A				Area B - Pond/Landfill				Area B - School			
	Potential Current		Potential Future		Potential Current		Potential Future		Potential Current		Potential Future	
Medium	HI	ICR	HI[3]	ICR[3]	HI	ICR	HI[3]	ICR[3]	HI	ICR	HI[3]	ICR
Soils	0.41[2]	2.4×10^{-5}[1]	**5.9**	**1.2×10^{-4}**	0.07[1]	1.0×10^{-5}[1]	**1.5**	3.3×10^{-5}	0.48[5]	8.5×10^{-6}[1]	**3.7**	4.9×10^{-5}[3]
Sediments	0.28[4]	1.2×10^{-5}[4]	**4.3**	9.5×10^{-5}	0.0092[1]	2.0×10^{-6}[1]	**1.6**	6.2×10^{-5}	[6]	[6]	0.01	[6]
Surface Waters	0.031[4]	4.2×10^{-5}[4]	0.15	**2.0×10^{-4}**	0.019[5]	3.1×10^{-6}[5]	0.06	2.1×10^{-5}	0.02[5]	3.1×10^{-6}[5]	0.03	6.3×10^{-6}[3]

Notes: Hazard indices exceeding 1 and Incremental Cancer Risks exceeding 1×10^{-4} are shown in bold face type.

[1] Industrial Use (Adults)
[2] Brig Prisoners
[3] Resident Young Child (1-6 yrs)
[4] Resident Older Child (6-15 yrs)
[5] School Children (6-12 yrs)
[6] No contaminants of concern detected.

Current - Current potential exposure
Future - Future potential (residential) exposure

TABLE 1-11

SUMMARY TABLE OF MAXIMUM INCREMENTAL CANCER RISKS (ICR) AND HAZARD INDICES (HI) FOR SHALLOW AND DEEP GROUNDWATER, AREAS A AND B CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

	Area A (and Glenwood Park Residential Area)							
	Potential Current				Potential Future			
	Child		Adult		Child		Adult	
Medium	HI	ICR	HI	ICR	HI	ICR	HI	ICR
Shallow	0.003	3.8×10^{-7}	0.001	6.4×10^{-7}	**320**	**3.8×10^{-2}**	**200**	**8.1×10^{-2}**
Deep Groundwater	NA	NA	NA	NA	**260**	**1.3×10^{-3}**	**170**	**2.8×10^{-3}**

	Area B							
	Potential Current				Potential Future			
	Child		Adult		Child		Adult	
Medium	HI	ICR	HI	ICR	HI	ICR	HI	ICR
Shallow	NA	NA	NA	NA	**24**	**1.0×10^{-2}**	**15**	**2.3×10^{-2}**
Deep Groundwater	NA	NA	NA	NA	**3.8**	3.2×10^{-5}	**2.5**	6.7×10^{-5}

Notes: Hazard indices exceeding 1 and Incremental Cancer Risks exceeding 1×10^{-4} are shown in bold face type.
Current Use - Potential nonpotable use of groundwater (child, swimming pools; adults, car washing).
Future Use - Potential residential potable use of groundwater.
NA - Scenario not applicable (i.e., groundwater in Area B currently not used for potable or nonpotable).

A summary of human health risks for Areas A and B at the site, by media, is described below.

Area A - Soil

Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

Area B - Soil

Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area B under the current land use in the area (i.e., for either employees or children at the Camp Allen Elementary School). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure of remedial construction workers to subsurface soils at the Area B Landfill/Pond under the current remediation scenario. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 1.5 at the Area B Landfill/Pond to 3.7 in the school area, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario. Also, these risks were calculated at the Area B Landfill/Pond based on existing conditions prior to the removal action that currently is being implemented in this area. Therefore, the actual risks will be much lower in this area when the removal action is completed.

Area A - Surface Water/Sediment

Results of the baseline risk assessment indicate that, under the current land use of this area as a brig, no unacceptable adverse human health effects would be expected from exposure (via ingestion and dermal contact) to surface water or sediment in Area A. Under a future residential land use scenario, the hazard index (HI) calculated for a child receptor ranged from 3.4 to 4.3 for exposure (via ingestion and dermal contact) to shallow and deep sediments, respectively, which exceeds the acceptable HI of 1.0 under

CERCLA; however, no unacceptable risks are indicated for an adult receptor for exposure to sediments under a future residential use scenario. Also, under a future residential land use scenario, the ICR for a child receptor associated with exposure (via ingestion and dermal contact) to surface water is 2.0×10^{-4}, which slightly exceeds the acceptable ICR of 1.0×10^{-4} under CERCLA. Under a future residential land use scenario, the ICR for an adult receptor associated with exposure (via ingestion and dermal contact) to surface water is 1.2×10^{-4}, which also slightly exceeds the acceptable ICR of 1.0×10^{-4} under CERCLA.

Area B - Surface Water/Sediment

Results of the baseline risk assessment for Area B indicate that, under the current land use of the Area B pond and school, no unacceptable human health effects would be expected from exposure (via ingestion and dermal contact) to the surface water and sediment. Under a future residential land use scenario, the hazard index (HI) calculated for a child receptor near the Area B Landfill and Pond was 1.6 for exposure (via ingestion and dermal contact) to sediments, which exceeds the acceptable HI of 1.0 under CERCLA. However, no unacceptable risks are indicated for a child receptor for exposure to surface water, and no unacceptable risks are indicated for an adult receptor for exposure to surface water or sediments under a future residential use scenario.

Area A Groundwater

Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact) to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

Area B Groundwater

Results of the baseline risk assessment for Area B indicate that no unacceptable adverse human health effects would be expected from exposure to either deep or shallow groundwater under the current land use in the area since groundwater currently is not used for any purpose at Area B.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

1.6 Summary of Site Risks to the Ecology

The ecological assessment included collection of physical water quality data, sampling and analysis of benthic macroinvertebrates, and qualitative evaluation of the terrestrial environment. A brief summary follows.

In most cases, physical water quality measurements (Ph, salinity, dissolved oxygen, etc.) were within the ranges typically encountered in waters in urban drainageways. Sediment grain size was also as expected.

Benthic macroinvertebrates were present in every benthic sample; populations in all samples appeared to be healthy. The number of individuals and taxa represented was consistent with healthy environments of the same type represented at Camp Allen. However, identification of organisms was conducted to family level only. These data were not sufficient for calculation of diversity indices or identification of tolerant and/or intolerant species.

The terrestrial environmental also appeared to be unaffected by site contaminants. Gross effects of contamination (i.e., death or illness of wildlife, vegetative stress) were not observed. Although the terrestrial study was qualitative only, habitats appeared to be diverse and included species to be expected, particularly in an urban environment. Wildlife was breeding and reproducing on site and natural processes such as habitat succession indicated that plants were germinating and competing successfully.

1.7 Feasibility Study Report Organization

Based on RI findings and the results of the baseline risk assessment, the FS process has emphasized the development of remedial alternatives that meet the following conditions:

- Provide permanent solutions to contamination problems and long-term effectiveness.
- Meet Applicable or Relevant and Appropriate Requirements (ARARs) on a federal level, or a state level if the state requirements are more stringent.

The FS Report is organized into seven sections. This introduction section (Section 1.0) presented a brief discussion of site background information, a summary of the RI, a summary of the pre-design investigation, a discussion of the nature and extent of contamination, and an overview of the baseline risk assessment. The remedial action objectives (including cleanup goals) that have been established for the site are outlined in Section 2.0. Identification and preliminary screening of general response actions, remedial action technologies, and process options are contained in Section 3.0. Development and screening of Area A remedial alternatives for soil are discussed in Section 4.0. The detailed analyses of remedial alternatives and a comparative analysis of alternatives for soils and surface water/sediments are presented in Section 5.0. The detailed analyses of remedial alternatives and a comparative analysis of alternatives for groundwater are presented in Section 6.0. The detailed analysis is based on a set of nine criteria including effectiveness, implementability, cost, acceptance, and overall protection of human health and the environment. References are listed in Section 7.0.

Six appendices are included with this FS: Appendix A presents the scope and results of the pre-design investigation; Appendix B contains soil cleanup goals development methodology; Appendix C details costing summaries and backup calculations for soil and surface water/sediment alternative cost estimates; Appendix D contains costing summaries and backup calculations for the groundwater alternative cost estimates; Appendix E presents a comparison of estimated air emissions from the air stripper to Virginia air emission standards; and Appendix F presents the risk assessment summary tables.

SECTION 2 - REMEDIAL ACTION OBJECTIVES

2.0 REMEDIAL ACTION OBJECTIVES

For purposes of the FS, three media of concern have been identified at the Camp Allen Landfill Site as follows:

- Soils
- Surface Water/Sediments
- Groundwater

2.1 General Approach

Applicable, or relevant and appropriate requirements (ARARs), and requirements "to be considered" (TBCs) are used to determine specific cleanup goals and control measures for remedial activities. ARARs and TBCs are discussed in Section 2.2.

Cleanup goals for the contaminated media will be based upon risk-based values (i.e., an acceptable risk level for potential receptors) or on ARAR-based concentrations, such as Maximum Contaminant Levels established under the Safe Drinking Water Act. Cleanup goals typically serve to define the extent of contamination for a medium and are used to determine the extent to which the remedial objectives have been met. Specific cleanup goals for each medium are presented in Section 2.3.

Remedial action objectives (RAOs) are developed to protect human health and the environment for medium-specific exposure scenarios. These objectives are developed considering the contaminants of concern, potential receptors and exposure scenarios, and acceptable contaminant concentrations for each exposure scenario. Remedial action objectives for the media of concern are identified in Section 2.4 for Areas A and B. General response actions are then developed in this section to address requirements of the remedial action objectives. Finally, areas and volumes of contaminated media are identified.

2.2 Applicable, or Relevant and Appropriate Requirements, and Requirements to be Considered

One of the main considerations during the development of remedial action alternatives for hazardous waste sites under CERCLA is the degree of human health and environmental protection provided by a given remedy. Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed applicable, or relevant and appropriate requirements (ARARs). The purpose of this

requirement is to make CERCLA response actions consistent with other pertinent federal and state environmental requirements. ARARs may include the following:

- Any standard, requirement, criterion, or limitation under federal environmental law.

- Any promulgated standard, requirement, criterion, or limitation under a state environmental or facility-citing law that is more stringent than the associated federal standard, requirement, criterion, or limitation.

A requirement may be either "applicable" or "relevant and appropriate," but not both.

Definitions of the two types of ARARs as well as other "to be considered" (TBC) criteria are given below:

- Applicable Requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that directly and fully address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

- Relevant and Appropriate Requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site, address problems or situations sufficiently similar (relevant) to those encountered at the CERCLA site, that their use is well suited (appropriate) to the particular site. Requirements must be relevant and appropriate to be an ARAR.

- "To be considered" (TBC) criteria are non-promulgated, non-enforceable guidelines or criteria that may be useful for developing remedial action, or necessary for determining what is protective to human health and/or the environment. Examples of TBC criteria include EPA Drinking Water Health Advisories, Carcinogenic Potency Factors, and Reference Doses.

Section 121(d)(4) of CERCLA allows the selection of a remedial alternative that will not attain all ARARs if any of six conditions for a waiver of ARARs exist. These conditions are as follows: (1) the remedial action is an interim measure whereby the final remedy will attain the ARAR upon completion;

(2) compliance will result in greater risk to human health and the environment than other options; (3) compliance is technically impracticable; (4) an alternative remedial action will attain the equivalent of the ARAR; (5) for state requirements, the state has not consistently applied the requirement in similar circumstances; (6) compliance with the ARAR will not provide a balance between protecting public health, welfare, and the environment at the facility with the availability of Superfund money for response at other facilities (fund-balancing).

ARARs fall into three categories, based on the manner in which they are applied. The characterization is not perfect, as many requirements are combinations of the three types of ARARs. These categories are as follows:

- Contaminant-Specific: Health-/risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples of contaminant-specific ARARs include Maximum Contaminant Levels (MCLs) and Clean Water Act (CWA) water quality criteria.

- Location-Specific: Restrictions based on the concentration of hazardous substances or the conduct of activities in specific locations. These may restrict or preclude certain remedial actions or may apply only to certain portions of a site. Examples of location-specific ARARs include RCRA location requirements and floodplain management requirements.

- Action-Specific: Technology- or activity-based controls or restrictions on activities related to management of hazardous waste.

In general, the contaminant-specific ARARs and TBCs are considered during the assessment of risks to human health and the environment. These ARARs and TBCs are also considered in the development of remedial action objectives. The action-specific ARARs and TBCs, which affect the implementation and/or operation of the remedial alternatives, are primarily used to assess the feasibility of remedial technologies and alternatives. Pertinent ARARs and TBCs for the Camp Allen Landfill Site are summarized in Tables 2-1 and 2-2, respectively.

TABLE 2-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Citation	Requirement	ARAR Determination	Comments
FEDERAL/CONTAMINANT-SPECIFIC			
Safe Drinking Water Act (42 USC 300(f)) a. Maximum Contaminant Levels (MCLs) 40 CFR 141.11-141.16 b. Maximum Contaminant Level Goals (MCLGs) 40 CFR 141.50-141.51	Standards for protection of drinking water sources serving at least 25 persons. MCLs consider health factors, as well as economic and technical feasibility of removing a contaminant; MCLGs do not consider the technical feasibility of contaminant removal. For a given contaminant, the more stringent of MCLs or MCLGs is applicable unless the MCLG is zero, in which case the MCL applies.	Relevant and appropriate in developing cleanup goals for contaminated groundwater and surface water that may potentially be used as a potable water supply.	MCLs will be used in developing cleanup goals for the Yorktown Aquifer.
FEDERAL/LOCATION-SPECIFIC			
The Endangered Species Act of 1973 (16 USC 1531) (40 CFR Part 502)	Requires action to conserve endangered and threatened species and their critical habitats.	Applicable because peregrine falcons can be seen any time of year (Audet, 1989).	VADEQ has been notified of this project and the Navy requests the involvement of the Virginia Board of Game and Inland Fisheries for determination of endangered species or habitats.
Coastal Zone Management Act (16 USC 3501)	Conduct activities in a manner consistent with approved State management programs.	Relevant and appropriate to activities conducted within the Virginia coastal zone (Baker, 1988).	VADEQ has been notified of this project and the Navy requests that VADEQ provide requirements to comply with this ARAR.
National Historic Preservation Act (32 CFR Parts 229 and 229.4; 43 CFR Parts 107 and 171.1-5)	Develops procedures for the protection of archaeological resources.	Applicable to any excavation on site. If archaeological resources are encountered during soil excavation, they must be reviewed by Federal and State archaeologists.	Compliance can be met by submitting copies of work plans to the Virginia Department of Historic Resources (VDHR). The Navy requests that VDEQ provide coordination of this project with SHPO.
Executive Order 11988 (related to Floodplain Management)	Regulates activities located in a floodplain must comply with this Executive Order. Federal activities in floodplains must reduce the risk of flood loss, minimize the impact of floods on human safety, health and welfare, and preserve the natural and beneficial values served by floodplains.	Applicable for remedial actions involving activities with a floodplain.	Activities during construction will comply with requirements.

TABLE 2-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Citation	Requirement	ARAR Determination	Comments
FEDERAL/ACTION-SPECIFIC			
DOT Rules for Hazardous Materials Transport (49 CFR Parts 107 and 171.1-500)	Regulates the transport of hazardous waste materials including packaging, shipping, and placarding.	Applicable for any action requiring off-site transportation of hazardous materials.	Remedial actions may include off-site treatment and disposal (e.g., off-site regeneration of activated carbon).
Resource Conservation and Recovery Act (RCRA) Subtitle C	Regulates the treatment, storage, and disposal of hazardous waste.	Applicable to remedial actions involving treatment, storage, or disposal of hazardous waste.	Remediation may involve treatment, storage, or disposal of hazardous waste.
Identification and Listing of Hazardous Waste (40 CFR Part 261)	Regulations concerning determination of whether or not a waste is hazardous based on characteristics or listing.	Applicable in determining waste classification.	Some site contaminants are considered listed wastes.
Treatment, Storage, and Disposal (TSD) of Hazardous Waste (40 CFR Parts 262-265, 266)	Regulates the treatment, storage, and disposal of hazardous waste.	Applicable in the event that wastes on site are classified as hazardous.	TSD activities related to hazardous waste will comply with regulations.
Manifest Systems, Recordkeeping, and Reporting (40 CFR Part 264, Subpart E)	Regulates manifest systems related to hazardous waste treatment, storage, and disposal.	Applicable to remedial actions where hazardous waste is generated or transported.	Remedial actions may include off-site disposal or treatment.
Releases from Solid Waste Management Unites (40 CFR Part 264, Subpart F)	Regulates releases from solid waste management units.	All solid waste management units on site shall comply with requirements.	Groundwater protection standards apply to solid waste management units.
Use and Management of Containers (40 CFR Part 264, Subpart I)	Regulates use and management of containers being stored at all hazardous waste facilities.	Applicable to containers stored on site.	Remedial actions may generate containerized waste. Investigation-derived waste (IDW) is containerized.
Resource Conservation and Recovery Act (RCRA) Subtitle D	Regulates the treatment, storage, and disposal of solid waste.	Applicable to remedial actions involving treatment, storage, or disposal of materials classified as solid waste.	Remediation may include treatment, storage, or disposal of solid waste.
National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61)	Standards promulgated under the Clean Air Act for significant sources of hazardous pollutants, such as vinyl chloride, benzene, trichloroethylene, dichlorobenzene, asbestos, and other hazardous substances. Considered for any source that has the potential to emit 10 tons of any hazardous air pollutant or 25 tons of a combination of hazardous air pollutants per year.	Applicable to releases or potential releases of hazardous pollutants. Remedial actions (e.g., air stripping) may result in release of hazardous air pollutants. The treatment design would include air emissions control equipment as required to comply with NESHAPs.	To be used during remedial design to determine that air emissions from the treatment facility will not exceed air emission standards.

TABLE 2-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Citation	Requirement	ARAR Determination	Comments
STATE/CONTAMINANT-SPECIFIC			
Virginia Water Quality Standards (VR 680-21-00)	Surface water quality standards based on water use and criteria class of surface water.	Applicable to remedial actions requiring discharge to surface water.	Will be used to determine the discharge limit from the treatment facility.
Virginia Groundwater Standard (VR 680-21-04.3)	Establishes groundwater standards for State Antidegradation policy.	Relevant and appropriate for contaminants for which no MCL exists.	MCLs available for all contaminants of concern.
Virginia Ambient Air Quality Standards (VAAQS) (VR 120-03-01)	Primary and secondary air quality standards for particulate matter, sulfur oxides, carbon monoxide, nitrogen dioxide, and lead.	Potentially applicable for remedial actions requiring discharge to the atmosphere.	Air emissions from the treatment facility will be monitored to comply with the substantive requirements of VAAQS provided by VADEQ.
Virginia Emission Standards for Toxic Pollutants (VR 120-01)	Establishes acceptable limits for toxic pollutants by applying a 1/40 correction factor to the occupational standard Threshold Limit Value-Ceiling (TLV-Ceiling).	These standards are applicable requirements for remedial actions requiring discharge to the atmosphere. Air calculations are provided in Appendix F that demonstrate compliance with standards.	To be used during remedial design to determine whether air emissions from the treatment facility will not exceed air emission standards.
Virginia Pollution Discharge Elimination System (VPDES) (VR 680-14-01) Regulation and Virginia Water Protection Permit Regulations (VR 680-15-01)	Regulated point-source discharges through the VPDES permitting program. Permit requirements include compliance with corresponding water quality standards, establishment of a discharge monitoring system, and completion of regular discharge monitoring records.	Applicable to discharge of treated water to surface water.	Substantive requirements of VPDES permit will be used to determine the discharge limits for the discharge of the treated water to surface water on site.
STATE/ACTION-SPECIFIC			
Virginia Solid Waste Management Regulations (VR 672-20-10)	Regulates the disposal of solid wastes.	Applicable for solid (nonhazardous) waste.	Remedial actions could include off-site disposal of nonhazardous waste.
Virginia Hazardous Waste Regulations (VR 72-30-1 and VR 672-10-1, Part VII)	Regulates the transport of hazardous waste materials including packaging, shipping, and placarding.	Applicable for any action requiring off-site transportation of hazardous materials.	Remedial actions may include off-site treatment and disposal (e.g., off-site regeneration of activated carbon).

TABLE 2-1

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Citation	Requirement	ARAR Determination	Comments
STATE/ACTION-SPECIFIC			
Virginia Hazardous Waste Management Regulations (VR 672-10-1)	Regulates the treatment, storage, and disposal of hazardous waste.	Applicable to remedial actions involving treatment, storage, or disposal of hazardous waste.	Remediation may include treatment, storage, or disposal of hazardous waste.
Identification and Listing of Hazardous Waste (VR 672-10-1, Part III)	Regulations concerning determination of whether or not a waste is hazardous based on characteristics or listing.	Applicable in determining waste classification.	Some site contaminants are considered listed wastes.
Manifest Systems, Recordkeeping, and Reporting (VR 672-10-1, Part X, Section 10.4)	Regulates manifest systems related to hazardous waste treatment, storage, and disposal.	Applicable to remedial actions where hazardous waste is generated or transported.	Remedial actions may include off-site disposal or treatment.
Releases from Solid Waste Management Unites (VR 672-10, Part X, Section 10.5)	Regulates releases from solid waste management units.	All solid waste management units on site shall comply with requirements.	Groundwater protection standards apply to solid waste management units.
Use and Management of Containers (VR 672-10, Part X, Section 10.8)	Regulates use and management of containers being stored at all hazardous waste facilities.	Applicable to containers stored on site.	Remedial actions may generate containerized waste. Investigation-derived waste (IDW) is containerized.
Virginia Stormwater Management Regulations (VR 215-02-00) and Virginia Erosion and Sediment Control Regulations (VR 625-02-00)	Regulates stormwater management and erosion/ sedimentation control practices that must be followed during land disturbing activities.	Applicable for remedial actions involving land disturbing activities.	Activities during construction will comply with the Virginia Storm Water Management Program. A sediment and erosion control plan will be submitted to LANTDIV for approval.
Virginia Endangered Species Act (Code of Virginia 29.1-563)	Requires action to conserve endangered and threatened species and their critical habitats.	Applicable because peregrine falcons can be seen any time of year (Audet, 1989).	VADEQ has been notified of this project. The Navy requests determination of endangered species or habitats from VADEQ.
Virginia Wetlands Regulations (VR 450-01-0051)	Regulates activities that impact tidal wetlands.	Relevant and appropriate to activities that could impact site wetlands.	Activities that could impact wetlands will comply with regulations.
Chesapeake Bay Preservation Area Designation and Management Regulations (VR 173-02--01)	Sets limitations in certain tidal and wetland areas for land-disturbing activities, removal of vegetation, use of impervious cover, E&S control, stormwater management, etc.	Potentially relevant and appropriate if site is within jurisdiction.	If required, plans will be submitted to the appropriate agency for approval.
Coastal Management Plan City of Norfolk	Activities within a Coastal Management Zone must be in compliance with local requirements.	Relevant and appropriate.	Remedial activities will comply with local requirements.

TABLE 2-2

TO BE CONSIDERED (TBC) REQUIREMENTS
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Citation	Requirement	TBC Determination	Comments
FEDERAL/CONTAMINANT-SPECIFIC			
Reference Doses (RfDs), EPA Office of Research and Development	Presents non-enforceable toxicity data for specific chemicals for use in public health assessments to characterize risks due to exposure to contaminants.	To be considered (TBC) requirement in the public health assessment.	Will be used in evaluating human health risks at the site.
Carcinogenic Potency Factors, EPA Environmental Criteria and Assessment Office; EPA Carcinogen Assessment Group	Presents non-enforceable toxicity data for specific chemicals for use in public health assessments to compute the individual incremental cancer risk resulting from exposure to carcinogens.	TBC requirement in the public health assessment.	Will be used in evaluating human health risks at the site.
Health Advisories, EPA Office of Drinking Water	Non-enforceable guidelines for chemicals that may intermittently be encountered in public water supply systems. Available for short- or long-term exposure for a child and/or adult.	TBC requirement in the public health assessment.	Will be used in evaluating human health risks at the site.
FEDERAL/LOCATION-SPECIFIC			
RCRA Subtitle C Landfills (40 CFR Part 264, Subpart N)	Regulates owners and operators of facilities that dispose hazardous wastes in landfills.	TBC to evaluate compliance of off-site landfills.	TBC for remedial actions that involve off-site landfill of hazardous waste (sludge or IDW).
Groundwater Protection Strategy	EPA policy to protect groundwater for its highest present or potential beneficial use. The strategy designates three categories of groundwater: Class 1 - Special Ground Waters Class 2 - Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses Class 3 - Groundwater Not a Potential Source of Drinking Water and of Limited Beneficial Use	TBC requirement.	Groundwater in the Yorktown Aquifer is considered a Class 2 given its historical, current, and expected future use. Groundwater in the surficial (water table) aquifer is considered a Class 3.

TABLE 2-2 (Continued)

TO BE CONSIDERED (TBC) REQUIREMENTS
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

Citation	Requirement	TBC Determination	Comments
FEDERAL/ACTION-SPECIFIC			
National Ambient Air Quality Standards (NAAQS) (40 CFR 50)	Standards for the following six criteria pollutants: particulates matter; sulfur dioxide; carbon monoxide; ozone; nitrogen dioxide; and lead. The attainment and maintenance of these standards are required to protect the public health and welfare.	TBC requirements for remedial actions requiring discharge to the atmosphere. The treatment design would include air emissions control equipment as required to comply with NAAQS.	Air emissions from the treatment plant will be monitored to comply with the substantive requirements of NAAQS.
Control of Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites (OSWER Directive 9355.0-28)	Guidance that establishes criteria as to whether air emission controls are necessary for air strippers. A maximum 3 lbs/hr or 15 lbs/day or 10 tons/yr of VOC emissions is allowable; air pollution controls are recommended for any emissions in excess of these quantities.	TBC requirement.	TBC as remedial action includes air stripping.
National Ambient Air Quality Standards (NAAQS) (40 CFR 50)	Standards for the following six criteria pollutants: particulates matter; sulfur dioxide; carbon monoxide; ozone; nitrogen dioxide; and lead. The attainment and maintenance of these standards are required to protect the public health and welfare.	TBC requirements for remedial actions requiring discharge to the atmosphere. The treatment design would include air emissions control equipment as required to comply with NAAQS.	Air emissions from the treatment plant will be monitored to comply with the substantive requirements of NAAQS.
STATE/LOCATION-SPECIFIC			
RCRA Subtitle C Landfills (VR 672-10, Part X, Section 10.13)	Regulates owners and operators of facilities that dispose hazardous wastes in landfills.	TBC to evaluate compliance of off-site landfills.	TBC for remedial actions that involve off-site landfill of hazardous waste (sludge or IDW).

2.3 Cleanup Goal Development

The three media of concern that have been identified at the site are: soils, groundwater and surface water/sediments. Cleanup goals are developed in the following sections for soils and groundwater. Cleanup goals have not been established for surface water/sediments because removal and/or treatment alternatives were not evaluated for site surface water/sediments, as discussed in Section 5.3.

2.3.1 Soil Cleanup Goals

Soil analytical data obtained during the Camp Allen Landfill pre-design investigation indicate the presence of volatile organic compounds (VOCs) in subsurface soils in Areas A1 and A2. The VOCs detected in test pit samples collected during the pre-design investigation include toluene, ethylbenzene, xylenes, vinyl chloride, trichloroethene, tetrachloroethene, and 1,2-dichloroethenes. Under the influence of infiltrating precipitation, these VOCs may migrate through the unsaturated zone soils to the water table aquifer. Thus, under current conditions, the contaminated subsurface soils in Areas A1 and A2 could potentially act as sources of continuing contamination to underlying groundwater. The objective of soil cleanup goal development is to determine subsurface soil cleanup goals based on the potential for the VOCs to migrate (i.e., leach) to the water table aquifer in Areas A1 and A2 at the Camp Allen Landfill.

A spreadsheet-based transport model described by Summers et al. (USEPA, 1980) was developed to determine the potential soil cleanup goals. The Summers Model is a one-dimensional advective transport model that estimates the potential contaminant concentration in leachate (emanating from the source area) at the top of the water table aquifer. The general input data for the spreadsheet model include contaminant characteristics, unsaturated zone characteristics, hydrogeological properties of the water table aquifer, and annual precipitation data. Site-specific data were obtained from the pre-design investigation as well as from previous field investigations. Multiple data descriptors were used to describe depth to the saturated zone, organic carbon content, and vertical hydraulic conductivity. Site data not available from site-specific field investigations were obtained from USEPA source documents.

A more detailed description of the Summers Model, as well as the specific modeling inputs and their sources used in the spreadsheet calculation of soil cleanup goals, are provided in Appendix B. Spreadsheet outputs from the Summers Model are also presented in Appendix B.

The draft soil cleanup goals developed using the Summers Model for the contaminants of concern in Areas A1 and A2 are provided in Table 2-3.

TABLE 2-3

SOIL CLEANUP GOALS
CAMP ALLEN LANDFILL SITE, NORFOLK, VIRGINIA

CONTAMINANTS OF CONCERN	GROUNDWATER GOAL* (ppm)	SOIL CLEANUP GOAL (ppm)
1,2-Dichloroethane	0.005	0.05
1,2-Dichloroethene (cis)	0.070	3.1
1,1,1-Trichloroethane	0.200	21.3
Benzene	0.005	0.2
Ethylbenzene(1)	0.700	500
Tetrachloroethene	0.005	1.4
Toluene	1.000	220.7
Trichloroethene	0.005	0.5
Vinyl Chloride	0.002	0.01
Xylenes(1)	10.00	7000

* Soil cleanup goals are derived from groundwater goals, which are based on Federal Safe Drinking Water Act Maximum Contaminant Levels (MCLs), USEPA, May 1993.

(1) Monte Carlo analyses not performed for these compounds.

The soil cleanup goals shown in Table 2-3 were based on attainment of Maximum Contaminant Levels (MCLs) in shallow groundwater immediately below the source area in order to protect the underlying Yorktown Aquifer to its potential future beneficial use (i.e., drinking water supply). Since the MCLs for the contaminants of concern are less than the Federal Ambient Water Quality Criteria and Virginia Water Quality Standards, soil cleanup goals are also protective of surface water.

In Section 2.4, the soil cleanup goals are used to estimate remediation areas for the FS. It should be noted that, since Area A is a landfill, the primary remedial action objective (RAO) for the soils is groundwater protection rather than soil cleanup, as discussed in Section 2.4. Therefore, achievement of this RAO will not necessarily be based on attainment of the developed soil cleanup goals since they represent theoretical values calculated through modeling. The soil cleanup goals were developed using conservative assumptions (see Appendix B) that may not be representative of actual site conditions. Therefore, achievement of groundwater protection will be determined through evaluation of actual environmental monitoring results (i.e., via on-going monitoring of contaminant levels in groundwater).

2.3.2 Groundwater Cleanup Goals

Groundwater on site is currently not used for any purpose. The shallow (water table) aquifer in the vicinity of the site is generally not suitable for potable (drinking water) use because of high concentrations of iron, manganese and suspended solids, as well as low pH (less than 6). The deeper Yorktown Aquifer is generally suitable for potable uses, except near tidal waters, which can cause the water to be brackish in quality. However, neither the water table or Yorktown aquifers are used for potable use on site or in the vicinity of the site. Potable water used on site and by the nearby community is supplied by the City of Norfolk, which obtains its water from a number of interconnected surface water sources (i.e., lakes, reservoirs, and rivers) and from several groundwater wells during drought conditions.

Residential wells are present within Glenwood Park, located west of the Brig Facility, but are used only for nonpotable uses such as lawn watering, car washing, and filling swimming pools. These wells reportedly are screened within the shallow (water table) aquifer. As a safety precaution, the residents in Glenwood Park were advised by the Navy to consider their private wells nonpotable. The deep groundwater (Yorktown Aquifer) in the vicinity of the site is also used for nonpotable purposes. Two active nonpotable wells located approximately 1 mile northwest of the site reportedly pump about 100,000 gallons per day from the Yorktown Aquifer for use as process water.

The National Contingency Plan (NCP), under 40 CFR Part 300.430(e)(2)(i), states that remediation goals shall be developed by considering the following:

(A) State and federal ARARs.

(B) Maximum contaminant level goals (MCLGs) established under the Safe Drinking Water Act (SDWA) that are set at levels above zero.

(C) SDWA maximum contaminant level (MCL) where the MCLG has been set at zero.

(D) Risked-based levels where attainment of state and federal ARARs will result in cumulative risk in excess of 10^{-4} (i.e., one in ten thousand).

Cleanup goals for each aquifer have been developed based on the potential beneficial use of the aquifer. For the Yorktown Aquifer, the groundwater cleanup goals were based on attainment of federal MCLs in order to protect the aquifer for its potential future beneficial use (i.e., potential future drinking water supply). The cleanup goals for the Yorktown Aquifer are shown in Table 2-4. The cleanup goals for potable water use were based on the following standards and ARARs:

- The federal CERCLA and its National Oil and Hazardous Substances Pollution Contingency Plan (i.e., National Contingency Plan (NCP)) (40 CFR Part 300).

- Safe Drinking Water Act (SDWA) and Amendments (40 CFR Part 141).

- Virginia Board of Health Water Works Regulations (VR 355-18-004).

The Virginia Board of Health MCLs for the contaminants of concern are identical to the federal MCLs. The federal MCLGs are either set at zero or are equal to the MCL for the contaminants of concern. Therefore, the MCLs will be used as cleanup goals for potable use for the groundwater contaminants of concern at the Camp Allen Landfill. However, it is recognized that MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant levels typically reach asymptotic levels, which may exceed MCLs. Performance curves will be periodically (e.g., annually) developed to monitor groundwater contaminant levels. If the performance curves indicate that asymptotic levels have been reached that exceed MCLs for some contaminants, then the cleanup goals may be reevaluated at that time.

TABLE 2-4

GROUNDWATER CLEANUP GOALS (μg/L)
CAMP ALLEN LANDFILL SITE, NORFOLK, VIRGINIA

CONTAMINANTS OF CONCERN	YORKTOWN AQUIFER[1] CLEANUP GOALS (μg/L)	WATER TABLE AQUIFER[2] CLEANUP GOALS (μg/L)
1,2-Dichloroethane	5	190
1,2-Dichloroethene (cis)	70	15,000
1,1,1-Trichloroethane	200	13,500
Benzene	5	600
Ethylbenzene	700	150,000
Tetrachloroethene	5	340
Toluene	1,000	301,000
Trichloroethene	5	1,600
Vinyl Chloride	2	9
Xylenes	10,000	3,000,000

(1) Based on federal Safe Drinking Water Act Maximum Contaminant Levels (MCLs), USEPA, May 1994.

(2) Based on incidental ingestion under a nonpotable use scenario and an incremental cancer risk of 1×10^{-6} and a hazard quotient (HQ) of 1.0 for children.

(3) Cleanup goals are based on contaminants found in soil and groundwater during the pre-design investigation.

Unlike the Yorktown Aquifer, the beneficial use of the water table aquifer is nonpotable use. Nonpotable use cleanup goals were developed for the water table aquifer, and were based on a 1 x 10^{-6} cancer risk level and a hazard quotient of 1.0 for children and the exposure pathways of incidental ingestion and dermal absorption of contaminants during outdoor activities, such as car washing and lawn watering.

2.4 Contaminated Media Areas/Volumes, Remedial Action Objectives, and General Response Actions

2.4.1 Area A Landfill

2.4.1.1 Area A Soils

The results of the risk assessment indicate that there would be no unacceptable risks to human health posed by exposure to the surface soils at the Area A Landfill under the current use (i.e., industrial type usage) scenario. However, since this site is a former landfill that received a variety of waste materials, it is likely that buried contamination is present within the landfill. Therefore, exposure to potential contamination within the landfill is still a human health concern. The entire Area A landfill encompasses an area of approximately 45 acres.

Leaching of contaminants from soils to groundwater is the primary concern with respect to potential soil contamination at the site. The main groundwater contaminants of concern at the Area A Landfill are the chlorinated VOCs (e.g., PCE, TCE, 1,2-DCE, and vinyl chloride) as well as the BTEX compounds, in particular, benzene. General source areas of these compounds were identified within the landfill during the RI and were refined during the pre-design study conducted by Baker in 1993. However, since the landfill contains randomly buried waste materials, there is still a potential for unidentified areas of contamination to be present within the landfill, which could serve as further sources of groundwater contamination. For this reason, source control general response actions (e.g., containment, in situ treatment, removal and disposal) for the Area A Landfill will be considered in the FS.

The groundwater monitoring results from the RI suggest that the sources of groundwater contamination are, or were, present in localized areas within the Area A Landfill since little or no contamination was detected in many of the shallow monitoring wells surrounding the landfill. Organic contaminants were detected in several shallow and deep monitoring wells located immediately west of the Brig Facility. The source(s), of the contamination most likely were located in the vicinity of the Brig Facility area since the general groundwater flow direction is toward the west and northwest in both the shallow and deep aquifers in this area.

During the pre-design investigation conducted by Baker in October 1993, a test pit investigation was conducted in Area A of the landfill in an attempt to delineate the source areas, or "hot spots," within Area A and to estimate the volume of contaminated soil to be addressed in the FS. A total of 24 test pits were excavated: 12 in Area A1 and 12 in Area A2. In general, the test pits were excavated to an average depth of 10 feet. Figures 1-6 and 1-7 show the test pit locations in Areas A1 and A2, respectively, and the VOC analytical results for samples from each test pit. Additional information is available in Appendix A, which presents the results of the pre-design activities conducted by Baker in the fall of 1993.

Based on the test pit investigation results for Area A1, three areas of soil contamination were identified, as shown in Figure 2-1. The estimated soil contamination depths and volumes for the three areas are indicated on Figure 2-1. The total estimated volume of contaminated soil in Area A1 is 10,605 cubic yards. Based on the test pit investigation results for Area A2, one area of soil contamination was identified, as shown in Figure 2-2. The estimated depth of soil contamination in Area A2 is 6 feet. The estimated volume of contaminated soil in Area A2 is 2,208 cubic yards. Therefore, the total estimated volume of contaminated soil in Areas A1 and A2 is 12,814 cubic yards (20,759 tons).

The following remedial action objectives will be considered for the Area A soils:

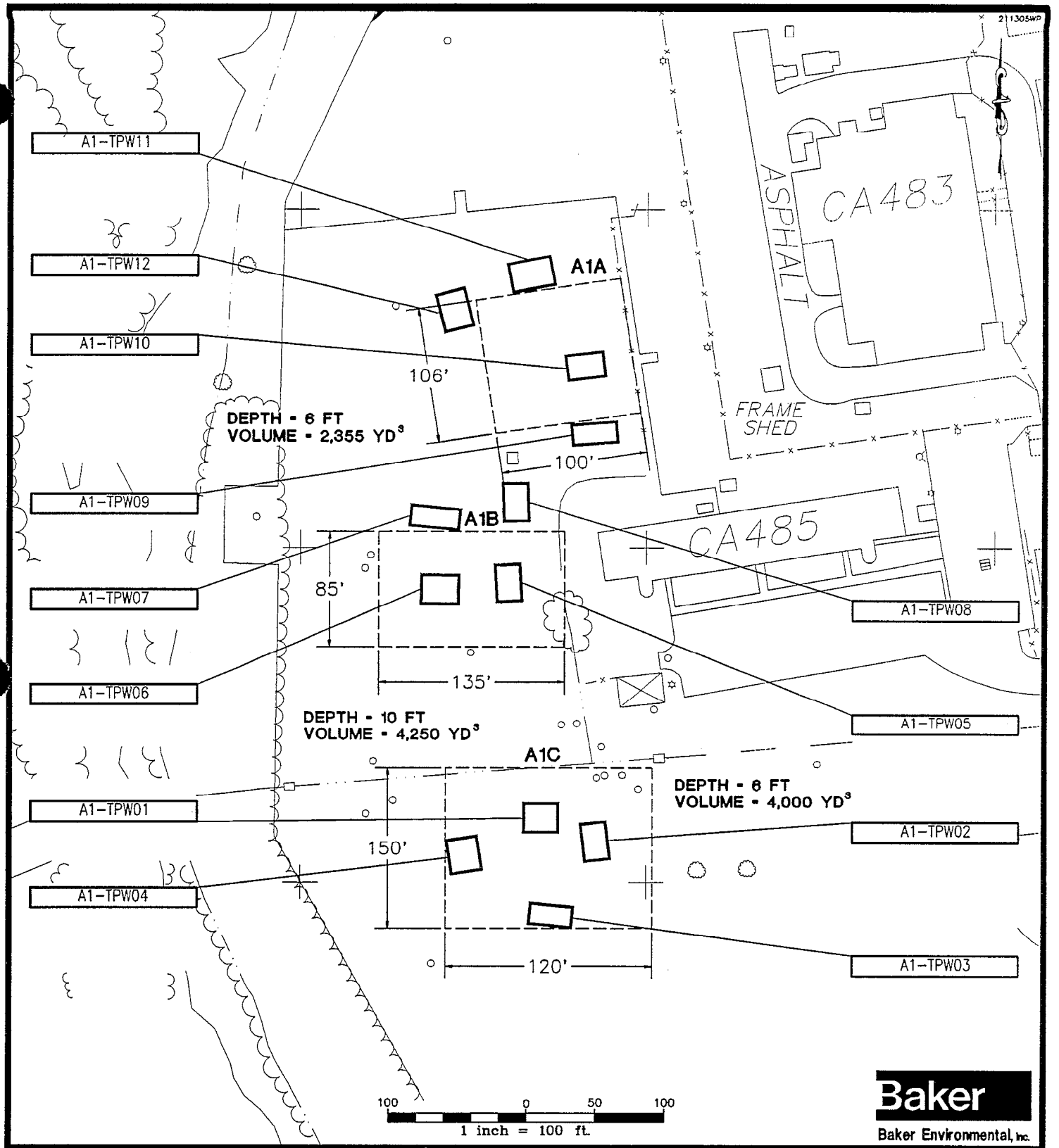
1. Prevent exposure to potential contaminants within subsurface soils and debris.

2. Minimize movement of potential contaminants from subsurface soils and debris to groundwater and surface water.

The following general response actions will be considered for the Area A soils:

- No action
- Institutional controls
- Containment
- Removal and disposal
- Removal, treatment, and disposal
- In situ treatment

The treatment (in situ and ex situ) and disposal general response actions will only be considered for the hot spot areas identified during the pre-design investigation. The containment general response action is applicable to the hot spot areas as well as to a larger, more general area of the landfill that could contain



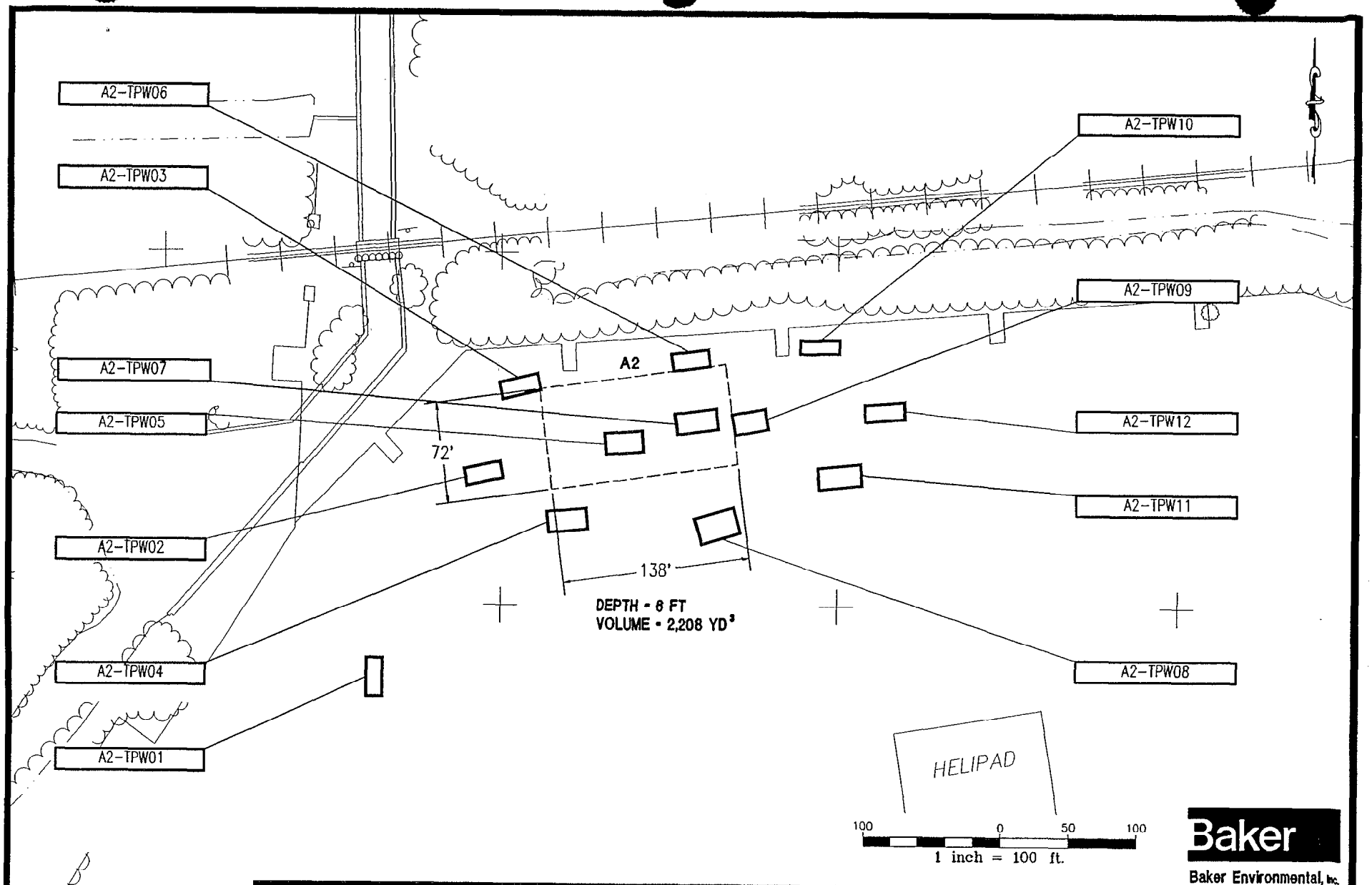
LEGEND

TEST PIT

BOUNDARY OF SOIL REMEDIATION AREA

FIGURE 2-1
AREA A1
SOIL REMEDIATION AREAS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

TEST PIT

BOUNDARY OF SOIL REMEDIATION AREA

FIGURE 2-2
AREA A2
SOIL REMEDIATION AREA
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

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sporadic areas of contamination. For purposes of the FS, this larger area was defined to encompass the Brig Facility area and the area located between the Brig and the landfill boundary. This area covers approximately 12 acres of the landfill.

2.4.1.2 Area A Surface Water/Sediments

The results of the risk assessment indicate that there would be no unacceptable risks to human health posed by exposure to the surface water or sediments at the Area A Landfill under the current use (i.e., industrial-type usage) scenario. Under a potential future residential use scenario, the calculated cancer risk is within acceptable levels, and the hazard index of 4.3 slightly exceeds the acceptable level of 1. Therefore, exposure to potential contamination in the Area A surface water/sediments is a human health concern only under a potential future residential use scenario.

Migration of contaminants from the sediments to groundwater is not considered to be a pathway of concern since VOCs were detected infrequently in the sediments and at low concentrations. Surface water contamination resulting from the sediments is also not expected to be a concern because of the low level of sediment contamination and the fact that very few surface water samples collected from the drainage ditches exceeded federal Ambient Water Quality Criteria (AWQC) and Virginia Water Quality Criteria. For these reasons, only one remedial action objective will be considered for the Area A surface water/sediments:

1. Prevent exposure to potential contaminants within Area A surface water/sediments.

Since there are currently no unacceptable risks to human health associated with surface water/sediments at the Area A Landfill, only the following two general response actions will be considered:

- No action
- Institutional controls

2.4.1.3 Area A Groundwater

As discussed in Section 1.0, groundwater contamination in the Area A region is located in two main areas of the landfill; directly west of the Brig Facility and along the northern portion of the site. For purposes of the FS, these areas have been identified as Areas A1 and A2, respectively. Both shallow (water table aquifer) and deep (Yorktown Aquifer) groundwater contamination are present within these areas. The

results of the human health risk assessment indicate that, although there are no unacceptable human health risks under the current nonpotable use scenario, there would be an unacceptable human health risk associated with Areas A1 and A2 if either the shallow or deep groundwaters were to be used as a drinking water source.

The general approach used for development of groundwater containment and treatment scenarios in the FS was to estimate the downgradient edge of contaminated areas based on available information while making only limited assumptions concerning the upgradient extents of contaminant plumes. In general, the groundwater cleanup goals developed in Section 2.3.2 for the organic contaminants were used to estimate the downgradient extents of groundwater contamination in the Yorktown Aquifer. As discussed in Section 1.0, the inorganic contaminants detected in the groundwater are believed to be associated with turbidity in the wells and not representative of actual groundwater contamination.

The estimated extents of groundwater contamination for Area A1 are shown in Figures 1-8 and 1-9 for the water table and Yorktown aquifers, respectively. The estimated extents of groundwater contamination for Area A2 are shown in Figures 1-10 and 1-11 for the water table and Yorktown aquifers, respectively.

As noted in Section 1.3.1, all of the shallow monitoring wells in Area A1 were bailed dry during the pre-design investigation and would not sustain a continuous pump rate. Based on the in situ and monitoring well sampling results from the pre-design investigation, groundwater contamination in the vicinity of the Brig (near wells A1-B20WSS, A1-MW20, and A1-MW21) appears to be present as small, isolated areas, or "pockets" of contamination rather than as one continuous contaminant plume. These pockets of groundwater contamination may be relatively stagnant because of the very low transmissivity of the water table aquifer in this area. In general, these small pockets of contamination appear to be located beneath the contaminated soil areas, which are indicated by the test pit results shown in Figure 1-6. Therefore, the extent of shallow groundwater contamination in Area A1 is assumed to be identical to the contaminated soil areas shown in Figure 2-1.

With respect to shallow groundwater in Area A2, the primary area of contamination appears to be located in the northern part of the landfill in the immediate vicinity of test pits A2-TPW05 and A2-TPW07 (Figure 2-2) based on the in situ sampling results from the pre-design investigation. No information is available concerning the transmissivity of the water table aquifer in this area. Similar to Area A1, for purposes of the FS, the extent of shallow groundwater contamination in Area A2 is assumed to be identical to the contaminated soil area shown in Figure 2-2.

The following remedial action objectives will be considered for the Area A groundwater:

1a. Prevent exposure to (ingestion, inhalation, and dermal contact) groundwater exceeding drinking water standards for the Yorktown Aquifer.

1b. Prevent exposure to (inhalation and dermal contact) groundwater exceeding nonpotable use cleanup goals for the water table aquifer.

2a. Prevent further migration of contaminated groundwater in excess of drinking water standards for the Yorktown Aquifer.

2b. Prevent further migration of contaminated groundwater in excess of nonpotable use cleanup goals for the water table aquifer.

3a. Restore contaminated groundwater to drinking water standards for the Yorktown Aquifer.

3b. Restore contaminated groundwater to nonpotable use cleanup goals for the water table aquifer.

The following general response actions will be considered for the Area A groundwater:

- No action
- Institutional controls
- Containment
- Collection, treatment, and discharge
- In situ treatment

2.4.2 Area B Landfill

2.4.2.1 Area B Soils

The results of the risk assessment indicate that there would be no unacceptable risks to human health posed by exposure to the surface soils at the Area B Landfill under the current land use (industrial-type usage for landfill and use of the Camp Allen Elementary School area by children). However, since this site is a former landfill that received a variety of waste materials, it is likely that buried contamination is present within the landfill. Therefore, exposure to potential contamination within the landfill is a human health concern. The Area B Landfill encompasses an area of approximately 3 acres.

As discussed in Section 1.0, a removal action is being implemented for the areas of contamination in the landfill that have been identified as potential sources of groundwater contamination. The objective of the removal action is to remove the sources of groundwater contamination within the Area B Landfill so that no further remedial actions are required for the soils and debris associated with the Area B Landfill. For this reason, source control general response actions for the Area B Landfill will not be considered in the FS. Only one remedial action objective will be considered for the Area B soils.

1. Prevent exposure to potential contaminants within subsurface soils and debris.

Since the surface soils do not pose an unacceptable risk to human health, and the potential sources of groundwater contamination will be eliminated by the removal action, only two general response actions will be considered for the Area B soils as follows:

- No action
- Institutional controls

2.4.2.2 Area B Surface Water/Sediments

The results of the risk assessment indicate that there would be no unacceptable risks to human health posed by exposure to the sediments at Area B under the current use scenarios. Under a potential future residential use scenario, the calculated incremental cancer risk is within acceptable levels, and the hazard index of 1.6 slightly exceeds the acceptable levels of 1. Therefore, exposure to potential contamination in the Area B sediments is a human health concern under a potential future residential use scenario.

Migration of contaminants from sediments to groundwater is not considered to be a pathway of concern since relatively low levels of contaminants were detected in the sediments, and shallow groundwater generally discharges into the drainage ditches. For this reason, only one remedial action objective will be considered for the Area B surface water/sediments:

1. Prevent exposure to potential contaminants within Area B surface water/sediments.

Since there are currently no unacceptable risks to human health associated with the surface water and sediments at Area B, only the following two general response actions will be considered for the Area B sediments:

- No action
- Institutional controls

2.4.2.3 Area B Groundwater

Groundwater contamination in Area B is located in the vicinity of the landfill. The groundwater in Area B currently is not used for any purpose; however, the results of the human health risk assessment indicate there would be an unacceptable risk level associated with Area B if either the water table or Yorktown aquifers were to be used for their respective beneficial use.

Similar to Area A, the general approach used for development of groundwater containment and treatment scenarios in the FS was to estimate the downgradient edge of contaminated areas based on available information while making only limited assumptions concerning the upgradient extents of contaminant plumes. In general, the groundwater cleanup goals developed in Section 2.3.2 were used to estimate the downgradient extents of groundwater defined as "contaminated." The estimated extents of groundwater contamination for Area B are shown in Figures 1-12 and 1-13 for the water table and Yorktown aquifers, respectively.

As shown in Figure 1-2, the general shallow groundwater flow direction in Area B is toward the southeast, and the Yorktown groundwater flow direction is also toward the southeast. The groundwater flow direction of the Yorktown Aquifer in Area B was determined to be toward the northeast during the RI. However, additional information obtained during the pre-design investigation indicates that a groundwater divide occurs in the Yorktown Aquifer at the site and that groundwater flow in this aquifer in Area B actually is toward the southeast.

The following remedial action objectives will be considered for the Area B groundwater:

1a. Prevent exposure to (ingestion, inhalation, and dermal contact) groundwater exceeding drinking water standards for the Yorktown Aquifer.

1b. Prevent exposure to (inhalation and dermal contact) groundwater exceeding nonpotable use cleanup goals for the water table aquifer.

2a. Prevent further migration of contaminated groundwater in excess of drinking water standards for the Yorktown Aquifer.

2b. Prevent further migration of contaminated groundwater in excess of nonpotable use cleanup goals for the water table aquifer.

3a. Restore contaminated groundwater to drinking water standards for the Yorktown Aquifer.

3b. Restore contaminated groundwater to nonpotable use cleanup goals for the water table aquifer.

The following general response actions will be considered for the Area B groundwater:

- No action
- Institutional controls
- Containment
- Collection, treatment, and discharge
- In situ treatment

SECTION 3 - IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

This section includes the identification and screening of remedial technologies and associated process options that may be applicable for remediation of contaminated soils and groundwater at the Camp Allen Landfill Site. The technologies and process options have been organized according to the general response actions developed in Section 2.4. As discussed in Section 2.4, No Action and Institutional Controls (including physical access restrictions) were the only two general response actions developed for sediments at the Camp Allen Landfill Site. The technologies and process options included under these two general response actions are essentially identical for the soils and sediments. Therefore, separate technology identification and screening subsections for the sediments have not been included in this section.

The identification and screening of remedial technologies and process options are provided in Sections 3.1 and 3.2 for soils and groundwater, respectively. In each section, a preliminary identification and screening of technologies and process options is first conducted to evaluate their overall applicability to the site contaminants as well as their general implementability to site-specific conditions (Sections 3.1.1 and 3.2.1). Following the preliminary screening, the retained technologies and process options are evaluated in more detail based on their effectiveness, implementability, and cost (Sections 3.1.2 and 3.2.2). Finally, the technology screenings are summarized in Sections 3.1.3 and 3.2.3 for the soils and groundwater, respectively. In these summary sections, representative process options will be selected for assembly into remedial alternatives in Sections 4.0 and 6.0 for soils and groundwater, respectively.

3.1 Identification and Screening of Technologies and Process Options for Soils

3.1.1 Preliminary Screening of Soil Technologies and Process Options

In this step, an initial set of soil technologies and process options was identified and screened by evaluating their technical implementability and site-specific factors, such as applicability to the contaminants of concern. All soil technologies and process options that may be applicable to the site contaminants and to the site conditions were retained for further evaluation in Section 3.1.2. A summary of the preliminary identification and screening of potentially applicable soil technologies and process options is presented in Table 3-1.

TABLE 3-1
INITIAL SCREENING OF SOIL REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	Not Applicable	No Action.	Required for consideration by NCP.
Institutional Actions	Access Restriction	Fencing	Erect fencing to reduce site access.	Not applicable, risk levels are currently within acceptable levels.
	Land Use Controls	Base Master Plan	Use of Base Master Plan to restrict current and future land use on Base.	Potentially applicable.
	Legal Restrictions	Deed Restrictions	Use of deed restrictions to restrict future site uses if the Base were to close in the future.	Potentially applicable.
Containment Actions	Capping	Clay Cap	Clay cap to prevent contact with soil and restrict infiltration of precipitation.	Potentially applicable.
		Synthetic Membrane	Synthetic membrane cap to prevent contact with soil and restrict infiltration of precipitation.	Potentially applicable.
		Composite Cap	Clay cap to prevent contact with soil and restrict infiltration of precipitation.	Potentially applicable.
		Asphalt Cap	Application of asphalt over areas of contamination to prevent contact with soil and restrict infiltration of precipitation.	Potentially applicable.
		Soil Cover	Soil layer to prevent contact with soil.	Not applicable. Landfills are already capped with a soil cover and surface soils do not pose an acceptable risk.
	Vertical Barriers	Slurry Wall	Trench around areas of contamination is filled with a soil (or cement) and bentonite slurry.	Potentially applicable.
		Sheet Piling	Sheet piling is constructed around areas of contamination.	Potentially applicable.

TABLE 3-1
INITIAL SCREENING OF SOIL REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Excavation/Disposal	Excavation	Conventional Excavation Equipment	Removal of contaminated soil using conventional excavation equipment.	Potentially applicable.
	Off-Site Disposal	RCRA Hazardous Waste Landfill	Excavated soils are transported to a RCRA-permitted facility for disposal.	Potentially applicable.
		Solid Waste Landfill	Excavated soils are transported to a permitted solid waste landfill such as a sanitary landfill, for disposal.	Potentially applicable to nonhazardous contaminated soil.
Excavation Treatment/Disposal	Excavation	Conventional Excavation Equipment	See "Excavation/Disposal" above	Potentially applicable.
	Physical Treatment	Soil Washing	The extraction of contaminants from excavated soil by mixing the soil with water solvent, surfactants or chelating agents.	Potentially applicable.
	Chemical Treatment	Chemical Dechlorination	Processes which use specially synthesized chemical reagents to destroy hazardous chlorinated molecules or to detoxify them to form other harmless compounds.	Not applicable to contaminants of concern.
	Biological Treatment	Land Treatment (Aerobic)	Contaminated soils are excavated and placed in a designated treatment bed where nutrients and water are applied to promote biodegradation. The soils are tilled to enhance biodegradation.	Potentially applicable.

TABLE 3-1
INITIAL SCREENING OF SOIL REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Excavation Treatment/Disposal (continued)	Biological Treatment (continued)	Composting (Aerobic)	Contaminated material is mixed with a bulking agent, such as manure or leaves. The mixture undergoes a self-heating process caused by microbial activity. Then the mixture is cured for 30 days.	Potentially applicable.
		Anaerobic Biological Treatment	Natural degradation of organic contaminants via microorganisms in an anaerobic (oxygen-deficient) environment.	Not feasible because this technology is relatively undeveloped.
	Thermal	Incineration	Volatilization and oxidation of organics via contact with high temperatures and oxygen. Common units include rotary kiln and fluidized/ circulating bed reactors.	Potentially applicable.
		Vitrification	Involves combining the contaminated soil with molten glass at a temperature of 1,5000 degrees C or greater.	Potentially applicable.
		Low Temperature Thermal Treatment	Use of moderate temperatures (400°F-800°F) to volatile organics. Constituents in the off-gas can be incinerated or recovered.	Potentially applicable.
	Solidification/Fixation/ Stabilization/ Immobilization	Cement-Based Solidification	This process involves mixing the soil directly with Portland cement.	Not applicable to contaminants of concern.
		Solicate-Based Solidification	This process involves the solidification/ stabilization of the soil with siliceous material and various setting agents.	Not applicable to contaminants of concern.

TABLE 3-1
INITIAL SCREENING OF SOIL REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Excavation Treatment/Disposal (continued)	Solidification/Fixation/ Stabilization/ Immobilization (continued)	Thermplastic Solidification	Involves sealing wastes in a matrix such as asphalt, bitumen, paraffin, or polyethylene.	Not applicable to contaminants of concern.
		Surface Microencapsulation	Physically microencapsulating wastes by sealing them in an organic binder or resin.	Not applicable to contaminants of concern.
	Off-Site Treatment	Soil Recycling - Asphalt Incorporation	Involves the incorporation of contaminated soils into hot asphalt mixes as a partial substitute for stone aggregate.	Not applicable to contaminants of concern.
		Soil Recycling - Cement Production	Contaminated soils are introduced as raw materials into the cement production process.	Not applicable to contaminants of concern.
		Soil Recycling - Brick Manufacturing	Contaminated soil is blended with clay and shale, raw materials used in the brick manufacturing process.	Not applicable to contaminants of concern.
		Bioremediation Cell Facility	Contaminated soils are bioremediated using a land treatment technique.	Potentially applicable.
		Incineration	Volatilization and oxidation of organics via contact with high temperatures and oxygen. Common units include rotary kiln and fluidized/ circulating bed reactors.	Potentially applicable.
		RCRA Hazardous Waste Landfill	See "Excavation/Disposal" above	Not applicable to contaminants of concern.
In Situ Treatment	Biological Treatment	Aerobic Bioremediation	System of injection and extraction wells to introduce bacteria and nutrients under aerobic conditions in order to degrade contaminants.	Potentially applicable.

TABLE 3-1
INITIAL SCREENING OF SOIL REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
In Situ Treatment (continued)	Biological Treatment (continued)	Anaerobic Bioremediation	System of injection and extraction wells to introduce bacteria and nutrients under anaerobic conditions in order to degrade contaminants.	Not feasible because this technology is relatively undeveloped.
	Chemical Treatment	Polymerization	Render contaminants insoluble through polymerization and thereby prevent migration.	Not applicable to contaminants of concern.
		Precipitation	Render contaminants insoluble through precipitation and thereby prevent migration.	Not applicable to contaminants of concern.
		Oxidation	Destroy, degrade, or reduce the toxicity of contaminants through oxidation.	Not applicable to contaminants of concern.
		Reduction	Destroy, degrade, or reduce the toxicity of contaminants through reduction.	Not applicable to contaminants of concern.
		Neutralization	Destroy, degrade, or reduce the toxicity of contaminants through neutralization.	Not applicable to contaminants of concern.
		Hydrolysis	Destroy, degrade, or reduce the toxicity of contaminants through hydrolysis.	Not applicable to contaminants of concern.
	Physical Treatment	Soil Vapor Extraction/ Dual Phase Vacuum Extraction	System of injection and extraction wells used to introduce clean air to remove volatile contaminants from the shallow groundwater and/or soil.	Potentially applicable.
		Soil Flushing	An aqueous solution is injected into or sprayed into the affected area and is collected downgradient and then treated.	Potentially applicable.
	Thermal Treatment	In Situ Vitrification	Contaminated soil is converted into a durable glass and crystalline form by melting the soil by electric heat.	Potentially applicable.

TABLE 3-1
INITIAL SCREENING OF SOIL REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
In Situ Treatment (continued)	Thermal Treatment (continued)	In Situ Heating	Destroys or removes organic contaminants in soil through thermal decomposition, vaporization, and distillation.	Potentially applicable.
		Artificial Ground Freezing	Involves the installation of freezing loops in the ground with a self-contained refrigeration system that pumps coolant around the loops. Soils around the waste are frozen. Temporary treatment.	Not applicable because this technology represents a temporary treatment.

3.1.2 Screening of Retained Soil Technologies and Process Options

3.1.2.1 No Action

A no action response provides the baseline assessment for the comparison with other remedial alternatives that have a greater level of response. The National Oil and Hazardous Substances Contingency Plan (NCP) requires the evaluation of the no action alternative as part of the FS process. A no action alternative scenario may be considered appropriate when an alternative response action may cause a greater environmental or health danger than a no action alternative itself or when estimated risks to human health and the environment are within acceptable levels. No action would not be effective in preventing contaminants in soils from leaching into the groundwater nor would it prevent direct contact with potentially contaminated soil.

Because the NCP requires the evaluation of the no action response action, this option will be retained for further evaluation.

3.1.2.2 Institutional Controls

Institutional controls consist of activities designed to minimize potential risks to human health by prohibiting or restricting access to contaminated soil. Institutional controls can include land use controls, such as through use of the master plan for the site, deed restrictions, as well as physical access restrictions, such as fences and barriers. Some physical access restrictions are currently in place at the site including fencing and Jersey barriers around the Area B landfill, fencing around much of the Camp Allen Elementary School, and fencing along some of the property boundary west of the Brig Facility.

3.1.2.2.1 Land Use Controls

Land use on site is currently designated under the existing base master plan entitled "Master Plan, Marine Corps Camp Elmore/Fleet Marine Force, Atlantic (MCE/FMFLANT), Norfolk, Virginia," October, 1990. Additional land use designations could be incorporated into the master plan, if necessary.

There are currently no plans to close Camp Allen. However, if the base were to close at some point in the future, deed restrictions could be implemented to prevent potentially contaminated areas of the site from being used for residential purposes. Deed restrictions would restrict future site activities and land uses,

thereby limiting future excavation and exposure to contaminated soils and waste materials present within the Area A and Area B landfills.

Land use controls are effective in preventing contact with potentially contaminated areas and are readily implementable. Therefore, they will be retained for further consideration.

3.1.2.3 Containment

3.1.2.3.1 Capping

The primary purpose of a cap at the Camp Allen Site would be to protect groundwater by reducing infiltration of precipitation through the waste material, thus reducing leaching of contaminants to groundwater. The effectiveness of the cap, however, would be limited because the landfill is not lined with a low-permeability material and the groundwater is very shallow (e.g., approximately 4 to 8 feet below ground surface) throughout the Camp Allen Site. Additionally, contaminated soils or debris have found to be present very close to, and in localized areas beneath, the water table, where fluctuations in groundwater levels could cause releases of contaminants to groundwater.

The cap would also prevent direct contact with contaminated soil and debris. However, Area A and B landfills are currently covered with a soil layer, and the results of the human health risk assessment indicate that risks associated with exposure to the surface soils are within acceptable levels.

Capping process options include clay caps, synthetic membranes, composite caps, and asphalt caps, which are described in the following paragraphs.

Clay Cap

This process option consists of the construction of a cap composed of a single clay layer. Typically, construction of a clay cap is readily performed. The material of construction, clay, is usually available locally. The equipment used for the placement of the cap is for the most part road construction equipment (Wagner, 1986). Based on these considerations, placement of a clay cap will be retained for further consideration.

Synthetic Membrane

This process option consists of the placement of a single synthetic membrane on the ground surface, above the contaminated soil areas. Typically, placement of a synthetic membrane cap is readily performed. A variety of synthetic membranes are manufactured and are widely available. The equipment used for the placement of the cap is for the most part road construction equipment (Wagner, 1986). Based on these considerations, this process option will be retained for further screening.

Composite Cap

This process option consists of the placement a composite cap above the contaminated soil areas. This cap would consist of three layers: an upper vegetative layer; a middle drainage layer; and a lower low-permeability layer. Typically, placement of a composite cap is readily performed. The materials of construction, including topsoil, sand, clay, and synthetic membranes, are available locally. The equipment used for the placement of the cap is for the most part road construction equipment (Wagner, 1986). Based on these factors, placement of a composite cap will be carried forward for further screening.

Asphalt Cap

This process option consists of the application of a layer of asphalt over the areas of soil contamination. Typically, construction of a asphalt cap is readily performed. The material of construction, asphalt, is usually available locally. The equipment used for the placement of the cap is for the most part road construction equipment (Wagner, 1986). Based on the relative ease of implementation, this process option will be retained for further consideration.

3.1.2.3.2 Vertical Barriers

Process options for vertical barriers include slurry walls and sheet piling. These options are summarized below.

Slurry Wall

Under this process option, a backhoe would be used to excavate a trench down to a low-permeability confining layer, such as bedrock or, in the case of the site, a clay layer. This trench would then be backfilled with soil materials mixed with a bentonite-water slurry. The purpose of the slurry wall is to

provide a barrier to groundwater flow in the horizontal direction, thus reducing the migration of groundwater through the contaminated area.

Slurry walls must be keyed into a low-permeability layer in order to effectively contain the waste or contaminated soil. The slurry wall would also need to be constructed around the area of soil contamination and be used in conjunction with a low permeability cap in order to be effective.

The slurry wall process option will be eliminated from further consideration. The absence of a low-permeability confining layer in large areas of the landfill would significantly limit the effectiveness of a slurry wall. Many of the contaminants of concern have densities that are greater than that of water and are therefore "sinkers." Contaminants present in the shallow aquifer could continue to migrate vertically into the Yorktown Aquifer even after a slurry wall is constructed.

Sheet Piling

This process option would include the installation of steel sheet pilings. The sheet pilings are essentially interlocking steel panels installed vertically within soil in order to form a horizontal barrier to groundwater flow. The primary constraint that would prevent the installation of sheet piling at a given site is that it cannot be installed in rocky soil. The presence of cobbles or boulders within the soil tends to deflect or damage the sheet piling as it is driven into the soil (Wagner, 1986).

Similar to slurry walls, sheet piling must be keyed into a low-permeability layer in order to effectively contain the waste or contaminated soil. The piling would also need to be constructed around the area of soil contamination and be used in conjunction with a low permeability cap in order to be effective.

The sheet piling process option will be eliminated from further consideration for the same reasons that slurry walls were eliminated.

3.1.2.4 Excavation/Disposal

3.1.2.4.1 Excavation

Excavation of contaminated soils is performed extensively in waste site remediation. There are no absolute limitations on the types of waste which can be excavated and removed (Wagner, 1986).

Excavation and removal activities involve the physical removal of contaminated soil by using conventional heavy construction equipment such as backhoes, cranes, bulldozers, and loaders. This is a common and well-established technique used at many waste sites. A typical practice is to excavate and remove contaminated "hot spots" and to employ other remedial technologies for less contaminated soils.

Excavation would be most readily implemented for shallow areas of soil contamination, which are easily accessible. Excavation under or near buildings would require shoring and therefore would be more difficult. Excavation would also be slightly more difficult in areas containing underground utilities or for contaminated soils beneath asphalt or concrete. Excavated soils may require screening, shredding, and/or crushing in order to remove debris and boulders prior to treatment and/or disposal.

Excavation is applicable to potential "hot spot" areas in Area A and will be retained for further evaluation.

3.1.2.4.2 Off-Site Disposal

Hazardous Disposal

This technology consists of transporting the excavated soils to a RCRA-permitted hazardous waste disposal facility for ultimate disposal. There are currently at least six RCRA-permitted disposal facilities located east of the Mississippi River. The closest facility is located approximately 375 miles from the site. Adequate landfill capacity is not expected to be a concern. If the soils are classified as a RCRA-listed hazardous waste, such as F001-F005 spent solvent waste, then contaminant levels must be below the RCRA Land Disposal Restriction (LDR) standards in order for them to be disposed. If the soils contain contaminants above the LDR standards, then they must be treated using the Best Demonstrated Available Technology (BDAT) prior to disposal. The BDAT for F001-F005 wastes is incineration.

With respect to the site, this is an applicable technology and will be retained for further evaluation.

Nonhazardous Disposal

This process option would consist of the disposal of the excavated soil in a nonhazardous, solid waste landfill, such as a sanitary, industrial, or construction debris landfill. Solid waste landfills are located near the site, such as the one located in Charles City, Virginia. Nonhazardous disposal would only be an applicable process option for soils that are not classified as a RCRA hazardous waste. Solid waste landfills will typically accept nonhazardous soils that contain petroleum hydrocarbons and low levels of metals.

However, these landfills are often not permitted to accept soils containing chlorinated organics, such as TCE and vinyl chloride (the primary contaminants of concern), even if they are not classified as a RCRA hazardous waste. For this reason, this technology is not to be retained for further evaluation as a primary disposal alternative. However, this technology will be retained as an auxiliary technology that could be used in conjunction with another technology, such as for disposal of debris generated from screening of soils prior to on-site thermal treatment, disposal of a temporary decontamination pad, or disposal of a temporary asphalt cap used for a vapor extraction system.

3.1.2.5 Excavation/Treatment/Disposal

3.1.2.5.1 Physical Treatment

Soil Washing

Soil washing, or solvent extraction, is the extraction of contaminants from excavated soil by mixing the soil with water, solvents, surfactants, or chelating agents. The contaminated water or solution is then treated for removal of the extracted contaminants (USEPA, 1987a). The extracted slurry of water and soil can be dewatered by conventional techniques such as sedimentation, filtration, evaporation, or drying beds. The treated soil can then be put back into the original excavation or disposed at a sanitary landfill. Extracted contaminants can be treated with activated carbon or other treatment methods. Heavily contaminated soils may need to be treated several times in a multistage countercurrent treatment system (USEPA, 1987a).

Several mechanical systems have been developed to wash soil, however, very few systems have actually been used on a full scale. These "washing machines" utilize pugmills, feed augers, or other mixing equipment to blend soil and washwater (or surfactants) to extract the contaminants (Testa, 1991). Mobile soil washing systems are available for set up at waste sites, however, the throughput of these systems is relatively low (i.e., 1 to 2 tons per hour). The USEPA has developed a mobile soil washing system which has been successfully demonstrated at hazardous waste sites (USEPA, 1987a). Some skid mounted units can process approximately 20 tons of soil per day.

Soil washing would be easier to implement when a single or a few specific contaminants are involved than for sites containing both metals and organic contaminants. The most suitable soils are those with a low organic content, a low cation exchange capacity, and a permeability greater than 1×10^{-4} centimeters per second. A sandy porous soil is more easily treated than clay or silt (USEPA, 1987a). For soils containing

fine-grained particles, such as silts or clays, material handling, dewatering of treated soils, and removal of fines from the solvent may be difficult.

Soil washing is potentially applicable to the treatment of heavy metals, halogenated aliphatics (e.g., trichloroethylene), aromatics (e.g., benzene, toluene), and volatile hydrocarbons such as gasoline. Surfactants have been used to remove hydrophobic organics (e.g., polynuclear aromatic hydrocarbons, PCBs, chlorinated phenols) from soils (USEPA, 1987a). Bench- and pilot-scale testing would most likely be required to demonstrate the effectiveness and implementability of this technology at the Camp Allen Site.

Soil washing appears to be potentially applicable to the contaminated soils at the site. However, this technology has been demonstrated on a full scale at only a few sites. The cost of this technology is expected to be, at best, comparable to that of low temperature thermal treatment (see Section 3.1.2.5.3) and could possibly be more than low temperature thermal treatment (e.g., $250 to $300/ton compared to $150 to $250/ton). In addition, low temperature thermal treatment has been more widely demonstrated, is expected to achieve an equal or greater degree of contaminant removal than soil washing, may achieve a higher throughput, and would not require dewatering of the treated material. For these reasons, soil washing is eliminated from further evaluation.

3.1.2.5.2 Biological Treatment

Biological treatment of contaminated soil is typically conducted aerobically (with oxygen). Two of the most commonly used process options for biological treatment are land treatment and composting, which are described in the following sections.

Land Treatment

Land treatment (or landfarming) is a biological process by which affected soils are excavated/removed and spread over an area to enhance naturally-occurring processes which include: volatilization, aeration, biodegradation, and photolysis. Landfarming is an effective method for the removal of hydrocarbons from affected soils, although a large amount of land and time may be required. Landfarming involves tilling and cultivating soils to enhance the biological degradation of hydrocarbon compounds (Weston, 1988). Additional agents (e.g., nitrogen, phosphorous, mulch, and organic nutrients) may be applied to provide nutrients, to control moisture, or to accomplish chemical or biological reactions (USEPA, 1987a).

In landfarming, the lighter hydrocarbons are removed through both volatilization and biodegradation, whereas biodegradation is mainly responsible for the decomposition of the heavier fraction of hydrocarbons. Factors influencing biodegradation of hydrocarbons in soil include: soil factors (microorganisms, topography, and moisture content); environmental factors (temperature and precipitation); chemical factors (soil pH and nutrients), and management factors (waste loading, hydraulic loading, and aeration) (Weston, 1988).

Landfarming is typically limited to organic wastes that are biodegradable, such as petroleum sludges, and to metals that can be immobilized in soil. Bench-scale testing may be required prior to field studies (USEPA, 1987a). It is a widely accepted and cost-effective practice for the treatment of petroleum hydrocarbons, chlorinated compounds, and pesticides. Landfarming is generally limited to wastes containing smaller hydrocarbon molecules; aromatic fractions are degraded nearly completely while PAHs degrade much slower.

With respect to the chlorinated organic compounds, which are the primary contaminants of concern at the Camp Allen Landfill Site (e.g., vinyl chloride, PCE, TCE), the biodegradability of these compounds is currently not well-demonstrated. Laboratory studies suggest that biodegradation of halogenated solvents, such as PCE and TCE, does not occur under aerobic conditions (Wilson et al., 1986, Bouwer et al., 1981). Recent laboratory studies have shown that TCE can be biodegraded to carbon dioxide and water in the presence of certain aromatic compounds, which include benzene and toluene (Litchfield, 1989) as well as in the presence of methane and propane (Fogel et al., 1986; Strand and Shippert, 1986; Henry and Grbic-Galic, 1986) through the process of cometabolism. The cometabolism process appears to work well for vinyl chloride and moderately well for TCE, but does not appear to be effective for PCE (Wilson, 1992). Bench- and pilot-scale studies are currently being conducted to develop a commercial process for biodegrading the chlorinated solvents via the cometabolism process, although no full-scale systems have been demonstrated to date.

Standard earth moving equipment such as dump trucks, front-end loaders, graders, bulldozers, rototillers, and/or disk tillers is used for landfarming application. In order to maintain proper soil moisture content, irrigation systems may be required during dry periods. A low-permeability liner and leachate collection system would most likely be required.

Biodegradation of chlorinated organic compounds is currently still in the developmental stages and is not commercially available. Therefore, landfarming will be eliminated from further consideration.

Composting

Composting is similar to landfarming because it relies on the destruction of organic compounds through microbial metabolism. It is an aboveground technology in which amended soil, containing organic wastes, is placed in large piles and aerated. Composting is a proven technology for achieving accelerated biodegradation of select industrial and municipal wastes under controlled conditions. In composting, the material to be composted may be mixed with a bulking agent such as wood chips, straw, horse manure, sawdust, leaves, or paper. The bulking agent can serve as a source of carbon, nutrients, or microbes, in addition to increasing porosity and aeration. Once the mixture is in place, it undergoes a self-heating process caused by microbial activity. After composting, the material is usually cured for approximately 30 days. During this period, additional decomposition as well as stabilization, pathogen destruction, and degassing take place (Weston, 1988). The decomposed waste is reduced in weight and volume, and the process produces a stabilized material which can be used as backfill.

Dump trucks, front-end loaders, graders, bulldozers, compost machines, mixing boxes, pugmills, and agricultural rototillers are typical equipment used for composting. Aeration equipment requires stationary and movable piping and blowers. Compost screening generally uses various types of screens or a vibratory deck (Weston, 1988).

With respect to chlorinated organic compounds, the effectiveness of this technology is similar to that of landfarming. Since biodegradation of chlorinated organic compounds is currently still in the developmental stages and is not commercially available, composting will be eliminated from further consideration.

3.1.2.5.3 Thermal Treatment

Incineration

Various types of incineration processes are commercially available and several are in development stages. Potential incineration process options include rotary kiln incineration, circulating bed combustion, fluidized bed incineration, infrared thermal treatment, plasma arc torch, and pyrolysis. Of these processes, rotary kiln incineration is the most commonly used process used for on-site treatment of waste materials.

A rotary kiln is a cylindrical, refractory-lined shell fueled by natural gas, oil, or pulverized coal. Waste is fed into the higher end of the rotating, tilted cylinder. As the cylinder rotates, the waste proceeds

toward the other end of the cylinder where it exits the system. Most rotary kilns are equipped with wet scrubber emission controls to treat off-gas of the system (Wagner, 1986).

Rotary kiln incinerators can process a large variety of waste (solids and liquids) with minimal preprocessing. PCBs, tars, obsolete munitions, polyvinyl chloride wastes, and bottoms from solvent reclamation operations have been treated using this technology. Solids and liquids can be incinerated independently or in combination (Wagner, 1986). This type of incineration is potentially applicable for the treatment of halogenated and nonhalogenated organics and inorganic cyanides.

Use of an on-site incinerator would most likely involve an extensive and expensive permitting process. The permitting process could involve an on-site trial burn, which are typically expensive to perform. Furthermore, on-site incineration would most likely encounter public opposition due to the close proximity of the Camp Allen Elementary School and Glenwood Park to the site. Finally, on-site incineration would be significantly more costly to implement (e.g., $500 to $1,000/ton compared to $150 to $250/ton) than would low temperature thermal treatment. For these reasons, on-site incineration is eliminated from further consideration.

Vitrification

Vitrification, or glassification, of wastes involves combining the wastes with molten glass at elevated temperatures. This melt is then cooled into a stable, noncrystalline solid. Of all of the common solidification methods, vitrification offers the greatest degree of containment (Wagner, 1986).

This process has been restricted to radioactive or very highly toxic waste (due to the high costs). Additionally, requirements for specialized equipment and trained personnel have limited the use of this technology to a great extent. Furthermore, this technology would be significantly more costly to implement than would low temperature thermal treatment. Because of these factors, vitrification will not be retained for further evaluation.

Low Temperature Thermal Treatment

Low Temperature Thermal Stripping (LTTS) technology consists of heating contaminated soil in a closed chamber to a temperature of approximately 400°F to 800°F to promote desorption and volatilization of organic contaminants. An LTTS system typically contains a pug mill or a rotary drum. Rotation of the

chamber increases the surface area of the soils exposed to the heating surfaces. The VOCs which are removed are then passed through an air emission control system.

Several vendors currently have transportable units for on-site implementation of this technology. One process consists of a dryer and an off-gas handling system. The dryer is a rotary kiln indirectly heated with propane. Contaminated soils are fed into the unit by an auger and heated to a temperature range of 500°F to 800°F. The temperature may be adjusted to volatilize SVOCs. Nitrogen is used as a carrier gas that conveys the volatilized vapors and organic compounds to a three-stage cooling and condensing train. The carrier gas is reheated and recycled. A part of the carrier gas is filtered and treated by activated carbon adsorption, prior to being vented.

Another company has a patented Low Temperature Thermal Treatment (LT^3) system. The LT^3 has been used at several sites on a full-scale to remediate soil contaminated with petroleum hydrocarbons as well as chlorinated organics. The thermal processor is an indirectly heated auger-type heat exchanger. The system operates at a temperature of approximately 400°F. Sweep gas, a mixture of air and exhaust gases from the indirect firing system (fired on propane, natural gas, or oil), carries volatiles to a baghouse, then through two condensers prior to being treated by activated carbon adsorption. The full-scale unit is designed to process 7.5 tons per hour (Nielson et al., 1989), and a larger, 15 ton per hour unit is currently being developed (Cosmos, 1993).

Low Temperature Thermal Stripping (LTTS) has been demonstrated at a number of sites. It can be very effective at removing VOCs from contaminated soil. This technology is most effective for VOCs. However, LTTS has been partially effective for SVOCs.

LTTS requires soil handling equipment, a heating chamber, and some type of air pollution control system. On-site trial runs to demonstrate compliance with permitting requirements might be needed, which could be costly and time consuming. Public opposition to this technology is a potential concern because of the close proximity of the Camp Allen Elementary School and Glenwood Park to the site.

Low temperature thermal treatment is an effective, demonstrated process of treating contaminated soils and would be significantly more cost-effective than incineration. Therefore, this technology will be retained for further consideration.

3.1.2.5.4 Off-site Treatment

Bioremediation Cell Facility

There are a limited number of commercial bioremediation cell facilities that are currently operating for treatment of nonhazardous contaminated soils and sludges. One facility, located near New Bern, North Carolina, operates a landfarming-type process that is performed indoors. The soil is treated in a containment cell constructed of a low-permeability liner with a leachate collection system. The soils are mixed with chicken manure to enhance biological activity and biodegradation of contaminants.

Bioremediation facilities are typically not permitted to accept chlorinated organic compounds, such as TCE and vinyl chloride. As discussed in Section 3.1.2.7, aerobic biodegradation of these chlorinated compounds is currently not well-proven. For this reason, off-site treatment of the soils in a bioremediation facility will be eliminated from further consideration.

Incineration

Off-site incineration technology is basically similar to on-site incineration only that it is conducted at a permanent facility and using larger equipment. Off-site incinerators must be RCRA-permitted in order to treat materials as classified RCRA hazardous waste. There are a limited number of RCRA-permitted incinerators in the United States (e.g., less than 10 facilities located within 1,000 miles of the site), therefore, capacity could potentially be a problem if the amount of contaminated soil is large. The closest RCRA-permitted incinerator is located approximately 300 miles from the site.

The easiest method of transporting contaminated soil to an incinerator would be in bulk form (e.g., lined trucks or roll-offs). However, some of the incinerators can only receive and incinerate solid materials in drums, which would increase material handling costs.

Off-site incineration would most likely not be selected for treatment of contaminated soils due to its high cost (e.g., $1,000 to $1,500/ton). However, incineration might be the most appropriate treatment method for small quantities of contaminated waste materials, such as drums containing waste oils/solvents or oily sludges, should they be identified within a "hot spot" area of the landfill. For this reason, off-site incineration will be retained for further consideration.

3.1.2.6 In Situ Treatment

3.1.2.6.1 Aerobic Biological Treatment

In-situ bioremediation can simultaneously remediate contaminated soils and groundwater. One process option involves pumping the groundwater to the ground surface into a bioreactor where nutrients and/or microorganisms are added, and the contamination is treated. The treated groundwater can then be discharged and recirculated back into the contaminated soil.

Bioreactor types include stirred-tank suspension, fixed-film, and plug-flow units. Fixed-film reactors offer higher biomass per unit volume and are more resistant to shock loading than suspension systems (Nelson, 1991). In addition, fixed-film systems also help to prevent washout, and the solid phase of some systems may consist of material capable of absorbing dissolved metallic compounds. Process environmental conditions can be controlled using standard equipment similar to those used in sewage treatment applications.

Nutrient-rich effluent from the bioreactors is re-introduced to the subsurface via injection wells or infiltration galleries to promote the biodegradation process in the subsurface. Essential nutrients can be used to stimulate the indigenous microbial population. Infiltration galleries may allow treatment within an unsaturated zone.

One of the major limitations for aerobic biodegradation in the subsurface is the minimal amount of available oxygen in the soil. Three different methods can be used to provide the necessary oxygen: addition of hydrogen peroxide to the groundwater prior to recirculation; addition of ozonation products to the groundwater prior to recirculation; and use of extraction/injection wells for inducing air flow through the soil (i.e., vapor extraction). The applicability of these techniques is contingent upon site-specific chemical, hydrogeologic, and microbial considerations.

For optimal bioremediation, soils with high hydraulic conductivity, Ph in the range of 6.0 to 8.0, and temperature range of 20°C to 35°C are necessary.

Although this technology has been demonstrated at several hazardous waste sites and underground storage tank locations, it is a relatively innovative technology, and a pilot-scale test would most likely be required.

In-situ bioremediation requires a moderate amount of process and operation equipment, depending on the type of system implemented. Key components could include a groundwater infiltration/injection system; extraction wells; and above-ground bioreactor system. This equipment can be purchased from and provided by a number of vendors. The bioreactors may require some type of off-gas treatment system. Surfactants/solubilizers may be added to enhance the process.

As described in Section 3.1.2.5.2, previous experience suggests that bioremediation can be used to degrade petroleum hydrocarbons, but that the effectiveness of bioremediation for treating chlorinated organics, such as TCE, is not well-proven and is currently in developmental stages. Therefore, in situ bioremediation will be eliminated from further consideration.

3.1.2.6.2 Soil Vapor Extraction/Dual Phase Vacuum Extraction

Soil vapor extraction is a proven and cost-effective technique for removing VOCs from contaminated soil. Soil vapor extraction systems are relatively easy to construct from standard, readily-available equipment. A soil vapor extraction system consists of: pumps or blowers to provide the vacuum for contaminant removal; piping and valves to transmit the air from the wells through the system; instrumentation to measure the contaminant concentration and total air flow; vapor pretreatment to remove soil and water from the vapor stream; and an emission control unit to collect or remove vapor-phase contaminants.

Soil vapor extraction is effective in reducing the concentration of VOCs in the vadose zone. This subsequently reduces the potential for further transport of contaminants because of the migration of vapor as well as infiltration of precipitation. This technology also can be used in conjunction with groundwater extraction and treatment.

Dual phase vacuum extraction (DPVE) is an innovative technology, similar to soil vapor extraction, for remediating soil and groundwater using a single extraction system. This technology is most useful for shallow aquifers with low hydraulic conductivities, such as the shallow aquifer at Area A. The system uses high vacuum (>25″ Hg vacuum) to strip the vadose zone of VOCs while simultaneously removing groundwater (in liquid and vapor form) from the shallow aquifer. This two-phase stream is then sent to an air/water separator. The vapor phase is typically treated using activated carbon, and the water stream is intermittently pumped to either an on-site groundwater treatment facility or a collection tank for off-site treatment and disposal.

Because of the proven nature of soil vapor extraction technology, its relative ease of construction, and its applicability to VOCs, both soil vapor extraction and DPVE will be retained for further consideration.

3.1.2.6.3 Soil Flushing

Soil flushing is the in situ version of soil washing. Soil flushing can also be referred to as solvent flushing, ground leaching, solution mining, or in situ chemical (mobilizing) treatment. Soil flushing is the process in which contaminants are washed from the soil by water or an aqueous solution. The contaminants are then collected by recovery wells and treated above ground. Soils lying above or below the water table can be treated via soil flushing. During the flushing process, the flushing solution mobilizes the sorbed contaminants by dissolution or emulsification. The collection system is usually a series of shallow well points or subsurface drains (Weston, 1988). At a site contaminated by organic constituents, recycling the elutriate back through the soil for treatment by biodegradation may be possible (USEPA, 1987a).

Flushing solutions may include water, acidic aqueous solutions, basic solutions, and surfactants. Water is used to extract water soluble or water-mobile constituents (high solubility, low octanol/water partition coefficient). Water flushing also can be used effectively to remove medium-solubility organics from soil, such as: low- to medium-molecular weight ketones, aldehydes, and aromatics; and lower molecular-weight halogenated hydrocarbons, such as trichloroethylene and tetrachloroethylene. Acidic solutions are used for metals recovery and for basic organic constituents (e.g., amines, ethers, and anilines). Basic solutions are used for flushing metals (e.g., tin, zinc, and lead), as well as for some phenols, complexing and chelating agents, and surfactants (low solubility, high octanol/water partition coefficient) (USEPA, 1987a). For contaminants with low water solubility, some type of surfactant solution or solvent is necessary.

Equipment necessary for soil flushing includes drains, an elutriate collection and distribution system, and a mixing area or hopper for the preparation and storage of the surfactant/water solution. Reapplication of collected elutriate may require construction of a holding tank for the elutriate (USEPA, 1987a).

Soil flushing may be easy or difficult to apply, depending on the ability to flood the soil with the flushing solution and to install collection wells or subsurface drains to recover all the applied liquids. The achievable level of treatment varies and depends on the contact of the flushing solution with the contaminants, the appropriateness of solutions for the contaminants, and the hydraulic conductivity of the soil. The technology is more applicable to highly permeable soils (USEPA, 1987a). A high water solubility, a low soil-water partition coefficient (K_{oc}), and a porous soil matrix aid in the effective removal of compounds from soils using soil flushing (Weston, 1988).

Soil flushing has been used on a full scale at very few hazardous waste sites. One reason for its limited use is that it is generally much more effective and economical to remediate the source area, either through excavation and treatment or via vapor extraction, than it is to flush contaminants into the groundwater and then remove them from the aqueous phase. For this reason, this technology will be eliminated from further consideration.

3.1.2.6.4 In Situ Vitrification

In situ vitrification is a relatively new (first tested in 1980) process by which contaminated soils are vitrified through the utilization of electricity. The process is actually the conversion of soil into a durable glass and crystalline form by melting the soil by electrical heat. The major portion of the compounds in the soils are volatilized, with the remainder being worked in place in the hardened soil (Weston, 1988). The technology is based upon electric melter technology, and the principle of operation is joule heating, which occurs when an electrical current is passed through a molten mass (Wagner, 1988).

The basic process of in situ vitrification includes inserting four electrodes into the soil in a square pattern (Typical spacing of the electrodes for large sites is 3.5 to 5.5 meters apart). To provide a conductive path for the initial electrical current, a small quantity of a mixture of graphite and glass frit (material used to produce glass) is placed in an "X" pattern between the electrodes. As the current is passed between electrodes, the internal resistance of the conducting medium causes temperatures to rise, resulting in the melting of the adjacent soils. Less dense materials such as rocks migrate upwards to create a layer near the surface. Organic materials become pyrolized and diffuse to the surface. Ash or inorganic materials are encapsulated within the glass form. One to two weeks are required for the vitrified mass to cool. During this time some subsidence occurs. The area can then be backfilled and revegetated (Weston, 1988). However, the depth of the waste is a significant limiting factor in the application of this technology; 1 to 1.5 meters of uncontaminated overburden lowers release fractions considerably (Wagner, 1986).

An off-gas hood is included as part of the vitrification process in order to collect the off-gases, provide a chamber for combustion of pyrolized organics, and serve as a support for the four electrodes embedded in the soil. The off-gas stream can be removed by a treatment system (Weston, 1988).

This technology is most applicable to soils that are heavily contaminated with nonvolatile organics and metals. Vitrification would be significantly more (i.e., more than twice as much) costly to implement than would in situ vapor extraction. Furthermore, this technology is currently still in developmental stages and

has not been demonstrated on a full scale. For these reasons, this technology will be eliminated from further evaluation.

3.1.2.6.5 In Situ Heating

In situ heating is an emerging technology that involves destroying or removing organic contaminants in the subsurface through thermal decomposition, vaporization, and distillation. Methods used for in situ heating include steam injection and radio frequency heating. The radio frequency process, which has been under development since the 1970s, involves laying a row of horizontal conductors on the surface and exciting them with a radio frequency generator. Decontamination is accomplished in a temperature range of 300°C to 400°C, assisted with steam, and requires a residence time of approximately two weeks. A gas or vapor recovery system is required on the surface. Field experiments have been conducted for the recovery of hydrocarbons and have resulting in positive results. Further research is needed to verify the technology's effectiveness (Wagner, 1986).

Because additional research needs to be conducted for this process option, unidentified pitfalls may be encountered in implementing in situ heating. Furthermore, this technology is expected to be significantly more costly (i.e., about twice as much) to implement than would in situ vapor extraction. For these reasons, this process option will not be retained for further consideration.

3.1.3 Summary of Soil Technology and Process Option Screening

A summary of the technology and process option screening for soils is presented in Table 3-2. A summary of the retained technologies and representative process options for soils is provided in Table 3-3. Representative process options are chosen to represent the technologies in the development of remedial alternatives. A representative process option does not necessarily reflect a preference for that process, but rather is selected to simplify development and evaluation of remedial alternatives in the FS. Other process options for a given technology could be considered during a remedial design phase.

TABLE 3-2
SUMMARY OF SOIL TECHNOLOGY EVALUATION AND SCREENING
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Screening Comments
No Action	None	Not Applicable	Retain for further consideration.
Institutional Controls	Access Restriction	Fencing	Retain for further consideration.
	Land Use Controls	Base Master Plan	Retain for further consideration.
		Deed Restrictions	Retain for further consideration.
Containment	Capping	Clay Cap	Eliminate as a representative process option in FS. Retain for possible detailed design consideration.
		Synthetic Membrane	Retain as a representative process option.
		Composite Cap	Retain as a representative process option.
		Asphalt Cap	Retain as a representative process option.
	Vertical Barriers	Slurry Wall	Eliminate from further consideration. Not implementable under site conditions.
		Sheet Piling	Eliminate from further consideration. Not implementable under site conditions.
Removal/Disposal	Excavation	Conventional Excavation Equipment	Retain for further consideration.
	Off-Site Disposal	RCRA Hazardous Waste Landfill	Retain for further consideration.
		Solid Waste Landfill	Eliminate from further considerations. Solid waste landfills would not accept soils with chlorinated contaminants.
Removal/ Treatment/Disposal	Excavation	Conventional Excavation Equipment	Retain for further consideration.
	Physical Treatment	Soil Washing	Eliminate from further consideration. Effectiveness not well-proven in the field. More difficult to implement and more costly than low temperature thermal treatment.

TABLE 3-2
SUMMARY OF SOIL TECHNOLOGY EVALUATION AND SCREENING
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Screening Comments
Removal/ Treatment/Disposal (continued)	Biological Treatment	Landfill Treatment (Aerobic)	Eliminate from further consideration. Effectiveness not well-proven. Not commercially available at this time.
		Composting (Aerobic)	Eliminate from further consideration. Effectiveness not well-proven. Not commercially available at this time.
	Thermal	Incineration	Retain for further consideration. More difficult and costly to implement than low temperature thermal treatment.
		Vitrification	Eliminate from further consideration. Not well proven in the field. More difficult and costly to implement than low temperature thermal treatment.
		Low Temperature Thermal Treatment	Retain for further consideration.
	Off-Site Treatment	Bioremediation Cell Facility	Eliminate from further consideration. Effectiveness not well-proven. Not commercially available at this time.
		Incineration	Retain for further consideration.
In Situ Treatment	Biological Treatment	Aerobic Bioremediation	Eliminate from further consideration. Effectiveness not well-proven. Not commercially available at this time.
	Physical Treatment	Soil Vapor Extraction/Dual Phase Vacuum Extraction	Retain for further consideration.
		Soil Flushing	Eliminate from further consideration. Not well-proven in the field. More difficult and costly to implement than vapor extraction.
	Thermal Treatment	In Situ Vitrification	Eliminate from further consideration. Not well-proven in the field. More difficult and costly to implement than vapor extraction.
		In Situ Heating	Eliminate from further consideration. Not commercially available. More difficult and costly to implement than vapor extraction.

TABLE 3-3

SUMMARY OF RETAINED SOIL TECHNOLOGIES
AND REPRESENTATIVE PROCESS OPTIONS
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

GENERAL RESPONSE ACTION	TECHNOLOGY	REPRESENTATIVE PROCESS OPTION
No Action	None	None
Institutional Controls	Land Use Control	Base Master Plan, Deed Restrictions
Containment	Capping	Geosynthetic Cap/ Asphalt Cap
Removal/Disposal	Excavation	Conventional Equipment
	Off-site Disposal	RCRA Hazardous Waste Landfill
Removal/Treatment/ Disposal	On-site Treatment	Low Temperature Thermal
	Off-site Treatment	Incineration[1]
In situ Treatment	Physical Treatment	Dual Phase Vacuum Extraction

[1] For purposes of alternative development, incineration and low temperature thermal treatment were combined into one "thermal treatment" alternative. A combination of these technologies could potentially be used for treatment of the "hot spot" area depending on the types of waste materials identified (e.g., contaminated soils, sludges, buried drums).

3.2 Identification and Screening of Technologies and Process Options for Groundwater

3.2.1 Preliminary Screening of Groundwater Technologies and Process Options

In this step, an initial set of groundwater technologies and process options was identified and screened by evaluating their technical implementability and site-specific factors, such as applicability to the contaminants of concern. All groundwater technologies and process options that may be applicable to the site contaminants and to the site conditions were retained for further evaluation in Section 3.2.2. A summary of the preliminary identification and screening of potentially applicable groundwater technologies and process options is presented in Table 3-4.

3.2.2 Screening of Retained Groundwater Technologies and Process Options

3.2.2.1 No Action

A no action response provides the baseline assessment for comparison with other remedial alternatives that have a greater level of response. The National Oil and Hazardous Substances Contingency Plan (NCP) requires the evaluation of the no action alternative as part of the FS process. A no action alternative scenario may be considered appropriate when an alternative response action may cause a greater environmental or health danger than a no action alternative itself or when potential risks to human health are within acceptable levels.

The no action alternative would not actively remediate contaminated groundwater nor prevent further migration of contaminants in the groundwater. Contaminant concentrations may gradually decrease over time through natural dilution and dispersion.

In terms of the site, no alternative response action would be implemented under the no action alternative. However, a groundwater monitoring program would be performed in conjunction with this alternative. A long-term monitoring program would be implemented at the site. This program would provide temporal as well as spacial information regarding the groundwater quality at the site. This information would be used to monitor any increase or decrease in groundwater quality at the site.

Monitoring wells that could be used in this program already exist at the site. Additional wells could be readily constructed, if necessary. A limited number of nearby residential wells would most likely also be

TABLE 3-4
INITIAL SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	Not Applicable	No Action.	Required for consideration by NCP.
	Monitoring	Groundwater Monitoring	On-going monitoring of wells.	Potentially applicable.
Institutional Controls	Alternate Water Supply/ Point-of-use Treatment	Existing Water Supply	Connect residences to existing water supply.	Not applicable, groundwater in Glenwood Park not currently impacted by site.
		New Water Supply	Develop a new water supply.	Not applicable, groundwater in Glenwood Park not currently impacted by site.
		Individual Home Treatment Units	Provide individual home treatment units.	Not applicable, groundwater in Glenwood Park not currently impacted by site.
	Land Use Controls	Base Master Plan	Use of Base Master Plan to restrict current and future use of groundwater on Base.	Potentially applicable.
		Deed Restrictions	All deeds for property would include restrictions on use of groundwater, denial of well permits, and aquisition of groundwater rights.	Potentially applicable.
	Public Education	Meetings, Written Notices, etc.	Public education activities such as meetings and written notices to inform public of potential health risks associated with groundwater usage.	Potentially applicable.
Containment	Horizontal Barriers	Liners	Placement of liner beneath contaminated material.	Not feasible because of active facilities on-site.
		Grout Injection	Pressure injection of grout in regular pattern of drilled holes.	Not feasible because of excessive depth to bedrock on-site.
		Block Displacement	In conjunction with vertical barriers, injection of slurry in notched injection holes.	Not feasible because of lack of development of technology.
	Gradient Control	Extraction Wells	Use of extraction wells to control groundwater flow.	Potentially applicable.

TABLE 3-4
INITIAL SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Collection/ Treatment/Discharge	Collection	Extraction Wells	Series of wells to extract contaminated groundwater.	Potentially applicable.
		Interceptor Drains	System of perforated pipe laid in trenches and backfilled with permeable media to intercept and collect contaminated groundwater.	Potentially applicable.
	Aerobic Biological Treatment	Activated Sludge	Contaminants in groundwater are metabolized by microorganisms in a continuously aerated tank.	Potentially applicable.
		Aerated lagoon	Large multicellular basins or individual basin that are mixed and aerated using surface aerators.	Potentially applicable.
		Biological Towers	The medium, such as PVC, polyethylene, polystyrene, or redwood, is stacked into a tower, typically 16 to 20 feet in height. The contaminated water is sprayed into the top of the tower. A slime layer on the media removes the organic contaminants.	Potentially applicable.
	Anaerobic Biological Treatment	Batch/Continuous Flow Reactors	Degradation of organics using microorganisms in an anaerobic environment. Groundwater is treated in batch or continuous flow reactors.	Not feasible due to a lack of development of technology.
	Chemical Treatment	Alkali Chlorination	Addition of chlorine to contaminated groundwater under alkaline conditions.	Not applicable to contaminants of concern.
		Alkali Metal Dechlorination	Displacement of chlorine from chlorinated organics using alkali metals.	Not applicable to contaminants of concern.
		Chemical Hydrolysis	Process of breaking a bond in a molecule so that it becomes soluble in water.	Not applicable to contaminants of concern.

TABLE 3-4
INITIAL SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Collection/ Treatment/Discharge (continued)	Chemical Treatment (continued)	Chemical Reduction	Lowering the oxidation state in a molecule in order to change its treatment characteristics.	Not applicable to contaminants of concern.
		Electrodialysis	Contaminants are removed from a waste stream and passed across a membrane due to an electrical potential.	Not applicable to contaminants of concern.
		Electrolytic Oxidation	Electrodes are immersed in a tank containing waste to be oxidized and a direct current is imposed on the system.	Not applicable to contaminants of concern.
		Neutralization	Adding acid or base to a waste stream to adjust its pH.	Potentially applicable for metals pretreatment of groundwater.
		Chlorination	Chemical oxidation of a contaminant using chlorine.	Not applicable to contaminants of concern.
		Oxidation with Hydrogen Peroxide	Addition of hydrogen peroxide to a waste stream to oxidize organic compounds.	Potentially applicable.
		Ozonation	Addition of ozone to a waste stream in order to oxidize organic compounds.	Potentially applicable.
		Oxidation with Potassium Permanganate	Addition of potassium permanganate to a waste stream to oxidize inorganic compounds.	Potentially applicable for metals pretreatment of groundwater.
		Oxidation with UV Light/ Ozonation	Oxidation of waste stream with UV light and ozone to destroy contaminants.	Potentially applicable.
		Oxidation with Hypochlorite	Addition of sodium or calcium hypochlorite to oxidize organic wastes.	Potentially applicable.

TABLE 3-4
INITIAL SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Collection/ Treatment/Discharge (continued)	Chemical Treatment (continued)	Precipitation	Adjust the pH of a solution to a value where the constituents to be removed have their lowest solubilities.	Potentially applicable for metals pretreatment of groundwater.
	Physical	Activated Carbon	Adsorption of contaminants onto activated carbon by passing water through a carbon vessel.	Potentially applicable.
		Air Stripping	Mixing large volume of air with water in a packed column or diffused aeration chamber to promote transfer of VOCs to air.	Potentially applicable.
		Dewatering	Mechanical removal of free water from sludges using equipment such as filter presses and centrifuges.	Potentially applicable for dewatering sludge generated during groundwater treatment.
		Clarification/ Sedimentation	Removal of solids from dilute suspensions through gravity settling.	Potentially applicable for metals pretreatment of groundwater.
		Coagulation/ Flocculation	Chemical additives used to promote the aggregation of particles in aqueous solution.	Potentially applicable for metals pretreatment of groundwater.
		Dissolved Air Floatation	Small air bubbles adhere to solids within the waste stream, causing solids to rise to the surface.	Potentially applicable.
		Distillation	The process of evaporation followed by condensation whereby separation can be optimized by controlling evaporation stage temperature and condenser temperature.	Potentially applicable.
		Equalization	A process that makes a treatment characteristic uniform, such as flow rate, pH, or temperature.	Potentially applicable.

TABLE 3-4
INITIAL SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
Collection/ Treatment/Discharge (continued)	Physical (continued)	Filtration	Process by which suspended solids are removed from solution by forcing the fluid through a porous medium.	Potentially applicable for metals pretreatment of groundwater.
		Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water.	Potentially applicable.
		Oil/Water Separation	Process that uses gravity to separate two or more immiscible liquids having sufficiently different densities.	Potentially applicable.
		Reverse Osmosis	Use of high pressure to force water through a membrane leaving contaminants behind.	Potentially applicable.
		Steam Stripping	Use of steam in a packed column to evaporate volatile organics from aqueous streams.	Potentially applicable.
	Discharge	Surface Water	Discharge treated groundwater to on-site drainage ditch.	Potentially applicable.
		Subsurface Discharge	Discharge treated groundwater to infiltration trenches or to injection wells to recharge the aquifer.	Potentially applicable.
		POTW	Discharge treated or untreated groundwater to local POTW.	Potentially applicable.
		Industrial Wastewater Treatment	Discharge treated or untreated groundwater to industrial treatment facility on Naval Base.	Potentially applicable.

TABLE 3-4
INITIAL SCREENING OF GROUNDWATER REMEDIAL TECHNOLOGIES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Description	Screening Comments
In Situ Treatment	Biological Treatment	Aerobic Bioremediation	System of injection and extraction wells to introduce bacteria and nutrients under aerobic conditions in order to degrade contaminants.	Potentially applicable.
		Anaerobic Bioremediation	System of injection and extraction wells to introduce bacteria and nutrients under anerobic conditions in order to degrade contaminants.	Not feasible because of a lack of development of this technology.
	Chemical Treatment	Chemical Reaction	System of injection wells to inject oxidizer such as hydrogen peroxide to degrade contaminants.	Not feasible because of a lack of development of this technology.
	Physical Treatment	Air Sparging	System of wells to inject air into the groundwater to remove volatiles by air stripping.	Potentially applicable.
		Permeable Treatment Beds	Downgradient trenches backfilled with activated carbon to remove contaminants from water.	Not applicable because it represents a temporary treatment.

included in the monitoring program. Groundwater sampling and sample analysis would be performed by established techniques.

Because the NCP requires the evaluation of the no action response action, this option will be retained for further evaluation.

3.2.2.2 Institutional Controls

Institutional controls consist of actions designed to minimize potential risks to human health by restricting or controlling access to contaminated groundwater. Institutional controls can include public education activities and land use controls, such as deed restrictions.

3.2.2.2.1 Land Use Controls

Land use on site is currently designated under the existing base master plan entitled "Master Plan, Marine Corps Camp Elmore/Fleet Marine Force, Atlantic (MCE/FMFLANT), Norfolk, Virginia," October, 1990. Groundwater usage is monitored and controlled on site, although formal groundwater usage restrictions have not been incorporated into the Master Plan. Such groundwater usage designations could be incorporated into the master plan, if necessary.

There are currently no plans to close Camp Allen. However, if the base were to close at some point in the future, deed restrictions could be implemented to restrict groundwater usage.

Land use controls are an effective means of controlling and restricting groundwater use and can be implemented on site. Therefore, they will be retained for further consideration. However, land use controls may be difficult to implement off site should contaminated groundwater migrate into residential wells in the future. The State may not have authority to deny groundwater use to residents who are currently using groundwater for nonpotable uses.

3.2.2.2.2 Public Education

This alternative consists of public education activities to inform residents of potential health risks that would be associated with potable, and possibly nonpotable, use of contaminated groundwater, should residential wells become contaminated in the future as a result of contaminant migration from the site. The Navy currently conducts regular Technical Review Committee (TRC) meetings to inform local citizens and

community groups of ongoing environmental activities being conducted at the site. Other public education measures could be implemented as needed, such as additional public meetings, news releases in local newspapers, and written notices to potentially affected residents.

Public education is an effective and implementable means of communicating ongoing environment activities and of explaining any potential health risks associated with the site to the community. Therefore, public education will be retained for further consideration.

3.2.2.3 Containment

Physical barriers, such as slurry walls, can be used to redirect groundwater around an area of waste material or soil contamination. Process options for physical barriers are described in Section 3.1.2.3.2. Extraction wells and interceptor drains, or collection trenches, which can be used to establish hydraulic barriers for groundwater containment, are discussed in Section 3.2.2.4.1.

3.2.2.4 Collection/Treatment/Discharge

3.2.2.4.1 Collection

Extraction Wells

This process option involves the management or manipulation of a groundwater in order to contain a plume (USEPA, 1987a). This would be accomplished through the installation and pumping of a series of extraction wells. By adjusting the groundwater elevations through pumping, the movement of the plume of contaminated groundwater can be halted or diverted. This would prevent the further migration of contaminated groundwater to domestic wells located adjacent to the site.

Extraction wells have been installed in a variety of geologic settings using conventional equipment. Additionally, numerous monitoring wells have been constructed at the site using the same equipment that would be used for the extraction wells. This process option will be retained for further consideration. However, as noted in Section 1.3.1, all of the shallow monitoring wells in Area A1 bailed dry during the pre-design investigation and would not sustain a continuous pumping rate. Therefore, it appears that operation of groundwater extraction wells in this area would not be practical. Operation of groundwater extraction wells in Area A2 also may not be practical, depending on the water table aquifer characteristics

in the area of contamination. No information is available concerning the transmissivity of the water table aquifer in this area.

Interceptor Drains

Interceptor drains include a variety of buried conduits used to carry and collect aqueous discharges by means of gravity flow (USEPA, 1987a). Construction of an interceptor drain would include the excavation of a trench, installation of a drain pipe or gravel bed within the trench, and connection of the drain pipe or gravel bed to a collection sump. Interceptor drains would only be applicable to contamination in the shallow aquifer.

Geologic conditions that would interfere with the construction of a trench at the site, such as the presence of rocky soil, do not exist. However, depending on the optimal location for the trench, structures and utilities may preclude construction of the trench. This option will be retained for further consideration.

3.2.2.4.2 Aerobic Biological Treatment

Aerobic biological water treatment systems include suspended growth processes, such as activated sludge systems and aerated lagoons, and attached growth processes, such as biological towers. These process options are described in the following sections.

Activated Sludge

An activated sludge system includes a mixed suspension of aerobic and facultative microorganisms (e.g., biomass), a settling basin for separation of the biomass, and a biomass recirculation system. In the presence of dissolved oxygen, the microorganisms serve to oxidize soluble organics and remove suspended solids. VOCs are partially volatilized during the aeration of the biomass. Also, metals are partially removed and accumulate in the sludge produced by the process (USEPA, 1990).

Chlorinated organics, aliphatics, amines, and aromatic compounds are not effectively removed through an activated sludge process. Some degree of removal would be achieved through volatilization. Additionally, the microorganisms within the biomass are inhibited by heavy metals and certain organics (USEPA, 1987a), which may include the chlorinated compounds detected in the groundwater at the Camp Allen Site. Therefore, this process option will be eliminated from further consideration.

Aerated Lagoon

Aerated lagoons are completely mixed biological reactors that, in contrast to an activated sludge process, do not employ biomass recycling. The aerated lagoons can be large multicellular basins or individual basins that are aerated using surface aerators. The primary mechanism by which contaminated water is treated is through the conversion of soluble organics to biomass (USEPA, 1990).

Potential problems with aerated lagoon include: excessive algae growth; offensive odors if sulfates are present and dissolved oxygen is depressed; and seasonal variations in effluent quality. Similar to the activated sludge process, chlorinated organics, such as TCE and vinyl chloride, are not effectively removed through this process. Some degree of removal would be achieved through volatilization. Additionally, the microorganisms within the biomass are inhibited by heavy metals and certain organics (USEPA, 1987a), which may include the chlorinated compound detected in the groundwater at the Camp Allen Site. Therefore, this process option will be eliminated from further consideration.

Biological Tower

Biological towers are actually modified trickling filters. A medium, such as polyvinyl chloride, polyethylene, polystyrene, or redwood, is stacked into a tower. Contaminated water is sprayed across the top of the tower. Air moves countercurrent to the water, upwards through the tower. Microorganisms that form a slime layer on the medium remove organic contaminants from the water (USEPA, 1987a).

Biological towers are constructed from materials that are readily available. Commonly used designs and construction techniques used for cooling towers and distillation columns in the chemical process industry could be employed in implementing this option.

As with the suspended growth processes, chlorinated organics, such as TCE and vinyl chloride, are not expected to be effectively removed through biodegradation during this process. Some degree of removal would be achieved through volatilization. With respect to volatilization, a shallow tray or packed tower air stripper would more effectively remove VOCs from the groundwater than would a biological tower. Therefore, this process option will be eliminated from further consideration.

3.2.2.4.3 Chemical Treatment

Neutralization

This treatment option involves the addition of an acid or a base to contaminated water in order to adjust its Ph. Multiple compartmental basins equipped with mixers in each compartment are most commonly used for neutralization systems. These basins are typically constructed of reinforced plastic or lined concrete. This process is applicable to any groundwater stream requiring Ph control. It can be used as a pretreatment step, such as for biological or chemical treatment, or as a final treatment step prior to discharge (USEPA, 1987a).

A neutralization system can be constructed from readily available equipment and operated with common reagents. Additionally, neutralization may be required for the implementation of other methods of treatment. As such, this technology will be retained for further evaluation.

Oxidation

In chemical oxidation, the oxidation state of the treated compound is raised. Common commercially-available oxidants include potassium permanganate, hydrogen peroxide, chlorine gas, and calcium and sodium hypochlorite. Chemical oxidation is used primarily for detoxification of cyanide and treatment of dilute contaminated groundwater containing oxidizing organics. Additionally, chemical oxidation also can be an effective way of pretreating wastes prior to biological treatment. Equipment requirements for chemical oxidation are simple and include readily available equipment such as contact vessels with agitators to provide suitable contact of the oxidant with the waste, storage vessels, and chemical metering equipment. Commonly used oxidation processes are described in the following sections.

Oxidation with Hydrogen Peroxide

For this process, hydrogen peroxide is added to contaminated water in order to oxidize organic contaminants. Since hydrogen peroxide is not the stable oxide of hydrogen, it readily gives up its extra oxygen and thus is an excellent oxidizing agent.

Hydrogen peroxide oxidation is a common industrial process. As such, the equipment used for the construction of the system and the hydrogen peroxide solution should be easily obtainable. The technology, however, has been used very infrequently for treatment of groundwater and is not well-proven for oxidation

of the chlorinated organic compounds detected at the site. Therefore, hydrogen peroxide oxidation will be eliminated from further consideration.

Ozonation

Ozonation refers to the process of oxidizing a contaminated media using the triatomic form of oxygen, ozone. Because ozone is a highly reactive and unstable form of oxygen, it must be generated on-site. The generation of ozone is usually accomplished by passing air or oxygen through an electronic arc (USEPA, 1990). Ozonation is commonly used for disinfection of wastewaters. The technology, however, has been used very infrequently for treatment of groundwater and is not well-proven for oxidation of the chlorinated organic compounds detected at the site. Therefore, ozonation oxidation will be eliminated from further consideration.

Oxidation with Potassium Permanganate

This technology involves the addition of potassium permanganate to an aqueous waste stream in order to oxidize contaminants. Generally, potassium permanganate is introduced to the process stream as a liquid of known concentration. Compared to other oxidation reagents, potassium permanganate is the most easily manageable. It lasts indefinitely if kept in a cool dry place (USEPA, 1990).

Oxidation is often used as a preliminary step prior to the precipitation of metals. Specific metals that can be removed through potassium permanganate oxidation include iron and manganese. Because these two metals may interfere with the operation of other treatment processes such as air stripping, their removal may be a necessary pretreatment step.

The system for oxidation with potassium permanganate is comprised of conventional equipment. At hazardous waste sites, application of this technology has been demonstrated using both pilot- and full-scale systems. Based on the ability to construct and operate this system as well as its applicability as a pretreatment step, this technology will be retained for further consideration.

Oxidation with UV/Ozonation

Under this technology, oxidation of organic contaminants is accomplished through the introduction of ozone into the water stream in combination with ultraviolet (UV) irradiation. The contaminants are either partially oxidized as a pretreatment step for other processes, such as biological degradation, or entirely

oxidized. UV/ozonation can treat a range of organic contaminants, including methylene chloride, pentachlorophenol, phenols, and PCBs (USEPA, 1990).

The UV/ozonation process is considered to be an innovative technology for groundwater treatment. This technology has been frequently tested on a bench-scale for groundwater treatment. However, there are currently few full-scale UV/ozonation groundwater treatment systems in operation. Furthermore, complete oxidation of the chlorinated organic compounds detected at the site has not been reliably proven. Preliminary cost estimates indicate that this technology would be more costly to implement and operate than air stripping and carbon adsorption, which are more reliable groundwater treatment technologies. Based on these considerations, UV/ozonation will be eliminated from further consideration.

Oxidation with Hypochlorite

For oxidation with hypochlorite, organic wastes are oxidized through the addition of sodium or calcium hypochlorite to wastewater streams to oxidize organic wastes. Equipment for this process is commercially available; oxidation by hypochlorite is commonly used to disinfect home swimming pools (USEPA, 1987a).

Toxic chlorinated organics are byproducts of this method. Additionally, one type of contaminant of concern at the site, volatile chlorinated hydrocarbons, is not amenable to treatment by this technology. As such, it will not be retained for further screening.

Precipitation

In precipitation, soluble metallic ions are converted to insoluble form, and thus removed from solution, through the addition of chemicals. The following equipment is typically used for a precipitation system: a reaction tank equipped with a mixer; a pH monitoring system; and pumps for influent flow and chemical addition. In order to remove precipitates from the water stream, a solids separation system, such as clarification/sedimentation or filtration, is used after the precipitation system (USEPA, 1990).

This process is commonly used and is well-demonstrated for metals removal. Chemical additives required for the process are readily available. Based on its applicability to the contamination on-site and the ease of construction and operation, this option will be considered in subsequent screenings.

3.2.2.4.4 Physical Treatment

Activated Carbon

For this technology, organic and inorganic species are separated from wastewater using the physical process of sorption. In sorption, material is attracted to and accumulates (i.e., adsorbs) onto the surface of the substance. In the case of activated carbon, contaminants are adsorbed onto the surface of the activated carbon. Activated carbon can be used in the following applications: the reduction of chemical oxygen demand (COD), biological oxygen demand (BOD), and related parameters; the removal of toxic or refractory organics; the removal and recovery of certain organics; and the removal of selected organic contaminants, including heavy metals (USEPA, 1990). Granular activated carbon (GAC) columns can be set-up quickly at a site and are readily available from manufacturers.

Most of the chlorinated organic contaminants detected in the groundwater on-site are amenable to treatment using activated carbon, with the exception of vinyl chloride. Vinyl chloride does not adsorb well to activated carbon, particularly in the aqueous phase. Activated carbon is partially effective in removing vinyl chloride in the vapor phase. Since vinyl chloride is one of the major contaminants of concern at the site, activated carbon will only be retained for further consideration as a polishing step for other treatment processes, such as air stripping, as well as for treatment of off-gases from an air stripping process.

Air Stripping

Air stripping refers to the process by which contaminants are removed from wastewater by contacting the water with large volumes of air, thereby transferring the contaminants to the air phase. This process had been effectively applied to the removal of ammonia, chlorinated solvents, monoaromatics, and other VOCs from waste streams (USEPA, 1990).

The air stripping system, or tower, is composed primarily of a cylindrical column filled with packing material. The packing material serves to enhance the contact area between the air and the water. The system is also equipped with: a liquid inlet, a liquid distribution device, and a gas outlet, found at the top of the tower; and a gas inlet, a distribution space, and a liquid outlet found at the bottom of the tower. In addition to packed towers, low-profile air stripping systems are available for groundwater treatment. These systems use diffused aeration to remove VOCs and are usually constructed of individual trays, which can be stacked upon one another to achieve the required degree of removal.

Air stripping systems are feasible and readily implementable for on-site treatment. On-site air stripping facilities have been shown to be effective on a wide variety of contaminants and flow rates. Based on these considerations, this technology will be retained for further consideration.

Dewatering

Dewatering is mainly used to remove free liquids from sludges generated by a groundwater treatment process prior to disposal. Dewatering increases the solids content of the sludge thereby decreasing the volume of waste to be managed. Mechanical dewatering is the most common type of dewatering technology. In mechanical dewatering, water is forced out of the sludge through pressures induced by filtration, centrifugation, or gravity. Filtration processes include belt and chamber filter presses and vacuum rotary filtration. In centrifugation, components in a fluid mixture are separated based on their relative densities by rotating the fluid rapidly in a rigid vessel. Components that are relatively more dense than the fluid medium are deposited further away from the axis of rotation. The supernatant fluid moves toward the axis.

Dewatering technologies have been widely used for thickening of sludge generated from metals pretreatment processes used in groundwater treatment systems. Therefore, this technology will be retained for further consideration.

Clarification/Sedimentation

The primary purpose of this process option is to produce a relatively clear overflow. This is accomplished through the concentration of suspended solids by gravity settling. The primary components of the clarifier are: a tank to contain the wastewater; feed piping, and a feed well to allow the feed stream to enter the tank; a rotating rake to assist in moving the solids to withdrawal points; an underflow solids withdrawal system; and an overflow launder (Perry, 1984).

Clarification/sedimentation is generally used for dilute suspensions, such as domestic industrial wastes. This process may be required as a subsequent treatment step for other technologies, such as flocculation. As such, this technology will be retained for further screening.

Coagulation/flocculation

In this process option, a substance called a coagulant, or flocculant, is added to a wastewater stream in order to reduce the repelling forces between colloidal particles. This increases the probability of interparticle collisions which in turn assists in the aggregation and subsequent removal of the particles. Coagulants typically used include polyelectrolytes and polymers and can be categorized as cationic, anionic, and nonionic (Rich, 1987).

Coagulation/flocculation is commonly used in the treatment of wastewater. It can be utilized of streams containing soluble heavy metals and colloidal hazardous substances. Because of this treatment process's common use and its applicability to contaminants found at the site, this technology will be retained for further review.

Dissolved Air Flotation

In dissolved flotation, suspended solids or mixed liquids are separated from an aqueous waste stream. The waste stream is saturated with air or another gas, and the pressure is reduced above the treatment tank. Bubbles form as the pressure is reduced on the suspended particles or non-aqueous liquid and thus increases the particle's or liquid's ability to float. Separated oil and other material "floated" out of solution are skimmed of the top in the separation chamber while the aqueous liquid is removed from the bottom (USEPA, 1987a).

Dissolved air floatation can only be used when the substance to be removed has a density close to that of water. Because the contaminants of concern at the site generally do not possess this property, dissolved air floatation will not be retained for further consideration.

Distillation

For this technology, volatile materials with different volatilities are separated through evaporation and subsequent condensation. The two primary types of distillation are batch distillation and continuous fractional distillation. Batch distillation equipment consists simply of a heated still pot with a condenser to accumulate the distillate. Tray columns or packed towers equipped with condensers and reboilers are used to perform continuous fractional distillation. In order to optimize the separation, the temperature and pressure within distillation systems are carefully monitored (USEPA, 1987).

Separation of liquid organic waste, such as spent solvents, is the primary application of distillation. Although solvents were detected in the groundwater at the site, this technology is not applicable to the relatively low concentrations that were detected. The more commonly used technologies, air stripping and carbon adsorption, would be more cost-effective for the nature of groundwater contamination at the site. As such, distillation will not be retained for further consideration.

Equalization

For many waste treatment processes, equalization is an initial treatment step (Rich, 1987). In equalization, contaminated media are held in a basin (or other equipment such as a tank) in order to obtain stable effluent qualities. Objectives of equalization would include: neutralization of alkaline and acid wastes; stable BOD levels in the equalization basin effluent; and precipitation from heavy metals. Some industrial wastes are equalized prior to discharge to public operated treatment works (POTWs) in order to prevent fluctuations in waste stream concentration and subsequent adverse impacts on the treatment process of the POTWs.

Because equalization may be required for the implementation of other technologies and this technology's demonstrated use in industry, it will be retained for further screening.

Filtration

In this process, suspended solids are physically removed from wastewater. The suspended material is trapped within a physically restrictive medium as the wastewater passes through this medium. Sand, coal, garnet, and diatomaceous earth are media used in filtration (USEPA, 1990).

This treatment technology is conventional and proven in the removal of suspended solids from wastewater. The filtration equipment itself is compact and easily installed. However, filtration would need to be used in combination with other technologies because contaminants other than suspended solids would not be removed by this technology. Because this technology is applicable to the metals associated with unfiltered groundwater at the site, as well as the technology's implementability, it will be retained for further consideration.

Ion Exchange

This process involves the exchange of certain dissolved ionic contaminants in a wastewater with a set of substitute ions. This is accomplished using a synthetic or natural resin containing the substitute ion, also

called the functional ionic groups. Traditionally, ion exchange has been used in selected dissolved metals as polishing or recovery steps, nitrate removal for drinking water purification, and decreasing total dissolved solids in waste streams (USEPA, 1990).

Equipment required for ion exchange is widely-available from several resin manufacturers. Additionally, to aid in selecting the appropriate resins and regenerating solutions, these manufacturers provide consulting services and brochures. Because this technology can be applied to the removal of dissolved metals from the groundwater and the relative ease of construction, this technology will be retained for further screening.

Oil/Water Separation

Using this technology, non-aqueous phase organic liquids (i.e., oils and grease) are separated from a waste discharge. Oil/water separators are designed based on the principal that under quiescent conditions, the less dense phase, in this case oil or grease, will rise to the top and thus may be collected. Oil and grease separators are used in the removal of oil and grease from leachate streams and in separating the organic phase from groundwater/floating product extraction systems (USEPA, 1990).

Oil/water separation in a well-demonstrated technology. Oil/water separators are readily available in a range of prepackaged designs for specific applications. Additionally, these prepackaged units require little additional site preparation. However, no oils or greases, or other non-aqueous phase organic liquids, were encountered in the groundwater at the site. As such, this technology will not be retained for further consideration.

Reverse Osmosis

In this technology, high pressure is used to force water through a membrane that is water-permeable, but is impermeable to the contaminant molecules dissolved in the water. Reverse osmosis has been apply in industrial settings primarily to demineralize brackish waters and to treat a variety of industrial wastewaters. A reverse osmosis unit is composed of: the membrane, the membrane support structure, a containing vessel, and a high pressure pump. Of this equipment's elements, the membrane and the membrane support are the more critical (USEPA, 1987a).

The concentrations of both organic and inorganic dissolved solids can be reduced by reverse osmosis. However, the units are subject to chemical attack, fouling, and plugging. Additionally, although compact reverse osmosis units are available commercially, a considerable effort may be required to acquire and

assemble the entire reverse osmosis system. Based on these operational and construction difficulties, this technology will not be retained for further screening.

Steam Stripping

Steam stripping refers to the process by which contaminants are removed from wastewater by contacting the water with large volumes of steam, thereby transferring the contaminants to the steam phase. This process uses steam for a stripping medium for increased efficiency over air stripping, removal of relatively less VOCs, or applications in cold weather (USEPA, 1990).

The steam stripping system, or tower, is composed primarily of a cylindrical column filled with packing material. The packing material serves to enhance the contact area between the steam and the water. The system is also equipped with: a liquid inlet, a distribution device, and a gas outlet, found at the top of the tower; and a gas inlet, a distribution space, and a liquid outlet found at the bottom of the tower.

Steam stripping is most well-suited for removing VOCs from waters with high concentrations of VOCs. Although this technology would effectively remove VOCs from the groundwater at the site, air stripping and carbon adsorption are more cost-effective for the low concentrations of contaminants detected in the groundwater at the site. Thus, this technology will be eliminated from further consideration.

3.2.2.4.5 Discharge

Potential discharge options for disposal of treated or untreated groundwater include surface water discharge, subsurface discharge, discharge to the base industrial wastewater treatment plant, and discharge to the Hampton Roads Sanitation District (HRSD) Wastewater Treatment Plant. These options are discussed in the following sections.

Surface Water Discharge

Treated groundwater would be discharged to surface water in compliance with local, State, and Federal regulations under this process option. There are two drainage ditches located around the southern/western and northern perimeters of the Area A Landfill, which could be used for the discharge of treated groundwater. A drainage ditch is also located along the southern boundary of Area B, south of the Camp Allen Elementary School, which flows into the southern/western ditch bordering the Area A Landfill.

Waters in all of these ditches flow off-site near the northwest portion of Area A and eventually flow into Willoughby Bay.

This process option is implementable and will be retained for further screening.

Subsurface Discharge

Subsurface discharge involves the reinjection of treated groundwater into the aquifer through the use of injection wells, spray irrigation, or infiltration trenches/galleries.

The injection wells under this process option would discharge the treated groundwater directly into the aquifer. Water could be reinjected upgradient of the extraction wells, which would serve to recharge the aquifer and subsequently increase the flow rate of the extraction system. Groundwater could also be reinjected downgradient of the extraction wells and allowed to migrate away from the plume and associated extraction system.

An infiltration gallery is a series of horizontal trenches that typically consist of perforated piping placed in a gravel-lined ditch. The drains are set below the frost line and above the water table. The infiltration trenches could be place either upgradient or downgradient of the extraction well system. Implementation of infiltration trenches in Area A could be a problem since most of the area consist of landfilled material. Infiltration of water through waste materials or contaminated soil could increase contaminant leaching to groundwater. Subsurface soil sampling may be required as a pre-design activity to identify suitable areas for infiltration trenches.

Under this technology, all or some of the treated groundwater could potentially be used for nonpotable uses at the site such as for lawn watering using spray irrigation. A portion of the treated groundwater would be released to the atmosphere through evaporation. Another portion of the treated groundwater would be utilized by the vegetation on the ground surface. The balance would percolate down to the water table, thus helping to recharge the aquifer.

Injection wells, infiltration trenches, and spray irrigation are commonly used for discharge of treated groundwater in "pump and treat" remediation scenarios. Because of its demonstrated applicability, all of these process options will be retained for further consideration.

Discharge to Local Publicly Owned Treatment Works (POTW)

The treated groundwater under this process option would be discharged to the sanitary sewer system served by the Camp Allen Site, which discharges to the Army Base Treatment Plant operated by the Hampton Roads Sanitary District (HRSD). The treated groundwater would be transported via the sewer system and would receive some degree of additional treatment at the facility, primarily through volatilization. Contaminant levels would also be reduced through dilution of the groundwater flow with the sanitary wastewater influent into the plant.

The capacity of the Army Base Treatment Plant is rated at about 18 million gallons per day (MGD). The plant is currently operating at about 15 MGD (Strohmeyer, 1993). Therefore, the plant would most likely have enough hydraulic capacity to accept effluent from a groundwater extraction and treatment system at the site. However, the HSRD has had a policy for approximately ten years of not accepting continuous flow from groundwater remediation systems (Strohmeyer, 1993). The HSRD's policy is to keep the capacities of their plants available for treatment of sanitary wastes. In addition, the introduction of groundwater effluents into their sanitary waste streams can upset their biological treatment processes by diluting their sanitary influent as well as by introducing contaminants that may be toxic to the microorganisms in their biological processes. Finally, discharge of treated groundwater to the HSRD Army Base Treatment Plant may violate the facility's permit, which would require a permit modification from the State. For these reasons, this process option will be eliminated from further consideration.

Discharge to Industrial Wastewater Treatment Facility

The Naval Aviation Depot (NADEP), adjacent to Camp Allen, operates an industrial wastewater treatment plant (IWTP) for treatment of wastewaters generated from industrial processes. The IWTP consists of the following processes:

- Reduction of hexavalent chromium using sulfur dioxide.
- Cyanide destruction using alkaline chlorination.
- Phenol oxidation using hydrogen peroxide.
- Metals removal via precipitation and filtration.
- Organics removal using carbon adsorption.

The IWTP plant was designed to treat 283,000 gallons per day (197 gpm). Current influent rates into the facility average about 80,000 gallons per day (55 gpm). Therefore, the IWTP currently has about 200,000 gallons per day of excess capacity.

The IWTP currently discharges its effluent to the wastewater treatment plant operated by the Hampton Roads Sanitary District (HRSD). As discussed in the previous section, the HSRD Treatment Plant may not be willing to accept additional water from the IWTP originating from a groundwater extraction and treatment system. Therefore, discharge of either treated or untreated groundwater to HRSD through the IWTP may not be implementable.

The feasibility and cost-effectiveness of treating contaminated groundwater from the Camp Allen Site at the IWTP were evaluated and the results presented in "IWTP Engineering Analysis Report" (Baker, January 1994). Treatment options that were considered included a direct treatment option, as well as three pretreatment options, as follows:

- IWTP-1: Direct Treatment by Existing Processes
- IWTP-2: Air Stripping Pretreatment
- IWTP-3: Diffused Aeration Pretreatment
- IWTP-4: UV/Oxidation Pretreatment

The feasibility of options IWTP-1 and IWTP-4 was determined to be questionable based on implementability concerns. Based on a cost analysis of the remaining options, costs were slightly higher for IWTP-3 (diffused aeration pretreatment) than for IWTP-2 (air stripping pretreatment). Overall, air stripping pretreatment was determined to be the preferred treatment option.

However, when the IWTP user's fee of $0.15/gallon or the $3.10/1,000 gallons sewerage charge were incorporated into the cost analysis, a new on-site treatment system was determined to be more cost-effective than utilizing the existing IWTP.

For these reasons, treatment of contaminated groundwater at the existing IWTP will be eliminated from further consideration.

3.2.2.5 In situ Treatment

3.2.2.5.1 Biological Treatment

Aerobic Bioremediation

In situ bioremediation is the process by which naturally-occurring soil microorganisms degrade organic contaminants at an enhanced rate through the optimization of environmental conditions. Of the various in situ bioremediation techniques available, aerobic bioremediation is the most often employed and thus the most developed. For this technology, an oxygen source and nutrients are delivered to the subsurface through an injection well or an infiltration system. In situ bioremediation, in general, also may include the introduction of specially-adapted or genetically-altered microorganisms to the subsurface (USEPA, 1987a).

Given the appropriate environmental conditions, the naturally-occurring microorganisms can degrade a wide variety of contaminants. These include petroleum hydrocarbons, aromatics, halogenated aromatics, polyaromatic hydrocarbons, phenols, halophenols, biphenols, organophosphates, and most pesticides and herbicides. Although in situ aerobic bioremediation is flexible in terms of contaminants that can be treated, it is not applicable to halogenated hydrocarbons with relatively low molecular weights. These hydrocarbons were the primary category of organic contaminants encountered at the site. As such, this technology will not be retained for further consideration.

As discussed in Section 3.1.2.5.2, the biodegradability of the chlorinated organic compounds, which are the primary contaminants of concern at the Camp Allen Landfill Site (e.g., vinyl chloride, PCE, TCE), is currently not well-demonstrated. Laboratory studies suggest that biodegradation of halogenated solvents, such as PCE and TCE, does not occur under aerobic conditions (Wilson, et al., 1986, Bouwer et al., 1981). Recent laboratory studies have shown that TCE can be biodegraded to carbon dioxide and water in the presence of certain aromatic compounds, which include benzene and toluene (Litchfield, 1989), as well as in the presence of methane and propane (Fogel et al., 1986; Strand and Shippert, 1986; Henry and Grbic-Galic, 1986) through the process of cometabolism. The cometabolism process appears to work well for vinyl chloride and moderately well for TCE, but does not appear to be effective for PCE (Wilson, 1992). Bench- and pilot-scale studies are currently being conducted to develop a commercial process for biodegrading the chlorinated solvents via the cometabolism process, although no full-scale systems have been demonstrated to date. For this reason, in situ biodegradation will be eliminated from further consideration.

3.2.2.5.2 Physical Treatment

Air Sparging

Air sparging is an innovative technology that is becoming more popular, particularly for petroleum-contaminated sites. Although the air sparging process is currently not well-understood, results from sites where it has been implemented appear very promising. Air sparging has been used for groundwater treatment of chlorinated organics at several sites in Europe, but has mostly been used for petroleum-contaminated sites in the United States (USEPA, 1992). Air sparging can be combined with vapor extraction to treat contaminated soil and groundwater in one system.

Air sparging systems are similar in construction to soil vapor extraction systems (Section 3.1.2.6.2), except that air is injected into the saturated zone and withdrawn from the unsaturated zone. The air sparging system operates by inducing air flow through the groundwater using a series of air injection wells. The injected air serves to strip, or volatilize, VOCs from the groundwater. The contaminated vapors rise to the unsaturated, or vadose, zone where they are collected by vapor extraction wells. Extracted air is typically treated using carbon adsorption units, which are regenerated off site, or by catalytic oxidation when high contaminant concentrations make activated carbon uneconomical. For contaminants that are readily biodegradable, such as many of the petroleum hydrocarbons, air sparging also serves to promote biodegradation by enhancing oxygen concentrations in the groundwater.

Air sparging could potentially be implemented for the shallow aquifer, but would be very difficult to implement for contaminants in the deeper Yorktown Aquifer, which may be present as deep as 100 feet below ground surface. For the shallow aquifer, groundwater extraction and treatment may be needed in conjunction with air sparging to effectively contain contaminated groundwater. At this time, air sparging will be eliminated from further consideration in the FS. However, when more data become available concerning the effectiveness and implementability of air sparging, this technology could be reevaluated at a later time for possible use in conjunction with groundwater extraction and treatment.

3.2.3 Summary of Groundwater Technology and Process Option Screening

A summary of the technology and process option screening for groundwater is presented in Table 3-5. A summary of the retained technologies and representative process options for groundwater is provided in Table 3-6. Representative process options are chosen to represent the technologies in the development of remedial alternatives. A representative process option does not necessarily reflect a preference for that

TABLE 3-5
SUMMARY OF GROUNDWATER TECHNOLOGY EVALUATION AND SCREENING
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Screening Comments
No Action	None	Not Applicable	Retain for further consideration.
	Monitoring	Groundwater Monitoring	Retain for further consideration.
Institutional Controls	Land Use Controls	Base Master Plan	Retain for further consideration.
		Deed Restrictions	Retain for further consideration.
	Public Education	Meetings, Written Notices, etc.	Retain for further consideration.
Containment	Gradient Control	Extraction Wells	Retain for further consideration.
Collection/ Treatment/Discharge	Collection	Extraction Wells	Retain as a representative process option for groundwater collection. Not practical for Area A1 shallow groundwater, possibly not practical for Area A2 shallow groundwater.
		Interceptor Drains	Eliminate as a representative process option in FS. Retain for potential detailed design consideration.
	Aerobic Biological Treatment	Activated Sludge	Eliminate as a representative process option in FS. Not well proven for chlorinated organic contaminants of concern.
		Aerated Lagoon	Eliminate as a representative process option in FS. Not well proven for chlorinated organic contaminants of concern.
		Biological Towers	Eliminate as a representative process option in FS. Not well proven for chlorinated organic contaminants of concern.
	Chemical Treatment	Neutralization	Retain as a pretreatment process for metals removal.
		Oxidation with Hydrogen Peroxide	Eliminate as a representative process option in FS. Not well proven for chlorinated organic contaminants of concern.

TABLE 3-5
SUMMARY OF GROUNDWATER TECHNOLOGY EVALUATION AND SCREENING
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Screening Comments
Collection/ Treatment/Discharge (continued)	Chemical Treatment (continued)	Ozonation	Eliminate as a representative process option in FS. Not well proven for chlorinated organic contaminants of concern.
		Oxidation with Potassium Permanganate	Retain as a pretreatment process for metals removal.
		Oxidation with UV Light/Ozonation	More costly to implement than air stripping and carbon adsorption.
		Oxidation with Hypochlorite	Eliminate as a representative process option in FS. Not well-proven for chlorinated organic contaminants of concern. More costly to implement than air stripping and carbon adsorption.
		Precipitation	Retain as a pretreatment process for metals removal.
	Physical Treatment	Activated Carbon	Retain for further consideration.
		Air Stripping	Retain for further consideration.
		Dewatering	Retain for dewatering of sludge generated during groundwater treatment.
		Clarification/ Sedimentation	Retain as a pretreatment process for metals removal.
		Coagulation/ Flocculation	Retain as a pretreatment process for metals removal.
		Dissolved Air Flotation	Eliminate as a representative process option in FS. Not well-proven for chlorinated organic contaminants of concern.
		Distillation	Eliminate as a representative process option in FS. Air stripping and carbon adsorption are more cost effective for contaminants of concern.
		Equalization	Retain as a pretreatment process for metals removal.
		Filtration	Retain as a pretreatment process for metals removal.

TABLE 3-5
SUMMARY OF GROUNDWATER TECHNOLOGY EVALUATION AND SCREENING
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

General Response Actions	Remedial Technology	Process Option	Screening Comments
Collection/ Treatment/Discharge (continued)	Physical Treatment (continued)	Ion Exchange	Eliminate as a representative process option in FS. Retain for potential detailed design consideration.
		Oil/water separation	Eliminate as a representative process option in FS. Free non-aqueous phase contamination not detected in groundwater.
		Reverse Osmosis	Eliminate as a representative process option in FS. More difficult to implement than air stripping and carbon adsorption.
		Steam Stripping	Eliminate as a representative process option in FS. Air stripping and carbon adsorption are more cost effective for contaminants of concern.
	Discharge	Surface Water	Retain for further consideration.
		Subsurface Discharge	Retain for further consideration.
		POTW	Eliminate as a representative process option in FS. Not implementable because local facility will not accept continuous groundwater discharge.
		Industrial Wastewater Treatment	Eliminate as a representative process option based on results of "IWTP Engineering Analysis Report" (Baker, January 1994).
In Situ Treatment	Biological Treatment	Aerobic Bioremediation	Eliminate as a representative process option in FS. Not well-proven for chlorinated organic contaminants of concern.
	Physical Treatment	Air Sparging	Eliminate as a representative process option in FS. Currently not well-proven for contaminants of concern. Could be considered at a later time to augment or replace shallow groundwater extraction and replacement system when more data become available.

TABLE 3-6

SUMMARY OF RETAINED GROUNDWATER TECHNOLOGIES
AND REPRESENTATIVE PROCESS OPTIONS
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

GENERAL RESPONSE ACTION	TECHNOLOGY	REPRESENTATIVE PROCESS OPTION
No Action	Monitoring	Groundwater Monitoring
Institutional Controls	Land Use Control	Base Master Plan Deed Restrictions
	Alternate Water Supply	Connection to Public Water Supply
	Public Education	Public Meetings
Containment	Gradient Control	Extraction Wells
Collection/Treatment/Discharge	Collection	Extraction Wells
	On-site Physical Treatment[1]	Air Stripping, Carbon Adsorption
	Discharge	Surface Water

[1] The following process options were not selected as primary treatment components for the organic contaminants but were retained for pretreatment of groundwater for removal of metals and suspended solids: equalization, neutralization, oxidation with potassium permanganate, precipitation, coagulation/flocculation, clarification/sedimentation, filtration, and sludge dewatering.

process, but rather is selected to simplify development and evaluation of remedial alternatives in the FS. Other process options for a given technology could be considered during a remedial design phase.

SECTION 4 - DEVELOPMENT AND SCREENING OF AREA A SOIL ALTERNATIVES

4.0 DEVELOPMENT AND SCREENING OF AREA A SOIL ALTERNATIVES

In this section, the general response actions and process options retained from the initial screening and evaluation of remedial technologies are combined to develop remedial action alternatives for the soils at Area A. The purpose of this section is to reduce the number of alternatives that will be subsequently subjected to the detailed analysis in Section 5.0. The surface water/sediment alternatives for Areas A and B, which are limited to No Action and Institutional Control with Monitoring, will be evaluated as part of the detailed analysis of alternatives in Section 5.0. Similarly, the soil alternatives for Area B, which are limited to No Action and Institutional Control, will be evaluated in Section 5.0.

As discussed in Section 1.0, a removal action is being implemented to remove the suspected source areas within the Area B Landfill. The objective of the removal action is to remove the sources of groundwater contamination within the Area B Landfill so that no further remedial actions are required for the soils and debris associated with the Area B Landfill. Confirmation soil sampling and analysis will be performed to verify that the soil cleanup levels, included in the Final EE/CA Report (Baker, 1993a), have been met. Therefore, source control alternatives for the Area B Landfill are not necessary, and were not developed in this FS.

The alternatives developed and screened in this section are based on the general response actions, remedial technologies, and representative process options selected in Section 3.1.3. The following alternatives have been developed for the soils in Area A:

- Alternative A-SO1: No Action
- Alternative A-SO2: Institutional Controls
- Alternative A-SO3: Asphalt/Geosynthetic Cap Over Brig Area with Institutional Controls
- Alternative A-SO4: Composite Cap Over Hot Spot Areas with Institutional Controls
- Alternative A-SO5: In Situ Treatment of Hot Spot Area Soils and Shallow Groundwater Using Dual Phase Vacuum Extraction with Institutional Controls
- Alternative A-SO6: Thermal Treatment of Hot Spot Area Soils with Institutional Controls

- Alternative A-SO7: Disposal of Hot Spot Area Soils in Off-site Hazardous Waste Landfill with Institutional Controls

As per USEPA guidance, the alternatives were evaluated for the short-term and long-term expectations of three broad criteria: effectiveness, implementability, and cost. The effectiveness criteria is measured in terms of protecting human health and the environment. Each alternative was evaluated on its effectiveness in providing protection and reduction in toxicity, mobility, or volume. Short-term effectiveness was evaluated based on the construction and implementation period, while long-term effectiveness was based on the period after the remedial action is complete (USEPA, 1988b).

The implementability criteria includes both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative with respect to site-specific conditions. Technical feasibility refers to the ability to construct, reliably operate, and meet technology-specific regulations for process options until a remedial action is complete. Administrative feasibility refers to the ability to obtain approvals for treatment, storage, and disposal services and capacity, and the requirements for, and availability of, specific equipment and technical specialists (USEPA, 1988b).

Finally, the focus of the cost evaluation was to make comparative estimates for alternatives with relative accuracy. Both capital and operation and maintenance (O&M) costs were considered during this screening.

4.1 Alternative A-SO1: No Action

Description: The No Action Alternative is required by the NCP to provide a baseline comparison for other remediation alternatives. Under the No Action Alternative, no remedial action would be performed to reduce the toxicity, mobility, or volume of contamination at the Camp Allen Area A Landfill. Groundwater monitoring would be implemented under one of the groundwater alternatives (Section 6.0).

Effectiveness: The No Action Alternative would not provide any additional short-term or long-term protection to human health or the environment than that currently offered by the existing soil and asphalt cover materials over the landfill. In addition, the alternative would not provide short-term reduction in toxicity, mobility, or volume of contaminants in the subsurface soil. However, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Implementability: The No Action Alternative would be both technically and administratively simple to implement since there are no remedial activities associated with this alternative.

Cost: There are no capital or annual operation and maintenance (O&M) costs associated with this alternative. However, an O&M cost of $20,000 occurs every five years for a site review.

The estimated net present worth cost for this alternative over a 30-year period is $55,600. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: No Action will be retained for further consideration to provide a baseline to which the other alternatives can be compared.

4.2 Alternative A-SO2: Institutional Controls

Description: Under this alternative, existing institutional controls at Camp Allen (i.e., fences and designation of non-residential areas) would be maintained to limit access and control future use of Area A as well as to indicate that wastes are buried at the site. The location of existing fencing is shown in Figure 4-1. In addition, the existing soil cover over the Area A Landfill would be maintained to limit surface water infiltration and minimize potential erosion. There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions proposed under this alternative would limit the Camp Allen Landfill to non-residential land uses.

Effectiveness: This alternative would not provide any additional short-term or long-term protection to the environment than that currently offered by the existing soil and asphalt cover materials over the landfill. In addition, the alternative would not provide short-term reduction in toxicity, mobility, or volume of contaminants in the subsurface soil. However, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

This alternative would provide some degree of short- and long-term protection to human health. The existing fencing would reduce the chance of exposure to potential contaminants within the landfill through the ingestion, dermal contact, and inhalation exposure pathways. Implementation of this alternative would not pose a short-term risk to human health or the environment since remedial action would be limited to maintenance of existing institutional controls.

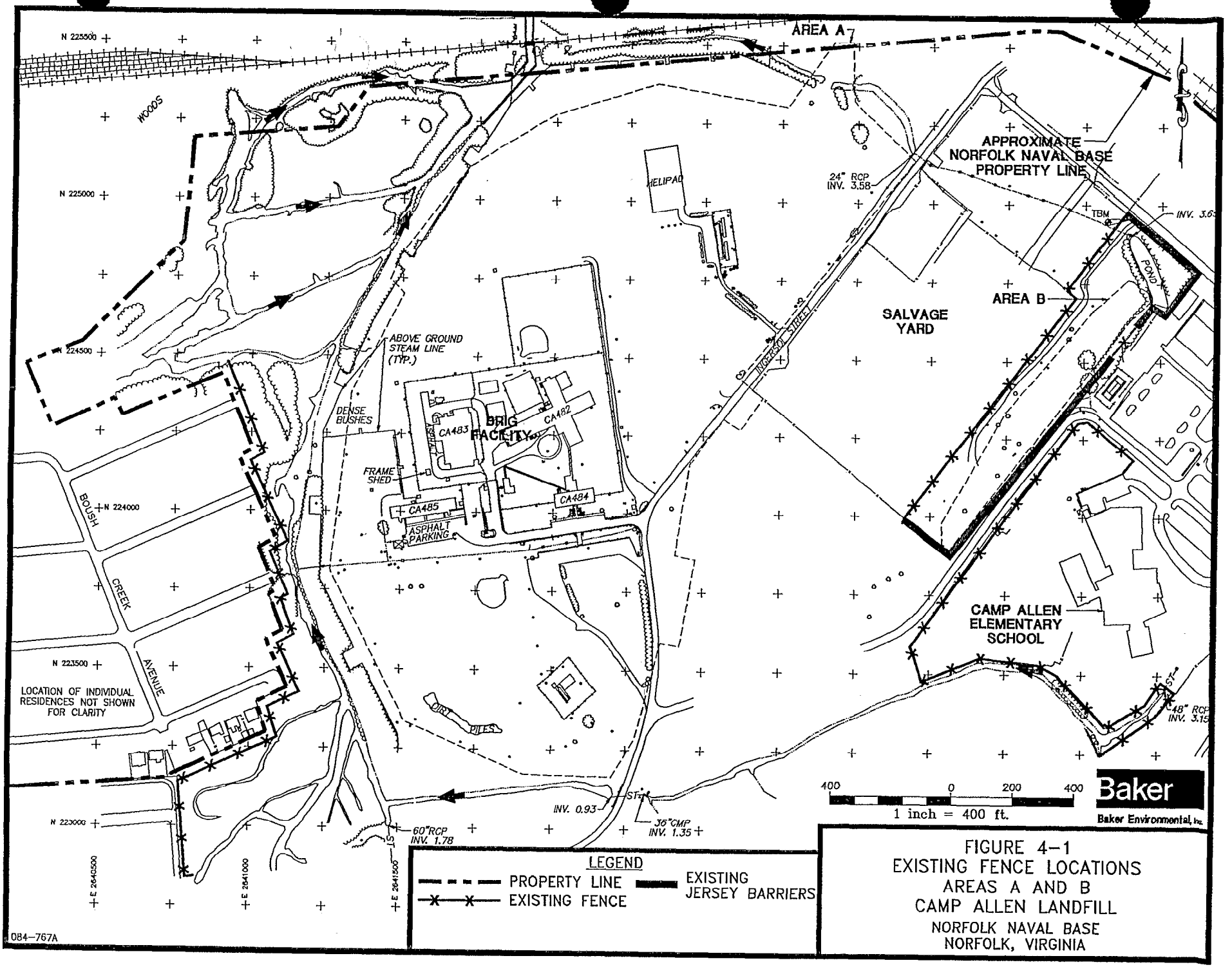


FIGURE 4-1
EXISTING FENCE LOCATIONS
AREAS A AND B
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Implementability: This alternative would be technically and administratively simple to implement. Fence maintenance services are readily available. Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: There are no capital costs associated with this alternative. Legal and administrative costs for implementation of deed restrictions have not been estimated at this time, but are expected to be low compared to the costs of the other remedial alternatives.

The annual operation and maintenance (O&M) costs for this alternative include: maintenance of the existing fence, which is estimated at approximately $600 annually; maintenance of the existing soil cover, which is estimated at $16,857 annually; and $20,000 every five years for site reviews.

The estimated net present worth cost for this alternative over a 30-year period is $325,500. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: Institutional controls would reduce the risk of exposure to potential contamination contained within the landfill by limiting access and control of future site uses. Additionally, maintenance of the existing soil cover would limit surface water infiltration and minimize potential erosion. Therefore, institutional controls will be retained for further consideration.

4.3 Alternative A-SO3: Asphalt/Geosynthetic Cap Over Brig Area with Institutional Controls

Description: This alternative includes placement of an asphalt/geosynthetic cap around the Brig Facility area, which is the more active portion of Area A, and the area immediately west of the Brig, towards the western boundary of the landfill. The cap would cover the hot spot areas identified during the pre-design investigation. The purpose of the cap would be to minimize the infiltration of rain water into the waste area, thus reducing leaching and transport of potential contaminants from the soil to groundwater and surface water. The cap would also prevent exposure (i.e, ingestion, inhalation, and dermal contact) to potential contaminants within the landfill.

The asphalt/geosynthetic cap would encompass an area of approximately 12 acres. Of this area, approximately 4 acres are currently covered by buildings or asphalt (e.g., roads and parking lots). The

approximate area to be capped is shown in Figure 4-2. For costing purposes, it was assumed that the cap would be constructed of a 30-mil very low density polyethylene (VLDPE) synthetic liner overlain by a 4-inch aggregate subbase layer, a 4-inch thick bituminous base course layer, and a 2-inch thick asphalt surface layer (Figure 4-3). Prior to capping, the soil would be stabilized via mechanical compaction techniques. This would improve the physical properties of the soil and assist in maintaining the integrity of the cap. A passive gas venting system would be installed to prevent the buildup of landfill gases under the cap. A typical venting system would consist of gas vents installed at a frequency of about one per acre. Surface water runoff would drain into a storm sewer system as well as to collection channels, which would both need to be constructed under this alternative. The collected surface water would be conveyed to the on-site drainage ditch located west of the Brig Facility.

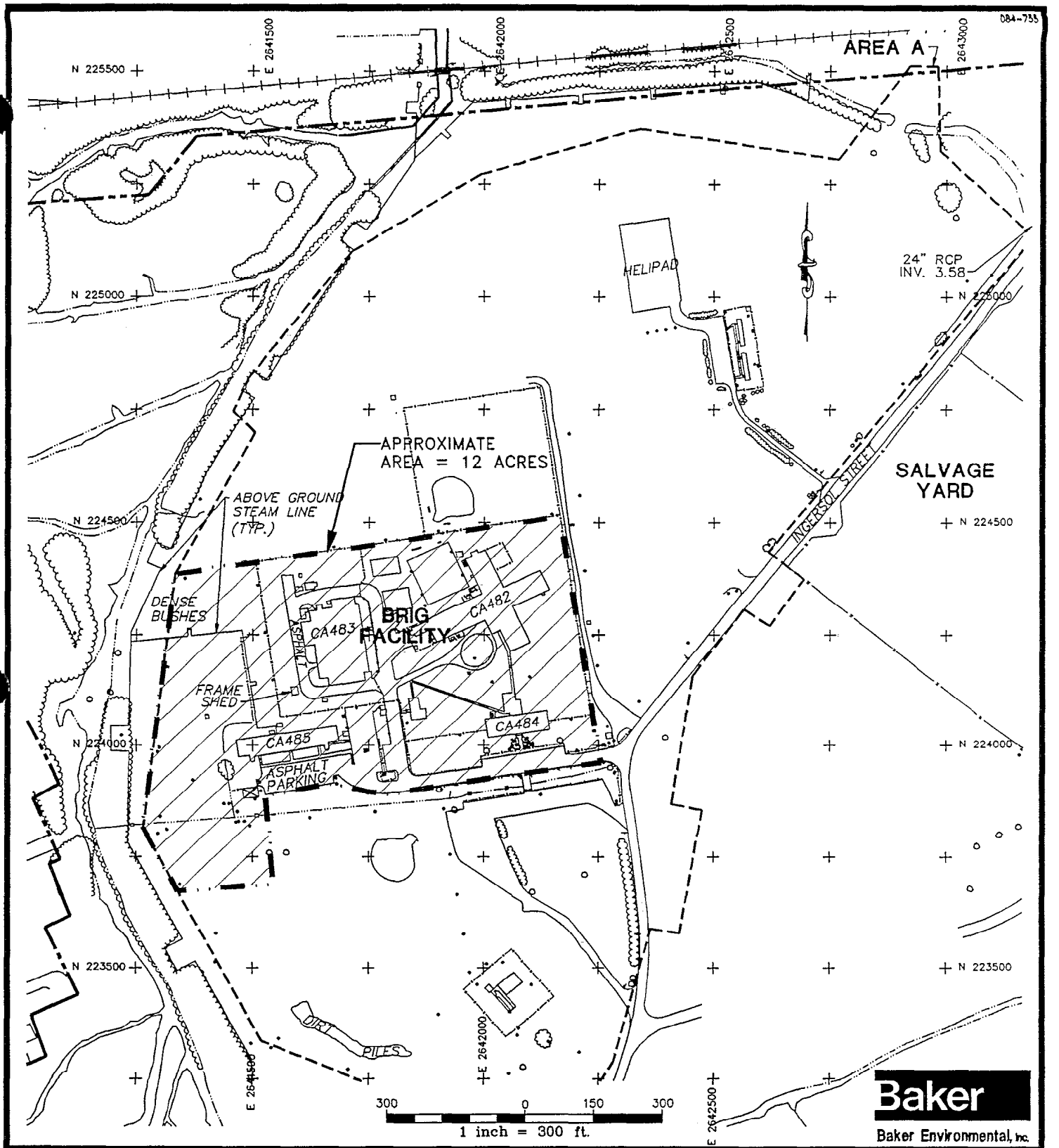
In addition to the asphalt/geosynthetic cap, the existing fencing and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Effectiveness: This alternative would provide a reduction in mobility of contaminants contained in the subsurface soil by minimizing infiltration of precipitation. The cap would also help to reduce potential off-base migration of contaminants by controlling surface water runoff and erosion. The cap would not eliminate leaching of contaminants to groundwater in areas where soil contamination is present near or below the water table. In these areas, fluctuations in groundwater levels could continue to cause releases of contaminants to groundwater.

This alternative would not provide an immediate reduction in toxicity and volume of contaminants in the landfill. There may be a gradual reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion. Additionally, this alternative would reduce potential exposure to potential contaminants within the landfill. No impact to the environment is anticipated to occur during installation of the asphalt/geosynthetic cap.

Implementability: Technically, this alternative should be relatively straight-forward to implement. The technologies for capping are all demonstrated and commercially available.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

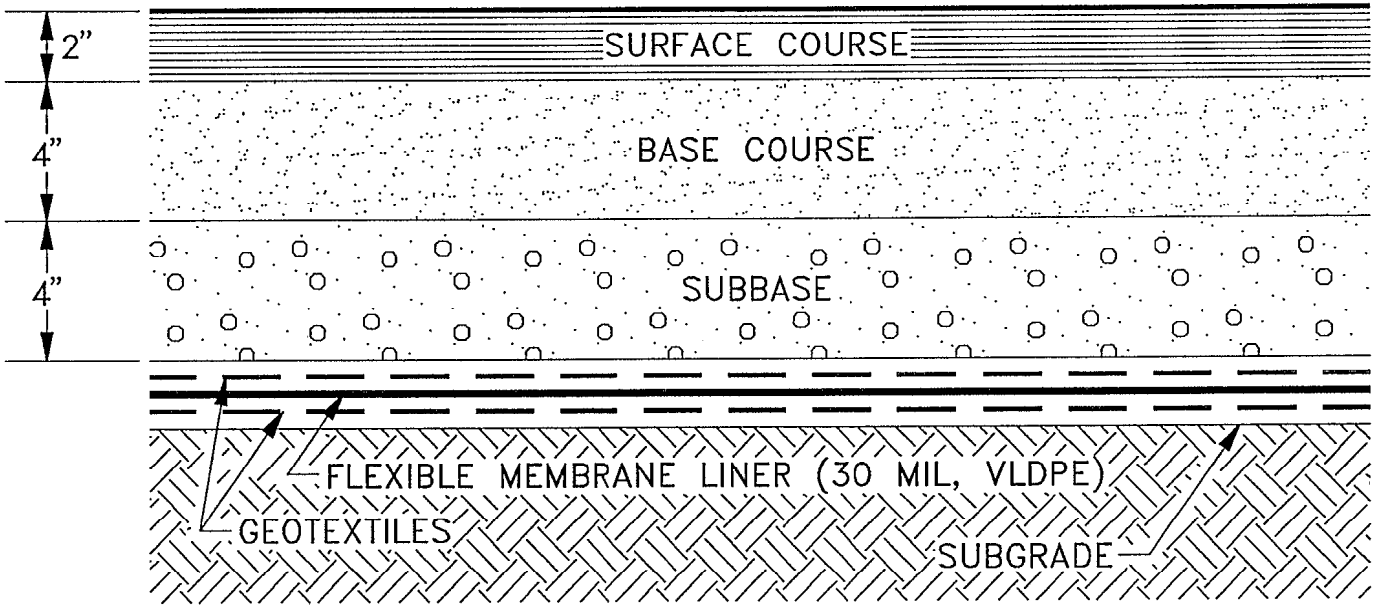


LEGEND

LIMITS OF PROPOSED ASPHALT CAP

SOURCE: 084-754

FIGURE 4-2
PROPOSED ASPHALT CAP LOCATION
ALTERNATIVE A-S03
AREA A
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



REF.: AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES, 1986.

Baker
Baker Environmental, Inc.

LEGEND

- SURFACE COURSE
- BASE COURSE
- SUBBASE
- GEOTEXTILE
- FLEXIBLE MEMBRANE LINER (30 MIL, VLDPE)
- SUBGRADE

FIGURE 4-3
ASPHALT CAP CROSS SECTION
ALTERNATIVE A-S03
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

084502FS

Cost: The primary capital cost for this alternative would be installation of the asphalt/geosynthetic cap and related work. The estimated capital cost for installation of the cap is $927,200. Legal and administrative costs related to implementation of deed restrictions have not been estimated at this time but are expected to be low compared to costs associated with installation of the cap.

The operation and maintenance (O&M) costs for this alternative include: maintenance of the asphalt/geosynthetic cap ($58,100 every five years); annual maintenance of the existing fence ($600/year); annual maintenance of the existing soil cover ($16,957/year); and, five-year site reviews ($20,000 each).

The estimated net present worth cost for this alternative over a 30-year period is $1,877,900. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: Capping would reduce migration of potential contaminants present in the Area A Landfill to surface water and groundwater and would reduce the risk of exposure to potential contamination contained within the landfill. Therefore, installation of an asphalt/geosynthetic cap will be retained for further consideration.

4.4 Alternative A-SO4: Composite Cap Over Hot Spot Areas with Institutional Controls

Description: This alternative includes the placement of a low-permeability composite cap over the "hot spot" area or areas in Area A1 and A2, as discussed in Section 2.4. The purpose of the cap would be to minimize the infiltration of rain water into the source areas, thus reducing leaching and transport of potential contaminants from the soil to groundwater and surface water. The cap would also prevent exposure to potential contaminants within the hot spot areas.

The composite cap would cover the hot spots in Areas A1 and A2, which total approximately 1.0 acre in size. The cap would be constructed in accordance with RCRA and Virginia Hazardous Waste Management Regulations (VR 672-10-1). For costing purposes, it was assumed that the cap would be constructed of a low hydraulic conductivity soil layer with an overlying 30-mil flexible membrane liner constructed of a geosynthetic material, such as very low density polyethylene (VLDPE). The geosynthetic material would be covered with a drainage layer and a soil layer to support vegetation. A typical cap cross section is shown in Figure 4-4. Prior to capping, the soil would be stabilized via mechanical compaction techniques. This would improve the physical properties of the soil and assist in maintaining the integrity of the cap. A passive gas venting system would be installed to prevent the buildup of landfill gases under the cap. The

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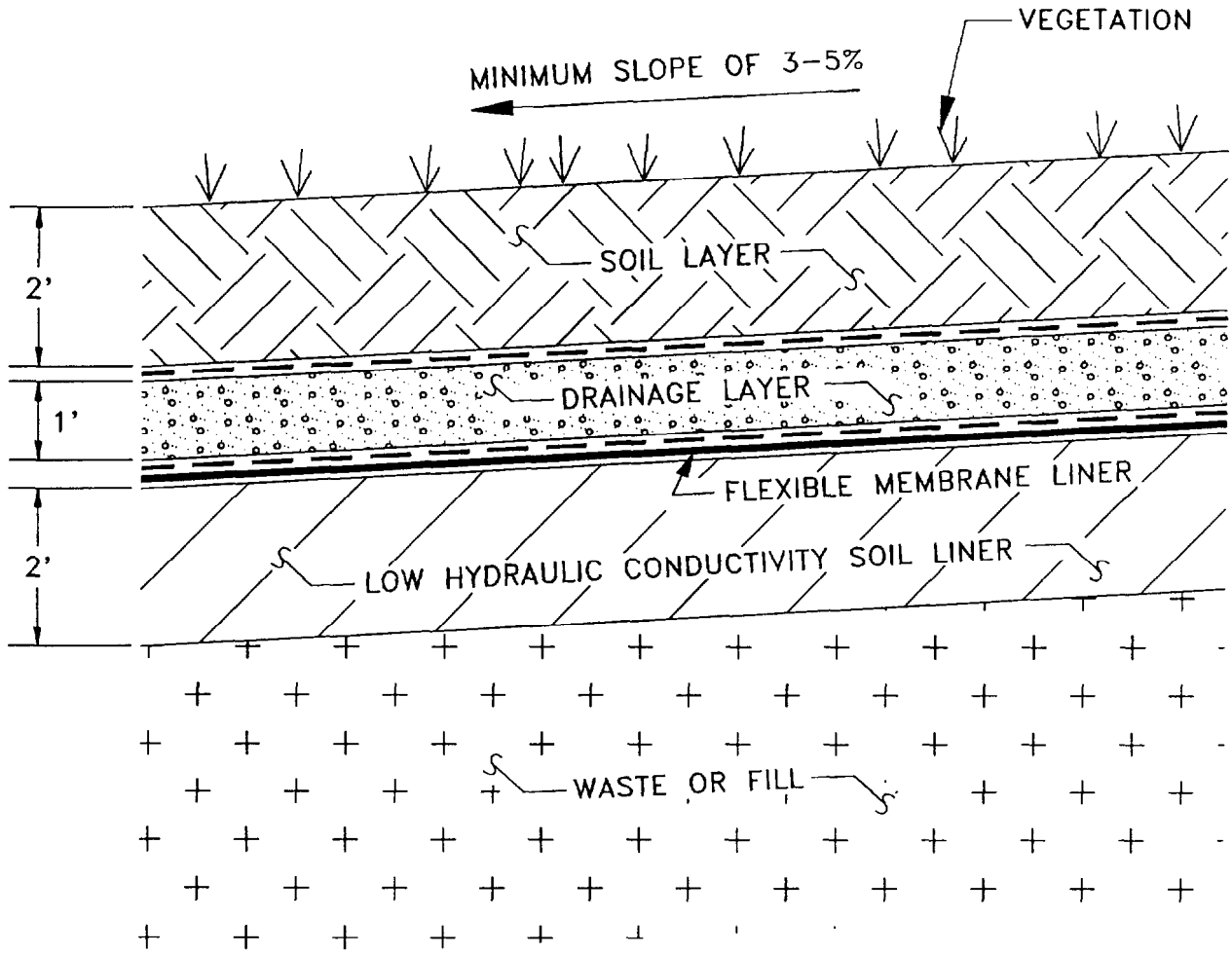

SOURCE: USEPA "DESIGN AND CONSTRUCTION OF RCRA/CERCLA FINAL COVERS," MAY 1991, EPA/625/4-91/025

Baker
Baker Environmental, Inc.

LEGEND

- VEGETATION/SOIL LAYER
- GEOTEXTILE (FILTRATION OR FML PROTECTION)
- DRAINAGE LAYER - AGGREGATE $k \geq 1 \times 10^{-2}$ cm/sec
- FLEXIBLE MEMBRANE LINER (FML) 30 MIL MINIMUM
- LOW HYDRAULIC CONDUCTIVITY SOIL LAYER $k \leq 1 \times 10^{-7}$ cm/sec
- WASTE OR FILL

FIGURE 4-4
COMPOSITE COVER CROSS-SECTION
ALTERNATIVE A-S04
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

venting system would consist of one passive gas vent installed at each of the four "hot spot" areas. Surface water runoff would drain into collection channels, which would be constructed around the perimeter of the cap areas.

In addition to the composite cap, the existing fencing and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Effectiveness: This alternative would provide a reduction in mobility of contaminants contained in the subsurface soil by minimizing infiltration of precipitation through the source area. The cap may not totally eliminate leaching of contaminants to groundwater if part of the source volume is present near the water table, where fluctuations in groundwater levels could cause releases of contaminants to groundwater. The cap would also help to reduce potential off-base migration of contaminants by controlling surface water runoff and erosion.

This alternative would not provide an immediate reduction in toxicity and volume of contaminants in the hot spot area. There may be a gradual reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion. Additionally, this alternative would reduce potential exposure (i.e, ingestion, inhalation, and dermal contact) to potential contaminants within the landfill. No impact to the environment is anticipated to occur during installation of the composite cap.

Implementability: Technically, this alternative should be relatively straight-forward to implement. The technologies for capping are all demonstrated and commercially available.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The primary capital cost for this alternative would be installation of the composite cap and related work. The estimated capital cost for installation of the cap is $465,300. Legal and administrative costs related to implementation of deed restrictions have not been estimated at this time but are expected to be low compared to costs associated with installation of the cap.

The operation and maintenance (O&M) costs for this alternative include: annual maintenance of the composite cap ($1,837/year); annual maintenance of the existing fence ($600/year); annual maintenance of the existing soil cover ($16,957/year); and, five-year site reviews ($20,000 each).

The estimated net present worth cost for this alternative over a 30-year period is $819,100. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: Capping would reduce migration of contaminants from the hot spot areas to surface water and groundwater and would reduce the risk of exposure to potential contamination contained within the source area. Therefore, installation of a composite cap over the hot spot area(s) will be retained for further consideration.

4.5 Alternative A-SO5: In Situ Treatment of Hot Spot Area Soils and Shallow Groundwater Using Dual Phase Vacuum Extraction with Institutional Controls

Description: This alternative includes in situ treatment of the "hot spot" or source areas. Under this alternative, approximately 12,814 cubic yards (20,759 tons) of contaminated soil would be treated using a dual phase vacuum extraction (DPVE) system, removing contaminated soil gas and shallow groundwater for subsequent treatment.

Dual phase vacuum extraction is a method to remediate soil and groundwater using only a single extraction system. This method is the most effective method for removing contaminated shallow groundwater when hydraulic conductivities of the shallow aquifers are less than 1.0 gpd/ft^2. The shallow aquifers in Areas A1 and A2 meet this criterion. The system uses high vacuum (>25" Hg vacuum) to strip the vadose zone of VOCs, while simultaneously removing groundwater (in liquid and vapor form) from the shallow aquifer. This two-phase stream is then sent to an air/water separator. The vapor phase is treated using activated carbon. The water stream is intermittently pumped to an on-site groundwater facility or to a collection tank for periodic off-site treatment and disposal.

The dual phase vacuum extraction and treatment system would consist of several major components. The extraction system would include the extraction wells and below-ground interconnecting well piping. The treatment system would include a liquid ring vacuum pump system, an air/water separator system, a vapor phase carbon adsorption system, and a groundwater transfer pump. The liquid ring vacuum pump system would entrain vapor and liquid from the extraction wells. This two-phase stream would be entrained in the air/water separator and split into a liquid and vapor stream. The liquid would collect in the separator

tank and would be periodically pumped to an on-site groundwater treatment system or transported to an off-site treatment and disposal facility. The vapor would continue through the vacuum pump system and would be discharged through the carbon adsorption system. The treated vapor would then be vented to the atmosphere. For high concentrations of contaminants where high carbon usage rates make activated carbon treatment cost-prohibitive, catalytic oxidation systems can be used for off-gas treatment. A schematic of a typical DPVE system is shown in Figure 4-5.

The major equipment for the DPVE treatment system would be located in a prefabricated metal building located adjacent to the contaminated area. Proposed locations for the treatment system building and the extraction wells for areas A1 and A2 are shown in Figures 4-6 and 4-7.

Soil cleanup goals developed in Section 2.3 were used to estimate remediation areas of concern. It should be noted that since Area A is a landfill, the remedial action objective (RAO) for the soils is groundwater protection rather than soil cleanup. Therefore, achievement of this RAO would not necessarily be based on attainment of the developed soil cleanup goals since they represent theoretical values calculated through modeling. In addition, the cleanup goals were developed using conservative assumptions and may not be representative of actual site conditions. Therefore, achievement of groundwater protection would be determined through development of treatment system performance curves and through evaluation of actual environmental monitoring results (i.e., via ongoing monitoring of contaminant levels in groundwater and in the extracted vapors from the in situ vacuum extraction system). Soil contaminant concentrations may eventually reach asymptotic levels below which contaminant levels cannot be reduced via in situ vacuum extraction. If treatment system performance curves indicate that the cleanup goals for some or all of the contaminants cannot be achieved, then the soil cleanup goals will be reevaluated.

For costing purposes, it was assumed that a total of seven vacuum extraction wells (each 20 feet deep) would be used, that the off-gas would be treated using activated carbon canisters, and that water collected from the air/water separator would be treated at an on-site groundwater treatment facility.

Prior to design and installation of the full-scale system, a short-term (e.g., less than one month) air permeability test would be required to determine optimum well spacings (i.e., radius of influence) for the source area. The test would also provide other design data, such as air flow rates and contaminant loading rates. The test would consist of extracting air from one or two wells and measuring the vacuum pressures at several surrounding monitoring points.

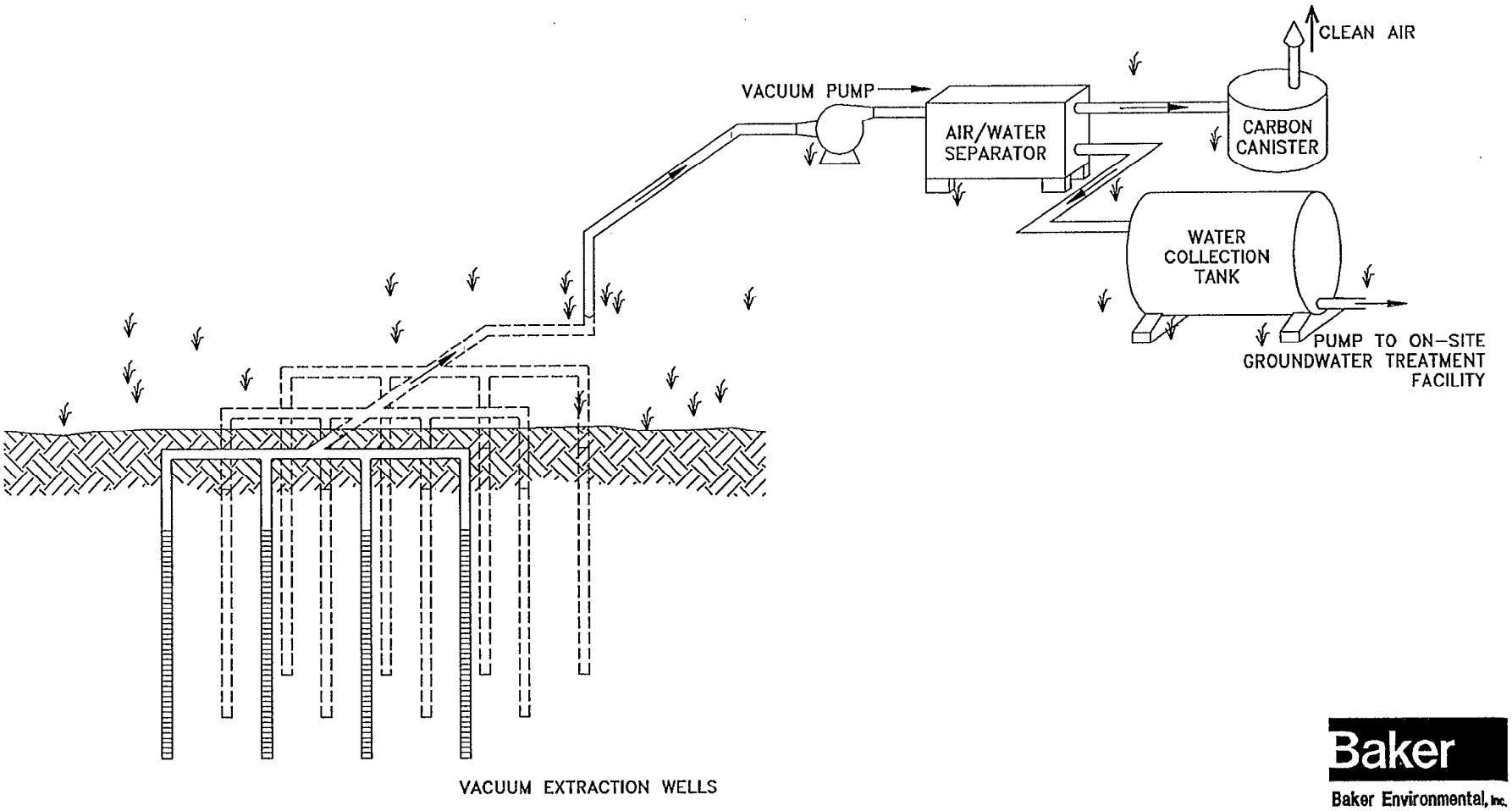

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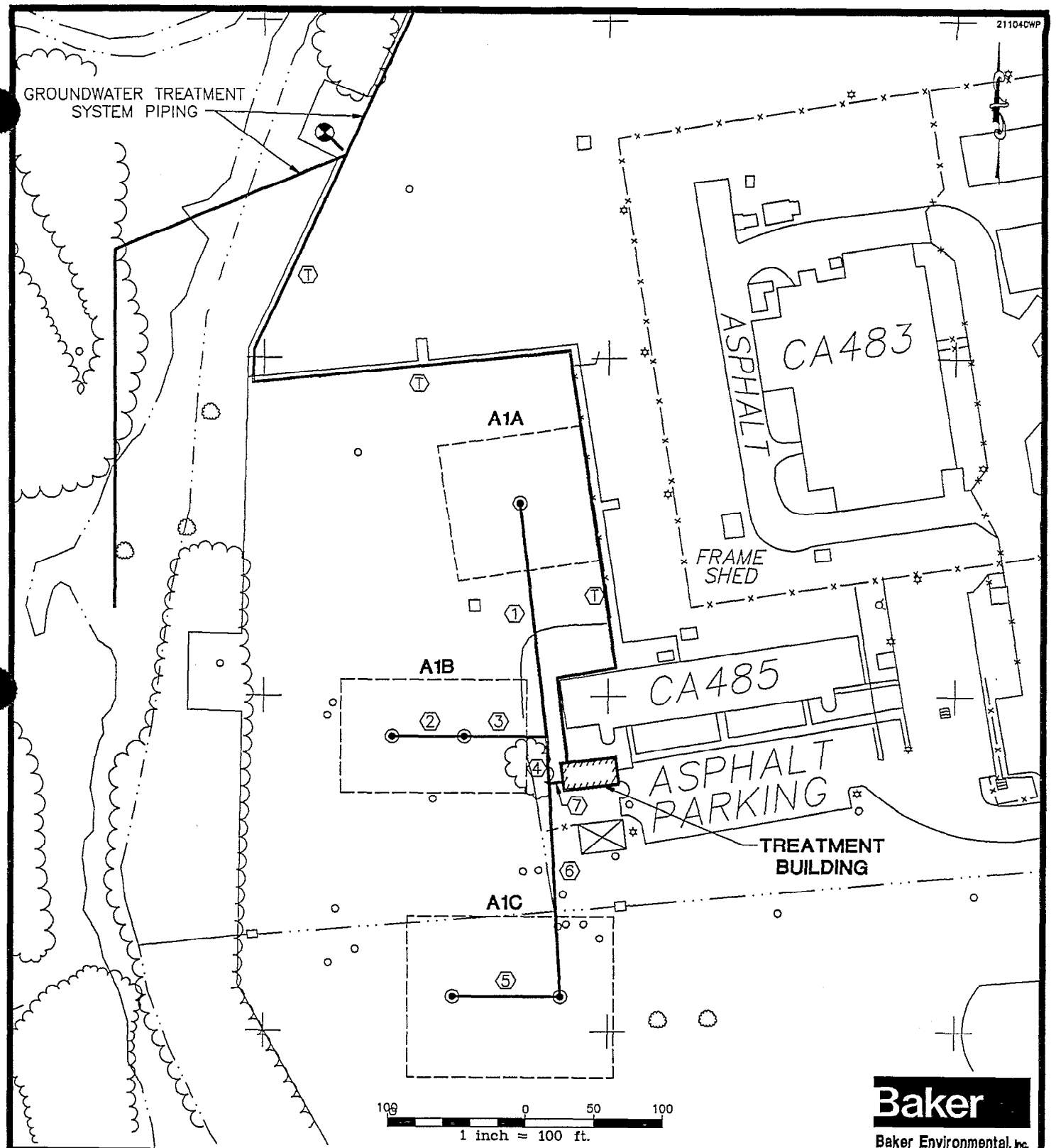
FIGURE 4-5
DUAL PHASE VACUUM EXTRACTION
ALTERNATIVE A-SO5
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

084-759



LEGEND

A1A SOIL REMEDIATION AREA

DUAL-PHASE EXTRACTION WELL

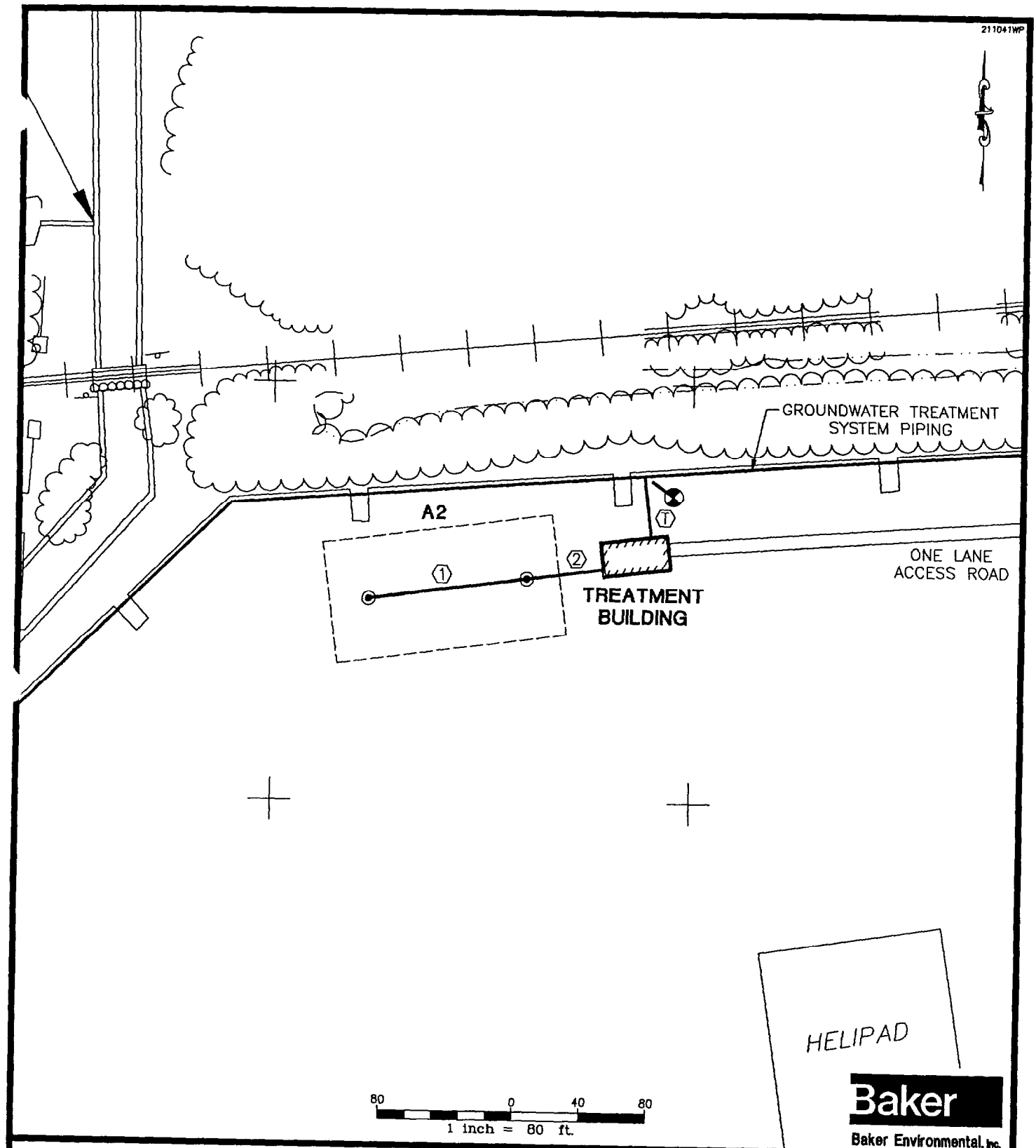
EXTRACTION WELL PIPE SEGMENT

TIE POINT TO GROUNDWATER TREATMENT SYSTEM PIPING

ABOVE GROUND DPVE SYSTEM GROUNDWATER PIPING

FIGURE 4-6
PROPOSED DUAL PHASE VACUUM EXTRACTION REMEDIATION FOR AREA A1
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

A2 SOIL REMEDIATION AREA

DUAL-PHASE EXTRACTION WELL

1 EXTRACTION WELL PIPE SEGMENT

TIE POINT TO GROUNDWATER TREATMENT SYSTEM PIPING

T ABOVE GROUND DPVE SYSTEM GROUNDWATER PIPING

FIGURE 4-7
PROPOSED DUAL PHASE VACUUM EXTRACTION REMEDIATION FOR AREA A2
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

In addition to installation and operation of the DPVE, the existing fencing and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Effectiveness: This alternative would be effective for soils and shallow groundwater contaminated with VOCs, and partially effective for SVOCs.

This alternative would reduce the volume and toxicity of the contaminated soil and shallow groundwater in the hot spot areas through removal and treatment of VOCs. By increasing oxygen levels in the soil and groundwater, DPVE would also reduce VOCs and SVOCs by enhancing natural biodegradation processes. DPVE may not be able to achieve the very low soil cleanup levels (i.e., low ppb range) due to the high silt content in the soils (contaminants are most strongly adsorbed to silt and clay particles). However, this technology has been demonstrated to be effective for removing large quantities of contaminant mass from soil. Residual soil contamination that cannot be removed through DPVE would exhibit low mobility, and therefore, should not pose a substantial risk to groundwater (i.e., through leaching). Furthermore, DPVE offers a significant advantage over the other alternatives in that it is able to treat both soil and shallow aquifer contamination. This benefit is especially valuable since recent data have shown that the conventional pump and treat method would not be feasible for treatment of the shallow aquifer in Area A1 due to its low hydraulic conductivity.

This alternative would prevent exposure of human receptors to potential contaminants in the landfill through institutional controls. Protection of the community, workers, and the environment from the extracted soil vapor during remediation would be provided by the off-gas treatment system. The treated off-gas would be periodically monitored to ensure proper operation and adequate protection of human health and the environment.

Implementability: DPVE technology is innovative, but is very similar to soil vapor extraction (SVE) technology, which has been used extensively. The technologies for DPVE are all demonstrated and commercially available. The DPVE system should be relatively easy to implement. The equipment that comprises the system consists of commonly-used items such as extraction wells, PVC piping, valves, and pumps. However, the presence of buried debris could make installation of a DPVE system more difficult. The implementation of this alternative is primarily dependent on the radius of influence of the extraction system, initial and final exhaust concentrations, obtainable flow rates, water level changes, and vacuum well pressures.

The major operational requirements include periodic (e.g., monthly) replacement of the carbon canisters used to treat soil gas and on-site treatment of the water collected in the air/water separator. (It is assumed that this alternative would be implemented in conjunction with a groundwater treatment alternative.) Periodic monitoring of off-gas contaminant concentrations, water level checks in the air/water separator, and servicing of the air compressor would also need to be performed. In general, operation and maintenance requirements are highest at system startup and should decline over time. Following treatment, no long-term monitoring, operation, or maintenance would be required for the soils. With respect to the entire landfill area, periodic inspection and maintenance of the existing cover would be required to ensure it remains intact.

The administrative activities associated with this alternative involve ensuring that construction activities are implemented correctly and that proper protective equipment is worn by remedial workers.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The primary capital cost for this alternative would be associated with installation and startup of the DPVE system. The estimated capital cost for this alternative is $490,700. Legal and administrative costs related to implementation of deed restrictions have not been estimated at this time but are expected to be low compared to the costs of installation of the DPVE system.

For costing purposes, it was assumed that the DPVE system would operate for five years. The operation and maintenance (O&M) costs for this alternative include: operation of the DPVE system, which is estimated at approximately $90,500 annually for years 1 through 5, $20,000 every five years for site reviews; annual maintenance of the existing fence ($600/year); annual maintenance of the existing soil cover ($16,957/year); and the removal of the DPVE system ($11,000).

The estimated net present worth cost for this alternative is $1,216,700. The present worth cost is based on a 5-year operation period for the DPVE system and a 30-year maintenance period for the landfill. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: Dual phase vacuum extraction is implementable and is expected to be effective in remediating soil and shallow groundwater contaminated with VOCs. Therefore, this alternative will be retained for further consideration.

4.6 Alternative A-SO6: Thermal Treatment of Hot Spot Area Soils with Institutional Controls

Description: This alternative includes excavation of the contaminated "hot spot" area soils and thermal treatment using either an on-site low temperature thermal treatment unit or off-site incineration. For costing purposes, it was assumed that all of the contaminated soil would be treated on site in a low temperature thermal desorption unit. However, if any waste materials that are not amenable to low temperature treatment (such as buried drums containing spent solvents or waste oil) were uncovered during excavation, it was assumed that these materials would be transported to an off-site RCRA-permitted incinerator.

A temporary staging area would be constructed on site (e.g., 150 foot x 150 foot asphalt pad) for the treatment unit and for treated and untreated soil stockpiles. Approximately 12,814 cubic yards (20,759 tons) of soil would be excavated using conventional equipment, such as a backhoe, loaded onto trucks, and hauled to the staging area for treatment.

The soil would be treated using a low-temperature (i.e., 400 - 800°F) thermal treatment unit. A typical low-temperature thermal treatment process is shown in Figure 4-8. Air pollution controls and stack emission monitoring would be provided as necessary to comply with local and/or state air emission regulations. Prior to treatment, soils would be screened to remove large boulders and any debris present in the soil. For costing purposes, it was assumed that the soil contained 10 percent debris by weight and that the debris would be decontaminated and disposed in a local sanitary landfill. For costing purposes, it was also assumed that condensate water generated from the treatment process would be mixed with treated soil, and that condensed solvents removed by the off-gas treatment system would be disposed off site at a RCRA-permitted hazardous waste incinerator. The treated soil would be used to backfill the excavated areas. Prior to backfilling, thermally treated soil would be analyzed for the contaminants of concern to verify that cleanup goals have been achieved.

In addition to thermal treatment of the contaminated soils, the existing fencing and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Effectiveness: This alternative would reduce the volume and toxicity of the contaminated soil in the hot spot areas through removal and thermal treatment of VOCs and SVOCs. The thermal treatment system is expected to remove more than 99 percent of the VOCs from the soil. SVOCs, if present, would be

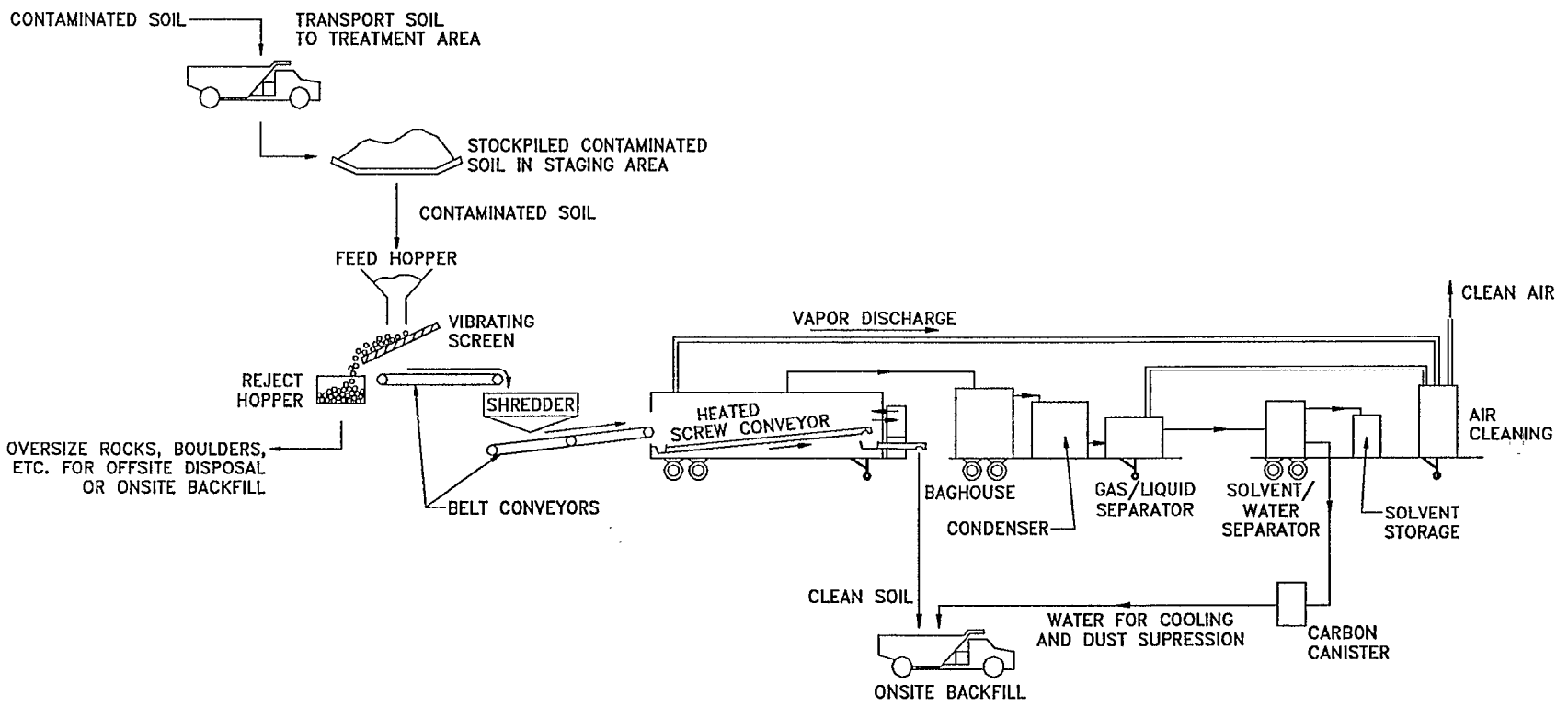


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FIGURE 4-8
ONSITE LOW TEMPERATURE THERMAL TREATMENT
ALTERNATIVE A-S06
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

084-758

removed to a lesser extent (e.g., 80 to 99 percent removal), depending on their boiling points. The treated soils would no longer pose potential risks to human health and the environment and would no longer be a potential source of groundwater contamination.

This alternative would prevent exposure of human receptors to potential contaminants in the landfill through institutional controls. Protection of the community, workers, and the environment from the treatment system air emissions during remediation would be provided by the off-gas treatment and monitoring system. The treated off-gas would be continuously monitored to ensure proper operation of the treatment system and adequate protection of human health and the environment.

Implementability: The technologies proposed for excavation, material handling, and thermal treatment are all demonstrated and commercially available. Excavation could be more difficult if the source area is located adjacent to a building or in an area containing many underground utilities. Material handling would also be more difficult if the contaminated soils contain a large amount of debris, such as glass, paper, metallic objects, or construction materials.

A typical throughput for a mobile thermal treatment unit is 7.5 tons per hour (180 tons per day). Therefore, using one on-site thermal unit, it would take approximately six months to treat 20,759 tons of soil, assuming about a 30 percent down time. Following treatment, no long-term monitoring, operation, or maintenance would be required for the soils in the "hot spot" area since contaminant concentrations would be reduced to their respective cleanup goals.

Thermal treatment technologies are expected to be technically feasible and implementable. However, since a residential community is located adjacent to the base property, there may be public opposition to operation of a thermal treatment unit on site. An on-site trial burn as well as extensive stack and site perimeter air monitoring could be required to satisfy regulatory agency and/or public concerns.

Other administrative activities associated with this alternative involve ensuring that construction activities are implemented correctly and that proper protective equipment is worn by remedial workers.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The primary capital cost for this alternative would be associated with mobilization, start-up, and operation of the thermal treatment unit. The estimated capital cost for this alternative is $6,141,500. This cost does not include the cost of conducting a trial burn or perimeter air monitoring, which could be required. Legal and administrative costs related to implementation of deed restrictions have not been estimated at this time but are expected to be low compared to the thermal treatment cost.

The operation and maintenance (O&M) costs for this alternative include: annual maintenance of the existing fence ($600/year); annual maintenance of the existing soil cover ($16,957/year); and, the performance of five-year site reviews ($20,000 each).

The estimated net present worth cost for this alternative is $6,467,100. The present worth cost is based on a 30-year maintenance period. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: On-site thermal treatment would effectively treat the contaminated soil, but would be more difficult and expensive to implement than dual phase vacuum extraction due to excavation, material handling, and monitoring requirements. In addition, the public could be opposed to a thermal unit operating on site. For these reasons, on-site low temperature thermal treatment would not be considered for treatment of contaminated soils that are amenable to vacuum extraction. However, if the source area were to contain highly concentrated waste materials that are not amenable to vapor extraction, such as oily sludges or buried drums, then thermal treatment, either on-site low temperature or off-site incineration, would be considered for these materials. Therefore, thermal treatment will be retained for further consideration.

4.7 Alternative A-SO7: Disposal of Hot Spot Area Soils in Off-site Hazardous Waste Landfill with Institutional Controls

Description: This alternative includes excavation of the "hot spot" area soils and off-site disposal in a RCRA-permitted hazardous waste disposal facility . Under this alternative, approximately 12,814 cubic yards (20,759 tons) of contaminated soil would be excavated using conventional equipment, such as a backhoe or front-end loader, loaded onto trucks, and transported to an off-site RCRA-permitted hazardous waste landfill. All equipment and trucks would be decontaminated before leaving the contamination zone.

For this alternative, it is assumed that all contaminant concentrations in the soil would be below the RCRA Land Disposal Restriction (LDR) treatment standards, and therefore, could be directly disposed in a hazardous waste landfill without pretreatment. However, if any waste materials that exceed the LDR standards (such as buried drums containing spent solvents or waste oil) were uncovered during excavation, these materials would be transported to an off-site RCRA-permitted incinerator for treatment. Soil samples would be collected and analyzed for VOCs, TCLP metals, and any other parameters required by the off-site facility to characterize the waste (e.g., pH, TOX, moisture content, etc.). The number of samples required would depend on the heterogeneity of the contaminated soil, but most likely would not be more than one sample per 100 tons of soil.

All excavated areas would be backfilled with clean fill, graded to original topography, and covered with either vegetated top soil or asphalt to stabilize the surface and restore the original appearance of the site.

In addition to off-site disposal of the "hot spot" area soils, the existing fencing and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Effectiveness: This alternative would reduce the volume of the contaminated soil in the "hot spot" areas through permanent removal and off-site disposal. The disposed material would be contained in a secure, off-site landfill cell constructed and operated in accordance with RCRA regulations for hazardous waste. Thus, the disposed soils would no longer pose potential risks to human health and the environment and would no longer be a potential source of groundwater contamination.

This alternative would prevent exposure of human receptors to potential contaminants in the landfill through institutional controls. Protection of the community, workers, and the environment from air and dust emissions during excavation would be accomplished through the use of dust control measures, decontamination procedures, and proper respiratory protection for on-site workers.

Implementability: The technologies proposed for excavation and disposal are all demonstrated and commercially available. Material handling would be more difficult in Area A2 where the contaminated soils contain some debris and construction materials (e.g., concrete).

There are currently at least six RCRA-permitted hazardous waste disposal facilities located east of the Mississippi River. Adequate landfill capacity is not expected to be a concern. The nearest facility is located approximately 375 miles from the site.

Excavation of the contaminated soil and site restoration activities would take approximately two months to complete. Following their removal, no long-term monitoring, operation, or maintenance would be required for the soils in the "hot spot" area. With respect to the entire landfill area, periodic inspection and maintenance of the existing cover would be required to ensure it remains intact.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The primary capital cost for this alternative would be associated with excavation, transportation, and disposal of the contaminated soil. The estimated capital cost for this alternative is $9,867,900. This cost estimate is based on a one-way transportation distance of 375 miles. Legal and administrative costs related to implementation of deed restrictions have not been estimated at this time but are expected to be low compared to the thermal treatment cost.

The operation and maintenance (O&M) costs for this alternative include: annual maintenance of the existing fence ($600/year); annual maintenance of the existing soil cover ($16,957/year); and, performance of five-year site reviews ($20,000 each).

The estimated net present worth cost for this alternative is $10,193,500. The present worth cost is based on a 30-year maintenance period. Detailed cost estimates and supporting calculations are provided in Appendix C.

Screening Summary: Although off-site disposal would permanently remove the contaminated soil from the site, it would be more difficult and expensive to implement than dual phase vacuum extraction due to excavation/material handling requirements and landfill fees. The estimated cost of this alternative ($10,193,500) is significantly more than the estimated present worth cost of performing thermal treatment ($6,467,100) or dual phase vacuum extraction ($1,216,700). However, in order to preserve an off-site alternative, disposal of the "hot spot" area soil in an off-site hazardous waste landfill will be retained for further consideration in the FS.

SECTION 5 - DETAILED ANALYSIS OF SOIL AND SURFACE WATER / SEDIMENT ALTERNATIVES

5.0 DETAILED ANALYSIS OF SOIL AND SURFACE WATER/SEDIMENT ALTERNATIVES

In this section, the detailed analyses of soil alternatives for Area A are presented in Section 5.1 and the detailed analyses of soil alternatives for Area B are presented in Section 5.2. The detailed analyses of surface water/sediment alternatives for Areas A and B are presented in Section 5.3.

Detailed analysis of alternatives will be conducted in accordance with the "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, 1988b) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), including the February 1990 revisions. In conformance with the NCP, seven of the following nine criteria will be used for the detailed analysis:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance (not evaluated at this time)
- Community acceptance (not evaluated at this time)

State acceptance and community acceptance will be evaluated in the Record of Decision (ROD) by addressing comments received after the FS and Proposed Remedial Action Plan (PRAP) have been reviewed by the Technical Review Committee (TRC), which includes participants from the Virginia Department of Environmental Quality and the public.

Overall Protection of Human Health and the Environment: The primary requirement is that remedial actions are protective of human health and the environment. A remedy is protective if it adequately eliminates, reduces, or controls all current and potential site risks posed through each exposure pathway at the site. A site where, after the remedy is implemented, hazardous substances remain without engineering or institutional controls, must allow for unrestricted use and unlimited exposure for human and environmental receptors. Alternatively, adequate engineering controls, institutional controls, or some combination of the two must be implemented to control exposure and thereby ensure reliable protection

over time. In addition, implementation of a remedy cannot result in unacceptable short-term risks or cross-media impacts on human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs): Compliance with ARARs is one of the statutory requirements for remedy selection. Alternatives are developed and refined throughout the FS process to ensure that they will meet all of the respective ARARs or that there is a good rational for waiving an ARAR. During the detailed analysis, information on federal and state action-specific ARARs will be assembled along with previously identified contaminant-specific and location-specific ARARs. Alternatives will be refined to ensure compliance with these requirements.

Long-term Effectiveness and Permanence: This criterion reflects CERCLA's emphasis on implementing remedies that will ensure protection of human health and the environment in the future, as well as in the near term. In evaluating alternatives for their long-term effectiveness and the degree of permanence they afford, the analysis will focus on the residual risks present at the site after the completion of the remedial action. The analysis will include consideration of the following:

- Degree of threat posed by the hazardous substances remaining at the site.
- Adequacy of any controls (e.g., engineering and institutional controls) used to manage the hazardous substances remaining at the site.
- Reliability of those controls.
- Potential impacts on human health and the environment, should the remedy fail, based on assumptions included in the reasonable maximum exposure scenario.

Reduction of Toxicity, Mobility, or Volume (TMV) through Treatment: This criterion addresses the statutory preference for remedies that employ treatment as a principal element by ensuring that the relative performance of the various treatment alternatives in reducing the toxicity, mobility, or volume will be assessed. Specifically, the analysis will examine the magnitude, significance, and irreversibility of reductions.

Short-term Effectiveness: This criterion examines the short-term impacts of the alternative (i.e., impacts of the implementation) on the neighboring community, workers, or surrounding environment. This

includes potential threats to human health and the environment associated with the excavation, treatment, and transportation of hazardous substances. The potential cross-media impacts of the remedy and the time to achieve protection of human health and the environment will also be analyzed.

Implementability: Implementability considerations include the technical and administrative feasibility of the alternatives, as well as the availability of goods and services (e.g., treatment, storage, or disposal capacity) on which the viability of the alternative depends. Implementability considerations often affect the timing of various remedial alternatives (e.g., limitations on the season in which the remedy can be implemented, the number and complexity of material handling steps, and the need to secure technical services). On-site activities must comply with the substantive portions of applicable permitting regulations.

Cost: Cost includes all capital costs and annual operation and maintenance costs incurred over the life of the project. The focus during the detailed analysis is on the present worth of these costs. Costs are used to select the most cost-effective alternative that will achieve the remedial action objectives.

State Acceptance: This criterion, which is an ongoing concern throughout the remedial process, reflects the statutory requirement to provide for substantial and meaningful state involvement. State comments will be addressed during the development of the PRAP and ROD, as appropriate.

Community Acceptance: This criterion refers to the community's comments on the remedial alternatives under consideration, where "community" is broadly defined to include all interested parties. These comments are taken into account throughout the FS process. However, only preliminary assessment of community acceptance can be conducted during the development of the FS, since formal public comment will not be received until after the public comment period for the PRAP is held.

5.1 Area A Soil Alternatives

The following Area A soil alternatives were retained from Section 4.0 and are evaluated in detail in the sections which follow:

- Alternative A-SO1: No Action
- Alternative A-SO2: Institutional Controls

- Alternative A-SO3: Asphalt/Geosynthetic Cap Over Brig Area with Institutional Controls

- Alternative A-SO4: Composite Cap Over Hot Spot Areas with Institutional Controls

- Alternative A-SO5: In Situ Treatment of Hot Spot Area Soils and Shallow Groundwater Using Dual Phase Vacuum Extraction with Institutional Controls

- Alternative A-SO6: Thermal Treatment of Hot Spot Area Soils with Institutional Controls

- Alternative A-SO7: Disposal of Hot Spot Area Soils in Off-site Hazardous Waste Landfill with Institutional Controls

5.1.1 Alternative A-SO1: No Action

Description: The No Action Alternative is required by the NCP to provide a baseline comparison for other remediation alternatives. Under the No Action Alternative, no remedial action would be performed to reduce the toxicity, mobility, or volume of soil contamination at the Camp Allen Area A Landfill. Groundwater monitoring would be implemented under one of the groundwater alternatives (Section 6.0).

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would not provide any additional protection against exposure to potential contamination than that currently offered by the existing soil and asphalt cover materials over the landfill as well as the existing fencing, which does not encompass the entire landfill.

Potential contamination present in the landfill could continue to provide a source of groundwater contamination, particularly in areas where the clay confining layer does not exist and in areas not covered

by buildings or asphalt. Contaminant trends would be analyzed using results from the groundwater monitoring program (included under groundwater alternatives in Section 6.0) to assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: There would be no remedial action under this alternative. The human health risks associated with exposure to the surface soils would remain the same as in the baseline risk assessment. This alternative is not a permanent solution in the sense that waste in the landfill would continue to remain a potential source of groundwater contamination.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the subsurface soil through active treatment. However, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: This alternative does not involve remedial actions that would pose a risk to human health or the environment during implementation.

Implementability: The No Action Alternative would be both technically and administratively simple to implement since there are no remedial activities associated with this alternative.

Cost: The estimated costs of this alternative are as follows:

- Capital: $0
- Operation and maintenance: $20,000 (every 5 years)
- Net present worth (30-year): $55,600

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.1.2 Alternative A-SO2: Institutional Controls

Description: Under this alternative, existing institutional controls at Camp Allen (i.e., fences and designation of non-residential areas) would be maintained to limit access and control future use of Area A, as well as to indicate that wastes are buried at the site. The location of the existing fencing is shown in Figure 4-1. In addition, the existing soil cover over the Area A Landfill would be maintained to limit surface water infiltration and minimize potential erosion. Area A is currently not used for residential purposes, and there are no plans to close the base or to convert the area to residential use. However, if the base were to close in the future, deed restrictions proposed under this alternative would limit the Camp Allen Landfill to non-residential land uses.

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would provide some degree of protection to human health through maintenance of the existing fencing and soil cover, and institutional controls. These actions would reduce the chance of exposure to potential contaminants within the landfill.

Potential contamination present in the landfill could continue to provide a source of groundwater contamination, particularly in areas where the clay confining layer does not exist and in areas not covered by buildings or asphalt. Contaminant trends would be analyzed using results from the groundwater monitoring program (included under groundwater alternatives in Section 6.0) to assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: The human health risks associated with exposure to the surface soils would remain the same as in the baseline risk assessment. There would be no remedial action under this alternative other than maintenance of existing fencing and soil cover, and institutional controls. Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes. However, this alternative is not a permanent solution in the sense that waste in the landfill would continue to provide a potential source of groundwater contamination.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the subsurface soil through active treatment. However, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Implementation of institutional controls would not pose a short-term risk to human health or the environment since no remedial action would be implemented.

Implementability: This alternative would be technically easy to implement. Periodic inspection and maintenance of the existing fencing would be required. With respect to the entire landfill area, periodic inspection and maintenance (e.g., revegetation) of the existing soil cover would also be required. Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $0
- Operation and maintenance: $17,557 (annually), $37,557 (every 5 years)
- Net present worth (30-year): $325,500

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.1.3 Alternative A-SO3: Asphalt/Geosynthetic Cap Over Brig Area with Institutional Controls

Description: This alternative includes placement of an asphalt/geosynthetic cap around the Brig Facility area, which is the more active portion of the Area A Landfill, and in the area between the Brig and the

drainage ditch (Figure 4-2). The purpose of the cap would be to minimize the infiltration of rain water into the waste area, thus reducing leaching and transport of potential contaminants from the soil to groundwater and surface water. The cap would also prevent exposure to potential contaminants within the landfill.

The asphalt/geosynthetic cap would encompass an area of approximately 12 acres. Of this area, approximately 4 acres are currently covered by buildings and asphalt (e.g., roads and parking lots). The cap would be constructed similar to the cross section shown in Figure 4-3 and as described in Section 4.3.

In addition to the asphalt/geosynthetic cap, the existing fencing and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2.

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would provide protection to human health through capping and institutional controls. These actions would significantly reduce the chance of exposure to potential contaminants within the landfill. Placement of the asphalt/geosynthetic cap would reduce, but not eliminate, migration of potential contaminants from the subsurface soils to groundwater. The effectiveness of the cap would be limited because the landfill does not contain a low-permeability bottom liner and leachate collection system. For this reason, leachate generated within the landfill would be reduced but not eliminated by the cap, and would continue to migrate to groundwater, particularly in areas where the clay confining layer is absent. Furthermore, the effectiveness of the cap would be limited because the waste in some areas of the landfill extends to a depth that is near or below the water table. In these areas, fluctuations in groundwater levels could cause releases of contaminants to groundwater. Contaminant trends would be analyzed using results from the groundwater monitoring program (included under groundwater alternatives in Section 6.0) to

assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils.

This alternative would comply with all pertinent state and federal wetlands regulations. No construction activities would be performed in wetland areas.

The asphalt/geosynthetic cap would be designed, installed, and maintained to meet state requirements for capping solid waste landfills, which are very similar to RCRA Subtitle D requirements.

Long-term Effectiveness and Permanence: The human health risks associated with exposure to the surface soils would remain essentially the same as in the baseline risk assessment.

Capping would reduce the potential for landfilled wastes to leach contaminants to the groundwater, although the cap would not eliminate leaching of contaminants to groundwater, particularly in areas where soil contamination is present near or below the water table. Therefore, this alternative is not a permanent solution in the sense that waste in the landfill would continue to remain a potential source of groundwater contamination. Long-term inspection and maintenance would be required to ensure that the cap remains intact.

Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the subsurface soil through active treatment. However, the cap would help to reduce the mobility of contaminants in the landfill by restricting infiltration of precipitation. There may also be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Implementation of the cap and institutional controls would not pose a short-term risk to human health or the environment.

Implementability: The technologies for grading and cap installation are demonstrated and commercially available. Periodic inspection and maintenance of the cap would be required. With respect to the entire landfill area, periodic inspection and maintenance (e.g., revegetation) of the existing soil cover would also be required.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $927,200
- Operation and maintenance: $17,557 (annually), $95,653 (every 5 years)
- Net present worth (30-year): $1,877,900

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.1.4 Alternative A-SO4: Composite Cap Over Hot Spot Areas with Institutional Controls

Description: This alternative includes the placement of a low-permeability composite cap over the "hot spot" areas, which total approximately 1.0 acre. The cap would be constructed similar to the cross section shown in Figure 4-4 and as described in Section 4.4.

In addition to the composite cap, the existing fencing and soil cover would be maintained and institutional controls would also be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 5.1.2).

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would provide protection to human health through capping of the "hot spot" areas and institutional controls, actions that would significantly reduce the chance of exposure to potential contaminants within the landfill. Placement of the composite cap would reduce, but not eliminate, migration of potential contaminants from the "hot spot" area soils to groundwater. The effectiveness of the cap would be limited because the landfill does not contain a low-permeability bottom liner and leachate collection system. For this reason, leachate generated within the "hot spot" areas would be reduced but not eliminated by the cap, and would continue to migrate to groundwater, particularly in areas where the clay confining layer is absent. Furthermore, the effectiveness of the cap may be limited if the waste in the source area extends to a depth that is near or below the water table. Under this condition, fluctuations in groundwater levels could cause releases of contaminants to groundwater. Contaminant trends would be analyzed using results from the groundwater monitoring program (included under groundwater alternatives in Section 6.0) to assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils.

This alternative would comply with all pertinent state and federal wetlands regulations. No construction activities would be performed in wetland areas.

The composite cap would be designed, installed, and maintained to meet state requirements for capping hazardous waste landfills, which are very similar to RCRA Subtitle C requirements.

Long-term Effectiveness and Permanence: The human health risks associated with exposure to the surface soils would remain essentially the same as in the baseline risk assessment.

Capping would reduce the potential for contaminants to leach to groundwater, although the cap would not eliminate leaching of contaminants to groundwater, particularly in areas where soil contamination is present near or below the water table. Therefore, this alternative is not a permanent solution in the sense that waste in the landfill would continue to remain a potential source of groundwater contamination. Long-term inspection and maintenance would be required to ensure that the cap remains intact.

Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the subsurface soil through active treatment. However, the cap would help to reduce the mobility of contaminants in the "hot spot" area by restricting infiltration of precipitation. There may also be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Implementation of the cap and institutional controls would not pose a short-term risk to human health or the environment.

Implementability: The technologies for grading and cap installation are demonstrated and commercially available. Periodic inspection and maintenance of the cap would be required. With respect to the entire landfill area, periodic inspection and maintenance (e.g., revegetation) of the existing soil cover would also be required.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $465,300
- Operation and maintenance: $19,395 (annually), $39,395 (every 5 years)
- Net present worth (30-year): $819,100

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.1.5 Alternative A-SO5: In Situ Treatment of Hot Spot Area Soils and Shallow Groundwater Using Dual Phase Vacuum Extraction with Institutional Controls

Description: This alternative includes in situ treatment of the "hot spot" areas using dual phase vacuum extraction (DPVE) technology. DPVE is a method to remediate soil and groundwater with a single extraction system. Under this alternative, approximately 12,814 cubic yards (20,759 tons) of contaminated soil would be treated via a DPVE system, removing contaminated soil gas and shallow groundwater for subsequent treatment. It is assumed that this alternative would be implemented in conjunction with a groundwater extraction/treatment alternative, and that the water extracted by the DPVE system would be treated at the on-site water treatment facility. The DPVE system is described in Section 4.5. A typical

DPVE system is shown in Figure 4-5. The major equipment for the DPVE system would be located in a prefabricated metal building located adjacent to the contaminated area. Proposed locations for the treatment system building and the extraction wells are shown in Figures 4-6 and 4-7.

In addition to installation and operation of the DPVE system, the existing fence and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 5.1.1.2).

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would provide protection to human health through treatment of the "hot spot" areas and institutional controls, actions that would significantly reduce the chance of exposure to potential contaminants within the landfill. The DPVE technology may remove VOCs from the "hot spot" areas to a level where they would no longer provide a source of groundwater contamination.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils. This alternative would comply with all pertinent state and federal wetlands regulations. No construction activities would be performed in wetland areas.

The off-gas generated by the vapor extraction system would be treated to comply with federal air quality standards as well as with the Virginia Air Emission Standards for toxic pollutants, particulate emissions, and VOCs, as set forth in Virginia Regulations for the Control and Abatement of Air Pollution (VR 120-01). Recovered solvents and any water generated by the extraction system would be treated at the on-site groundwater treatment plant and discharged in accordance with all applicable Virginia and RCRA regulations.

Long-term Effectiveness and Permanence: Vacuum extraction would permanently remove VOCs from the "hot spot" areas, significantly reducing the potential for contaminants in the "hot spot" areas to leach to groundwater. This alternative would provide a permanent remedy for the "hot spot" areas, but may require several years to achieve soil cleanup levels that are protective of groundwater.

Soil cleanup goals developed in Section 2.3 were used to estimate remediation areas of concern, as shown in Figure 2-1 and 2-2. It should be noted that since Area A is a landfill, the remedial action objective (RAO) for the soils is groundwater protection rather than soil cleanup. Therefore, achievement of this RAO would not necessarily be based on attainment of the developed soil cleanup goals since they represent theoretical values calculated through modeling. In addition, the cleanup goals were developed using conservative assumptions and may not be representative of actual site conditions. Therefore, achievement of groundwater protection would be determined through development of treatment system performance curves and through evaluation of actual environmental monitoring results (i.e., via ongoing monitoring of contaminant levels in groundwater and in the extracted vapors from the in situ vacuum extraction system). Soil contaminant concentrations may eventually reach asymptotic levels below which contaminant levels cannot be reduced via in situ vacuum extraction. If treatment system performance curves indicate that the cleanup goals for some or all of the contaminants cannot be achieved, then the soil cleanup goals will be reevaluated.

The long-term effectiveness and reliability would be demonstrated through groundwater monitoring (included under groundwater alternatives in Section 6.0). Contaminant trends would be analyzed using results from the groundwater monitoring program to assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes.

Reduction of Toxicity, Mobility, or Volume: This alternative would employ treatment that would substantially reduce the toxicity, mobility, and volume of potential contaminants in the subsurface soil and shallow groundwater in the treated areas. In addition, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Protection of the community, workers, and the environment from the extracted soil vapor during remediation would be provided by the off-gas treatment system. The treated off-gas would be periodically monitored to ensure proper operation and adequate protection of human health and the environment. Groundwater extracted via the DPVE system would be treated at the on-site water treatment system to the required discharge limits. It is estimated that the DPVE system could be installed within 1 to 2 months. For purposes of the FS, it is assumed that the DPVE system would be operated for a five-year period to achieve cleanup levels required for groundwater protection.

Implementability: Technically, the DPVE system should be relatively straight-forward to implement. DPVE technology is innovative, but is very similar to soil vapor extraction (SVE) technology, which has been used extensively. The equipment and technology for DPVE systems are demonstrated and commercially available. However, the presence of buried debris could make installation of a DPVE system more difficult. The implementation of this alternative is primarily dependent on the radius of influence of the extraction system, initial and final exhaust concentrations, obtainable flow rates, water level changes, and vacuum well pressures.

The major operational requirements include periodic (e.g., monthly) replacement of the carbon canisters used to treat soil gas and on-site treatment of the water collected in the air/water separator. It is assumed that this alternative would be implemented in conjunction with a groundwater treatment alternative, and that the water from DPVE system would be treated in the on-site water treatment facility. Periodic monitoring of off-gas contaminant concentrations, water level checks in the air/water separator, and servicing of the air compressor would also need to be performed. In general, operation and maintenance requirements are highest at system startup and should decline over time. Following treatment, no long-term monitoring, operation, or maintenance would be required for the soils. With respect to the entire landfill area, periodic inspection and maintenance (e.g., revegetation) of the existing soil cover would be required.

The administrative activities associated with this alternative also involve ensuring that construction activities are implemented correctly and that proper protective equipment is worn by remedial workers.

Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $490,700
- Operation and maintenance: $108,066 (annually) years 1-4, $139,022 for year 5; $17,557 (annually) years 6-30; $37,557 for years 6-30 in which a five-year review occurs.
- Net present worth (30-year): $1,216,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.1.6 Alternative A-SO6: Thermal Treatment of Hot Spot Area Soils with Institutional Controls

Description: This alternative includes excavation of the contaminated "hot spot" area soils and thermal treatment using either an on-site low temperature thermal treatment unit or off-site incineration. For costing purposes, it was assumed that all of the contaminated soil would be treated on site in a low temperature thermal desorption unit. However, if any waste materials that are not amenable to low temperature treatment (such as buried drums containing spent solvents or waste oil) were uncovered during excavation, it was assumed that these materials would be transported to an off-site RCRA-permitted incinerator.

Approximately 12,814 cubic yards (20,759 tons) of soil would be excavated using conventional equipment such as a backhoe, loaded onto trucks, and hauled to a stockpile adjacent to the low temperature thermal treatment unit. The low temperature thermal process is described in Section 4.6. A typical low-temperature thermal treatment process is shown in Figure 4-8. Air pollution controls and stack emission monitoring would be provided as necessary to comply with local and/or state air emission regulations.

In addition to thermal treatment of the contaminated soils, the existing fence and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial

construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would provide protection to human health through treatment of the "hot spot" areas and institutional controls. These actions would significantly reduce the chance of exposure to potential contaminants within the landfill.

The thermal treatment technology is expected to remove the VOCs and SVOCs from the "hot spot" area soils to a level where they would no longer provide a source of groundwater contamination.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils.

This alternative would comply with all pertinent state and federal wetlands regulations. No construction activities would be performed in wetland areas. Proper erosion controls, such as silt fencing, would be used during excavation and treatment to minimize any potential impacts to wetland areas adjacent to the site.

The off-gas generated by the thermal treatment system would be treated to comply with federal air quality standards as well as with the Virginia Air Emission Standards for toxic pollutants, particulate emissions, and VOCs, as set forth in Virginia Regulations for the Control and Abatement of Air Pollution (VR 120-01). Recovered solvents and any water generated by the treatment system that is considered to be hazardous would be properly containerized, treated, and disposed off site in accordance with all applicable Virginia and RCRA hazardous waste management regulations.

Long-term Effectiveness and Permanence: This alternative would permanently reduce the volume and toxicity of the contaminated soil in the "hot spot" area through removal and thermal treatment of both VOCs and SVOCs. The thermal treatment system is expected to remove more than 99 percent of the VOCs from the soil. SVOCs, if present, would be removed to a lesser extent (e.g., 80 to 99 percent removal), depending on their boiling points. The treated soils would no longer pose potential risks to human health and the environment and would no longer provide a potential source of groundwater contamination.

The long-term effectiveness and reliability would be demonstrated through groundwater monitoring (included under groundwater alternatives in Section 6.0). Potential contaminants in other areas of the landfill would continue to remain a possible source of groundwater contamination. Contaminant trends would be analyzed using results from the groundwater monitoring program to assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes.

Reduction of Toxicity, Mobility, or Volume: This alternative would employ treatment that would substantially reduce the toxicity, mobility, and volume of potential contaminants in the treated subsurface soil. In the other areas of the landfill, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Protection of the community, workers, and the environment from the air emissions during remediation would be provided by the off-gas treatment system. The treated off-gas would be periodically monitored to ensure proper operation and adequate protection of human health and the environment.

A typical throughput for a mobile thermal treatment unit is 7.5 tons per hour (180 tons per day). Therefore, using one on-site thermal unit, it would take approximately six months to treat 20,759 tons of soil, assuming about a 30 percent down time.

Implementability: The technologies proposed for excavation, material handling, and thermal treatment are all demonstrated and commercially available. Excavation could be more difficult if the source area is located adjacent to a building or in an area containing many underground utilities. Material handling would also be more difficult if the contaminated soils contain a large amount of debris, such as glass, paper, metallic objects, or construction materials.

Thermal treatment technologies are expected to be technically feasible and implementable. However, since a residential community is located adjacent to the base property, there may be public opposition to operation of a thermal treatment unit on site. An on-site trial burn with extensive stack and site perimeter air monitoring could be required to satisfy regulatory agency and/or public concerns.

Other administrative activities associated with this alternative involve ensuring that construction activities are implemented correctly and that proper protective equipment is worn by remedial workers.

Following their removal, no long-term monitoring, operation, or maintenance would be required for the soils in the "hot spot" area. With respect to the entire landfill area, periodic inspection and maintenance (e.g., revegetation) of the existing soil cover would be required. Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $6,141,500
- Operation and maintenance: $17,557 (annually); $37,557 (every 5 years)
- Net present worth (30-year): $6,467,100

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.1.7 Alternative A-SO7: Disposal of Hot Spot Area Soils in Off-site Hazardous Waste Landfill with Institutional Controls

Description: This alternative includes excavation of the "hot spot" area soils and off-site disposal in a RCRA-permitted hazardous waste disposal facility. For costing purposes, it was assumed that all of the contaminated soil would be disposed of in an off-site RCRA-permitted hazardous waste landfill without pretreatment. However, if the source area were to contain any waste materials that exceed the RCRA Land Disposal Restriction (LDR) standards (such as buried drums containing spent solvents or waste oil), these materials would be transported to an off-site RCRA-permitted incinerator for treatment.

Approximately 12,814 cubic yards (20,759 tons) of soil would be excavated using conventional equipment, such as a backhoe, loaded onto trucks, and transported to a RCRA-permitted hazardous waste landfill. All equipment and trucks would be decontaminated before leaving the contamination zone.

In addition to off-site disposal of the contaminated soils, the existing fence and soil cover would be maintained and institutional controls would be implemented to limit the site to non-residential use, as described under Alternative A-SO2 (Section 4.2).

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse human health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area A under the current land use of the area as a brig (for either prisoners or brig employees). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure to subsurface soils at Area A under a future use scenario for remedial construction workers. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 5.4 to 5.9, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario.

This alternative would provide protection to human health through removal and off-site disposal of the "hot spot" area soil and institutional controls. These actions would significantly reduce the chance of exposure to potential contaminants within the landfill. This alternative would permanently remove the "hot spot" area soils from the site; therefore, they would no longer provide as a source of groundwater contamination.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils.

This alternative would comply with all pertinent state and federal wetlands regulations. No construction activities would be performed in wetland areas. Proper erosion controls, such as silt fencing, would be used during excavation and treatment to minimize any potential impacts to wetland areas adjacent to the site.

Appropriate dust controls would be used to ensure compliance with the Virginia Air Pollution Control Standards. Any soils, debris, or waste materials considered to be hazardous would be properly containerized, treated, and disposed off site in accordance with all applicable Virginia and RCRA hazardous waste management regulations.

Long-term Effectiveness and Permanence: This alternative would reduce the volume of contaminated soil at the site through removal and off-site disposal of the "hot spot" area soils. These soils would no longer pose potential risks to human health and the environment and would no longer provide a potential source of groundwater contamination.

The long-term effectiveness and reliability of the removal action would be demonstrated through groundwater monitoring (included under groundwater alternatives in Section 6.0). Contaminant trends

would be analyzed using results from the groundwater monitoring program to assess whether any portion of the landfill is acting as a source of groundwater contamination over the long term.

Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes.

Reduction of Toxicity, Mobility, or Volume: This alternative would not employ treatment that would reduce the toxicity or volume of potential contaminants in the subsurface soil. However, the mobility of contaminants in the soil at the site would be eliminated through off-site disposal of the "hot spot" area soils in a secure RCRA-permitted hazardous waste disposal facility. In the other areas of the landfill, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Protection of the community, workers, and the environment from dust emissions during excavation would be provided through the use of dust control measures.

It would take approximately two months to excavate and dispose of the "hot spot" area soils off site.

Implementability: The technologies proposed for excavation, material handling, and off-site disposal are all demonstrated and commercially available. Material handling would also be more difficult in Area A2 where the contaminated soils contain some debris and construction materials (i.e., concrete).

There are currently at least six RCRA-permitted hazardous waste disposal facilities located east of the Mississippi River. Adequate landfill capacity is not expected to be a concern. The nearest facility is located approximately 375 miles from the site.

Other administrative activities associated with this alternative involve ensuring that construction activities are implemented correctly and that proper protective equipment is worn by remedial workers.

Following their removal, no long-term monitoring, operation, or maintenance would be required for the soils in the "hot spot" area. With respect to the entire landfill area, periodic inspection and maintenance (e.g., revegetation) of the existing soil cover would be required. Under a base closure scenario, deed restrictions limiting the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $9,867,900
- Operation and maintenance: $17,557 (annually); $37,557 (every 5 years)
- Net present worth (30-year): $10,193,500

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.2 Area B Soil Alternatives

The following Area B soil alternatives are evaluated in detail in the sections which follow:

- Alternative B-SO1: No Action
- Alternative B-SO2: Institutional Controls

As discussed in Section 1.0, a removal action is being implemented at the Area B Landfill. At the completion of the removal action, the primary areas of contaminated soil within the landfill will be permanently removed from the site. This removal action will also eliminate the primary sources of groundwater contamination associated with the Area B Landfill. Therefore, alternatives which remove or treat Area B soils are not necessary and were not evaluated in this FS.

5.2.1 Alternative B-SO1: No Action

Description: The No Action Alternative is required by the NCP to provide a baseline comparison for other remediation alternatives. Under the No Action Alternative, no remedial action would be performed to reduce the toxicity, mobility, or volume of soil contamination at Area B. Groundwater monitoring would be implemented under one of the groundwater alternatives (Section 6.0).

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area B under the current land use in the area (for either employees or children at the Camp Allen Elementary School). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure of remedial construction workers to subsurface soils at the Area B Landfill/Pond under the current remediation scenario. The hazard index (HI) calculated for a child receptor

under a future residential use scenario ranged from 1.5 at the Area B Landfill/Pond to 3.7 in the school area, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario. Also, the risks were calculated at the Area B Landfill/Pond based on existing conditions prior to the removal action that is being implemented in this area. Therefore, the actual risks will be much lower in this area when the removal action is completed.

At the completion of the removal action, the primary sources of groundwater contamination associated with Area B will have been removed. However, there may still be a potential for residual contamination to be present within other areas of Area B landfill. This alternative would not provide any additional protection against exposure to potential contamination in other areas of the Area B Landfill than that currently offered by the existing soil cover over the landfill as well as the existing fencing, which does not encompass the entire landfill.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: There would be no remedial action under this alternative. The human health risks associated with exposure to the surface soils would remain the same as in the baseline risk assessment. This alternative is not a permanent solution in the sense that remaining wastes in the landfill could continue to be a potential source of groundwater contamination. However, the areas containing the highest degree of contamination in the landfill will be removed during the removal action.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the subsurface soil through active treatment. However, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: This alternative does not involve remedial actions that would pose a risk to human health or the environment during implementation.

Implementability: The No Action Alternative would be both technically and administratively simple to implement since there are no remedial activities associated with this alternative.

Cost: The costs of this alternative are as follows:

- Capital: $0
- Operation and maintenance: $20,000 (every 5 years)
- Net present worth (30-year): $55,600

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.2.2 Alternative B-SO2: Institutional Controls

Description: Under this alternative, existing institutional controls at Camp Allen (i.e., fences and designation of non-residential areas) would be maintained to limit access and control future use of Area B as well as to indicate that wastes are buried within the landfill at the site. The salvage yard and landfill areas in Area B are currently not used for residential purposes, and there are no plans to close the base or to convert these areas to residential use. If the base were to close in the future, deed restrictions are proposed under this alternative to limit these areas to non-residential land uses.

Overall Protection: Results of the baseline risk assessment indicate that no unacceptable adverse health effects would be expected from exposure (via ingestion, inhalation, and dermal contact) to the surface soil at Area B under the current land use in the area (for either employees or children at the Camp Allen Elementary School). Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure of remedial construction workers to subsurface soils at the Area B Landfill/Pond under the current remediation scenario. The hazard index (HI) calculated for a child receptor under a future residential use scenario ranged from 1.5 at the Area B Landfill/Pond to 3.7 in the school area, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario. Also, the risks were calculated at the Area B Landfill/Pond based on existing conditions prior to the removal action that is being implemented in this area. Therefore, the actual risks will be much lower in this area when the removal action is completed.

At the completion of the removal action, the primary sources of groundwater contamination associated with Area B will have been removed. However, there may still be a potential for residual contamination to be present within other areas of the landfill. This alternative would provide some degree of protection to human health through maintenance of the existing fencing and institutional controls. These actions would reduce the chance of exposure to potential residual contaminants within the landfill.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for soils. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: There would be no remedial action under this alternative other than maintenance of the existing fencing and institutional controls. Institutional controls, such as deed restrictions, would be effective in the long term in restricting the site to non-residential uses, thereby reducing the potential health hazards posed by the buried wastes. This alternative is not a permanent solution in the sense that remaining wastes in the landfill could continue to be a potential source of groundwater contamination. However, the areas containing the highest degree of contamination in the landfill will be removed during the removal action.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the subsurface soil through active treatment. However, there may be a reduction in toxicity, mobility, or volume of contaminants in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Implementation of institutional controls would not pose a short-term risk to human health or the environment.

Implementability: This alternative would be technically straight-forward to implement. Periodic inspection and maintenance of the existing fencing would be implemented. Under a base closure scenario, deed restrictions limiting the salvage yard and landfill areas of the site to non-residential uses would be implemented, which would require certain administrative and legal activities.

Cost: The estimated costs of this alternative are as follows:

- Capital: $0
- Operation and maintenance: $600 (annually), $20,000 (every 5 years)
- Net present worth (30-year): $63,200

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.3 Areas A and B Surface Water/Sediment Alternatives

The following surface water/sediment alternatives are evaluated in detail in the sections which follow:

- Alternative SD1: No Action
- Alternative SD2: Institutional Controls with Monitoring

Alternatives that would remove or treat surface water/sediment at the site were not evaluated in this FS for the following reasons:

- Relatively low levels of contaminants were detected in site surface water and sediments.

- Migration of contaminants from the surface water and sediments to groundwater is not considered to be a pathway of concern since shallow groundwater generally discharges to the drainage ditches (i.e., surface water generally does not recharge the shallow groundwater).

- Source control measures that are currently being implemented at Area B, and source control measures that are planned for Area A, are expected to improve the quality of surface water and sediment in these areas over time.

- Results of the baseline risk assessment for Area A and Area B surface water and sediment are summarized below. There are no exceedances of human health criteria associated with exposure (via ingestion and dermal contact) to surface water or sediment under the current land uses. Therefore, under the current land uses at Area A and Area B, no unacceptable human health effects would be expected from exposure to surface water and sediment.

Area A Baseline Risk Assessment

Results of the baseline risk assessment for Area A indicate that, under the current land use of this area as a brig, no unacceptable human health effects would be expected from exposure (via ingestion and dermal contact) to surface water and sediment in the vicinity of Area A. Under a future residential land use scenario, the hazard index (HI) calculated for a child receptor ranged from 3.4 to 4.3 for exposure (via ingestion and dermal contact) to shallow and deep sediments, respectively, which exceeds the acceptable

HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor for exposure to sediments under a future residential use scenario. Also, under a future residential land use scenario, the incremental lifetime cancer risks (ILCR) for a child receptor associated with exposure (via ingestion and dermal contact) to surface water is 2.0×10^{-4}, which slightly exceeds the acceptable ILCR of 1.0×10^{-4} under CERCLA. Under a future residential land use scenario, the incremental lifetime cancer risks (ILCR) for an adult receptor associated with exposure (via ingestion and dermal contact) to surface water is 1.2×10^{-4}, which slightly exceeds the acceptable ILCR of 1.0×10^{-4} under CERCLA.

Area B Baseline Risk Assessment

Results of the baseline risk assessment for Area B indicate that, under the current land use of this area as a school, no unacceptable human health effects would be expected from exposure (via ingestion and dermal contact) to the surface water and sediment in the vicinity of Area B. Under a future residential land use scenario, the hazard index (HI) calculated for a child receptor near the Area B Landfill and Pond was 1.6 for exposure (via ingestion and dermal contact) to shallow sediments, which exceeds the acceptable HI of 1.0 under CERCLA. However, no unacceptable risks are indicated for a child receptor for exposure to surface water, and no unacceptable risks are indicated for an adult receptor for exposure to surface water or sediments under a future residential use scenario.

Also, the risk assessment indicates that no unacceptable adverse human health effects would be expected from exposure of remedial construction workers to subsurface soils at the Area B Landfill/Pond under the current remediation scenario. The hazard index (HI) calculated for a child receptor under a future residential use scenario for exposure to surface soil ranged from 1.5 at the Area B Landfill/Pond to 3.7 in the school area, which exceeds the acceptable HI of 1.0 under CERCLA; however, no unacceptable risks are indicated for an adult receptor under a future residential use scenario. Also, the risks were calculated at the Area B Landfill/Pond based on existing conditions prior to the removal action that is being implemented in this area. Therefore, the actual risks will be much lower in this area when the removal action is completed.

5.3.1 Alternative SD1: No Action

Description: The No Action Alternative is required by the NCP to provide a baseline comparison for other remediation alternatives. Under the No Action Alternative, no remedial action would be performed to reduce the toxicity, mobility, or volume of surface water/sediment contamination at the Camp Allen

Landfill. Groundwater monitoring would be implemented under one of the groundwater alternatives (Section 6.0).

Overall Protection: Results of the baseline risk assessment are presented above. The no action alternative would not provide any additional protection against exposure to potential contamination than that currently provided by the existing fencing.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for sediments. Although there were sporadic minor exceedances of federal Ambient Water Quality Criteria and Virginia Water Quality Standards in surface waters, there were no gross exceedances and no clear pattern of exceedances that would suggest a significant problem with site surface water. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: There would be no remedial action under this alternative. The human health risks associated with exposure to surface water and sediments are would remain the same as in the baseline risk assessment. However, source control measures that are currently being implemented at Area B, and source control measures that are planned for Area A, are expected to improve the quality of surface water and sediment over time.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the sediments through active treatment. There may be a reduction in toxicity, mobility, or volume of contaminants in the long term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: This alternative does not involve remedial actions that would pose a risk to human health or the environment during implementation.

Implementability: The No Action Alternative would be both technically and administratively simple to implement since there are no activities associated with this alternative.

Cost: The estimated costs of this alternative are as follows:

- Capital: $0
- Operation and maintenance: $20,000 (every 5 years)
- Net present worth (30-year): $55,600

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.3.2 Alternative SD2: Institutional Controls with Monitoring

Description: The remedial action for this alternative is essentially identical to Alternative SO2 in Section 5.2.2 in that existing institutional controls at Camp Allen (i.e., fences and designation of non-residential areas) would be maintained to limit access and control future land use. In addition, however, a surface water and sediment monitoring program would be implemented to track trends in surface water and sediment contamination at the site. The monitoring program would include semi-annual sampling and analysis of surface water and sediment at approximately 12 locations along the ditches around the site perimeter. For costing purposes, it was assumed that the monitoring program would continue for a five-year period, at which time trends would be evaluated and the need for remedial action or continued monitoring would be assessed.

The Camp Allen Landfill Areas A and B and the salvage yard are currently not used for residential purposes, and there are no plans to close the base or to convert these areas to residential use. If the base were to close in the future, deed restrictions are proposed under this alternative to limit these areas to non-residential land uses.

Overall Protection: Results of the baseline risk assessment are presented above. This alternative would provide some degree of additional protection against exposure to potential contamination by maintenance of the existing fencing in Area B and through deed restrictions that would limit the Camp Allen Landfill area to non-residential land uses. The surface water and sediment monitoring program would track trends in contamination in these media.

Compliance with ARARs: State and federal contaminant-specific ARARs are not available for sediments. Although there were sporadic minor exceedances of federal Ambient Water Quality Criteria and Virginia Water Quality Standards in surface waters, there were no gross exceedances and no clear pattern of

exceedances that would suggest a significant problem with site surface water. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: There would be no remedial action under this alternative other than maintenance of the existing fencing, institutional controls, and monitoring. Institutional controls, such as deed restrictions, would be effective in the long term in restricting the salvage yard and landfill areas to non-residential land uses, thereby reducing any health hazards posed by potential contamination in these areas. The surface water and sediment monitoring program would provide information needed to evaluate contaminant levels in these media and to evaluate the need for potential future remedial actions.

Additionally, source control measures that are currently being implemented at Area B, and source control measures that are planned for Area A, are expected to improve the quality of surface water and sediment over time.

Reduction of Toxicity, Mobility, or Volume: This alternative would not reduce the toxicity, mobility, or volume of potential contaminants in the sediments through active treatment. There may be a reduction in toxicity, mobility, or volume of potential contaminants in the sediments in the long-term through natural processes such as biodegradation, volatilization, and dispersion.

Short-term Effectiveness: Implementation of institutional controls would not pose a short-term risk to human health or the environment since no remedial action would be implemented other than maintenance of the existing fencing, institutional controls, and monitoring.

Implementability: This alternative would be technically straight-forward to implement. Periodic inspection and maintenance of the existing fencing would be required. Under a base closure scenario, deed restrictions limiting the Camp Allen Landfill Areas A and B and the salvage yard to non-residential land uses would be implemented, which would require certain administrative and legal activities. The monitoring program would utilize standard sample collection and analytical methodology.

Cost: The estimated costs of this alternative are as follows:

- Capital: $0
- Operation and maintenance: $50,477 (annually), $70,477 (every 5 years)
- Net present worth (30-year): $831,600

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix C.

5.4 Comparison of Soil and Surface Water/Sediment Alternatives

Soil and surface water/sediment alternatives for Areas A and B are compared in the following sections:

Section 5.4.1	Comparison of Area A Soil Alternatives
Section 5.4.2	Comparison of Area B Soil Alternatives
Section 5.4.3	Comparison of Surface Water/Sediment Alternatives (Areas A and B)

5.4.1 Comparison of Area A Soil Alternatives

A side-by-side comparison of the alternatives for addressing contaminants in Area A soils, based on the seven evaluation criteria used in the previous sections, is presented in Table 5-1. A summary of the alternative comparison based on the seven criteria is provided in the following sections.

Overall Protection: With respect to surface soils, all alternatives would essentially provide a similar level of protection to human health and the environment since little contamination was detected in the surface soils, and potential risks to human health are within acceptable levels. With respect to potential contamination in subsurface soils, Alternative A-SO1 would not provide any additional protection to human health than that currently provided by existing site fencing. Alternative A-SO2 would provide a higher degree of protection through institutional controls and maintenance of the existing landfill soil cover.

Alternatives A-SO1 and A-SO2 would not provide any additional protection of groundwater than that provided by existing pavement and buildings. Alternatives A-SO3 and A-SO4 would provide partial protection of groundwater through capping. The caps would only be partially effective because the landfill is unlined, and wastes are present near, or below, the water table in some areas. The caps would also provide protection against direct contact with potential soil contaminants. Of the seven alternatives, Alternative A-SO6 would provide the maximum level of protection of human health and the environment through removal and active treatment of the hot spot(s). Alternative A-SO7 would also permanently remove the "hot spot" area(s) from the site but would not provide any treatment. Alternative A-SO5 would treat the soil and shallow groundwater in the "hot spot" area(s) in situ but would not achieve the same degree of contaminant removal from soil as Alternative A-SO6.

TABLE 5-1

COMPARISON OF AREA A SOIL ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A-SO1 NO ACTION	ALTERNATIVE A-SO2 INSTITUTIONAL CONTROLS	ALTERNATIVE A-SO3 ASPHALT/GEOSYNTHETIC CAP OVER BRIG AREA[1]	ALTERNATIVE A-SO4 COMPOSITE CAP OVER HOT SPOT AREAS[1]	ALTERNATIVE A-SO5 DUAL PHASE VACUUM EXTRACTION OF HOT SPOT AREAS[1]	ALTERNATIVE A-SO6 THERMAL TREATMENT OF HOT SPOT AREAS[1]	ALTERNATIVE A-S07 OFF-SITE DISPOSAL OF HOT SPOT AREAS[1]
OVERALL PROTECTION TO HUMAN HEALTH AND THE ENVIRONMENT						
No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. No additional protection from direct contact with potential soil contamination. No additional protection of groundwater.	No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. Protection from direct contact provided by institutional controls. No additional protection of groundwater.	No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. Protection from direct contact provided by institutional controls and cap. Partial protection of groundwater provided by cap over Brig area.	No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. Protection from direct contact provided by institutional controls and cap. Partial protection of groundwater provided by cap over hot spot area(s).	No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. Protection from direct contact provided by institutional controls. Protection of groundwater provided by in situ treatment of source area(s).	No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. Protection from direct contact provided by institutional controls. Protection of groundwater provided by ex situ treatment of source(s).	No unacceptable risks from surface soils for current land use. Marginal risk from surface soils for future residential use. Potential risks from buried wastes. Protection from direct contact provided by institutional controls. Protection of groundwater by off-site disposal of source area(s).
COMPLIANCE WITH ARARS						
No contaminant-, location-, or action-specific ARARs.	No contaminant-, location- or action-specific ARARs.	No contaminant-specific ARARs. Cap designed in accordance with RCRA and state solid waste regulations.	No contaminant-specific ARARs. Cap designed in accordance with RCRA and state hazardous waste regulations.	No contaminant-specific ARARs. Air emissions would be treated to comply with state air pollution standards. Any hazardous materials would be handled/ disposed in accordance with RCRA and state hazardous waste regulations.	No contaminant-specific ARARs. Air emissions would be treated to comply with state air pollution standards. Any hazardous materials would be handled/disposed in accordance with RCRA and state hazardous waste regulations.	No contaminant-specific ARARs. Air emissions would be treated to comply with state air pollution standards. Any hazardous materials would be handled/disposed in accordance with RCRA and state hazardous waste regulations.
LONG-TERM EFFECTIVENESS AND PERMANENCE						
No remedial action would be taken. No reduction in risk levels; however, risks are acceptable under current use, and site is not used for residential use. No additional protection of groundwater.	Institutional actions would administratively limit future site use to nonresidential use. Risks are acceptable under current use, and site is not used for residential use. Maintenance of landfill soil cover effective in limiting surface water infiltration and erosion.	Institutional actions would administratively restrict access to site and limit future site use to nonresidential use. Risks are acceptable under current use, and site is not used for residential use. Partial long-term protection of groundwater provided by cap over potential source areas in vicinity of Brig.	Institutional actions would administratively restrict access to site and limit future site use to nonresidential use. Risks are acceptable under current use, and site is not used for residential use. Partial long-term protection of groundwater provided by cap over hot spot area(s).	Institutional actions would administratively restrict access to site and limit future site use to nonresidential use. Risks are acceptable under current use, and site is not used for residential use. Permanent long-term protection of groundwater provided by in situ treatment.	Institutional actions would administratively restrict access to site and limit future site use to nonresidential use. Risks are acceptable under current use, and site is not used for residential use. Permanent long-term protection of groundwater provided by ex situ treatment.	Institutional actions would administratively restrict access to site and limit future site use to nonresidential use. Risks are acceptable under current use, and site is not used for residential use. Permanent long-term protection of groundwater provided by off-site disposal.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV) THROUGH TREATMENT						
No reduction in TMV through treatment. Possible reduction in TMV through natural processes.	No reduction in TMV through treatment. Possible reduction in TMV through natural processes.	No reduction in TMV through treatment. Possible reduction in TMV through natural processes. Partial reduction in mobility through capping.	No reduction in TMV through treatment. Possible reduction in TMV through natural processes. Partial reduction in mobility through capping.	Reduction in TMV through in situ vacuum extraction/treatment. Effective removal of VOCs, partial removal of SVOCs.	Reduction in TMV through ex situ thermal treatment. Very effective removal of VOCs and effective removal of SVOCs.	No reduction in TMV through treatment. Reduction in mobility via disposal in secure off-site landfill.

TABLE 5-1 (CONTINUED)

COMPARISON OF AREA A SOIL ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A-SO1 NO ACTION	ALTERNATIVE A-SO2 INSTITUTIONAL CONTROLS	ALTERNATIVE A-SO3 ASPHALT/GEOSYNTHETIC CAP OVER BRIG AREA[1]	ALTERNATIVE A-SO4 COMPOSITE CAP OVER HOT SPOT AREAS[1]	ALTERNATIVE A-SO5 DUAL PHASE VACUUM EXTRACTION OF HOT SPOT AREAS[1]	ALTERNATIVE A-SO6 THERMAL TREATMENT OF HOT SPOT AREAS[1]	ALTERNATIVE A-S07 OFF-SITE DISPOSAL OF HOT SPOT AREAS[1]
SHORT-TERM EFFECTIVENESS						
No risk to human health or environment during implementation.	No risk to human health or environment during implementation.	No risk to human health or environment during implementation.	No risk to human health or environment during implementation.	Potential risks to human health and environment during operation would be controlled by air emission treatment/ monitoring. Several years required to achieve cleanup levels.	Potential risks to human health and environment during operation would be controlled by air emission treatment/ monitoring. Approx. 6 months required to complete remediation.	Potential risks to human health and environment during excavation would be controlled by dust controls. Approx. 2 months required to complete remediation.
IMPLEMENTABILITY						
Readily implementable.	Straight-forward installation of fencing. Periodic inspection and maintenance of fenced required. Legal/administrative requirements for institutional controls.	Legal/administrative requirements for institutional controls. Capping technologies demonstrated and commercially available. Periodic inspection and maintenance of cap required.	Legal administrative requirements for institutional controls. Capping technologies demonstrated and commercially available. Periodic inspection and maintenance of cap required.	Administrative requirements for institutional controls. Technologies demonstrated and commercially available. Approx. 5-year operation of treatment system.	Administrative requirements for institutional controls. Technologies demonstrated and commercially available. Trial runs may be required. Potential public opposition. Approx. 6-month operation of treatment system.	Administrative requirements for institutional controls. Technologies demonstrated and commercially available.
COST						
Capital: $0 O&M: $20,000 (every 5 years) NPW: $55,600	Capital: $0 O&M: $17,557 (annually); $20,000 (every 5 years) NPW: $325,500	Capital: $927,200 O&M: $17,557 (annually); $95,653 (every 5 years) NPW: $1,877,900	Capital: $465,300 O&M: $19,395 (annually); $39,395 (every 5 years) NPW: $819,100	Capital: $490,700 O&M: $108,066 (years 1-4) $139,022 (year 5) $17,557 (years 6-30) NPW: $1,216,700	Capital: $6,141,500 O&M: $17,557 (annually); $37,557 (every 5 years) NPW: $6,467,100	Capital: $9,867,900 O&M: $17,557 (annually); $37,557 (every 5 years) NPW: $10,193,500

[1] Alternative includes Institutional Controls
O&M: Operation and Maintenance
NPW: 30-year Net Present Worth

Compliance with ARARs: There are no contaminant-specific ARARs available for soil. Cap designs under Alternatives A-S03 and A-S04 would comply with applicable RCRA and state regulations. Air emissions generated under Alternatives A-SO5, A-SO6, and A-SO7 would be treated to comply with state and federal air standards. Any hazardous wastes generated during implementation of Alternatives A-SO5, A-SO6, and A-SO7 would be handled, containerized, transported, and disposed in accordance with RCRA and state hazardous waste regulations.

Long-term Effectiveness and Permanence: Estimated risk levels for exposure to surface soils are currently within acceptable levels. Therefore, all alternatives would be protective of human health with respect to surface soils. Alternative A-SO2 would provide a greater degree of protection against possible exposures to subsurface contamination through deed restrictions. Alternatives A-SO1 and A-SO2 would not provide a permanent solution in the sense that potential "hot spots" would continue to provide sources of groundwater contamination. Alternatives A-SO3 and A-SO4 would provide partial protection of groundwater through capping. Under Alternatives A-SO5, A-SO6, and A-SO7, "hot spot" area(s) would be permanently removed and/or treated.

Reduction of Toxicity, Mobility, or Volume: Alternatives A-SO1 and A-SO2 would not actively reduce the toxicity, mobility, or volume of contaminants in the soils through remedial actions. Some reduction may be achieved under these alternatives through natural processes, such as dispersion, volatilization, and biodegradation. Alternatives A-SO3 and A-SO4 also would not reduce the toxicity, mobility, or volume of contaminants in the soils through treatment. However, these alternatives would partially reduce the mobility of contaminants through capping. Alternatives A-SO5 and A-SO6 would reduce the toxicity and volume of contaminants in the soils through in situ vacuum extraction and ex situ thermal treatment, respectively. Alternative A-S05 would also reduce the toxicity and volume of contaminants in shallow groundwater through treatment. Alternative A-SO6, thermal treatment, would provide a higher degree of contaminant removal from soil than would vacuum extraction under Alternative A-SO5. Alternative A-SO7 would permanently remove the source area(s) from the site but would not provide any reduction in toxicity, mobility, or volume through treatment.

Short-term Effectiveness: Alternatives A-SO1 through A-SO4 would not pose potential risks to human health or the environment during implementation. Alternatives A-SO5 and A-SO6 could pose potential risks to these receptors through air emissions; however, treatment and monitoring of air emissions would be used to minimize such potential risks. Implementation of Alternative A-SO7 could pose potential risks to human health and the environment from dust emissions during excavation; however, dust controls would

be used minimize such risks. It is estimated that Alternative A-SO5 would require several years to achieve soil cleanup levels that are protective of groundwater, whereas, thermal treatment of the soil under Alternative A-SO6 could be completed in within approximately six months once on-site work begins. Alternative A-SO7 could be completed within approximately two months once on-site work begins.

Implementability: There are no implementability considerations under Alternatives A-SO1 and A-S02. Alternative A-SO4 would be easier to implement than Alternative A-SO3 since the cap would cover only limited "hot spot" areas (e.g., 1.0 acre) as opposed to the entire Brig Facility area (approximately 12 acres). Alternative A-SO5 would be easier to implement than Alternatives A-SO6 and A-SO7 in the sense that excavation and handling of contaminated soils would not be required. In addition, demonstration of compliance with air pollution standards for Alternative A-SO5 could be less complex than those for Alternative A-SO6. There may also be fewer public concerns associated with implementation of Alternative A-SO5 than with Alternative A-SO6. With respect to operation and maintenance requirements, on-site thermal treatment under Alternative A-SO6 would be more complex to operate and monitor than would in situ vapor extraction under Alternative A-SO5. However, the duration of on-site operation would be less than one year for on-site thermal treatment (assuming extensive trial runs are not needed), compared to potentially several years of operation for Alternative A-SO5. For Alternative A-SO7, off-site disposal capacity is not expected to be a concern.

Cost: The 30-year net present worth costs for the six Area A soil alternatives are summarized below:

- Alternative A-SO1: $55,600
- Alternative A-SO2: $325,500
- Alternative A-SO3: $1,877,900
- Alternative A-SO4: $819,100
- Alternative A-SO5: $1,216,700
- Alternative A-SO6: $6,467,100
- Alternative A-SO7: $10,193,500

With respect to the capping alternatives, A-SO3 and A-SO4, the estimated cost of capping the "hot spot" areas (A-S04) is approximately one-half the cost of capping the entire Brig Facility area (A-S03). With respect to the treatment alternatives, A-SO5 and A-SO6, the estimated cost of treating the "hot spot" area via vacuum extraction ($1,216,700) is approximately one-fifth the cost of thermal treatment ($6,467,100), based on the estimated volume of contamination (i.e., 12,814 cubic yards) and assumed duration of

operation (i.e., 5 years for vacuum extraction). Based on the estimated volume of contamination, the estimated cost of disposing the contaminated material off site ($10,193,500) is almost double the cost of treating the "hot spot" area via on-site thermal treatment ($6,467,100).

5.4.2 Comparison of Area B Soil Alternatives

A side-by-side comparison of the alternatives for addressing Area B soils, based on the seven evaluation criteria used in previous sections, is presented in Table 5-2. A summary of the alternative comparison based on the seven criteria is provided below.

Overall Protection: With respect to Area B soils, Alternative B-SO1 would not provide any additional protection to human health than that currently provided by existing site fencing. Alternative B-SO2 would provide a higher degree of protection through institutional controls.

Compliance with ARARs: There are no contaminant-specific ARARs available for soils. In addition, there are no location- or action-specific ARARs associated with either alternative.

Long-term Effectiveness and Permanence: Risks associated with exposure to the surface soils are currently within acceptable levels established under CERCLA under both industrial and residential use scenarios. A removal action is being implemented to remove the sources of groundwater contamination within the Area B landfill. Therefore, both alternatives would provide the same level of groundwater protection following the removal action. The landfill is currently surrounded by fencing and Jersey barriers. Alternative B-SO2 would provide a slightly greater degree of protection against possible exposures to any remaining contamination in the landfill through institutional controls.

Reduction of Toxicity, Mobility, or Volume: Alternatives B-SO1 and B-SO2 would not reduce the toxicity, mobility, or volume of contaminants in the soils through treatment. However, a removal action is planned for the source areas within the Area B Landfill. Some reduction may be achieved under these alternatives through natural processes such as dispersion, volatilization, and biodegradation.

Short-term Effectiveness: Alternatives B-SO1 and B-SO2 would not pose potential risks to human health or the environment during implementation.

TABLE 5-2

COMPARISON OF AREA B SOIL ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE B-SO1 NO ACTION	ALTERNATIVE B-SO2 INSTITUTIONAL CONTROLS
OVERALL PROTECTION TO HUMAN HEALTH AND THE ENVIRONMENT	
No unacceptable risks from surface soils for current land uses, marginal risks for future residential use. Provides no additional protection from direct contact, no additional protection of groundwater. However, the removal action of sources at Area B will provide protection.	No unacceptable risks from surface soils for current land uses, marginal risks for future residential use. Provides some additional protection from direct contact by institutional controls, no additional protection of groundwater. However, the removal action of sources at Area B will provide protection.
COMPLIANCE WITH ARARS	
No contaminant-, location-, or action-specific ARARs.	No contaminant-, location- or action-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE	
No remedial action; however, the removal action will provide effective and permanent source removal.	Institutional controls would limit future land use to non-residential. The removal action will provide effective and permanent source control.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV) THROUGH TREATMENT	
No reduction in TMV through treatment. Possible reduction in TMV through natural processes.	No reduction in TMV through treatment. Possible reduction in TMV through natural processes.
SHORT-TERM EFFECTIVENESS	
No risks to human health or environment during implementation.	No risks to human health or environment during implementation.
IMPLEMENTABILITY	
No action; therefore, no implementability concerns.	Periodic inspection and maintenance of fenced required. Legal/administrative requirements for institutional controls.
COST	
Capital: $0 O&M: $20,000 (every 5 years) NPW: $55,600	Capital: $0 O&M: $600 (annually); $20,000 (every 5 years) NPW: $63,200

O&M: Operation and Maintenance
NPW: 30-year Net Present Worth

Implementability: There are no implementability considerations under Alternative B-SO1 or Alternative B-SO2.

Cost: The estimated 30-year net present worth cost of Alternative B-SO1 is $55,600, which is the cost of performing site reviews every 5 years. The estimated 30-year net present worth cost of Alternative B-SO2 is $63,200 to maintain the existing fencing as well as to conduct 5-year site reviews.

5.4.3 Comparison of Surface Water/Sediment Alternatives

A side-by-side comparison of the alternatives for addressing site surface water and sediment, based on the seven evaluation criteria used in previous sections, is presented in Table 5-3. A summary of the alternative comparison based on the seven criteria is provided below.

Overall Protection: With respect to surface water/sediments, Alternative SD1 would not provide any additional protection to human health than that currently provided by existing site fencing. Alternative SD2 would provide a higher degree of protection through institutional controls. In addition, a surface water and sediment monitoring program would be implemented under Alternative SD2 to track trends in contaminant levels over time in these media.

Compliance with ARARs: There are no contaminant-specific ARARs available for sediments. Although there were sporadic minor exceedances of federal Ambient Water Quality Criteria and Virginia Water Quality Standards, there were no gross exceedances and no clear pattern of exceedances that would suggest a significant problem with site surface water. There are no location- or action-specific ARARs associated with either alternative.

Long-term Effectiveness and Permanence: Under Alternative SD1, there would be no remedial action taken. The human health risks associated with exposure to surface water and sediment would remain the same as in the baseline human health risk assessment. Alternative SD2 would provide a greater degree of protection against possible exposures to potential contamination in surface water and sediments through institutional controls. For both alternatives, source control measures that are currently being implemented at Area B (removal action), and source control measures that are planned for Area A, are expected to improve the quality of surface water and sediment over time.

TABLE 5-3

COMPARISON OF SURFACE WATER/SEDIMENT ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE SD-1 NO ACTION	ALTERNATIVE SD-2 INSTITUTIONAL CONTROLS WITH MONITORING
OVERALL PROTECTION TO HUMAN HEALTH AND THE ENVIRONMENT	
No unacceptable human health risks associated with exposure to Area A or Area B surface water/sediment. Marginal risks for future residential use. Low levels of contaminants. Migration of contaminants to groundwater not considered to be a pathway. Provides no additional protection.	No unacceptable human health risks associated with exposure to the Area A or Area B surface water/sediment. Marginal risks for future residential use. Low levels of contaminants. Migration of contaminants to groundwater not considered to be a pathway. Provides some additional protection through institutional controls.
COMPLIANCE WITH ARARS	
Minor exceedances of federal and state standards for surface water. No action- or location-specific ARARs.	Minor exceedances of federal and state standards for surface water. No action- or location-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE	
No remedial action -- risks same as in baseline risk assessment. However, source control actions in Areas A and B are expected to improve surface water/sediment quality over time.	Institutional controls would limit future land use to non-residential. Monitoring would provide information to track contaminant levels in these media.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV) THROUGH TREATMENT	
No reduction in TMV through treatment. Possible reduction in TMV through natural processes.	No reduction in TMV through treatment. Possible reduction in TMV through natural processes.
SHORT-TERM EFFECTIVENESS	
No risks to human health during implementation.	No risks to human health during implementation.
IMPLEMENTABILITY	
No action; therefore, no implementability concerns.	Legal/administrative requirements for institutional controls. Monitoring easily implemented.
COST	
Capital: $0 O&M: $20,000 (every 5 years) NPW: $55,600	Capital: $0 O&M: $50,477 (annually); $70,477 (every 5 years) NPW: $831,600

O&M: Operation and Maintenance
NPW: 30-year Net Present Worth

Reduction of Toxicity, Mobility, or Volume: Alternatives SD1 and SD2 would not reduce the toxicity, mobility, or volume of contaminants in the sediments through treatment. There may be a reduction in toxicity, mobility, or volume of contaminants in the long term through natural attenuation processes.

Short-term Effectiveness: Alternatives SD1 and SD2 would not pose potential risks to human health or the environment during implementation.

Implementability: There are no implementability considerations under Alternative SD1 or Alternative SD2.

Cost: The estimated 30-year net present worth cost of Alternative SD1 is $55,600 for performing site reviews every 5 years. The estimated 30-year net present worth cost of Alternative SD2 is $831,600 for maintaining existing fencing, implementing a five-year surface water and sediment monitoring program, and conducting five-year site reviews.

SECTION 6 - DETAILED ANALYSIS OF GROUNDWATER ALTERNATIVES

6.0 DETAILED ANALYSIS OF GROUNDWATER ALTERNATIVES

Groundwater alternatives were developed based on the remedial action objectives and general response actions identified in Section 2.4 for groundwater as well as on the remedial technologies and representative process options retained for further consideration in Section 3.2. As with the soil alternatives, separate groundwater alternatives were developed for Areas A1, A2, and B at the site since these areas represent different regions of groundwater contamination, which have originated from different sources. The groundwater remedial alternatives developed for Areas A1, A2, and B are summarized below:

Area A1 Groundwater Alternatives

- Alternative A1-GW1: No Action with Monitoring
- Alternative A1-GW2: Institutional Controls with Monitoring
- Alternative A1-GW3: Protection of the Yorktown Aquifer for Beneficial Use Through Extraction and Treatment, Institutional Controls, and Monitoring

Area A2 Groundwater Alternatives

- Alternative A2-GW1: No Action with Monitoring
- Alternative A2-GW2: Institutional Controls with Monitoring
- Alternative A2-GW3: Protection of the Yorktown Aquifer for Beneficial Use Through Extraction and Treatment, Institutional Controls, and Monitoring

Area B Groundwater Alternatives

- Alternative B-GW1: No Action with Monitoring
- Alternative B-GW2: Institutional Controls with Monitoring
- Alternative B-GW3: Protection of the Water Table and Yorktown Aquifers for Beneficial Use Through Extraction and Treatment, Institutional Controls, and Monitoring

In this section, the groundwater alternatives are analyzed in detail based on the seven criteria described in Section 5.0. The groundwater alternatives are evaluated in Sections 6.1, 6.2, and 6.3 for Areas A1, A2, and B, respectively.

6.1 Area A1 Alternatives

6.1.1 Alternative A1-GW1: No Action with Monitoring

Description: Under this alternative, no actions would be taken to contain or treat contaminated groundwater associated with Area A1 at Camp Allen. As discussed in Section 1.3.2, groundwater contamination is present in both the water table and upper Yorktown aquifers in Area A1 (Figures 1-8 and 1-9). Potable water used throughout the area is supplied by the City of Norfolk. Groundwater on site currently is not used for any purpose.

Residential wells located in Glenwood Park, downgradient (west) of Area A1, supply water for nonpotable uses, such as lawn watering and car washing. These wells reportedly are screened within the shallow, water table aquifer. Residential and monitoring well sampling results indicate that these wells have not been impacted by the site. Potable water is supplied to the community by the City of Norfolk.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, seven monitoring wells and three other perimeter monitoring wells associated with Area A1 would be periodically sampled.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact)

to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the Brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. Groundwater off site (in Glenwood Park) currently is used for nonpotable purposes only. This alternative would not prevent nonpotable use of contaminated groundwater off site should groundwater contaminant concentrations exceed proposed cleanup goals in the future.

This alternative does not include controls for minimizing the migration of contaminants. The groundwater monitoring program would be used to assess future migration of contaminants into off-site downgradient areas.

Compliance with ARARs: Contaminated groundwater in both the shallow (water table) and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state Maximum Contaminant Levels (MCLs) established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively. However, neither aquifer currently is used for drinking water purposes since potable water in the area is provided by the City of Norfolk. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: Exposure pathways would be unaffected by the implementation of this alternative. This alternative would not actively restore contaminated groundwater to proposed cleanup goals through extraction and treatment. Contaminated groundwater would be allowed to migrate. Contaminant concentrations in the groundwater may eventually decrease below cleanup goals through

natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Contaminant concentrations on site currently exceed proposed cleanup goals. However, groundwater currently is not used for any purpose on site. Residential wells located in Glenwood Park, downgradient (west) of Area A1, are used only for nonpotable uses. Contaminant concentrations in Glenwood Park currently do not exceed the proposed cleanup goals, but could exceed these levels if contaminants were to migrate toward this area. However, groundwater monitoring results indicate that shallow groundwater contamination is not migrating off site. Periodic groundwater sampling of monitoring wells, a reliable means of tracking contaminant migration, would be used to assess potential off-site migration of contaminated groundwater.

Reduction of Toxicity, Mobility, or Volume: No reduction of toxicity, mobility, or volume would be provided by this alternative. The toxicity of contaminated groundwater may be reduced over time through natural dilution and dispersion, depending on the nature and extent of the contaminant sources.

Short-term Effectiveness: This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation.

Implementability: A groundwater monitoring program could be readily implemented for Area A1.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $38,600 (annually years 1-10), $19,600 (annually years 11-20), $10,100 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $476,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.1.2 Alternative A1-GW2: Institutional Controls with Monitoring

Description: Under this alternative, no actions would be taken to contain or treat contaminated groundwater associated with Area A1 at Camp Allen. As discussed in Section 1.3.2, groundwater contamination is present in both the water table and upper Yorktown aquifers in Area A1 (Figures 1-8 and 1-9). Potable water used throughout the area is supplied by the City of Norfolk. Groundwater on site currently is not used for any purpose.

Under this alternative, existing institutional controls would be maintained to prevent groundwater usage at Camp Allen. Formal institutional controls could also be incorporated into the existing Base "Master Plan." There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions would be implemented to limit nonpotable use and prevent potable use of contaminated groundwater.

Residential wells located in Glenwood Park, downgradient (west) of Area A1, are used for nonpotable uses, such as lawn watering and car washing. These wells reportedly are screened within the shallow, water table aquifer. Residential and monitoring well sampling results indicate that these wells have not been impacted by the site. Potable water is supplied to the community by the City of Norfolk.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, seven monitoring wells and three other perimeter monitoring wells associated with Area A1 would be periodically sampled.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact)

to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the Brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. Groundwater off site (in Glenwood Park) currently is used for nonpotable purposes only since residents in Glenwood Park are connected to public water. This alternative would prevent nonpotable use of off-site contaminated groundwater through institutional controls should contaminated groundwater migrate off site in the future.

This alternative does not include controls for minimizing the migration of contaminants. The groundwater monitoring program would be used to assess future migration of contaminants into off-site downgradient areas.

Compliance with ARARs: Contaminated groundwater in both the water table and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively. However, neither aquifer currently is used for drinking water purposes since potable water in the area is provided by the City of Norfolk. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: This alternative would not actively restore contaminated groundwater to the proposed cleanup goals through extraction and treatment. Contaminated groundwater would be allowed to migrate. Contaminant concentrations may eventually decrease below cleanup goals

through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Contaminant concentrations on site currently exceed proposed cleanup goals. However, groundwater currently is not used for any purpose on site. Residential wells located in Glenwood Park, downgradient (west) of Area A1, are used for nonpotable uses. Contaminant concentrations in Glenwood Park currently do not exceed the proposed cleanup goals, but could exceed these levels if contaminants were to migrate toward this area. However, groundwater monitoring results indicate that shallow groundwater contamination is not migrating off site. Periodic groundwater sampling of monitoring wells, a reliable means of tracking contaminant migration, would be used to assess potential off-site migration of contaminated groundwater. Potential unacceptable risks associated with nonpotable groundwater use would be mitigated through provision of institutional controls.

Reduction of Toxicity, Mobility, or Volume: No reduction of toxicity, mobility, or volume would be provided by this alternative. The toxicity of contaminated groundwater may be reduced over time through natural dilution and dispersion, depending on the nature and extent of the contaminant sources.

Short-term Effectiveness: This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation.

Implementability: A groundwater monitoring program could be readily implemented for Area A1. Existing site institutional controls could easily be maintained. Under a base closure scenario, deed restrictions to restrict groundwater to nonpotable usage would require certain legal and administrative procedures.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $38,600 (annually years 1-10), $19,600 (annually years 11-20), $10,100 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $476,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

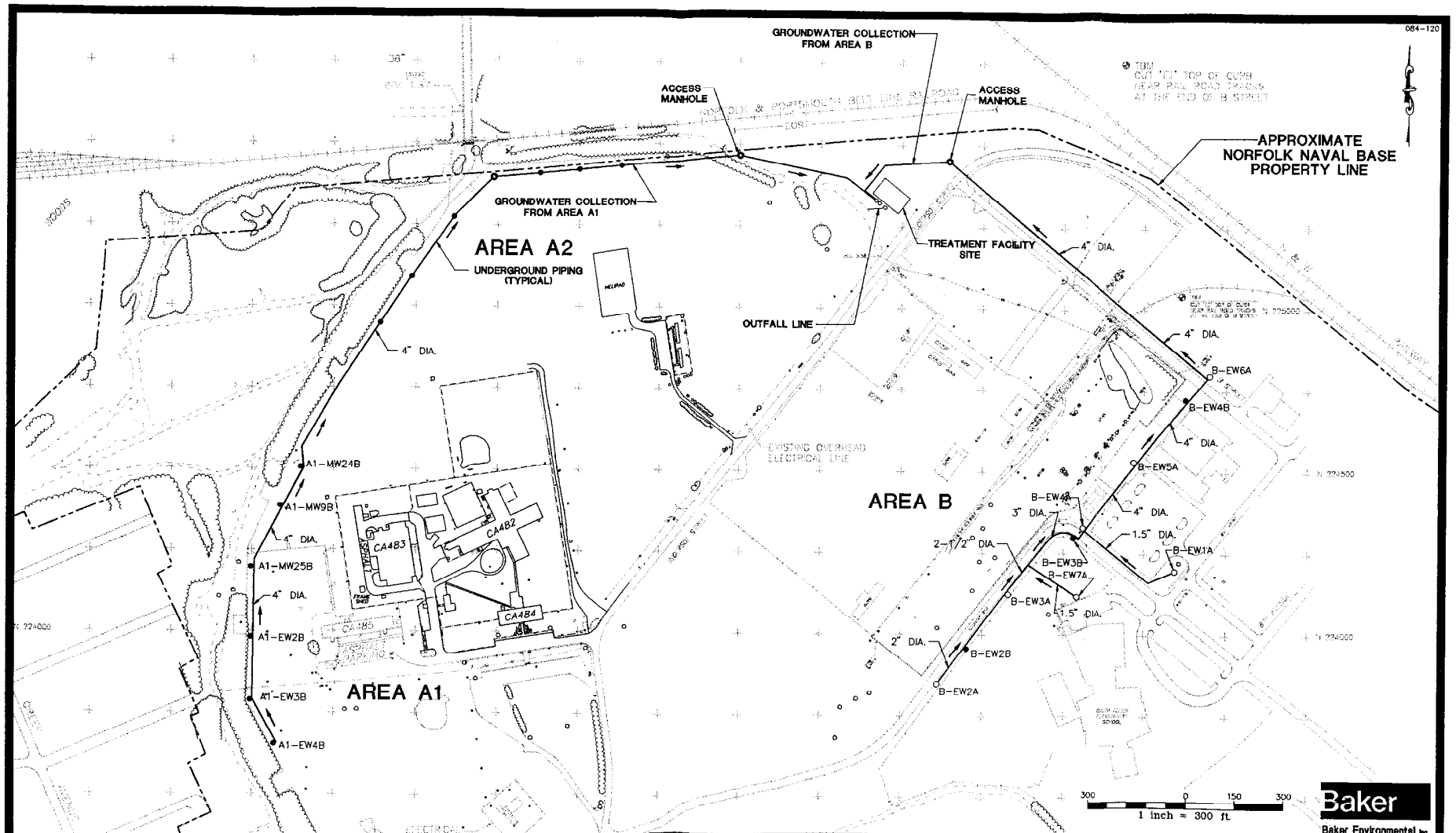
6.1.3 Alternative A1-GW3: Protection of the Yorktown Aquifer for Beneficial Use Through Extraction and Treatment, Institutional Controls, and Monitoring

Description: Under this alternative, a groundwater extraction, treatment, and discharge system would be constructed for the Yorktown Aquifer in Area A1 and operated on site. As noted in Section 1.3.1, all of the shallow monitoring wells in Area A1 were bailed dry during the pre-design investigation and would not sustain a continuous pumping rate. Therefore, operation of a conventional groundwater extraction system in the water table aquifer in Area A1, using wells and submersible pumps, is not feasible because of the aquifer's very low transmissivity. Another technology for remediating shallow groundwater in Area A1, in situ dual phase vacuum extraction, is discussed under Alternative A-SO5 in Sections 4.5 and 5.1.5.

The Yorktown Aquifer extraction system would be used to extract and contain groundwater contaminated above the cleanup goals developed for the Yorktown Aquifer, as discussed in Section 2.3. If possible, the system would be operated until groundwater cleanup goals are achieved. However, MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant levels typically reach asymptotic levels, which may exceed MCLs. Performance curves would be periodically (e.g., annually) developed to monitor the effectiveness of the groundwater remediation system. If the performance curves indicate that asymptotic levels have been reached, which exceed MCLs for some contaminants, then the cleanup goals may be re-evaluated at that time.

Groundwater would be pumped using a series of mid-depth (approximately 65 feet deep in the Yorktown Aquifer) pumping wells connected to a common treatment system. An estimated groundwater pumping rate of approximately 82 gallons per minute (gpm) would be required to contain the current extent of contamination in Area A1. The conceptual pumping well arrangement, shown in Figure 6-1, includes three existing wells each pumping at 5 gpm and three new extraction wells with flow rates ranging from 16 to 27 gpm.

The conceptual extraction system was developed based on the pumping rate necessary to contain the plume, the number of wells needed to achieve the pumping rate, and the optimum spacing between the wells to capture the groundwater. The extraction system design is a containment-type system, designed to contain contaminated groundwater rather than attempt to aggressively restore it to the cleanup goals. With this approach, the groundwater is extracted at a rate equal to the natural flow through the contaminated portion



LEGEND

- ○ SHALLOW EXTRACTION WELLS (TYPE II)
- ● UPPER YORKTOWN EXTRACTION WELLS (TYPE II)
- ◉ ACCESS MANHOLE

FIGURE 6-1
CONCEPTUAL GROUNDWATER EXTRACTION & TREATMENT SYSTEM FOR AREAS A1, A2 & B – CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

of the Yorktown Aquifer. It has been estimated that a flow rate of 82 gpm would be required to contain Area A1 contamination in the Yorktown Aquifer.

The groundwater treatment system included under this alternative has also been sized to accommodate flows from Areas A1, A2, and B. This approach has been taken to achieve an economy of scale by constructing and operating one large treatment system common to all three areas rather than potentially constructing and operating three individual systems, which would be significantly more costly. The estimated groundwater flow rate for Area A1 is 82 gpm. As will be discussed in Sections 6.2.3 and 6.3.3, the estimated groundwater flow rates for Areas A2 and B are 82 and 42 gpm, respectively. Thus, the estimated total flow rate for Areas A1, A2, and B is 206 gpm. In order to provide additional capacity for potential future increases in groundwater flow rates, the groundwater treatment system was designed to accommodate a total flow rate of up to 300 gpm.

The conceptual groundwater treatment system used for costing purposes for Area A1 is presented in Figure 6-2. The actual treatment components would be determined during the remedial design phase. The primary components of the groundwater treatment system would consist of the following processes for removal of organic contaminants:

- Air stripping
- Carbon adsorption

A pretreatment system would be used to remove suspended solids and nuisance metals, such as iron, as well as any toxic metals, such as arsenic and chromium, that may be present in the water prior to treatment of the organic contaminants. The pretreatment could consist of equalization, precipitation, flocculation, clarification, and pressure filtration. The pretreatment system would reduce clogging of the air stripper and carbon units, thereby improving their efficiencies and reducing maintenance requirements.

Following pretreatment for suspended solids and metals removal, groundwater would be first pumped through an air stripper for removal of volatile organic contaminants and then through a carbon adsorption "polishing" step for removal of contaminants not removed by the air stripper. The treated groundwater would be discharged to the on-site drainage ditch located along the northern boundary of Area A.

Contaminated air generated by the air stripper would be treated, if necessary, to comply with the Virginia Air Emission Standards for Toxic Pollutants (VR 120-04-0301). A comparison of estimated air emission concentrations to these standards (provided in Appendix F) indicates that the air emissions would comply

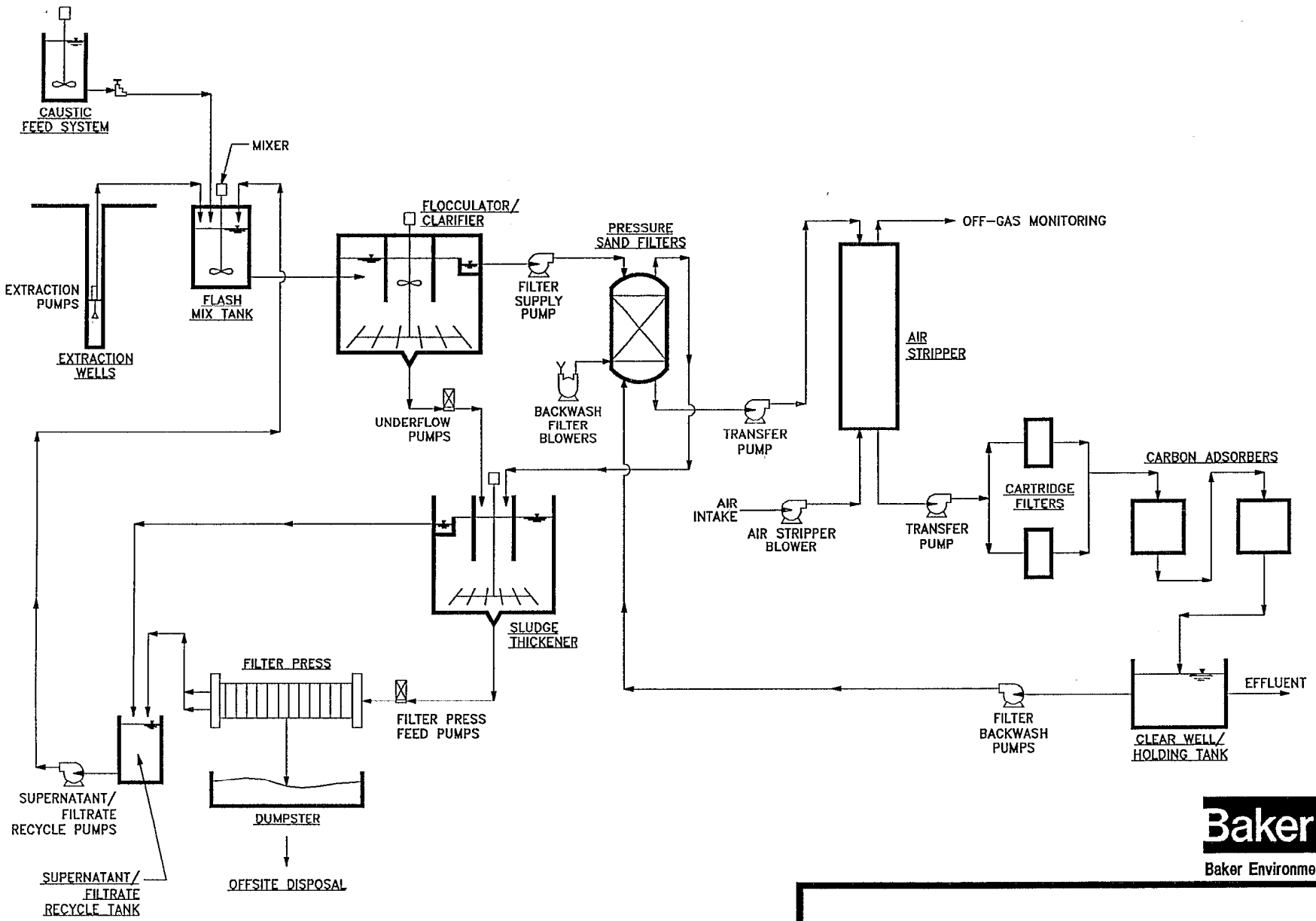


FIGURE 6-2
CONCEPTUAL GROUNDWATER TREATMENT SYSTEMS FOR AREAS A1, A2 AND B

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

084504FS

with the exemption requirements of VR 120-04-0301, and therefore, treatment of the air stripper off-gas would not be required.

Under this alternative, existing institutional controls would be maintained to prevent groundwater usage at Camp Allen. Formal institutional controls could also be incorporated into the existing base "Master Plan." There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions would be implemented to limit nonpotable use and prevent potable use of contaminated groundwater.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, seven monitoring wells and three other perimeter monitoring wells associated with Area A1 would be periodically sampled.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact) to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the Brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

The intent of this alternative is to contain the groundwater contaminated above proposed groundwater cleanup goals until these goals are achieved. Thus, this alternative is also intended to eventually restore the contaminated groundwater to cleanup goals.

Any groundwater located downgradient of the extraction system, or outside of its capture zone, that is contaminated below groundwater cleanup goals would be allowed to migrate. Groundwater concentrations may decrease below cleanup goals through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Among other factors, the time to achieve groundwater cleanup goals is dependent on the nature and extent of the sources, which are difficult to characterize within a landfill. Therefore, the time to achieve these cleanup goals cannot accurately be predicted at this time. It is possible that cleanup goals could require 10 to 20 years, or longer, to achieve. Also, MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant concentrations typically reach asymptotic levels, which may exceed MCLs. Performance curves will be periodically (e.g., annually) developed to monitor the effectiveness of the groundwater remediation system. If the performance curves indicate that asymptotic levels have been reached, that exceed MCLs for some contaminants, then the cleanup goals may be re-evaluated at that time.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. Groundwater off site (in Glenwood Park) is currently used for nonpotable purposes only since residents in Glenwood Park are connected to public water. This alternative would prevent nonpotable use of off-site contaminated groundwater through institutional controls should contaminated groundwater migrate off site in the future.

Compliance with ARARs: Contaminated groundwater in both the water table and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively.

The intent of this alternative is to restore groundwater in the Yorktown Aquifer to its beneficial use through extraction and treatment. Treated groundwater and associated air emissions resulting from groundwater

treatment would comply with all pertinent local, state, and federal location- and action-specific ARARs before being discharged to the environment. Specifically, treated groundwater must meet the Virginia Groundwater Standards found in VR 680-21-04.3. In addition, discharge to the on-site drainage ditch (discharge to surface waters) would require compliance with the substantive requirements of the Virginia Pollution Discharge Elimination System (VPDES) regulations, VR80-14-01.

Long-term Effectiveness and Permanence: Contaminant concentrations on site currently exceed proposed cleanup goals. However, groundwater currently is not used for any purpose on site. Residential wells located in Glenwood Park, downgradient (west) of Area A1, are used for nonpotable uses. Contaminant concentrations in Glenwood Park currently do not exceed the proposed cleanup goals. The proposed groundwater extraction and treatment system would prevent groundwater contaminated above the cleanup goals in the Yorktown Aquifer from migrating towards this area. Periodic groundwater sampling of monitoring wells is a reliable means of tracking contaminant migration and for verifying that contaminated groundwater is effectively being contained by the extraction and treatment system.

Reduction of Toxicity, Mobility, or Volume: The volume and toxicity of the contaminated groundwater would be permanently reduced to cleanup goals. Air stripping transfers contaminants from the aqueous to the vapor phase where they are eventually oxidized in the atmosphere. Migration of contaminated groundwater (mobility) in the Yorktown Aquifer would be contained by the extraction system.

Short-term Effectiveness: The major short-term effectiveness concern associated with this alternative is control of air stripper emissions. These emissions would be effectively monitored through sampling and analysis to ensure compliance with federal and state standards.

Implementability: Air stripping and carbon adsorption are commonly used for groundwater remediation for treatment of organic contaminants. Equipment and services for these systems are offered by numerous commercial vendors.

The most common problem associated with air strippers is clogging and channeling in the packing materials in packed towers and clogging of air diffusers in diffused aeration strippers. The pretreatment system would remove suspended solids and any nuisance metals that may cause clogging.

A groundwater monitoring program could be readily implemented for Area A1. Existing site institutional controls could easily be maintained, and revisions to the Base Master Plan could be readily implemented.

Under a base closure scenario, deed restrictions to restrict groundwater to nonpotable usage would require certain legal and administrative procedures.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $6,108,500
- Annual operation and maintenance: $187,300 (annually years 1-10), $168,300 (annually years 11-20), $158,800 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $8,870,200

The cost estimate for this alternative includes the capital cost of constructing a 300 gpm groundwater treatment system that has sufficient capacity to also accept groundwater flows from Areas A2 and B. Therefore, capital costs for the treatment system were not included in the groundwater extraction and treatment alternatives for Areas A2 and B. Annual O&M costs for this alternative include groundwater monitoring for Area A1 and the treatment system operating costs associated with treating groundwater from Area A1 only (82 gpm). Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.2 Area A2 Alternatives

6.2.1 Alternative A2-GW1: No Action with Monitoring

Description: Under this alternative, no actions would be taken to contain or treat contaminated groundwater associated with Area A2 at Camp Allen. As discussed in Section 1.3.2, groundwater contamination is present in both the water table and upper Yorktown aquifers in Area A2 (Figures 1-10 and 1-11). Potable water used throughout the area is supplied by the City of Norfolk. Groundwater on site currently is not used for any purpose.

There are no residential areas located downgradient (northwest) of Area A2. There are two industrial nonpotable wells located approximately 4000 feet northwest of Area A2, which are used by the Sheller Globe facility, a plant which manufactures cork gaskets.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, seven monitoring wells at Area A2 and three other perimeter monitoring wells would be periodically sampled.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact) to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the Brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. Groundwater off site currently is used for nonpotable purposes only. This alternative would not prevent nonpotable use of contaminated groundwater off site should groundwater contaminant concentrations exceed proposed cleanup goals in the future.

This alternative does not include controls for minimizing the migration of contaminants. The groundwater monitoring program would be used to assess future migration of contaminants into off-site downgradient areas.

Compliance with ARARs: Contaminated groundwater in both the shallow (water table) and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively. However, neither aquifer currently is used for drinking water purposes since potable water in the area is provided by the City of Norfolk. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: Exposure pathways would be unaffected by the implementation of this alternative. This alternative would not actively restore contaminated groundwater to proposed cleanup goals through extraction and treatment. Contaminated groundwater would be allowed to migrate. Contaminant concentrations in the groundwater may eventually decrease below cleanup goals through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Contaminant concentrations on site currently exceed the proposed cleanup goals. However, groundwater currently is not used for any purpose on site. There are no residential areas located downgradient (northwest) of Area A2. Periodic groundwater sampling of monitoring wells, a reliable means of tracking contaminant migration, would be used to assess potential off-site migration of contaminated groundwater.

Reduction of Toxicity, Mobility, or Volume: No reduction of toxicity, mobility, or volume would be provided by this alternative. The toxicity of contaminated groundwater may be reduced over time through natural dilution and dispersion, depending on the nature and extent of the contaminant sources.

Short-term Effectiveness: This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation.

Implementability: A groundwater monitoring program could be readily implemented for Area A2.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0

- Annual operation and maintenance: $38,600 (annually years 1-10), $19,600 (annually years 11-20), $10,100 (annually years 21-30), $20,000 (every 5 years)

- Net present worth: $476,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.2.2 Alternative A2-GW2: Institutional Controls with Monitoring

Description: Under this alternative, no actions would be taken to contain or treat contaminated groundwater associated with Area A2 at Camp Allen. As discussed in Section 1.3.2, groundwater contamination is present in both the water table and upper Yorktown aquifers in Area A2 (Figures 1-10 and 1-11). Potable water used throughout the area is supplied by the City of Norfolk. Groundwater on site currently is not used for any purpose.

Under this alternative, existing institutional controls would be maintained to prevent groundwater usage at Camp Allen. Formal institutional controls could also be incorporated into the existing Base "Master Plan." There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions would be implemented to limit nonpotable use and prevent potable use of contaminated groundwater.

There are no residential areas located downgradient (northwest) of Area A2. There are two industrial (nonpotable) wells located approximately 4000 feet northwest of Area A2, which are used for industrial (nonpotable) purposes.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, seven monitoring wells at Area A2 and three other perimeter monitoring wells would be periodically sampled.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive

sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact) to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the Brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. This alternative does not include controls for minimizing the migration of contaminants. The groundwater monitoring program would be used to assess future migration of contaminants into off-site downgradient areas.

Compliance with ARARs: Contaminated groundwater in both the shallow and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively. However, neither aquifer currently is used for drinking water purposes since potable water in the area is provided by the City of Norfolk. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: This alternative would not actively restore contaminated groundwater to the proposed cleanup goals through extraction and treatment. Contaminated groundwater would be allowed to migrate. Contaminant concentrations may eventually decrease below cleanup goals

through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Contaminant concentrations on site currently exceed proposed cleanup goals. However, groundwater currently is not used for any purpose on site. There are no residential areas located downgradient (northwest) of Area A2. Periodic groundwater sampling of monitoring wells, a reliable means of tracking contaminant migration, would be used to assess potential off-site migration of contaminated groundwater. Potential unacceptable risks associated with nonpotable groundwater use would be mitigated through provision of institutional controls.

Reduction of Toxicity, Mobility, or Volume: No reduction of toxicity, mobility, or volume would be provided by this alternative. The toxicity of contaminated groundwater may be reduced over time through natural dilution and dispersion, depending on the nature and extent of the contaminant sources.

Short-term Effectiveness: This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation.

Implementability: A groundwater monitoring program could be readily implemented for Area A2. Existing site institutional controls could easily be maintained. Under a base closure scenario, deed restrictions to restrict groundwater to nonpotable usage would require certain legal and administrative procedures.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $38,600 (annually years 1-10), $19,600 (annually years 11-20), $10,100 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $476,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.2.3 Alternative A2-GW3: Protection of the Yorktown Aquifer for Beneficial Use Through Extraction and Treatment, Institutional Controls, and Monitoring

Description: Under this alternative, groundwater from the Yorktown Aquifer in Area A2 would be extracted and treated on site. Operation of a conventional groundwater extraction system in the water table aquifer in Area A2, using wells and submersible pumps, may not be feasible because of the aquifer's very low transmissivity. Another technology for remediating shallow groundwater in Area A2, in situ dual phase vacuum extraction, is discussed under Alternative A-SO5 in Sections 4.5 and 5.1.5.

The Yorktown Aquifer extraction system would be used to extract and contain groundwater contaminated above the cleanup goals. If possible, the system would be operated until groundwater cleanup goals are achieved. However, MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant levels typically reach asymptotic levels, which may exceed MCLs. Performance curves will be periodically (e.g., annually) developed to monitor the effectiveness of the groundwater remediation system. If the performance curves indicate that asymptotic levels have been reached, which exceed MCLs for some contaminants, then the cleanup goals may be re-evaluated at that time.

Groundwater would be pumped using a series of mid-depth (approximately 65 feet deep in the Yorktown Aquifer) pumping wells connected to a common treatment system. An estimated groundwater pumping rate of approximately 82 gallons per minute (gpm) would be required to contain the current extent of contamination in Area A2. A conceptual pumping well arrangement is shown in Figure 6-1.

The conceptual extraction system was based on the pumping rate necessary to contain the plume, the number of wells needed to achieve the pumping rate, and the optimum spacing between the wells to capture the groundwater. The extraction system design is a containment-type system, designed to contain contaminated groundwater rather than attempt to aggressively restore it to the cleanup goals. With this approach, the groundwater is extracted at a rate equal to the natural flow through the contaminated portion of the Yorktown Aquifer. It has been estimated that a flow rate of 82 gpm would be required to contain Area A2 contamination in the Yorktown Aquifer.

As described under Alternative A1-GW3 (Section 6.1.3), extracted groundwater would be pumped to a groundwater treatment system that is sized to accommodate flows from Areas A1, A2, and Area B. This approach has been taken to achieve an economy of scale by constructing and operating one large treatment system common to all three areas rather than potentially constructing and operating three individual systems, which would be significantly more costly. The estimated groundwater flow rates for Areas A1

and B are 82 and 42 gpm, respectively. Thus, the estimated total flow rate for Areas A1, A2, and B is 206 gpm. In order to provide additional capacity for potential future increases in groundwater flow rates, the groundwater treatment system was designed to accommodate a total flow rate of up to 300 gpm.

The conceptual groundwater treatment system used for costing purposes for Area A2 is presented in Figure 6-2. The primary components of the groundwater treatment system would consist of the following processes for removal of organic contaminants:

- Air stripping
- Carbon adsorption

A pretreatment system would be used to remove suspended solids and nuisance metals, such as iron, as well as any toxic metals, such as arsenic and chromium, from the water prior to treatment of the organic contaminants. The pretreatment could consist of equalization, precipitation, flocculation, clarification, and pressure filtration. The pretreatment system would reduce clogging of the air stripper and carbon units, thereby improving their efficiencies and reducing maintenance requirements.

Following pretreatment for suspended solids and metals removal, groundwater would be first pumped through an air stripper for removal of volatile organic contaminants and then through a carbon adsorption "polishing" step for removal of contaminants not removed by the air stripper. The treated groundwater would be discharged to the on-site drainage ditch along the northern boundary of Area A.

Contaminated air generated by the air stripper would be treated, if necessary, to comply with the Virginia Air Emission Standards for Toxic Pollutants (VR 120-04-0301). A comparison of estimated air emission concentrations to these standards (provided in Appendix F) indicates that the air emission would comply with the exemption requirements of VR 120-04-0301, and therefore, treatment of the air stripper off-gas would not be required.

Under this alternative, existing institutional controls would be maintained to prevent groundwater usage at Camp Allen. Formal institutional controls could also be incorporated into the existing base "Master Plan." There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions would be implemented to limit nonpotable use and prevent potable use of contaminated groundwater.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, seven monitoring wells at Area A2 and three other perimeter monitoring wells would be periodically sampled.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the cleanup levels potable use for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area A indicate that no unacceptable adverse human health effects would be expected from exposure (via incidental ingestion and dermal contact) to the shallow groundwater under the current land use in the area (i.e., nonpotable use of groundwater by Glenwood Park residents). Groundwater currently is not used for any purpose at the Brig facility in Area A.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

The intent of this alternative is to contain the groundwater contaminated above proposed groundwater cleanup goals until these goals are achieved. Thus, this alternative is also intended to eventually restore the contaminated groundwater to cleanup goals.

Any groundwater located downgradient of the extraction system, or outside of its capture zone, that is contaminated below groundwater cleanup goals would be allowed to migrate. Groundwater concentrations may decrease below cleanup goals through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Among other factors, the time to achieve groundwater cleanup goals is dependent on the nature and extent of the sources, which are difficult to characterize within a landfill. Therefore, the time to achieve these cleanup goals cannot accurately be predicted at this time. It is possible that cleanup goals could require 10 to 20 years, or longer, to achieve. Also, MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant concentrations typically reach asymptotic levels, which may exceed MCLs. Performance curves would be periodically (e.g., annually) developed to monitor the effectiveness of the groundwater remediation system. If the performance curves indicate that asymptotic levels have been reached that exceed MCLs for some contaminants, then the cleanup goals may be re-evaluated at that time.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage.

Compliance with ARARs: Contaminated groundwater in both the water table and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively.

The intent of this alternative is to restore groundwater in the Yorktown Aquifer to its beneficial use through extraction and treatment. Treated groundwater and associated air emissions resulting from groundwater treatment would comply with all pertinent local, state, and federal location- and action-specific ARARs before being discharged to the environment. Specifically, treated groundwater must meet the Virginia Groundwater Standards found in VR 680-21-04.3. In addition, discharge to the on-site drainage ditch (discharge to surface waters) would require compliance with substantive requirements of the Virginia Pollution Discharge Elimination System (VPDES) regulations, VR 680-14-01.

Long-term Effectiveness and Permanence: Contaminant concentrations on site currently exceed proposed cleanup goals. However, groundwater currently is not used for any purpose on site. Two nonpotable industrial wells are located northwest of Area A2. No residential wells are located downgradient of Area A2. The groundwater extraction and treatment system would prevent groundwater contaminated above the proposed cleanup goals in the Yorktown Aquifer from migrating downgradient.

Periodic groundwater sampling is a reliable means of tracking contaminant migration and for verifying that contaminated groundwater is effectively being contained by the extraction and treatment system.

Reduction of Toxicity, Mobility, or Volume: The volume and toxicity of the contaminated groundwater would be permanently reduced to proposed cleanup goals. Air stripping transfers contaminants from the aqueous to the vapor phase where they are eventually oxidized in the atmosphere. Migration (mobility) of contaminated groundwater in the Yorktown Aquifer would be contained by the extraction system.

Short-term Effectiveness: The major short-term effectiveness concern associated with this alternative is the control of air stripper emissions. These emissions would be effectively monitored through sampling and analysis to ensure compliance with federal and state standards.

Implementability: Air stripping and carbon adsorption are commonly used for groundwater remediation for treatment of organic contaminants. Equipment and services for these systems are offered by numerous commercial vendors.

The most common problem associated with air strippers is clogging and channeling in the packing materials in packed towers and clogging of air diffusers in diffused aeration strippers. The pretreatment system would remove suspended solids and any nuisance metals that may cause clogging.

A groundwater monitoring program could be readily implemented for Area A2. Existing site institutional controls could easily be maintained, and revisions to the Base Master Plan could be readily implemented. Under a base closure scenario, deed restrictions to restrict groundwater usage would require certain legal and administrative procedures.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $59,400 (annually years 1-10), $40,400 (annually years 11-20), $30,900 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $796,000

The capital cost of the groundwater extraction and treatment system has been included under Alternative A1-GW3 (see Section 6.1.3). Therefore, capital costs for the groundwater extraction and treatment system are not included in this alternative. Annual O&M costs for this alternative include groundwater monitoring and the incremental treatment system operating costs associated with treating the additional flow rate (82 gpm) from Area A2. Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.3 Area B Alternatives

6.3.1 Alternative B-GW1: No Action with Monitoring

Description: Under this alternative, no actions would be taken to contain or treat contaminated groundwater associated with Area B at Camp Allen. As discussed in Section 1.3.2, groundwater contamination is present in both the water table and upper Yorktown aquifer in Area B (Figures 1-12 and 1-13). Potable water used throughout the area is supplied by the City of Norfolk. Groundwater on site currently is not used for any purpose. There are no residential wells or currently used Navy nonpotable wells located immediately downgradient (south-southeast) of the shallow contaminated groundwater in the water table aquifer or downgradient (southeast) of the deep contaminated groundwater in the Yorktown Aquifer.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, ten monitoring wells would be sampled at Area B.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area B indicate that no unacceptable adverse human health effects would be expected from exposure to either deep or shallow groundwater under the current land use in the area since groundwater currently is not used for any purpose at Area B.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. There are no residential wells located downgradient of the shallow or deep areas of groundwater contamination.

This alternative does not include controls for minimizing the migration of contaminants. The groundwater monitoring program would be used to assess potential future migration of contaminants into off-site downgradient areas.

Compliance with ARARs: Contaminated groundwater in both the shallow and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively. However, neither aquifer currently is used for drinking water purposes since potable water in the area is provided by the City of Norfolk. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: Exposure pathways would be unaffected by the implementation of this alternative. This alternative would not actively restore contaminated groundwater to proposed cleanup goals through extraction and treatment. Contaminated groundwater would be allowed to migrate. Contaminant concentrations in the groundwater may eventually decrease below cleanup goals through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Contaminant concentrations on site currently exceed the proposed cleanup goals. However, groundwater currently is not used for any purpose on site. No residential wells are located downgradient of the contaminated areas. Periodic groundwater sampling of monitoring wells, a reliable means of tracking contaminant migration, would be used to assess potential off-site migration of contaminated groundwater.

Reduction of Toxicity, Mobility, or Volume: No reduction of toxicity, mobility, or volume would be provided by this alternative. The toxicity of contaminated groundwater may be reduced over time through natural dilution and dispersion, depending on the nature and extent of the contaminant sources.

Short-term Effectiveness: This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation.

Implementability: A groundwater monitoring program could be readily implemented for Area B.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $38,600 (annually years 1-10), $19,600 (annually years 11-20), $10,100 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $476,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.3.2 Alternative B-GW2: Institutional Controls with Monitoring

Description: Under this alternative, no actions would be taken to contain or treat contaminated groundwater associated with Area B at Camp Allen. As discussed in Section 1.3.2, groundwater contamination is present in both the water table and upper Yorktown aquifers in Area B (Figures 1-12 and 1-13). Potable water used throughout the area is supplied by the City of Norfolk. Groundwater on site currently is not used for any purpose. There are no residential wells or currently used Navy nonpotable wells located immediately downgradient (south-southwest) of the shallow contaminated groundwater in the water table aquifer or downgradient (southeast) of the deep contaminated groundwater in the Yorktown Aquifer.

Under this alternative, existing institutional controls would be maintained to prevent groundwater usage at Camp Allen. Formal institutional controls could also be incorporated into the existing base "Master Plan." There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions would be implemented to limit nonpotable use and prevent potable use of contaminated groundwater.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, ten monitoring wells would be sampled at Area B.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the proposed cleanup goals for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area B indicate that no unacceptable adverse human health effects would be expected from exposure to either deep or shallow groundwater under the current land use in the area since groundwater currently is not used for any purpose at Area B.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage. There are no residential wells located immediately downgradient of both the shallow and deep contaminated aquifers.

This alternative does not include controls for minimizing the migration of contaminants. The groundwater monitoring program would be used to assess future migration of contaminants into off-site downgradient areas.

Compliance with ARARs: Contaminated groundwater in both the shallow and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively. However, neither aquifer currently is used for drinking water purposes since potable water in the area is provided by the City of Norfolk. There are no location- or action-specific ARARs associated with this alternative.

Long-term Effectiveness and Permanence: This alternative would not actively restore contaminated groundwater to the proposed cleanup goals through extraction and treatment. Contaminated groundwater would be allowed to migrate. Contaminant concentrations may eventually decrease below the cleanup goals through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Contaminant concentrations on site currently exceed the proposed cleanup goals. However, groundwater currently is not used for any purpose on site. There are no residential areas located downgradient of Area B.

Periodic groundwater sampling of monitoring wells, a reliable means of tracking contaminant migration, would be used to assess potential off-site migration of contaminated groundwater. Potential unacceptable risks associated with nonpotable groundwater use would be mitigated through maintenance of existing institutional controls.

Reduction of Toxicity, Mobility, or Volume: No reduction of toxicity, mobility, or volume would be provided by this alternative. The toxicity of contaminated groundwater may be reduced over time through natural dilution and dispersion, depending on the nature and extent of the contaminant sources.

Short-term Effectiveness: This alternative does not involve remedial action that would pose a risk to human health or the environment during implementation.

Implementability: A groundwater monitoring program could be readily implemented for Area B. Existing site institutional controls could easily be maintained. Under a base closure scenario, deed restrictions to restrict groundwater to nonpotable usage would require certain legal and administrative procedures. Revisions to the Base Master Plan could be readily implemented.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $38,600 (annually years 1-10), $19,600 (annually years 11-20), $10,100 (annually years 21-30), $20,000 (every 5 years)
- Net present worth: $476,700

Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.3.3 Alternative B-GW3: Protection of the Water Table and Yorktown Aquifers for Beneficial Use Through Extraction and Treatment, Institutional Controls, and Monitoring

Description: Under this alternative, groundwater from the water table aquifer and Yorktown Aquifer in Area B would be extracted and treated on site. The extraction system would be used to contain groundwater contaminated above the respective cleanup goals developed for the water table and Yorktown Aquifers. If possible, the system would be operated until groundwater cleanup goals are achieved. However, MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant levels typically reach asymptotic levels, which may exceed MCLs. Performance curves will be periodically (e.g., annually) developed to monitor the effectiveness of the groundwater remediation system. If the performance curves indicate that asymptotic levels have been reached, which exceed MCLs for some contaminants, then the cleanup goals may be re-evaluated at that time.

Groundwater would be pumped using a series of shallow (approximately 25 feet deep in water table aquifer) and mid-depth (approximately 65 feet deep in Yorktown Aquifer) pumping wells connected to a common treatment system. An estimated groundwater pumping rate of approximately 42 gpm would be required to contain the current extent of contamination in Area B. A conceptual pumping well arrangement is shown in Figure 6-1.

The conceptual extraction system was developed based on the pumping rate necessary to contain the plume, the number of wells needed to achieve the pumping rate, and the optimum spacing between the wells to capture the groundwater. The extraction system design is a containment-type system, designed to contain contaminated groundwater rather than attempt to aggressively restore it to the cleanup goals. With this approach, the groundwater is extracted at a rate equal to the natural flow through the contaminated portions of the shallow and deep aquifers. It has been estimated that a flow rate of 42 gpm would be required to contain Area B contamination in the water table and Yorktown Aquifers.

As described under Alternative A1-GW3 (Section 6.1.3), extracted groundwater would be pumped to a groundwater treatment system that is sized to accommodate flows from Areas A1, A2, and Area B. This approach has been taken to achieve an economy of scale by constructing and operating one large treatment system common to all three areas rather than potentially constructing and operating three individual systems, which would be significantly more costly. The estimated groundwater flow rate for both Area A1 and Area A2 is 82 gpm (total of 164 gpm). Thus, the estimated total flow rate for Areas A1, A2, and B is 206 gpm. In order to provide additional capacity for potential future increases in groundwater flow rates, the groundwater treatment system was designed to accommodate a total flow rate of up to 300 gpm.

The conceptual groundwater treatment system used for costing purposes for Area B is presented in Figure 6-2. The primary components of the groundwater treatment system would consist of the following processes for removal of organic contaminants:

- Air stripping
- Carbon adsorption

A pretreatment system would be used to remove suspended solids and nuisance metals, such as iron, as well as any toxic metals, such as arsenic and chromium, from the water prior to treatment of the organic contaminants. The pretreatment could consist of equalization, precipitation, flocculation, clarification, and pressure filtration. The pretreatment system would reduce clogging of the air stripper and carbon units, thereby improving their efficiencies and reducing maintenance requirements.

Following pretreatment for suspended solids and metals removal, groundwater would be first pumped through an air stripper for removal of volatile organic contaminants and then through a carbon adsorption "polishing" step for removal of contaminants not removed by the air stripper. The treated groundwater would be discharged to the on-site drainage ditch along the northern boundary of Area A.

Contaminated air generated by the air stripper would be treated, if necessary, to comply with the Virginia Air Emission Standards for Toxic Pollutants (VR 120-04-0301). A comparison of estimated air emission concentrations to these standards (provided in Appendix F) indicates that the air emission would comply with the exemption requirements of VR 120-04-0301, and therefore, treatment of the air stripper off-gas would not be required.

Under this alternative, existing institutional controls would be maintained to prevent groundwater usage at Camp Allen. Formal institutional controls could also be incorporated into the existing base "Master Plan." There are currently no plans to close Camp Allen. However, if the base were to close at some time in the future, deed restrictions would be implemented to limit nonpotable use and prevent potable use of contaminated groundwater.

This alternative would incorporate the periodic sampling of existing groundwater monitoring wells. Wells in the path of the contaminated groundwater would be sampled as well as a limited number of perimeter and upgradient wells. For costing purposes, it was assumed that, on average, ten monitoring wells would be sampled at Area B.

Initially, sampling would be conducted on a quarterly basis (i.e., four times per year) until a stable or decreasing trend in contaminant levels is observed. Once a reliable trend is established, the frequency of monitoring would be reduced to a semi-annual basis and eventually to an annual basis. Sampling would continue until contaminant levels have decreased below the cleanup levels potable use for several consecutive sampling rounds. For costing purposes, it was assumed that quarterly sampling would be conducted for a 10-year period, followed by a 10-year semi-annual sampling period, and finally by a 10-year period of annual sampling.

Overall Protection: Results of the baseline risk assessment for Area B indicate that no unacceptable adverse human health effects would be expected from exposure to either deep or shallow groundwater under the current land use in the area since groundwater currently is not used for any purpose at Area B.

Under a potential future residential use scenario (potable use of shallow or deep groundwater), the baseline risk assessment indicates unacceptable risks for both children and adult receptors would be expected from exposure via ingestion, dermal contact, and inhalation. A summary of maximum incremental cancer risks and hazard indices for shallow and deep groundwater under potential current and future use scenarios is presented in Table 1-11.

The intent of this alternative is to contain the groundwater contaminated above proposed groundwater cleanup goals until these goals are achieved. Thus, this alternative is also intended to eventually restore the contaminated groundwater to cleanup goals.

Any groundwater located downgradient of the extraction system, or outside of its capture zone, that is contaminated below groundwater cleanup goals would be allowed to migrate. Groundwater concentrations may decrease below cleanup goals through natural dilution and dispersion. The groundwater monitoring program would be used to assess whether or not contaminant concentrations are decreasing.

Among other factors, the time to achieve groundwater cleanup goals is dependent on the nature and extent of the sources, which are difficult to characterize within a landfill. Therefore, the time to achieve these cleanup goals cannot accurately be predicted at this time. It is possible that cleanup goals could require 10 to 20 years, or longer, to achieve. Also, MCLs may be impossible to achieve since it has been demonstrated that groundwater contaminant concentrations typically reach asymptotic levels, which may exceed MCLs. Performance curves will be periodically (e.g., annually) developed to monitor the effectiveness of the groundwater remediation system. If the performance curves indicate that asymptotic levels have been reached that exceed MCLs for some contaminants, then the cleanup goals may be re-evaluated at that time.

With respect to achievement of remedial action objectives, this alternative would prevent consumption and nonpotable use of contaminated groundwater on site since institutional controls are currently in place to monitor and control groundwater usage.

Compliance with ARARs: Contaminated groundwater in both the water table and deep (Yorktown) aquifers currently exceeds the Virginia Water Quality Standards for Groundwater (VR 680-21-04) and does not comply with the General Requirements and Anti-degradation Policy for Groundwater (VR 680-21-04.3). In addition, contaminated groundwater in both aquifers exceeds federal and state MCLs established pursuant to the Safe Drinking Water Act (SDWA) and the Virginia Board of Health (VR 355-18-004), respectively.

The intent of this alternative is to restore groundwater in the water table and Yorktown Aquifers to their respective beneficial uses through extraction and treatment. Treated groundwater and associated air emissions resulting from groundwater treatment would comply with all pertinent local, state, and federal location- and action-specific ARARs before being discharged to the environment. Specifically, treated

groundwater must meet the Virginia Groundwater Standards found in VR 680-21-04.3. In addition, discharge to the on-site drainage ditch (discharge to surface waters) would require compliance with substantive requirements of the Virginia Pollution Discharge Elimination System (VPDES) regulations, VR 680-14-01.

Long-term Effectiveness and Permanence: Contaminant concentrations on site currently exceed proposed cleanup goals. However, groundwater currently is not used for any purpose on site. The groundwater extraction and treatment system would prevent groundwater contaminated above the proposed cleanup goals from migrating downgradient. There are no active Navy or residential potable or nonpotable wells located immediately downgradient of Area B shallow and deep areas of groundwater contamination.

Periodic groundwater sampling is a reliable means of tracking contaminant migration and for verifying that contaminated groundwater is effectively being contained by the extraction and treatment system. Potential unacceptable risks associated with nonpotable groundwater use would be mitigated through institutional controls.

Reduction of Toxicity, Mobility, or Volume: The volume and toxicity of the contaminated groundwater would be permanently reduced to proposed cleanup goals. Air stripping transfers contaminants from the aqueous to the vapor phase where they are eventually oxidized in the atmosphere. Migration (mobility) of contaminated groundwater would be contained by the extraction system.

Short-term Effectiveness: The major short-term effectiveness concern associated with this alternative is the control of air stripper emissions. These emissions would be effectively monitored through sampling and analysis to ensure compliance with federal and state standards.

Implementability: Air stripping and carbon adsorption are commonly used for groundwater remediation for treatment of organic contaminants. Equipment and services for these systems are offered by numerous commercial vendors.

The most common problem associated with air strippers is clogging and channeling in the packing materials in packed towers and clogging of air diffusers in diffused aeration strippers. The pretreatment system would remove suspended solids and any nuisance metals that may cause clogging.

A groundwater monitoring program could be readily implemented for Area B. Existing site institutional controls could easily be maintained. Under a base closure scenario, deed restrictions to restrict groundwater to nonpotable usage would require certain legal and administrative procedures. Revisions to the Base Master Plan could be readily implemented.

Cost: The estimated costs associated with this alternative are as follows:

- Capital: $0
- Annual operation and maintenance: $62,400 (annually years 1-10), $43,400 (annually years 11-20), $34,000 (annually years 21-30), $20,000 (every five years)
- Net present worth: $842,500

The capital cost of the groundwater extraction and treatment system has been included under Alternative A1-GW3 (see Section 6.1.3). Therefore, capital costs for the groundwater extraction and treatment system are not included in this alternative. Annual O&M costs for this alternative include groundwater monitoring costs and the incremental treatment system operating costs associated with treating the additional flow rate (42 gpm) associated with Area B. Detailed cost estimate spreadsheets and supporting calculations are provided in Appendix D.

6.4 Comparison of Groundwater Alternatives

6.4.1 Comparison of Area A1 Groundwater Alternatives

A side-by-side comparison of the alternatives for addressing contamination in Area A1 groundwater, based on the seven evaluation criteria used in the previous sections, is presented in Table 6-1. A summary of the alternative comparison based on the seven criteria is provided in the following sections.

Overall Protection: Alternatives A1-GW1 and A1-GW2 would not contain or treat contaminated groundwater. Alternative A1-GW3 would achieve protection of the Yorktown Aquifer for beneficial use through groundwater extraction and treatment.

TABLE 6-1

COMPARISON OF AREA A1 GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A1-GW1 NO ACTION[1]	ALTERNATIVE A1-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE A1-GW3 PROTECTION OF YORKTOWN AQUIFER FOR BENEFICIAL USE THROUGH EXTRACTION AND TREATMENT[2]
OVERALL PROTECTION TO HUMAN HEALTH AND THE ENVIRONMENT		
Would not contain or treat contaminated groundwater. Groundwater on site not currently used for any purpose. Off-site shallow groundwater used for nonpotable residential use. Off-site deep groundwater used for industrial use. Deep groundwater contamination would continue to migrate off site. Shallow groundwater contamination does not appear to be migrating off site.	Would not contain or treat contaminated groundwater. Groundwater on site not currently used for any purpose. Off-site shallow groundwater used for nonpotable residential use. Off-site deep groundwater used for industrial use. Deep groundwater contamination would continue to migrate off site. Shallow groundwater contamination does not appear to be migrating off site. If necessary in the future, institutional controls would prevent potable use and limit nonpotable use of contaminated groundwater.	Would contain and treat contaminated groundwater in the Yorktown Aquifer to established cleanup goals. Groundwater on site not currently used for any purpose. Off-site shallow groundwater used for nonpotable residential use. Off-site deep groundwater used for industrial use. Shallow groundwater contamination does not appear to be migrating off site. If necessary in the future, institutional controls would prevent or limit use of contaminated groundwater.
COMPLIANCE WITH ARARs		
Shallow and deep contaminated groundwater exceeds state and federal MCLs. Both aquifers, however, currently are not used for drinking water purposes.	Shallow and deep contaminated groundwater exceeds state and federal MCLs. Both aquifers, however, currently are not used for drinking water purposes.	Both aquifers currently are not used for drinking water purposes. Intent of alternative is to restore Yorktown Aquifer to state and federal MCLs. Extracted groundwater and air emissions would comply with all local, state, and federal ARARs.

TABLE 6-1 (CONTINUED)

COMPARISON OF AREA A1 GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A1-GW1 NO ACTION[1]	ALTERNATIVE A1-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE A1-GW3 PROTECTION OF YORKTOWN AQUIFER FOR BENEFICIAL USE THROUGH EXTRACTION AND TREATMENT[2]
LONG-TERM EFFECTIVENESS AND PERMANENCE		
Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Currently no unacceptable risks associated with off-site nonpotable use of groundwater. Periodic groundwater monitoring would effectively track potential contaminant migration.	Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Currently no unacceptable risks associated with off-site nonpotable use of groundwater. Potential future risks would be mitigated through institutional controls. Periodic groundwater monitoring would effectively track potential contaminant migration.	Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Currently no unacceptable risks associated with off-site nonpotable use of groundwater. Extraction system should prevent off-site migration of contamination above cleanup goals. Potential future risks would be mitigated through institutional controls. Periodic groundwater monitoring would effectively track potential contaminant migration.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV) THROUGH TREATMENT		
No reduction in TMV through treatment. Possible reduction in toxicity over time through dilution and dispersion.	No reduction in TMV through treatment. Possible reduction in toxicity over time through dilution and dispersion.	Toxicity and volume reduced to established cleanup goals through extraction and treatment. Mobility reduced through extraction.
SHORT-TERM EFFECTIVENESS		
No risk to human health or environment during implementation.	No risk to human health or environment during implementation.	Air emissions from treatment system would be monitored to protect human health and the environment.

TABLE 6-1 (CONTINUED)

COMPARISON OF AREA A1 GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A1-GW1 NO ACTION[1]	ALTERNATIVE A1-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE A1-GW3 PROTECTION OF YORKTOWN AQUIFER FOR BENEFICIAL USE THROUGH EXTRACTION AND TREATMENT[2]
IMPLEMENTABILITY		
Groundwater monitoring could be readily implemented.	Groundwater monitoring could be readily implemented.	Treatment system components are demonstrated and commercially available.
COST		
Capital: $0 O&M: $38,600 (years 1-10) $19,600 (years 11-20) $10,100 (years 21-30) $20,000 (every 5 years) NPW: $476,700	Capital: $0 O&M: $38,600 (years 1-10) $19,600 (years 11-20) $10,100 (years 21-30) $20,000 (every 5 years) NPW: $476,700	Capital: $6,108,500 O&M: $187,300 (yrs 1-10) $168,300 (yrs 11-20) $158,800 (yrs 21-30) $20,000 (every 5 yrs) NPW: $8,870,200

[1] Alternative includes groundwater monitoring.
[2] Alternative cost includes extraction and treatment system capital cost.
O&M: Operation and maintenance.
NPW: Net present worth.

Compliance with ARARs: Alternatives A1-GW1 and A1-GW2 would not treat or contain groundwater contaminated above federal and state MCLs. However, groundwater on-site and in the vicinity of the site currently is not used for drinking water purposes. Alternative A1-GW3 would comply with these ARARs by containing and potentially restoring contaminated groundwater within the Yorktown Aquifer to the federal and state MCLs. Under Alternative A1-GW3, treated groundwater and associated air emissions would comply with all local, state, and federal ARARs.

Long-term Effectiveness and Permanence: All alternatives currently provide on-site protection of human health since groundwater is not currently used on site. All alternatives, except Alternative A1-GW1, would provide on-site protection of human health through institutional controls.

Under Alternatives A1-GW1 and A1-GW2, risks would exceed acceptable levels if the groundwater were to be used for potable use. Under Alternative A1-GW3, risks associated with potable use of groundwater would be within acceptable levels following groundwater restoration. Thus, Alternative A1-GW3 would ultimately provide the greatest degree of long-term effectiveness.

Reduction of Toxicity, Mobility, or Volume: Alternatives A1-GW1 and A1-GW2 would not reduce the toxicity, mobility, or volume of contaminants in the groundwater through treatment. Alternative A1-GW3 would reduce the toxicity and volume of contaminants to the established cleanup goals through treatment and would reduce contaminant mobility through extraction.

Short-term Effectiveness: There would be no risks to human health or the environment associated with implementation of Alternatives A1-GW1 and A1-GW2. Under Alternative A1-GW3, air emissions would be regularly monitored to ensure compliance with state and federal air quality standards.

Implementability: Alternative A1-GW3 would be more difficult to implement than would Alternatives A1-GW1 and A1-GW2 since it involves groundwater extraction and treatment. The treatment system components are demonstrated and commercially available.

Cost: The 30-year net present worth costs for the Area A1 groundwater alternatives are summarized below:

- Alternative A1-GW1: $476,700
- Alternative A1-GW2: $476,700
- Alternative A1-GW3: $8,870,200 (includes extraction and treatment system capital cost)

6.4.2 Comparison of Area A2 Groundwater Alternatives

A side-by-side comparison of the alternatives for addressing contamination in Area A2 groundwater, based on the seven evaluation criteria used in the previous sections, is presented in Table 6-2. A summary of the alternative comparison based on the seven criteria is provided in the following sections.

Overall Protection: Alternatives A2-GW1 and A2-GW2 would not contain or treat contaminated groundwater. Alternative A2-GW3 would achieve protection of the Yorktown Aquifer for beneficial use through groundwater extraction and treatment.

Compliance with ARARs: Alternatives A2-GW1 and A2-GW2 would not treat or contain groundwater contaminated above federal and state MCLs. However, groundwater on-site and in the vicinity of the site currently is not used for drinking water purposes. Alternative A2-GW3 would comply with these ARARs by containing and potentially restoring contaminated groundwater within the Yorktown Aquifer to the federal and state MCLs. Under Alternative A2-GW3, treated groundwater and associated air emissions would comply with all local, state, and federal ARARs.

Long-term Effectiveness and Permanence: All alternatives currently provide on-site protection of human health since groundwater is not currently used on site. All alternatives, except Alternative A2-GW1, would provide off-site protection of human health, if necessary, through institutional controls.

Under Alternatives A2-GW1 and A2-GW2, risks would exceed acceptable levels if the groundwater were to be used for potable use. Under Alternative A2-GW3, risks associated with potable use of groundwater would be within acceptable levels following groundwater restoration. Thus, Alternative A2-GW3 would ultimately provide the greatest degree of long-term effectiveness.

Reduction of Toxicity, Mobility, or Volume: Alternatives A2-GW1 and A2-GW2 would not reduce the toxicity, mobility, or volume of contaminants in the groundwater through treatment. Alternative A2-GW3 would reduce the toxicity and volume of contaminants to the established cleanup goals through treatment and would reduce contaminant mobility through extraction.

Short-term Effectiveness: There would be no risks to human health or the environment associated with implementation of Alternatives A2-GW1 and A2-GW2. Under Alternative A2-GW3, air emissions would be regularly monitored to ensure compliance with state and federal air quality standards.

TABLE 6-2

COMPARISON OF AREA A2 GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A2-GW1 NO ACTION[1]	ALTERNATIVE A2-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE A2-GW3 PROTECTION OF YORKTOWN AQUIFER FOR BENEFICIAL USE THROUGH EXTRACTION AND TREATMENT[2]
OVERALL PROTECTION TO HUMAN HEALTH AND THE ENVIRONMENT		
Would not contain or treat contaminated groundwater. Groundwater on site not currently used for any purpose. Off-site shallow groundwater used for nonpotable residential use. Off-site deep groundwater used for industrial use. Deep groundwater contamination would continue to migrate off site. Shallow groundwater contamination does not appear to be migrating off site.	Would not contain or treat contaminated groundwater. Groundwater on site not currently used for any purpose. Off-site shallow groundwater used for nonpotable residential use. Off-site deep groundwater used for industrial use. Deep groundwater contamination would continue to migrate off site. Shallow groundwater contamination does not appear to be migrating off site. If necessary in the future, institutional controls would prevent potable use and limit nonpotable use of contaminated groundwater.	Would contain and treat contaminated groundwater to established cleanup goals. Groundwater on site not currently used for any purpose. Off-site shallow groundwater used for nonpotable residential use. Off-site deep groundwater used for industrial use. Shallow groundwater contamination does not appear to be migrating off site. If necessary in the future, institutional controls would prevent or limit use of contaminated groundwater.
COMPLIANCE WITH ARARs		
Shallow and deep contaminated groundwater exceeds state and federal MCLs. Both aquifers, however, currently are not used for drinking water purposes.	Shallow and deep contaminated groundwater exceeds state and federal MCLs. Both aquifers, however, currently are not used for drinking water purposes.	Both aquifers currently are not used for drinking water purposes. Intent of alternative is to restore Yorktown Aquifer to state and federal MCLs. Extracted groundwater and air emissions would comply with all local, state, and federal ARARs.

TABLE 6-2 (CONTINUED)

COMPARISON OF AREA A2 GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A2-GW1 NO ACTION[1]	ALTERNATIVE A2-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE A2-GW3 PROTECTION OF YORKTOWN AQUIFER FOR BENEFICIAL USE THROUGH EXTRACTION AND TREATMENT[2]
LONG-TERM EFFECTIVENESS AND PERMANENCE		
Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Currently no unacceptable risks associated with off-site nonpotable use of groundwater. Periodic groundwater monitoring would effectively track potential contaminant migration.	Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Currently no unacceptable risks associated with off-site nonpotable use of groundwater. Potential future risks would be mitigated through institutional controls. Periodic groundwater monitoring would effectively track potential contaminant migration.	Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Currently no unacceptable risks associated with off-site nonpotable use of groundwater. Extraction system should prevent off-site migration of contamination above cleanup goals. Potential future risks would be mitigated through institutional controls. Periodic groundwater monitoring would effectively track potential contaminant migration.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV) THROUGH TREATMENT		
No reduction in TMV through treatment. Possible reduction in toxicity over time through dilution and dispersion.	No reduction in TMV through treatment. Possible reduction in toxicity over time through dilution and dispersion.	Toxicity and volume reduced to established cleanup goals through extraction and treatment. Mobility reduced through extraction.
SHORT-TERM EFFECTIVENESS		
No risk to human health or environment during implementation.	No risk to human health or environment during implementation.	Air emissions from treatment system would be monitored to protect human health and the environment.

TABLE 6-2 (CONTINUED)

COMPARISON OF AREA A2 GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE A2-GW1 NO ACTION[1]	ALTERNATIVE A2-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE A2-GW3 PROTECTION OF YORKTOWN AQUIFER FOR BENEFICIAL USE THROUGH EXTRACTION AND TREATMENT[2]
IMPLEMENTABILITY		
Groundwater monitoring could be readily implemented.	Groundwater monitoring could be readily implemented.	Treatment system components are demonstrated and commercially available.
COST		
Capital: $0 O&M: $38,600 (years 1-10) $19,600 (years 11-20) $10,100 (years 21-30) $20,000 (every 5 years) NPW: $476,700	Capital: $0 O&M: $38,600 (years 1-10) $19,600 (years 11-20) $10,100 (years 21-30) $20,000 (every 5 years) NPW: $476,700	Capital: $0 O&M: $59,400 (yrs 1-10) $40,400 (yrs 11-20) $30,900 (yrs 21-30) $20,000 (every 5 yrs) NPW: $796,000

[1] Alternative includes groundwater monitoring.
[2] Alternative cost includes only additional O&M costs for Area A2 groundwater treatment.
O&M: Operation and maintenance.
NPW: Net present worth.

Implementability: Alternative A2-GW3 would be more difficult to implement than would Alternatives A2-GW1 and A2-GW2 since it involves groundwater extraction and treatment. The treatment system components are demonstrated and commercially available.

Cost: The 30-year net present worth costs for the Area A2 groundwater alternatives are summarized below:

- Alternative A2-GW1: $476,700
- Alternative A2-GW2: $476,700
- Alternative A2-GW3: $796,000 (includes only additional O&M costs for Area A2)

6.4.3 Comparison of Area B Groundwater Alternatives

A side-by-side comparison of the Area B groundwater alternatives, based on the seven evaluation criteria used in the previous sections, is presented in Table 6-3. A summary of the alternative comparison based on the seven criteria is provided in the following sections.

Overall Protection: Alternatives B-GW1 and B-GW2 would not contain or treat contaminated groundwater. Alternative B-GW3 would achieve protection of the water table and Yorktown Aquifers for their beneficial uses through groundwater extraction and treatment.

Compliance with ARARs: Alternatives B-GW1 and B-GW2 would not treat or contain groundwater contaminated above federal and state MCLs. However, groundwater on-site and in the vicinity of the site currently is not used for drinking water purposes. Alternative B-GW3 would comply with these ARARs by containing and potentially restoring contaminated groundwater within the Yorktown Aquifer to the federal and state MCLs. Groundwater within the water table aquifer would be contained and potentially restored to cleanup levels based on nonpotable use. Under Alternative B-GW3, treated groundwater and associated air emissions would comply with all local, state, and federal ARARs.

Long-term Effectiveness and Permanence: All alternatives currently provide on-site protection of human health since groundwater is not currently used on site. All alternatives, except Alternative B-GW1, would provide on-site protection of human health through institutional controls.

TABLE 6-3

COMPARISON OF AREA B GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE B-GW1 NO ACTION[1]	ALTERNATIVE B-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE B-GW3 PROTECTION OF WATER TABLE AND YORKTOWN AQUIFERS FOR BENEFICIAL USES THROUGH EXTRACTION AND TREATMENT[2]
OVERALL PROTECTION TO HUMAN HEALTH AND THE ENVIRONMENT		
Would not contain or treat contaminated groundwater, however, groundwater on site and immediately downgradient of contamination is not currently used for any purpose.	Would not contain or treat contaminated groundwater, however, groundwater on site and immediately downgradient of contamination is not currently used for any purpose. Institutional controls would prevent future potable use and limit nonpotable use of contaminated groundwater.	Would contain and treat contaminated groundwater to established cleanup goals. Contamination below cleanup goals would continue to migrate off site. Groundwater on site and immediately downgradient of contamination is not currently used for any purpose. If necessary in the future, institutional controls would prevent or limit use of contaminated groundwater.
COMPLIANCE WITH ARARs		
Shallow and deep contaminated groundwater exceeds state and federal MCLs. Both aquifers, however, currently are not used for drinking water purposes.	Shallow and deep contaminated groundwater exceeds state and federal MCLs. Both aquifers, however, currently are not used for drinking water purposes.	Both aquifers currently are not used for drinking water purposes. Intent of alternative is to restore the water table and Yorktown Aquifers to their respective cleanup goals. Extracted groundwater and air emissions would comply with all local, state, and federal ARARs.

TABLE 6-3 (CONTINUED)

COMPARISON OF AREA B GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE B-GW1 NO ACTION[1]	ALTERNATIVE B-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE B-GW3 PROTECTION OF WATER TABLE AND YORKTOWN AQUIFERS FOR BENEFICIAL USES THROUGH EXTRACTION AND TREATMENT[2]
LONG-TERM EFFECTIVENESS AND PERMANENCE		
Risks would exceed acceptable levels if shallow or deep aquifers were used for potable use on site. Periodic groundwater monitoring would effectively track potential contaminant migration.	Risks would exceed acceptable levels if shallow or deep aquifers were used for potable use on site. Potential future risks would be mitigated through institutional controls. Periodic groundwater monitoring would effectively track potential contaminant migration.	Risks would exceed acceptable levels if shallow and deep aquifers were used for potable use on site. Extraction system should prevent off-site migration of contamination above cleanup goals. Potential future risks would be mitigated through institutional controls. Periodic groundwater monitoring would effectively track potential contaminant migration.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME (TMV) THROUGH TREATMENT		
No reduction in TMV through treatment. Possible reduction in toxicity over time through dilution and dispersion.	No reduction in TMV through treatment. Possible reduction in toxicity over time through dilution and dispersion.	Toxicity and volume reduced to established cleanup goals through extraction and treatment. Mobility reduced through extraction.
SHORT-TERM EFFECTIVENESS		
No risk to human health or environment during implementation.	No risk to human health or environment during implementation.	Air emissions from treatment system would be treated and monitored to protect human health and the environment.

TABLE 6-3 (CONTINUED)

COMPARISON OF AREA B GROUNDWATER ALTERNATIVES
CAMP ALLEN LANDFILL, NORFOLK, VIRGINIA

ALTERNATIVE B-GW1 NO ACTION[1]	ALTERNATIVE B-GW2 INSTITUTIONAL CONTROLS[1]	ALTERNATIVE B-GW3 PROTECTION OF WATER TABLE AND YORKTOWN AQUIFERS FOR BENEFICIAL USES THROUGH EXTRACTION AND TREATMENT[2]
IMPLEMENTABILITY		
Groundwater monitoring could be readily implemented.	Groundwater monitoring could be readily implemented.	Treatment system components are demonstrated and commercially available.
COST		
Capital: $0 O&M: $38,600 (years 1-10) $19,600 (years 11-20) $10,1000 (years 21-30) $20,000 (every 5 years) NPW: $476,700	Capital: $0 O&M: $38,600 (years 1-10) $19,600 (years 11-20) $10,100 (years 21-30) $20,000 (every 5 years) NPW: $476,700	Capital: $0 O&M: $62,400 (years 1-10) $43,400 (years 11-20) $34,000 (years 21-30) $20,000 (every 5 years) NPW: $842,500

[1] Alternative includes groundwater monitoring.
[2] Alternative cost includes only additional O&M costs for Area B groundwater treatment.
O&M: Operation and maintenance.
NPW: Net present worth.

Under Alternatives B-GW1 and B-GW2, risks would exceed acceptable levels if the groundwater were to be used for potable use. Under Alternative B-GW3, risks associated with potable use of groundwater would be within acceptable levels following groundwater restoration. Thus, Alternative B-GW3 would ultimately provide the greatest degree of long-term effectiveness.

Reduction of Toxicity, Mobility, or Volume: Alternatives B-GW1 and B-GW2 would not reduce the toxicity, mobility, or volume of contaminants in the groundwater through treatment. Alternative B-GW3 would reduce the toxicity and volume of contaminants to the established cleanup goals through treatment and would reduce contaminant mobility through extraction.

Short-term Effectiveness: There would be no risks to human health or the environment associated with implementation of Alternatives B-GW1 and B-GW2. Under Alternative B-GW3, air emissions would be regularly monitored to ensure compliance with state and federal air quality standards.

Implementability: Alternative B-GW3 would be more difficult to implement than would Alternatives B-GW1 and B-GW2 since it involves groundwater extraction and treatment. The treatment system components are demonstrated and commercially available.

Cost: The 30-year net present worth costs for the Area A groundwater alternatives are summarized below:

- Alternative B-GW1: $476,700
- Alternative B-GW2: $476,700
- Alternative B-GW3: $842,500 (includes only additional O&M costs for Area B)

SECTION 7 - REFERENCES

7.0 REFERENCES

Audet, D., 1988. Fish and Wildlife Plan for Naval Base Norfolk Virginia for Plan Period 1988 through 1993. United States Department of the Interior, United States Fish and Wildlife Service, Appendix B and Appendix C.

Baker, 1993a. Engineering Evaluation/Cost Analysis. Final. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. August 1993.

Baker, 1993b. Preliminary Assessment/Site Inspection Report. Draft. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. April 16, 1993.

Baker, 1994a. Remedial Investigation Report. Final. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. July 1994.

Baker, 1994b. Baseline Risk Assessment. Final. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. November 1994.

Baker, 1994c. Remedial Design Work Plan. Final. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. May 1994.

Baker, 1994d. Industrial Wastewater Treatment Plant Engineering Analysis Report. Final. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. January 1994.

Baker, 1994e. Basis of Design Report. Final. Prepared for the Department of the Navy, Atlantic Division Naval Facilities Engineering Command. May 1994.

Baker, 1994f. Preliminary Assessment/Site Inspection, Camp Allen Salvage Yard. May 1994.

Bouwer, E.J., B.E. Rittman, and P.L. McCarty,, 1981. "Anaerobic degradation of halogenated 1– and 2–carbon organic compounds." Environmental Scientific Technology. 15:590. (From EPA/600/2087/008).

CH_2M Hill, 1992. Remedial Investigation, Site Summary, Camp Allen Landfill. April 1992.

Cosmos, Michael G., 1993. Weston Services. Personal Communication with G. Ruggaber, Baker Environmental, Inc. May 21, 1993.

Dragun, J., 1988. The Soil Chemistry of Hazardous Materials. Hazardous Materials Control Research Institute, Silver Spring, Maryland.

Fogel, M. M., A.R. Tadeo, and S. Fogel, 1986. "Biodegradation of Chlorinated Ethenes by a Methane Utilizing Mixed Culture." Applied Environmental Microbiology. 51:720.

Henry, S. M. and D. Grbic-Galic, 1986. "Aerobic Degradation of Trichloroethylene (TCE) by Methylotrophs Isolated from a Contaminated Aquifer," presented at the 86th Annual Meeting American Society of Microbiologists, Washington, D.C.

Holtz, Robert D., 1981. An Introduction to Geotechnical Engineering. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Koerner, Robert M., 1990. Designing with Geosynthetics. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Litchfield, C., 1989. DuPont Biosystems. Personal Communication with G. Ruggaber, Baker Environmental, Inc. February 6, 1989.

Malcolm Pirnie, 1984. Site Suitability Assessment, Proposed Brig Expansion, (P-977) Naval Station, Norfolk, Virginia. June 1984.

Malcolm Pirnie, 1987. NACIP Program, Confirmation Study, Sewell's Point Naval Complex, Norfolk, Virginia. April 1987.

Malcolm Pirnie, 1988. Installation Restoration Program, Remedial Investigation, Interim Report, Norfolk Naval Base, Norfolk, Virginia. May 1988.

Navy Energy and Environmental Support Activity, 1983. Initial Assessment Study of Sewells Point Naval Complex, Norfolk, Virginia. NEESA 13-016. February 1983.

Nelson, M., 1991. Ecova Corporation. Personal Communication with J.P. Pradeep, HALLIBURTON NUS Environmental Corporation. August 9, 1991.

Nielson, Roger K. and Michael G. Cosmos, 1989. "Low Temperature Thermal Treatment (LT3) of Volatile Organic Compounds from Soil: A Technology Demonstrated. Environmental Progress. Vol. 8, No. 2, May 1989. pp. 139–142.

Perry, Robert H. and Don W. Green, 1984. Perry's Chemical Engineer's Handbook. Sixth Edition. McGraw Hill Book Company. New York, New York.

Rich, Gerald and Kenneth Cherry, 1987. Hazardous Waste Treatment Technologies. Third Printing. Pudvan Publishing Co., Northbrook, Illinois.

Sims, Ronald C., 1990. "Soil Remediation Techniques at Uncontrolled Hazardous Waste Sites," Air Waste Management. Volume 40, No. 5, May 1990.

Strand, S. E., and L. Shippert, 1986. "Oxidation of Chloroform in Aerobic Soil Exposed to Natural Gas." Applied Environmental Microbiology. 52:203.

Strohmeyer, B., 1993. Hampton Roads Sanitation District. Personal Communication with G. Ruggaber, Baker Environmental, Inc. June 4, 1993.

Testa, Stephen M. and Duane L. Winegardner, 1991. Restoration of Petroleum–Contaminated Aquifers. Lewis Publishers, Chelsea, Michigan.

USEPA, 1982. Handbook: Remedial Action at Waste Disposal Sites. Final Report. EPA 625/6–82–006.

USEPA, 1987a. Underground Storage Tank Corrective Action Technologies. Hazardous Waste Engineering Research Laboratory. Cincinnati, Ohio. USEPA–625/6–87–015.

USEPA, 1987b. Compendium of Costs of Remedial Technologies at Hazardous Waste Sites. EPA–600/287/087.

USEPA, 1987c. Technical Resource Document–Treatment Technologies for Halogenated Organic Containing Wastes. Hazardous Waste Engineering Research Laboratory. Cincinnati, Ohio. EPA 600/2–87/098.

USEPA, 1988a. Technology Screening Guide for Treatment of CERCLA Soils and Sludges. Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/2–88/004.

USEPA, 1988b. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G–89/004.

USEPA, 1988c. Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/G–88/003. OSWER Directive. 9283 1–2.

USEPA, 1989. Risk Assessment Guidance for Superfund Volume II. Environmental Evaluation Manual Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. March 1989. EPA/540/189–001.

USEPA, 1990b. Technologies of Delivery or Recovery for the Remediation of Hazardous Waste Sites. University of Cincinnati. Cincinnati, Ohio. EPA/600/2–89/066.

USEPA, 1991a. Handbook – Remediation of Contaminated Sediments. Office of Research and Development. Washington, D.C. EPA/625/6–91/028.

USEPA, 1991b. Contaminated Sediments Seminar – Speaker Slide Copies. Office of Research and Development. Cincinnati, Ohio. CERI –01 –19.

USEPA, 1992a. National Oil and Hazardous Substances Pollution Contingency Plan. 40 CFR 300.

USEPA, 1992b. Potential Reuse of Petroleum–Contaminated Soil: A Directory of Permitted Recycling Facilities. Risk Reduction Engineering Laboratory. Cincinnati, Ohio. EPA/600/R–92/096.

Wagner, Kathleen; et al., 1986. Remedial Action Technology for Waste Disposal Sites. Second Edition. Noyes Data Corporation. Park Ridge, New Jersey.

Roy F. Weston, Inc. (Weston), 1988. Remedial Technologies for Leaking Underground Storage Tanks. Prepared for Electric Power Research Institute. Lewis Publishers, Inc. Chelsea, Michigan.

Wilson, B. H. and M.V. White, 1986. A Fixed–Film Bioreactor to Treat Trichloroethylene Laden Waters from Interdiction Wells in Proc. 6th National Symposium and Exposition on Aquifer Restoration and Groundwater Monitoring. National Water Well Association. Columbus, Ohio.

Wilson, John, 1992. R. S. Kerr Environmental Research Laboratory, Ada, Oklahoma. Personal Communication with G. Ruggaber, Baker Environmental, Inc. January 15, 1992.

APPENDIX A - PRE-DESIGN INVESTIGATION

APPENDIX A
PRE-DESIGN INVESTIGATION

2.0 PREDESIGN ACTIVITIES

In order to prepare design requirement packages for the planned remedial alternatives at the Camp Allen Landfill, various predesign activities have been developed and completed. Predesign activities are discussed in this section of the Work Plan. Utility clearance for proposed study areas was obtained from NAVBASE personnel prior to implementing predesign activities. In addition, the existing staging area adjacent to Area B was used for controlling site operations and equipment storage. Working areas around both Area A and Area B also were established. Predesign activities performed in and around the Brig Facility were coordinated with authorized personnel.

2.1 In Situ Groundwater Sampling Results

Initial predesign activities at Area A consisted of in situ groundwater sampling in the suspected source areas (Areas A1 and A2). Baker supervised and coordinated the installation and in situ sampling of hydraulic drive points (Geoprobe sampling points) to further delineate the extent of shallow groundwater contamination in Areas A1 and A2 and to help locate potential source areas. A soil gas subcontractor with in situ groundwater sampling capabilities performed drive point installation, in situ groundwater sampling, on-site analysis, and drive point abandonment, which consisted of backfilling the drive point hole with a cement/bentonite grout to the ground surface. In situ groundwater sampling results were used to confirm/modify proposed test pit and temporary monitoring well locations.

Shallow groundwater samples were collected from the upper portion of the water table aquifer. Samples were analyzed on site using a portable gas chromatograph unit for selected primary volatile organic compounds (VOCs) of concern. On-site QA/QC and equipment decontamination were performed as required by subcontractor standard operating procedures.

Sample locations were based primarily on 600 foot by 800 foot grids with 200 foot intervals superimposed onto each suspected source area (Area A1 and Area A2). In situ groundwater sampling began in known areas of groundwater contamination and continued following the 200 foot sampling interval. Sampling nodes within the 600 foot by 800 foot grid were selectively chosen based on the results from the ongoing on-site analysis of in situ groundwater samples. Each of the established grids was extended or modified (e.g., sampling intervals reduced to 100 feet in some areas), as required based on the nature and extent of VOC contamination observed from the sampling results.

In situ sampling locations and volatile organic results for Areas A1 and A2 are depicted in Figures 2-1 and 2-2, respectively. Sampling results show the greatest levels of contamination in the southwest portion of Area A1 and the north-northwestern portion of Area A2. The following compounds were detected in several groundwater samples:

- 1,2-DCE
- 1,2-DCA/benzene
- TCE
- toluene
- PCE
- xylenes
- acetone

In both areas, the primary contaminant was 1,2-DCE, which was found at 640 μg/L at sampling point A1-IS05 and at 3,807 μg/L at in situ sampling point A2-IS21. In addition, analytical results from the shallow groundwater investigation are presented in the subcontractor's report included in Appendix B.

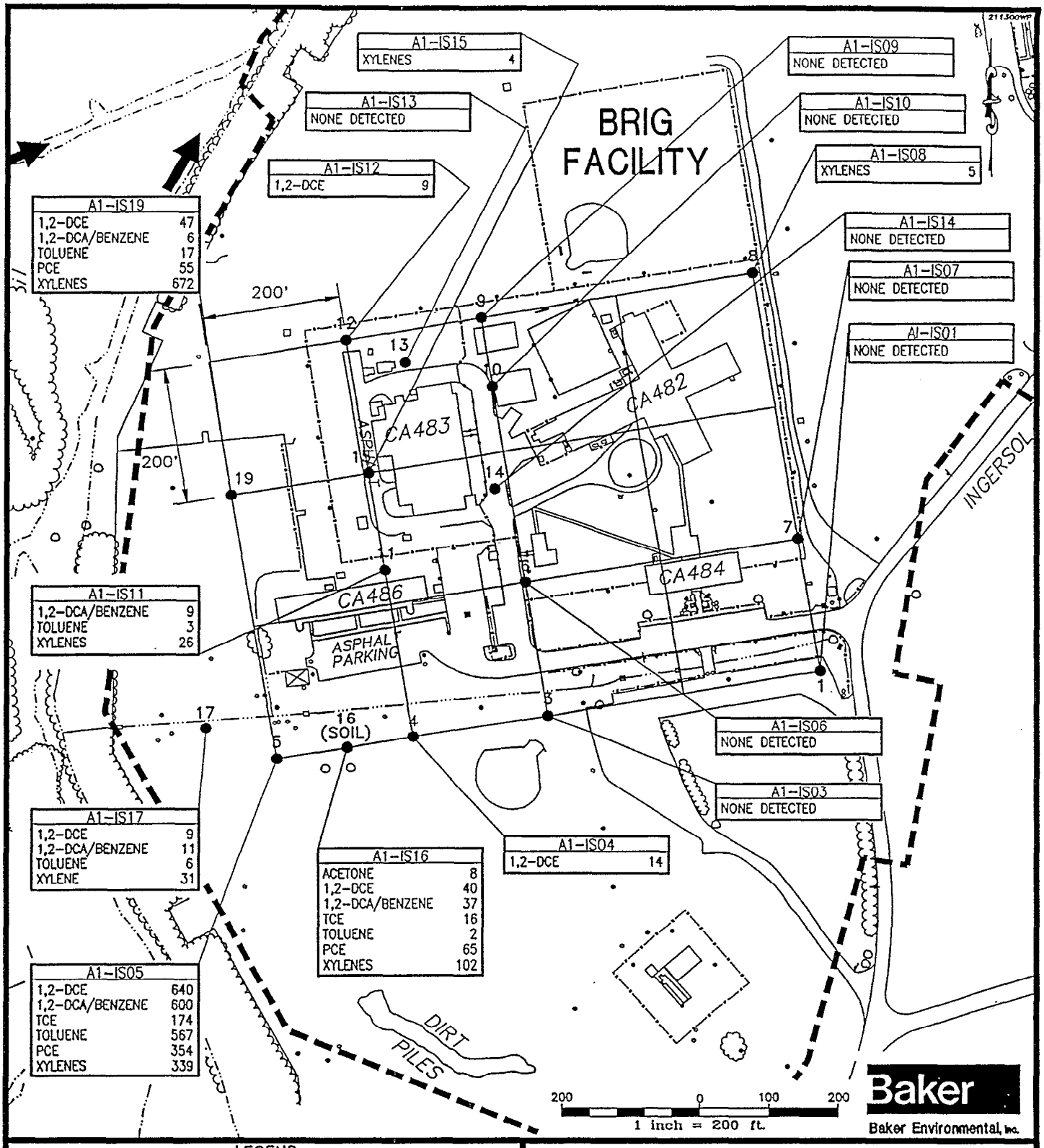
2.2 Source Delineation Results

2.2.1 Summary of Source Characterization Activities and Analytical Results

Baker performed source characterization activities to determine potential source areas (i.e., "hot spot" areas requiring remediation in order to protect groundwater) in Areas A1 and A2. The source characterization efforts consisted of installation and sampling of test pits in the suspected source areas.

Based on in situ groundwater sampling results, two potential source areas were identified in Areas A1 and A2. Test pit activities were concentrated in these areas where shallow groundwater was found to contain the highest levels of VOCs. Test pit locations were based on subdividing the grid used for in situ groundwater sampling activities into 50-foot intervals in the potential "hot spot" areas. In some areas, grid spacing was reduced to 25-foot intervals, as required.

Test pit activities were conducted using a backhoe and a qualified operator. Test pit operations were conducted using Level B personal protection. Test pit dimensions varied depending on stability of unconsolidated materials, space limitations, and depth to groundwater. Test pit depths generally ranged from 6 to 11 feet below ground surface (bgs) in Areas A1 and A2. Field observations, including



LEGEND

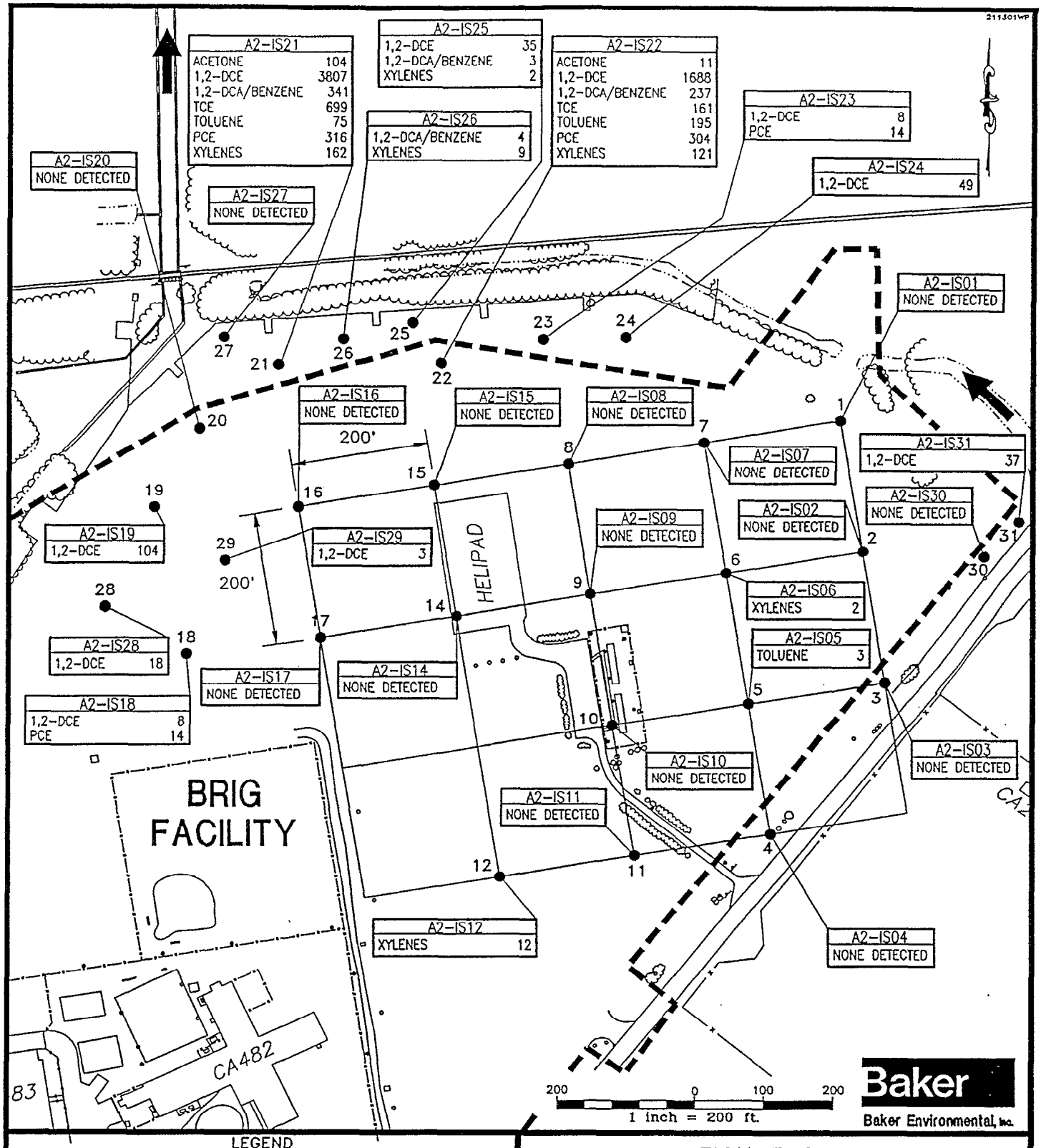
— — LIMIT OF AREA A LANDFILL

1 ● IN SITU SAMPLING POINTS

← STREAM FLOW DIRECTION

NOTE: ALL CONCENTRATIONS IN ug/L

FIGURE 2-1
AREA A1 IN SITU GROUNDWATER SAMPLE LOCATIONS AND VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

— — LIMIT OF AREA A LANDFILL

12 ● IN SITU SAMPLING POINTS

← STREAM FLOW DIRECTION

NOTE: ALL CONCENTRATIONS IN ug/L

FIGURE 2-2
AREA A2 IN SITU GROUNDWATER SAMPLE LOCATIONS AND VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

description of encountered materials and organic vapor analyzer readings, were recorded during soil sampling activities. Dedicated sampling equipment was used, and gross soils adhering to the backhoe bucket were removed at each test pit location. Boring logs for the test pits are presented in Appendix C, which describe the types of materials found in the test pits.

A total of 12 test pits were excavated in Area A1; an additional 12 test pits were located in Area A2. In Area A1, soil samples were analyzed as follows:

- 14 samples for CLP VOCs: one sample per test pit, plus a duplicate sample and one additional sample collected from test pit A1-TPW01).

- 13 soil samples for CLP semi-VOCs: one sample per test pit, plus an additional sample collected from test pit A1-TPW01).

- 2 composite soil samples for toxicity characteristic leaching procedure (TCLP) parameters, total petroleum hydrocarbons (TPH) and total organic carbon (TOC) in order to obtain waste characteristic properties: 1 from test pit A1-TPW02 and 1 from test pit A1-TPW08, which contained high levels of contamination based on field observations.

In Area A2, soil samples were analyzed as follows:

- 13 samples for CLP VOCs: (1) one sample per pit, plus a duplicate sample collected from test pit A2-TPW08.

- 12 samples for CLP semi-VOCs: one per pit.

- One (1) composite soil sample for TCLP parameters, TPH, and TOC in order to obtain waste characteristic properties: one (1) from test pit A2-TPW01, which contained miscellaneous metal debris and some ash material.

2.2.2 Soil Remedial Action Objectives and Cleanup Level Development

The following remedial action objectives for the soils in Area A were developed in the Draft Final FS:

(1) Prevent exposure to potential contaminants within subsurface soil and debris.

(2) Minimize movement of potential contaminants from subsurface soil and debris to groundwater and surface water.

Since Area A is a former landfill, the first objective will primarily be achieved through institutional controls that restrict future use of the area (i.e., prevent residential development) and limit future construction activities that disturb the subsurface materials.

With respect to the second remedial action objective, protection of groundwater, soil cleanup levels are being developed as part of the Feasibility Study effort. These levels will be based on the potential for volatile organic contaminants to migrate vertically (i.e., leach) to groundwater and surface water. The soil cleanup levels will be provided in the Basis of Design section of the design package.

2.2.3 Source Characterization Results and Estimated Soil Volumes

Analytical results are presented in Tables 2-1 through 2-5 for Areas A1 and A2 test pit samples. Figures 2-3 and 2-4 show the test pit locations in Areas A1 and A2, respectively, and the VOC laboratory analytical results for each test pit. With respect to the sample numbers shown in the tables, the last two numbers represent the depth of the sampled interval as follows:

00 = ground surface
01 = 1-2 foot range
02 = 2-4 foot range
03 = 4-6 foot range
04 = 6-8 foot range
05 = 8-10 foot range

The analytical data were not validated by an independent data validation subcontractor since the data are being used for design purposes rather than for risk assessment. QA/QC samples were collected following NEESA guidelines, and CLP analyses were performed following NEESA Level C protocol. Therefore, if necessary, sample analytical data can undergo data validation following NEESA 20.2-047B in the future.

Table 2-1
Summary of Chemical Composition Analytical Results for Area A1 Soils
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/kg)

Parameter	A1TPW0102 (Ash)	A1TPW0102RE (Ash)	A1TPW0102DRE (Ash)	A1TPW0104 (Soil)	A1TPW0202 (Soil/Ash)	A1TPW0304 (Soil/Ash)	A1TPW0404 (Soil)	A1TPW0505 (Ash)
Acetone	18 B	72 JB	13 JB	ND	350 J	160 B	180 B	ND
2-Butanone	ND	30 JB	ND	ND	ND	ND	28 J	ND
Chloroform	6 J	ND	ND	ND	ND	ND	ND	12000
Ethylbenzene	ND	ND	ND	ND	3100	ND	ND	800 J
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	6900
1,2-Dichloroethene (total)	ND	ND	10 J	ND	2900	ND	ND	ND
Methylene Chloride	28 B	46 J	13 J	ND	ND	40 JB	20 JB	ND
4-Methyl-2-Pentanone	ND	1100	ND	ND	ND	ND	ND	ND
Styrene	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	1000	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	12000	ND	ND	890 J
Trichloroethene	6 J	900	6 J	ND	7900	ND	ND	ND
Vinyl Chloride	1300	1300	220	ND	ND	100	23 J	ND
Xylenes (total)	ND	ND	ND	ND	9800	ND	ND	8400
Total Unknown Hydrocarbons	1217 J	3320 J	10 J	486000 J	372000 J	83600 J	30700 J	486000 J

Notes:

ND = Not detected.

B = Compound also detected in blank.

J = Compound detected below quantitation limit; value estimated.

(Ash) = Type of material sampled; soil/ash represents a mixture of soil and ash.

Table 2-1 (con't)
Summary of Chemical Composition Analytical Results for Area A1 Soils
- -- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/kg)

Parameter	A1TPW0604 (Soil/Ash)	A1TPW0705 (Ash)	A1TPW0805 (Ash)	A1TPW0905 (Ash/Soil)	A1TPW1004 (Soil)	A1TPW1105 (Ash)	A1TPW1205 (Ash/Soil)	A1TPW1205D (Ash/Soil)
Acetone	ND	ND	ND	ND	850 J	ND	ND	200 B
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	500 J	1900 J	ND	ND	10000	400 J	100
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	840000	ND	ND	ND	8400	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND	ND	ND	ND	ND
4-Methyl-2-Pentanone	ND	ND	ND	ND	6500	ND	ND	ND
Styrene	ND	ND	ND	ND	ND	2800	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	8100000	5300	3200	ND	5000	6800	ND	ND
Trichloroethene	510000	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND	3000	ND	ND	ND
Xylenes (total)	410000	9200	8500	ND	400 J	35000	ND	ND
Total Unknown Hydrocarbons	12640000 J	319000 J	340000 J	95100 J	43200 J	99800 J	245000 J	10030 J

Notes:

ND = Not detected.
B = Compound also detected in blank.
J = Compound detected below quantitation limit; value estimated.
(Ash) = Type of material sampled; soil/ash represents a mixture of soil and ash.

Table 2-2
Summary of Chemical Composition Analytical Results for Area A1 Soils
-- Semi-Volatile Organics --

Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/kg)

Parameter	A1TPW0102 (Ash)	A1TPW0102D (Ash)	A1TPW0104 (Soil)	A1TPW0202 (Soil/Ash)	A1TPW0304 (Soil/Ash)	A1TPW0404 (Soil)	A1TPW0505 (Ash)	A1TPW0604 (Soil/Ash)	A1TPW0705 (Ash)
Acenaphthene	ND	ND	ND	ND	ND	ND	610 J	ND	32 J
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	ND	ND	ND	ND	ND	ND	170 J	ND	ND
Di-n-Butylphthalate	220 JB	190 JB	ND	730 JB	110 JB	120 JB	320 JB	40000 J	340 JB
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	1600 J	ND	ND
bis(2-Ethylhexyl)phthalate	120 JB	48 JB	ND	ND	220 JB	ND	ND	ND	ND
Fluoranthene	ND	ND	1100 J	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	170 J	ND	30 J
2-Methanol	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methanol	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	1000 J	2100 J	350 J	ND	930 J	36000 J	140 J
Naphthalene	ND	ND	ND	4200 J	130 J	63 J	3200	150000 J	210 J
3-Nitroaniline	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	2000 J	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	1300 J	ND	ND	ND	ND	ND	ND

Notes:

ND = Not detected.
B = Compound also detected in blank.
D = Sample diluted to obtain value in range.
E = Value exceeds range for which equipment was calibrated; sample dilution required.
J = Compound detected below quantitation limit; value estimated.
(Ash) = Type of material sampled; soil/ash represents a mixture of soil and ash.

Table 2-2 (con't)
Summary of Chemical Composition Analytical Results for Area A1 Soils
-- Semi-Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/kg)

Parameter	A1TPW0805 (Ash)	A1TPW0905 (Ash/Soil)	A1TPW1004 (Ash)	A1TPW1004D (Ash)	A1TPW1105 (Soil)	A1TPW1105DL (Soil)	A1TPW1205 (Ash/Soil)	A1TPW1205D (Ash/Soil)
Acenaphthene	1600 J	110 J	ND	ND	ND	ND	ND	ND
Chrysene	ND	56 J	ND	ND	ND	ND	ND	ND
Dibenzofuran	1300 J	80 J	ND	ND	ND	ND	ND	ND
Di-n-Butylphthalate	2900 JB	150 JB	140 JB	ND	250 JB	260 DJB	120 JB	230 JB
1,4-Dichlorobenzene	ND	69 J	56 J	ND	69 J	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	2600	2400 DJ	ND	ND
bis(2-Ethylhexyl)phthalate	2500 J	430 JB	ND	ND	550	600 DJB	300 JB	ND
Fluoranthene	ND	37 J	ND	ND	ND	ND	ND	ND
Fluorene	1200 J	75 J	ND	ND	ND	ND	ND	46 J
2-Methylphenol	ND	ND	25000 E	19000 D	ND	ND	ND	ND
4-Methylphenol	ND	ND	42000 E	28000 D	18000 E	12000 D	ND	ND
2-Methylnaphthalene	4700 J	350 J	32 J	ND	200 J	240 DJ	300 J	340 J
Naphthalene	6000	81 J	100 J	ND	490 J	500 DJ	600	390 J
3-Nitroaniline	ND	23 J	ND	ND	ND	ND	ND	ND
Phenanthrene	1000 J	93 J	ND	ND	46 J	ND	40 J	ND
Phenol	ND	ND	2500	2000 DJ	26000 E	20000 D	ND	ND
Pyrene	ND	40 J	ND	ND	ND	ND	ND	ND

Notes:

ND = Not detected.
B = Compound also detected in blank.
D = Sample diluted to obtain value in range.
E = Value exceeds range for which equipment was calibrated; sample dilution required.
J = Compound detected below quantitation limit; value estimated.
(Ash) = Type of material sampled; soil/ash represents a mixture of soil and ash.

Table 2-3
Summary of Chemical Composition Analytical Results for Area A2 Soils
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/kg)

Parameter	A2TPW0103	A2TPW0103D	A2TPW0203	A2TPW0301	A2TPW0404	A2TPW0502	A2TPW0602	A2TPW0703
Acetone	38	140	ND	130	79	ND	ND	470 J
Benzene	ND	ND	25 J	ND	ND	ND	ND	ND
2-Butanone	12 J	52 J	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	27	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	ND	ND	ND	130000	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	620 J
Methylene Chloride	4 J	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	2200 J	ND	570 J
Toluene	7 J	ND	ND	18 J	ND	ND	380 J	330 J
Trichloroethene	ND	ND	ND	ND	ND	12000	ND	500 J
Xylenes (total)	13	ND	ND	ND	ND	ND	ND	1900
Total Unknown Hydrocarbons	3883 J	4159 J	8090 J	3429 J	1266 J	----	82500 J	337100 J

Notes:

ND = Not detected.

B = Compound also detected in blank.

J = Compound detected below quantitation limit; value estimated.

Table 2-3 (con't)
Summary of Chemical Composition Analytical Results for Area A2 Soils
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/kg)

Parameter	A2TPW0802	A2TPW0802RE	A2TPW0902	A2TPW1004	A2TPW1004D	A2TPW1102	A2TPW1203
Acetone	73	63	250 B	360 B	220 B	240 B	98 B
Benzene	ND	ND	ND	ND	ND	ND	ND
2-Butanone	6 J	ND	53 J	43 J	16 J	50 J	16 J
Carbon Disulfide	ND	ND	16 J	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	2 J	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	14 J	ND
Methylene Chloride	2 J	ND	33 JB	15 J	37 JB	32 JB	34 JB
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND
Toluene	3 J	3 J	ND	33 J	17 J	ND	ND
Trichloroethene	ND	ND	18 J	ND	ND	ND	ND
Xylenes (total)	ND	ND	ND	ND	ND	ND	ND
Total Unknown Hydrocarbons	----	26 J	3342 J	2090 J	3000 J	3187 J	2902 J

Notes:

ND = Not detected.

B = Compound also detected in blank.

J = Compound detected below quantitation limit; value estimated.

Table 2-4
Summary of Chemical Composition Analytical Results for Area A2 Soils
-- Semi-Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/kg)

Parameter	A2TPW0103	A2TPW0103D	A2TPW0203	A2TPW0301	A2TPW0404	A2TPW0502	A2TPW0602	A2TPW0703
Acenaphthene	150 J	160 J	ND	ND	ND	ND	ND	1200 J
Anthracene	180 J	340 J	ND	ND	ND	ND	ND	1100 J
Benzo(a)anthracene	630 J	2000	ND	ND	ND	630 J	ND	3200 J
Benzo(b)fluoranthene	790 J	2200	ND	ND	ND	850	ND	2400 J
Benzo(k)fluoranthene	340 J	760 J	ND	ND	ND	350 J	ND	1200 J
Benzo(ghi)perylene	240 J	640 J	ND	ND	ND	170 J	ND	950 J
Benzo(a)pyrene	500 J	1300	ND	ND	ND	550 J	ND	1700 J
Butyl benzyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND
Carbazole	87 J	150 J	ND	ND	ND	ND	ND	ND
Chrysene	620 J	1600	ND	ND	ND	630 J	ND	2600 J
Dibenzo(a,h)anthracene	89 J	220 J	ND	ND	ND	95 J	ND	ND
Dibenzofuran	67 J	82 J	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	130 JB	ND	91 JB	60 JB	ND	120 JB	ND	ND
1,2-Dichlorobenzene	79 J	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	60 J	76 J	27 J	20 J	ND	50 J	ND	ND
Diethylphthalate	ND	ND	ND	ND	ND	450 J	ND	ND
2,4-Dimethylphenol	57 J	ND	ND	ND	ND	ND	ND	ND
bis(2-Ethylhexyl)phthalate	6300	4200	ND	200 J	ND	54 J	6400 J	4400 J
Fluoranthene	1200	2600	ND	ND	ND	270 J	ND	6300 J
Fluorene	180 J	210 J	ND	ND	ND	ND	ND	1100 J
Indeno(1,2,3-cd)pyrene	270 J	780 J	ND	ND	ND	250 J	ND	1100 J
2-Methylnaphthalene	120 J	130 J	ND	ND	ND	ND	ND	2200 J
4-Methylphenol	110 J	70 J	ND	ND	ND	ND	ND	ND
Naphthalene	120 J	130 J	ND	ND	240 J	ND	ND	1000 J
Phenanthrene	930	1500	ND	ND	ND	44 J	ND	5400 J
Phenol	56 J	59 J	ND	ND	ND	ND	ND	ND
Pyrene	890	1900	ND	ND	ND	300 J	ND	5800 J

Notes:

ND = Not detected.

B = Compound also detected in blank.

J = Compound detected below quantitation limit; value estimated

Table 2-4 (con't)
Summary of Chemical Composition Analytical Results for Area A2 Soils
-- Semi-Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/kg)

Parameter	A2TPW0802	A2TPW0902	A2TPW1004	A2TPW1004D	A2TPW1102	A2TPW1203
Acenaphthene	83 J	470 J	ND	ND	ND	ND
Anthracene	84 J	270 J	270 J	250 J	260 J	ND
Benzo(a)anthracene	310 J	1400 J	1400 J	1700 J	3500	540 J
Benzo(b)fluoranthene	440	2800 J	1900	2300	3500	1100 J
Benzo(k)fluoranthene	140 J	960 J	560 J	630 J	1100 J	260 J
Benzo(ghi)perylene	110 J	1400 J	540 J	750 J	720 J	420 J
Benzo(a)pyrene	200 J	1700 J	1200 J	1400 J	2100 J	480 J
Butyl benzyl phthalate	ND	ND	150 J	ND	190 J	ND
Carbazole	59 J	ND	100 J	110 J	ND	ND
Chrysene	310 J	1500 J	1500 J	1500 J	2800	700 J
Dibenzo(a,h)anthracene	32 J	340 J	160 J	ND	240 J	ND
Dibenzofuran	60 J	430 J	ND	ND	ND	ND
Di-n-butyl phthalate	83 JB	460 JB	240 JB	310 JB	270 JB	500 JB
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	42 J	ND	ND	ND	ND	1200 J
Diethylphthalate	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND
bis(2-Ethylhexyl)phthalate	270 J	1800 J	5900	3600	5600	7500
Fluoranthene	660	2100 J	2600	2400	4300	ND
Fluorene	84 J	780 J	ND	ND	220 J	ND
Indeno(1,2,3-cd)pyrene	100 J	1300 J	560 J	750 J	840 J	390 J
2-Methylnaphthalene	32 J	1100 J	210 J	160 J	400 J	ND
4-Methylphenol	ND	ND	ND	ND	230 J	530 J
Naphthalene	140 J	570 J	160 J	ND	260 J	ND
Phenanthrene	410	870 J	870 J	850 J	1200 J	770 J
Phenol	44 J	ND	ND	ND	ND	ND
Pyrene	390	2000 J	1700 J	3000	2800	1100 J

Notes:

ND = Not detected.

B = Compound also detected in blank.

J = Compound detected below quantitation limit; value estimated

Table 2-5
Summary of TCLP Extraction Analytical Results for Areas A1 and A2 Soils
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

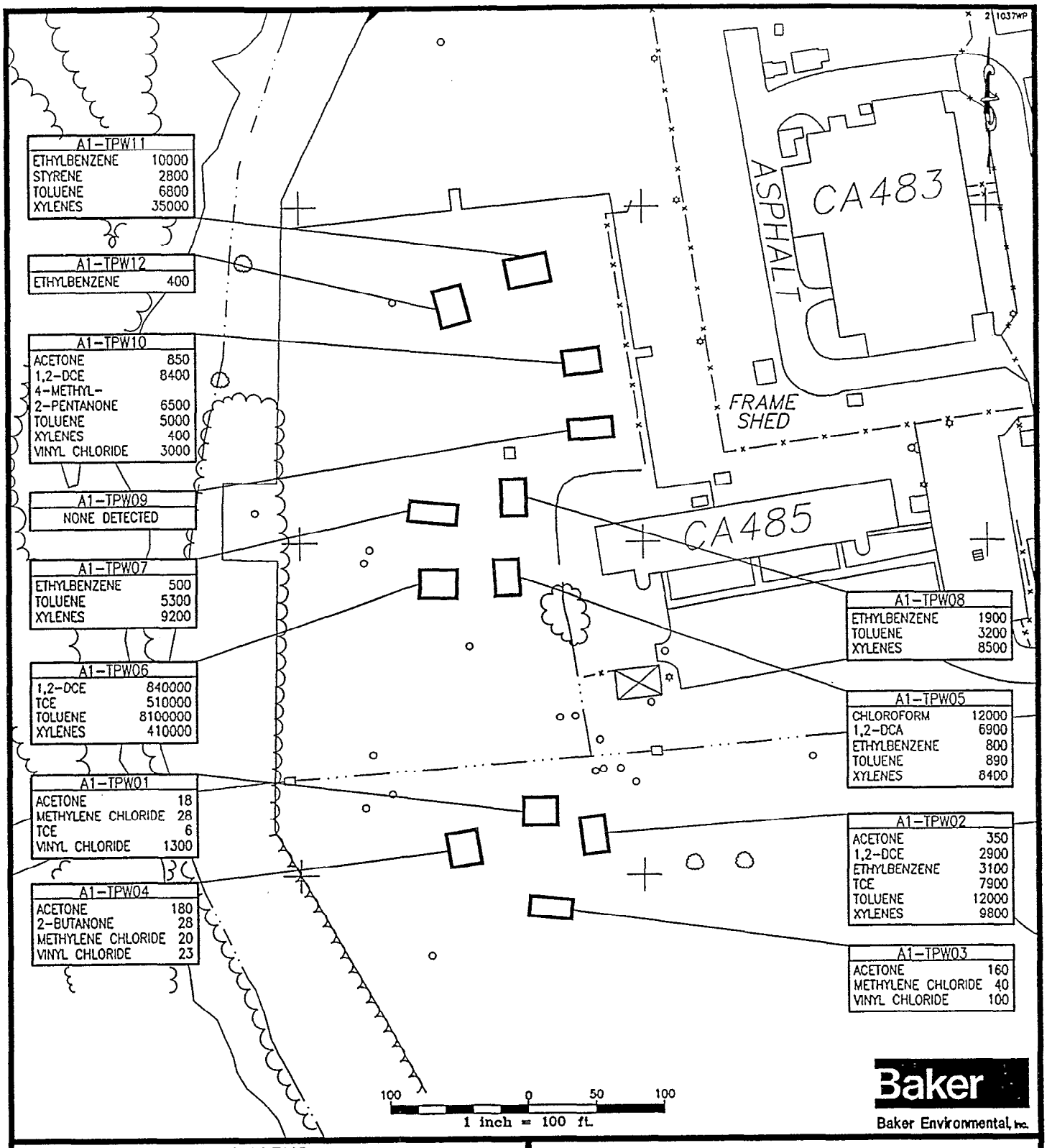
Parameter	Regulatory Level	A1-TPW02-02 (Ash/Soil)	A1-TPW08-05 (Ash)	A2-TPW01-03 (Soil)
TCLP VOCs (mg/l)				
Benzene	0.5	ND	ND	ND
2-Butanone	200	ND	ND	ND
Carbon Tetrachloride	0.5	ND	ND	ND
Chlorobenzene	100	ND	ND	ND
Chloroform	6	ND	ND	ND
1,2-Dichloroethane	0.5	ND	ND	ND
1,1-Dichloroethene	0.7	ND	ND	ND
Tetrachloroethene	0.7	ND	ND	ND
Toluene	---	0.093	13	ND
Trichloroethene	0.5	0.094	ND	ND
Vinyl Chloride	0.2	ND	ND	ND
TCLP SVOCs (mg/l)				
1,4-Dichlorobenzene	7.5	ND	ND	ND
2,4-Dinitrotoluene	0.13	ND	ND	ND
Hexachlorobenzene	0.13	ND	ND	ND
Hexachlorobutadiene	0.5	ND	ND	ND
Hexachloroethane	3	ND	ND	ND
2-Methylphenol	200	ND	0.11	ND
4-Methylphenol	200	ND	0.19	ND
Nitrobenzene	2	ND	ND	ND
Pentachlorophenol	100	ND	ND	ND
Pyridine	5	ND	ND	ND
2,4,5-Trichlorophenol	400	ND	ND	ND
2,4,6-Trichlorophenol	2	ND	ND	ND
TCLP Pesticides (mg/l)				
Chlordane	0.03	ND	ND	ND
Endrin	0.02	ND	ND	ND
Heptachlor	0.008	ND	ND	ND
Heptachlor Epoxide	0.008	ND	ND	ND
Lindane	0.4	ND	ND	ND
Methoxychlor	10	ND	ND	ND
Toxaphene	0.5	ND	ND	ND

Note: ND = Not detected.

Table 2-5 (con't)
Summary of TCLP Extraction Analytical Results for Areas A1 and A2 Soils
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

Parameter		Regulatory Level	A1-TPW02-02 (Ash/Soil)	A1-TPW08-05 (Ash)	A2-TPW01-03 (Soil)
TCLP Herbicides (mg/l)					
2,4-D		10	ND	ND	ND
2,4,5-TP (Silvex)		1	ND	ND	ND
TCLP Inorganics (mg/l)					
Arsenic		5	ND	ND	ND
Barium		100	ND	ND	1.8
Cadmium		1	ND	ND	0.14
Chromium		5	ND	ND	ND
Lead		5	0.11	7.5	0.16
Mercury		0.2	ND	ND	ND
Selenium		1	ND	ND	ND
Silver		5	ND	ND	ND
Others					
Reactive Cyanide	(mg/kg)	---	ND	ND	ND
Reactive Sulfide	(mg/kg)	---	ND	ND	ND
pH	(S.U.)	---	7.9	7.2	9.3
Flash Point	(deg F)	---	>180	>180	>180
Total Solids	(%)	---	69.9	73.5	81.9
Total Organic Carbon	(mg/kg)	---	11000	56000	11000
Total Recoverable Petroleum Hydrocarbons	(mg/kg)	---	15000	54000	670

Note: ND = Not detected.



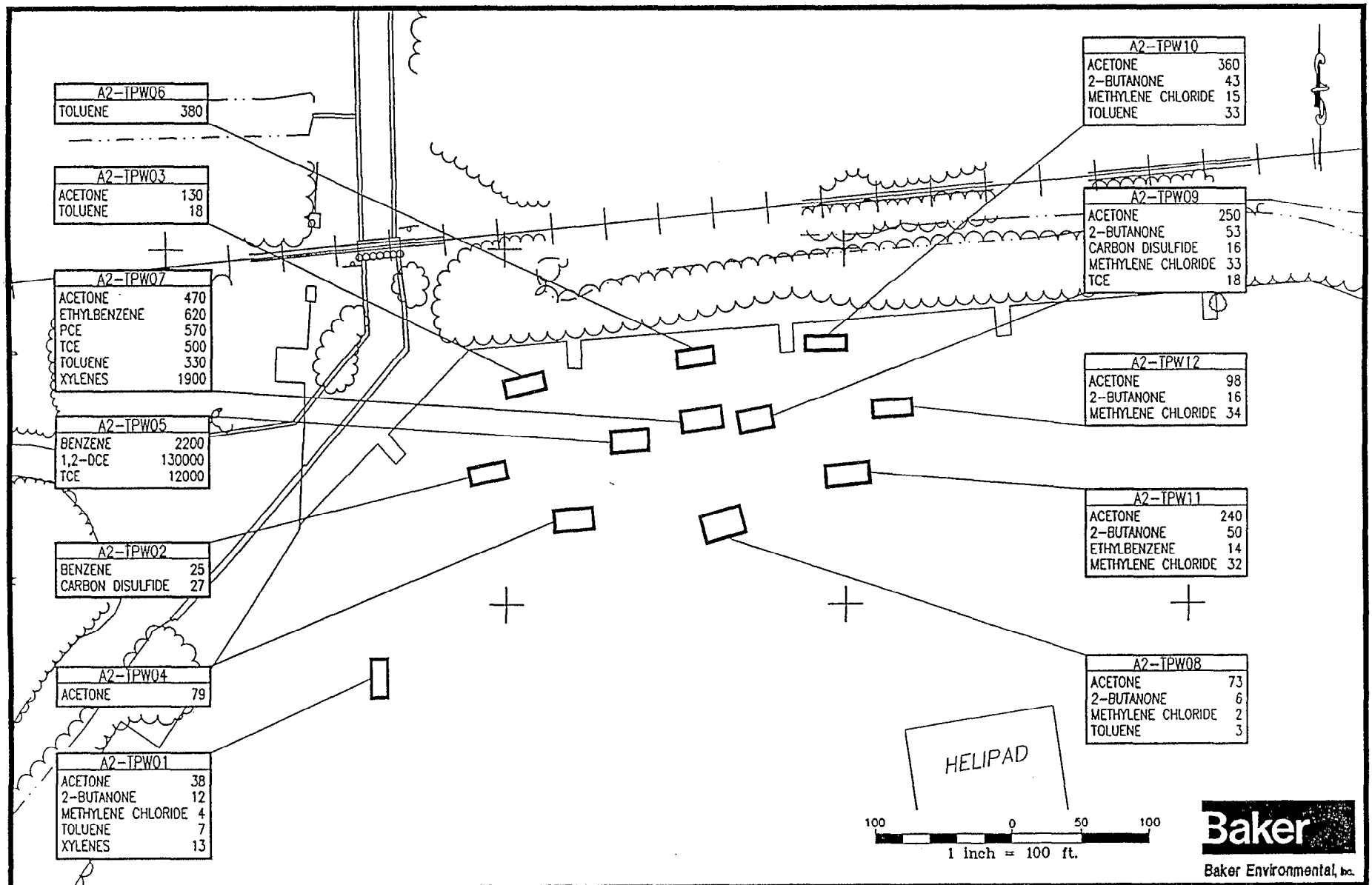
LEGEND

TEST PIT

NOTE: ALL CONCENTRATIONS IN ug/kg.

FIGURE 2-3
AREA A1 TEST PIT LOCATIONS
AND VOLATILES RESULTS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

TEST PIT

NOTE: ALL CONCENTRATIONS IN ug/kg.

FIGURE 2-4
AREA A2 TEST PIT LOCATIONS
AND VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

As shown in Figure 2-3, test pits numbers A1-TPW01, A1-TP02, A1-TP03, A1-TP05, A1-TP06, and A1-TP10 contained the highest concentrations of chlorinated VOCs (e.g., TCE, vinyl chloride, 1,2-DCE) in Area A1. Toluene, ethylbenzene, and/or xylenes were detected in many of the test pits, with pits A1-TPW02, A1-TP05, A1-TP06, A1-TP07, A1-TP08, and A1-TP11 exhibiting the highest concentrations of these constituents.

As shown in Table 2-2, a number of semi-volatile compounds were detected in the Area A1 test pits including naphthalene, 2-methylnaphthalene, and several phenolic compounds. As discussed in Section 2.3, semi-VOCs were infrequently detected in the groundwater. Therefore, the semi-VOCs in soil do not appear to pose a risk to groundwater (i.e., through leaching) and are not considered as contaminants of concern for the remedial design.

A black, powder-like ash material was observed in all test pits in Area A1 at depths ranging from 1 to 10 feet bgs. Based on the sampling results shown in Table 2-1, there appears to be no correlation between contaminant concentrations detected in the test pit samples and the ash material. Therefore, it is possible that the organic contamination originated from other waste materials that were combined with the ash during disposal rather than from the ash itself. In addition to the ash, the following materials were observed:

- A1-TP04: a 30-gallon crushed drum at 1-2 feet bgs.
- A1-TP05, A1-TP07, A1-TP08: fill material containing bricks, cinder blocks, and concrete rubble at 1-3 feet bgs.
- A1-TP06: paper debris at 6-6.5 feet bgs.
- A1-TP08: paint cans and dried paint wastes.

Soils located above (1-3 feet bgs) the ash material consisted mainly of medium-grained sands and fill material, and soils beneath (7-12 feet bgs) the ash consisted mostly of clay.

Results for the TCLP analyses (Table 2-5) suggest that the soils in Area A1 are not classified as a characteristic hazardous waste under the Resource Conservation and Recovery Act (RCRA) but that the ash material may be considered hazardous since sample A1-TPW08-05 slightly exceeded the TCLP

standard for lead. As also shown in Table 2-5, the ash material observed in Area A1 contains a significant amount of total petroleum hydrocarbons (TPH), the majority of which are semi-volatile compounds.

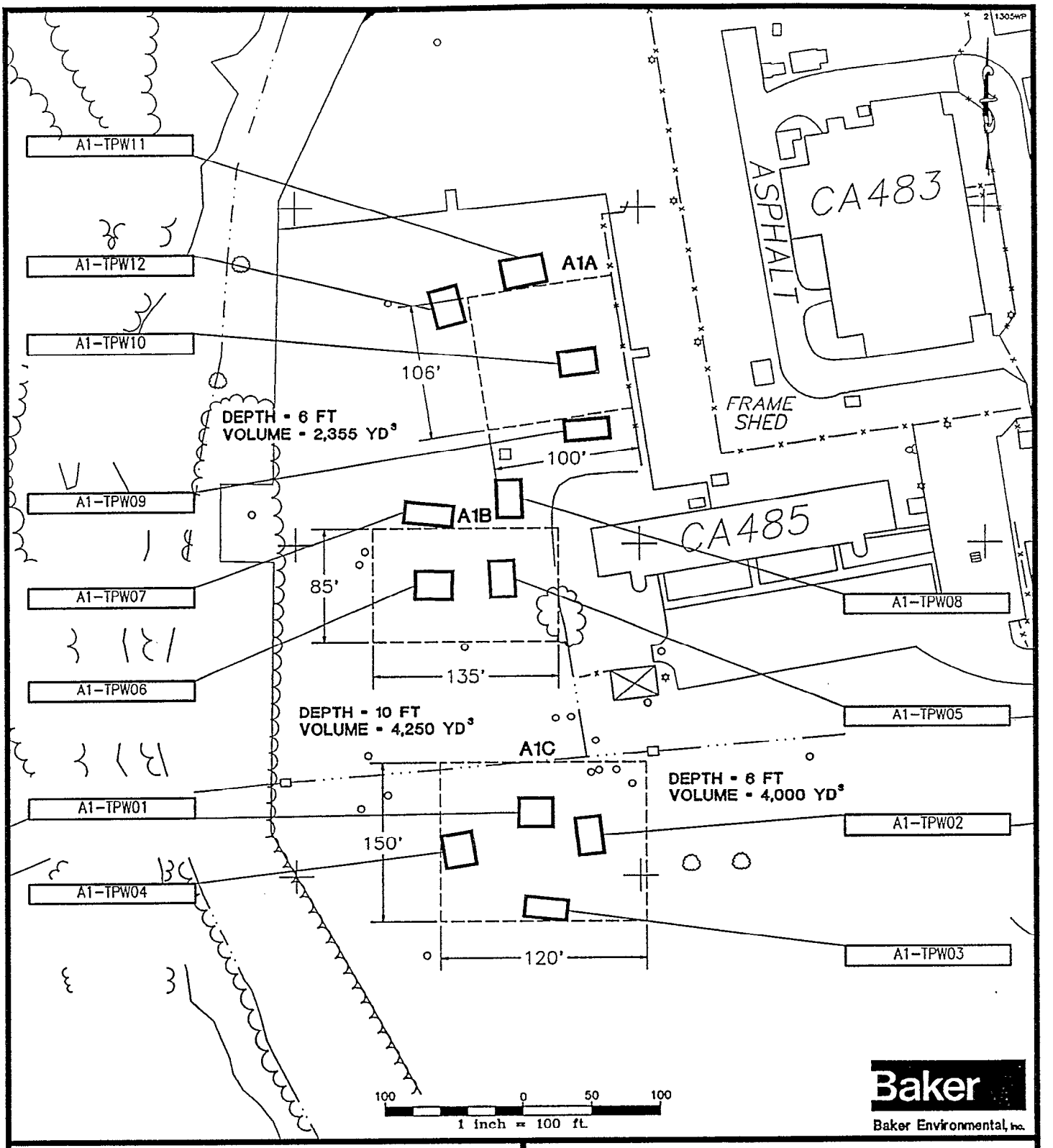
Three areas of soil contamination were identified in Area A1, as shown in Figure 2-5. These areas contained the highest concentrations of chlorinated VOCs, which are the primary contaminants of concern in both the water table and upper Yorktown Aquifers. During the basis of design task, these areas may be revised based on the soil cleanup levels being developed as part of the Feasibility Study effort. The estimated volume of soil contamination in Area A1, based on the areas and depths of contamination shown in Figure 2-5, is 10,605 cubic yards.

As shown in Figure 2-4, test pits numbers A2-TPW05 and A2-TPW07 contain the highest concentrations of chlorinated VOCs (e.g., TCE, 1,2-DCE, PCE) in Area A2. In addition, test pit 5 contains benzene at 2,000 μg/kg. Fill material containing extensive debris (e.g., metal pipes, steel cable, glass, wood, paper, and miscellaneous scrap metal) and construction debris (e.g., concrete rubble and brick) were observed in many of the test pits in Area A2 at depths ranging from 2 to 9 feet bgs. Soil types consisted mainly of medium-grained sands, although clay lenses were observed in test pits A2-TPW01 and A2-TPW02 ranging from 5 to 7 feet in thickness.

As shown in Table 2-4, a variety of semi-volatile compounds were detected in the Area A2 test pits including several polyaromatic hydrocarbons (PAHs). As discussed in Section 2.3, semi-VOCs were infrequently detected in the groundwater. Therefore, the semi-VOCs in soil do not appear to pose a risk to groundwater and are not considered as contaminants of concern for the remedial design.

Results for the TCLP analysis (Table 2-5) indicate that the soils in Area A2 are not classified as a characteristic hazardous waste under RCRA. As also shown in Table 2-5, the soils in Area A2 appear to contain a much lower amount of TPH than those in Area A1.

One area of soil contamination was identified in Area A2, as shown in Figure 2-6. The soil remedial design will address this area of contamination. The estimated volume of soil contamination in Area A2, based on an average contaminated soil thickness of 6 feet in the vadose zone, is 2,208 cubic yards.

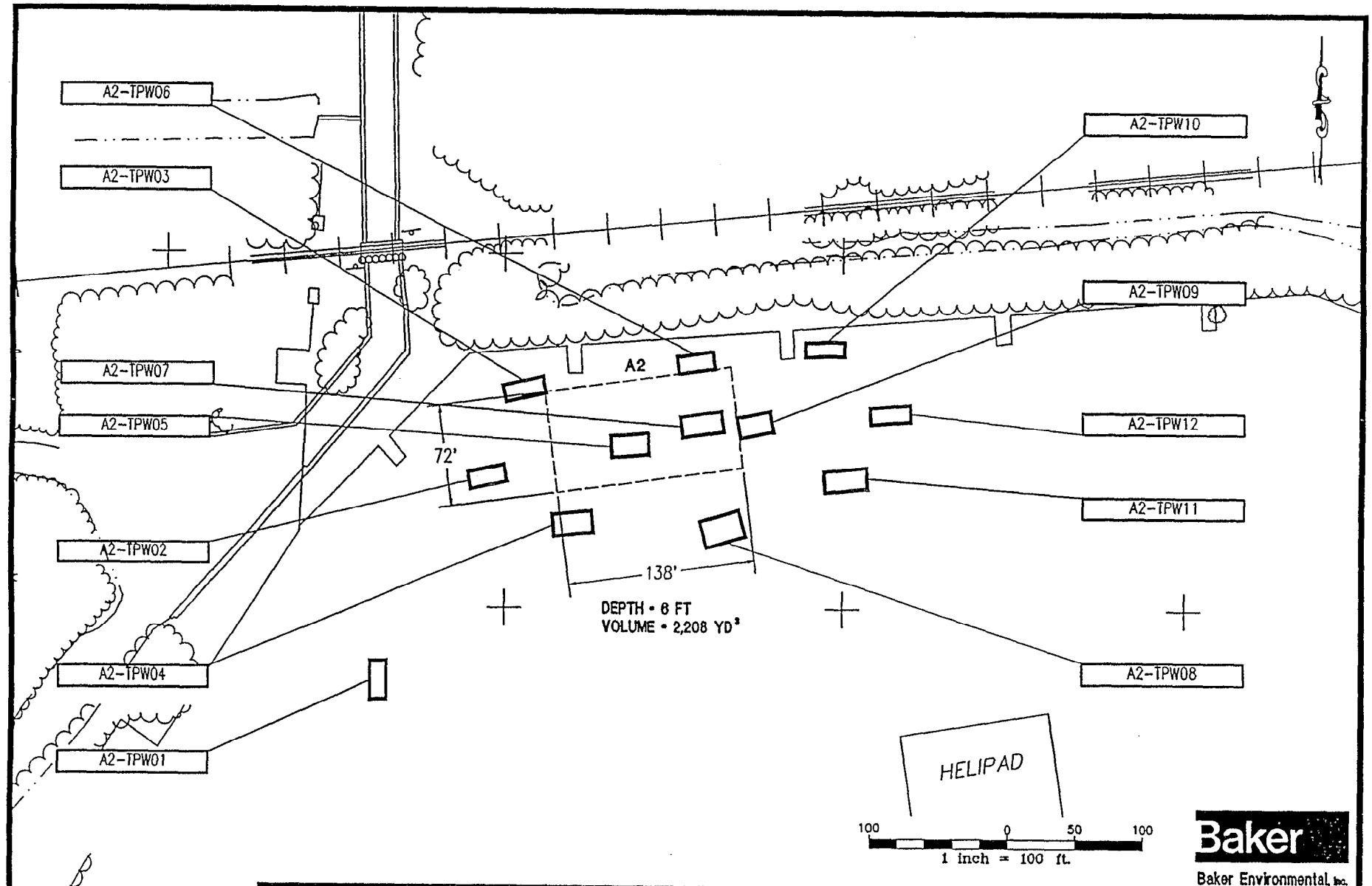


LEGEND

TEST PIT

FIGURE 2-5
AREA A1
SOIL REMEDIATION AREAS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

TEST PIT

FIGURE 2-6
AREA A2
SOIL REMEDIATION AREAS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

211304WP

2.3 Temporary Wells and Groundwater Sampling Results

2.3.1 Temporary Well Installation and Sampling

Temporary shallow and deep monitoring/observation wells were installed to further delineate the extent of shallow and deep groundwater contamination and to provide additional aquifer characteristics in Areas A1, A2, and B. The temporary monitoring wells, similar in construction to the existing on-site monitoring wells, are referred to as "temporary" because they are not necessarily intended to serve as permanent, long-term monitoring wells. Long-term monitoring wells will be selected later during development of the operations and maintenance plan for the site. In general, temporary well locations were selected based on previous investigation results and in situ groundwater sampling results. The following temporary wells were installed in each area:

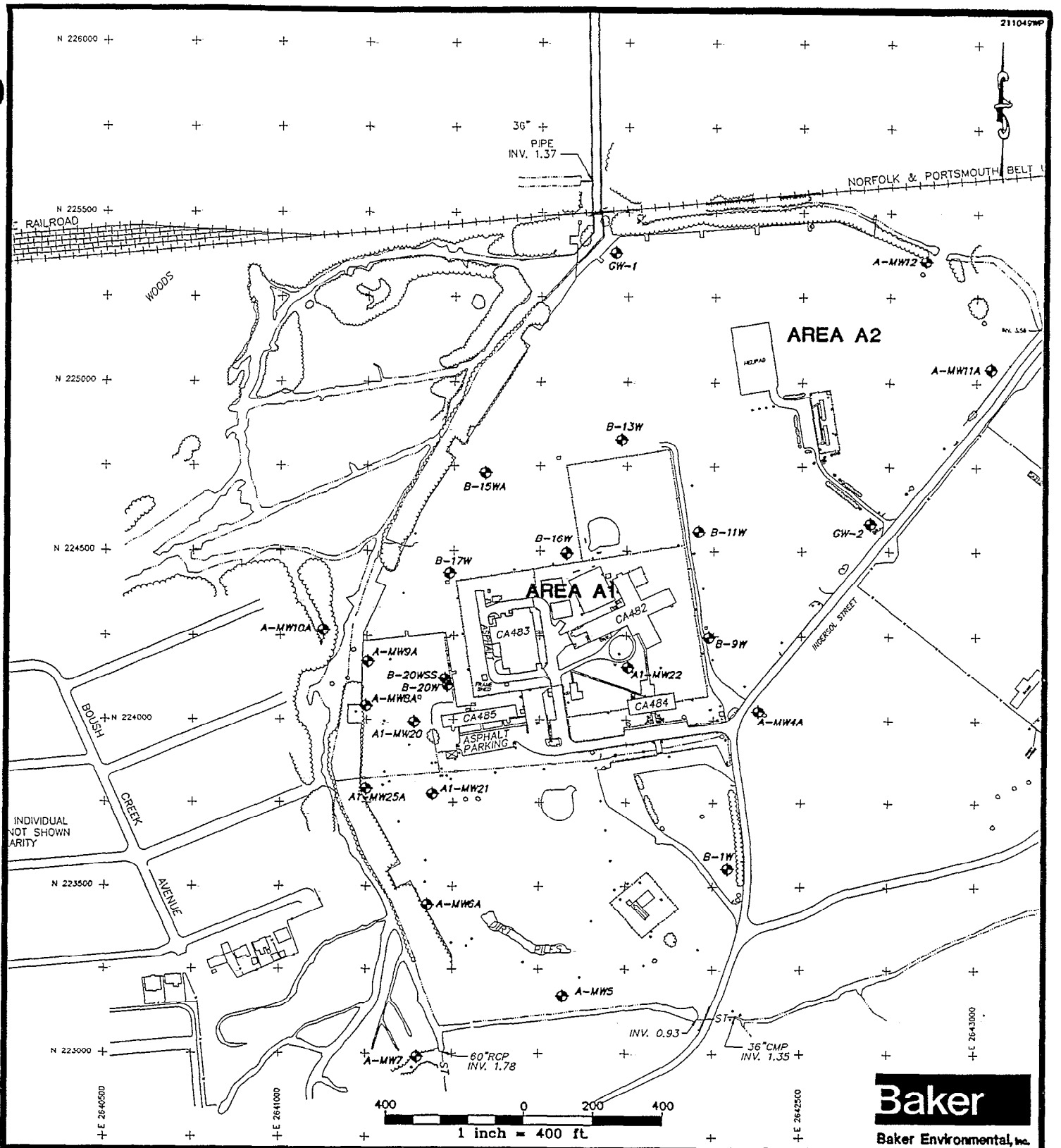
- Area A1 - Four (4) shallow and four (4) deep temporary wells
- Area A2 - Two (2) deep temporary wells
- Area B - Six (6) shallow and four (4) deep temporary wells

In addition to the temporary monitoring/observation wells, a total of four (4) pumping/pilot test extraction wells also were installed in Area A1 and Area B as follows:

- Area A1 - One (1) deep extraction well
- Area B - One (1) shallow and one (1) deep extraction well

Existing and newly installed well locations for Areas A1 and A2 are presented in Figures 2-7 and 2-8 for shallow and deep wells, respectively. Shallow and deep well locations for Area B are presented in Figures 2-9 and 2-10, respectively. Please note that the well coding for temporary wells generally follows that of the existing wells, with the exception that Area A has now been divided into Areas A1 and A2 (e.g., A1-MW20, A2-MW23). As in previous sampling rounds, wells are designated with an A, B, or C qualifier to denote shallow (water table), upper Yorktown, and deep Yorktown wells, respectively (e.g, A-MW9A, A-MW9B, and A-MW9C). Please note that shallow wells which are not part of a well nest do not have an "A" suffix; however, all upper Yorktown and all lower Yorktown wells have a "B" and "C" suffix respectively. Extraction wells are noted by an "EW" (e.g., A1-EW1B).

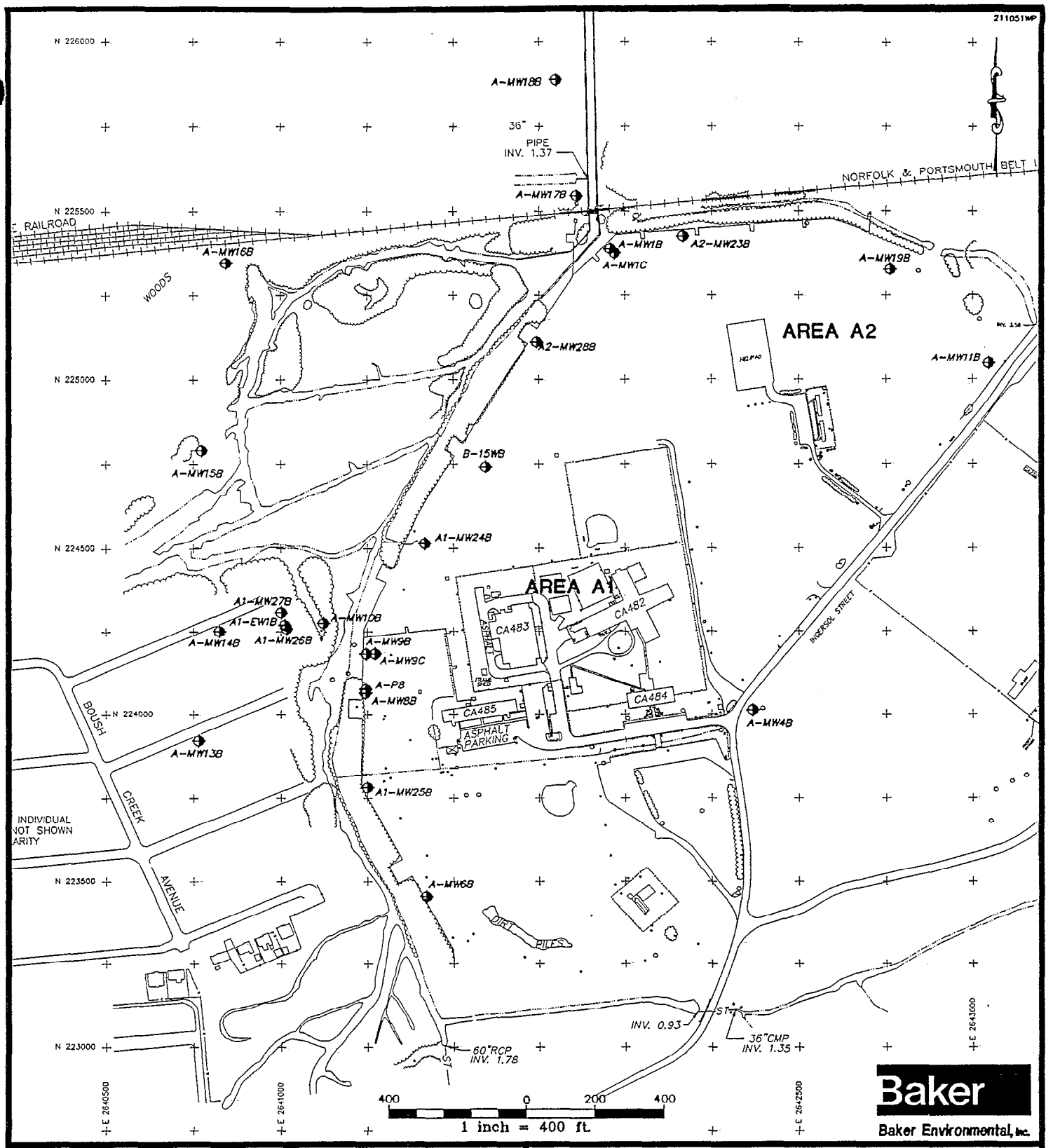
A total of 14 confirmation groundwater samples were collected for 24-hour turnaround analysis (non-CLP) of volatile organic constituents via EPA Method 601 during predesign activities. Confirmation sample



LEGEND

SHALLOW MONITORING WELL LOCATION

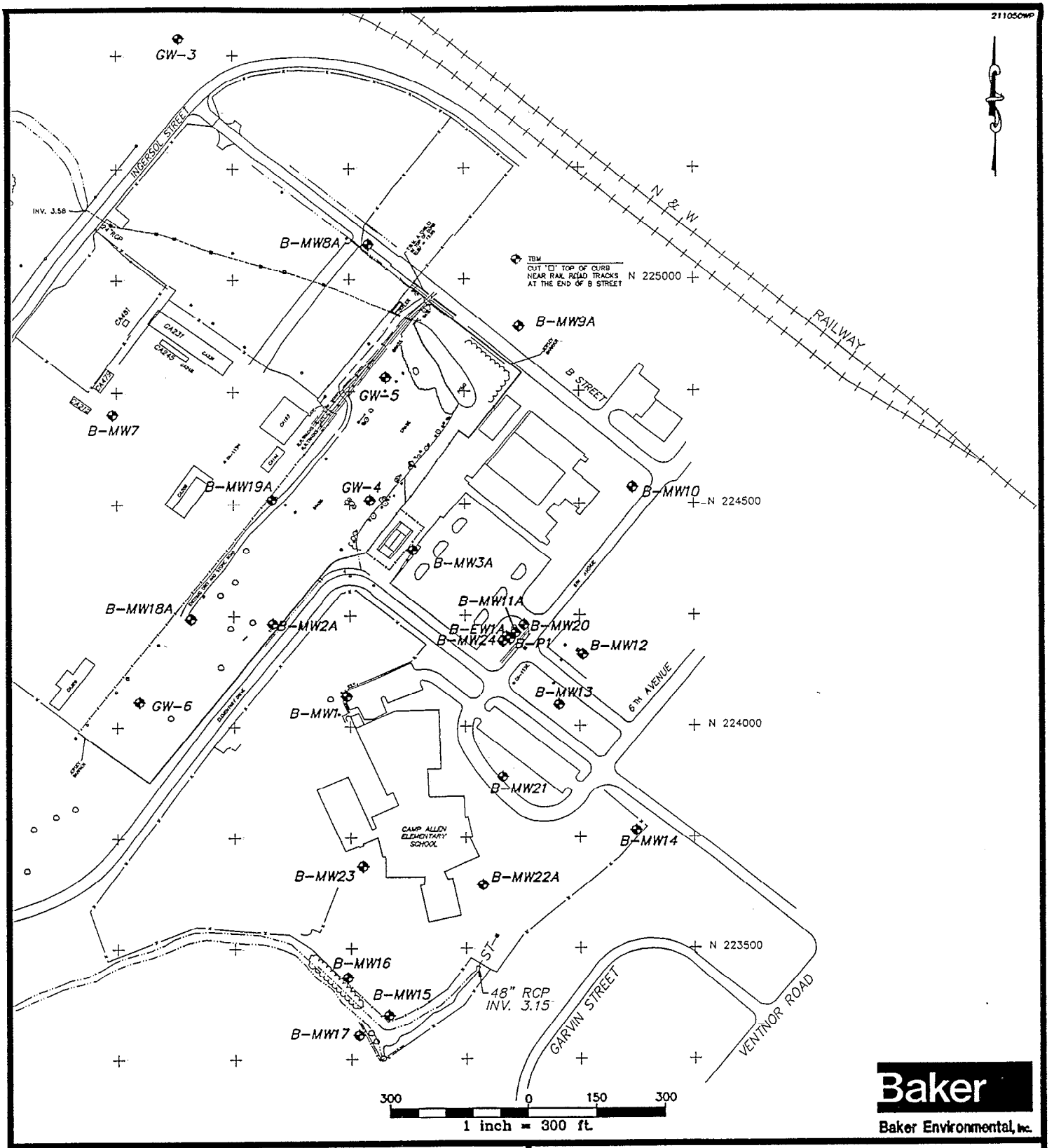
FIGURE 2-7
SHALLOW GROUNDWATER MONITORING WELL LOCATIONS
CAMP ALLEN LANDFILL
AREAS A1 AND A2
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

◆ DEEP MONITORING WELL LOCATION

FIGURE 2-8
DEEP GROUNDWATER
MONITORING WELL LOCATIONS
CAMP ALLEN LANDFILL
AREAS A1 AND A2
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

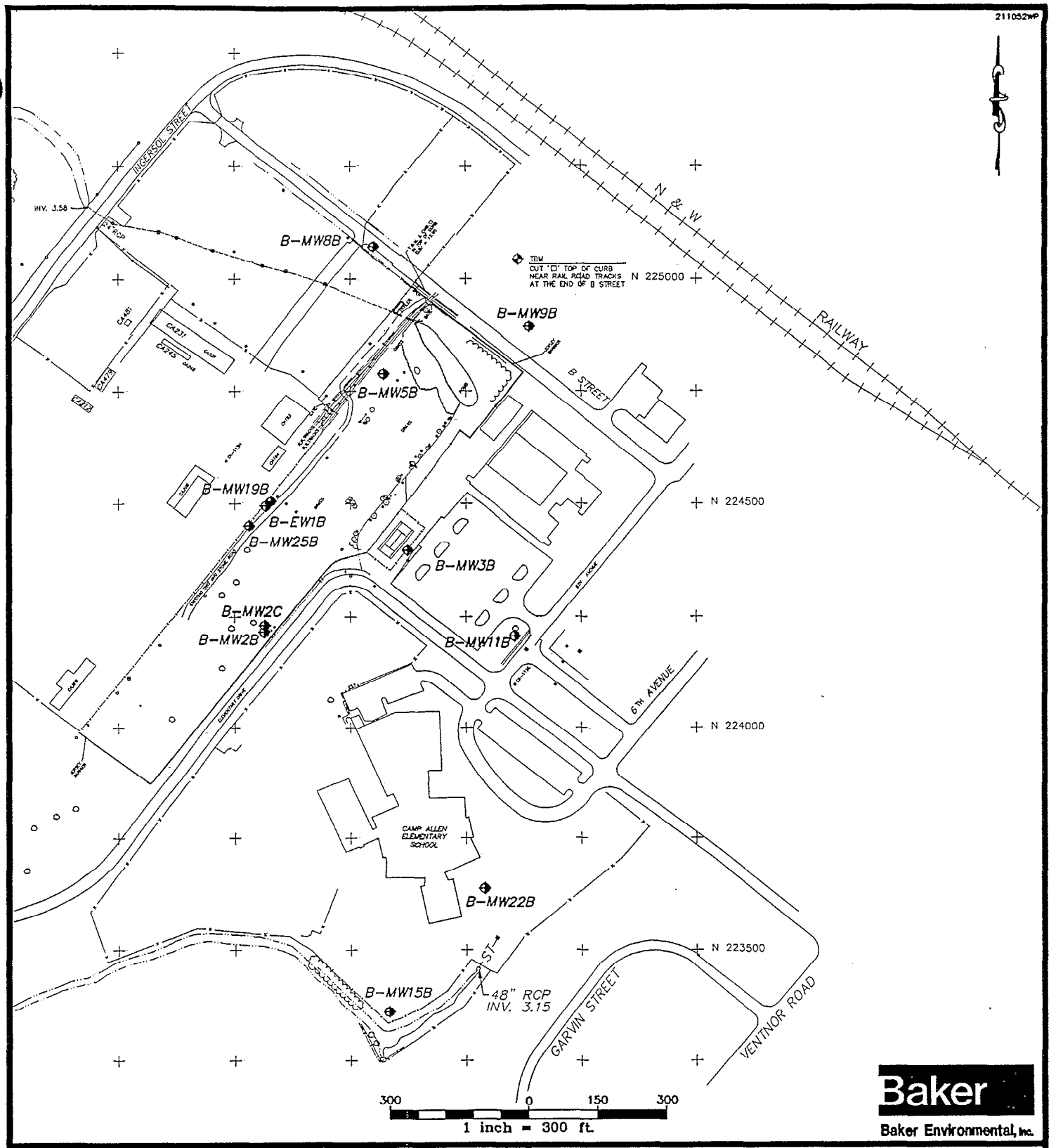


LEGEND

◆ SHALLOW MONITORING WELL LOCATION

FIGURE 2-9
SHALLOW GROUNDWATER
MONITORING WELL LOCATIONS
CAMP ALLEN LANDFILL
AREA B

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

◆ DEEP MONITORING WELL LOCATION

FIGURE 2-10
DEEP GROUNDWATER
MONITORING WELL LOCATIONS
CAMP ALLEN LANDFILL
AREA B
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

results were used to aid in determining both optimum location and depth of proposed well points. Initial confirmation samples were collected from three (3) existing monitoring wells that monitor the lower portion of the Yorktown Aquifer (A-MW1C, A-MW9C, and B-MW2C). Only one contaminant, TCE, was detected in well A-MW9C at a concentration of 1.12 μg/L, and only one contaminant, 1,2-DCA, was detected in well B-MW2C at a concentration of 9.3 μg/L. No contaminants were detected in well A-MW1C. These confirmation sample results supported previous conclusions that contaminants are limited to groundwater in the upper portion of the Yorktown Aquifer; therefore, deep well points in Area A1 were installed to monitor the upper portion of the Yorktown Aquifer (approximately 65 feet bgs). Remaining confirmation samples were collected on an as needed basis to support in situ groundwater sampling results and to aid in selection of temporary well locations in Area A2 and Area B. Confirmation sample results are contained in Appendix D.

Well borings were advanced using truck-mounted and ATV type drill rigs. Hollow stem augering was the drilling method used for placement of shallow temporary wells and to set surface casing of deep temporary wells. Wash rotary methods were used to complete the deep well locations. Shallow wells were constructed as Type II wells (unconfined water table) with depths ranging from 15 to 29 feet below ground surface (bgs). Deep wells were constructed as Type III wells (with surface casing) in order to "case off" the water table aquifer prior to advancing the boring into the upper portion of the Yorktown Aquifer. Deep wells extend into the upper portion of the Yorktown Aquifer (depths range from 64 to 65 feet bgs). Please note that temporary well B-MW2C extends to 120 feet bgs in order to monitor the lower Yorktown Aquifer in Area B.

Temporary wells were constructed using two-inch, schedule 40, PVC riser pipe; two-inch, 10 slot, schedule 40, PVC screen at a length of 10 feet; a No. 1 filter pack sand; bentonite pellets; and bentonite/cement slurry. Pilot test extraction wells were constructed of four-inch, schedule 40, PVC riser and 10-slot, stainless steel screen piping. Well completion and development procedures followed standard operating procedures (SOPs) contained in the Sampling and Analysis Plan.

Following well installation and development activities, groundwater from selected new and existing shallow and deep wells in/near the areas of contamination was sampled to help confirm the extent of groundwater contamination in each area. Groundwater samples were analyzed for VOCs using EPA Methods 601 and 602. Since a pumping/pilot test could not be performed for the Area A1 shallow aquifer (see Section 2.5), groundwater samples from wells A1-MW20 and A1-MW21 were analyzed for the parameters that were planned for the treatment system influent samples (see Section 2.5.2). These parameters included VOCs, semi-VOCs, total and dissolved metals, and several engineering parameters.

QA/QC samples were collected following NEESA guidelines. CLP analyses were performed following NEESA Level C protocol. The analytical data were not validated by an independent data validation subcontractor since the data are being used for design purposes rather than for risk assessment. If necessary, sample analytical data can undergo data validation following NEESA 20.2-047B in the future.

2.3.2 Groundwater Sampling Results

A summary of groundwater sampling locations is contained in Table 2-6. Groundwater sampling points are presented by area (A1/A2/B), as well as by existing and proposed well locations. Analytical results (volatile organics only) are presented in Tables 2-7 through 2-12. These results are also depicted on the tag maps presented as Figures 2-11 through 2-16. In addition, samples from monitoring wells A1-MW20 and A1-MW21 were analyzed for semivolatiles, inorganics (total and dissolved metals), and other engineering parameters; these results are presented in Tables 2-13 and 2-14. With respect to the estimated areas of groundwater contamination developed in the Feasibility Study, as part of the basis of design task, these areas will be revised based on the predesign investigation results.

In previous sampling rounds (rounds 2 and 3), semi-volatile contaminants were detected very infrequently and in low concentrations in the water table and Yorktown Aquifers in Areas A1, A2, and B. The highest levels of semi-VOCs detected in the groundwater in the previous sampling rounds were in the shallow aquifer in Area A1. As shown in Table 2-13, only phenol and/or bis(2-ethylhexyl)phthalate were detected groundwater samples collected from wells A1-MW20 and A1-MW21 at very low concentrations.

Volatile organic concentrations detected in the shallow groundwater in Area A1 during the predesign investigation (Figure 2-11) were much lower than those observed in sampling round 2 (based on well A1-B20WSS results). Similarly to round 2 results, no VOCs were detected in wells A1-MW8A, A1-MW9A, and A1-MW10A, suggesting that shallow contaminated groundwater is not discharging to the creek or migrating beneath it. Based on the in situ and monitoring well sampling results, groundwater contamination in the vicinity of the Brig (near A1-B20WSS, A1-MW20, and A1-MW-21) appears to be present as small, isolated areas, or "pockets," of contamination rather than as one continuous contaminant plume.

With the exception of new monitoring well A1-MW25B, VOC concentrations detected in the upper Yorktown Aquifer in Area A1 during the predesign investigation (Figure 2-12) were lower than those observed in sampling rounds 2 and 3. The VOC contamination detected in well A1-MW25B will require the southern extent of contamination estimated in the Feasibility Study to be expanded in the design.

TABLE 2-6

SUMMARY OF GROUNDWATER SAMPLING POINTS

Well Description	Area A1	Area A2	Area B	
Shallow Groundwater				
Existing Monitoring Wells	B–20WSS A–MW8A A–MW9A A–MW10A	GW–1 GW–2 A–MW11A A–MW12	GW–4 B–MW1 B–MW2A B–MW3A B–MW11A	B–MW13 B–MW14 B–MW15 B–MW16 B–MW19A
New Temporary Wells	A1–MW20 A1-MW21 A1-MW22 A1-MW25A		B–MW20 B–MW21	B–MW22A B–MW23 B–MW24
Deep Groundwater				
Existing Monitoring Wells	A–MW9B A–MW9C A–MW10B A–MW13B A–MW14B	A–MW1B A–MW1C A–MW17B A–MW18B A–MW19B	B–MW2B B–MW3B B–MW5B B–MW11B B–MW19B	
New Temporary Wells	A1–MW24B A1–MW25B A1-MW26B A1-MW27B	A2–MW21B A2–MW28B	B–MW2C B–MW15B B–MW22B B–MW25B	

Table 2-7
Summary of Chemical Composition Analytical Results for Area A1 Shallow Aquifer Groundwater
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	A1-MW8A 12-6-93	A1-MW9A 12-6-93	A1-MW10A 12-6-93	A1-B20WSS 12-6-93	A1-MW20 12-6-93	A1-MW21 12-6-93	A1-MW22 12-6-93	A1-MW22D 12-6-93	A1-MW25A 12-6-93
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	12
Benzene	ND	ND	ND	3.2 *	ND	5.7	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	3
1,2-Dichloroethene (total)	ND	ND	ND	8.6	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	3.9 *	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	8 *	ND	3.7 J	ND	ND	ND
Xylene (total)	ND	ND	ND	22 *	ND	4.9 J	ND	ND	ND

Notes:

ND = Not detected.

J = Compound detected below quantitation limit; value estimated.

* = Calibration criteria not met - quantitation suspect.

Table 2-8
Summary of Chemical Composition Analytical Results for Area A1 Yorktown Aquifer Groundwater
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	A-MW9B 12-4-93	A-MW9C 12-4-93	A1-MW10B 12-5-93	A-MW13B 12-4-93	A-MW14B 12-5-93	A1-MW24B 12-5-93	A1-MW25B 12-4-93	A1-MW26B 12-4-93	A1-MW27B 12-4-93	A1-MW27BD 12-4-93
Chloroform	ND	ND	ND	ND	ND	ND	ND	1.7	ND	ND
1,2-Dichloroethene (total)	68	ND	18	ND	ND	18	660	15	4.1	2.1
Trichloroethene	ND	ND	1.4	ND	ND	7.2	ND	1.2	ND	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND	350	ND	ND	ND

Note: ND = Not detected.

Table 2-9
Summary of Chemical Composition Analytical Results for Area A2 Shallow Aquifer Groundwater
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/l)

Parameter	A2-GW1 12-6-93	A2-GW2 12-6-93	A2-MW11A 12-6-93	A2-MW11AD 12-6-93	A2-MW12 12-6-93
1,2-Dichloroethane	1.4	ND	ND	ND	ND
1,2-Dichloroethene (total)	9.6	ND	48	56	ND
Vinyl Chloride	7	ND	ND	ND	ND

Note: ND = Not detected.

Table 2-10
Summary of Chemical Composition Analytical Results for Area A2 Yorktown Aquifer Groundwater
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/l)

Parameter	A2-MW1B 12-6-93	A2-MW1C 12-6-93	A2-MW17B 12-7-93	A2-MW18B 12-7-93	A2-MW19B 12-7-93	A2-MW23B 12-7-93	A2-MW28B 12-7-93	A2-MW28BD 12-7-93
Benzene	ND	ND	ND	2.1	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	6.2	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	170	ND	42	6.9	2.8	260	280	280
Trichloroethene	ND	ND	ND	ND	ND	38	34	47
Vinyl Chloride	ND	ND	ND	1.3	ND	ND	ND	ND

Note: ND = Not detected.

Table 2-11
Summary of Chemical Composition Analytical Results for Area B Shallow Aquifer Groundwater
-- Volatile Organics --

Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/l)

Parameter	B-MW1 11-22-93	B-MW2A 11-22-93	B-MW2AD 11-22-93	B-MW3A 11-22-93	B-GW4 11-22-93	B-MW11A 11-22-93	B-MW13 11-22-93	B-MW14 11-22-93	B-MW15 11-22-93
Acetone	ND	ND	ND	ND	1400	ND	ND	ND	ND
Benzene	ND	ND	ND	210	21	ND	ND	ND	ND
Chlorobenzene	15	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	4.5	4.2	ND
1,2-Dichloroethane	ND	1.1	1.1	ND	ND	ND	ND	ND	26
1,2-Dichloroethene (total)	ND	ND	ND	1300	240	2200	ND	ND	170
Tetrachloroethene	ND	3.7	4.3	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	1.6	1.6	ND
Trichloroethene	ND	ND	ND	210	160	ND	ND	ND	71
Trichlorofluoromethane	ND	ND	ND	840	ND	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	990	35	1600	ND	ND	120
Xylenes (total)	ND	ND	ND	ND	62	ND	ND	ND	ND

Note: ND = Not detected

Table 2-11 (con't)
Summary of Chemical Composition Analytical Results for Area B Shallow Aquifer Groundwater
-- Volatile Organics --

Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

(all values in units of ug/l)

Parameter	B-MW16 11-22-93	B-MW19A 11-22-93	B-MW20 11-22-93	B-MW20D 11-22-93	B-MW21 11-22-93	B-MW22A 11-22-93	B-MW23 11-22-93	B-MW24 11-22-93
Acetone	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	210
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	5.4	ND
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	1.9	ND	340	420	ND	3.2	ND	990
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	1.4	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	360
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	250
Vinyl Chloride	1.1	ND	420	580	ND	3.3	ND	390
Xylenes (total)	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND = Not detected

Table 2-12
Summary of Chemical Composition Analytical Results for Area B Yorktown Aquifer Groundwater
-- Volatile Organics --
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	B-MW2B 11-23-93	B-MW2C 11-23-93	B-MW3B 11-23-93	B-MW5B 11-23-93	B-MW11B 11-23-93	B-MW15B 11-23-93	B-MW15BD 11-23-93	B-MW19B 11-23-93	B-MW22B 11-23-93	B-MW25B 11-23-93
Benzene	ND	1.8	ND	ND	ND	ND	ND	42	ND	100
Chloroethane	ND	ND	ND	ND	ND	ND	ND	54	ND	240
1,2-Dichloroethane	400	12	80	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	ND	ND	ND	5.4	ND	ND	ND	ND	ND	ND
Toluene	ND	2.4	ND	5.5	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	28	ND	ND	ND	44	ND	ND
Xylene (total)	ND	2.5	ND	ND	ND	ND	ND	ND	ND	ND

Note: ND = Not detected.

Table 2-13
Semi-Volatile Constituent Analytical Results for Monitoring Wells A1-MW20 and A1-MW21 Groundwater
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	A1-MW20	A1-MW21
2-Methylphenol	ND	ND
4-Methylphenol	ND	ND
Acenaphthene	ND	ND
Acenaphthylene	ND	ND
Anthracene	ND	ND
Benzidine	ND	ND
Benzo(a)anthracene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Benzo(ghi)perylene	ND	ND
Benzo(a)pyrene	ND	ND
Bis(2-chloroethoxy)methane	ND	ND
Bis(2-chloroethyl)ether	ND	ND
Bis(2-chloroisopropyl)ether	ND	ND
Bis(2-ethylhexyl)phthalate	9.6 J	1.5 J
4-Bromophenyl phenyl ether	ND	ND
Butyl benzyl phthalate	ND	ND
2-Chloronaphthalene	ND	ND
4-Chlorophenyl phenyl ether	ND	ND
Chrysene	ND	ND
Dibenzo(a,h)anthracene	ND	ND
Di-n-butyl phthalate	ND	ND
1,2-Dichlorobenzene	ND	ND
1,3-Dichlorobenzene	ND	ND
1,4-Dichlorobenzene	ND	ND
3,3'-Dichlorobenzidine	ND	ND
Diethyl phthalate	ND	ND
Dimethyl phthalate	ND	ND
2,4-Dinitrotoluene	ND	ND
2,6-Dinitrotoluene	ND	ND

Notes:

ND = Not detected.

J = Compound detected below quantitiation limit; value estimated.

Table 2-13 (con't)
Semi-Volatile Constituent Analytical Results for Monitoring Wells A1-MW20 and A1-MW21 Groundwater
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	A1-MW20	A1-MW21
Di-n-octyl phthalate	ND	ND
1,2-Diphenylhydrazene	ND	ND
Fluoranthene	ND	ND
Fluorene	ND	ND
Hexachlorobenzene	ND	ND
Hexachlorobutadiene	ND	ND
Hexachlorocyclopentadiene	ND	ND
Hexachloroethane	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND
Isophorone	ND	ND
Naphthalene	ND	ND
Nitrobenzene	ND	ND
N-Nitrosodiphenylamine	ND	ND
N-Nitrosodiphenylamine	ND	ND
N-Nitorosodi-n-propylamine	ND	ND
Phenanthrene	ND	ND
Pyrene	ND	ND
1,2,4-Trichlorobenzene	ND	ND
4-Chloro-3-methylphenol	ND	ND
2-Chlorophenol	ND	ND
2,4-Dichlorophenol	ND	ND
2,4-Dimethylphenol	ND	ND
2,4-Dinitrophenol	ND	ND
4,6-Dinitro-2-methylphenol	ND	ND
2-Nitrophenol	ND	ND
4-Nitrophenol	ND	ND
Pentachlorophenol	ND	ND
Phenol	2.8 J	ND
2,4,6-Trichlorophenol	ND	ND

Notes:

ND = Not detected.

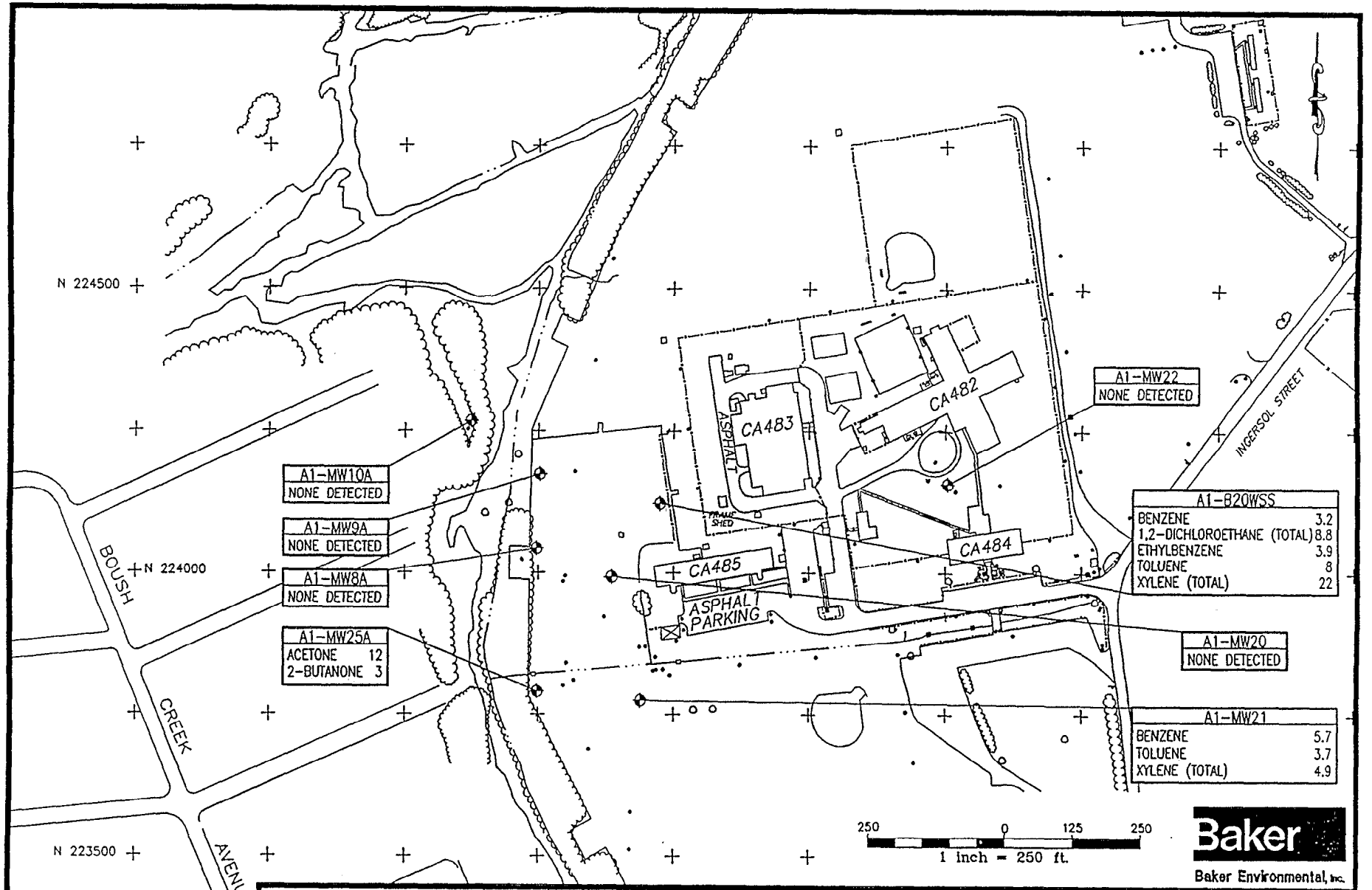
J = Compound detected below quantitiation limit; value estimated.

Table 2-14
Inorganic Constituent Analytical Results for Monitoring Wells A1-MW20 and A1-MW21 Groundwater
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

Parameter		A1-MW20		A1-MW21	
		Total	Dissolved	Total	Dissolved
Inorganics (mg/l)					
Aluminum		58	ND	2.6	ND
Antimony		ND	ND	ND	ND
Arsenic		0.14	0.026	0.022	0.014
Barium		1.9	0.48	0.02	ND
Beryllium		0.009	ND	ND	ND
Cadmium		0.044	ND	ND	ND
Calcium		213	226	106	103
Chromium		0.38	ND	ND	ND
Cobalt		0.055	ND	ND	ND
Copper		0.21	0.014	ND	ND
Iron		56.5	0.12	17.4	9.7
Lead		0.43	ND	ND	ND
Magnesium		438	487	42.4	39.9
Manganese		0.58	0.25	0.4	0.41
Mercury		0.00043	ND	ND	ND
Nickel		0.11	ND	ND	ND
Potassium		168	181	31	30
Selenium		ND	ND	ND	ND
Silver		ND	ND	ND	ND
Sodium		4430	5000	307	292
Thallium		ND	ND	ND	ND
Vanadium		0.23	ND	ND	ND
Zinc		0.85	ND	ND	ND
Others					
pH	(S.U.)	7.4	NA	6.8	NA
Total Suspended Solids	(mg/l)	3100	NA	120	NA
Total Dissolved Solids	(mg/l)	16000	NA	1600	NA
Settleable Solids	(ml/l/hr)	6.5	NA	ND	NA
Alkalinity, Total	(mg/l)	1800	NA	740	NA
Total Organic Carbon	(mg/l)	8	NA	17	NA
Biochemical Oxygen Demand (5-Day)	(mg/l)	13	NA	12	NA

Notes:

NA = Not analyzed.
ND = Not detected.



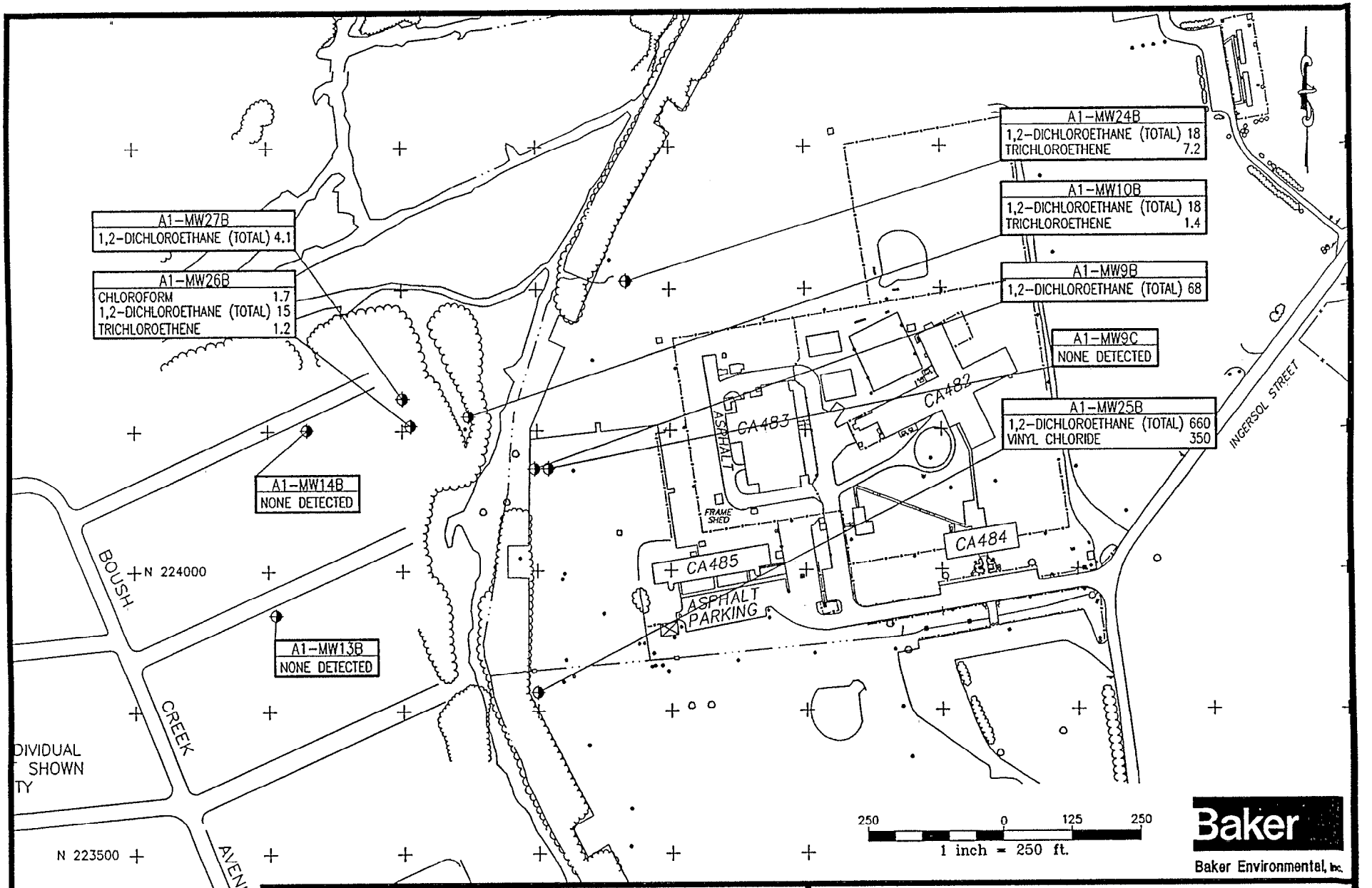
LEGEND

◆ SHALLOW MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

211042WP

FIGURE 2-11
AREA A1 SHALLOW GROUNDWATER MONITORING WELL LOCATIONS & VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

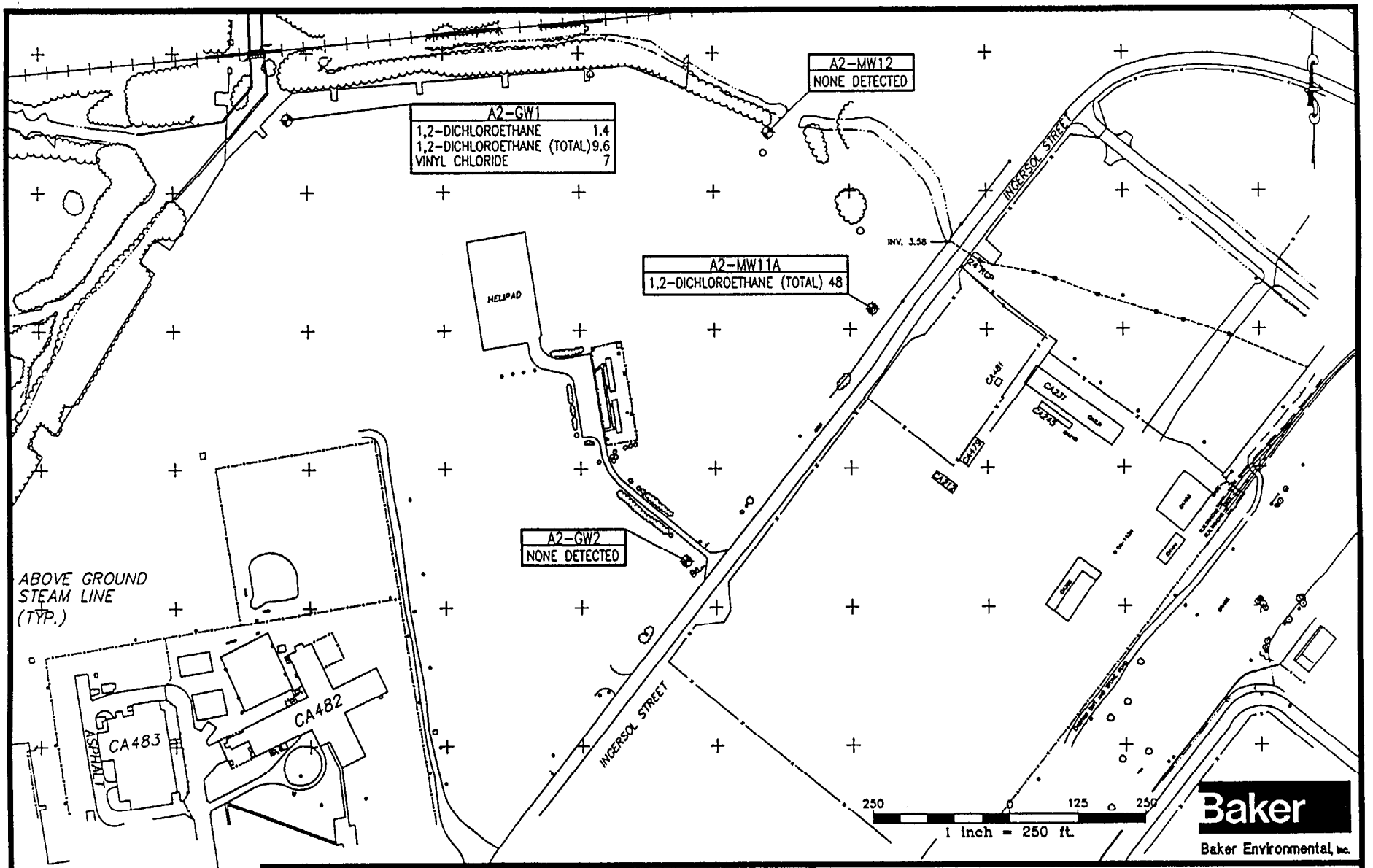
DEEP MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.

SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

211045WP

FIGURE 2-12
AREA A1 DEEP GROUNDWATER MONITORING WELL LOCATIONS & VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

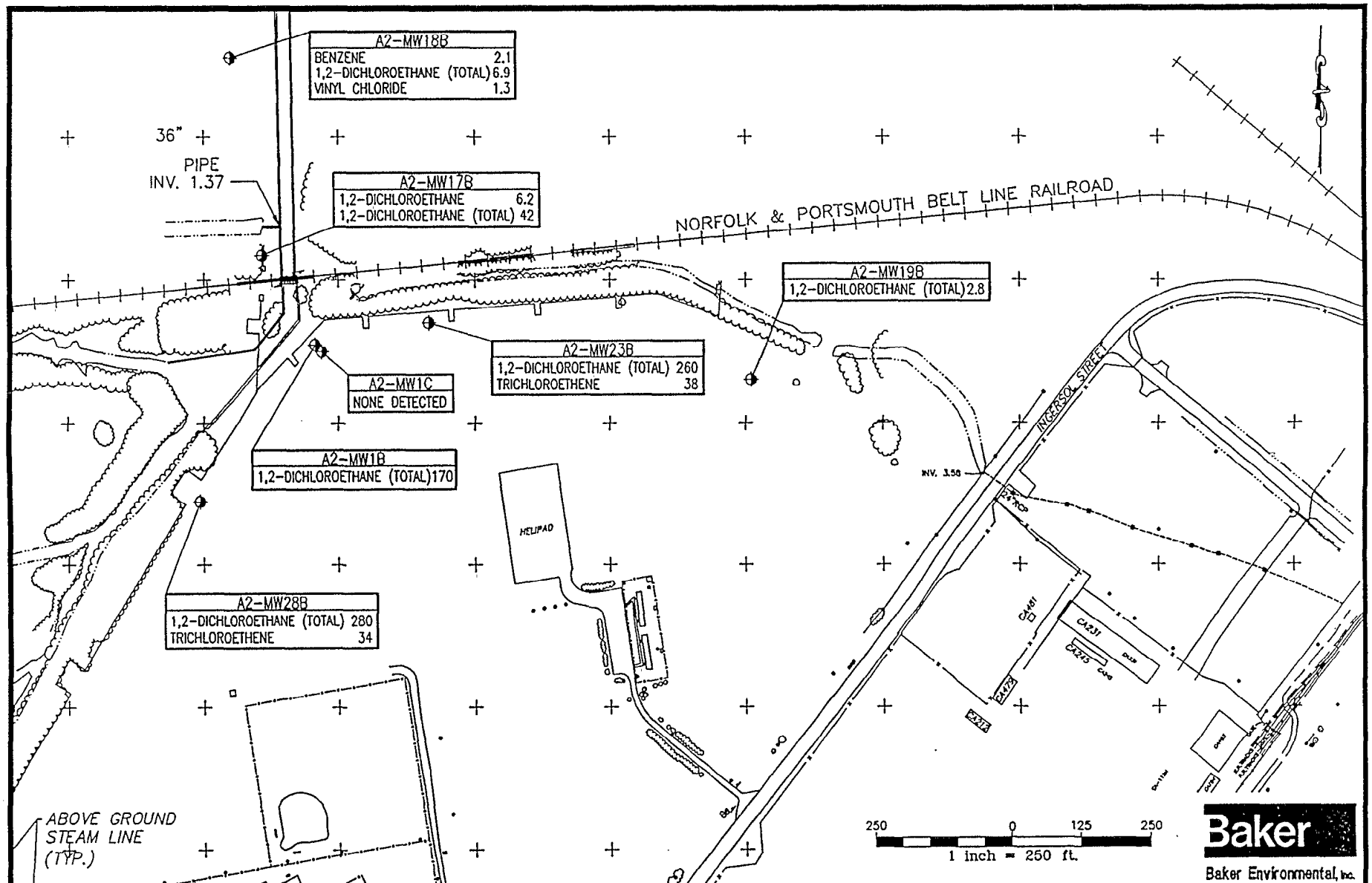
◆ SHALLOW MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.

SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

211043WP

FIGURE 2-13
AREA A2 SHALLOW GROUNDWATER MONITORING WELL LOCATIONS & VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



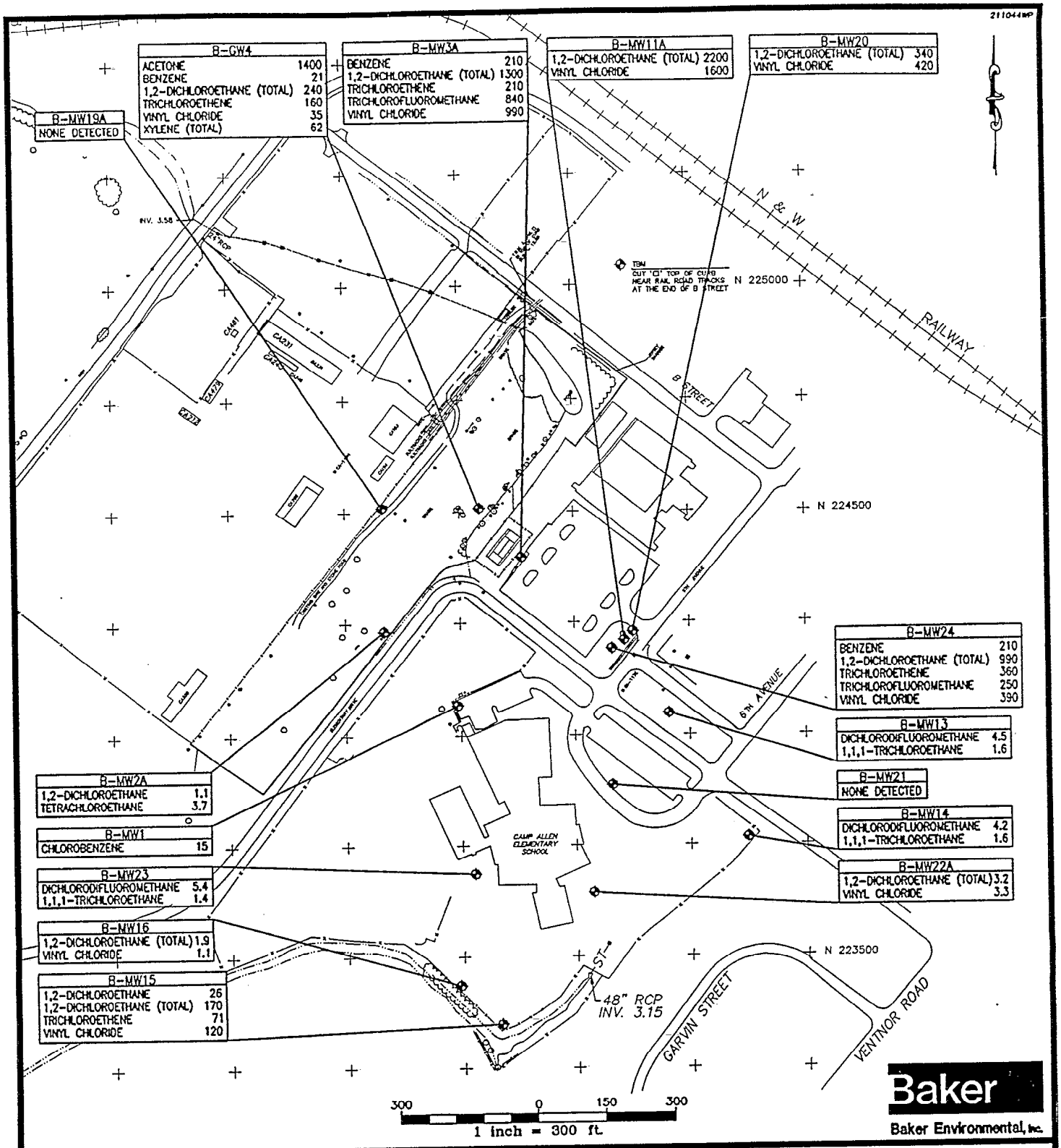
LEGEND

DEEP MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.

SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 2-14
AREA A2 DEEP GROUNDWATER MONITORING WELL LOCATIONS & VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

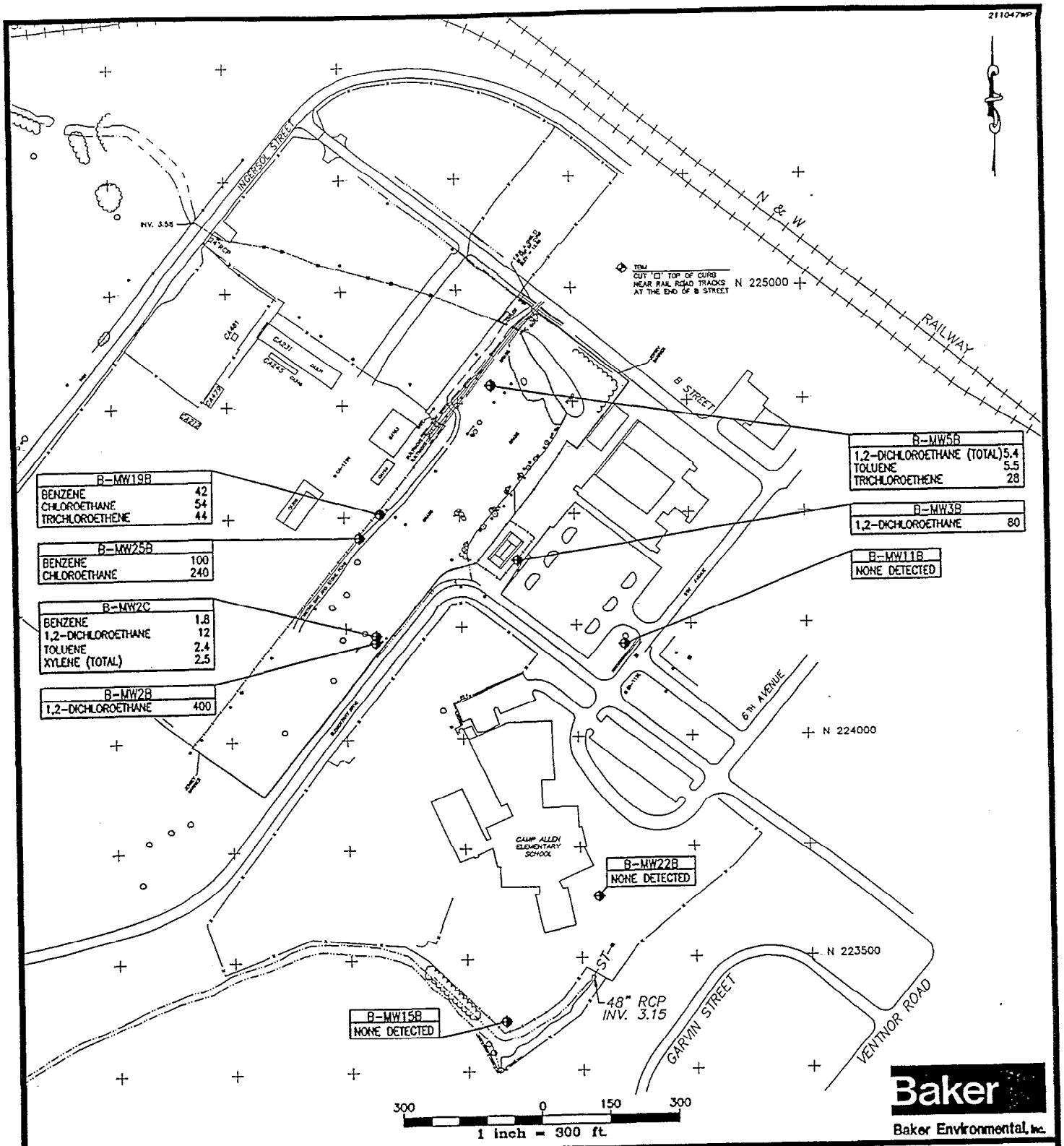


LEGEND

◆ SHALLOW MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 2-15
AREA B SHALLOW GROUNDWATER MONITORING WELL LOCATIONS & VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

◆ DEEP MONITORING WELL

NOTE: ALL CONCENTRATIONS IN ug/L.
SOURCE: MILLER-STEPHENSON & ASSOC. JUNE 1992

FIGURE 2-16
AREA B DEEP GROUNDWATER MONITORING WELL LOCATIONS & VOLATILES RESULTS
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

With respect to Area A2, VOC concentrations detected in the water table and upper Yorktown Aquifers during the predesign investigation (Figures 2-13 and 2-14) were similar to or lower than those observed in sampling rounds 2 and 3. The VOC contamination detected in well A2-MW28B may require the southwestern extent of contamination estimated in the Feasibility Study to be expanded.

Concentrations of VOCs detected in the water table and upper Yorktown Aquifers in Area B during the predesign investigation (Figures 2-15 and 2-16) were also similar to or lower than those observed in sampling rounds 2 and 3. The highest levels of VOCs detected in the shallow aquifer were centered around wells B-GW4, B-MW3A, and B-MW11A and also south of the elementary school in well B-MW15. Analytical results for the wells located along the east and west sides of the school showed sporadic VOC levels in the low part per billion (ppb) range with no clearly defined east/west boundaries of the contaminant plume. As shown in Figure 2-16, contamination was not detected in wells B-MW15B and B-MW22B located south of the elementary school.

2.4 Percolation Tests

After further evaluation, the percolation tests proposed in the Draft Work Plan to test infiltration rates were deleted from the scope of work. Reinfiltration of treated groundwater was determined to be more costly and more difficult to implement and operate at the Camp Allen Landfill than surface water discharge.

2.5 Pumping/Pilot Tests

The on-site pumping/pilot predesign tests were conducted to achieve the following objectives:

- Aquifer hydraulic characterization to confirm, and if necessary, support revisions to the conceptual groundwater extraction system parameters (e.g., pumping rates, well spacings, screen intervals, shallow/deep aquifer interactions) developed during the RI/FS.

- Aquifer chemical characterization to enable a more accurate prediction of the actual groundwater influent characteristics under pumping conditions, which will facilitate design of the most optimum, cost-effective treatment system.

Thus, the pumping/pilot tests were conducted to better characterize the hydraulic and chemical properties of the aquifers. In addition, information to evaluate the performance of the pilot-scale treatment system

was gathered during the tests. Four 3-day (approximately 75 hour) constant rate pumping/pilot tests were originally scheduled to be performed. However, the shallow aquifer test for Area A1 was cancelled because all of the shallow wells in this area (B-20WSS, A1-MW20, and A1-MW21) bailed dry during development and would not sustain a continuous pumping rate. In addition to this change, the Yorktown Aquifer test was shortened to a 1-day (approximately 30 hours) test. This change was a result of a pump failure at pumping station CA-487, to which treated groundwater was discharged, and also a result of a generator malfunction, which was used to power the treatment system (see Section 2.5.2 for treatment system description). In summary, the following tests were conducted in the sequence shown:

- Area B - One 72-hour water table (shallow aquifer) test
- Area B - One 72-hour upper Yorktown test
- Area A1 - One 30-hour upper Yorktown test

To facilitate the pumping/pilot tests, 4-inch groundwater extraction wells were installed in Areas A1 and B, as described in Section 2.3. As described in Section 2.5.1.2, a step-rate test was performed prior to each 3-day constant-rate pumping/pilot test to determine the optimum pumping rate.

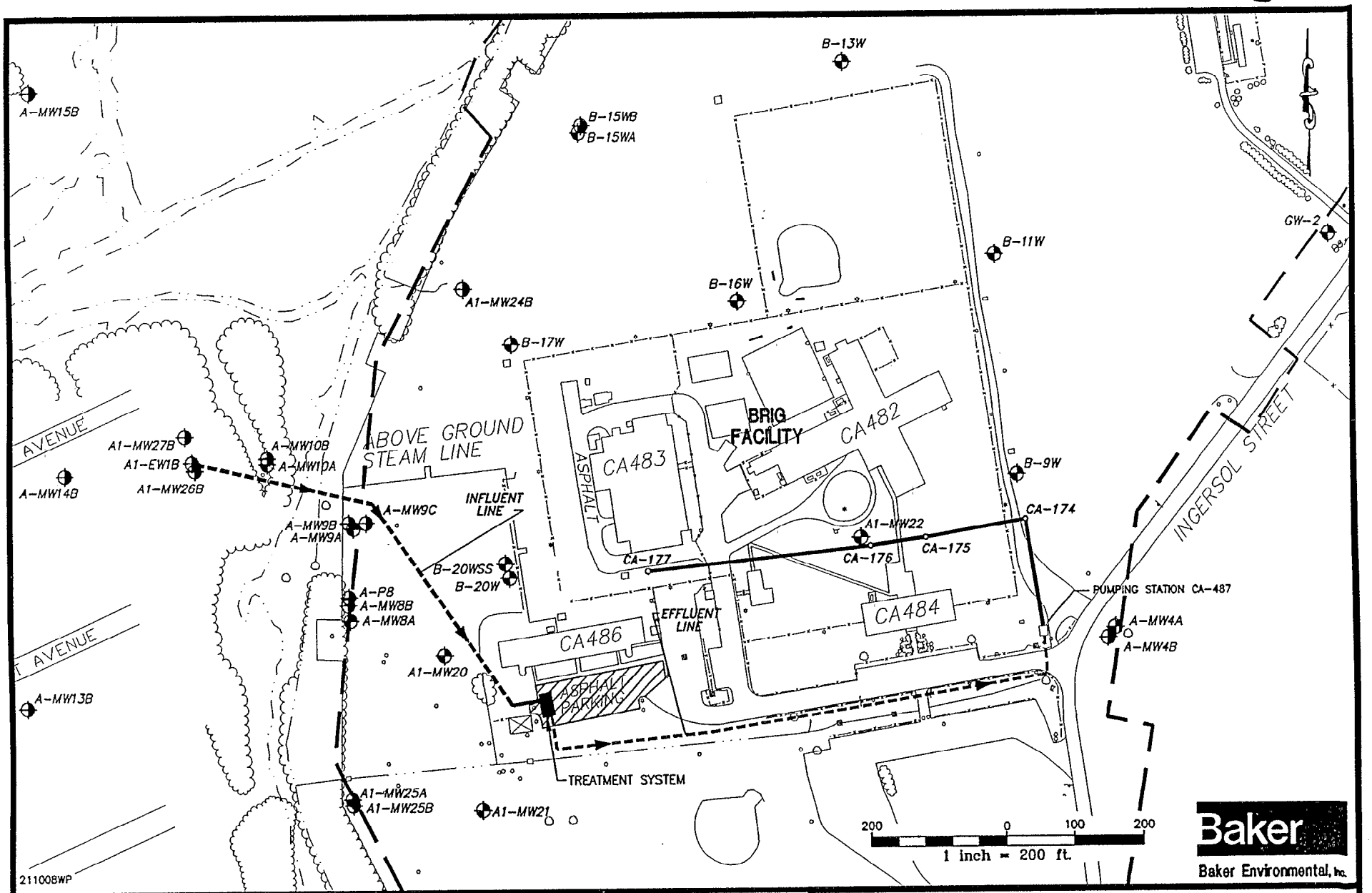
Staging areas for the pumping/pilot tests were set up at Area A1 and Area B, as shown in Figures 2-17 and 2-18, respectively. Staging and operations locations were selected to minimize interference with normal Base traffic and operations. Extracted groundwater was discharged to the sanitary sewer system as shown in Figures 2-17 and 2-18. Extracted groundwater was treated to comply with the pretreatment standards (Part III and Appendix D) of the Hampton Roads Sanitation District (HRSD) using an on-site groundwater treatment system (see Section 2.5.2).

2.5.1 Aquifer Hydraulic Characterization

This section describes the aquifer hydraulic characterization component of the pumping/pilot test program.

2.5.1.1 Report of Activities and Chronologic Log

The field activities comprised: monitoring of static conditions (including both general mapping and trend analysis); test rigging; aquifer tests (with function, initial, step-rate discharge, constant-rate discharge and recovery tests); and the preliminary evaluation of data. The detailed analyses of data were conducted after the field data had been collated and organized for calculation and presentation. The objectives and processes of these activities are described below; the chronologic log is presented in Table 2-15.

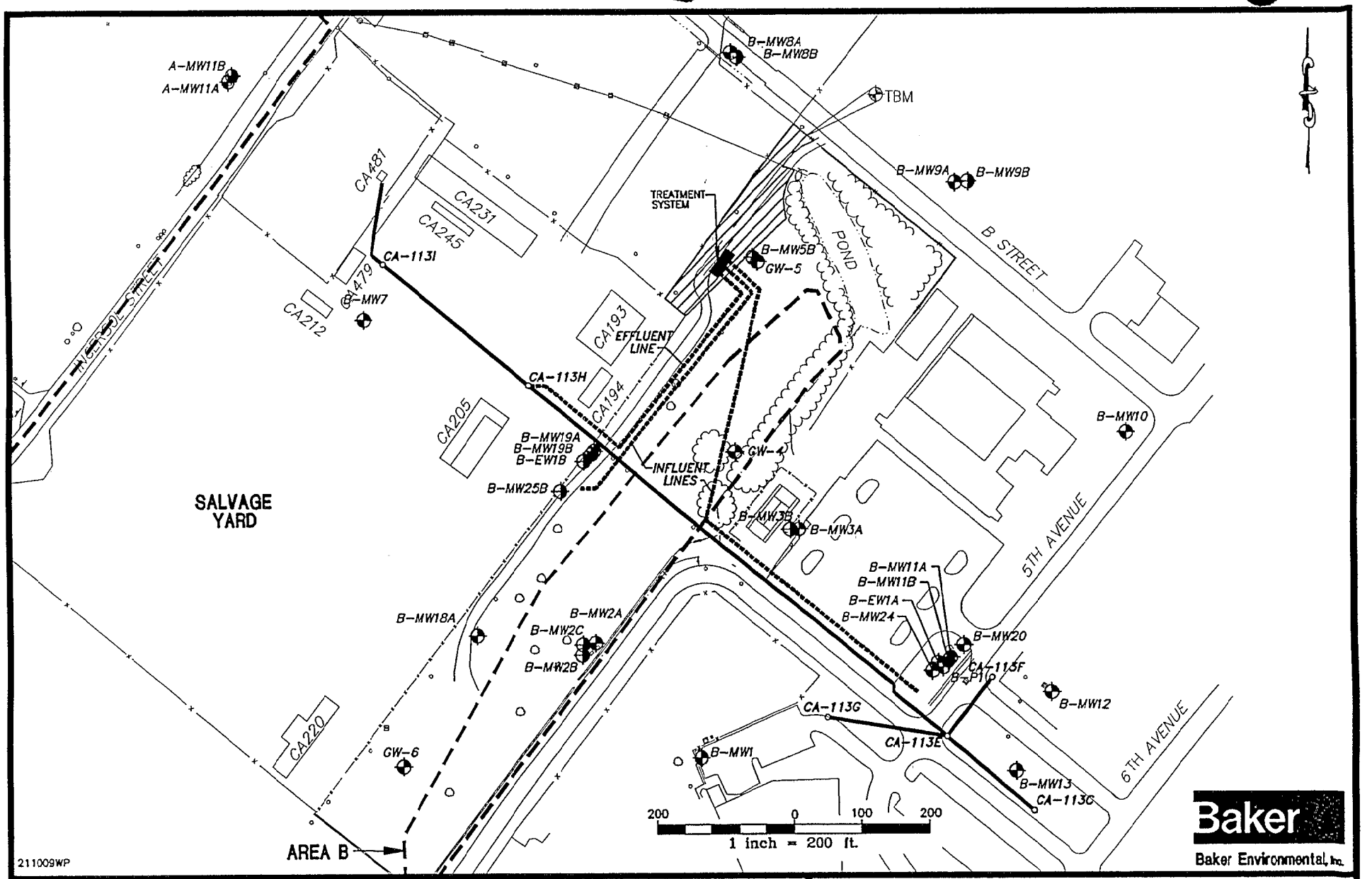


LEGEND

- SHALLOW GROUNDWATER MONITORING WELL LOCATION
- DEEP GROUNDWATER MONITORING WELL LOCATION
- CA-177 MANHOLE
- LIMITS OF AREA A AND AREA B LANDFILL
- STAGING AREA
- SANITARY SEWER LINE

FIGURE 2-17
AREA A1 PUMPING/PILOT TEST
STAGING/OPERATIONS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA



LEGEND

- SHALLOW GROUNDWATER MONITORING WELL LOCATION
- DEEP GROUNDWATER MONITORING WELL LOCATION
- CA-177 MANHOLE
- LIMITS OF AREA A AND AREA B LANDFILL
- STAGING AREA
- SANITARY SEWER LINE

FIGURE 2-18
AREA B PUMPING/PILOT TEST
STAGING/OPERATIONS
CAMP ALLEN LANDFILL

NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

TABLE 2-15

CHRONOLOGIC LOG
FIELD ACTIVITIES
NOVEMBER 28 - DECEMBER 22, 1993

Date	Activity	
November 28, 1993	Operations briefing	
November 29, 1993	B-EW1A	Step-discharge test General water level measurements - Morning
November 30, 1993	B-EW1A	Step-discharge test
December 1, 1993	B-EW1A	Begin constant-rate discharge test DTG/0112001293R General water level measurements - Afternoon
December 2, 1993	B-EW1A	Continue test
December 3, 1993	B-EW1A	Continue test General water level measurements - Morning
December 4, 1993	B-EW1A	End constant-rate discharge test Recovery test DTG/0412301293R General water level measurements - Morning
December 5, 1993	Data evaluation General water level measurements - Morning	
December 6, 1993	Data evaluation General water level measurements - Noon General water level measurements - Afternoon	
December 7, 1993	B-EW1B	Rig for test General water level measurements - Morning General water level measurements - Afternoon
December 8, 1993	B-EW1B	Function test General water level measurements - Noon
December 9, 1993	Off site	
December 10, 1993	Off site	
December 11, 1993	Off site	
December 12, 1993	Static monitoring	
December 13, 1993	B-EW1B	Initial test - begin constant-rate discharge test - DTG/1314001293R General water level measurements - Morning General water level measurements - Afternoon
December 14, 1993	B-EW1B	Continue test General water level measurements - Morning

TABLE 2-15 (Continued)

CHRONOLOGIC LOG
FIELD ACTIVITIES
NOVEMBER 28 - DECEMBER 22, 1993

Date	Activity	
December 15, 1993	B-EW1B	Continue test - detailed briefing for Activity Representative General water level measurements - Morning General water level measurements - Afternoon
December 16, 1993	B-EW1B	End constant-rate discharge test Recovery test DTG/1614301293R Reposition treatment plant General water level measurements - Noon
December 17, 1993	A1-EW1B	Function test General water level measurements - Morning
December 18, 1993	A1-EW1B	Constant-rate discharge test delayed by Station Public Works Center General water level measurements - Morning
December 19, 1993	A1-EW1B	Begin constant-rate discharge test - DTG/1909001293R General water level measurements - Noon
December 20, 1993	A1-EW1B	Treatment plant failure - end constant-rate discharge test Recovery test DTG/2014301293R General water level measurements - Noon General water level measurements - Afternoon
December 21, 1993	Data evaluation - demobilization General water level measurements - Afternoon General water level measurements - Noon	
December 22, 1993	Data evaluation - demobilization	

Monitoring of Static Conditions

Part of the general monitoring of static conditions involved mapping of the water table in the upper water-bearing layer, and of the potentiometric surfaces of the Upper and Lower Yorktown Aquifer. The general measurements of static conditions examined the accessible wells of each area, dividing the wells at each well by interception interval (water table, Upper Yorktown or Lower Yorktown). The plan locations of the wells are shown in Figures 2-7 (Area A1; water table), 2-8 (Area A1; upper and lower Yorktown), 2-9 (Area B; water table) and 2-10 (Area B; upper and lower Yorktown).

The monitoring of static trends assessed the natural variations in the elevations of the water table, and of the potentiometric surfaces of the upper and lower Yorktown Aquifer. These natural variations would be subsumed in the changes later caused by the artificial stresses of the aquifer tests. Interferences from the natural variations could be misinterpreted as responses to the test stresses. Analysis of the static monitoring data allowed the influences of these natural variations to be neglected during calculation of the aquifer parameters.

The general measurements of static conditions were made manually for each operations area within the shortest time available. The monitoring for trend analysis was made by automatic logger, set on 30-minute intervals.

Test Rigging

Rigging for each test (wells B-EW1A, B-EW1B and A1-EW1B) involved setting the pump, the discharge line, the flow measurement devices, the flow control devices, the effluent line, and the sensors and data-loggers at selected wells. A treatment plant was also set for temporary operation to condition the test discharge to acceptable standards prior to approved disposal in a sanitary sewer.

Aquifer Tests

The aquifer tests were conducted in several stages: Function tests (wells A1-EW1B and B-EW1B); an initial test (well B-EW1B); a step-rate discharge test (well B-EW1A); and constant-rate discharge and recovery tests (wells A1-EW1B, B-EW1A and B-EW1B).

The function tests were multiple and of short duration (less than five minutes); they primarily examined the operation of the various components of the test equipment. A part of these tests was the initial flooding of treatment system to prevent surge-loading at the start of extended production; water from the function tests was pumped over a short period into a header tank at a high rate and then into the treatment plant at a low rate over a longer period. Data were, however, reviewed to provide estimation of the expectable performance of the production well.

The initial test also used short duration pumping. This procedure followed the function test of well B-EW1B and also allowed an estimation of expectable performance during production. This test, however, was used primarily to refill the treatment system after the stand-down period of four days following the function tests of this well.

The step-rate discharge test was conducted prior to starting the main test of well B-EW1A. This step-test varied pumpage of well B-EW1A to aid in selecting the nominal production for the constant-rate discharge test.

The constant-rate discharge tests involved production at a constant rate (within 10% variation) for: A1-EW1B at 1780 minutes; B-EW1A at 4350 minutes; and, B-EW1B at 4350 minutes. (Note: Well A1-EW1A was neglected from all testing due to extremely poor performance on initial development.)

The recovery tests immediately followed shutdown of the constant-rate discharge test for a period of less than 2000 minutes for each well.

Preliminary Evaluation of Data

During each test phase, production performance was monitored, and the aquifer response was analyzed for preliminary calculation of parameters, for control of testing, and for planning of the recovery test (for example, monitoring was switched from unresponsive wells for the recovery of wells B-EW1B, B-MW3B, and B-MW5B). The procedures of the preliminary evaluation included: identifying responding wells; estimating the available drawdown remaining in the production well; and calculating the test trends by variations of the Jacob, Boulton and Hantush methods used in the parametric analysis of aquifer characteristics.

Detailed Analyses

As part of the basis of design task, detailed analyses of the aquifer test and water level data will be performed which will include: construction of representative maps of the water table and potentiometric surfaces; calculation of regional gradients for the water table and upper Yorktown Aquifers; assessment of the responses of the water-bearing layers to precipitation and to tides; an examination of head-differences between the layers; parametric characterization of the hydraulic and hydrologic regimes of the water table and upper Yorktown Aquifers; and an examination of hydraulic connections between layers. These evaluations will support design of groundwater extraction systems for Areas A1 and B, as described in Section 4.2.1.

2.5.2 Aquifer Chemical Characterization

In addition to aquifer hydraulic characterization, the other objective of the pumping/pilot tests was to obtain chemical characteristics of the groundwater under continuous pumping conditions. Of particular interest were the concentrations of total suspended and dissolved solids as well as "nuisance" metals, such as iron and manganese. The concentrations of these engineering parameters, which varied significantly from well to well during previous sampling rounds, affect the type of pretreatment needed for the organics groundwater treatment system. In addition to the solids and metals data, the pumping/pilot tests have provided VOC and semi-volatile contaminant data collected under sustained pumping conditions as well as data needed to evaluate compliance with Federal and State surface water discharge regulations, such as biochemical oxygen demand (BOD). During each test, influent and effluent samples were periodically collected and analyzed by an off-site laboratory for the following parameters:

Influent

- VOCs
- Semivolatiles
- TAL Metals (Total)
- TAL Metals (Dissolved)
- Total Suspended Solids (TSS)
- Total Dissolved Solids (TDS)
- Settleable Solids
- Total Organic Carbon (TOC)
- 5-Day Biochemical Oxygen Demand (BOD_5)
- pH
- Alkalinity (as $CaCO_3$)

Effluent

- Semivolatiles
- TAL Metals (Total)
- TAL Metals (Dissolved)
- TOC
- BOD_5
- pH

A groundwater treatment system was used to reduce contaminant levels in the water table aquifer in Areas A1 and B below the HRSD pretreatment standards. Contaminant levels in the upper Yorktown Aquifer in Areas A1 and B from previous sampling rounds were below the HRSD pretreatment standards, however, this water also was treated to obtain a further reduction in contaminant levels prior to discharge. The HRSD pretreatment standards are as follows:

CONTAMINANT	DISCHARGE LIMIT (mg/L)
BTEX [1]	1.0
1,2-DCE	1.0
Arsenic	0.1
Lead	1.0
Chromium	2.0
Cadmium	0.1
Zinc	2.0
Acetone	3.0 [2]
Total Toxic Organics	2.13 [3]

(1) Benzene, toluene, ethylbenzene, and xylene.
(2) Established for the water table aquifer based on a maximum flow rate of 15 gpm and 3-day duration.
(3) With no single organic exceeding 1.0 mg/L per 40 CFR 433.11(e).

The groundwater treatment system consisted of the following unit processes:

- Filtration (disposable cartridge type)
- Air Stripping
- Carbon Adsorption

The groundwater treatment system was selected to meet the HRSD pretreatment requirements using the simplest operation at the lowest possible cost. The filtration system was used to remove suspended solids from the groundwater to prevent clogging of the air stripper and carbon units. The air stripper and carbon adsorption system effectively removed the organic contaminants of concern. Based on air emission calculations that indicated that air stripper emissions would be well below the Virginia Emission Standards for Toxic Pollutants, written permission was received from the Virginia Department of Environmental

Quality (DEQ) to discharge air stripper off-gas without treatment (November 16, 1993 correspondence from Ms. Michele Monti, VA DEQ to Mr. Kenneth Walker, LANTDIV Code 1822). To ensure that the treatment system would effectively reduce contaminant concentrations below the HRSD pretreatment standards during the 3-day water table aquifer constant rate tests, each extraction well was sampled and analyzed before initiation of the tests to determine influent contaminant concentrations. Prior to the start of each test, the analytical results were forwarded to HRSD for their review and approval to begin the test.

Schematics of the treatment systems used for the shallow and Yorktown Aquifer tests are shown in Figures 2-19 and 2-20, respectively. As shown in these figures, for the Yorktown Aquifer tests, an identical parallel treatment process was added to the treatment system to provide additional capacity needed for the higher Yorktown Aquifer flowrate. The air strippers used in the treatment system were shallow tray-style strippers consisting of two trays and equipped with one horsepower, 625 cubic feet per minute (CFM) air blowers. The activated carbon units each contained 800 pounds of carbon. Following completion of the Area B Yorktown Aquifer test, the lead carbon units were replaced with new units as a precautionary measure to ensure compliance with HRSD pretreatment standards.

Influent samples were collected every 24 hours (i.e., after 24, 48, and 72 hours) and analyzed for the above parameters, with the exception of settleable solids, alkalinity, and biochemical oxygen demand, for which only the 72-hour samples were analyzed. The analytical method for each parameter is provided in Section 3.3.5.2 in the Sampling and Analysis Plan. Effluent samples were collected every 24 hours and analyzed on a 24-hour turnaround basis for VOCs (EPA Method 601/602) to determine treatment system performance (i.e., carbon breakthrough) and compliance with HRSD pretreatment standards. The effluent samples were collected from a sampling port located between the carbon units and from a sampling port on the final effluent (i.e., after all carbon units). Results of the effluent sampling indicated that carbon breakthrough did not occur during the pumping/pilot tests. Analytical VOC results for all of the effluent samples (provided in Appendix E) were below detection limits.

The analytical results for samples collected during the pilot/pumping tests are provided in Tables 2-16 through 2-18. As part of the basis of design task (see Section 4.2), these data will be compiled and evaluated along with the groundwater monitoring results. Following development of groundwater extraction rates, flow-weighted averages will be calculated for the inorganic and organic constituents as well as for the solids data, which will be presented in the Basis of Design section of the design package. This information will be used to estimate influent concentrations to the groundwater treatment system, on which the selection and design of the treatment system components will be based.

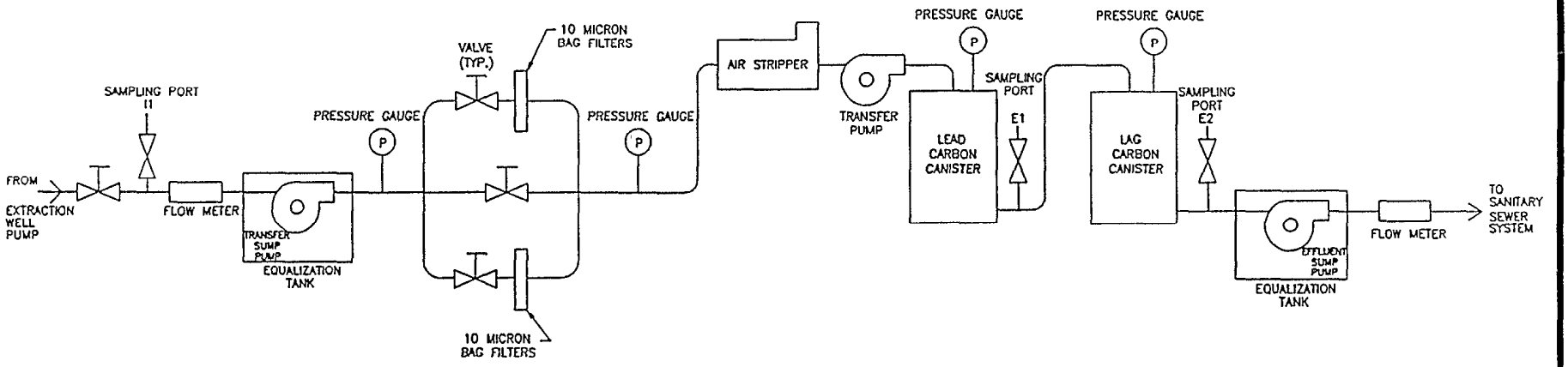


FIGURE 2-19
SHALLOW AQUIFER TEST
PUMPING/PILOT TEST TREATMENT SYSTEM
SCHEMATIC
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

211302WP

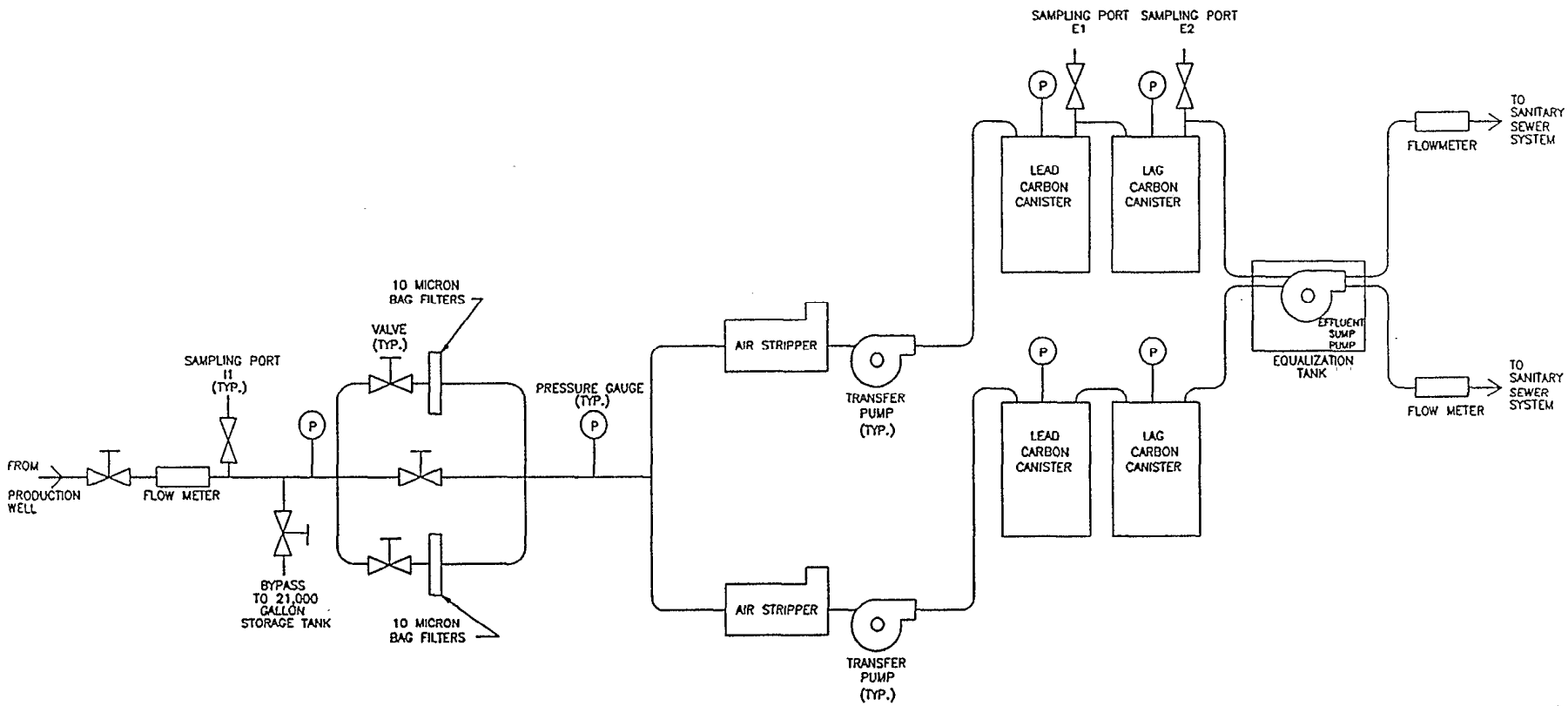


FIGURE 2-20
YORKTOWN AQUIFER TEST
PUMPING/PILOT TEST TREATMENT SYSTEM
SCHEMATIC
CAMP ALLEN LANDFILL
NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

211303WP

Table 2-16
Pilot Test Analytical Results: Volatile Organics
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	Area A1 - Yorktown Aquifer			
	24 Hr Sample	30 Hr Samples		
	A1-IN102D	A1-IN103D	A1-EF103D	A1-EF203D
Acetone	ND	ND	ND	ND
Acrolein	ND	ND	ND	ND
Acrylonitrile	ND	ND	ND	ND
Benzene	ND	ND	ND	ND
Bromodichloromethane	ND	ND	ND	ND
Bromoform	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND
2-Chloroethyl vinyl ether	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND
1,2-Dichloroethane	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND
1,2-Dichloroethene (total)	15	13	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND
cis-1,3-Dichloropropene	ND	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND
4-Methyl-2-Pentanone	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND
Toluene	ND	2.3 J	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND
Trichloroethene	2.1 J	ND	ND	ND
Trichlorofluoromethane	ND	ND	ND	ND
Vinyl Chloride	ND	ND	ND	ND
Xylene (total)	ND	2.1 J	ND	ND

Notes:

ND = Not detected.
J = Compound detected below quantitation limit; value estimated.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

Table 2-16 (con't)
Pilot Test Analytical Results: Volatile Organics
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	Area B - Shallow Aquifer			
	24 Hr Sample	48 Hr Sample	72 Hr Samples	
	B-IN102S	B-IN103S	B-IN104S	B-IN204S
Acetone	ND	ND	ND	ND
Acrolein	ND	ND	ND	ND
Acrylonitrile	ND	ND	ND	ND
Benzene	110	110	100	100
Bromodichloromethane	ND	ND	ND	ND
Bromoform	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND
2-Chloroethyl vinyl ether	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND
1,2-Dichlorobenzene	28 J	24 J	21 J	18 J
1,3-Dichlorobenzene	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND
1,1-Dichloroethane	33 J	ND	26 J	25 J
1,2-Dichloroethane	72	72	73	73
1,1-Dichloroethene	ND	ND	ND	ND
1,2-Dichloroethene (total)	1100	980	880	880
1,2-Dichloropropane	ND	ND	ND	ND
cis-1,3-Dichloropropene	ND	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND
Methylene Chloride	ND	ND	ND	ND
4-Methyl-2-Pentanone	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND
Toluene	ND	ND	ND	37
1,1,1-Trichloroethane	ND	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND
Trichloroethene	180	170	160	160
Trichlorofluoromethane	160	170	180	160
Vinyl Chloride	1200	1300	930	890
Xylene (total)	ND	ND	ND	61

Notes:

ND = Not detected.
J = Compound detected below quantitation limit; value estimated.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

Table 2-16 (con't)
Pilot Test Analytical Results: Volatile Organics
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	Area B - Yorktown Aquifer		
	24 Hr Sample	48 Hr Sample	72 Hr Sample
	B-IN102D	B-IN103D	B-IN104D
Acetone	ND	ND	ND
Acrolein	ND	ND	ND
Acrylonitrile	ND	ND	ND
Benzene	210	220	210
Bromodichloromethane	ND	ND	ND
Bromoform	ND	ND	ND
Bromomethane	ND	ND	ND
Carbon Tetrachloride	ND	ND	ND
Chlorobenzene	ND	ND	ND
Chlorobenzene	ND	ND	ND
Chloroethane	ND	ND	ND
2-Chloroethyl vinyl ether	ND	ND	ND
Chloroform	ND	ND	ND
Chloromethane	ND	ND	ND
Dibromochloromethane	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND
1,1-Dichloroethane	9.6 J	9.4	8.5
1,2-Dichloroethane	16	17	18
1,1-Dichloroethene	ND	ND	ND
1,2-Dichloroethene (total)	65	66	63
1,2-Dichloropropane	ND	ND	ND
cis-1,3-Dichloropropene	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND
Ethylbenzene	ND	ND	ND
Methylene Chloride	4.1 J	ND	4.1 J
4-Methyl-2-Pentanone	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND
Tetrachloroethene	ND	ND	ND
Toluene	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND
Trichloroethene	190	200	210
Trichlorofluoromethane	ND	ND	ND
Vinyl Chloride	ND	ND	ND
Xylene (total)	ND	ND	ND

Notes:

ND = Not detected.
J = Compound detected below quantitation limit; value estimated.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

Table 2-17
Pilot Test Analytical Results: Semi-Volatile Organics
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	Area A1 - Yorktown	Area B - Shallow Aquifer									Area B - Yorktown Aquifer			
	24 Hr Sample	24 Hr Samples			48 Hr Samples			72 Hr Samples			24 Hr Sample	48 Hr Sample	72 Hr Sample	
	A1-IN102D	B-IN102S	B-EF102S	B-EF202S	B-IN103S	B-EF103S	B-EF203S	B-IN104S	B-EF104S	B-EF204S	B-IN102D	B-IN103D	B-IN104D	B-EF204D
2-Methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	ND	1.2 J	ND	ND	1.6 J	ND	ND	1.9 J	ND	ND	ND	ND	ND	ND
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(ghi)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-chloroethoxy)methane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-chloroethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(2-chloroisopropyl)ether	ND	ND	ND	ND	ND	ND	1.9 J	ND	ND	1.1 J	ND	ND	ND	ND
Bis(2-ethylhexyl)phthalate	ND	ND	1.2 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Bromophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butyl benzyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Chlorophenyl phenyl ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-butyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	19	ND	ND	18	ND	ND	16	ND	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	3.6 J	ND	ND	3.3 J	ND	ND	3 J	ND	ND	ND	ND	ND	ND
3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

ND = Not detected.
J = Compound detected below quantitation limit; value estimated.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

Table 2-17 (con't)
Pilot Test Analytical Results: Semi-Volatile Organics
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia
(all values in units of ug/l)

Parameter	Area A1 - Yorktown	Area B - Shallow Aquifer									Area B - Yorktown Aquifer			
	24 Hr Sample	24 Hr Samples			48 Hr Samples			72 Hr Samples			24 Hr Sample	48 Hr Sample	72 Hr Sample	
	A1-IN102D	B-IN102S	B-EF102S	B-EF202S	B-IN103S	B-EF103S	B-EF203S	B-IN104S	B-EF104S	B-EF204S	B-IN102D	B-IN103D	B-IN104D	B-EF204D
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octyl phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Diphenylhydrazene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	2.1 J	ND	ND	2 J	ND	ND	1.9 J	ND	ND	ND	ND	ND	ND
Nitrobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodimethylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodi-n-propylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	1.4 J	ND	ND	1.3 J	ND	ND	1.7 J	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

ND = Not detected.
J = Compound detected below quantitation limit; value estimated.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

Table 2-18

Pilot Study Analytical Results: Inorganics and Engineering Parameters

Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

Parameter	Area A1 - Yorktown Aquifer		Area B - Shallow Aquifer							
	A1-IN102D		B-IN102S		B-IN103S		B-IN104S		B-EF204S	
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Metals (mg/l)										
Aluminum	ND	ND	ND	ND	ND	ND	ND	ND	2.2	ND
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	0.033	0.033	0.034	0.034	0.045	0.04	0.018	0.015
Barium	0.036	0.037	0.059	0.057	0.058	0.06	0.057	0.059	0.064	0.02
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium	178	181	45	44	44.4	46.5	43.5	44	49.4	52.2
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	ND	ND	ND	ND	0.032	ND	0.046	0.012	0.063	ND
Iron	0.91	0.44	57.4	54.8	56.5	57.9	55.3	54.2	11.1	ND
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium	5.6	6.4	30.7	29.9	28.3	30	27.3	26.8	26.9	29.4
Manganese	0.24	0.24	0.8	0.77	0.78	0.82	0.76	0.76	0.18	0.13
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potassium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	164	171	45.1	43.7	41.5	44.2	42.2	40	39.2	42
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	ND	ND	0.15	0.11	0.15	0.13	0.16	0.15	0.11	ND
Others										
pH (S.U.)	7.3	NA	5.9	NA	6	NA	5.8	NA	8.1	NA
Total Suspended Solids (mg/l)	ND	NA	15	NA	23	NA	17	NA	NA	NA
Total Dissolved Solids (mg/l)	1100	NA	480	NA	510	NA	480	NA	NA	NA
Settleable Solids (ml/l/hr)	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA
Alkalinity, Total (mg/l)	NA	NA	NA	NA	NA	NA	150	NA	NA	NA
Total Organic Carbon (mg/l)	ND	NA	10	NA	9	NA	10	NA	1	NA
Biochemical Oxygen Demand (5-Day) (mg/l)	NA	NA	NA	NA	NA	NA	3	NA	ND	NA

Notes:

NA = Not analyzed.
ND = Not detected.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

Table 2-18 (con't)
Pilot Study Analytical Results: Inorganics and Engineering Parameters
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

Parameter		Area B - Yorktown Aquifer							
		B-IN102D		B-IN103D		B-IN104D		B-EF204D	
		Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Metals (mg/l)									
Aluminum		ND	ND	ND	ND	ND	ND	ND	ND
Antimony		ND	ND	ND	ND	ND	ND	ND	ND
Arsenic		ND	ND	ND	ND	ND	ND	ND	ND
Barium		0.05	0.052	0.045	0.038	0.039	0.039	0.042	0.04
Beryllium		ND	ND	ND	ND	ND	ND	ND	ND
Cadmium		ND	ND	ND	ND	ND	ND	ND	ND
Calcium		210	221	203	181	185	181	194	191
Chromium		ND	ND	0.034	ND	ND	ND	ND	ND
Cobalt		ND	ND	ND	ND	ND	ND	ND	ND
Copper		ND	ND	ND	ND	0.1	ND	ND	ND
Iron		6.9	6.4	6.8	4.5	6.3	4.2	0.068	0.066
Lead		ND	ND	ND	ND	ND	ND	ND	ND
Magnesium		11.6	12.2	11.5	10.3	11.1	11.2	11.6	11.4
Manganese		0.34	0.36	0.33	0.29	0.31	0.3	0.28	0.27
Mercury		ND	ND	ND	ND	ND	ND	ND	ND
Nickel		ND	ND	ND	ND	ND	ND	ND	ND
Potassium		ND	ND	ND	ND	ND	ND	ND	ND
Selenium		ND	ND	ND	ND	ND	ND	ND	ND
Silver		ND	ND	ND	ND	ND	ND	ND	ND
Sodium		160	169	160	142	151	152	156	154
Thallium		ND	ND	ND	ND	ND	ND	ND	ND
Vanadium		ND	ND	ND	ND	ND	ND	ND	ND
Zinc		ND	ND	ND	ND	ND	ND	ND	ND
Others									
pH	(S.U.)	6.8	NA	7	NA	6.9	NA	7.2	NA
Total Suspended Solids	(mg/l)	ND	NA	13	NA	ND	NA	NA	NA
Total Dissolved Solids	(mg/l)	1300	NA	1200	NA	1100	NA	NA	NA
Settleable Solids	(ml/l/hr)	NA	NA	NA	NA	ND	NA	NA	NA
Alkalinity, Total	(mg/l)	NA	NA	NA	NA	150	NA	NA	NA
Total Organic Carbon	(mg/l)	2	NA	ND	NA	ND	NA	ND	NA
Biochemical Oxygen Demand (5-Day)	(mg/l)	NA	NA	NA	NA	ND	NA	2	NA

Notes:

NA = Not analyzed.
ND = Not detected.
IN1 = Influent sample before air stripper
IN2 = Influent sample after air stripper
EF1 = Effluent sample after lead carbon unit
EF2 = Effluent sample after lag carbon unit

APPENDIX B - SOIL CLEANUP GOALS DEVELOPMENT

APPENDIX B
SOIL CLEANUP GOALS DEVELOPMENT

Attachment I

POTENTIAL CONTAMINANT LEACHING

The potential concentration of a contaminant in source area soil leachate eminating from the unsaturated zone was estimated using a one-dimensional advective transport model described by Summers et. al (USEPA 1980). The Summers model utilizes a saturated flow equation to approximate flow in the unsaturated zone. The governing equation describing one dimensional advective transport with dispersion and adsorption is:

$$D \frac{\delta^2 c}{\delta z^2} - V_s \frac{\delta c}{\delta z} = \frac{\delta c}{\delta t} + \left(\frac{1}{s}\right) \frac{\delta n}{\delta t}$$

Where:

c = contaminant concentration in the fluid stream

n = amount of contaminant adsorbed by the soil

V_s = the seepage velocity of leachate through soil

t = time

z = depth of the unsaturated soil column

D = the dispersion coefficient

s = the fractional soil voids volume

The terms in the governing equation represent, from left to right, transport because of dispersion, transport associated with advection, the time rate of change in contaminant concentration and the last term describes contaminant adsorption by the soil matrix. The n term is derived by multiplying c by an emperically derived adsorption coefficient (k). The use of a linear estimate of n implies that the assumption of equilibrium exists between solute in leachate and adsorbed solute. This approximation approaches actual adsorption conditions when typically unsaturated soils are saturated during precipitation events or when seepage velocities are low. When n = kc the general solution for the governing equation becomes:

$$\frac{C(z,t)}{Co} = \frac{1}{2}\left[1 + erf\left(\frac{R - y}{(4\ RyS)^{0.5}}\right) + e^{1/s}\ erfc\left(\frac{R + y}{(4\ RyS)^{0.5}}\right)\right]$$

Where:

$C_{(z,t)}$ = the contaminant concentration at depth z, and time t

C_o = initial contaminant concentration at z = 0

y = a dimensionless adsorption factor

R = a dimensionless time variable

S = a dimensionless mixing factor

z = distance to the saturated zone

erf(x) = the error function of x

erfc(x) = the complementary error function

If dispersion is considered negligable with respect to seepage velocity, the following equation is used:

$$\frac{C(z,t)}{C_o} = \frac{1}{2}\left[1 + erf\left(\frac{R-y}{(4RyS)^{0.5}}\right)\right]$$

This equation was used to calculate leachate concentrations at specific depths below the surface. The initial concentration term, C_o, was modified to account for source strength decay using the following equation:

$$C = C_o * e^{-kt}$$

Where:

k = source decay factor

Source decay was assumed to be equivalent to the thirty year time frame for soil treatability.

A spreadsheet based Summers model was developed to determine the potential soil cleanup goal protective of leaching to the saturated zone under the influence of infiltrating precipitation. Spreadsheet output is presented in Attatchment II. Mixing in the shallow zone was also considered in the form of a mass balance equation, however, relatively low estimates of seepage velocity and the limited thickness of the shallow aquifer does not provide significant dilution for either area A1 or A2. Therefore, mass balance mixing in the shallow aquifer is only presented on the first Attatchment II spreadsheet.

Modeling Inputs

The general input data for the spreadsheet included contaminant characteristics, unsaturated zone characteristics, hydrogeological properties of the shallow aquifer and annual precipitation data. Site specific data were obtained from the most recent RI report. Site data not available in the RI was obtained from USEPA source documents.

The model was used to predict potential leaching over a ten year duration. A source area decay value of 30 years was used to represent the amount of time necessary for the completion of potential remediation activities. Table A1-1 presents the modeling inputs and their respective sources used in the spreadsheet calculation of soils cleanup goals.

Table A1-1
Inputs to the Summers Model
Camp Allen Landfill Site
Norfolk, Virginia

INPUTS	VALUE	REFERENCE
Source Area (m2)	8100/787	1
Yearly Precipitation	111	2
Unsaturated Zone Depth (m)	0.5 - 3.0	2
Fraction Organic Carbon	0.01 - 0.1	1
Soil Bulk Density (Kg/L)	2.65	3, 5
Porosity	0.3	3, 5
Vertical Hydraulic Cond. (m/d)	0.005 - 0.5	3, 5
Soil Decay Coeff. (d-1)	*	4
Water Decay Coeff. (d-1)	*	4
Time (d)	3650	5
Source Decay (d-1)	0.00009	5

References:
1 - Draft Test Pit Data (Baker, 1994)
2 - Draft Final Remedial Investigation Report (Baker, 1993)
3 - USEPA Water Quality Assessment. EPA/600/6-85/002a
4 - USEPA Handbook of Environmental Degradation Rates. Howard et al., 1991
5 - Predesign Investigations and Field Observations
* - Chemical dependent value. See Attachment II

MCL values were selected as attainment standards for shallow zone groundwater. Shallow groundwater is not currently being used as a potable supply in the vicinity of the Camp Allen Landfill. The use of MCLs as attainment standards in conjunction with shallow groundwater remediation strategies should protect the shallow aquifer from further degredation when site remediation is complete. Protecting the shallow zone from further degredation will also assure that the deeper Yorktown aquifer (which could be used for potable purposes) is not adversely affected upon completion of remediation activities.

Contamination detected in the shallow aquifer is, in general, significantly higher than contaminant concentrations detected in the underlying Yorktown aquifer. This attenuation is probably afforded by the discontinuous clay layer between the two water bearing units in addition to simple dilution in the larger Yorktown water bearing unit. Attenuation of contaminant concentrations by migration from the shallow aquifer to the Yorktown aquifer was not considered in this modeling effort.

Uncertainties

Uncertainties are inherent in determining soil cleanup goals through the use of spreadsheet based models. These uncertainties stem from the assumption that a model can represent the physical transport system throughout an entire source area using generalized inputs such as vertical seepage velocities and porosities. To prevent an underestimation of contaminant leaching at the site, conservative inputs were used. These inputs may overestimate the potential for contaminant leaching in the unsaturated zone.

The use of a one-dimensional advective transport model considering adsorption and dispersion in porous media was used to approximate the potential leaching of contaminants from and through the unsaturated zone. Flow properties of unsaturated porous media are a function of the soil water content of site soils. The one-dimensional model is conservative because it assumes that the greatest potential for contaminant migration through the unsaturated zone occurs when unsaturated zone soil moisture contents are at maximum capacity. It does not consider situations where soils in the unsaturated zone are less than saturated, nor does the model consider the potential evapotranspiration of the study area. Therefore, leaching, as predicted by the model, is likely to be greater than actual site leaching.

The Summers Model estimates the potential contaminant concentration in leachate (eminating from the source area) at the top of the shallow aquifer. In order to determine corresponding soil concentrations, an estimate of retardation must be applied to modify the leachate concentration. Retardation is estimated using USEPA octanol-water partitioning coefficients and estimates of soil organic carbon content. An organic carbon content of 1 percent (0.01) was used to approximate subsurface soil fraction of organic carbon content (f_{oc}). Analytical data suggest that subsurface soil f_{oc} values may be somewhat higher. These values may be attributable to the presence of site associated contaminants, therefore, a lesser value was selected. Using an f_{oc} of 1 percent instead of some higher value increases the likelyhood of overestimating source area leaching potential.

Attachment II
Summer's Model Spreadsheet Calculations

ELEMENT NUMBER 1. ONE-DIMENSIONAL MASS TRANSPORT THROUGH THE UNSATURATED ZONE.

Chemical Name = 1,2-Dichloroethane

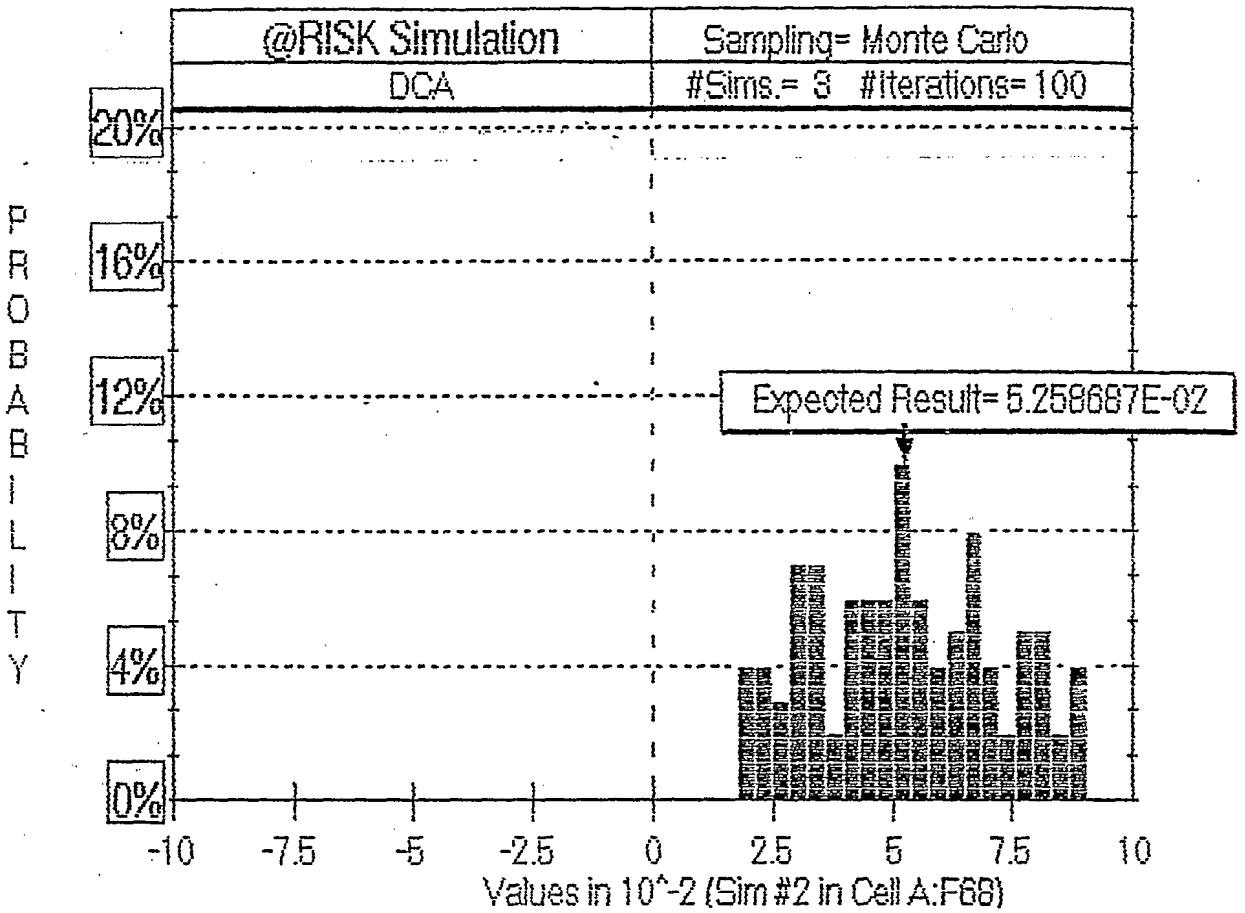
		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	14
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.2
k2 =	Water decay (d-1)	0.2
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values	
vz =	Seepage Vel. (m/d)	0.617	
Kd =	Koc*foc (L/Kg)	0.770	
Rd =	Retardation ()	7.80	
D =	Dipersion Coeff. (m2/d)	0.123	
k =	Overall decay (d-1)	0.2000	
Co =	Initial Conc. (mg/L)	0.046	
R =		1286.190	
S =		0.114	
A1 =		18.875	
A2 =		19.106	
erf(A1) =		1.00000000	*
erf(A2) =		1.00000000	*
erfc(A2) =		0.00000000	*
C =	Conc. at"z" (mg/L)	0.033224937	

** PRG For Leaching **

Chemical = 1,2-Dichloroethane

CGW =	Groundwater PRG (mg/L)	0.005
Csoil =	Soil PRG (mg/Kg)	0.054


@RISK Simulation
Sampling= Monte Carlo
DCA
#Sims.= 3 #Iterations= 100
PROBABILITY
20%
16%
12%
8%
4%
0%
Expected Result= 5.258687E-02
-10
-7.5
-5
-2.5
0
2.5
5
7.5
10
Values in 10^-2 (Sim #2 in Cell A:F68)

Chemical Name = cis-1,2-dichloroethene

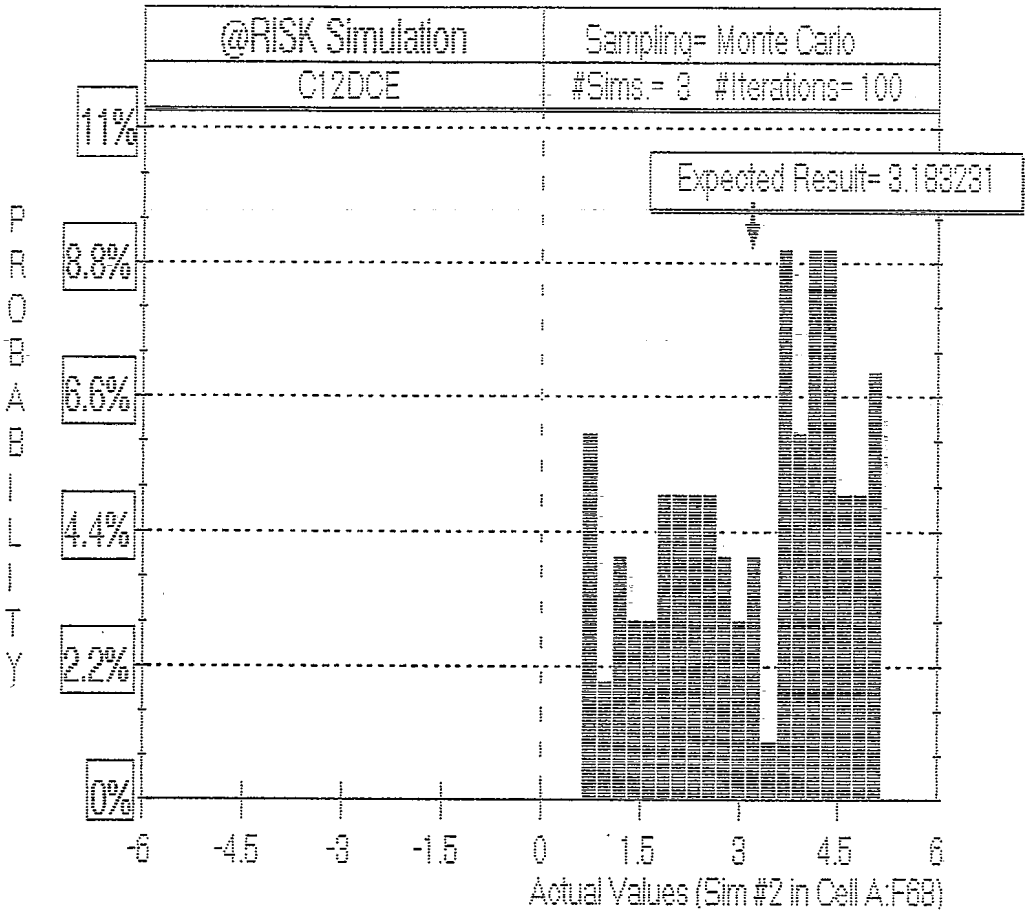
		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	59
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.2525
k1 =	Soil decay (d-1)	0.0111
k2 =	Water decay (d-1)	0.0111
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values
vz =	Seepage Vel. (m/d)	0.842
Kd =	Koc*foc (L/Kg)	3.245
Rd =	Retardation ()	29.66
D =	Dipersion Coeff. (m2/d)	0.168
k =	Overall decay (d-1)	0.0111
Co =	Initial Conc. (mg/L)	0.012
R =		1755.476
S =		0.114
A1 =		11.185
A2 =		11.570
erf(A1) =		1.00000000 *
erf(A2) =		1.00000000 *
erfc(A2) =		0.00000000 *
C =	Conc. at"z" (mg/L)	0.008738148

** PRG For Leaching **

Chemical = cis-1,2-dichloroethene

CGW =	Groundwater PRG (mg/L)	0.07
Csoil =	Soil PRG (mg/Kg)	2.884


@RISK Simulation
Sampling= Monte Carlo
C12DCE
#Sims.= 3 #Iterations= 100
Expected Result= 3.183231
PROBABILITY
11%
8.8%
6.6%
4.4%
2.2%
0%
-6
-4.5
-3
-1.5
0
1.5
3
4.5
6
Actual Values (Sim #2 in Cell A:F68)

ELEMENT NUMBER 1. ONE-DIMENSIONAL MASS TRANSPORT THROUGH THE UNSATURATED ZONE.

Chemical Name = 1,1,1-Trichloroethane

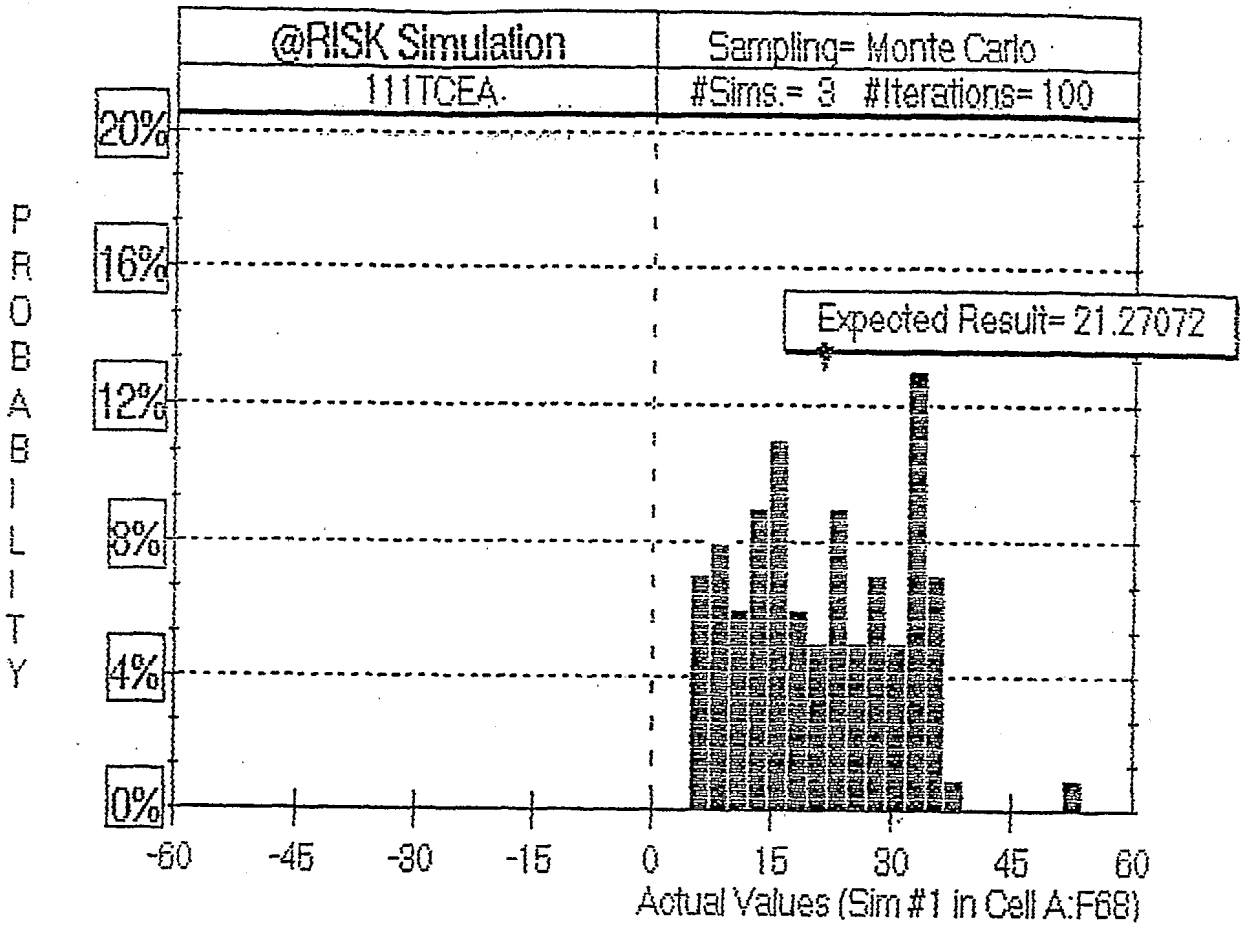
		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	152
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.0111
k2 =	Water decay (d-1)	0.0111
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values
vz =	Seepage Vel. (m/d)	0.617
Kd =	Koc*foc (L/Kg)	8.360
Rd =	Retardation ()	74.85
D =	Dipersion Coeff. (m2/d)	0.123
k =	Overall decay (d-1)	0.0111
Co =	Initial Conc. (mg/L)	0.005
R =		1286.190
S =		0.114
A1 =		5.774
A2 =		6.488
erf(A1) =		1.00000000 *
erf(A2) =		1.00000000 *
erfc(A2) =		0.00000000 *
C =	Conc. at"z" (mg/L)	0.003463212

** PRG For Leaching **

Chemical = 1,1,1-Trichloroethane

CGW =	Groundwater PRG (mg/L)	0.2
Csoil =	Soil PRG (mg/Kg)	20.790


@RISK Simulation
111TCEA
Sampling= Monte Carlo
#Sims.= 3 #Iterations= 100
Expected Result= 21.27072
PROBABILITY
20%
16%
12%
8%
4%
0%
-60
-45
-30
-15
0
15
30
45
60
Actual Values (Sim #1 in Cell A:F68)

ELEMENT NUMBER 1. ONE-DIMENSIONAL MASS TRANSPORT THROUGH THE UNSATURATED ZONE.

Chemical Name = Benzene

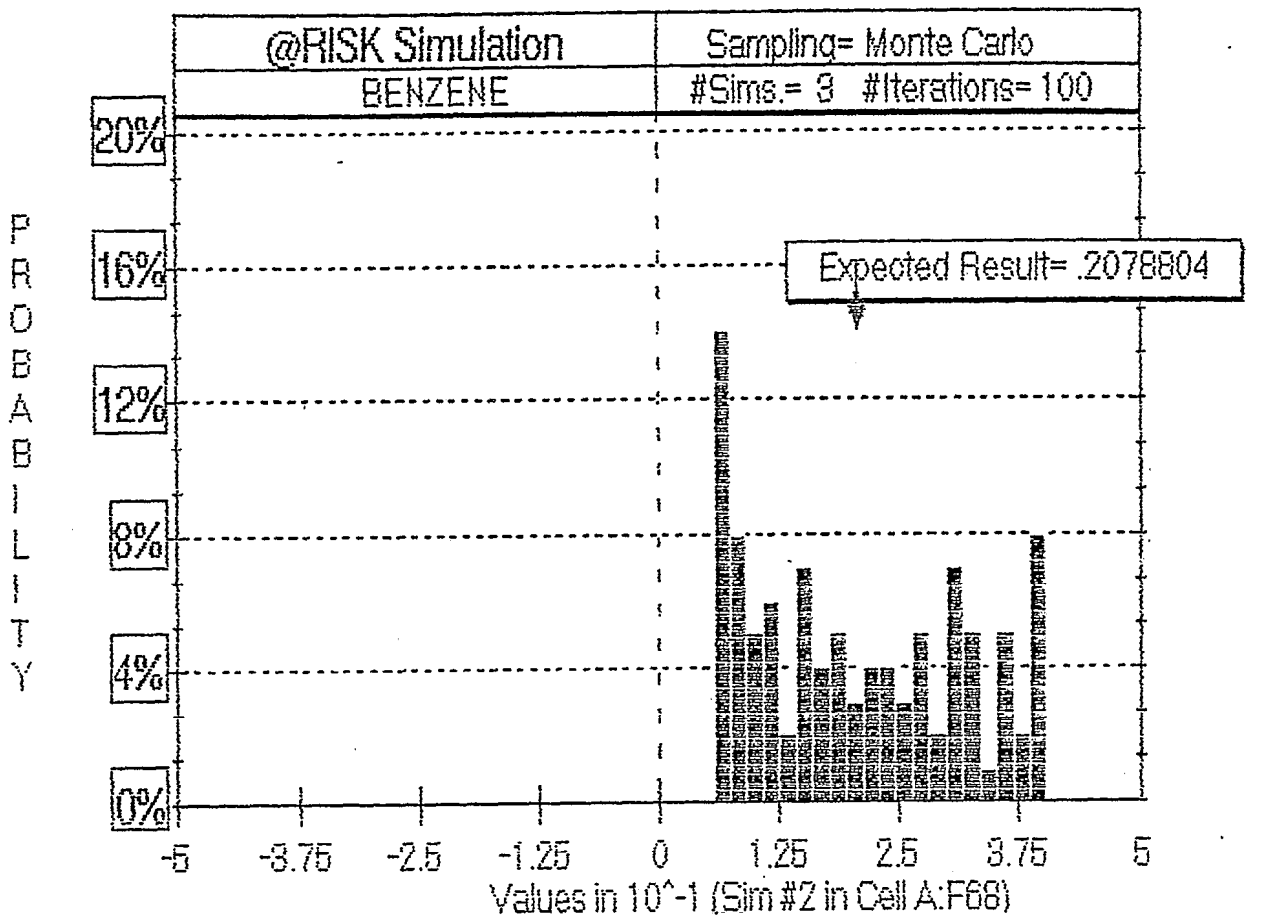
		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	65
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.0625
k2 =	Water decay (d-1)	0.00893
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values	
vz =	Seepage Vel. (m/d)	0.617	
Kd =	Koc*foc (L/Kg)	3.575	
Rd =	Retardation ()	32.58	
D =	Dipersion Coeff. (m2/d)	0.123	
k =	Overall decay (d-1)	0.0609	
Co =	Initial Conc. (mg/L)	0.011	
R =		1286.190	
S =		0.114	
A1 =		9.058	
A2 =		9.528	
erf(A1) =		1.00000000	*
erf(A2) =		1.00000000	*
erfc(A2) =		0.00000000	*
C =	Conc. at"z" (mg/L)	0.007956308	

** PRG For Leaching **

Chemical = Benzene

CGW =	Groundwater PRG (mg/L)	0.005
Csoil =	Soil PRG (mg/Kg)	0.226


@RISK Simulation
Sampling= Monte Carlo
BENZENE
#Sims.= 3 #Iterations= 100
PROBABILITY
20%
16%
12%
8%
4%
0%
Expected Result= .2078804
-5
-3.75
-2.5
-1.25
0
1.25
2.5
3.75
5
Values in 10^-1 (Sim #2 in Cell A:F68)

Chemical Name = Ethylbenzene

		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	1100
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.0357
k2 =	Water decay (d-1)	0.0179
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values	
vz =	Seepage Vel. (m/d)	0.617	
Kd =	Koc*foc (L/Kg)	60.500	
Rd =	Retardation ()	535.42	
D =	Dipersion Coeff. (m2/d)	0.123	
k =	Overall decay (d-1)	0.0357	
Co =	Initial Conc. (mg/L)	0.001	
R =		1286.190	
S =		0.114	
A1 =		1.338	
A2 =		3.247	
erf(A1) =		0.93882844	*
erf(A2) =		0.99996465	*
erfc(A2) =		0.00003535	*
C =	Conc. at"z" (mg/L)	0.00046932	

** PRG For Leaching **

Chemical = Ethylbenzene

CGW =	Groundwater PRG (mg/L)	0.7
Csoil =	Soil PRG (mg/Kg)	536.947

LEMENT NUMBER 1. ONE-DIMENSIONAL MASS TRANSPORT THROUGH THE UNSATURATED ZONE.

Chemical Name = Tetrachloroethene (PCE)

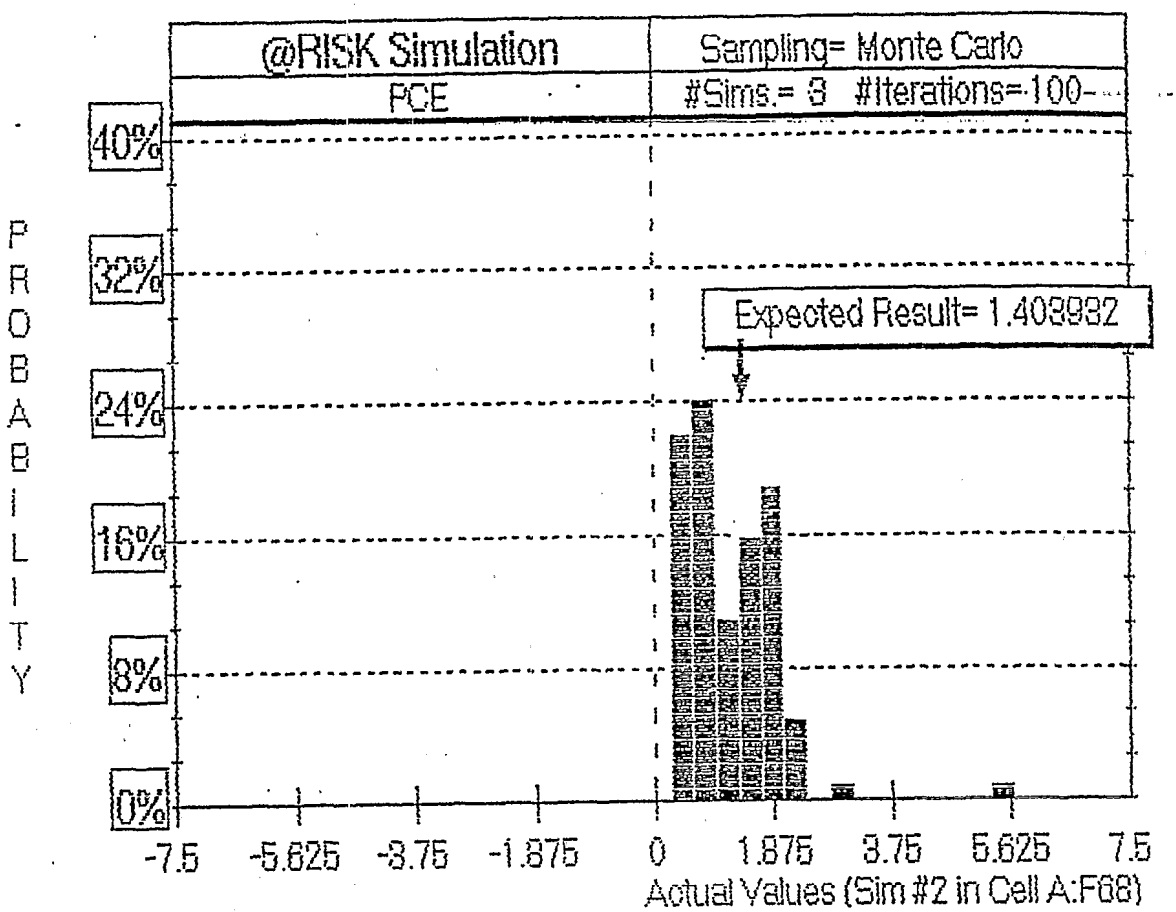
		Inputs
z =	Unsat. depth (m)	1.75-
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	364
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.0111
k2 =	Water decay (d-1)	0.0111
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values	
vz =	Seepage Vel. (m/d)	0.617	
Kd =	Koc*foc (L/Kg)	20.020	
Rd =	Retardation ()	177.84	
D =	Dipersion Coeff. (m2/d)	0.123	
k =	Overall decay (d-1)	0.0111	
Co =	Initial Conc. (mg/L)	0.002	
R =		1286.190	
S =		0.114	
A1 =		3.428	
A2 =		4.527	
erf(A1) =		0.99998571	*
erf(A2) =		0.99999997	*
erfc(A2) =		0.00000003	*
C =	Conc. at"z" (mg/L)	0.001457508	

** PRG For Leaching **

Chemical = Tetrachloroethene (PCE)

CGW =	Groundwater PRG (mg/L)	0.005
Csoil =	Soil PRG (mg/Kg)	1.235


@RISK Simulation
Sampling= Monte Carlo
PCE
#Sims.= 3 #Iterations=100
Expected Result= 1.403932
PROBABILITY
40%
32%
24%
16%
8%
0%
-7.5
-5.625
-3.75
-1.875
0
1.875
3.75
5.625
7.5
Actual Values (Sim #2 in Cell A:F68)

ELEMENT NUMBER 1. ONE-DIMENSIONAL MASS TRANSPORT THROUGH THE UNSATURATED ZONE.

Chemical Name = Toluene

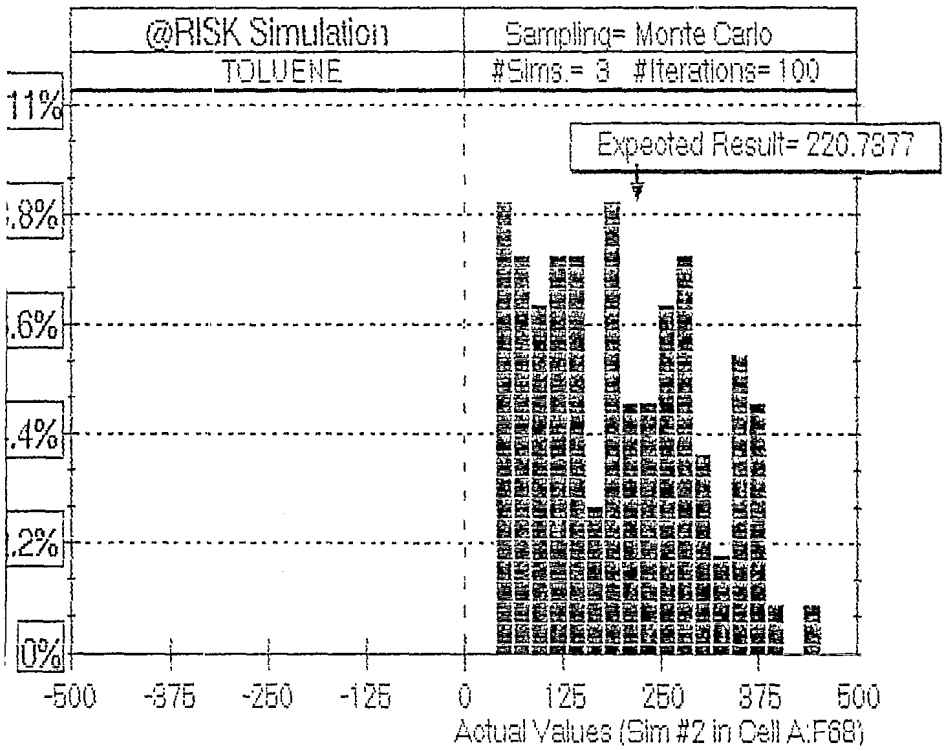
		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	300
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.0455
k2 =	Water decay (d-1)	0.00476
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values	
vz =	Seepage Vel. (m/d)	0.617	
Kd =	Koc*foc (L/Kg)	16.500	
Rd =	Retardation ()	146.75	
D =	Dipersion Coeff. (m2/d)	0.123	
k =	Overall decay (d-1)	0.0452	
Co =	Initial Conc. (mg/L)	0.002	
R =		1286.190	
S =		0.114	
A1 =		3.879	
A2 =		4.878	
erf(A1) =		0.99999874	*
erf(A2) =		1.00000000	*
erfc(A2) =		0.00000000	*
C =	Conc. at"z" (mg/L)	0.001766335	

** PRG For Leaching **

Chemical = Toluene

CGW =	Groundwater PRG (mg/L)	1
Csoil =	Soil PRG (mg/Kg)	203.812


@RISK Simulation
TOLUENE
Sampling= Monte Carlo
#Sims.= 3 #Iterations= 100
Expected Result= 220.7877
11%
.8%
.6%
.4%
.2%
0%
-500
-375
-250
-125
0
125
250
375
500
Actual Values (Sim #2 in Cell A:F68)

Chemical Name = trichloroethene

		Inputs
z	= Unsat. depth (m)	1.75
a	= Dispersivity (m)	0.2
Cs	= Soil Conc. (mg/Kg)	0.36
Koc	= Oct/H2O coeff. (L/Kg)	126
foc	= Organic Carbon	0.055
sb	= soil bulk density (Kg/L)	2.65
por	= soil porosity	0.3
Ksat	= Vert. Hydraulic Cond. (m/d)	0.2525
k1	= Soil decay (d-1)	0.0111
k2	= Water decay (d-1)	0.0111
t	= time (d)	3650
ks	= Source decay rate (d-1)	0.00009

		Values
vz	= Seepage Vel. (m/d)	0.842
Kd	= Koc*foc (L/Kg)	6.930
Rd	= Retardation ()	62.22
D	= Dipersion Coeff. (m2/d)	0.168
k	= Overall decay (d-1)	0.0111
Co	= Initial Conc. (mg/L)	0.006

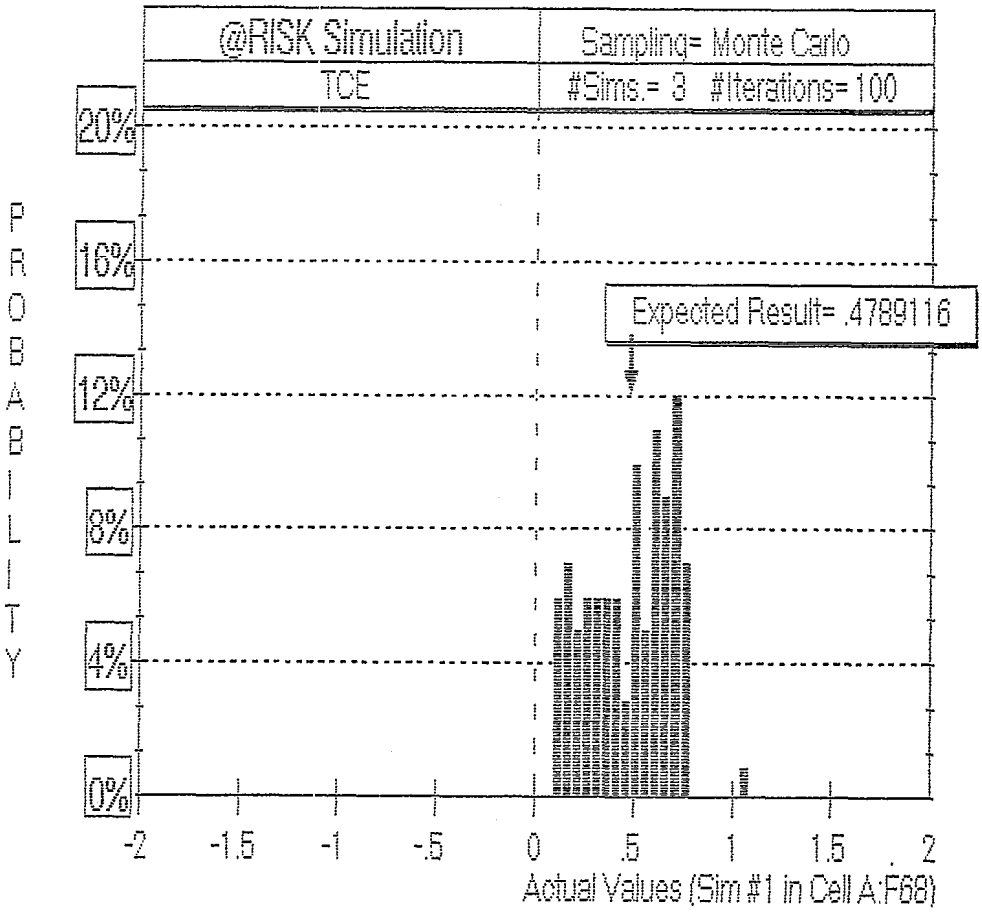
R	=	1755.476
S	=	0.114
A1	=	7.578
A2	=	8.135

erf(A1)	=	1.00000000	*
erf(A2)	=	1.00000000	*
erfc(A2)	=	0.00000000	*
C	= Conc. at"z" (mg/L)	0.004166357	

** PRG For Leaching **

Chemical = trichloroethene

CGW	= Groundwater PRG (mg/L)	0.005
Csoil	= Soil PRG (mg/Kg)	0.432


@RISK Simulation
Sampling= Monte Carlo
TCE
#Sims.= 3 #Iterations= 100
Expected Result= .4789116
PROBABILITY
20%
16%
12%
8%
4%
0%
-2
-1.5
-1
-.5
0
.5
1
1.5
2
Actual Values (Sim #1 in Cell A:F68)

LEMENT NUMBER 1. ONE-DIMENSIONAL MASS TRANSPORT THROUGH THE UNSATURATED ZONE.

Chemical Name = Vinyl Chloride

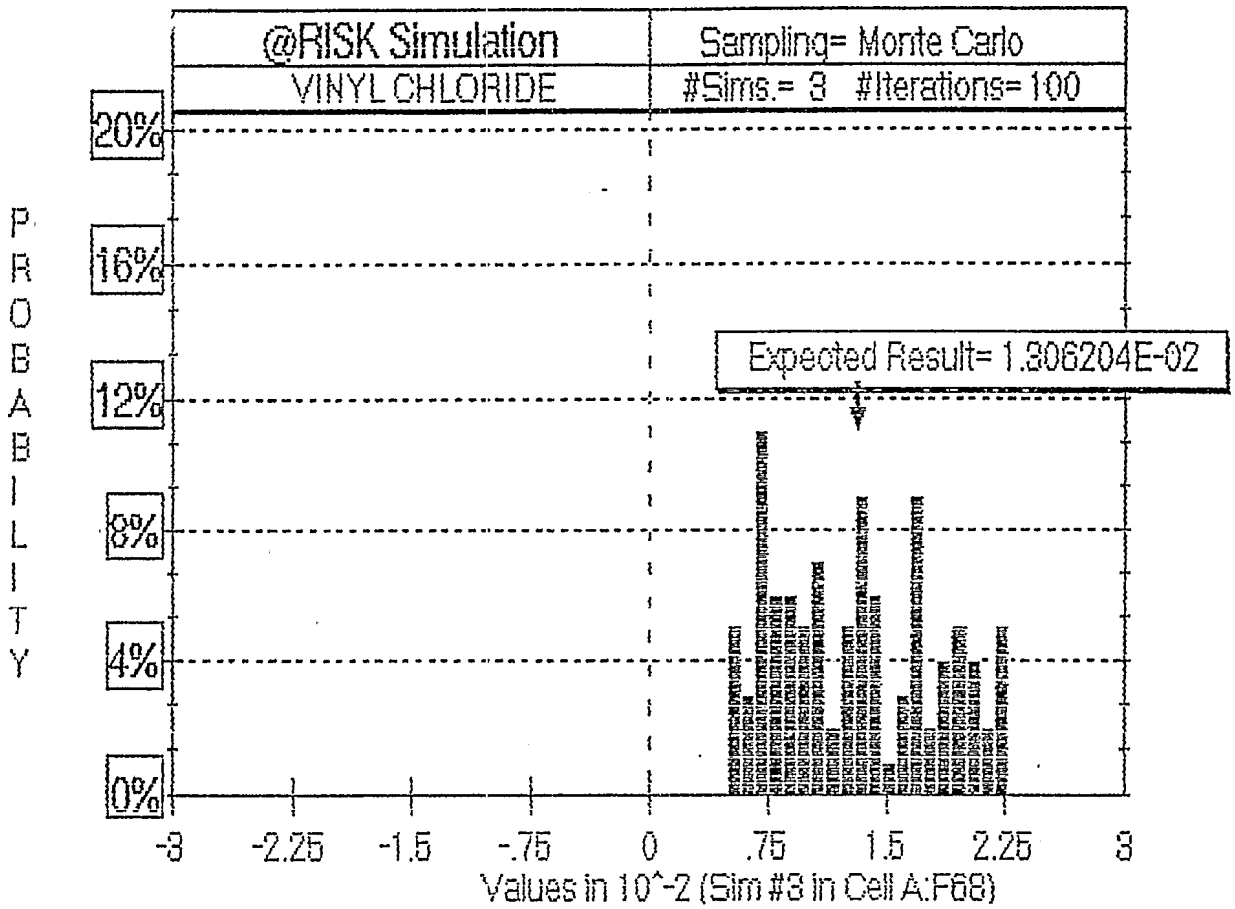
		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H2O coeff. (L/Kg)	8.2
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.2
k2 =	Water decay (d-1)	0.2
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values	
vz =	Seepage Vel. (m/d)	0.617	
Kd =	Koc*foc (L/Kg)	0.451	
Rd =	Retardation ()	4.98	
D =	Dipersion Coeff. (m2/d)	0.123	
k =	Overall decay (d-1)	0.2000	
Co =	Initial Conc. (mg/L)	0.072	
R =		1286.190	
S =		0.114	
A1 =		23.668	
A2 =		23.852	
erf(A1) =		1.00000000	*
erf(A2) =		1.00000000	*
erfc(A2) =		0.00000000	*
C =	Conc. at"z" (mg/L)	0.052010143	

** PRG For Leaching **

Chemical = Vinyl Chloride

CGW =	Groundwater PRG (mg/L)	0.002
Csoil =	Soil PRG (mg/Kg)	0.014


@RISK Simulation
Sampling= Monte Carlo
VINYL CHLORIDE
#Sims.= 3 #Iterations= 100
Expected Result= 1.306204E-02
PROBABILITY
20%
16%
12%
8%
4%
0%
-3
-2.25
-1.5
-.75
0
.75
1.5
2.25
3
Values in 10^-2 (Sim #3 in Cell A:F68)

Chemical Name = Xylenes

		Inputs
z =	Unsat. depth (m)	1.75
a =	Dispersivity (m)	0.2
Cs =	Soil Conc. (mg/Kg)	0.36
Koc =	Oct/H20 coeff. (L/Kg)	1047
foc =	Organic Carbon	0.055
sb =	soil bulk density (Kg/L)	2.65
por =	soil porosity	0.3
Ksat =	Vert. Hydraulic Cond. (m/d)	0.185
k1 =	Soil decay (d-1)	0.0357
k2 =	Water decay (d-1)	0.02
t =	time (d)	3650
ks =	Source decay rate (d-1)	0.00009

		Values
vz =	Seepage Vel. (m/d)	0.617
Kd =	Koc*foc (L/Kg)	57.585
Rd =	Retardation ()	509.67
D =	Dipersion Coeff. (m2/d)	0.123
k =	Overall decay (d-1)	0.0357
Co =	Initial Conc. (mg/L)	0.001

R =	1286.190	
S =	0.114	
A1 =	1.419	
A2 =	3.281	
erf(A1) =	0.95198051	*
erf(A2) =	0.99997010	*
erfc(A2) =	0.00002990	*
C = Conc. at"z" (mg/L)	0.000496375	

** PRG For Leaching **

Chemical = Xylenes

CGW =	Groundwater PRG (mg/L)	10
Csoil =	Soil PRG (mg/Kg)	7252.578

APPENDIX C - SOIL AND SURFACE WATER / SEDIMENT COSTING SUMMARIES

APPENDIX C
SOIL AND SURFACE WATER/SEDIMENT COSTING SUMMARIES

APPENDIX C.1
SOIL ALTERNATIVE COST ESTIMATE SPREADSHEETS

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO1: NO ACTION

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO1: NO ACTION

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$0.00	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR	$20,000.00	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO1: NO ACTION

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$0.00	$0.00	0.9524	$0.00
2	$0.00	$0.00	$0.00	0.9070	$0.00
3	$0.00	$0.00	$0.00	0.8638	$0.00
4	$0.00	$0.00	$0.00	0.8227	$0.00
5	$0.00	$20,000.00	$20,000.00	0.7835	$15,670.52
6	$0.00	$0.00	$0.00	0.7462	$0.00
7	$0.00	$0.00	$0.00	0.7107	$0.00
8	$0.00	$0.00	$0.00	0.6768	$0.00
9	$0.00	$0.00	$0.00	0.6446	$0.00
10	$0.00	$20,000.00	$20,000.00	0.6139	$12,278.27
11	$0.00	$0.00	$0.00	0.5847	$0.00
12	$0.00	$0.00	$0.00	0.5568	$0.00
13	$0.00	$0.00	$0.00	0.5303	$0.00
14	$0.00	$0.00	$0.00	0.5051	$0.00
15	$0.00	$20,000.00	$20,000.00	0.4810	$9,620.34
16	$0.00	$0.00	$0.00	0.4581	$0.00
17	$0.00	$0.00	$0.00	0.4363	$0.00
18	$0.00	$0.00	$0.00	0.4155	$0.00
19	$0.00	$0.00	$0.00	0.3957	$0.00
20	$0.00	$20,000.00	$20,000.00	0.3769	$7,537.79
21	$0.00	$0.00	$0.00	0.3589	$0.00
22	$0.00	$0.00	$0.00	0.3418	$0.00
23	$0.00	$0.00	$0.00	0.3256	$0.00
24	$0.00	$0.00	$0.00	0.3101	$0.00
25	$0.00	$20,000.00	$20,000.00	0.2953	$5,906.06
26	$0.00	$0.00	$0.00	0.2812	$0.00
27	$0.00	$0.00	$0.00	0.2678	$0.00
28	$0.00	$0.00	$0.00	0.2551	$0.00
29	$0.00	$0.00	$0.00	0.2429	$0.00
30	$0.00	$20,000.00	$20,000.00	0.2314	$4,627.55
TOTAL PRESENT WORTH					$55,640.52

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO2: INSTITUTIONAL CONTROLS
Deed Restrictions

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO2: INSTITUTIONAL CONTROLS
Deed Restrictions

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
b. Existing Soil Cover Maintenance	$16,956.98	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$17,557.89	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR	$37,557.89	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO2: INSTITUTIONAL CONTROLS
Deed Restrictions

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$17,557.89	$17,557.89	0.9524	$16,721.80
2	$0.00	$17,557.89	$17,557.89	0.9070	$15,925.53
3	$0.00	$17,557.89	$17,557.89	0.8638	$15,167.17
4	$0.00	$17,557.89	$17,557.89	0.8227	$14,444.92
5	$0.00	$37,557.89	$37,557.89	0.7835	$29,427.59
6	$0.00	$17,557.89	$17,557.89	0.7462	$13,101.97
7	$0.00	$17,557.89	$17,557.89	0.7107	$12,478.07
8	$0.00	$17,557.89	$17,557.89	0.6768	$11,883.87
9	$0.00	$17,557.89	$17,557.89	0.6446	$11,317.98
10	$0.00	$37,557.89	$37,557.89	0.6139	$23,057.29
11	$0.00	$17,557.89	$17,557.89	0.5847	$10,265.74
12	$0.00	$17,557.89	$17,557.89	0.5568	$9,776.89
13	$0.00	$17,557.89	$17,557.89	0.5303	$9,311.33
14	$0.00	$17,557.89	$17,557.89	0.5051	$8,867.93
15	$0.00	$37,557.89	$37,557.89	0.4810	$18,065.99
16	$0.00	$17,557.89	$17,557.89	0.4581	$8,043.47
17	$0.00	$17,557.89	$17,557.89	0.4363	$7,660.45
18	$0.00	$17,557.89	$17,557.89	0.4155	$7,295.67
19	$0.00	$17,557.89	$17,557.89	0.3957	$6,948.26
20	$0.00	$37,557.89	$37,557.89	0.3769	$14,155.18
21	$0.00	$17,557.89	$17,557.89	0.3589	$6,302.27
22	$0.00	$17,557.89	$17,557.89	0.3418	$6,002.16
23	$0.00	$17,557.89	$17,557.89	0.3256	$5,716.35
24	$0.00	$17,557.89	$17,557.89	0.3101	$5,444.14
25	$0.00	$37,557.89	$37,557.89	0.2953	$11,090.95
26	$0.00	$17,557.89	$17,557.89	0.2812	$4,938.00
27	$0.00	$17,557.89	$17,557.89	0.2678	$4,702.85
28	$0.00	$17,557.89	$17,557.89	0.2551	$4,478.91
29	$0.00	$17,557.89	$17,557.89	0.2429	$4,265.63
30	$0.00	$37,557.89	$37,557.89	0.2314	$8,690.05
TOTAL PRESENT WORTH					$325,548.40

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO3: ASPHALT CAP OVER BRIG AREA
Asphalt Brig and Institutional Controls

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
1. Asphalt Cap			
a. Mapping	$5,587.00	See itemized costs.	0
b. Asphalt Cap	$842,610.65	See itemized costs.	0
c. Gas Vents	$13,811.66	See itemized costs (12 vents).	0
d. Storm Water Management Structures	$60,764.94	See itemized costs.	0
e. Construction Trailer	$4,435.33	See itemized costs (Rent 4 mo).	0
TOTAL DIRECT COST	$927,209.59		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$92,720.96	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$46,360.48	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$92,720.96	10% of Direct Cost	0
b. Health and Safety	$46,360.48	5% of Direct Cost	0
4. Contingency Allowance	$185,441.92	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$463,604.79		
TOTAL CAPITAL COSTS	$1,390,814.38		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO3: ASPHALT CAP OVER BRIG AREA
Asphalt Brig and Institutional Controls

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
b. Existing Soil Cover Maintenance	$16,956.98	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
3. Asphalt Cap Maintence			
a. Asphalt & Sewer Maintenance	$58,095.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$17,557.89	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR	$95,652.89	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO3: ASPHALT CAP OVER BRIG AREA
Asphalt Brig and Institutional Controls

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$1,390,814.38	$0.00	$1,390,814.38	1.0000	$1,390,814.38
1	$0.00	$17,557.89	$17,557.89	0.9524	$16,721.80
2	$0.00	$17,557.89	$17,557.89	0.9070	$15,925.53
3	$0.00	$17,557.89	$17,557.89	0.8638	$15,167.17
4	$0.00	$17,557.89	$17,557.89	0.8227	$14,444.92
5	$0.00	$95,652.89	$95,652.89	0.7835	$74,946.55
6	$0.00	$17,557.89	$17,557.89	0.7462	$13,101.97
7	$0.00	$17,557.89	$17,557.89	0.7107	$12,478.07
8	$0.00	$17,557.89	$17,557.89	0.6768	$11,883.87
9	$0.00	$17,557.89	$17,557.89	0.6446	$11,317.98
10	$0.00	$95,652.89	$95,652.89	0.6139	$58,722.58
11	$0.00	$17,557.89	$17,557.89	0.5847	$10,265.74
12	$0.00	$17,557.89	$17,557.89	0.5568	$9,776.89
13	$0.00	$17,557.89	$17,557.89	0.5303	$9,311.33
14	$0.00	$17,557.89	$17,557.89	0.5051	$8,867.93
15	$0.00	$95,652.89	$95,652.89	0.4810	$46,010.68
16	$0.00	$17,557.89	$17,557.89	0.4581	$8,043.47
17	$0.00	$17,557.89	$17,557.89	0.4363	$7,660.45
18	$0.00	$17,557.89	$17,557.89	0.4155	$7,295.67
19	$0.00	$17,557.89	$17,557.89	0.3957	$6,948.26
20	$0.00	$95,652.89	$95,652.89	0.3769	$36,050.57
21	$0.00	$17,557.89	$17,557.89	0.3589	$6,302.27
22	$0.00	$17,557.89	$17,557.89	0.3418	$6,002.16
23	$0.00	$17,557.89	$17,557.89	0.3256	$5,716.35
24	$0.00	$17,557.89	$17,557.89	0.3101	$5,444.14
25	$0.00	$95,652.89	$95,652.89	0.2953	$28,246.56
26	$0.00	$17,557.89	$17,557.89	0.2812	$4,938.00
27	$0.00	$17,557.89	$17,557.89	0.2678	$4,702.85
28	$0.00	$17,557.89	$17,557.89	0.2551	$4,478.91
29	$0.00	$17,557.89	$17,557.89	0.2429	$4,265.63
30	$0.00	$95,652.89	$95,652.89	0.2314	$22,131.92
TOTAL PRESENT WORTH					$1,877,984.59

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO4: VEGETATED COMPOSITE COVER OVER SOURCE AREA
Cover Source Area and Institutional Controls

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
1. Vegetated Composite Cover System			
a. Mapping	$5,587.00	See itemized costs.	0
b. Vegetated Composite Cover System	$299,187.17	See itemized costs.	0
c. Construction Trailer	$5,419.33	See itemized costs (Rent 5 mo).	0
TOTAL DIRECT COST	$310,193.50		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$31,019.35	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$15,509.68	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$31,019.35	10% of Direct Cost	0
b. Health and Safety	$15,509.68	5% of Direct Cost	0
4. Contingency Allowance	$62,038.70	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$155,096.75		
TOTAL CAPITAL COSTS	$465,290.25		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO4: VEGETATED COMPOSITE COVER OVER SOURCE AREA
Cover Source Area and Institutional Controls

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
b. Existing Soil Cover Maintenance	$16,956.98	See itemized costs.	1-30
c. Vegetated Composite Cover System Maintenance	$1,836.65	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$19,394.55	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR	$39,394.55	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO4: VEGETATED COMPOSITE COVER OVER SOURCE
Cover Source Area and Institutional Controls

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$465,290.25	$0.00	$465,290.25	1.0000	$465,290.25
1	$0.00	$19,394.55	$19,394.55	0.9524	$18,471.00
2	$0.00	$19,394.55	$19,394.55	0.9070	$17,591.43
3	$0.00	$19,394.55	$19,394.55	0.8638	$16,753.74
4	$0.00	$19,394.55	$19,394.55	0.8227	$15,955.94
5	$0.00	$39,394.55	$39,394.55	0.7835	$30,866.66
6	$0.00	$19,394.55	$19,394.55	0.7462	$14,472.51
7	$0.00	$19,394.55	$19,394.55	0.7107	$13,783.34
8	$0.00	$19,394.55	$19,394.55	0.6768	$13,126.99
9	$0.00	$19,394.55	$19,394.55	0.6446	$12,501.90
10	$0.00	$39,394.55	$39,394.55	0.6139	$24,184.83
11	$0.00	$19,394.55	$19,394.55	0.5847	$11,339.59
12	$0.00	$19,394.55	$19,394.55	0.5568	$10,799.61
13	$0.00	$19,394.55	$19,394.55	0.5303	$10,285.34
14	$0.00	$19,394.55	$19,394.55	0.5051	$9,795.56
15	$0.00	$39,394.55	$39,394.55	0.4810	$18,949.45
16	$0.00	$19,394.55	$19,394.55	0.4581	$8,884.87
17	$0.00	$19,394.55	$19,394.55	0.4363	$8,461.78
18	$0.00	$19,394.55	$19,394.55	0.4155	$8,058.84
19	$0.00	$19,394.55	$19,394.55	0.3957	$7,675.08
20	$0.00	$39,394.55	$39,394.55	0.3769	$14,847.39
21	$0.00	$19,394.55	$19,394.55	0.3589	$6,961.52
22	$0.00	$19,394.55	$19,394.55	0.3418	$6,630.02
23	$0.00	$19,394.55	$19,394.55	0.3256	$6,314.31
24	$0.00	$19,394.55	$19,394.55	0.3101	$6,013.63
25	$0.00	$39,394.55	$39,394.55	0.2953	$11,633.32
26	$0.00	$19,394.55	$19,394.55	0.2812	$5,454.54
27	$0.00	$19,394.55	$19,394.55	0.2678	$5,194.80
28	$0.00	$19,394.55	$19,394.55	0.2551	$4,947.43
29	$0.00	$19,394.55	$19,394.55	0.2429	$4,711.83
30	$0.00	$39,394.55	$39,394.55	0.2314	$9,115.01
TOTAL PRESENT WORTH					$819,072.51

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO5: INSITU TREATMENT - VACUUM EXTRACTION
Dual Phase Vacuum Extraction and Institutional Controls

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
1. Vacuum Extraction System			
a. Mapping	$5,587.00	See itemized costs.	0
b. Construction of Vacuum Extraction System	$305,564.90	See itemized costs.	0
c. Construction Trailer	$15,999.33	See itemized costs (Purchase).	0
TOTAL DIRECT COST	$327,151.24		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$32,715.12	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$16,357.56	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$32,715.12	10% of Direct Cost	0
b. Health and Safety	$16,357.56	5% of Direct Cost	0
4. Contingency Allowance	$65,430.25	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$163,575.62		
TOTAL CAPITAL COSTS	$490,726.85		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO5: INSITU TREATMENT - VACUUM EXTRACTION
Dual Phase Vacuum Extraction and Institutional Controls

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
b. Existing Soil Cover Maintenance	$16,956.98	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
3. Vacuum Extraction System			
a. Operation and Maintenance	$90,508.00	See itemized costs.	1,2,3,4,5
b. Removal of Vacuum Extraction System	$10,955.92	See itemized costs.	5
TOTAL ANNUAL O&M COST FOR YEARS ONE TO FOUR	$108,065.89	-	-
TOTAL ANNUAL O&M COST FOR YEAR FIVE	$139,021.81	-	-
TOTAL ANNUAL O&M COST FOR YEARS SIX TO THIRTY	$17,557.89	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR FOR YEARS SIX TO THIRTY	$37,557.89	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO5: INSITU TREATMENT - VACUUM EXTRACTION
Dual Phase Vacuum Extraction and Institutional Controls

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$490,726.85	$0.00	$490,726.85	1.0000	$490,726.85
1	$0.00	$108,065.89	$108,065.89	0.9524	$102,919.90
2	$0.00	$108,065.89	$108,065.89	0.9070	$98,018.95
3	$0.00	$108,065.89	$108,065.89	0.8638	$93,351.38
4	$0.00	$108,065.89	$108,065.89	0.8227	$88,906.08
5	$0.00	$139,021.81	$139,021.81	0.7835	$108,927.23
6	$0.00	$17,557.89	$17,557.89	0.7462	$13,101.97
7	$0.00	$17,557.89	$17,557.89	0.7107	$12,478.07
8	$0.00	$17,557.89	$17,557.89	0.6768	$11,883.87
9	$0.00	$17,557.89	$17,557.89	0.6446	$11,317.98
10	$0.00	$37,557.89	$37,557.89	0.6139	$23,057.29
11	$0.00	$17,557.89	$17,557.89	0.5847	$10,265.74
12	$0.00	$17,557.89	$17,557.89	0.5568	$9,776.89
13	$0.00	$17,557.89	$17,557.89	0.5303	$9,311.33
14	$0.00	$17,557.89	$17,557.89	0.5051	$8,867.93
15	$0.00	$37,557.89	$37,557.89	0.4810	$18,065.99
16	$0.00	$17,557.89	$17,557.89	0.4581	$8,043.47
17	$0.00	$17,557.89	$17,557.89	0.4363	$7,660.45
18	$0.00	$17,557.89	$17,557.89	0.4155	$7,295.67
19	$0.00	$17,557.89	$17,557.89	0.3957	$6,948.26
20	$0.00	$37,557.89	$37,557.89	0.3769	$14,155.18
21	$0.00	$17,557.89	$17,557.89	0.3589	$6,302.27
22	$0.00	$17,557.89	$17,557.89	0.3418	$6,002.16
23	$0.00	$17,557.89	$17,557.89	0.3256	$5,716.35
24	$0.00	$17,557.89	$17,557.89	0.3101	$5,444.14
25	$0.00	$37,557.89	$37,557.89	0.2953	$11,090.95
26	$0.00	$17,557.89	$17,557.89	0.2812	$4,938.00
27	$0.00	$17,557.89	$17,557.89	0.2678	$4,702.85
28	$0.00	$17,557.89	$17,557.89	0.2551	$4,478.91
29	$0.00	$17,557.89	$17,557.89	0.2429	$4,265.63
30	$0.00	$37,557.89	$37,557.89	0.2314	$8,690.05
TOTAL PRESENT WORTH					$1,216,711.78

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO6: ON-SITE TREATMENT, THERMAL TREATMENT
Low Temperature Thermal Treatment and Institutional Controls

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
1. Low Temp. Treatment System			
a. Mapping	$5,587.00	See itemized costs.	0
a. Low Temp Treatment System	$4,082,361.86	See itemized costs.	0
b. Construction Trailer	$6,403.33	See itemized costs (Rent 6 mo).	0
TOTAL DIRECT COST	$4,094,352.19		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$409,435.22	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$204,717.61	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$409,435.22	10% of Direct Cost	0
b. Health and Safety	$204,717.61	5% of Direct Cost	0
4. Contingency Allowance	$818,870.44	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$2,047,176.10		
TOTAL CAPITAL COSTS	$6,141,528.29		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO6: ON-SITE TREATMENT, THERMAL TREATMENT
Low Temperature Thermal Treatment and Institutional Controls

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
b. Existing Soil Cover Maintenance	$16,956.98	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$17,557.89	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR	$37,557.89	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO6: ON-SITE TREATMENT, THERMAL TREATMENT
Low Temperature Thermal Treatment and Institutional Controls

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors	Present
0	$6,141,528.29	$0.00	$6,141,528.29	1.0000	$6,141,528.29
1	$0.00	$17,557.89	$17,557.89	0.9524	$16,721.80
2	$0.00	$17,557.89	$17,557.89	0.9070	$15,925.53
3	$0.00	$17,557.89	$17,557.89	0.8638	$15,167.17
4	$0.00	$17,557.89	$17,557.89	0.8227	$14,444.92
5	$0.00	$37,557.89	$37,557.89	0.7835	$29,427.59
6	$0.00	$17,557.89	$17,557.89	0.7462	$13,101.97
7	$0.00	$17,557.89	$17,557.89	0.7107	$12,478.07
8	$0.00	$17,557.89	$17,557.89	0.6768	$11,883.87
9	$0.00	$17,557.89	$17,557.89	0.6446	$11,317.98
10	$0.00	$37,557.89	$37,557.89	0.6139	$23,057.29
11	$0.00	$17,557.89	$17,557.89	0.5847	$10,265.74
12	$0.00	$17,557.89	$17,557.89	0.5568	$9,776.89
13	$0.00	$17,557.89	$17,557.89	0.5303	$9,311.33
14	$0.00	$17,557.89	$17,557.89	0.5051	$8,867.93
15	$0.00	$37,557.89	$37,557.89	0.4810	$18,065.99
16	$0.00	$17,557.89	$17,557.89	0.4581	$8,043.47
17	$0.00	$17,557.89	$17,557.89	0.4363	$7,660.45
18	$0.00	$17,557.89	$17,557.89	0.4155	$7,295.67
19	$0.00	$17,557.89	$17,557.89	0.3957	$6,948.26
20	$0.00	$37,557.89	$37,557.89	0.3769	$14,155.18
21	$0.00	$17,557.89	$17,557.89	0.3589	$6,302.27
22	$0.00	$17,557.89	$17,557.89	0.3418	$6,002.16
23	$0.00	$17,557.89	$17,557.89	0.3256	$5,716.35
24	$0.00	$17,557.89	$17,557.89	0.3101	$5,444.14
25	$0.00	$37,557.89	$37,557.89	0.2953	$11,090.95
26	$0.00	$17,557.89	$17,557.89	0.2812	$4,938.00
27	$0.00	$17,557.89	$17,557.89	0.2678	$4,702.85
28	$0.00	$17,557.89	$17,557.89	0.2551	$4,478.91
29	$0.00	$17,557.89	$17,557.89	0.2429	$4,265.63
30	$0.00	$37,557.89	$37,557.89	0.2314	$8,690.05
TOTAL PRESENT WORTH					$6,467,076.69

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO7: EXCAVATION AND DISPOSAL
Off Site Disposal in RCRA Landfill and Institutional Controls

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
1. Removal/Disposal			
a. Excavation/Disposal	$6,518,181.76	See itemized costs.	0
b. Decontamination Facility	$57,977.00	See itemized costs.	0
c. Construction Trailer	$2,467.33	See itemized costs (Rent 2 mo).	0
TOTAL DIRECT COST	$6,578,626.10		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$657,862.61	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$328,931.30	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$657,862.61	10% of Direct Cost	0
b. Health and Safety	$328,931.30	5% of Direct Cost	0
4. Contingency Allowance	$1,315,725.22	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$3,289,313.05		
TOTAL CAPITAL COSTS	$9,867,939.15		

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO7: EXCAVATION AND DISPOSAL
Off Site Disposal in RCRA Landfill and Institutional Controls

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
b. Existing Soil Cover Maintenance	$16,956.98	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$17,557.89	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR	$37,557.89	-	-

CAMP ALLEN LANDFILL
AREA A SOURCE CONTROL ALTERNATIVE A-SO7: EXCAVATION AND DISPOSAL
Off Site Disposal in RCRA Landfill and Institutional Controls

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$9,867,939.15	$0.00	$9,867,939.15	1.0000	$9,867,939.15
1	$0.00	$17,557.89	$17,557.89	0.9524	$16,721.80
2	$0.00	$17,557.89	$17,557.89	0.9070	$15,925.53
3	$0.00	$17,557.89	$17,557.89	0.8638	$15,167.17
4	$0.00	$17,557.89	$17,557.89	0.8227	$14,444.92
5	$0.00	$37,557.89	$37,557.89	0.7835	$29,427.59
6	$0.00	$17,557.89	$17,557.89	0.7462	$13,101.97
7	$0.00	$17,557.89	$17,557.89	0.7107	$12,478.07
8	$0.00	$17,557.89	$17,557.89	0.6768	$11,883.87
9	$0.00	$17,557.89	$17,557.89	0.6446	$11,317.98
10	$0.00	$37,557.89	$37,557.89	0.6139	$23,057.29
11	$0.00	$17,557.89	$17,557.89	0.5847	$10,265.74
12	$0.00	$17,557.89	$17,557.89	0.5568	$9,776.89
13	$0.00	$17,557.89	$17,557.89	0.5303	$9,311.33
14	$0.00	$17,557.89	$17,557.89	0.5051	$8,867.93
15	$0.00	$37,557.89	$37,557.89	0.4810	$18,065.99
16	$0.00	$17,557.89	$17,557.89	0.4581	$8,043.47
17	$0.00	$17,557.89	$17,557.89	0.4363	$7,660.45
18	$0.00	$17,557.89	$17,557.89	0.4155	$7,295.67
19	$0.00	$17,557.89	$17,557.89	0.3957	$6,948.26
20	$0.00	$37,557.89	$37,557.89	0.3769	$14,155.18
21	$0.00	$17,557.89	$17,557.89	0.3589	$6,302.27
22	$0.00	$17,557.89	$17,557.89	0.3418	$6,002.16
23	$0.00	$17,557.89	$17,557.89	0.3256	$5,716.35
24	$0.00	$17,557.89	$17,557.89	0.3101	$5,444.14
25	$0.00	$37,557.89	$37,557.89	0.2953	$11,090.95
26	$0.00	$17,557.89	$17,557.89	0.2812	$4,938.00
27	$0.00	$17,557.89	$17,557.89	0.2678	$4,702.85
28	$0.00	$17,557.89	$17,557.89	0.2551	$4,478.91
29	$0.00	$17,557.89	$17,557.89	0.2429	$4,265.63
30	$0.00	$37,557.89	$37,557.89	0.2314	$8,690.05
TOTAL PRESENT WORTH					$10,193,487.54

CAMP ALLEN LANDFILL
AREA B SOURCE CONTROL ALTERNATIVE B-SO1: NO ACTION

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
AREA B SOURCE CONTROL ALTERNATIVE B-SO1: NO ACTION

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$0.00	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR	$20,000.00	-	-

CAMP ALLEN LANDFILL
AREA B SOURCE CONTROL ALTERNATIVE B-SO1: NO ACTION

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$0.00	$0.00	0.9524	$0.00
2	$0.00	$0.00	$0.00	0.9070	$0.00
3	$0.00	$0.00	$0.00	0.8638	$0.00
4	$0.00	$0.00	$0.00	0.8227	$0.00
5	$0.00	$20,000.00	$20,000.00	0.7835	$15,670.52
6	$0.00	$0.00	$0.00	0.7462	$0.00
7	$0.00	$0.00	$0.00	0.7107	$0.00
8	$0.00	$0.00	$0.00	0.6768	$0.00
9	$0.00	$0.00	$0.00	0.6446	$0.00
10	$0.00	$20,000.00	$20,000.00	0.6139	$12,278.27
11	$0.00	$0.00	$0.00	0.5847	$0.00
12	$0.00	$0.00	$0.00	0.5568	$0.00
13	$0.00	$0.00	$0.00	0.5303	$0.00
14	$0.00	$0.00	$0.00	0.5051	$0.00
15	$0.00	$20,000.00	$20,000.00	0.4810	$9,620.34
16	$0.00	$0.00	$0.00	0.4581	$0.00
17	$0.00	$0.00	$0.00	0.4363	$0.00
18	$0.00	$0.00	$0.00	0.4155	$0.00
19	$0.00	$0.00	$0.00	0.3957	$0.00
20	$0.00	$20,000.00	$20,000.00	0.3769	$7,537.79
21	$0.00	$0.00	$0.00	0.3589	$0.00
22	$0.00	$0.00	$0.00	0.3418	$0.00
23	$0.00	$0.00	$0.00	0.3256	$0.00
24	$0.00	$0.00	$0.00	0.3101	$0.00
25	$0.00	$20,000.00	$20,000.00	0.2953	$5,906.06
26	$0.00	$0.00	$0.00	0.2812	$0.00
27	$0.00	$0.00	$0.00	0.2678	$0.00
28	$0.00	$0.00	$0.00	0.2551	$0.00
29	$0.00	$0.00	$0.00	0.2429	$0.00
30	$0.00	$20,000.00	$20,000.00	0.2314	$4,627.55
TOTAL PRESENT WORTH					$55,640.52

CAMP ALLEN LANDFILL
AREA B SOURCE CONTROL ALTERNATIVE B-SO2: INSTITUTIONAL CONTROLS
Deed Restrictions

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)	$0.00		0
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
AREA B SOURCE CONTROL ALTERNATIVE B-SO2: INSTITUTIONAL CONTROLS
Deed Restrictions

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Annual Maintenance			
a. Existing Fence Maintenance	$600.91	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$600.91	-	-
O&M COST IN WHICH FIVE-YEAR REVIEW OCCUR	$20,000.00	-	-

CAMP ALLEN LANDFILL
AREA B SOURCE CONTROL ALTERNATIVE B-SO2: INSTITUTIONAL CONTROLS
Deed Restrictions

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$600.91	$600.91	0.9524	$572.30
2	$0.00	$600.91	$600.91	0.9070	$545.04
3	$0.00	$600.91	$600.91	0.8638	$519.09
4	$0.00	$600.91	$600.91	0.8227	$494.37
5	$0.00	$20,000.00	$20,000.00	0.7835	$15,670.52
6	$0.00	$600.91	$600.91	0.7462	$448.41
7	$0.00	$600.91	$600.91	0.7107	$427.06
8	$0.00	$600.91	$600.91	0.6768	$406.72
9	$0.00	$600.91	$600.91	0.6446	$387.35
10	$0.00	$20,000.00	$20,000.00	0.6139	$12,278.27
11	$0.00	$600.91	$600.91	0.5847	$351.34
12	$0.00	$600.91	$600.91	0.5568	$334.61
13	$0.00	$600.91	$600.91	0.5303	$318.68
14	$0.00	$600.91	$600.91	0.5051	$303.50
15	$0.00	$20,000.00	$20,000.00	0.4810	$9,620.34
16	$0.00	$600.91	$600.91	0.4581	$275.28
17	$0.00	$600.91	$600.91	0.4363	$262.18
18	$0.00	$600.91	$600.91	0.4155	$249.69
19	$0.00	$600.91	$600.91	0.3957	$237.80
20	$0.00	$20,000.00	$20,000.00	0.3769	$7,537.79
21	$0.00	$600.91	$600.91	0.3589	$215.69
22	$0.00	$600.91	$600.91	0.3418	$205.42
23	$0.00	$600.91	$600.91	0.3256	$195.64
24	$0.00	$600.91	$600.91	0.3101	$186.32
25	$0.00	$20,000.00	$20,000.00	0.2953	$5,906.06
26	$0.00	$600.91	$600.91	0.2812	$169.00
27	$0.00	$600.91	$600.91	0.2678	$160.95
28	$0.00	$600.91	$600.91	0.2551	$153.29
29	$0.00	$600.91	$600.91	0.2429	$145.99
30	$0.00	$20,000.00	$20,000.00	0.2314	$4,627.55
TOTAL PRESENT WORTH					$63,206.25

CAMP ALLEN LANDFILL
AREAS A AND B SURFACE WATER/SEDIMENT ALTERNATIVES
Surface Water/Sediment Sampling Program

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
AREAS A AND B SURFACE WATER/SEDIMENT ALTERNATIVES
Surface Water/Sediment Sampling Program

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Surface Water/Sediment Sampling a. Semi-annual Sampling	$50,477.14	See itemized costs.	1-30
2. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
TOTAL ANNUAL O&M COST	$50,477.14	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR	$70,477.14	-	-

CAMP ALLEN LANDFILL
AREAS A AND B SURFACE WATER/SEDIMENT ALTERNATIVES
Surface Water/Sediment Sampling Program

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate =	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$50,477.14	$50,477.14	0.9524	$48,073.47
2	$0.00	$50,477.14	$50,477.14	0.9070	$45,784.25
3	$0.00	$50,477.14	$50,477.14	0.8638	$43,604.05
4	$0.00	$50,477.14	$50,477.14	0.8227	$41,527.67
5	$0.00	$70,477.14	$70,477.14	0.7835	$55,220.68
6	$0.00	$50,477.14	$50,477.14	0.7462	$37,666.82
7	$0.00	$50,477.14	$50,477.14	0.7107	$35,873.16
8	$0.00	$50,477.14	$50,477.14	0.6768	$34,164.91
9	$0.00	$50,477.14	$50,477.14	0.6446	$32,538.01
10	$0.00	$70,477.14	$70,477.14	0.6139	$43,266.85
11	$0.00	$50,477.14	$50,477.14	0.5847	$29,512.94
12	$0.00	$50,477.14	$50,477.14	0.5568	$28,107.56
13	$0.00	$50,477.14	$50,477.14	0.5303	$26,769.10
14	$0.00	$50,477.14	$50,477.14	0.5051	$25,494.39
15	$0.00	$70,477.14	$70,477.14	0.4810	$33,900.71
16	$0.00	$50,477.14	$50,477.14	0.4581	$23,124.16
17	$0.00	$50,477.14	$50,477.14	0.4363	$22,023.01
18	$0.00	$50,477.14	$50,477.14	0.4155	$20,974.29
19	$0.00	$50,477.14	$50,477.14	0.3957	$19,975.52
20	$0.00	$70,477.14	$70,477.14	0.3769	$26,562.09
21	$0.00	$50,477.14	$50,477.14	0.3589	$18,118.38
22	$0.00	$50,477.14	$50,477.14	0.3418	$17,255.60
23	$0.00	$50,477.14	$50,477.14	0.3256	$16,433.91
24	$0.00	$50,477.14	$50,477.14	0.3101	$15,651.34
25	$0.00	$70,477.14	$70,477.14	0.2953	$20,812.09
26	$0.00	$50,477.14	$50,477.14	0.2812	$14,196.23
27	$0.00	$50,477.14	$50,477.14	0.2678	$13,520.22
28	$0.00	$50,477.14	$50,477.14	0.2551	$12,876.40
29	$0.00	$50,477.14	$50,477.14	0.2429	$12,263.24
30	$0.00	$70,477.14	$70,477.14	0.2314	$16,306.82
TOTAL PRESENT WORTH					$831,597.87

APPENDIX C.2
SURFACE WATER/ SEDIMENT ALTERNATIVE
ITEMIZED COSTS AND BACKUP CALCULATIONS

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
CAPITAL COSTS						
MAPPING						
Aerial Surveying	1	LS	$4,420.00	$4,420	1993 Site Means 013-306-1500/1510	Aerial surveying, including ground control, cost interpolated between 10 and 100 acres.
Contour	15	Acre	$68.00	$1,020	1993 Site Means 013-306-1800	Generate 2' contours for 50 acres.
Detail Contouring	15	Acre	$9.80	$147	1993 Site Means 013-306-2150	Add for 1' contours (low relief of site could require more detailed mapping).
TOTAL				$5,587		
ASPHALT PAVING – BRIG AREA WITH WESTERN EDGE ALONG LIMIT OF AREA A						
Total Area:	528,000	SF	12.1	Acre		
Area Buildings:	63,000	SF	1.4	Acre		
Existing Pavement:	107,000	SF	2.5	Acre		
New Pavement:	358,000	SF	8.2	Acre		
New Pavement w/geomembrane						
Mobilization	7	LS	$300.00	$2,100	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, assume: dozer, backhoe, compactor, water truck, 2 trucks, & paver.
Light clearing	8.2	Acre	$1,675.00	$13,766	1993 Site Means 021-108-0500	Dozer & brush rake, light density for open areas.
Subgrade preparation	39,778	SY	$0.78	$31,027	1993 Site Means 022-304-0100	Prepare and roll subgrade, large area, over 2500 sy
Asphalt Pavement						
Subbase (4")	39,778	SY	$3.61	$143,598	1993 Site Means 022-308-0050/0100	Interpolated between 3" and 6" subbase, 3/4" stone
Base coarse (4"-BCBC)	39,778	SY	$6.90	$274,467	1993 Site Means 025-104-0200	Binder course, 4" thick BCBC
Surface coarse (2")	39,778	SY	$4.04	$160,702	1993 Site Means 025-104-0380	Wearing course, 2" thick
Liner System						
Geomembrane, 30 mil VLDPE	358,000	SF	$0.35	$125,300	Vendor Estimate	Gundle 30 mil VLDPE for 30+ acres, installed.
Geotextile (protection)	39,778	SY	$1.29	$51,313	1993 Site Means 027-054-0100	
CQA/CQC	10%	LS		$12,530	Approximated from previous projects	
Erosion and Sediment Control	4,635	LF	$6.00	$27,808	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Assume there will be 15 separate areas receiving new pavement, each area will be enclosed by silt fence.
TOTAL				$842,611		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
GAS VENT						
Solid Wall Pipe	9	LF	$8.25	$74	1993 Site Means 026-854-1600	Polyethylene piping, SDR 11, 4" diameter
Perforated Pipe	8	LF	$9.25	$74	1993 Site Means 026-854-1600	Polyethylene piping, SDR 11, 4" diameter – perforated by hand, est $1 extra/LF.
Pipe Fittings						
Elbows	2	EA	$57.00	$114	1993 Site Means 151-558-0610	Schedule 40 PVC, 4" diameter, assume similar cost for PE pipe
Tee	1	EA	$97.50	$98	1993 Site Means 151-558-0880	Schedule 40 PVC, 4" diameter, assume similar cost for PE pipe
Aggregate Backfill around laterals	0.34	CY	$19.30	$7	1993 Site Means 027-054-0300	Drainage material, 3/4" stone
Geotextile	5.2	SY	$1.29	$7	1993 Site Means 027-054-0100	Drainage geotextile, polypropylene, ideal conditions
Guard Post, 6" steel	20	LF	$30.50	$610	1993 Site Means 026-856-4240	Steel Schedule 40, plain end
Concrete Base & fill pipe	0.37	CY	$183.00	$68	1993 Site Means 033-130-0800	Concrete Base, 1'x1'x1.5, cost for cast in place spead footing.
Paint for guard posts	4	EA	$25.00	$100	Estimate	Assume 30 min/post @ $40/hr and $5 for materials.
TOTAL				$1,151		
STORMWATER MANAGEMENT STRUCTURES						Needed to manage increase in surface water runoff.
Piping	4,200	LF	$2.98	$12,516	1993 Site Means 027-111-0080	8" plastic corrugated
Trenching	4,200	LF	$1.94	$8,148	1993 Site Means 12.3-110-1310	2' wide x 2' deep trench
Pipe Bedding	4,200	LF	$1.35	$5,670	1993 Site Means 12.3-310-1460	Backfill w/sand in 2' wide trench, 8" dia pipe.
Geotextile	4,200	SY	$1.29	$5,418	1993 Site Means 027-054-0100	Drainage geotextile, polypropylene, ideal conditions
Backfill above bedding	622	CY	$1.19	$740	1993 Site Means 022-226-7500	Compaction, 24" wide vibrating roller, 6" lift 2 passes, use excavated site soils.
Manholes	10	EA	$1,310.00	$13,100	1993 Site Means 12.3-710-5820	Precase concrete, 4'ID riser, 4' deep
Curb inlets	21	EA	$722.50	$15,173	1993 Site Means 027-152-1582/1590	Curb inlet frame, grate, and curb box (avg), assume 1/200 lf
TOTAL				$60,765		
CONSTRUCTION TRAILER – RENTAL						
Initial Costs						
Mobilization	100	Mile	$1.82	$182	1993 Site Means 015-904-0800	Assume delivery distance of 50 miles, one way.
Access road	89	SY	$3.57	$317	1993 Site Means 015-552-0050	Assume 10'x80' gravel drive
SUBTOTAL				$499		
Monthly Usage Costs – Rental						
Furnished Field Trailer	1	Month	$450.00	$450	1993 Site Means 015-904-0550	Rent 50'x12' furnished field trailer, assume supplies included.
Office lights and HVAC	1	Month	$275.00	$275	1993 Site Means 010-034-0160	Average cost for office supplies.
Telephone	1	Month	$259.00	$259	1993 Site Means 010-034-0140	
S[illegible]AL / MONTH				$984		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
CONSTRUCTION TRAILER – PURCHASE						
Initial Costs						
Mobilization	100	Mile	$1.82	$182	1993 Site Means 015-904-0800	Assume delivery distance of 50 miles, one way.
Furnished Field Trailer	1	LS	$15,500.00	$15,500	1993 Site Means 015-904-0500	
Access road	89	SY	$3.57	$317	1993 Site Means 015-552-0050	Assume 10'x80' gravel drive
SUBTOTAL				$15,999		
Monthly Usage Costs – Purchase						
Supplies	1	Month	$275.00	$275	1993 Site Means 010-034-0120	
Office lights and HVAC	1	Month	$275.00	$275	1993 Site Means 010-034-0160	
Telephone	1	Month	$259.00	$259	1993 Site Means 010-034-0140	
SUBTOTAL / MONTH				$809		
SUBTITLE C – VEGETATED COMPOSITE COVER SYSTEM — COST/ACRE						
Vegetative Cover	43.56	MSF	$44.50	$1,938	1993 Site Means 029-308-0200	Athletic field mix, hydro seed with mulch and fertilizer.
Cover Soil layer (24")						*Assume off site source required.*
Material	3227	CY	$17.00	$54,853	1993 Site Means 022-286-0700	Topsoil/loam, end dumped.
Placement	3227	CY	$3.86	$12,455	1993 Site Means 022-286-0400	Spread from pile to rough finish grade w/ 1.5 cy front end loader.
Drainage Layer						
Geotextile (filter)	4840	SY	$1.29	$6,244	1993 Site Means 027-054-0100	Drainage geotextile, polypropylene, ideal conditions
Aggregate (12")	4840	SY	$9.95	$48,158	1993 Site Means 022-308-0300	Base coarse for roadways and large paved areas, 3/4" stone compacted, 12" deep.
Geotextile (protection)	4840	SY	$1.29	$6,244	1993 Site Means 027-054-0100	
Liner System						
Geomembrane, 30 mil VLDPE	43560	SF	$0.35	$15,246	Vendor Estimate	Gundle 30 mil VLDPE for 30+ acres, installed.
Clay Soil (24")						Assume off site source required.
Excavate and Haul	3227	CY	$13.55	$43,721	1993 Site Means A12.1-416-1200	Excavate clay, 3/4 cy backhoe, three 6 cy dump trucks, 4 mile round trip.
Clay Borrow	3227	CY	$3.70	$11,939	1993 Site Means 022-216-6000	Clay borrow, material cost only.
Backfill and Compact	3227	CY	$3.63	$11,713	1993 Site Means A12.1-726-1250	75 hp dozer and tamper compactor, 150' haul, 6" lift 4 passes.
Prepare and Roll Subgrade	4840	SY	$0.78	$3,775	1993 Site Means 022-304-0100	Prepare and roll sub-base, large areas over 2500 sy.
Hand Remove Rocks and Debris	43.56	MSF	$10.65	$464	1993 Site Means 029-204-1900	Remove rocks and debris from grade by hand.
Collection Channels	4000	SY	$3.00	$12,000	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Assume grass drainage swale along one edge of a square acre of approximately 200' long x 20' wide.
CQA/CQC	10%	LS		$22,875	Appriximated from previous projects	
TOTAL – COVER SYSTEM (acre):				$251,625		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
VEGETATED COMPOSITE COVER SYSTEM OVER SOURCE AREA						
AREA A HOT SPOTS =	1.0	Acre				
Mobilization	7	EA	$300.00	$2,100	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, <25 miles, assume: dozer, backhoe, compactor, water truck, 2 haul trucks, & scraper
Light clearing	1.0	Acre	$1,675.00	$1,675	1993 Site Means 021-108-0500	Dozer & brush rake, light density for open areas.
Earthwork						Based on regrading for 3% min slope, entire Area A, assume on-site borrow available.
Load and Haul off-site material	1,750	CY	$7.12	$12,460	1993 Site Means 12.1-614-5000	Load and haul common earth, most expensive option selected.
Compact borrow material	1,750	CY	$3.61	$6,318	1993 Site Means 12.1-724-1800/1900	Common earth backfill, 105 hp dozer, 150' haul, 6" lift, 2 passes
Cover System – Vegetated	1.0	Acre	$251,624.78	$251,625	See itemized costs.	
Gas Vent	4	EA	$1,150.97	$4,604	See itemized costs.	Assume one vent per capped area.
Toe Drain	1,800	LF	$8.67	$15,606	See itemized costs.	Assume toe drain around perimeter of site.
Erosion and Sediment Control	800	LF	$6.00	$4,800	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Assume downslope area lined by silt fence.
TOTAL				$299,187		
VACUUM EXTRACTION SYSTEM – SOURCE AREA A-1						
Vacuum Extraction Well Installation, # of 20' deep wells =			7			
Construct Well, 20'/well	140	LF	$15.00	$2,100	EPA/600/R-92/173	Extraction Well Construction
Well Casing, 2'/well	14	LF	$5.00	$70	EPA/600/R-92/173	4" PVC, solid wall
Well Screen, 18'/well	126	LF	$7.00	$882	EPA/600/R-92/173	4" PVC, slotted/perforated
Screen Backfill	3.57	CY	$20.00	$71	EPA/600/R-92/173	Sand and Gravel Pack, assume 12.5" diameter auger boring.
Bentonite Casing Seal	10.71	CF	$12.10	$130	1993 Site Means 071-301-0300	Granular Bentonite, assume 12.5" diameter auger boring.
Piping and Valving						
Vapor Extraction Piping, 4"	675	LF	$34.53	$23,309	1993 Mechanical Means 151-701-3360/3190	Schedule 40 steel pipe, flanged, 150 lb weld neck, no hangers.
Gasket and bolt set, 4" piping	32	EA	$51.50	$1,648	1993 Mechanical Means 151-720-0670	Assume 2 for each elbow, 3 for each tee.
Groundwater Piping, 1"	800	LF	$4.60	$3,679	1993 Mechanical Means 151-701-0580/1240	Schedule 40 steel pipe, without couplings and hangers
Threaded couplings, 1"	80	EA	$24.50	$1,960	1993 Mechanical Means 151-716-5710	Malleable iron, 150 lb, black
Tracing	800	LF	$2.65	$2,120	Richardson 1993 Process Plant/Const Stds	
Trap	8	EA	$500.00	$4,000	Richardson 1993 Process Plant/Const Stds	Assume one trap/100 lf
Insulation	800	LF	$3.04	$2,432	1993 Mechanical Means 155-651-7835	Polyethylene tubing flexible closed cell foam, UV resistant.
Valves, 6"	1	EA	$1,470.00	$1,470	Vendor Estimate	Carbon Steel Ball Valves
Valves, 4"	10	EA	$860.00	$8,600	Vendor Estimate	Carbon Steel Ball Valve
Valve/Gate Boxes	10	EA	$128.50	$1,285	1993 Site Means 026-690-8800	Curb box, 6' long
Tees, 6"	72	EA	$370.00	$26,640	1993 Mechanical Means 151-720-0420	Flanged joints, cast iron, standard weight, black
Tees, 4"	4	EA	$270.00	$1,080	1993 Mechanical Means 151-720-0400	Flanged joints, cast iron, standard weight, black
90 deg. Elbows, 4"	10	EA	$174.00	$1,740	1993 Mechanical Means 151-720-0110	Flanged joints, cast iron, standard weight, black
Central Header Pipe – 6"	250	LF	$60.16	$15,040	1993 Mechanical Means 151-701-3360/3190	Schedule 40 steel pipe, flanged joints, 150# weld neck, no hangers

(Continued)

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
(Vacuum Extraction System – continued)						
Gasket and bolt set, 6" piping	222	EA	$70.00	$15,540	1993 Mechanical Means 151-720-0690	Assume 2 for each elbow, 3 for each tee.
90 deg. Elbows, 6"	3	EA	$260.00	$780	1993 Mechanical Means 151-720-0130	Flanged joints, cast iron, standard weight, black
Vapor Treatment System Equipment						
Vacuum Pump System	1	EA	$75,000.00	$75,000	Vendor Estimate	Two (2) skid mojunted systems w/controls – a total of 175 scfm at 27" Hg.
Instrumentation/Control	1	EA	$4,723.50	$4,723	Estimate	Based on 5% of total capital cost of vapor treatment system equipment, and piping and valving
Vacuum Breaker	1	EA	$225.00	$225	EPA/600/R-92/173	Relief Valve for vacuum service
Air/Water Separator	1	EA	$2,150.00	$2,150	EPA/600/R-92/173	105 Gal Unit
Groundwater Pump	1	EA	$2,500.00	$2,500	Vendor Estimate	10 gpm Transfer Pump (positive displacement)
1800 Gal Water Collection Tank	1	EA	$2,270.00	$2,270	1993 Mechanical Means 132-051-3100/3120	Above Ground Steel Storage Tank
Vapor Phase Activated Carbon Unit	2	EA	$8,000.00	$16,000	Vendor Estimate	Cost for 2000 lb unit, price does not include installation.
Install Carbon Unit	80	HR	$41.50	$3,320	1993 Means Mechanical	Crew Q-3: 2-Plumbers
Temp E & S control measures	800	LF	$6.00	$4,800	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Assume silt fence around perimeter of site.
Initial Soil-Air Permeability Test	1	LS	$20,000.00	$20,000	Estimate	
Prefab Metal Building, 40'x20'	800	SF	$50.00	$40,000	Previous Report	Includes utility Conections (Area A1)
Prefab Metal Building, 20'x20'	400	SF	$50.00	$20,000	Previous Report	Includes utility Conections (Area A2)
TOTAL				$305,565		

CAMP ALLEN LANDFILL

FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
ON-SITE LOW TEMPERATURE TREATMENT – SOURCE AREA A-1						
Earth moving	12,814	CY				
Mobilization	7	LS	$300.00	$2,100	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, assume: backhoe, loader, compactor, water truck, 3 dump trucks.
Excavate w/Backhoe	12,814	CY	$5.22	$66,887	1993 Site Means A12.1-414-2000	Excavate common earth, 3/4 cy backhoe, three dump trucks, 1 MRT, includes 25% swell, and spotter.
Screening	12,814	CY	$5.21	$66,759	1993 Site Means 029-204-3500/3550	Screen from stockpile, vibrating screen, avg cost of wet @$6.25 and dry @$4.17.
Temp E & S control measures	961	LF	$6.00	$5,763	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	
Treatment						
Mobilization/Demobilization	1	LS	$400,000.00	$400,000	Vendor Estimate	Move treatment system on-site.
State Air Permit	2%	LS	$15,940.85	$15,941	1993 Site Means 010-070-0100	Permits, rule of thumb, most cities, maximum=2%, minimum=0.5%.
Treatment Cost	18,682	ton	$175.00	$3,269,379	Vendor Estimate	Based on unit weight of 120 pcf, assumes 10% disposed off site not treated.
Staging area – asphalt pad	2,500	SY				
Subbase (4")	2,500	SY	$3.61	$9,025	1993 Site Means 022-308-0050/0100	Interpolated between 3" and 6" subbase, 3/4" stone
Base coarse (4"-BCBC)	2,500	SY	$6.90	$17,250	1993 Site Means 025-104-0200	Binder course, 4" thick BCBC
Surface coarse (2")	2,500	SY	$4.04	$10,100	1993 Site Means 025-104-0380	Wearing course, 2" thick
System Operation						
Condensate Water	300,000	Gal	$0.00	$0	Vendor Estimate	Mix with treated soil (cost included in treatment cost).
Solvent Disposal						Off-site disposal of condensed solvents.
Analytical Charges	1	EA	$275.00	$275	Vendor Estimate	Assume 1 test/load
Transportation	1	Load	$3,800.00	$3,800	Vendor Estimate	Maximum capacity/truck load is 3500 gal.
Disposal Charges	1688	Gal	$4.88	$8,229	Vendor Estimate	Average disposal cost.
Off site disposal of oversized debris						Assume 10% disposed off site
Loading and Trucking	1,281	CY	$12.10	$15,504	1993 Site Means 020-620-3080	Machine loading and trucking, including 2 mile haul.
Hauling	1,281	CY	$9.89	$12,673	1993 Site Means 020-620-5100	Assume an additional 25 miles to dump site above distance included above.
Dump Charges	1,281	CY	$30.00	$38,441	1993 Site Means 020-612-0100	Dump charges, typical urban city fees, building construction materials.
Borrow to replace soil						
Excavate Common Earth	1,281	CY	$6.12	$7,842	1993 Site Means A12.1-414-2000	Excavate common earth, 3/4 cy backhoe, two 20 cy dump trucks, 4 mile round trip.
Revegetate Borrow Area	1.92	MSF	$44.50	$86	1993 Site Means 029-308-0200	Athletic field mix. Area based on an assume excation depth of 1.5'.
Temp E & S control measures	175	LF	$6.00	$1,052	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Silt Fence
Soil replacement of treated material						
Load and Haul	12,814	CY	$3.45	$44,591	1993 Site Means 12.1-614-2600	Load and haul common earth. 2.5 cy loader, 3-20 cy trucks, 1 MRT.
Compaction	12,814	CY	$6.59	$84,441	1993 Site Means 12.1-724-1650	Dozer 105 hp, and roller compactor, 150' haul, 4" lift, 4 passes
Revegetation	50.0	MSF	$44.50	$2,225	1993 Site Means 029-308-0200	Athletic field mix
TOTAL				$4,082,362		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
EXCAVATION AND DISPOSAL AT OFF-SITE RCRA PERMITED LANDFILL - SOIL						
Volume of material =	12,814	CY			Volume of contaminated soil material based on area of 38,536 sf x 6 ft in all areas except 11,475 sf x 10 ft in Area A1B.	
Excavation						
Mobilization	6	EA	$300.00	$1,800	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, assume: backhoe, loader, compactor, water truck, 2 trucks.
Backhoe	12,814	CY	$1.55	$19,861	1993 Site Means 022-238-0260	Remove waste material with backhoe, 2 cy cap (130 cy/hr)
Load	12,814	CY	$0.23	$2,979	1993 Site Means 022-238-0020	Add for loading
Roll-off box	16,017	CY	$8.63	$138,146	1993 Site Means 020-620-0840	Calculated cost per cy based on renting a 40 cy debris box container for 1 week.
Transportation	16,017	CY	$105.00	$1,681,779	1993 Site Means 020-717-1260/1270	Calculated cost per CY using a 25 cy truck, swell=125%, 375 miles.
Analytical Testing	208	EA	$235.00	$48,781	1993 Site Means 014-108-1600	Profile waste for off site disposal, assume 1 test/100 tons.
Disposal Charge	20,758	Ton	$214.00	$4,442,203	1993 Site Means 020-880-1110/1111	Disposal of contaminated soil to hazardous waste landfill, assume 120 pcf.
Borrow to replace soil						
Excavate Common Earth	12,814	CY	$6.12	$78,419	1993 Site Means A12.1-414-2000	Excavate common earth, 3/4 cy backhoe, two 20 cy dump trucks, 4 mile round trip.
Revegetate Borrow Area	230.64	MSF	$44.50	$10,264	1993 Site Means 029-308-0200	Athletic field mix. Area based on an assume excation depth of 1.5'.
Temp E & S control measures	1214	LF	$6.00	$7,282	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Silt fence around excavation area.
Compaction	12,814	CY	$6.59	$84,441	1993 Site Means 12.1-724-1850	Dozer 105 hp, and roller compactor, 150' haul, 4" lift, 4 passes
Revegetation Site	50	MSF	$44.50	$2,225	1993 Site Means 029-308-0200	Athletic field mix
TOTAL				$6,518,182		

CAMP ALLEN LANDFILL

FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
DECONTAMINATION FACILITY (for Excavation and Removal)						
Vehicle Decon Pad						
Concrete Pad	60	CY	$50.00	$3,000	1993 Mechanical Means 033-126-0010	100'X25'X8" Concrete only
Forms	167	SF	$12.85	$2,146	1993 Mechanical Means 031-154-0010	1 use pad forms
Gravel Subase (4")	2500	SF	$3.61	$9,025	1993 Site Means 022-308-0050/0100	Interpolated between 3" and 6" subbase, 3/4" stone
Containment Curb	50	LF	$5.80	$290	1993 Site Means 025-254-0410	Steel forms, 6"x18", straight
Collection Sump	1	EA	$520.00	$520	1993 Mechanical Means 027-152-1110	Concrete Manhole
Sump pump	1	Month	$246.00	$246	1993 Site Means 016-420-5500	Rental of 2" trash pump
Frame and Cover	1	EA	$175.00	$175	1993 Mechanical Means 027-152-1800	Metal Grate Light Traffic
Splash Guard	2500	SF	$0.07	$175	1993 Mechanical Means 015-602-0200	Plastic Sheeting @ Perimeter 250 LF X 10 LF
Spray cleaning	160	Hr	$33.39	$5,348	1993 Mechanical Means Crew Cost A-1A	Labor and sprayer, 15 min/20 cy truck.
Personnel Decon for Excavation Operations						
Concrete Pad	1	CY	$50.00	$46	1993 Mechanical Means 033-126-0010	10'x10'x4" Concrete only
Gravel Subase (4")	100	SF	$3.61	$361	1993 Site Means 022-308-0050/0100	Interpolated between 3" and 6" subbase, 3/4" stone
Containment Curb	40	LF	$5.80	$232	1993 Site Means 025-254-0410	Steel forms, 6"x18", straight
All Decon Operations						
Clean Water Storage Tank	1	EA	$370.00	$370	1993 Mechanical Means 132-051-3040	Tank, 275 gal
Water	3203	gal	$0.0025	$8	Proposed Municipality Water Charges	Decontamination water, assume 5 gal/truck, at cost of $2.55/1000 gal.
Spent Water Storage Tank	1	EA	$370.00	$370	1993 Mechanical Means 132-051-3040	Tank, 275 gal
Disposal of Spent Water	3203	gal	$6.00	$19,220	Vendor Estimate	Off site disposal of hazardous water, assume 5 gal/20 cy truck.
Removal of Decon. Pads	2600	SF	$6.20	$16,120	1993 Site Means 020-554-1750	Pavement removal, 4" to 6" thick.
Disposal of Decon. Pads	32	CY	$10.10	$324	1993 Site Means 020-554-5600	Disposal, 5 miles.
TOTAL				$57,977		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
OPERATION AND MAINTENANCE COSTS						
EXISTING FENCE O & M – AREA A AND AREA B						
Existing Fence Lengths:						
Area A	2,070	LF				
Area B	1,255	LF				
School	2,600	LF				
Total:	5,925	LF				
O & M:						
General Labor	2.2	HR	$37.16	$83	1993 Site Means, Crew A-1	Laborer and gas engine power tool (chain saw), rate of approx. 0.5 miles/hr.
Material for repairs	5,925	LF	$0.09	$513	1993 Site Means 028-308-0500	Assume material costs are 1% of new fence cost.
Replacement Locks for Gates	1.0	EA	$5.00	$5	Estimated lock cost	Assume locks on gates will need to be replaced every 3 years, assume one gate/fence.
TOTAL				$601		
ANNUAL MAINTENANCE – EXISTING SOIL COVERED AREAS						
Existing Vegetated Soil Cover =	46	Acres =	2,000,000	square feet		
Inspection	46	HR	$40.43	$1,856	CTO Modification 008404, 12/4/92	Assume annual inspection allowing one hour/acre – includes everything.
Mobilization	4	EA	$300.00	$1,200	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, <25 miles, assume one mowing tractor quarterly.
Mobilization	1	EA	$300.00	$300	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, <25 miles, assume one backhoe or dozer annually.
Regrade erosion depressions/gullie	185	CY	$11.43	$2,116	1993 Site Means 12.1-214-2000/2100	Assume 0.5% of cover/year, avg depth of 6" (EPA/625/4-91/025, pg 145)
Revegetate	10	MSF	$44.50	$445	1993 Site Means 029-308-0200	Athletic field mix, assume 0.5% area needs revegetation/year (EPA/625/4-91/025, pg 145)
Mowing w/tractor	8,000	MSF	$1.38	$11,040	1993 Site Means 029-730-4210	Using cutter or sickle-bar, 5' smooth terrain (quarterly).
TOTAL				$16,957		
ANNUAL MAINTENANCE – VEGETATED COMPOSITE COVER SYSTEM OVER SOURCE AREA						
Area of Vegetated Soil Cover over Hot Spots =			43,560	square feet		
Inspection	1	HR	$40.43	$40	CTO Modification 008404, 12/4/92	Assume annual inspection allowing one hour/acre – includes everything.
Mobilization	4	EA	$300.00	$1,200	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, <25 miles, assume one mowing tractor quarterly.
Mobilization	1	EA	$300.00	$300	1993 Site Means 022-274-XXXX	Typical cost/piece of equipment, <25 miles, assume backhoe or dozer annually.
Regrade erosion depressions/gullie	4	CY	$11.43	$46	1993 Site Means 12.1-214-2000/2100	Assume 0.5% of cover/year, avg depth of 6" (EPA/625/4-91/025, pg 145)
Revegetate	0.22	MSF	$44.50	$10	1993 Site Means 029-308-0200	Athletic field mix, assume 0.5% area needs revegetation (EPA/625/4-91/025, pg 145)
Mowing w/tractor	174	MSF	$1.38	$240	1993 Site Means 029-730-4210	Using cutter or sickle-bar, 5' smooth terrain (quarterly).
TOTAL				$1,837		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
FIVE YEAR REVIEW						
Information Review						
Gather Data						
Project Manager (P2)	40	HR	$53.47	$2,139	CTO Modification 008404, 12/4/92	
Project Engineer (P1)	40	HR	$40.43	$1,617	CTO Modification 008404, 12/4/92	
Pre-Meeting						
Project Manager (P2)	16	HR	$53.47	$856	CTO Modification 008404, 12/4/92	
Project Engineer (P1)	16	HR	$40.43	$647	CTO Modification 008404, 12/4/92	
Secretary (A1)	8	HR	$26.08	$209	CTO Modification 008404, 12/4/92	
Data Review						
Analysis						
Project Manager (P2)	40	HR	$53.47	$2,139	CTO Modification 008404, 12/4/92	
Project Engineer (P1)	80	HR	$40.43	$3,234	CTO Modification 008404, 12/4/92	
Prepare Report						
Project Manager (P2)	20	HR	$53.47	$1,069	CTO Modification 008404, 12/4/92	
Project Engineer (P1)	60	HR	$40.43	$2,426	CTO Modification 008404, 12/4/92	
Secretary (A1)	24	HR	$26.08	$626	CTO Modification 008404, 12/4/92	
Follow Up Meeting						
Project Manager (P2)	16	HR	$53.47	$856	CTO Modification 008404, 12/4/92	
Project Engineer (P1)	16	HR	$40.43	$647	CTO Modification 008404, 12/4/92	
Other Direct Costs						
Travel-Airfare	4	EA	$506.00	$2,024	CTO Modification 008404, 12/4/92	
Travel-Car Rental	2	Day	$65.00	$130	CTO Modification 008404, 12/4/92	
Lodging	4	Day	$66.00	$264	CTO Modification 008404, 12/4/92	
Meals	4	Day	$26.00	$104	CTO Modification 008404, 12/4/92	
Repoduction	1	LS	$1,014.28	$1,014	Estimate	
TOTAL				$20,000		

CAMP ALLEN LANDFILL
FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
ASPHALT AND SEWER MAINTENANCE (ASSUME 5 YEAR MAINTENANCE CYCLE)						
Asphalt Paved Areas						
Prepare and clean surface	51,667	SY	$0.10	$5,167	1993 Site Means 025-458-0800	Area based on assuming sealing entire brig area
Sealcoating	51,667	SY	$0.64	$33,067	1993 Site Means 025-458-0010	Area based on assuming sealing entire brig area
Seal cracks	5,167	LF	$0.72	$3,720	1993 Site Means 025-458-3040	Length based on assuming 1 lf crack/10 sy/year for entire brig area
Patch pavements	517	SY	$7.75	$4,004	1993 Site Means 029-710-5910	Area based on assuming 1 sy patch/100 sy/year for entire brig area
Storm Sewers						
Mobilization	1	LS	$377.50	$378	1993 Site Means 026-108-6110/6120	Average mobilization charge ($285 and $470).
Clean storm sewers	4,200	LF	$2.80	$11,760	1993 Site Means 026-108-6150	Cleaning sewage systems, power rodder w/header and cutters, 8" dia pipe.
TOTAL				$58,095		
VACUUM EXTRACTION SYSTEM – ANNUAL OPERATION AND MAINTENANCE COSTS						
Pump Power Requirements	1	Year	$9,600.00	$9,600	EPA/600/R-92/173	Based on cost of 25 HP modified to 30 HP.
Carbon Usage	24,000	LB	$2.20	$52,800	EPA/600/R-92/173	Based on replacing 2,000 lb/month, includes transportation.
Labor	1	Year	$15,000.00	$15,000	EPA/600/R-92/173	
Monitoring	24	EA	$141.67	$3,400	EPA/600/R-92/173	Based on twice a month evaluation of extraction well concentrations with a portable GC.
Collected Water Disposal	1200	Gal	$0.00	$0		Water will be treated on-site in groundwater treatment system.
Construction Trailer	12	Months	$809.00	$9,708	See itemized cost.	
TOTAL				$90,508		
VACUUM EXTRACTION SYSTEM – REMOVAL						
Seal Extraction Wells						
Drill out Well	140	LF	$15.00	$2,100	EPA/600/R-92/173	Extraction Well Construction
Bentonite Backfill	140	LF	$15.13	$2,118	1993 Site Means 071-301-0300	Granular Bentonite, volume to fill 6" dia hole.
Revegetate Site	44	MSF	$44.50	$1,938	1993 Site Means 029-308-0200	Athletic field mix
Temp E & S control	800	LF	$6.00	$4,800	Sept. 19, 1992 Fed. Reg., Vol. 57, No. 175, Table 1	Silt fence around perimeter of site.
TOTAL				$10,956		

CAMP ALLEN LANDFILL

FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
SURFACE WATER/SEDIMENT SAMPLING PROGRAM -- PER EVENT						
Labor						
Project Engineer (P1)	40	HR	$40.43	$1,617	CTO Modification 008404, 12/4/92	Sample collection.
Project Manager (P2)	20	HR	$53.47	$1,069	CTO Modification 008404, 12/4/92	Data management and reporting.
Travel						
Airfare	1	EA	$608.00	$608	Standard Airfare.	Round-trip airfare (Pittsburgh, PA to Norfolk, VA)
Car Rental	2	Day	$45.00	$90	Estimated.	Car rental.
Lodging	2	Day	$80.00	$160	Estimated.	
Per Diem	2	Day	$30.00	$60	Estimated.	
Sample Collection						
Field Equipment	1	LS	$100.00	$100	Estimated.	Field equipment (sampling equipment, coolers, etc.).
Expendable Supplies	1	LS	$50.00	$50	Estimated.	Miscellaneous expendable supplies (tyvek, ice, etc.).
Sample Shipping	1	LS	$100.00	$100	Estimated shipping rate.	Sample shipping via overnight courier to laboratory.
Analytical Costs (Including Validation)						
Surface Water:						
Volatiles	12	EA	$173.00	$2,076	Navy negotiated price.	Analytical cost.
Semi-Volatiles	12	EA	$347.00	$4,164	Navy negotiated price.	Analytical cost.
Metals	12	EA	$212.00	$2,544	Navy negotiated price.	Analytical cost.
Pesticides/PCBs	12	EA	$138.00	$1,656	Navy negotiated price.	Analytical cost.
Sediment:						
Volatiles	12	EA	$189.00	$2,268	Navy negotiated price.	Analytical cost.
Semi-Volatiles	12	EA	$359.00	$4,308	Navy negotiated price.	Analytical cost.
Metals	12	EA	$219.00	$2,628	Navy negotiated price.	Analytical cost.
Pesticides/PCBs	12	EA	$145.00	$1,740	Navy negotiated price.	Analytical cost.
TOTAL / EVENT				$25,239		
SURFACE WATER/SEDIMENT SAMPLING PROGRAM -- ANNUAL COSTS						
Water/Sediment Sampling	2	Event	$25,238.57	$50,477	See itemized costs.	Semi-annual Sampling Event

APPENDIX D - GROUNDWATER COSTING SUMMARIES

APPENDIX D
GROUNDWATER COSTING SUMMARIES

APPENDIX D.1
GROUNDWATER ALTERNATIVE COST ESTIMATE SPREADSHEETS

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW1: NO ACTION WITH MONITORING

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW1: NO ACTION WITH MONITORING

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$38,638.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$58,638.77	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$19,645.57	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$39,645.57	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$10,148.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$30,148.97	-	-

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW1: NO ACTION WITH MONITORING

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$38,638.77	$38,638.77	0.9524	$36,798.83
2	$0.00	$38,638.77	$38,638.77	0.9070	$35,046.51
3	$0.00	$38,638.77	$38,638.77	0.8638	$33,377.62
4	$0.00	$38,638.77	$38,638.77	0.8227	$31,788.21
5	$0.00	$58,638.77	$58,638.77	0.7835	$45,945.01
6	$0.00	$38,638.77	$38,638.77	0.7462	$28,832.85
7	$0.00	$38,638.77	$38,638.77	0.7107	$27,459.85
8	$0.00	$38,638.77	$38,638.77	0.6768	$26,152.24
9	$0.00	$38,638.77	$38,638.77	0.6446	$24,906.90
10	$0.00	$58,638.77	$58,638.77	0.6139	$35,999.12
11	$0.00	$19,645.57	$19,645.57	0.5847	$11,486.36
12	$0.00	$19,645.57	$19,645.57	0.5568	$10,939.39
13	$0.00	$19,645.57	$19,645.57	0.5303	$10,418.47
14	$0.00	$19,645.57	$19,645.57	0.5051	$9,922.35
15	$0.00	$39,645.57	$39,645.57	0.4810	$19,070.20
16	$0.00	$19,645.57	$19,645.57	0.4581	$8,999.86
17	$0.00	$19,645.57	$19,645.57	0.4363	$8,571.30
18	$0.00	$19,645.57	$19,645.57	0.4155	$8,163.14
19	$0.00	$19,645.57	$19,645.57	0.3957	$7,774.42
20	$0.00	$39,645.57	$39,645.57	0.3769	$14,942.00
21	$0.00	$10,148.97	$10,148.97	0.3589	$3,642.90
22	$0.00	$10,148.97	$10,148.97	0.3418	$3,469.42
23	$0.00	$10,148.97	$10,148.97	0.3256	$3,304.21
24	$0.00	$10,148.97	$10,148.97	0.3101	$3,146.87
25	$0.00	$30,148.97	$30,148.97	0.2953	$8,903.08
26	$0.00	$10,148.97	$10,148.97	0.2812	$2,854.30
27	$0.00	$10,148.97	$10,148.97	0.2678	$2,718.39
28	$0.00	$10,148.97	$10,148.97	0.2551	$2,588.94
29	$0.00	$10,148.97	$10,148.97	0.2429	$2,465.66
30	$0.00	$30,148.97	$30,148.97	0.2314	$6,975.79
TOTAL PRESENT WORTH					$476,664.19

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW2: INSTITUTIONAL CONTROLS AND MONITORING

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW2: INSTITUTIONAL CONTROLS AND MONITORING

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$38,638.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$58,638.77	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$19,645.57	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$39,645.57	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$10,148.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$30,148.97	-	-

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW2: INSTITUTIONAL CONTROLS AND MONITORING

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$38,638.77	$38,638.77	0.9524	$36,798.83
2	$0.00	$38,638.77	$38,638.77	0.9070	$35,046.51
3	$0.00	$38,638.77	$38,638.77	0.8638	$33,377.62
4	$0.00	$38,638.77	$38,638.77	0.8227	$31,788.21
5	$0.00	$58,638.77	$58,638.77	0.7835	$45,945.01
6	$0.00	$38,638.77	$38,638.77	0.7462	$28,832.85
7	$0.00	$38,638.77	$38,638.77	0.7107	$27,459.85
8	$0.00	$38,638.77	$38,638.77	0.6768	$26,152.24
9	$0.00	$38,638.77	$38,638.77	0.6446	$24,906.90
10	$0.00	$58,638.77	$58,638.77	0.6139	$35,999.12
11	$0.00	$19,645.57	$19,645.57	0.5847	$11,486.36
12	$0.00	$19,645.57	$19,645.57	0.5568	$10,939.39
13	$0.00	$19,645.57	$19,645.57	0.5303	$10,418.47
14	$0.00	$19,645.57	$19,645.57	0.5051	$9,922.35
15	$0.00	$39,645.57	$39,645.57	0.4810	$19,070.20
16	$0.00	$19,645.57	$19,645.57	0.4581	$8,999.86
17	$0.00	$19,645.57	$19,645.57	0.4363	$8,571.30
18	$0.00	$19,645.57	$19,645.57	0.4155	$8,163.14
19	$0.00	$19,645.57	$19,645.57	0.3957	$7,774.42
20	$0.00	$39,645.57	$39,645.57	0.3769	$14,942.00
21	$0.00	$10,148.97	$10,148.97	0.3589	$3,642.90
22	$0.00	$10,148.97	$10,148.97	0.3418	$3,469.42
23	$0.00	$10,148.97	$10,148.97	0.3256	$3,304.21
24	$0.00	$10,148.97	$10,148.97	0.3101	$3,146.87
25	$0.00	$30,148.97	$30,148.97	0.2953	$8,903.08
26	$0.00	$10,148.97	$10,148.97	0.2812	$2,854.30
27	$0.00	$10,148.97	$10,148.97	0.2678	$2,718.39
28	$0.00	$10,148.97	$10,148.97	0.2551	$2,588.94
29	$0.00	$10,148.97	$10,148.97	0.2429	$2,465.66
30	$0.00	$30,148.97	$30,148.97	0.2314	$6,975.79
TOTAL PRESENT WORTH					$476,664.19

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW3: EXTRACTION AND TREATMENT

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
1. Groundwater Extraction and Treatment System	$4,072,314.00	See itemized costs.	0
TOTAL DIRECT COST	$4,072,314.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$407,231.40	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$203,615.70	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$407,231.40	10% of Direct Cost	0
b. Health and Safety	$203,615.70	5% of Direct Cost	0
4. Contingency Allowance	$814,462.80	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$2,036,157.00		
TOTAL CAPITAL COSTS	$6,108,471.00		

Note: Capital costs for the groundwater extraction and treatment system includes costs for Area A1, Area A2, and Area B. (No capital costs are included for Area A2 and Area B extraction and treatment alternatives).

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW3: EXTRACTION AND TREATMENT

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Well Maintenance			
a. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
b. Extraction Well Maintenance	$1,750.00	See itemized costs.	1-30
4. Groundwater Treatment System	$148,647.84	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$187,286.61	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$207,286.61	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$168,293.41	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$188,293.41	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$158,796.81	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$178,796.81	-	-

Note: O&M costs for groundwater treatment system assumes treatment of Area A1 groundwater only.

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A1-GW3: EXTRACTION AND TREATMENT

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$6,108,471.00	$0.00	$6,108,471.00	1.0000	$6,108,471.00
1	$0.00	$187,286.61	$187,286.61	0.9524	$178,368.20
2	$0.00	$187,286.61	$187,286.61	0.9070	$169,874.48
3	$0.00	$187,286.61	$187,286.61	0.8638	$161,785.22
4	$0.00	$187,286.61	$187,286.61	0.8227	$154,081.16
5	$0.00	$207,286.61	$207,286.61	0.7835	$162,414.48
6	$0.00	$187,286.61	$187,286.61	0.7462	$139,756.15
7	$0.00	$187,286.61	$187,286.61	0.7107	$133,101.10
8	$0.00	$187,286.61	$187,286.61	0.6768	$126,762.95
9	$0.00	$187,286.61	$187,286.61	0.6446	$120,726.62
10	$0.00	$207,286.61	$207,286.61	0.6139	$127,256.00
11	$0.00	$168,293.41	$168,293.41	0.5847	$98,397.67
12	$0.00	$168,293.41	$168,293.41	0.5568	$93,712.07
13	$0.00	$168,293.41	$168,293.41	0.5303	$89,249.59
14	$0.00	$168,293.41	$168,293.41	0.5051	$84,999.61
15	$0.00	$188,293.41	$188,293.41	0.4810	$90,572.35
16	$0.00	$168,293.41	$168,293.41	0.4581	$77,097.15
17	$0.00	$168,293.41	$168,293.41	0.4363	$73,425.86
18	$0.00	$168,293.41	$168,293.41	0.4155	$69,929.39
19	$0.00	$168,293.41	$168,293.41	0.3957	$66,599.42
20	$0.00	$188,293.41	$188,293.41	0.3769	$70,965.81
21	$0.00	$158,796.81	$158,796.81	0.3589	$56,998.90
22	$0.00	$158,796.81	$158,796.81	0.3418	$54,284.67
23	$0.00	$158,796.81	$158,796.81	0.3256	$51,699.69
24	$0.00	$158,796.81	$158,796.81	0.3101	$49,237.80
25	$0.00	$178,796.81	$178,796.81	0.2953	$52,799.19
26	$0.00	$158,796.81	$158,796.81	0.2812	$44,660.13
27	$0.00	$158,796.81	$158,796.81	0.2678	$42,533.46
28	$0.00	$158,796.81	$158,796.81	0.2551	$40,508.06
29	$0.00	$158,796.81	$158,796.81	0.2429	$38,579.10
30	$0.00	$178,796.81	$178,796.81	0.2314	$41,369.55
TOTAL PRESENT WORTH					$8,870,216.83

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW1: NO ACTION WITH MONITORING

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW1: NO ACTION WITH MONITORING

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$38,638.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$58,638.77	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$19,645.57	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$39,645.57	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$10,148.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$30,148.97	-	-

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW1: NO ACTION WITH MONITORING

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$38,638.77	$38,638.77	0.9524	$36,798.83
2	$0.00	$38,638.77	$38,638.77	0.9070	$35,046.51
3	$0.00	$38,638.77	$38,638.77	0.8638	$33,377.62
4	$0.00	$38,638.77	$38,638.77	0.8227	$31,788.21
5	$0.00	$58,638.77	$58,638.77	0.7835	$45,945.01
6	$0.00	$38,638.77	$38,638.77	0.7462	$28,832.85
7	$0.00	$38,638.77	$38,638.77	0.7107	$27,459.85
8	$0.00	$38,638.77	$38,638.77	0.6768	$26,152.24
9	$0.00	$38,638.77	$38,638.77	0.6446	$24,906.90
10	$0.00	$58,638.77	$58,638.77	0.6139	$35,999.12
11	$0.00	$19,645.57	$19,645.57	0.5847	$11,486.36
12	$0.00	$19,645.57	$19,645.57	0.5568	$10,939.39
13	$0.00	$19,645.57	$19,645.57	0.5303	$10,418.47
14	$0.00	$19,645.57	$19,645.57	0.5051	$9,922.35
15	$0.00	$39,645.57	$39,645.57	0.4810	$19,070.20
16	$0.00	$19,645.57	$19,645.57	0.4581	$8,999.86
17	$0.00	$19,645.57	$19,645.57	0.4363	$8,571.30
18	$0.00	$19,645.57	$19,645.57	0.4155	$8,163.14
19	$0.00	$19,645.57	$19,645.57	0.3957	$7,774.42
20	$0.00	$39,645.57	$39,645.57	0.3769	$14,942.00
21	$0.00	$10,148.97	$10,148.97	0.3589	$3,642.90
22	$0.00	$10,148.97	$10,148.97	0.3418	$3,469.42
23	$0.00	$10,148.97	$10,148.97	0.3256	$3,304.21
24	$0.00	$10,148.97	$10,148.97	0.3101	$3,146.87
25	$0.00	$30,148.97	$30,148.97	0.2953	$8,903.08
26	$0.00	$10,148.97	$10,148.97	0.2812	$2,854.30
27	$0.00	$10,148.97	$10,148.97	0.2678	$2,718.39
28	$0.00	$10,148.97	$10,148.97	0.2551	$2,588.94
29	$0.00	$10,148.97	$10,148.97	0.2429	$2,465.66
30	$0.00	$30,148.97	$30,148.97	0.2314	$6,975.79
TOTAL PRESENT WORTH					$476,664.19

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW2: INSTITUTIONAL CONTROLS AND MONITORING

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW2: INSTITUTIONAL CONTROLS AND MONITORING

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$38,638.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$58,638.77	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$19,645.57	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$39,645.57	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$10,148.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$30,148.97	-	-

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW2: INSTITUTIONAL CONTROLS AND MONITORING

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$38,638.77	$38,638.77	0.9524	$36,798.83
2	$0.00	$38,638.77	$38,638.77	0.9070	$35,046.51
3	$0.00	$38,638.77	$38,638.77	0.8638	$33,377.62
4	$0.00	$38,638.77	$38,638.77	0.8227	$31,788.21
5	$0.00	$58,638.77	$58,638.77	0.7835	$45,945.01
6	$0.00	$38,638.77	$38,638.77	0.7462	$28,832.85
7	$0.00	$38,638.77	$38,638.77	0.7107	$27,459.85
8	$0.00	$38,638.77	$38,638.77	0.6768	$26,152.24
9	$0.00	$38,638.77	$38,638.77	0.6446	$24,906.90
10	$0.00	$58,638.77	$58,638.77	0.6139	$35,999.12
11	$0.00	$19,645.57	$19,645.57	0.5847	$11,486.36
12	$0.00	$19,645.57	$19,645.57	0.5568	$10,939.39
13	$0.00	$19,645.57	$19,645.57	0.5303	$10,418.47
14	$0.00	$19,645.57	$19,645.57	0.5051	$9,922.35
15	$0.00	$39,645.57	$39,645.57	0.4810	$19,070.20
16	$0.00	$19,645.57	$19,645.57	0.4581	$8,999.86
17	$0.00	$19,645.57	$19,645.57	0.4363	$8,571.30
18	$0.00	$19,645.57	$19,645.57	0.4155	$8,163.14
19	$0.00	$19,645.57	$19,645.57	0.3957	$7,774.42
20	$0.00	$39,645.57	$39,645.57	0.3769	$14,942.00
21	$0.00	$10,148.97	$10,148.97	0.3589	$3,642.90
22	$0.00	$10,148.97	$10,148.97	0.3418	$3,469.42
23	$0.00	$10,148.97	$10,148.97	0.3256	$3,304.21
24	$0.00	$10,148.97	$10,148.97	0.3101	$3,146.87
25	$0.00	$30,148.97	$30,148.97	0.2953	$8,903.08
26	$0.00	$10,148.97	$10,148.97	0.2812	$2,854.30
27	$0.00	$10,148.97	$10,148.97	0.2678	$2,718.39
28	$0.00	$10,148.97	$10,148.97	0.2551	$2,588.94
29	$0.00	$10,148.97	$10,148.97	0.2429	$2,465.66
30	$0.00	$30,148.97	$30,148.97	0.2314	$6,975.79
TOTAL PRESENT WORTH					$476,664.19

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW3: EXTRACTION AND TREATMENT

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

Note: Capital costs for the groundwater extraction and treatment system are included under Alternative A1-GW3.

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW3: EXTRACTION AND TREATMENT

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Well Maintenance			
a. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
b. Extraction Well Maintenance	$1,750.00	See itemized costs.	1-30
4. Groundwater Treatment System	$20,771.20	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$59,409.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$79,409.97	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$40,416.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$60,416.77	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$30,920.17	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$50,920.17	-	-

Note: O&M costs for groundwater treatment system represents adding Area A2 groundwater to treatment system.

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE A2-GW3: EXTRACTION AND TREATMENT

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$59,409.97	$59,409.97	0.9524	$56,580.93
2	$0.00	$59,409.97	$59,409.97	0.9070	$53,886.60
3	$0.00	$59,409.97	$59,409.97	0.8638	$51,320.57
4	$0.00	$59,409.97	$59,409.97	0.8227	$48,876.73
5	$0.00	$79,409.97	$79,409.97	0.7835	$62,219.79
6	$0.00	$59,409.97	$59,409.97	0.7462	$44,332.64
7	$0.00	$59,409.97	$59,409.97	0.7107	$42,221.56
8	$0.00	$59,409.97	$59,409.97	0.6768	$40,211.01
9	$0.00	$59,409.97	$59,409.97	0.6446	$38,296.20
10	$0.00	$79,409.97	$79,409.97	0.6139	$48,750.83
11	$0.00	$40,416.77	$40,416.77	0.5847	$23,630.85
12	$0.00	$40,416.77	$40,416.77	0.5568	$22,505.57
13	$0.00	$40,416.77	$40,416.77	0.5303	$21,433.88
14	$0.00	$40,416.77	$40,416.77	0.5051	$20,413.22
15	$0.00	$60,416.77	$60,416.77	0.4810	$29,061.50
16	$0.00	$40,416.77	$40,416.77	0.4581	$18,515.39
17	$0.00	$40,416.77	$40,416.77	0.4363	$17,633.70
18	$0.00	$40,416.77	$40,416.77	0.4155	$16,794.00
19	$0.00	$40,416.77	$40,416.77	0.3957	$15,994.29
20	$0.00	$60,416.77	$60,416.77	0.3769	$22,770.45
21	$0.00	$30,920.17	$30,920.17	0.3589	$11,098.56
22	$0.00	$30,920.17	$30,920.17	0.3418	$10,570.06
23	$0.00	$30,920.17	$30,920.17	0.3256	$10,066.72
24	$0.00	$30,920.17	$30,920.17	0.3101	$9,587.35
25	$0.00	$50,920.17	$50,920.17	0.2953	$15,036.87
26	$0.00	$30,920.17	$30,920.17	0.2812	$8,696.01
27	$0.00	$30,920.17	$30,920.17	0.2678	$8,281.92
28	$0.00	$30,920.17	$30,920.17	0.2551	$7,887.54
29	$0.00	$30,920.17	$30,920.17	0.2429	$7,511.94
30	$0.00	$50,920.17	$50,920.17	0.2314	$11,781.78
TOTAL PRESENT WORTH					$795,968.44

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW1: NO ACTION WITH MONITORING

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW1: NO ACTION WITH MONITORING

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$38,638.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$58,638.77	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$19,645.57	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$39,645.57	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$10,148.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$30,148.97	-	-

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW1: NO ACTION WITH MONITORING

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$38,638.77	$38,638.77	0.9524	$36,798.83
2	$0.00	$38,638.77	$38,638.77	0.9070	$35,046.51
3	$0.00	$38,638.77	$38,638.77	0.8638	$33,377.62
4	$0.00	$38,638.77	$38,638.77	0.8227	$31,788.21
5	$0.00	$58,638.77	$58,638.77	0.7835	$45,945.01
6	$0.00	$38,638.77	$38,638.77	0.7462	$28,832.85
7	$0.00	$38,638.77	$38,638.77	0.7107	$27,459.85
8	$0.00	$38,638.77	$38,638.77	0.6768	$26,152.24
9	$0.00	$38,638.77	$38,638.77	0.6446	$24,906.90
10	$0.00	$58,638.77	$58,638.77	0.6139	$35,999.12
11	$0.00	$19,645.57	$19,645.57	0.5847	$11,486.36
12	$0.00	$19,645.57	$19,645.57	0.5568	$10,939.39
13	$0.00	$19,645.57	$19,645.57	0.5303	$10,418.47
14	$0.00	$19,645.57	$19,645.57	0.5051	$9,922.35
15	$0.00	$39,645.57	$39,645.57	0.4810	$19,070.20
16	$0.00	$19,645.57	$19,645.57	0.4581	$8,999.86
17	$0.00	$19,645.57	$19,645.57	0.4363	$8,571.30
18	$0.00	$19,645.57	$19,645.57	0.4155	$8,163.14
19	$0.00	$19,645.57	$19,645.57	0.3957	$7,774.42
20	$0.00	$39,645.57	$39,645.57	0.3769	$14,942.00
21	$0.00	$10,148.97	$10,148.97	0.3589	$3,642.90
22	$0.00	$10,148.97	$10,148.97	0.3418	$3,469.42
23	$0.00	$10,148.97	$10,148.97	0.3256	$3,304.21
24	$0.00	$10,148.97	$10,148.97	0.3101	$3,146.87
25	$0.00	$30,148.97	$30,148.97	0.2953	$8,903.08
26	$0.00	$10,148.97	$10,148.97	0.2812	$2,854.30
27	$0.00	$10,148.97	$10,148.97	0.2678	$2,718.39
28	$0.00	$10,148.97	$10,148.97	0.2551	$2,588.94
29	$0.00	$10,148.97	$10,148.97	0.2429	$2,465.66
30	$0.00	$30,148.97	$30,148.97	0.2314	$6,975.79
TOTAL PRESENT WORTH					$476,664.19

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW2: INSTITUTIONAL CONTROLS AND MONITORING

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW2: INSTITUTIONAL CONTROLS AND MONITORING

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$38,638.77	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$58,638.77	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$19,645.57	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$39,645.57	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$10,148.97	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$30,148.97	-	-

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW2: INSTITUTIONAL CONTROLS AND MONITORING

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$38,638.77	$38,638.77	0.9524	$36,798.83
2	$0.00	$38,638.77	$38,638.77	0.9070	$35,046.51
3	$0.00	$38,638.77	$38,638.77	0.8638	$33,377.62
4	$0.00	$38,638.77	$38,638.77	0.8227	$31,788.21
5	$0.00	$58,638.77	$58,638.77	0.7835	$45,945.01
6	$0.00	$38,638.77	$38,638.77	0.7462	$28,832.85
7	$0.00	$38,638.77	$38,638.77	0.7107	$27,459.85
8	$0.00	$38,638.77	$38,638.77	0.6768	$26,152.24
9	$0.00	$38,638.77	$38,638.77	0.6446	$24,906.90
10	$0.00	$58,638.77	$58,638.77	0.6139	$35,999.12
11	$0.00	$19,645.57	$19,645.57	0.5847	$11,486.36
12	$0.00	$19,645.57	$19,645.57	0.5568	$10,939.39
13	$0.00	$19,645.57	$19,645.57	0.5303	$10,418.47
14	$0.00	$19,645.57	$19,645.57	0.5051	$9,922.35
15	$0.00	$39,645.57	$39,645.57	0.4810	$19,070.20
16	$0.00	$19,645.57	$19,645.57	0.4581	$8,999.86
17	$0.00	$19,645.57	$19,645.57	0.4363	$8,571.30
18	$0.00	$19,645.57	$19,645.57	0.4155	$8,163.14
19	$0.00	$19,645.57	$19,645.57	0.3957	$7,774.42
20	$0.00	$39,645.57	$39,645.57	0.3769	$14,942.00
21	$0.00	$10,148.97	$10,148.97	0.3589	$3,642.90
22	$0.00	$10,148.97	$10,148.97	0.3418	$3,469.42
23	$0.00	$10,148.97	$10,148.97	0.3256	$3,304.21
24	$0.00	$10,148.97	$10,148.97	0.3101	$3,146.87
25	$0.00	$30,148.97	$30,148.97	0.2953	$8,903.08
26	$0.00	$10,148.97	$10,148.97	0.2812	$2,854.30
27	$0.00	$10,148.97	$10,148.97	0.2678	$2,718.39
28	$0.00	$10,148.97	$10,148.97	0.2551	$2,588.94
29	$0.00	$10,148.97	$10,148.97	0.2429	$2,465.66
30	$0.00	$30,148.97	$30,148.97	0.2314	$6,975.79
TOTAL PRESENT WORTH					$476,664.19

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW3: EXTRACTION AND TREATMENT

CAPITAL COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
DIRECT CAPITAL COST:			
(No costs associated with this alternative.)			
TOTAL DIRECT COST	$0.00		
INDIRECT CAPITAL COSTS:			
1. Engineering and Design	$0.00	10% of Direct Cost	0
2. Remedial Action Contractor Fee	$0.00	5% of Direct Cost	0
3. Oversite Costs			
a. Administrative Costs	$0.00	10% of Direct Cost	0
b. Health and Safety	$0.00	5% of Direct Cost	0
4. Contingency Allowance	$0.00	20% of Direct Cost	0
TOTAL INDIRECT COSTS	$0.00		
TOTAL CAPITAL COSTS	$0.00		

Note: Capital costs for the groundwater extraction and treatment system are included under Alternative A1-GW3.

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW3: EXTRACTION AND TREATMENT

OPERATIONS AND MAINTENANCE COSTS

COST COMPONENT	COST ESTIMATE	BASIS OF ESTIMATE	YEAR INCURRED
1. Five Year Review	$20,000.00	See itemized costs.	5,10,15,20,25,30
2. Groundwater Sampling			
a. Quarterly Sampling	$37,986.40	See itemized costs.	1-10
b. Semi-annual Sampling	$18,993.20	See itemized costs.	11-20
c. Annual Sampling	$9,496.60	See itemized costs.	21-30
3. Well Maintenance			
a. Monitoring Well Maintenance	$652.37	See itemized costs.	1-30
b. Extraction Well Maintenance	$1,750.00	See itemized costs.	1-30
4. Groundwater Treatment System	$23,801.08	See itemized costs.	1-30
TOTAL ANNUAL O&M COST YEARS ONE TO TEN	$62,439.85	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ONE TO TEN	$82,439.85	-	-
TOTAL ANNUAL O&M COST YEARS ELEVEN TO TWENTY	$43,446.65	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS ELEVEN TO TWENTY	$63,446.65	-	-
TOTAL ANNUAL O&M COST YEARS TWENTY-ONE TO THIRTY	$33,950.05	-	-
O&M COST IN WHICH FIVE-YEAR REVIEWS OCCUR FOR YEARS TWENTY-ONE TO THIRTY	$53,950.05	-	-

Note: O&M costs for groundwater treatment system represents adding Area B groundwater to treatment system.

CAMP ALLEN LANDFILL
GROUNDWATER ALTERNATIVE B-GW3: EXTRACTION AND TREATMENT

PRESENT WORTH COST ANALYSIS

YEAR	COST COMPONENT				
	Capital Costs	O & M Costs	Annual Expenditures	Discount Factors Discount Rate = 5%	Present Worth
0	$0.00	$0.00	$0.00	1.0000	$0.00
1	$0.00	$62,439.85	$62,439.85	0.9524	$59,466.53
2	$0.00	$62,439.85	$62,439.85	0.9070	$56,634.79
3	$0.00	$62,439.85	$62,439.85	0.8638	$53,937.89
4	$0.00	$62,439.85	$62,439.85	0.8227	$51,369.42
5	$0.00	$82,439.85	$82,439.85	0.7835	$64,593.78
6	$0.00	$62,439.85	$62,439.85	0.7462	$46,593.58
7	$0.00	$62,439.85	$62,439.85	0.7107	$44,374.84
8	$0.00	$62,439.85	$62,439.85	0.6768	$42,261.75
9	$0.00	$62,439.85	$62,439.85	0.6446	$40,249.29
10	$0.00	$82,439.85	$82,439.85	0.6139	$50,610.92
11	$0.00	$43,446.65	$43,446.65	0.5847	$25,402.36
12	$0.00	$43,446.65	$43,446.65	0.5568	$24,192.72
13	$0.00	$43,446.65	$43,446.65	0.5303	$23,040.69
14	$0.00	$43,446.65	$43,446.65	0.5051	$21,943.51
15	$0.00	$63,446.65	$63,446.65	0.4810	$30,518.92
16	$0.00	$43,446.65	$43,446.65	0.4581	$19,903.41
17	$0.00	$43,446.65	$43,446.65	0.4363	$18,955.63
18	$0.00	$43,446.65	$43,446.65	0.4155	$18,052.98
19	$0.00	$43,446.65	$43,446.65	0.3957	$17,193.32
20	$0.00	$63,446.65	$63,446.65	0.3769	$23,912.38
21	$0.00	$33,950.05	$33,950.05	0.3589	$12,186.11
22	$0.00	$33,950.05	$33,950.05	0.3418	$11,605.82
23	$0.00	$33,950.05	$33,950.05	0.3256	$11,053.16
24	$0.00	$33,950.05	$33,950.05	0.3101	$10,526.82
25	$0.00	$53,950.05	$53,950.05	0.2953	$15,931.60
26	$0.00	$33,950.05	$33,950.05	0.2812	$9,548.14
27	$0.00	$33,950.05	$33,950.05	0.2678	$9,093.46
28	$0.00	$33,950.05	$33,950.05	0.2551	$8,660.44
29	$0.00	$33,950.05	$33,950.05	0.2429	$8,248.04
30	$0.00	$53,950.05	$53,950.05	0.2314	$12,482.83
TOTAL PRESENT WORTH					$842,545.12

APPENDIX D.2
GROUNDWATER ALTERNATIVE ITEMIZED COSTS AND BACKUP CALCULATIONS

Camp Allen Landfill
Groundwater Collection and Treatment System
Estimate of Annual Operation and Maintenance Costs

No.	Description	Unit	Unit Cost	Operation of the Treatment Facility With Area A1 Only (82 GPM)			Operation of the Treatment Facility with Areas A1 and B (124 GPM)			Operation of the Treatment Plant with Areas A1, B and A2 (206 GPM)		
				Hours Per Day	Days per Year	Total Annual Cost	Hours Per Day	Days per Year	Total Annual Cost	Hours Per Day	Days per Year	Total Annual Cost
	Labor Costs											
1	Routine Operations	Hours	$ 29.10	8	250	$ 58,200.00	10	250	$ 72,750.00	12	250	$ 87,300.00
2	Sludge Processing	Hours	$ 29.10	8	26	$ 6,052.80	8	26	$ 6,052.80	8	36	$ 8,380.80
3	Heavy Maintenance	Hours	$ 29.10	8	12	$ 2,793.60	8	18	$ 4,190.40	8	18	$ 4,190.40
4	Sampling	Hours	$ 29.10	8	12	$ 2,793.60	8	12	$ 2,793.60	8	12	$ 2,793.60
						$ 69,840.00			$ 85,786.80			$ 102,664.80
	Analytical Costs											
					Samples / Year	Cost Per Year		Samples / Year	Cost Per Year		Samples / Year	Cost Per Year
5	TCL Volatiles	Sample	$ 210.00		12	$ 2,520.00		12	$ 2,520.00		12	$ 2,520.00
6	TCL Semi-Volatiles	Sample	$ 450.00		12	$ 5,400.00		12	$ 5,400.00		12	$ 5,400.00
7	NPDES Metals	Sample	$ 305.00		12	$ 3,660.00		12	$ 3,660.00		12	$ 3,660.00
8	PCB/Pesticides	Sample	$ 175.00		12	$ 2,100.00		12	$ 2,100.00		12	$ 2,100.00
9	Miscellaneous	Sample	$ 50.00		12	$ 600.00		12	$ 600.00		12	$ 600.00
						$ 14,280.00			$ 14,280.00			$ 14,280.00
	Electrical											
	Cost /KWH	$ 0.10										
				Efficiency	Utilization	Cost per Year	Efficiency	Utilization	Cost per Year	Efficiency	Utilization	Cost per Year
10	Groundwater Pumps	Horsepower	15	60%	40%	$ 2,352.59	60%	60%	$ 3,528.88	60%	90%	$ 5,293.32
11	Influent Pumps	Horsepower	10	70%	80%	$ 3,659.58	70%	80%	$ 3,659.58	70%	80%	$ 3,659.58
12	Metals Rem. Feed	Horsepower	10	70%	80%	$ 3,659.58	70%	80%	$ 3,659.58	70%	80%	$ 3,659.58
13	Sand Filter Feed	Horsepower	15	70%	80%	$ 5,489.37	70%	80%	$ 5,489.37	70%	80%	$ 5,489.37
14	GAC Feed	Horsepower	15	70%	80%	$ 5,489.37	70%	80%	$ 5,489.37	70%	80%	$ 5,489.37
15	Chemical Feed	Horsepower	1	90%	80%	$ 470.52	90%	80%	$ 470.52	90%	80%	$ 470.52
16	Air Compressor	Horsepower	30	70%	40%	$ 5,489.37	70%	40%	$ 5,489.37	70%	40%	$ 5,489.37
17	Backwash Pumps	Horsepower	15	70%	10%	$ 686.17	70%	20%	$ 1,372.34	70%	25%	$ 1,715.43
18	Air Stripper Fan	Horsepower	5	70%	80%	$ 1,829.79	70%	80%	$ 1,829.79	70%	80%	$ 1,829.79
19	Bldg Ventilation	KW	20	100%	90%	$ 15,768.00	100%	90%	$ 15,768.00	100%	90%	$ 15,768.00
20	Bldg Heat	KW	20	100%	60%	$ 10,512.00	100%	60%	$ 10,512.00	100%	60%	$ 10,512.00
21	Mixers/Agitators	Horsepower	2	60%	90%	$ 705.78	60%	90%	$ 705.78	60%	90%	$ 705.78
22	Lighting	KW	5	100%	30%	$ 1,314.00	100%	40%	$ 1,752.00	100%	50%	$ 2,190.00
23	Miscellaneous	Horsepower	2	70%	50%	$ 457.45	70%	50%	$ 457.45	70%	50%	$ 457.45
						$ 57,883.54			$ 60,184.00			$ 62,729.53
	Chemicals											
					Consumption	Annual Cost		Consumption	Annual Cost		Consumption	Annual Cost
24	50% NaOH	Ton	$ 285.00		8	$ 2,280.00		12	$ 3,420.00		18	$ 5,130.00
25	HCL	Gallon	$ 0.75		150	$ 112.50		200	$ 150.00		300	$ 225.00
26	Polymer	Gallon	$ 12.50		50	$ 625.00		75	$ 937.50		125	$ 1,562.50
						$ 3,017.50			$ 4,507.50			$ 6,917.50
	Sludge Disposal											
					Volume	Annual Cost		Volume	Annual Cost		Volume	Annual Cost
27	Transportation	Ton	$ 11.00		30	$ 330.00		45	$ 495.00		75	$ 825.00
28	Disposal	Ton	$ 30.00		30	$ 900.00		45	$ 1,350.00		75	$ 2,250.00
						$ 1,230.00			$ 1,845.00			$ 3,075.00
	Miscellaneous Costs											
						Annual Cost			Annual Cost			Annual Cost
29	Carbon Disposal	Estimated Lump Sum				$ 1,000.00			$ 1,100.00			$ 1,500.00
30	Administrative	Estimated at 2% of Labor Cost				$ 1,398.80			$ 1,715.74			$ 2,053.30
						$ 2,398.80			$ 2,815.74			$ 3,553.30
	Total Annual O&M Cost					$ 148,647.84			$ 169,419.04			$ 193,220.12

CAMP ALLEN LANDFILL

FEASIBILITY COST ESTIMATE – ITEMIZED COSTS

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL COST	REFERENCE	ITEM DESCRIPTION
GROUNDWATER ALTERNATIVES						
GROUNDWATER MONITORING WELL ANNUAL MAINTENANCE – AREA A1, AREA A2, AND AREA B						
Number of Wells	10					
Well maintenance (repainting)	10	EA	$10.00	$100	Estimate	Annualized cost based on 0.5 hr/well @ $40/hr, every 2 years, includes material costs.
Replacement Well	1	EA	$552.37	$552	Estimate, see itemized costs for well installation.	Annualized cost based on replacing one well every five years.
TOTAL				$652		
GROUNDWATER SAMPLING PER EVENT – AREA A1, AREA A2, AND AREA B						
Number of Wells/Samples:	10					
Sampling						
Labor	20	HR	$40.43	$809	Final fee proposal, CTO Modification 008404, 12/4/	Based on cost of technicial @ $40/hr, 2 hr/well.
Travel (1 person)						
Lodging	3	Day	$66.00	$198	Final fee proposal, CTO Modification 008404, 12/4/	Assume 4 wells per day (2 deep and 2 shallow).
Meals	3	Day	$26.00	$78	Final fee proposal, CTO Modification 008404, 12/4/92	
Car rental	3	Day	$65.00	$195	Final fee proposal, CTO Modification 008404, 12/4/92	
Airfair	1	EA	$506.00	$506	Final fee proposal, CTO Modification 008404, 12/4/92	
Analytical Costs						
Water – TCL Volatiles	10	EA	$210.00	$2,100	Previous Report	Wadsworth/Alert 1992 Fee Schedule
Water – TCL Semivolatiles	10	EA	$260.00	$2,600	Previous Report	Wadsworth/Alert 1992 Fee Schedule
Water – Metals	10	EA	$231.00	$2,310	Previous Report	Wadsworth/Alert 1992 Fee Schedule
QA/QC	10%	LS		$701	Estimate at 10% of analytical costs.	
TOTAL				$9,497		
EXTRACTION WELLS – ANNUAL O&M						
Area A1 Wells	1	EA	$1,750.00	$1,750	Estimate	Assume replacement of 1 well/2 years.
Area A2 Wells	1	EA	$1,750.00	$1,750	Estimate	Assume replacement of 1 well/2 years.
Area B Wells	1	EA	$1,750.00	$1,750	Estimate	Assume replacement of 1 well/2 years.
TOTAL				$5,250		

PROJECT LOCATION: NAVAL BASE, NORFOLK, VIRGINIA
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	LABOR		
1	Direct Labor		$538,616
2	Indirect Costs		$510,847
3	TOTAL LABOR	(1 + 2)	$1,049,463
	SUBCONTRACTOR COSTS		
4	TOTAL SUBCONTRACTOR COSTS		$1,527,531
	TRAVEL COSTS		
5	TRAVEL COSTS (Air Fares + Per Diem [Meals, Lodging])		$161,925
	OTHER DIRECT COSTS		
6	Equipment		
7	Site Operations Costs		
8	Operating & Maintenance Costs		
9	TOTAL OTHER DIRECT COSTS	(6 + 7 + 8)	$807,697
	TOTAL COSTS LESS AWARD FEES & FCCOM		
10	SUBTOTAL	(3 + 4 + 5 + 9)	$3,546,615
11	G & A COSTS		$231,016
12	SUBTOTAL COST LESS AWARD FEES & FCCOM	(10 + 11)	$3,777,631
	MAXIMUM AWARD FEES		
13	Contractor Award Fee		$208,817
14	Contractor Award Fee on Subs		$76,377
15	TOTAL MAXIUM AWARD FEES	(13 + 14)	$285,194
	FCCOM		
16	FCCOM Labor		$5,750
17	FCCOM Equipment		$0
18	FCCOM G & A		$3,346
19	FCCOM Project Supplies		$393
20	TOTAL FCCOM	(16 + 17 + 18 + 19)	$9,489
21	**TOTAL ESTIMATED COST INCLUDING AWARD FEES**	(12 + 15 + 20)	$4,072,314

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33.01	MOBILIZATION AND PREPARATORY WORK	1	LS	37,353	5,165	15,476	1,371	12,521	2,820	37,353
33.03	SITE WORK	1	LS	156,238	8,299	10,670	9,754	127,515		156,238
33.05	SURFACE WATER COLLECTION AND CONTROL	1	LS	1,365	910	455				1,365
33.06	GROUNDWATER COLLECTION AND CONTROL	1	LS	559,660	89,185	71,288	22,844	376,344		559,660
33.07	AIR POLLUTION/GAS COLLECTION AND CONTROL	1	LS	13,500		2,250	11,250			13,500
33.12	CHEMICAL TREATMENT	1	LS	138,563	73,300	65,263				138,563
33.13	PHYSICAL TREATMENT	1	LS	719,079	558,800	160,279				719,079
33.18	DISPOSAL (OTHER THAN COMMERCIAL)	1	LS	973,194				973,194		973,194
33.20	SITE RESTORATION	1	LS	4,895		1,650	2,032	1,212		4,895
33.21	DEMOBILIZATION	1	LS	13,371		6,821	549	3,901	2,100	13,371
33.99	DISTRIBUTIVE COSTS	1	LS	394,314		204,465		32,844	157,005	394,314
	SUBTOTAL				735,659	538,616	47,799	1,527,531	161,925	3,011,530

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33.01.---	**MOBILIZATION AND PREPARATORY WORK**									
33.01.01.-	MOBILIZATION - CONSTRUCTION EQUIPMENT AND FACILITIES									
33.01.01.90	Backhoe, Dozer, Loader, Bobcat, Trucks	1	LS	1,795				1,795		1,795
	Hydraulic Truck Crane, Cherry Picker Dozer	1	EA	308						
	Air Compressor Backhoe	1	EA	341						
	Forklift	1	EA	75						
	Utility Tractor w/Backhoe	1	EA	75						
	Loader (1 CY)	1	EA	273						
	Hydraulic Truck Crane (55 Ton)	1	EA	308						
	Self-Propelled, 4 X 4 (25 Ton) (Cherry Picker)	1	EA	341						
	Air Compressor (850 CFM)	1	EA	75						
33.01.01.91	Site Office Trailer, Site Storage Trailer	5	EA	50				250		250
	32' X 8' Office Trailer	2	EA	50						
	24' X 8' Storage Trailer	3	EA	50						

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33.01.02.--	MOBILIZATION OF PERSONNEL									
33.01.02.01	Relocation of Supervisory Personnel	5	EA	476		880			1,500	2,380
	Site Supervisor	1	EA	540						
	Project Control Tech - Excavation & Concrete	1	EA	460						
	Project Control Tech - Building Erection	1	EA	460						
	Project Control Tech - Mechanical	1	EA	460						
	Project Control Tech - Electrical	1	EA	460						
33.01.02.90	Relocation of Administrative Personnel	1	EA	396		96			300	396
	Timekeeper/Clerk	1	EA	396						
33.01.02.91	Relocation of Labor Crew	1	EA	460		160			300	460
	Foreman	1	EA	460						
33.01.03.--	PRECONSTRUCTION SUBMITTALS/ IMPLEMENTATION PLANS									
33.01.03.01	Chemical Data Acquisition Plan	1	LS	1,200		1,200				1,200
33.01.03.03	Erosion Control Plan	1	LS	800		800				800
33.01.03.04	Environmental Protection Plan	1	LS	400		400				400
33.01.03.08	Site Safety and Health Plan	1	LS	1,200		1,200				1,200
33.01.03.13	General Site Work Plan	1	LS	5,040		5,040				5,040
33.01.03.14	Construction Quality Control Plan	1	LS	800		800				800
33.01.03.30	Local Permits	1	LS	800		800				800
33.01.03.90	Site Visit, Miscellaneous	1	LS	2,960		2,240			720	2,960

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33.01.04.--	SETUP/CONSTRUCT TEMPORARY FACILITIES									
33.01.04.01	Office Trailer	2	EA	200		400				400
33.01.04.02	Storage Trailer	3	EA	60		180				180
33.01.04.24	Security Fencing (Temporary Fencing)	500	LF	2	575	610				1,185
33.01.04.25	Roads and Parking (including Laydown Area)	1,700	SY	3	3,995	493	1,326			5,814

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33.01.04.91	Fuel Storage Area	45	SY	17	545	147	45			736

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33.01.05.--	CONSTRUCT TEMPORARY UTILITIES									
33.01.05.01	Temporary Construction Power & Lighting	1	LS	9,200				9,200		9,200
33.01.05.03	Telephone/Communications Hookup	1	LS	1,276				1,276		1,276
33.01.05.04	Water Connection/Distribution	1	EA	80	50	30				80

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33.03.--.--	SITE WORK									
33.03.03.--	EARTHWORK									
33.03.03.07	Grading	5,725	SY	1.69		3,779	5,897			9,675
33.03.03.90	Excavation for Parking Lot	390	CY	5.83		854	1,420			2,274
33.03.03.91	Strip and Stockpile Topsoil	954	CY	2.55		591	1,841			2,433

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33.03.04.--	ROADS/PARKING CURBS/WALKS									
33.03.04.01	Bituminous Surfacing	92	TON	43				3,988		3,988
33.03.04.02	Prime Coat/ Tack Coat	168	GAL	43				7,283		7,283
33.03.04.05	Base Courses	524	TON	23				12,240		12,240
	Base Courses, Asphaltic Concrete Base	244	TON	38						
	Base Courses Stone Subbase	280	TON	11						
33.03.04.08	Curbs and Gutters	720	LF	2.10				1,514		1,514

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33.03.04.09	Sidewalks	115	LF	14				1,578		1,578
33.03.05.–	FENCING									
33.03.05.01	Fencing	450	LF	14				6,371		6,371
33.03.05.02	Gates	2	EA	673				1,347		1,347
	Vehicle gate	1	EA	1,087						
	Pedestrian Gate	1	EA	259						
33.03.06.–	ELECTRICAL DISTRIBUTION									
33.03.06.90	Incoming Power	1	LS	38,650				38,650		38,650
	Incoming Power	1	LS	36,437						
	Meter	1	EA	2,214						

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33.03.08.--	WATER/SEWER/GAS DISTRIBUTION									
33.03.08.01	Water Distribution	220	LF	14	1,547	1,353	216			3,115

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33.03.08.02	Sanitary Sewer Collection	475	LF	7.39	632	2,641	238			3,510

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33.03.08.90	Water Distribution Appurtenances	1	LS	4,526	3,696	687	143			4,526
	Utility Vault	2	EA	455						
	Meter Box	1	EA	490						
	Meter	1	EA	191						
	Valves	2	EA	264						
	Hydrant	1	EA	1,550						
	Fittings	1	LS	357						
	Service Connection	1	LS	500						
33.03.08.91	Sewer Collection Appurtenances	1	LS	3,190	2,425	765				3,190
33.03.09.01	Steam Distribution	1	LS	54,544				54,544		54,544
	Exterior Steam Piping Distribution	300	LF	44,289						
	Pressure Reducing Station	1	LS	10,255						

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33.05.--.--	**SURFACE WATER COLLECTION AND CONTROL**									
33.05.07.--	SEDIMENT BARRIERS									
33.05.07.01	Silt Fence	910	LF	1.50	910	455				1,365

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33.06.---	**GROUNDWATER COLLECTION AND CONTROL**									
33.06.01.--	EXTRACTION AND INJECTION WELLS									
33.06.01.09	Well Development/Testing	23	EA	200				4,600		4,600
33.06.01.12	Well House	23	EA	1,810	24,610	13,041	3,979			41,630

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33.06.01.16	Flow Meter	23	EA	210	4,278	552				4,830
33.06.01.17	Holding Tank T110 GW Feed Tank	1	EA	43,000	25,800	17,200				43,000
33.06.01.18	Electrical (Wells)	1	LS	263,884				263,884		263,884
	Conduit & Wiring	8000	LF	22						
	Handholes	32	EA	1,179						
	Well Pump Power	23	EA	1,760						
	Control Wire	130	CLF	104						
33.06.01.90	Wells - Shallow	7	EA	700				4,900		4,900
33.06.01.91	Wells - Deep	16	EA	5,200				83,200		83,200

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33.06.01.92	Environmental Pumps - 1/2 HP	7	EA	795	4,445	1,120				5,565
33.06.01.93	Environmental Pumps - 3/4 HP	3	EA	895	2,145	540				2,685
33.06.01.94	Environmental Pumps - 3/4 HP	6	EA	1,036	4,962	1,254				6,216
33.06.01.95	Environmental Pumps - 1.5 HP	5	EA	1,199	4,790	1,205				5,995
33.06.01.96	Environmental Pumps - 3/4 HP	2	EA	2,380	3,780	980				4,760
33.06.01.97	Drums for Development Water & Cuttings	1	LS	19,760				19,760		19,760
	Shallow Wells	7	WELL	80						
	Deep Wells	16	WELL	1,200						

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33.06.01.98	Well Piping Valves & Fittings	23	WELL	89	1,265	782				2,047
33.06.07.~ 33.06.07.90	PUMPING/COLLECTION 2" Piping	700	LF	3.35	364	1,449	532			2,345

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33.06.07.91	3" Piping	510	LF	4.82	459	1,454	546			2,458

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33.06.07.92	4" Piping	5,750	LF	5.18	7,475	16,215	6,095			29,785
33.06.07.93	Road Crossing - Boring	4	EA	8,000	4,812	15,496	11,692			32,000
	Jacking Pits	4	EA	3,000						
	Boring	4	EA	5,000						

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CONTRACT NUMBER: CTO-0084 FS

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DATE: 06-Jul-94
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HTRW ACCT. NUMBER	DESCRIPTION OF ITEM	QUANT.	UNIT OF MEASURE	COST/ UNIT ($)	TOTAL MAT'L. COST($)	TOTAL LABOR COST($)	TOTAL EQUIP. COST($)	TOTAL SUBCON. COST($)	TOTAL TRAVEL COST($)	TOTAL CONTRACT COST($)
33.07.--.--	**AIR POLLUTION/GAS COLLECT. AND CONTROL**									
33.07.04.--	FUGITIVE DUST CONTROL									
33.07.04.04	Water Spraying	150	DAY	90		2,250	11,250			13,500

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33.12.--.--	CHEMICAL TREATMENT									
33.12.06.--	NEUTRALIZATION									
33.12.06.90	NaOH Feed Pump P121	1	EA	3,636	1,000	2,636				3,636
33.12.06.90	Effluent Backwash/Recycle Pump P241	1	EA	7,953	4,000	3,953				7,953
33.12.06.90	NaOH Mix Tank Agitator A120	1	EA	1,818	500	1,318				1,818
33.12.06.90	NaOH Mix Tank T120	1	EA	7,291	4,500	2,791				7,291
33.12.06.91	GW Feed Pump P110A/B	2	EA	8,953	10,000	7,907				17,907
33.12.06.91	Initial pH Adjustment Tank T130	1	EA	9,291	6,500	2,791				9,291
33.12.06.91	Initial pH Adjustment Tank Agitator A130	1	EA	2,068	750	1,318				2,068
33.12.06.91	Backwash Tank Effluent Pump P205	1	EA	6,453	2,500	3,953				6,453
33.12.06.91	Backwash Holding Tank T205	1	EA	43,000	25,800	17,200				43,000
33.12.06.91	pH Adjustment Pumps P120A/B	2	EA	3,886	2,500	5,271				7,771
33.12.06.92	Final pH Adjustment Tank T200	1	EA	8,791	6,000	2,791				8,791
33.12.06.92	Final pH Adjustment Tank Agitator A200	1	EA	2,068	750	1,318				2,068
33.12.06.92	Final pH Adjustment Tank Pumps P212A/B	2	EA	3,886	2,500	5,271				7,771
33.12.06.93	HCl Mix Tank Agitator A211	1	EA	1,818	500	1,318				1,818
33.12.06.93	HCl Feed Pump P211	1	EA	3,636	1,000	2,636				3,636
33.12.06.93	HCl Mix Tank T211	1	EA	7,291	4,500	2,791				7,291

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33.13.--.--	PHYSICAL TREATMENT									
33.13.01.--	FILTRATION/ULTRAFILTRATION									
33.13.01.90	Final pH Adjustment Tank Effluent Pumps P200A/B	2	EA	8,953	10,000	7,907				17,907
33.13.01.90	Sand Filters X200A/B/C	3	EA	27,300	75,000	6,900				81,900
33.13.01.90	Cartridge Filters F220A/B/C	3	EA	8,922	22,500	4,265				26,765
33.13.01.91	Air Compressor & Tank X100A/B	1	EA	31,407	23,500	7,907				31,407
33.13.01.92	Sump Pump P180	1	EA	1,159	500	659				1,159
33.13.02.--	SEDIMENTATION									
33.13.02.90	Sludge Holding Tank T140	1	EA	19,109	15,000	4,109				19,109
33.13.02.90	Clarifier Feed Pumps P130A/B	2	EA	8,953	10,000	7,907				17,907
33.13.02.90	Sludge Blowdown Pump P143	1	EA	4,953	1,000	3,953				4,953
33.13.02.90	Supernatant Surge Tank T145	1	EA	9,791	7,000	2,791				9,791
33.13.02.90	Sludge Holding Tank Supernatant Pump P145	1	EA	6,153	2,200	3,953				6,153
33.13.02.90	Sludge Recycle Pumps P140A/B	2	EA	5,153	2,400	7,907				10,307
33.13.02.90	Mixing Chamber w/Mixer X130A	1	EA	10,609	6,500	4,109				10,609
33.13.02.90	Flocculation Chamber w/Mixer X130B	1	EA	12,109	8,000	4,109				12,109
33.13.02.90	Lamella Clarifier X130C	1	EA	66,745	60,000	6,745				66,745

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33.13.02.90	Polymer Mix Tank T125	1	EA	7,791	5,000	2,791				7,791
33.13.02.90	Polymer Mix Tank Agitator A125	1	EA	1,818	500	1,318				1,818
33.13.02.90	Polymer Feed Pumps P132A/B	2	EA	3,886	2,500	5,271				7,771
33.13.02.90	Polymer Drum Pump P131	1	EA	4,953	1,000	3,953				4,953
33.13.02.90	Treated Effluent Pump P240	1	EA	6,453	2,500	3,953				6,453
33.13.02.90	Effluent Flow Measuring Weir	1	EA	2,945	1,500	1,445				2,945
33.13.05.--	EQUALIZATION									
33.13.05.90	Treated Effluent Tank T240	1	EA	40,000	24,000	16,000				40,000
33.13.07.--	AIR STRIPPING									
33.13.07.90	Stripping Column Fan K200	1	EA	8,953	5,000	3,953				8,953
33.13.07.90	Stripping Column C200	1	EA	28,218	20,000	8,218				28,218
33.13.07.90	Air Stripper Effluent Holding Tank T220	1	EA	9,927	4,500	5,427				9,927
33.13.20.--	CARBON ADSORPTION (LIQUID)									
33.13.20.90	Air Stripper Effluent Holding Tank Pumps P220A/B	2	EA	7,703	7,500	7,907				15,407
33.13.20.90	Liquid Phase GAC Absorber X220A/B/C/D	4	EA	54,031	200,000	16,125				216,125
33.13.30.--	FILTER PRESSES									
33.13.30.90	Sludge Filter Press X140	1	EA	46,745	40,000	6,745				46,745
33.13.30.90	Filter Press Feed Pump P141	1	EA	5,153	1,200	3,953				5,153

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33.18.--.--	**DISPOSAL (OTHER THAN COMMERCIAL)**									
33.18.01.--	STORAGE/DISPOSAL FACILITY									
	CONSTRUCTION/OPERATION									
33.18.01.90	Groundwater Treatment Plant	1	LS	973,194						
	Construction of Plant									
	Structural	1	LS	287,110				287,110		287,110
	Concrete Foundations	320	LF	89						
	Floor Slab	6,000	SF	5.10						
	Structural Precast	252	SF	4.80						
	Cavity Wall	6,634	SF	18						
	8" Interior CMU Walls	390	SF	5						
	6" Interior CMU Walls	176	SF	5						
	Bond Beams	972	LF	6.50						
	SS Flashing	46	SF	5.25						
	Steel WF/Plate Lintels	1	LS	1,700						
	Steel Angle Lintels	1	LS	810						
	SS Railings	24	LF	54						
	Interior Ladder	15	VLF	47						
	6" dia. Bollards	20	EA	450						
	Joint Sealant	1	LS	3,000						
	Perimeter Insulation	1,280	SF	0.75						
	Steel Doors & Frames:									
	Single Door, Frame and Hardware	5	EA	1,000						
	Double Door, Frame and Hardware	1	EA	1,750						
	Coiling Doors									
	12' wide Door with Electric Opener	1	EA	3,200						
	18' wide Door with Electric Opener	1	EA	7,500						
	Painting									
	Interior Painting - Masonry	8,280	SF	1.10						
	Paint Doors, Frames, & Miscellaneous Metals	1	EA	1,000						
	Toilet & Bath Accessories	1	LS	1,400						
	Pre-Engineered Building Components									
	Structural Steel Frames & Metal Roof - Shipped & Erected	6,000	SF FLR	7.50						
	Eave Flashing	204	LF	4.10						
	Rake Flashing	128	LF	4.25						
	Gutters	204	LF	3.65						
	Downspouts	120	LF	3.25						
	Roof Insulation	6,528	SF	0.65						

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	Mechanical	1	LS	169,107				169,107		169,107
	Process HVAC	1	LS	19,266						
	Building HVAC	1	LS	97,141						
	Plumbing	1	LS	52,700						
	Electrical	1	LS	516,976				516,976		516,976
	Panel MDP	1	EA	10,636						
	Panel PP1, PP2	2	EA	5,060						
	Panel PP3	1	EA	4,083						
	Panel PPA	1	EA	1,955						
	Transformer 45 KVA	1	EA	2,271						
	Lighting, Inside	64	EA	208						
	Lighting, Outdoor	11	EA	396						
	Exit & Emergency Lighting	7	EA	552						
	Conduits, Wiring, Terminations	1	LS	58,350						
	PLC Equipment	1	LS	127,100						
	PLC Conduit, Wire, Terminations	1	LS	20,240						
	Instrumentation/Control Equipment	1	LS	262,593						

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33.20.--.--	**SITE RESTORATION**									
33.20.01.--	EARTHWORK									
33.20.01.90	Spreading Stockpiled Topsoil	954	CY	3.86		1,650	2,032			3,682
33.20.04.--	REVEGETATION									
33.20.04.01	Seeding/Mulch/Fertilizer	1	ACRE	1,144				1,212		1,212

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33.21.--.--	DEMOBILIZATION									
33.21.01.--	REMOVAL OF TEMPORARY FACILITIES									
33.21.01.01	Office Trailer	2	EA	170		240		100		340
	Demob	2	EA	120						
	Transport Cost	2	EA	50						
33.21.01.02	Storage Trailer	3	EA	110		180		150		330
	Demob	3	EA	60						
	Transport Cost	3	EA	50						
33.21.01.24	Security Fencing (Temporary Fencing)	500	LF	1		610				610
33.21.01.25	Roads and Parking (Laydown Area)	297	CY	3.32		437	549			986
	Excavation	297	CY	2.87						
	Stabilization Fabric	297	CY	0.45						

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33.21.02.--	REMOVAL OF TEMPORARY UTILITIES									
33.01.05.01	Temporary Construction Power & Lighting	1	LS	1,000				1,000		1,000
33.21.02.03	Telephone/Communications Hookup	1	LS	856				856		856
33.21.02.04	Water Connection/Distribution	1	LS	30		30				30
33.21.04.--	DEMOBILIZATION OF CONSTRUCTION EQUIP.									
33.21.04.07	Construction Equipment	1	LS	2,215		420		1,795		2,215
	Decon	7	EA	60						
	Demob	8	EA	224						
33.21.05.--	DEMOBILIZATION OF PERSONNEL									
33.21.05.01	Relocation of Supervisory Personnel	5	EA	476		880			1,500	2,380
33.21.05.90	Relocation of Administrative Personnel	1	EA	396		96			300	396
33.21.05.91	Relocation of Labor Crew	1	EA	460		160			300	460

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33.21.06.–	POST-CONSTRUCTION SUBMITTALS									
33.21.06.01	Punch List	1	LS	480		480				480
33.21.06.01	Punch List	1	EA	240						
		4	EA	60						
33.21.06.03	Post-Construction Documentation (Disposal Certifications)	1	LS	480		480				480
33.21.06.06	Construction Documentation Report (Final Engineering Report)	1	LS	2,120		2,120				2,120
	Report Sections,	2	hrs	25						
	Supervision, QC,	8	hrs	25						
	& Production	8	hrs	25						
		8	hrs	25						
		8	hrs	25						
		4	hrs	25						
		4	hrs	25						
		4	hrs	25						
		8	hrs	25						
		16	hrs	30						
		24	hrs	10						
		5	hrs	10						
33.21.06.07	As Built Drawings	1	LS	688		688				688
	Supervision	4	EA	120						
	Draft Tech (CAD)	4	EA	52						

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33.99.--.--	**DISTRIBUTIVE COSTS**									
33.99.01.--	SUPERVISION/MANAGEMENT									
33.99.01.01	Project Manager	1	EA	9100		9,100				9,100
33.99.01.02	General Superintendent (Site Supervisor)	1	EA	62400		62,400				62,400
33.99.01.90	Project Control Technician - Excavation, Concrete, and Masonry	1	EA	7875		7,875				7,875
33.99.01.91	Project Control Technician - Building Erection	1	EA	5250		5,250				5,250
33.99.01.92	Project Control Technician - Mechanical	1	EA	26250		26,250				26,250
33.99.01.93	Project Control Technician - Electrical	1	EA	26250		26,250				26,250
33.99.01.94	Foreman	1	EA	42000		42,000				42,000
33.99.03.--	OFFICE MANAGEMENT									
33.99.03.03	Accountant	1	EA	3120		3,120				3,120
33.99.03.09	Typist/Secretary	1	EA	2080		2,080				2,080
33.99.04.--	ENGINEERING									
33.99.04.01	Project Engineer	1	EA	1300		1,300				1,300
33.99.04.02	Civil Engineer	1	EA	1920		1,920				1,920
33.99.04.03	Mechanical Engineer (including Process)	1	EA	3200		3,200				3,200
33.99.04.04	Electrical Engineer	1	EA	3200		3,200				3,200
33.99.04.14	Cost Engineer	1	EA	1520		1,520				1,520
33.99.04.17	Quality Control Engineer	1	EA	2600		2,600				2,600
33.99.05.--	PURCHASING									
33.99.05.02	Purchasing Agent	1	EA	1300		1,300				1,300

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33.99.07.--	EQUIPMENT MAINTENANCE AND MOTOR POOL									
33.99.07.02	Mechanic	1	EA	780		780				780
33.99.08.--	TEMPORARY CONSTRUCTION FACILITIES									
33.99.08.01	Office Trailer	24	MO	171				4,104		4,104
33.99.08.02	Storage Trailer	36	MO	102				3,672		3,672
33.99.08.09	Toilets (Portable)	24	MO	78				1,872		1,872
33.99.08.17	Office Equipment/Furnishings	24	MO	154				3,696		3,696
33.99.09.--	TEMPORARY UTILITIES									
33.99.09.01	Power	12	MO	200				2,400		2,400
33.99.09.02	Water	12	MO	56				672		672
33.99.09.04	Telephone	12	MO	259				3,108		3,108
33.99.13.--	VEHICLES FOR PERSONNEL									
33.99.13.01	Pickup Trucks (2)	24	MO	555				13,320		13,320
33.99.16.--	MISCELLANEOUS COSTS									
33.99.16.06	Project Travel - Home Office Personnel	27	EA	760		4,320			16,200	20,520
	Project Manager	12	EA	810						
	Civil Engineer	3	EA	720						
	Mechanical Engineer	4	EA	720						
	Electrical Engineer	4	EA	720						
	QC Engineer	4	EA	720						

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33.99.16.90	Per Diem - Home Office Personnel	27	EA	255					6885	6885
33.99.16.91	Project Travel - Site Personnel Air Fare	26	EA	600					15,600	15,600
	General Superintendent (Site Supervisor)	11	EA	600						
	Project Control Tech - Excavation, Concrete, Masonry	2	EA	600						
	Project Control Tech - Building Erection	1	EA	600						
	Project Control Tech - Mechanical	4	EA	600						
	Project Control Tech - Electrical	3	EA	600						
	Foreman	5	EA	600						

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33.99.16.92	Site Personnel Per Diem (Meals)	1120	DAY	34					38,080	38,080
	General Superintendent (Site Supervisor)	365	DAY	34						
	Project Control Tech - Excavation, Concrete, Masonry	90	DAY	34						
	Project Control Tech - Building Erection	60	DAY	34						
	Project Control Tech - Mechanical	150	DAY	34						
	Project Control Tech - Electrical	90	DAY	34						
	Foreman	365	DAY	34						
33.99.16.93	Site Personnel Per Diem (Lodging)	1180	DAY	68					80,240	80,240
	General Superintendent (Site Supervisor)	365	DAY	68						
	Project Control Tech - Excavation, Concrete, Masonry	90	DAY	68						
	Project Control Tech - Building Erection	60	DAY	68						
	Project Control Tech - Mechanical	150	DAY	68						
	Project Control Tech - Electrical	150	DAY	68						
	Foreman	365	DAY	68						
	SUBTOTAL				735,659	538,616	47,799	1,527,531	161,925	3,011,530

APPENDIX E - ESTIMATED AIR EMISSION CONCENTRATIONS FOR AIR STRIPPER

APPENDIX E
ESTIMATED AIR EMISSION CONCENTRATIONS FOR AIR STRIPPER

Table 6-3
Air Emissions Standards for Toxic Pollutants - Exemption Determination
Camp Allen Landfill, Norfolk Naval Base, Norfolk, Virginia

	TLV-C	TLV-STEL	TLV-TWA	Calculated Limit (TLV-STEL, TLV-TWA)		Calculated Limit (TLV-TWA only)		Maximum Limit		Relevant Standard		Groundwater Concentration (1)	Calculated Air Emissions (2)		Estimated Emissions Exemption Determination	
	mg/m3	mg/m3	mg/m3	lb/day	tons/yr	lb/day	tons/yr	lb/day	tons/yr	lb/day	tons/yr	(ug/L)	lb/day	tons/yr	lb/day	tons/yr
Acetone		2,380	1,780	7.85E+01	2.58E+02			2.28E+01	1.00E+02	2.28E+01	1.00E+02	262.3	3.53E-01	6.44E-02	Exempt	Exempt
Chloroethane			2,640			1.74E+02	3.83E+02	2.28E+01	1.00E+02	2.28E+01	1.00E+02	19.3	2.60E-02	4.74E-03	Exempt	Exempt
Chloroform			49			3.23E+00	7.11E+00	2.28E+01	1.00E+02	3.23E+00	7.11E+00	1.2	1.62E-03	2.95E-04	Exempt	Exempt
Benzene			32			2.11E+00	4.64E+00	2.28E+01	1.00E+02	2.11E+00	4.64E+00	47.4	6.38E-02	1.16E-02	Exempt	Exempt
Chlorobenzene			46			3.04E+00	6.67E+00	2.28E+01	1.00E+02	3.04E+00	6.67E+00	2.8	3.77E-03	6.88E-04	Exempt	Exempt
1,2-Dichloroethane			40			2.64E+00	5.80E+00	2.28E+01	1.00E+02	2.64E+00	5.80E+00	37	4.98E-02	9.09E-03	Exempt	Exempt
1,2-Dichloroethene			793			5.23E+01	1.15E+02	2.28E+01	1.00E+02	2.28E+01	1.00E+02	895	1.20E+00	2.20E-01	Exempt	Exempt
Dichlorofluromethane			42			2.77E+00	6.09E+00	2.28E+01	1.00E+02	2.77E+00	6.09E+00	1	1.35E-03	2.46E-04	Exempt	Exempt
1,1,1-Trichloroethane		2,460	1,910	8.12E+01	2.77E+02			2.28E+01	1.00E+02	2.28E+01	1.00E+02	0.3	4.04E-04	7.37E-05	Exempt	Exempt
Trichloroethene		50	269	1.65E+00	3.90E+01			2.28E+01	1.00E+02	1.65E+00	3.90E+01	76.2	1.03E-01	1.87E-02	Exempt	Exempt
Trichlorofluromethane			5,620			3.71E+02	8.15E+02	2.28E+01	1.00E+02	2.28E+01	1.00E+02	157	2.11E-01	3.86E-02	Exempt	Exempt
Toluene			188			1.24E+01	2.73E+01	2.28E+01	1.00E+02	1.24E+01	2.73E+01	0.5	6.06E-04	1.11E-04	Exempt	Exempt
Vinyl Chloride			13			8.58E-01	1.89E+00	2.28E+01	1.00E+02	8.58E-01	1.89E+00	556	7.48E-01	1.37E-01	Exempt	Exempt
Xylene (Total)		651	434	2.15E+01	6.29E+01			2.28E+01	1.00E+02	2.15E+01	6.29E+01	11.8	1.59E-02	2.90E-03	Exempt	Exempt
Total VOCs									7.00E+00		7.00E+00	2,068		5.08E-01		Exempt

TLV-C - Threshold Limit Value - Ceiling

TLV-STEL - Threshold Limit Value - Short-Term Exposure Limit

TLV-TWA - Treshold Limit Value - Time-Weighted Average

(1) Maximum detected concentration in groundwater during samping rounds 2 and 3; detection limit assumed when chemical not detected.

(2) Assume 100 percent transfer of chemical from groundwater to air at a pumping rate of 112 gpm, 24 hrs/day, for 365 days/yr.

APPENDIX F - RISK ASSESSMENT SUMMARY TABLES

APPENDIX F
RISK ASSESSMENT SUMMARY TABLES

TABLE 5-1

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR CURRENT LOCAL ADULTS AND CHILDREN - RESIDENTIAL AREA AND AREA A CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

	Receptors					
	Adults		Children (0-6 yrs.)		Children (6-15 yrs.)	
Pathway	HI	ILCR	HI	ILCR	HI	ILCR
Shallow Groundwater						
Ingestion	1.4×10^{-04}	2.4×10^{-07}	6.6×10^{-04}	2.3×10^{-07}	--	--
Dermal Contact	1.2×10^{-03}	4.0×10^{-07}	2.3×10^{-03}	1.5×10^{-07}	--	--
Subtotal	1.3×10^{-03}	6.4×10^{-07}	3.0×10^{-03}	3.8×10^{-07}	--	--
Surface Water						
Ingestion	7.9×10^{-03}	8.7×10^{-07}	--	--	1.9×10^{-02}	2.0×10^{-06}
Dermal Contact	2.3×10^{-03}	2.6×10^{-05}	--	--	1.2×10^{-02}	4.0×10^{-05}
Subtotal	1.0×10^{-2}	2.7×10^{-05}	--	--	3.1×10^{-02}	4.2×10^{-05}
Shallow Sediment						
Ingestion	1.8×10^{-02}	2.5×10^{-06}	--	--	2.7×10^{-01}	1.1×10^{-05}
Dermal Contact	2.2×10^{-03}	4.0×10^{-07}	--	--	1.2×10^{-02}	6.4×10^{-07}
Subtotal	2.0×10^{-02}	2.4×10^{-06}	--	--	2.8×10^{-01}	1.2×10^{-05}
Outdoor (Ambient) Air						
Inhalation	7.6×10^{-03}	9.1×10^{-08}	--	--	2.9×10^{-02}	1.0×10^{-07}
TOTAL	3.9×10^{-02}	3.1×10^{-05}	3.0×10^{-03}	3.8×10^{-07}	3.4×10^{-01}	5.4×10^{-05}

Notes: -- = Not applicable

TABLE 5-2

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR CURRENT BRIG PRISONERS AND BRIG EMPLOYEES - AREA A
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptors			
	Brig Prisoners (Military)		Brig Employees (Civilian)	
	HI	ILCR	HI	ILCR
Surface Soil				
Ingestion	3.1×10^{-01}	2.2×10^{-06}	2.2×10^{-01}	2.0×10^{-05}
Dermal Contact	1.0×10^{-01}	4.4×10^{-07}	7.2×10^{-02}	3.9×10^{-06}
Inhalation[1]	7.4×10^{-05}	8.0×10^{-10}	2.6×10^{-04}	3.6×10^{-08}
Subtotal	4.1×10^{-01}	2.6×10^{-06}	2.9×10^{-01}	2.4×10^{-05}
Surface Water				
Ingestion	--	--	1.1×10^{-02}	1.2×10^{-06}
Dermal Contact	--	--	3.1×10^{-03}	2.8×10^{-05}
Subtotal	--	--	1.4×10^{-02}	2.9×10^{-05}
Shallow Sediment				
Ingestion	--	--	1.5×10^{-02}	1.8×10^{-06}
Dermal Contact	---	--	2.9×10^{-03}	4.5×10^{-07}
Subtotal	--	--	1.8×10^{-02}	2.2×10^{-06}
Indoor Air				
Inhalation	2.5×10^{-01}	3.1×10^{-07}	8.2×10^{-02}	1.3×10^{-06}
Outdoor (Ambient) Air				
Inhalation	3.6×10^{-02}	2.8×10^{-08}	6.0×10^{-01}	1.3×10^{-06}
TOTAL	7.0×10^{-01}	3.0×10^{-06}	1.0×10^{00}	5.8×10^{-05}

Notes: [1] Fugitive dusts
-- = Not applicable

TABLE 5-3

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ON-SITE RESIDENTS - AREA A, SHALLOW WELL LOCATION B-20W
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Shallow Groundwater (Well B20W)				
Ingestion	$1.8 \times 10^{+02}$ ($1.8 \times 10^{+02}$)	7.8×10^{-02} (7.8×10^{-02})	$2.9 \times 10^{+02}$ ($2.8 \times 10^{+02}$)	3.7×10^{-02} (3.6×10^{-02})
Dermal Contact	$1.8 \times 10^{+01}$ ($1.8 \times 10^{+01}$)	3.2×10^{-03} (3.2×10^{-03})	$3.4 \times 10^{+01}$ ($3.4 \times 10^{+01}$)	1.2×10^{-03} (1.2×10^{-03})
Inhalation(1)	8.7×10^{-02}	2.1×10^{-04}	2.9×10^{-01}	1.4×10^{-04}
Subtotal	$2.0 \times 10^{+02}$ ($2.0 \times 10^{+02}$)	8.1×10^{-02} (8.1×10^{-02})	$3.2 \times 10^{+02}$ ($3.1 \times 10^{+02}$)	3.8×10^{-02} (3.7×10^{-02})
Surface Soil				
Ingestion	6.2×10^{-01}	6.7×10^{-05}	$5.8 \times 10^{+00}$	1.2×10^{-04}
Dermal Contact	1.3×10^{-01}	8.5×10^{-06}	9.3×10^{-02}	1.2×10^{-06}
Inhalation(2)	3.7×10^{-05}	6.0×10^{-09}	2.5×10^{-04}	8.0×10^{-09}
Subtotal	7.5×10^{-01}	7.6×10^{-05}	5.9×10^{00}	1.2×10^{-04}
Surface Water				
Ingestion	2.8×10^{-02}	4.2×10^{-06}	6.8×10^{-02}	1.6×10^{-05}
Dermal Contact	1.1×10^{-02}	1.2×10^{-04}	8.0×10^{-02}	1.8×10^{-04}
Subtotal	3.9×10^{-02}	1.2×10^{-04}	1.5×10^{-01}	2.0×10^{-04}
Shallow Sediment				
Ingestion	8.7×10^{-02}	1.2×10^{-05}	$3.3 \times 10^{+00}$	9.2×10^{-05}
Dermal Contact	1.1×10^{-02}	2.0×10^{-06}	7.7×10^{-02}	2.8×10^{-06}
Subtotal	9.8×10^{-02}	1.4×10^{-05}	3.4×10^{00}	9.5×10^{-05}
Deep Sediment				
Ingestion	1.1×10^{-01}	7.5×10^{-06}	$4.1 \times 10^{+00}$	5.7×10^{-05}
Dermal Contact	2.3×10^{-02}	1.8×10^{-06}	1.7×10^{-01}	2.5×10^{-06}
Subtotal	1.3×10^{-01}	9.3×10^{-06}	4.3×10^{00}	5.9×10^{-05}

TABLE 5-3 (Continued)

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE RESIDENTS - AREA A, SHALLOW WELL LOCATION B-20W CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

	Receptors			
	Adults		Children (0-6 yrs.)	
Pathway	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$2.0 \times 10^{+02}$ ($2.0 \times 10^{+02}$)	8.2×10^{-02} (8.2×10^{-02})	$3.3 \times 10^{+02}$ ($3.2 \times 10^{+02}$)	3.9×10^{-02} (3.8×10^{-02})

Notes: (1) Shower model; Andelman, 1985
(2) Fugitive dusts
( ) = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 5-4

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE RESIDENTS - AREA A, SHALLOW WELL LOCATION B-20WSS CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Shallow Groundwater (Well B-20WSS)				
Ingestion	$3.7 \times 10^{+01}$ ($1.8 \times 10^{+01}$)	2.4×10^{-03} (8.6×10^{-04})	$5.8 \times 10^{+01}$ ($2.8 \times 10^{+01}$)	1.1×10^{-03} (4.0×10^{-04})
Dermal Contact	$2.7 \times 10^{+00}$ ($2.7 \times 10^{+00}$)	2.5×10^{-04} (2.5×10^{-04})	$5.1 \times 10^{+00}$ ($5.0 \times 10^{+00}$)	9.4×10^{-05} (9.3×10^{-05})
Inhalation(1)	2.2×10^{-02}	2.7×10^{-06}	7.3×10^{-02}	1.8×10^{-06}
Subtotal	$4.0 \times 10^{+01}$ ($2.1 \times 10^{+01}$)	2.6×10^{-03} (1.1×10^{-03})	$6.3 \times 10^{+01}$ ($3.3 \times 10^{+01}$)	1.2×10^{-03} (4.9×10^{-04})
Surface Soil				
Ingestion	6.2×10^{-01}	6.7×10^{-05}	5.8 x 10+00	1.2×10^{-04}
Dermal Contact	1.3×10^{-01}	8.5×10^{-06}	9.3×10^{-02}	1.2×10^{-06}
Inhalation(2)	3.7×10^{-05}	6.0×10^{-09}	2.5×10^{-04}	8.0×10^{-09}
	7.5×10^{-01}	7.6×10^{-05}	5.9×10^{00}	1.2×10^{-04}
Surface Water				
Ingestion	2.8×10^{-02}	4.2×10^{-06}	6.8×10^{-02}	1.6×10^{-05}
Dermal Contact	1.1×10^{-02}	1.2×10^{-04}	8.0×10^{-02}	1.8×10^{-04}
Subtotal	3.9×10^{-02}	1.2×10^{-04}	1.5×10^{-01}	2.0×10^{-04}
Shallow Sediment				
Ingestion	8.7×10^{-02}	1.2×10^{-05}	$3.3 \times 10^{+00}$	9.2×10^{-05}
Dermal Contact	1.1×10^{-02}	2.0×10^{-06}	7.7×10^{-02}	2.8×10^{-06}
Subtotal	9.8×10^{-02}	1.4×10^{-05}	3.4×10^{00}	9.5×10^{-05}
Deep Sediment				
Ingestion	1.1×10^{-01}	7.5×10^{-06}	$4.1 \times 10^{+00}$	5.7×10^{-05}
Dermal Contact	2.3×10^{-02}	1.8×10^{-06}	1.7×10^{-01}	2.5×10^{-06}
Subtotal	1.3×10^{-01}	9.3×10^{-06}	4.3×10^{00}	5.9×10^{-05}

TABLE 5-4 (Continued)

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE RESIDENTS - AREA A, SHALLOW WELL LOCATION B-20WSS CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$4.1 \times 10^{+01}$ ($2.2 \times 10^{+01}$)	2.9×10^{-03} (1.3×10^{-03})	$7.7 \times 10^{+01}$ ($4.7 \times 10^{+01}$)	1.7×10^{-03} (9.7×10^{-04})

Notes: (1) Shower model; Andelman, 1985
(2) Fugitive dust
( ) = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 5-5

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ON-SITE RESIDENTS - AREA A, DEEP WELL LOCATION A-MW1B CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Deep Groundwater (Well A-MW1B)				
Ingestion	$1.7 \times 10^{+02}$ ($1.5 \times 10^{+00}$)	2.7×10^{-03} (2.3×10^{-03})	$2.6 \times 10^{+02}$ ($2.3 \times 10^{+00}$)	1.3×10^{-03} (1.1×10^{-03})
Dermal Contact	2.0×10^{-01} (1.9×10^{-01})	6.5×10^{-05} (6.4×10^{-05})	3.7×10^{-01} (3.5×10^{-01})	2.4×10^{-05} (2.4×10^{-05})
Inhalation(1)	7.2×10^{-05}	6.1×10^{-06}	2.4×10^{-04}	4.1×10^{-06}
Subtotal	$1.7 \times 10^{+02}$ (1.7×10^{00})	2.8×10^{-03} (2.3×10^{-03})	2.6×10^{02} (2.6×10^{00})	1.3×10^{-03} (1.1×10^{-03})
Surface Soil				
Ingestion	6.2×10^{-01}	6.7×10^{-05}	$5.8 \times 10^{+00}$	1.2×10^{-04}
Dermal Contact	1.3×10^{-01}	8.5×10^{-06}	9.3×10^{-02}	1.2×10^{-06}
Inhalation(2)	3.7×10^{-05}	6.0×10^{-09}	2.5×10^{-04}	8.0×10^{-09}
Subtotal	7.5×10^{-01}	7.6×10^{-05}	5.9×10^{00}	1.2×10^{-04}
Surface Water				
Ingestion	2.8×10^{-02}	4.2×10^{-06}	6.8×10^{-02}	1.6×10^{-05}
Dermal Contact	1.1×10^{-02}	1.2×10^{-04}	8.0×10^{-02}	1.8×10^{-04}
Subtotal	3.9×10^{-02}	1.2×10^{-04}	1.5×10^{-01}	2.0×10^{-04}
Shallow Sediment				
Ingestion	8.7×10^{-02}	1.2×10^{-05}	$3.3 \times 10^{+00}$	9.2×10^{-05}
Dermal Contact	1.1×10^{-02}	2.0×10^{-06}	7.7×10^{-02}	2.8×10^{-06}
Subtotal	9.8×10^{-02}	1.4×10^{-05}	3.4×10^{00}	9.5×10^{-05}
Deep Sediment				
Ingestion	1.1×10^{-01}	7.5×10^{-06}	$4.1 \times 10^{+00}$	5.7×10^{-05}
Dermal Contact	2.3×10^{-02}	1.8×10^{-06}	1.7×10^{-01}	2.5×10^{-06}
Subtotal	1.3×10^{-01}	9.3×10^{-06}	4.3×10^{00}	5.9×10^{-05}

TABLE 5-5 (Continued)

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ON-SITE RESIDENTS - AREA A, DEEP WELL LOCATION A-MW1B
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$1.7 \times 10^{+02}$ ($2.7 \times 10^{+00}$)	3.0×10^{-03} (2.6×10^{-03})	$2.7 \times 10^{+02}$ ($1.6 \times 10^{+01}$)	1.8×10^{-03} (1.6×10^{-03})

Notes: (1) Shower model; Andelman, 1985
(2) Fugitive dusts
( ) = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 5-6

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE CONSTRUCTION WORKERS - AREA A CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

Pathway	Receptor	
	Construction Workers	
	HI	ILCR
Subsurface Soil		
Ingestion	2.7×10^{-02}	8.5×10^{-07}
Dermal Contact	2.3×10^{-03}	4.1×10^{-07}
Inhalation[1]	1.2×10^{-07}	1.5×10^{-13}
TOTAL	2.9×10^{-02}	1.3×10^{-06}

Notes: [1] Fugitive dusts

TABLE 5-7

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR CURRENT ADULT WORKERS - AREA B POND AND LANDFILL
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptor	
	Adult Workers	
	HI	ILCR
Surface Soil		
Ingestion	5.3×10^{-02}	4.6×10^{-06}
Dermal Contact	1.9×10^{-02}	5.5×10^{-06}
Inhalation[1]	1.3×10^{-04}	1.4×10^{-8}
Subtotal	7.2×10^{-02}	1.0×10^{-05}
Surface Water		
Ingestion	5.4×10^{-03}	1.2×10^{-06}
Dermal Contact	2.0×10^{-03}	8.9×10^{-07}
Subtotal	7.4×10^{-03}	2.1×10^{-06}
Shallow Sediments		
Ingestion	7.4×10^{-03}	9.8×10^{-07}
Dermal Contact	1.8×10^{-03}	1.9×10^{-06}
Subtotal	9.2×10^{-03}	2.9×10^{-06}
Outdoor (Ambient) Air		
Inhalation	1.3×10^{-01}	1.3×10^{-06}
TOTAL	2.2×10^{-01}	1.6×10^{-05}

Notes: [1] Fugitive dusts

TABLE 5-8

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR CURRENT EMPLOYEES AND CHILDREN - AREA B SCHOOL CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (6-12 yrs.)	
	HI	ILCR	HI	ILCR
Surface Soil				
Ingestion	1.4×10^{-01}	7.7×10^{-06}	4.6×10^{-01}	6.0×10^{-06}
Dermal Contact	1.2×10^{-02}	8.0×10^{-07}	1.5×10^{-02}	2.5×10^{-07}
Inhalation (1)	7.7×10^{-06}	2.3×10^{-08}	2.5×10^{-05}	1.8×10^{-08}
Subtotal	1.5×10^{-01}	8.5×10^{-06}	4.8×10^{-01}	6.3×10^{-06}
Surface Water				
Ingestion	9.5×10^{-03}	4.6×10^{-07}	2.9×10^{-03}	2.8×10^{-06}
Dermal Contact	7.8×10^{-04}	5.9×10^{-08}	1.6×10^{-02}	2.9×10^{-07}
Subtotal	1.0×10^{-02}	5.2×10^{-07}	1.9×10^{-02}	3.1×10^{-06}
Shallow Sediment				
Ingestion	--	--	--	--
Dermal Contact	--	--	--	--
Indoor Air				
Inhalation	7.4×10^{-02}	1.1×10^{-06}	9.4×10^{-02}	3.4×10^{-07}
Outdoor (Ambient) Air				
Inhalation	1.3×10^{-02}	1.3×10^{-07}	2.1×10^{-02}	4.9×10^{-08}
TOTAL	2.5×10^{-01}	1.0×10^{-05}	6.1×10^{-01}	9.8×10^{-06}

Notes: -- = No COPCs
(1) Fugitive dusts

TABLE 5-9

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS
AREA B POND AND LANDFILL, SHALLOW WELL LOCATION B-MW11A
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Shallow Groundwater (Well B-MW11A)				
Ingestion	$1.5 \times 10^{+01}$ ($9.0 \times 10^{+00}$)	2.2×10^{-02} (2.1×10^{-02})	$2.3 \times 10^{+01}$ ($1.4 \times 10^{+01}$)	1.0×10^{-02} (9.8×10^{-03})
Dermal Contact	4.0×10^{-01} (3.9×10^{-01})	8.9×10^{-04} (8.9×10^{-04})	7.5×10^{-01} (7.3×10^{-01})	3.3×10^{-04} (3.3×10^{-04})
Inhalation(1)	6.6×10^{-04}	5.8×10^{-06}	2.2×10^{-03}	3.9×10^{-06}
Subtotal	1.5×10^{01} (9.4×10^{00})	2.3×10^{-02} (2.2×10^{-02})	$2.4 \times 10^{+01}$ ($1.5 \times 10^{+01}$)	1.0×10^{-02} (1.0×10^{-02})
Surface Soil				
Ingestion	1.5×10^{-01}	1.5×10^{-05}	$1.4 \times 10^{+00}$	2.9×10^{-05}
Dermal Contact	3.5×10^{-02}	1.2×10^{-05}	6.1×10^{-02}	4.2×10^{-06}
Inhalation (2)	7.5×10^{-06}	9.7×10^{-10}	5.1×10^{-05}	1.3×10^{-09}
Subtotal	1.9×10^{-01}	2.7×10^{-05}	1.5×10^{00}	3.3×10^{-05}
Surface Water				
Ingestion	1.5×10^{-02}	4.1×10^{-06}	5.2×10^{-03}	1.5×10^{-05}
Dermal Contact	7.2×10^{-03}	4.0×10^{-06}	5.1×10^{-02}	5.6×10^{-06}
Subtotal	2.2×10^{-02}	8.1×10^{-06}	5.6×10^{-02}	2.1×10^{-05}
Shallow Sediment				
Ingestion	4.2×10^{-02}	6.7×10^{-06}	$1.6 \times 10^{+00}$	5.0×10^{-05}
Dermal Contact	6.7×10^{-03}	8.4×10^{-06}	4.8×10^{-02}	1.2×10^{-05}
Subtotal	4.9×10^{-02}	1.5×10^{-05}	1.6×10^{00}	6.2×10^{-05}
Deep Sediment				
Ingestion	6.2×10^{-03}	2.2×10^{-07}	2.3×10^{-01}	1.7×10^{-06}
Dermal Contact	2.4×10^{-03}	5.4×10^{-08}	1.7×10^{-02}	7.6×10^{-08}
Subtotal	8.6×10^{-03}	2.7×10^{-07}	2.5×10^{-01}	1.8×10^{-06}

TABLE 5-9 (Continued)

**INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS
AREA B POND AND LANDFILL, SHALLOW WELL LOCATION B-MW11A
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA**

	Receptors			
	Adults		Children (0-6 yrs.)	
Pathway	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$1.6 \times 10^{+01}$ ($9.7 \times 10^{+00}$)	2.3×10^{-02} (2.2×10^{-02})	$2.7 \times 10^{+01}$ ($1.8 \times 10^{+01}$)	1.0×10^{-02} (1.0×10^{-02})

Notes: -- = No COPCs
(1) Shower model; Andelman, 1985
(2) Fugitive dusts
( ) = Unfiltered inorganics

TABLE 5-10

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS
AREA B POND AND LANDFILL, DEEP WELL LOCATION B-MW19B
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

	Receptors			
	Adults		Children (0-6 yrs.)	
Pathway	HI	ILCR	HI	ILCR
Deep Groundwater (Well B-MW19B)				
Ingestion	$2.5 \times 10^{+00}$ ($2.2 \times 10^{+00}$)	6.5×10^{-05} (3.6×10^{-05})	$3.8 \times 10^{+00}$ ($3.4 \times 10^{+00}$)	3.0×10^{-05} (1.7×10^{-05})
Dermal Contact	2.0×10^{-02} (2.0×10^{-02})	6.0×10^{-06} (5.9×10^{-06})	3.8×10^{-02} (3.7×10^{-02})	2.2×10^{-06} (2.2×10^{-06})
Inhalation(1)	2.3×10^{-04}	8.7×10^{-09}	7.9×10^{-04}	5.9×10^{-09}
Subtotal	2.5×10^{00} (2.2×10^{00})	7.1×10^{-05} (4.2×10^{-05})	3.8×10^{00} (3.4×10^{00})	3.2×10^{-05} (1.9×10^{-05})
Surface Soil				
Ingestion	1.5×10^{-01}	1.5×10^{-05}	$1.4 \times 10^{+00}$	2.9×10^{-05}
Dermal Contact	3.5×10^{-02}	1.2×10^{-05}	6.1×10^{-02}	4.2×10^{-06}
Inhalation (2)	7.5×10^{-06}	9.7×10^{-10}	5.1×10^{-05}	1.3×10^{-09}
Subtotal	1.9×10^{-01}	2.7×10^{-05}	1.5×10^{00}	3.3×10^{-05}
Surface Water				
Ingestion	1.5×10^{-02}	4.1×10^{-06}	5.2×10^{-03}	1.5×10^{-05}
Dermal Contact	7.2×10^{-03}	4.0×10^{-06}	5.1×10^{-02}	5.6×10^{-06}
Subtotal	2.2×10^{-02}	8.1×10^{-06}	5.6×10^{-02}	2.1×10^{-05}
Shallow Sediment				
Ingestion	4.2×10^{-02}	6.7×10^{-06}	$1.6 \times 10^{+00}$	5.0×10^{-05}
Dermal Contact	6.7×10^{-03}	8.4×10^{-06}	4.8×10^{-02}	1.2×10^{-05}
Subtotal	4.9×10^{-02}	1.5×10^{-05}	1.6×10^{00}	6.2×10^{-05}
Deep Sediment				
Ingestion	6.2×10^{-03}	2.2×10^{-07}	2.3×10^{-01}	1.7×10^{-06}
Dermal Contact	2.4×10^{-03}	5.4×10^{-08}	1.7×10^{-02}	7.6×10^{-08}
Subtotal	8.6×10^{-03}	2.7×10^{-07}	2.5×10^{-01}	1.8×10^{-06}

TABLE 5-10 (Continued)

**INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS
AREA B POND AND LANDFILL, DEEP WELL LOCATION B-MW19B
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA**

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$2.8 \times 10^{+00}$ ($2.5 \times 10^{+00}$)	1.2×10^{-04} (9.2×10^{-05})	$7.3 \times 10^{+00}$ ($6.9 \times 10^{+00}$)	1.5×10^{-04} (1.4×10^{-04})

Notes: -- = No COPCs
(1) Shower model; Andelman, 1985
(2) Fugitive dusts
( ) = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 5-11

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS
AREA B SCHOOL, SHALLOW WELL LOCATION B-MW11A
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Shallow Groundwater (Well B-MW11A)				
Ingestion	$1.5 \times 10^{+01}$ ($9.0 \times 10^{+00}$)	2.2×10^{-02} (2.1×10^{-02})	$2.3 \times 10^{+01}$ ($1.4 \times 10^{+01}$)	1.0×10^{-02} (9.8×10^{-03})
Dermal Contact	4.0×10^{-01} (3.9×10^{-01})	8.9 x 10-04 (8.9×10^{-04})	7.5×10^{-01} (7.3×10^{-01})	3.3×10^{-04} (3.3×10^{-04})
Inhalation(1)	6.6×10^{-04}	5.8×10^{-06}	2.2×10^{-03}	3.9×10^{-06}
Subtotal	$1.5 \times 10^{+01}$ (9.4×10^{00})	2.3×10^{-02} (2.2×10^{-02})	$2.4 \times 10^{+01}$ ($1.5 \times 10^{+01}$)	1.0×10^{-02} (1.0×10^{-02})
Surface Soil				
Ingestion	3.9×10^{-01}	2.6×10^{-05}	$3.7 \times 10^{+00}$	4.8×10^{-05}
Dermal Contact	2.1×10^{-02}	1.7×10^{-06}	3.7×10^{-02}	6.1×10^{-07}
Inhalation (2)	4.6×10^{-06}	1.7×10^{-08}	3.1×10^{-05}	2.2×10^{-08}
Subtotal	4.1×10^{-01}	2.8×10^{-05}	3.7×10^{00}	4.9×10^{-05}
Surface Water				
Ingestion	2.7×10^{-02}	1.6×10^{-06}	8.2×10^{-03}	5.9×10^{-06}
Dermal Contact	2.9×10^{-03}	2.6×10^{-07}	2.0×10^{-02}	3.7×10^{-07}
Subtotal	3.0×10^{-02}	1.9×10^{-06}	2.8×10^{-02}	6.3×10^{-06}
Shallow Sediment				
Ingestion	--	--	--	--
Dermal Contact	--	--	--	--
Deep Sediment				
Ingestion	3.5×10^{-04}	--	1.3×10^{-02}	--
Dermal Contact	1.9×10^{-04}	--	1.3×10^{-03}	--
Subtotal	5.4×10^{-04}		1.4×10^{-02}	

TABLE 5-11 (Continued)

**INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS
AREA B SCHOOL, SHALLOW WELL LOCATION B-MW11A
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA**

	Receptors			
	Adults		Children (0-6 yrs.)	
Pathway	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$1.6 \times 10^{+01}$ ($9.8 \times 10^{+00}$)	2.3×10^{-02} (2.2×10^{-02})	$2.8 \times 10^{+01}$ ($1.9 \times 10^{+01}$)	1.0×10^{-02} (1.0×10^{-02})

Notes: -- = No COPCs
(1) Shower model; Andelman, 1985
(2) Fugitive dusts
( ) = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 5-12

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS - AREA B SCHOOL, DEEP WELL LOCATION B-MW19B CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

	Receptors			
	Adults		Children (0-6 yrs.)	
Pathway	HI	ILCR	HI	ILCR
Deep Groundwater (Well B-MW19B)				
Ingestion	$2.5 \times 10^{+00}$ ($2.2 \times 10^{+00}$)	6.5×10^{-05} (3.6×10^{-05})	$3.8 \times 10^{+00}$ ($3.4 \times 10^{+00}$)	3.0×10^{-05} (1.7×10^{-05})
Dermal Contact	2.0×10^{-02} (2.0×10^{-02})	6.0×10^{-06} (5.9×10^{-06})	3.8×10^{-02} (3.7×10^{-02})	2.2×10^{-06} (2.2×10^{-06})
Inhalation(1)	2.3×10^{-04}	8.7×10^{-09}	7.9×10^{-04}	5.9×10^{-09}
Subtotal	2.5×10^{00} (2.2×10^{00})	7.1×10^{-05} (4.2×10^{-05})	3.8×10^{00} (3.4×10^{00})	3.2×10^{-05} (1.9×10^{-05})
Surface Soil				
Ingestion	3.9×10^{-01}	2.6×10^{-05}	$3.7 \times 10^{+00}$	4.8×10^{-05}
Dermal Contact	2.1×10^{-02}	1.7×10^{-06}	3.7×10^{-02}	6.1×10^{-07}
Inhalation (2)	4.6×10^{-06}	1.7×10^{-08}	3.1×10^{-05}	2.2×10^{-08}
Subtotal	4.1×10^{-01}	2.8×10^{-05}	3.7×10^{00}	4.9×10^{-05}
Surface Water				
Ingestion	2.7×10^{-02}	1.6×10^{-06}	8.2×10^{-03}	5.9×10^{-06}
Dermal Contact	2.9×10^{-03}	2.6×10^{-07}	2.0×10^{-02}	3.7×10^{-07}
Subtotal	3.0×10^{-02}	1.9×10^{-06}	2.8×10^{-02}	6.3×10^{-06}
Shallow Sediment				
Ingestion	--	--	--	--
Dermal Contact	--	--	--	--
Deep Sediment				
Ingestion	3.5×10^{-04}	--	1.3×10^{-02}	--
Dermal Contact	1.9×10^{-04}	--	1.3×10^{-03}	--
Subtotal	5.4×10^{-04}		1.4×10^{-02}	

TABLE 5-12 (Continued)

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs) FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS - AREA B SCHOOL, DEEP WELL LOCATION B-MW19B CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE NORFOLK, VIRGINIA

Pathway	Receptors			
	Adults		Children (0-6 yrs.)	
	HI	ILCR	HI	ILCR
Outdoor (Ambient) Air				
Inhalation	7.6×10^{-03}	9.1×10^{-08}	5.2×10^{-02}	1.2×10^{-07}
TOTAL	$3.0 \times 10^{+00}$ ($2.7 \times 10^{+00}$)	1.0×10^{-04} (7.1×10^{-05})	$7.7 \times 10^{+00}$ ($7.3 \times 10^{+00}$)	8.7×10^{-05} (7.4×10^{-05})

Notes: -- = No COPCs
(1) Shower model; Andelman, 1985
(2) Fugitive dusts
( ) = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 5-13

INCREMENTAL LIFETIME CANCER RISKS (ILCRs) AND HAZARD INDICES (HIs)
FOR FUTURE CONSTRUCTION WORKERS - AREA B
CAMP ALLEN LANDFILL, NORFOLK NAVAL BASE
NORFOLK, VIRGINIA

Pathway	Receptor	
	Construction Workers	
	HI	ILCR
Subsurface Soil		
Ingestion	6.0×10^{-01}	5.2×10^{-06}
Dermal Contact	8.9×10^{-03}	9.0×10^{-07}
Inhalation[1]	8.3×10^{-05}	6.9×10^{-11}
TOTAL	6.1×10^{-01}	6.1×10^{-06}

Notes: [1] Fugitive dusts