

02.08-11/16/95-00661

FINAL
POST-REMOVAL CONFIRMATION SAMPLING
REPORT AND BASELINE RISK ASSESSMENTS

VOLUME II OF II
TEXT

SITES 4 AND 21
NAVAL WEAPONS STATION YORKTOWN
YORKTOWN, VIRGINIA

CONTRACT TASK ORDER 0297

NOVEMBER 16, 1995

Prepared for:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

TABLE OF CONTENTS

	Page
LIST OF ACRONYMS AND ABBREVIATIONS	xii
EXECUTIVE SUMMARY	ES-1
1.0 INTRODUCTION	1-1
1.1 RI Objectives	1-1
1.2 WPNSTA Yorktown Description and History	1-2
1.3 Site-Specific Description and History	1-2
1.3.1 Site 4 - Burning Pad Residue Landfill	1-3
1.3.2 Site 21 - Battery and Drum Disposal Area	1-4
1.4 Previous Investigations	1-5
1.4.1 History of the Installation Restoration Program at WPNSTA Yorktown	1-5
1.4.2 Initial Assessment Study	1-7
1.4.3 Confirmation Studies	1-7
1.4.4 Interim RI	1-11
1.4.5 Site Inspection of Site 21	1-12
1.4.6 Round One RI	1-14
1.4.7 Waste Characterization Investigation	1-14
1.4.8 Engineering Evaluation/Cost Analysis for Removal Actions	1-16
1.4.9 Removal Action	1-16
1.5 Report Organization	1-17
1.6 References	1-18
2.0 STUDY AREA INVESTIGATION	2-1
2.1 Overview of Round One RI Activities	2-1
2.1.1 Geophysical Investigations	2-2
2.1.2 Soil Investigation	2-3
2.1.3 Groundwater Investigation	2-6
2.1.4 Surface Water and Sediment Investigations	2-9
2.1.5 Aquifer Slug Tests	2-11
2.1.6 Surface Water Flow Measurements	2-12
2.1.7 Groundwater Level and Tidal Influence Monitoring	2-13
2.1.8 Quality Assurance/Quality Control Samples	2-13
2.1.9 Decontamination Procedures	2-14
2.1.10 Investigative Derived Waste (IDW) Management	2-15
2.2 Overview of Background Investigation Activities	2-16
2.2.1 Subsurface Soil Sampling/Monitoring Well Installation	2-16
2.2.2 Groundwater	2-17
2.2.3 Surface Soils	2-17
2.2.4 Surface Water and Sediment Sampling	2-17
2.3 Overview of Removal Action Activities	2-18
2.3.1 Preliminary Removal Action Activities	2-18

TABLE OF CONTENTS
(Continued)

	<u>Page</u>
2.3.2	Removal Action Activities 2-20
2.3.3	Post Removal Action Activities 2-23
2.4	References 2-27
3.0	PHYSICAL CHARACTERISTICS OF STUDY AREA 3-1
3.1	Surface Features 3-1
3.1.1	Physical Geography 3-1
3.1.2	Geophysical Investigation Results 3-1
3.2	Meteorology 3-4
3.3	Surface Water Hydrology 3-5
3.4	Geology 3-6
3.4.1	Regional Geology 3-7
3.4.2	Site-Specific Geology 3-8
3.5	Soils 3-9
3.6	Hydrogeology 3-10
3.6.1	WPNSTA Yorktown Hydrogeology 3-11
3.6.2	Site-Specific Hydrogeology 3-12
3.7	Land Use 3-14
3.8	Local Ecology 3-14
3.8.1	Aquatic Habitats 3-15
3.8.2	Terrestrial Habitats 3-16
3.8.3	Wetlands 3-19
3.8.4	Threatened and Endangered Species 3-19
3.9	References 3-20
4.0	NATURE AND EXTENT OF CONTAMINATION 4-1
4.1	Source Areas 4-2
4.1.1	Battery and Soil Area at Site 4 4-3
4.1.2	Disposal Area 1 at Site 4 4-3
4.1.3	Disposal Areas 2 and 3 at Site 4 4-3
4.1.4	Ash Pile at Site 4 4-4
4.1.5	Battery and Soil Area at Site 21 4-4
4.1.6	Drums at Site 21 4-4
4.2	Data Quality 4-5
4.3	Analytical Results 4-5
4.3.1	Non-Site Related Analytical Results 4-6
4.3.2	Quality Assurance/Quality Control Procedures 4-9
4.3.3	Round One Background Sampling Results 4-12
4.4	Site 4 - Burning Pad Residue Landfill 4-13
4.4.1	Analysis of Soils 4-13
4.4.2	Analysis of Groundwater 4-16
4.4.3	Analysis of Surface Water and Sediment 4-18

TABLE OF CONTENTS
(Continued)

	<u>Page</u>
4.4.4 Summary of Site 4	4-20
4.5 Site 21 - Battery and Drum Disposal Area	4-21
4.5.1 Analysis of Soils	4-21
4.5.2 Analysis of Groundwater	4-24
4.5.3 Summary of Site 21	4-26
4.6 Extent of Contamination - Sites 4 and 21	4-27
4.6.1 Extent of Soil Contamination - Site 4	4-27
4.6.2 Extent of Soil Contamination - Site 21	4-29
4.6.3 Extent of Groundwater Contamination	4-31
4.6.4 Extent of Surface Water Contamination	4-33
4.6.5 Extent of Sediment Contamination	4-34
4.7 References	4-35
5.0 CONTAMINANT FATE AND TRANSPORT	5-1
5.1 Chemical and Physical Properties of Contaminants Detected at Sites 4 and 21	5-1
5.1.1 Vapor Pressure	5-1
5.1.2 Water Solubility	5-2
5.1.3 Octanol/Water Partition Coefficient	5-2
5.1.4 Organic Carbon Adsorption Coefficient	5-2
5.1.5 Specific Gravity	5-3
5.1.6 Henry's Law Constant	5-3
5.1.7 Mobility Index	5-3
5.2 Contaminant Transport Pathways	5-4
5.2.1 Off-Site Deposition of Windblown Dust	5-5
5.2.2 Surface Soil and Sediment Runoff	5-5
5.2.3 Sediment Migration	5-6
5.2.4 Leaching of Sediment Contaminants to Surface Water	5-6
5.2.5 Migration of Contaminants in Surface Water	5-7
5.2.6 Leaching of Soil Contaminants to Groundwater	5-8
5.2.7 Migration of Groundwater Contaminants	5-8
5.3 Fate and Transport Summary	5-11
5.3.1 Volatile Organic Compounds	5-12
5.3.2 Semivolatile Organic Compounds	5-12
5.3.3 Pesticides	5-12
5.3.4 Polychlorinated Biphenyls	5-12
5.3.5 Nitramine Compounds (Explosives)	5-12
5.3.6 Inorganics Constituents	5-13
5.4 References	5-14

TABLE OF CONTENTS
(Continued)

	<u>Page</u>
6.0 HUMAN HEALTH RISK ASSESSMENT	6-1
6.1 Sites 4 and 21 Overview	6-1
6.2 Identification of Chemicals of Potential Concern	6-2
6.2.1 COPC Selection Criteria	6-2
6.2.2 Other COPC Selection Criteria	6-4
6.2.3 Selection of COPCs	6-6
6.2.4 Summary of COPCs	6-15
6.3 Exposure Assessment	6-16
6.3.1 Chemical Fate and Transport	6-18
6.3.2 Potential Migration Pathways	6-22
6.3.3 Conceptual Site Model	6-24
6.3.4 Potential Exposure Pathways and Potential Receptors	6-24
6.3.5 Quantification of Exposure	6-29
6.3.6 Exposure Factors Used To Derive Chronic Daily Intakes	6-36
6.4 Toxicity Assessment	6-40
6.4.1 Toxicological Evaluation	6-41
6.4.2 Dose-Response Evaluation	6-42
6.5 Risk Characterization	6-44
6.5.1 Carcinogenic Compounds	6-45
6.5.2 Noncarcinogenic Compounds	6-46
6.6 Potential Human Health Effects	6-47
6.6.1 Current Adult On-Site Civilian Workers	6-47
6.6.2 Future Adult and Child On-Site Residents	6-49
6.6.3 Future Construction Workers	6-55
6.7 Sources of Uncertainty	6-56
6.7.1 Sampling and Analysis	6-57
6.7.2 Selection of COPCs	6-58
6.7.3 Exposure Assessment	6-59
6.7.4 Toxicological Assessment	6-60
6.7.5 Human Risk Characterization	6-61
6.7.6 Compounds Not Quantitatively Evaluated	6-61
6.8 Summary of Risk Assessment Results	6-62
6.8.1 Current Potential Receptors	6-62
6.8.2 Future Potential Receptors	6-63
6.9 References	6-66
7.0 ECOLOGICAL RISK ASSESSMENT	7-1
7.1 Objectives, Scope, and Organization of the Ecological Risk Assessment ...	7-1
7.2 Problem Formulation	7-2
7.2.1 Stressor Characteristics	7-3
7.2.2 Ecological Chemicals of Concern	7-3
7.2.3 Selection of Ecological Contaminants of Concern	7-6
7.2.4 Ecosystems Potentially at Risk	7-9

TABLE OF CONTENTS
(Continued)

		<u>Page</u>
	7.2.5 Ecological Endpoints	7-10
	7.2.6 Conceptual Model	7-12
7.3	Exposure Assessment	7-14
	7.3.1 Exposure Assessment/Profile	7-15
7.4	Ecological Effects Characterization	7-16
	7.4.1 Surface Soil	7-16
	7.4.2 Surface Water	7-18
	7.4.3 Sediment	7-19
7.5	Risk Characterization	7-20
	7.5.1 Surface Soil	7-20
	7.5.2 Surface Water	7-20
	7.5.3 Sediment	7-21
	7.5.4 Threatened and/or Endangered Species	7-21
	7.5.5 Wetlands	7-22
	7.5.6 Other Sensitive Environments	7-22
7.6	Ecological Significance	7-22
	7.6.1 Aquatic Assessment Endpoint	7-22
	7.6.2 Terrestrial Assessment Endpoint	7-23
7.7	Uncertainty Analysis	7-24
7.8	Conclusions	7-27
	7.8.1 Aquatic Ecosystem	7-27
	7.8.2 Terrestrial Ecosystem	7-27
7.9	References	7-28
8.0	SUMMARY AND CONCLUSIONS	8-1
8.1	Nature and Extent of Contamination	8-1
	8.1.1 Surface Soil	8-1
	8.1.2 Subsurface Soil	8-2
	8.1.3 Groundwater	8-3
	8.1.4 Surface Water	8-5
	8.1.5 Sediments	8-6
8.2	Human Health Risk Assessment	8-6
	8.2.1 Site 4	8-7
	8.2.2 Site 21	8-8
8.3	Ecological Risk Assessment	8-8
	8.3.1 Aquatic Ecosystem	8-9
	8.3.2 Terrestrial Ecosystem	8-9
8.4	Recommendations	8-9

APPENDICES

- A Geophysical Report**
- B Well Construction and Test Boring Records**
- C Slug Test Data**
- D Analytical Summaries**
 - D.1 Dames & Moore Analytical Summaries**
 - D.2 Weston Analytical Summaries**
 - D.3 IT Corporation Analytical Summaries**
- E Statistical Summaries**
- F Risk Spreadsheets**
- G Shower Model**
- H Human Health Toxicity Profiles**
- I Ecological Toxicity Profiles**

LIST OF TABLES

- 1-1 Summary of Confirmation Study Groundwater Data (1986 & 1987)
- 1-2 Summary of Confirmation Study Surface Water and Sediment Data (1986 & 1987)
- 1-3 Summary of Site 21 SI Groundwater Data
- 1-4 Summary of Site 21 SI Soil Data

- 2-1 Summary of Round One RI Surface Soil Sample Information
- 2-2 Summary of Round One RI Soil Samples Collected from Monitoring Well Boreholes
- 2-3 Summary of Round One RI Groundwater Sample Information
- 2-4 Summary of Monitoring Well Construction Details
- 2-5 Summary of Round One RI Groundwater Elevation Data
- 2-6 Summary of Round One RI Monitoring Well Survey Data
- 2-7 Summary of Round One RI Surface Water and Sediment Sample Information
- 2-8 Round One RI Hydraulic Conductivities Based on Aquifer Slug Tests
- 2-9 Summary of Surface Water Flow Measurements Collected at Site 21 During the Week of 17 August 1992

- 3-1 Representative Meteorological Data - WPNSTA Yorktown Region
- 3-2 Geologic Formations and Hydrogeologic Unit in the Vicinity of WPNSTA Yorktown

- 4-1 Background - Soil Organic Compounds
- 4-2 Background - Soil Inorganic Compounds
- 4-3 Background - Surface Water Organic Compounds
- 4-4 Background - Groundwater Inorganic Compounds
- 4-5 Background - Groundwater Dissolved Inorganic Compounds
- 4-6 Background - Surface water Organic Compounds
- 4-7 Background - Surface Water Inorganic Compounds
- 4-8 Background - Surface Water Dissolved Inorganic Compounds
- 4-9 Background - Sediment Organic Compounds
- 4-10 Background - Sediment Inorganic Compounds
- 4-11 Site 4 - Removal Action Surface Soil Volatile Organic Compounds
- 4-12 Site 4 - Removal Action Surface Soil Semivolatile Organic Compounds
- 4-13 Site 4 - Removal Action Surface Soil Pesticides and PCBs
- 4-14 Site 4 - Removal Action Surface Soil Inorganic Compounds
- 4-15 Site 4 - Removal Action Surface Soil Explosives
- 4-16 Site 4 - Groundwater Volatile Organic Compounds
- 4-17 Site 4 - Groundwater Inorganic Compounds
- 4-18 Site 4 - Groundwater Dissolved Inorganic Compounds
- 4-19 Site 4 - Groundwater Explosives
- 4-20 Site 4 - Surface Water Semivolatile Organic Compounds
- 4-21 Site 4 - Surface Water Inorganic Compounds
- 4-22 Site 4 - Surface Water Dissolved Inorganic Compounds
- 4-23 Site 4 - Surface Water Nitroexplosives
- 4-24 Site 4 - Surface Water Volatile Organic Compounds
- 4-25 Site 4 - Sediment Semivolatile Organic Compounds
- 4-26 Site 4 - Sediment Pesticides and PCBs
- 4-27 Site 4 - Sediment Inorganic Compounds

LIST OF TABLES
(Continued)

- 4-28 Site 21 - Surface Soil Volatile Organic Compounds
- 4-29 Site 21 - Surface Soil Semivolatile Organic Compounds
- 4-30 Site 21 - Surface Soil Pesticides
- 4-31 Site 21 - Surface Soil Inorganic Compounds
- 4-32 Site 21 - Subsurface Soil Volatile Organic Compounds
- 4-33 Site 21 - Subsurface Soil Semivolatile Organic Compounds
- 4-34 Site 21 - Subsurface Soil Pesticides and PCBs
- 4-35 Site 21 - Subsurface Soil Inorganic Compounds
- 4-36 Site 21 - Groundwater Inorganic Compounds
- 4-37 Site 21 - Groundwater Dissolved Inorganics

- 5-1 Organic Physical and Chemical Properties, Sites 4 and 21
- 5-2 Relative Mobilities of Inorganics as a Function of Environmental Conditions (Eh and pH), Sites 4 and 21

- 6-1 Surface Soil Data Summary - Site 4, Frequency and Range of Positive Detections Compared to USEPA Region III COC Screening Values
- 6-2 Groundwater Data Summary - Site 4, Frequency and Range of Positive Detections Compared to Federal, Regional, and Commonwealth Criteria
- 6-3 Surface Water Data Summary - Site 4, Frequency and Range of Positive Detections Compared to Federal, Regional, and Commonwealth Criteria
- 6-4 Sediment Data Summary - Site 4, Frequency and Range of Positive Detections Compared to Sediment Screening Values and USEPA Region III COC Screening Values
- 6-5 Surface Soil Data Summary - Site 21, Frequency and Range of Positive Detections Compared to USEPA Region III COC Screening Values
- 6-6 Subsurface Soil Data Summary - Site 21, Frequency and Range of Positive Detections Compared to USEPA Region III COC Screening Values
- 6-7 Groundwater Data Summary - Site 21, Frequency and Range of Positive Detections Compared to Federal, Regional, and Commonwealth Criteria
- 6-8 Physical and Chemical Properties for Organic Chemicals of Potential Concern
- 6-9 Relative Mobilities of Inorganics as a Function of Environmental Conditions (Eh, pH)
- 6-10 Exposure Input Parameters for Current Adult On-Site Civilian Workers Potentially Exposed to COPCs in Surface Soil, Surface Water, and Sediment Via Ingestion, Dermal Contact, and Inhalation of Fugitive Dust
- 6-11 Exposure Input Parameters for Future Resident Children and Adults Potentially Exposed to COPCs in Surface Soil, Groundwater, Surface Water, and Sediment via Ingestion, Dermal Contact, and Inhalation
- 6-12 Exposure Input Parameters for Future Adult Construction Workers Potentially Exposed to COPCs in Subsurface Soil Via Ingestion, Dermal Contact, and Inhalation
- 6-13 Human Health Risk Assessment Toxicity Factors
- 6-14 Incremental Lifetime Cancer Risks (ICRs) and Hazard Indices (HIs) for Current Adult Civilian Workers - Site 4
- 6-15 Incremental Lifetime Cancer Risks (ICRs) and Hazard Indices (HIs) for Current Adult Civilian Workers - Site 21
- 6-16 Incremental Lifetime Cancer Risks (ICRs) and Hazard Indices (HIs) for Future Adult and Child On-Site Residents - Site 4

LIST OF TABLES
(Continued)

- 6-17 Incremental Lifetime Cancer Risks (ICRs) and Hazard Indices (HIs) for Future Adult and Child On-Site Residents - Site 21
- 6-18 Incremental Lifetime Cancer Risks (ICRs) and Hazard Indices (HIs) for Future Construction Workers - Site 4
- 6-19 Incremental Lifetime Cancer Risks (ICRs) and Hazard Indices (HIs) for Future Construction Workers - Site 21
- 6-20 Summary of Uncertainties in the Results of the Human Health Risk Assessment
- 6-21 Total Site Lifetime Incremental Cancer Risk (ICR) and Hazard Index (HI) for Current Potential Human Receptors - Site 4
- 6-22 Total Site Lifetime Incremental Cancer Risk (ICR) and Hazard Index (HI) for Current Potential Human Receptors - Site 21
- 6-23 Total Site Lifetime Incremental Cancer Risk (ICR) and Hazard Index (HI) for Future Potential Human Receptors - Site 4
- 6-24 Total Site Lifetime Incremental Cancer Risk (ICR) and Hazard Index (HI) for Future Potential Human Receptors - Site 21

- 7-1 Sites 4 and 21 - Contaminants of Potential Concern Per Media
- 7-2 Site 4 - Surface Soils, Frequency and Range of Detection Compared to USEPA Region III Soil Screening Levels
- 7-3 Site 21 - Surface Soils, Frequency and Range of Detection Compared to USEPA Region III Soil Screening Levels
- 7-4 Sites 4 and 21, Frequency and Range of Detection Compared to USEPA Region III Estuarine Water Screening Levels
- 7-5 Sites 4 and 21, Frequency and Range of Detection Compared to USEPA Region III Sediment Screening Levels
- 7-6 Sites 4 and 21 - Physical/Chemical Characteristics of the Ecological Contaminants of Concern
- 7-7 Site 4 - Range and 95% UCL of Contaminant Detections Compared to Soil Flora and Fauna Toxicity Values
- 7-8 Site 21 - Range and 95% UCL of Contaminant Detections Compared to Soil Flora and Fauna Toxicity Values
- 7-9 Sites 4 and 21 - Surface Water Quotient Index Levels
- 7-10 Sites 4 and 21 Sediment Quotient Index

- 8-1 Summary of Human Health Risk Assessment ICR and HI Values

LIST OF FIGURES

- 1-1 Location of Naval Weapons Station Yorktown, Yorktown, Virginia
- 1-2 Location of Sites 4 and 21
- 1-3 Site Plans of Sites 4 and 21

- 2-1 Round One Soil Sample Locations at Sites 4 and 21
- 2-2 Round One Groundwater Monitoring Well Locations at Sites 4 and 21
- 2-3 Round One Surface Water and Sediment Sampling Locations at Sites 4 and 21
- 2-4 Removal Action Sites 4 and 21 Excavation Area
- 2-5 Removal Action Surface Soil Sample Locations - Site 4
- 2-6 Removal Action Surface Soil Sample Locations at Site 21

- 3-1 Generalized Geologic Cross Section - Sites 4 and 21
- 3-2 Hydrogeologic Cross Section A-A' - Sites 4 and 21
- 3-3 Hydrography Comparing Staff Gauge and Monitoring Well Water Levels at WPNSTA Yorktown
- 3-4 Potentiometric Surface (Nov. 1992) for Cornwallis Cave Aquifer at Sites 4 and 21

- 4-1 Round One RI Positive Detections of Organic Compounds in Surface Soil - Sites 4 and 21
- 4-2 Round One RI Positive Detections of Select Inorganic Analytes in Surface Soil - Sites 4 and 21
- 4-3 Round One RI Positive Detections of Organic Compounds and Select Inorganic Analytes in Subsurface Soil - Site 21
- 4-4 Round One RI Positive Detections of Organic Compounds in Groundwater - Sites 4 and 21
- 4-5 Round One RI Positive Detections of Select Inorganic Analytes in Groundwater - Sites 4 and 21
- 4-6 Round One RI Positive Detections of Organic Compounds in Surface Water - Sites 4 and 21
- 4-7 Round One RI Positive Detections of Select Inorganic Analytes in Surface Water - Sites 4 and 21
- 4-8 Round One RI Positive Detections of Organic Compounds in Sediment - Sites 4 and 21
- 4-9 Round One RI Positive Detections of Select Inorganic Analytes in Sediment - Sites 4 and 21
- 4-10 Removal Action Positive Detections of Total Organics in Surface Soil - Site 4
- 4-11 Removal Action Positive Detections of Select Inorganic Analytes in Surface Soils - Site 4
- 4-12 Removal Action Positive Detections of Organic Compounds in Surface Soil - Site 21
- 4-13 Removal Action Positive Detections of Select Inorganic Analytes in Surface Soils - Site 21

- 6-1 Conceptual Site Model

- 7-1 Potential Exposure Pathways and Ecological Receptors

- 8-1 Approximate TPH Isoconcentrations in Surface Soil at Site 4

LIST OF ACRONYMS AND ABBREVIATIONS

ABS	absorbed fraction
AET	Apparent Effects Threshold
AF	adherence factor
AT	averaging time
AWQS	Ambient Water Quality Criteria
Baker	Baker Environmental, Inc.
B _p	Beef Transfer Coefficients
BCF	bioconcentration factor
bgs	below ground surface
BSLs	Biological Technical Assistance Group Screening Levels
BTAG	Biological Technical Assistance Group
B _v or B _r	Plant Transfer Coefficients
BW	body weight
Ca	chemical concentration in air as fugitive dust
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Conversion Factor
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CO	carbon monoxide
COC	Chemicals of Concern
COPC	chemical of potential concern
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
Cs	chemical concentration in soil or sediment
CSFs	carcinogenic slope factors
CTO	Contract Task Order
Cw	chemical concentration in water
CWA	Clean Water Act
cy	cubic yards
DCE	1,1-dichloroethene
DEQPPM	Defense Environmental Quality Program Policy Memorandum
DNB	dinitrobenzene
DNT	4-amino-2,6-dinitrotoluene
DoD	Department of Defense
DoN	Department of the Navy
DRMO	Defense Reutilization and Marketing Organization

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

ECOC	Ecological Contaminant of Concern
ED	Exposure Duration
EE/CA	Engineering Evaluation/Cost Analysis
EF	Frequency of Exposure
Eh	oxidation reduction potential
EM	electromagnetic
ER-L	Effects Range-Low
ER-M	Effects Range-Median
ESQD	Explosive Safety Quantity Distance
ET	Exposure Time
FFA	Federal Facility Agreement
FS	Feasibility Study
ft ³ /sec	cubic feet per second
GPR	ground penetrating radar
HEAST	Health Effects Assessment Summary Table
HHI	Harden Huber, Inc.
HMX	cyclotetramethylenetranitramine
HQ	hazard quotient
HRSD	Hampton Roads Sanitation District
IAS	Initial Assessment Study
ICR	incremental lifetime cancer risk
ID	inside diameter
IDW	Investigative Derived Waste
IR	Ingestion Rate or Inhalation Rate
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
K _{oc}	organic carbon adsorption coefficient
K _{ow}	octanol/water partition coefficient
K _p	equations and chemical-specific constants
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LOAEL	lowest-observed-adverse-effect-level
MCL	maximum contaminant level
MCLGs	maximum contaminant level goals
MeCL ₂	methylene chloride
MF	modifying factor
mg/kg	milligrams per kilogram
mg/L	milligrams per liter

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

MI	Mobility Index
MS/DS	matrix spike/matrix spike duplicate
msl	mean sea level
NACIP	Naval Assessment and Control of Installation Pollutants
NEESA	Navy Energy and Environmental Support Activity
NOAA	National Oceanic and Atmospheric Administration
NOAEL or NOEL	no-observed-adverse-effect-level
NOC	East Coast Naval Ordnance Center
NPDES	Virginia National Pollutant Discharge Elimination System
NSC	Naval Supply Center
NTR	Navy Technical Representative
O ₃	ozone
ORNL	Oak Ridge National Laboratory
PA	Preliminary Assessment
PAH	polycyclic aromatic hydrocarbons
PC	chemical-specific permeability constant
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PEF	Particulate Emission Factor
PPE	personal protective equipment
ppm	parts per million
ppt	parts per thousand
PRAP	Proposed Remedial Action Plan
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QI	quotient indices
R & D	research and development
RA	Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RBC	risk-based concentration
RCRA	Resource Conservation Recovery Act
RDX	cyclotrimethylenetrinitroamine
RfCs	Reference Concentrations for Inhalation
RfDs	Standard Reference Doses
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RPD	relative percent difference

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

S	water solubility
SA	surface area of exposed skin
SARA	Superfund Amendments and Reauthorization Act
SCCRBS	Selecting Exposure Routes and Contaminants of Concern , by Risk-Based Screening
SI	Site Inspection
SO ₂	sulfur dioxide
SOPs	Standard Operating Procedures
SSLs	Sediment Screening Levels
SSSLs	Surface Soil Screening Levels
SSVs	sediment screening values
SVOCs	semivolatile organic compounds
SWMF	Virginia Solid Waste Management Facility
SWSLs	Surface water Screening Levels
T-O-C	top-of-casing
TAL	Target Analyte List
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedures
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	total organic content
TPH	total petroleum hydrocarbons
TSCA	Toxic Substance Control Act
UCL	upper confidence limit
UF	uncertainty factor
µg/L	micrograms per liter
µg/kg	micrograms per kilogram
µg/m ³	micrograms per cubic meter
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VGS	Virginia Groundwater Standards
VOCs	volatile organic compounds
VP	vapor pressure
VR	Virginia Regulation
VWQS	Virginia Water Quality Standards
Weston	Roy F. Weston, Inc.
WPNSTA	U.S. Naval Weapons Station
WQS	Water Quality Standards

6.0 HUMAN HEALTH RISK ASSESSMENT

A baseline human health risk assessment was performed as part of the RI/FS for Sites 4 and 21 at WPNSTA Yorktown, to evaluate the potential risks associated with exposure to environmental media resulting from existing conditions at the site if no additional remedial action is undertaken. The baseline RA considers the most likely routes of potential human exposure for both current and future risk scenarios. The baseline RA was conducted in accordance with the Risk Assessment Guidance for Superfund (RAGS), Part A, Human Health Evaluation Manual (USEPA, 1989b), and the most recent updates. The baseline RA is comprised of nine sections; Section 6.1 presents an overview of the historical information for Sites 4 and 21 pertinent to the development of the risk assessment technical approach. Section 6.2 presents the selection of chemicals of potential concern. Sections 6.3 and 6.4 present the Exposure Assessment and Toxicity Assessment, respectively. The risk characterization is presented in Section 6.5 and potential human health effects are provided in Section 6.6. Section 6.7 presents sources of uncertainty inherent in the estimation of inferential potential human health effects. A summary of the baseline RA is provided in Section 6.8, where and total site risk to each potential human receptor is presented therein. Section 6.9 presents the references.

6.1 Sites 4 and 21 Overview

Site 4 is a 10-acre area bordered to the northeast by West Road. Site 22, the former explosive burning facility is located southwest of the site. Site 21 is situated approximately 50 yards to southeast of Site 4. Site 4 is physically separated by an unnamed drainage way from Site 21. Felgates Creek is located south of Site 4 and the explosive burning facility. From 1940 to 1975, Site 4 was the location of an industrial landfill. It received waste which consisted of carbon-zinc batteries, landscape waste, boiler ash, explosives burning residues, and tree stumps. The removal of batteries, ash and other surface debris was the focus of the Removal Action performed by IT Corporation in 1994 (IT, 1995).

Similar to Site 4, Site 21 was the former location of a disposal area for wastes, which included battery cases, drums and other empty containers. Specifically, batteries, drums, cans, scrap metal and other scattered waste were found throughout the site. IT Corporation conducted an extensive

removal action at Site 21 during 1994. Subsequent to the Removal Action, the site was brought back to grade.

6.2 Identification of Chemicals of Potential Concern

The selection of COPCs was based on the information provided in the USEPA Region III Technical Guidance on Selecting Exposure Routes and Contaminants of Concern, by Risk-Based Screening (SCCRBS), dated January 1993 (USEPA, 1993b) and USEPA's Risk Assessment Guidance for Superfund (RAGS), Volume I. Human Health Evaluation Manual (Part A), Interim Final, December 1989 (USEPA, 1989b). COPCs can be defined as "chemicals detected at the site that have the greatest relative potential to affect human health based on a set of selection criteria." COPC selection was completed for each environmental medium at each site using analytical data obtained during the RI as well as analytical data obtained during the removal action in 1994 (IT, 1995).

A discussion of laboratory analytical results and nature and extent of constituent contamination are presented in Section 4.0 of this report. In the RI report, chemicals detected in environmental media were discussed with respect to applicable federal and Commonwealth standards and/or criteria. In these sections, a preliminary account of analytical results was presented. Chemicals detected in environmental media sampled during the RI and after the removal action were reevaluated in this section to select COPCs for quantitative evaluation in the baseline RA. Chemicals selected as COPCs that could not be quantitatively evaluated, are discussed in the uncertainties section (Section 6.7) of the baseline RA.

6.2.1 COPC Selection Criteria

The primary criteria used in selecting a chemical as a COPC at Sites 4 and 21 included comparing the maximum detected concentration to the USEPA Region III Chemicals of Concern (COC) Screening Table (USEPA, 1993a), in accordance with USEPA Region III SCCRBS guidance (USEPA, 1993b).

The prevalence of a chemical detected in a given environmental medium, as well as the history of site-related activities are other important criteria applied in potentially reincluding chemicals as COPCs despite the fact that maximum detected concentrations were less than COC values. In

conjunction with evaluations of chemical prevalence and site history, a comparison of groundwater, surface water and sediment to available Commonwealth and Federal standards and criteria was conducted to determine whether chemicals eliminated by a direct comparison to COC values should be re-included as COPCs. Each of the aforementioned criteria are discussed in the following paragraphs.

USEPA Region III COC Screening Concentrations - Risk-based COC screening concentrations (COC values) were derived by USEPA, Region III in January of 1993 and provided in tabular format to support selection of COCs and address two major limitations in the COPC selection process presented in RAGS. First, using COC screening concentrations prioritizes chemical toxicity and focuses the risk assessment on those COPCs and potential exposure routes. Second, using the screening concentration provides an absolute comparison of potential risks associated with the presence of a COPC in a given medium.

COC values were derived using conservative USEPA promulgated default values and the most recent toxicological criteria available. COC values for potentially carcinogenic and noncarcinogenic chemicals were individually derived based on a target incremental lifetime cancer risk (ICR) of 1×10^{-6} and a target hazard quotient (HQ) of 0.1, respectively. For potential carcinogens, the toxicity criteria applicable to the derivation of COC values are oral and inhalation cancer slope factors; for noncarcinogens, they are chronic oral and inhalation reference doses. These toxicity criteria are subject to change as more updated information and results from the most recent toxicological/epidemiological studies become available. Therefore, the use of toxicity criteria in the derivation of COPC screening concentrations requires that the screening concentrations be updated periodically to reflect changes in the toxicity criteria.

The last set of COC values published by USEPA were in tables dated March 1993. The values from these tables can be updated by incorporating information from another set of tables containing risk-based concentrations (RBCs) that are issued by USEPA Region III on a quarterly basis. The RBCs are derived using similar equations and USEPA promulgated default exposure assumptions that were used to derive the original set of COPC screening concentrations (USEPA, 1993b) and COC values (USEPA, 1993a). The only difference in the derivation methodologies for the COPC and the COC values is that the COC values for noncarcinogens are derived based on a target HQ of 0.1, and the COPC values on a target HQ of 1.0. An updated set of COC values can, therefore, be obtained each

quarter by using the carcinogenic RBCs issued quarterly by USEPA Region III (USEPA, 1995a) and dividing the accompanying noncarcinogenic RBCs by a factor of 10.

Prevalence - The prevalence of a chemical in an environmental medium can be described by the frequency and concentration with which it is detected. A detection frequency greater than 5 percent (e.g., 1 positive detection in 20 samples) was the detection frequency considered in the selection of COPCs in data sets comprised of 20 or more samples. Data sets with fewer than 20 samples were evaluated for any positive detections to determine whether the chemical should be reincluded as a COPC.

Sediment Screening Values - At present, promulgated sediment quality criteria do not exist to protect human health. However, sediment screening values (SSVs) have been published (Long, et al., 1995) for evaluating the potential for chemical constituents in sediment to cause adverse biological effects. This screening method was developed through evaluation of biological effects data for aquatic (marine and freshwater) organisms that were obtained through equilibrium partitioning calculations, spiked-sediment bioassays, and concurrent biological and chemical field surveys. For each constituent having sufficient data available, the concentrations causing adverse biological effects were arrayed and the lower 10 percentile (called an Effects Range-Low, or ER-L) and the median (called an Effects Range-Median, or ER-M) were determined. If contaminant concentrations are above the ER-M, adverse effects on the biota are considered probable.

Since the use of SSVs in human health RAs may be considered overly conservative, constituents detected in the sediment at Sites 4 and 21 were compared to the SSV ER-Ms, rather than ER-Ls, to determine if any criteria were exceeded. According to USEPA Region III, exceedences of the ER-M would constitute a chemical's retention as a COPC.

6.2.2 Other COPC Selection Criteria

Chemicals may also be selected or re-included as COPCs if detected concentrations exceed the following federal/Commonwealth standards or criteria.

Maximum Contaminant Levels - MCLs are potentially enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of

human health. MCLs have been adopted as enforceable standards for public drinking water systems, and apply to drinking water supplies consumed by a minimum of 25 persons. They have been developed for the prevention of human health effects associated with lifetime exposure (70 year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical and economic feasibility of removing the constituent from a public water supply (USEPA, 1994a).

Maximum Contaminant Level Goals (MCLGs) - MCLGs are usually non-enforceable guidelines based entirely on the potential for human health effects. The MCLs have been set as close to the MCLGs as is considered technically and economically feasible. MCLGs are specified as zero for carcinogenic substances, based on the assumption of nonthreshold toxicity, and do not consider the technical or economic feasibility of achieving these goals. In addition, MCLGs for noncarcinogens are set based upon chronic toxicity or other data (USEPA, 1994a).

Virginia Drinking Water Standards - Virginia Drinking Water Standards are the maximum contaminant level concentrations of a contaminant in water which is delivered to the users of a public water system. With the exception of nitrate, all inorganic chemical contaminant levels are based on potential adverse health effects resulting from long term exposure to the contaminant in drinking water. The maximum contaminant levels for organics apply to community water supplies, the volatile organics also apply to nontransient, noncommunity water systems.

Virginia Water Quality Standards (WQS) for the Protection of Human Health - The WQSs are Commonwealth-enforceable standards used for identifying the potential for human health risks. WQSs are protective of human health and consider potential carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day), or from ingestion of water alone (2 liters/day). Commonwealth WQSs available for the protection of human health from potential carcinogenic substances are derived based on an incremental lifetime cancer risk of one additional case of cancer in an exposed population of 100,000 persons (i.e., 1×10^{-5}).

Federal Ambient Water Quality Criteria (AWQC) - AWQC are non-enforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic organisms for surface water bodies. AWQCs consider acute and chronic effects in both freshwater and

saltwater aquatic life, and potential carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day), or from ingestion of organisms alone (6.5 grams/day). The AWQCs for protection of human health for potential carcinogenic substances are based on the USEPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 10,000,000 to 100,000 persons (i.e., the 1.0×10^{-07} to 1.0×10^{05} range). The AWQCs used for comparison in this baseline RA included the human health recalculated values for water and organisms, and organisms only. Published criteria were used in the absence of recalculated values.

Finally, chemicals which could be considered as essential nutrients were eliminated from consideration as COPCs.

Essential Nutrients - Despite their inherent toxicity, certain inorganic constituents are essential nutrients. Essential nutrients need not be considered for further consideration in the baseline RA if they are present in relatively low concentrations (i.e., slightly elevated above naturally occurring levels), or if the constituent is toxic at doses much higher than those which could be assimilated through exposures at the site. Elements considered to be as essential nutrients include calcium, iron, magnesium, sodium, and potassium.

6.2.3 Selection of COPCs

Four environmental media (soil, groundwater, sediment and surface water) were investigated at Sites 4 and 21. Surface soil samples were collected during the removal action in 1994 while groundwater samples (shallow monitoring wells) were collected during the RI performed by Baker/Weston in 1993. Also during the RI, surface water and sediment samples were collected in a tributary to Felgates Creek. These samples were collected two years before the removal action and are no longer representative of current site conditions. These results will, however, be used in risk calculations for Sites 4 and 21. The selection of soil COPCs was stratified to include the surface soil (0- to 6-inches bgs) and the subsurface soil (greater than 6-inches bgs); each of these intervals was evaluated individually. Tables 6-1 through 6-7 present the selection of COPCs for each environmental medium based on comparisons of USEPA Region III COPC screening concentrations and other applicable criteria, with the maximum detected concentration. Information (i.e., ranges of detected concentrations and frequency of detections) is presented in these tables only for those

constituents detected at least once, in the medium of interest. Analytical summary tables are presented in Appendix E.

The following paragraphs present the rationale for selection of COPCs. Sample locations, analytical results, and corresponding figures are presented in other sections of this RI report.

6.2.3.1 Site 4

Surface Soil

Surface soil samples were collected from the 0- to 6-inch interval and analyzed for VOCs, SVOCs, pesticides, PCBs, nitramine compounds, and inorganics. The sample set included 47 samples (43 environmental and 4 duplicate samples), from the removal action conducted by IT Corporation in the spring of 1994 (surface soil samples collected during the RI will not be used to calculate risk, as this soil was removed during the removal action performed in 1994). The COPC selection summaries for surface soil are presented in Table 6-1.

Five VOCs (acetone, methylene chloride, 2-butanone, trichloroethene, and toluene) were detected in the surface soil samples. Acetone and trichloroethene were detected infrequently in only one sample. All the VOCs were detected at concentrations below the industrial and residential COC values, and therefore were not retained as COPCs.

Twenty-seven SVOCs were detected in the surface soil. 4-Methylphenol, 3-nitroaniline, n-nitrosodiphenylamine, pentachlorophenol, butylbenzylphthalate, and di-n-octylphthalate were detected infrequently in the surface soil in either one or two samples. 4-Methylphenol, naphthalene, 3-nitroaniline, acenaphthene, dibenzofuran, fluorene, n-nitrosodiphenylamine, pentachlorophenol, anthracene, butylbenzylphthalate, fluoranthene, pyrene, chrysene, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, di-n-octyl phthalate, and benzo(k)fluoranthene were detected at concentrations below industrial and residential COC values. Therefore, these chemicals were not retained as surface soil COPCs. 2-Methylnaphthalene, acenaphthylene, phenanthrene, and benzo(g,h,i)perylene were all detected frequently in the surface soil and were retained as COPCs. Carbazole, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and

dibenz(a,h)anthracene were detected at concentrations that exceeded the residential COC values and also were retained as surface soil COPCs.

Twelve pesticides were detected in the surface soil. Heptachlor epoxide, endrin, endrin aldehyde and endrin ketone were detected infrequently and their concentrations did not exceed residential COC values. Therefore, these pesticides were not retained as surface soil COPCs. Heptachlor, dieldrin, endosulfan II, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, alpha-chlordane, and gamma-chlordane were detected at concentrations below residential COC values, and were not retained as surface soil COPCs.

Three PCBs (Aroclor-1016, 1254, and 1260) were detected in the surface soil. Aroclor-1016 was detected in one sample at a concentration below the residential COC value and was therefore not retained as a COPC. Aroclor-1254 and Aroclor-1260 were detected in 5 and 4 out of 46 samples, respectively, and at concentrations which exceeded the residential COC values. Therefore, these PCBs were retained as surface soil COPCs.

Five nitramine compounds (HMX, RDX, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, and 2,4,6-trinitrotoluene) were detected in the surface soil at Site 4. 1,3,5-Trinitrobenzene and 1,3-dinitrobenzene were detected at frequencies less than five percent (1 out of 47 samples); therefore, these chemicals were not retained as a surface soil COPC. HMX was detected in the surface soil at a concentration less than the residential COC values and was not retained as a surface soil COPCs. RDX and 2,4,6-trinitrotoluene were detected frequently in the surface soil at concentrations exceeding residential COC values; therefore, these chemicals were retained as surface soil COPCs.

Inorganics were detected in all surface soil samples collected. The maximum detected concentrations of barium, chromium, cobalt, mercury, nickel, silver, thallium, vanadium, and cyanide did not exceed the corresponding Region III residential soil COC values and were not retained as COPCs. The maximum concentration of lead did not exceed the action level for residential soils (USEPA, 1994c) and was not retained as a surface soil COPC. Calcium, iron, magnesium, potassium, and sodium were also detected in almost every sample. However, these constituents are considered to be essential nutrients and are not expected to cause adverse effects at the detected concentrations. Therefore, these chemicals were not retained as COPCs. Therefore,

aluminum, antimony, arsenic, beryllium, cadmium, copper, manganese, and zinc are retained as surface soil COPCs for evaluation in the baseline RA.

Subsurface Soil

There were no subsurface soil samples collected at Site 4.

Groundwater

Table 6-2 summarizes the COPC selections performed for constituents detected in groundwater (shallow). The sample set included five samples collected during the RI conducted by Baker/Weston in 1993. All samples were analyzed for VOCs, SVOCs, pesticides/PCBs, nitramine compounds, unfiltered (total) and filtered (dissolved) inorganics.

Four VOCs were detected in groundwater samples collected from Site 4: 1,1,1-trichloroethane, 1,1-dichloroethene, 1,2-dichloroethene, and trichloroethene. 1,1,1-Trichloroethane did not exceed Region III tap water COC values or other applicable groundwater criteria and therefore was not retained as a groundwater COPC. 1,2-Dichloroethene, 1,1-dichloroethene and trichloroethene were detected relatively frequently at concentrations greater than Region III tap water COC values and groundwater criteria. Consequently, these three VOCs were included as groundwater COPCs.

SVOCs, pesticides and PCBs were not detected in the groundwater at Site 4.

Two nitramine compounds (HMX and RDX) were detected in the groundwater at Site 4. HMX was detected at a concentration below the tap water COC level and was not retained as a COPC. RDX was detected at a concentration greater than the tap water COC value. It was retained as a groundwater COPC.

Eighteen unfiltered (total) inorganics were detected in the groundwater. Cobalt, mercury, and zinc were detected at concentrations less than the corresponding tap water COC values and were not retained as COPCs. Calcium, iron, magnesium, potassium, and sodium were also detected in almost every sample; however, these constituents are considered to be essential nutrients and are not expected to cause adverse effects at the detected concentrations. Therefore, these chemicals were

not retained as COPCs. Aluminum, arsenic, barium, beryllium, cadmium, chromium, lead, manganese, nickel, and vanadium were retained due to exceedances of the tap water-COC values.

Ten filtered (dissolved) inorganics were detected in the groundwater. Aluminum, barium, silver, and zinc were detected at concentrations less than the corresponding tap water COC values and groundwater criteria. Consequently, these chemicals were not retained as COPCs. Calcium, iron, magnesium, and sodium were also detected in almost every sample. However, these constituents are considered to be essential nutrients were not retained as COPCs. Antimony and manganese exceeded the tap water COC values and are retained as COPCs for evaluation in the baseline RA.

Surface Water

Table 6-3 summarizes the COPC selections performed for constituents detected in the surface water from a tributary to Felgates Creek. Five surface water samples collected during the RI were analyzed for VOCs, SVOCs, pesticides/PCBs, nitramine compounds, unfiltered (total) and filtered (dissolved) inorganics. (Surface water samples were collected before the removal action and are not representative of current site conditions.)

VOCs, pesticides and PCBs were not detected in the surface water at Site 4.

Di-n-butyl phthalate was the only SVOC detected in the surface water. It was detected in 1 out of 5 samples at a concentration below surface water criteria and was not retained as a surface water COPC.

Seven nitramine compounds (1,3,5-trinitrobenzene, 1,3-dinitrobenzene, 2,4,6-trinitrotoluene, 2,4-dinitrobenzene, HMX, nitrobenzene, and RDX) were detected in the surface water. 1,3-Dinitrobenzene, 2,4-dinitrotoluene and HMX were detected at concentrations below surface water criteria and were not retained as COPCs. 1,3,5-Trinitrobenzene, 2,4,6-trinitrotoluene, nitrobenzene, and RDX exceeded surface water criteria and were retained as COPCs.

Inorganics were detected in most of the surface water samples collected. Nineteen unfiltered (total) metals were detected in the surface water. Barium, cobalt, and nickel were detected at concentrations below surface water criteria and standards and were not retained as surface water

COPCs. Aluminum, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, vanadium, and zinc exceeded surface water criteria and were retained as COPCs in the surface water.

Thirteen filtered (dissolved) inorganics were detected in the surface water. Barium, lead, nickel, vanadium, and zinc were detected at concentrations below surface water criteria and were not retained as COPCs. Antimony, arsenic, cadmium, and manganese exceeded surface water criteria and were retained as COPCs. In addition, calcium, iron, magnesium, potassium, and sodium were also detected in these samples. However, these constituents are considered to be essential nutrients and were not retained as COPCs.

Sediment

Table 6-4 summarizes the COPC selections performed for constituents detected in sediment. Ten sediment samples collected during the RI were analyzed for VOCs, SVOCs, pesticides/PCBs, nitramine compounds, and inorganics. (Sediment samples were collected before the removal action and are not representative of current site conditions.)

Four VOCs (2-butanone, carbon disulfide, 1,1,1-trichloroethane, and methylene chloride) were detected in the sediment samples. 2-Butanone, carbon disulfide, 1,1,1-trichloroethane and methylene chloride did not exceed the criteria used for sediment comparison and were not retained as COPCs.

Benzo(g,h,i)perylene was the only SVOC detected in the sediment at Site 4 and was retained as a sediment COPC.

Five pesticides (alpha-chlordane, gamma-chlordane, 4,4'-DDD, 4,4'-DDE and 4,4'-DDT) were detected in the sediment. All pesticides, except 4,4'-DDE, were detected at concentrations that did not exceed the criteria for sediment comparison and were not retained as sediment COPCs. Consequently, 4,4'-DDE was the only pesticide retained as a COPC in Site 4 sediment. PCBs were not detected in the sediment.

Inorganics were detected in a majority of sediment samples collected. Twenty-one inorganics were detected in the sediment samples. The maximum detected concentrations of barium, cadmium,

chromium, cobalt, copper, lead, mercury, nickel, selenium, and vanadium did not exceed the corresponding sediment comparison criteria. Therefore, these chemicals were not retained as sediment COPCs. Calcium, iron, magnesium, potassium, and sodium were also detected in a majority of the sample. However, these constituents are considered to be essential nutrients and were not retained as COPCs. Therefore, aluminum, antimony, arsenic, beryllium, manganese and zinc were retained as sediment COPCs for evaluation in the RA.

6.2.3.2 Site 21

Surface Soil

Surface soil samples were collected from the 0- to 6-inch interval and analyzed for VOCs, SVOCs, pesticides, PCBs, nitramine compounds, and inorganics. The sample set included fourteen samples (12 environmental and 2 duplicate samples), from the removal action conducted in 1994. The COPC selection summaries for surface soil are presented in Table 6-5.

Four VOCs (acetone, methylene chloride, styrene and toluene) were detected in the surface soil samples. Acetone, toluene, methylene chloride and styrene were detected at concentrations below the Region III residential and industrial soil COC values and were not retained as surface soil COPCs.

Thirteen SVOCs were detected in the surface soil. Benzo(a)anthracene, fluoranthene, pyrene, butylbenzylphthalate, chrysene, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene were detected at concentrations below residential soil COC values and were not retained as COPCs. Benzo(g,h,i)perylene and acenaphthylene were detected frequently in the surface soil and were retained as COPCs. Benzo(b)fluoranthene and benzo(a)pyrene exceeded the residential soil COC values and were retained as surface soil COPCs.

Eleven pesticides were detected in the surface soil. Gamma-BHC, heptachlor, aldrin, 4,4'-DDE, endrin, 4,4'-DDD, 4,4'-DDT, alpha-chlordane, and gamma-chlordane were detected at concentrations below residential and industrial soil COC values, and therefore, were not retained as surface soil COPCs. Dieldrin and endrin ketone were detected frequently in the surface soil and dieldrin

exceeded the residential soil COC value. Therefore, these pesticides were retained as surface soil COPCs.

Nitramine compounds were not detected in the surface soil at Site 21.

Twenty-one inorganics were detected in the surface soil samples collected. The maximum detected concentrations of barium, chromium, cobalt, copper, nickel, selenium, silver, and vanadium did not exceed the corresponding Region III residential soil COC values and were not retained as COPCs. The maximum concentrations of lead did not exceed the action level for residential soils and was not retained as a surface soil COPC. Calcium, iron, magnesium, potassium, and sodium were also detected in almost every sample; however, these constituents are considered to be essential nutrients and are not expected to cause adverse effects at the detected concentrations. Therefore, these chemicals were not retained as COPCs. Therefore, aluminum, arsenic, beryllium, cadmium, manganese, mercury, and zinc were retained as surface soil COPCs for evaluation in the baseline RA.

Subsurface Soil

Eight subsurface soil samples (seven samples and one duplicate sample) were analyzed for VOCs, SVOCs, pesticides, PCBs, nitramine compounds, and inorganics. This sample set includes samples collected during the RI and the removal action. The COPC selection summaries for subsurface soil are presented in Table 6-6.

Three VOCs (acetone, methylene chloride, and toluene) were detected in the subsurface soil. All were detected at concentrations less than their corresponding residential soil COC values and, therefore, were not retained as subsurface soil COPCs.

Nine semivolatile organic compounds were detected in the subsurface soil. Phenol, di-n-butyl phthalate, fluoranthene, pyrene, chrysene, bis(2-ethylhexyl)phthalate, benzo(b)fluoranthene, and benzo(a)pyrene were detected at concentrations below the Region III residential and industrial COC values and therefore are not retained as COPCs. Benzo(g,h,i)perylene was detected frequently and is retained as a subsurface soil COPC.

Five pesticides were detected in the subsurface soil (4,4'-DDE, 4,4'-DDD, 4,4'-DDT, alpha-chlordane and gamma-chlordane). All of the pesticides were detected at concentrations below the Region III COC values and therefore were not retained as subsurface soil COPCs.

Aroclor-1260 was the only PCB detected in the subsurface soil. It was detected at a concentration below the Region III COC value for total PCBs and therefore is not retained as a COPC.

Twenty-one inorganics were detected in the subsurface soil at Site 21. Aluminum, barium, cadmium, chromium, cobalt, copper, mercury, nickel, selenium, silver, vanadium and zinc were detected at concentrations less than residential soil COC values and, therefore, were not retained as COPCs. Lead did not exceed the action level for residential soils and was not retained as a surface soil COPC. Calcium, iron, magnesium, potassium, and sodium were also detected in almost every sample. However, these constituents are considered to be essential nutrients and are not expected to cause adverse effects at the detected concentrations. Therefore, these chemicals were not retained as COPCs. Arsenic, beryllium, and manganese are retained as subsurface soil COPCs.

Groundwater

Table 6-7 summarizes the COPC selections performed for constituents detected in groundwater (shallow). The sample set includes four samples collected during the RI conducted by Baker/Weston. All samples were analyzed for VOCs, SVOCs, nitramine compounds, unfiltered (total) and filtered (dissolved) inorganics.

VOCs, SVOCs, and nitramines were not detected in the groundwater at Site 21.

Eighteen unfiltered (total) inorganics were detected in the groundwater. Cobalt and mercury were detected at concentrations less than the corresponding Region III tap water COC values and groundwater criteria. Therefore, these chemicals were not retained as COPCs. Calcium, iron, magnesium, potassium, and sodium were also detected in almost every sample. However, these constituents are considered to be essential nutrients and are not expected to cause adverse effects at the detected concentrations. Therefore, these chemicals were not retained as COPCs. Aluminum, arsenic, barium, beryllium, cadmium, chromium, lead, manganese, nickel, vanadium, zinc were retained as COPCs because of exceedances of the tap water COC values and groundwater criteria.

Ten filtered (dissolved) inorganics were detected in the groundwater. Barium, nickel and vanadium were detected at concentrations less than the corresponding tap water COC values and groundwater criteria. Therefore, these chemicals were not retained as COPCs. Calcium, iron, magnesium, and sodium were also detected in almost every sample. However, these constituents are considered to be essential nutrients, and were not retained as COPCs. Cadmium, manganese, and zinc exceeded the tap water COC values and were retained as COPCs for evaluation in the baseline RA.

Surface Water and Sediment

Surface water and sediment samples were not collected at Site 21. Surface water and sediment samples were collected from a tributary of Felgates Creek. These samples are associated with Site 4; therefore, COPCs from Site 4 surface water and sediment will be used to calculate risk for Site 21.

6.2.4 Summary of COPCs

The following presents a comprehensive list of all selected COPCs, by media, identified at Sites 4 and 21.

SITE 4:

- **Surface Soil:** 2-methylnaphthalene, acenaphthylene, phenanthrene, carbazole, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene, Aroclor-1254, Aroclor-1260, RDX, 2,4,6-trinitrotoluene, aluminum, antimony, arsenic, beryllium, cadmium, copper, manganese, and zinc.
- **Groundwater (total):** RDX, 1,1-dichloroethene, 1,2-dichloroethene, trichloro-ethene, aluminum, arsenic, barium, beryllium, cadmium, chromium, lead, manganese, nickel, and vanadium.

- **Groundwater (dissolved):** RDX, 1,1-dichloroethene, 1,2-dichloroethene, trichloroethene, antimony, and manganese.
- **Surface Water (total):** 1,3,5-trinitrobenzene, 2,4,6-trinitrotoluene, nitrobenzene, RDX, aluminum, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, vanadium, and zinc.
- **Surface Water (dissolved):** 1,3,5-trinitrobenzene, 2,4,6-trinitrotoluene, nitrobenzene, RDX, antimony, arsenic, cadmium, and manganese.
- **Sediment:** benzo(g,h,i)perylene, 4,4'-DDE, aluminum, antimony, arsenic, beryllium, manganese, and zinc.

SITE 21:

- **Surface Soil:** acenaphthylene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, dieldrin, endrin ketone, aluminum, arsenic, beryllium, cadmium, manganese, mercury, and zinc.
- **Subsurface Soil:** benzo(g,h,i)perylene, arsenic, beryllium, and manganese.
- **Groundwater (total):** aluminum, arsenic, barium, beryllium, cadmium, chromium, lead, manganese, nickel, vanadium, and zinc.
- **Groundwater (dissolved):** cadmium, manganese, and zinc.

6.3 Exposure Assessment

The exposure assessment addresses each current and future potential exposure pathway in soil, groundwater, surface water, sediment, and air. To determine whether human exposure could occur at Sites 4 and 21 in the absence of remedial action, an exposure assessment which identifies potential exposure pathways and receptors was conducted. The following four elements were considered to ascertain whether a complete exposure pathway was present (USEPA, 1989b):

- A source and potential mechanism of chemical release
- An environmental retention or transport medium
- A point of potential human contact with the contaminated medium
- An exposure route (e.g., ingestion) at the contact point

The exposure scenarios discussed herein represent USEPA's Reasonable Maximum Exposure (RME). Relevant equations for assessing intakes and exposure factors were obtained from RAGS (USEPA, 1989b), Exposure Factors Handbook (USEPA, 1989a), Dermal Exposure Assessment: Principles and Applications. Interim Report (USEPA, 1992a), Superfund Exposure Assessment Manual (USEPA, 1988), and Standard Default Exposure Factors. Interim Final (USEPA, 1991a).

WPNSTA Yorktown, will continue to function as one of the key Naval ordnance installations on the East Coast for the foreseeable future. Station housing for enlisted personnel is limited to areas around the golf course; Mason Row (senior officers Quarters), which overlooks the York River; and cottage types of homes scattered throughout the Station. Housing for most enlisted personnel is situated in the Skiffes Creek area south of the Station and Highway 143. There is currently no Station housing of enlisted personnel at Sites 4 and 21.

The Station has been divided by the Navy into three basic land use areas: (1) explosive/ordnance storage, (2) ordnance production/maintenance, and (3) non-explosive and support functions (DoN, 1991). Categorized from an "explosives" standpoint, two general land use types emerge: real estate encumbered by the Explosive Safety Quantity Distance (ESQD) arc and that which is not encumbered. Sites 4 and 21 is situated in an area encumbered by the ESQD arc and therefore, cannot be developed for Station housing of enlisted personnel. The area is also restricted, and only individuals having the proper clearance or Station passes are allowed in the area.

Current potential human receptors to COPCs detected in environmental media at Sites 4 and 21 are limited to on-site adult civilian workers that work at the Station, not specifically at Site 4 or 21. Although future residential development of Sites 4 and 21 is highly unlikely, future residential exposure to potential adult and child receptors was considered. In addition to the future on-site resident exposure scenario, future construction workers performing excavation and housing construction activities were also evaluated as a potential receptor.

6.3.1 Chemical Fate and Transport

This section discusses the potential release and migration of COPCs between or within media. The potential for a chemical to migrate spatially and persist in environmental media is important in the estimation of exposure. Section 5.0 presents a general discussion of the chemical fate and transport for the detected analytes; this subsection focuses only on the selected COPCs.

The distribution relationships for a chemical between the environmental compartments of air, water, and soil can be evaluated using a series of equilibrium constants. By utilizing the physiochemical properties of a constituent, it is possible to estimate a chemical's expected environmental distribution and its ultimate environmental fate.

The environmental mobility and persistence of a chemical will be influenced primarily by its physical and chemical properties and the chemistry of the medium in which it occurs. Table 6-8 presents the physical and chemical properties associated with the organic COPCs including: vapor pressure, water solubility, octanol-water partition coefficient, soil adsorption coefficient, specific gravity, Henry's Law constant, and mobility index. Calculated values, obtained using approximation methods, are presented when literature values are unavailable. A discussion of the environmental significance of each of these properties follows.

- Vapor pressure is an indication of the rate at which a chemical will volatilize. It is of primary significance as a removal mechanism at environmental interfaces such as surface soil-air and surface water-air. Volatilization is not a significant removal mechanism when evaluating groundwater, subsurface soil, and sediment, but it is for surface water and surface soil. Vapor pressures for volatile organics, would be higher than vapor pressures for pesticides. Chemicals with higher vapor pressures are expected to enter the atmosphere much more readily than chemicals with lower vapor pressures. Volatilization is a significant loss process for VOCs in surface soil and surface water.
- Water solubility is used to determine the rate at which a chemical can be solubilized and potentially leached from soil by infiltrating precipitation. In general, more soluble chemicals are more readily leached than less soluble chemicals.

- The octanol-water partition coefficient (K_{ow}) is a measure of the equilibrium partitioning of chemicals between octanol and water. A linear relationship between the octanol water partition coefficient and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor, BCF) has been determined (Lyman et al., 1982). The coefficient also is useful in characterizing the sorption of compounds by organic soil where experimental values are not available. The octanol water partition coefficient also is used to estimate BCFs in aquatic organisms.
- The organic carbon adsorption coefficient (K_{oc}) is an indication of the tendency of a chemical to adhere to soil particles containing organic carbon. Chemicals with high soil/sediment adsorption coefficients generally have low water solubilities and vice versa. This parameter may be used to infer the relative rates at which the more mobile chemicals (e.g., monocyclic aromatics) are transported in the aqueous media. Chemicals such as pesticides/PCBs are relatively immobile in the environment and are preferentially bound to the soil. These compounds are not subject to aqueous transport to the extent as compounds with higher water solubilities, such as VOCs.
- Specific gravity is the ratio of the weight of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a constituent will have a tendency to float or sink (as an immiscible liquid) in water if it is present as a pure compound or at concentrations which exceed its water solubility.
- Both vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. The ratio of these two parameters (Henry's Law constant) is used to calculate the equilibrium constituent concentrations in the vapor (air) phase versus the liquid (water) phase for the dilute solutions commonly encountered in environmental settings.

A quantitative assessment of mobility has been developed (Laskowski, et al., 1983) that uses water solubility (S), vapor pressure (VP), and the organic carbon partition coefficient (K_{oc}). This value is referred to as the Mobility Index (MI). It is calculated as follows:

$$MI = \log[(S \times VP)/K_{oc}]$$

A scale to evaluate MI is presented by Ford and Gurba (1984) as the following:

MI	Description
>5	Extremely mobile
<5 to 0	Very mobile
0 to -5	Slightly mobile
-5 to -10	Immobile
<-10	Very immobile

The MIs for the potential COPCs are also presented in Table 6-8.

The following paragraphs summarize the fate and transport data, by chemical class, for the potential COPCs at Sites 4 and 21.

6.3.1.1 Volatile Organic Compounds

Volatile organic COPCs can be divided into two distinct classes, volatile aromatics, and chlorinated aromatics. Since none of the volatile aromatics (benzene, toluene, xylenes, and ethylbenzene) were chosen as COPCs at Sites 4 and 21, only the chlorinated aromatics will be discussed.

1,1-Dichloroethene, 1,2-dichloroethene and trichloroethene are included in the chlorinated aromatic group. These chemicals are comprised of chlorine substituted ethane or ethene moiety. 1,2-Dichloroethene is most likely present as a result of the degradation of higher chlorinated ethenes and ethanes.

Volatile organics tend to be very mobile in environmental media as indicated by their presence in groundwater at Sites 4 and 21. Their inherent mobility and relatively high MIs result from high water solubilities, high vapor pressures, and low K_{oc} and K_{ow} values. Volatile organics do not tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal. They are seldom detected in surface soil where volatilization and other removal processes predominate, as is the case at Sites 4 and 21.

6.3.1.2 Semivolatile Organic Compounds

In general, SVOCs are less mobile than the VOCs by virtue of their lower vapor pressures and lower water solubilities. K_{oc} and K_{ow} values for SVOCs are generally greater in magnitude than those for the VOCs, indicating the tendency for this class of compounds to adsorb strongly to soil and sediment. A class of this chemical group, PAHs, are ubiquitous in the environment. PAHs are produced naturally by plants, and are products of the incomplete combustion of fossil fuels. PAHs tend not to migrate appreciable distances through groundwater or surface water as solutes. Their MIs indicate that they are relatively immobile from a physical-chemical standpoint.

Transport of soil particulates containing PAHs is considered to be one of the primary migration mechanisms. The overland flow of surface water, toward the tributary to Felgates Creek and Felgates Creek, carrying entrained particles (i.e., stormwater runoff) and with subsequent sedimentation, resuspension, and settling throughout is possible. PAHs generally lack adequate vapor pressures to be transmitted via vaporization and subsequent airborne transport. However, PAHs adsorbed to particulates can be transported by wind as fugitive dust.

PAHs are somewhat persistent in the environment, although several processes do contribute to their in situ degradation. Half-lives range from 10 years (pyrene) to 1 day (naphthalene) in groundwater. Photolysis and oxidation may be important removal mechanisms in surface water and surficial soil, while biodegradation is an important fate process in groundwater and soil.

6.3.1.3 Pesticides/PCBs

Pesticides/PCBs are extremely persistent and immobile chemicals in environmental media. These chemicals also are bioaccumulated and biomagnified in the food chain. They generally exhibit low

vapor pressures, low water solubilities, and high K_{oc} and K_{ow} values (Clement, 1985). Adsorption to organic material in soil or sediment is probably the major fate of these contaminants in the environment.

PCBs are degraded by soil microorganisms and photolysis. Heavily chlorinated PCBs like Aroclor-1260 can be photolyzed by ultraviolet light, which is an extremely slow process. Photolysis of the heavier chlorinated PCBs might be the most important degradation process for these persistent contaminants.

Technical grade DDT is a mixture of DDT and two primary isomers DDD and DDE. Volatilization is probably the most important transport process from soil and water, as evidenced by the ubiquitous nature of DDT, DDD, and DDE in the environment (Clement, 1985). In addition, sorption, bioaccumulation, photolysis, and biodegradation are other fate processes contributing to the environmental transport of DDT.

6.3.1.4 Inorganics

Different inorganic species behave differently in various environmental media. In general, inorganics can be transported through air, adhering to blowing dust, or move through surface water and groundwater as dissolved salts. Inorganics can also be carried with flowing water on suspended solids or attached to colloidal materials.

The most complicated pathway for inorganic chemicals is migration in subsurface soil and groundwater, where Eh and pH play critical roles. Table 6-9 presents an assessment of relative inorganic environmental mobilities as a function of Eh and pH. Subsurface soil at Site 21 is slightly acidic, therefore, inorganics in the subsurface should be slightly mobile.

6.3.2 **Potential Migration Pathways**

This section identifies the potential migration routes of COPCs at Sites 4 and 21. These mechanisms were identified through an evaluation of the analytical results and known site characteristics.

6.3.2.1 Soil

Inorganic and organic compounds were detected in surface soil at Site 4 and the surface and subsurface soil at Site 21. COPCs present at Sites 4 and 21 soil can migrate by leaching of infiltrating precipitation, advective transport in the direction of surface drainage (runoff), towards the tributary to Felgates Creek and Felgates Creek, or by suspension of soil particulates in ambient air (dust).

The factors which control contaminant migration through soil, and then to groundwater, are dependent on the chemical and physical nature of the contaminants and of the soil and site hydrology. Some of the factors which influence the migration of chemicals in soil include: pH, Eh, particle size distribution, pore size or voids volume, lime content, content of organic matter, concentration of ions or salts, aerobic and anaerobic conditions, presence or absence of hydrous oxides, vegetative cover, topography, and climate.

6.3.2.2 Groundwater

Contaminants which come into contact with groundwater can migrate under the influence of groundwater flow. Migration through groundwater is dependent on the chemical nature of the contaminant and the chemical and physical nature of the aquifer. Groundwater flow velocity (a function of hydraulic gradient and conductivity), groundwater chemistry, porosity of the aquifer, and the chemical make up of the aquifer are all factors which affect contaminant migration. Mobility of a contaminant in groundwater is particularly influenced by its water solubility and the organic carbon content of the substrate, as well as the nature of the aquifer materials (subsurface soil) through which the groundwater flows. In general, compounds that have high solubility and low K_{oc} values tend to be more mobile in groundwater than those with low solubility and high K_{oc} values.

6.3.2.3 Surface Water/Sediment

Migratory pathways associated with surface water and sediment from the tributary to Felgates Creek include the transport of contaminants via surface water movement, adsorption/desorption process, from surface water to sediment, and discharge to or from groundwater. The adsorption/desorption process, from surface water to sediment, can create contaminant "sinks". Adsorption/desorption

mechanisms involve complex chemical and biochemical reactions. As chemicals are desorbed from sediment, they may then be available for uptake by receptors from the water column.

6.3.2.4 Air

COPCs adsorbed to soil particulates or as vapors can become entrained in ambient air. Because of the limited number and low concentrations of COPCs volatile and semivolatile detected in soil at Sites 4 and 21, volatilization is likely to be a very minor potential migration pathway. COPCs migrating via air from Sites 4 and 21 would most likely be as particulates entrained in air. This pathway is likely also limited by the vegetative cover and wooded areas in and surrounding these sites.

6.3.3 Conceptual Site Model

Development of a conceptual site model of potential exposure is critical in evaluating all potential exposures for the aforementioned human receptors. The conceptual site model describes the area of concern in terms of potential sources of contamination, affected media and all potential routes of migration of the contaminants present and potential receptors. A conceptual site model for Sites 4 and 21 is presented in Figure 6-1.

The primary source of contamination is the former landfill area at Site 4 and the former disposal area at Site 21. The primary release mechanisms are volatile emissions, surface runoff, fugitive dust generation, and contaminant migration through groundwater.

6.3.4 Potential Exposure Pathways and Potential Receptors

The potential receptors and exposure routes evaluated at Sites 4 and 21 were selected considering current and future potential land use in accordance with the Master Plan for WPNSTA Yorktown (DoN, 1991). The following paragraphs present the rationale for the selection of potential exposure pathways for human receptors at Sites 4 and 21.

Based on information available regarding the physical features, site setting, site historical activities, removal action data, the sites being located in the restricted area of the Station, current and expected

land uses, and the restricted areas surrounding the sites, four potential human receptors are proposed for evaluation. These include:

- Future adult construction workers
- Future resident children (1-6 years)
- Future resident adults (30 years)
- Current on-site adult civilian worker

6.3.4.1 Site 4

In the current scenario, a civilian adult on-site worker will be evaluated for potential risk. Although no work-related activities occur at the site currently, it is assumed that a civilian receptor could become exposed to site media while periodically working at the site. The site itself is secured and restricted to off-site access by civilians. Therefore, current adult trespassers will not be evaluated. The potential exposure pathways include incidental ingestion and dermal contact with surface soil, surface water and sediment. The inhalation pathway will only be considered for soil. Exposure from inhalation of contaminants from surface water and sediment is assumed to be of less importance in comparison to exposure from ingestion and dermal contact. Groundwater currently is not used for potable purposes at the site. Consequently, groundwater exposure in the current case will not be evaluated.

In the future case, it is conservatively assumed that residential development of the site will occur. As a result, residential receptors and a future adult construction worker will be evaluated. For the future residential adult and child receptors, exposure to surface soil, groundwater, surface water and sediment are assumed. Exposure to groundwater as a potable source will be assessed, which includes exposure via ingestion, dermal contact and inhalation while showering. An adult and child receptor could also become exposed to soil (i.e., as a result of landscaping activities), surface water and sediment while participating in outdoor recreational activities (i.e., wading) along the tributary to Felgates Creek. The potential exposure pathways include incidental ingestion and dermal contact with soil, surface water and sediment, and soil particulate inhalation. Exposure to surface water and sediment via inhalation is not considered to be as viable as from ingestion and dermal contact. For the future adult construction worker, exposure to surface soil via incidental ingestion, dermal contact, and soil particulate inhalation were evaluated. Subsurface soil samples were not collected

at Site 4; therefore, the subsurface soil exposure pathway will not be evaluated for the future adult construction worker.

In summary, the following potential human exposure receptors and exposure pathways are being retained for quantitative evaluation in this baseline RA:

- **Current on-site adult civilian worker:**
 - ▶ Incidental ingestion of surface soil
 - ▶ Dermal contact with surface soil
 - ▶ Inhalation of fugitive dust
 - ▶ Incidental ingestion of surface water
 - ▶ Dermal contact with surface water
 - ▶ Incidental ingestion of sediment
 - ▶ Dermal contact with sediment

- **Future on-site adult residents (30 years) and child residents (1 - 6 years):**
 - ▶ Incidental ingestion of surface soil
 - ▶ Dermal contact with surface soil
 - ▶ Inhalation of fugitive dust
 - ▶ Ingestion of groundwater used as drinking water
 - ▶ Dermal contact with groundwater while showering
 - ▶ Inhalation of volatiles in groundwater while showering
 - ▶ Incidental ingestion of surface water
 - ▶ Dermal contact with surface water
 - ▶ Incidental ingestion of sediment
 - ▶ Dermal contact with sediment

- **Future adult construction worker:**
 - ▶ Incidental ingestion of surface soil
 - ▶ Dermal contact with surface soil
 - ▶ Inhalation of fugitive dust

6.3.4.2 Site 21

Similar to Site 4, in the present scenario, civilian adult on-site workers will be evaluated for potential risk. Although no work-related activities occur at the site currently, it is assumed that a civilian adult receptor could become exposed to site media while periodically working at the site. The site itself is secured and restricted to off-site access by civilians. Therefore, current adult trespassers will not be evaluated. The potential exposure pathways include incidental ingestion and dermal contact with surface soil, surface water and sediment, and inhalation of fugitive particles in surface soil. Surface water and sediment samples were collected from a tributary to Felgates Creek, these samples were associated with Site 4. Due to the close proximity of Sites 4 and 21, the surface water and sediment samples collected at Site 4 will be used to evaluate risk at Site 21. Exposure from inhalation to contaminants from surface water and sediment is assumed to be of less importance on comparison to exposure from ingestion and dermal contact. Groundwater currently is not used for potable purposes at the site. Consequently, groundwater exposure in the current scenario will not be evaluated.

In the future scenario, it is conservatively assumed that residential development of the site will occur. As a result, a construction worker and residential receptors will be evaluated. It is assumed that an on-site construction worker could become exposed to surface and subsurface soil via incidental ingestion, dermal contact and inhalation during construction and excavation activities. For the residential adult and child receptor, exposure to surface soil, groundwater, surface water and sediment are assumed. Exposure to groundwater as a potable source will be assessed, which includes exposure via ingestion, dermal contact and inhalation (while showering). An adult and child receptor could also become exposed to soil (i.e., as a result of landscaping activities), surface water and sediment while participating in outdoor recreational activities (i.e., wading) in the tributary to Felgates Creek (calculated risks from surface water and sediment at Site 4 will be used). The potential exposure pathways include incidental ingestion and dermal contact with the soil, surface water, and sediment, and inhalation of fugitive particulate from the soil. Exposure to surface water and sediment via inhalation is not considered to be as viable as from ingestion and dermal contact.

In summary, the following potential human exposure receptors and exposure pathways are being retained for quantitative evaluation in this baseline RA:

- **Current on-site adult civilian worker:**
 - ▶ **Incidental ingestion of surface soil**
 - ▶ **Dermal contact with surface soil**
 - ▶ **Inhalation of fugitive dust**
 - ▶ **Incidental ingestion of surface water**
 - ▶ **Dermal contact with surface water**
 - ▶ **Incidental ingestion of sediment**
 - ▶ **Dermal contact with sediment**

- **Future on-site adult residents and child residents (1 - 6 years):**
 - ▶ **Incidental ingestion of surface soil**
 - ▶ **Dermal contact with surface soil**
 - ▶ **Inhalation of fugitive dust**
 - ▶ **Ingestion of groundwater used as drinking water**
 - ▶ **Dermal contact with groundwater while showering**
 - ▶ **Inhalation of volatiles in groundwater while showering**
 - ▶ **Incidental ingestion of surface water**
 - ▶ **Dermal contact with surface water**
 - ▶ **Incidental ingestion of sediment**
 - ▶ **Dermal contact with sediment**

- **Future on-site adult construction workers:**
 - ▶ **Incidental ingestion of subsurface soil**
 - ▶ **Dermal contact with subsurface soil**
 - ▶ **Inhalation of fugitive dust (surface and subsurface soil)**
 - ▶ **Incidental ingestion of surface soil**
 - ▶ **Dermal contact with surface soil**

(Note: Surface water and sediment data collected from Site 4 will be used for both sites.)

6.3.5 Quantification of Exposure

The chemical concentrations used in the estimation of chronic daily intakes (CDIs) for each medium are considered to be representative of the types of potential exposure encountered by each receptor. Exposure can occur discretely or at a number of sampling locations depending on the type of scenario considered for a given receptor. Furthermore, certain environmental media such as groundwater and surface water are migratory, and chemical concentrations detected in this medium change frequently over time. Soil and sediment are, by nature, less transitory. The manner in which environmental data are represented also depends on the number of samples and sampling locations available for a given area and a given medium.

Potential exposure to soil, surface water, and sediment at any location is considered as having an equal probability of occurrence as an individual moves randomly across the site. Therefore, for these media, the concentration term for a constituent in the intake equation can be reasonably estimated as the arithmetic average concentration of site sampling data. USEPA supplemental risk assessment guidance (1992c) states that the average concentration is an appropriate estimator or the exposure concentration for two reasons: 1) carcinogenic and chronic noncarcinogenic toxicity criteria are based on lifetime average exposures; and 2) the average concentration is most representative of the concentration that would be contacted over time. However, uncertainty is inherent in the estimation of the true average constituent concentration at the site.

In order to account for this uncertainty to be health protective, USEPA risk assessment guidance (1989b) requires that an upper bound estimate of the arithmetic mean concentration, be used to calculate CDI. This estimate, which should be in the high end of the concentration frequency distribution, is called the reasonable maximum exposure (RME) concentration. The RME concentration is defined as the highest concentration that could reasonably be expected to be contacted via a given pathway over a long-term exposure period. A conservative estimate of the arithmetic average concentration that best represents the RME is the 95 percent upper confidence limit of the arithmetic mean concentration (95% UCL). In order to estimate the 95% UCL for soil, surface water and sediment data sets, a normal distribution was assumed to represent the occurrence of all COPC detected concentrations.

The 95% UCL was calculated using the following equation (USEPA, 1992c):

$$95\% \text{ UCL} = \bar{x} + t(s/\sqrt{n})$$

Where:

\bar{x}	=	arithmetic mean
s	=	normal standard deviation
t	=	Student t statistic
n	=	number of samples

For results reported as "nondetect" (e.g., U, UJ, UL, and UK), a value of one half of the sample-specific detection limit was used to calculate the 95% UCL. A value of half the detection limit was assigned to nondetects when estimating the 95% UCL because the actual value could be between zero and a value just below the detection limit. Ninety-five percent UCLs were calculated only for the constituents detected in at least one sample collected from the environmental medium of interest. Qualified data were also used in the calculation of the 95% UCL, such as "J"-qualified (estimated), "L"-qualified (estimated, biased low) and "K"-qualified (estimated, biased high) data. Reported concentrations qualified with an "R" (rejected) were not used in the statistical evaluation.

Because a "plume" of contamination was not evident in Site 4 or Site 21 groundwater samples, the 95% UCL was not selected as the exposure point concentration for groundwater, instead, two groundwater wells at each site were selected to spatially represent the selected groundwater COPCs. The maximum detected concentration for each of these wells was used as the concentration term.

If 95% UCL values derived for a COPC in a given data set exceed the maximum detected COPC concentration the maximum detected concentration for the COPC was used to represent the concentration term.

The equations for estimating exposure to site contaminants for the various identified exposure pathways are presented in the following subsections. Site-specific calculations are presented in Appendix F, for each potential pathway and receptor.

6.3.5.1 Surface/Subsurface Soil and Sediment

Incidental Ingestion of Soil/Sediment

The daily intake associated with the potential incidental ingestion of COPCs detected in soil or sediment was calculated using the following equation (USEPA, 1989b):

$$CDI = \frac{Cs \times IR \times CF \times EF \times ED}{BW \times AT}$$

Where:

CDI	=	Chronic Daily Intake, milligram per kilogram day (mg/kg-day)
Cs	=	Chemical concentration in soil or sediment, mg/kg
IR	=	Ingestion rate, mg/day
CF	=	Conversion factor, 10 ⁻⁶ kg/mg
EF	=	Frequency of exposure, days/year
ED	=	Exposure duration, years
BW	=	Average body weight, kg
AT	=	Averaging time, days

Relevant equations and factors required for estimating the daily intake were calculated and are presented in Appendix F.

Dermal Contact with Soil/Sediment

The absorbed dose associated with the potential dermal contact of COPCs in soil and sediment was calculated using the following equation (USEPA, 1989b):

$$ICR = \frac{Cs \times AF \times ABS \times CF \times SA \times EF \times ED}{BW \times AT}$$

Where:

CDI	=	Chronic Daily Intake, mg/kg-day
Cs	=	Chemical concentration in the soil or sediment, mg/kg
AF	=	Adherence factor, milligram per square centimeter day (mg/cm ² ·d)
ABS	=	Absorbed fraction, unitless
CF	=	Conversion factor, 10 ⁻⁰⁶ mg/kg
SA	=	Surface area of exposed skin, cm ²
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
BW	=	Average body weight, kg
AT	=	Averaging time, days

Relevant equations and factors required for estimating the absorbed dose were calculated and are presented in Appendix F. Toxicity factors were dermally adjusted for these pathways.

Inhalation of Fugitive Dust from Soil

The daily intake resulting from the inhalation of COPCs adsorbed onto fugitive dust particulates was estimated using the following equation (USEPA, 1989b):

$$CDI = \frac{Ca \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

CDI	=	Chronic Daily Intake, mg/kg-day
Ca	=	Chemical concentration in air as fugitive dust, milligrams per cubic meter (mg/m ³)
IR	=	Inhalation rate, m ³ /day
ET	=	Exposure time, hours/day
EF	=	Frequency of exposure, days/year
ED	=	Exposure duration, years
BW	=	Average body weight, kg

AT = Averaging time, days

The air concentration (Ca) of a chemical in fugitive dust emissions was estimated from the following equation, as determined by Cowherd (1985), and provided by USEPA (1991b).

$$Ca = Cs \times I/PEF$$

Where:

Cs = Concentration of chemical in the soil, mg/kg

PEF = Particulate emission factor, m³/kg

The value used for the PEF was a USEPA default factor of 4.63 x 10⁹ m³/kg (USEPA, 1991b).

6.3.5.2 Groundwater/Surface Water

Ingestion of Potable Groundwater

The daily intake associated with the direct potential ingestion of the COPCs in groundwater under a potable use scenario was calculated using the following equation (USEPA, 1989b):

$$CDI = \frac{Cw \times IR \times EF \times ED}{BW \times AT}$$

Where:

CDI = Chronic Daily Intake, mg/kg-day

Cw = Chemical concentration in water, mg/L

IR = Ingestion rate, L/day

EF = Frequency of exposure, days/year

ED = Exposure duration, years

BW = Average body weight, kg

AT = Averaging time, days

Incidental Ingestion of Surface Water

The daily intake associated with the incidental ingestion of the COPCs in surface water was calculated using the following equation (USEPA, 1989b):

$$CDI = \frac{C_w \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

CDI	=	Chronic Daily Intake, mg/kg-day
C _w	=	Chemical concentration in water, mg/L
IR	=	Ingestion rate, L/day
ET	=	Exposure time, hours/day
EF	=	Frequency of exposure, days/year
ED	=	Exposure duration, years
BW	=	Average body weight, kg
AT	=	Averaging time, days

Dermal Contact with Groundwater/Surface Water

The absorbed dose associated with potential dermal contact with COPCs in groundwater (while showering) or surface water was calculated using the following equation (USEPA, 1989b):

$$CDI = \frac{C_w \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

CDI	=	Chronic Daily Intake, mg/kg-day
C _w	=	Concentration in water, mg/L
SA	=	Surface area of exposed skin, cm ²

PC	=	Chemical-specific permeability constant, cm/hr
ET	=	Exposure time, hours/day
EF	=	Exposure frequency, days/year
ED	=	Exposure duration, years
CF	=	Conversion factor, 1 L/1000 cm ³
BW	=	Average body weight, kg
AT	=	Averaging time, days

Relevant equations and factors required for estimating the absorbed dose were calculated and are presented in Appendix F. Toxicity factors were dermally adjusted for these pathways.

Inhalation of Volatile COPCs in Groundwater while Showering

The daily intake associated with the potential inhalation of the volatile COPCs in groundwater while showering was calculated using the following equation (USEPA, 1989b):

$$CDI = \frac{Ca \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where:

CDI	=	Chronic Daily Intake, mg/kg-day
Ca	=	Chemical concentration in air, mg/m ³ , as determined from Foster Shower Model (Foster, 1986)
IR	=	Inhalation rate, m ³ /day
ET	=	Exposure time, hours/day
EF	=	Frequency of exposure, days/year
ED	=	Exposure duration, years
BW	=	Average body weight, kg
AT	=	Averaging time, days

Relevant equations and factors required for estimating the daily intake were calculated and are presented in Appendix F. The shower model (Foster and Chrostowski Model) used for these calculations is presented in Appendix G.

6.3.6 Exposure Factors Used To Derive Chronic Daily Intakes

Tables 6-10 through 6-12 present the exposure factors used in the estimation of potential CDIs for COPCs retained for each receptor identified below. USEPA promulgated exposure factors are used in conjunction with USEPA standard default exposure factors. When USEPA exposure factors are not available, best professional judgment and site-specific information are used to derive a conservative and defensible value. The following paragraphs present the rationale for the selection of exposure factors for each receptor group evaluated in the baseline RA.

6.3.6.1 Current Adult On-Site Civilian Worker

Surface Soil

This scenario assumes that an adult working in the areas of Sites 4 and 21 could potentially be exposed to COPCs in the surface soil via incidental ingestion, dermal contact, and from inhalation of fugitive dust, as they are liberated during cutting/clearing of tall grasses and trees. It was also assumed that the on-site adult could contact surface water and sediment, via incidental ingestion and dermal contact, as part of a daily work routine. An inhalation rate of 20 m³/day or 0.83 m³/hour (USEPA, 1991a) for a 70 kg adult was assumed for 90 days/year over a 25 year period, for eight hours per day. The ingestion rate was 100 mg/day, the fraction ingested was assumed to be 50% (0.5). The adult skin surface area (SA) available for dermal contact with soil was estimated to be 5,300 cm², representing the skin surface area available for contact assuming an adult wears a short-sleeved shirt, short pants, and shoes. Equations and chemical-specific permeability constants (Kp) presented by USEPA (USEPA, 1992a) were used to estimate the absorption of COPCs by skin exposed to soil. Experimentally derived dermal absorption values of 6 percent (0.06) for PCBs (USEPA, 1992a), 3 percent (0.03) (Webster, et al., 1993) for arsenic (0.03), and default values of 10 percent (0.10) for organics (Ryan, et al., 1987) and 1.0 percent (0.01) for inorganics were also used to estimate soil exposures. The averaging time of 9,125 days for noncarcinogens and 25,550 days for carcinogens, respectively, were also used.

Surface Water

The adult skin surface area (SA) available for dermal contact with surface water was estimated to be 5,300 cm², representing the skin surface area available for contact assuming an adult wears a short-sleeved shirt, short pants, and shoes. Equations and chemical-specific permeability constants (Kp) presented by USEPA (USEPA, 1992a) were used to estimate the absorption of COPCs by skin exposed to surface water. The ingestion rate was 0.05 L/day. The body weight, exposure frequency, exposure duration, exposure time, dermal absorption values, and the averaging times were the same as those used for the surface soil scenario.

Sediment

The ingestion rate was assumed to be 100 mg/day, with a soil to skin adherence factor of 1 mg/cm² for clay mineral kaolin (USEPA, 1992b). The surface area, exposure duration, exposure time, exposure frequency, dermal absorption values, averaging time and body weight were the same as those presented for the surface water scenario.

6.3.6.2 Future Child and Adult Residents

Future residential development of Sites 4 and 21 is unlikely, and it is not projected for development in the current Master Plan for WPNSTA, Yorktown (DoN, 1991). However, for the sake of conservatism, the potential exposure pathways associated with future potential residential development were evaluated. Future adult and young child (ages 1-6 years) residents were evaluated for potential exposures via ingestion, dermal contact, and inhalation of volatiles in groundwater used for potable purposes. Future residents were also evaluated for potential exposures from accidental ingestion and dermal contact with surface soil, surface water, and sediment, and inhalation of fugitive dust from the soil.

Surface Soil

The ingestion rate was assumed to be 200 mg/day for a child weighing 15 kg and 100 mg/day for an adult weighing 70 kg. The exposure frequency was 350 days per year. The inhalation rate was assumed to be 20 m³/day for both receptors. The exposure duration assumed for the adult was 24 years and for the child was 6 years. The respiration rate for the inhalation of volatile organic compounds while showering was assumed to be 20 m³/day or 0.83 m³/hour for both receptors. The averaging times were 8,760 days for the adult and 2,190 for the child for the noncarcinogens and 25,550 days for the carcinogens for both receptors. The adult and child skin SA for dermal contact with soil was estimated to be 5,300 and 2,115 cm², respectively, representing the skin surface area available for contact assuming a short-sleeved shirt, short pants, and shoes are worn by the receptor. The soil to skin adherence factor of 1 mg/cm² for clay mineral kaolin (USEPA, 1992b) and experimentally derived dermal absorption values of 6 percent (0.06) for PCBs, 3 percent (0.03) for arsenic, 1 percent (0.01) for cadmium and default values of 10 percent (0.10) for organics and 1.0 percent (0.01) for inorganics were also used to estimate soil exposures.

Groundwater

The adult skin SA available for dermal contact with groundwater during bathing was estimated to be 20,000 cm², representing total body exposure. The exposure frequency was assumed to be 350 days/year at 0.2 hours (10 minutes) a day. Equations and chemical-specific K_p presented by USEPA (USEPA, 1992a) were used to estimate the absorption of COPCs by skin exposed to groundwater. The ingestion rate for the adult was 2 L/day. The respiration rate for the inhalation of volatile organic compounds while showering was assumed to be 20 m³/day or 0.83 m³/hour. The averaging times were 8,760 days for the noncarcinogens and 25,550 days for the carcinogens. The exposure duration, averaging time and body weight were the same as those presented for the soil medium.

A skin SA value of 8,023 cm² was used to represent the 95th percentile whole body surface area of a young child. The exposure frequency, exposure time, and respiration rate are the same as the adult's. However the exposure duration was assumed to be 6 years with an ingestion rate of 1 L/day. Equations and chemical-specific K_p presented by USEPA (USEPA, 1992a) were used to estimate

the absorption of COPCs by skin exposed to groundwater. The averaging times were 2,190 days for the noncarcinogens and 25,550 days for the carcinogens.

Surface Water

The adult skin SA available for dermal contact with surface water was estimated to be 6,420 cm², representing the skin surface area available for contact assuming an adult wears a short-sleeved shirt and short pants. The exposure frequency was assumed to be 40 days/year during fair-weather months (5 months at 2 days per week) at 2.6 hours a day, for 24 years. Equations and chemical-specific K_p presented by USEPA (USEPA, 1992a) were used to estimate the absorption of COPCs by skin exposed to surface water. An ingestion rate of 0.05 L/day was also used. The averaging times were 8,760 days for the noncarcinogens and 25,550 days for the carcinogens.

A skin SA value of 2,700 cm² was used to represent the 95th percentile average skin SA for a male/female young child (1-6 years), wearing a short-sleeved shirt and short pants. The exposure frequency, ingestion rate, and exposure time are the same as the adult's, however the exposure duration was assumed to be 6 years. As with the adult, equations and chemical-specific K_p were used to estimate the absorption of COPCs by skin exposed to surface water. The averaging times were 2,190 days for the noncarcinogens and 25,550 days for the carcinogens.

Sediment

The ingestion rate was assumed to be 200 mg/day for the child and 100 mg/day for the adult, for 2.6 hours per day over 40 days per year. The soil to skin adherence factor of 1 mg/cm² for clay mineral kaolin (USEPA, 1992b) and experimentally derived dermal absorption values of 6 percent (0.06) for PCBs, 3 percent (0.03) for arsenic and default values of 10 percent (0.10) for organics and 1.0 percent (0.01) for inorganics were also used to estimate sediment exposures. The exposure duration, exposure frequency, surface area, averaging time and body weight were the same as those presented for the surface water medium.

6.3.6.3 Future Adult Construction Workers

Surface Soil

Potential exposures to surface soil COPCs may occur to construction workers while performing soil excavation and construction activities at Sites 4 and 21. Exposure pathways evaluated include incidental ingestion, dermal contact, and inhalation of fugitive dust. Exposure was assumed to occur for 8 hours per day, 250 days per year, for a construction period of 1 year. A USEPA default value for the soil ingestion rate (480 mg/day) and a respiration rate of 20 m³/day or 0.83 m³/hour (USEPA, 1991a) were also assumed for a 70 kg construction worker. A skin surface area of 4,300 cm² representing the surface area available for contact assuming an adult wears a short-sleeved shirt, long pants and shoes, was evaluated for dermal contact with subsurface soil. The soil to skin adherence factor of 1 mg/cm² for clay mineral kaolin (USEPA, 1992b) and experimentally derived dermal absorption values of 0.06 for PCBs (USEPA, 1992a), 0.03 for arsenic, 0.10 for organics and 0.01 for inorganics were also used to estimate soil exposures. The averaging times were 365 days for the noncarcinogens and 25,550 days for the carcinogens.

Subsurface Soil

Potential exposures to subsurface soil COPCs may occur to construction workers while performing soil excavation and construction activities at Site 21. Exposure pathways evaluated include incidental ingestion, dermal contact and inhalation of fugitive dust. The ingestion rate, exposure frequency, adherence factor, dermal adsorption factor, exposure time, inhalation rate, exposed surface area, exposure duration, fraction ingested, body weight, and averaging times were the same as those used for the surface soil scenario.

6.4 Toxicity Assessment

Section 6.3 presented potential exposure pathways and receptors for this baseline RA. This section will review the available toxicological information for COPCs retained for quantitative evaluation.

6.4.1 Toxicological Evaluation

The purpose of this section is to identify the potential health and environmental effects associated with potential exposure to the COPCs. A toxicological evaluation characterizes the inherent toxicity of a compound. It consists of the review of scientific data to determine the nature and extent of the potential human health and environmental effects associated with potential exposure to the various chemicals. The end product is a collection of toxicological profiles for the COPCs. These toxicological profiles provide the qualitative weight-of-evidence that demonstrate whether the COPCs pose any actual or potential health and/or environmental effects.

Toxicological profiles addressing the COPCs at Sites 4 and 21 are presented in Appendix H. In these toxicological profiles, the available human and animal data are presented. Human data from occupational exposures are often insufficient for determining quantitative indices of toxicity because of uncertainties in exposure estimates, and inherent difficulties in determining causal relationships established by epidemiological studies. For this reason, animal bioassays are conducted under controlled conditions and their results are extrapolated to humans. There are several stages to this extrapolation. First, to account for species differences, conversion factors are used to extrapolate from test animals to humans. Second, the relatively high doses administered to test animals must be extrapolated to the lower doses more typical of human exposures. For potential noncarcinogens, safety factors and modifying factors are applied to animal results when developing acceptable human doses. For potential carcinogens, mathematical models are used to extrapolate effects at high doses to effects at lower doses. Epidemiological data can then be used for inferential purposes to establish the credibility of the experimentally derived indices.

Toxic effects considered in these profiles include noncarcinogenic (toxic) and potentially carcinogenic health effects as well as environmental effects. Toxicological endpoints, routes of exposure, and doses in humans and/or animal studies are discussed. Potential carcinogenic health effects are associated with exposure to a potential carcinogen. Routes of exposure and doses in humans and/or animal studies are provided. Also considered is the USEPA's weight-of-evidence of a compound's carcinogenicity (i.e., Group A, known human carcinogens; Group-B, probable human carcinogens; Group C, possible human carcinogens; Group D, not classifiable as to its carcinogenicity). Environmental effects include acute and chronic toxic effects observed in aquatic biota and terrestrial wildlife.

The available toxicological information indicates that many of the COPCs have both noncarcinogenic and potential carcinogenic health effects in humans and/or in experimental animals. Although the COPCs may potentially cause adverse health and environmental impacts, dose-response relationships and the potential for exposure must be evaluated before the risk to receptors can be determined. Dose-response relationships correlate the magnitude of the dose with the probability of toxic effects, as discussed in the following section.

6.4.2 Dose-Response Evaluation

An important component of the RA process is the relationship between the dose of a compound (amount to which an individual or population is potentially exposed) and the potential for adverse health effects resulting from exposure to that dose. Dose-response relationships provide a means by which potential public health impacts may be evaluated. Standard reference doses (RfDs) and/or carcinogenic slope factors (CSFs) have been developed for many of the COPCs. This section provides a brief description of these parameters.

6.4.2.1 Reference Doses

The RfDs and Reference Concentrations (RfCs for inhalation) are developed for chronic and/or subchronic human exposure to chemicals and are based solely on the noncarcinogenic effects of chemical substances. These values are defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of adverse effects during a lifetime. The RfD is usually expressed as dose (mg) per unit body weight (kg) per unit time (day). The RfC is expressed as dose (mg) per cubic meter of air (m^3). They are generally derived by dividing a no-observed-(adverse)-effect-level (NOAEL or NOEL) or a lowest observed-adverse-effect-level (LOAEL) for the critical toxic effect by an appropriate "uncertainty factor (UF)." Effect levels are determined from laboratory or epidemiological studies. The UF is based on the availability of toxicity data.

UFs usually consist of multiples of 10, where each factor represents a specific area of uncertainty naturally present in the extrapolation process. These UFs are presented below and were taken from the RAGS (USEPA, 1989b).

- A UF of 10 is used to account for variation in the general population and is intended to protect sensitive subpopulations (e.g., elderly, children).
- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.
- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.
- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to UFs, a modifying factor (MF) is applied to each reference dose and is defined as:

A MF ranging from >1 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default value for the MF is 1.

Thus, the RfD incorporates the certainty of the evidence for chronic human health effects. Even if applicable human data exist, the RfD still maintains a margin of safety such that chronic human health effects are not underestimated.

6.4.2.2 Carcinogenic Slope Factor

CSFs are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen (USEPA, 1989b). This factor is generally reported in units of (mg/kg/day)⁻¹ and is derived through an assumed low-dosage linear multistage model and an extrapolation from high to low dose-responses determined from animal studies. The value used in reporting the slope factor is the 95% UCL.

CSFs can also be derived from USEPA promulgated unit risk values for air and/or water. CSFs derived from unit risks cannot, however, be applied to environmental media other than the medium considered in the unit risk estimate.

These slope factors are also accompanied by weight-of-evidence classifications which designate the strength of the evidence that the COPC is a potential human carcinogen.

Quantitative indices of toxicity and USEPA weight-of-evidence classifications are presented in Table 6-13 for the identified COPCs. The hierarchy (USEPA, 1989b) for choosing these values was:

- Integrated Risk Information System (IRIS) (USEPA, 1995)
- Health Effects Assessment Summary Table (HEAST) (USEPA, 1994b)
- Region III Specific Directives (USEPA, 1994c)

The IRIS data base is updated monthly and contains both verified RfDs, RfCs and CSFs. The USEPA has formed an RfD work group to review existing data used to derive RfDs and RfCs. Once this task has been completed the verified RfD appears in IRIS. Like the RfD Work Group, the USEPA has also formed the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work group to review and validate toxicity values used in developing CSFs. Once the slope factors have been verified via extensive peer review, they also appear in the IRIS data base.

HEAST, on the other hand, provides both interim (unverified) and verified RfDs, RfCs and CSFs. This document is published quarterly and incorporates any applicable changes to its data base.

6.5 Risk Characterization

The risk characterization combines the selected COPCs, the exposure assessment, and the toxicity assessment to produce a quantitative estimate of current potential human health risks associated with Sites 4 and 21. Estimated ICRs and HIs for the identified potential adult and child receptor groups which could be exposed to COPCs via dermal contact, accidental ingestion, and inhalation of fugitive dust in the surface and subsurface soil, as well as dermal contact and ingestion of surface water, sediment, and groundwater by adults and children, and the inhalation of volatile groundwater COPCs while showering, are discussed in this section. The ICRs and HIs were calculated for each

of the soil, surface water, and sediment COPC using the 95% UCL of the arithmetic mean, while groundwater ICRs and HIs used the maximum detected concentrations in selected groundwater monitoring wells as the exposure point concentration. The maximum concentration was selected if the exposure point concentration 95% UCL exceeded the maximum concentration. The human health risks expected due to chronic exposure through these exposure pathways, are estimated.

6.5.1 Carcinogenic Compounds

Quantitative risk calculations for potentially carcinogenic compounds estimate inferentially (versus probabilistically) the potential ICR for an individual in a specified population. This unit of risk refers to a potential cancer risk that is above the background cancer risk in unexposed individuals. For example, an ICR of 1×10^{-6} indicates that an exposed individual has an increased probability of one in one million of developing cancer subsequent to exposure, over the course of their lifetime.

The potential lifetime ICR for an individual was estimated from the following relationship:

$$ICR = \sum_{i=1}^n CDI_i \times CSF_i$$

where the CSF_i is expressed as $(mg/kg/day)^{-1}$ for compound i , and the CDI is expressed as $mg/kg/day$ for compound i . Since the units of CSF are $(mg \text{ chemical}/kg \text{ body weight-day})^{-1}$ and the units of intake or dose are $(mg \text{ chemical}/kg \text{ body weight-day})$, the ICR value is dimensionless. The aforementioned equation was derived assuming that cancer is a nonthreshold process and that the potential excess risk level is proportional to the cumulative intake over a lifetime.

Estimated ICR values will be compared to the target risk range of 1×10^{-6} to 1×10^{-4} which represents the range of ICR values considered by USEPA to be generally acceptable (USEPA, 1990).

For quantitative estimation of risk, it is assumed that cancer risks from various exposure routes are additive. This method of adding risks may overestimate the overall risks since each individual risk uses the maximum detected concentration in the calculation. Since there are no mathematical

models that adequately describe chemical antagonism or synergism (i.e., potential reverse or enhancement of effects), these issues will be discussed in narrative fashion in the uncertainty analysis.

6.5.2 Noncarcinogenic Compounds

Noncarcinogenic compounds assume that a threshold toxicological effect exists. Therefore, the potential for noncarcinogenic effects are calculated by comparing (i.e., dividing) CDI_i levels with threshold levels (RfDs) for each COPC.

Noncarcinogenic effects are estimated by calculating the Hazard Index (HI) which is derived as:

$$HI = \sum_{i=1}^n HQ_i$$

where: $HQ_i = CDI_i/RfD_i$

An HQ is the ratio of the daily intake or absorbed dose to the reference dose (or reference concentration for inhalation exposure). HQ_i is the hazard quotient for contaminant i , CDI_i is the chronic daily intake (mg/kg/day) of contaminant i , and RfD_i is the reference dose (mg/kg/day) of the contaminant i over a prolonged period of exposure. RfC is the reference concentration used when determining exposure due to inhalation. Since the units of RfD are mg/kg-day and the units of CDI are mg/kg-day, the hazard quotient is dimensionless.

To account for the additivity of noncarcinogenic risk following exposure to numerous chemicals, the HI, which is the sum of all the HQs, will be calculated. A ratio of 1.0 is used for examination of the HI. Ratios less than 1.0 indicate that adverse noncarcinogenic health effects are unlikely. Ratios greater than 1.0 indicate the potential for adverse noncarcinogenic health effects to occur at that exposure level and caution should be exercised. This does not mean, however, that adverse effects will definitely be observed since the RfD incorporates safety and modifying factors to ensure that it is well below that dose for which adverse effects have been observed. This procedure

assumes that the risks from exposure to multiple chemicals are additive, an assumption that is probably valid for compounds that have the same target organ or cause the same toxic effect. It should be noted that this summation approach ignores potential interactions among the various chemicals at the site which may either enhance or reduce the potential health effects.

6.6 Potential Human Health Effects

The human health estimates are based upon the exposure assumptions presented in Section 6.3. Potential human health effects considered in the baseline RA include carcinogenic effects and systemic or noncarcinogenic effects. Carcinogenic effects are expressed as ICRs while noncarcinogenic effects are expressed as HIs. Cancer effects are expressed as risk (ICRs) because the expression of cancer does not occur immediately after exposure but typically occurs years after the exposure. Estimated ICR values are compared to the target risk range of 1×10^{-6} to 1×10^{-4} which USEPA considers to be generally acceptable and protective of human health (USEPA, 1990). Noncarcinogenic health effects usually occur subsequent to exposure if a threshold intake level is exceeded. Therefore, noncarcinogenic health effects are expressed as HIs. Estimated HI values less than unity (i.e., 1.0) are considered by USEPA to be generally acceptable and protective of public health (USEPA, 1990). Risk estimates and HIs are not intended as a true indication of actual exposure; they are intended to provide decision makers with useful information regarding the significance of the observed contamination. Risk calculation spreadsheets, showing risk estimates and HIs, are presented in Appendix F.

6.6.1 Current Adult On-Site Civilian Workers

The following subsection describes the risk calculations for potential current adult on-site civilian workers from three environmental media, surface soil, surface water, and sediment at Sites 4 and surface soil at Site 21. Surface water and sediment samples were not collected at Site 21. The risk calculations for surface water and sediment from Site 4 will be used to generate potential risk to adult on-site civilian workers. Tables 6-14 and 6-15 summarize the ICR and HI values for each pathway and medium, respectively.

6.6.1.1 Site 4

Surface Soil

The ICR and HI values associated with direct contact of surface soil by current civilian adult on-site workers via accidental ingestion, dermal contact, or inhalation (e.g., fugitive dust) of surface soil at Site 4 resulted in an ICR value of 7.7×10^{-05} and an HI value of 2.0×10^{-01} . The HI value was below the noncarcinogenic risk level of 1.0, and the ICR value fell within USEPA's target risk range of 1×10^{-06} to 1×10^{-04} .

Surface Water

The HI values associated with direct contact of surface water by current civilian adult on-site workers via accidental ingestion and dermal contact of surface water at Site 4 resulted in an HI value of $1.3 \times 10^{+00}$ (using total inorganic results) and an HI value of 8.4×10^{-01} (using filtered or dissolved inorganic results). The HI value using dissolved inorganic results was below 1.0 indicating that the potential for systemic health effects to occur subsequent to exposure is limited. The HI value using total inorganic results exceeded 1.0 due primarily to the presence of manganese in the surface water. The total ICR values associated with direct contact of surface water were 4.3×10^{-05} (using total inorganic results) and 1.4×10^{-05} (using dissolved inorganic results), respectively. Each of these values fall within the target risk range of 1×10^{-06} to 1×10^{-04} which USEPA considers to be "generally" acceptable.

Sediment

The HI value associated with direct contact of sediment by current civilian adult on-site workers via accidental ingestion and dermal contact of sediment at Site 4 was 1.3×10^{-01} . This HI value was below 1.0; therefore, systemic health effects are not expected to occur subsequent to exposure. The total ICR value for ingestion and dermal contact was 4.1×10^{-06} . This value falls within USEPA's target risk range of 1×10^{-06} to 1×10^{-04} .

6.6.1.2 Site 21

Surface Soil

The HI value associated with direct contact of surface soil by current civilian adult on-site workers via accidental ingestion, dermal contact, or inhalation (e.g., fugitive dust) of surface soil at Site 21 was 3.9×10^{-02} . These HI values were below the noncarcinogenic risk level of 1.0. The total ICR value for ingestion, dermal contact and inhalation at Site 21 was 3.6×10^{-06} , which falls within USEPA's "generally" acceptable target risk range of 1×10^{-06} to 1×10^{-04} .

6.6.2 **Future Adult and Child On-Site Residents**

The following subsections present the hazard indices and incremental lifetime cancer risks for potential future adult and child on-site residents from four environmental media, surface soil, groundwater, surface water, and sediment at Sites 4 and 21. Tables 6-16 and 6-17 summarize the ICR and HI values for each pathway and medium, respectively.

6.6.2.1 Site 4

Surface Soil

The ICR and HI values associated with direct contact of surface soil by future child residents via accidental ingestion and dermal contact, resulted in a total HI of 3.3 and an ICR of 2.3×10^{-04} . The HI value exceeded 1.0 primarily due to the presence of arsenic in the surface soil. Arsenic accounted for approximately 67 percent of the HI. The ICR value also fell outside of the acceptable target risk range due to the presence of benzo(a)pyrene and arsenic in the surface soil. Benzo(a)pyrene accounted for approximately 28 percent of the ICR value while arsenic accounted for approximately 56 percent of the ICR value.

An evaluation of potential risk subsequent to exposure to the accidental ingestion and dermal contact with the surface soil for the future adult resident resulted in a total HI of 4.2 and an ICR of 5.4×10^{-04} . The HI value was greater than 1.0, and the ICR value falls outside of the USEPA's generally acceptable target risk range of 1×10^{-06} to 1×10^{-04} , indicating a risk to the future

residential adult from the soil pathway due to the presence of benzo(a)pyrene, arsenic and manganese.

Groundwater

Potential human health effects associated with the future potable use of groundwater exposure was using the analytical data obtained from two monitoring wells at Site 4. A summary of the results for each of these wells is provided in the paragraphs that follow.

4GW03

The ICR and HI values associated with direct exposure to COPCs detected in monitoring well 4GW03 by future on-site child residents via ingestion, dermal contact, and inhalation of VOCs while showering included an HI of $4.1 \times 10^{+01}$ and an ICR of 3.9×10^{-04} (using total inorganic results), and an HI of 1.1×10^{-01} and an ICR of 5.3×10^{-06} (using dissolved inorganic results). The HI value using the total inorganics exceeded 1.0 due to the presence of aluminum, chromium, and manganese in the ground water. Total aluminum accounted for approximately 11 percent of the HI value, chromium accounted for approximately 9 percent of the HI value, and manganese accounted for approximately 70 percent of the HI value. The ICR derived using total inorganics also exceeded the upper end of the target risk range, due to the presence of beryllium in unfiltered groundwater samples which accounted for approximately 99 percent of the total ICR value. HI values do not exceed 1.0 and ICR values fall within the generally acceptable risk range of 1×10^{-06} to 1×10^{-04} when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

An evaluation of potential risk subsequent to the ingestion and dermal contact of groundwater from well 4GW03 by future on-site adult residents included an HI value of $5.9 \times 10^{+01}$ and an ICR value of 1.1×10^{-03} (using total inorganic results), and an HI of 1.6×10^{-01} and an ICR value of 1.4×10^{-05} (using dissolved inorganic results). The HI value derived using total inorganics exceeded the acceptable value of 1.0 due to the presence of aluminum, chromium, and manganese in the groundwater. Total aluminum accounted for approximately 11 percent of the HI, chromium accounted for approximately 9 percent of the total HI value, and manganese accounted for approximately 70 percent of the HI value. The ICR value derived using the total inorganic analytical

results exceeded the upper end of the target risk range due to the presence of beryllium in unfiltered groundwater samples which accounted for approximately 99 percent of the total ICR value. HI values do not exceed 1.0 and ICR values fall within the generally acceptable risk range of 1×10^{-6} to 1×10^{-4} when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

4GW05

The ICR and HI values associated with direct exposure to COPCs detected in monitoring well 4GW05 by future on-site child residents via ingestion, dermal contact, and inhalation of VOCs while showering included an HI of $5.2 \times 10^{+01}$ and an ICR of 5.2×10^{-04} (using total inorganic results), and an HI of $1.1 \times 10^{+01}$ and an ICR of 1.7×10^{-06} (using dissolved inorganic results). The HI value using the total inorganics exceeded 1.0 due to the presence of aluminum, chromium, manganese, and vanadium in the ground water. Total aluminum accounted for approximately 7 percent of the HI value, chromium accounted for approximately 5 percent of the HI value, manganese accounted for approximately 79 percent of the HI value, and vanadium accounted for approximately 2 percent of the HI value. The ICR derived using total inorganics also exceeded the upper end of the target risk range, because of the presence of beryllium in unfiltered groundwater samples which accounted for approximately 91 percent of the total ICR value. The HI values using dissolved (filtered) inorganics exceeded 1.0 due to the presence of antimony and manganese. Dissolved antimony accounted for approximately 68 percent of the HI value, while manganese accounted for approximately 28 percent of the HI value. ICR values fall within the generally acceptable risk range of 1×10^{-6} to 1×10^{-4} when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

The ICR and HI values associated with direct exposure to COPCs detected in monitoring well 4GW05 by future on-site adult residents via ingestion, dermal contact, and inhalation of VOCs while showering included an HI of $7.5 \times 10^{+01}$ and an ICR of 1.4×10^{-03} (using total inorganic results), and an HI of $1.6 \times 10^{+01}$ and an ICR of 4.6×10^{-06} (using dissolved inorganic results). The HI value using the total inorganics exceeded 1.0 due to the presence of aluminum, chromium, and manganese in the ground water. Total aluminum accounted for approximately 7 percent of the HI value, chromium accounted for approximately 5 percent of the HI value, and manganese accounted for

approximately 79 percent of the HI value. The ICR derived using total inorganics also exceeded the upper end of the target risk range, because of the presence of beryllium in unfiltered groundwater samples which accounted for approximately 91 percent of the total ICR value. The HI values using dissolved (filtered) inorganics exceeded 1.0 due to the presence of antimony and manganese. Dissolved antimony accounted for approximately 68 percent of the HI value, while manganese accounted for approximately 28 percent of the HI value. ICR values fall within the generally acceptable risk range of 1×10^{-6} to 1×10^{-4} when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

Surface Water

The ICR and HI values associated with direct contact of surface water by future on-site child residents via ingestion and dermal contact included an HI of 6.8×10^{-02} and an ICR of 6.5×10^{-06} (using the total inorganic results) and an HI of 4.4×10^{-02} with an ICR of 1.9×10^{-06} (using the dissolved inorganic results). Both of the HI values were below 1.0. ICR values derived using total and dissolved inorganic analytical results did not exceed USEPA's generally acceptable risk range.

Potential exposure to COPCs in surface water by future adult residents resulted in an HI value of 9.0×10^{-03} and an ICR value of 1.2×10^{-05} (using total inorganic results), and an HI of 5.7×10^{-03} and an ICR of 3.8×10^{-06} (using dissolved inorganic results). HI values were below 1.0 and ICR values fall below USEPA's generally acceptable risk range of 1×10^{-06} to 1×10^{-04} .

Sediment

The ICR and HI values associated with direct contact (accidental ingestion and dermal contact) of COPCs detected in Site 4 sediment samples by future child residents resulted in an HI of 2.5×10^{-01} and an ICR of 2.3×10^{-06} . The HI value was below 1.0. The ICR value of 2.3×10^{-06} falls within USEPA's generally acceptable risk range of 1×10^{-06} to 1×10^{-04} .

An evaluation of potential risk subsequent to exposure to the accidental ingestion and dermal contact with the sediment for the future adult resident resulted in an HI of 3.2×10^{-02} and an ICR of

4.2×10^{-06} . The HI value was well below 1.0. The ICR value falls within USEPA's target risk range of 1×10^{-06} to 1×10^{-04} .

6.6.2.2 Site 21

Surface Soil

An evaluation of potential risk subsequent to exposure to the accidental ingestion and dermal contact with the surface soil for the future child resident resulted in a total HI of 6.5×10^{-01} and an ICR of 1.3×10^{-05} . The HI value was less than 1.0, and the ICR value fell within the USEPA's generally acceptable target risk range of 1×10^{-06} to 1×10^{-04} .

The ICR and HI values associated with direct contact of surface soil by future adult residents via accidental ingestion and dermal contact, resulted in a total HI of 8.2×10^{-01} and an ICR of 2.7×10^{-05} . The ICR value fell within the target risk range of 1×10^{-06} to 1×10^{-04} which USEPA considers to be "generally" acceptable. The HI value was less than 1.0 indicating that the potential for systemic health effects to occur subsequent to exposure is limited.

Groundwater

Potential human health effects associated with the future potable use of groundwater exposure was using the analytical data obtained from two monitoring wells at Site 21. A summary of the results for each of these wells is provided in the paragraphs that follow.

21GW01

The ICR and HI values associated with direct exposure to COPCs detected in monitoring well 21GW01 by future on-site child residents via ingestion, and dermal contact while showering included an HI of 5.3×10^{-01} and an ICR of 4.5×10^{-04} (using total inorganic results), and an HI of 7.1×10^{-02} (using dissolved inorganic results). There were no dissolved COPCs that had inhalation cancer slope factors. The HI value using the total inorganics exceeded 1.0 due to the presence of aluminum, chromium, manganese and vanadium in the ground water. Total aluminum accounted for approximately 7 percent of the HI value, chromium accounted for approximately 6 percent of

the HI value, manganese accounted for approximately 76 percent of the HI value, and vanadium accounted for approximately 7 percent of the HI value. The ICR derived using total inorganics also exceeded the upper end of the target risk range, because of the presence of beryllium in unfiltered groundwater samples which accounted for approximately 94 percent of the total ICR value. HI values did not exceed 1.0 when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

An evaluation of potential risk subsequent to the ingestion and dermal contact of groundwater from well 21GW01 by future on-site adult residents included an HI value of 7.6×10^{-01} and an ICR value of 1.2×10^{-03} (using total inorganic results), and an HI of 1.0×10^{-01} (using dissolved inorganic results). The HI value derived using total inorganics exceeded the acceptable value of 1.0 due to the presence of aluminum, chromium, manganese and vanadium in the groundwater. Total aluminum accounted for approximately 7 percent of the HI, chromium accounted for approximately 6 percent of the total HI value, manganese accounted for approximately 76 percent of the HI value, and vanadium accounted for approximately 7 percent of the HI value. The ICR value derived using the total inorganic analytical results exceeded the upper end of the target risk range due to the presence of beryllium in unfiltered groundwater samples which accounted for approximately 94 percent of the total ICR value. HI values do not exceed 1.0 when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

21GW03

The ICR and HI values associated with direct exposure to COPCs detected in monitoring well 21GW03 by future on-site child residents via ingestion and dermal contact while showering included an HI of 9.9×10^{-01} and an ICR of 2.5×10^{-04} (using total inorganic results), and an HI of 5.9×10^{-02} (using dissolved inorganic results). The HI value using the total inorganics exceeded 1.0 due to the presence of aluminum, arsenic, cadmium, chromium, manganese, vanadium and zinc in the ground water. Total aluminum accounted for approximately 5 percent of the HI value, arsenic accounted for approximately 1 percent, cadmium accounted for approximately 19 percent, chromium accounted for approximately 2 percent of the HI value, manganese accounted for approximately 63 percent of the HI value, vanadium accounted for approximately 2 percent of the HI value, and

zinc accounted for approximately 7 percent of the HI value. The ICR derived using total inorganics also exceeded the upper end of the target risk range, because of the presence of beryllium in unfiltered groundwater samples which accounted for approximately 79 percent of the total ICR value. The HI values using dissolved (filtered) inorganics exceeded 1.0 due to the presence of cadmium, manganese, and zinc. Dissolved cadmium accounted for approximately 2 percent of the HI value, manganese accounted for approximately 8 percent of the HI value, and zinc accounted for approximately 90 percent of the HI value. ICR values fall within the generally acceptable risk range of 1×10^{-6} to 1×10^{-4} when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

The ICR and HI values associated with direct exposure to COPCs detected in monitoring well 21GW03 by future on-site adult residents via ingestion and dermal contact while showering included an HI of $1.4 \times 10^{+02}$ and an ICR of 6.8×10^{-04} (using total inorganic results), and an HI of $8.5 \times 10^{+02}$ (using dissolved inorganic results). The HI value using the total inorganics exceeded 1.0 due to the presence of aluminum, cadmium, manganese, and zinc in the ground water. Total aluminum accounted for approximately 5 percent of the HI value, cadmium accounted for approximately 19 percent of the HI value, manganese accounted for approximately 63 percent of the HI value, and zinc accounted for approximately 7 percent of the HI value. The ICR derived using total inorganics also exceeded the upper end of the target risk range, because of the presence of beryllium in unfiltered groundwater samples which accounted for approximately 79 percent of the total ICR value. The HI values using dissolved (filtered) inorganics exceeded 1.0 due to the presence of cadmium, manganese and zinc. Dissolved cadmium accounted for approximately 2 percent of the HI value, manganese accounted for approximately 8 percent of the HI value, and zinc accounted for approximately 90 percent of the HI value. ICR values fall within the generally acceptable risk range of 1×10^{-6} to 1×10^{-4} when dissolved (filtered) groundwater sample analytical results were used to determine the future potential human health effects associated with potable groundwater use scenarios.

6.6.3 Future Construction Workers

The following subsection will describe the risk calculations for potential future on-site adult construction workers at Site 4 from one environmental medium, surface soil, and Site 21 from two

environmental medium, surface and subsurface soil. Table 6-18 and 6-19 summarizes the ICR and HI values for each pathway and medium, respectively.

6.6.3.1 Site 4

Surface Soil

ICR and HI values associated with direct contact (accidental ingestion, dermal contact, and inhalation of fugitive dust) of COPCs detected in surface soil samples by future construction workers were evaluated. An HI of 1.2×10^{-01} and a total ICR of 1.3×10^{-05} were derived. The HI value was below 1.0, while the ICR value falls within USEPA's target risk range of 1×10^{-04} to 1×10^{-06} .

6.6.3.2 Site 21

Surface Soil

ICR and HI values associated with direct contact (accidental ingestion, dermal contact, and inhalation of fugitive dust) of COPCs detected in surface soil samples by future construction workers were evaluated. An HI of 2.2×10^{-01} and a total ICR of 7.6×10^{-07} were derived. The HI value was below 1.0, while the ICR value falls within USEPA's target risk range of 1×10^{-04} to 1×10^{-06} .

Subsurface Soil

ICR and HI values associated with direct contact (accidental ingestion, dermal contact and inhalation of fugitive dust) of COPCs detected in subsurface soil samples by future construction workers were evaluated. An HI of 1.2×10^{-01} and a total ICR of 8.6×10^{-07} were derived. The HI value was below 1.0, while the ICR value falls within USEPA's target risk range of 1×10^{-04} to 1×10^{-06} .

6.7 Sources of Uncertainty

Uncertainties are encountered throughout the process of performing a risk assessment. This section discusses the sources of uncertainty inherent in the following elements of the public health evaluation performed for Sites 4 and 21:

- Sampling and analysis
- Selection of COPCs
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Chemicals not quantitatively evaluated

Uncertainties associated with this risk assessment are discussed in the following paragraphs. Table 6-20 summarizes the potential effects of certain uncertainties on the estimation of human health risks.

6.7.1 Sampling and Analysis

The development of a risk assessment depends on the reliability of, and uncertainties associated with, the analytical data available to the risk assessor. These, in turn, are dependent on the operating procedures and techniques applied to the collection of environmental samples in the field and their subsequent analyses in the laboratory. To minimize the uncertainties associated with sampling and analysis at Sites 4 and 21, USEPA approved sampling and analytical methods were employed. Data was generated following USEPA's Statement of Work for Contract Laboratory Program (CLP). Samples were analyzed for TCL organics (plus nitramine compounds), TAL inorganics, and cyanide. Samples were taken from locations specified in the approved Work Plan (Baker, 1994) along with the necessary QA/QC samples.

Analytical data are limited by the precision and accuracy of the methods of analysis and the inherent variability in environmental sample matrices. The statistical methods used to compile and analyze the data (mean concentrations, detection frequencies) are subject to the overall uncertainty in data measurement. Furthermore, chemical concentrations in environmental media fluctuate over time and with respect to sampling location. Also, the surface water and sediment samples that were collected before the removal action are no longer representative of current site conditions. Therefore, it is difficult to evaluate the risks associated with these media. Analytical data must be sufficient to consider the temporal and spatial characteristics of contamination at the site with respect to exposure.

6.7.2 Selection of COPCs

The selection of COPCs is performed in a risk assessment following the evaluation of data. Analytical data also must be comprehensive in order to address the COPCs associated with the site. Types of COPCs encountered at Sites 4 and 21 include some VOCs, SVOCs, pesticides and PCBs, and nitramine (explosives); inorganic and PAH constituent concentrations were the most dominant at the site.

Soil COPCs were selected based on comparisons of exposure point concentrations with Region III COC risk-based screening values.

Groundwater COPCs were selected based on comparisons of exposure point concentrations with Region III COC screening values, Federal MCLs, and Commonwealth groundwater standards.

Surface water COPCs were selected based on comparisons of exposure point concentrations to COC screening values, Federal and Commonwealth Water Quality Criteria.

Sediment COPCs were selected based on comparisons of exposure point concentrations to SSVs and COC screening values.

Region III COC screening values are based on exposure assumptions and equations that are intended to introduce conservatism in the risk assessment process by changing the COPC screening method from a relative toxicity screen as presented in RAGS, to an absolute comparison of risk. However, the use of the Region III COC screening concentrations results in the application of a set of non-site-specific assumptions in the determination of COPCs at Sites 4 and 21. In addition, the use of SSVs, which are intended for aquatic organisms and residential soil COC screening values for the selection of human health COPCs, provides a very conservative screening tool.

Currently, no Station closures are planned for WPNSTA Yorktown and future residential development is not considered an expected land use for the area. The application of the residential COC screening values to soil and tap water COC screening values to groundwater COPC selections would, therefore, tend to result in a list of COPCs that could be considered overly conservative for a military base. The use of conservative COPC selections in the baseline RA ensures the protection

of public health in that the results of the baseline RA are incorporated into the determination of remedial alternatives and remedial action objectives in the FS.

6.7.3 Exposure Assessment

In performing exposure assessments, uncertainties arise from two main sources. First, uncertainties arise in estimating the fate of a compound in the environment, including estimating release and transport in a particular environmental medium. Second, uncertainties arise in the estimation of chemical intakes resulting from contact by a receptor with a particular medium.

To estimate an intake, certain assumptions must be made about exposure events, exposure durations, and the corresponding assimilation of constituents by the receptor. Exposure factors have been generated by the scientific community and have undergone review by the USEPA. The USEPA has published an Exposure Factors Handbook which contains the best and latest values. Regardless of the validity of these exposure factors, they have been derived from a range of values generated by studies of limited numbers of individuals. In all instances, values used in this risk assessment, scientific judgments, and conservative assumptions agree with those of the USEPA.

Potential exposure to soil, surface water and sediment at any location is considered as having an equal probability of occurrence as an individual moves randomly across the site. The use of a RME approach, designed as not to underestimate daily intakes, was employed throughout this risk assessment. The RME concentration is defined as the highest concentration that could reasonably be expected to be contacted via a given pathway over a long-term exposure period. The use of the normal 95% UCL estimates of the arithmetic mean for the exposure point concentration in soil, surface water and sediment as well as the use of the maximum value as the groundwater concentration term in estimating the CDI, reduces the potential for underestimating exposure at the Sites 4 and 21. Recent research using Monte-Carlo estimation techniques indicate that USEPA's RME represents the 98 to 99.99 percent upper limit of the estimated risk distribution. However, this uncertainty is usually associated with the variability of the analytical data set and the selection of certain inputs.

The use of total (unfiltered) inorganic analytical results in groundwater to represent conditions "at the tap", may result in an overestimation of potential risks for these COPCs. The presence of fine

particulates in unfiltered groundwater samples may contribute to the concentration of inorganic constituents such as lead, beryllium, antimony, and chromium. The presence of fine particulates in groundwater samples can be attributed to the design of monitoring wells and sampling techniques, which is different than potable well design. Also, because two wells were picked at each site to designate the exposure point concentration, not all COPCs were evaluated at each well.

6.7.4 Toxicological Assessment

In making quantitative estimates of the toxicity of varying dosages of compounds to human receptors, uncertainties arise from two sources. First, data on human exposure and the subsequent effects are usually insufficient, if they are at all available. Human exposure data usually lack adequate concentration estimations and suffer from inherent temporal variability. Therefore, animal studies are often used and new uncertainties arise from the process of extrapolating animal results to humans. Second, to obtain observable effects with a manageable number of experimental subjects, high doses of a compound are often used. In this situation, a high dose means that high exposures are used in the experiment with respect to most environmental exposures. Therefore, when applying the results of the animal experiment to the human condition, the effects at the high doses must be extrapolated to approximate effects at lower doses.

In extrapolating effects from high doses in animals to low doses in humans, scientific judgment and conservative assumptions are employed. In selecting animal studies for use in dose-response calculations, the following factors are considered:

- Studies are preferred where the animal closely mimics human pharmacokinetics.
- Studies are preferred where dose intake most closely mimics the intake route and duration for humans.
- Studies are preferred which demonstrate the most sensitive response to the compound in question.

For compounds believed to cause threshold effects (i.e., noncarcinogens) safety factors are employed in the extrapolation of effects from animals to humans and from high doses to low doses. In

deriving carcinogenic potency factors, the 95% UCL value is promulgated by the USEPA to prevent underestimation of potential risk.

The use of conservative assumptions results in quantitative indices of toxicity that are not expected to underestimate potential toxic effects, but may overestimate these effects by an order of magnitude or more. Also, toxicity factors were dermally adjusted for the dermal contact exposure pathway for all media evaluated. This may also cause an over estimate of toxic effects.

6.7.5 Human Risk Characterization

The risk characterization bridges the gap between potential exposure and the possibility of systemic or carcinogenic human health effects, ultimately providing impetus for the remediation of the site or providing a basis for no remedial action.

Uncertainties associated with risk characterization include the assumption of chemical additivity and the inability to predict synergistic or antagonistic interactions between COPCs. These uncertainties are inherent in any inferential risk assessment. USEPA promulgated inputs to the quantitative risk assessment and toxicological indices are calculated to be protective of the human receptor and to err conservatively, so as to not underestimate the potential human health risks.

6.7.6 Compounds Not Quantitatively Evaluated

The inorganic COPC lead, was not quantitatively evaluated in the baseline RA. Lead is currently considered a B2 - probable human carcinogen, as well as a developmental toxin in young children. The lack of promulgated toxicological indices for lead does not have significant effects on the underestimation of risk due to the presence of other COPCs such as arsenic, in environmental media at relatively high levels. Although this constituent was not quantitatively evaluated, this risk assessment has been performed using conservative exposure point concentrations, exposure scenarios (use of the groundwater aquifer as a drinking water source), and available toxicological information.

In addition to lead, there are a few other COPCs that currently do not have USEPA-verified toxicity factors (i.e., RfDs and CSFs) available to quantitate risk. These COPCs are 2-methynaphthalene and

endrin ketone. Although these COPCs were not included in the risk evaluation, the COPCs that were evaluated exhibit properties that address the toxicological nature of the excluded chemicals. For example, benzo(a)pyrene was a semivolatile organic compound (SVOC) identified as a COPC. Benzo(a)pyrene is a Class A carcinogen. It is reasonable to assume that the inclusion of benzo(a)pyrene as a COPC sufficiently addresses the toxicological effects of the excluded SVOCs. Similarly, dieldrin was identified as a COPC. It is assumed that the evaluation of this pesticide adequately addresses the exclusion of the previously mentioned pesticide.

6.8 Summary of Risk Assessment Results

This section summarizes the results of the baseline RA and identifies environmental media and COPCs which could potentially pose human health risks and/or effects.

Risk results from each logical exposure pathway were summed for each receptor to determine the total site risk posed by Sites 4 and 21. The following paragraphs present the potential current and future exposure pathways and the subsequent potential total site risk to humans.

6.8.1 Current Potential Receptors

Potential current receptors to COPCs detected in environmental media at Sites 4 and 21 include on-site adult civilian workers.

6.8.1.1 Site 4

Potential current total site risks/hazards to this receptor are presented in Table 6-21. The total ICR values for organic and dissolved inorganics fall within USEPA's target risk range of 1×10^{-6} to 1×10^{-4} . The total ICR value for organic and total inorganics exceeds USEPA's target risk range of 1×10^{-6} to 1×10^{-4} . This is due primarily from dermal contact with the surface soil and ingestion of surface water. The target risk range represents the range of potential risks that USEPA generally believes to be acceptable. HI values presented in Table 6-21 for current potential human receptors is greater than 1.0 for both organic and total inorganics as well as organic and dissolved inorganic concentrations. This is due primarily to the presence of total and dissolved manganese in the surface water.

6.8.1.2 Site 21

Potential current total site risks/hazards to this receptor are presented in Table 6-22. The total ICR values for both organic and total inorganics as well as organic and dissolved inorganics fall within USEPA's target risk range of 1×10^{-6} to 1×10^{-4} . The target risk range represents the range of potential risks that USEPA generally believes to be acceptable. HI values presented in Table 6-22 for current potential human receptors are greater than 1.0 for both organic and total inorganics as well as organic and dissolved inorganic concentrations. This is due primarily to the presence of total and dissolved manganese in the surface water.

6.8.2 **Future Potential Receptors**

Property use at Sites 4 and 21 will remain the same in the foreseeable future. Future residential development of Sites 4 and 21 is highly unlikely given its location within the restricted area of the Station and the newly-constructed security fence that encloses the site. However for the sake of conservatism, future residential development and associated potential risks were evaluated. The potential human receptors evaluated for under the future scenarios were:

- Future resident adults
- Future resident children
- Future construction workers

The results of each of these scenarios are presented below.

6.8.2.1 Site 4

Future Residents

Table 6-23 presents the total ICR and HI values for the future potential residential development of Site 4. It was assumed that future adult and child residents could potentially be exposed to COPCs in surface soil, groundwater, surface water, and sediment. Future development of groundwater for potable purposes is unlikely even in the event of future residential development because of the

availability of municipal water, however, potential potable exposure to COPCs in groundwater was evaluated for the sake of conservatism. Total ICR and HI values for future adult residents are the sum total of the resident adult and resident child HI and ICR values, respectively.

ICR values for future resident children and adults exceed USEPA's target risk range of 1×10^{-6} to 1×10^{-4} when evaluating the organic and total and dissolved inorganic concentrations. This is due predominantly to the presence of total beryllium in the groundwater at monitoring wells 4GW03 and 4GW05 and benzo(a)pyrene and arsenic in the surface soil.

HI values for future resident adults and children were greater than 1.0, for organic and total inorganic concentrations as well as organic and dissolved inorganic concentrations, suggesting that noncarcinogenic adverse health effects may occur subsequent to exposure. Aluminum, chromium, manganese, and vanadium in groundwater were the main contributors to the total HI value using organic and total inorganic groundwater concentrations. HI values using organic and dissolved inorganic results generally resulted in a slight decrease to the total HI value, but still exceeded the target HI value of 1.0. The HI value for organic and dissolved inorganic concentrations was primarily the result of dissolved antimony and manganese in the groundwater at 4GW05. Arsenic and manganese in the surface soil also contributed to the HI value.

Future Adult Construction Worker

Future potential adult construction workers could be exposed to COPCs in surface soil during future building/excavation activities at Site 4. The total ICR value for the future adult construction worker was within the USEPA's target risk range; the HI value did not exceed 1.0. Therefore, carcinogenic or noncarcinogenic health effects would not be expected for adult construction workers subsequent to exposure to surface soil. Table 6-23 presents the total ICR and HI values for this receptor.

6.8.2.2 Site 21

Table 6-24 presents the total ICR and HI values for the future potential residential development of Site 21. It was assumed that future adult and child residents could potentially be exposed to COPCs in surface soil, groundwater, surface water, and sediment. Future potential exposure by resident children and adults to groundwater accounted for the greatest portion of total site risk to these

receptors. Future development of groundwater for potable purposes is unlikely because of the availability of municipal water, and station restrictions and future land use which prohibits residential development. Potential potable exposure to COPCs in groundwater was, however evaluated for the sake of conservatism. Total ICR and HI values for future adult residents are the sum total of the resident adult and resident child HI and ICR values, respectively.

ICR values for future resident children and adults using groundwater as a potable source of drinking water exceed USEPA's target risk range of 1×10^{-6} to 1×10^{-4} when evaluating the organic and total inorganic concentrations. This is due predominantly to the presence of total beryllium in the groundwater at monitoring wells 21GW01 and 21GW03. ICR values using organic and dissolved inorganic concentrations did not exceed the USEPA's target risk range.

HI values for future resident adults and children using groundwater as a potable supply were greater than 1.0, for organic and total inorganic concentrations as well as organic and dissolved inorganic concentrations, suggesting that noncarcinogenic adverse health effects may occur subsequent to exposure. Aluminum, arsenic, cadmium, chromium, manganese, vanadium, and zinc in groundwater were the main contributors to the total HI value using organic and total inorganic groundwater concentrations from 21GW03. HI values using organic and dissolved inorganic results generally resulted in a slight decrease to the total HI value, but still exceeded the target HI value of 1.0. The HI value for organic and dissolved inorganic concentrations was primarily the result of dissolved cadmium, manganese and zinc in the groundwater at 21GW03.

Future Adult Construction Worker

Future potential adult construction workers could be exposed to COPCs in surface and subsurface soil during future building/excavation activities at Site 21. The total ICR value for the future adult construction worker was within the USEPA's target risk range; the HI value did not exceed 1.0. Therefore, carcinogenic or noncarcinogenic health effects would not be expected for adult construction workers, subsequent to exposure to subsurface soil. Table 6-24 presents the total ICR and HI values for this receptor.

6.9 References

Roy F. Weston, Inc. (Weston) and Baker. 1993. Final Round One RI Report, Naval Weapons station Yorktown, Yorktown, Virginia. Prepared for the Atlantic Division Naval Facilities Engineering Command, Norfolk, Virginia. July.

Baker Environmental, Inc. 1994. Final Work Plan for Sites 6, 7, 12, 16, Site Screening Area 16, and Background, Naval Weapons Station Yorktown, Yorktown, Virginia. June, 1994.

Bureau of National Affairs, Inc. 1994. Environment Reporter-State Water Laws. Volume 6. Washington, D.C.

Clement Associates, Inc. 1985. Chemical, Physical, and Biological properties of Compounds Present at Hazardous Waste Sites. Final Report.

Cowherd et al., 1985. Rapid Assessment of Exposure to Particulate Emissions from surface contamination. Prepared by Midwest Research Institute, Washington, D.C. EPA/600/8-85-002.

Department of the Navy. 1991. The Master Plan for the U.S. Naval Weapons Station, Yorktown. Atlantic Division, Naval Facilities Engineering Command, Norfolk, Virginia.

Ford and Gurba, 1984. Methods of Determining Relative Contaminant Mobilities and Migration Pathways Using Physical-Chemical Data.

Foster, 1986. Foster, S.A. and P.C. Chrostowski. 1986. "Integrated Household Exposure Model for Use of Tap Water Contaminated with Volatile Organic Chemicals." Presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis, Minnesota. June 22-27, 1986.

IT, Corporation. 1995. (To be published). Removal Action Report, Naval Weapons Station Yorktown, Yorktown, Virginia.

Laskowski, D.A., Goring, C.A., McCall, P.J. and Swann, R.L. 1983. "Terrestrial Environment in Environmental Risk Analysis for Chemicals", Environmental Risk Analysis for Chemicals, R.A. Conways, ed., Van Nostrand Reinhold Co., New York, NY.

Long, Edward R., Donald D. MacDonald, Sherri L. Smith, and Fred D. Calder. 1995. "Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediment," Environmental Management, Vol. 19, No. 1, PP. 81-97. Springer-Verland New York Inc.

Lyman, W.J., Reehl W.F., Rosenblatt, D.H. 1982. Handbook of Chemical Property Estimation Methods. Environmental Behavior of Organic Compounds.

Ryan, E.A. Hawkins, E.T., et al. 1987. Assessing Risk from Dermal Exposure at Hazardous Waste Sites. Bennet, G. and Bennet, J. editors. Superfund '87: Proceedings of the 8th National Conference. November 16-18, 1987. Washington, D.C. Hazardous Controls Research Institute.

Swartzbaugh, et al. 1992. "Remediating Sites Contaminated with Heavy Metals." Hazardous Materials Control, November/December, 1992.

United States Environmental Protection Agency. 1988. Superfund Exposure Assessment Manual, Office of Emergency and Remedial Response. Washington, D.C. April 1988. EPA/540/1-88/001 and OSWER Directive 9285.5-1.

United States Environmental Protection Agency. 1989a. Exposure Factors Handbook. Office of Health and Environmental Assessment. Washington, D.C. July 1989. EPA/600/8-89-043.

United States Environmental Protection Agency. 1989b. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual (Part A) Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. December 1989. EPA/540/1-89-002.

United States Environmental Protection Agency. 1990. National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule. Federal Register, 40 Code of Federal Regulations Part 300, March 8, 1990.

United States Environmental Protection Agency. 1991a. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual Supplemental Guidance: "Standard Default Exposure Factors" Interim Final. Office Solid Waste and Emergency Response. Washington, D.C. March 25, 1991. OSWER Directive 9285.6-03.

United States Environmental Protection Agency. 1991b. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual (Part B) (Development of Risk-Based Preliminary Remediation Goals). Interim. Office Solid Waste and Emergency Response. Washington, D.C. December, 1991. OSWER Directive 9285.7-01B.

United States Environmental Protection Agency. 1992a. Dermal Exposure Assessment: Principles and Applications. Interim. Office of Research and Development. Washington, D.C. January 1992. EPA/600/8-91/011B.

United States Environmental Protection Agency. 1992b. New Interim Region IV Guidance. USEPA Region IV, Atlanta, Georgia. February 10, 1992.

United States Environmental Protection Agency. 1992c. Supplemental Guidance to RAGS: Calculating the Concentration Term. OSWER Publication Number 9285.7-081. May 1992.

United States Environmental Protection Agency. 1993a. Region III Supplementary Risk Assessment Guidance for Superfund, COC Screening Table. Region III, Philadelphia, Pennsylvania. March 1993.

United States Environmental Protection Agency. 1993b. Region III Technical Guidance Manual, Selecting Exposure Routes and Contaminant of Concern by Risk-Based Screening. Region III, Philadelphia, Pennsylvania. January 1993. EPA/903/R-93-001.

United States Environmental Protection Agency. 1994a. Drinking Water Regulations and Health Advisories. Office of Water U.S. Environmental Protection Agency. Washington, D.C. May, 1994.

United States Environmental Protection Agency. 1994b. Health Effects Summary Tables Annual FY 1994. Office of Solid Waste and Emergency Response, Washington, D.C. March 1994. OERR 9200.6-303(94-1).

United States Environmental Protection Agency. 1994c. Revised Soil Lead Guidance for CERCLA Sites and Corrective Action Facilities. OSWER Directive 9355.4-12, July 14, 1994.

United States Environmental Protection Agency. 1995. Integrated Risk Information System. Environmental Criteria and Assessment Office, Cincinnati, Ohio.

United States Environmental Protection Agency. 1995a. "Risk-Based Concentration Summary Table, First Quarter, February 9, 1995." Region III, Philadelphia, Pennsylvania.

Webster, R.C. Maibach, H.I., et al. 1993. *InVivo and InVitro* Percutaneous Absorption and Skin Decontamination of Arsenic from Water and Soil, Fundamental and Applied Toxicology, 20, pp. 336-340.

SECTION 6.0 TABLES

TABLE 6-1

**SURFACE SOIL DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Volatiles:							
Acetone	20,000	780	1/47	0.005	0	0	No
2-Butanone	100,000	4,700	12/47	0.004-0.007	0	0	No
Trichloroethene	520	58	1/47	0.008	0	0	No
Toluene	41,000	1,600	3/47	0.002-0.027	0	0	No
Methylene Chloride	760	85	23/47	0.001-0.06	0	0	No
Semivolatiles:							
4-Methylphenol	1,000	39	1/47	0.22J	0	0	No
Naphthalene	8,200	310	8/47	0.045J-8.9	0	0	No
2-Methylnaphthalene	--	--	4/47	0.062J-3.0	--	--	Yes
Acenaphthylene	--	--	9/47	0.044J-2.9	--	--	Yes
3-Nitroaniline	610	23	1/46	1.0J	0	0	No
Acenaphthene	12000	470	10/47	0.053J-25.0J	0	0	No
Dibenzofuran	820	31	8/47	0.046J-8.1	0	0	No
Fluorene	8200	310	12/47	0.045J-12.0	0	0	No

TABLE 6-1 (Continued)

SURFACE SOIL DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Semivolatiles (Continued):							
N-Nitrosodiphenylamine	1200	130	1/47	0.22J	0	0	No
Pentachlorophenol	48	5.3	1/47	0.052J	0	0	No
Anthracene	61000	2300	22/47	0.043J-34.0J	0	0	No
Benzo(a)anthracene	7.8	0.88	30/47	0.041J-67J	2	8	Yes
Benzo(a)pyrene	0.78	0.088	28/47	0.038J-56.0J	8	25	Yes
Benzo(b)fluoranthene	7.8	0.88	31/47	0.045J-54.0J	2	9	Yes
Benzo(k)fluoranthene	78	8.8	25/47	0.043J-7.8	0	0	No
Bis(2-ethylhexyl)phthalate	410	46	37/47	0.04J-0.64	0	0	No
Butylbenzylphthalate	41,000	1,600	2/47	0.046J-0.15J	0	0	No
Carbazole	290	32	19/47	0.043J-44.0J	0	1	Yes
Chrysene	780	88	30/47	0.044J-63.0J	0	0	No
Di-n-butylphthalate	20,000	780	29/47	0.04J-0.24J	0	0	No
Dibenz(a,h)anthracene	1	0.088	8/47	0.08J-6.1	2	7	Yes
Di-n-octylphthalate	4,100	160	1/47	0.059	0	0	No

TABLE 6-1 (Continued)

**SURFACE SOIL DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Semivolatiles (Continued):							
Fluoranthene	8,200	310	32/47	0.036-140	0	0	No
Benzo(g,h,i)perylene	--	--	26/47	0.039-14.0	--	--	Yes
Indeno (1,2,3-cd) pyrene	7.8	0.88	27/47	0.045-32.0	2	6	Yes
Phenanthrene	--	--	27/47	0.054-120	--	--	Yes
Pyrene	6,100	230	31/47	0.056-110	0	0	No
Pesticides/PCBs:							
alpha-Chlordane	4.4	0.49	9/44	0.00039J-0.038J	0	0	No
gamma-Chlordane	4.4	0.49	7/44	0.00013J-0.045J	0	0	No
4,4 - DDD	24	2.7	15/44	0.0045J-0.23J	0	0	No
4,4'-DDE	17.0	1.9	18/44	0.001J-0.073J	0	0	No
4,4'-DDT	17.0	1.9	21/44	0.00074J-0.93J	0	0	No
Dieldrin	0.36	0.04	2/44	0.008-0.011	0	0	No
Endrin	61	2.3	1/44	0.0026J	0	0	No
Endosulfan II	1,200 ⁽⁴⁾	47 ⁽⁴⁾	5/44	0.0038J-0.02J	0	0	No

TABLE 6-1 (Continued)

**SURFACE SOIL DATA SUMMARY - SITE 4
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Pesticides/PCBs (Continued):							
Endrin Ketone	--	--	1/44	0.0084J	--	--	No
Endrin Aldehyde	--	--	3/44	0.003J-0.011J	--	--	No
Heptachlor	1.3	0.14	3/44	0.0002J-0.031J	0	0	No
Heptachlor Epoxide	0.63	0.07	2/44	0.0019J-0.002J	0	0	No
Aroclor-1016	14	0.55	1/44	0.081J	0	0	No
Aroclor-1254	4.1	0.16	5/44	0.064J-0.28J	0	1	Yes
Aroclor-1260	0.74	0.083	4/44	0.053J-0.4J	0	2	Yes
Nitroamine Compounds:							
HMX	10000	390	3/47	13 - 38	0	0	No
RDX	52	5.8	5/47	1.2 - 110	2	3	Yes
1,3,5-Trinitrobenzene	10	0.39	1/47	0.5	0	1	No
1,3-Dinitrobenzene	20	0.78	1/47	0.97	0	1	No
2,4,6-Trinitrotoluene	190	21	4/47	0.22 - 130	0	2	Yes

TABLE 6-1 (Continued)

SURFACE SOIL DATA SUMMARY - SITE 4
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES

CTO-0297

NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Inorganics:							
Aluminum	100,000	7,800	47/47	1,380J-81,200J	0	10	Yes
Antimony	82	3.1	4/47	3.5J-20.4J	0	4	Yes
Arsenic	3.3/61	0.37/2.3	46/47	0.94B-486	31/1	46/38	Yes
Barium	14,000	550	46/47	14.4B-180	0	0	No
Beryllium	1.3	0.15	46/47	0.08B-1.2	0	45	Yes
Cadmium	100	3.9	19/47	0.59B-6.0	0	2	Yes
Calcium+	--	--	46/47	169B-144,000	--	--	No
Chromium (VI)	1,000	39	46/47	2.6-36.5	0	0	No
Cobalt	12,000	470	46/47	0.85B-14.1	0	0	No
Copper	7,600	290	46/47	1.9B-337	0	1	Yes
Cyanide (total)	4,100	160	3/47	4.8J-36.8J	0	0	No
Iron+	--	--	47/47	2,120-42,600J	--	--	No
Lead	--	400 ⁽³⁾	47/47	6.3J-383	--	0	No
Magnesium+	--	--	47/47	102J-1,540	--	--	No

TABLE 6-1 (Continued)

**SURFACE SOIL DATA SUMMARY - SITE 4
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Inorganics (Continued):							
Manganese	1,000	39	47/47	30.9-17,700	1	46	Yes
Mercury	61	2.3	14/47	0.11J-1.3J	0	0	No
Nickel	4,100	160	47/47	1.9B-20.3	0	0	No
Potassium+	--	--	47/47	107B-1,600	--	--	No
Silver	1,000	39	5/47	0.48B-1.3B	0	0	No
Sodium+	--	--	47/47	19.7J-1,270B	--	--	No
Thallium	16 ⁽³⁾	0.63 ⁽⁵⁾	12/47	0.08J-0.2B	0	0	No
Vanadium	1,400	55	47/47	5.5B-42.5	0	0	No
Zinc	61,000	2,300	47/47	13.6J-15,200J	0	1	Yes

(1) Organic concentrations reported in µg/kg, converted to mg/kg. Inorganic concentrations reported in mg/kg.

(2) COC Values = USEPA Region III COC screening value (USEPA, 1993a)

(3) Action level for residential soils (USEPA, 1994c)

(4) COC value for Endosulfan

(5) COC value for thallium carbonate, chloride and/or sulfate

-- = No criteria published

+ = Essential Nutrients

J = Value is Estimated.

B = Value is Estimated (for inorganics).

D = Value is from diluted sample.

TABLE 6-2

GROUNDWATER DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Groundwater Criteria ⁽²⁾			Frequency/Range ⁽³⁾		Comparison to Criteria			COPC Selection
	Federal MCL (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Virginia PMCLs (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	No. of Detects Above MCL	No. of Detects Above COC Value	No. of Detects Above Virginia Criteria	Retained as a COPC?
VOCs:									
1,1-Dichloroethene	7	0.044	--	1/5	1.0J	0	1	--	Yes
1,2-Dichloroethene	70**	5.5	--	2/5	12-20	0	2	--	Yes
1,1,1-Trichloroethane	200	130	200	1/5	2.0J	0	0	0	No
Trichloroethene	5	1.6	--	3/5	3J-17	2	3	--	Yes
Nitroamine Compounds:									
HMX	--	180	--	2/5	0.99-1.1	--	0	--	No
RDX	--	0.61	--	3/5	0.91-3.3	--	3	--	Yes
Inorganics (Total):									
Aluminum	--	3,700	--	5/5	26,000J-70,800J	--	5	--	Yes
Arsenic (as carcinogen)	50	0.038	50	4/5	4.7-20.6	0	4	0	Yes
Barium	2,000	260	1,000	5/5	102-287	0	1	0	Yes
Beryllium	4	0.016	--	5/5	3.3-20.2	4	5	--	Yes
Cadmium	5	1.8	10	3/5	4.8J-5.2J	2	3	0	Yes
Calcium+	--	--	--	5/5	52,900-1,270,000	--	--	--	No
Chromium	100	18	50	5/5	150-286	5	5	5	Yes
Cobalt	--	220	--	3/5	59.1-82.1	--	0	--	No

TABLE 6-2 (Continued)

GROUNDWATER DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Groundwater Criteria ⁽²⁾			Frequency/Range ⁽³⁾		Comparison to Criteria			COPC Selection
	Federal MCL (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Virginia PMCLs (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	No. of Detects Above MCL	No. of Detects Above COC Value	No. of Detects Above Virginia Criteria	Retained as a COPC?
Inorganics (Total) (Continued):									
Iron+	--	--	--	5/5	99,300J-228,000J	--	--	--	No
Lead	15 ⁽³⁾	--	50	5/5	33.3-54.8	5	--	1	Yes
Magnesium+	--	--	--	5/5	10,700J-31,900J	--	--	--	No
Manganese	--	18	--	5/5	404-3,140	--	5	--	Yes
Mercury	2	1.1	2	2/5	0.18-0.19	0	0	0	No
Nickel (soluble salts)	100	73	--	5/5	63.6-209	3	4	--	Yes
Potassium+	--	--	--	4/5	8,900-18,300	--	--	--	No
Sodium+	--	--	--	5/5	4,790-11,700	--	-	--	No
Vanadium	--	26	--	5/5	97.8-201	--	5	--	Yes
Zinc	--	1,100	--	5/5	246-735	--	0	--	No
Inorganics (Dissolved):									
Aluminum	--	3,700	--	1/5	150J	--	0	--	No
Antimony	6	1.5	--	1/5	45.7	1	1	--	Yes
Barium	2,000	260	1,000	1/5	77.1	0	0	0	No
Calcium+	--	--	--	5/5	41,300-322,000	--	--	--	No
Iron+	--	--	--	1/5	449J	--	--	--	No

TABLE 6-2 (Continued)

**GROUNDWATER DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Groundwater Criteria ⁽²⁾			Frequency/Range ⁽³⁾		Comparison to Criteria			COPC Selection
	Federal MCL (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Virginia PMCLs (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	No. of Detects Above MCL	No. of Detects Above COC Value	No. of Detects Above Virginia Criteria	Retained as a COPC?
Inorganics (Dissolved) (Continued):									
Magnesium+	--	--	--	5/5	2,150J-11,900J	--	--	--	No
Manganese	--	18	--	4/5	3.9-239	--	2	--	Yes
Silver	--	18	50	1/5	7.5J	--	0	0	No
Sodium+	--	--	--	5/5	4,870-7,820	--	--	--	No
Zinc	--	1,100	--	5/5	10.3-22.6	--	0	--	No

- (1) All concentrations reported in µg/L
- (2) Federal MCL - Federal Safe Drinking Water Act Maximum Contaminant Level (USEPA, 1994a; Drinking Water Regulations and Health Advisories)
Virginia Drinking Water Standards - PMCLs - Primary Maximum Contaminant Levels (Bureau of National Affairs - December, 1994)
COC values - USEPA Region III COC screening value (USEPA, 1993a)
- (3) The MCL provided for lead is the action level.
-- = No criteria published
** = Criteria for cis-1,2-dichloroethene
+ = Essential Nutrient
J = Value is Estimated.

NOTE: The Federal MCLs for inorganics are based on total inorganics. The VA MCLs for inorganics are based on dissolved inorganics.

TABLE 0-3

**SURFACE WATER DATA SUMMARY - SITE 4
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Federal/Regional Criteria ⁽²⁾			Virginia Water Quality Standards ⁽³⁾		Frequency/Range		COPC Selection
	WQC Water and Organisms (µg/L)	WQC Organisms Only (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Public Water Supplies (µg/L)	All Other Surface Waters (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	Retained as a COPC?
Semivolatiles:								
Di-n-butylphthalate	2,700	12,000	370	--	--	1/5	11	No
Nitroamine Compounds:								
1,3,5-Trinitrobenzene	--	--	0.18	--	--	2/5	1.5-2.6	Yes
1,3-Dinitrobenzene	--	--	0.37	--	--	2/5	0.32J-0.34	No
2,4,6-Trinitrotoluene	--	--	2.2	--	--	2/5	4.1J-8.3	Yes
2,4-Dinitrotoluene	--	--	7.3	1.1	91	2/5	0.31J-0.44J	No
HMX	--	--	180	--	--	4/5	1.4-19	No
Nitrobenzene	--	--	0.34	--	--	2/5	0.27J-0.38J	Yes
RDX	--	--	0.61	--	--	4/5	0.41J-170	Yes
Inorganics (Total):								
Aluminum	--	--	3,700	--	--	5/5	57.1-40,500	Yes
Arsenic (as carcinogen)	0.018	0.14	0.038	50	--	3/5	2.6J-43.4	Yes
Barium	1,000*	--	260	2,000	--	5/5	20-243	No
Beryllium	0.0076	0.131	0.016	--	--	1/5	2.2	Yes
Cadmium	10	170	1.8	16	170	1/5	11.6	Yes

TABLE 6-3 (Continued)

SURFACE WATER DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Federal/Regional Criteria ⁽²⁾			Virginia Water Quality Standards ⁽³⁾		Frequency/Range		COPC Selection
	WQC Water and Organisms (µg/L)	WQC Organisms Only (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Public Water Supplies (µg/L)	All Other Surface Waters (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	Retained as a COPC?
Inorganics (Total) (Continued):								
Calcium+	--	--	--	--	--	5/5	65,900J-116,000J	No
Chromium	170	3,400	18	170	3,400	1/5	46	Yes
Cobalt	--	--	220	--	--	1/5	25.2	No
Copper	1,300	--	140	1,300	--	2/5	7.7J-200	Yes
Iron+	300*	--	--	300	--	5/5	1,050-143,000	No
Lead	50*	--	--	15	--	4/5	2.8J-215J	Yes
Magnesium+	--	--	--	--	--	5/5	3,610J-272,000J	No
Manganese	50*	100*	18	50	--	5/5	83.5J-1,020J	Yes
Mercury	0.14	0.15	1.1	0.144	0.146	2/5	0.13-5.56	Yes
Nickel	610	4,600	73	607	4,583	2/5	20.1-29	No
Potassium+	--	--	--	--	--	5/5	1,790J-89,900J	No
Sodium+	--	--	--	--	--	5/5	4,650J-997,000	No
Vanadium	--	--	26	--	--	2/5	6.4J-37.8J	Yes
Zinc	--	--	1100	5,000	--	3/5	61.1-3,880	Yes

TABLE 6-3 (Continued)

SURFACE WATER DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Federal/Regional Criteria ⁽²⁾			Virginia Water Quality Standards ⁽³⁾		Frequency/Range		COPC Selection
	WQC Water and Organisms (µg/L)	WQC Organisms Only (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Public Water Supplies (µg/L)	All Other Surface Waters (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	Retained as a COPC?
Inorganics (Dissolved):								
Antimony	14	4,300	1.5	--	--	1/5	44.1	Yes
Arsenic (carcinogen)	0.018	0.14	0.038	50	--	2/5	2.1J-3.1	Yes
Barium	1,000*	--	260	2,000	--	5/5	22-81.2J	No
Cadmium	10	170	1.8	16	170	1/5	7.3	Yes
Calcium+	--	--	--	--	--	5/5	63,900-131,000	No
Iron+	300*	--	--	300	--	5/5	31.6-528	No
Lead	50*	--	--	15	--	1/4	2.2J	No
Magnesium+	--	--	--	--	--	5/5	2,690-311,000	No
Manganese	50*	100*	18	50	--	5/5	54.3-567	Yes
Nickel	610	4,600	73	607	4,583	2/5	18.1-29.2	No
Potassium+	--	--	--	--	--	3/5	1,440J-105,000J	No
Vanadium	--	--	26	--	--	1/5	10.4	No
Zinc	--	--	1,100	5,000	--	4/5	9.8-30.4	No

Notes:

- (1) All concentrations reported in µg/L
(2) Water Quality Criteria (WQC) human health values (recalculated) using IRIS as of 1990; Surface Water Quality Criteria - Human Health (1.0 x 10⁻⁶ risk for carcinogens), December 22, 1992
COC value - USEPA Region III COC screening value (USEPA, 1993a)
(3) Virginia Water Standards (Bureau of National Affairs - December 1994)

- J = Value is estimated.
-- = No criteria published
+ = Essential Nutrient
* = Hardness dependent criteria (100 mg/L CaCO₃ used)

TABLE 6-4

SEDIMENT DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO SEDIMENT SCREENING VALUES AND USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Sediment Criteria ⁽²⁾		Contaminant Frequency/Range ⁽³⁾		Comparison to Criteria		COPC Selection
	SSV ER-M (mg/kg)	Residential Soil COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detections (mg/kg)	Positive Detects Above ER-M	Positive Detects Above Residential COC Value	Retained as a COPC?
Volatiles:							
2-Butanone	--	4,700	1/10	0.2J	--	0	No
1,1,1-Trichloroethane	--	700	1/10	0.006J	--	0	No
Methylene Chloride	--	85	1/10	0.013J	--	0	No
Carbon Disulfide	--	780	1/10	0.04	--	0	No
Semivolatiles:							
Benzo(g,h,i)perylene	--	--	1/10	0.34J	--	--	Yes
Pesticides/PCBs:							
Alpha-chlordane	--	0.49	3/6	0.005J-0.04J	--	0	No
Gamma-chlordane	--	0.49	2/6	0.0042J-0.033	--	0	No
4,4'-DDD	--	2.7	6/6	0.015-0.91D	--	0	No
4,4'-DDE	0.027	1.9	6/6	0.0032J-0.056J	1	0	Yes
4,4'-DDT	0.046	1.9	3/6	0.005J-0.015J	0	0	No
Inorganics:							
Aluminum	--	7800	10/10	5,720J-32,900J	--	9	Yes
Antimony	--	3.1	1/10	43.1	--	1	Yes

TABLE 6-4 (Continued)

SEDIMENT DATA SUMMARY - SITE 4
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO SEDIMENT SCREENING VALUES AND USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Sediment Criteria ⁽²⁾		Contaminant Frequency/Range ⁽³⁾		Comparison to Criteria		COPC Selection
	SSV ER-M (mg/kg)	Residential Soil COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detections (mg/kg)	Positive Detects Above ER-M	Positive Detects Above Residential COC Value	Retained as a COPC?
Inorganics (Continued):							
Arsenic	70	0.37/2.3	7/10	2.5-9.7J	0	7/7	Yes
Barium	--	550	10/10	15-41.7	--	0	No
Beryllium	--	0.15	3/10	0.81-1.5	--	3	Yes
Cadmium+	9.6	3.9	3/10	1.76-2.99	0	0	No
Calcium+	--	--	10/10	920-5,530	--	--	No
Chromium (VI)	370	39	7/10	4.3-34.2	0	0	No
Cobalt	--	470	7/10	7-17.6	--	0	No
Copper	270	290	10/10	0.03-33.6J	0	0	No
Iron+	--	--	10/10	341J-41,700J	--	--	No
Lead	218	400 ⁽³⁾	10/10	6.9J-114.8J	0	0	No
Magnesium+	--	--	10/10	155-8,130J	--	--	No
Manganese	--	39	10/10	29J-468J	--	9	Yes
Mercury	0.71	2.3	7/10	0.13-0.61	0	0	No
Nickel	51.6	160	4/10	12.3-33.6	0	0	No
Potassium+	--	--	5/10	1,080-3,760	--	--	No

TABLE 6-4 (Continued)

**SEDIMENT DATA SUMMARY - SITE 4
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO SEDIMENT SCREENING VALUES AND USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Sediment Criteria ⁽²⁾		Contaminant Frequency/Range ⁽³⁾		Comparison to Criteria		COPC Selection
	SSV ER-M (mg/kg)	Residential Soil COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detections (mg/kg)	Positive Detects Above ER-M	Positive Detects Above Residential COC Value	Retained as a COPC?
Inorganics (Continued):							
Selenium	--	39	2/10	1.1J-2.5	--	0	No
Sodium+	--	--	9/10	27.9-15,900J	--	--	No
Vanadium	--	55	10/10	3.9-44.6	--	0	No
Zinc	410	2,300	10/10	124-1,200J	4	0	Yes

⁽¹⁾ Organic concentrations converted to mg/kg, Inorganic concentrations reported in mg/kg.

⁽²⁾ SSV = Sediment Screening Value (Long, et al, 1995)
 COC value = USEPA Region III COC screening value (USEPA, 1993a)

⁽³⁾ Action level for residential soils (USEPA, 1994c)

-- = No criteria published

+ = Essential Nutrients

* = Contaminant re-included as COPC based on site history.

J = Value is estimated.

D = Value is from a diluted sample.

TABLE G-5

SURFACE SOIL DATA SUMMARY - SITE 21
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Volatiles:							
Acetone	20,000	780	1/14	0.007J	0	0	No
Stryene	41,000	1,600	1/14	0.001	0	0	No
Toluene	41,000	1,600	3/14	0.001J-0.003J	0	0	No
Methylene Chloride	760	85	1/14	0.06	0	0	No
Semivolatiles:							
Acenaphthylene	--	--	1/14	0.11J	--	--	Yes
Benzo(a)anthracene	7.8	0.88	1/14	0.2J	0	0	No
Benzo(a)pyrene	0.78	0.088	1/14	0.14J	0	1	Yes
Benzo(b)fluoranthene	7.8	0.88	1/14	0.91	0	1	Yes
Benzo(k)fluoranthene	78	8.8	1/14	0.22J	0	0	No
Bis(2-ethylhexyl)phthalate	410	46	10/14	0.074J-0.26J	0	0	No
Butylbenzylphthalate	41,000	1,600	7/14	0.043J-1.4	0	0	No
Chrysene	780	88	1/14	0.26J	0	0	No
Di-n-butylphthalate	20,000	780	3/14	0.042J-0.36J	0	0	No

TABLE 6-5 (Continued)

**SURFACE SOIL DATA SUMMARY - SITE 21
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	
Semivolatiles (Continued):							
Fluoranthene	8,200	310	1/14	0.27J	0	0	No
Benzo(g,h,i)perylene	--	--	1/14	0.11J	--	--	Yes
Indeno (1,2,3-cd) pyrene	7.8	0.88	1/14	0.13J	0	0	No
Pyrene	6,100	230	1/14	0.26J	0	0	No
Pesticides/PCBs:							
alpha-Chlordane	4.4	0.49	2/14	0.0032-0.015	0	0	No
gamma-Chlordane	4.4	0.49	2/14	0.003-0.013	0	0	No
4,4'-DDD	24	2.7	2/14	0.03-0.19J	0	0	No
4,4'-DDE	17	1.9	5/14	0.00082J-0.039	0	0	No
4,4'-DDT	17	1.9	2/14	0.0043-0.033	0	0	No

TABLE 6-5 (Continued)

**SURFACE SOIL DATA SUMMARY - SITE 21
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	Selected as a COPC?
Pesticides/PCBs (Continued):							
Aldrin	0.34	0.038	2/14	0.011-0.02	0	0	No
Dieldrin	0.36	0.04	2/14	0.028-0.046	0	1	Yes
Endrin	61	2.3	2/14	0.031-0.051	0	0	No
Endrin Ketone	--	--	1/14	0.00095J	--	--	Yes
Heptachlor	1.3	0.14	2/14	0.013-0.022	0	0	No
gamma-BHC	4.4	0.49	2/14	0.013-0.022	0	0	No
Inorganics:							
Aluminum	100,000	7,800	14/14	938-43,300	0	2	Yes
Arsenic (carc./noncarc.)	3.3/6.1	0.37/2.3	14/14	0.34J-4.0B	2/0	13/3	Yes
Barium	14,000	550	14/14	4.7B-50.7B	0	0	No
Beryllium	1.3	0.15	13/14	0.05B-0.73B	0	10	Yes

TABLE 6-5 (Continued)

SURFACE SOIL DATA SUMMARY - SITE 21
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	
Inorganics (Continued):							
Cadmium	100	3.9	4/14	1.5J-38.4J	0	2	Yes
Calcium+	--	--	14/14	113B-4,620	--	--	No
Chromium (VI)	1,000	39	14/14	1.9B-21.9	0	0	No
Cobalt	12,000	470	13/14	0.48B-3.9B	0	0	No
Copper	7,600	290	14/14	0.87B-61.9	0	0	No
Iron+	--	--	14/14	1,400-14,400	--	--	No
Lead	--	400 ⁽³⁾	14/14	4.6-43	--	0	No
Magnesium+	--	--	14/14	61.6B-699B	--	--	No
Manganese	1,000	39	14/14	3.7B-1,310J	1	8	Yes
Mercury	61	2.3	4/14	0.18-3.5	0	1	Yes
Nickel	4,100	160	12/14	1.2B-13.6B	0	0	No
Potassium+	--	--	11/14	99.5B-537B	--	--	No
Selenium	1,000	39	1/14	0.44B	0	0	No
Silver	1,000	39	1/14	1.3B	0	0	No

TABLE 6-5 (Continued)

**SURFACE SOIL DATA SUMMARY - SITE 21
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Soil Criteria ⁽²⁾		Contaminant Frequency/Range		Comparison to Criteria		COPC Selection
	Industrial COC Value (mg/kg)	Residential COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detection (mg/kg)	No. of Positive Detects Above Industrial COC Value	No. of Positive Detects Above Residential COC Value	
Inorganics (Continued):							
Sodium+	--	--	14/14	16.1B-55.1B	--	--	No
Vanadium	1,400	55	14/14	3B-18.3B	0	0	No
Zinc	61,000	2,300	14/14	3.6B-6,780	0	1	Yes

⁽¹⁾ Organic concentrations reported in µg/kg, Inorganic concentrations reported in mg/kg.

⁽²⁾ COC Value = USEPA Region III COC screening value (USEPA, 1993a); values provided for alpha- and gamma- chlordane are for total chlordane.

⁽³⁾ Action level for residential soils (USEPA, 1994c)

-- = No criteria published

+ = Essential Nutrients

J = Value is Estimated.

B = Value is Estimated (for inorganics).

TABLE 6-6

**SUBSURFACE SOIL DATA SUMMARY - SITE 21
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Region III Criteria		Contaminant Frequency/Range ⁽²⁾		Comparison to Criteria		COPC Selection
	Industrial Soil COC Value (mg/kg)	Residential Soil COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detections (mg/kg)	Positive Detects Above Industrial COC Value	Positive Detects Above Residential COC Value	Selected as a COPC?
Volatiles:							
Methylene Chloride	760	85	3/8	0.018-0.038	0	0	No
Toluene	41,000	1,600	2/8	0.002J-0.004J	0	0	No
Acetone	20,000	780	1/8	0.11	0	0	No
Semivolatiles:							
Phenol	100,000	4,700	1/8	0.026	0	0	No
Di-n-butylphthalate	20,000	780.0	3/8	0.044J-0.17J	0	0	No
Fluoranthene	8,200	310	1/8	0.048J	0	0	No
Pyrene	6,100	230.0	1/8	0.05J	0	0	No
Chrysene	780	88.0	3/8	0.042J-0.051J	0	0	No
Bis(2-ethylhexyl)phthalate	410	46.0	4/8	0.043J-0.071J	0	0	No
Benzo(b)fluoranthene	7.8	0.88	3/8	0.052J-0.085J	0	0	No
Benzo(a)pyrene	0.78	0.1	3/8	0.049J-0.085J	0	0	No
Benzo(g,h,i)perylene	--	--	1/8	0.037J	--	--	Yes
Pesticides/PCBs:							
4,4'-DDE	17	1.9	2/8	0.002J-0.0067	0	0	No

TABLE 6-6 (Continued)

SUBSURFACE SOIL DATA SUMMARY - SITE 21
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO USEPA REGION III COC SCREENING VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Region III Criteria		Contaminant Frequency/Range ⁽²⁾		Comparison to Criteria		COPC Selection
	Industrial Soil COC Value (mg/kg)	Residential Soil COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detections (mg/kg)	Positive Detects Above Industrial COC Value	Positive Detects Above Residential COC Value	Selected as a COPC?
Pesticides/PCBs (continued):							
4,4'-DDD	24	2.7	2/8	0.0028J-0.025J	0	0	No
4,4'-DDT	17	1.9	2/8	0.0081-0.038J	0	0	No
alpha-Chlordane	4.4	0.49	1/8	0.0024	0	0	No
gamma-Chlordane	4.4	0.49	1/8	0.002J	0	0	No
Aroclor-1260	0.74*	0.083*	1/8	0.032J	0	0	No
Inorganics:							
Aluminum	100,000	7,800	8/8	1,040-5,230	0	0	No
Arsenic	3.3/61	0.37/2.3	8/8	0.73-10.10	2/0	8/3	Yes
Barium	14,000	550	8/8	6-20	0	0	No
Beryllium	1.30	0.15	6/8	0.09-0.44	0	4	Yes
Cadmium	100	3.9	2/8	0.66B-0.74B	0	0	No
Calcium+	--	--	8/8	94.8-706	--	--	No
Chromium	1,000	39	6/8	2.4-28.2	0	0	No
Cobalt	12,000	470	5/8	0.74B-4.0B	0	0	No
Copper	7,600	290	8/8	3.6-31.8	0	0	No

TABLE 6-6 (Continued)

**SUBSURFACE SOIL DATA SUMMARY - SITE 21
 FREQUENCY AND RANGE OF POSITIVE DETECTIONS
 COMPARED TO USEPA REGION III COC SCREENING VALUES
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Region III Criteria		Contaminant Frequency/Range ⁽³⁾		Comparison to Criteria		COPC Selection
	Industrial Soil COC Value (mg/kg)	Residential Soil COC Value (mg/kg)	No. of Positive Detects/ No. of Samples	Range of Positive Detections (mg/kg)	Positive Detects Above Industrial COC Value	Positive Detects Above Residential COC Value	Selected as a COPC?
Inorganics (Continued)							
Iron+	--	--	8/8	1,890-20,300	--	--	No
Lead	--	400 ⁽⁴⁾	8/8	5.2J-68.9J	--	0	No
Magnesium+	--	--	8/8	58.7-333	--	--	No
Manganese	1,000	39	8/8	35.7-383	0	6	Yes
Mercury	61	2.3	3/8	0.09-0.69J	0	0	No
Nickel	4,100	160	4/8	1.9B-5.7B	0	0	No
Potassium	--	--	3/8	93.8B-450B	--	--	No
Selenium	1,000	39	1/8	0.29B	0	0	No
Silver	1,000	39	1/6	0.68B	0	0	No
Sodium	--	--	6/8	17.4B-26.3B	--	--	No
Vanadium	1,400	55	6/8	3.4B-27.3	0	0	No
Zinc	61,000	2,300	7/8	35.6-719J	0	0	No

⁽¹⁾ Organic concentrations converted to mg/kg, Inorganic concentrations reported in mg/kg.

⁽²⁾ COC value = USEPA Region III COC screening value (USEPA, 1993a)

⁽³⁾ J = Analyte was positively identified. Reported value may not be accurate or precise.
 B = Value is estimated (for inorganics)

⁽⁴⁾ Action level for residential soils (USEPA, 1994c)

-- = No criteria published

* = Value is for Total PCBs

+ = Essential Nutrients

TABLE 6-7

GROUNDWATER DATA SUMMARY - SITE 21
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant ⁽¹⁾	Groundwater Criteria ⁽²⁾			Frequency/Range ⁽³⁾		Comparison to Criteria			COPC Selection
	Federal MCL (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Virginia PMCLs (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	No. of Detects Above MCL	No. of Detects Above COC Value	No. of Detects Above Virginia Criteria	Retained as a COPC?
Inorganics (Total):									
Aluminum	--	3,700	--	4/4	10,300J-80,300J	--	4	--	Yes
Arsenic (as carcinogen)	50	0.038	50	3/4	2.7-5.8	0	3	0	Yes
Barium	2,000	260	1,000	4/4	110-412	0	1	0	Yes
Beryllium	4	0.016	--	4/4	2.3-18.1	2	4	--	Yes
Cadmium	5	1.8	10	3/4	5.8J-145	3	3	2	Yes
Calcium+	--	--	--	4/4	45,200-151,000	--	--	--	No
Chromium	100	18	50	4/4	35.7-244	2	4	3	Yes
Cobalt	--	220	--	3/4	93.5-202	--	0	--	No
Iron+	--	--	--	4/4	21,600J-398,000J	--	--	--	No
Lead	15 ⁽³⁾	--	50	4/4	19.6-83	4	--	2	Yes
Magnesium+	--	--	--	4/4	8,210J-13,700J	--	--	--	No
Manganese	--	18	--	4/4	288-7,590	--	4	--	Yes
Mercury	2	1.1	2	2/4	0.25-0.25	0	0	0	No
Nickel (soluble salts)	100	73	--	4/4	27.3-117	1	2	--	Yes
Potassium+	--	--	--	2/4	6,750-11,200	--	--	--	No
Sodium+	--	--	--	4/4	3,480-6,130	--	-	--	No

TABLE 6-7 (Continued)

**GROUNDWATER DATA SUMMARY - SITE 21
FREQUENCY AND RANGE OF POSITIVE DETECTIONS
COMPARED TO FEDERAL, REGIONAL, AND COMMONWEALTH CRITERIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant ⁽¹⁾	Groundwater Criteria ⁽²⁾			Frequency/Range ⁽³⁾		Comparison to Criteria			COPC Selection
	Federal MCL (µg/L)	USEPA Region III Tapwater COC Value (µg/L)	Virginia PMCLs (µg/L)	No. of Positive Detects/No. of Samples	Concentration Range (µg/L)	No. of Detects Above MCL	No. of Detects Above COC Value	No. of Detects Above Virginia Criteria	Retained as a COPC?
Inorganics (Total) (Continued):									
Vanadium	--	26	--	4/4	38.1-394	--	4	--	Yes
Zinc	--	1,100	--	4/4	263-30,800	--	2	--	Yes
Inorganics (Dissolved)									
Barium	2,000	260	1,000	2/4	112-147	0	0	0	No
Cadmium	5	1.8	10	2/4	29.4J-99.8	2	2	2	Yes
Calcium+	--	--	--	4/4	19,800-125,000	--	--	--	No
Iron+	--	--	--	1/4	1,960J	--	--	--	No
Magnesium+	--	--	--	4/4	2,820J-8,880J	--	--	--	No
Manganese	--	18	--	4/4	5.4-3,630	--	3	--	Yes
Nickel	100	73	--	1/4	33	0	0	--	No
Sodium+	--	--	--	4/4	4,410-5,620	--	--	--	No
Vanadium	--	26	--	1/4	6.6	--	0	--	No
Zinc	--	1,100	--	4/4	8-2,490,000	--	2	--	Yes

⁽¹⁾ All concentrations reported in µg/L

⁽²⁾ Federal MCL - Federal Safe Drinking Water Act Maximum Contaminant Level (USEPA, 1994a; Drinking Water Regulations and Health Advisories)
Virginia Drinking Water Standards - PMCLs - Primary Maximum Contaminant Levels (Bureau of National Affairs - December, 1994)
COC value - USEPA Region III COC screening value (USEPA, 1993a)

⁽³⁾ The MCL provided for lead is the action level.

-- = No criteria published

+ = Essential Nutrient

J = Value is estimated.

NOTE: The Federal MCL for metals are based on total metals. The VA MCLs for metals are based on dissolved metals.

TABLE 6-8

PHYSICAL AND CHEMICAL PROPERTIES FOR ORGANIC CHEMICALS OF POTENTIAL CONCERN
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Constituents	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log K_{oc}	Log K_{ow}	Specific Gravity (g/cm ³)	Henry's Law Constant (atm-m ³ /mole)	Mobility Index
VOCs:							
1,1-Dichloroethene	$5.0 \times 10^{+02}$	$2.25 \times 10^{+03}$	1.81	2.13	1.218	3.4×10^{-02}	4
1,2-Dichloroethene, cis-	$3.4 \times 10^{+02}$	$6.3 \times 10^{+03}$	1.69	2.06	1.260	3.37×10^{-03}	5
1,2-Dichloroethene, trans-	$2.0 \times 10^{+02}$	$3.5 \times 10^{+03}$	1.77	1.86	--	6.72×10^{-03}	4
Trichloroethene	$5.9 \times 10^{+01}$	$1.07 \times 10^{+03}$	2.10	2.29	1.465	2.0×10^{-02}	3
SVOCs:							
Benzo(a)pyrene	5.5×10^{-09}	3.8×10^{-03}	6.74	6.06	1.351	1.55×10^{-06}	-16
2-Methylnaphthalene	--	--	3.03	3.6	1.0058	--	--
Acenaphthylene	9.1×10^{-4}	$1.6 \times 10^{+1}$	3.40	4.1	0.8988	1.1×10^{-5}	-5
Benzo(a)anthracene	3.1×10^{-8}	9.4×10^{-3}	6.14	5.7	1.274	9.8×10^{-7}	-16
Benzo(b)fluoranthene	5.0×10^{-7}	1.4×10^{-2}	5.74	6.6	--	1.19×10^{-5}	-14
Carbazole	$6.0 \times 10^{+01}$	1.03	--	3.72	1.1	2.07×10^{-03}	--
Dibenz(a,h)anthracene	1.0×10^{-10}	2.5×10^{-6}	6.52	6.5	--	1.2×10^{-4}	-22
Benzo(g,h,i)perylene	1.0×10^{-10}	2.6×10^{-4}	6.20	6.5	--	1.4×10^{-7}	--
Indeno(1,2,3-cd)pyrene	1.0×10^{-10}	5.3×10^{-4}	6.20	6.5	--	6.86×10^{-8}	-20
Phenanthrene	1.1×10^{-4}	$1.2 \times 10^{+00}$	4.46	4.5	1.025	2.3×10^{-5}	-8
Nitroamine Compounds:							
RDX	--	--	--	--	--	--	--
1,3,5-Trinitrobenzene	2.0×10^{-5}	$3.5 \times 10^{+2}$	--	1.2	--	1.6×10^{-8}	--
2,4,6-Trinitrotoluene	2.0×10^{-4}	$1.3 \times 10^{+2}$	--	1.6	--	4.6×10^{-7}	--
Nitrobenzene	2.5×10^{-1}	$2.1 \times 10^{+3}$	1.56	1.85	--	1.9×10^{-5}	1
Pesticides:							
Endrin Ketone	--	--	--	--	--	--	--
4,4'-DDE	6.0×10^{-6}	1.2×10^{-1}	6.64	5.7	--	2.1×10^{-5}	-13
Dieldrin	5.9×10^{-6}	2.0×10^{-1}	5.25	4.6	--	1.5×10^{-5}	-11

TABLE 6-8 (Continued)

PHYSICAL AND CHEMICAL PROPERTIES OF CHEMICALS OF POTENTIAL CONCERN
 CTO-297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Constituents	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log K_{oc}	Log K_{ow}	Specific Gravity (g/cm ³)	Henry's Law Constant (atm-m ³ /mole)	Mobility Index
PCBs:							
Aroclor 1254	7.7×10^{-05}	0.03	5.72	5.6	1.50	2.8×10^{-03}	-11
Aroclor 1260	4.1×10^{-05}	0.003	5.72	5.6	1.58	7.1×10^{-03}	-13

Notes: -- = Value not available.

TABLE 6-9

RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh, pH)

CTO-0297

NAVAL WEAPONS STATION YORKTOWN,
YORKTOWN, VIRGINIA

Relative Mobility	Environmental Conditions			
	Oxidizing	Acidic	Neutral/Alkaline	Reducing
Very High			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg, Ag		
Medium	Cu, Ni, Hg, Ag, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Se	Pb, Ba, Be	Pb, Ba, Be	
Very Low	Fe, Cr	Cr	Cr, Zn, Cu, Ni, Hg, Ag	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Ag

Notes:

As = Arsenic
Ag = Silver
Ba = Barium
Be = Beryllium
Cd = Cadmium
Cr = Chromium
Cu = Copper

Fe = Iron
Hg = Mercury
Ni = Nickel
Pb = Lead
Se = Selenium
Zn = Zinc

Source: Swartzbaugh, et al. "Remediating Sites Contaminated with Heavy Metals." Hazardous Materials Control, November/December 1992.

TABLE 6-10

EXPOSURE INPUT PARAMETERS FOR CURRENT ADULT ON-SITE CIVILIAN WORKERS
POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL, SURFACE WATER, AND SEDIMENT
VIA INGESTION, DERMAL CONTACT, AND INHALATION OF FUGITIVE DUST

CTO-0297

NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Input Parameter	Media	Units	Current Receptor	Comments/References
			Adult Civilian	
ED, Exposure Duration	All Media	years	25	USEPA, 1991a
IR, Ingestion Rate	Soil/Sediment	mg/day	100	USEPA, 1991a
	Surface Water	L/hr	0.05	USEPA, 1989b
EF, Exposure Frequency	All Media	days/yr	90	Professional Judgement
AF, Adherence Factor	Soil/Sediment	mg/cm ²	1.0	USEPA, 1991a and 1992a
ABS, Dermal Absorption Factor for Organics/Inorganics	Soil/Sediment	unitless	Chemical-specific ⁽¹⁾	USEPA, 1992a and 1992b Ryan, et al., 1987 Webster, et al., 1993
ET, Exposure Time	All Media	hrs/day	8	USEPA, 1991a
SA, Surface Area	All Media	cm ² /day	5,300 ⁽²⁾	USEPA, 1992a
PC, Permeability Constant	Surface Water	cm/hr	Chemical-Specific	USEPA, 1992a
FI, Fraction Ingested	Soil	unitless	0.5	USEPA, 1989b
AT, Averaging Time				
AT _{nc} , noncarcinogens	All Media	days	9125	USEPA, 1989b
AT _c , carcinogens	All Media	days	25550	USEPA, 1989b
BW, Body Weight	All Media	kg	70	USEPA, 1989b
IR, Inhalation Rate	Air (fugitive dust)	m ³ /hr	0.83	USEPA, 1991a
		m ³ /day	20	

Notes:

- ⁽¹⁾ The following absorbance factors will be applied to estimate dermal intake of COPCs:
 Experimentally Derived (USEPA, 1992a):
 PCBs - 0.06
 Cadmium - 0.01
 Organics - 0.10
 Inorganics - 0.01
 Arsenic - 0.03
 Other Values (Ryan, et al., 1987 and Webster, et al., 1993):

- ⁽²⁾ Skin surface area available for contact assuming an adult wears a short-sleeved shirt, short pants, and shoes.

References:

Ryan, et al., 1987. Assessing Risk from Dermal Exposure at Hazardous Waste Sites.
 USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.
 USEPA, 1991a. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors." Interim Final.
 USEPA, 1989a. Exposure Factors Handbook.
 USEPA, 1989b. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual (Part A) Interim Final.
 Webster, et al., 1993. InVivo and InVivo Percutaneous Absorption and Skin Decontamination of Arsenic from Water and Soil.

TABLE 6-11

**EXPOSURE INPUT PARAMETERS FOR FUTURE RESIDENT CHILDREN AND ADULTS
POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL,
GROUNDWATER, SURFACE WATER, AND SEDIMENT
VIA INGESTION, DERMAL CONTACT, AND INHALATION
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Input Parameter	Media	Units	Future Receptor		Comments/References
			Child (1 to 6 years)	Adult	
ED, Exposure Duration	All media	years	6	24	USEPA, 1991a
EF, Exposure Frequency	Groundwater	days/year	350	350	USEPA, 1991a
	Soil	days/year	350	350	USEPA, 1991a
	Sediment/ Surface Water	days/year	40	40	Professional Judgment (5mon., 2day/week)
ET, Exposure Time	Sediment/ Surface Water	hrs/day	2.6	2.6	USEPA, 1989b
	Groundwater	hrs/day	0.2	0.2	USEPA, 1989a
IR, Ingestion Rate	Groundwater	L/day	1	2	USEPA, 1991a
	Soil/Sediment	mg/day	200	100	USEPA, 1989b
	Surface Water	L/hr	0.05	0.05	USEPA, 1989b
SA, Surface Area	Groundwater	cm ²	8,023	20,000	USEPA, 1992a
	Surface Water /Sediment	cm ³	2,700 ⁽⁴⁾	6,420 ⁽⁴⁾	USEPA, 1989a and 1992a
	Soil	cm ²	2,115 ⁽¹⁾	5,300 ⁽²⁾	USEPA, 1989a and 1992a
FI, Fraction Ingested	Soil/Sediment	unitless	1	1	USEPA, 1989b
ABS, Absorbance Factor Organics/Inorganics	Soil/Sediment	unitless	Chemical Specific ⁽³⁾	Chemical Specific ⁽³⁾	USEPA, 1992a and 1992b Ryan, et al., 1987 Webster, et al., 1993
AF, Adherence Factor	Soil/Sediment	mg/cm ²	1	1	USEPA, 1992a
AT, Averaging Time AT _{nc} , noncarcinogens	All Media	day	2,190	8,760	USEPA, 1989b and 1991a
AT _c , carcinogens	All Media	day	25,550	25,550	USEPA, 1989b
BW, Body Weight	All Media	kg	15	70	USEPA, 1989b
PC, Permeability Constant	Groundwater/ Surface Water	cm/hr	Chemical- Specific	Chemical- Specific	USEPA, 1992a
IR, Inhalation Rate	Air	m ³ /hr	0.83	0.83	USEPA, 1991a
		m ³ /day	20	20	

TABLE 6-11 (Continued)

**EXPOSURE INPUT PARAMETERS FOR FUTURE RESIDENT CHILDREN AND ADULTS
POTENTIALLY EXPOSED TO COPCs IN SURFACE SOIL,
GROUNDWATER, SURFACE WATER, AND SEDIMENT
VIA INGESTION, DERMAL CONTACT, AND INHALATION
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

- Notes: (1) Average skin surface area for a male/female child (95th percentile), 1-6 years, wearing a short-sleeved shirt, short pants, and shoes.
- (2) Skin surface area available for contact assuming an adult wears a short-sleeved shirt, short pants, and shoes
- (3) The following absorbance factors will be applied to estimate dermal intake of COPCs:
- | | |
|---|-------------------|
| Experimentally Derived (USEPA, 1992a): | PCBs - 0.06 |
| | Cadmium - 0.01 |
| Other Values (Ryan, et al., 1987
and Webster, et al., 1993): | Organics - 0.10 |
| | Inorganics - 0.01 |
| | Arsenic - 0.03 |
- (4) Average skin surface area for adult or child, wearing short-sleeved shirt and short pants

References:

- Ryan, et al., 1987. Assessing Risk from Dermal Exposure at Hazardous Waste Sites.
- USEPA, 1992b. Interim Region IV Guidance.
- USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.
- USEPA, 1991a. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors." Interim Final.
- USEPA, 1989b. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual (Part A) Interim Final.
- USEPA, 1989a. Exposure Factors Handbook.
- Webster, et al., 1993. InVivo and InVitro Percutaneous Absorption and Skin Decontamination of Arsenic from Water and Soil.

TABLE 6-12

**EXPOSURE INPUT PARAMETERS FOR FUTURE ADULT CONSTRUCTION WORKERS
POTENTIALLY EXPOSED TO COPCs IN SURFACE AND SUBSURFACE SOIL
VIA INGESTION, DERMAL CONTACT, AND INHALATION
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Input Parameter	Units	Future Receptor	Comments/Reference
		Adult Construction Worker	
IR, Ingestion Rate	mg/day	480	USEPA, 1991a
EF, Exposure Frequency	days/year	250	USEPA, 1991a
AF, Adherence Factor	mg/cm ²	1	USEPA, 1991a and 1992a
ABS, Dermal Absorption Factor Organics/Inorganics	unitless	Chemical- specific ⁽¹⁾	USEPA, 1992a Ryan, et al., 1987 Webster, et al., 1993
ET, Exposure Time	hrs/day	8	USEPA, 1991a
IR, Inhalation Rate	m ³ /hr m ³ /day	0.83 20	USEPA, 1991a
SA, Exposed Surface Area	cm ² /day	4,300 ⁽²⁾	USEPA, 1992a
ED, Exposure Duration	years	1	USEPA, 1991a
FI, Fraction Ingested	unitless	1	USEPA, 1989b
BW, Body Weight	kg	70	USEPA, 1989b
AT, Averaging Times			
AT _{nc} , noncarcinogens	days	365	USEPA, 1989b
AT _c , carcinogens	days	25,550	USEPA, 1989b

Notes:

⁽¹⁾ The following absorbance factors will be applied to estimate dermal intake of COPCs:

Experimentally Derived (USEPA, 1992a): PCBs - 0.06
Cadmium - 0.01
Other Values (Ryan, et al., 1987:
and Webster, et al., 1993): Organics - 0.10
Inorganics - 0.01
Arsenic - 0.03

⁽²⁾ Skin surface area available for contact for an individual wearing a sleeveless shirt, long pants, and shoes.

NA - Not Applicable

References:

Ryan, et al., 1987. Assessing Risk from Dermal Exposure at Hazardous Waste Sites.

USEPA, 1992a. Dermal Exposure Assessment: Principles and Applications - Interim Report.

USEPA, 1991a. Risk Assessment Guidance for Superfund. Volume I - Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors." Interim Final.

USEPA, 1989a. Exposure Factors Handbook.

USEPA, 1989b. Risk Assessment Guidance for Superfund. Volume I - Human Health Evaluation Manual (Part A). Interim Final.

Webster, et al., 1993. In Vivo and In Vitro Percutaneous Absorption and Skin Decontamination of Arsenic from Water and Soil.

TABLE 6-13

**HUMAN HEALTH RISK ASSESSMENT TOXICITY FACTORS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Constituents	Oral CSF (mg/kg/day) ⁻¹	Inhal. CSFi (mg/kg/day) ⁻¹	Oral RfD (mg/kg/day)	Inhal. RfDi (mg/kg/day)	Dermal Absorption Values	WOE
VOCs:						
1,2-Dichloroethene	--	--	9.0 x 10 ⁻³ (i)	--	100%	D
1,1-Dichloroethene	6.0 x 10 ⁻¹ (i)	1.75 x 10 ⁻¹ (i)	9.0 x 10 ⁻³ (i)	--	100%	C
Trichloroethene	1.1 x 10 ⁻² (w)	6.0 x 10 ⁻³ (e)	6.0 x 10 ⁻³ (e)	--	100%	B2
SVOCs:						
Benzo(a)pyrene	7.3 (i)	6.1 (h)	--	--	50%	B2
2-Methylnaphthalene	--	--	--	--	50%	--
Acenaphthylene	--	--	3.0 x 10 ⁻²⁽¹⁾	--	50%	D
Benzo(a)anthracene	7.3 x 10 ⁻¹ (e)	6.1 x 10 ⁻¹ (e)	--	--	50%	B2
Benzo(b)fluoranthene	7.3 x 10 ⁻¹ (e)	6.1 x 10 ⁻¹ (e)	--	--	50%	B2
Benzo(g,h,i)perylene	--	--	3.0 x 10 ⁻²⁽¹⁾	--	50%	B2
Carbazole	2.0 x 10 ⁻² (h)	--	--	--	50%	--
Dibenz(a,h)anthracene	7.3 (e)	6.1 (e)	--	--	50%	B2
Indeno(1,2,3-cd)pyrene	7.3 x 10 ⁻¹ (e)	6.1 x 10 ⁻¹ (e)	--	--	50%	B2
Phenanthrene	--	--	3.0 x 10 ⁻²⁽¹⁾	--	50%	D
Pesticides and PCBs:						
4,4'-DDE	3.4 x 10 ⁻¹ (i)	--	--	--	50%	B2
Dieldrin	1.6 x 10 ⁺¹ (i)	1.61 x 10 ⁺¹ (i)	5.0 x 10 ⁻⁵ (i)	--	50%	B2
Endrin Ketone	--	--	--	--	50%	--
Aroclor-1254	--	--	2.0 x 10 ⁻⁵ (i)	--	100%	B2
Aroclor-1260 ⁽²⁾	7.7 (i)	--	--	--	100%	B2

TABLE 6-13 (Continued)

HUMAN HEALTH RISK ASSESSMENT TOXICITY FACTORS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Constituents	Oral CSF (mg/kg/day) ⁻¹	Inhal. CSFi (mg/kg/day) ⁻¹	Oral RfD (mg/kg/day)	Inhal. RfDi (mg/kg/day)	Dermal Absorption Values	WOE
Nitramine Compounds:						
1,3,5-Trinitrobenzene	--	--	5.0 x 10 ⁻⁵ (i)	--	50%	D
2,4,6-Trinitrotoluene	3.0 x 10 ⁻² (i)	--	5.0 x 10 ⁻⁴ (i)	--	74%	C
Nitrobenzene	--	--	5.0 x 10 ⁻⁴ (i)	5.71 x 10 ⁻⁴ (a)	50%	--
RDX	1.10 x 10 ⁻¹ (i)	--	3.0 x 10 ⁻³ (i)	--	100%	C
Inorganics:						
Aluminum	--	--	1.00 (e)	--	20%	--
Antimony	--	--	4.0 x 10 ⁻⁴ (i)	--	20%	D
Arsenic	1.75 (i)	15.1 (i)	3.0 x 10 ⁻⁴ (i)	--	95%	A
Barium	--	--	7.0 x 10 ⁻² (i)	1.43 x 10 ⁻⁴ (a)	100%	D
Beryllium	4.30 (i)	8.40 (i)	5.0 x 10 ⁻³ (i)	--	--	B2
Cadmium (water)	--	6.30 (i)	5.0 x 10 ⁻⁴ (i)	--	66% ⁽³⁾	B1
Cadmium (food)	--	6.30 (i)	1.0 x 10 ⁻² (i)	--	66% ⁽³⁾	B1
Chromium	--	42.0 (i)	5.0 x 10 ⁻³ (i)	--	--	A
Copper	--	--	3.71 x 10 ⁻² (h)	--	60%	D
Lead	--	--	--	--	--	B2
Manganese (water)	--	--	5.0 x 10 ⁻³ (i)	1.43 x 10 ⁻⁵ (i)	5%	D
Manganese (food)	--	--	1.4 x 10 ⁻¹ (i)	1.43 x 10 ⁻⁵ (i)	5%	D
Mercury	--	--	3.0 x 10 ⁻⁴ (h)	8.57 x 10 ⁻⁵ (h)	15%	D
Nickel	--	--	2.0 x 10 ⁻² (i)	--	4.3%	D
Vanadium	--	--	7.0 x 10 ⁻³ (h)	--	20%	D
Zinc	--	--	3.0 x 10 ⁻¹ (i)	--	25%	D

TABLE 6-13 (Continued)

HUMAN HEALTH RISK ASSESSMENT TOXICITY FACTORS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Notes:

- (1) Value is for pyrene.
- (2) Toxicity factor for polychlorinated biphenyls.
- (3) Derived considering the percent difference between oral absorption (12%) and dermal absorption (4%) (Cassarett and Doull's, 1980).
- i = Integrated Risk Information System (IRIS), 1995
- e = Environmental Criteria and Assessment Office (ECAO) (as cited from 1st quarter 1995 USEPA, Region III RBC Tables)
- h = Health Effects Assessment Summary Tables (HEAST), 1994
- a = HEAST Alternative Method, 1994
- s = HEAST Summary Tables FY 1994 Supplement No. 1
- W = Withdrawn from IRIS or HEAST
- NA = Not Available
- = Information not published.

TABLE 6-14

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR CURRENT ADULT CIVILIAN WORKERS - SITE 4
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptors	
	Civilian Worker	
	ICR	HI
<u>Surface Soil</u>		
Ingestion	6.5 x 10 ⁻⁰⁶	2.9 x 10 ⁻⁰²
Dermal Contact	7.0 x 10 ⁻⁰⁵	1.7 x 10 ⁻⁰¹
Inhalation ⁽¹⁾	3.0 x 10 ⁻⁰⁹	1.2 x 10 ⁻⁰³
Subtotal	7.7 x 10 ⁻⁰⁵	2.0 x 10 ⁻⁰¹
<u>Surface Water</u>		
Ingestion	3.8 x 10 ⁻⁰⁵ (1.1 x 10 ⁻⁰⁵)	6.6 x 10 ⁻⁰¹ (4.4 x 10 ⁻⁰¹)
Dermal Contact	4.6 x 10 ⁻⁰⁶ (1.7 x 10 ⁻⁰⁶)	6.8 x 10 ⁻⁰¹ (4.0 x 10 ⁻⁰¹)
Subtotal	4.3 x 10 ⁻⁰⁵ (1.4 x 10 ⁻⁰⁵)	1.3 x 10 ⁺⁰⁰ (8.4 x 10 ⁻⁰¹)
<u>Sediment</u>		
Ingestion	1.7 x 10 ⁻⁰⁶	3.5 x 10 ⁻⁰²
Dermal Contact	2.4 x 10 ⁻⁰⁶	9.2 x 10 ⁻⁰²
Subtotal	4.1 x 10 ⁻⁰⁶	1.3 x 10 ⁻⁰¹
TOTAL	1.2 x 10 ⁻⁰⁴ (9.5 x 10 ⁻⁰⁵)	1.6 x 10 ⁺⁰⁰ (1.2 x 10 ⁺⁰⁰)

Notes:⁽¹⁾ Fugitive dusts

() = Risk value derived using dissolved (filtered) inorganic concentrations.

TABLE 6-15

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR CURRENT ADULT CIVILIAN WORKERS - SITE 21
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptors	
	Civilian Worker	
	ICR	HI
<u>Surface Soil</u>		
Ingestion	4.5×10^{-07}	5.5×10^{-03}
Dermal Contact	3.1×10^{-06}	3.3×10^{-02}
Inhalation ⁽¹⁾	5.6×10^{-10}	3.4×10^{-04}
Subtotal	3.6×10^{-06}	3.9×10^{-02}
<u>Surface Water</u>		
Ingestion	3.8×10^{-05} (1.1×10^{-05})	6.6×10^{-01} (4.4×10^{-01})
Dermal Contact	4.6×10^{-06} (1.7×10^{-06})	6.8×10^{-01} (4.0×10^{-01})
Subtotal	4.3×10^{-05} (1.5×10^{-05})	$1.3 \times 10^{+00}$ (8.4×10^{-01})
<u>Sediment</u>		
Ingestion	1.7×10^{-06}	3.5×10^{-02}
Dermal Contact	2.4×10^{-06}	9.2×10^{-02}
Subtotal	4.1×10^{-06}	1.3×10^{-01}
TOTAL	5.1×10^{-05} (2.3×10^{-05})	$1.5 \times 10^{+00}$ ($1.0 \times 10^{+00}$)

Notes: ⁽¹⁾ Fugitive dusts

() = Risk value derived using dissolved (filtered) inorganic concentrations.

Surface water and sediment ICR and HI values from Site 4.

TABLE 6-16

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS - SITE 4
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptors			
	Adults (30 yrs.)		Children (1-6 yrs.)	
	ICR	HI	ICR	HI
Surface Soil				
Ingestion	1.6×10^{-04}	$2.3 \times 10^{+00}$	1.1×10^{-04}	$2.1 \times 10^{+00}$
Dermal Contact	3.8×10^{-04}	$1.9 \times 10^{+00}$	1.2×10^{-04}	$1.2 \times 10^{+00}$
Fugitive Dust	2.4×10^{-08}	2.8×10^{-02}	1.3×10^{-08}	2.3×10^{-02}
Subtotal	5.4×10^{-04}	$4.2 \times 10^{+00}$	2.3×10^{-04}	$3.3 \times 10^{+00}$
Groundwater (GW03)				
Ingestion	1.1×10^{-03} (1.4×10^{-05})	$5.7 \times 10^{+01}$ (1.6×10^{-01})	3.9×10^{-04} (5.3×10^{-06})	$4.0 \times 10^{+01}$ (1.1×10^{-01})
Dermal Contact	1.9×10^{-06} (4.0×10^{-08})	$1.5 \times 10^{+00}$ (1.5×10^{-03})	6.3×10^{-07} (1.3×10^{-08})	9.9×10^{-01} (1.0×10^{-03})
Inhalation	1.0×10^{-09}	NA	1.8×10^{-10}	NA
Subtotal	1.1×10^{-03} (1.4×10^{-05})	$5.9 \times 10^{+01}$ (1.6×10^{-01})	3.9×10^{-04} (5.3×10^{-06})	$4.1 \times 10^{+01}$ (1.1×10^{-01})
Groundwater (GW05)				
Ingestion	1.4×10^{-03} (4.6×10^{-06})	$7.3 \times 10^{+01}$ ($1.6 \times 10^{+01}$)	5.2×10^{-04} (1.7×10^{-06})	$5.1 \times 10^{+01}$ ($1.1 \times 10^{+01}$)
Dermal Contact	2.6×10^{-06} (1.2×10^{-08})	$2.1 \times 10^{+00}$ (2.0×10^{-01})	8.4×10^{-07} (4.1×10^{-09})	$1.4 \times 10^{+00}$ (1.6×10^{-01})
Inhalation	4.1×10^{-10}	NA	8.2×10^{-11}	NA
Subtotal	1.4×10^{-03} (4.6×10^{-06})	$7.5 \times 10^{+01}$ ($1.6 \times 10^{+01}$)	5.2×10^{-04} (1.7×10^{-06})	$5.2 \times 10^{+01}$ ($1.1 \times 10^{+01}$)

TABLE 6-16 (Continued)

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS - SITE 4
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptors			
	Adults (30 yrs.)		Children (1-6 yrs.)	
	ICR	HI	ICR	HI
<u>Surface Water</u>				
Ingestion	1.1 x 10 ⁻⁰⁵ (3.4 x 10 ⁻⁰⁶)	5.5 x 10 ⁻⁰¹ (3.6 x 10 ⁻⁰¹)	6.1 x 10 ⁻⁰⁶ (1.8 x 10 ⁻⁰⁶)	4.5 x 10 ⁻⁰¹ (3.0 x 10 ⁻⁰¹)
Dermal Contact	1.2 x 10 ⁻⁰⁶ (4.2 x 10 ⁻⁰⁷)	3.5 x 10 ⁻⁰¹ (2.1 x 10 ⁻⁰¹)	3.8 x 10 ⁻⁰⁷ (1.4 x 10 ⁻⁰⁷)	2.3 x 10 ⁻⁰¹ (1.4 x 10 ⁻⁰¹)
Subtotal	1.2 x 10 ⁻⁰⁵ (3.8 x 10 ⁻⁰⁶)	9.0 x 10 ⁻⁰¹ (5.7 x 10 ⁻⁰¹)	6.5 x 10 ⁻⁰⁶ (1.9 x 10 ⁻⁰⁶)	6.8 x 10 ⁻⁰¹ (4.4 x 10 ⁻⁰¹)
<u>Sediment</u>				
Ingestion	2.4 x 10 ⁻⁰⁶	1.7 x 10 ⁻⁰¹	1.7 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰¹
Dermal Contact	1.8 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰¹	6.1 x 10 ⁻⁰⁷	9.7 x 10 ⁻⁰²
Subtotal	4.2 x 10 ⁻⁰⁶	3.2 x 10 ⁻⁰¹	2.3 x 10 ⁻⁰⁶	2.5 x 10 ⁻⁰¹
TOTAL (GW03)	1.7 x 10 ⁻⁰³ (5.6 x 10 ⁻⁰⁴)	6.4 x 10 ⁺⁰¹ (5.3 x 10 ⁺⁰⁰)	6.3 x 10 ⁻⁰⁴ (2.4 x 10 ⁻⁰⁴)	4.5 x 10 ⁺⁰¹ (4.1 x 10 ⁺⁰⁰)
(GW05)	2.0 x 10 ⁻⁰³ (5.5 x 10 ⁻⁰⁴)	8.0 x 10 ⁺⁰¹ (2.1 x 10 ⁺⁰¹)	7.6 x 10 ⁻⁰⁴ (2.4 x 10 ⁻⁰⁴)	5.6 x 10 ⁺⁰¹ (1.5 x 10 ⁺⁰¹)

Notes:

(1) Fugitive dusts

() = Risk value derived using dissolved (filtered) inorganic concentrations.

NA = Not Applicable

TABLE 6-17

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS - SITE 21
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptors			
	Adults (30 yrs.)		Children (1-6 yrs.)	
	ICR	HI	ICR	HI
Surface Soil				
Ingestion	1.1×10^{-05}	4.4×10^{-01}	7.8×10^{-06}	4.0×10^{-01}
Dermal Contact	1.6×10^{-05}	3.7×10^{-01}	5.3×10^{-06}	2.4×10^{-01}
Fugitive Dust	4.0×10^{-09}	7.5×10^{-03}	2.4×10^{-09}	6.2×10^{-03}
Subtotal	2.7×10^{-05}	8.2×10^{-01}	1.3×10^{-05}	6.5×10^{-01}
Groundwater (GW01)				
Ingestion	1.2×10^{-03} (NA)	$7.4 \times 10^{+01}$ (1.0×10^{-01})	4.5×10^{-04} (NA)	$5.2 \times 10^{+01}$ (7.1×10^{-02})
Dermal Contact	2.3×10^{-06} (NA)	$2.0 \times 10^{+00}$ (3.4×10^{-03})	7.3×10^{-07} (NA)	$1.3 \times 10^{+00}$ (2.2×10^{-03})
Inhalation	NA	NA	NA	NA
Subtotal	1.2×10^{-03} (NA)	$7.6 \times 10^{+01}$ (1.0×10^{-01})	4.5×10^{-04} (NA)	$5.3 \times 10^{+01}$ (7.3×10^{-02})
Groundwater (GW03)				
Ingestion	6.8×10^{-04} (NA)	$1.4 \times 10^{+02}$ ($8.4 \times 10^{+02}$)	2.5×10^{-04} (NA)	$9.7 \times 10^{+01}$ ($5.9 \times 10^{+02}$)
Dermal Contact	1.3×10^{-06} (NA)	$3.2 \times 10^{+00}$ ($7.5 \times 10^{+00}$)	4.1×10^{-07} (NA)	$2.1 \times 10^{+00}$ ($4.9 \times 10^{+00}$)
Inhalation	NA	NA	NA	NA
Subtotal	6.8×10^{-04} (NA)	$1.4 \times 10^{+02}$ ($8.5 \times 10^{+02}$)	2.5×10^{-04} (NA)	$9.9 \times 10^{+01}$ ($5.9 \times 10^{+02}$)

TABLE 6-17 (Continued)

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR FUTURE ADULT AND CHILD ON-SITE RESIDENTS - SITE 21
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptors			
	Adults (30 yrs.)		Children (1-6 yrs.)	
	ICR	HI	ICR	HI
Surface Water				
Ingestion	1.1 x 10 ⁻⁰⁵ (3.4 x 10 ⁻⁰⁶)	5.5 x 10 ⁻⁰¹ (3.6 x 10 ⁻⁰¹)	6.1 x 10 ⁻⁰⁶ (1.8 x 10 ⁻⁰⁶)	4.5 x 10 ⁻⁰¹ (3.0 x 10 ⁻⁰¹)
Dermal Contact	1.2 x 10 ⁻⁰⁶ (4.2 x 10 ⁻⁰⁷)	3.5 x 10 ⁻⁰¹ (2.1 x 10 ⁻⁰¹)	3.8 x 10 ⁻⁰⁷ (1.4 x 10 ⁻⁰⁷)	2.3 x 10 ⁻⁰¹ (1.4 x 10 ⁻⁰¹)
Subtotal	1.2 x 10 ⁻⁰⁵ (3.8 x 10 ⁻⁰⁶)	9.0 x 10 ⁻⁰¹ (5.7 x 10 ⁻⁰¹)	6.5 x 10 ⁻⁰⁶ (1.9 x 10 ⁻⁰⁶)	6.8 x 10 ⁻⁰¹ (4.4 x 10 ⁻⁰¹)
Sediment				
Ingestion	2.4 x 10 ⁻⁰⁶	1.7 x 10 ⁻⁰¹	1.7 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰¹
Dermal Contact	1.8 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰¹	6.1 x 10 ⁻⁰⁷	9.7 x 10 ⁻⁰²
Subtotal	4.2 x 10 ⁻⁰⁶	3.2 x 10 ⁻⁰¹	2.3 x 10 ⁻⁰⁶	2.5 x 10 ⁻⁰¹
TOTAL (GW01)	1.2 x 10 ⁻⁰³ (3.5 x 10 ⁻⁰⁵)	7.8 x 10 ⁺⁰¹ (1.8 x 10 ⁺⁰⁰)	4.7 x 10 ⁻⁰⁴ (1.7 x 10 ⁻⁰⁵)	5.5 x 10 ⁺⁰¹ (1.4 x 10 ⁺⁰⁰)
(GW03)	7.1 x 10 ⁻⁰⁴ (3.5 x 10 ⁻⁰⁵)	1.4 x 10 ⁺⁰² (8.5 x 10 ⁺⁰²)	2.7 x 10 ⁻⁰⁴ (1.7 x 10 ⁻⁰⁵)	1.0 x 10 ⁺⁰² (5.9 x 10 ⁺⁰²)

Notes:

(1) Fugitive dusts

() = Risk value derived using dissolved (filtered) inorganic concentrations.

NA = Not Applicable

Surface water and sediment ICR and HI values from Site 4.

TABLE 6-18

**INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
FOR FUTURE CONSTRUCTION WORKERS - SITE 4
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Pathway	Receptor	
	Construction Workers	
	ICR	HI
<u>Surface Soil</u>		
Ingestion	7.0×10^{-06}	7.8×10^{-01}
Dermal Contact	6.3×10^{-06}	3.8×10^{-01}
Inhalation ⁽¹⁾	3.3×10^{-10}	3.5×10^{-03}
TOTAL	1.3×10^{-05}	1.2×10^{-01}

Notes: ⁽¹⁾ Fugitive dust from outdoor work activities

TABLE 6-19

INCREMENTAL LIFETIME CANCER RISKS (ICRs) AND HAZARD INDICES (HIs)
 FOR FUTURE CONSTRUCTION WORKERS - SITE 21
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Pathway	Receptor	
	Construction Workers	
	ICR	HI
<u>Surface Soil</u>		
Ingestion	4.8×10^{-07}	1.5×10^{-01}
Dermal Contact	2.8×10^{-07}	7.4×10^{-02}
Inhalation ⁽¹⁾	6.2×10^{-11}	9.5×10^{-04}
Subtotal	7.6×10^{-07}	2.2×10^{-01}
<u>Subsurface Soil</u>		
Ingestion	6.8×10^{-07}	8.7×10^{-02}
Dermal Contact	1.8×10^{-07}	3.4×10^{-02}
Inhalation ⁽¹⁾	4.8×10^{-11}	5.8×10^{-04}
Subtotal	8.6×10^{-07}	1.2×10^{-01}
TOTAL	1.6×10^{-06}	3.4×10^{-01}

Notes: ⁽¹⁾ Fugitive dust from outdoor work activities

TABLE 6-20

**SUMMARY OF UNCERTAINTIES IN THE RESULTS OF THE
HUMAN HEALTH RISK ASSESSMENT
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

	Potential Magnitude for Over-Estimation of Risks	Potential Magnitude for Under-Estimation of Risks	Potential Magnitude for Over or Under-Estimation of Risks
<u>Environmental Sampling and Analysis</u>			
Sufficient samples may not have been taken to characterize the media being evaluated.			High
Systematic or random errors in the chemical analysis may yield erroneous data.			Low
<u>Selection of COPCs</u>			
The use of USEPA Region III COPC screening concentrations in selecting COPCs in soil and groundwater.			Low
The use of SSVs and USEPA Region III residential COPC screening concentrations in selecting COPCs in sediment for human health evaluation.	Moderate		
<u>Exposure Assessment</u>			
The standard assumptions regarding body weight, exposure period, life expectancy, population characteristics, and lifestyle may not be representative of the actual exposure situations.			Moderate
The use of the normal 95% UCL data in the estimation of the soil, surface water and sediment exposure point concentrations.	Low		
Using the maximum concentration in point-source groundwater monitoring wells in the estimation of the exposure point concentration.	Moderate		
Using one-half of the detection limit or the CRQL as a surrogate concentration in the derivation of the 95% UCL.			Moderate
Assessing future residential property use when the likelihood of residential development is low.	High		
The use of total inorganic results for groundwater to evaluate potential chronic daily intakes associated with potable use.	Moderate		
The amount of media intake is assumed to be constant and representative of any actual exposure.			Low
Compound not evaluated in groundwater wells.		Low	

TABLE 6-20 (Continued)

SUMMARY OF UNCERTAINTIES IN THE RESULTS OF THE
HUMAN HEALTH RISK ASSESSMENT - SITE 21
CTO-297

NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

	Potential Magnitude for Over-Estimation of Risks	Potential Magnitude for Under-Estimation of Risks	Potential Magnitude for Over or Under-Estimation of Risks
Toxicological Assessment			
Toxicological indices derived from high dose animal studies, extrapolated to low dose human exposure.	Moderate		
Lack of promulgated toxicological indices for the inhalation pathway.		Low	
Risk Characterization			
Assumption of additivity in the quantitation of cancer risks without consideration of synergism, antagonism, promotion and initiation.			Moderate
Assumption of additivity in the estimation of systemic health effects without consideration of synergism, antagonism, etc.			Moderate
Additivity of risks by individual exposure pathways (dermal, ingestion and inhalation)			Low
Compounds not quantitatively evaluated.		Low	

Notes:

Low - Assumptions categorized as "low" may effect risk estimates by less than one order of magnitude.

Moderate - Assumptions categorized as "moderate" may effect estimates of risk by between one and two orders of magnitude.

High - Assumptions categorized as "high" may effect estimates of risk by more than two orders of magnitude.

Source: Risk Assessment Guidance for Superfund, Volume 1, Part A: Human Health Evaluation Manual. USEPA, 1989b.

TABLE 6-21

**TOTAL SITE LIFETIME INCREMENTAL CANCER RISK (ICR)
AND HAZARD INDEX (HI) VALUES FOR CURRENT POTENTIAL
HUMAN RECEPTORS - SITE 4**

CTO-0297

NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Receptors	Total ICR	Total HI
On-site Adult Civilian Workers ⁽¹⁾	1.2 x 10 ⁻⁰⁴ (9.5 x 10 ⁻⁰⁵)	1.6 x 10 ⁺⁰⁰ (1.2 x 10 ⁺⁰⁰)

Notes:

- ⁽¹⁾ On-site adult civilian workers could potentially be exposed to COPCs by accidental ingestion and dermal contact of surface soils, surface water and sediments, as well as inhalation of fugitive dusts from surface soil during clearing/cutting activities. Values presented in parenthesis included Total ICR and HI values using dissolved surface water concentrations.

TABLE 6-22

**TOTAL SITE LIFETIME INCREMENTAL CANCER RISK (ICR) AND
HAZARD INDEX (HI) VALUES FOR CURRENT POTENTIAL HUMAN
RECEPTORS - SITE 21
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Receptors	Total ICR	Total HI
On-site Adult Civilian Workers ⁽¹⁾	5.1 x 10 ⁻⁰⁵ (2.3 x 10 ⁻⁰⁵)	1.5 x 10 ⁺⁰⁰ (1.0 x 10 ⁺⁰⁰)

Notes:

- ⁽¹⁾ On-site adult civilian workers could potentially be exposed to COPCs by accidental ingestion and dermal contact of surface soils, surface water and sediments, as well as inhalation of fugitive dusts from surface soil during clearing/cutting activities. Values presented in parenthesis included Total ICR and HI values using dissolved surface water concentrations.

TABLE 6-23

TOTAL SITE LIFETIME INCREMENTAL CANCER RISK (ICR) AND
HAZARD INDEX (HI) VALUES FOR FUTURE POTENTIAL HUMAN RECEPTORS - SITE 4
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Future Receptors	Total ICR	Total HI
Resident Adults ⁽¹⁾⁽²⁾		
(GW03)	1.7 x 10 ⁻⁰³ (5.6 x 10 ⁻⁰⁴)	6.4 x 10 ⁺⁰¹ (5.3 x 10 ⁺⁰⁰)
(GW05)	2.0 x 10 ⁻⁰³ (5.5 x 10 ⁻⁰⁴)	8.0 x 10 ⁺⁰¹ (2.1 x 10 ⁺⁰¹)
Resident Children ⁽³⁾		
(GW03)	6.3 x 10 ⁻⁰⁴ (2.4 x 10 ⁻⁰⁴)	4.5 x 10 ⁺⁰¹ (4.1 x 10 ⁺⁰⁰)
(GW05)	7.6 x 10 ⁻⁰⁴ (2.4 x 10 ⁻⁰⁴)	5.6 x 10 ⁺⁰¹ (1.5 x 10 ⁺⁰¹)
Construction Worker ⁽⁴⁾	1.3 x 10 ⁻⁰⁵	1.2 x 10 ⁻⁰¹

Notes:

- (1) Resident adults could potentially be exposed to COPCs by dermal contact and accidental ingestion of surface soils, groundwater, surface water and sediments, as well as inhalation of volatile organics in groundwater while showering and inhalation of fugitive dust. Values presented in parenthesis included Total ICR and HI values using dissolved groundwater and surface water concentrations.
- (2) Total HI and ICR values for resident adults are the sum total of the resident adult and resident child HI and ICR values.
- (3) Resident children could potentially be exposed to COPCs by dermal contact and accidental ingestion of surface soils, groundwater, surface water and sediments, as well as inhalation of volatile organics in groundwater while showering and inhalation of fugitive dust. Values presented in parenthesis included Total ICR and HI values using dissolved groundwater and surface water concentrations.
- (4) Construction workers could potentially be exposed to COPCs by dermal contact and accidental ingestion of surface soils, as well as the inhalation of fugitive dusts during excavation activities.

NA = Not Applicable

TABLE 6-24

TOTAL SITE LIFETIME INCREMENTAL CANCER RISK (ICR) AND
HAZARD INDEX (HI) VALUES FOR FUTURE POTENTIAL HUMAN RECEPTORS - SITE 21
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Future Receptors	Total ICR	Total HI
Resident Adults ⁽¹⁾⁽²⁾		
(GW01)	1.2 x 10 ⁻⁰³ (3.5 x 10 ⁻⁰⁵)	7.8 x 10 ⁺⁰¹ (1.8 x 10 ⁺⁰⁰)
(GW03)	7.2 x 10 ⁻⁰⁴ (3.5 x 10 ⁻⁰⁵)	1.4 x 10 ⁺⁰² (8.5 x 10 ⁺⁰²)
Resident Children ⁽³⁾		
(GW01)	4.7 x 10 ⁻⁰⁴ (1.7 x 10 ⁻⁰⁵)	5.5 x 10 ⁺⁰¹ (1.4 x 10 ⁺⁰⁰)
(GW03)	2.7 x 10 ⁻⁰⁴ (1.7 x 10 ⁻⁰⁵)	1.0 x 10 ⁺⁰² (5.9 x 10 ⁺⁰²)
Construction Worker ⁽⁴⁾	1.6 x 10 ⁻⁰⁶	3.4 x 10 ⁻⁰¹

Notes:

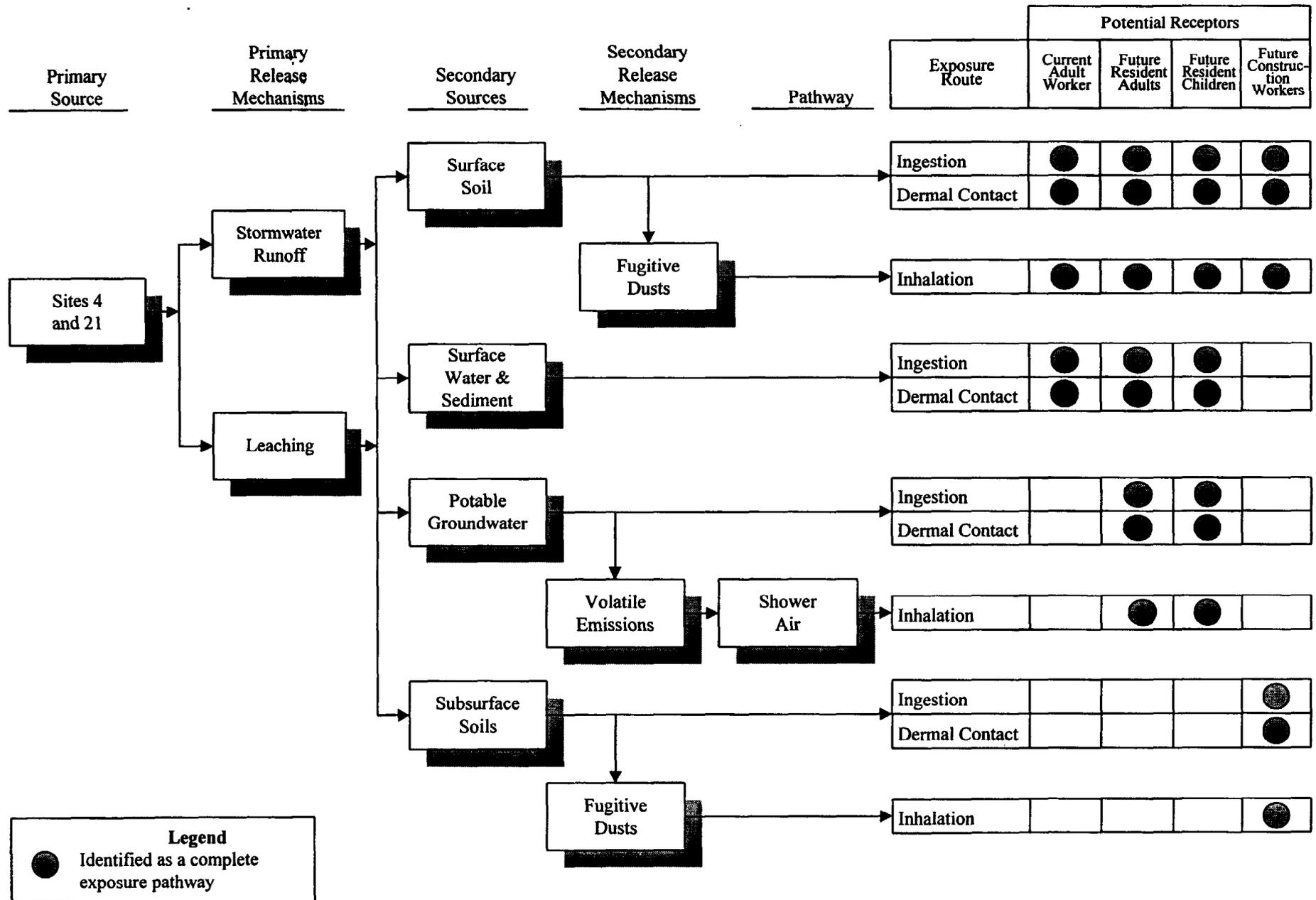
- (1) Resident adults could potentially be exposed to COPCs by dermal contact and accidental ingestion of surface soils, groundwater, surface water and sediments, as well as inhalation of volatile organics in groundwater while showering and inhalation of fugitive dust. Values presented in parenthesis included Total ICR and HI values using dissolved groundwater and surface water concentrations.
- (2) Total HI and ICR values for resident adults are the sum total of the resident adult and resident child HI and ICR values.
- (3) Resident children could potentially be exposed to COPCs by dermal contact and accidental ingestion of surface soils, groundwater, surface water and sediments, as well as inhalation of volatile organics in groundwater while showering and inhalation of fugitive dust. Values presented in parenthesis included Total ICR and HI values using dissolved groundwater and surface water concentrations.
- (4) Construction workers could potentially be exposed to COPCs by dermal contact and accidental ingestion of surface and subsurface soils, as well as the inhalation of fugitive dusts during excavation activities.

NA = Not Applicable

SECTION 6.0 FIGURES

FIGURE 6

CONCEPTUAL SITE MODEL
SITES 4 AND 21
NAVAL WEAPONS STATION YORKTOWN
YORKTOWN VIRGINIA



7.0 ECOLOGICAL RISK ASSESSMENT

The CERCLA of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, directs the USEPA to protect human health and the environment with respect to releases or potential releases of contaminants from abandoned hazardous waste sites (USEPA, 1989a). This section presents the Phase I ecological RA conducted at Sites 4 and 21 that assesses the potential impacts to ecological receptors from contaminants detected at these sites.

7.1 Objectives, Scope, and Organization of the Ecological Risk Assessment

This Phase I ecological RA is a screening phase conducted to evaluate the potential for past site operations at Sites 4 and 21 to have adversely affected terrestrial and aquatic communities on or adjacent to the sites. The screening phase will provide a basis for additional data collection (if necessary) to quantify any ecological risks posed to Sites 4 and 21.

A Phase I ecological RA was conducted because additional data were not collected at Sites 4 or 21 to conduct a more detailed ecological RA. These data were not collected prior to the initiation of this RI report because of the Removal Actions conducted by IT Corporation and their potential effects on source areas and the ecology at both sites.

This Phase I ecological RA evaluated and analyzed the results from the Round One RI including sampling and chemical analysis of the soil, groundwater, surface water, and sediment. Surface water and sediment samples were collected from a tributary of Felgates Creek located between Sites 4 and 21. Surface soil samples were collected from both Site 4 and Site 21. Data collected at Sites 4 and 21 were compared to data collected from background locations representative of base-wide and regional conditions.

Information used to evaluate sensitive environments was obtained from the Natural Heritage Inventory conducted at WPNSTA Yorktown by the Commonwealth of Virginia (Buhlmann and Ludwig, 1992). Because of the extensive nature of the Removal Actions conducted in 1994, the qualitative habitat evaluation conducted at Sites 4 and 21 in 1993 (Baker, 1995a) was used to tentatively identify potential terrestrial and aquatic receptors.

The risk assessment methodologies used in this evaluation were consistent with those outlined in the Framework for Ecological Risk Assessment (USEPA, 1992a). In addition, information found in the following documents was used to supplement the USEPA guidance document:

- USEPA Risk Assessment Guidance for Superfund. Volume II. Environmental Evaluation Manual (USEPA, 1989b)
- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989c)
- Region III Interim Ecological Risk Assessment Guidelines (USEPA, 1994)

Based on the USEPA Framework for Ecological Risk Assessment, an ecological RA consists of three main components: (1) Problem Formulation, (2) Analysis, and (3) Risk Characterization (USEPA, 1992a). The problem formulation section includes a preliminary characterization of exposure and effects of the stressors on ecological receptors. During the analysis phase, the data are evaluated to determine the exposure and potential effects on the ecological receptors from the stressors. Finally, in the risk characterization, the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. This section also evaluates the potential impact on the ecological environment at the site from the contaminants detected in the media. This assessment is organized to parallel the three components of an ecological RA.

7.2 Problem Formulation

Problem formulation is the first step of an ecological RA and includes a preliminary characterization of exposure and effects. Chemical analyses were performed on samples collected from soil, groundwater, surface water, and sediment at Sites 4 and 21 to evaluate the presence, concentrations, and variabilities of the Ecological Contaminants of Concern (ECOCs). Based on site visit observations and evaluation of habitats in the vicinity of the site, potential ecological receptors were identified. Finally, toxicological information for the ECOCs detected in the media was obtained from available references and literature and used to evaluate the potential adverse ecological effects to the ecological receptors.

The components of the problem formulation include stressor characteristics, ecosystems potentially at risk, ECOCs, endpoint selection, and a conceptual model. The following sections discuss the components of the problem formulation and how they were evaluated in this ecological RA.

7.2.1 Stressor Characteristics

One of the initial steps in the problem formulation stage of an ecological RA is identifying the stressor characteristics. For this ecological RA, the stressors evaluated were the contaminants detected in the surface soil, surface water, and sediment from the Round One RI. Contaminants in the subsurface soil and groundwater were not evaluated in this ecological RA. Some terrestrial species burrow in the soil and may contact the subsurface soil, and some microorganisms most likely exist in the groundwater. However, current guidance does not provide sufficient information to evaluate risk to these receptors.

The nature and extent of contaminants detected in the environmental media at Sites 4 and 21 are discussed in Section 4.0 of this report. Sampling locations were chosen based on historical information available for the site. Tables 4-1 to 4-37 summarize the contaminants that were detected in all media at Sites 4 and 21. Figures 4-1 to 4-13 provide a graphical description of the analytical results.

7.2.2 Ecological Chemicals of Concern

During the problem formulation stage, the chemical stressors to the site are identified. For this RA, the stressors that were evaluated include the ECOCs detected in the surface soil, surface water, and sediment.

7.2.2.1 Criteria for Selecting Ecological Contaminants of Concern

Quantifying risk for all positively identified contaminants may distract from the dominant risk-driving contaminants at the sites. Therefore, the data set of all positively identified contaminants was reduced to a list of ECOCs. ECOCs are site-related contaminants used to estimate ecological exposures and associated potential adverse effects.

The criteria used in selecting the ECOCs from the contaminants detected during the field sampling and analytical phase of the investigation were:

- Historical information
- Prevalence
- Toxicity
- Comparison to background or naturally occurring levels
- Comparison to regional screening levels and other appropriate criteria

Historical Information

The historical information for Sites 4 and 21 is presented in Section 1.0 of this report. Contaminants that are definitely not related to the site were not retained as ECOCs. To be conservative, contaminants that may have been historically used are retained as ECOCs.

Prevalence

The frequency of positive detections in sample sets and the level at which a contaminant is detected in a given medium are factors that determine a chemical's prevalence. Contaminants that were detected in five percent or less of the samples were not retained as ECOCs.

Toxicity

The potential toxicity of a contaminant is an important consideration when selecting ECOCs for further evaluation in the Phase I ecological RA. Several of the contaminants detected in the media at Sites 4 and 21 are prevalent; however, their inherent toxicity to ecological receptors is low and, therefore, they may not be retained as ECOCs. In addition, several of the contaminants have not been adequately studied to develop screening values, or accepted toxicological data does not exist with which to assess the contaminants. Contaminants that fall into this category will be evaluated by the use of background concentrations to determine whether they should be retained as a ECOC. Information used to support ECOC selection is included in the Ecological Toxicological Profiles found in Appendix I.

Background Levels

The prevalence of contaminants common to the region are taken into consideration when selecting ECOCs. Analytical data collected from ecologically comparable background stations are used to eliminate contaminants from consideration as ECOCs. Background surface water and sediment samples were collected off-Station in ecologically similar areas to the site. For Sites 4 and 21, surface water and sediment background stations were selected in tidal freshwater streams (Timberneck and Taskinas Creeks). Background Station-wide surface soil samples were used to select the surface soil ECOCs. The background surface soil samples represented all soil associations and included an anthropogenic railroad study. A complete list of the background data for WPNSTA Yorktown can be found in the Final Summary of Background Constituent Concentrations and Characterization of Biotic Community from the York River Drainage Basin (Baker, 1995b). A contaminant is eliminated as an ECOC if the range of detection in Sites 4 and 21 media is within the range of detection in the background media.

Screening Levels

The Biological Technical Assistance Group (BTAG) Screening Levels (BSLs) developed by the USEPA Region III (1995a) were the primary source of soil, surface water, and sediment screening levels used in this ecological RA. Secondary soil screening levels were obtained from the Oak Ridge National Laboratory (ORNL). ORNL has developed soil benchmarks that are used to evaluate potential ecological risks to terrestrial flora and fauna. These values, along with the BSLs, are referred to as Surface Soil Screening Levels (SSSLs) and are used as a criteria for retaining ECOCs.

Secondary sources of screening levels for surface water were obtained from the Commonwealth of Virginia's Water Quality Standards for surface water (VSWCB, 1992) and the USEPA Ambient Water Quality Criteria (USEPA, 1992b). These water quality screening levels will be herein referred to as Surface Water Screening Levels (SWSLs).

Finally, secondary sources of screening levels for the sediment were obtained from: Long et al. (1995); Long and Morgan (1990); Apparent Effect Threshold values (TetraTech, 1986); and, the Wisconsin Department of Natural Resources interim guidance criteria for in-water disposal of

dredged sediment (Sullivan et al., 1985). These sediment screening values will be referred to as Sediment Screening Levels (SSLs).

The SSSLs, SWSLs, and SSLs were used for comparative purposes to infer potential ecological risks. Contaminants that were detected at concentrations less than these screening levels were not retained as ECOCs since contaminants detected at concentrations less than these levels are not expected to pose a significant risk to the ecological population.

A brief description of the above values used in the ECOC selection is presented in Section 7.4 (Ecological Effects Characterization).

7.2.3 Selection of Ecological Contaminants of Concern

Section 4.0 of this report presents an overview of the analytical data obtained for each medium during the RI and the subsequent retention or elimination of ECOCs using the aforementioned criteria for selection of ECOCs. The following sections present the selection of the ECOCs in each of the media. A summary of the ECOCs in each of the media is presented in Table 7-1.

7.2.3.1 Surface Soil

Forty-seven surface soil samples were collected from Site 4 and fourteen surface soil samples were collected from Site 21. The surface soil ECOCs screening was conducted per site due to the variations in the number and concentrations of constituents detected between Site 4 and Site 21 soil. Removal actions of source contaminants have occurred at both sites prior to the surface soil sampling events.

Site 4

VOCs, SVOCs, pesticides/PCBs, explosives, and inorganics were selected as ECOCs in soil at Site 4. Table 7-2 summarizes the frequency and range of detections in surface soil and selection criteria and identifies those contaminants that were retained for the ecological RA. A rationale for exclusion also is given for those chemicals that were not retained.

The only VOC retained as an ECOC at Site 4 is 2-butanone. SVOCs retained as surface soil ECOCs at Site 4 include the following: acenaphthene; acenaphthylene; anthracene; benzo(a)anthracene; benzo(b)fluoranthene; benzo(k)fluoranthene; benzo(g,h,i)perylene; benzo(a)pyrene; carbazole; chrysene; dibenzo(a,h)anthracene; dibenzofuran; fluoranthene; fluorene; indeno(1,2,3-cd)pyrene; 2-methylnaphthalene; naphthalene; phenanthrene; and pyrene. Pesticides retained as ECOCs include 4,4'-DDD; 4,4'-DDT; and endosulfan II. PCBs retained as ECOCs in the surface soil at Site 4 are Aroclor-1254 and Aroclor-1260. The following explosives detected in the surface soil at Site 4 are ECOCs: 3,5-dinitrotoluene; HMX; and RDX. Surface soil inorganic ECOCs retained at Site 4 include aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, thallium, and zinc.

Site 21

SVOCs, pesticides and inorganics were selected as ECOCs in surface soil at Site 21. Table 7-3 summarizes the frequency and range of detections in surface soil and selection criteria and identifies those contaminants that were retained for the ecological RA. A rationale for exclusion also is given for those chemicals that were not retained.

SVOCs retained as surface soil ECOCs at Site 21 include the following: acenaphthylene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(g,h,i)perylene. Although not considered to be site related, di-n-butylphthalate was also retained as an ECOC for the Phase I ecological RA. Pesticides retained as ECOCs in the surface soils collected from Site 21 include 4,4'-DDD and 4,4'-DDT. Surface soil inorganic ECOCs retained at Site 21 include aluminum, cadmium, copper, manganese, mercury, nickel, and zinc.

7.2.3.2 Surface Water

Five surface water samples were collected from a tributary to Felgates Creek that receives surface water drainage from both Sites 4 and 21. The surface water collected in the tributary is tidally influenced. It is noted that the surface water samples collected during this Round One investigation were collected prior to the removal action conducted at Site 4.

Table 7-4 presents a summary of the frequency and range of the total surface water contaminant detections. This table also presents a comparison of the contaminant detections to the SWSLs and the selection of ECOCs. Although not considered to be site related, di-n-butylphthalate was the only SVOC retained in the surface water. The explosives retained include 1,3,5-trinitrobenzene; 1,3-dinitrotoluene; 2,4,6-trinitrotoluene; HMX; and RDX. Inorganics retained as ECOCs in the surface water include aluminum, arsenic, barium, cadmium, cobalt, copper, iron, lead, manganese, mercury, and zinc.

7.2.3.3 Sediment

Five shallow sediment samples and five deep sediment samples were collected from the tributary to Felgates Creek situated between Sites 4 and 21. Frequency, range of positive detection, and selection criteria of ECOCs in sediment are summarized in Table 7-5. Compounds that were retained as ECOCs also are identified, and the rationale for excluding those that were not retained is presented. One VOC, five pesticides, and six inorganic compounds were retained as ECOCs in the sediments. The VOCs retained as a ECOCs for sediment are 2-butanone and 1,1,1-trichloroethane. The pesticides retained include 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; alpha-chlordane; and gamma-chlordane. The inorganic compounds retained as sediment ECOCs were antimony, cadmium, cobalt, lead, mercury, selenium, and zinc.

7.2.3.4 Physical/Chemical Characteristics of Ecological Contaminants of Concern

Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include bioconcentration factors (BCFs), organic carbon partition coefficient (K_{oc}), octanol water partition coefficient (K_{ow}), plant transfer co-efficients (B_p or B_r) and beef transfer coefficients (B_b). Table 7-6 summarizes these values for the ECOCs detected in the surface soil, surface water, and sediment at Sites 4 and 21. The following paragraphs discuss the significance of each parameter included in the table.

BCFs measure the tendency for a chemical to partition from the water column or sediment and concentrate in aquatic organisms. BCFs are important for ecological receptors because chemicals with high BCFs could accumulate in lower-order species and subsequently accumulate to toxic levels in species higher up the food chain. The BCF is the concentration of the chemical in the

organism at equilibrium divided by the concentration of the chemical in the water. Therefore, the BCF is unitless.

The organic carbon partition coefficient (K_{oc}) measures the tendency for a chemical to partition between soil or sediment particles containing organic carbon and water. This coefficient is important in the ecological environment because it determines how strongly an organic chemical will be bound to the organic matter in the sediment.

The octanol/water partition coefficient (K_{ow}) is the ratio of a chemical concentration in octanol divided by the concentration in water. The K_{ow} has been shown to correlate well with bioconcentration factors in aquatic organisms and with adsorption to soil or sediment.

The plant transfer coefficients (B_v or B_r) measure the potential for a chemical to accumulate in a plant. These coefficients can be used to calculate the concentration of the ECOCs in either the leafy part of the plant (B_v) or the fruit of the plant (B_r). The coefficients for inorganics were obtained from Baes et al. (1984), while the coefficients for organics were calculated according to Travis and Arms, (1988). The B_v and B_r values for the organics were assumed to be same value.

Finally, the beef transfer coefficient (B_b) measures the potential for a chemical to accumulate in an animal. The coefficients for inorganics were obtained from Baes et al. (1984), while the coefficients for organics were calculated according to Travis and Arms (1988).

7.2.4 Ecosystems Potentially at Risk

Ecosystems that may be affected by contamination at Sites 4 and 21 were identified during a habitat evaluation (Baker, 1995a). Specific details on the local ecology are presented in Section 3.0 of this report. Fringing wetlands classified as estuarine, intertidal, emergent, irregularly flooded, persistent wetland occur along Felgates Creek south of Site 4. A marsh area classified as estuarine, intertidal, emergent, irregularly flooded, persistent wetland is present along the tributary separating Sites 4 and 21 at its confluence with Felgates Creek. Aquatic receptors in the wetland and tributary may be affected by contaminants in the surface water and sediment. Although, biota sampling was not undertaken as part of the Round One RI, fish and benthic macroinvertebrates are expected to be present in the surface water and sediment in this area.

Three general terrestrial habitat types are present at Site 4: an open field, scrub shrub/mixed forest edge, and upland forest. Signs of turtles, white-tailed deer, and squirrels were present at Site 4. At Site 21, two terrestrial habitats are present: upland forest and mixed forest. A box turtle was found on Site 21 during the habitat evaluation. In addition, signs of white-tailed deer, grey squirrels, striped skunk, racoon, and fox were observed at Site 21. The terrestrial receptors may be affected by contaminants in the surface soil. Receptors that drink surface water or feed in stream sediment might be affected by contaminants in these media as well.

7.2.5 Ecological Endpoints

The information compiled on stressor characteristics, ecosystems potentially at risk, and ecological effects was used to select the ecological endpoints for this ecological RA. The following section of this report contains a description of the ecological endpoints selected and the rationale for their selection.

There are two primary types of ecological endpoints: assessment endpoints and measurement endpoints. Assessment endpoints are environmental characteristics, which, if they were found to be significantly affected, would indicate a need for remediation. Measurement endpoints are quantitative expressions of an observed or measured effect of the ECOCs. Measurement endpoints may be identical to assessment endpoints (e.g., measurement of abundance of fish), or they may be used as surrogates for assessment endpoints (e.g., toxicity test endpoints).

A measurement endpoint, or "ecological effects indicator" as it is sometimes called, is used to evaluate the assessment endpoint. Therefore, measurement endpoints must correspond to, or be predictive of, assessment endpoints. In addition, they must be readily measurable, preferably quickly and inexpensively, using existing techniques. Measurement endpoints must take into consideration the magnitude of the contamination and the exposure pathway. The measurement endpoint should be an indicator of effects that are temporally distributed. Low natural variability in the endpoint is preferred to aid in attributing the variability in the endpoint to the contaminant. Measurement endpoints should be diagnostic of the pollutants of interest, as well as broadly applicable to allow comparison among sites and regions. Also, measurement endpoints should be standardized (e.g., standard procedures for toxicity tests). Finally, it is desirable to use endpoints that already are being measured (if they exist) to determine baseline conditions.

Measurement and assessment endpoints are divided into four primary ecological groups: individual, population, community, and ecosystem endpoints. Individual endpoints (e.g., death, growth, tissue concentrations) are evaluated through toxicity tests, models, and other methods used to assess the effects on individual organisms. Population endpoints (e.g., occurrence, abundance, reproductive performance) are evaluated to determine presence and absence of species through field studies. Community endpoints (e.g., number of species, species diversity) are used to describe the complexity of the community. Finally, ecosystem endpoints (e.g., biomass, productivity, nutrient dynamics) are used to determine the effects between groups of organisms and between organisms and the environment.

The following sections discuss the assessment and measurement endpoints for ecological RA conducted at Sites 4 and 21.

7.2.5.1 Aquatic Endpoints

The aquatic assessment endpoint is the potential for contaminants detected in the surface water and sediment to adversely impact aquatic receptors. The measurement endpoints for the aquatic assessment includes the calculation of quotient indices (QI) using the Region III screening levels for surface water and sediment. Quotient indices were calculated for each surface water and sediment sample that exceeded screening levels. Individual sample QIs were calculated due to the transient nature of surface water.

7.2.5.2 Terrestrial Endpoints

The terrestrial assessment endpoint is the potential for contaminants detected in the surface soil to adversely impact the terrestrial environment at Sites 4 and 21. The measurement endpoints for the terrestrial assessment include exceedances of contaminant-specific soil effect concentrations using a qualitative comparison to literature toxicity values established for indicator trophic level groups. The indicator trophic level groups were selected to represent a comprehensive coverage of a variety of direct soil exposure pathways. These indicator trophic level groups included: plants, earthworms, invertebrates, microorganisms, and microbial processes.

7.2.6 Conceptual Model

The site-specific conceptual model diagrams the routes by which stressors might affect ecological components of the natural environment. It includes multiple exposure pathways that are considered during the ecological RA. For this risk assessment, the following pathways were considered: soil pathway, groundwater pathway, surface water pathway, sediment pathway, and air pathway.

7.2.6.1 Soil Pathway

Potential release sources to be considered in evaluating the soil pathway are surface or buried wastes and contaminated soil. Contaminated soil may be released via fugitive dust, leaching, and surface runoff. The potential routes to be considered for ecological exposure to the contaminated soil are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the soil.

Terrestrial receptors potentially are exposed to contaminants in the soil through ingestion, dermal contact, and/or direct uptake (for flora). The magnitude of the exposure depends on the feeding habits and the amount of time spent in the contaminated soil. For example, burrowing animals such as earthworms, groundhogs, or moles will be exposed to a greater degree than grazing animals that occasionally feed in the area. In addition, terrestrial species may ingest organisms (e.g., insects, small mammals, plants) that have bioconcentrated contaminants from the soil.

7.2.6.2 Groundwater Pathway

Potential release source to be considered in evaluating the groundwater pathway is contaminated soil. The release mechanism to be considered is leaching. The routes to be considered for ecological exposure to the contaminated groundwater are ingestion and dermal contact. Groundwater discharge to area surface water may represent a pathway for contaminant migration.

Potential release sources to be considered in evaluating the surface water pathway are contaminated surface soil and groundwater. Groundwater seepage and surface runoff can release contaminants from the surface water. Ecological receptors may then be exposed to contaminants via ingestion and

dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the surface water on site, off-site, and downgradient.

7.2.6.3 Surface Water Pathway

Aquatic organisms (i.e., fish, benthic macroinvertebrates) are exposed to contaminants in the surface water by direct contact and by ingesting water while feeding. In addition, because of their position within a food web or food chain, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the surface water. Overall, aquatic organisms have a high exposure to contaminants in the surface water.

Terrestrial faunal receptors potentially are exposed to contaminants in the surface water through ingestion and dermal contact. The magnitude of the exposure depends on their feeding habits and the amount of time they spend in the contaminated water. In addition, because of their position within a food web or food chain, terrestrial species may ingest organisms (e.g., fish, insects, plants) that have bioconcentrated contaminants from the surface water.

7.2.6.4 Sediment Pathway

The potential release sources to be considered in evaluating the sediment pathway are contaminated surface soil and groundwater. Groundwater seepage and surface runoff can release contaminants to sediment. Ecological receptors are exposed to the contaminated sediment via ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the sediment.

Aquatic receptors (i.e. fish, benthic macroinvertebrates) are exposed to contaminants in the sediment through ingestion and dermal contact. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the sediment.

Terrestrial fauna may be exposed to contaminants in the sediment through ingestion and dermal contact. The magnitude of the exposure depends on feeding habits and the amount of time spent in the contaminated sediment. In addition, terrestrial species may ingest organisms (e.g., fish, insects, small mammals, plants) that have bioconcentrated contaminants from the sediment.

7.2.6.5 Air Pathway

There are two potential release mechanisms to be considered in evaluating the atmospheric pathway: release of contaminated particulates and volatilization from surface soil, groundwater, and surface water. The potential exposure points for receptors are areas on or adjacent to the site where they can be exposed to dust or volatilized vapors.

The conceptual model for Sites 4 and 21 is included as Figure 7-1.

7.3 Exposure Assessment

The exposure assessment evaluates the interaction of the stressor with the ecological environment. The remedial investigations involved collecting samples from four media; soil, groundwater, surface water, and sediment. The analytical results of these investigations, source identification, and the extent of contamination are discussed in Section 4.0 of this report.

Regional ecology of the coastal plain and the habitats present at Sites 4 and 21 as well as information on sensitive environments, wetlands, and endangered species are included in Section 3.8 of this report. The areas used as background stations for surface water and sediment comparisons included two tidal freshwater streams (Taskinas and Timberneck Creeks, tributaries to the York River). Identified on-base background stations were used as reference stations for the surface soil samples. Specific descriptions of the background areas can be found in the Summary of Background Constituent Concentrations and Characterization of the Biotic Community from the York River Drainage Basin, Naval Weapons Station, Yorktown, Virginia (Baker, 1995b).

Exposure of contaminants in the sediment to aquatic receptors were assumed to be equal to the contaminant concentration in the sediment. Exposure of contaminants in the surface soil to terrestrial flora and fauna (invertebrates and microorganisms) were assumed to be equal to the contaminant concentrations in the surface soil.

7.3.1 Exposure Assessment/Profile

The next step in the characterization of exposure is to combine the spatial and temporal distributions of both the ecological environment and the stressor to evaluate exposure. This section of the ecological RA addresses and quantifies each exposure pathway via soil, groundwater, surface water, sediment, and air.

To evaluate if ecological exposure via these pathways may occur, the exposure pathways were identified and characterized. The following four elements were examined to determine if a complete exposure pathway was present:

- A source and mechanism of chemical release
- An environmental transport medium
- A feasible receptor exposure route
- A receptor exposure point

ECOCs were detected in the surface soil, demonstrating a release from a source to the surface soil transport medium. Potential receptors that may be exposed to contaminants in surface soil include animals that feed or burrow and plants growing in contaminated areas.

Subsurface biota (i.e., microorganisms) are the only ecological receptors expected to be directly exposed to groundwater. These biota will not be assessed in the Phase I ecological RA because current guidance does not provide sufficient information to evaluate risk. The groundwater to surface water exposure is accounted for in the surface water section of the ecological RA.

ECOCs were detected in the surface water and sediment, demonstrating a release from a source to the surface water/sediment transport medium. Potential receptors that may be exposed to contaminants in surface water and sediment include invertebrates, fish, aquatic vegetation, reptiles, amphibians, and birds.

The air exposure pathway will not be evaluated in this Phase I ecological RA. A majority of the areas that were sampled are covered with grass and trees which reduces the potential for contaminants in the soil to become suspended in the air.

7.4 Ecological Effects Characterization

The ecological effects data that were used to assess potential risks to aquatic and/or terrestrial receptors in this ecological RA include the USEPA Region III BSLs for surface soil, surface water, and sediment. In addition to the BSLs used for screening ECOCs; various other criteria, reference values, and benchmarks also were utilized as SSSLs, SWSLs, and SSLs. The following paragraphs provide a brief description of the values used for ECOC selection and overall risk characterization.

7.4.1 Surface Soil

SSSLs have been compiled for evaluating the potential for chemical contaminants in surface soil to cause adverse biological effects to terrestrial flora, fauna, and microorganisms (USEPA, 1995a; Will and Suter, 1994a,b). Concentrations below these screening levels are not expected to cause adverse impacts to terrestrial flora or fauna.

Potential risks to terrestrial receptors from contaminants in the soil were addressed by a comparison to SSSLs and by comparison to literature toxicity values.

7.4.1.1 Comparison to Surface Soil Screening Levels and Literature Values

At Sites 4 and 21, VOCs, SVOCs, pesticides, PCBs and inorganics exceeded SSSLs (see Tables 7-2 and 7-3). In addition to the SSSLs used for ECOC screening, surface soil toxicological effect data on plants, earthworms, invertebrates, and microorganisms also were used. This soil toxicity data for the ECOCs identified in the surface soil at Sites 4 and 21 are provided on Tables 7-7 and 7-8, respectively. Soil toxicity values were compared to the range of concentrations detected at the sites 95% Upper Confidence Limit (UCL) of the arithmetic average of each ECOC. The toxicity values presented are benchmark values; therefore, these values represent a concentration at which no or low toxic effects are observed. It is noted that the soil toxicity data cannot be used to evaluate potential risks to other terrestrial fauna (e.g., birds, deer, and rabbits) because the exposure doses for these species are different than the exposure doses for invertebrates and plants, which are in constant direct contact with the contaminants in the soil. In addition, the sensitivity of the organisms to the ECOCs is not similar.

Site 4

As depicted on Table 7-7, most of the ECOCs identified in the surface soil at Site 4 exceeded literature toxicity values for plants, earthworms, invertebrates, microorganisms, and microbial processes. The PAH compounds exceeded the toxicity values by the highest magnitude. All of the SVOC ECOCs in the surface soils were above the literature toxicity values, with the exception of fluorene which was below earthworm toxicity values. In addition, the 95% UCL value calculated for benzo(a)pyrene is below literature toxicity values. The pesticides 4,4'-DDD and 4,4'-DDT detected in the surface soils at Site 4 were higher than literature values for earthworms and invertebrates, but the 95% UCL for DDD is below literature values. The surface soil concentrations detected for PCBs and endosulfan II were below literature values for plants.

The following inorganic compounds detected in the surface soil at Site 4 exceeded all of the available literature toxicity values for plants, earthworm, invertebrates, and microorganisms: aluminum, chromium, manganese, and zinc. Antimony, cadmium, cobalt, nickel, and thallium were detected at Site 4 at concentrations below soil toxicity values. In addition, 95% UCL values calculated for antimony and cadmium were below soil toxicity values. 95% UCL values calculated for arsenic and lead were below soil toxicity values, except for plant values. Cadmium concentrations were below benchmark values for earthworms and microorganisms. The following ECOCs detected in the surface soil at Site 4 did not have literature values to evaluate soil toxicity: 2-butanone; carbazole; dibenzofuran; 2-methylnaphthene; 3,5-dinitrotoluene; HMX; RDX; 1,3,5-trinitrotoluene; 1,3-dinitrobenzene; and, cyanide.

Site 21

As displayed on Table 7-8, the surface soil samples collected at Site 21 contained concentrations of ECOCs that were higher than literature toxicity values for plants, earthworms, invertebrates, microorganisms, and microbial processes. All of the SVOCs in the surface soils at Site 21 were detected above soil toxicity values, except di-n-butylphthalate which is below the benchmark value for plant toxicity. However, it should be noted that the SVOC concentrations in the soil only slightly exceeded the literature values and the majority of SVOCs were only detected in one surface soil sample. The two pesticides retained as ECOCs at Site 21 (4,4'-DDD and 4,4'-DDT) were detected at concentrations above toxicity values established for earthworms and invertebrates. However, the

95% UCL value calculated for DDD is below the literature toxicity values for all soil flora and fauna except earthworm values.

Of the inorganics detected at Site 21, aluminum and zinc greatly exceeded soil toxicity values. The surface soil 95% UCL value for copper is below toxicity values for plants, earthworms, and microorganisms. Nickel and the 95% UCL value for mercury are below soil toxicity values. The 95% UCL calculated for manganese is below toxicity values for plants, earthworms, and invertebrates, but exceed values for microorganisms.

7.4.2 Surface Water

USEPA Region III has compiled a list of SWSLs that are non-enforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic systems. SWSLs are provided for both freshwater and marine aquatic systems, and are reported as acute and/or chronic values (USEPA, 1995a). In addition to the SWSLs, USEPA has promulgated Water Quality Standards (WQS) for states that have not developed their own standards. These WQS are based primarily on the USEPA Ambient Water Quality Criteria, with some of the values updated with more recent information. In addition, Virginia Water Quality Standards (Surface Water) also were used. These water quality standards are the concentrations of toxic substances that will not result in chronic and acute toxicity to aquatic life (VSWCB, 1992). Virginia Water Quality Standards and USEPA criteria were used for contaminants that did not have BSLs.

Potential risks to aquatic receptors from contaminants detected in the surface water were evaluated by comparison to SWSLs. Table 7-4 summarizes the SWSLs used to evaluate the surface water quality at Sites 4 and 21. There were no VOCs, pesticides, or PCBs detected in the surface water at Sites 4 and 21. Di-n-butylphthalate was the only SVOC retained as a ECOC in the surface water. Of the explosives, 1,3,5-trinitrobenzene; 1,3-dinitrobenzene; 2,4,6-trinitrotoluene; HMX; and RDX were retained as ECOCs in the surface water because there were no available SWSLs for comparison and the levels were detected above background concentrations. The following inorganics were retained as ECOCs because they were above SWSLs and/or above background concentrations: aluminum; arsenic; barium; cadmium; cobalt; copper; iron; lead; manganese; mercury; and, zinc.

7.4.3 Sediment

USEPA Region III has compiled a list of SSLs that are non-enforceable regulatory guidelines and are of primary utility in assessing toxic effects in aquatic systems. In addition, SSLs have been compiled for evaluating the potential for chemical contaminants in sediment to cause adverse biological effects (Long et al., 1995; Long and Morgan, 1991; and USEPA, 1995a). The lower ten percentile (Effects Range-Low [ER-L]) and the median percentile (Effects Range-Median [ER-M]) of biological effects have been developed for several of the contaminants. The concentration below the ER-L represents a minimal-effects range (adverse effects would be rarely observed). The concentration above the ER-L but below the ER-M represents a possible-effects range (adverse effects would occasionally occur). Finally, the concentration above the ER-M represents a probable-effects range (adverse effects would probable occur). It is noted that the SSLs developed by the USEPA Region III are primarily ER-L values.

In addition to SSLs, Apparent Effects Threshold (AET) sediment quality values have been developed for the Puget Sound (Tetra Tech, Inc., 1986). AETs are the concentrations of contaminants above which statistically significant biological effects always would be expected. Finally, the Wisconsin Department of Natural Resources has developed interim criteria for in-water disposal of dredged sediment (Sullivan et al., 1985). However, these criteria were established using background concentration data and were not based on toxicity data.

Potential risks to aquatic receptors from contaminants detected in the sediment were evaluated by comparison of sediment concentrations to SSLs. The SSLs used to evaluate the sediment quality at Sites 4 and 21 are presented on Table 7-5. The one SVOC detected in the sediment was eliminated as a ECOC because the sample concentration was below the established SSL. Two VOCs (2-butanone and 1,1,1-trichloroethane) were retained as ECOCs because the concentrations were above background concentrations. The following pesticides were retained as sediment ECOCs because they were above SSLs and were not detected in background sediment samples: 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; alpha-chlordane; and gamma-chlordane. Of the inorganics, antimony, cadmium, cobalt, lead, mercury, selenium, and zinc were retained as ECOCs because they were detected above SSLs and/or above background concentrations.

7.5 Risk Characterization

The risk characterization is the final phase of a risk assessment. In risk characterization, the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. This section evaluates the potential adverse effects on the ecological receptors at Sites 4 and 21 from contaminants identified at the site. The QI approach was used to characterize risks posed to the aquatic community. A ratio greater than one indicates a possibility for adverse effects to aquatic life. The QI was calculated as follows:

$$QI = \frac{\text{Concentration in Sample}}{SWSL \text{ or } SSL}$$

where: QI = Quotient Index

SWSL = Surface Water Screening Level, µg/L

SSL = Sediment Screening Level, mg/kg (inorganics) and µg/kg (volatiles)

7.5.1 Surface Soil

Risk to terrestrial receptors was not characterized using the QI method. A qualitative characterization of the risk to terrestrial receptors is presented in Section 7.4 (Ecological Effects Characterization).

7.5.2 Surface Water

Table 7-4 contains a comparison of the ECOCs identified in the surface water at Sites 4 and 21 to the SWSLs. Table 7-9 presents only the QIs greater than one for the ECOCs detected in each sample. Di-n-butylphthalate had a chronic QI greater than one (there is no acute SWSL established). Of the inorganics, arsenic, cadmium, copper, lead, manganese, mercury, nickel, and zinc exceeded one for the chronic QIs. High chronic (>40) QIs were calculated for copper, lead, manganese, mercury, and zinc. Furthermore, copper, lead, mercury, and zinc exceeded one for the acute QIs. It is noted that there is no acute SWSL established for manganese. High acute QIs (>40) were calculated for copper and zinc. There were no QI ratios calculated for 1,3,5-trinitrobenzene; 1,3-dinitrobenzene; 2,4,6-trinitrotoluene; HMX; RDX; aluminum; barium; and cobalt due to a lack of SWSLs established for these chemicals.

7.5.3 Sediment

Table 7-5 contains a comparison of the ECOCs identified in the sediment to the SSLs to determine if exceedances of published values occurred. The QI ratio of the detected values at each sampling station and the SSLs were calculated for each ECOC at Sites 4 and 21 using the formula presented in Section 7.5 (Risk Characterization).

QIs calculated equal to and above the ER-L, but below the ER-M, represent a possible effects range within which effects would occasionally occur. QIs calculated equal to or above the ER-M, represent a probable-effects range within which effects would frequently occur (Long et al., 1995). Table 7-10 summarizes the QIs for the ECOCs in the sediment. The QI calculated for the ER-Ls of alpha-chlordane; gamma-chlordane; 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; antimony; cadmium; cobalt; lead; mercury; selenium; and zinc were greater than one. The QIs calculated for the ER-Ms were greater than one for alpha-chlordane; gamma-chlordane; 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; and zinc. However, the ER-Ms calculated for cadmium, lead, and mercury were below one. There are no ER-Ms established for antimony, cobalt, and selenium; therefore, an ER-M calculation could not be obtained. The VOCs, 2-butanone and 1,1,1-trichloroethane, do not have any screening levels to calculate QIs.

7.5.4 Threatened and/or Endangered Species

The Commonwealth of Virginia prepared a Natural Heritage Resources Inventory for WPNSTA Yorktown in March, 1992 (Buhlmann and Ludwig, 1992). During this inventory, threatened, and endangered species and sensitive environments on the Station were identified. None of these species or environments were identified in the vicinity of Sites 4 and 21. Two of the wading birds feeding in Felgates Creek are listed as rare by the Natural Heritage Resources Inventory report: the great blue heron (*Ardea herodias*) and great egret (*Casmerodius alba*). Because of the size of the tributary at Sites 4 and 21 and the limited number of fish present, it is unlikely that these wading birds feed regularly in the area.

7.5.5 Wetlands

Site-specific wetland delineations were not conducted at Sites 4 and 21, although potential wetland areas were noted during the habitat evaluation. These wetlands were verified in the National Wetland Inventory maps. The wetland located in the ravine between Sites 4 and 21 is classified as an estuarine, intertidal, emergent, persistent wetland. Impacts to wetland were evaluated as part of the aquatic portion of this ecological RA.

Potential adverse impacts to wetlands at Sites 4 and 21 may occur due to the exceedances of surface water and sediment screening levels from site-related contaminants.

7.5.6 Other Sensitive Environments

Sensitive environments were evaluated as part of the Natural Heritage Resources Inventory at WPNSTA. Although sensitive environments were identified in the Kings Creek portion of the Station, they are not close enough to Sites 4 and 21 to be affected by site contaminants nor are they in the Felgates Creek watershed.

7.6 Ecological Significance

This section essentially summarizes the overall risks to the ecology at Sites 4 and 21. It addresses impacts to the ecological environment at Sites 4 and 21 from the ECOCs detected in the media and to determine which ECOCs are impacting the site to the greatest degree. This information, to be used in conjunction with the human health RA, supports the evaluation of remedial action(s) for the site that are protective of human health and the environment.

7.6.1 Aquatic Assessment Endpoint

The aquatic assessment endpoint for this ecological RA is the potential for contaminants detected in the surface water and sediment to adversely impact aquatic receptors. The measurement endpoint for the aquatic assessment endpoint is the exceedance of contaminant-specific surface water and sediment effect concentrations and the calculation of QI ratios.

Due to the concentrations of di-n-butylphthalate, explosives, arsenic, cadmium, copper, lead, manganese, mercury, nickel, and zinc detected in the surface water collected from Sites 4 and 21; the surface water potentially is adversely impacting the aquatic community. The inorganic compounds and di-n-butylphthalate may be attributable to previous land use of the sites. The explosives are probably a site-related contaminant; however, the surface water samples were collected prior to the removal action conducted at Site 4. Therefore, the surface water analyzed in this ecological RA does not represent present day conditions. It is noted that the quality of the surface water may fluctuate due to the tidal influence of Felgates Creek.

The sediment collected at Sites 4 and 21 contained concentrations of alpha-chlordane; gamma-chlordane; 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; antimony; cobalt; cadmium; lead; mercury; selenium; and, zinc that potentially may affect the benthic community based on QI ER-Ls calculated greater than one. The ER-Ms calculated for sediment concentrations were greater than one for alpha-chlordane, gamma-chlordane, 4,4'-DDD; 4,4'-DDE; 4,4'-DDT; and, zinc, indicating a high potential for adverse impacts to aquatic life. The pesticides detected in the sediment are probably residual effects from previous pesticide management programs at WPNSTA Yorktown and not specifically site related. The zinc detected in the sediment may be a result of previous land uses at Sites 4 and 21.

7.6.2 Terrestrial Assessment Endpoint

The assessment endpoint selected for the terrestrial portion of this ecological RA is the potential for contaminants detected in the surface soil to adversely impact the terrestrial environment at Sites 4 and 21. The measurement endpoint is the exceedance of soil effect concentrations as determined by a qualitative comparison to literature toxicity values established for soil flora and fauna. It is noted that the literature values presented are concentrations at which no or low toxic effects to terrestrial flora and fauna are observed. In addition, the majority of the benchmark values presented have low confidence associated with them due to a limited number of experiments and/or a limited number of species tested.

Site 4

VOCs, SVOCs, pesticides, explosives, and inorganic compounds were retained as ECOCs at Site 4. In addition, literature toxicity information was reviewed to assess potential contaminant effects. Based on the toxicity values, the ECOCs detected in the surface soil at Sites 4 and 21 are potentially adversely impacting terrestrial flora and fauna. The PAHs detected at Site 4 greatly exceeded the literature toxicity values. The pesticide, DDT, along with PCBs also exceeded literature values. The inorganics aluminum, manganese, and zinc exceeded literature toxicity values by a high magnitude. However, it is noted that background soil concentrations for aluminum (1,960 to 24,100 mg/kg) and manganese (7.6L to 491 mg/kg) also exceed literature values.

Site 21

SVOCs, pesticides, and inorganic compounds detected in the surface soil at Site 21 exceeded SSSLs. In addition, literature toxicity values were slightly exceeded by SVOCs and DDT detected in the surface soil. The inorganic compounds aluminum and zinc were the only inorganics that greatly exceeded literature values at Site 21. Therefore, aluminum and zinc in the surface soils at Site 21 may adversely impact the terrestrial flora and fauna. Aluminum and zinc may, however, be site-related ECOCs from the ash pile at Site 4. It should also be noted that background soil concentrations for zinc (3.2 to 48.4 mg/kg) and aluminum (1,960 to 24,100 mg/kg) also exceeded literature toxicity values.

The assessment of potential risk posed to the terrestrial environment from inorganic contaminants detected in the surface soil is highly variable. This variability in the terrestrial ecological risk assessment is due to the high degree of variability associated with inorganic concentrations in surface soil samples. For example, aluminum values in background soil concentrations appear to fluctuate greatly between samples as do the samples collected for Sites 4 and 21.

7.7 Uncertainty Analysis

The procedures used in this evaluation to assess risks to ecological receptors, as in all such assessments, are subject to uncertainties. The following discusses the uncertainty in this ecological RA associated with the sampling, data, and screening levels.

Sampling Area

Sampling stations for surface water and sediment at Sites 4 and 21 were located in a tidally-influenced stream. The concentrations of chemicals in the surface water will vary with the tides; the concentrations are expected to be lower at higher tides (more dilution) and higher at low tides (less dilution).

The ecological investigation consisted of one sampling effort. The results of this sampling only will provide a "snapshot in time" of the ecological environment. Because of the fluctuating tide conditions, the "snapshot in time" may not be an accurate representation of actual site conditions. In addition, surface water was collected prior to the removal action conducted at Site 4. Therefore, the surface soil runoff that potentially was impacting the surface water at the time of sampling no longer exists.

Data

The screening of the surface water and sediment concentrations indicate a potential risk to the aquatic environment. However, there is no biota data available to verify or dispute an ecological risk. In addition, there is no aquatic data collected upstream and downstream of the tributary to Felgates Creek to assess impact of the tributary to Felgates Creek and vice versa.

Screening Levels

Potential adverse impacts to terrestrial invertebrates and plants were evaluated by comparing the ECOC concentration in the surface soil to benchmark values obtained in the literature. Most of these studies do not take into account the soil type, which may have a great influence on the toxicity of the contaminants. For example, soil with high organic carbon content will tend to absorb many of the organic ECOCs, thus making them less bioavailable to terrestrial receptors. The benchmark values are based on both field and growth chamber studies; therefore, the reported toxic concentrations are not always equivalent to actual field conditions. In addition, the majority of the benchmark values used for comparison purposes had low levels of confidence assigned to the values based on the number of studies performed (less than ten studies) and the diversity of species tested.

There is uncertainty in assessing the terrestrial environment using these benchmark values. Various inorganics in surface soil have a high degree of variability as demonstrated in the aluminum concentrations detected in the background samples. The high degree of variability of inorganic concentrations in surface soil in turn magnifies the uncertainty associated with using literature toxicity values to assess risk posed to a terrestrial environment.

There is uncertainty in the ecological endpoint comparison. The surface water screening levels are established to be protective of a majority of the potential receptors. However, there will be some species not protected by the values because of their increased sensitivity to the chemicals. In addition, most of the values are established using laboratory tests, where the concentrations of certain water quality parameters (pH, total organic carbon) that may influence toxicity are most likely at different concentrations in the site water.

Potential adverse impacts to aquatic receptors from contaminants in the sediment were evaluated by comparing the ECOC concentration in the sediment to sediment screening levels. These SSLs have more uncertainty associated with them than do the SWSLs, since the procedures for developing them are not as established as those used in developing SWSLs. In addition, sediment type (pH, acid volatile sulfide, total organic carbon) has a significant impact on the bioavailability and toxicity of contaminants. The SSLs were developed using data obtained from freshwater, estuarine, and marine environments. Therefore, their applicability for use to evaluate potential effects to aquatic organisms from contaminants in oligohaline and freshwater habitats introduces uncertainty because of differences in both the toxicity of individual contaminants to freshwater and saltwater organisms, and the bioavailability of contaminants in the two aquatic systems.

The toxicity of chemical mixtures is not well understood. All the toxicity information used in the ecological RA for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals due to synergistic or antagonistic effects. In addition, the species that were used to develop the toxicity data may not be present at the site, or have the potential to exist at the site. Depending on the sensitivity of the tested species to the species at the site use of the toxicity values may overestimate or underestimate risk.

7.8 Conclusions

Overall, PAHs, explosives, and inorganics appear to be the most significant site related ECOCs that have the potential to affect the aquatic and terrestrial receptors at Sites 4 and 21.

7.8.1 Aquatic Ecosystem

The concentrations of chemicals detected in the surface water and sediment indicate a potential risk to the aquatic environment. However, due to the absence of benthic macroinvertebrate data in this investigation, the potential impact of the surface water and sediment to the aquatic environment has uncertainty associated with the magnitude of the impact. In addition, the surface water was evaluated in this ecological RA prior to the completion of a removal action conducted at Site 4. Therefore, the current surface water conditions are not known. Additional aquatic investigations at Sites 4 and 21 are recommended for surface water, sediment, and benthic macroinvertebrate species to further quantify the ecological risk posed to the sites.

7.8.2 Terrestrial Ecosystem

In evaluating the impacts to terrestrial ecosystem, it should be acknowledged that both Sites 4 and 21 have undergone extensive removal actions. The source contamination has been eliminated from the sites and the surface soils have been regraded. Areas where soils were removed were backfilled with clean soil.

Soil concentrations of PAHs and inorganics at Site 4 are significantly greater than some of the effects levels presented in the literature for terrestrial flora and fauna. The removal action at Site 4 was conducted prior to the surface soil sampling event; however, the number and concentrations of contaminants detected in the surface soil at Site 4 indicate a high potential for risk to the terrestrial environment. The results from this screening phase RA indicate that further investigations are warranted at Site 4.

At Site 21, aluminum and zinc were detected at concentrations greater than the literature toxicity data. However, background aluminum concentrations are the same order of magnitude greater than the literature toxicity values as Site 21 concentrations. Zinc was also detected in background surface

soils at concentrations exceeding literature toxicity data. Background zinc concentrations are, however, lower than those concentrations detected at select locations at Site 21. Zinc could potentially affect the terrestrial environment at the site. However, aluminum and zinc were detected at limited soil sampling locations at Site 21 at concentration in excess of background.

7.9 References

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. Toxicological Profile for Endosulfan. Atlanta, Georgia. U.S. Public Health Service. April 1993.

Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Toxicological Profile for Naphthalene and 2-Methylnaphthalene. U.S. Public Health Service. February 1990.

Baes, C.F., A.L. Sharp, and R.W. Shor. September 1984. "Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture." Oak Ridge National Laboratory.

Baker Environmental, Inc. 1995a. Final Habitat Evaluation Report, Sites 1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 16, 17, 18, 19, and 21, Naval Weapons Station Yorktown, Yorktown, Virginia. July 1995.

Baker Environmental, Inc. 1995b. Final Summary of Background Constituent Concentrations and Characterizations of Biotic Community from the York River Drainage Basin. July 1995.

Buhlmann, K.A. and J.C. Ludwig. 1992. A Natural Heritage Resources Inventory and Biological Assessment of the Naval Weapons Station Yorktown, Department of the Navy Yorktown, Virginia. Natural Heritage Technical Report #92-18, Department of Conservation and Recreation, Division of Natural Heritage. Richmond, Virginia. 31 March 1992. 36pp.

Fitchko, J. 1989. Criteria for Contaminated Soil/Sediment Cleanup. Pudvan Publishing Co., Inc. Northbrook IL.

Integrated Risk Information System. 1995. Accessed through Chemical Information Systems, Inc., Baltimore, MD.

Integrated Risk Information System. 1994. Accessed through Chemical Information Systems, Inc., Baltimore, MD.

Long, Edward R., Donald D. Mac Donald, Sherri L. Smith., and Fred Calder. 1995. "Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." Environmental Management. Volume 19.

Long, E. R., and L.G. Morgan. 1990. "The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program." NOAA Technical Memorandum. NOS OMA 62. National Oceanic and Atmospheric Administration, Seattle, WA. Cited in: Sediment Classification Methods Compendium. USEPA - Office of Water. September 1992.

Montgomery, J.H. 1991. Groundwater Chemicals Desk Reference. Lewis Publishers, Inc. Chelsea, Michigan.

Sullivan, J.J. Ball, E. Brick, S. Hausman, G. Pilarski, and D. Sopcich. 1985. Report for the Technical Subcommittee on Determination of Dredge Material Suitability for In-Water Disposal. Wisconsin Department of Natural Resources. Cited in: Criteria for Contaminated Soil/Sediment Cleanup. 1989.

Superfund Chemical Data Matrix (SCDM). 1991. United States Environmental Protection Agency Hazardous Site Evaluation Division. December 1991.

Tetra Tech, Inc. 1986. Development of Sediment Quality Values for Puget Sound. Volume I. Puget Sound Dredged Disposal Analysis Report. Cited in: Criteria for Contaminated Soil/Sediment Cleanup. 1989.

Travis, Curtis C. and Angela Arms. 1988. Bioconcentration of Organics in Beef, Milk, and Vegetation. Environmental Science Technology. Vol. 22, No. 3.

United States Environmental Protection Agency. 1995a. Region III - Biological Technical Assistance Group Screening Levels. Region III, Philadelphia, Pennsylvania. January 1995.

United States Environmental Protection Agency. 1995b. Toxic Substance Spreadsheet. Region IV. Atlanta, Georgia. January 1995.

United States Environmental Protection Agency. 1994. Region III Interim Ecological Risk Assessment Guidelines. Region III, Philadelphia, Pennsylvania.

United States Environmental Protection Agency. 1992a. Framework for Ecological Risk Assessment. Risk Assessment Forum. EPA/630/R-92/001. February 1992.

United States Environmental Protection Agency. 1992b. Surface Water Quality Criteria. Federal Register. Volume 57, No. 246. December 1992.

United States Environmental Protection Agency. 1989a. Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A). Interim Final EPA/540/1-89/002. December, 1989.

United States Environmental Protection Agency. 1989b. Risk Assessment Guidance for Superfund Volume II. Environmental Evaluation Manual Interim Final. Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/1-89-001. March 1989.

United States Environmental Protection Agency. 1989c. Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference. Environmental Research Laboratory, Corvallis, OR. EPA/600/3-89/013. March 1989.

United States Environmental Protection Agency. 1986. Chemical, Physical, and biological Properties of Compounds Present at Hazardous Waste Sites. Office of Solid Waste and Remedial Response. Washington, D.C. EPA/540/1-86/060. October 1986.

VSWCB. Virginia State Water Control Board Regulations. 1992. Water Quality Standards. VR 680-21-00. May 1992.

Will, M.E. and G.W. Suter II. 1994a. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants: 1994 Revision. Environmental Sciences Division, Oak Ridge National Laboratory. September 1994.

Will, M.E. and G.W. Suter II. 1994b. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process. Environmental Sciences Division, Oak Ridge National Laboratory. September 1994.

SECTION 7.0 TABLES

TABLE 7-1

**SITES 4 AND 21 - ECOLOGICAL CONTAMINANTS OF CONCERN PER MEDIA
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant	Site 4 Surface Soil	Site 21 Surface Soil	Surface Water	Sediment
Volatile Organics				
2-Butanone	X			X
1,1,1-Trichloroethane				X
Semivolatile Organics				
Acenaphthene	X			
Acenaphthylene	X	X		
Anthracene	X			
Benzo(a)anthracene	X			
Benzo(b)fluoranthene	X	X		
Benzo(k)fluoranthene	X	X		
Benzo(g,h,i)perylene	X	X		
Benzo(a)pyrene	X			
Carbazole	X			
Chrysene	X			
Dibenzofuran	X			
Dibenz(a,h)anthracene	X			
Di-n-butylphthalate		X	X	
Fluoranthene	X			
Fluorene	X			
Indeno(1,2,3-cd)pyrene	X			
2-Methylnaphthalene	X			
Naphthalene	X			
Phenanthrene	X			
Pyrene	X			
Pesticides/PCBs				
4,4'-DDD	X	X		X
4,4'-DDE				X
4,4'-DDT	X	X		X
alpha-Chlordane				X
gamma-Chlordane				X
Endosulfan II	X			
Aroclor 1254	X			
Aroclor 1260	X			

TABLE 7-1 (Continued)

SITES 4 AND 21 - ECOLOGICAL CONTAMINANTS OF CONCERN PER MEDIA
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Site 4 Surface Soil	Site 21 Surface Soil	Surface Water	Sediment
Explosives				
1,3-Dinitrobenzene	X		X	
HMX	X		X	
RDX	X		X	
1,3,5-Trinitrobenzene			X	
2,4,6-Trinitrotoluene			X	
Inorganics				
Aluminum	X	X	X	
Antimony	X			X
Arsenic	X		X	
Barium			X	
Cadmium	X	X	X	X
Chromium	X			
Cobalt	X		X	X
Copper	X	X	X	
Cyanide, total	X			
Iron			X	
Lead	X		X	X
Manganese	X	X	X	
Mercury	X	X	X	X
Nickel	X	X		
Selenium				X
Thallium	X			
Zinc	X	X	X	X

TABLE 7-2

SITE 4 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Volatile Organics ($\mu\text{g}/\text{kg}$)							
Acetone	NE	1/47	5J	NA	8J - 13	NO	Background
2-Butanone	NE	12/47	4J - 7J	NA	ND	YES	
Methylene Chloride	<300	23/47	1J - 60	0	7J	NO	Below SSSL
Toluene	100	3/47	2J - 27	0	ND	NO	Below SSSL
Trichloroethene	<300	1/47	8J	0	ND	NO	Below SSSL
Semivolatile Organics ($\mu\text{g}/\text{kg}$)							
Acenaphthene	100	10/47	53J - 25,000J	7	ND	YES	
Acenaphthylene	100	9/47	44J - 2,900	5	ND	YES	
Anthracene	100	22/47	43J - 34,000J	13	ND	YES	
Benzo(a)anthracene	100	30/47	41J - 67,000J	25	120J - 240J	YES	
Benzo(b)fluoranthene	100	31/47	45J - 54,000J	26	230J - 500	YES	
Benzo(k)fluoranthene	100	25/47	43J - 7,800	22	120J - 130J	YES	
Benzo(g,h,i)perylene	100	26/47	39J - 14,000	19	ND	YES	
Benzo(a)pyrene	20,000	28/47	38J - 56,000J	1	140J - 180J	YES	
Bis(2-ethylhexyl)phthalate	1,900 ⁽¹⁾	37/47	40J - 640	0	ND	NO	Below SSSL
Butylbenzylphthalate	5,300 ⁽³⁾	2/47	46J - 150J	0	ND	NO	Below SSSL

TABLE 7-2 (Continued)

SITE 4 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Semivolatile Organics (Continued) (µg/kg)							
Carbazole	NE	19/47	43J - 44,000J	NA	ND	YES	
Chrysene	100	30/47	44J - 63,000J	26	150J - 270J	YES	
Di-n-butylphthalate	200,000 ⁽²⁾	29/47	40J - 240J	0	ND	NO	Below SSSL
Di-n-octylphthalate	5,300 ⁽³⁾	1/47	59J	0	ND	NO	Below SSSL/ Infreq. Detect.
Dibenzo(a,h)anthracene	100	8/47	80J - 6,100	7	ND	YES	
Dibenzofuran	540 ⁽¹⁾	8/47	46J - 8,100	2	ND	YES	
Fluoranthene	100	32/47	36J - 140,000J	29	200J - 430	YES	
Flourene	100	12/47	45J - 12,000	8	ND	YES	
Ideno(1,2,3-cd)pyrene	100	27/47	45J - 32,000J	20	160J	YES	
2-Methylnapthalene	NE	4/47	62J - 3,000	NA	ND	YES	
4-Methylphenol	100	1/47	220J	1	ND	NO	Infreq. Detect.
N-Nitrosodiphenylamine	20,000 ⁽⁴⁾	1/47	220J	0	ND	NO	Below SSSL
Napthalene	100	8/47	45J - 8,900	4	ND	YES	
3-Nitroaniline	NE	1/46	1,000J	NA	ND	NO	Infreq. Detect.

TABLE 7-2 (Continued)

SITE 4 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Semivolatile Organics (Continued) ($\mu\text{g}/\text{kg}$)							
Pentachlorophenol	100	1/47	52J	0	ND	NO	Below SSSL
Phenanthrene	100	27/47	54J - 120,000J	25	ND	YES	
Pyrene	100	31/47	56J - 110,000J	26	160J - 320J	YES	
Pesticides/PCBs ($\mu\text{g}/\text{kg}$)							
4,4'-DDE	<100	18/44	1J - 73J	0	ND	NO	Below SSSL
4,4'-DDD	<100	15/44	4.5J - 230J	1	ND	YES	
4,4'-DDT	4	21/44	0.74J - 930J	19	ND	YES	
alpha-Chlordane	<100 ⁽⁵⁾	9/44	0.39J - 38J	0	ND	NO	Below SSSL
gamma-Chlordane	<100 ⁽⁵⁾	7/44	0.13J - 45J	0	ND	NO	Below SSSL
Dieldrin	<100	2/44	8 - 11	0	ND	NO	Below SSSL
Endosulfan II	NE	5/44	3.8J - 20J	NA	ND	YES	
Endrin	<100	1/44	2.6J	0	ND	NO	Below SSSL
Endrin Aldehyde	<100 ⁽⁶⁾	3/44	3J - 11J	0	ND	NO	Below SSSL
Endrin Ketone	<100 ⁽⁶⁾	1/44	8.4J	0	ND	NO	Below SSSL
Heptachlor	<100 ⁽⁷⁾	3/44	0.2J - 31J	0	ND	NO	Below SSSL

TABLE 7-2 (Continued)

SITE 4 - SURFACE SOILS
 FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Pesticides/PCBs (Continued) ($\mu\text{g}/\text{kg}$)							
Heptachlor Epoxide	<100	2/44	1.9J - 2J	0	ND	NO	Below SSSL
Aroclor-1016	40 ⁽⁸⁾	1/44	81J	1	ND	NO	Infreq. Detected
Aroclor-1254	40 ⁽⁸⁾	5/44	64J - 280J	5	ND	YES	
Aroclor-1260	40 ⁽⁸⁾	4/44	53J - 400J	4	ND	YES	
Nitramine Compounds (mg/kg)							
3,5-Dinitrotoluene	NE	4/47	0.22 - 130	NA	1.55	YES	
HMX	NE	3/47	13 - 38	NA	ND	YES	
RDX	NE	5/47	1.2 - 110	NA	ND	YES	
1,3,5-Trinitrobenzene	NE	1/47	0.5	NA	ND	NO	Infreq. Detected
1,3-Dinitrobenzene	NE	1/47	0.97	NA	ND	NO	Infreq. Detected
Inorganics (mg/kg)							
Aluminum	50 ⁽²⁾	47/47	1,380J - 81,200J	47	1,960 - 24,100	YES	
Antimony	0.48	4/47	3.5J - 20.4J	4	9.22 - 11L	YES	
Arsenic	5	46/47	0.94B - 486	19	0.46L - 63.9	YES	
Barium	440	46/47	14.4B - 180	0	4.2B - 80.2	NO	Below SSSL

TABLE 7-2 (Continued)

SITE 4 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Inorganics (Continued) (mg/kg)							
Beryllium	0.02	46/47	0.08B - 1.2	46	0.23B - 0.93B	NO	Background
Cadmium	2.5	19/47	0.59B - 6	6	1.2J - 1.5	YES	
Calcium	NE	46/47	169B - 144,000	NA	39.4J - 7,820	NO	Low Toxicity
Chromium	0.0075	46/47	2.6 - 36.5	46	2.6 - 33.5	YES	
Cobalt	0.1	46/47	0.85B - 14.1	46	0.88B - 6.7B	YES	
Copper	0.04	46/47	1.9B - 337	46	1.2B - 24.4	YES	
Cyanide	NE	3/47	4.8J - 36.8J	NA	ND	YES	
Iron	100	47/47	2,120 - 42,600J	47	1,440 - 46,400	NO	Background
Lead	0.01	47/47	6.3J - 383	47	2.1 - 43.1	YES	
Magnesium	NE	47/47	102J - 1,540	NA	61.5B - 2,700	NO	Background
Manganese	330	47/47	30.9 - 17,700	3	7.6L - 491	YES	
Mercury	0.058	14/47	0.11J - 1.3J	14	0.05B	YES	
Nickel	2.5	47/47	1.9B - 20.3	44	3.8B - 12.5	YES	
Potassium	NE	47/47	107B - 1,600	NA	387B - 1,640B	NO	Background

TABLE 7-2 (Continued)

SITE 4 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detects				
Inorganics (Continued) (mg/kg)							
Silver	2 ⁽²⁾	5/47	0.48B - 1.3B	0	1B - 2.1B	NO	Below SSSL/ Background
Sodium	NE	47/47	19.7J - 1,270B	NA	12B - 115B	NO	Low Toxicity
Thallium	0.001	12/47	0.08J - 0.2B	12	ND	YES	
Vanadium	58	47/47	5.5B - 42.5	0	5.2B - 64.7	NO	BelowSSSL/ Background
Zinc	4.8	47/47	13.6J - 15,200J	47	3.2KB - 48.4	YES	

Notes:

NE - Not Established

NA - Not Applicable

ND - Not Detected

J - Estimated

B - Reported value is less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

K - Biased high

⁽¹⁾ Tetra Tech, 1986 (Sediment Apparent Effects Threshold)

⁽²⁾ Will and Suter, 1994a (Plants)

⁽³⁾ BSL Sediment Screening Level

⁽⁴⁾ Will and Suter, 1994b (Invertebrates)

⁽⁵⁾ Total chlordane level

⁽⁶⁾ Total endrin level

⁽⁷⁾ BSL for Heptachlor Epoxide

⁽⁸⁾ BSL for Total PCBs

TABLE 7-3

SITE 21 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Volatile Organics (µg/kg)							
Acetone	NE	1/14	7J	NA	8J - 13	NO	Background
Methylene Chloride	<300	1/14	60	0	7J	NO	Below SSSL
Styrene	100	1/14	1J	0	ND	NO	Below SSSL
Toluene	100	3/14	1J - 3J	0	ND	NO	Below SSSL
Semivolatile Organics (µg/kg)							
Acenaphthylene	100	1/14	110J	1	ND	YES	
Benzo(a)anthracene	100	1/14	200J	1	120J - 240J	NO	Background
Benzo(b)fluoranthene	100	1/14	910	1	230J - 500	YES	
Benzo(k)fluoranthene	100	1/14	220J	1	120J - 130J	YES	
Benzo(a)pyrene	20,000	1/14	140J	0	140J - 180J	NO	Below SSSL/ Background
Benzo(g,h,i)perylene	100	1/14	110J	1	ND	YES	
Bis(2-ethylhexyl)phthalate	1,900 ⁽⁸⁾	10/14	74J - 260J	0	ND	NO	Below SSSL
Butylbenzylphthalate	5,300 ⁽¹⁾	7/14	43J - 1,400J	0	ND	NO	Below SSSL
Chrysene	100	1/14	260J	1	150J - 270J	NO	Background
Di-n-butylphthalate	200 ⁽⁶⁾	3/14	42J - 360J	1	ND	YES	

TABLE 7-3 (Continued)

SITE 21 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Semivolatile Organics (Continued) (µg/kg)							
Fluoranthene	100	1/14	270J	1	200J - 430	NO	Background
Ideno(1,2,3-cd)pyrene	100	1/14	130J	1	160J	NO	Background
Pyrene	100	1/14	260J	1	160J - 320J	NO	Background
Pesticides/PCBs (µg/kg)							
4,4'-DDD	<100	2/14	30 - 190J	1	ND	YES	
4,4'-DDE	<100	5/14	0.82J - 39	0	ND	NO	Below SSSL
4,4'-DDT	4	2/14	4.3 - 33	2	ND	YES	
Aldrin	100	2/14	11 - 20	0	ND	NO	Below SSSL
gamma-BHC	<100 ⁽⁴⁾	2/14	13 - 22	0	ND	NO	Below SSSL
alpha-Chlordane	<100 ⁽²⁾	2/14	3.2 - 15	0	ND	NO	Below SSSL
gamma-Chlordane	<100 ⁽²⁾	2/14	3 - 13	0	ND	NO	Below SSSL
Dieldrin	<100	2/14	28 - 46	0	ND	NO	Below SSSL
Endrin	<100	2/14	31 - 51	0	ND	NO	Below SSSL
Endrin Ketone	<100 ⁽³⁾	1/14	0.95J	0	ND	NO	Below SSSL
Heptachlor	<100 ⁽⁷⁾	2/14	13 - 22	0	ND	NO	Below SSSL

TABLE 7-3 (Continued)

SITE 21 - SURFACE SOILS
 FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Inorganics (mg/kg)							
Aluminum	50 ⁽⁶⁾	14/14	938 - 43,300	14	1,960 - 24,100	YES	
Arsenic	5	14/14	0.34J - 4B	0	0.46L - 63.9	NO	Background
Barium	440	14/14	4.7B - 50.7B	0	4.2B - 80.2	NO	Below SSSL/ Background
Beryllium	0.02	13/14	0.05B - 0.73B	13	0.23B - 0.93B	NO	Background
Cadmium	2.5	4/14	1.5J - 38.4J	2	1.2J - 1.5	YES	
Calcium	NE	14/14	113B - 4,620	NA	39.4J - 7,820	NO	Background
Chromium	0.0075	14/14	1.9B - 21.9	14	2.6 - 33.5	NO	Background
Cobalt	0.1	13/14	0.48B - 3.9B	13	0.88B - 6.7B	NO	Background
Copper	0.04	14/14	0.87B - 61.9	14	1.2B - 24.4	YES	
Iron	100	14/14	1,400 - 14,400	14	1,440 - 46,400	NO	Background
Lead	0.01	14/14	4.6 - 43	14	2.1 - 43.1	NO	Background
Magnesium	NE	14/14	61.6B - 699B	NA	61.5B - 1,610	NO	Background
Manganese	330	14/14	3.7J - 1,310J	1	7.6L - 491	YES	
Mercury	0.058	4/14	0.18 - 3.5	4	0.5B	YES	
Nickel	2.5	12/14	1.2B - 13.6B	7	3.8B - 12.5	YES	

TABLE 7-3 (Continued)

SITE 21 - SURFACE SOILS
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SOIL SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Surface Soil Screening Levels (SSSLs)	Contaminant Frequency/Range		No. of Positive Detects Above SSSL	Station-wide and Anthropogenic Background	Ecological Chemical of Concern ?	Reason for Exclusion
		No. of Positive Detects/No. of Samples	Range of Positive Detections				
Inorganics (mg/kg) (Continued)							
Potassium	NE	11/14	99.5B - 537B	NA	387B - 1,640B	NO	Background
Selenium	0.26	1/14	0.44B	1	0.053L - 0.61L	NO	Background
Silver	2	1/14	1.3B	0	1B - 2.1B	NO	Below SSSL/ Background
Sodium	NE	14/14	16.1B - 55.1B	NA	12B - 115B	NO	Background
Vanadium	58	14/14	3B - 18.3B	0	5.2B - 64.7	NO	Below SSSL/ Background
Zinc	4.8	14/14	3.6B - 6,780	13	3.2KB - 48.4	YES	

Notes:

NE - Not Established

NA - Not Applicable

ND - Not Detected

J - Estimated

B - Reported value is less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

K - Biased high

(1) BSL Sediment Screening Level

(2) Total chlordane level

(3) Total endrin level

(4) Lindane level

(5) Total PCB Level

(6) Will and Suter, 1994 (Plants)

(7) BSL for Heptachlor Epoxide

(8) Tetra Tech, 1986 (Sediment Apparent Effects Threshold)

TABLE 7-4

SITES 4 AND 21
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III ESTUARINE WATER SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Surface Water Screening Levels (SWSLs)*		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Tidal Freshwater Stream Background	Ecological Contaminant of Concern ?	Reason for Exclusion
	Acute	Chronic	No. of Positive Detects/No. of Samples	Range of Positive Detections	Acute	Chronic			
Semivolatiles (µg/L)									
Di-n-butylphthalate	NE	3.4	1/5	11	NA	1	ND	YES	
Explosives (µg/L)									
1,3,5-Trinitrobenzene	NE	NE	2/5	1.5 - 2.6	NA	NA	ND	YES	
1,3-Dinitrobenzene	NE	NE	2/5	0.32J - 0.34	NA	NA	ND	YES	
2,4,6-Trinitrotoluene	NE	NE	2/5	4.1J - 8.3	NA	NA	ND	YES	
2,4-Dinitrotoluene	NE	370	2/5	0.31J - 0.44J	NA	0	ND	NO	Below SWSL
HMX	NE	NE	4/5	1.4 - 19	NA	NA	ND	YES	
Nitrobenzene	6,680	NE	2/5	0.27J - 0.38J	0	NA	ND	NO	Below SWSL
RDX	NE	NE	4/5	0.41J - 170	NA	NA	ND	YES	
Inorganics (µg/L)									
Aluminum	NE	NE	5/5	57.1 - 40,500	NA	NA	171B-5,600	YES	
Arsenic	69 ⁽¹⁾	13 ⁽²⁾	3/5	2.6J - 43.4	0	1	1.2L-3.5L	YES	
Barium	NE	NE	5/5	20 - 243	NA	NA	26.7B-49.1B	YES	
Cadmium	43 ⁽¹⁾	9.3	1/5	11.6	0	1	5.1K-6.7K	YES	
Calcium	NE	NE	5/5	65,900J - 116,000J	NA	NA	29,200J-198,000J	NO	Background

TABLE 7-4 (Continued)

SITES 4 AND 21
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III ESTUARINE WATER SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Surface Water Screening Levels (SWSLs)*		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Tidal Freshwater Stream Background	Ecological Contaminant of Concern ?	Reason for Exclusion
	Acute	Chronic	No. of Positive Detects/No. of Samples	Range of Positive Detections	Acute	Chronic			
Inorganics (Continued) (µg/L)									
Chromium	10,300 ⁽³⁾	50 ⁽⁴⁾	1/5	46	0	0	ND	NO	Below SWSL
Cobalt	NE	NE	1/5	25.2	NA	NA	5.3B-8.5B	YES	
Copper	2.9	2.9 ⁽¹⁾	2/5	7.7J - 200	2	2	5.6B-6.7B	YES	
Iron	NE	NE	5/5	1,050 - 143,000	NA	NA	289J-6,650	YES	
Lead	220 ⁽¹⁾	5.1	4/5	2.8J - 215J	0	3	1.2L-5.4L	YES	
Magnesium	NE	NE	5/5	3,610J - 272,000J	NA	NA	23,000-656,000J	NO	Background
Manganese	NE	10	5/5	83.5J - 1,020J	NA	5	33.1-379	YES	
Mercury	2.1 ⁽¹⁾	0.025	2/5	0.13 - 5.56	1	2	ND	YES	
Nickel	75 ⁽¹⁾	8.3	2/5	20.1 - 29	0	2	19.8K-55.5K	NO	Background
Potassium	NE	NE	5/5	1,790J - 89,900J	NA	NA	8,950-220,000J	NO	Background
Sodium	NE	NE	5/5	4,560J - 997,000	NA	NA	180,000-5,760,000J	NO	Background

TABLE 7-4 (Continued)

SITES 4 AND 21
 FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III ESTUARINE WATER SCREENING LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Surface Water Screening Levels (SWSLs)*		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Tidal Freshwater Stream Background	Ecological Contaminant of Concern ?	Reason for Exclusion
	Acute	Chronic	No. of Positive Detects/No. of Samples	Range of Positive Detects	Acute	Chronic			
Vanadium	<10,000	NE	2/5	6.4J - 37.8J	0	NA	7.7B-13.6B	NO	Below SWSL
Zinc	95 ⁽¹⁾	86	3/5	61.1 - 3,880	2	2/3	7.9B-20.2	YES	

Notes:

* Values are based on Region III BTAG Screening Levels unless otherwise indicated.

NE = Not Established

NA = Not Applicable

J - Estimated

B - Reported value is less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

K - Biased high

L - Biased low

⁽¹⁾ USEPA Ambient Water Quality Criteria and Virginia Water Quality Standards

⁽²⁾ Value for Arsenic V

⁽³⁾ Value for Chromium III

⁽⁴⁾ Value for Chromium VI

TABLE 7-5

SITES 4 AND 21
FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SEDIMENT SCREENING LEVELS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Sediment Screening Values (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Tidal Freshwater Stream Background	Ecological Contaminant of Concern?	Reason for Exclusion
	ER-L/BSLs	ER-M ⁽²⁾⁽⁴⁾	No. of Positive Detects/No. of Samples	Range of Positive Detections				
Volatile Organics (µg/kg)								
2-Butanone	NE	NE	1/10	200J	NA	13J-38J	YES	
Carbon Disulfide	NE	NE	1/10	40	NA	7J-120J	NO	Background
Methylene Chloride	<300 ⁽¹⁾	NE	1/10	13J	0	9J-67J	NO	Below SSL/ Background
1,1,1-Trichlorethane	NE	NE	1/10	6J	NA	ND	YES	
Semivolatile Organics (µg/kg)								
Benzo(g,h,i)perylene	670	NE	1/10	340J	0	ND	NO	Below SSL
Pesticides/PCBs (µg/kg)								
4,4'-DDD	2 ⁽²⁾	20	6/6	15J - 910D	6	ND	YES	
4,4'-DDE	2.2	27	6/6	3.2J - 56J	6	ND	YES	
4,4'-DDT	1.58 ⁽⁴⁾	7	3/6	5J - 15J	3	ND	YES	
alpha-Chlordane	0.5 ⁽²⁾⁽³⁾	6 ⁽³⁾	3/6	5J - 40J	3	ND	YES	
gamma-Chlordane	0.5 ⁽²⁾⁽³⁾	6 ⁽³⁾	2/6	4.2J -33	2	ND	YES	

TABLE 7-5 (Continued)

SITES 4 AND 21
 FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SEDIMENT SCREENING LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Sediment Screening Values (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Tidal Freshwater Stream Background	Ecological Contaminant of Concern?	Reason for Exclusion
	ER-L/BSLs	ER-M ⁽²⁾⁽⁴⁾	No. of Positive Detects/ No. of Samples	Range of Positive Detections				
Inorganics (mg/kg)								
Aluminum	NE	NE	10/10	5,720J - 32,900J	NA	1,510-40,500	NO	Background
Antimony	3.2 ⁽⁵⁾	NE	1/10	43.1	1	18.9L	YES	
Arsenic	8.2	70	7/10	2.5 - 9.7J	2	1.4B-13.1	NO	Background
Barium	500 ⁽⁶⁾	NE	10/10	15 - 41.7	0	3.9B-93.2B	NO	Below SSL/ Background
Beryllium	0.36 ⁽⁵⁾	NE	3/10	0.81 - 1.5	3	0.55B-1.6B	NO	Background
Cadmium	0.676	9.6	3/10	1.76 - 2.99	3	ND	YES	
Calcium	NE	NE	10/10	920 - 5,530	NA	217B-4,270	NO	Naturally Occurring/ Low Toxicity
Chromium	81	370	7/10	4.3 - 34.2	0	3.8-66.1	NO	Below SSL/ Background
Cobalt	1.5 ⁽¹⁾	NE	7/10	7 - 17.6	7	3.8B-15B	YES	
Copper	34	270	10/10	0.03 - 33.6J	0	3.7B-43.1	NO	Below SSL/ Background
Iron	27,000 ⁽⁵⁾	NE	10/10	341J - 41,700J	3	3,060-46,000	NO	Background

TABLE 7-5 (Continued)

SITES 4 AND 21
 FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SEDIMENT SCREENING LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Sediment Screening Values (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Tidal Freshwater Stream Background	Ecological Contaminant of Concern?	Reason for Exclusion
	ER-L/BSLs	ER-M ⁽²⁾⁽⁴⁾	No. of Positive Detects/No. of Samples	Range of Positive Detections				
Inorganics (Continued) (mg/kg)								
Lead	46.7	218	10/10	6.9J - 114.8J	1	3.4-51.6	YES	
Magnesium	NE	NE	10/10	155 - 8,130J	NA	292B-9,720K	NO	Background
Manganese	230 ⁽⁴⁾	NE	10/10	29J - 468J	5	7.4-1,980	NO	Background
Mercury	0.15	0.71	7/10	0.13 - 0.61	6	0.18L-0.29L	YES	
Nickel	20.9	51.6	4/10	12.3 - 33.6	1	9.3K-55.2	NO	Background
Potassium	NE	NE	5/10	1,080 - 3,760	NA	1,200B-6,080	NO	Background
Selenium	>1.0 ⁽⁵⁾	NE	2/10	1.1J - 2.5	2	0.46L-1.5L	YES	
Sodium	NE	NE	9/10	27.9 - 15,900J	NA	177B-16,700	NO	Background

TABLE 7-5 (Continued)

SITES 4 AND 21
 FREQUENCY AND RANGE OF DETECTION COMPARED TO USEPA REGION III SEDIMENT SCREENING LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Contaminant	Sediment Screening Values (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Tidal Freshwater Stream Background	Ecological Contaminant of Concern?	Reason for Exclusion
	ER-L/BSLs	ER-M ⁽²⁾⁽⁴⁾	No. of Positive Detects/No. of Samples	Range of Positive Detections				
Vanadium	58 ⁽¹⁾	NE	10/10	3.9 - 44.6	0	4.8B-67.6	NO	Below SSL/Background
Zinc	150	410	10/10	124 - 1,200J	9	4B-202J	YES	

Notes:

- NE = Not Established
- NA = Not Applicable
- J = Estimated
- D - Diluted
- ER-L = Effects Range Low
- ER-M = Effects Range - Median
- BSL = Biological Technical Assistance Group
- B - Reported value is less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).
- K - Biased high
- L - Biased low

- ⁽¹⁾ Region III BTAG Screening level for soil-fauna
- ⁽²⁾ Long and Morgan, 1990
- ⁽³⁾ Value for total chlordane
- ⁽⁴⁾ Long et al., 1995
- ⁽⁵⁾ Tetra Tech, 1986
- ⁽⁶⁾ Sullivan et al., 1985

TABLE 7-6

**SITES 4 AND 21 - PHYSICAL/CHEMICAL CHARACTERISTICS
OF THE ECOLOGICAL CONTAMINANTS OF CONCERN
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant of Concern	BCF	Organic Carbon Partition Coefficient (mL/g)	Log Octanol/Water Coefficient	Biotransfer Factors		
				$B_v^{(1)(2)}$	$B_f^{(1)(2)}$	$B_b^{(1)(2)}$
Volatile Organics						
2-Butanone	ND	4.5 ⁽⁵⁾	0.29 ⁽⁶⁾	2.63×10^{-1}	2.63×10^{-1}	4.90×10^{-8}
Semivolatile Organics						
Acenaphthene	242 ⁽³⁾	5,754 ⁽¹⁰⁾	3.9 ⁽⁶⁾	2.16×10^{-1}	2.16×10^{-1}	2.00×10^{-4}
Acenaphthylene	30 ⁽⁴⁾	2,500 ⁽⁵⁾	4.1 ⁽⁶⁾	1.65×10^{-1}	1.65×10^{-1}	3.16×10^{-4}
Anthracene	16,800 ⁽³⁾	14,000 ⁽⁵⁾	4.5 ⁽⁶⁾	9.70×10^{-2}	9.70×10^{-2}	7.94×10^{-4}
Benzo(a)anthracene	9,200 ⁽³⁾	1,380,000 ⁽⁵⁾	5.7 ⁽⁶⁾	2.00×10^{-2}	2.00×10^{-2}	1.26×10^{-2}
Benzo(a)pyrene	930 ⁽³⁾	5,500,000 ⁽⁵⁾	6.0 ⁽⁶⁾	1.30×10^{-2}	1.30×10^{-2}	2.51×10^{-2}
Benzo(b)fluoranthene	30 ⁽⁴⁾	550,000 ⁽⁵⁾	6.6 ⁽⁶⁾	6.00×10^{-3}	6.00×10^{-3}	1.00×10^{-1}
Benzo(k)fluoranthene	30 ⁽⁴⁾	550,000	6.1 ⁽⁵⁾	1.20×10^{-2}	1.20×10^{-2}	3.16×10^{-2}
Benzo(g,h,i)perylene	30 ⁽⁴⁾	1,600,000 ⁽⁵⁾	6.5 ⁽⁵⁾	7.00×10^{-3}	7.00×10^{-3}	7.94×10^{-2}
Carbazole	ND	ND	6 ⁽⁸⁾	1.30×10^{-2}	1.30×10^{-2}	2.51×10^{-2}
Chrysene	30 ⁽⁴⁾	200,000 ⁽⁵⁾	5.7 ⁽⁶⁾	2.00×10^{-2}	2.00×10^{-2}	1.26×10^{-2}
Dibenz(a,h)anthracene	30 ⁽⁴⁾	3,300,000 ⁽⁵⁾	6.5 ⁽⁶⁾	7.00×10^{-3}	7.00×10^{-3}	7.94×10^{-2}
Dibenzofuran	ND	ND	6 ⁽⁸⁾	1.30×10^{-2}	1.30×10^{-2}	2.51×10^{-2}
Di-n-butylphthalate	89 ⁽⁴⁾	170,000 ⁽⁵⁾	5.2 ⁽⁶⁾	3.80×10^{-2}	3.80×10^{-2}	3.98×10^{-3}
Fluoranthene	1,150 ⁽⁴⁾	38,000 ⁽¹¹⁾	4.9 ⁽⁵⁾	5.70×10^{-2}	5.70×10^{-2}	2.00×10^{-3}
Fluorene	30 ⁽⁴⁾	7,300 ⁽⁵⁾	4.2 ⁽⁶⁾	1.45×10^{-1}	1.45×10^{-1}	3.98×10^{-4}
Indeno(1,2,3-cd)pyrene	30 ⁽⁴⁾	1,600,000 ⁽⁵⁾	6.5 ⁽¹⁵⁾	7.00×10^{-3}	7.00×10^{-3}	8.13×10^{-2}
2-Methylnaphthalene	3 ⁽⁹⁾	1,072 ⁽⁹⁾	3.6 ⁽⁹⁾	3.22×10^{-1}	3.22×10^{-1}	1.00×10^{-4}
Naphthalene	3 ⁽³⁾	1,072 ⁽¹²⁾	3.6 ⁽⁶⁾	3.22×10^{-1}	3.22×10^{-1}	1.00×10^{-4}
Phenanthrene	30 ⁽⁴⁾	28,840 ⁽¹³⁾	4.5 ⁽⁵⁾	9.70×10^{-2}	9.70×10^{-2}	7.94×10^{-4}
Pyrene	970 ⁽³⁾	38,000 ⁽⁵⁾	5.3 ⁽⁶⁾	3.30×10^{-2}	3.30×10^{-2}	5.01×10^{-3}
Pesticides/PCBs						
4,4'-DDD	52,500 ⁽³⁾	770,000 ⁽⁵⁾	6 ⁽⁶⁾	1.32×10^{-2}	1.32×10^{-2}	2.51×10^{-2}
4,4'-DDT	21,580 ⁽³⁾	243,000 ⁽⁵⁾	6.4 ⁽⁶⁾	8.00×10^{-3}	8.00×10^{-3}	6.31×10^{-2}
Chlordane	14,100 ⁽⁴⁾	140,000 ⁽⁵⁾	5.5 ⁽⁶⁾	2.60×10^{-2}	2.60×10^{-2}	7.94×10^{-3}
Endosulfan II	270 ⁽⁴⁾	3,162 ⁽¹⁴⁾	3.6 ⁽⁶⁾	3.22×10^{-1}	3.22×10^{-1}	1.00×10^{-4}
PCBs, total	270,000 ⁽³⁾	530,000 ⁽⁵⁾	5.6 ⁽⁶⁾	2.20×10^{-2}	2.20×10^{-2}	1.00×10^{-2}

TABLE 7-7

**SITE 4 - RANGE AND 95% UCL OF CONTAMINANT DETECTIONS
COMPARED TO SOIL FLORA AND FAUNA TOXICITY VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant	Soil Flora and Fauna Toxicity Values ⁽¹⁾				Range of Positive Detections	95% Upper Confidence Limit
	Plant	Earthworm	Invertebrate	Microorganisms and Microbial Processes		
Volatile Organics (µg/kg)						
2-Butanone	NE	NE	NE	NE	4J - 7J	6
Semivolatile Organics (µg/kg)						
Acenaphthene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	5 3J - 25,000J	1,733
Acenaphthylene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	44J - 2,900	372
Anthracene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	43J - 34,000J	2,346
Benzo(a)anthracene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	41J - 67,000J	4,787
Benzo(b)fluoranthene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	45J - 54,000J	4,002
Benzo(k)fluoranthene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	43J - 7,800	891
Benzo(g,h,i)perylene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	39J - 14,000	1,315
Benzo(a)pyrene	NE	20,000 ⁽²⁾	25,000	NE	38J - 56,000J	4,056
Carbazole	NE	NE	NE	NE	43J - 44,000J	2,846
Chrysene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	44J - 63,000J	4,578
Dibenzo(a,h)anthracene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	80J - 6,100	608
Dibenzofuran	NE	NE	NE	NE	46J - 8,100	689
Fluoranthene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	36J - 140,000J	9,915
Fluorene	NE	30,000	100 ⁽²⁾	NE	45J - 12,000	937
Indeno(1,2,3-cd)pyrene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	45J - 32,000J	2,362
4-Methylnaphthalene	NE	NE	NE	NE	62J - 3,000	268
Naphthalene	100 ⁽⁴⁾	100 ⁽²⁾	100 ⁽²⁾	NE	45J - 8,900	717
Phenanthrene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	54J - 120,000J	8,121
Pyrene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	56J - 110,000J	7,827
Pesticides/PCBs (µg/kg)						
4',4-DDD	NE	100 ⁽²⁾	100 ⁽²⁾	NE	4.5J - 230J	24
4',4-DDT	NE	4 ⁽²⁾	4 ⁽²⁾	NE	0.74J - 930J	76
Endosulfan II	1,000 ⁽³⁾	NE	NE	NE	3.8J - 20J	3

TABLE 7-7 (Continued)

**SITE 4 - RANGE AND 95% UCL OF CONTAMINANT DETECTIONS
COMPARED TO SOIL FLORA AND FAUNA TOXICITY VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Contaminant	Soil Flora and Fauna Toxicity Values ⁽¹⁾				Range of Positive Detections	95% Upper Confidence Limit
	Plant	Earthworm	Invertebrate	Microorganisms and Microbial Processes		
Pesticides/PCBs (Continued) (µg/kg)						
Aroclor-1016 ⁽⁴⁾	40,000	40 ⁽²⁾	40 ⁽²⁾	NE	81	24
Aroclor-1254 ⁽⁴⁾	40,000	40 ⁽²⁾	40 ⁽²⁾	NE	64 - 280	42
Aroclor-1260 ⁽⁴⁾	40,000	40 ⁽²⁾	40 ⁽²⁾	NE	53J - 400J	49
Inorganics (mg/kg)						
Aluminum	50	NE	NE	600	1,380J - 81,200J	12,748
Antimony	5	NE	NE	NE	3.5J - 20.4J	2.79
Arsenic	10	60	NE	100	0.94B - 486	33
Cadmium	3	20	3	20	0.59B - 6	1
Chromium	1	0.4	NE	10	2.6-36.5	13.05
Cobalt	20	1,500 ⁽²⁾	1,500 ⁽²⁾	1,000	0.85B - 14.1	4
Copper	100	50	20	100	1.9B - 337	38
Cyanide	NE	NE	NE	NE	4.8J - 36.8J	4
Lead	50	500	300	900	6.3J - 383	61
Manganese	500	330 ⁽²⁾	330 ⁽²⁾	100	30.9 - 17,700	1,173
Mercury	0.3	0.1	300	30	0.11J - 1.3J	0.19
Nickel	30	200	NE	90	1.9B - 20.3	7
Thallium	1	NE	NE	NE	0.08J - 0.2B	0.13
Zinc	50	200	500	100	13.6J - 15,200J	976

Notes:

NE - Not Established

J - Estimated

B - Reported value is less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL)

⁽¹⁾ Will and Suter, 1994a and 1994b unless indicated otherwise (Values presented for plants, earthworms, and microorganisms and microbial processes are benchmarks below which adverse impacts to these species are not expected. Values for invertebrates are No Observed Effects Concentrations; however, they are based on less data than the benchmarks)

⁽²⁾ USEPA, 1995 (Region III BTAG Soil Screening Values for Soil Fauna)

⁽³⁾ Hulzebos et al., 1993 (EC50)

⁽⁴⁾ Value for total PCBs

TABLE 7-8

**SITE 21 - RANGE AND 95% UCL OF CONTAMINANT DETECTIONS
COMPARED TO SOIL FLORA AND FAUNA TOXICITY VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN YORKTOWN, VIRGINIA**

Contaminant	Soil Flora and Fauna Toxicity Values ⁽¹⁾				Range of Positive Detections	95% Upper Confidence Limit
	Plant	Earthworm	Invertebrate	Microorganisms and Microbial Processes		
Semivolatile Organics (µg/kg)						
Acenaphthylene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	110J	381
Benzo(b)fluoranthene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	52J - 910	466
Benzo(k)fluoranthene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	220J	220
Benzo(g,h,i)perylene	NE	100 ⁽²⁾	100 ⁽²⁾	NE	37J - 110J	110
Di-n-butylphthalate	200,000	NE	NE	NE	42J - 360J	360
Pesticides/PCBs (µg/kg)						
4',4-DDD	NE	100 ⁽²⁾	100 ⁽²⁾	NE	2.8J - 190J	41
4',4-DDT	NE	4 ⁽²⁾	4 ⁽²⁾	NE	4.3 - 38J	11
Inorganics (mg/kg)						
Aluminum	50	NE	NE	600	938 - 43,300	11,567
Cadmium	3	20	3	20	0.66B - 38.4J	10
Copper	100	50	20	100	0.87B - 61.9	21
Lead	50	500	300	900	4.6 - 68.9J	21
Manganese	500	330 ⁽²⁾	330 ⁽²⁾	100	3.7J - 1,310J	322
Mercury	0.3	0.1	300	30	0.1J - 3.5	0.97
Nickel	30	200	NE	90	1.2B - 13.6B	5
Zinc	50	200	500	100	3.6B - 6,780	1,499

Notes:

NE - Not Established

J - Estimated

B - Reported value is less than the Contract Required Detection Limit (CRDL), but greater than the Instrument Detection Limit (IDL).

⁽¹⁾ Will and Suter, 1994a and 1994b unless indicated otherwise (Values presented for plants, earthworms, and microorganisms and microbial processes are benchmarks below which adverse impacts to these species are not expected. Values for invertebrates are No Observed Effects Concentrations; however, they are based on less data than the benchmarks)

⁽²⁾ USEPA, 1995 (Region III BTAG Soil Screening Values for Soil Fauna)

TABLE 7-9

SITES 4 AND 21 - SURFACE WATER QUOTIENT INDEX LEVELS
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Sample Number	Sample Concentration	Surface Water Screening Levels Quotient Index	
			Acute	Chronic
Volatile Organics (µg/L)				
Di-n-butylphthalate	4SW03-001	11	NA	3.24
Explosives (µg/L)				
1,3,5-Trinitrobenzene	NA	NA	NA	NA
1,3-Dinitrobenzene	NA	NA	NA	NA
2,4,6-Trinitrotoluene	NA	NA	NA	NA
HMX	NA	NA	NA	NA
RDX	NA	NA	NA	NA
Inorganics (µg/L)				
Arsenic	4SW02-001	43.4	0.63	3.34
Cadmium	4SW03-001	11.6	0.27	1.23
Copper	4SW03-001	200	68.97	68.97
	4SW05-001	7.7J	2.66	2.66
Lead	4SW03-001	215J	0.98	42.16
	4SW04-001	6.5J	0.03	1.27
	4SW05-001	12.5J	0.06	2.45
Manganese	4SW02-001	208J	NA	20.80
	4SW03-001	1,020J	NA	102.00
	4SW04-001	83.5J	NA	8.35
	4SW05-001	997J	NA	99.7
	4SW06-001	503J	NA	50.30
Mercury	4SW05-001	5.56	2.65	222.4
	4SW06-001	0.13	0.06	5.20
Nickel	4SW03-001	20.1	0.27	2.49
	4SW05-001	29	0.39	3.50
Zinc	4SW03-001	3,880	40.84	45.12
	4SW05-001	786	8.27	9.14

Notes:

NA = Not Applicable
 J = Estimated Value

TABLE 7-10

**SITES 4 AND 21 - SEDIMENT QUOTIENT INDEX
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA**

Analyte	Sample Number	Sample Concentration	Sediment Screening Level Quotient Index	
			BSL/ER-L	ER-M
Volatile Organics (µg/kg)				
2-Butanone	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	NA
Pesticides/PCBs (µg/kg)				
alpha-Chlordane	4SD04-001	5.9J	11.80	0.98
	4SD04-002	40J	80.00	6.67
	4SD05-001	5J	10.00	0.84
gamma-Chlordane	4SD04-001	4.2J	8.40	0.70
	4SD04-002	33	66.00	5.50
4,4'-DDD	4SD03-001	32	16.00	1.60
	4SD03-002	21	10.50	1.05
	4SD04-001	160	80.00	8.00
	4SD04-002	910D	455.00	45.50
	4SD05-001	44J	22.00	2.20
	4SD05-002	15J	7.50	0.75
4,4'-DDE	4SD03-001	5.4J	2.45	0.20
	4SD03-002	3.2J	1.45	0.12
	4SD04-001	8.4J	3.82	0.32
	4SD04-002	56J	28.45	2.07
	4SD05-001	8.9J	4.05	0.33
	4SD05-002	3.5J	1.59	0.13
4,4'-DDT	4SD03-001	15J	9.49	2.14
	4SD04-001	5J	3.16	0.71
	4SD04-002	9.6NJ	6.08	1.37

TABLE 7-10 (Continued)

SITES 4 AND 21 - SEDIMENT QUOTIENT INDEX
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Sample Number	Sample Concentration	Sediment Screening Level Quotient Index	
			BSL/ER-L	ER-M
Inorganics (mg/kg)				
Antimony	4SD02-002	43.1	13.47	NA
Cadmium	4SD03-002	2.1	3.11	0.22
	4SD04-001	2.99	4.42	0.31
	4SD04-002	1.76	2.60	0.18
Cobalt	4SD02-002	17.6	11.73	NA
	4SD03-001	7	4.67	NA
	4SD04-002	8.37	5.38	NA
	4SD05-001	9.3	6.20	NA
	4SD05-002	8	5.34	NA
	4SD06-001	7	4.67	NA
	4SD06-002	9.8	6.54	NA
Lead	4SD04-001	114.8J	2.46	0.53
Mercury	4SD03-001	0.61	4.07	0.86
	4SD04-001	0.24	1.60	0.34
	4SD04-002	0.21	1.40	0.30
	4SD05-001	0.34	2.27	0.48
	4SD05-002	0.26	1.74	0.37
	4SD06-002	0.21	1.40	0.30
Selenium	4SD04-001	1.1J	1.10	NA
	4SD04-002	2.5	2.50	NA

TABLE 7-10 (Continued)

SITES 4 AND 21 - SEDIMENT QUOTIENT INDEX
 CTO-0297
 NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Analyte	Sample Number	Sample Concentration	Sediment Screening Level Quotient Index	
			BSL/ER-L	ER-M
Zinc	4SD02-002	161	1.07	0.39
	4SD03-001	330J	2.20	0.80
	4SD03-002	187J	1.25	0.46
	4SD04-001	508J	3.39	1.24
	4SD04-002	454J	3.03	1.11
	4SD05-001	1,200J	8.00	2.93
	4SD05-002	577J	3.85	1.41
	4SD06-001	184J	1.23	0.45
	4SD06-002	174J	1.16	0.42

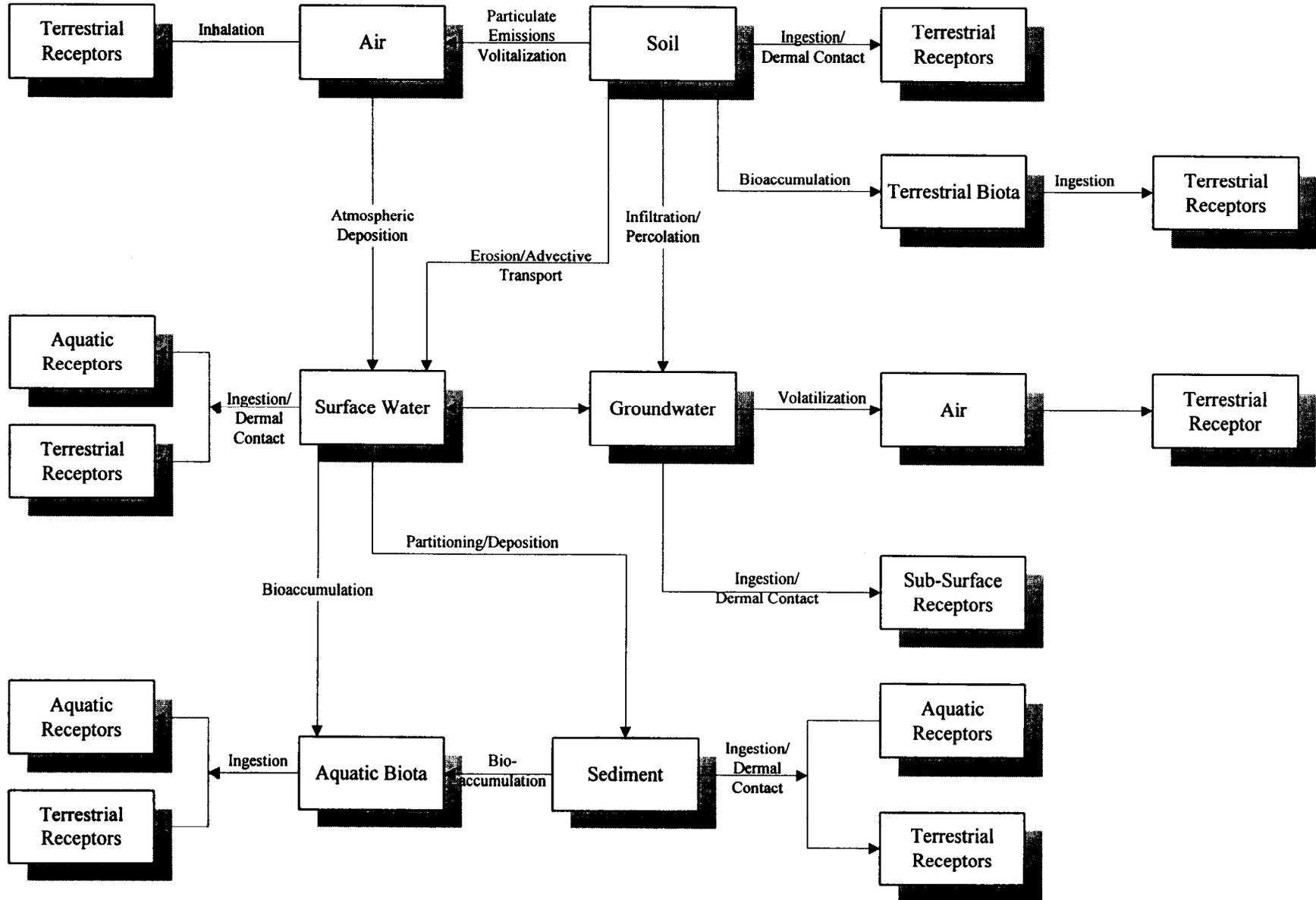
Notes:

- NE = Not Established
- J = Estimated
- D = Diluted
- N = Tentative identification - consider analyte present.
- ER-L = Effects Range-Low
- ER-M = Effects Range - Median
- NA = Not Applicable

SECTION 7.0 FIGURES

FIGURE 7-1

SITES 4 AND 21 - POTENTIAL EXPOSURE PATHWAYS AND ECOLOGICAL RECEPTORS
CTO-0297
NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA



8.0 SUMMARY AND CONCLUSIONS

A summary of the results of the Post-Removal Report is presented in this section with respect to nature and extent of contamination, the human health risk assessment, and the ecological risk assessment. Recommendations based on these results are also presented in this section.

8.1 Nature and Extent of Contamination

Data was obtained during the Round One RI at Sites 4 and 21 for the following media: surface soil, subsurface soil, groundwater, surface water, and sediment. Surface and subsurface soil data was obtained from the Removal Action confirmation sampling. Based on this data the following conclusions were reached for each media.

8.1.1 Surface Soil

8.1.1.1 Site 4

With respect to organics, PAHs were the most predominant contaminants detected at Site 4. Two areas within the site exhibited levels of PAHs as high as 53,250 µg/kg and 562,680 µg/kg. These two areas were located in the northwest and southwest corners of the site (see Figure 8-1). The other organics detected at Site 4 (i.e., VOCs, other SVOCs, and pesticides) did not appear to be of concern and/or present due to past site operations. PCBs were detected at concentrations (ranging from 53 µg/kg to 400 µg/kg) which are not characteristic of PCB disposal activities.

Explosive constituents were detected in three surface soil samples in the northeast portion of Site 4. The detected concentrations were 15 mg/kg, 60 mg/kg, and 99 mg/kg. These detections were isolated and most likely indicative of past operations. The presence of these compounds correlated with locations found in previous investigations where explosives were identified at greater concentrations. The Removal Action addressed those areas.

With respect to inorganics, several compounds were detected at concentrations orders of magnitude above Station background samples. No distinct patterns of inorganic contamination were present

which was probably due to the widespread surface disposal activities which had reportedly occurred at the sites.

There do not appear to be any significant data gaps in surface soil data for Site 4. A total of 42 surface soil confirmation samples (0 to 6 inches) were collected at the site for the Removal Action. Six surface soil samples (0 to 2 feet) were collected as part of the Round One RI investigation. The samples were distributed throughout the Site 4 area.

8.1.1.2 Site 21

With respect to organics, relatively low levels of PAHs and pesticides were the most detected compounds in the Site 21 surface soil samples collected from the Removal Action. The detected concentrations do not appear to be indicative of past disposal activities. PCBs and explosives were not detected in the surface soil samples.

Several inorganic constituents were detected in the surface soil samples. Levels of aluminum as high as 43,300 mg/kg were detected in a limited area in the northern-most portion of the site. This is immediately south of the former ash pile located within Site 4. Levels of zinc as high as 6,780 mg/kg and 1,570 mg/kg were detected in the southwestern portion of the site, immediately adjacent to the unnamed drainage way. The presence of aluminum in soils collected at Site 21 may be related to runoff from the former ash pile at Site 4. The presence of zinc may be related to runoff from the former ash pile and/or from the prior disposal of dry carbon-zinc batteries at Site 21.

Twelve surface soil confirmation samples (0 to 6 inches) were collected as part of the Removal Action. Fourteen surface soil samples (0 to 2 feet) were collected during the Round One RI. The samples were distributed throughout the Site 21 area.

8.1.2 **Subsurface Soil**

8.1.2.1 Site 4

Subsurface soil samples were not collected at Site 4 during the Round One RI. With respect to the Removal Action, 42 confirmation soil samples have been identified as surface soil samples. It should be noted that a few of the samples, specifically the ones located within excavation areas, may

actually be subsurface soil samples. For purposes of this report, all of the confirmation soil samples collected at Site 4 have been assumed to be surface (0 to 6 inches). Therefore, additional subsurface soil data is necessary for Site 4.

8.1.2.2 Site 21

One subsurface soil sample was collected from one soil boring/monitoring well installed during the Round One RI (21GW04). No organic compounds were detected in this Round One RI subsurface soil sample. Several inorganic compounds were detected in the sample.

Six of the soil samples collected during the Removal Action were collected below ground surface within the excavation area at Site 21. Since the Removal Action involved excavating the majority of the area within Site 21 to a depth of 2 to 6 feet (due to the depth the batteries were found) then replacing and regrading the excavation with clean fill, these six samples were assumed to be subsurface soil samples. There does not appear to be a need for any additional subsurface soil data at Site 21 within the areas of excavation.

8.1.3 **Groundwater**

8.1.3.1 Site 4

With respect to organics, VOCs and explosives were detected in the downgradient groundwater samples collected at Site 4. The VOCs included TCE, 1,2-DCE, 1,1-DCE, and 1,1,1-TCA. TCE concentrations exceeded Federal drinking water criteria in two wells. The source and the extent of the TCE contamination could not be defined based on the available data. The explosives detected in the groundwater samples included RDX and HMX. The concentrations did not exceed Federal or State standards.

With respect to inorganics, several inorganics (total) were detected in the groundwater samples that exceeded Federal and/or State standards. To a lesser extent, dissolved inorganic concentrations also exceeded the standards for a few of the inorganics. The source and the extent of the inorganic detected in the groundwater could not be defined based on the available data.

The following data gaps identified related to groundwater at Site 4:

- Only one round of groundwater samples were collected at Site 4. This round of sampling was conducted during the Round One RI investigation in 1992. No groundwater samples have been collected since the Removal Action to assess possible changes related to probable source removal.
- The downgradient extent of the groundwater contamination has not been defined. There are no wells to the southwest of well 4GW04.
- The source of the groundwater contamination has not been defined or confirmed. There are no wells located within the Site 4 boundary.
- The vertical extent of groundwater contamination cannot be defined since there are no deep groundwater monitoring wells at Site 4.

8.1.3.2 Site 21

Organic compounds were not detected in the groundwater samples collected at Site 21. Even though these samples were collected during the Round One RI, it is not anticipated that any organic contamination would currently exist at the site especially following the extensive source removal actions that were conducted at Site 21.

With respect to inorganics, several inorganics (total) were detected in the groundwater samples that exceeded Federal and/or State standards. To a lesser extent, dissolved inorganic concentrations also exceeded the standards for a few of the inorganics. The source and the extent of the inorganics detected in the groundwater could not be defined based on the available data.

The following data gaps identified related to groundwater at Site 21:

- Only one round of groundwater samples was collected at Site 21. This round of sampling was conducted during the Round One RI investigation in 1992. No

groundwater samples have been collected since the Removal Action to assess possible changes related to probable source removal.

- The extent of the inorganic groundwater contamination has not been defined. All of the existing wells exhibited inorganic contamination which in both total and dissolved samples Federal or state standards.
- The vertical extent of groundwater contamination has not been defined since there are no deep groundwater monitoring wells at Site 21.

8.1.4 Surface Water

Five surface water samples were collected in the unnamed drainage way adjacent to Sites 4 and 21 and in Felgates Creek during the Round One RI investigation. No surface water samples were collected during the Removal Action.

With respect to organics, one SVOC (di-n-butylphthalate) and several explosives were detected in the samples. The explosives included RDX, HMX, 1,3,5-TNB, 1,3-DNB, nitrobenzene, 2,4,6-TNT, and 2,4-DNT. The highest detected concentrations were found in the two samples located immediately downgradient of the Sites 4 and 21 (in the unnamed drainage way).

Several inorganics were detected in the surface water samples. The highest detected concentrations were found in the sample collected to the east of Site 4 and north of Site 21.

The following data gaps identified related to surface waters:

- Only one round of surface water samples were collected at the sites. This round of sampling was conducted during the Round One RI investigation in 1992. No surface water samples have been collected following the Removal Action.
- The potential source of the inorganic contamination is not identified, but may have been removed during the Removal Action.

8.1.5 Sediments

Five sediment samples were collected in the unnamed drainage way adjacent to Sites 4 and 21 and in Felgates Creek during the Round One RI investigation. No sediment samples were collected during the Removal Action.

With respect to organics, VOCs, one SVOC (benzo(g,h,i) perylene), and pesticides were detected in the sediment samples. The VOCs included methylene chloride, acetone, 2-butanone, carbon disulfide, and 1,1,1-TCA. Each of these VOCs were detected only once and therefore, may be laboratory contaminants. Pesticides were detected in samples collected from the unnamed drainage way. The detected pesticides included 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, and chlordane. Their concentrations ranged from 3.2J $\mu\text{g/L}$ to 910 $\mu\text{g/L}$.

The explosives and SVOC detected in the surface water samples were not detected in the sediment samples. Several inorganics were detected in the sediment samples. No trends or sources could be identified.

The following data gaps identified related to sediments:

- Only one round of sediment samples were collected at the sites. This round of sampling was conducted during the Round One RI investigation in 1992. No sediment samples have been collected following the Removal Action.
- The potential source of the inorganic contamination is not identified, but may have been removed during the Removal Action.
- Benthic macroinvertebrate samples were not collected during the previous investigations. This type of data is pertinent to the ecological RA.

8.2 Human Health Risk Assessment

The results of the baseline human health RA are summarized below for both Site 4 and Sites 21. It is important to note that the RA assumed, for the sake of conservatism, that future potential receptors

could be exposed to contaminants in groundwater. Future development of groundwater for potable purposes at Sites 4 or 21 is unlikely even in the event of future residential development because of the availability of municipal water and station restrictions on property use.

8.2.1 Site 4

The potential receptors evaluated under the baseline human health RA for Site 4 included: on-site adult civilian workers, future resident adults, future resident children, and future construction worker. Table 8-1 presents a summary of the ICR and HI values calculated for each of these potential receptors.

As shown on this table, the RA evaluated that the on-site adult civilian worker and the future adult and children resident scenarios presented potential risks that exceed USEPA's target ranges (i.e., the ICRs do not fall within the 1.0×10^{-04} to 1.0×10^{-06} range and the HIs are not less than 1.0). With respect to using the organic and total inorganic concentrations, the unacceptable risk result was due predominantly to the presence of total beryllium in the groundwater. With respect to using the organic and dissolved inorganic concentrations, the unacceptable risk result was due to the risk from surface soil ingestion and was based on benzo(a) pyrene and arsenic.

HI values for on-site adult civilian worker and the future resident adults and children were greater than 1.0 suggesting that noncarcinogenic adverse health effects may occur subsequent to exposure. This was true for organic and total inorganic concentrations as well as organic and dissolved inorganic concentrations. Aluminum, chromium, manganese, and vanadium in groundwater were the main contributors to the total HI values for the residential scenarios when evaluating organics and total inorganics. Dissolved antimony and manganese in the groundwater and arsenic and manganese in the surface soil were the main contributors to the total HI values for the residential scenarios when evaluating organics and dissolved inorganics. For the adult civilian work, total and dissolved manganese in the surface water were the main contributors to the total HI values.

Unacceptable carcinogenic and noncarcinogenic health effects would not be expected for the future construction worker at Site 4.

8.2.2 Site 21

The potential receptors evaluated under the baseline human health RA for Site 21 included: on-site adult civilian workers, future resident adults, future resident children, and future construction workers. Table 8-1 presents a summary of the ICR and HI values calculated for each of these potential receptors.

As shown on this table, the RA indicated that the future adult and children resident scenarios exhibit potential risks that exceed USEPA's target ranges using the organic and total inorganic concentrations. In this case, the unacceptable risk result was due predominantly to the presence of total beryllium in the groundwater. Using the organic and dissolved inorganic concentrations, the ICR values did not exceed the USEPA's target risk range.

HI values for the on-site adult civilian workers and for the future resident adults and children were greater than 1.0 suggesting that noncarcinogenic adverse health effects may occur subsequent to exposure. This was true for organic and total inorganic concentrations as well as organic and dissolved inorganic concentrations. Aluminum, cadmium, and manganese in groundwater were the main contributors to the total HI values for the residential scenarios when evaluating organics and total inorganics. Dissolved cadmium, manganese, and zinc in the groundwater were the main contributors to the total HI values for the residential scenarios when evaluating organics and dissolved inorganics. For the adult civilian worker, total and dissolved manganese in the surface water were the main contributors to the total HI values.

Risks to future resident children and adults associated with potential exposure to COPCs in soils fell within USEPA's generally acceptable target risk range. HI values were below 1.0 for both children and adults indicating that systemic health effects would not occur subsequent to soil exposure. Furthermore, unacceptable carcinogenic and noncarcinogenic health effects would not be expected for the future construction workers at Site 21.

8.3 Ecological Risk Assessment

The results of the baseline ecological RA are summarized below with respect to the aquatic ecosystem and the terrestrial ecosystem.

8.3.1 Aquatic Ecosystem

The concentrations of contaminants detected in the surface water and sediment indicated that a potential risk to the aquatic environment may exist. However, due to the absence of benthic macroinvertebrate data, the impact of the surface water and sediment on the aquatic environment cannot be evaluated.

In addition, the surface water data (most current) used in the ecological RA was collected prior to the Removal Action conducted at Sites 4 and 21. Therefore, the current surface water conditions are not known.

The ecological RA concluded that additional investigations at Sites 4 and 21 are needed for surface water, sediment, and benthic macroinvertebrate species to further quantify the potential risks to the aquatic ecosystem posed by the two sites.

8.3.2 Terrestrial Ecosystem

The ecological RA concluded that soil concentrations of PAHs and inorganics at Site 4 are significantly greater than some of the effects levels presented in literature for terrestrial flora and fauna. The number and concentrations of contaminants detected in the surface soil at Site 4 indicated a potential for risk to the terrestrial environment. The results from this screening phase ecological RA indicate that further investigations are warranted at Site 4.

At Site 21, aluminum and zinc concentrations were detected at concentrations significantly greater than the literature toxicity data. The concentrations could potentially affect the terrestrial environment at the site. The results from this screening phase ecological RA indicate that further investigations are warranted at Site 21.

8.4 Recommendations

Based on the results of the Round One RI, the Removal Action, and the baseline RAs conducted for Sites 4 and 21, the following recommendations are made:

- Additional investigation should be conducted on the groundwater at Sites 4 and 21. The source and the extent of the VOC contamination at Site 4 should be identified through the installation of additional monitoring wells and additional groundwater sampling. Post-removal action sampling for organics is needed to evaluate the effects of the Removal Action.
- The vertical extent of groundwater contamination should be investigated. Deep monitoring wells should be installed at areas with shallow groundwater contamination.
- A re-evaluation of the apparent inorganic groundwater contamination at both sites should be made. Additional groundwater sampling should be conducted. Afterwards, the extent of the inorganic contamination should be re-examined. Post-removal action sampling for inorganics is needed to evaluate the effects of the removal action. The additional recommended groundwater investigations could be included with the future RI activities to be conducted for Site 22 which is located immediately downgradient from Sites 4 and 21.
- A re-evaluation of the surface water and sediment contamination identified in the unnamed drainage way and Felgates Creek should be made. Post-removal action sampling is needed to evaluate the effects of the removal action since potential source(s) of contamination have been removed from the Sites. This additional recommended investigation could be included with the future RI activities to be conducted for Site 22 which is also located along Felgates Creek.
- Benthic macroinvertebrate and fish data should be collected from the unnamed drainage way and Felgates Creek. Additional surface water and sediment data should be collected and then evaluated with the benthic and fish data. This information will be needed to further evaluate potential human health and ecological risks. This additional recommended investigation could be included with the future RI activities to be conducted for Site 22 which is also located along Felgates Creek.

- Subsurface soil data should be collected at Site 4 and possibly at Site 21 to characterize conditions at the site and determine if there are any potential sources of contamination remaining following the Removal Action.
- Additional surface soil data should be collected throughout Sites 4 and 21 to determine the extent of the PAH contamination identified in the surface soil at two locations within Site 4 and to determine the extent of other remaining potential source areas at both sites.
- After conducting the additional investigations, the data obtained should be evaluated along with a re-evaluation of the existing Sites 4 and 21 data. Work Plans for additional remedial investigation activities at Sites 4 and 21, and 22 will be initiated in the first quarter of fiscal year 1996. A comprehensive RI which evaluates potential human health and ecological risks associated with Sites 4 and 22 and groundwater at Site 21 should be prepared. Subsequent to the comprehensive RI, an FS should then be prepared to evaluate the potential remedial action alternatives that may be appropriate for the environmental media at these three sites.

SECTION 8.0 TABLES

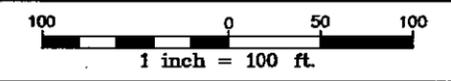
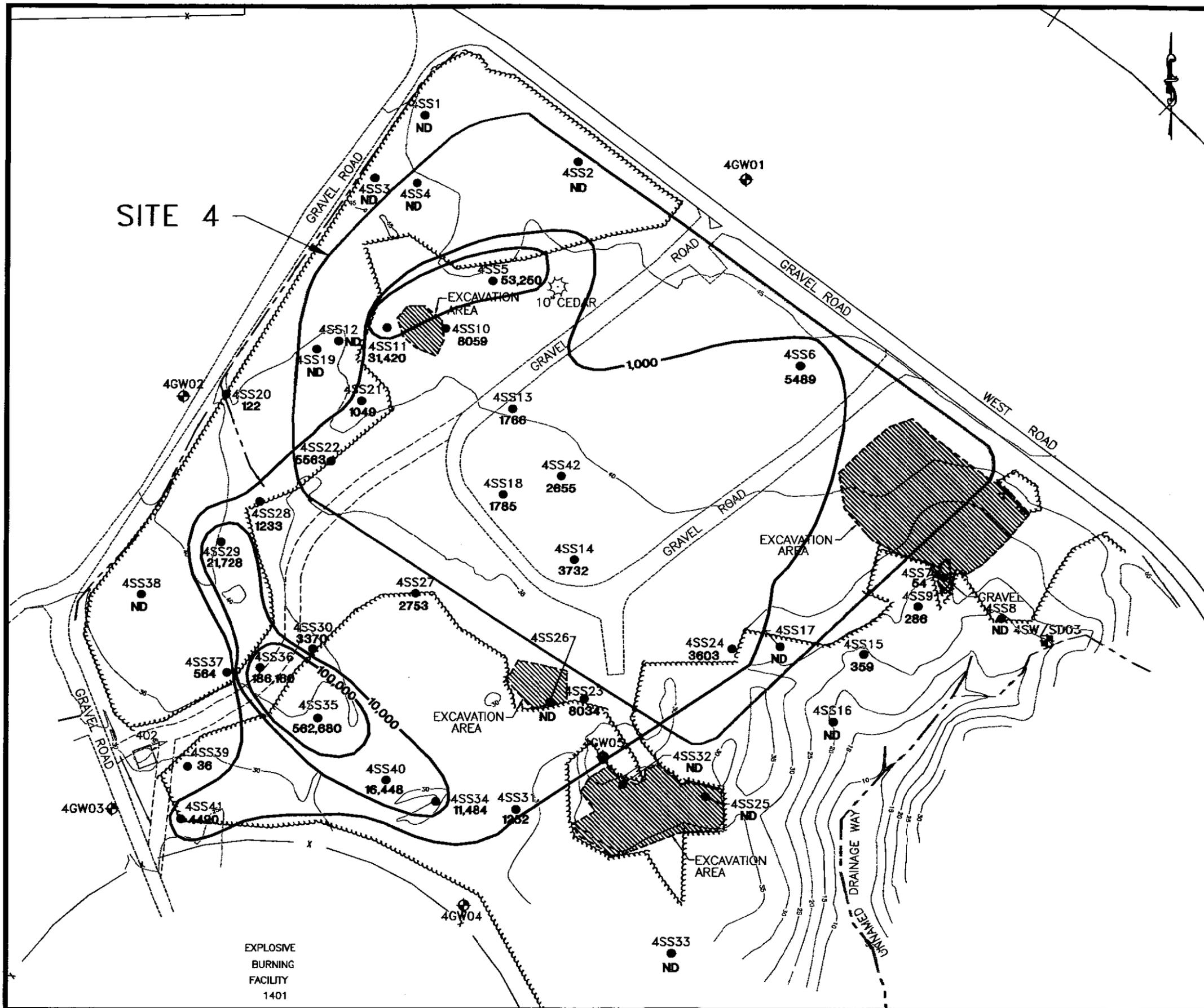
TABLE 8-1

**SUMMARY OF HUMAN HEALTH RISK ASSESSMENT ICR AND HI VALUES
CTO-0297
NAVAL WEAPONS STATION YORKTOWN,
YORKTOWN, VIRGINIA**

Site	Receptor	Total ICR	Total HI
Site 4	Adult Civilian Worker	1.2×10^{-04} (9.5×10^{-05})	$1.6 \times 10^{+00}$ ($1.2 \times 10^{+00}$)
	Future Adult Resident	2.0×10^{-03} (5.6×10^{-04})	$8.0 \times 10^{+01}$ ($2.1 \times 10^{+01}$)
	Future Children Resident	7.6×10^{-04} (2.4×10^{-04})	$5.6 \times 10^{+01}$ ($1.5 \times 10^{+01}$)
	Future Construction Worker	1.3×10^{-5}	1.2×10^{-01}
Site 21	Adult Civilian Worker	5.1×10^{-05} (2.3×10^{-05})	$1.5 \times 10^{+00}$ ($1.0 \times 10^{+00}$)
	Future Adult Resident	1.2×10^{-03} (3.5×10^{-05})	$1.4 \times 10^{+02}$ ($8.5 \times 10^{+02}$)
	Future Children Resident	4.7×10^{-04} (1.7×10^{-05})	$1.0 \times 10^{+02}$ ($5.9 \times 10^{+02}$)
	Future Construction Worker	1.6×10^{-06}	3.4×10^{-01}

Note: Values presented in parenthesis include total ICR and HI values using dissolved groundwater and surface water concentrations.

SECTION 8.0 FIGURES



- | | | | |
|-------|----------|---|---------------------------|
| — | BOUNDARY | — | EDGE OF PAVEMENT |
| - - - | DRAINAGE | ▭ | STRUCTURE |
| ▲ | MARSH | ○ | APPROXIMATE SITE BOUNDARY |
| + | RAILROAD | ▨ | EXCAVATION AREA |
| - x - | FENCE | | |
-
- 4GW01 EXISTING MONITORING WELL LOCATION
 - 21GW04 ROUND ONE MONITORING WELL LOCATION
 - 4SW/SD02 ROUND ONE SURFACE WATER/ SEDIMENT SAMPLING LOCATION
 - 4SS1 ROUND ONE SURFACE SOIL SAMPLE LOCATION
 - 1252 TOTAL PAHs ug/kg
 - ND NOT DETECTED
 - ISOCOCONCENTRATION CONTOUR LINE
 - 25- CONTOUR LINE WITH ELEVATION, MSL

FIGURE 8-1
APPROXIMATE TPH
ISOCONCENTRATIONS IN
SURFACE SOIL AT
SITE 4