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Section: 04.03
Site 20903-5640 (White Oak)
Doc. #: 0004
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NSWC WHITE OAK
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Final

Feasibility Study for Site 49 at NSWC White Oak

Silver Spring, Maryland

Prepared for

Department of the Navy

Atlantic Division
Naval Facilities Engineering Command
Engineering Field Activity Chesapeake

Contract No. N62470-95-D-6007
CTO-0093

June 2004

Prepared by

CH2MHILL

Section: 04.03
Site 20903-5640 (White Oak)
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June 24, 2004
04-350-SJM

Attention: Code 181, Mr. Walter Legg
Chesapeake Division NFEC
Building 212, 1314 Harwood Street, SE
Washington DC 20374-5018

Dear Mr. Legg:

Subject: Final Feasibilty Study Report for Site 49, former NSWC White Oak
Contract N62470-95-D-6007
Navy CLEAN II Program
Contract Task Order 0093

Enclosed are two copies of the final Feasibility Study for Site 49 at the former NSWC White Oak. One copy is for the administative record. Any questions can be directed to me at (703) 471-6405, extension 4332.

Sincerely,

CH2M HILL

Scott MacEwen, P.E.
Activity Manager

Enclosure
cc: Mr. Bruce Beach/EPA Region 3 (4 copies)
Mr. Andy Zarins/MDE (1 copy)
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Ms. Brenda Smith/LANTDIV Code 02 (cover letter only)
CTO 093 File (1 copy)

Final

Feasibility Study for Site 49 at the Former NSWC White Oak

Contract Task Order Number 093

February 2004

Prepared for

Department of the Navy

Naval Facilities Engineering Command
Engineering Field Activity Chesapeake

Under the

Navy CLEAN II Program
Contract Number N62470-95-D-6007

Prepared by

CH2MHILL

Herndon, Virginia

Executive Summary

Introduction

This feasibility study (FS) develops and evaluates remedial alternatives to address contamination and related risks from Site 49 at the former Naval Surface Warfare Center White Oak (NSWC White Oak) in Silver Spring, Maryland. Site 49 is that portion of the former NSWC White Oak located at the eastern end of the Arnold Engineering Development Center (AEDC) in the north-central portion of the facility (see Figure 1-2). The site consists of groundwater in the vicinity and downgradient of Building 427.

The primary objective of the FS was to develop and evaluate groundwater remedial alternatives that will mitigate the current and potential future risks posed by contamination in the groundwater throughout Site 49.

Contamination at Site 49 initially was identified during a screening investigation of the sanitary sewer system at White Oak. Trichloroethene (TCE) was detected in groundwater samples collected using direct-push technology (DPT) on two occasions from one location (near Manhole 32142) along the backfill of Washington Suburban Sanitary Commission (WSSC) sewers that run along Paint Branch hydraulically downgradient of AEDC. Groundwater samples collected from sewer bedding up- and down-pipe of AEDC did not contain TCE. A subsequent screening investigation indicated that the TCE was originating on what is now the AEDC facility at concentrations as great as approximately 4,000 micrograms per liter (µg/L). Following a review of the screening investigation data, this area was designated Site 49. A comprehensive remedial investigation (RI) was conducted to define the nature and extent of contamination in the groundwater and surface water within Site 49, and to identify the possible sources of this contamination throughout the area.

Site 49 Description

The former NSWC White Oak, located 4 miles northeast of Washington, DC, is situated close to the Fall Line, which marks the surficial expression of the contact between the Piedmont and Atlantic Coastal Plain physiographic provinces. Site 49 is that portion of the facility located at the eastern end of the AEDC, located in the north-central portion of the former NSWC White Oak (Figure 1-2). The site consists of the groundwater in the vicinity and downgradient of Building 427, and extends to Paint Branch from approximately 200 feet north of Perimeter Road Bridge to approximately 200 feet south of the Dahlgren Road bridge (Figure 1-3).

The groundwater contaminants associated with this area and the resultant plume exceed maximum contaminant levels (MCLs) for drinking water. The contaminants of concern (COCs) for Site 49 are iron and TCE and its degradation by-products: cis-1,2-dichloroethene (cis-DCE), and vinyl chloride. No site-related contaminants are present in the soil within the Site 49 area nor in the surface water in Paint Branch.

Feasibility Study Process

The CERCLA feasibility study process consists of the following steps:

1. Development of remedial action objectives (What risks do the remedial actions need to address?) and chemical-specific preliminary remediation goals (What concentrations do site contaminants need to be reduced to in order to meet the remedial action objectives?)
2. Identification of general response actions (What are the general methods for achieving the remedial action objectives?)
3. Identification and screening of remedial technologies (Of all potentially applicable remediation technologies available, which could be applied to the site based on what is known about the site?)
4. Development of remedial alternatives (Using the technologies likely to be applicable to the site, develop a range of remedial alternatives, or conceptual plans for implementation.)
5. Evaluation of remedial alternatives (How do the developed remedial alternatives rate against the seven CERCLA evaluation criteria and against each other, including what would they cost to implement and how long would they take to clean up the site?)

The remedial action objectives identified for Site 49 are to:

- Prevent unacceptable risks to human receptors from exposure to contaminants in the groundwater
- Where practicable, restore the contaminated groundwater to a quality that is amenable to beneficial use
- Prevent further migration of contaminants

To help achieve these objectives, preliminary remediation goals (PRGs) were established for the groundwater. PRGs were calculated to ensure that the cumulative risks associated with the PRGs are within EPAs acceptable range and that the PRG for any one chemical is below the drinking water standard (if one exists for that chemical).

The contaminants found in the groundwater were compared to the PRGs to determine if remedial action is necessary. If contaminants found exceeded the PRGs, remedial action would be warranted.

This comparison concluded that exceedances are present at Site 49. As a result it was determined that remedial alternatives would be developed and evaluated to address the groundwater contamination. No site-related soil or surface water contamination has been identified.

The remedial alternatives were developed following Steps 2 through 4 above. The following alternatives were developed:

- Alternative 1—No Action
- Alternative 2—Institutional Controls with Long-Term Monitoring

- Alternative 3— Groundwater Extraction and Treatment (P&T)
  Alternative 3A- Groundwater Extraction and Treatment (P&T) with Rock Fracturing
- Alternative 4— In situ Chemical Oxidation (ISCO)
  Alternative 4A- In situ Chemical Oxidation (ISCO) with Rock Fracturing
- Alternative 5— Enhanced In situ Anaerobic Bioremediation with Rock Fracturing

Remedial Alternatives Evaluation

Each alternative was evaluated with respect to threats to human health and the environment posed by contamination at each site. The National Contingency Plan (NCP) requires that the first seven of the nine criteria identified below are addressed in the FS process. The last two will be addressed in the record of decision (ROD). The nine criteria are:

- Protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The first two criteria are considered the threshold criteria and must be met by any proposed remedial alternative. With the exception of the no-action alternative, any alternative that did not meet the first two criteria was not considered in the FS. The next five criteria are considered balancing criteria. Section 4.4.1 provides a detailed description of the specific characteristics of a remedial alternative that are evaluated under each criteria. The evaluation process involved a qualitative assessment including assigning a numerical value from 0 to 5 for each of the five balancing criteria. Where significant uncertainty existed in the value of the ranking, a numerical range was provided to include the bracket of uncertainty. The values were added to arrive at a final total score for each alternative. Each criterion was assigned equal weight in the final score.

The evaluation also involved doing a comparative cost estimate (+50 to –30percent) of each alternative and an estimate of time to remediation. The results of these evaluations are presented in the following table:

Remedial Alternatives	Relative Score	Present Worth Cost ($1,000s)
1. No Action	10	17
2. Institutional Controls (ICs) with Long-Term Monitoring (LTM)	14	312
3. Groundwater Extraction and Treatment (P&T)	13	1,507
3A. P&T with Rock Fracturing	13-15	1,715
4. In situ Chemical Oxidation (ISCO)	19	832
4A. ISCO with Rock Fracturing	19-20	1,174
5. Enhanced In situ Anaerobic Bioremediation with Rock Fracturing	16	1,340

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Acronyms and Abbreviations

AEDC	Arnold Engineering Development Center
ARAR	applicable or relevant and appropriate requirement
BCP	BRAC Cleanup Plan
BIR	Background Investigation Report
BRAC	Base Realignment and Closure
CBC	Chillum-Beltsville-Croom
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	40 Code of Federal Regulations
cis-DCE	cis-1,2-dichloroethene
CLEAN	Comprehensive Long-term Action Navy
COC	chemicals of concern
COPC	chemicals of potential concern
DPT	direct-push technology
EFA CHES	Engineering Field Activity, Chesapeake
FS	Feasibility Study
ft/min	feet per minute
GMC	Glenelg-Manor-Chester
GSA	General Services Administration
HI	hazard index
HRC	Hydrogen Release Compound
IC	institutional control
IR	Installation Restoration
ISCO	In situ chemical oxidation
LANTDIV	Atlantic Division
LGAC	liquid-phase granular activated carbon
LTM	long-term monitoring
MCL	maximum contaminant level
msl	mean sea level
NAPL	nonaqueous phase liquid
NAVFAC	Naval Facilities Engineering Command
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NSWC White Oak	Naval Surface Warfare Center White Oak

O&M	operation and maintenance
OU-1	Operable Unit 1
PCE	tetrachloroethene
PRG	preliminary remediation goal
RAO	remedial action objective
RI	remedial investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SVOC	semivolatile organic compound
TBC	to-be-considered
TCE	trichloroethene
UCL	upper confidence limit
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound
WSSC	Washington Suburban Sanitary Commission
µg/L	micrograms per liter
µg/kg	micrograms per kilogram

SECTION 1

Introduction

This feasibility study (FS) report is submitted to the Department of the Navy, Engineering Field Activity, Chesapeake (EFA CHES), Naval Facilities Engineering Command (NAVFAC) under the Atlantic Division (LANTDIV) Comprehensive Long-term Action Navy (CLEAN) II Program, Contract No. N62470-95-D-6007. The FS was conducted at Site 49 at the former Naval Surface Warfare Center White Oak (NSWC White Oak) in Silver Spring, Maryland (see Figure 1-1) to identify appropriate remedial strategies to mitigate unacceptable human health risks.

The FS was conducted in response to the closure of the former NSWC White Oak under the Base Realignment and Closure (BRAC) program. The FS is prepared in accordance with the process outlined in the Navy's Installation Restoration (IR) Program and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidance. The regulatory basis for the process is described further in the latest version of the BRAC Cleanup Plan (BCP) for the former NSWC White Oak (DON, 1999).

Site 49 is that portion of the facility located at the eastern end of the Arnold Engineering Development Center (AEDC), in the north-central portion of the former NSWC White Oak (Figure 1-2). The contaminated medium requiring remediation is groundwater, extending from Building 427 to Paint Branch from approximately 200 feet north of Perimeter Road Bridge to approximately 200 feet south of the Dahlgren Road bridge (Figure 1-3).

The FS addresses the areas of Site 49 where chemicals in the groundwater have been found to pose an unacceptable risk, as identified in the Site 49 Remedial Investigation (RI) (CH2M HILL, May 2004). That document presents an evaluation of the nature and extent of contamination and human health risks in the groundwater, surface water, and soil within Site 49. The conclusions of the Site 49 RI indicate that no unacceptable risks are associated with the surface water or the soil at Site 49.

Contamination at Site 49 initially was identified during the Washington Suburban Sanitation Commission (WSSC) sanitary sewer lines investigation (CH2M HILL, January 2004). Trichloroethene (TCE) was detected in groundwater samples collected using direct-push technology (DPT) on two occasions from one location (near Manhole 32142) along the bedding of the WSSC sewer that runs along Paint Branch hydraulically downgradient of AEDC (Figure 1-4). Groundwater samples collected from sewer bedding up- and down-pipe of AEDC did not contain TCE. A subsequent screening investigation indicated that TCE was present in groundwater near Building 427 at concentrations as great as approximately 4,000 micrograms per liter (µg/L). The locations of the groundwater sample collected from the sewer bedding and the samples collected during the screening investigation are shown in Figure 1-4. Following a review of the screening investigation data, this area was designated IR Site 49.

1.1 Objectives of the Feasibility Study

The RI determined that contaminant sources at Site 49 have affected groundwater quality and presented unacceptable risks to human health under specific future groundwater use scenarios, including future residential potable use.

The unacceptable human health risks were due primarily to chlorinated volatile organic compounds including TCE, cis-1,2-dichloroethene (cis-DCE), and vinyl chloride (VC). Soil sampling at the site has not identified any continuing source of contamination above the water table. The objectives of this FS are:

- Identify applicable or relevant and appropriate requirements (ARARs) and to-be-considered (TBC) criteria that may affect remedy selection for groundwater at site 49;
- Develop remedial action objectives (RAOs) and preliminary remediation goals (PRGs); and
- Develop and evaluate remedial alternatives to mitigate risks from exposure to groundwater in the site.

1.2 Organization of the Feasibility Study

Section 1 of the FS summarizes the history of Site 49 at White Oak and describes the previous environmental investigations conducted to date. Section 2 discusses the physical characteristics and environmental site conditions of Site 49. Section 3 presents the ARARs that may affect remedy selection and identifies the RAOs and PRGs that the selected remedy should be capable of attaining. Section 3 also outlines the remedial action alternative analysis process. Section 4 provides the initial technology screening. Section 5 presents the remedial action alternative development and evaluation for the site. Section 6 is a list of the references cited in this report. Supporting information is provided in the appendices to this report. Additionally, an Executive Summary is presented at the beginning of this report.

1.3 Description and History of Site 49

The former NSWC White Oak, located 4 miles northeast of Washington, DC, is situated close to the Fall Line, which marks the surficial expression of the contact between the Piedmont and Atlantic Coastal Plain physiographic provinces. Site 49 is that portion of the facility located at the eastern end of the AEDC, located in the north-central portion of the former NSWC White Oak (Figure 1-2). The site consists of the groundwater in the vicinity and downgradient of Building 427, and extends to Paint Branch from approximately 200 feet north of Perimeter Road Bridge to approximately 200 feet south of the Dahlgren Road bridge (Figure 1-3).

Details of the administrative history of the former NSWC White Oak are provided in the Master Work Plans (Brown and Root Environmental, 1998) and are not repeated here. The Navy facility officially closed in mid-1997 following the 1995 BRAC Commission closure decisions. The majority of the former Navy facility was transferred to, and is currently managed by, the General Services Administration (GSA), in preparation for eventual reuse

by other government agencies. A portion of the original Navy facility, including part of Site 49, currently is occupied by AEDC, which leases the property from GSA.

The terrain in the vicinity of Site 49 consists of a steep stream valley. The drainage pattern at Site 49 is dominated by Paint Branch. The land cover at Site 49 varies between woodland, grass lawn, paved areas, and buildings. Elevations at Site 49 range from approximately 275 feet above mean sea level (msl) around Building 427 to approximately 180 feet above msl, at Paint Branch (Figure 1-3).

Building 427 is a nine-story hydrostatic testing facility that includes a 35-ft by 100-ft by 75-ft-deep interior water tank. This tank was fed by the exterior aboveground storage tank located immediately southeast of Building 427 (Figure 1-3). Much of Building 427 (three floors) is below ground. Building 427 was built in the mid 1960s and used by the Navy up until the mid 1990s. It has since been abandoned and is slated for demolition within the next few years.

The Navy used the tank and building for hydrostatic testing of underwater weapons. Discussions with personnel who worked in, or had knowledge of the activities that took place in, Building 427 indicated that there was no known use of TCE in the building. A 2002 visual inspection of the interior of the abandoned Building 427 found two 2 empty five-gallon cans labeled "solvent, dry-cleaning type" in a storage room on the 100 level.

A "limestone pit" or leaching well was present on the west side of the building and, according to construction drawings, was to be used for disposing of acidic waste water from the water treatment system used to pre-treat water before filling the testing tank. Former building personnel stated that the leaching well was never used for its designed purpose and that the wastewater lines leading to the leaching well were reportedly connected to sinks in rooms that were initially designed to be laboratories but were in actuality used as offices. The leaching well was excavated in 2002 as part of the Site 49 remedial investigation (RI). Design drawings of the building and leaching well, and pictures and details of the removal are provided in the RI report (CH2M HILL, May 2004).

It was noted by former building personnel that inert torpedoes used for testing in the tank were sometimes cleaned on the loading dock area on the north side of Building 427. It was also noted that a small area outside the back (east) gate along the perimeter road was used for debris disposal and may conceivably been used for unauthorized dumping of wastes because it is relatively remote and hidden from view. This area is designated as the Debris Disposal Area on Figure 1-3.

Construction drawings also indicate that a subsurface foundation drain runs along the perimeter of the building about 17 to 27 feet below grade. The drain consists of 6-inch perforated clay pipe draining to two manholes, one at the northwest corner of the building and one near the southeast corner of the building. The northwest manhole is a sump that collects and pumps water to the southeast manhole. The southeast manhole also receives water from two interior basement sumps. Water was discharged from the southeast manhole to Paint Branch by a pipe and open channel.

1.4 Previous Investigations

An RI was conducted for Site 49 (CH2M HILL, May 2004). During the investigation activities the former leaching well, also referred to as a limestone pit (Figure 1-3) was excavated using a backhoe. Samples were collected from two basement sumps in Building 427, and the two manholes used to access a perimeter foundation drain around Building 427. Soil samples were collected from beneath the former leaching well and in an area where debris was reportedly dumped (debris disposal area; Figure 1-3). Groundwater samples were collected using grab methods from the bedding of sewer lines, from nine temporary and permanent monitoring wells, and using direct push methods along the west bank of Paint Branch. Surface water samples were collected from Paint Branch.

The primary chemicals found in the environment at Site 49 are chlorinated solvents (TCE and its likely degradation products, *cis*-DCE and VC) occurring in groundwater. The maximum concentration of TCE was 4,400 µg/L and was encountered at well 49GW201D. Based on the site geology, the contaminated groundwater is mostly located in the fractured bedrock, and was encountered to a maximum depth of 200 feet. The contaminant plume extends downgradient to Paint Branch. Investigation of soil conditions and potential source areas found no significant sources for the TCE. Surface water quality is consistent with background data, and therefore there are no anthropogenic influences from Site 49 into Paint Branch.

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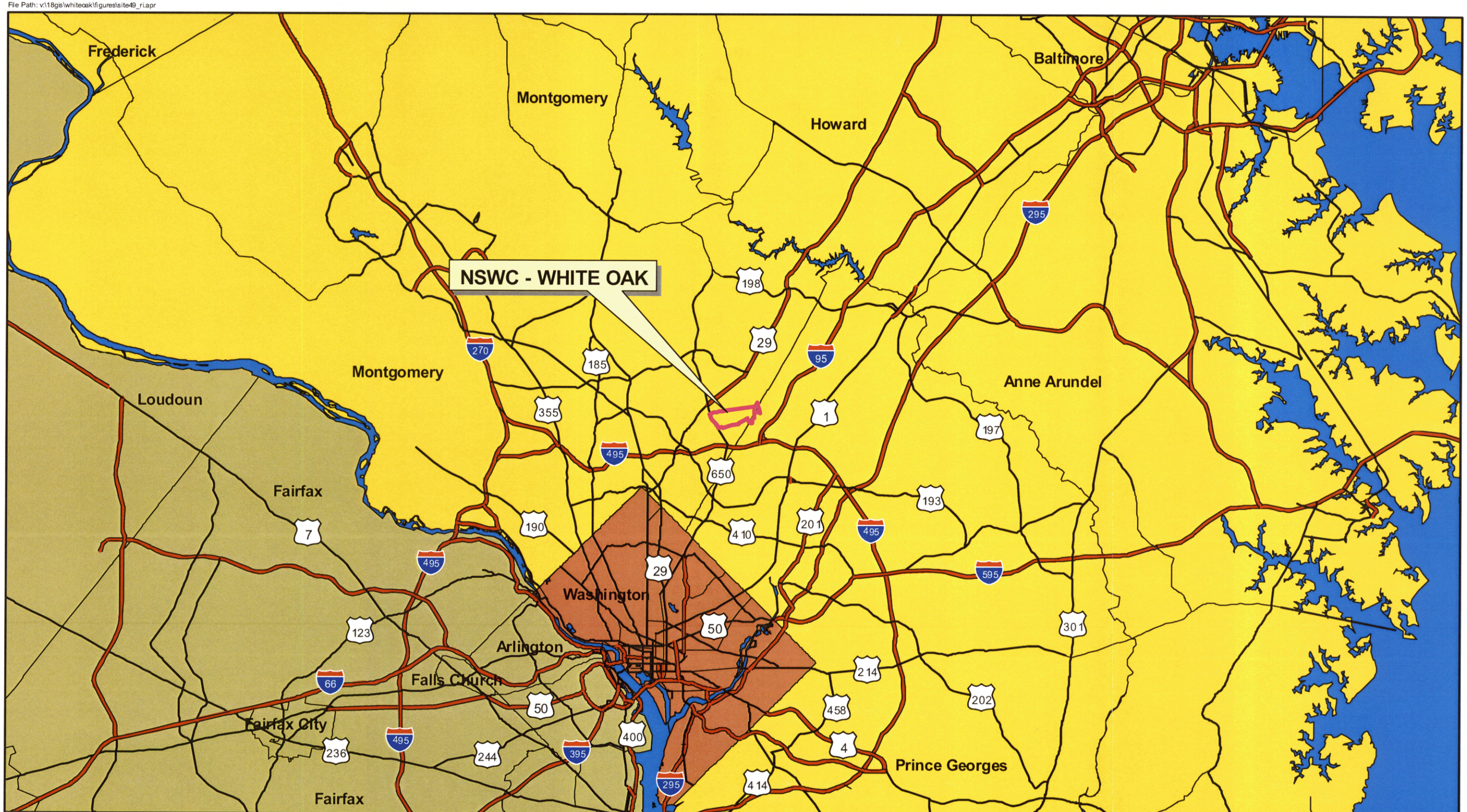

LEGEND

- Base Boundary
- Interstate, Freeway, or Expressway
- Water Bodies
- District of Columbia
- Maryland
- Virginia

N

0 20000 40000 Feet

Figure 1-1
Regional Map
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

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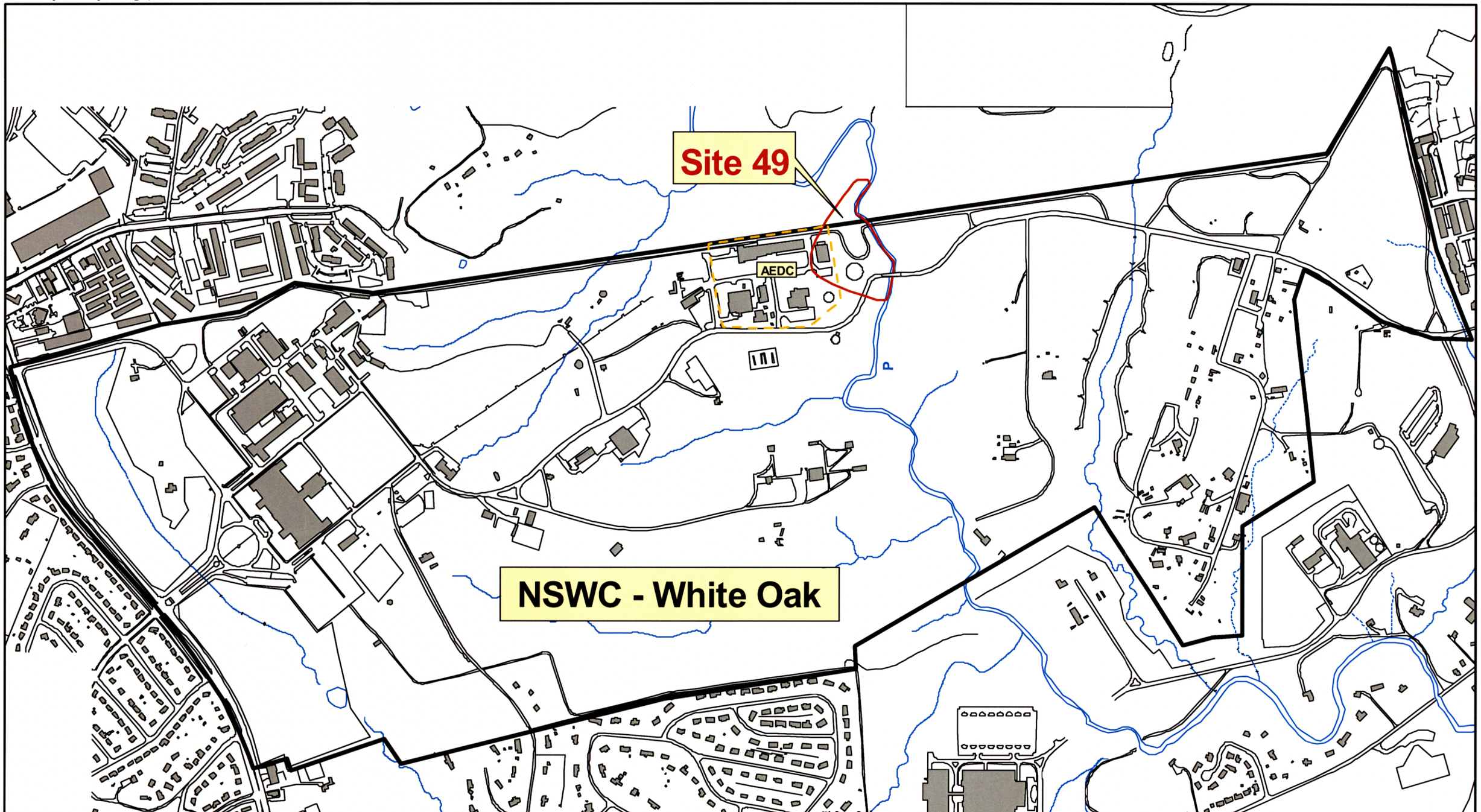

LEGEND

- IR Site Boundary
- AEDC Fence Line
- Base Boundary
- Buildings
- Roads
- Water Bodies

N

700 0 700 1400 Feet

Figure 1-2
Site Location Map
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

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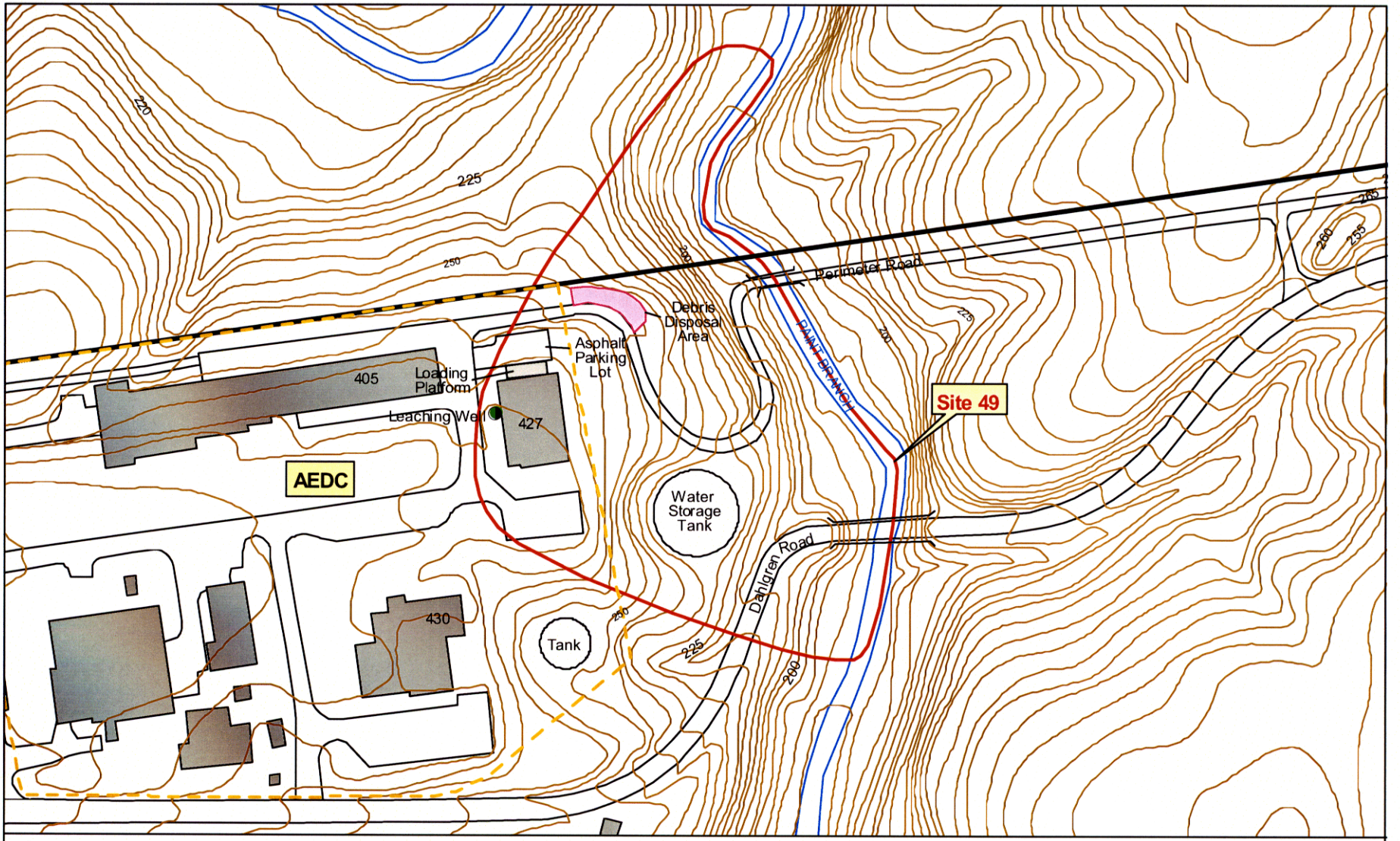

LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

0 200 400 Feet

Figure 1-3
Site 49 Site Map
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

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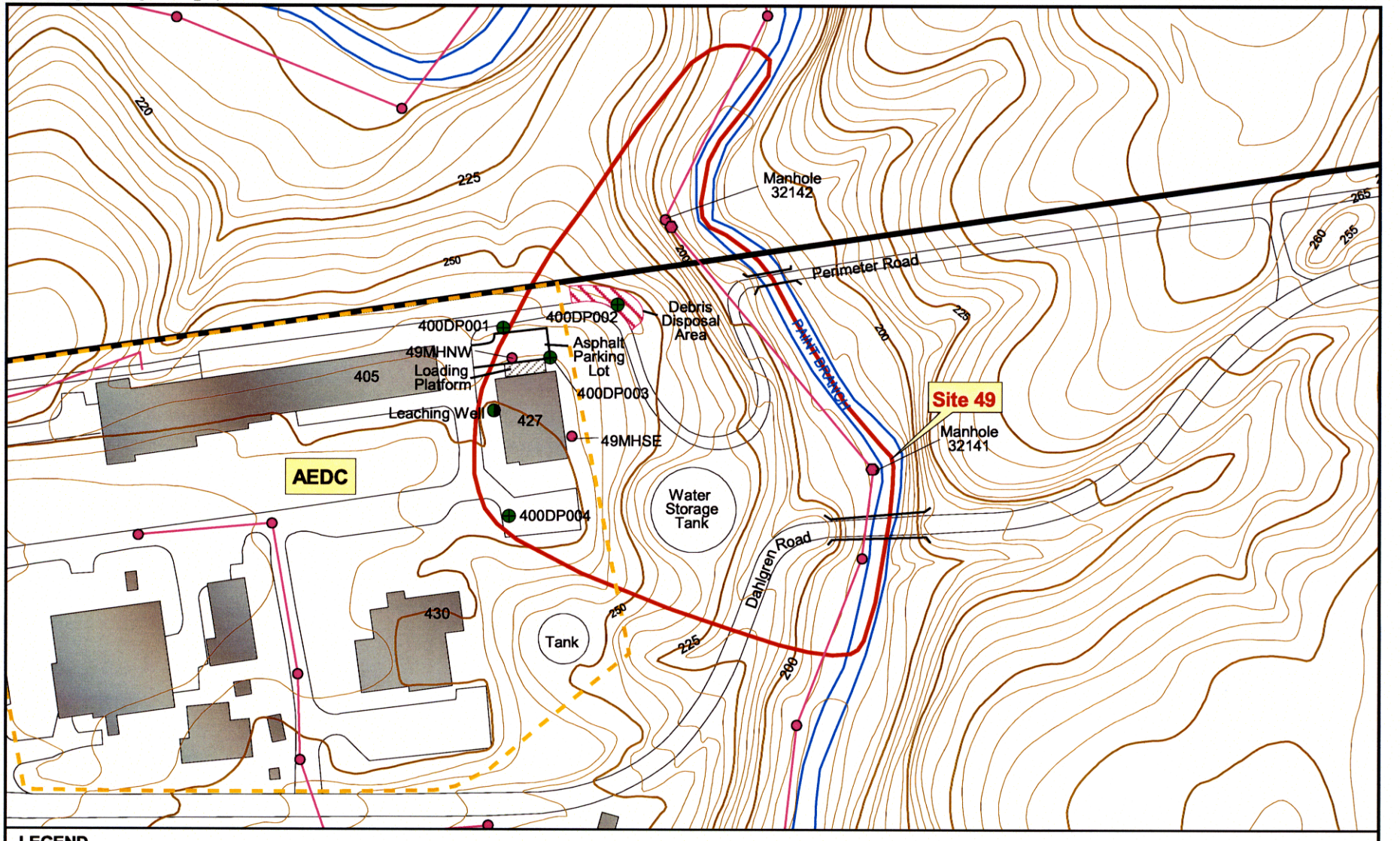

LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Direct Push Sample Location
- Sewer Bedding/Groundwater Sample Location
- Sewer Manhole
- Sewer Alignment
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

0 200 400 Feet

Figure 1-4
Sample Locations
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

SECTION 2

Description of Site Conditions

This section presents a summary of the site conditions including the site physical characteristics, the nature and extent of contamination and contaminant transport pathways. The section also summarizes the current and potential future risks to human health and the environment posed by the chemicals in the groundwater. This information is provided in greater detail in the RI. This summary is presented as background for the remedial alternative development and evaluation process provided in Sections 4 and 5 of this FS.

2.1 Physical Characteristics of Site 49

2.1.1 Physiography, Topography, and Climate

The former NSWC White Oak, located 4 miles northeast of Washington, DC, is situated close to the Fall Line, which marks the surficial expression of the contact between the Piedmont and Atlantic Coastal Plain physiographic provinces. The terrain in the vicinity of Site 49 is hilly and dissected by a stream channel forming a steep valley (Figure 2-1). The drainage pattern at Site 49 is dominated by Paint Branch. The land cover at Site 49 varies between woodland, lawns, paved areas, and buildings.

Elevations at Site 49 range from approximately 275 feet above msl around Building 427 to approximately 180 feet above msl at Paint Branch (Figure 2-1).

Average annual precipitation is about 42 inches with little seasonal variation, based on data available from 1961 through 1990. Fluctuation is gradual, with a minimum of 2.6 inches in February and a maximum of 4.3 inches in May.

2.1.2 Hydrology

The only surface water body in the vicinity of Site 49 is Paint Branch, which forms its eastern boundary. Paint Branch flows generally southeast from headwaters north of the former NSWC White Oak to its discharge into the upper reaches of the Anacostia River approximately 5 miles downstream, draining an area of 17.5 square miles. In the immediate vicinity of Site 49, Paint Branch flows south. The Paint Branch channel likely is fracture-controlled and its channel appears to be incised into bedrock in places.

2.1.3 Soil

Soil consists of weathered rock and organic material that has been broken down by physical processes, bacteria, and other small biota (e.g., plants, fungi, and small animals). The two main classes of soils on the facility are:

- The Glenelg-Manor-Chester (GMC) association, which was developed from materials weathered from the Piedmont metamorphic rocks. It is present in the stream valleys of Paint Branch, West Farm Branch, and smaller streams present on the facility. These soils

are silty, micaceous, and more homogeneous than the local Atlantic Coastal Plain soils (USDA, 1961).

- The Chillum-Beltsville-Croom (CBC) association, which was developed from the Atlantic Coastal Plain deposits. Found across the site, these soils often contain varying amounts of gravel, sand, silt, and clay. A sub-cemented subsoil layer of considerably lower permeability than the surface, known as a fragipan, commonly exists a few feet below the surface. The soil horizons in this association have a greater range in permeability due to the larger variability in grain size distribution (USDA, 1961).

Generally, the soils at the former NSWC White Oak are moderately drained to well-drained and tend toward the acidic because as they are heavily influenced by organic acids derived from decaying organic matter. Soils in wooded areas may have a pH as low as 4 due to the relatively higher source of organic plant material. Grassland areas are expected to be slightly less acidic and have a pH closer to 6 (USDA, 1961).

2.1.4 Geology

The geologic characteristics of Site 49 and the surrounding region are discussed in this section. This discussion focuses on the geologic units encountered at the site and their hydrogeologic features. Table 2-1 summarizes the geological material encountered at the site in the context of various characterization systems (i.e., physiographic, chronostratigraphic, lithostratigraphic, and hydrostratigraphic units).[1]

2.1.4.1 Regional Geology

The regional geology is discussed in detail in the *Master Project Plans for the former NSWC–White Oak* (Brown and Root Environmental, 1998). In summary, the facility is located about one mile east of the boundary between the Piedmont and Atlantic Coastal Plain physiographic provinces, also known as the Fall Line. This boundary runs southwest to northeast and is generally parallel to the Montgomery – Prince George's County line in the White Oak area (shown in Figure 1-1). Geologically, the Fall Line represents the unconformable contact where older Precambrian to Cambrian[2] Piedmont bedrock, exposed to the northwest, dips beneath the unconsolidated, Cretaceous-age Potomac Group deposits, which increase in thickness to the southeast, and recent surficial deposits.

The Atlantic Coastal Plain in the region comprises unconsolidated fluvial sediments of the Potomac Group. These sediments consist of micaceous quartz, quartz sandstone, and quartzite grains ranging in size from sands to cobbles, in close association with clays and silts. The gravels at the base of the formation may be cemented with iron oxide (Volkes and Edwards, 1974). These sediments form a wedge that pinches out at the Fall Line and thickens in a southeasterly direction. Underlying the Atlantic Coastal Plain sediments is the crystalline Piedmont bedrock.

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[1] Chronostratigraphic units are generally formal, named geologic units based on temporal associations, as described in scientific literature; Lithostratigraphic units are informally named, generally site-specific geologic units that are organized on the basis of lithology (i.e., geologic materials having similar physical characteristics). These units may be the same as, subdivisions of, or different from chronostratigraphic units; Hydrostratigraphic units are informally named geologic units, generally site-specific, that are organized on the basis of hydrogeologic similarities and connections (i.e., geologic materials through which groundwater moves in a consistent manner). These units may be the same as, subdivisions of, or different from chronostratigraphic or lithostratigraphic units.

[2] More recent research indicates that the Wissahickon may be late-Cambrian to early-Ordovician in age (MGS, 2003).

The Piedmont bedrock in this region is generally characterized by sequences of metamorphic rocks such as gneiss and schist of Precambrian to Cambrian age. The upper portion of the Piedmont has weathered to a saprolite, which has been removed in many stream valleys (including that of Paint Branch) by erosion.

Cloos (1964) reports fractures and foliation in the Piedmont rocks. Specifically, Froelich (1975) reported foliations with a northeast-southwest strike, dipping southeast and joints with a north-south or northeast-southwest strike and a vertical orientation at outcrops in Paint Branch.

2.1.4.2 Site 49 Geology

There are two primary lithostratigraphic units underlying Site 49: Piedmont bedrock and derived saprolite. Potomac Group deposits and recent sediments are present at Site 49 only as a thin layer. Figures 2-2 and 2-5 show the schematic of a geologic cross-section generated from Site 49-specific information to illustrate schematically the geology of the site.

2.1.4.3 Saprolite

The term saprolite describes a rock that has been subjected to in situ chemical weathering, resulting in the breakdown of the parent material by dissolution of the more labile constituent minerals, often preserving the structural elements of the parent rock. In the context of this report, the term saprolite also is used as the name of the layer of generally unconsolidated materials immediately above the bedrock. At Site 49, the saprolite is composed of the same materials as the underlying schist bedrock (i.e., no diagenetic or metasomatic alteration during weathering). The saprolite is strongly foliated, preserving the structures of the parent schist. Its thickness ranges from about 5 feet in the north and west to about 25 feet to the south and east. Although the upper part of the saprolite is heavily weathered, soft, and friable, lower portions are less weathered, more consolidated, and harder to penetrate (split-spoon samplers could not penetrate to depths greater than auger refusal). The boundary between saprolite and bedrock is gradational.

2.1.4.4 Bedrock

Underlying the saprolite is a crystalline bedrock likely belonging to the Wissahickon Formation of the Glenarm Series (Volkes and Edwards, 1974; Froelich, 1975). The Wissahickon is a metasedimentary rock of late Precambrian to Cambrian age.

The top of bedrock appears generally to conform to topography. A continuous rock core was collected during the installation of bedrock monitoring well 49GW201DD. In the remaining ten (of eleven) wells advanced into bedrock, cuttings were observed as they were brought to the surface during drilling. Garnet-bearing schist was the primary rock encountered in the collected core; however, quartzite or psammitic granulite was observed near the surface. These components are consistent with descriptions of the Wissahickon in published literature. Fractures were numerous in the shallower portion of the core and decreased with depth. Many of the fractures contained iron and manganese staining, likely present due to fluid flow, with some exhibiting evidence of secondary mineralization. One outcrop of the Wissahickon is exposed along the side of Dahlgren Road southeast of Site 49.

2.1.5 Hydrogeology

2.1.5.1 Regional Hydrogeology

As mentioned earlier, the former NSWC White Oak is located near the Fall Line. The primary hydrostratigraphic units in the region are the unconsolidated Potomac Groups deposits and the Wissahickon bedrock. Recent surficial deposits generally are not large enough to provide a significant reservoir of groundwater.

Regionally, aquifers within the Potomac Group are a much larger source of water than those of the Wissahickon bedrock. As noted in Section 2.1.4 on regional geology, Potomac Group deposits contain varying sequences of clays, silts, sands, and gravels extending to depths of 1,500 feet or more increasing eastward from the former NSWC White Oak region, including several distinct hydrostratigraphic units and aquifers within these sequences. Groundwater in the aquifers of the Potomac Group exists under both unconfined conditions at the water table and under confined conditions in deeper portions of the sequences, though this phenomenon generally occurs much further east in the Atlantic Coastal Plain. In the region around the former NSWC White Oak, the Potomac Group deposits constitute a relatively shallow, unconsolidated aquifer from which the few groundwater supply wells in the area extract water.

The saprolite present at the gradational contact between the Potomac Group and the Wissahickon bedrock also contains significant amounts of water under unconfined conditions. Saprolite often exhibits secondary porosity induced by relict structures. Groundwater flow in the saprolite often is affected by these relict structures as well as by interstitial pore spaces.

The Wissahickon bedrock underlying the Atlantic Coastal Plain deposits, however, primarily contains water in fractures within the rock. However, these fractures generally are not productive sources of water in the former NSWC White Oak region.

2.1.5.2 Site 49 Hydrogeology

There are two primary hydrostratigraphic units at the Site 49 area (Table 2-1), the saprolite and the bedrock. Monitoring wells at Site 49 are screened in these units. The Potomac Group and Recent surficial deposits, present only as a thin veneer, are unsaturated and are not therefore transmissive enough to exert a significant influence on Site 49 hydrogeology.

Groundwater at Site 49 originates as recharge during and following precipitation events. Precipitation at the Site generally exceeds the infiltration rate, producing overland flow and directed stormwater discharge to Paint Branch. Some portion of the precipitation infiltrates into the saprolite and moves in a primarily vertical direction until it reaches the water table to become part of the groundwater flow system.

The water table occurs in the bedrock in the western portions of Site 49 and in the saprolite in the eastern portions. Groundwater flows from west to east and discharges to Paint Branch (Figure 2-3). Presumably, at some depth, flow becomes more regional and discharge likely occurs directly to the Anacostia River. On the basis of the water levels measured on March 25, 2003 (CH2M HILL, May 2004), it is determined that the depth at which groundwater bypasses Paint Branch and discharges to the Anacostia River is greater than that penetrated by site monitoring wells.

The hydraulic gradient of the water table, represented graphically on the cross section in Figure 2-5, varies depending upon location, and generally follows the topographic gradient.

Site 49 is in close proximity to White Oak Operable Unit 1 (OU-1), located to the east across Paint Branch. A comprehensive discussion of the hydrogeology at the former NSWC–White Oak is presented in the *Final Remedial Investigation of Operable Unit 1, NSWC–White Oak* (CH2M HILL, 2002). The hydraulic conductivity of the saprolite unit was estimated to be in the range of 6.9×10^{-6} and 1.0×10^{-4} feet per minute (ft/min). The hydraulic conductivity of the bedrock units was estimated to be in the range of 2.3×10^{-6} and 2.8×10^{-6} ft/min.

At Site 49, groundwater appears to have a downward component of flow, based on the water levels in monitoring wells 49GW206S, M, and D. The water elevation measured in the deep well (D) is approximately 150 feet lower than that measured in the shallow well (S). This indicates that either a strong downward gradient is present, or that the water-bearing fractures sampled during the packer testing program have been dewatered and are recovering at extremely slow rates. Further east and downgradient, water levels in the monitoring well cluster 49GW201 are in much closer agreement, differing by approximately 2 feet between shallow, intermediate and deep wells. The gradient from the intermediate monitoring well to the shallow monitoring well is upward, and from the intermediate to the deep well is downward, indicating a potential divergence of flow. In the 49GW202 monitoring well cluster, located hydraulically cross-gradient, the vertical gradient is downward.

Groundwater likely discharges to Paint Branch (Figure 2-2), which is perennial, indicating that this stream is baseflow-controlled. Some underflow of groundwater likely occurs, but not directly across, or perpendicular to Paint Branch. The topographic and hydraulic gradient on the east side of Paint Branch will preclude significant groundwater flow from Site 49 east past Paint Branch. Some refraction of groundwater flow likely occurs at depth in the bedrock, inducing a southerly component of flow.

2.2 Nature and Extent of Contamination

This section provides a discussion on the nature and extent of contamination.

2.2.1 Soil

The potential source areas for groundwater contamination at Site 49 included the Building 427 leaching well and the Debris Disposal Area (Figure 2-4). Soil samples collected during the leaching well excavation were analyzed for only VOCs and contained no significant amounts of anthropogenic chemicals in soil. Soil samples from the Debris Disposal Area were analyzed for the full suite of TCL and TAL parameters.

2.2.1.1 Volatile Organic Compounds

Relatively few VOCs were detected in soil at Site 49 during the RI. Tetrachloroethene (PCE) was ubiquitous throughout the Debris Disposal Area, detected in all seven soil samples collected from this area at low (estimated) concentrations (from 1.5 to 3.0 micrograms per kilogram (µg/kg)). Chloromethane was detected less frequently (in five of nine samples), at similarly low concentrations. Bromomethane and carbon disulfide (common laboratory

artifacts) were detected in one sample each at concentrations of 1.4 and 1.7 µg/kg, respectively.

2.2.1.2 Explosives

No explosives-related compounds were detected in soil samples during the RCRA Facility Investigation.

2.2.1.3 Pesticides and PCBs

Two pesticides, 4,4'-DDT and dieldrin, were detected in one soil sample from boring 49SB201 at estimated[3] concentrations of 2.4 and 6.6 µg/kg, respectively. No other pesticides were detected in soil. PCBs were not detected in any samples.

2.2.1.4 Semivolatile Organic Compounds

Semivolatile organic compounds (SVOCs) were detected in all seven samples associated with the Debris Disposal Area. Sixteen individual SVOCs were detected at least once. One SVOC, bis(2-ethylhexl)phthalate [BEHP], was detected in all seven samples, at concentrations ranging from 230 to 2,200 µg/kg. BEHP is a very commonly used chemical in plasticizers and is often detected as a laboratory or sampling equipment artifact; its detections in these samples may not represent site conditions.

2.2.1.5 Metals

Metals, which are common mineral constituents of soil, were detected in all seven soil samples. Detected metals included:

Aluminum	Arsenic	Barium	Beryllium
Cadmium	Calcium	Chromium	Cobalt
Copper	Iron	Lead	Magnesium
Manganese	Nickel	Potassium	Sodium
Vanadium	Zinc		

Concentrations at which these metals were detected ranged from trace levels (part-per-million; ppm) to percent levels (i.e., 10,000 ppm) for common soil mineral constituents. The only metals that were detected in one or more samples at concentrations above EPA Region 3 residential soil risk-based concentrations are arsenic, iron, and manganese.

The results of soil sampling were compared to background data reported in the *Background Investigation Report* (TtNUS, December 1998b). The data also were compared to the following reference documents for background concentrations of metals:

- Shacklette, H.T. and J.G. Boerngen, 1984. *Elemental Concentrations in Soil and Other Surficial Materials of the Conterminous United States*. US Geological Survey Professional Paper 1270.
- Dragun, J., 1991. *Elements in North American Soils*. HMCRI, Greenbelt, Maryland.

[3] Estimated concentration because detected concentration was below laboratory reporting limit.

The maximum detected concentration of arsenic was below the 95 percent upper confidence limits (UCLs) for background. The maximum detected concentration of iron and manganese exceeded the 95 percent UCLs for background. The maximum detected concentration of manganese was also greater than the maximum detected background concentration. It is unlikely, however, that these iron and manganese results indicate anthropogenic soil contamination. The metal concentrations observed in subsurface soils are highly variable, but consistent with the regional-scale ranges (i.e., for Maryland or eastern United States; Dragun, 1991) for background concentrations as noted in the reference documents.

In addition to the inter-boring variability, intra-boring variability (i.e., variations and lack of associations between individual metals and/or different soil horizons) suggest that the exceedances of background concentrations are due to natural variability rather than anthropogenic influences.

2.2.2 Groundwater

The RI included the installation and sampling of temporary wells, the installation and sampling of permanent monitoring wells, and sampling discrete vertical intervals of open deep boreholes using packer test methods (Figure 2-5).

A phased approach was employed to investigate Site 49. Initial groundwater samples collected in the bedding of sewer lines along Paint Branch contained TCE, suggesting that VOCs (specifically the chlorinated solvent TCE and its degradation products) were originating from the area surrounding Building 427. The groundwater quality investigation continued by collecting samples from nine temporary monitoring wells installed with hollow stem auger and percussion techniques. Four of the temporary wells were installed in 2001 and five in June and July 2002. Eleven permanent monitoring wells were installed or converted from temporary wells between August 2002 and February 2003 in six locations throughout Site 49. Three of these locations included nested wells designed to provide vertical delineation of contamination. In addition, direct push groundwater samples were collected from eight locations along Paint Branch in November 2002. The locations of all permanent and temporary wells, and direct push sampling points are shown on Figure 2-4. To refine the vertical delineation, packer test samples were collected on 10-foot intervals (Figure 2-5) from the open boreholes of two deep monitoring wells (49GW201DD and 49GW206D) prior to completion. The permanent monitoring wells were sampled in phases as they were installed and in subsequent partially synoptic sampling events. Concentrations of all analytes detected in groundwater are summarized in Appendix A.

2.2.2.1 Volatile Organic Compounds (VOCs)

The primary VOCs detected in groundwater samples were TCE and its degradation products (*cis*-DCE, and VC). The discussion of TCE degradation and its products is present in Appendix D. Concentrations of TCE are shown in Figures 2-6 through 2-8. Figure 2-9 shows a generalized delineation of the TCE concentrations in shallow groundwater. Figure 2-10 shows a vertical delineation of the TCE concentrations in groundwater.

The following discussion will treat TCE as the parent product and *cis*-DCE and VC as its breakdown products. TCE is a widely-used industrial solvent, whereas *cis*-DCE and VC are less common as industrial or commercial chemicals and are known degradation products of TCE. Therefore, the most likely usage and disposal history of these compounds assumes

that TCE was employed in one or more processes with the subsequent generation of *cis*-DCE and VC in the subsurface following release and degradation of the parent product. It should be noted that, without documentation pertaining to processes that have taken place at Building 427, this usage and disposal history cannot be confirmed.

TCE was detected in shallow groundwater during the three sampling events. TCE concentrations in shallow groundwater generally increase with distance from Building 427. TCE concentrations increased from the postulated source towards Paint Branch. TCE was detected in well 49GW203 at 120 micrograms per liter (µg/L) near the Leaching Well and 380 µg/L at 49GW201S downgradient. TCE concentrations in well 49GW203 increased from 17 µg/L in June 2002 to 120 µg/L in October 2002. TCE concentrations in well 49GW201S, however, decreased from 730 µg/L in August 2002 to 380 µg/L in October 2002. TCE was detected in samples from monitoring well 49GW202S at 44 µg/L in June 2002 and at 60 µg/L in October 2002.

TCE concentrations increase with depth near the source area and decrease with depth away from the source (Figure 2-10). This may be due to the complex vertical gradients and groundwater flow patterns near Paint Branch. TCE concentrations in borehole/well 49GW206D increased from 54 µg/L at approximately 175 feet msl to 1,900 µg/L at 100 feet msl. The permanent screen was installed in this borehole at approximately 85 feet msl (screen midpoint elevations); TCE was detected in this horizon at 1,600 µg/L. However, this concentration declined to 140 µg/L in subsequent sampling events. This may indicate a true decrease in concentrations, though the samples were collected with different methods (i.e., open borehole packer test versus low-flow sampling from the permanent well). Further downgradient, in the well 49GW201 cluster, TCE was detected in shallow groundwater (185 feet MSL) at 380 µg/L and 4,400 µg/L at 155 feet msl (at the greatest concentration detected at Site 49), then declined to 4.3 µg/L at approximately 100 feet MSL. Detected concentrations in the deepest horizon at 49GW201 remained relatively constant at low concentrations during subsequent sampling events.

Generally, all samples contained *cis*-DCE and VC at concentrations ranging from a factor of four to several orders of magnitude less than respective TCE concentrations. The samples collected from 49GW201S and 49GW201D contained concentrations of VC two orders of magnitude lower than their respective *cis*-DCE concentrations.

The three clustered monitoring wells 49GW206S, 49GW206M, and 49GW206D, each contained TCE and *cis*-DCE. Concentrations of TCE decrease somewhat with depth, ranging from 560 µg/L in 49GW206S to 140 µg/L in 49GW206D. Concentrations of *cis*-DCE fluctuate with depth, decreasing from 150 µg/L in 49GW206S to 64 µg/L in 49GW206M, then increase to 90 µg/L in 49GW206D.

2.2.2.2 SVOCs, Pesticides, and PCBs

Three SVOCs (acenaphthene, dimethylphthalate, and phenanthrene) were detected at very low concentrations in groundwater: 2.8, 7.1, and 1.3 µg/L, respectively. Each was detected in a single groundwater sample. No PCBs or pesticides were detected in Site 49 groundwater.

2.2.2.3 Metals

Total and dissolved metals were detected in samples from the permanent monitoring wells. The metals detected were consistent with those detected in soil, surface water, and with the expected geochemical signatures for natural groundwater in this environment.

2.2.2.4 Explosives and Perchlorate

No explosives-related compounds or perchlorate were detected in Site 49 groundwater.

2.2.3 Surface Water

Surface water samples were collected during the RFI from three locations along Paint Branch. These samples were analyzed for VOCs, SVOCs, total and dissolved metals, and hardness.

2.2.3.1 Volatile Organic Compounds

No VOCs were detected in surface water samples.

2.2.3.2 Semivolatile Organic Compounds

Two SVOCs, 4-chloro-3-methylphenol and bis(2-ethylexyl)phthalate, were detected in the surface water samples at low concentrations, ranging from 1.4 to 3.9 µg/L.

2.2.3.3 Metals

Paint Branch surface water appears to be of the general Ca-Na-Mg-K association, which is consistent with the background data set discussed in the Background Investigation Report (TtNUS, December 1998b). Other detected metals included barium, iron, manganese, nickel, and vanadium. The minor constituent metals were detected at concentrations ranging from 1 to 511 µg/L. All detected concentrations were less than the corresponding 95 percent UCLs for background surface water quality.

Dissolved metals concentration patterns generally parallel the total metals concentrations. In addition, surface water quality data generally are consistent with the patterns of metals detected in groundwater.

2.2.4 Perimeter Drain and Building Sump Samples

Water samples were collected during the RI from various components of the Building 427 perimeter drain system. Two samples were collected from sumps inside Building 427. Two samples were collected from manholes outside the building on the northwest and southeast corners of the building. All four samples were analyzed for VOCs. Only the manhole sample from the northwest corner of the building contained any detectable concentrations of VOCs: TCE was detected at a concentration of 0.33 µg/L, as well as ethylbenzene, toluene, and total xylenes at concentrations of 0.27, 0.38, and 0.91 µg/L, respectively. All these detected concentrations are estimated, below the laboratory reporting limits.

2.3 Fate and Transport

Many organic and inorganic constituents were detected in environmental media at Site 49. However, the only anthropogenic chemicals detected in groundwater at concentrations impairing groundwater quality are TCE, *cis*-DCE, and VC. Other VOCs were detected in soil and groundwater, but at concentrations below screening criteria. Of these, TCE likely is the primary contaminant released. *Cis*-DCE and VC, while sometimes used as primary products, are much less commonly used in cleaning/degreasing applications. Accordingly, it is assumed that these chemicals were not released directly into the environment, but produced from TCE as a consequence of well-accepted degradation processes discussed later in this section. This assumption is consistent with conceptual models of other sites at the former NSWC White Oak and is supported by the ratios of contaminants detected in groundwater.

There appears to be one general source area at Site 49: Building 427. This is the only feature at Site 49 at which chemicals were likely to have been used. Releases from research, development, and testing operations and waste management practices at and around Building 427 are assumed to be the source of TCE. The topography of Site 49 away from Building 427 likely inhibited other operations. Because the specific purpose(s) for which TCE may have been used are unknown, the point(s) and mechanism(s) of release are not known. However, Building 427 and the adjacent Leaching Well and Debris Disposal Areas are the potential source area(s). It is unclear, however, based on soil sampling, the leaching well excavation, and the building inspection, where the actual release or releases have occurred. The most likely scenario for release is TCE disposal in the Leaching Well, discharging TCE directly to the subsurface, from which it subsequently migrated to the water table.

TCE may have been released as a separate phase liquid or as an aqueous (dissolved or emulsion) phase from cleaning operations in and around Building 427. For the purpose of the fate and transport discussion, TCE releases are assumed to have been to the shallow subsurface soil (i.e., the unsaturated or vadose zone).

2.3.1 Contaminant Migration and Fate

Groundwater originating in the area surrounding Building 427, travels east-northeast towards and discharges to Paint Branch. Flow occurs primarily in the bedrock at higher elevations and the bedrock and saprolite at lower elevations. Groundwater flows toward Paint Branch, contributing to base flow, based on the steep topography between Building 427 and Paint Branch and the hydraulic gradients that follow topography, as well as the perennial nature of Paint Branch. Although Paint Branch may not capture all groundwater flow, the similar gradients on the east side of Paint Branch preclude groundwater flow past Paint Branch. Groundwater flow in deeper horizons may refract south, along Paint Branch, as indicated by the hydraulic head data and detected TCE concentrations in well 49GW202D.

Monitoring well 49GW204, located south of Building 427, is the background monitoring well at Site 49. The well is located approximately 150 feet south (cross-gradient) of the former leaching well. The samples collected from 49GW204 during initial round of

groundwater sample did not contain detectable concentrations of VOCs, SVOCs, or explosives.

One presumed source of VOCs (the leaching well) was previously abandoned and, as discussed above, a remaining soil source is not likely. Effects to groundwater remain evident near Building 427; however, the highest concentrations are observed downgradient near Paint Branch (49GW201S and 49GW201D). This suggests that although contaminant mass is distributed areally throughout Site 49 and vertically in the bedrock, much of the mass has migrated towards Paint Branch. Further, although an estimate of the initial mass released is not possible, it is likely that much has already discharged to the stream, where the turbulent nature of ambient conditions caused the VOCs to volatilize. No impairment of water quality in Paint Branch has been observed, indicating that the mass loading to Paint Branch from Site 49 groundwater is small relative to the overall water balance and attenuates rapidly.

2.4 Human Health Risk Assessment Summary

A baseline human health risk assessment was conducted during the RI to assess the potential adverse affects from exposure to groundwater and surface water at the site under current and future conditions. This risk assessment was prepared using conservative assumptions and was presented in the RI.

The baseline risk assessment was conducted to evaluate the potential human health risks associated with the site-related activities for:

- surface water in Paint Branch, and
- bedrock groundwater.

Potential risks were calculated for a:

- future adult resident,
- future child resident,
- future lifetime resident, and
- future construction worker.

The risk assessment quantifies potential human health risks at Site 49 under current and future use scenarios, if no remediation is implemented.

No chemicals of potential concern (COPCs) were retained for Paint Branch surface water and, therefore, no unacceptable risks were identified for this medium. The bedrock aquifer groundwater presents carcinogenic risks and non-carcinogenic hazards greater than the USEPA target levels. USEPA target levels for carcinogens and non-carcinogens are incremental excess lifetime cancer risks of $1x10^{-6}$ to $1x10^{-4}$ and a hazard index (HI) greater than 1.0, respectively. Risks exceeded these target levels for the following receptors under reasonable maximum exposure scenario (HI and CR from the Site 49 RI report, CH2M HILL, May 2004):

- For a future residential adult and child exposed to groundwater, the non-carcinogenic HIs are 34 and 79 respectively. The carcinogenic risk associated with groundwater lifetime exposure is $1.3x10^{-1}$.

- For a future construction worker exposed to groundwater, the non-carcinogenic HI is 3.7 and the carcinogenic risk associated with exposure to groundwater is 9.7×10^{-5}.

Risks for these same receptors were significantly less under the central tendency scenarios:

- For a future residential adult and child exposed to groundwater, the His are 0.79 and 2.5 respectively. Only the value for the child resident exceeds the USEPA target HI 1.0. The carcinogenic risk associated with groundwater lifetime exposure is 1.3×10^{-3}.

- For a future construction worker exposed to groundwate, the HI is 0.11, which is below the USEPA target hazard index of 1.0. The carcinogenic risk associated with exposure to groundwater is 2.7×10^{-6}.

Central tendency is defined as the center or general location of the cancer risk or hazard index. The main risk drivers for the bedrock aquifer groundwater are TCE, cis-DCE, 1,2-dibromoethane, and VC. PCE, chromium, iron, and manganese also contribute to the risks and hazards, but to a much lesser extent.

Table 2-1
Summary of Geologic Units
Site 49, NSWC White Oak
Silver Spring, Maryland

Physiographic Provinces	Chronostratigraphic Units	Subunits	Age	Lithostratigraphic Units	Lithology	Hydrostratigraphic Units
NA	Recent[1]	NA		Overburden soil	Soil Glenelg-Manor-Chester Chillum-Beltsville-Croom	NS
Atlantic Coastal Plain	Potomac Group[1,2]	Patapsco Fm.[2] Arundel Fm.[2] Patuxent Fm.[2]	Cretaceous	Potomac Group[2]	Unconsolidated fluvial clay, silt, sand, gravel	NS
Piedmont Province	Wissahickon Formation[3] Glen Arm Series		Late-Precambrian to Early-Cambrian[4]	*Saprolite* Bedrock	*Saprolite derived* from underlying bedrock Crystalline schist, quartzite	*Saprolite* Bedrock

Notes:
-Units presented in order encountered with increasing depth from ground surface
-Chronostratigraphic units are generally formal, named geologic units based on temporal associations, as described in scientific literature.
-Lithostratigraphic units are informally named, generally site-specific geologic units that are organized on the basis of lithology (i.e., geologic materials having similar physical characteristics). These units may be the same as, subdivisions of, or different from chronostratigraphic units.
-Hydrostratigraphic units are informally named geologic units, generally site-specific, that are organized on the basis of hydrogeologic similarities and connections (i.e., geologic materials through which groundwater moves in a consistent manner). These units may be the same as, subdivisions of, or different from chronostratigraphic or lithostratigraphic units.
NA-Not applicable
NS-Not *significant at Site; may be significant at regional- and larger-scales*
1. Unconformable contact with lower unit
2. Undifferentiated at site, not all named members may be present or differentiable
3. The Wissahickon has been differentiated by some authors into several components, with the consensus that "Wissahickon" is an obsolete term (MGS, 2003). In the vicinity of NSWC White Oak, the most likely Wissahickon component is the Lower Pelitic Schist, formerly mapped as the Wissahickon, Eastern Sequence or the Wissahickon-oligoclase facies (MGS, 2003; Southwick and Fisher, 1967). The designation Wissahickon will be used in this report for consistency with earlier reports.
4. More recent research indicates that the Wissahickon may be late-Cambrian to early-Ordovician in age (MGS, 2003).

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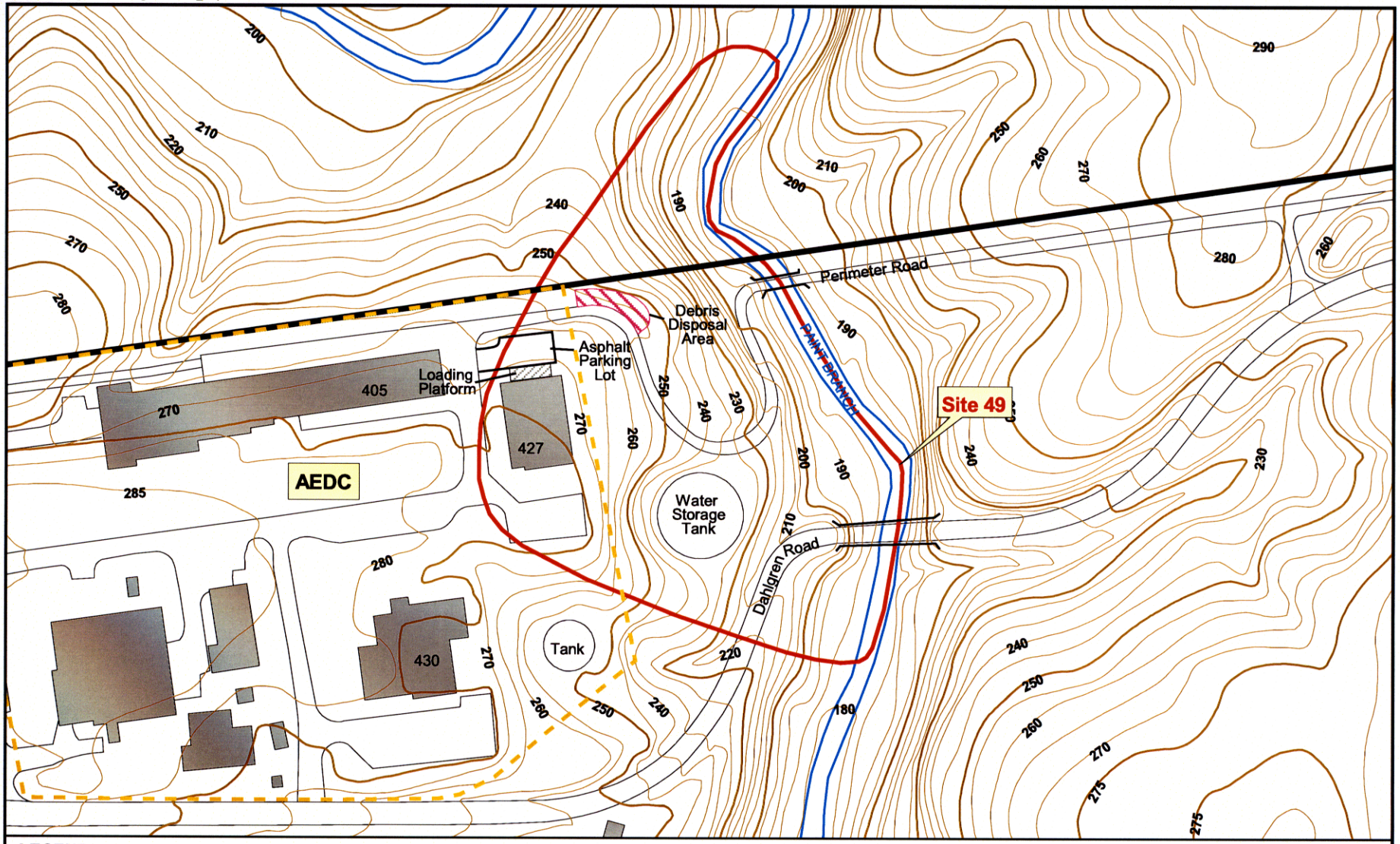

LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

0 200 400 Feet

Figure 2-1
Site Topography
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

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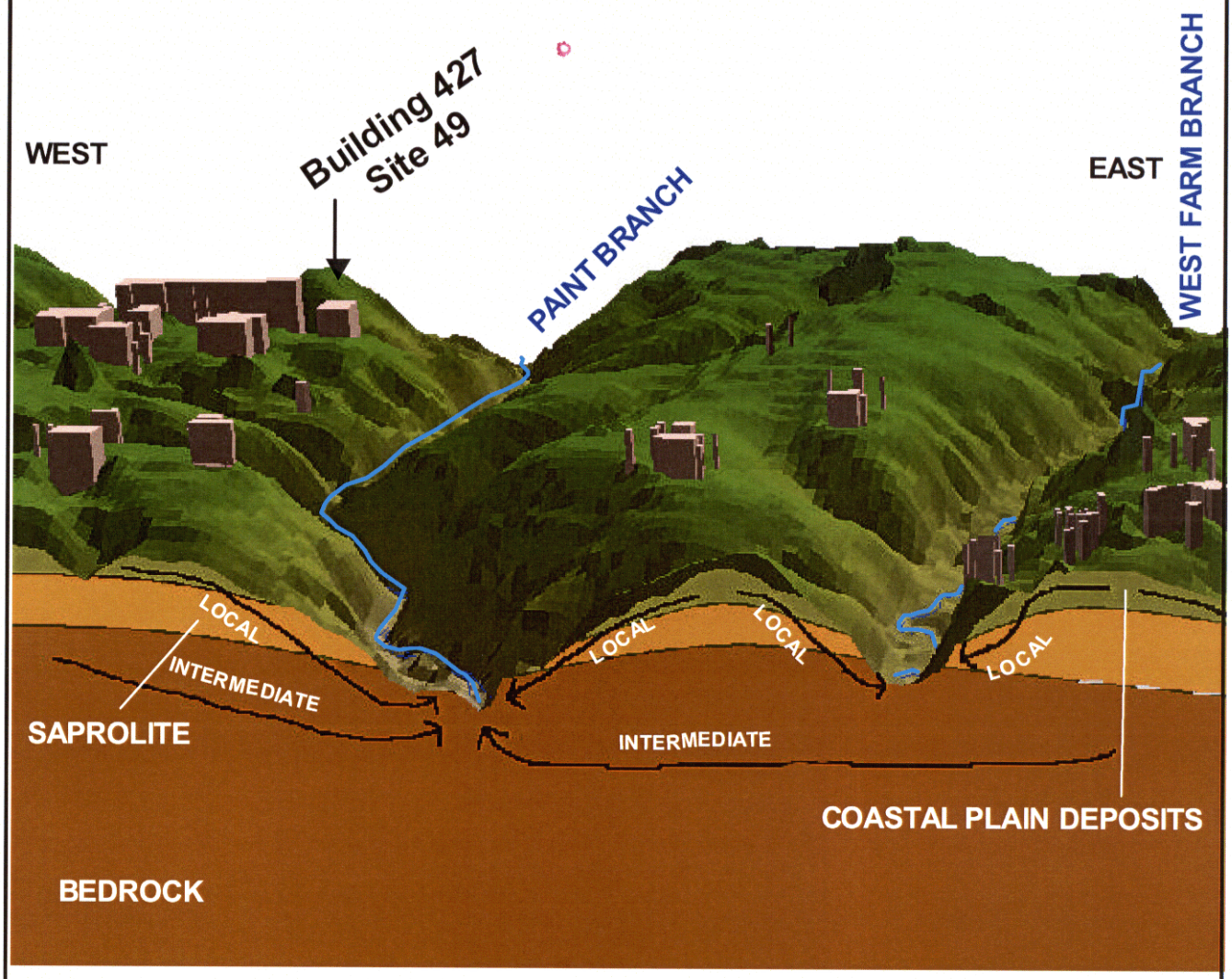

LEGEND

- Surface Topography
- Coastal Plain Deposits
- Saprolite
- Bedrock
- Conceptual Groundwater Flow Directions

0 500 1000 1500
HORIZONTAL FEET
WEST - EAST

Figure 2-2
Schematic Hydrogeologic Cross-Section
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

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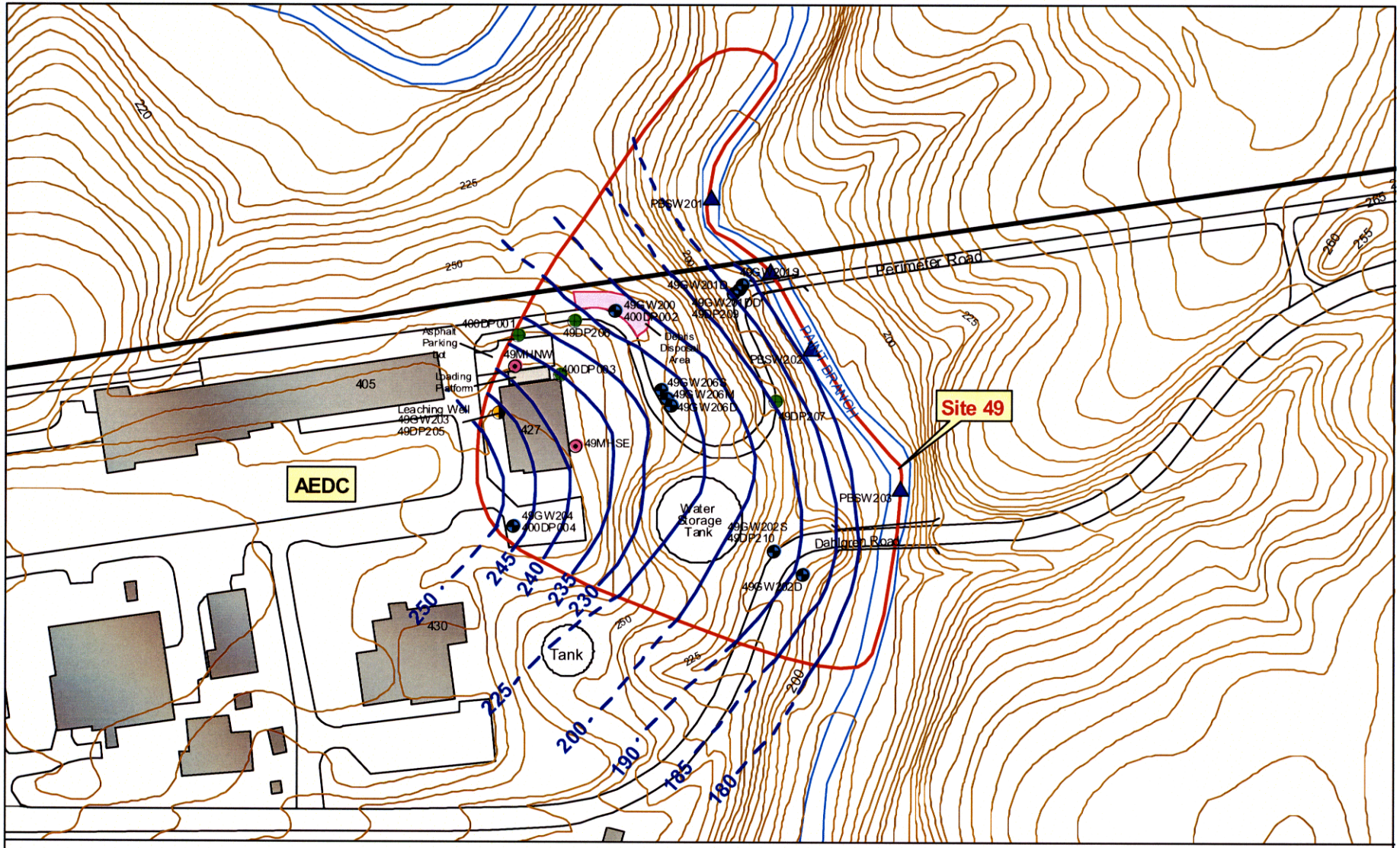


LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- Topographic Contour Lines
  '250' (feet above mean sea level, 5 foot intervals)
- Monitoring Well Location
- Direct Push Sample Location
- Leaching Well Location
- Surface Water Sample Location
- Manhole Location

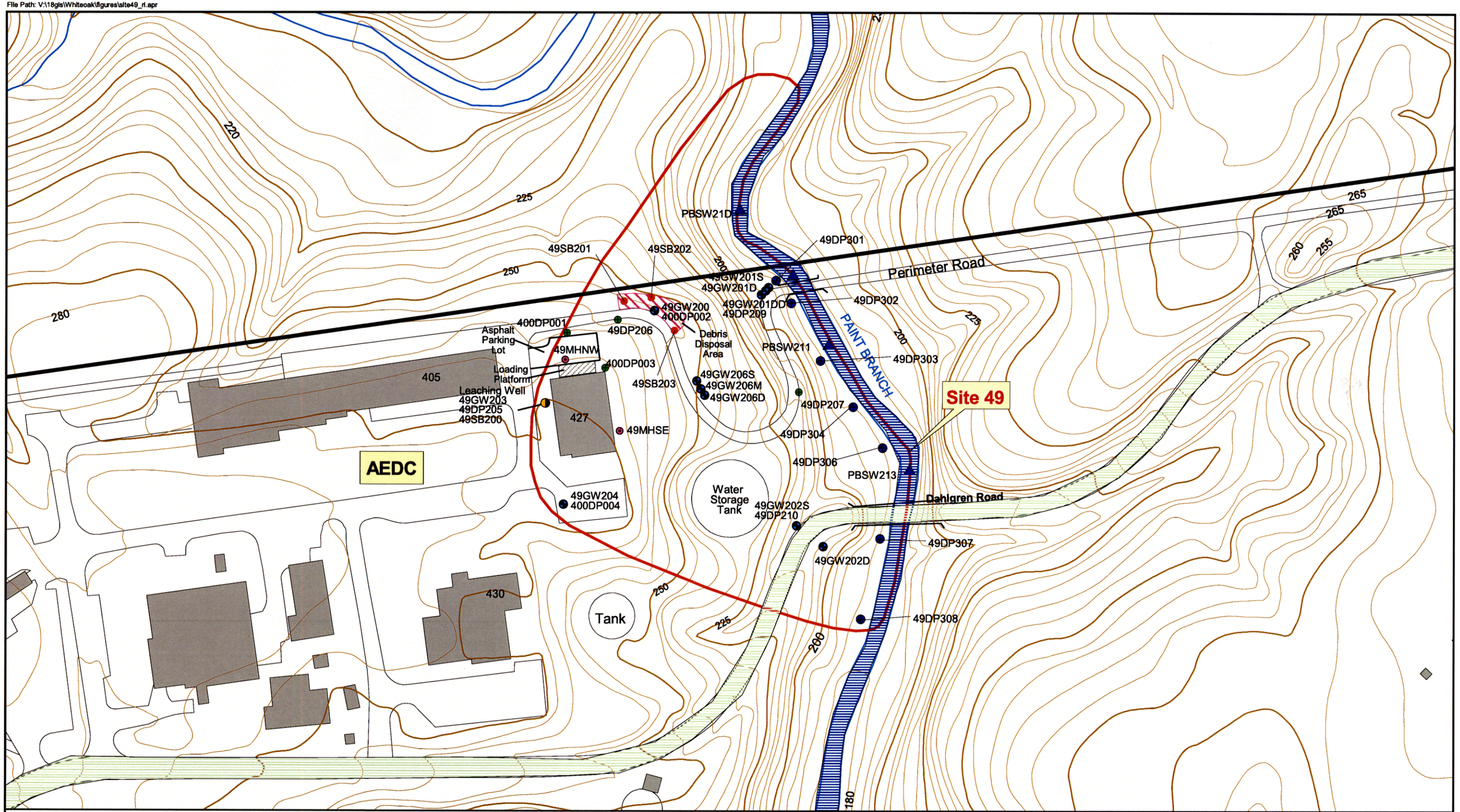
N

0 200 400 Feet

Figure 2-3
Water Table Contours
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

File Path: V:\18gis\Whiteoak\figures\site49_ri.apr



LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Monitoring Well Location
- Temporary Well Sample Location
- Leaching Well Location
- Surface Water Sample Location
- Manhole Location
- Soil Borring
- Direct Push Groundwater Sample
- '250' Topographic Contour Lines (feet above mean sea level, 5 foot intervals)

N

0 150 300 450 Feet

Figure 2-4
RI Sampling Locations
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

9208f030.dgn 07-MAY-2004

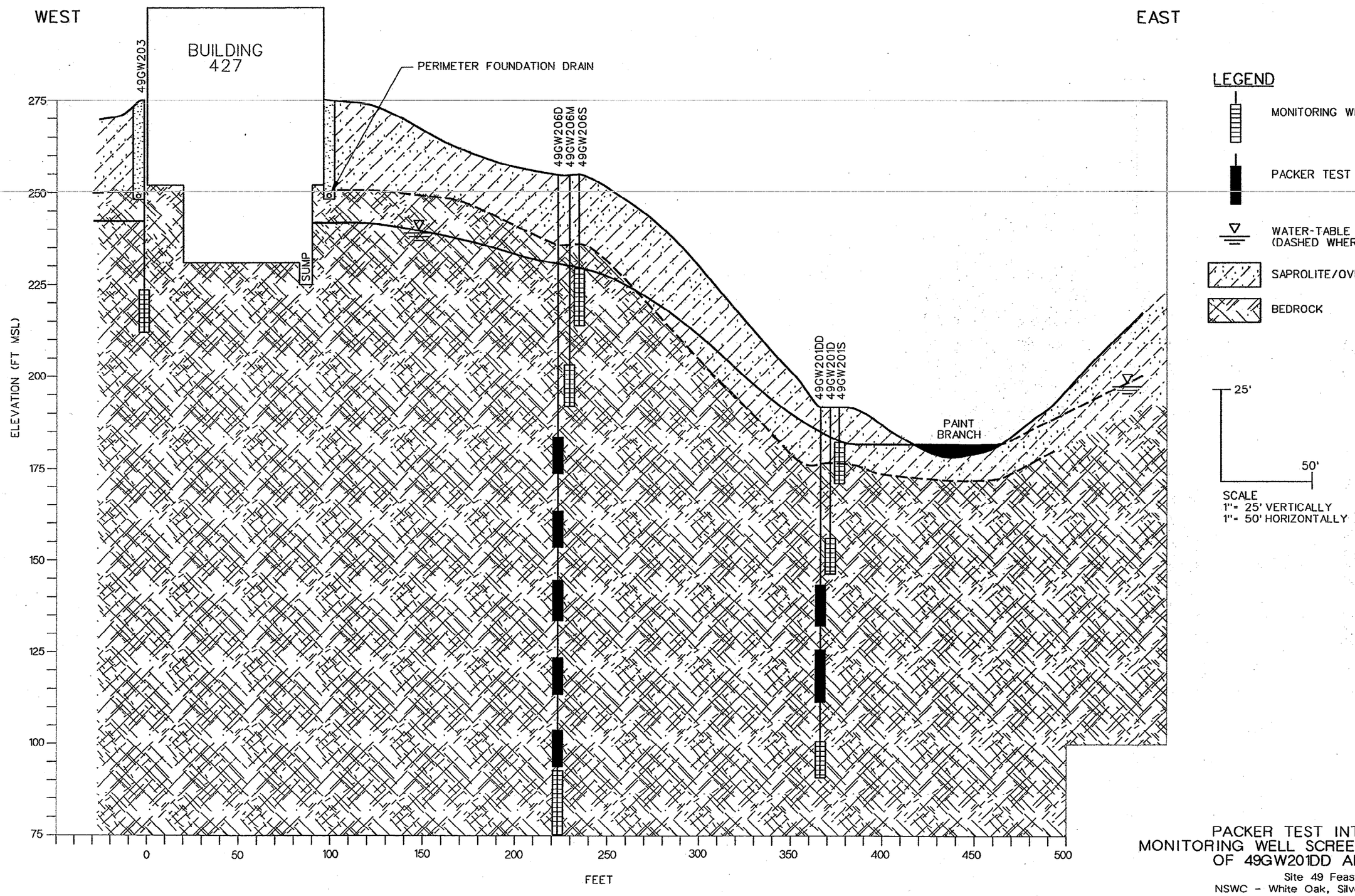


Figure 2-5
PACKER TEST INTERVALS AND MONITORING WELL SCREEN INTERVALS OF 49GW201DD AND 49GW206D

Site 49 Feasibility Study Report
NSWC - White Oak, Silver Spring, Maryland

CH2MHILL

00538B03Z

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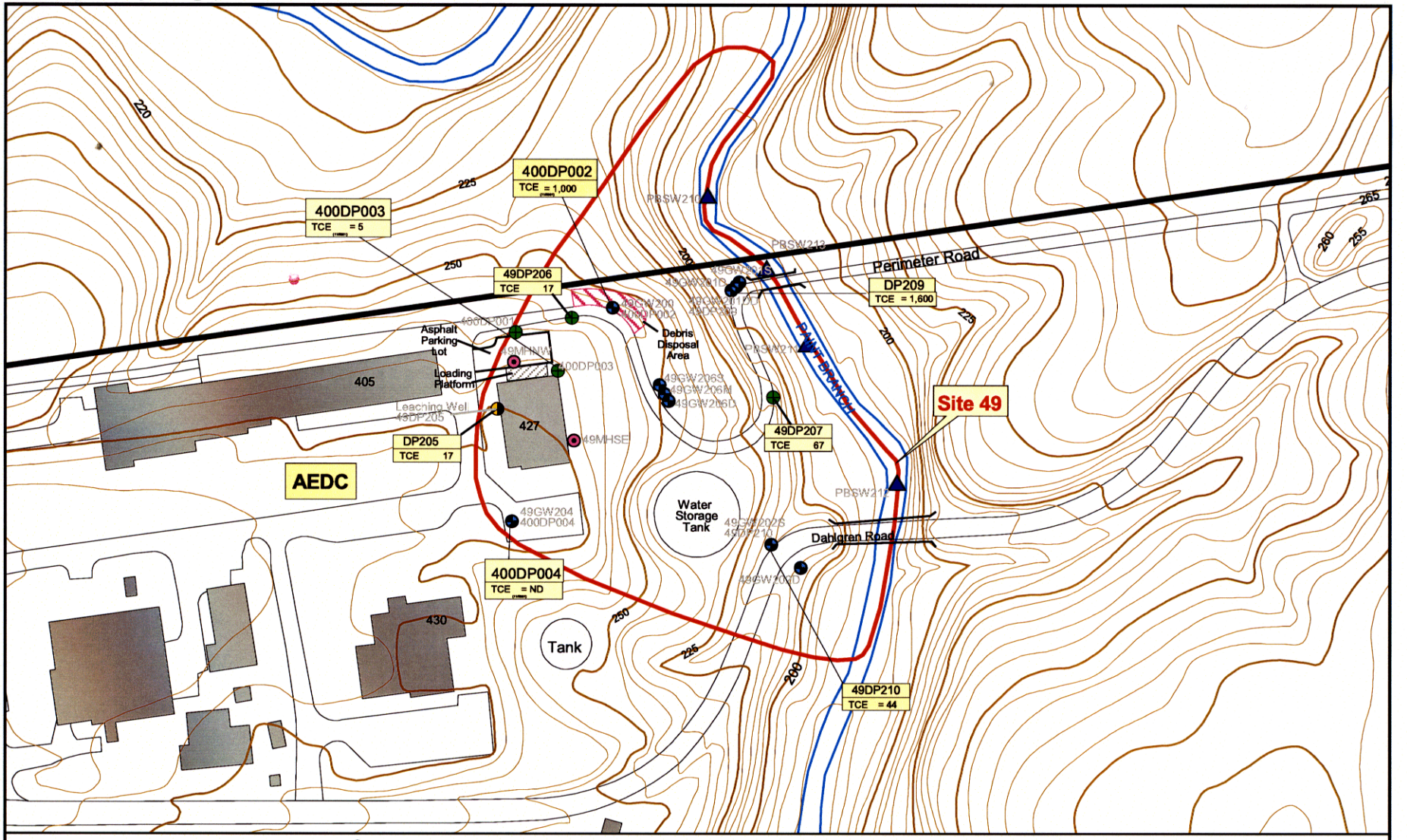


LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- Stream
- Base Boundary
- Monitoring Well Location
- Temporary Well Sample Location
- Leaching Well Location
- Surface Water Sample Location
- Manhole Location
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

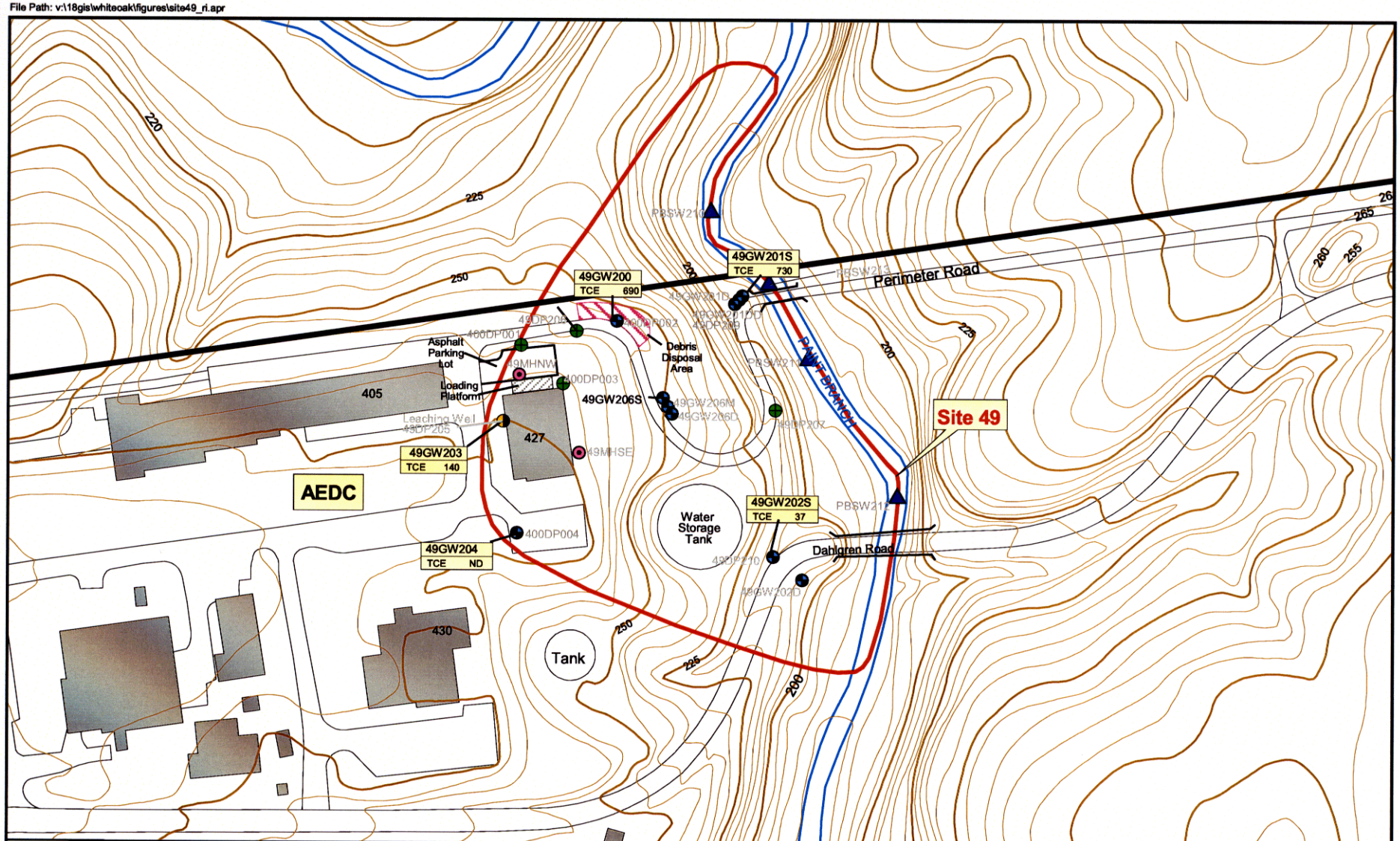
0 200 400 Feet

All Concentrations in ug/L

Figure 2-6
TCE in Shallow Groundwater - June 2002
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

File Path: v:\18gis\whiteoak\figures\site49_ri.apr



LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- Stream
- Base Boundary
- Monitoring Well Location
- Direct Push Sample Location
- Leaching Well Location
- Surface Water Sample Location
- Manhole Location
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

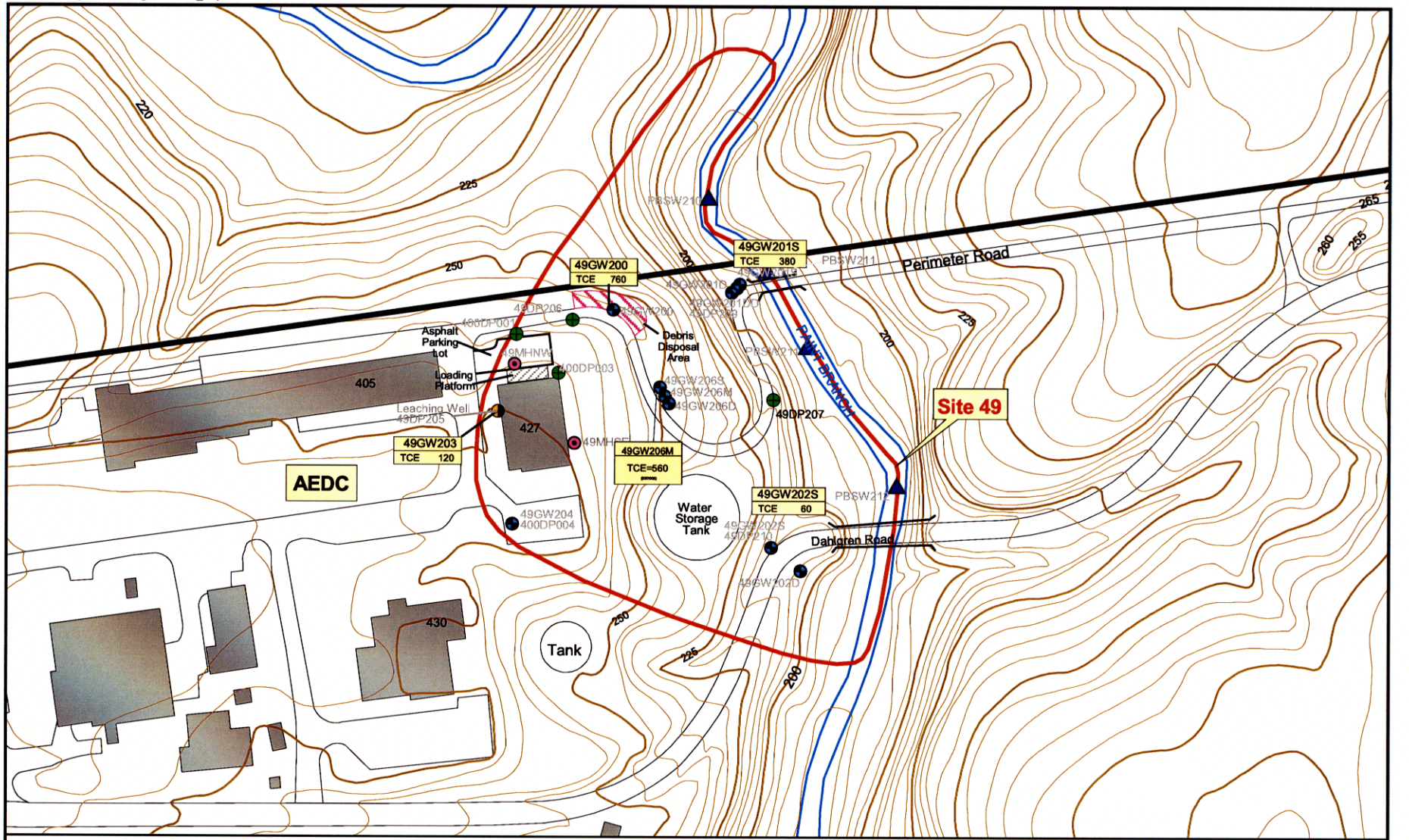
0 200 400 Feet

All Concentrations in ug/L
ND = Non-detect

Figure 2-7
TCE in Shallow Groundwater - August 2002
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

File Path: v:\18gis\whiteoak\figures\site49_ri.apr



LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- Stream
- Base Boundary
- Monitoring Well Location
- Direct Push Sample Location
- Leaching Well Location
- Surface Water Sample Location
- Manhole Location
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

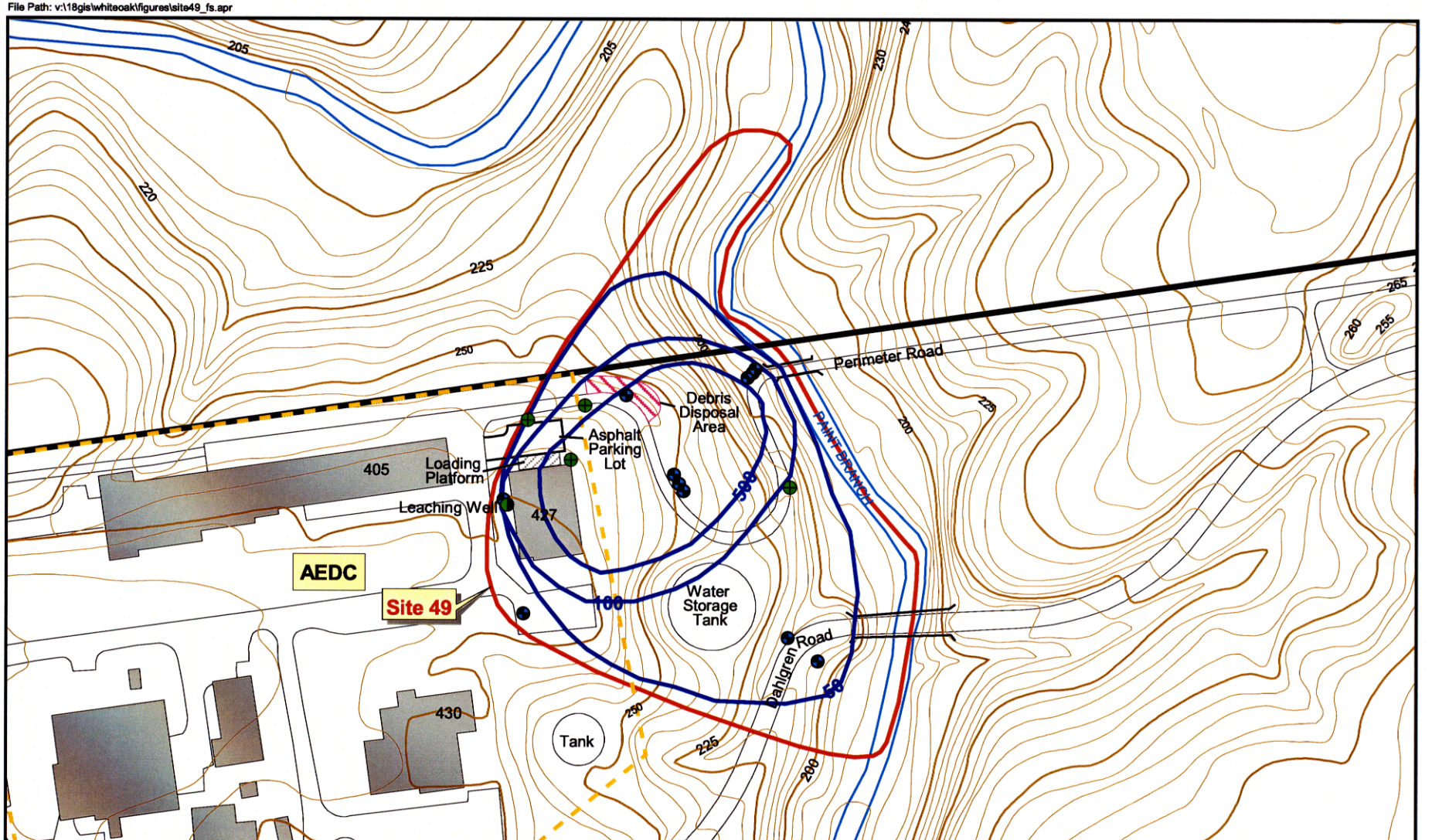
0 200 400 Feet

All Concentrations in ug/L

Figure 2-8
TCE in Shallow Groundwater - October 2002
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

File Path: v:\18gis\whiteoak\figures\site49_fs.apr



LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RI
- AEDC Fence Line
- Stream
- Base Boundary
- TCE Concetrations in µg/L
- Monitoring Well Location
- Temporary Well Sample Location
- Topographic Contour Lines
  '250' (feet above mean sea level, 5 foot intervals)

N

0 200 400 Feet

Figure 2-9
Site 49 Conceptual Isoconcentrations
for TCE in Shallow Groundwater
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

CH2MHILL

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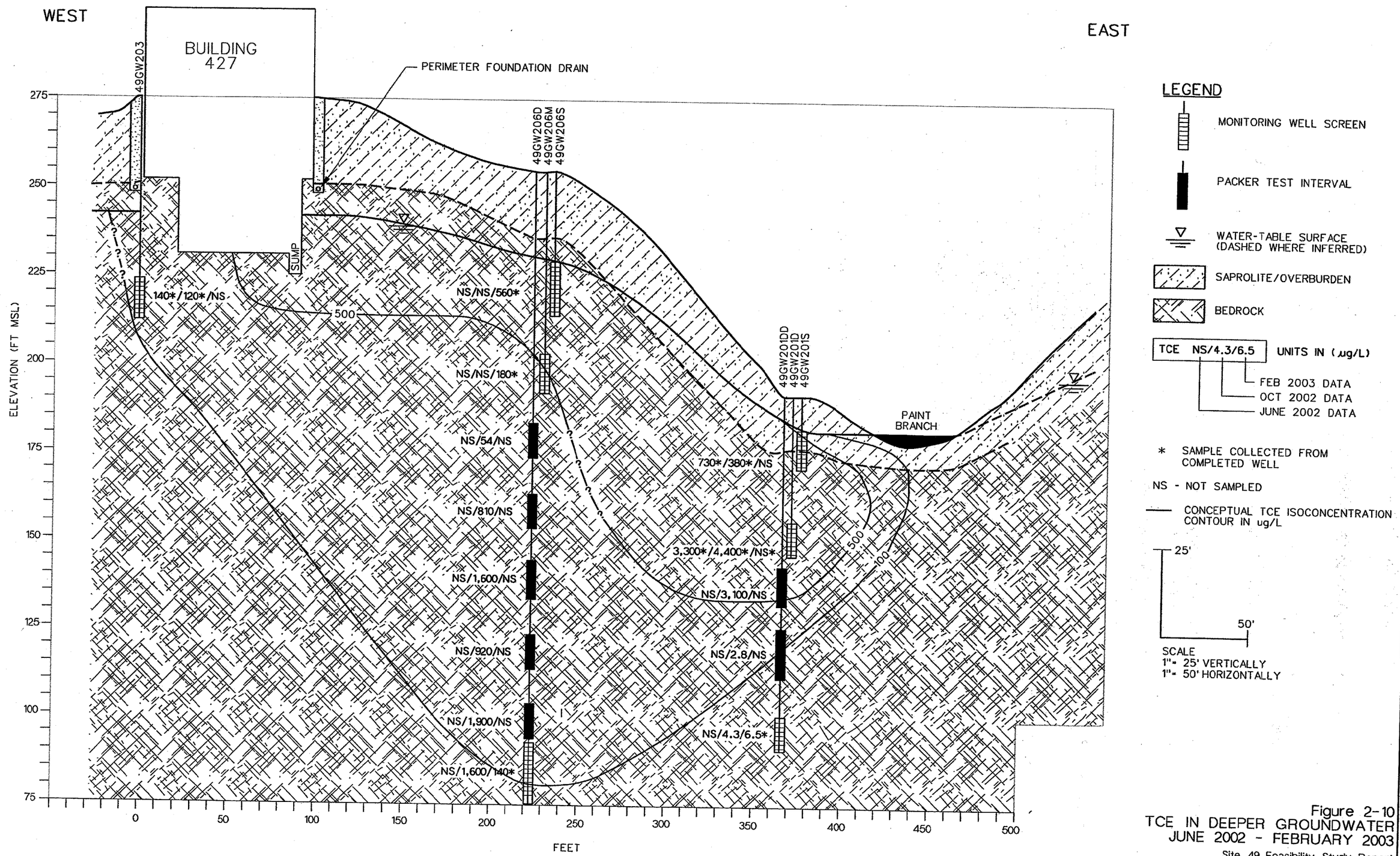

Figure 2-10
TCE IN DEEPER GROUNDWATER
JUNE 2002 - FEBRUARY 2003

Site 49 Feasibility Study Report
NSWC - White Oak, Silver Spring, Maryland

CH2MHILL

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SECTION 3

Remedial Action Objectives

This Section presents general and site-specific RAOs and identifies ARARs for Site 49.

Because the site characterization and remediation process at White Oak is being conducted in accordance with the guidelines established under CERCLA, the general RAOs are defined by the National Contingency Plan (NCP) and CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). CERCLA defines the statutory requirements for developing remedies.

Site-specific RAOs relate to specific contaminated media and the potential exposure routes. Site-specific RAOs, which require an understanding of the contaminants and the physical properties in their respective media, are based on an evaluation of the risks to public health and to the environment and evaluation of the ARARs.

Section 121(d) of SARA mandates that site remediation under CERCLA must achieve a level or standard of control for hazardous substances that at least attains such levels as specified in ARARs. Only promulgated Federal and State laws and regulations can be considered ARARs. In addition to ARARs, proposed rules, guidance documents, directives, etc., that may impact the conduct of a CERCLA action are called TBC documents.

3.1 NCP and CERCLA Objectives

The NCP requires that the selected remedy meet the following general RAOs:

- Each remedial action selected shall be protective of human health and the environment [40 Code of Federal Regulations (CFR) 300.430 (f)(ii)(A)].
- Onsite remedial actions that are selected must attain those ARARs that are identified at the time of the Record of Decision (ROD) signature [40 CFR 300.430 (f)(ii)(B)].
- Each remedial action selected shall be cost-effective. A remedy shall be cost-effective if its costs are proportional to its overall effectiveness [40 CFR 300.430 (f)(ii)(D)].
- Each remedial action shall use permanent solutions and alternative treatment technologies or resource-recovery technologies to the maximum extent practicable [40 CFR 300.430 (f)(ii)(E)].
- Where practicable, contaminated groundwater will be restored to a quality at which it can be put to beneficial use.

The statutory scope of CERCLA was amended by SARA to include the following general objectives for remedial action at all CERCLA sites:

- Remedial actions "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further releases at a

minimum which assures protection of human health and the environment" (CERCLA Section 121(d)).

- Remedial actions "in which treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants is a principal element" (CERCLA Section 121(b)) are preferred. If the treatment or recovery technologies selected are not a permanent solution, an explanation must be provided.
- The least-favored remedial actions are those that include "offsite transport and disposal of hazardous substances or contaminated materials without treatment where practicable treatment technologies are available" (CERCLA Section 121(b)).
- The selected remedy must comply with or attain the level of any "standard, requirement, criteria, or limitation under Federal environmental law...or any promulgated standard, requirement, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation" (CERCLA Section 121(d)(2)(A)).

3.2 Development of Site-Specific Remedial Action Objectives

Site-specific RAOs are developed to address potential exposure scenarios for groundwater at Site 49. The potential exposure routes for Site 49 were identified in the Baseline Human Health Risk Assessment presented in the Site 49 RI report (CH2M HILL, May 2004) and are summarized below.

3.2.1 Identification of Environmental Media

The RI identified the following environmental media as posing a potential risk to human health or the environment:

- Groundwater beneath Site 49, if used as a source of drinking water.

No COCs were identified in surface water, and soil did not contain site-related contaminants; therefore, these media were eliminated from this analysis.

3.2.2 Site-Specific Remedial Action Objectives

The site-specific RAOs are based on mitigating the current and potential future risks to human health and the environment. The site-specific RAOs for Site 49 are to:

- Prevent unacceptable risks to human receptors from exposure to contaminants in the groundwater;
- Where practicable, restore contaminated groundwater to a quality such that it could be put to beneficial use; and
- Prevent further migration of contaminants.

The remedial action alternatives presented and evaluated in Sections 4 and 5 were developed with the objective of meeting the site-specific RAOs. Remedial action alternatives

must meet standards as defined by the ARARs of EPA and MDE. If the ARARs do not address a particular situation, remedial actions should be based on the TBC criteria or guidelines. ARARs and TBC criteria are described below.

3.2.3 Applicable or Relevant and Appropriate Requirements

As required by Section 121 of CERCLA, remedial actions carried out under Section 104 or secured under Section 106 must attain the levels of standards of control for hazardous substances, pollutants, or contaminants specified by the ARARs of federal and state environmental laws and state facility-siting laws, unless waivers are obtained. According to USEPA guidance, remedial actions should also be based on nonpromulgated TBC criteria or guidelines if the ARARs do not address a particular situation.

ARARs are identified by the USEPA as either being applicable to a situation or relevant and appropriate to it. These distinctions are critical to understanding the constraints imposed on remedial alternatives by environmental regulations other than CERCLA. The definitions of ARARs below are from the USEPA guidance (USEPA, October 1988).

"Applicable requirements" are standards and other environmental protection requirements of federal or state law dealing with a hazardous substance, pollutant, or contaminant and its remedial action.

"Relevant and appropriate requirements" are standards and environmental protection criteria of federal or state law that, although not "applicable" to a hazardous substance or remedial action, address situations sufficiently similar to those at the site that their use is suitable and appropriate.

A requirement may be "relevant" to a particular situation but not "appropriate" because of differences in the duration of the regulated activity or the physical characteristics of the affected media.

A requirement that is relevant and appropriate must be met as if it were applicable. Relevant and appropriate requirements that are more stringent than applicable requirements take precedence. However, more discretion is allowed in determining relevant and appropriate requirements than in determining applicable requirements.

Another factor in determining which response or remedial requirements must be met is whether the requirement is substantive or administrative. Onsite CERCLA response actions must meet substantive requirements but not administrative requirements. Substantive requirements are those dealing directly with actions or with conditions in the environment. Administrative requirements implement substantive requirements by prescribing procedures such as fees, permitting, and inspection that make substantive requirements effective. This distinction applies to onsite actions only; offsite response actions are subject to all applicable standards and regulations, including administrative requirements such as permits. However, remedial actions must meet all substantive requirements of ARARs, even when administrative requirements are not met.

3.2.4 Other Criteria or Guidelines to be Considered

Many Federal and State programs have criteria, advisories, guidelines, and proposed standards that provide recommended procedures if no ARARs exist or if existing ARARs

are inadequate. In such instances, the TBC criteria or guidelines should be used to set remedial action levels.

3.2.5 Determination of Applicable or Relevant and Appropriate Requirements

The purpose of this ARARs section is to identify and summarize those Federal and State laws, regulations, and guidance that affect remediation activities at Site 49.

There are three classifications of ARARs: chemical-specific, location-specific, and action-specific ARARs. Potential chemical-, location-, and action-specific ARARs for Site 49 are presented in the following subsections.

The remedial action alternatives developed in this FS were analyzed for compliance with the potential Federal and State ARARs. The analysis involved identifying potential requirements for each of the alternatives, evaluating their applicability or relevance and appropriateness, and determining if the remedial alternatives can achieve the ARARs. The results of the analyses are found in Section 5 of this report.

3.2.5.1 Chemical-Specific ARARs and TBC Criteria

Chemical-specific ARARs set health-based concentration limits or discharge limits in various environmental media for specific hazardous substances, pollutants, or contaminants. Examples of federal chemical specific ARARs for Site 49 are Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs) and MCL goals which are enforceable standards for drinking water sources and water quality criteria, which set limits for the discharge of water to surface water bodies. TBC criteria would include EPA Region III risk-based criteria and other site specific human health and ecological risk based criteria developed for Site 49. PRGs for groundwater, which were developed based on the chemical-specific ARARs and TBCs, are discussed in section 3.3. A summary of potential regulatory programs identifying chemical specific ARARs and TBCs is provided in Table B-1 of Appendix B.

3.2.5.2 Location-Specific ARARs and TBC Criteria

Location-specific requirements are design requirements or activity restrictions that are based on the geographic position of a site. The analysis of Federal and State of Maryland location-specific ARARs and TBC criteria is presented in Table B-2 of Appendix B.

3.2.5.3 Action-Specific ARARs and TBC Criteria

Action-specific requirements set performance, design, or other standards for particular activities in managing hazardous substances or pollutants. The analysis of Federal and State of Maryland action-specific ARARs is presented in Table B-3 of Appendix B.

3.3 Development of Preliminary Remediation Goals

PRGs are proposed for each of the COPCs found in the affected environmental media at Site 49. As discussed in section 3.2.1, groundwater is the only affected environmental medium at the site. The following sections identify the COPCs and PRGs for groundwater and, based on these, identify the specific areas of Site 49 that may require remediation.

Risk-based PRGs were developed for each of the COPCs identified in the groundwater (i.e.: those constituents with concentrations contributing appreciably to the calculated risks and hazards from exposure to groundwater within Site 49.)

Based on the baseline human-health risk assessment conducted as part of the RI for Site 49 (CH2M HILL, May 2004), eight COPCs were identified (See Table 3-1).

PRGs for groundwater are set with the goal of reducing the cumulative risk from all non-background-related constituents to an acceptable level.

PRGs were identified for the list of COPCs identified in Table 3-1. These values were developed to ensure that overall cancer risk from COPCs across the site will not exceed $5x10^{-5}$, and the overall HI will not exceed 1 for a specific target organ. For each of the identified COPCs in Table 3-1, relevant MCLs were also identified where they have been established. Where they exist, MCLs are used as PRGs. The proposed PRGs for each COPC are shown in Table 3-2. The backup calculations for identifying COCs and PRGs are presented in Appendix E.

The PRGs were then compared to the maximum detected contaminant concentration at the site in order to identify chemicals of concern (COCs). COCs are a subset of the COPCs comprising those chemicals requiring remedial action. In general, if the maximum concentration of a chemical exceeds the PRG, then that chemical is considered a COC. Exceptions to this include:

- If a chemical is present at background concentrations;
- If a metal exceeds its PRG in an unfiltered sample but not in a filtered sample; or
- If a chemical only exceeds a risk-based PRG in one or two isolated wells (if a chemical exceeds a MCL-based PRG in a well it is considered a COC).

The COPCs that have qualified as COCs are identified in Table 3-2. The table includes an explanation for those COPCs that are not carried through as COCs.

Table 3-1
Chemicals of Potential Concern for Groundwater Throughout Site 49
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

VOCs
1,2-Dibromoethane
Chloroform
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
Tetrachloroethene
Trichloroethene
Vinyl Chloride

Metals
Aluminium
Chromium
Iron
Manganese
Nickel

Table 3-2
Risk-Based PRGs and MCLs for Chemicals of Potential Concern for Groundwater Throughout Site 49
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Attainment Area/Chemical	Proposed PRG (mg/L)	Source[A]	Max Conc. (mg/L)	COC?
Site 49 PRG Attainment Area				
1,2-Dibromoethane			6.50E-02	No[B]
Chloroform	8.00E-02	M	3.80E-02	No[C]
cis-1,2-Dichloroethene	7.00E-02	M	1.10E+00	Yes
trans-1,2-Dichloroethene	1.00E-01	M	4.60E-02	No[C]
Tetrachloroethene	5.00E-03	M	1.10E-03	No[C]
Trichloroethene	5.00E-03	M	4.40E+00	Yes
Vinyl Chloride	2.00E-03	M	5.70E-03	Yes
Aluminium (Dissolved)	7.80E+00	RB	6.80E+00	No[C]
Chromium	1.00E-01	M	7.50E-03	No[C]
Iron (Dissolved)	4.70E+00	RB	1.41E+01	Yes
Manganese (Dissolved)	1.50E-01	RB	2.29E+00	No[D]
Nickel (Dissolved)	3.10E-01	RB	8.10E-03	No[C]

Footnotes:
[A] M=Proposed PRG is based on MCL, RB=proposed PRG is based on calculated risk-based PRG (HI=0.5 for aluminum and manganese, HI=1 for iron and nickel)
[B] Chemical is not considered a COC because it was only found in one or two scattered wells/samples at concentrations above the risk-based PRG
[C] Chemical is not considered a COC because maximum concentration does not exceed PRG
[D] Chemical is not considered a COC because it is present at concentrations similar to background.
Boldface chemicals are those considered COCs

SECTION 4

Alternative Evaluation Process and Screening of Remedial Technologies

This Section presents the process by which remedial alternatives were developed and evaluated. The process consist of the following steps:

1. Identification of general response actions
2. Identification and screening of remedial technologies
3. Development of remedial alternatives
4. Evaluation of remedial alternatives

The general approach for meeting the RAOs for groundwater at Site 49 is to remediate (actively or passively) the dissolved-phase plumes downgradient of Building 427 that contain chemical concentrations above PRGs.

With this in mind, general response actions were identified and remedial technologies were screened as they may pertain to conditions found in the dissolved-phase portions of the plume. Remedial alternatives were then developed from the general response actions.

4.1 General Response Actions

General response actions are broad classes of responses, remedies, or technologies developed to meet the site-specific RAOs. Each general response action is intended to address specific contaminants and the possible migration pathways and exposure routes in groundwater. Although an action may be capable of meeting the objective, combinations of actions may later prove to be more effective in meeting all the objectives for the site. Therefore, to comply with the site RAOs, the general response actions are combined to form Site-wide remedial alternatives.

The general response actions listed below have been identified are as follows:

- No Action
- Institutional Control Actions (possibly with long-term monitoring)
- Containment Actions
- Removal Actions
  - Disposal Actions
- Treatment Actions

Under the *no-action response,* the current site conditions would remain. The NCP requires that a no-action alternative be developed as a baseline for evaluating remedial alternatives.

Institutional control actions consist of a number of alternatives that rely on legal restrictions of access. They can be used singly or in concert with other remedies to mitigate risk. Access restrictions can be effective as a means of preventing exposure to the groundwater and preventing unacceptable risks to future residential populations. Examples of institutional

controls include legal restrictions on groundwater withdrawal and use, recorded in the deed for the land.

Monitoring actions include long-term monitoring, monitoring active remediation, or monitoring natural attenuation. Long-term monitoring consists of tracking groundwater quality over time to assess the potential for offsite plume migration or improving or worsening conditions.

Containment actions for groundwater would include engineering controls like physical barriers (e.g. caps) to preclude exposure or hydraulic controls like pumping systems to prevent contaminated groundwater from migrating.

A *removal action* for groundwater would be groundwater extraction with the objective of removing mass and reaching PRGs throughout the plume. This differs from extraction for containment where the objective is to prevent off-site migration.

Treatment actions include technologies that reduce the toxicity, mobility, or volume of the contaminants in groundwater in situ. An example would be enhanced biodegradation for groundwater. *Treatment actions* may include biological, physical, or chemical processes. Monitored natural attenuation is considered an *in situ* treatment action. Treatment technologies may be used also to facilitate disposal for extracted media.

Disposal actions for groundwater include discharge of treated or untreated water to sanitary sewers or surface water, via permitted conveyances.

The above general response actions have been used to create a range of site-wide alternatives that can be compared on the NCP criteria and compliance with the site-specific RAOs.

4.2 Target Remediation Zone and Mass Estimate

Figures 2-9 and 2-10 present the approximate horizontal and vertical extent of groundwater contamination. This area encompasses TCE and all other VOCs present at concentrations greater than PRGs. No significant or widespread area of soil contamination was encountered above or below the water table that would indicate the presence of nonaqueous phase liquid (NAPL).

The source of the plume is presumed to be the former leaching well on the west side of Building 427. Paint Branch is the eastern (downgradient) limit to the plume. The plume is estimated to extend somewhat south of monitoring well 49GW202D, and beyond the property boundary towards the north. The plume area is approximately 5 acres. The vertical extent is approximately 130 feet below the ground surface (on average) or approximately 105 feet below the water table.

The estimate of contaminant mass within the plume is based on the following assumptions:

- Target treatment area = 217,000 sf
- Average thickness of plume = 105 ft
- Porosity = 0.05 (fractured rock)
- Average TCE concentration = 1,000 µg/L

- Average DCE concentration = 150 μg/L
- Average VC concentration = 2 μg/L

This translates into an approximate volume of 8.5 million gallons of contaminated groundwater containing approximately 85 lbs. of chlorinated VOCs of which 71 lbs. are TCE.

These mass estimates can be considered order-of-magnitude estimates only and are based on best available information. In addition to the simplifying assumptions, subsurface heterogeneities render the sampling data, upon which these estimates are based, only partially effective for use in quantifying the mass of contamination present in the subsurface.

4.3 Identification and Screening of Technologies

A broad list of remedial technologies were identified for each general response action which, when implemented separately or combined with other actions have the potential to meet the RAOs for Site 49. These technologies were then subject to a preliminary and secondary screening. The screening process is presented in Table 4-1. The preliminary screen focussed on the question of whether the technology was appropriate for the site contaminants or the site physical characteristics. The secondary screening considered the effectiveness, implementability, and cost of the technology relative to other technologies within the same general response action.

The contaminants of concern and the volume and type of media to be treated are summarized in section 4.2. A detailed discussion of the nature and extent of contamination at the site is provided in Section 2.2.

Technologies that were found to be suitable were carried through to the remedial alternative development process and were considered for inclusion in a remedial alternative. Table 4-1 identifies the technologies that passed the screening.

4.4 Alternative Development and Analysis Process

Six alternatives were developed for the groundwater at Site 49.

4.4.1 Evaluation Criteria

Each alternative was evaluated with respect to the site RAOs and ability of the alternative to mitigate threats to human health and the environment posed by contamination. The NCP requires that the remedial alternatives be evaluated using the nine criteria listed below, as defined in the NCP. The first seven criteria are addressed in this Feasibility Study (FS). The last two will be addressed in the ROD after the state and public have the opportunity to comment. The nine NCP criteria comprise three categories: (1) threshold criteria; (2)balancing criteria; and (3) modifying criteria. Threshold criteria are binary criteria; an alternative meets or does not meet the criterion (note that certain ARARs may be waived). Balancing criteria are used to compare the relative merits of each alternative, both singly and collectively. Modifying criteria are used to assess the acceptability of an alternative to other stakeholders. The nine criteria are:

Threshold criteria

- Protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirements (ARARs)

Balancing criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Short-term effectiveness
- Implementability
- Cost

Modifying criteria

- State acceptance
- Community acceptance

The following paragraphs define and detail each of the nine criteria.

4.4.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion is an assessment of whether each alternative achieves and maintains adequate protection of human health and the environment. The overall appraisal of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, and short-term effectiveness. Another consideration is the CERCLA statutory preference treatment.

4.4.1.2 Compliance with ARARs

This evaluation criterion is used to determine whether an alternative would meet all federal, state, and local ARARs. When an ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA would be discussed.

4.4.1.3 Long-Term Effectiveness and Permanence

Under this criterion the results of a remedial alternative are evaluated in terms of the risk remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the actions or controls that may be required to manage the risk posed by treatment residuals or untreated wastes. Factors to be considered and addressed are magnitude of residual risk, adequacy of controls, and reliability of controls. Magnitude of residual risk is the assessment of the risk remaining from untreated waste or treatment residuals after remediation. Adequacy and reliability of controls is the evaluation of the controls that can be used to manage treatment residuals or untreated wastes that remain at the facility. The evaluation may include an assessment of institutional controls to determine whether they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels.

4.4.1.4 Reduction of Toxicity, Mobility, and Volume

This evaluation criterion addresses the statutory preference for selecting remedial actions that, as their principal element, use technologies that permanently remediate and significantly reduce the toxicity, mobility, or volume of the hazardous substances. This preference is satisfied when treatment is used to reduce the principal threats at a site

through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction of contaminant mobility, or reduction of total volume of contaminated media. When evaluating this criterion, an assessment is made as to whether remediation is used to reduce principal threats, including the extent to which toxicity, mobility, or volume are reduced either separately or in combination with one another. Factors to be considered include:

- Remediation processes employed by the remedy;
- Amount of hazardous materials that would be remediated;
- Degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction;
- Degree to which the remediation would be irreversible;
- Type and quantity of treatment residuals that would remain following remediation; and
- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

4.4.1.5 Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until RAOs are met. Alternatives would be evaluated with respect to their effects on human health and the environment during implementation of the remedial action. The following factors would be addressed for each alternative:

- Protection of the community during remedial actions
- Protection of workers during remedial actions
- Environmental impacts during remedial actions
- Time until RAOs are achieved

4.4.1.6 Implementability

The implementability criterion addresses the technical and administrative feasibility of executing a given alternative and the availability of various services and materials required during its implementation. Technical feasibility includes construction, operation, reliability of technology, ease of undertaking additional remedial action, and monitoring. Administrative feasibility refers to the activities needed to coordinate with other offices and agencies (e.g., local permits). Availability of services and materials includes availability of adequate off-facility treatment, storage capacity, and disposal services; necessary equipment and specialists; services and materials; and prospective technologies.

4.4.1.7 Cost

For the cost analysis of alternatives, the expenditures required to complete each remedial action are estimated in terms of both capital and annual operation and maintenance (O&M) costs. Using these values with an estimate of time to meet RAOs, a present-worth cost estimate for each alternative then can be made for comparison.

Capital costs consist of direct and indirect costs. Direct costs include the cost of construction, equipment, land and site development, treatment, transportation, and disposal. Indirect costs include engineering expenses, license or permit costs, and contingency allowances. Reasonable allowances are typically provided for sitework, mechanical, instrumentation and controls, electrical, and miscellaneous equipment as a percentage of capital costs based on engineering experience. The typical range of values for these allowances varies depending upon the size and complexity of the project, but generally ranges from 5 to 15 percent of the subtotal capital cost.

Annual O&M costs are the post-construction costs required to ensure the continued effectiveness of the remedial action. Components of annual O&M cost include the cost of operating labor, maintenance materials and labor, auxiliary materials and energy, residue disposal, purchased services, administration, maintenance reserve and contingency funds, rehabilitation, monitoring, and periodic site reviews.

Appropriate allowances were provided for Project Management, Remedial Design/Technical Support, Construction Management, Subcontractor General Requirements, and Contingency, based on guidance provided by the EPA and USACE (USEPA and USACE, 2000) and engineering experience. Subcontractor General Requirements includes items such as cost for bonds, insurance, and permits.

Expenditures that occur in the future are analyzed using present worth, which discounts all future costs to a common base year. Present-worth analysis allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the life of the remedial project. Assumptions associated with the present-worth calculations include a discount rate of 4.2 percent (OMB Circular No. A-94, Appendix C, Revised February 2003), cost estimates in the planning years in constant dollars, and a period of performance that would vary depending on the activity, but would not exceed 30 years.

In accordance with USEPA guidance, cost estimates in feasibility studies are intended to represent a range of +50 percent to -30 percent of the final cost. The alternative cost estimates are in 2004 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project will depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables. Most of these factors are not expected to affect the relative cost differences between alternatives.

4.4.1.8 State Acceptance

This assessment evaluates the technical and administrative issues and concerns that the State of Maryland may have regarding each of the alternatives. This criterion is not discussed in this report, but would be addressed in the ROD.

4.4.1.9 Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with state acceptance, this criterion is not discussed in this report, but would be addressed in the ROD.

4.4.2 Qualitative Comparative Screening Process

The remedial alternatives were then compared to each other as they address the seven criteria. A numeric value ranging from 0 to 5 was assigned to each alternative depending on how it meets a particular evaluation criteria relative to other alternatives. The values assigned for each criteria were added to arrive at a final total score. These scores are not used as the sole means of selecting the proposed alternative, but rather are used as a means of comparing alternatives.

Table 4-1
Remedial Action Technology Screening Table for Groundwater
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

				Primary Screening			Secondary Screening			
General Response Action	Remedial Technology	Process Options	Description	Retain	Reject	Primary Screening Comments	Effectiveness	Implementability	Relative Cost	Secondary Screening Comments
No Action	None	N/A	No action provided.	X		Retained as baseline comparison.				Retained as baseline comparison
Institutional Control	Administrative Restrictions	Deed Restrictions and Notices	May also include restrictive covenant on deed for onsite property.	X		Although there are currently no groundwater uses onsite or offsite, a Land Use Control Remedial Design will be required for any remediation that will not meet the PRGs instantaneously.	Moderate to high. Can be effective in protecting human health given consistent implementation.	Moderate to High. Requires working with the local government to establish well prohibition within and adjacent to the plume. Legal aspects can require extended timeframe.	Very low.	Retained
Groundwater Containment	Physical Barriers	Slurry wall, sheet piling, vibrating barrier wall, etc.	Physical and/or chemical mechanism to create subsurface hydraulic barrier to prevent contaminated groundwater flow either horizontally or vertically.		X	Rejected because the objective of the remediation is to restore groundwater across the site				
	Hydraulic Barriers	Groundwater Extraction Wells and Trenches	A groundwater extraction/injection system that alters the natural hydraulic gradient to prevent contaminated groundwater flow either horizontally or vertically.		X	Rejected because the objective of the remediation is to restore groundwater across the site				
Groundwater Removal	Groundwater Extraction	Vertical Extraction Wells	Series of wells to extract contaminated groundwater.	X		Technically feasible. Requires little space for construction.	Moderate to high. Effective at hydraulic containment, but less effective for aquifer treatment. Likely to require a long timeframe to meet MCLs in aquifer.	Low. Easily implemented.	Low to moderate. Requires treatment system for discharge to surface water.	Retained to extract contaminated water while creating a hydraulic barrier to prevent lateral migration of plume. Can be utilized in deep aquifer zones.
		Collection Trenches	Perforated pipe in trenches backfilled with porous media to collect water.	X		Retained because of greater assurance of hydraulic containment.	Moderate to high. More effective than wells for hydraulic containment in areas of very low or variable permeability. Likely to require a long timeframe to meet MCLs in aquifer.	Low. Can be installed to depths of 50 feet or more with key trenching. Very difficult in areas of bedrock contamination.	Moderate. Requires treatment system for discharge to surface water.	Rejected. Difficult to implement in bedrock.
		Horizontal Wells	Directional drilling techniques are used to position wells horizontally, or at an angle, to reach contaminants that are not accessible by direct vertical drilling.	X		Retained because horizontal wells can be used to extract groundwater from areas of limited surficial access.	Moderate. Highly dependent upon the geology at the site and proper installation. If well is installed within the appropriate formation, than it can be more effective than vertical wells for hydraulic containment. Likely to require a long timeframe to meet MCLs in aquifer.	Low to high. Implementable at sites with shallow or deep groundwater in a permeable formation. Implement in areas of deep contamination in bedrock. Generally not feasible.	High. Costs for horizontal wells much greater on a unit cost basis. Step slopes may require construction lot platforms.	Rejected. Step hillside on east side of site 49 may provide access for horizontal wells, but access constraints reduce cost effectiveness.
		Skimmer Wells and Pumps	Mobile LNAPLs floating on top of the water table are extracted via pump. Mobile DNAPLs are extracted by pumps at the bottom of the well. Dual-pump systems may allow extraction of water and NAPLs.		X	Rejected because no NAPL was identified.				
Groundwater Treatment (In-situ)	Chemical	Chemical Oxidation	Oxidant such as hydrogen peroxide, permanganate, and ozone is injected, which chemically oxidizes organic contaminants to less harmful compounds such as CO_2 and H_2O.	X		Technically feasible	Moderate. Effective, but requires good contact between contaminant and reagent.	Moderate. Injection methodologies are improving, difficult to achieve good mixing in situ.	Moderate. Evolving technology, considered to have good potential for cost-effectiveness in proper situations. Oxidation may not be cost-effective on large volume dilute dissolved VOC plumes. Bench and pilot scale test would be required to determine appropriate chemical and dosage.	Retained. Effective technology in sites with elevated CVOC concentrations.
		Reactive Barrier	Treats groundwater plume as it passes through a permeable reactive zone. Reactive zone may be a combination of physical, chemical, and biological processes. May also include measures, such as low-permeability barriers, to channel groundwater towards treatment zone. Zero valent iron, for chemical reductive dechlorinatioon, is the most commonly applied reactive media.		X	Rejected because the objective of the remediation is to restore groundwater across the site				
		Iron Injection	Several innovative technologies exist for injecting micro or nano scale zero-valent iron particles in boreholes to treat VOCs and explosives. These include injecting iron in a nitrogen carrier gas (Ferox) and injecting it in an emulsion with vegetable oil (EZVI). Both approaches have been touted as being applicable to treating source area concentrations.	X		Can be effective in treating VOCs	Moderate to high. Theoretically effective in treating VOCs. No significant track record. May require implementation with pnuematic fracturing to be effective in rock.	Low. Surface plugging and decreased permeability may be encountered. Depth of contamination would warrant injection points to 100 ft bgs.	High. Permanent injection wells are required. Application in rock would be enhanced with pnuematic fracturing which would drive up costs.	Reject.

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Table 4-1
Remedial Action Technology Screening Table for Groundwater
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

				Primary Screening			Secondary Screening			
General Response Action	Remedial Technology	Process Options	Description	Retain	Reject	Primary Screening Comments	Effectiveness	Implementability	Relative Cost	Secondary Screening Comments
Groundwater Treatment (In-situ) Cont.	Physical Treatment	Air Sparging	Air injected into groundwater through a system of wells or horizontal perforated pipes to remove volatile compounds. May be combined with soil-vapor extraction to collect VOCs in the vadose zone.		X	Rejected because of depth of contaminant plume and nature of the medium.				
		Hydraulic Fracturing	High-pressure injection of fluids, followed by granular slurry, to create porous subsurface fracture patterns that enhance vapor or fluid extraction technologies. The fracturing extends and enlarges existing fissures and introduces new fractures, primarily in the horizontal direction.	X		Retained to augment in-situ treatment technologies, if necessary, especially to address contamination in the bedrock.	Low to moderate. Fracturing is an enhancement technology designed to increase the efficiency of other in situ technologies (i.e., fluid injection) in low permeability soil/rock conditions. Its effectiveness is highly dependent upon bedrock conditions.	Moderate. Fracturing is widely used in the petroleum and water-well construction industries. While commercially available, it is an innovative method for use in hazardous waste remediation. Extreme care must be taken around existing structures and subsurface utilities.	Low. Cost may be higher for longer remediation programs that require refracturing.	Retained to augment in-situ treatment technologies such as chemical oxidation and in-situ bio, to achieve better distribution of chemicals.
		Pneumatic Fracturing	High-pressure injection of air to create self-propped porous subsurface fracture patterns that enhance vapor and fluid extraction/injection technologies. The fracturing extends and enlarges existing fissures and introduces new fractures, primarily in the horizontal direction.	X		Retained to augment in-situ treatment technologies, if necessary, especially to address contamination in the bedrock.	Low to moderate. Fracturing is an enhancement technology designed to increase the efficiency of other in situ technologies (i.e., fluid injection) in difficult soil/rock conditions. Its effectiveness is highly dependent upon soil/bedrock conditions.	Moderate. Fracturing is widely used in the petroleum and water-well construction industries. While commercially available, it is an innovative method for use in hazardous waste remediation. Extreme care must be taken around existing structures and subsurface utilities.	Moderate. The approximate cost range for pneumatic fracturing is $9 to $13 per metric ton ($8 to $12 per ton). Costs may be higher for longer remediation programs that require refracturing.	Retained to augment in-situ treatment technologies such as chemical oxidation and in-situ bio, to achieve better distribution of chemicals.
		Enhanced Reductive Dechlorination (anaerobic bioremediation)	Use of an organic substrate such as hydrogen releasing compound, vegetable oil, or molasses to promote chlorinated compound degradation via dechlorination mechanism where the chlorine molecular is replaced by hydrogen. Also involves the use of engineered microorganisms to promote biodegradation.	X		Effective in expediting remediation of chlorinated VOCs over natural attenuation.	Low to moderate. Although still an emerging technology, it has been proven to be effective at reducing low to moderate levels of CVOCs to below MCLs.	Moderate to high. Easily implemented, but challenging to obtain good distribution of amendment into the contaminated aquifer.	Moderate to high. It is typically considered a cost-effective alternative, but depends greatly upon the amount of substrate required.	Retained .
		Monitored Natural Attenuation	Natural attenuation processes such as dilution, biotransformation, volatilization, adsorption, and dispersion coupled with regular monitoring for chemicals of concern as well as a range of indicators of biodegradation.	X		Natural attenuation is occurring in the groundwater and may be sufficient to continue to remediate the plume and prevent risks from occurring.	Low to moderate. Effective for sites where there are no unacceptable current risks and future risks are minimal.	High. Easily implemented, only monitoring would be required to monitor the progress.	Low	Retained.
Groundwater Treatment (Ex-situ)	Chemical Treatment	Chemical Oxidation	Contaminated water mixed with an oxidant, such as hydrogen peroxide, ozone, UV light, etc., to destroy the organic compounds.	X		Retained for VOC treatment	Unknown effectiveness; stated effective in the literature.	Implementable	High	Rejected due to high cost and unknown effectiveness
		Air Stripping	Large volumes of air mixed with water in a low-profile tray system or packed column to promote transfer of VOCs to air.	X		Well-established technology and highly reliable for removing VOCs.	High. Generally achieves over 95% removal of VOCs.	Requires permitting for disharge.	Moderate.	Retained for its proven effectiveness in VOC removal .
		Carbon Adsorption	Contaminants adsorbed onto activated carbon by passing contaminated water or air through a granular activated carbon unit.	X		Effective and well established at removing organic compounds with the exception of vinyl chloride.	High to moderate. Well proven technology with high removal efficiency.The duration of GAC is usually short-term. Vinyl chloride is poorly adsorbed on carbon.	Requires permitting for disharge.	Moderate to high. There are costs to regenerate and replace GAC.	Retained for its proven effectiveness in VOC removal .
Disposal	Discharge of Treated Groundwater	Industrial Wastewater Treatment System	Treated groundwater discharged to industrial wastewater treatement system.		X	There is no industrial wastewater treatment plant on base.				
		Publicly Owned Treatment Works (POTW)	Treated groundwater discharged into municipal sanitary sewer system.		X	Rejected because of POTW resistance to accepting water and high cost of sewer user charge.				
		Surface Water	Treated groundwater discharged into a nearby stream or river.	X		Existing pump and treat systems in the base are discharging to Paint Branch.	Discharge criteria protective of human health and aquatic life can consistently be met by the treatment system.	Requires an NPDES permit.	Low	Retained. Is currently the preferred method of discharge for sites located near the streams.

Note:
Technologies in darker areas are rejected in primary or secondary screening.

SECTION 5

Site 49 Groundwater Alternatives Analysis

As discussed in Section 2, a plume of contaminated groundwater originates in the vicinity of Building 427 and extends approximately 400 ft downgradient to Paint Branch. The contaminant concentrations are at a level that would require action in order to meet PRGs. No contamination has been identified in the unsaturated zone soil. This section presents a an analysis of remedial alternatives for the groundwater within the plume at Site 49.

5.1 Remedial Alternatives for Groundwater

Several remedial alternatives were developed to address the COCs in groundwater at Site 49. These alternatives were developed on the basis of the results of the screening of remedial technologies presented in Section 4. The alternatives identified for detailed evaluation include the following:

- Alternative 1—No Action
- Alternative 2—Institutional Controls with Long-Term Monitoring
- Alternative 3— Groundwater Extraction and Treatment (P&T)
  Alternative 3A- Groundwater Extraction and Treatment (P&T) with Fracturing
- Alternative 4— In situ Chemical Oxidation (ISCO) with MNA
  Alternative 4A- In situ Chemical Oxidation (ISCO) with MNA with Fracturing
- Alternative 5— Enhanced In situ Anaerobic Bioremediation with Fracturing

A brief description of each alternative is presented in Table 5-1. Detailed descriptions and analyses are provided in Section 5.3 and evaluations against the seven CERCLA criteria (the two threshold criteria and the five primary balancing criteria) are provided in Table 5-2. Cost estimates for each alternative are provided in Appendix C.

5.2 Detailed Description and Evaluation of Remedial Alternatives for Groundwater

5.2.1 Alternative 1—No Action

The no action alternative is required by the NCP and serves as the baseline alternative for comparison purposes. All other remedial action alternatives are judged against the no action alternative. Under this alternative, no controls or remedial technologies would be implemented. No additional monitoring would be performed. The no action alternative involves no effort to meet ARARs or PRGs and therefore, risk of potential future exposure to contaminated groundwater remain.

CERCLA (Section 121(c)), as amended by SARA (1986), requires that, even under the No-action alternative, the site be reviewed every 5 years since contamination in the

groundwater would remain onsite. Reporting costs are minimal because it is assumed that this will be a small part of a larger 5-year report that addresses other sites at White Oak. Estimated costs for this alternative are presented in Appendix C-1.

5.2.2 Alternative 2—Institutional Controls with Long-Term Monitoring

The primary components of this alternative are:

- The preparation and implementation of a Land Use Control Remedial Design
- Installation of additional monitoring wells to delineate extent of ICs
- Long-term monitoring of the groundwater

Under this alternative, a Land Use Control Remedial Design would be prepared, implemented, and enforced to prohibit installation of water supply wells into the contaminated aquifer. The goal would be to prevent the future use of the aquifer in areas where exposure to contaminants above drinking water standards might occur. Natural attenuation processes may reduce contaminant concentrations over time.

Offsite land overlying the contaminated groundwater plume could be purchased or restrictions against groundwater pumping could be implemented to eliminate the potential exposure pathway. Such conditions exist in the north portion of the Site 49 plume, on land owned by the Maryland/National Capital Parks and Planning Commission. The work required includes preparation, negotiation, and final implementation of the Land Use Control Remedial Design including legal and administrative activities with the federal, state and county governments to impart any deed restrictions. These could include placing a notation in the property development plan (or similar) indicating that groundwater use in the vicinity of this plume is prohibited. Future sale of this land would carry restrictions for groundwater use.

It is assumed that as many as four new bedrock monitoring wells would be needed to monitor the presence of contamination within the deeper groundwater formations to identify the horizontal extent to which the groundwater restrictions would apply.

Under this alternative, groundwater monitoring would be performed every 9 months to track contaminant concentrations within and migrating from the current plume. Monitoring will be required as long as contaminants are present above PRGs. It is anticipated that monitoring will be required for 30 years. This data will be used during the 5-year reviews to determine the effectiveness of the controls (i.e., do controls need to be expanded to include a greater area or can they be relaxed.) It was assumed that 5 wells would be sampled for VOCs.

Since contamination will remain on site, 5-year reviews will be required. Estimated costs for this alternative are presented in Appendix C-2.

5.2.3 Alternative 3—Groundwater Extraction and Treatment

Alternative 3 involves installation of a groundwater extraction system to achieve both hydraulic control of the plume and mass removal throughout the plume. It would include a combination of several response actions that were retained during the initial screening: groundwater removal followed by ex situ treatment to address the contaminants of concern. The primary components of this alternative are:

- Installation, testing and startup of groundwater extraction wells
- Construction of a groundwater conveyance and treatment system for extracted water
- Instrumentation and process control, to monitor and record flow rates and notify maintenance personnel of malfunction
- Discharging the treated water to Paint Branch under a National Pollutant Discharge Elimination System (NPDES)-permit
- Annual operation and maintenance to monitor performance and assure proper operation
- Groundwater monitoring for contaminant concentrations and hydraulic capture
- Preparation of annual technical memoranda and 5-year report
- Implementation of institutional controls until PRGs are met

Each primary component is discussed below. Costs are presented in Appendix C-3.

5.2.3.1 Installation of Groundwater Extraction Wells and Piezometers

Groundwater extraction serves two purposes: contaminant mass removal and hydraulic containment, by altering the natural hydraulic gradient to prevent contaminated groundwater flow (horizontally or vertically) from migrating outside the current area of the plume. The technology that was retained for consideration for this site during the initial screening process was vertical wells. A network of ten groundwater extraction wells is assumed to be necessary to achieve remedial goals (Figure 5-1).

In addition, approximately five piezometers would also be installed to monitor water levels around the extraction wells and determine if the necessary capture zones were being established. It is assumed that these piezometers would be constructed identical to 2-inch monitoring wells.

A pre-design aquifer test is recommended for Site 49 to ensure that groundwater can be extracted from the bedrock at a reasonable rate. The test would comprise installing an extraction well and several piezometers in an area with significant levels of contamination and performing and evaluating a pumping test. For cost estimating purposes, a lump sum cost for a predesign pumping test was included.

5.2.3.2 Groundwater Treatment System

Given the uncertainties associated with the fractured bedrock flow system and the low permeabilities, it is difficult to predict the pumping system's performance. Extracted groundwater will be directed to a centralized treatment system consisting of a filter, equalization tank, liquid-phase granular activated carbon (LGAC) system with gravity drain to Paint Branch.

LGAC was selected as the preferred technology for groundwater treatment of the COCs due to its low maintenance and relatively good treatment efficiency. Appendix C-3 contains calculations supporting the selection of LGAC. It was assumed that the water would be treated in continuous flow. It was conservatively assumed that approximately 3,800 lb. of

LGAC would be consumed annually. This is based on as assumed adsorption rate of 2.8 percent by weight, average influent flow rate of 10 gpm, and an average influent total chlorinated VOC concentration of 1,150 µg/L.

The treatment system would be equipped with instrumentation to record and totalize flow rates and to shut down the system and notify maintenance personnel in the event of malfunction.

5.2.3.3 Discharge of Treated Water

The treated water would be discharged by gravity flow to Paint Branch, under a NPDES-permit. Discharge concentrations would have to meet the State of Maryland surface water discharge requirements.

5.2.3.4 Annual O&M and Groundwater Monitoring

The time estimated to achieve PRGs in the plume via groundwater extraction and treatment is difficult to determine and can range from 10 years to higher than 30 depending on the aquifer's behavior under pumping and the amount of adsorbed-phase contaminant in the rock matrix. An estimate of 10 years was used for the purposes of this FS; however, the model assumes no residual- or adsorbed-phase mass remains as a source.

During this 10-year period, annual O&M and monitoring would be performed. In addition to routine mechanical system maintenance and checks, O&M would include sampling the discharge from each well quarterly and LGAC influent and effluent monthly, and collecting water levels in the surrounding wells and piezometers monthly.

Groundwater monitoring would include collecting groundwater samples from a network of an estimated eight wells quarterly for 2 years and then semiannually for the duration of the remediation (estimated at 10 years). All samples would be analyzed for VOCs and some attenuation parameters.

5.2.3.5 Reporting

A 5-year report would be prepared that documents the effectiveness of the treatment system and meets the requirements of CERCLA. Technical memoranda would be prepared on a quarterly basis during the first 2 years and semiannually thereafter to report treatment performance.

5.2.3.6 Institutional Controls

Institutional controls to prevent groundwater exposure from the site would be the same as included in Alternative 2. These would remain in effect until groundwater PRGs are met and risks to groundwater are shown to be reduced to acceptable levels.

5.2.3.7 Uncertainties and Assumptions

The time to remediation and subsequent costs are based on the assumption that only very little or no residual contamination remains adsorbed to the soil/rock that will continue to act as a source of contamination. The validity of this assumption and definition of the remediation timeframe is questionable and has a large effect on the alternative cost.

Groundwater flow through a formation composed of unconsolidated sediment can be well characterized in terms of direction and magnitude at the macro-level as well as smaller scales. In addition, pumping tests can be conducted to determine the expected pumping rate and capture zone of a well, which can then be applied throughout the formation with relative accuracy. However, the fractured bedrock flow system at Site 49 is not so easily characterized. At the largest scale, it is known that groundwater flows from west to east and discharges to Paint Branch. Beyond this, not much is known about flow paths. Pumping tests can be conducted to try to determine capture zones, but the data from one well is not necessarily applicable to a second well that may be only tens of feet away because it may intercept different water-bearing fractures. Because of this, there is considerable uncertainty regarding the effectiveness of the number and location of the extraction wells assumed under this alternative.

5.2.4 Alternative 3-A—Groundwater Extraction and Treatment with Fracturing

In order to enhance the effectiveness of the extraction system, the existing fractures in the bedrock will be expanded using pneumatic fracturing techniques. Pneumatic fracturing would be conducted to create better flow through the existing fractured network. This process involves injecting gas (nitrogen) at high pressures into packered intervals of an open borehole. Existing fractures are widened outward from the borehole to various distances depending on the site geology. Experience indicates that fractures are expanded up-to 30 feet from the borehole. This procedure will allow for a reduction in the time required to achieve PRGs due to the increase in hydraulic conductivity. It is assumed that the number of extraction wells will not decrease over Alternative 3 (see Figure 5-1). Estimated costs for this alternative are presented in Appendix C-3A

5.2.5 Alternative 4—In situ Chemical Oxidation

In this alternative, an oxidative reagent would be injected and distributed throughout the target remediation zone in the aquifer to promote oxidization of the contaminants to innocuous compounds such as carbon dioxide and water. The distribution of the reagent would be done using the injection well configuration presented in figure 5-2. The objective is to oxidize targeted contaminants to meet the PRGs.

The primary components of this alternative are:

- Installation of additional wells to define treatment area, collect oxidant demand samples, and to establish an optimum groundwater monitoring network
- Performance of a source area pilot test
- Installation of injection wells
- Injection of oxidizing reagent
- Groundwater monitoring of baseline and post-injection conditions
- Preparation of a remediation completion report and 5-year reviews
- Long-term monitoring of the plume until PRGs are met
- Implementation of institutional controls until PRGs are met

5.2.5.1 In situ Chemical Oxidation Technology Background and Reagents

ISCO is considered an accepted technology for the treatment of chlorinated VOCs. Typical oxidants include potassium and sodium permanganate, Fenton's Reagent (iron and hydrogen peroxide), hydrogen peroxide, sodium persulfate, and ozone. ISCO has been used to successfully treat TCE in groundwater to less than PRGs at multiple sites.

The major components of this alternative are discussed below. Costs are provided in Appendix C-4.

5.2.5.2 Installation of Additional Wells

A design phase investigation involving the installation of an estimated five monitoring wells would be conducted. The wells would be used to more precisely define the treatment area to avoid injecting oxidant in areas not needing treatment and to monitor current and future conditions in the vertical direction of groundwater flow. Samples would be collected from aquifer solids and groundwater for natural oxidant demand tests.

5.2.5.3 Performance of a Pilot Test

A detailed ISCO design and implementation work plan would be required as part of this alternative to identify the optimum oxidant based on literature review and geochemical conditions of the groundwater. The pilot test will be performed within the target treatment zone. COC degradation will be tracked with time at surrounding monitoring points to determine the parameters for full-scale application.

For cost estimating purposes, it was assumed that potassium permanganate ($KMnO_4$) would be appropriate. Potassium permanganate is an oxidant that is suitable for *in situ* application at this site because it is a strong oxidizer, and has been proven to oxidize TCE. Its rapid reaction kinetics are favorable for expedited site remediation. A lump sum cost was included in Alternative 4 for a pilot test.

5.2.5.4 Installation of Injection Wells, and Oxidizing Reagent Injection

A series of 25 4-inch diameter open boreholes would be installed in the contaminant plume to 130 feet bgs. The borings would be placed at 20-foot centers.

The potassium permanganate would be injected one well at a time in 3-foot packered intervals working from the bottom of the bore hole to the water table.

It is estimated that approximately 307 lbs. of potassium permanganate (at a 3-percent solution) would be required. Groundwater conditions are reported to return to background conditions within several days after injection.

Through pressurized injection, the oxidant/catalyst solution will be distributed throughout the contaminated groundwater to destroy dissolved and adsorbed chlorinated VOCs. It is estimated that approximately 20 days will be required to drill the injection wells and 20 working days will be required perform chemical injection into all the points.

Aside from the aforementioned well network, equipment requirements for ISCO would include fracturing and injection equipment.

The estimated design parameters are shown in Appendix C-4 and are summarized below:

- **Size of Target Remediation Zone -** two 200 foot-long treatment arrays
- **Radius of Influence -** 12 ft
- **Number of Injection Wells and Spacing –** 25 wells
- **$KMnO_4$ Dose Concentration—** approx. 100 gallons per boring
- **$KMnO_4$ Requirement -** 2,500 gallons of 3% solution

A typical industry practice is two chemical treatments, an initial injection followed by a polishing injection within a small fraction of the target treatment zone where monitoring well data shows COC rebound. A polishing injection would typically be required where conditions of solubility and chemical partitioning cause further desorption of the contaminant of concern. Since ISCO is a relatively rapid treatment process, it is assumed that the site can be treated to PRGs within 4 years using one or two injections in the first 2 years to obtain the necessary treatment. A range of costs are provided for this alternative with the low end corresponding to one injection and the upper end corresponding to two injections. The borings would be left in the ground after the first treatment so as to be used for the second treatment (and any subsequent treatment) until PRGs are met.

5.2.5.5 Baseline and Post-injection Monitoring

Effectiveness of the treatment will be monitored by collecting and analyzing groundwater samples from selected wells prior to and following the treatment. Sampling and analysis will be conducted to track disappearance of chlorinated VOCs and other chemicals for which PRGs have been established, to determine if additional applications are necessary.

Baseline sampling will be conducted prior to the injection of the oxidant, and then at 3 months, 6 months, 9 months, and 12 months after the initial injection to determine if a second injection is needed. After the final injection, additional sampling rounds would be performed semiannually until PRGs are met (assumed 4 years). Field sampling efforts to support the injection effort would include testing monitoring wells for the oxidant concentration using a field test kit and temperature, pH, DO, ORP, and specific conductance using standard field instrumentation. Laboratory samples will be collected from the monitoring wells and analyzed for chlorinated VOCs. The data would be evaluated to determine if additional oxidant injection is necessary. Field sampling efforts may be conducted more frequently for parameters such as oxidant concentration, DO, and ORP. The frequency of sampling events may be adjusted based on the results of the early sampling events.

5.2.5.6 Reporting

A closeout report would be generated to document the result of the ISCO treatment. Technical memoranda would also be generated to document the results of the out-year verification sampling rounds. 5-year reports would be generated if PRGs are not met within 5 years.

5.2.5.7 Institutional Controls

Institutional controls to prevent exposure to contaminated groundwater at the site would be the same as those included in Alternative 2. These would remain in effect until groundwater PRGs are met and risks to groundwater are shown to be reduced to acceptable levels.

5.2.5.8 Uncertainties and Assumptions

Appropriate design and implementation of a large ISCO system such as this typically benefits from a pilot test to determine performance. Factors such as natural oxidant demand of the groundwater will have a large effect on the oxidant dose requirement.

Similar to any in situ technology, its effectiveness will be limited by the subsurface heterogeneities present at the site and the ability to deliver the chemicals throughout the heterogeneous formation. Groundwater flow through a formation composed of unconsolidated sediment can be well characterized in terms of direction and magnitude at the macro-level as well as smaller scales. However, the fractured bedrock flow system at Site 49 is not so easily characterized. At the largest scale, it is known that groundwater flows from west to east and discharges to Paint Branch. Beyond this, not much is known about flow paths. The effectiveness and radius of distribution achieved at one injection boring will not be applicable to others, and it will not be possible to confirm or even estimate what radius has been achieved. The term "radius of distribution" is also misleading because distribution will be governed by the number and continuity of the fractures that are intercepted by an injection boring and will not be comparable from boring to boring, at different depths within the same boring, nor even in all directions at a particular depth in a boring. Because of these inherent properties of fractured rock it is highly unlikely that all fractures containing impacted groundwater will be treated under this alternative.

It has been observed at other sites that after the injection of the treatment fluid, some trace metals (iron, chromium, mercury, potassium, and manganese) are released from the formation into the groundwater. Elevated concentrations of manganese , potassium chromium, and mercury could be associated with the permanganate reagent. Elevated concentrations of metals like iron, occur through reactions by the treatment fluid with the aquifer matrix. Manganese dioxide usually precipitates on existing manganese or iron oxide coatings on fracture surfaces. Metals previously sorbed to these surfaces are displaced by the manganese dioxide surface precipitation reaction, releasing metals into the surrounding groundwater. Regardless of the mechanism that results in the elevated metals (iron, chromium, and mercury), their concentrations within the treatment area would remain above background concentrations only as long as permanganate persists. However, based on the small volume of chemical oxidant required to treat the TCE and overcome the demands of the natural carbon content of the formation, it is considered unlikely that an increase in soluble metals in the groundwater or Paint Branch surface water will be observed.

5.2.6 Alternative 4-A—In situ Chemical Oxidation with Fracturing

Pneumatic fracturing would be conducted to create better flow and chemical distribution through the existing fractured bedrock. This process involves injecting gas (nitrogen) at high pressures into packered intervals of an open borehole. Existing fractures are widened outward from the borehole to various distances depending on the site geology. Experience indicates that fractures are expected to be expanded up-to 30 feet from the borehole. It is assumed that the oxidizing reagent can then be injected out to at least a 20-foot radius. Under current conditions, 12-foot radius is expected.

By increasing the radius of distribution of the injection wells to 20 feet or more, the spacing between wells can be increased from 20 to 40 feet (allowing for overlap). This leads to a

reduction in the number of injection wells. It is expected that 13 injection wells will be sufficient to reach the same coverage if fracturing is used (Figure 5-3). Estimated costs for this alternative are presented in Appendix C-4A.

5.2.7 Alternative 5—Enhanced In situ Anaerobic Bioremediation with Fracturing

The primary components of this alternative are:

- Installation of additional wells to define treatment area and establish an optimum groundwater monitoring network
- Installation of injection wells, pneumatic fracturing, and injection of electron donor in the contaminated aquifer
- Groundwater monitoring of baseline and post-injection conditions
- Preparation of annual technical memoranda and 5-year report
- Implementation of institutional controls until PRGs are met

In this alternative, the naturally occurring process of biological decomposition of site contaminants under reducing conditions will be enhanced through injection and distribution of an electron donor or cosubstrate (food source) to increase the biodegradation rates of the contaminants by indigenous microorganisms. Reagents such as acetate, molasses, sodium lactate, or the proprietary agent Hydrogen Release Compound (HRC) by Regenesis are possible electron donor candidates for this type of application. Complete biodegradation would transform the contaminants to innocuous compounds such as carbon dioxide and water along the pathways described in Appendix C-5.

The reducing conditions enhanced by the addition of the electron donor may be important in several respects. It may enable bacteria to utilize the contaminants as an electron acceptor, or the hydrogen generated may be used by anaerobic bacteria, or as part of the direct chemical attack on the chemical constituent. Addition of electron donors to the environment to promote reducing conditions has also been used to remediate groundwater containing mixtures of contaminants.

Various types of electron donors may be used to enhance anaerobic bioremediation. Sodium lactate or HRC appears to be the most promising. HRC is used for costing purposes because its use and costs are better documented; lactate would be slightly less expensive. Numerous field studies have indicated that HRC may be used to promote reductive dechlorination of TCE.

The major components of this alternative are discussed below.

5.2.7.1 Installation of Additional Monitoring Wells

Five additional wells would be installed at Site 49 to assist with design, and provide an optimum monitoring network for enhanced bioremediation.

5.2.7.2 Performance of a Pilot Test

Evaluation of the selected amendment will be conducted during a field-scale pilot test. Distribution of the amendment and disappearance of TCE, as well as byproduct generation will be tracked with time at surrounding monitoring points to determine the feasibility of full-scale application. A lump sum cost was included in Alternative 5 for a pilot test.

5.2.7.3 Installation of Injection Wells, Pneumatic Fracturing and Hydrogen Releasing Compound Injection

HRC is a proprietary polylactate ester that, upon being deposited into the subsurface, slowly releases lactate. Lactate is metabolized by naturally occurring microorganisms, resulting in the creation of anaerobic aquifer conditions and the production of hydrogen. HRC is manufactured as a viscous gel that can be injected into the saturated zone for plume remediation.

An HRC slurry would be injected along a two 200-foot long treatment arrays as presented in Figure 5-3. Rock fracturing using high pressure nitrogen gas would be done at every well prior to HRC injection. Sampling and analysis would then be performed to ensure degradation of TCE, and to determine if an additional HRC application is necessary.

A series of 13 4-inch diameter open boreholes would be installed in the contaminant plume to 130 feet bgs. The borings would be placed at 40-foot centers. The bore holes would be 130 ft deep on average. The HRC will be heated for injection using a heated grout pump, to reduce the viscosity and allow improved migration of the HRC into the formation. The estimated HRC application configurations is summarized as follows:

- **Size of Target Remediation Zone -** 5 acres
- **Radius of Influence -** 20 ft
- **Number of Injection Wells and Spacing –** 13 wells;
- **Dose Rate in lbs/vertical ft of Injection—** 4 pounds/linear foot
- **Material Requirement –** 12,480 pounds

The duration of an enhanced in situ bioremediation is difficult to predict with any accuracy due to uncertainty about the total contaminant mass and site specific biodegradation rates that can be achieved. Based on previous studies and the site hydrogeological conditions, the remediation goals may be achieved in 4 years. For costing purposes, it is assumed that remediation to PRGs at Site 49 will take 5 to 6 years.

5.2.7.4 Baseline and Post-injection Monitoring

Bioremediation effectiveness will be monitored by collecting and analyzing groundwater samples from selected wells prior to, and throughout the duration of, the treatment. Sampling and analysis will be conducted to track the degradation of contaminants and byproduct generation, and the dispersion of the electron donor, to determine effectiveness and if additional applications are necessary.

The scope of each sampling event would be similar to that described in Alternative 4, with modifications to better understand the effectiveness of the electron donor injection. Laboratory analysis of the initial sampling rounds would involve analysis of additional

parameters, particularly metabolic organic acids, to track the degradation of the HRC material.

Baseline sampling will be conducted prior to the injection of the electron donor, quarterly for the next year, and then semiannually until PRGs are achieved. Field sampling efforts may be conducted more frequently for parameters such as metabolic acids, DO and ORP. The frequency of sampling events may be adjusted based on the results of the early sampling events. It is estimated that sampling will be performed at 8 wells during each round.

5.2.7.5 Reporting

A closeout report would be generated to document the result of the treatment. Technical memoranda would also be generated to document the results of the out-year verification sampling rounds. Five-year reports would be prepared as required by CERCLA to document the effectiveness of the remedy, if PRGs are not met within 5 years.

5.2.7.6 Institutional Controls

Institutional controls to prevent exposure to contaminated groundwater at the site would be the same as those included in Alternative 2. These would remain in effect until groundwater PRGs are met throughout the plume and risks to groundwater are shown to be reduced to acceptable levels.

5.2.7.7 Uncertainties and Assumption

The effectiveness of the various reagents that could be used to enhance in situ bioremediation in fractured rock have not been well documented to date. The rock matrix will present some inherent problems in trying to establish a viable colony of dechlorinating bacteria that can effectively treat the groundwater. The microbes grow on solid surfaces, and the large diameter void spaces in rock fractures (as compared to unconsolidated soil) would not allow the necessary contact time between the contaminants in the water and the microbes on the rock edges.

Similar to any in situ technology, its effectiveness will be limited by the subsurface heterogeneities present at the site and the ability to deliver the chemicals throughout the heterogeneous formation. Groundwater flow through a formation composed of unconsolidated sediment can be well characterized in terms of direction and magnitude at the macro-level as well as smaller scales. However, the fractured bedrock flow system at Site 49 is not so easily characterized. At the largest scale, it is known that groundwater flows from west to east and discharges to Paint Branch. Beyond this, not much is known about flow paths. The effectiveness and radius of distribution achieved at one injection boring will not be applicable to others, and it will not be possible to confirm or even estimate what radius has been achieved. The term "radius of distribution" is also misleading because distribution will be governed by the number and continuity of the fractures that are intercepted by an injection boring and will not be comparable from boring to boring, at different depths within the same boring, nor even in all directions at a particular depth in a boring. Because of these inherent properties of fractured rock it is highly unlikely that all fractures containing impacted groundwater will be treated under this alternative.

The areal extent and vertical distribution of the plume is not completely defined. Further groundwater sampling may lead to a modified area of treatment.

5.3 Comparative Analysis and Summary of Groundwater Alternatives

Table 5-3 provides a summary of the results of the detailed analysis and a numeric ranking of each criterion. A numeric value from 0 to 5 was assigned to each of the balancing criteria. Where significant uncertainty existed in the value of the ranking, a numeric range was provided to include the bracket of uncertainty. The values were added to arrive at a final total score for each alternative. Each criterion was assigned equal weight in the final score. The highest-ranking alternatives are as follows:

- Alternatives 4 and 4A – In situ Chemical Oxidation without/with Rock Fracturing
- Alternative 5 – Enhanced In situ Anaerobic Bioremediation with Rock Fracturing

Alternative 4, ISCO has a similar ranking to Alternative 4A, however the increase in effectiveness due to the rock fracturing compensates for the small increase in price. Alternatives 4 and 4A would be closer in price if a second injection is required.

Alternative 5, enhanced in situ bioremediation, had a score of 16, 4 points below the highest score. This alternative has a higher cost and its short term effectiveness is lower due to the fact that bioremediation is slower than ISCO and because there is considerable uncertainty with the ability to grow a viable and effective dechlorinating microbe colony in the rock matrix. However, the need for a second injection is less likely with Alternative 5 than it is under Alternative 4A.

Pump and treat alternatives 3 and 3A have scores of 13 to 15, and are not as effective in reducing the contamination at Site 49. Also the cost of implementing these alternatives is considerably higher due to the long-term operation and maintenance requirements for the treatment system.

Two alternatives do not comply with the threshold criteria. These alternatives are no-further action and institutional controls.

TABLE 5-1
Summary of Remediation Alternatives for Site 49 Groundwater
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Alt. ID	Alternative Name	Description and Objective
ALT-1	No Action	No remedy will be implemented. No additional monitoring will be performed. This alternative is included in part for baseline comparison. It is assumed that 5-year reviews will be conducted because contamination will be left in place
ALT-2	Institutional Controls and Monitored Natural Attenuation	A Land Use Control and Implementation Plan (LUCIP) will be prepared, implemented, and enforced to prohibit installation of production wells into the contaminated aquifer. This will ensure that there is no human exposure pathway to the contaminants left in-place. Remediation of the site will be left to the naturally occurring processes of biodegradation, adsorption, dilution, and dispersion. A network of monitoring wells will be observed for trends in contaminant concentrations and NA indicator parameters to support the effectiveness of MNA. The objective is to attenuate contaminants to PRGs in groundwater.
ALT-3	Groundwater Extraction and Treatment (P&T)	A groundwater pump and treat system will be installed to hydraulically control and remove dissolved contaminants from the groundwater in the TRZ. A network of pumping wells will discharge to a centralized treatment system comprised of a liquid-phase granular activated carbon (LGAC) system to remove the VOCs from the groundwater prior to discharge to a surface water body via an NPDES permit. The objective is to control migration of the dissolved contamination containing elevated contaminant concentrations and remediate the groundwater to PRGs.
ALT-3A	P&T with rock fracturing	The effectiveness of the pump and treat system will be enhanced by fracturing the rock.
ALT-4	Insitu Chemical Oxidation (ISCO)	A chemical such as potassium permanganate will be injected and distributed throughout the TRZ of groundwater contamination to oxidize the contaminants to innocuous compounds such as carbon dioxide and water. The objective is to oxidize contaminants to PRGs in groundwater.
ALT-4A	ISCO with rock fracturing	The effectiveness of the potassium permanganate will be enhanced by fracturing the rock.
ALT-5	Enhanced Reductive Dechlorination with rock fracturing	The naturally occurring process of reductive anaerobic degradation will be enhanced through injection and distribution of an electron donor and/or bioaugmentation to increase the biodegradation rates of the contaminants. The objective is biodegradation of the groundwater contaminants to PRGs. Institutional Controls as described in Alternative 2 will be put in place until RAOs are achieved by this technology. Rock fracturing will be used to improve the effectiveness of HRC.

TABLE 5-2
Detailed Analysis of Site 49 Groundwater Remediation Alternatives
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

	CERCLA Criteria	ALT-1 – No Action	ALT-2 – Institutional Controls with LTM	ALT-3 – Groundwater Extraction and Treatment	ALT-3A – Groundwater Extraction and treatment with Rock Fracturing
Threshold Criteria	Protection of Human Health and the Environment	NOT PROTECTIVE – This alternative does not provide any increased protection of human health and the environment. However there are no current risks and there are local ordinances that prevent the private use of groundwater for drinking water purposes.	PROTECTIVE – Site specific administrative measures will be used to prevent exposure to contaminated groundwater.	PROTECTIVE – Plume migration will be controlled and mass removed from the site via dissolution and pumping. There is significant uncertainties as to whether ARARs can be met, and the theoretical time to remediation which varies widely (10 year estimate).	PROTECTIVE – See ALT-3
	Compliance with ARARs	NOT COMPLIANT– Groundwater above MCLs will be left in-place.	NOT COMPLIANT – Contaminant concentrations exceeding MCLs will persist in the groundwater, however monitoring will be implemented assess contaminant trends over time.	COMPLIANT – P&T systems are effective at plume control, but LESS effective at returning groundwater to MCLs. Ex-situ granular activated carbon treatment systems have been proven highly reliable to treat the extracted groundwater to surface water discharge criteria over the long-term.	COMPLIANT – See ALT- 3
Balancing Criteria	Long-term Effectiveness and Permanence	NONE (0) – No measures will be taken to manage contamination left in-place. No site-specific restrictions would be put in place to prevent future exposure..	MODERATE (3) – Administrative measures can be effective, but only if long-term site access is managed diligently. Sale or reuse of the land will be affected by restrictions on use of groundwater.	MODERATE (3) – The P&T system would remove the contaminants from the subsurface yielding low residual risk levels. However, as with use of any in-situ treatment technology, small pockets of undetected contamination may remain after treatment and pose a small risk. Rebound effects are also common in pump and treat applications.	MODERATE (3-4) – Effectiveness and performance are improved over alternative 3.
	Reduction in Toxicity, Mobility, or Volume	NONE (0) – The site will be left as is and only the relatively slow natural processes of dilution, volatilization, biodegradation, adsorption, and dispersion will act to reduce the levels of groundwater contamination.	NONE (0) – The site will be left as is and only the relatively slow natural processes of dilution, volatilization, biodegradation, adsorption, and dispersion will act to reduce the levels of groundwater contamination.	MODERATE (3) – The P&T system will be very effective at controlling migration of the contaminants in the groundwater. It will, however, be slow at mass removal. Contaminants that are removed will be transferred to the carbon.	MODERATE (4) – Mass removal rates are increased compared to alternative 3.
	Short-term Effectiveness	NONE (0) – no remediation activity, however the remediation timeframe is estimated at over 30 years depending on NA processes' effectiveness.	LOW to MODERATE (2) - There is no increased risk during implementation however the remediation timeframe is estimated to be grater than 30 depending on the NA processes' effectiveness.	MODERATE (3) – There is a relatively long remediation time frame, between 10 and 30 years depending on system performance. Since the P&T system removes mass through dissolution only, it requires an extended remediation timeframe if NAPL or significant adsorbed phase is present. The ability of the P&T system to meet MCLs in a reasonable timeframe is uncertain. It will depend upon the presence of residual-NAPL stringers that will act as long-term sources of contamination. Risks to workers and the community during construction are minimal since it involves well, piping, and equipment installation only. P&T will not adversely affect downgradient attenuation of the dissolved contaminant plume.	MODERATE (3-4) – Since system performance is improved, six years is more achievable compared to alternative 3.
	Implementability	HIGH (5) – Nothing to implement.	HIGH (5) - While this alternative is highly feasible on a technical basis, it may present administrative issues if controls are to be in place in perpetuity.	MODERATE (3) – A National Pollutant Discharge Elimination System (NPDES) permit will be required to discharge treated water to a nearby surface water stream. The facility already holds NPDES permit for an existing P&T system, therefore, this is not expected to be difficult to obtain. P&T system components are all readily accessible.	MODERATE (3) – See alternative 3.
	Cost *	LOW (5) - $ 17,000 present worth cost - $ 0.00 capital cost - $ 5,500 Five-Year Review - $ 0.00 post-closure cost	LOW to MODERATE (4) - $ 312,000 present worth cost - $ 65,000 capital cost - $ 13,000 annual O&M cost	HIGH (1) - $ 1,506,000 present worth cost - $ 717,000 capital cost - $ 83,000 annual O&M - $ 76,000 post-closure cost	HIGH (0) - $ 1,716,000 present worth cost - $ 1,126,000 capital cost - $ 89,000 annual O&M - $ 76,000 post-closure cost

* The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2003 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

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TABLE 5-2 (CONTINUED)
Detailed Analysis of Site Site 49 Groundwater Remediation Alternatives
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

	CERCLA Criteria	ALT-4 – In- Situ Chemical Oxidation	ALT-4 A– In- Situ Chemical Oxidation with Rock Fracturing	ALT-5 – Enhanced Reductive Dechlorination with Rock Fracturing
Threshold Criteria	Protection of Human Health and the Environment	PROTECTIVE – Human health and the environment will be protected through permanent insitu destruction of the contamination. ICs will be used to control exposure to contamination during implementation of the remedy.	PROTECTIVE – See Alternative 4.	PROTECTIVE – Human health and the environment will be protected through treatment of the contamination. Groundwater monitoring will be performed to track the plume during treatment. ICs will be used to control exposure to contamination during implementation of the remedy. While there a significant uncertainties as to whether ARARs can be met, the theoretical time to remediation is moderately fast. A pilot test would be warranted.
	Compliance with ARARs	COMPLIANT – Theoretically, ISCO should be able to treat the TCE in groundwater to MCLs. However, there are few site case studies where MCLs have been achieved.	COMPLIANT – Oxidant delivery problems should be solved with pneumatic fracturing.	COMPLIANT – ERD is primarily effective at treating dissolved contamination and will treat residual NAPL. The ability of ERD to meet ARARs (i.e., MCLs) will depend on the ability to deliver the electron donor to the aquifer effectively through the rock formation. If residual NAPL is present, then ERD alone will likely not meet MCLs in a reasonable timeframe.
Balancing Criteria	Long-term Effectiveness and Permanence	MODERATE TO HIGH(4) – Contaminants are destroyed in place through permanent, rapid, irreversible reactions.	MODERATE TO HIGH(4) – See alternative 4.	MODERATE to HIGH (4) - The mechanisms of ERD will act to convert the contaminants to harmless by-products. Therefore, assuming MCLs are met and there are no rebound effects the residual risk level will be low. However, as with use of any in-situ treatment technology, small pockets of contamination may remain after treatment and pose a small risk. Use of the land will be unrestricted after treatment.
	Reduction in Toxicity, Mobility, or Volume	HIGH (5) – TCE and other alkenes will be destroyed insitu through chemical oxidation to harmless by-products.	HIGH (5) – See alternative 4	MODERATE to HIGH (4) – The effect of ERD on reduction of TCE is similar to the Alternative 2, however the enhancement of the biological process would likely make it more dominant than would otherwise be experienced in ALT 2. (more degradation and less dispersion and dilution). The expedited remediation timeframe, will lessen the risk for potential plume migration.
	Short-term Effectiveness	MODERATE TO HIGH (4) - Remediation timeframe is relatively fast if ISCO is effective: an estimated 1-2 years. ISCO is effective at treating residual TCE NAPL, if present, and therefore, can greatly reduce the remediation timeframe. Handling of hazardous chemicals presents a minimal risk to workers, but can be simply controlled using proper equipment and trained personnel. ISCO will likely negatively impact MNA by consuming electron donor and raising redox conditions, however rebound of favorable conditions would be expected in a relatively quick time frame (less than a year after ISCO treatment stops).	HIGH (4 -5)– Effectiveness and performance are improved by using rock fracturing.	MODERATE (3) – The remediation timeframe is estimated at 5 years for the Target Remediation Zone (TRZ), Significant uncertainties are present due to the low permeability of the rock. Chemical handling of the electron donor is not especially hazardous and can be performed using typical injection wells and pumps.
	Implementability	MODERATE (3) – A class V injection permit may be required for treatment using ISCO. Many states allow injection of ISCO chemicals, therefore, it is not expected to be a problem since the chemicals are for treatment and will be consumed as part of the process. ISCO chemicals are readily available. Successful implementation of this remedy requires delivery of reagent to and mixing with contaminants. Given the uncertainties associated with the fractured bedrock flow system and the low permeability of the bedrock, delivery efficiency is expected to be low, requiring dense injection well grids, uncertainty in time to achieve RAOs and high contingency costs. Pilot test would be warranted.	MODERATE (3) – Pneumatic fracturing is relatively innovative and would add complexity to alternative 4. Pneumatic fracturing will improve the delivery efficiency of the reagent. Pilot test would be warranted to measure the effectiveness of rock fracturing.	MODERATE (3) – A subsurface injection permit will be required for treatment using ERD. Many states allow injection of ERD chemicals, therefore, it is not expected to be a problem since the chemicals are generally harmless and will be consumed as part of the process. ERD chemicals are readily available. Successful implementation of this remedy requires delivery of reagent to and mixing with contaminants. Given the uncertainties associated with the fractured bedrock flow system and the low permeability of the bedrock, delivery efficiency is expected to be low, requiring dense injection well grids, uncertainty in time to achieve RAOs and high contingency costs.. Pilot test would be warranted.
	Cost	MODERATE (3) - $ 833,000 – 983,000 present worth cost (depending on second injection) - $ 590,000 capital cost - $ 21,000 annual O&M - $ 68,000 post-closure cost	MODERATE (3) - $ 1,175,000 – 1,275,000 present worth (Depending on second injection) - $ 938,000 capital cost - $ 22,000 annual O&M - $ 57,000 post-closure cost	MODERATE TO HIGH (2) - $ 1,341,000 present worth cost - $ 1,020,000 capital cost - $ 43,000 annual O&M cost - $ 51,000 post-closure cost

TABLE 5-3
Summary of Detailed Alternatives Analysis for Site 49 Groundwater
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

	CERCLA Criteria	Site 49 Groundwater Remediation Alternatives						
		ALT-1 NFA	ALT-2 IC	ALT-3 P&T	ALT-3A P&T + RF	ALT-4 ISCO	ALT-4A ISCO + RF	ALT-5 ERD
Threshold criteria	Protection of Human Health and the Environment	No	Yes	Yes	Yes	Yes	Yes	Yes
	Compliance with ARARs	No	No	Yes	Yes	Yes	Yes	Yes
Balancing criteria	Long-term Effectiveness and Permanence[1]	0	3	3	3-4	4	4	4
	Reduction in Toxicity, Mobility, or Volume[1]	0	0	3	4	5	5	4
	Short-term Effectiveness[1]	0	2	3	3-4	4	4-5	3
	Implementability[1]	5	5	3	3	3	3	3
	Cost [2]	5	4	1	0	3	3	2
	TOTAL SCORE	10	14	13	13-15	19	19-20	16

NOTES:
1 - Alternatives are ranked relative to each other in each category with zero (0) the lowest ranking and five (5) the highest ranking. A numeric range is provided in parenthesis where significant uncertainty exists.
2 - The ranking for cost is reversed, an assessed quality of Low Cost is equivalent to the highest score of five (5).
3 – Shaded columns failed one or both of the threshold criteria

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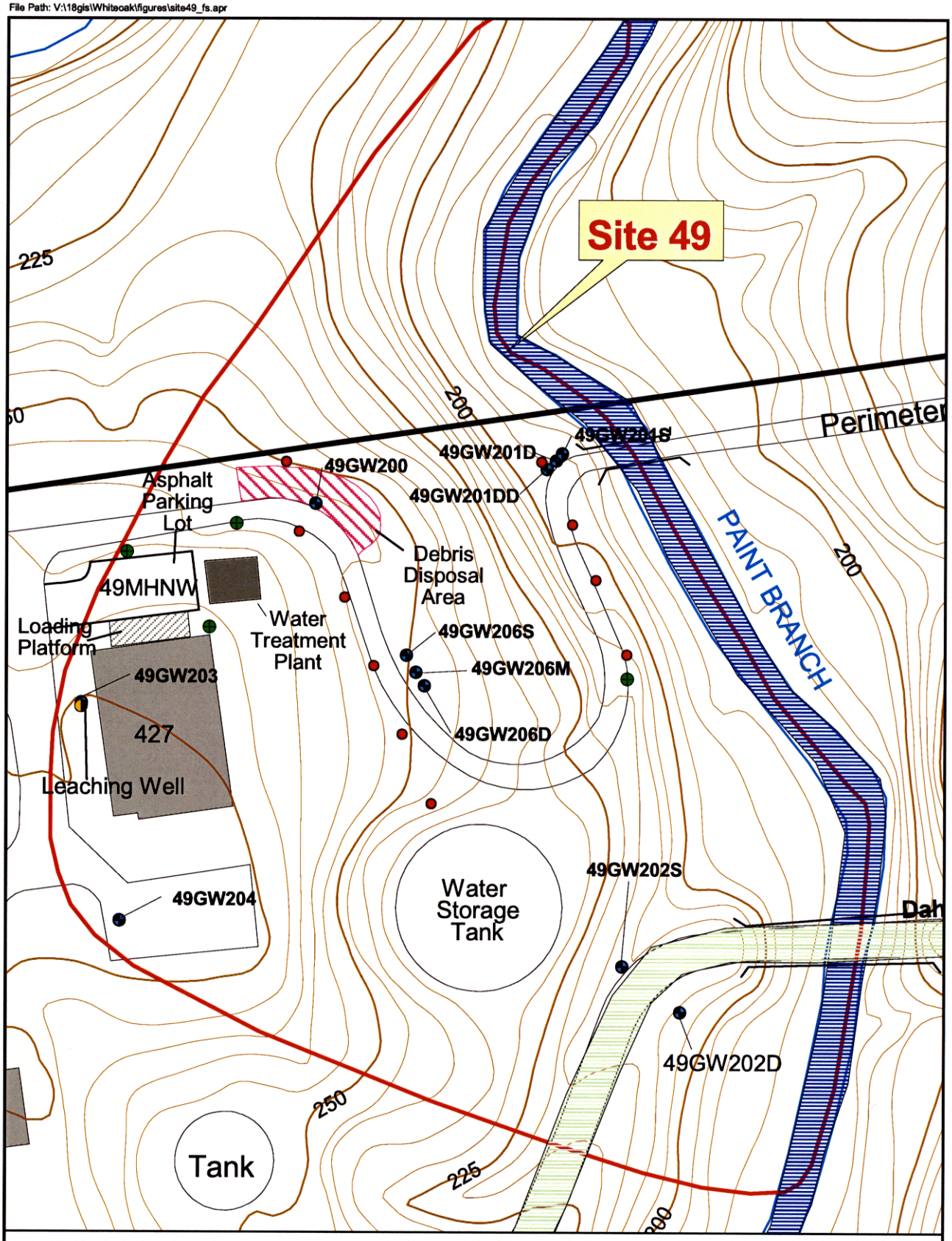

LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Monitoring Well Location
- Leaching Well Location
- Proposed Extraction well
- Topographic Contour Lines (feet above mean sea level, 5 foot intervals) '250'

N

0 100 200 Feet

Figure 5-1
Alternative 3 and 3A
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

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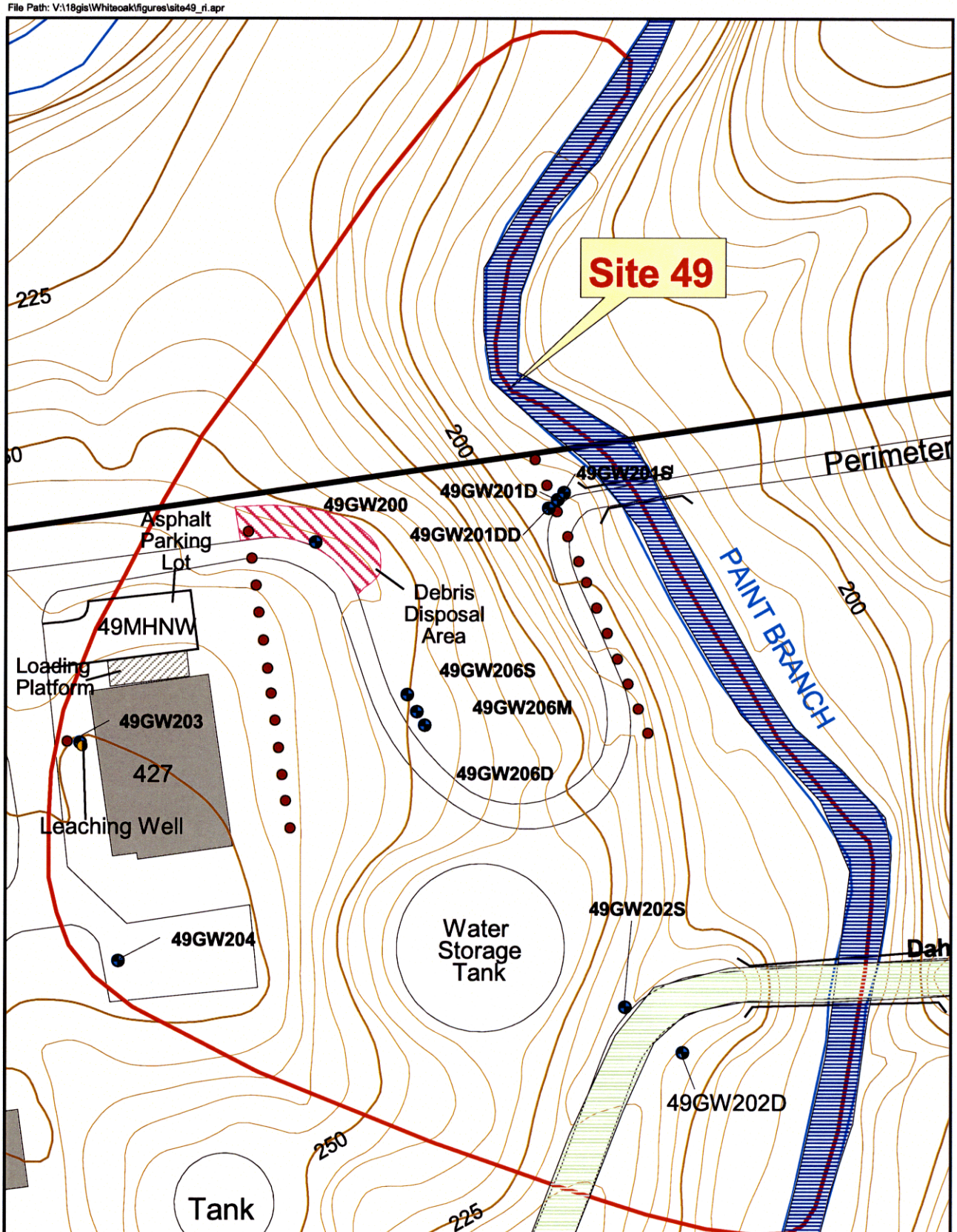

LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Monitoring Well Location
- Leaching Well Location
- Proposed injection well
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

0 100 200 Feet

Figure 5-2
Alternative 4
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

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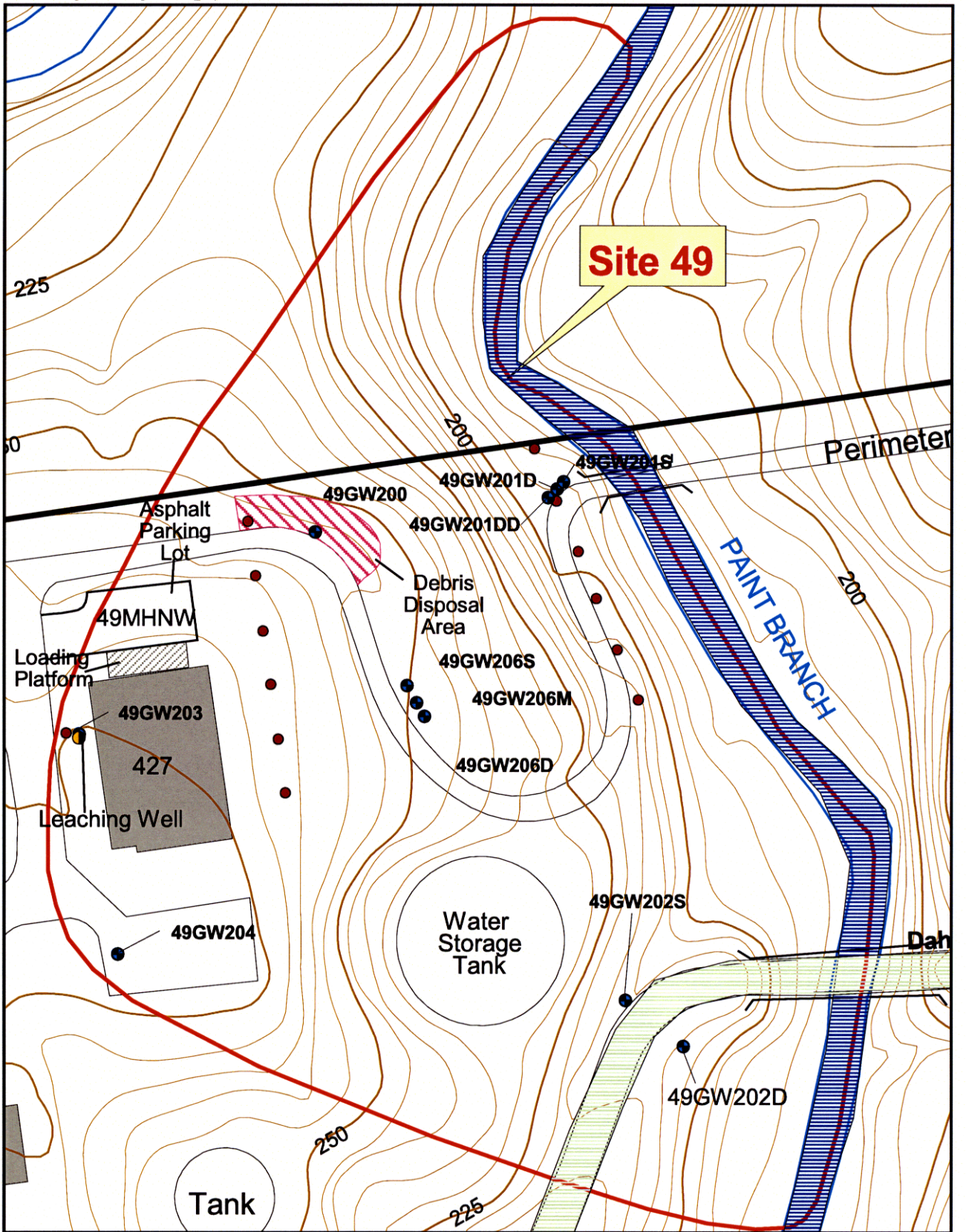

LEGEND

- Buildings (427=Building Number)
- Area Included in Site 49 RCRA Facility Investigation
- AEDC Fence Line
- Stream
- Base Boundary
- Monitoring Well Location
- Leaching Well Location
- Proposed injection well
- Topographic Contour Lines '250' (feet above mean sea level, 5 foot intervals)

N

0 100 200 Feet

Figure 5-3
Alternative 4A and 5
Site 49 Feasibility Study Report
NSWC - White Oak
Silver Spring, Maryland

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SECTION 6

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Appendix A
Groundwater Analytical Results

Table A-1
Detections In Groundwater Samples from Temporary Wells
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	400DP001		400DP002		400DP003		400DP004		49DP205		49DP206		49DP207		49DP209		49DP210	
Sample ID	400DP01-25		400DP002-82		400DP003-53		400DP004-48		049DP20562		049DP20636		049DP20763		049DP20946		049DP21032	
Sample Date	08/21/01		11/07/01		11/07/01		11/08/01		06/27/02		07/01/02		06/30/02		06/30/02		07/02/02	
Chemical Name																		
Volatile Organic Compounds (UG/L)																		
1,1-Dichloroethane	1	U	0.6	J	1	U	1	U	0.5	UJ	0.5	UJ	0.5	UJ	0.86	J	0.5	UJ
1,1-Dichloroethene	1	U	1		1	U	1	U	0.5	UJ	0.21	J	0.5	UJ	4.2	J	0.5	UJ
Acetone	1.22	J	5	U	20		6		1.9	B	13	B	4.1	B	5	UJ	2.9	B
Carbon disulfide	1	U	1	U	1	U	1	U	0.5	UJ	0.21	J	0.5	UJ	0.5	UJ	0.5	UJ
Chloroform	2.62		1	U	1	U	10		0.5	UJ	0.38	J	0.92	J	0.66	J	1.8	J
Chloromethane	1	U	1	U	1	U	1	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Toluene	1	U	1	U	1	U	1	U	0.5	UJ	0.63	J	0.45	J	0.66	J	0.34	J
Trichloroethene	1.6		1,000		5		1	U	17	J	17	J	67	J	1,600	J	44	J
Vinyl chloride	1	U	2		1	U	1	U	0.5	UJ	0.5	UJ	0.5	UJ	1.7	J	0.5	UJ
cis-1,2-Dichloroethene	1	U	200		1		1	U	4.3	J	6.3	J	16	J	360	J	6.9	J
trans-1,2-Dichloroethene	1	U	30	J	1	U	1	U	0.5	UJ	0.29	J	0.5	UJ	17	J	0.5	UJ

NA - Not analyzed
B - Blank contamination
J - Estimated
UJ - Undetected, estimated limit
U - Undetected

Table A-2
Detections In Groundwater Samples from Drive Points along Point Branch Bed
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49DP301		49DP302		49DP303		49DP304		49DP305		49DP306		49DP307		49DP308	
Sample ID	049DP30102		049DP30203		049DP30302		049DP30402		049DP30503		049DP30602		049DP30702		049DP30802	
Sample Date	11/20/02		11/20/02		11/20/02		11/20/02		11/22/02		11/22/02		11/22/02		11/22/02	
Depth of Sample (ft)	2		3		2		2		3		2		2		2	
Chemical Name																
Volatile Organic Compounds (UG/L)																
1,1-Dichloroethane	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.29	J	0.5	U
1,1-Dichloroethene	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Acetone	7.7	B	9.2	B	5	U	4	B	20	B	4.8	B	9.2	B	6.7	B
Carbon disulfide	0.5	U	0.5	U	0.99		0.5	U	1.1		1.2		0.5	U	0.38	J
Chloroform	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Chloromethane	0.5	U	0.5	U	0.5	U	0.5	U	0.5	J	0.5	U	0.32	J	0.5	U
Toluene	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Trichloroethene	0.5	U	0.5	U	0.5	U	0.75		0.37	J	1.3		1.1		1.2	
Vinyl chloride	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.79		0.5	U	0.5	U
cis-1,2-Dichloroethene	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	3.1		0.63		0.24	J
trans-1,2-Dichloroethene	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U

NA - Not analyzed
B - Blank contamination
J - Estimated
UJ - Undetected, estimated limit
U - Undetected

Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW200		49GW201D		49GW201DD	49GW201S		
Sample ID	049GW2000001	049GW2000002	049GW201D001	049GW201D002	049GW201DD001	049GW201S001	049GW201S002	049GW201S9902
Sample Date	08/02/02	10/10/02	08/02/02	10/10/02	02/10/03	08/02/02	10/10/02	10/10/02
Notes								Duplicate
Chemical Name								
Volatile Organic Compounds (UG/L)								
1,1,1-Trichloroethane	50 UJ	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
1,1-Dichloroethane	50 UJ	1.1	50 UJ	1.9 K	10 U	5 UJ	0.5 U	0.5 U
1,1-Dichloroethene	50 UJ	2.1	50 UJ	11 K	10 U	5 UJ	1.1	0.99
1,2-Dibromoethane	65 J	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
1,2-Dichloropropane	50 UJ	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
Acetone	500 R	250 R	610 R	1,300 R	13 B	260 R	59 R	49 B
Bromoform	50 UJ	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
Bromomethane	50 UJ	0.5 U	50 UJ	0.26 K	10 U	5 UJ	0.5 U	0.5 U
Chloroform	50 UJ	0.5 U	50 UJ	0.5 U	2.6 J	5 UJ	0.5 U	0.5 U
Cyclohexane	50 UJ	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
Methane	73 J	NA	61 J	NA	NA	27 J	NA	NA
Methyl-tert-butyl ether (MTBE)	50 UJ	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
Styrene	41 J	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
Tetrachloroethene	50 UJ	0.5 U	50 UJ	0.5 U	10 U	5 UJ	0.5 U	0.5 U
Toluene	50 UJ	0.5 U	50 UJ	0.5 U	1.8 J	5 UJ	0.5 U	0.5 U
Trichloroethene	690 J	760 J	3,300	4,400	6.5 J	730 J	380 L	310 J
Vinyl chloride	50 UJ	0.96	50 UJ	5.7 K	10 U	5 UJ	0.59	0.57
cis-1,2-Dichloroethene	130 J	140 J	600 J	1,100	1.3 J	150 J	100 L	110 J
trans-1,2-Dichloroethene	20 J	29	31 J	46 K	10 U	6.9 J	4.8	4.4
Semivolatile Organic Compounds (UG/L)								
Acenaphthene	5.3 U	NA	5.3 U	NA	NA	5.3 U	NA	NA
Dimethyl phthalate	7.1	NA	5.3 U	NA	NA	5.3 U	NA	NA
Phenanthrene	5.3 U	NA	5.3 U	NA	NA	5.3 U	NA	NA
Explosives (UG/L)								
No Detections								
Unfiltered Metals (UG/L)								
Aluminum	956	NA	783	NA	120 B	528	NA	NA
Arsenic	2.8 U	NA	2.8 U	NA	2.3 U	2.8 U	NA	NA
Barium	113 J	NA	102 J	NA	27.2 J	26.6 J	NA	NA

NA - Not analyzed
B - Blank contamination
J - Estimated
K - Biased high
L - Biased low

R - Unusable
U - Undetected
UJ - Undetected, estimated limit
UL - Undetected, limit biased low

Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW200		49GW201D		49GW201DD	49GW201S		
Sample ID	049GW2000001	049GW2000002	049GW201D001	049GW201D002	049GW201DD001	049GW201S001	049GW201S002	049GW201S9902
Sample Date	08/02/02	10/10/02	08/02/02	10/10/02	02/10/03	08/02/02	10/10/02	10/10/02
Notes								Duplicate
Beryllium	0.1 U	NA	0.14 J	NA	0.1 U	0.1 U	NA	NA
Cadmium	0.46 J	NA	0.21 J	NA	0.3 U	0.2 U	NA	NA
Calcium	54,700	NA	25,700	NA	8,510 K	17,000	NA	NA
Chromium	15.9	NA	15.5	NA	2.1 B	12.7	NA	NA
Cobalt	1.5 J	NA	0.71 J	NA	0.5 U	1.4 J	NA	NA
Copper	4.7 B	NA	3 B	NA	3.5 B	4.2 B	NA	NA
Iron	1,680	NA	4,250	NA	46.1 B	778	NA	NA
Lead	1.6 U	NA	1.6 U	NA	1 UL	1.6 U	NA	NA
Magnesium	14,600	NA	9,530	NA	4,150 J	7,150	NA	NA
Manganese	253	NA	426	NA	9.1 J	30.8	NA	NA
Nickel	18.1 J	NA	11.3 J	NA	1.5 B	10.8 J	NA	NA
Potassium	9,820	NA	5,020	NA	12,300	3,320 J	NA	NA
Selenium	2.5 U	NA	2.5 U	NA	1.6 U	3.1 B	NA	NA
Sodium	14,900	NA	11,300	NA	45,400 K	13,400	NA	NA
Vanadium	1.4 J	NA	0.93 J	NA	1.8 B	0.9 J	NA	NA
Zinc	17.9 J	NA	12.3 J	NA	4.4 B	17.3 J	NA	NA
Filtered Metals (UG/L)								
Aluminum	23.1 U	NA	23.1 U	NA	49 B	46 J	NA	NA
Barium	101 J	NA	91.7 J	NA	38.3 J	24.8 J	NA	NA
Beryllium	0.1 U	NA	0.1 U	NA	0.1 U	0.1 U	NA	NA
Cadmium	0.35 J	NA	0.24 J	NA	0.3 U	0.35 J	NA	NA
Calcium	54,300	NA	25,200	NA	14,100 K	17,000	NA	NA
Chromium	0.5 U	NA	0.5 U	NA	1.4 B	0.74 J	NA	NA
Cobalt	0.57 J	NA	0.68 J	NA	0.5 U	0.5 U	NA	NA
Copper	1.4 B	NA	0.7 U	NA	0.5 U	3.2 B	NA	NA
Iron	49 J	NA	2,670	NA	20.6 B	42.7 J	NA	NA
Lead	1.6 U	NA	1.6 U	NA	1 UL	1.6 U	NA	NA
Magnesium	13,800	NA	9,370	NA	4,430 J	6,960	NA	NA
Manganese	213	NA	408	NA	23.6	17.1	NA	NA
Nickel	2.8 J	NA	2.9 J	NA	2.6 B	4.3 J	NA	NA
Potassium	9,620	NA	4,840 J	NA	8,210	3,360 J	NA	NA
Selenium	2.5 U	NA	2.5 U	NA	1.6 U	4 B	NA	NA
Sodium	14,600	NA	11,800	NA	43,000 K	13,500	NA	NA
Vanadium	0.8 U	NA	0.8 U	NA	0.99 B	0.8 U	NA	NA

NA - Not analyzed
B - Blank contamination
J - Estimated
K - Biased high
L - Biase

R - Unusable
U - Undetected
UJ - Undetected, estimated limit
UL - Undetected, limit biased low

Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW200		49GW201D		49GW201DD	49GW201S		
Sample ID	049GW2000001	049GW2000002	049GW201D001	049GW201D002	049GW201DD001	049GW201S001	049GW201S002	049GW201S9902
Sample Date	08/02/02	10/10/02	08/02/02	10/10/02	02/10/03	08/02/02	10/10/02	10/10/02
Notes								Duplicate
Zinc	14 J	NA	8.6 J	NA	4.9 B	32.1	NA	NA
Wet Chemistry (MG/L)								
Alkalinity	150	NA	80	NA	140	39	NA	NA
Chloride	31	NA	35	NA	4.8	25	NA	NA
Nitrate	0.31 J	NA	0.19 J	NA	0.1 UL	0.57 J	NA	NA
Nitrogen	0.16	NA	0.1 U	NA	0.1 U	0.1 U	NA	NA
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	16	NA	3.8	NA	8.4	8.4	NA	NA

NA - Not analyzed
B - Blank contamination
J - Estimated
K - Biased high
L - Biased low

R - Unusable
U - Undetected
UJ - Undetected, estimated limit
UL - Undetected, limit biased low

Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW202D		49GW202S						49GW203				49GW204			
Sample ID	049GW202D001		049GW2020001		049GW2029901		049GW2020002		049GW2030001		049GW2030002		049GW2040001		049GW2040002	
Sample Date	02/11/03		08/01/02		08/01/02		10/09/02		08/02/02		10/09/02		08/01/02		10/09/02	
Notes					Duplicate											
Chemical Name																
Volatile Organic Compounds (UG/L)																
1,1,1-Trichloroethane	1.2	J	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
1,1-Dichloroethane	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
1,1-Dichloroethene	10	U	0.5	UJ	0.5	UJ	0.5	U	0.21	J	0.27	J	0.5	UJ	0.5	UJ
1,2-Dibromoethane	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
1,2-Dichloropropane	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.83	J
Acetone	10	U	2.3	J	2.7	J	1.3	B	5	R	5	R	3	J	5	R
Bromoform	10	U	0.5	UJ	0.23	J	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Bromomethane	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Chloroform	10	U	2.7	J	2.8	J	2.1	B	0.5	UJ	0.5	UJ	11	J	8.9	J
Cyclohexane	10	U	0.88	J	0.7	J	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Methane	NA		3.5	J	4.1	J	NA		100	J	NA		3.6	J	NA	
Methyl-tert-butyl ether (MTBE)	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Styrene	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Tetrachloroethene	10	U	0.48	J	0.45	J	0.5	U	0.5	UJ	0.23	B	0.5	UJ	0.5	UJ
Toluene	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Trichloroethene	22		37	J	32	J	60		140		120		0.5	UJ	0.27	B
Vinyl chloride	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
cis-1,2-Dichloroethene	3	J	5.2	J	5.3	J	7.9		15	J	18	J	0.5	UJ	0.5	UJ
trans-1,2-Dichloroethene	10	U	0.5	UJ	0.5	UJ	0.5	U	0.5	UJ	0.5	UJ	0.5	UJ	0.5	UJ
Semivolatile Organic Compounds (UG/L)																
Acenaphthene	NA		5.6	R	5.6	R	NA		2.8	J	NA		5.3	U	NA	
Dimethyl phthalate	NA		5.6	R	5.6	R	NA		5.3	U	NA		5.3	U	NA	
Phenanthrene	NA		5.6	R	5.6	R	NA		1.3	J	NA		5.3	U	NA	
Explosives (UG/L)																
No Detections																
Unfiltered Metals (UG/L)																
Aluminum	62.2	B	29,000		25,600		NA		88.8	J	NA		2,840		NA	
Arsenic	2.3	U	6.4	J	8.6	J	NA		2.8	U	NA		2.8	U	NA	
Barium	75.6	J	190	J	170	J	NA		81.7	J	NA		85.9	J	NA	

NA - Not analyzed
B - Blank contamination
J - Estimated
K - Biased high
L - Biase

R - Unusable
U - Undetected
UJ - Undetected, estimated limit
UL - Undetected, limit biased low

Table A-3
Detections in Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW202D	49GW202S			49GW203		49GW204	
Sample ID	049GW202D001	049GW2020001	049GW2029901	049GW2020002	049GW2030001	049GW2030002	049GW2040001	049GW2040002
Sample Date	02/11/03	08/01/02	08/01/02	10/09/02	08/02/02	10/09/02	08/01/02	10/09/02
Notes			Duplicate					
Beryllium	0.1 U	1.7 J	1.5 J	NA	0.14 J	NA	0.46 J	NA
Cadmium	0.33 B	0.2 U	0.2 U	NA	0.2 U	NA	0.2 U	NA
Calcium	20,500	19,200	18,300	NA	24,600	NA	16,100	NA
Chromium	3.1 B	910	769	NA	0.68 B	NA	104	NA
Cobalt	0.5 U	29 J	26.5 J	NA	4.4 J	NA	10.8 J	NA
Copper	10.2 J	80.5	67.1	NA	1.4 B	NA	21.6 B	NA
Iron	49.2 B	41,700	35,900	NA	9,150	NA	9,880	NA
Lead	20.3 L	16	14.7	NA	1.6 U	NA	5.3 B	NA
Magnesium	10,200 K	14,100	13,100	NA	11,200	NA	7,700	NA
Manganese	29.3	857	778	NA	2,250	NA	935	NA
Nickel	14 J	625	528	NA	13.5 J	NA	74.3	NA
Potassium	5,520	18,700	17,400	NA	6,420	NA	5,550	NA
Selenium	1.6 U	2.5 U	2.8 B	NA	2.5 U	NA	2.5 U	NA
Sodium	26,000 K	25,100	25,200	NA	39,200	NA	17,600	NA
Vanadium	0.75 B	39.7 J	34.6 J	NA	1.2 J	NA	2.8 J	NA
Zinc	57.8	143	132	NA	17.1 J	NA	98.2	NA
Filtered Metals (UG/L)								
Aluminum	46 B	262	219	NA	23.1 U	NA	48.2 B	NA
Barium	75.1 J	26.9 J	26.3 J	NA	83.5 J	NA	68.7 J	NA
Beryllium	0.1 U	0.1 U	0.1 U	NA	0.1 U	NA	0.12 J	NA
Cadmium	0.3 U	0.2 U	0.2 U	NA	0.2 U	NA	0.2 U	NA
Calcium	20,400	14,900	14,500	NA	24,600	NA	14,800	NA
Chromium	0.87 B	8.6 B	5.3 B	NA	0.5 U	NA	0.5 U	NA
Cobalt	0.5 U	8 J	7.6 J	NA	4 J	NA	3 J	NA
Copper	6.8 J	3.8 B	3.1 B	NA	1.5 B	NA	3.8 B	NA
Iron	14.4 B	738	659	NA	9,350	NA	6,080	NA
Lead	13.9 L	1.6 U	2.1 B	NA	1.6 U	NA	1.6 U	NA
Magnesium	10,100 K	6,420	6,210	NA	10,900	NA	7,010	NA
Manganese	27.9	336	328	NA	2,290	NA	831	NA
Nickel	13.5 J	38.9 J	47.7	NA	12.9 J	NA	11.3 J	NA
Potassium	5,510	6,310	6,330	NA	6,080	NA	4,480 J	NA
Selenium	1.6 U	2.5 U	2.5 U	NA	2.5 U	NA	2.5 U	NA
Sodium	25,000 K	20,800	20,600	NA	31,800	NA	15,900	NA
Vanadium	0.51 B	0.8 U	0.8 U	NA	0.8 U	NA	0.8 U	NA

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Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW202D	49GW202S			49GW203		49GW204	
Sample ID	049GW202D001	049GW2020001	049GW2029901	049GW2020002	049GW2030001	049GW2030002	049GW2040001	049GW2040002
Sample Date	02/11/03	08/01/02	08/01/02	10/09/02	08/02/02	10/09/02	08/01/02	10/09/02
Notes			Duplicate					
Zinc	39.5 B	47.5	42	NA	12 J	NA	41.6	NA
Wet Chemistry (MG/L)								
Alkalinity	24	1 U	47	NA	24	NA	38	NA
Chloride	78	25	23	NA	100	NA	34	NA
Nitrate	0.3 L	42	0.14	NA	0.1 UJ	NA	1.4	NA
Nitrogen	0.1 UL	0.1 U	0.1 U	NA	0.1 U	NA	0.1 U	NA
Phosphorus	NA	1	0.1 U	NA	NA	NA	0.1 U	NA
Sulfate	13	12	14	NA	6.4	NA	2.5	NA

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Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW206D				49GW206M		49GW206S	
Sample ID	049GW206D9901		049GW206D001		049GW206M001		049GW206S0001	
Sample Date	02/12/03		02/13/03		02/12/03		02/11/03	
Notes	Duplicate							
Chemical Name								
Volatile Organic Compounds (UG/L)								
1,1,1-Trichloroethane	10	U	10	U	10	U	10	U
1,1-Dichloroethane	10	U	10	U	10	U	10	U
1,1-Dichloroethene	10	U	10	U	10	U	1.3	J
1,2-Dibromoethane	10	U	10	U	10	U	10	U
1,2-Dichloropropane	10	U	10	U	10	U	10	U
Acetone	40	B	43	B	7.2	B	10	U
Bromoform	10	U	10	U	10	U	10	U
Bromomethane	10	U	10	U	10	U	10	U
Chloroform	37		37		10	U	4.2	J
Cyclohexane	10	U	10	U	10	U	10	U
Methane	NA		NA		NA		NA	
Methyl-tert-butyl ether (MTBE)	1.2	J	1.3	J	10	U	10	U
Styrene	10	U	10	U	10	U	10	U
Tetrachloroethene	10	U	10	U	10	U	1.1	J
Toluene	10	U	10	U	1.5	J	10	U
Trichloroethene	140		140		180		560	
Vinyl chloride	10	U	10	U	10	U	10	U
cis-1,2-Dichloroethene	91		90		64		150	
trans-1,2-Dichloroethene	2.9	J	3.1	J	10	U	10	U
Semivolatile Organic Compounds (UG/L)								
Acenaphthene	NA		NA		NA		NA	
Dimethyl phthalate	NA		NA		NA		NA	
Phenanthrene	NA		NA		NA		NA	
Explosives (UG/L)								
No Detections								
Unfiltered Metals (UG/L)								
Aluminum	898		2,600		35,600		161	B
Arsenic	2.8	J	2.3	U	8.7	J	2.3	U
Barium	27.9	J	43	J	225		37.6	J

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Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW206D		49GW206M	49GW206S
Sample ID	049GW206D9901	049GW206D001	049GW206M001	049GW206S0001
Sample Date	02/12/03	02/13/03	02/12/03	02/11/03
Notes	Duplicate			
Beryllium	0.1 U	0.1 U	1.9 J	0.1 U
Cadmium	0.3 U	0.3 U	0.3 U	0.3 U
Calcium	37,600 K	44,600	24,200 K	9,870
Chromium	39	62.6	339	16.7
Cobalt	2.5 B	3.2 J	42.5 J	3 J
Copper	22 J	45.5	166	3.9 B
Iron	1,420	4,080	72,400	2,630
Lead	6.2	12.2 L	15.2 L	4.7 L
Magnesium	7,920 K	8,880 K	19,600 K	4,710 J
Manganese	47.7	90.6	1,630	275
Nickel	26.5 J	40.7	278	21.2 J
Potassium	9,450	10,200	21,900	3,670 J
Selenium	4.8 J	4.1 J	1.6 U	1.6 U
Sodium	136,000 K	135,000 K	27,900 K	20,900 K
Vanadium	20.1 J	23.9 J	62.5	0.5 U
Zinc	26.6 B	127	185	24.1 B
Filtered Metals (UG/L)				
Aluminum	NA	105 B	6,800	30.8 B
Barium	NA	24.2 J	67.6 J	34 J
Beryllium	NA	0.1 U	0.25 B	0.1 U
Cadmium	NA	0.3 U	0.3 U	0.3 U
Calcium	NA	38,200	17,400 K	9,140
Chromium	NA	25.4	75.5	2.4 B
Cobalt	NA	0.5 U	10.6 J	2.2 B
Copper	NA	5.4 B	28.6	0.5 U
Iron	NA	500	14,100	1,810
Lead	NA	3 L	2.9 J	5.2 L
Magnesium	NA	8,000 K	10,200 K	4,360 J
Manganese	NA	38.1	898	216
Nickel	NA	13.1 J	81	17.1 J
Potassium	NA	9,650	11,300	3,240 J
Selenium	NA	5.3	1.6 U	1.6 U
Sodium	NA	132,000 K	21,400 K	19,400 K
Vanadium	NA	20.6 J	10 J	0.5 U

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Table A-3
Detections In Monitoring Well Samples
Site 49 RFI Report
NSWC - White Oak, Silver Spring, Maryland

Station ID	49GW206D				49GW206M		49GW206S	
Sample ID	049GW206D9901		049GW206D001		049GW206M001		049GW206S0001	
Sample Date	02/12/03		02/13/03		02/12/03		02/11/03	
Notes	Duplicate							
Zinc	NA		28.1	B	44.8	B	17.8	B
Wet Chemistry (MG/L)								
Alkalinity	110		120		51		15	
Chloride	33		34		40		42	
Nitrate	0.1	U	0.1	U	0.1	U	0.38	L
Nitrogen	0.1	U	0.1	U	0.1	U	0.1	UL
Phosphorus	NA		NA		NA		NA	
Sulfate	250		230		18		15	

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Appendix B
ARAR Tables

Table B-1
Chemical-Specific ARARs
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Chemicals & Relevant Media	Requirement	Prerequisites	Citation	ARAR or TBC	Comments
Groundwater, residential water supplies	Meet National Primary Standards for maximum contaminant levels (MCLs).	Drinking water source or potential source	Safe Drinking Water Act (SDWA): 40 CFR 141 National Primary Drinking Water Regulations.	Applicable	Regulation does not apply where groundwater quality has concentrations of total dissolved solids (TDS) greater than 2,500 mg/L. In these instances, the Medium-Specific Concentration for groundwater may be multiplied by 100. MCL used as PRG for Site 49 groundwater.
Surface water	Water Management Program approval for short-term discharges and NPDES for long-term discharges.	Surface water discharges	CWA: 40 CFR 122-123 NPDES permit program	Applicable	
Surface waters of the State	Protect and maintain the quality of surface water in the State of Maryland. Criteria and standards for discharges. Limitations and policy for antidegradation of the State's surface water.	Activities that will pollute the State's surface waters	COMAR 26.08, chapters 1 through 7	Applicable	This regulation is applicable for remedial actions that may affect surface water quality in the State of Maryland.
Surface water	Ambient Water Quality Criteria established to protect aquatic life and human consumers of water or aquatic life.	Activities that affect or may affect the surface water onsite	40 CFR 129	Applicable	These regulations were used in the development of PRGs for Site 49.
Carcinogens in groundwater and surface water	Not to exceed media-specific concentration that causes a lifetime cancer risk of between 1 in 10,000 and 1 in 100,000.	Potential exposure	NCP	TBC	Use to calculate site-specific PRGs for Site 49 groundwater.
Systemic toxicants in groundwater and surface water	Not to exceed media-specific levels where people could be exposed by direct ingestion or inhalation on a daily basis without appreciable risk of deleterious effects.	Potential exposure	NCP	TBC	Use to calculate site-specific PRGs for groundwater.
Air	Emissions limitations related to attainment of National Ambient Air Quality Standards and Emission Standards for Hazardous Air Pollutants.	Air emissions	Clean Air Act (CAA). Annotated code of Maryland Tittle 2	Applicable	Treatment alternatives such as air stripping, soil vapor extraction, or air sparging will involve air emissions.

ARAR - Applicable or relevant and appropriate requirement
CAA - Clean Air Act
RCRA - Resource Conservation and Recovery Act
CFR - Code for Federal Regulations
CWA - Clean Water Act
EPA - U.S. Environmental Protection Agency
NPDES - National Pollutant Discharge Elimination System.
OSHA - Occupational Safety and Health Administration
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
SDWA - Safe Drinking Water Act
SMCLs - Secondary Maximum Contaminant Levels
TBC - To be considered

Table B-2
Location-Specific ARARs
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Location	Requirement	Prerequisite	Citation	Applicability Determination	Comments
Federal Location-Specific ARARs					
Historic Sites, Buildings, and Antiquities Act					
Historic sites	Avoid undesirable impacts on landmarks.	Areas designated as historic sites.	16 USC 461-467; 40 CFR 6.301 (a)	Relevant and Appropriate	The regulations are relevant and appropriate in situations where remedial actions may adversely affect the historical structures located on Site 49.
Endangered Species Act of 1973					
Critical habitat upon which endangered species or threatened species depend.	Action to conserve endangered species or threatened species, including consultation with the Department of the Interior. Reasonable mitigation and enhancement measures must be taken, including live propagation, transplantation, and habitat acquisition and improvement.	Determination of effect upon endangered or threatened species or their habitat by conducting biological assessments.	16 USC 1531; 16 USC 1536(a); 50 CFR 81, 225, 402	Potentially applicable	There are no records of federal endangered plant and animal species located at White Oak. These regulations are applicable only if this situation changes.
Fish and Wildlife Coordination Act, Fish and Wildlife Improvement Act of 1978, Fish and Wildlife Conservation Act of 1980					
Area affecting streams or other water body	Provides protection for actions that would affect streams, wetlands, other water bodies or protected habitats. Any action taken should protect fish or wildlife.	Diversion, channeling or other activity that modifies a stream or other water body and affects fish or wildlife.	16 USC 661; 16 USC 662; 16 USC 742a; 16 USC 2901; 50 CFR 83	Applicable	Response actions will incorporate protection against any area water body, wetlands, or protected habitats.
Procedures for Implementing the Requirements of the Council on Environmental Quality on the National Environmental Policy Act and Executive Order 11990, Protection of Wetlands					
Wetland	Action to minimize the destruction, loss, or degradation of wetlands. Wetlands of primary ecological significance must not be altered so that ecological systems in the wetlands are unreasonably disturbed.	Wetlands as defined by Executive Order 11990 Section 7.	40 CFR 6, Appendix A, excluding Sections 6(a)(2), 6(a)(4), 6(a)(6); 40 CFR 6.302	Applicable	This regulation may be an ARAR for activities occurring in areas that meet the definition of a wetland. Remedial activities must minimize the destruction, loss, or degradation of the wetlands.
Clean Water Act, Section 404					
Wetland	The degradation Section requires degradation or destruction of wetlands and other aquatic sites be avoided to the extent possible. Dredged or fill material must not be discharged to navigable waters if the activity: contributes to the violation of Maryland water quality standards; CWA Sec. 307; jeopardizes endangered or threatened species; or violates requirements of the Title III of the Marine Protection, Research, and Sanctuaries Act of 1972.	Wetland as defined by Executive Order 11990 Section 7.	40 CFR 230.10; 40 CFR 231 (231.1, 231.2, 231.7, 231.8)	Applicable	Wetlands and navigable waters are present in the vicinity of Site 49. Remedial activities will comply with the requirements of this section of the Clean Water Act.
Surface Water	Ambient Water Quality Criteria established to protect aquatic life and human consumers of water aquatic life.	Activities that affect or may affect the surface water onsite	40 CFR 129	Applicable	These regulations were used in the development of the PRGs for Site 49.
Hazardous Waste Control Act (HWCA)					
Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout.	RCRA hazardous waste; treatment, storage, or disposal of hazardous waste.	40 CFR 264.18 (b)	TBC	Portions of Site 49 are within the 100-year flood zones. However, actions are not expected to involve hazardous waste. This would be TBC for nonhazardous waste.
Executive Order 11988, Protection of Floodplains					
Within floodplain	Actions taken should avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values.	Action that will occur in a floodplain, i.e., lowlands, and relatively flat areas adjoining inland and coastal waters and other flood-prone areas.	40 CFR 6, Appendix A; excluding Sections 6(a)(2), 6(a)(4), 6(a)(6); 40 CFR 6.302	Applicable	Portions of Site 49 are within the 100-year flood zones, therefore the requirements of this regulation are applicable for any response actions that might involve the use of these areas.
State Location-Specific ARARs					
Threatened and Endangered Species					
Critical habitat upon which endangered species or threatened species depend.	Requires action to conserve endangered or threatened fish species and the critical habitats they depend on. May not reduce the likelihood of either the survival or recovery of a listed species in the wild by reducing the reproduction, numbers or distribution of a listed species or otherwise adversely affect the species.	Determination of effect upon endangered or threatened species or its habitat.	COMAR 08.03.08	Potentially applicable	There are no records of state or federal endangered or threatened plant and animal species located within White Oak, based on inquiries to the Maryland DNR. These regulations are applicable if this situation changes.

Table B-2
Location-Specific ARARs
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Location	Requirement	Prerequisite	Citation	Applicability Determination	Comments
Threatened and Endangered Fish Species					
Critical habitat upon which endangered or threatened fish species depend.	Requires action to conserve endangered or threatened fish species and the critical habitats they depend on.	Determination of effect upon endangered or threatened fish species or its habitat.	COMAR 08.02.12	Potentially applicable	These regulations are applicable if remedial actions may jeopardize endangered or threatened fish species. Currently, there are no federal or state endangered fish species at White Oak.
Fish and Fisheries					
Fisheries, locations where species of fish exist	Requirements to conserve species of fish for human enjoyment, for scientific purposes and to ensure their perpetuation as viable components of their ecosystems.	Determination of effect upon fish species or its habitat.	Annotated Code of Maryland Title 4	Applicable	Fish species inhabit Paint Branch. If response actions affect these species, the requirements of this title are applicable.
Wildlife					
Areas inhabited by wildlife	Requirements to conserve species of wildlife for human enjoyment, for scientific purposes and to ensure their perpetuation as viable components of their ecosystems.	Determination of effect upon wildlife species or its habitat.	Annotated Code of Maryland Title 10	Applicable	Wildlife species are present at White Oak. If response actions may affect these species, the requirements of this title are applicable.
Nontidal Wetlands Protection Act, Maryland Nontidal Wetlands Regulations					
Wetland	Provides regulations for activities on or near nontidal wetlands (an area that is inundated or saturated by surface water or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions). Must obtain a permit from the State in order to conduct certain regulated activities in a nontidal wetland, or within a buffer or an expanded buffer.	Activities that will occur on or near nontidal wetlands.	COMAR 26.23; Annotated Code of Maryland, Title 5; Code of MD, Title 8-1201;	Applicable	Nontidal wetlands are present at White Oak. A permit or letter of exemption from the Department of Natural Resources is required if remedial activities involve activities on or in nontidal wetlands.
Wetlands and Riparian Rights					
Wetlands	Requirements to preserve wetlands and prevent their destruction; requires a license for dredging or filling of wetlands.	Activities that can affect the integrity of wetlands, such as dredging or filling.	Annotated Code of Maryland Title 16	Applicable	Wetlands (tidal and nontidal) are present at White Oak. The requirements of this title are applicable for any response actions that may affect the integrity of these wetlands.
Construction on Nontidal Waters and Floodplains					
Nontidal waters and floodplains	Protect and maintain nontidal waterways and/or state of Maryland floodplains must follow these regulations	Activities that affect nontidal waterways and floodplains	COMAR 08.05.03	Potentially Applicable	Any remedial actions involving alteration to the streams bounding Site 49 or floodplains (including temporary construction) are subject to these requirements.
Water Pollution Control Law					
Waters of the State	Establishes effective programs and provides additional and cumulative remedies to prevent, abate, and control pollution of the waters in the state.	Activities that will pollute the waters in the state.	COMAR 9, Parts 301-351	Applicable	This regulation is applicable for remedial actions that may affect water quality in the streams around Site 49.
Maryland Water Pollution Control Regulations					
Surface waters of the State	Protect and maintain the quality of surface water in the State of Maryland. Criteria and standards for discharges limitations and policy for antidegradation of the State's limitations and policy for antidegradation of the State's surface water.	Activities that will pollute the surface waters of the state.	COMAR 26.08, Chapters 01-07	Applicable	This regulation is applicable for remedial actions that may affect surface water quality in the State of Maryland.
Water Management					
Water resources of the State	Provides for the conservation and protection of the water resources of the State by requiring that any land-clearing, grading, or other earth disturbances require an erosion- and sediment-control plan. Also provides that stormwater must be managed to prevent offsite sedimentation and maintain current site conditions.	Activities that affect the water resources of the State.	COMAR 26.17.01 COMAR 26.17.02, Annotated Code of Maryland Title 4	Applicable	The design for the remedial actions will incorporate the requirements of this regulation.

ARARs - Applicable or relevant and appropriate requirements.
RCRA - Resource Conservation and Recovery Act.
CFR - Code of Federal Regulations.
CWA- Clean Water Act.
DON - Department of Navy.
EO - Executive Order
FR - Federal Register.
HWCA - Hazardous Waste Control Act.
USC - United States Code.
TBC - To Be Considered.

Table B-3
Action-Specific ARARs
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Action	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Federal Action-Specific ARARs					
Resource Conservation and Recovery Act (RCRA) 42 USC 6901 et seq.*					
Onsite waste generation	Waste generator shall determine if waste is hazardous waste.	Generator of hazardous waste.	40 CFR 262.10 (a), 262.11	Applicable	Applicable for any operation where waste is generated. Remedial alternatives for Site 49 may generate contaminated wastes.
Hazardous waste accumulation	Generator may accumulate waste on site for 90 days or less or must comply with requirements for operating a storage facility.	Accumulate hazardous waste.	40 CFR 262.34	Potentially applicable	If waste generated at White Oak is determined to be hazardous, any storage of the hazardous waste will not exceed 90 days. Accumulation of hazardous wastes onsite for longer than 90 days would be subject to the substantive RCRA requirements for storage facilities.
Recordkeeping	Generator must keep records.	Generate hazardous waste.	40 CFR 262.40	Potentially applicable	Administrative requirements are not ARARs for onsite CERCLA actions.
Excavation	Movement of excavated materials to new location and placement in or on land will trigger land disposal restrictions for the excavated waste or closure requirements for the unit in which the waste is being placed.	Materials containing RCRA hazardous wastes subject to land disposal restrictions are placed in another unit.	40 CFR 268.40	Potentially applicable	Applicable to disposal of soil to a new location and placement in or on land containing land-disposal-restricted RCRA hazardous waste. The wastes generated from response actions at White Oak may be RCRA hazardous wastes.
Safe Drinking Water Act					
Actions that affect drinking water supply	Promulgates National Primary Drinking Water Standard Maximum Contaminant Levels (MCLs)	Actions that affect drinking water supply	40 CFR 141	Relevant and appropriate	These regulations are ARARs for remedial actions at Site 49 that affect the groundwater.
U.S. Department of Transportation, 49 USC 1802, et seq.*					
Hazardous Materials Transportation	No person shall represent that a container or package is safe unless it meets the requirements of 49 USC 1802, et seq. or represent that a hazardous material is present in a package or motor vehicle if it is not.	Interstate carriers transporting hazardous waste and substances by motor vehicle. Transportation of hazardous material under contract with any department of the executive branch of the Federal Government.	49 CFR 171.2(f)	Potentially applicable	Offsite transport of hazardous materials must comply with both substantive and administrative requirements.
	No person shall unlawfully alter or deface labels, placards, or descriptions, packages, containers, or motor vehicles used for transportation of hazardous materials.		49 CFR 171.2(g)	Potentially applicable	
Hazardous Materials Marking, Labeling, and Placarding	Each person who offers hazardous material for transportation or each carrier that transports it shall mark each package, container, and vehicle in the manner required.	Person who offers hazardous material for transportation; carries hazardous material; or packages, labels, or placards hazardous material.	49 CFR 172.300	Potentially applicable	To be determined. Offsite transport of hazardous materials must comply with both substantive and administrative requirements.
	Each person offering non-bulk hazardous materials for transportation shall mark the proper shipping name and identification number (technical name) and consignee's name and address.		49 CFR 172.301	Potentially applicable	

Table B-3
Action-Specific ARARs
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Action	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Hazardous Materials Marking, Labeling, and Placarding (cont.)	Hazardous materials for transportation in bulk packages must be labeled with proper identification (ID) number, specified in 49 CFR 172.101 table, with required size of print. Packages must remain marked until cleaned or refilled with material requiring other marking.	Person who offers hazardous material for transportation; carries hazardous material; or packages, labels, or placards hazardous material.	49 CFR 172.302	Potentially applicable	
	No package marked with a proper shipping name or ID number may be offered for transport or transported unless the package contains the identified hazardous material or its residue.		49 CFR 172.303	Potentially applicable	To be determined. Offsite transport of hazardous materials must comply with both substantive and administrative requirements.
	The marking must be durable, in English, in contrasting colors, unobscured, and away from other markings.		49 CFR 172.304	Potentially applicable	
	Labeling of hazardous material packages shall be as specified in the list.	Person who offers hazardous material for transportation; carries hazardous material; or packages, labels, or placards hazardous material.	49 CFR 172.400	Potentially applicable	
	Non-bulk combination packages containing liquid hazardous materials must be packed with closures upward, and marked with arrows pointing upward.		49 CFR 172.312	Potentially applicable	
	Each bulk packaging or transport vehicle containing any quantity of hazardous material must be placarded on each side and each end with the type of placards listed in Tables 1 and 2 of 49 CFR 172.504.		49 CFR 172.504	Potentially applicable	
Occupational Safety and Health Administration (OSHA)					
Hazardous waste work	Requirements for hazardous waste workers such as training, personal protective equipment (PPE), and clothing must be met.	Hazardous waste work.	29 CFR 1904, 29 CFR 1910, 29 CFR 1926	Applicable	Remedial action activities at White Oak will involve hazardous waste workers; therefore the requirements of OSHA must be met.
State Action-Specific ARARs					
Maryland Hazardous Waste Regulations					
Storage, treatment or disposal, and transportation of hazardous waste	Regulations and procedures for the identifications, listing, transportation, treatment, storage, and disposal of hazardous wastes must be met.	Handling of hazardous wastes	COMAR 26.13.01 through COMAR 26.13.04, Annotated Code of Maryland Title 7	Potentially Applicable	Any hazardous waste found during site remediation will be disposed of according to regulations. Any residues or by-products from treatment systems that are hazardous must be disposed of properly.
Solid Waste and Water Supply Regulations					
Well Construction and Abandonment	Specifications for well construction and abandonment must be met. Also provides a mechanism to provide the State of Maryland with a database of existing and abandoned wells. Permits are required for well construction.		COMAR 26.04.03 (A&D); COMAR 26.04.04	Applicable	The requirements of this regulation are applicable to the response actions at White Oak if monitoring wells have to be installed or abandoned.

Table B-3
Action-Specific ARARs
Feasibility Study for Site 49
Former NSWC White Oak, Silver Spring, Maryland

Action	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Stormwater Management					
Design and construction	Regulations require the design and construction of a system necessary to control stormwater.	Design and construction activities	COMAR 26.17.02	Applicable	The remedial action will incorporate measures to control and manage stormwater as necessary.
Erosion and Sediment Control					
Land clearing, grading, and earth disturbances	Regulations require the preparation and implementation of a plan to control erosion and sediment for activities involving land clearing, and grading and earth disturbances. Erosion and sediment control criteria are also established.	Land clearing, grading, and earth disturbances	COMAR 26.17.01	Potentially Applicable	The remedial action will incorporate the standards required for clearing, grading, and other earth disturbances, including compliance with county and municipal erosion and sediment control ordinances, and the Commission's erosion- and sedimentation-control regulations.
Maryland Drinking Water Law					
Actions that affect state drinking water	Ensures that the State has the primary enforcement responsibility for drinking water standards under the Federal Safe Drinking Water Act.	Action causing pollution of drinking water supply	COMAR 9.04, Parts 401-413	Applicable	This regulation may be an ARAR for Site 49 if activities that affect water quality are conducted.
Occupational, Industrial, and Residential Hazards					
Action that will generate noise	Limits set on the levels of noise must be met; these limits are protective of the health, welfare, and property of the people in the State of Maryland. The maximum permitted levels for construction activities may not exceed 90 dBA during the day and 75 dBA during night.	Action that will generate noise	COMAR 26.02.03.02A (2) and B(2), COMAR 26.02.03.02.03A, Annotated Code of Maryland Title 3	Applicable	During site remediation work, the maximum allowable noise levels will not be exceeded at site boundaries.
Air Quality					
Actions that involve emissions to air	Provides ambient air quality standards, general emissions standards, and restrictions for air emissions from construction activities, vents, and treatment technologies such as incinerators. Also includes nuisance and odor control. Construction activities may emit particulate matter into the ambient air. Remedial activities must follow regulations.	Actions that involve emissions to air above specific limits.	COMAR 26.11	Applicable	May apply to airstrippers, SVE, or air sparging alternatives.

Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs. Specific potential ARARs are addressed in the table below each heading.
Acronyms used in the table:

ARAR - Applicable or relevant and appropriate requirement
CAA - Clean Air Act
RCRA - Resource Conservation and Recovery Act
CFR - Code for Federal Regulations
CWA - Clean Water Act
DOT - U.S. Department of Transportation
EPA - U.S. Environmental Protection Agency
NPDES - National Pollutant Discharge Elimination System.
OSHA - Occupational Safety and Health Administration
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
SDWA - Safe Drinking Water Act
SMCLs - Secondary Maximum Contaminant Levels
TBC - To be considered
USC - United States Code

Appendix C-1
Alternative 1—No Action

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	1
DESCRIPTION:	No Action
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Construction	$	-
Project Management	$	-
Design	$	-
Construction Management	$	-
Subcontractor General Requirements	$	-
Contingency	$	-
Total Capital Cost	**$**	**-**
Annual Operation and Maintenance Cost		
Reporting	$	-
Professional Services [1]	$	-
Subcontractor General Requirements	$	-
Contingency	$	-
Total Annual Operations and Maintenance Cost	**$**	**-**
Five Year Review Cost		
5-year Review Report	$	5,000
Professional Services [1]	$	-
Subcontractor General Requirements	$	-
Contingency	$	500
Total Five Year Review Cost	**$**	**5,500**
TOTAL PRESENT WORTH	**$**	**17,072**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2003 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 1
DESCRIPTION: No Action
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

NO ACTIVITY FOR NO FURTHER ACTION ALTERNATIVE.

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	1
DESCRIPTION:	No Action
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST						
Item/Activity	Qty	Unit		Unit Cost	Cost	Comments and References
Subtotal Capital Cost					$ -	
Project Management	8%		of	$ -	$ -	
Technical Support	15%		of	$ -	$ -	
Construction Management	0%		of	$ -	$ -	
Subcontractor General Requirements	0%		of	$ -	$ -	
Subtotal Capital Cost					$ -	
Contingency	25%			$ -	$ -	
TOTAL CAPITAL COST					$ -	

ANNUAL OPERATIONS AND MAINTENANCE COST						
Item/Activity	Qty	Unit		Unit Cost	Cost	Comments
Subtotal Annual Operations and Maintenance Cost					$ -	
Project Management	8%		of	$ -	$ -	
Technical Support	15%		of	$ -	$ -	
Construction Management	0%		of	$ -	$ -	
Subcontractor General Requirements	0%		of	$ -	$ -	
Subtotal Annual Operations and Maintenance Cost					$ -	
Contingency	25%			$ -	$ -	
TOTAL ANNUAL OPERATIONS AND MAINTENANCE COST					$ -	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	1
DESCRIPTION:	No Action
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

FIVE YEAR REVIEW COST						
Item/Activity	Qty	Unit		Unit Cost	Cost	Comments
5-year Review Report						
5-year Review Report	1	LS		$ 5,000.00	$ 5,000	
Subtotal Five Year Review Cost					$ 5,000	
Project Management	0%		of	$ 5,000.00	$ -	
Technical Support	0%		of	$ 5,000.00	$ -	
Construction Management	0%		of	$ 5,000.00	$ -	
Subcontractor General Requirements	0%		of	$ 5,000.00	$ -	
Subtotal Five Year Review Cost					$ 5,000	
Contingency	10%		of	$ 5,000.00	$ 500	
TOTAL FIVE YEAR REVIEW COST					$ 5,500	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 1
DESCRIPTION: No Action
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ -		$ -	$ -	$ -	$ -	$ 17,789
1	2003	0.960		$ -	$ -	$ -	$ -	$ -	$ 18,536
2	2004	0.921		$ -	$ -	$ -	$ -	$ -	$ 19,315
3	2005	0.884		$ -	$ -	$ -	$ -	$ -	$ 20,126
4	2006	0.848		$ -	$ -	$ -	$ -	$ -	$ 20,971
5	2007	0.814		$ 5,500	$ 5,500	$ -	$ 4,477	$ 4,477	$ 16,121
6	2008	0.781		$ -	$ -	$ -	$ -	$ -	$ 16,798
7	2009	0.750		$ -	$ -	$ -	$ -	$ -	$ 17,504
8	2010	0.720		$ -	$ -	$ -	$ -	$ -	$ 18,239
9	2011	0.691		$ -	$ -	$ -	$ -	$ -	$ 19,005
10	2012	0.663		$ 5,500	$ 5,500	$ -	$ 3,645	$ 3,645	$ 14,072
11	2013	0.636		$ -	$ -	$ -	$ -	$ -	$ 14,663
12	2014	0.610		$ -	$ -	$ -	$ -	$ -	$ 15,279
13	2015	0.586		$ -	$ -	$ -	$ -	$ -	$ 15,921
14	2016	0.562		$ -	$ -	$ -	$ -	$ -	$ 16,589
15	2017	0.539		$ 5,500	$ 5,500	$ -	$ 2,967	$ 2,967	$ 11,555
16	2018	0.518		$ -	$ -	$ -	$ -	$ -	$ 12,041
17	2019	0.497		$ -	$ -	$ -	$ -	$ -	$ 12,546
18	2020	0.477		$ -	$ -	$ -	$ -	$ -	$ 13,073
19	2021	0.458		$ -	$ -	$ -	$ -	$ -	$ 13,622
20	2022	0.439		$ 5,500	$ 5,500	$ -	$ 2,416	$ 2,416	$ 8,463
21	2023	0.421		$ -	$ -	$ -	$ -	$ -	$ 8,819
22	2024	0.404		$ -	$ -	$ -	$ -	$ -	$ 9,189
23	2025	0.388		$ -	$ -	$ -	$ -	$ -	$ 9,575
24	2026	0.373		$ -	$ -	$ -	$ -	$ -	$ 9,977
25	2027	0.358		$ 5,500	$ 5,500	$ -	$ 1,966	$ 1,966	$ 4,665
26	2028	0.343		$ -	$ -	$ -	$ -	$ -	$ 4,861
27	2029	0.329		$ -	$ -	$ -	$ -	$ -	$ 5,066
28	2030	0.316		$ -	$ -	$ -	$ -	$ -	$ 5,278
29	2031	0.303		$ -	$ -	$ -	$ -	$ -	$ 5,500
30	2032	0.291		$ 5,500	$ 5,500	$ -	$ 1,601	$ 1,601	$ (0)
Total Alternative 1			**$ -**	**$ 33,000**	**$ 33,000**	**$ -**	**$ 17,072**	**$ 17,072**	

Appendix C-2
Alternative 2—Institutional Controls

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	2
DESCRIPTION:	Institutional Controls with Long-Term Monitoring
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Well Installation and LUCIP Preparation	$	40,340
Project Management	$	3,227
Design	$	2,017
Construction Management	$	4,034
Subcontractor General Requirements	$	2,017
Contingency	$	12,909
Total Capital Cost	**$**	**64,544**
First Year Operations and Maintenance		
Well Development	$	940
Annual Groundwater Monitoring	$	5,550
Annual Reporting	$	4,640
Professional Services [1]	$	2,560
Subcontractor General Requirements	$	557
Contingency	$	3,562
Total First Year Operations and Maintenance	**$**	**17,808**
Following Years Annual Operation and Maintenance		
Annual Groundwater Monitoring	$	5,550
Annual Reporting	$	2,840
Professional Services [1]	$	1,930
Subcontractor General Requirements	$	420
Contingency	$	2,685
Total Following Years Annual Operations and Maintenance	**$**	**13,424**
Five Year Review Cost		
5-year Review Report	$	5,000
Professional Services [1]	$	-
Subcontractor General Requirements	$	-
Contingency	$	500
Total Five Year Review Cost	**$**	**5,500**
TOTAL PRESENT WORTH	**$**	**312,417**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2003 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 2
DESCRIPTION: Institutional Controls with Long-Term Monitoring
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

NO DESIGN ACTIVITY FOR INSTITUTIONAL CONTROLS ALTERNATIVE.

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	2
DESCRIPTION:	Institutional Controls with Long-Term Monitoring
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%
3. The number of new bedrock monitoring wells required to be installed 4 wells
4. The number of compliance wells to be sampled is 10 wells per year (5 wells per round, 1 round every 9 months)

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST						
Item/Activity	Qty	Unit		Unit Cost	Cost	Comments and References
Bedrock/Saprolite Groundwater Monitoring Well Installation	4	well		$ 5,005.00	$ 20,020	Assume 130' deep @ $38.5/ft
Well Permits	4	ea		$ 30.00	$ 120	
Equipment Rental	1	wk		$ 200.00	$ 200	
LUCIP Preparation	1	LS		$ 20,000.00	$ 20,000	
Subtotal Capital Cost					$ 40,340	
Project Management	8%		of	$ 40,340.00	$ 3,227	
Design	5%		of	$ 40,340.00	$ 2,017	
Construction Management	10%		of	$ 40,340.00	$ 4,034	
Subcontractor General Requirements	5%		of	$ 40,340.00	$ 2,017	
Subtotal Capital Cost					$ 51,635	
Contingency	25%		of	$ 51,635.20	$ 12,909	
TOTAL CAPITAL COST					$ 64,544	

YEAR 1 OPERATIONS AND MAINTENANCE COST					
Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Well Development					
Labor - Technician	8	hr	$ 55.00	$ 440	2 hrs/well, 1 people
Well Development Equipment Rental	1	ls	$ 500.00	$ 500	
Total *Well Development*				$ 940	
Annual Groundwater Monitoring					
Labor - Technician	45	hr	$ 55.00	$ 2,475	3 hrs/well, 2 people
Groundwater Sample Analysis	15	sample	$ 135.00	$ 2,025	VOC 5 extra QA/QC samples.
Sampling Supplies	1.5	round	$ 200.00	$ 300	
GW Sampling Equipment Rental	1.5	round	$ 500.00	$ 750	
Total *Annual Groundwater Monitoring*				$ 5,550	
Annual Reporting					
Labor - Engineer/Hydrogeologist	40	hr	$90.00	$ 3,600	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	2
DESCRIPTION:	Institutional Controls with Long-Term Monitoring
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Labor - Editor	8 hr		$65.00	$	520
Labor - CAD Technician	8 hr		$65.00	$	520
Total *Annual Reporting*				$	4,640
Subtotal Year 1 Operations and Maintenance Cost				$	11,130
Project Management	8%	of	$ 11,130.00	$	890
Technical Support	15%	of	$ 11,130.00	$	1,670
Construction Management	0%	of	$ 11,130.00	$	-
Subcontractor General Requirements	5%	of	$ 11,130.00	$	557
Subtotal Year 1 Operations and Maintenance Cost				$	14,246
Contingency	25%	of	$ 14,246.40	$	3,562
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST				$	17,808

FOLLOWING YEARS OPERATIONS AND MAINTENANCE COST

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Annual Groundwater Monitoring					
Labor - Technician	45	hr	$ 55.00	$ 2,475	3 hrs/well, 2 people
Groundwater Sample Analysis	15	sample	$ 135.00	$ 2,025	VOC, 5 extra QA/QC samples.
Sampling Supplies	1.5	round	$ 200.00	$ 300	
GW Sampling Equipment Rental	1.5	round	$ 500.00	$ 750	
Total *Annual Groundwater Monitoring*				$ 5,550	
Annual Reporting					
Labor - Engineer/Hydrogeologist	20	hr	$90.00	$ 1,800	
Labor - Editor	8	hr	$65.00	$ 520	
Labor - CAD Technician	8	hr	$65.00	$ 520	
Total *Annual Reporting*				$ 2,840	
Subtotal Following Years Operations and Maintenance Cost				$ 8,390	
Project Management	8%	of	$ 8,390.00	$ 671	
Technical Support	15%	of	$ 8,390.00	$ 1,259	
Construction Management	0%	of	$ 8,390.00	$ -	
Subcontractor General Requirements	5%	of	$ 8,390.00	$ 420	
Subtotal Following Years Operations and Maintenance Cost				$ 10,739	
Contingency	25%	of	$ 10,739.20	$ 2,685	
TOTAL FOLLOWING YEARS OPERATIONS AND MAINTENANCE COST				$ 13,424	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	2
DESCRIPTION:	Institutional Controls with Long-Term Monitoring
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

FIVE YEAR REVIEW COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
5-year Review Report							
5-year Review Report	1	LS		$ 5,000.00	$	5,000	
Subtotal Five Year Review Cost					$	5,000	
Project Management	0%		of	$ 5,000.00	$	-	
Technical Support	0%		of	$ 5,000.00	$	-	
Construction Management	0%		of	$ 5,000.00	$	-	
Subcontractor General Requirements	0%		of	$ 5,000.00	$	-	
Subtotal Five Year Review Cost					$	5,000	
Contingency	10%		of	$ 5,000.00	$	500	
TOTAL FIVE YEAR REVIEW COST					$	5,500	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 2
DESCRIPTION: Institutional Controls with Long-Term Monitoring
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ 64,544		$ 64,544	$ 64,544	$ -	$ 64,544	$ 258,284
1	2003	0.960		$ 17,808	$ 17,808	$ -	$ 17,090	$ 17,090	$ 250,576
2	2004	0.921		$ 13,424	$ 13,424	$ -	$ 12,364	$ 12,364	$ 247,112
3	2005	0.884		$ 13,424	$ 13,424	$ -	$ 11,865	$ 11,865	$ 243,503
4	2006	0.848		$ 13,424	$ 13,424	$ -	$ 11,387	$ 11,387	$ 239,742
5	2007	0.814		$ 18,924	$ 18,924	$ -	$ 15,405	$ 15,405	$ 230,093
6	2008	0.781		$ 13,424	$ 13,424	$ -	$ 10,488	$ 10,488	$ 225,769
7	2009	0.750		$ 13,424	$ 13,424	$ -	$ 10,065	$ 10,065	$ 221,263
8	2010	0.720		$ 13,424	$ 13,424	$ -	$ 9,659	$ 9,659	$ 216,569
9	2011	0.691		$ 13,424	$ 13,424	$ -	$ 9,270	$ 9,270	$ 211,677
10	2012	0.663		$ 18,924	$ 18,924	$ -	$ 12,541	$ 12,541	$ 200,848
11	2013	0.636		$ 13,424	$ 13,424	$ -	$ 8,538	$ 8,538	$ 195,296
12	2014	0.610		$ 13,424	$ 13,424	$ -	$ 8,193	$ 8,193	$ 189,511
13	2015	0.586		$ 13,424	$ 13,424	$ -	$ 7,863	$ 7,863	$ 183,482
14	2016	0.562		$ 13,424	$ 13,424	$ -	$ 7,546	$ 7,546	$ 177,201
15	2017	0.539		$ 18,924	$ 18,924	$ -	$ 10,209	$ 10,209	$ 164,925
16	2018	0.518		$ 13,424	$ 13,424	$ -	$ 6,950	$ 6,950	$ 157,864
17	2019	0.497		$ 13,424	$ 13,424	$ -	$ 6,670	$ 6,670	$ 150,506
18	2020	0.477		$ 13,424	$ 13,424	$ -	$ 6,401	$ 6,401	$ 142,839
19	2021	0.458		$ 13,424	$ 13,424	$ -	$ 6,143	$ 6,143	$ 134,851
20	2022	0.439		$ 18,924	$ 18,924	$ -	$ 8,311	$ 8,311	$ 120,796
21	2023	0.421		$ 13,424	$ 13,424	$ -	$ 5,658	$ 5,658	$ 111,881
22	2024	0.404		$ 13,424	$ 13,424	$ -	$ 5,430	$ 5,430	$ 102,593
23	2025	0.388		$ 13,424	$ 13,424	$ -	$ 5,211	$ 5,211	$ 92,914
24	2026	0.373		$ 13,424	$ 13,424	$ -	$ 5,001	$ 5,001	$ 82,828
25	2027	0.358		$ 18,924	$ 18,924	$ -	$ 6,766	$ 6,766	$ 66,588
26	2028	0.343		$ 13,424	$ 13,424	$ -	$ 4,606	$ 4,606	$ 55,397
27	2029	0.329		$ 13,424	$ 13,424	$ -	$ 4,420	$ 4,420	$ 43,736
28	2030	0.316		$ 13,424	$ 13,424	$ -	$ 4,242	$ 4,242	$ 31,565
29	2031	0.303		$ 13,424	$ 13,424	$ -	$ 4,071	$ 4,071	$ 18,924
30	2032	0.291		$ 18,924	$ 18,924	$ -	$ 5,508	$ 5,508	$ (0)
Total Alternative 2			$ 64,544	$ 440,104	$ 504,648	$ 64,544	$ 247,873	$ 312,417	

Appendix C-3
Alternative 3—Groundwater Extraction

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3
DESCRIPTION:	Groundwater Extraction and Treatment
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Construction	$	401,373
Project Management	$	32,110
Design	$	60,206
Construction Management	$	60,206
Subcontractor General Requirements	$	20,069
Contingency	$	143,491
Total Capital Cost	**$**	**717,453**
Year 1 Operations and Maintenance		
Well Development	$	3,800
Groundwater Sampling (Baseline and 4 Qtrs after Startup)	$	26,450
System Startup	$	8,350
Routine System O&M	$	39,270
Reporting (4 Qtrly Reports incl. Construction Completion Report)	$	18,375
Professional Services [1]	$	25,024
Subcontractor General Requirements	$	4,812
Contingency	$	31,520
Total Year 1 Operations and Maintenance	**$**	**157,602**
Years 2-10 Operation and Maintenance		
Groundwater Sampling (Semiannual Events)	$	10,580
Routine System O&M	$	34,590
Reporting (Semiannual Reports)	$	8,650
Professional Services [1]	$	9,688
Subcontractor General Requirements	$	2,691
Contingency	$	16,550
Total Years 2 Thru 10 Operations and Maintenance	**$**	**82,749**
Five Year Review Cost		
5-year Review Report	$	5,000
Professional Services [1]	$	-
Subcontractor General Requirements	$	-
Contingency	$	500
Total Five Year Review Cost	**$**	**5,500**
Post Closure Cost		
Closure Reporting	$	13,875
Well Abandonment and Equipment Demobilization	$	33,930
Professional Services [1]	$	15,776
Subcontractor General Requirements	$	2,390
Contingency	$	9,896
Total Post Closure Cost	**$**	**75,867**
TOTAL PRESENT WORTH (10 year cleanup)	**$**	**1,506,550**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2004 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 3
DESCRIPTION: Groundwater Extraction and Treatment
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Site Background Data

Elevation of Site = 250 ft amsl or 14.56 psia
Length of Target Groundwater Contamination Zone = 466 ft
Width of Target Groundwater Contamination Zone = 466 ft
Area of Contaminated Groundwater Target Zone = 217,156 sf
Depth to Top of Target Zone = 25 ft
Depth to Bottom of Target Zone = 130 ft (estimate of average depthof contaminant)
Rock Porosity = 0.05
Volume of Contaminated Groundwater = 1,140,069 cf or 32,286,754 liters 8,523,703 gallons

Hydraulic Conductivity, K = 0.003 ft/day (assumption) or 1 ft/yr or 1.06E-06 cm/sec
Hydraulic Gradient, i = 0.2 ft/ft (taken from interpolated groundwater contour map Figure 2-3)

Average contaminant concentrations

PCE	50	µg/L
TCE	1,000	µg/L
DCE	150	µg/L
VC	2	µg/L
Total CVOCs	1,202	µg/L

Mass Estimate

Assumptions
1. Bedrock formations are the target of this remediation.
2. No mobile NAPL is present.

Mass of CVOCs in gw = 85.6 lbs of CVOCs

Conceptual Design

Pumping System Design Parameters
Estimated Number of Pumping Wells = 10 wells
Estimated pumping rate from each well = 1 gpm
Total Maximum Pumping Rate 10 gpm or a sustained pumping rate of 10 gpm
Depth of pumping wells = 130 ft bgs

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 3
DESCRIPTION: Groundwater Extraction and Treatment
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

System Construction Time

Estimated drilling rate = 100 lf/day Using air rotary
Total linear footage drilling = 1,040 lf
Estimated duration of drilling = 10.4 days or 11 days
Estimated linear footage of field piping per pumping well = 80 ft per well
Total linear footage of field piping = 800 lf
Estimated field piping placing rate = 50 lf/day
Estimated duration of field piping = 16.0 days or 16 days (rounded up)
Total construction timeframe = 27 days

Granular Activated Carbon (GAC) Conceptual Design Parameters

All organic contaminants found in water are adsorbable with GAC.
GAC treatment system design flowrate is 10 gpm
Governing contaminant TCE at 1,000 mg/L (use no safety factor for average GAC consumption estimate)

Carbon adsorption Freundlich Isotherm data obtained from USACOE Adsorption Design Guide 1110-1-2 (March 2001)
Adsorption constant, q = K*c^(1/n) where: q = mg CTC / g GAC
K and (1/n) are Freundlich Isotherm constants
c = concentration of CTC in mg/L

Use average constants for several brands of GAC. (USACOE Design Guide 1110-1-2, March 2001)
Assume: K = 28
(1/n) = 0.62
c = 1,000 µg/L
Calculate q = 28.0 mg TCE/gm GAC or 0.028 gm TCE/gm GAC or 2.8% pickup
GAC usage rate for TCE only 0.1786 lbs GAC/hr or 4.3 lbs GAC/day or 1,564 lbs GAC/yr
Assuming a multiplier of 2.40 for additional organic contaminants that will also adsorb and use carbon, and iron fouling
The total GAC usage rate = 0.4 lbs GAC/hr or 10.3 lbs GAC/day or 3,761 lbs GAC/yr
Assuming a carbon cost of $2.00 per lb GAC for supply and changeout --> $7,521 per year GAC

Assume a changeout period of 2 times per year
The desired changeout period drives the size of the vessels = 1,880 lb size
Assume a carbon vessel size of 2,000 lb and we need 2 vessels in series for safety factor.

Assuming a 2,000 lb vessel costs $15,000 with GAC, total cost = $30,000 for vessels and GAC only.
In addition, there would be an annual recurring cost of $7,521 for GAC changeout

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3
DESCRIPTION:	Groundwater Extraction and Treatment
PREPARED BY:	José Amaya
PROJECT NUMBER:	149206.SA.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%
2. See "Conceptual Design" spreadsheet for basis of cost estimate assumptions.
3. The number of new Coastal Plain monitoring wells required to be installed [ ] wells
4. The number of new bedrock/Saprolite monitoring wells required to be installed 5 wells
5. Number of Groundwater Extraction Wells to be installed = 10 wells
6. Number of piezometers to be installed = [ ] piezometers
7. Assume that the duration of construction is 30 working days (includes 20 working days for treatment system construction and installation)
8. The number of wells to be sampled for VOCs is 6 wells per round
9. The number of wells on-site to be abandoned for post-closure is 26 wells

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST						
Item/Activity	Qty	Unit		Unit Cost	Cost	Comments and References
Construction						
Coastal Plain Groundwater Monitoring Well Installation	0	well		$ 2,320.00	$ -	Assume 2-inch wells are 130 ft deep @ $40/ft
Bedrock/Saprolite Groundwater Monitoring Well Installation	5	well		$ 5,000.00	$ 25,000	Assume 100' deep @ $50/ft
Pre-Design Pump Test	1	LS		$ 10,000.00	$ 10,000	
Groundwater Extraction Well Installation	10	well		$ 7,000.00	$ 70,000	4-inch wells @ $50/ft
Piezometer Installation	0	well		$ 2,320.00	$ -	Assume 2-inch wells are 130 ft deep @ $40/ft
Influent Field Piping	800	lf		$ 5.00	$ 4,000	underground piping, 1-1/2-in PVC, est. 80 ft per well
Effluent Field Piping	500	lf		$ 5.00	$ 2,500	assume discharge to West Farm Branch stream
Trenching, Backfill, and Compaction	1,300	lf		$ 10.00	$ 13,000	
Groundwater Extraction Pumps	10	ea		$ 5,000.00	$ 50,000	1 gpm ea at approx. 150 ft head
Treatment Building	1	LS		$ 20,000.00	$ 20,000	
Influent Bag Filter	1	LS		$ 2,000.00	$ 2,000	
Liquid-Phase GAC Vessels	4	ea		$ 15,000.00	$ 60,000	2000 lb vessels
Well Permits	15	ea		$ 30.00	$ 450	
Equipment Rental	10	wk		$ 200.00	$ 2,000	
Subtotal Capital Cost					$ 258,950	
Site Work Allowance	15%		of	$ 258,950.00	$ 38,843	
Mechanical Allowance	10%		of	$ 258,950.00	$ 25,895	
Instrumentation and Controls Allowance	5%		of	$ 258,950.00	$ 12,948	
Electrical Allowance	20%		of	$ 258,950.00	$ 51,790	
Miscellaneous Equipment Allowance	5%		of	$ 258,950.00	$ 12,948	
Subtotal Capital Cost					$ 401,373	
Project Management	8%		of	$ 401,372.50	$ 32,110	
Design	15%		of	$ 401,372.50	$ 60,206	
Construction Management	15%		of	$ 401,372.50	$ 60,206	
Subcontractor General Requirements	5%		of	$ 401,372.50	$ 20,069	
Subtotal Capital Cost					$ 573,963	
Contingency	25%		of	$ 573,962.68	$ 143,491	
TOTAL CAPITAL COST					$ 717,453	

COST ESTIMATE DETAILS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 3
DESCRIPTION: Groundwater Extraction and Treatment
PREPARED BY: José Amaya
PROJECT NUMBER: 149209.SA.SM

YEAR 1 OPERATIONS AND MAINTENANCE

Item/Activity	Qty Unit		Unit Cost	Cost	Comments
Well Development					
Labor - Technician	60 hr		$ 55.00	$ 3,300	3 hrs/well, 2 people
Well Development Equipment Rental	1 LS		$ 500.00	$ 500	
Total *Well Development*				$ 3,800	
Groundwater Sampling (Baseline and 4 Qtrs after Startup)					
Labor - Technician	240 hr		$ 55.00	$ 13,200	3 hrs/well, 2 people
Groundwater Sample Analysis	65 sample		$ 150.00	$ 9,750	VOC analysis only, incl 5 QA/QC samples and data valid.
Sampling Supplies	5 round		$ 200.00	$ 1,000	
GW Sampling Equipment Rental	5 round		$ 500.00	$ 2,500	
Total *Groundwater Sampling*				$ 26,450	
System Startup					
Labor - Technician	50 hr		$ 55.00	$ 2,750	Assume 5 days for startup, 10 hrs/day
Labor - Engineer	50 hr		$ 90.00	$ 4,500	Assume 5 days for startup, 10 hrs/day
Water Sample Analysis	6 sample		$ 150.00	$ 900	3 sets, VOC analysis for inf/effl, incl data valid.
Startup Equipment Rental	1 week		$ 200.00	$ 200	
Total *System Startup*				$ 8,350	
Routine System O&M					
Labor - Technician	208 hr		$ 55.00	$ 11,440	4 hours/week
Labor - Engineer	104 hr		$ 90.00	$ 9,360	50% of the Tech time
Water Sample Analysis	29 sample		$ 150.00	$ 4,350	monthly inf/effl sampling for permit, plus 20% extra for QA/QC
Liquid-Phase GAC Changeout	3,761 lb		$ 2.00	$ 7,521	Estimated annual LGAC usage
O&M Supplies	1 LS		$ 2,000.00	$ 2,000	
Electricity	65,700 kw-hr		$ 0.07	$ 4,599	assume 10 hp total, full-time operations
Total *Routine System O&M*				$ 39,270	
Reporting (4 Qtrly Reports incl. Construction Completion Report)					
Labor - Engineer/Hydrogeologist	150 hr		$ 90.00	$ 13,500	
Labor - Editor	50 hr		$ 65.00	$ 3,250	
Labor - CAD Technician	25 hr		$ 65.00	$ 1,625	
Total *Reporting*				$ 18,375	
Subtotal Year 1 Operations and Maintenance				$ 96,245	
Project Management	8%	of	$ 96,245.22	$ 7,700	
Technical Support	15%	of	$ 96,245.22	$ 14,437	
Construction Management	3%	of	$ 96,245.22	$ 2,887	
Subcontractor General Requirements	5%	of	$ 96,245.22	$ 4,812	
Subtotal Year 1 Operations and Maintenance				$ 126,081	
Contingency	25%	of	$ 126,081.24	$ 31,520	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST				**$ 157,602**	

YEARS 2-10 OPERATIONS AND MAINTENANCE

Item/Activity	Qty Unit		Unit Cost	Cost	Comments
Groundwater Sampling (Semiannual Events)					
Labor - Technician	96 hr		$ 55.00	$ 5,280	3 hrs/well, 2 people
Sample Analysis	26 sample		$ 150.00	$ 3,900	VOC analysis only, incl 5 QA/QC samples and data valid.
Sampling Supplies	2 round		$ 200.00	$ 400	
GW Sampling Equipment Rental	2 round		$ 500.00	$ 1,000	
Total *Groundwater Sampling*				$ 10,580	
Routine System O&M					
Labor - Technician	208 hr		$ 55.00	$ 11,440	4 hours/week
Labor - Engineer	52 hr		$ 90.00	$ 4,680	25% of the Tech time
Water Sample Analysis	29 sample		$ 150.00	$ 4,350	monthly inf/effl sampling for permit, plus 20% extra for QA/QC
Liquid-Phase GAC Changeout	3,761 lb		$ 2.00	$ 7,521	Estimated annual LGAC usage
O&M Supplies	1 LS		$ 2,000.00	$ 2,000	
Electricity	65,700 kw-hr		$ 0.07	$ 4,599	assume 10 hp total, full-time operations
Total *Routine System O&M*				$ 34,590	
Reporting (Semiannual Reports)					
Labor - Engineer/Hydrogeologist	60 hr		$ 90.00	$ 5,400	
Labor - Editor	30 hr		$ 65.00	$ 1,950	
Labor - CAD Technician	20 hr		$ 65.00	$ 1,300	
Total *Reporting*				$ 8,650	
Subtotal Following Years Operations and Maintenance				$ 53,820	
Project Management	8%	of	$ 53,820.22	$ 4,306	
Technical Support	10%	of	$ 53,820.22	$ 5,382	
Construction Management	0%	of	$ 53,820.22	$ -	
Subcontractor General Requirements	5%	of	$ 53,820.22	$ 2,691	
Subtotal Following Years Operations and Maintenance				$ 66,199	
Contingency	25%	of	$ 66,198.87	$ 16,550	
TOTAL FOLLOWING YEARS OPERATIONS AND MAINTENANCE COST				**$ 82,749**	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3
DESCRIPTION:	Groundwater Extraction and Treatment
PREPARED BY:	José Ameya
PROJECT NUMBER:	149206.SA.SM

FIVE YEAR REVIEW COST

Item/Activity	Qty	Unit		Unit Cost	Cost	Comments
5-year Review Report						
5-year Review Report	1	LS		$ 5,000.00	$ 5,000	
Subtotal Five Year Review Cost					$ 5,000	
Project Management	0%		of	$ 5,000.00	$ -	
Technical Support	0%		of	$ 5,000.00	$ -	
Construction Management	0%		of	$ 5,000.00	$ -	
Subcontractor General Requirements	0%		of	$ 5,000.00	$ -	
Subtotal Five Year Review Cost					$ 5,000	
Contingency	10%		of	$ 5,000.00	$ 500	
TOTAL FIVE YEAR REVIEW COST					$ 5,500	

POST CLOSURE COST

Item/Activity	Qty	Unit		Unit Cost	Cost	Comments
Closure Reporting						
Labor - Engineer/Hydrogeologist	100	hr		$90.00	$ 9,000	
Labor - Editor	50	hr		$65.00	$ 3,250	
Labor - CAD Technician	25	hr		$65.00	$ 1,625	
Total *Closure Reporting*					$ 13,875	
Well Abandonment and Equipment Demobilization						
Well Abandonment	26	well		$ 500.00	$ 13,000	
Equipment Demobilization	1	LS		$ 10,000.00	$ 10,000	
Equipment Rental	2	wk		$ 200.00	$ 400	
Subtotal Well Abandonment and Equipment Demobilization					$ 23,400	
Site Work Allowance	10%		of	$ 23,400.00	$ 2,340	
Mechanical Allowance	15%		of	$ 23,400.00	$ 3,510	
Instrumentation and Controls Allowance	5%		of	$ 23,400.00	$ 1,170	
Electrical Allowance	15%		of	$ 23,400.00	$ 3,510	
Miscellaneous Equipment Allowance	0%		of	$ 23,400.00	$ -	
Total *Well Abandonment and Equipment Demobilization*					$ 33,930	
Subtotal Post-Closure Cost					$ 47,805	
Project Management	8%		of	$ 47,805.00	$ 3,824	
Technical Support	15%		of	$ 47,805.00	$ 7,171	
Construction Management	10%		of	$ 47,805.00	$ 4,781	
Subcontractor General Requirements	5%		of	$ 47,805.00	$ 2,390	
Subtotal Post-Closure Cost					$ 65,971	
Contingency	15%		of	$65,970.90	$ 9,896	
TOTAL POST CLOSURE COST					$ 75,867	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 3
DESCRIPTION: *Groundwater Extraction and Treatment*
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ 717,453		$ 717,453	$ 717,453	$ -	$ 717,453	$ 822,239
1	2003	0.960		$ 157,602	$ 157,602	$ -	$ 151,249	$ 151,249	$ 692,552
2	2004	0.921		$ 82,749	$ 82,749	$ -	$ 76,212	$ 76,212	$ 635,415
3	2005	0.884		$ 82,749	$ 82,749	$ -	$ 73,140	$ 73,140	$ 575,878
4	2006	0.848		$ 82,749	$ 82,749	$ -	$ 70,192	$ 70,192	$ 513,841
5	2007	0.814		$ 88,249	$ 88,249	$ -	$ 71,840	$ 71,840	$ 443,468
6	2008	0.781		$ 82,749	$ 82,749	$ -	$ 64,648	$ 64,648	$ 375,869
7	2009	0.750		$ 82,749	$ 82,749	$ -	$ 62,042	$ 62,042	$ 305,432
8	2010	0.720		$ 82,749	$ 82,749	$ -	$ 59,541	$ 59,541	$ 232,036
9	2011	0.691		$ 82,749	$ 82,749	$ -	$ 57,141	$ 57,141	$ 155,557
10	2012	0.663		$ 82,749	$ 82,749	$ -	$ 54,838	$ 54,838	$ 75,867
11	2013	0.636	$ 75,867		$ 75,867	$ 56,882	$ -	$ 48,251	$ 0
12	2014	0.610			$ -	$ -	$ -	$ -	$ 0
13	2015	0.586			$ -	$ -	$ -	$ -	$ 0
14	2016	0.562			$ -	$ -	$ -	$ -	$ 0
15	2017	0.539			$ -	$ -	$ -	$ -	$ 0
16	2018	0.518			$ -	$ -	$ -	$ -	$ 0
17	2019	0.497			$ -	$ -	$ -	$ -	$ 0
18	2020	0.477			$ -	$ -	$ -	$ -	$ 0
19	2021	0.458			$ -	$ -	$ -	$ -	$ 0
20	2022	0.439			$ -	$ -	$ -	$ -	$ 0
21	2023	0.421			$ -	$ -	$ -	$ -	$ 0
22	2024	0.404			$ -	$ -	$ -	$ -	$ 0
23	2025	0.388			$ -	$ -	$ -	$ -	$ 0
24	2026	0.373			$ -	$ -	$ -	$ -	$ 0
25	2027	0.358			$ -	$ -	$ -	$ -	$ 0
26	2028	0.343			$ -	$ -	$ -	$ -	$ 0
27	2029	0.329			$ -	$ -	$ -	$ -	$ 0
28	2030	0.316			$ -	$ -	$ -	$ -	$ 0
29	2031	0.303			$ -	$ -	$ -	$ -	$ 0
30	2032	0.291			$ -	$ -	$ -	$ -	$ 0
Total Alternative 3			**$ 793,320**	**$ 907,839**	**$ 1,701,159**	**$ 774,336**	**$ 740,846**	**$ 1,506,550**	

Appendix C-3A
Alternative 3A—Groundwater Extraction with Rock Fracturing

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3 - A
DESCRIPTION:	Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Construction	$	720,373
Project Management	$	57,630
Design	$	43,222
Construction Management	$	43,222
Subcontractor General Requirements	$	36,019
Contingency	$	225,116
Total Capital Cost	**$**	**1,125,582**
Year 1 Operations and Maintenance		
Well Development	$	3,800
Groundwater Sampling (Baseline and 4 Qtrs after Startup)	$	26,450
System Startup	$	8,350
Routine System O&M	$	43,031
Reporting (4 Qtrly Reports incl. Construction Completion Report)	$	18,375
Professional Services [1]	$	26,002
Subcontractor General Requirements	$	5,000
Contingency	$	32,752
Total Year 1 Operations and Maintenance	**$**	**163,760**
Years 2 thru 6 Operation and Maintenance		
Groundwater Sampling (Semiannual Events)	$	10,580
Routine System O&M	$	38,351
Reporting (Semiannual Reports)	$	8,650
Professional Services [1]	$	10,365
Subcontractor General Requirements	$	2,879
Contingency	$	17,706
Total Following Years Operations and Maintenance	**$**	**88,531**
Post Closure Cost		
Closure Reporting	$	13,875
Well Abandonment and Equipment Demobilization	$	33,930
Professional Services [1]	$	15,776
Subcontractor General Requirements	$	2,390
Contingency	$	9,896
Total Post Closure Cost	**$**	**75,867**
TOTAL PRESENT WORTH (10 year cleanup)	**$**	**1,715,744**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2004 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3 - A
DESCRIPTION:	Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Site Background Data

Elevation of Site = 250 ft amsl or 14.56 psia
Length of Target Groundwater Contamination Zone = 465 ft
Width of Target Groundwater Contamination Zone = 466 ft
Area of Contaminated Groundwater Target Zone = 217,156 sf
Depth to Top of Target Zone = 25 ft
Depth to Bottom of Target Zone = 130 ft (estimate of average depthof contaminant)
Rock Porosity = 0.05
Volume of Contaminated Groundwater = 1,140,069 cf or 32,286,754 liters

Hydraulic Conductivity, K = 0.006 ft/day (assumption) or 2 ft/yr or 2.12E-06 cm/sec
Hydraulic Gradient, i = 0.2 ft/ft (taken from interpolated groundwater contour map Figure 2-3)

Average contaminant concentrations

PCE	50	µg/L
TCE	1,000	µg/L
DCE	150	µg/L
VC	2	µg/L
Total CVOCs	1,202	µg/L

Mass Estimate

Assumptions
1. Bedrock formations are the target of this remediation.
2. No mobile NAPL is present.

Mass of CVOCs in groundwat 85.6 lbs of CVOCs

Conceptual Design

Pumping System Design Parameters
Estimated Number of Pumping Wells = 10 wells
Estimated pumping rate from each well = 1.5 gpm
Total Maximum Pumping Rate 15 gpm or a sustained pumping rate of 15 gpm
Depth of pumping wells = 130 ft bgs

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 3 - A
DESCRIPTION: Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

System Construction Time

Estimated drilling rate = 100 lf/day Using air rotary
Total linear footage drilling = 1,040 lf
Estimated duration of drilling = 10.4 days or 11 days
Estimated linear footage of field piping per pumping well = 80 ft per well
Total linear footage of field piping = 800 lf
Estimated field piping placing rate = 50 lf/day
Estimated duration of field piping = 16.0 days or 16 days (rounded up)
Total construction timeframe = 27 days

Granular Activated Carbon (GAC) Conceptual Design Parameters

All organic contaminants found in water are adsorbable with GAC.
GAC treatment system design flowrate is 15 gpm
Governing contaminant TCE at 1,000 mg/L (use no safety factor for average GAC consumption estimate)

Carbon adsorption Freundlich Isotherm data obtained from USACOE Adsorption Design Guide 1110-1-2 (March 2001)
Adsorption constant, q = K*c^(1/n) where: q = mg CTC / g GAC
K and (1/n) are Freundlich Isotherm constants
c = concentration of CTC in mg/L

Use average constants for several brands of GAC. (USACOE Design Guide 1110-1-2, March 2001)
Assume: K = 28
(1/n) = 0.62
c = 1,000 µg/L
Calculate q = 28.0 mg TCE/gm GAC or 0.028 gm TCE/gm GAC or 2.8% pickup
GAC usage rate for TCE only 0.27 lbs GAC/hr or 6.4 lbs GAC/day or 2,346 lbs GAC/yr
Assuming a multiplier of 2.40 for additional organic contaminants that will also adsorb and use carbon, and iron fouling
The total GAC usage rate = 0.6 lbs GAC/hr or 15.5 lbs GAC/day or 5,641 lbs GAC/yr
Assuming a carbon cost of $2.00 per lb GAC for supply and changeout --> $11,282 per year GAC

Assume a changeout period of 4 times per year
The desired changeout period drives the size of the vessels = 1,410 lb size
Assume a carbon vessel size of 2,000 lb and we need 2 vessels in series for safety factor.

Assuming a 2,000 lb vessel costs $15,000 with GAC, total cost = $30,000 for vessels and GAC only.
in addition, there would be an annual recurring cost of $11,282 for GAC changeout

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3 - A
DESCRIPTION:	Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%
2. See "Conceptual Design" spreadsheet for basis of cost estimate assumptions.
3. The number of new Coastal Plain monitoring wells required to be installed [ ] wells
4. The number of new bedrock/Saprolite monitoring wells required to be installed [5] wells
5. Number of Groundwater Extraction Wells to be installed = [10] wells
6. Number of piezometers to be installed = [ ] piezometers
7. Assume that the duration of construction is [50] working days (includes 20 working days for treatment system construction and installation)
8. The number of wells to be sampled for VOCs is [8] wells per round
9. The number of wells on-site to be abandoned for post-closure is [26] wells

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments and References
Construction							
Coastal Plain Groundwater Monitoring Well Installation	0	well	$	2,320.00	$	-	Assume 2-inch wells are 130 ft deep @ $40/ft
Bedrock/Saprolite Groundwater Monitoring Well Installation	5	well	$	5,000.00	$	25,000	Assume 100' deep @ $50/ft
Pre-Design Pump Test	1	LS	$	10,000.00	$	10,000	
Groundwater Extraction Well Installation	10	well	$	7,000.00	$	70,000	4-inch wells @ $50/ft
Pneumatic Fracturing	1400	LF	$	250.00	$	350,000	
Piezometer Installation	0	well	$	2,320.00	$	-	Assume 2-inch wells are 130 ft deep @ $40/ft
Influent Field Piping	800	lf	$	5.00	$	4,000	underground piping, 1-1/2-in PVC, est. 80 ft per well
Effluent Field Piping	500	lf	$	5.00	$	2,500	assume discharge to West Farm Branch stream
Trenching, Backfill, and Compaction	1,300	lf	$	10.00	$	13,000	
Groundwater Extraction Pumps	10	ea	$	5,000.00	$	50,000	1.5 gpm ea at approx. 150 ft head
Influent Bag Filter	1	LS	$	2,000.00	$	2,000	
Liquid-Phase GAC Vessels	4	ea	$	15,000.00	$	60,000	2000 lb vessels
Well Permits	15	ea	$	30.00	$	450	
Equipment Rental	10	wk	$	200.00	$	2,000	
Subtotal Capital Cost					$	588,950	
Site Work Allowance	15%	of	$	238,950.00	$	35,843	
Mechanical Allowance	10%	of	$	238,950.00	$	23,895	
Instrumentation and Controls Allowance	5%	of	$	238,950.00	$	11,948	
Electrical Allowance	20%	of	$	238,950.00	$	47,790	
Miscellaneous Equipment Allowance	5%	of	$	238,950.00	$	11,948	
Subtotal Capital Cost					$	720,373	
Project Management	8%	of	$	720,372.50	$	57,630	
Design	6%	of	$	720,372.50	$	43,222	
Construction Management	6%	of	$	720,372.50	$	43,222	
Subcontractor General Requirements	5%	of	$	720,372.50	$	36,019	
Subtotal Capital Cost					$	900,466	
Contingency	25%	of	$	900,465.63	$	225,116	
TOTAL CAPITAL COST					$	1,125,582	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3 - A
DESCRIPTION:	Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

YEAR 1 OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Well Development							
Labor - Technician	60	hr	$	55.00	$	3,300	3 hrs/well, 2 people
Well Development Equipment Rental	1	LS	$	500.00	$	500	
Total *Well Development*					$	3,800	
Groundwater Sampling (Baseline and 4 Qtrs after Startup)							
Labor - Technician	240	hr	$	55.00	$	13,200	3 hrs/well, 2 people
Groundwater Sample Analysis	65	sample	$	150.00	$	9,750	VOC analysis only, incl 5 QA/QC samples and data valid.
Sampling Supplies	5	round	$	200.00	$	1,000	
GW Sampling Equipment Rental	5	round	$	500.00	$	2,500	
Total *Groundwater Sampling*					$	26,450	
System Startup							
Labor - Technician	50	hr	$	55.00	$	2,750	Assume 5 days for startup, 10 hrs/day
Labor - Engineer	50	hr	$	90.00	$	4,500	Assume 5 days for startup, 10 hrs/day
Water Sample Analysis	6	sample	$	150.00	$	900	3 sets, VOC analysis for infl/effl, incl data valid.
Startup Equipment Rental	1	week	$	200.00	$	200	
Total *System Startup*					$	8,350	
Routine System O&M							
Labor - Technician	208	hr	$	55.00	$	11,440	4 hours/week
Labor - Engineer	104	hr	$	90.00	$	9,360	50% of the Tech time
Water Sample Analysis	29	sample	$	150.00	$	4,350	monthly infl/effl sampling for permit, plus 20% extra for QA/QC
Liquid-Phase GAC Changeout	5,641	lb	$	2.00	$	11,282	Estimated annual LGAC usage
O&M Supplies	1	LS	$	2,000.00	$	2,000	
Electricity	65,700	kw-hr	$	0.07	$	4,599	assume 10 hp total, full-time operations
Total *Routine System O&M*					$	43,031	
Reporting (4 Qtrly Reports incl. Construction Completion Report)							
Labor - Engineer/Hydrogeologist	150	hr	$	90.00	$	13,500	
Labor - Editor	50	hr	$	65.00	$	3,250	
Labor - CAD Technician	25	hr	$	65.00	$	1,625	
Total *Reporting*					$	18,375	
Subtotal Year 1 Operations and Maintenance					$	100,006	
Project Management	8%	of	$	100,005.83	$	8,000	
Technical Support	15%	of	$	100,005.83	$	15,001	
Construction Management	3%	of	$	100,005.83	$	3,000	
Subcontractor General Requirements	5%	of	$	100,005.83	$	5,000	
Subtotal Year 1 Operations and Maintenance					$	131,008	
Contingency	25%	of	$	131,007.63	$	32,752	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST					$	163,760	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	3 - A
DESCRIPTION:	Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

YEARS 2 THRU 6 OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Groundwater Sampling (Semiannual Events)							
Labor - Technician	96	hr	$	55.00	$	5,280	3 hrs/well, 2 people
Sample Analysis	26	sample	$	150.00	$	3,900	VOC analysis only, incl 5 QA/QC samples and data valid.
Sampling Supplies	2	round	$	200.00	$	400	
GW Sampling Equipment Rental	2	round	$	500.00	$	1,000	
Total *Groundwater Sampling*					$	10,580	
Routine System O&M							
Labor - Technician	208	hr	$	55.00	$	11,440	4 hours/week
Labor - Engineer	52	hr	$	90.00	$	4,680	25% of the Tech time
Water Sample Analysis	29	sample	$	150.00	$	4,350	monthly infl/effl sampling for permit, plus 20% extra for QA/QC
Liquid-Phase GAC Changeout	5,641	lb	$	2.00	$	11,282	Estimated annual LGAC usage
O&M Supplies	1	LS	$	2,000.00	$	2,000	
Electricity	65,700	kw-hr	$	0.07	$	4,599	assume 10 hp total, full-time operations
Total *Routine System O&M*					$	38,351	
Reporting (Semiannual Reports)							
Labor - Engineer/Hydrogeologist	60	hr	$	90.00	$	5,400	
Labor - Editor	30	hr	$	65.00	$	1,950	
Labor - CAD Technician	20	hr	$	65.00	$	1,300	
Total *Reporting*					$	8,650	
Subtotal Years 2 Thru 6 Operations and Maintenance					$	57,581	
Project Management	8%	of	$	57,580.83	$	4,606	
Technical Support	10%	of	$	57,580.83	$	5,758	
Construction Management	0%	of	$	57,580.83	$	-	
Subcontractor General Requirements	5%	of	$	57,580.83	$	2,879	
Subtotal Following Years Operations and Maintenance					$	70,824	
Contingency	25%	of	$	70,824.42	$	17,706	
TOTAL FOLLOWING YEARS OPERATIONS AND MAINTENANCE COST					$	88,531	

POST CLOSURE COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Closure Reporting							
Labor - Engineer/Hydrogeologist	100	hr		$90.00	$	9,000	
Labor - Editor	50	hr		$65.00	$	3,250	
Labor - CAD Technician	25	hr		$65.00	$	1,625	
Total *Closure Reporting*					$	13,875	
Well Abandonment and Equipment Demobilization							
Well Abandonment	26	well	$	500.00	$	13,000	
Equipment Demobilization	1	LS	$	10,000.00	$	10,000	
Equipment Rental	2	wk	$	200.00	$	400	
Subtotal Well Abandonment and Equipment Demobilization					$	23,400	
Site Work Allowance	10%	of	$	23,400.00	$	2,340	
Mechanical Allowance	15%	of	$	23,400.00	$	3,510	
Instrumentation and Controls Allowance	5%	of	$	23,400.00	$	1,170	
Electrical Allowance	15%	of	$	23,400.00	$	3,510	
Miscellaneous Equipment Allowance	0%	of	$	23,400.00	$	-	
Total *Well Abandonment and Equipment Demobilization*					$	33,930	
Subtotal Post-Closure Cost					$	47,805	
Project Management	8%	of	$	47,805.00	$	3,824	
Technical Support	15%	of	$	47,805.00	$	7,171	
Construction Management	10%	of	$	47,805.00	$	4,781	
Subcontractor General Requirements	5%	of	$	47,805.00	$	2,390	
Subtotal Post-Closure Cost					$	65,971	
Contingency	15%	of		$65,970.90	$	9,896	
TOTAL POST CLOSURE COST					$	75,867	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 3 - A
DESCRIPTION: Groundwater Extraction and Treatment with Rock Fracturing
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ 1,125,582		$ 1,125,582	$ 1,125,582	$ -	$ 1,125,582	$ 614,948
1	2003	0.960		$ 163,760	$ 163,760	$ -	$ 157,159	$ 157,159	$ 470,139
2	2004	0.921		$ 88,531	$ 88,531	$ -	$ 81,538	$ 81,538	$ 397,636
3	2005	0.884		$ 88,531	$ 88,531	$ -	$ 78,251	$ 78,251	$ 322,088
4	2006	0.848		$ 88,531	$ 88,531	$ -	$ 75,097	$ 75,097	$ 243,367
5	2007	0.814		$ 88,531	$ 88,531	$ -	$ 72,070	$ 72,070	$ 161,339
6	2008	0.781		$ 88,531	$ 88,531	$ -	$ 69,165	$ 69,165	$ 75,867
7	2009	0.750	$ 75,867		$ 75,867	$ 56,882	$ -	$ 56,882	$ (0)
8	2010	0.720			$ -	$ -	$ -	$ -	$ (0)
9	2011	0.691			$ -	$ -	$ -	$ -	$ (0)
10	2012	0.663			$ -	$ -	$ -	$ -	$ (0)
11	2013	0.636			$ -	$ -	$ -	$ -	$ (0)
12	2014	0.610			$ -	$ -	$ -	$ -	$ (0)
13	2015	0.586			$ -	$ -	$ -	$ -	$ (0)
14	2016	0.562			$ -	$ -	$ -	$ -	$ (0)
15	2017	0.539			$ -	$ -	$ -	$ -	$ (0)
16	2018	0.518			$ -	$ -	$ -	$ -	$ (0)
17	2019	0.497			$ -	$ -	$ -	$ -	$ (0)
18	2020	0.477			$ -	$ -	$ -	$ -	$ (0)
19	2021	0.458			$ -	$ -	$ -	$ -	$ (0)
20	2022	0.439			$ -	$ -	$ -	$ -	$ (0)
21	2023	0.421			$ -	$ -	$ -	$ -	$ (0)
22	2024	0.404			$ -	$ -	$ -	$ -	$ (0)
23	2025	0.388			$ -	$ -	$ -	$ -	$ (0)
24	2026	0.373			$ -	$ -	$ -	$ -	$ (0)
25	2027	0.358			$ -	$ -	$ -	$ -	$ (0)
26	2028	0.343			$ -	$ -	$ -	$ -	$ (0)
27	2029	0.329			$ -	$ -	$ -	$ -	$ (0)
28	2030	0.316			$ -	$ -	$ -	$ -	$ (0)
29	2031	0.303			$ -	$ -	$ -	$ -	$ (0)
30	2032	0.291			$ -	$ -	$ -	$ -	$ (0)
Total Alternative 3 - A			**$ 1,201,449**	**$ 606,412**	**$ 1,807,861**	**$ 1,182,464**	**$ 533,279**	**$ 1,715,744**	

Appendix C-4
Alternative 4—In situ Chemical Oxidation

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	4
DESCRIPTION:	In-Situ Chemical Oxidation
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Construction	$	365,935
Project Management	$	29,275
Design	$	21,956
Construction Management	$	36,594
Subcontractor General Requirements	$	18,297
Contingency	$	118,014
Total Capital Cost	**$**	**590,071**
Year 1 Operations and Maintenance		
4 Rnds Groundwater Sampling	$	57,325
Reporting (Annual Reports)	$	23,200
Professional Services [1]	$	12,884
Subcontractor General Requirements	$	4,026
Contingency	$	24,359
Total Year 1 Operations and Maintenance	**$**	**121,794**
Year 2 - 6 Operations and Maintenance		
Annual Groundwater Sampling	$	9,190
Reporting (Annual Report)	$	6,775
Professional Services [1]	$	2,395
Subcontractor General Requirements	$	-
Contingency	$	2,754
Total Year 2 Operations and Maintenance	**$**	**21,114**
Post Closure Cost		
Closure Reporting	$	13,875
Well Abandonment and Equipment Demobilization	$	29,041
Professional Services [1]	$	14,162
Subcontractor General Requirements	$	2,146
Contingency	$	8,884
Total Post Closure Cost	**$**	**68,108**
TOTAL PRESENT WORTH	**$**	**833,371**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2004 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 4
DESCRIPTION: In-Situ Chemical Oxidation
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Site Background Data

Elevation of Site = 250 ft amsl or 14.55 psia
Length of Target Groundwater Contamination Zone = 466 ft
Width of Target Groundwater Contamination Zone = 466 ft
Area of Contaminated Groundwater Target Zone = 217,156 sf
Depth to Top of Target Zone = 25 ft
Depth to Bottom of Target Zone = 130 ft (estimate of the approximate depth to the Saprolite formation)
Rock Porosity = 0.05
Volume of Contaminated Groundwater = 1,140,069 cf or 32,286,754 liters

Hydraulic Conductivity, K = 0.003 ft/day (assumption) or 1 ft/yr or 1.06E-06 cm/sec
Hydraulic Gradient, I = 0.2 ft/ft (taken from interpolated groundwater contour map Figure 2-3)

Average contaminant concentrations in the two source area wells 19GW02 and 19GW202 are:

PCE	50	µg/L
TCE	1,000	µg/L
DCE	150	µg/L
VC	2	µg/L
Total CVOCs	1,202	µg/L

Mass Estimate

Assumptions
1. Bedrock formations are the target of this remediation.
2. No mobile NAPL is present.

Mass of CVOCs in groundwater = 85.6 lbs

Conceptual Design

Assumptions
1. Use potasium permanganate.
2. Specific gravity of 3% permanganate = 1.02 or 8.51 lbs/gal
3. Stoichiometric premanganate Dose = 2 mol permanganate per mol of TCE

ISCO Injection Only System Conceptual Design

Injection Well Design
Assume a vertical well delivery system will be installed to inject the permanganate into the target zone.
Estimated number of permanganate injection wells = 25 2 lines of 12 wells, and 1 well at the former leaching well

Potasium Permanganate Dose Calculations
Mass of CVOCs in groundwater = 86 lbs
Total mass of hydrogen peroxide needed = 205 lbs to satisfy the stoichiometric requirements
307 with 50% contingency

Assume permanganate will be diluted 3% by weight
Total Volume of Solution to be Injected = 2,468 gallons of of permanganate solution with 100 % contingency

Construction and Treatment Time
Total linear feet of drilling = 3,235 lf (assuming injection occure throughout the target zone)
Assume HSA rig can drill 80 lf/day including installation of the injection point
Number of on-site days for drill rig = 40.4 days or rounding up = 41 days

Assume the treatment will be performed during two injections to be performed within one year timeframe.

Assume first injection will utilize 100% of the total potassium permanganate

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	4
DESCRIPTION:	In-Situ Chemical Oxidation
PREPARED BY:	José Amaya
PROJECT NUMBER:	146206.9A.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%
2. See "Conceptual Design" spreadsheet for basis of cost estimate assumptions.
3. The number of new Coastal Plain monitoring wells required to be installed [redacted] wells
4. The number of new bedrock/Saprolite monitoring wells required to be installed [redacted] wells
5. Number of ISCO Wells to be installed = 25 wells
6. Assume that the duration of well installation is 41 working days (includes time for monitoring and treatment well installation)
7. Assume that the duration of solution injection is 25 working days
8. The number of wells to be sampled for VOCs is [redacted] wells per round
9. The number of wells on-site to be abandoned for post-closure is [redacted] wells

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments and References
Construction							
Source Area Pilot Test	1	LS	$	100,000.00	$	100,000	Test to determine optimum electron donor/dose
Bedrock ISCO Well Installation	60	well	$	5,000.00	$	150,000	Assume 100' deep @ $50/ft
Pneumatic Fracturing	[redacted]	LF	$	250.00	$	-	
Well Permits	60	ea	$	30.00	$	900	
Equipment Rental	25	day	$	200.00	$	5,000	
System Startup - Permanganate Injection							
Reagent Supply	307	lb	$	23.00	$	7,066	
Injection Equipment Rental - Subcontractor	42	day	$	100.00	$	4,200	
Injection Subcontractor - Labor	42	day	$	2,180.80	$	91,594	
Labor - Engineer		hr	$	50.00	$	-	
Total System Startup - Permanganate Injection					$	102,860	
Subtotal Capital Cost					$	358,760	
Site Work Allowance	0%	of	$	358,760.17	$	-	
Mechanical Allowance	0%	of	$	358,760.17	$	-	
Instrumentation and Controls Allowance	0%	of	$	358,760.17	$	-	
Electrical Allowance	0%	of	$	358,760.17	$	-	
Miscellaneous Equipment Allowance	2%	of	$	358,760.17	$	7,175	
Subtotal Capital Cost					$	365,935	
Project Management	8%	of	$	365,935.87	$	29,275	
Design	6%	of	$	365,935.87	$	21,956	
Construction Management	10%	of	$	365,935.87	$	36,594	
Subcontractor General Requirements	5%	of	$	365,935.87	$	18,297	
Subtotal Capital Cost					$	472,057	
Contingency	25%	of	$	472,053.69	$	118,014	
TOTAL CAPITAL COST					$	590,071	

YEAR 1 OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
4 Rnds Groundwater Sampling							
Labor - Technician	240	hr	$	55.00	$	13,200	3 hrs/well, 2 people
Groundwater Sample Analysis	65	sample	$	625.00	$	40,625	VOC analysis, incl 5 QA/QC samples and data valid.
Sampling Supplies	5	round	$	200.00	$	1,000	
GW Sampling Equipment Rental	5	round	$	500.00	$	2,500	
Total Groundwater Sampling					$	57,325	
Reporting (Annual Reports)							
Labor - Engineer/Hydrogeologist	200	hr	$	90.00	$	18,000	
Labor - Editor	40	hr	$	65.00	$	2,600	
Labor - CAD Technician	40	hr	$	65.00	$	2,600	
Total Reporting					$	23,200	
Subtotal Year 1 Operations and Maintenance					$	80,525	
Project Management	8%	of	$	80,525.00	$	6,442	
Technical Support	5%	of	$	80,525.00	$	4,026	
Construction Management	3%	of	$	80,525.00	$	2,416	
Subcontractor General Requirements	5%	of	$	80,525.00	$	4,026	
Subtotal Year 1 Operations and Maintenance					$	97,435	
Contingency	25%	of	$	97,435.25	$	24,359	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST					$	121,794	

COST ESTIMATE DETAILS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 4
DESCRIPTION: In-Situ Chemical Oxidation
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

YEAR 2 THRU 6 OPERATIONS AND MANTENANCE

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Annual Groundwater Sampling							
Labor - Technician	48	hr	$	55.00	$	2,640	3 hrs/well, 2 people
Groundwater Sample Analysis	19	sample	$	450.00	$	5,950	VOC/MNA/metals analysis, incl 5 QA/QC samples and data valid.
Sampling Supplies	1	round	$	200.00	$	200	
GW Sampling Equipment Rental	1	round	$	500.00	$	500	
Total *Quarterly Groundwater Sampling*					$	9,190	
Reporting (Annual Report)							
Labor - Engineer/Hydrogeologist	50	hr	$	90.00	$	4,500	
Labor - Editor	25	hr	$	65.00	$	1,625	
Labor - CAD Technician	10	hr	$	65.00	$	650	
Total *Reporting*					$	6,775	
Subtotal *Year 2 Operations and Maintenance*					$	15,965	
Project Management	5%	of	$	15,965.00	$	798	
Technical Support	10%	of	$	15,965.00	$	1,597	
Construction Management	0%	of	$	15,965.00	$	-	
Subcontractor General Requirements	0%	of	$	15,965.00	$	-	
Subtotal *Year 2 Operations and Maintenance*					$	18,360	
Contingency	15%	of	$	18,359.75	$	2,754	
TOTAL YEAR 2 THRU 6 OPERATIONS AND MAINTENANCE COST					$	21,114	

POST CLOSURE COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Closure Reporting							
Labor - Engineer/Hydrogeologist	100	hr		$90.00	$	9,000	
Labor - Editor	50	hr		$65.00	$	3,250	
Labor - CAD Technician	25	hr		$65.00	$	1,625	
Total *Closure Reporting*					$	13,875	
Well Abandonment and Equipment Demobilization							
Well Abandonment	41	well	$	500.00	$	20,500	Assume abandon 10 wells/day
Equipment Demobilization	1	LS	$	5,000.00	$	5,000	
Equipment Rental	1	wk	$	200.00	$	200	MultiRAE
Subtotal *Well Abandonment and Equipment Demobilization*					$	25,700	
Site Work Allowance	8%	of	$	25,700.00	$	2,055	
Mechanical Allowance	0%	of	$	25,700.00	$	-	
Instrumentation and Controls Allowance	0%	of	$	25,700.00	$	-	
Electrical Allowance	0%	of	$	25,700.00	$	-	
Miscellaneous Equipment Allowance	5%	of	$	25,700.00	$	1,285	
Total *Well Abandonment and Equipment Demobilization*					$	29,041	
Subtotal Post-Closure Cost					$	42,916	
Project Management	8%	of	$	42,916.00	$	3,433	
Technical Support	15%	of	$	42,916.00	$	6,437	
Construction Management	10%	of	$	42,916.00	$	4,292	
Subcontractor General Requirements	5%	of	$	42,916.00	$	2,146	
Subtotal Post-Closure Cost					$	59,224	
Contingency	15%	of		$59,224.09	$	8,884	
TOTAL POST CLOSURE COST					$	68,108	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 4
DESCRIPTION: In-Situ Chemical Oxidation
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ 590,071		$ 590,071	$ 590,071	$ -	$ 590,071	$ 253,519
1	2003	0.960		$ 121,794	$ 121,794	$ -	$ 116,885	$ 116,885	$ 137,258
2	2004	0.921		$ 21,114	$ 21,114	$ -	$ 19,446	$ 19,446	$ 121,022
3	2005	0.884		$ 21,114	$ 21,114	$ -	$ 18,662	$ 18,662	$ 104,104
4	2006	0.848		$ 21,114	$ 21,114	$ -	$ 17,910	$ 17,910	$ 86,476
5	2007	0.814		$ 21,114	$ 21,114	$ -	$ 17,188	$ 17,188	$ 68,108
6	2008	0.781	$ 68,108		$ 68,108	$ 53,210	$ -	$ 53,210	$ (0)
7	2009	0.750			$ -	$ -	$ -	$ -	$ (0)
8	2010	0.720			$ -	$ -	$ -	$ -	$ (0)
9	2011	0.691			$ -	$ -	$ -	$ -	$ (0)
10	2012	0.663			$ -	$ -	$ -	$ -	$ (0)
11	2013	0.636			$ -	$ -	$ -	$ -	$ (0)
12	2014	0.610			$ -	$ -	$ -	$ -	$ (0)
13	2015	0.586			$ -	$ -	$ -	$ -	$ (0)
14	2016	0.562			$ -	$ -	$ -	$ -	$ (0)
15	2017	0.539			$ -	$ -	$ -	$ -	$ (0)
16	2018	0.518			$ -	$ -	$ -	$ -	$ (0)
17	2019	0.497			$ -	$ -	$ -	$ -	$ (0)
18	2020	0.477			$ -	$ -	$ -	$ -	$ (0)
19	2021	0.458			$ -	$ -	$ -	$ -	$ (0)
20	2022	0.439			$ -	$ -	$ -	$ -	$ (0)
21	2023	0.421			$ -	$ -	$ -	$ -	$ (0)
22	2024	0.404			$ -	$ -	$ -	$ -	$ (0)
23	2025	0.388			$ -	$ -	$ -	$ -	$ (0)
24	2026	0.373			$ -	$ -	$ -	$ -	$ (0)
25	2027	0.358			$ -	$ -	$ -	$ -	$ (0)
26	2028	0.343			$ -	$ -	$ -	$ -	$ (0)
27	2029	0.329			$ -	$ -	$ -	$ -	$ (0)
28	2030	0.316			$ -	$ -	$ -	$ -	$ (0)
29	2031	0.303			$ -	$ -	$ -	$ -	$ (0)
30	2032	0.291			$ -	$ -	$ -	$ -	$ (0)
Total Alternative 4			**$ 658,178**	**$ 206,249**	**$ 864,427**	**$ 643,280**	**$ 190,091**	**$ 833,371**	

Appendix C-4A
Alternative 4A—ISCO with Rock Fracturing

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	4 - A
DESCRIPTION:	In-Situ Chemical Oxidation with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Construction	$	581,913
Project Management	$	46,553
Design	$	34,915
Construction Management	$	58,191
Subcontractor General Requirements	$	29,096
Contingency	$	187,667
Total Capital Cost	**$**	**938,335**
Year 1 Operations and Maintenance		
4 Rnds Groundwater Sampling	$	57,325
Reporting (Annual Reports)	$	23,200
Professional Services [1]	$	12,884
Subcontractor General Requirements	$	4,026
Contingency	$	24,359
Total Year 1 Operations and Maintenance	**$**	**121,794**
Year 2 Thru 6 Operations and Maintenance		
Annual Groundwater Sampling	$	9,190
Reporting (Annual Report)	$	6,775
Professional Services [1]	$	2,874
Subcontractor General Requirements	$	-
Contingency	$	2,826
Total Year 2 Thru 6 Operations and Maintenance	**$**	**21,665**
Post Closure Cost		
Closure Reporting	$	13,875
Well Abandonment and Equipment Demobilization	$	22,261
Professional Services [1]	$	11,925
Subcontractor General Requirements	$	1,807
Contingency	$	7,480
Total Post Closure Cost	**$**	**57,348**
TOTAL PRESENT WORTH	**$**	**1,175,139**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2004 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 4 - A
DESCRIPTION: In-Situ Chemical Oxidation with Rock Fracturing
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Site Background Data

Elevation of Site = 250 ft amsl or 14.56 psia
Length of Target Groundwater Contamination Zone = 466 ft
Width of Target Groundwater Contamination Zone = 466 ft
Area of Contaminated Groundwater Target Zone = 217,156 sf
Depth to Top of Target Zone = 25 ft
Depth to Bottom of Target Zone = 135 ft (estimate of the approximate depth to the Saprolite formation)
Rock Porosity = 0.05
Volume of Contaminated Groundwater = 1,140,069 cf or 32,286,754 liters

Hydraulic Conductivity, K = 0.006 ft/day (assumption) or 2 ft/yr or 2.12E-06 cm/sec
Hydraulic Gradient, i = 0.2 ft/ft (taken from interpolated groundwater contour map Figure 2-3)

Average contaminant concentrations in the two source area wells 13GW02 and 13GW202 are:

PCE	50	µg/L
TCE	1,000	µg/L
DCE	150	µg/L
VC	2	µg/L
Total CVOCs	1,202	µg/L

Mass Estimate

Assumptions
1. Bedrock formations are the target of this remediation.
2. No mobile NAPL is present.

Mass of CVOCs in groundwater = 85.6 lbs

Conceptual Design

Assumptions
1. Use potasium permanganate.
2. Specific gravity of 3% permanganate = 1.02 or 8.51 lbs/gal
3. Stoichiometric premanganate Dose = 2 mol permanganate per mol of TCE

ISCO Injection Only System Conceptual Design

Injection Well Design
Assume a vertical well delivery system will be installed to inject the permanganate into the target zone.
Estimated number of peroxide injection wells = 13 2 lines of 6 wells, and 1 well at the former leaching well

Potasium Permanganate Dose Calculations
Mass of CVOCs in groundwater = 86 lbs
Total mass of pot. permanganate needed = 205 lbs to satisfy the stoichiometric requirements
307 with 50% contingency

Assume permanganate will be diluted 3% by weight
Total Volume of Solution to be Injected = 2,466 gallons of of permanganate solution with 100 % contingency

Construction and Treatment Time
Total linear feet of drilling = 1,705 lf (assuming injection occurs throughout the target zone)
Assume HSA rig can drill 80 lf/day including installation of the injection point
Number of on-site days for drill rig = 21.3 days or rounding up = 22 days

Assume the treatment will be performed during two injections to be performed within one year timeframe.

Assume first injection will utilize 100% of the total potassium permanganate

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	4 - A
DESCRIPTION:	In-Situ Chemical Oxidation with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%
2. See "Conceptual Design" spreadsheet for basis of cost estimate assumptions.
3. The number of new Coastal Plain monitoring wells required to be installed [ ] wells
4. The number of new bedrock/Saprolite monitoring wells required to be installed [5] wells
5. Number of ISCO Wells to be installed = 13 wells
6. Assume that the duration of well installation is 22 working days (includes time for monitoring and treatment well installation)
7. Assume that the duration of solution injection is 13 working days
8. The number of wells to be sampled for VOCs is [8] wells per round
9. The number of wells on-site to be abandoned for post-closure is [29] wells

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments and References
Construction							
Source Area Pilot Test	1	LS		$ 100,000.00	$	100,000	Test to determine optimum electron donor/dose
Bedrock ISCO Well Installation	18	well		$ 5,000.00	$	90,000	Assume 100' deep @ $50/ft
Pneumatic Fracturing	1,300	LF		$ 250.00	$	325,000	
Well Permits	18	ea		$ 30.00	$	540	
Equipment Rental		day		$ 200.00	$	-	
System Startup - Permanganate Injection							
Reagent Supply	307	lb		$ 23.00	$	7,066	
Injection Equipment Rental - Subcontractor	21	day		$ 100.00	$	2,100	
Injection Subcontractor - Labor	21	day		$ 2,180.80	$	45,797	
Labor - Engineer		hr		$ 90.00	$	-	
Total *System Startup - Permanganate Injection*					$	54,963	
Subtotal Capital Cost					$	570,503	
Site Work Allowance	0%		of	$ 570,503.28	$	-	
Mechanical Allowance	0%		of	$ 570,503.28	$	-	
Instrumentation and Controls Allowance	0%		of	$ 570,503.28	$	-	
Electrical Allowance	0%		of	$ 570,503.28	$	-	
Miscellaneous Equipment Allowance	2%		of	$ 570,503.28	$	11,410	
Subtotal Capital Cost					$	581,913	
Project Management	8%		of	$ 581,913.34	$	46,553	
Design	6%		of	$ 581,913.34	$	34,915	
Construction Management	10%		of	$ 581,913.34	$	58,191	
Subcontractor General Requirements	5%		of	$ 581,913.34	$	29,096	
Subtotal Capital Cost					$	750,668	
Contingency	25%		of	$ 750,668.21	$	187,667	
TOTAL CAPITAL COST					$	938,335	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	4 - A
DESCRIPTION:	In-Situ Chemical Oxidation with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

YEAR 1 OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
4 Rnds Groundwater Sampling							
Labor - Technician	240	hr	$	55.00	$	13,200	3 hrs/well, 2 people
Groundwater Sample Analysis	65	sample	$	625.00	$	40,625	VOC analysis, incl 5 QA/QC samples and data valid.
Sampling Supplies	5	round	$	200.00	$	1,000	
GW Sampling Equipment Rental	5	round	$	500.00	$	2,500	
Total *Groundwater Sampling*					$	57,325	
Reporting (Annual Reports)							
Labor - Engineer/Hydrogeologist	200	hr	$	90.00	$	18,000	
Labor - Editor	40	hr	$	65.00	$	2,600	
Labor - CAD Technician	40	hr	$	65.00	$	2,600	
Total *Reporting*					$	23,200	
Subtotal Year 1 Operations and Maintenance					$	80,525	
Project Management	8%	of	$	80,525.00	$	6,442	
Technical Support	5%	of	$	80,525.00	$	4,026	
Construction Management	3%	of	$	80,525.00	$	2,416	
Subcontractor General Requirements	5%	of	$	80,525.00	$	4,026	
Subtotal Year 1 Operations and Maintenance					$	97,435	
Contingency	25%	of	$	97,435.25	$	24,359	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST					$	121,794	

YEAR 2 THRU 6 OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Annual Groundwater Sampling							
Labor - Technician	48	hr	$	55.00	$	2,640	3 hrs/well, 2 people
Groundwater Sample Analysis	13	sample	$	450.00	$	5,850	VOC/MNA/metals analysis, incl 5 QA/QC samples and data valid.
Sampling Supplies	1	round	$	200.00	$	200	
GW Sampling Equipment Rental	1	round	$	500.00	$	500	
Total *Quarterly Groundwater Sampling*					$	9,190	
Reporting (Annual Report)							
Labor - Engineer/Hydrogeologist	50	hr	$	90.00	$	4,500	
Labor - Editor	25	hr	$	65.00	$	1,625	
Labor - CAD Technician	10	hr	$	65.00	$	650	
Total *Reporting*					$	6,775	
Subtotal Year 2 Operations and Maintenance					$	15,965	
Project Management	8%	of	$	15,965.00	$	1,277	
Technical Support	10%	of	$	15,965.00	$	1,597	
Construction Management	0%	of	$	15,965.00	$	-	
Subcontractor General Requirements	0%	of	$	15,965.00	$	-	
Subtotal Year 2 Operations and Maintenance					$	18,839	
Contingency	15%	of	$	18,838.70	$	2,826	
TOTAL YEAR 2 THRU 10 OPERATIONS AND MAINTENANCE COST					$	21,665	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	4 - A
DESCRIPTION:	In-Situ Chemical Oxidation with Rock Fracturing
PREPARED BY:	José Amaya
PROJECT NUMBER:	149208.SA.SM

POST CLOSURE COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Closure Reporting							
Labor - Engineer/Hydrogeologist	100	hr		$90.00	$	9,000	
Labor - Editor	50	hr		$65.00	$	3,250	
Labor - CAD Technician	25	hr		$65.00	$	1,625	
Total *Closure Reporting*					$	13,875	
Well Abandonment and Equipment Demobilization							
Well Abandonment	29	well	$	500.00	$	14,500	Assume abandon 10 wells/day
Equipment Demobilization	1	LS	$	5,000.00	$	5,000	
Equipment Rental	1	wk	$	200.00	$	200	MultiRAE
Subtotal Well Abandonment and Equipment Demobilization					$	19,700	
Site Work Allowance	8%	of	$	19,700.00	$	1,576	
Mechanical Allowance	0%	of	$	19,700.00	$	-	
Instrumentation and Controls Allowance	0%	of	$	19,700.00	$	-	
Electrical Allowance	0%	of	$	19,700.00	$	-	
Miscellaneous Equipment Allowance	5%	of	$	19,700.00	$	985	
Total *Well Abandonment and Equipment Demobilization*					$	22,261	
Subtotal Post-Closure Cost					$	36,136	
Project Management	8%	of	$	36,136.00	$	2,891	
Technical Support	15%	of	$	36,136.00	$	5,420	
Construction Management	10%	of	$	36,136.00	$	3,614	
Subcontractor General Requirements	5%	of	$	36,136.00	$	1,807	
Subtotal Post-Closure Cost					$	49,868	
Contingency	15%	of		$49,867.68	$	7,480	
TOTAL POST CLOSURE COST					$	57,348	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 4 - A
DESCRIPTION: In-Situ Chemical Oxidation with Rock Fracturing
PREPARED BY: José Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ 938,335		$ 938,335	$ 938,335	$ -	$ 938,335	$ 246,750
1	2003	0.960		$ 121,794	$ 121,794	$ -	$ 116,885	$ 116,885	$ 130,204
2	2004	0.921		$ 21,665	$ 21,665	$ -	$ 19,953	$ 19,953	$ 113,098
3	2005	0.884		$ 21,665	$ 21,665	$ -	$ 19,149	$ 19,149	$ 95,274
4	2006	0.848		$ 21,665	$ 21,665	$ -	$ 18,377	$ 18,377	$ 76,701
5	2007	0.814		$ 21,665	$ 21,665	$ -	$ 17,636	$ 17,636	$ 57,348
6	2008	0.781	$ 57,348		$ 57,348	$ 44,803	$ -	$ 44,803	$ (0)
7	2009	0.750			$ -	$ -	$ -	$ -	$ (0)
8	2010	0.720			$ -	$ -	$ -	$ -	$ (0)
9	2011	0.691			$ -	$ -	$ -	$ -	$ (0)
10	2012	0.663			$ -	$ -	$ -	$ -	$ (0)
11	2013	0.636			$ -	$ -	$ -	$ -	$ (0)
12	2014	0.610			$ -	$ -	$ -	$ -	$ (0)
13	2015	0.586			$ -	$ -	$ -	$ -	$ (0)
14	2016	0.562			$ -	$ -	$ -	$ -	$ (0)
15	2017	0.539			$ -	$ -	$ -	$ -	$ (0)
16	2018	0.518			$ -	$ -	$ -	$ -	$ (0)
17	2019	0.497			$ -	$ -	$ -	$ -	$ (0)
18	2020	0.477			$ -	$ -	$ -	$ -	$ (0)
19	2021	0.458			$ -	$ -	$ -	$ -	$ (0)
20	2022	0.439			$ -	$ -	$ -	$ -	$ (0)
21	2023	0.421			$ -	$ -	$ -	$ -	$ (0)
22	2024	0.404			$ -	$ -	$ -	$ -	$ (0)
23	2025	0.388			$ -	$ -	$ -	$ -	$ (0)
24	2026	0.373			$ -	$ -	$ -	$ -	$ (0)
25	2027	0.358			$ -	$ -	$ -	$ -	$ (0)
26	2028	0.343			$ -	$ -	$ -	$ -	$ (0)
27	2029	0.329			$ -	$ -	$ -	$ -	$ (0)
28	2030	0.316			$ -	$ -	$ -	$ -	$ (0)
29	2031	0.303			$ -	$ -	$ -	$ -	$ (0)
30	2032	0.291			$ -	$ -	$ -	$ -	$ (0)
Total Alternative 4 - A			**$ 995,683**	**$ 208,452**	**$ 1,204,135**	**$ 983,139**	**$ 192,001**	**$ 1,175,139**	

Appendix C-5
Alternative 5—Enhanced Reductive Dechlorination with Rock Fracturing

COST ESTIMATE SUMMARY [2]

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	5
DESCRIPTION:	Enhanced Reductive Dechlorination with rock fracturing
PREPARED BY:	José A. Amaya
PROJECT NUMBER:	149208.SA.SM

Capital Cost		
Construction	$	632,354
Project Management	$	50,588
Design	$	37,941
Construction Management	$	63,235
Subcontractor General Requirements	$	31,618
Contingency	$	203,934
Total Capital Cost	**$**	**1,019,671**
Year 1 Operations and Maintenance		
Groundwater Sampling (Baseline and 4 Rounds after Startup)	$	57,325
Reporting (2 Seminannual Reports plus construction completion report)	$	23,200
Professional Services [1]	$	12,884
Subcontractor General Requirements	$	4,026
Contingency	$	24,359
Total Year 1 Operations and Maintenance	**$**	**121,794**
Years 2-5 Operation and Maintenance		
Groundwater Sampling (Semiannual Events)	$	22,930
Reporting (Annual Reports)	$	8,650
Professional Services [1]	$	5,684
Subcontractor General Requirements	$	-
Contingency	$	5,590
Total Years 3-5 Operations and Maintenance	**$**	**42,854**
Years 6 MNA		
Groundwater Sampling (Annual Events)	$	7,490
Reporting (Annual Reports)	$	6,005
Professional Services 1	$	3,104
Subcontractor General Requirements	$	675
Contingency	$	2,591
Total Year 6 MNA	**$**	**19,865**
Post Closure Cost		
Closure Reporting (and 5-year report)	$	13,875
Well Abandonment and Equipment Demobilization	$	18,370
Professional Services [1]	$	10,641
Subcontractor General Requirements	$	1,612
Contingency	$	6,675
Total Post Closure Cost	**$**	**51,173**
TOTAL PRESENT WORTH	**$**	**1,340,639**

NOTES:

1 - Professional Services includes Project Management, Design/Technical Support, and Construction Management.

2 - The cost estimates provided are to an accuracy of +50 percent to -30 percent and are prepared for the sole purpose of alternative comparison. The alternative cost estimates are in 2004 dollars and are based on conceptual design from information available at the time of this study. The actual cost of the project would depend on the final scope and design of the selected remedial action, the schedule of implementation, competitive market conditions, and other variables.

SITE DATA AND ALTERNATIVE CONCEPTUAL DESIGN

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 5
DESCRIPTION: Enhanced Reductive Dechlorination with rock fracturing
PREPARED BY: José A. Amaya
PROJECT NUMBER: 149208.SA.SM

Site Background Data

Elevation of Site = 200 ft amsl or 14.59 psia
Length of Target Groundwater Contamination Zone = 466 ft
Width of Target Groundwater Contamination Zone = 466 ft
Area of Contaminated Groundwater Target Zone = 217,156 sf
Depth to Top of Target Zone = 26 ft
Depth to Bottom of Target Zone = 130 ft
Soil Porosity = 0.05
Volume of Contaminated Groundwater = 1,140,069 cf or 32,286,754 liters

Hydraulic Conductivity, K = 0.006 ft/day or 2 ft/yr or 2.12E-06 cm/sec (taken as geometric mean of slug tests done for the RI)
Hydraulic Gradient, i = 0.2 ft/ft (taken from interpolated groundwater contour map for April 2000)

Average contaminant concentrations in the two source area wells 13GW02 and 13GW202 are:

PCE	50	µg/L
TCE	1,000	µg/L
DCE	150	µg/L
VC	2	µg/L
Total CVOCs	1,202	µg/L

Mass Estimate

Assumptions
1. Bedrock formations are the target of this remediation.
2. No mobile NAPL is present.

Mass of CVOCs in groundwa 85.6 lbs lbs of contaminant to be degraded

Conceptual Design

See "HRC PreDesign" spreadsheet for detailed analysis.

Total mass of HRC needed = 12,450 lbs (Ref: spreadsheet named Site13_Alt4_HRCDesign.xls)
Density of HRC = 1.347 g/cc or 83.91 lbs/cf or 11.22 lbs/gal (water = 8.34 lbs/gal)

Assume a vertical well delivery system will be installed to inject the HRC into the target zone.
Number of HRC injection wells to be installed = 13 wells @ 130 ft bgs (Ref: spreadsheet named Alt4_HRCDesignv1.xls)
Total HSA drilling = 1,690 lf
HSA drilling rate = 100 lf/day
Number of days of HSA drilling = 17 working days

Assume an aquifer delivery rate of 5 gpm per injection point at approximately 1000 psig pressure (typ injection rate is 5 gpm)
Mass of HRC to be injected into each well = 180 lbs/well
Desired delivery time of HRC slurry = 4 hours per injection cycle
Estimated volumetric delivery rate = 600 gallons of 4% by weight HRC slurry
Assume injection system will serve 1 wells at one time
Total required system injection rate = 5.0 gpm
Estimated time for completion of all HRC injection = 52.0 hours or 13 days (4-hrs per day, rounded up)

Mixing tank volume = 600 gallons

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	5
DESCRIPTION:	Enhanced Reductive Dechlorination with rock fracturing
PREPARED BY:	José A. Amaya
PROJECT NUMBER:	149208.SA.SM

Assumptions

1. The accuracy of the cost estimate is +50%/-30%
2. See "Conceptual Design" spreadsheet for basis of cost estimate assumptions.
3. The number of new Coastal Plain monitoring wells required to be installed 0 wells
4. The number of new bedrock/Saprolite monitoring wells required to be installed 5 wells
5. Number of HRC Injection Wells to be installed = 13 wells
6. Assume that the duration of inj. well installation is 18 working days (includes time for monitoring and treatment well installation)
7. Assume that the duration of solution injection is 13 working days
8. The number of wells to be sampled for VOCs and MNA parameters is 8 wells per round
9. The number of wells on-site to be abandoned for post-closure is 29 wells

Detailed Capital and Operations and Maintenance Costs

CAPITAL COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments and References
Construction							
Source Area Pilot Test	1	LS	$	100,000.00	$	100,000	Test to determine effectiveness, incl fracture test
Coastal Plain Groundwater Monitoring Well Installation	0	well	$	2,000.00	$	-	Assume 50' deep @ $40/ft
Bedrock Groundwater Well Installation	18	well	$	5,000.00	$	90,000	Assume 100' deep @ $50/ft
Well development Labor - Technician	18	hr	$	55.00	$	990	
Well Development Equipment Rental	1	LS	$	3,000.00	$	3,000	
Pneumatic fracturing	1,530	LF	$	200.00	$	306,000	
Chemically Resistant Mixing Tank	14	days	$	50.00	$	700	
Injection Pump	13	days	$	250.00	$	3,250	10 gpm pump at 200 psig
Injection well construction supplies	13	well	$	50.00	$	650	
Well Permits	18	ea	$	30.00	$	540	
Equipment Rental	0	wk	$	600.00	$	-	
System Startup - HRC Injection							
HRC Supply and shipment	12,450	lb	$	5.50	$	68,475	See Conceptual Design spreadsheet for details
Labor - Technician	130	hr	$	55.00	$	7,150	10 hrs/day
Labor - Engineer	130	hr	$	90.00	$	11,700	
Startup Equipment Rental	5	wk	$	5,500.00	$	27,500	
Subtotal Capital Cost					$	619,955	
Site Work Allowance	0%	of	$	619,955.00	$	-	
Mechanical Allowance	0%	of	$	619,955.00	$	-	
Instrumentation and Controls Allowance	0%	of	$	619,955.00	$	-	
Electrical Allowance	0%	of	$	619,955.00	$	-	
Miscellaneous Equipment Allowance	2%	of	$	619,955.00	$	12,399	
Subtotal Capital Cost					$	632,354	
Project Management	8%	of	$	632,354.10	$	50,588	
Design	6%	of	$	632,354.10	$	37,941	
Construction Management	10%	of	$	632,354.10	$	63,235	
Subcontractor General Requirements	5%	of	$	632,354.10	$	31,618	
Subtotal Capital Cost					$	815,737	
Contingency	25%	of	$	815,736.79	$	203,934	
TOTAL CAPITAL COST					$	1,019,671	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	5
DESCRIPTION:	Enhanced Reductive Dechlorination with rock fracturing
PREPARED BY:	José A. Amaya
PROJECT NUMBER:	149208.SA.SM

YEAR 1 OPERATIONS AND MAINTENANCE						
Item/Activity	Qty Unit		Unit Cost		Cost	Comments
Groundwater Sampling (Baseline and 4 Rounds after Startup)						
Labor - Technician	240 hr		$ 55.00	$	13,200	3 hrs/well, 2 people
Groundwater Sample Analysis	65 sample		$ 625.00	$	40,625	VOC/MNA analysis, incl 5 QA/QC samples and data valid.
Sampling Supplies	5 round		$ 200.00	$	1,000	
GW Sampling Equipment Rental	5 round		$ 500.00	$	2,500	
Total *Groundwater Sampling*				$	57,325	
Reporting (2 Seminannual Reports plus construction completion report)						
Labor - Engineer/Hydrogeologist	200 hr		$ 90.00	$	18,000	
Labor - Editor	40 hr		$ 65.00	$	2,600	
Labor - CAD Technician	40 hr		$ 65.00	$	2,600	
Total *Reporting*				$	23,200	
Subtotal Year 1 Operations and Maintenance				$	80,525	
Project Management	8%	of	$ 80,525.00	$	6,442	
Technical Support	5%	of	$ 80,525.00	$	4,026	
Construction Management	3%	of	$ 80,525.00	$	2,416	
Subcontractor General Requirements	5%	of	$ 80,525.00	$	4,026	
Subtotal Year 1 Operations and Maintenance				$	97,435	
Contingency	25%	of	$ 97,435.25	$	24,359	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST				$	121,794	

YEARS 2-5 OPERATIONS AND MAINTENANCE						
Item/Activity	Qty Unit		Unit Cost		Cost	Comments
Groundwater Sampling (Semiannual Events)						
Labor - Technician	96 hr		$ 55.00	$	5,280	3 hrs/well, 2 people
Groundwater Sample Analysis	26 sample		$ 625.00	$	16,250	VOC/MNA analysis, incl 5 QA/QC samples and data valid.
Sampling Supplies	2 round		$ 200.00	$	400	
GW Sampling Equipment Rental	2 round		$ 500.00	$	1,000	
Total *Groundwater Sampling*				$	22,930	
Reporting (Annual Reports)						
Labor - Engineer/Hydrogeologist	60 hr		$ 90.00	$	5,400	
Labor - Editor	30 hr		$ 65.00	$	1,950	
Labor - CAD Technician	20 hr		$ 65.00	$	1,300	
Total *Reporting*				$	8,650	
Subtotal Following Years Operations and Maintenance				$	31,580	
Project Management	8%	of	$ 31,580.00	$	2,526	
Technical Support	10%	of	$ 31,580.00	$	3,158	
Construction Management	0%	of	$ 31,580.00	$	-	
Subcontractor General Requirements	0%	of	$ 31,580.00	$	-	
Subtotal Following Years Operations and Maintenance				$	37,264	
Contingency	15%	of	$ 37,264.40	$	5,590	
TOTAL YEARS 2-5 OPERATIONS AND MAINTENANCE COST				$	42,854	

COST ESTIMATE DETAILS

PROJECT:	Site 49 Feasibility Study
SITE:	Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE:	5
DESCRIPTION:	Enhanced Reductive Dechlorination with rock fracturing
PREPARED BY:	José A. Amaya
PROJECT NUMBER:	149208.SA.SM

YEARS 6 THRU 6 OPERATIONS AND MAINTENANCE COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Annual Groundwater Sampling							
Labor - Technician	48	hr	$	55.00	$	2,640	3 hrs/well, 2 people
Groundwater Sample Analysis - MNA Parameters	4	sample	$	475.00	$	1,900	MNA and VOC analysis, incl data valid.
Groundwater Sample Analysis - VOC only	13	sample	$	150.00	$	1,950	VOC analysis only, 5 extra QA/QC samples, incl data valid.
Sampling Supplies	1	round	$	500.00	$	500	
GW Sampling Equipment Rental	1	round	$	500.00	$	500	
Total *Annual Groundwater Sampling*					$	7,490	
Annual Reporting							
Labor - Engineer/Hydrogeologist	40	hr	$	90.00	$	3,600	
Labor - Editor	25	hr	$	65.00	$	1,625	
Labor - CAD Technician	12	hr	$	65.00	$	780	
Total Annual *Reporting*					$	6,005	
Subtotal Following Years Operations and Maintenance					$	13,495	
Project Management	8%	of	$	13,495.00	$	1,080	
Technical Support	15%	of	$	13,495.00	$	2,024	
Construction Management	0%	of	$	13,495.00	$	-	
Subcontractor General Requirements	5%	of	$	13,495.00	$	675	
Subtotal Following Years Operations and Maintenance					$	17,274	
Contingency	15%	of	$	17,273.60	$	2,591	
TOTAL YEARS 6 OPERATIONS AND MAINTENANCE COST					$	19,865	

POST CLOSURE COST

Item/Activity	Qty	Unit		Unit Cost		Cost	Comments
Closure Reporting (and 5-year report)							
Labor - Engineer/Hydrogeologist	100	hr		$90.00	$	9,000	
Labor - Editor	50	hr		$65.00	$	3,250	
Labor - CAD Technician	25	hr		$65.00	$	1,625	
Total *Closure Reporting*					$	13,875	
Well Abandonment and Equipment Demobilization							
Well Abandonment	29	well	$	500.00	$	14,500	Assume abandon 10 wells/day
Equipment Demobilization	1	LS	$	2,000.00	$	2,000	
Equipment Rental	1	wk	$	200.00	$	200	MultiRAE
Subtotal Well Abandonment and Equipment Demobilization					$	16,700	
Site Work Allowance	5%	of	$	16,700.00	$	835	
Mechanical Allowance	0%	of	$	16,700.00	$	-	
Instrumentation and Controls Allowance	0%	of	$	16,700.00	$	-	
Electrical Allowance	0%	of	$	16,700.00	$	-	
Miscellaneous Equipment Allowance	5%	of	$	16,700.00	$	835	
Total *Well Abandonment and Equipment Demobilization*					$	18,370	
Subtotal Post-Closure Cost					$	32,245	
Project Management	8%	of	$	32,245.00	$	2,580	
Technical Support	15%	of	$	32,245.00	$	4,837	
Construction Management	10%	of	$	32,245.00	$	3,225	
Subcontractor General Requirements	5%	of	$	32,245.00	$	1,612	
Subtotal Post-Closure Cost					$	44,498	
Contingency	15%	of		$44,498.10	$	6,675	
TOTAL POST CLOSURE COST					$	51,173	

PRESENT WORTH ANALYSIS

PROJECT: Site 49 Feasibility Study
SITE: Site 49, NSWC - White Oak, Silver Spring, Maryland
ALTERNATIVE: 5
DESCRIPTION: Enhanced Reductive Dechlorination with rock fracturing
PREPARED BY: José A. Amaya
PROJECT NUMBER: 149208.SA.SM

Assumptions

Discount Rate 4.20%

Assumes Total PV earns interest for an entire year (12 months), compound annually.

Present Worth Analysis

		E	A	B	C=A+B	C*A	C*B	C*E	
Elapsed Time	Year	Discount Factor at 4.2%	Capital Cost	O&M Cost	Total Cost	Total PV Capital Costs at 4.2%	Total PV O&M Costs at 4.2%	Total PV Costs at 4.2%	Balance of Interest Bearing Account at 4.2%
0	2002	1.000	$ 1,019,671		$ 1,019,671	$ 1,019,671	$ -	$ 1,019,671	$ 334,449
1	2003	0.960		$ 121,794	$ 121,794	$ -	$ 116,885	$ 116,885	$ 221,586
2	2004	0.921		$ 42,854	$ 42,854	$ -	$ 39,469	$ 39,469	$ 186,239
3	2005	0.884		$ 42,854	$ 42,854	$ -	$ 37,878	$ 37,878	$ 149,407
4	2006	0.848		$ 42,854	$ 42,854	$ -	$ 36,351	$ 36,351	$ 111,028
5	2007	0.814		$ 42,854	$ 42,854	$ -	$ 34,886	$ 34,886	$ 71,037
6	2008	0.781	$ 51,173	$ 19,865	$ 71,037	$ 39,979	$ 15,519	$ 55,498	$ (0)
7	2009	0.750			$ -	$ -	$ -	$ -	$ (0)
8	2010	0.720			$ -	$ -	$ -	$ -	$ (0)
9	2011	0.691			$ -	$ -	$ -	$ -	$ (0)
10	2012	0.663			$ -	$ -	$ -	$ -	$ (0)
11	2013	0.636			$ -	$ -	$ -	$ -	$ (0)
12	2014	0.610			$ -	$ -	$ -	$ -	$ (0)
13	2015	0.586			$ -	$ -	$ -	$ -	$ (0)
14	2016	0.562			$ -	$ -	$ -	$ -	$ (0)
15	2017	0.539			$ -	$ -	$ -	$ -	$ (0)
16	2018	0.518			$ -	$ -	$ -	$ -	$ (0)
17	2019	0.497			$ -	$ -	$ -	$ -	$ (0)
18	2020	0.477			$ -	$ -	$ -	$ -	$ (0)
19	2021	0.458			$ -	$ -	$ -	$ -	$ (0)
20	2022	0.439			$ -	$ -	$ -	$ -	$ (0)
21	2023	0.421			$ -	$ -	$ -	$ -	$ (0)
22	2024	0.404			$ -	$ -	$ -	$ -	$ (0)
23	2025	0.388			$ -	$ -	$ -	$ -	$ (0)
24	2026	0.373			$ -	$ -	$ -	$ -	$ (0)
25	2027	0.358			$ -	$ -	$ -	$ -	$ (0)
26	2028	0.343			$ -	$ -	$ -	$ -	$ (0)
27	2029	0.329			$ -	$ -	$ -	$ -	$ (0)
28	2030	0.316			$ -	$ -	$ -	$ -	$ (0)
29	2031	0.303			$ -	$ -	$ -	$ -	$ (0)
30	2032	0.291			$ -	$ -	$ -	$ -	$ (0)
Total Alternative 5			**$ 1,070,844**	**$ 313,075**	**$ 1,383,919**	**$ 1,059,650**	**$ 280,989**	**$ 1,340,639**	

Appendix D
Biodegradation Pathways for TCE

Appendix D

Biodegradation of TCE

The biodegradation process uses soil organisms to degrade contaminants to innocuous byproducts such as carbon dioxide and water. Not all contaminants are biodegradable, and chlorinated solvents, such as those found within Site 49, are only completely degraded under special conditions. If these conditions are not met, or if one of the necessary requirements are limiting, the contaminant will not completely degrade.

In the soil matrix, microorganisms exist in two states: dormant and active. In order to degrade contaminants the organisms need to be in the active state. For this to occur, there are four requirements: nutrients, moisture, an electron donor, and a terminal electron acceptor. Moisture and nutrients are generally readily available in the subsurface. Therefore, availability of electron donors or terminal electron acceptors are generally the limiting factors in biodegradation.

Three processes govern the biodegradation of chlorinated hydrocarbons. They are reductive dechlorination, oxidation, and co-metabolism. In general a chlorinated hydrocarbon contaminant must first be dechlorinated before complete degradation can occur. This process is called reductive dechlorination, where the contaminant acts as the terminal electron acceptor and hydrogen is the electron donor (Wiedemeier *et al*, 1999). The reduction of TCE and its daughter products to carbon dioxide, water, and chloride ions, the redox conditions necessary, and the relative speed of the reactions are shown in Figure D-1.

TCE has been shown to biodegrade by reductive dechlorination. The typical TCE degradation pathway would be followed (see Figure E-1-1) except that *trans*-1,2-DCE and 1,1-DCE are typically observed in addition to *cis*-1,2-DCE.

Reductive dechlorination is the process where chlorine atoms are replaced by hydrogen atoms. This only occurs in anaerobic (dissolved oxygen concentrations less than 1 mg/L) conditions, and as each chlorine atom is removed, it becomes increasingly difficult to remove the next one. This is because TCE is more electronegative than *cis*-1,2-DCE (because it has more negatively charged chlorine atoms attached) and thus the process of reducing TCE to ethene slows down with each removal of a chlorine atom. Under anaerobic conditions, complete degradation of chlorinated compounds can only occur after all the chlorine atoms have been removed. Frequently only the first, or the first and second chlorine atoms are removed, resulting in the accumulation of daughter products, *cis*-1,2-DCE and vinyl chloride. The accumulation of vinyl chloride is of great concern to regulators as it is a known human carcinogen, is highly toxic even at low concentrations, and is more mobile than TCE and *cis*-1,2-DCE.

Reductive dechlorination, otherwise known as halorespiration, is performed by a group of organisms known as halorespirators. These organisms utilize hydrogen as the electron donor, the availability of which is frequently the limiting factor, and the chlorinated compound as the terminal electron acceptor. Halorespirators are the only organisms which conduct reductive dechlorination, but they are not the only organisms which utilize hydrogen. Halorespirators are most competitive for hydrogen when the redox conditions are low (between –150 and –320 millivolts; mV).

The following trends occur in environments undergoing reductive dechlorination through biodegradation and can be monitored to determine if natural attenuation is occurring:

- Reduction in parent concentrations
- Increase in daughter product concentrations
- Increase in ethene and ethane concentrations
- Elevated chloride concentrations
- Methane production
- Low redox conditions
- Production of iron (II)

Oxidation is the process where the contaminant is used as a carbon source and is broken down directly into carbon dioxide and water. TCE is not degradable via this process. There is limited evidence that *cis*-1,2-DCE is degradable, but vinyl chloride is rapidly degraded in circumstances where oxygen is available as the terminal electron acceptor.

Co-metabolism occurs under aerobic conditions (dissolved oxygen concentrations greater than 1 mg/L). The microorganisms utilize a carbon source other than the contaminant and as a byproduct of respiration the contaminant is fortuitously degraded. This occurs because cells are 'leaky', meaning that during the growth process some cellular components and products are released into the environment. For example, during the degradation of methane, an enzyme called methane monooxygenase (MMO) is produced. This enzyme adds an oxygen molecule to the methane. As the cell grows and divides, this enzyme is released into the environment, and will add an oxygen molecule to TCE, making it more amenable to degradation by other organisms. In the environment, co-metabolism will only occur when there is oxygen and another carbon source, such as petroleum hydrocarbons or methane, available. When either the oxygen or the carbon source is depleted, co-metabolism will cease (usually oxygen is depleted first). In engineered conditions, co-metabolism can be achieved by the addition of oxygen and a carbon source such as methane, ethane, propane, butane, toluene, or phenol. The addition of oxygen and ammonium (NH_4^+) has also been documented to support this process (Wiedemeier *et al*, 1999).

In summary there are three sets of conditions that may achieve the degradation of TCE to carbon dioxide, water, and chloride ions:

- Anaerobic conditions where the requirements for reductive dechlorination are met, followed by anaerobic degradation of vinyl chloride and ethene

- Anaerobic conditions where the requirements for reductive dechlorination are met, followed by aerobic conditions

- Aerobic degradation via co-metabolism, which may require the addition of oxygen and a carbon source such as methane

Figure D-1

Biodegradation Process of Chlorinated Hydrocarbons

Feasibility Study for Site 49

Former NSWC-White Oak, Silver Spring, Maryland

	Process	Redox Conditions/Speed
TCE	reductive dehalogenation	anaerobic/rapid
	cometabolism	aerobic
↓		
Cis-1,2-DCE = Cl^-		
↓	reductive dehalogenation	anaerobic/slower
	oxidation	aerobic/slow
	cometabolism	aerobic
Vinyl Chloride + Cl^-		
↓	reductive dehalogenation	anaerobic/slower
	oxidation	aerobic/rapid
	cometabolism	aerobic
Ethene + cl^-		
↓	oxidation	anaerobic/slow
		aerobic/rapid
$CO_2 + H_2O$		

Footnote: Reaction sequences, redox conditions and rates for the reduction and degradation of TCE. Speeds for cometabolism depend on the substrate added (Adapted from Wiedemier *et al*, 1999)

Appendix E
Groundwater PRG Development Backup Tables

Table E-1a
Calculation of DAevent
Groundwater, Adult
Feasibility Study for Site 49, former NSWC White Oak

Chemical of Potential Concern	Permeability Constant (Kp) (cm/hr)	Lag Time (t) (hr)	Duration of Event (ET) (hr)	t* (hr)	B (dimensionless)	DAevent (L/cm^2-day)	Eq
1,2-Dibromoethane	2.0E-03	1.2E+00	2.0E-01	2.8E+00	1.1E-02	2.8E-06	2
Chloroform	6.8E-03	5.0E-01	2.0E-01	1.2E+00	2.9E-02	5.9E-06	2
cis-1,2-Dichloroethene	3.3E-02	9.1E-01	2.0E-01	2.2E+00	1.6E-01	3.9E-05	2
trans-1,2-Dichloroethene	1.2E-02	5.8E-01	2.0E-01	1.4E+00	5.3E-02	1.1E-05	2
Tetrachloroethene	5.6E-03	2.4E-01	2.0E-01	5.7E-01	1.7E-02	3.4E-06	2
Trichloroethene	7.7E-03	3.7E-01	2.0E-01	8.9E-01	2.9E-02	5.8E-06	2
Vinyl chloride	7.7E-03	3.7E-01	2.0E-01	8.9E-01	2.9E-02	5.8E-06	2
Aluminium	1.0E-03	N/A	2.0E-01	N/A	N/A	2.0E-07	1
Chromium	2.0E-03	N/A	2.0E-01	N/A	N/A	4.0E-07	1
Iron	1.0E-03	N/A	2.0E-01	N/A	N/A	2.0E-07	1
Manganese	1.0E-03	N/A	2.0E-01	N/A	N/A	2.0E-07	1
Nickel	2.0E-04	N/A	2.0E-01	N/A	N/A	4.0E-08	1

Inorganics: DAevent (mg/cm2-event) =
Kp x ET x 0.001 L/cm3 (eq 1)

Organics: DAevent (mg/cm2-event) =

ET<t*: DAevent (mg/cm2-event) =
2 x Kp x (sqrt((6 x t x ET)/3.1415)) x 0.001 L/cm3 (eq 2)

ET>t*: DAEvent (mg/cm2-event) =
Kp x (tevent/(1+B) + 2 x tevent x ((1 + 3xB + 3xB2)/(1+B)2) x 0.001 L/cm3 (eq 3)

Permeability constants from EPA 2001, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). EPA/540/R/99/005.
N/A - not applicable.

Table E-1b
Inhalation Exposure Concentrations from Foster and Chrostowski Shower Model
Feasibility Study for Site 49, former NSWC White Oak

Chemical	Molecular weight (MW) (g/mole)	Henry's Law Constant (H) (atm-m^3/mole)	Kg (VOC) (cm/hr)	Kl(VOC) (cm/hr)	KL (cm/hr)	Kal (cm/hr)	Cwd	S (L/m^3-min)	Inhalation Exposure (InExp) (L/kg-shower)	Shower Exposure (InExp X BW) (L/day)
1,2-Dibromoethane	190	3.2E-04	9.2E+02	9.6E+00	5.4E+00	7.3E+00	2.2E-01	1.4E+00	4.2E-05	3.0E-03
Chloroform	120	2.9E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	3.9E-01	2.6E+00	7.7E-05	5.4E-03
cis-1,2-Dichloroethene	97	7.6E-03	1.3E+03	1.3E+01	1.3E+01	1.8E+01	4.4E-01	3.0E+00	8.7E-05	6.1E-03
trans-1,2-Dichloroethene	97	6.6E-03	1.3E+03	1.3E+01	1.3E+01	1.8E+01	4.4E-01	2.9E+00	8.7E-05	6.1E-03
Tetrachloroethane	170	2.6E-02	9.8E+02	1.0E+01	1.0E+01	1.4E+01	3.6E-01	2.4E+00	7.1E-05	5.0E-03
Trichloroethene	131	1.0E-02	1.1E+03	1.2E+01	1.1E+01	1.5E+01	4.0E-01	2.7E+00	7.8E-05	5.5E-03
Vinyl chloride	63	8.2E-02	1.6E+03	1.7E+01	1.7E+01	2.3E+01	5.3E-01	3.5E+00	1.0E-04	7.2E-03

Variables	Units	Exposure Assumptions
Kg(VOC) = gas-film mass transfer coefficient	cm/hr	Solved by Eq 1
Kl(VOC) = liquid-film mass transfer coefficient	cm/hr	Solved by Eq 2
KL = overall mass transfer coefficient	cm/hr	Solved by Eq 3
Kal = adjusted overall mass transfer coeff.	cm/hr	Solved by Eq 4
Tl = Calibration temp. of water	K (20C +273)	293
Ts = Shower water temperature	k (45C)	318
Us = water viscosity at Ts	centipoise	0.596
Ul = water viscosity at Tl	cp	1.002
Cwd = conc. leaving droplets after time sdt		Solved by Eq 5
sdt = shower droplet drop time	sec	2
d = shower droplet diameter	mm	1
FR = shower water flow rate	l/min	20
SV = shower room air volume	m^3	3
S = indoor VOC generation rate	L/m^3-min	Solved by Eq 6
VR = ventilation rate	l/min	13.8
BW = body weight	kg	70
Ds = duration of shower	min	12
Dt = total duration in shower room	min	20
R = air exchange rate	min^{-1}	0.0167
Ca = indoor air concentration of VOCs	L-ug/mg-m^3	Solved by Eq 7
Einh = inhalation exposure per shower	L/kg-shower	Solved by Eq 8

Equation 1:	Kg(VOC) =	3000 * (18 / MW)$^{0.5}$	
Equation 2:	Kl(VOC) =	20 * (44 / MW)$^{0.5}$	
Equation 3:	KL =	((1 / Kl(VOC)) + (0.024 / (Kg (VOC) * H)))$^{-1}$	
Equation 4:	Kal =	(KL * (((Tl * Us) / (Ts * Ul))$^{-0.5}$))	
Equation 5:	Cwd =	((1-EXP((-1 * Kal * sdt)/(60 * d))))	
Equation 6:	S =	(Cwd * FR / SV)	
Equation 7:	see time series example on Table I-GW-6		
Equation 8:	Einh =	If t>Ds	(((VR * S) / (BW * R * 1000000)) * ((Ds + (EXP(-R * Dt) / R)-(EXP(R * (Ds - Dt))) / R)))

Table E-2
Risk-Based Screening Values
Groundwater
Child Residential Scenario
Feasibility Study for Site 49, former NSWC White Oak

Chemical	Chronic Oral RfD (RfDo) (mg/kg-day)	Chronic Dermal RfD (RfDd) (mg/kg-day)	Chronic Inhalation RfD (RfDi) (mg/kg-day)	Target Organ	DAevent (L/cm²-day)	An (kg-L/mg)	Bn (kg-L/mg)	Noncarcinogen Groundwater Screen HQ = 0.1 (mg/L)	HQ = 0.5 (mg/L)	HQ = 1 (mg/L)	Noncarcinogen Screen PRG (mg/kg)	Target HQ[1] (mg/kg)
VOCs												
1,2-Dibromoethane	NA	NA	5.70E-05	reproductive	3.5E-06							
Chloroform	1.00E-02	1.00E-02	8.60E-05	liver, kidney	7.6E-06	1.0E+02	6.1E+00	1.5E-02	7.4E-02	1.5E-01	3.7E-02	0.25
cis-1,2-Dichloroethene	1.00E-02	1.00E-02	NA	blood	5.0E-05	1.0E+02	4.0E+01	1.1E-02	5.6E-02	1.1E-01	5.6E-02	0.50
trans-1,2-Dichloroethene	2.00E-02	2.00E-02	NA	blood	1.5E-05	5.0E+01	5.8E+00	2.8E-02	1.4E-01	2.8E-01	1.4E-01	0.50
Tetrachloroethane	1.00E-02	1.00E-02	1.40E-01	liver	4.4E-06	1.0E+02	3.5E+00	1.5E-02	7.6E-02	1.5E-01	3.8E-02	0.25
Trichloroethene	6.00E-03	4.80E-03	NA	liver, kidney	7.4E-06	1.7E+02	1.2E+01	8.7E-03	4.4E-02	8.7E-02	2.2E-02	0.25
Vinyl Chloride	3.00E-03	3.00E-03	2.80E-02	liver	7.4E-06	3.3E+02	2.0E+01	4.4E-03	2.2E-02	4.4E-02	1.1E-02	0.25
Metals												
Aluminium	1.00E+00	1.00E+00	NV	CNS	3.3E-07	1.0E+00	2.6E-03	1.6E+00	7.8E+00	1.6E+01	7.8E+00	0.50
Chromium	3.00E-03	3.00E-03	NV	NOAEL	6.6E-07	3.3E+02	1.7E+00	4.7E-03	2.3E-02	4.7E-02	4.7E-02	1.00
Iron	3.00E-01	3.00E-01	NV	NOAEL	3.3E-07	3.3E+00	8.7E-03	4.7E-01	2.3E+00	4.7E+00	4.7E+00	1.00
Manganese	2.00E-02	8.00E-04	NV	GI	3.3E-07	5.0E+01	3.3E+00	2.9E-02	1.5E-01	2.9E-01	1.5E-01	0.50
Nickel	2.00E-02	8.00E-04	NV	CNS	6.6E-08	5.0E+01	6.5E-01	3.1E-02	1.5E-01	3.1E-01	3.1E-01	1.00

Noncarcinogenic calculations:

$$\text{Groundwater RBC (mg/L)} = \frac{THQ \times BW \times AT_n}{EF \times ED \times (An + Bn)}$$

An = 1/RfDo x IR

Bn = 1/RfDd x SA x DAevent

EXPOSURE ASSUMPTIONS	
BW - Body weight (kilograms)	15
ATnc - Averaging time for noncarcinogens (days)	2,190
ATc - Averaging time for carcinogens (days)	25,550
EF - Exposure frequency (days/year)	350
ED - Exposure duration (year)	6
IR - Ingestion rate (L/day)	1
SA - Skin surface area (cm²)	7,930

NA - No reference dose or slope factor available.

NV - Not volatile.

1 Applicable HQ calculated so that total HQ for a target organ does not exceed 1.

Table E-2a
Calculation of DAevent
Groundwater, Child
Feasibility Study for Site 49, former NSWC White Oak

Chemical of Potential Concern	Permeability Constant (Kp) (cm/hr)	Lag Time (t) (hr)	Duration of Event (ET) (hr)	t* (hr)	B (dimensionless)	DAevent (L/cm^2-day)	Eq
1,2-Dibromoethane	2.0E-03	1.2E+00	3.3E-01	2.8E+00	1.1E-02	3.5E-06	2
Chloroform	6.8E-03	5.0E-01	3.3E-01	1.2E+00	2.9E-02	7.6E-06	2
cis-1,2-Dichloroethene	3.3E-02	9.1E-01	3.3E-01	2.2E+00	1.6E-01	5.0E-05	2
trans-1,2-Dichloroethene	1.2E-02	5.8E-01	3.3E-01	1.4E+00	5.3E-02	1.5E-05	2
Tetrachloroethane	5.6E-03	2.4E-01	3.3E-01	5.7E-01	1.7E-02	4.4E-06	2
Trichloroethene	7.7E-03	3.7E-01	3.3E-01	8.9E-01	2.9E-02	7.4E-06	2
Vinyl chloride	7.7E-03	3.7E-01	3.3E-01	8.9E-01	2.9E-02	7.4E-06	2
Aluminium	1.0E-03	N/A	3.3E-01	N/A	N/A	3.3E-07	1
Chromium	2.0E-03	N/A	3.3E-01	N/A	N/A	6.6E-07	1
Iron	1.0E-03	N/A	3.3E-01	N/A	N/A	3.3E-07	1
Manganese	1.0E-03	N/A	3.3E-01	N/A	N/A	3.3E-07	1
Nickel	2.0E-04	N/A	3.3E-01	N/A	N/A	6.6E-08	1

Inorganics: DAevent (mg/cm2-event) =

Kp x ET x 0.001 L/cm3 (eq 1)

Organics: DAevent (mg/cm2-event) =

ET<t*: DAevent (mg/cm2-event) =
2 x Kp x (sqrt((6 x t x ET)/3.1415)) x 0.001 L/cm3 (eq 2)

ET>t*: DAEvent (mg/cm2-event) =
Kp x (tevent/(1+B) + 2 x tevent x ((1 + 3xB + 3xB2)/(1+B)2) x 0.001 L/cm3 (eq 3)

Permeability constants from EPA 2001, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). EPA/540/R/99/005.
N/A - not applicable.

Table E-3
Risk-Based Screening Values
Groundwater
Lifetime Residential Scenario
Feasibility Study for Site 49, former NSWC White Oak

Chemical	Oral Slope Factor (CSFo) (kg-day/mg)	Dermal Slope Factor (CSFd) (kg-day/mg)	Inhalation Slope Factor (CSFi) (kg-day/mg)	DAevent-a (L/cm²-day)	DAevent-c (L/cm²-day)	Shower Exposure (L/day)	Ac (L-yr/mg)	Bc (L-yr/mg)	Cc (L-yr/mg)	Carcinogen Screening Value Risk = 1E-06 (mg/L)	Risk = 1E-05 (mg/L)	Risk = 1E-04 (mg/L)
VOCs												
1,2-Dibromoethane	8.50E+01	8.5E+01	7.60E-01	2.8E-06	3.5E-06	3.0E-03	9.3E+01	2.6E+00	7.7E-04	7.7E-07	7.7E-06	7.7E-05
Chloroform	NA	NA	8.10E-02	5.9E-06	7.6E-06	5.4E-03			1.5E-04	4.9E-01	4.9E+00	4.9E+01
cis-1,2-Dichloroethene	NA	NA	NA	3.9E-05	5.0E-05	6.1E-03						
trans-1,2-Dichloroethene	NA	NA	NA	1.1E-05	1.5E-05	6.1E-03						
Tetrachloroethene	5.40E-01	5.4E-01	2.00E-02	3.4E-06	4.4E-06	5.0E-03	5.9E-01	2.0E-02	3.4E-05	1.2E-04	1.2E-03	1.2E-02
Trichloroethene	1.10E-02	1.1E-02	6.00E-03	5.8E-06	7.4E-06	5.5E-03	1.2E-02	7.0E-04	1.1E-05	5.7E-03	5.7E-02	5.7E-01
Vinyl Chloride	1.40E+00	1.4E+00	3.10E-02	5.8E-06	7.4E-06	7.2E-03	1.5E+00	8.9E-02	7.7E-05	4.5E-05	4.5E-04	4.5E-03
Metals												
Aluminium	NA	NA	NV	2.0E-07	3.3E-07							
Chromium	NA	NA	NV	4.0E-07	6.6E-07							
Iron	NA	NA	NV	2.0E-07	3.3E-07							
Manganese	NA	NA	NV	2.0E-07	3.3E-07							
Nickel	NA	NA	NV	4.0E-08	6.6E-08							

Carcinogen calculations:

$$\text{Groundwater RBC (mg/L)} = \frac{TR \times AT_c}{EF \times (Ac + Bc + Cc)}$$

Ac = CSFo x IRadj

Bc = CSFd x [(SAa x DAevent-a x EDa)/BWa + (SAc x DAevent-c X EDc)/BWc]

Cc = CSFi x Shower Exposure x EDa x 1/BWa

EXPOSURE ASSUMPTIONS	Lifetime	Adult (a)	Child (c)
BW - Body weight (kilograms)		70	15
ATnc - Averaging time for noncarcinogens (days)		8,760	2,190
ATc - Averaging time for carcinogens (days)		25,550	25,550
EF - Exposure frequency (days/year)		350	350
ED - Exposure duration (year)		24	6
IR [illegible]stion rate (L/day)		2	1
[illegible]estion rate (L-year/kg-day)	1.09		
SA - [illegible]in surface area (cm²)		20,000	7,930
ET - Exposure Time (hours/day)		0.20	0.33

NA - No reference dose or slope factor available.

Table E-4
Risk-Based Screening Values
Groundwater
Residential Scenario
Feasibility Study for Site 49, former NSWC White Oak

Chemical	Recommended Screening Value (mg/L)	Basis	MCL (mg/L)
VOCs			
1,2-Dibromoethane	7.7E-06	Lifetime, CR = 10^{-5}	
Chloroform	3.7E-02	Child, HQ=0.25	0.08
cis-1,2-Dichloroethene	5.6E-02	Child, HQ=0.5	0.07
trans-1,2-Dichloroethene	1.4E-01	Child, HQ=0.5	0.1
Tetrachloroethene	1.2E-03	Lifetime, CR = 10^{-5}	0.005
Trichloroethene	2.2E-02	Child, HQ=0.25	0.005
Vinyl Chloride	4.5E-04	Lifetime, CR = 10^{-5}	0.002
Metals			
Aluminium	7.8E+00	Child, HQ=0.5	
Chromium	4.7E-02	Child, HQ=1	0.1
Iron	4.7E+00	Child, HQ=1	
Manganese	1.5E-01	Child, HQ=0.5	
Nickel	3.1E-01	Child, HQ=1	

Child scenario selected for noncarcinogenic screening value since child scenario more conservative (lower value).
For constituents with basis of CR = 10^{-5}, screening value for CR =10^{-5} less than screening value for applicable HQ.
Used CR of 10^{-5} to keep overall carcinogenic risk below 10^{-4}.
Applicabe HQ chosen to keep total HI for each target organ below 1.