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CNC CHARLESTON
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RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION REPORT
ZONE G VOLUME I OF VI SECTIONS 1 TO 9 CNC CHARLESTON SC
2/20/1998
NAVFAC SOUTHERN

**ZONE G
RCRA FACILITY
INVESTIGATION REPORT
NAVBASE CHARLESTON**

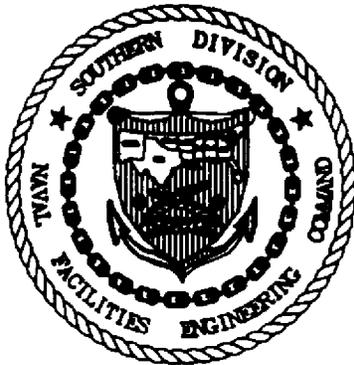


**VOLUME I of VI
SECTIONS 1 to 9**

**CONTRACT N62467-89-D-0318
CTO-029**

Prepared for:

**Comprehensive Long-Term Environmental Action Navy
(CLEAN)
Charleston Naval Shipyard
Charleston, South Carolina**



Prepared by:

**EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901)372-7962**

**February 20, 1998
Revision: 0**



DEPARTMENT OF THE NAVY

SOUTHERN DIVISION

NAVAL FACILITIES ENGINEERING COMMAND

P.O. BOX 190010

2155 EAGLE DRIVE

NORTH CHARLESTON, S.C. 29419-9010

5090/11
Code 1877
26 February, 1998

Mr. John Litton, P.E.
Director, Division of Hazardous and Infectious Waste Management
Bureau of Land and Waste Management
South Carolina Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201

Subj: SUBMITTAL OF ZONE G RCRA FACILITY INVESTIGATION REPORT

Dear Mr. Litton,

The purpose of this letter is to submit the Zone G Final RCRA Facility Investigation Report for Naval Base Charleston. The Report is submitted to fulfill the requirements of condition IV.B.2 of the RCRA Part B permit issued to the Navy by the South Carolina Department of Health and Environmental Control and U.S. Environmental Protection Agency.

The results of Zone G RFI field work has been reviewed with Department and EPA representatives during previous Project Team meetings and concerns have been incorporated into this draft report. We request that the Department and the EPA review the report and provide comment or approval as appropriate. If you should have any questions, please contact Bill Drawdy or Matthew Hunt at (803) 743-9985 and (803) 820-5525 respectively.

Sincerely,

A handwritten signature in black ink that reads "H. J. Shepard II PE for".

P. M. ROSE
LCDR, U.S. Navy
Caretaker Site Officer
by direction

Encl: Draft Zone G RFI Report, dated 20 February 1998

Copy to:

SCDHEC (Paul Bergstrand, Johnny Tapia)

USEPA (Dann Spariosu)

SOUTHNAVFACENGCOM (Matthew Hunt)

CSO Naval Base Charleston (Billy Drawdy, Daryle Fontenot)

SPORTENVDETCNASN (Bobby Dearhart)

Bechtel (Mac McNeil)



200 Bull Street
Columbia, SC 29201-1708

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July 17, 1998

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Mr. Henry Shepard II, P.E.
Caretaker Site Office
Naval Facilities Engineering Command, Southern Division
1690 Turnbull Ave., Building NH-51
Charleston Naval Complex
Charleston, SC 29405

Re: Interim Measures Work Plan
for Zone G PCB Samples Locations
Dated July 10, 1998
SC0 170 022 560

Dear Mr. Shepard:

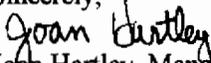
The Department has received and reviewed the above mentioned document which is a revised version of the March 27, 1998 Work Plan. The revised work plan is not in accordance with the Department's comments. Therefore the Navy should implement the July 10, 1998 work plan with variations, as agreed upon in a phone conversation with Mr. Reece Batten of SOUTHDIV on July 17, 1998. The conditions for the implementation of this work plan are:

1. The sampling pattern proposed, and the cited EPA guidance on the July 10, 1998 work plan should not be used or applied for this confirmatory sampling.
2. The proposed sampling pattern on Figure 2 of the March 27, 1998 work plan should be used as the basis for the implementation of the confirmatory sampling (attachment). In addition, as agreed on July 17, 1998 phone call, the number of confirmatory samples after excavation should increase, in accordance to the attached figure, to determine if the soil removal achieved the work plan objective.
3. It should be noted that the March 27, 1998 Work Plan received conditional approval, which means that the DET was able to commence work after receiving this approval. The May 18, 1998 letter was the starting point to implement the proposed work. Considering this, an implementation schedule should have been submitted with the revision of the work plan, which is still needed.

Hartley to Shepard
July 17, 1998
Page 2

Should you have any questions regarding this issue, please contact me at (803) 896-4179 or Paul Bergstrand at (803) 896-4016.

Sincerely,


Joan Hartley, Manager
Corrective Action Engineering Section
Bureau of Land & Waste Management

Attachments

cc: Paul Bergstrand, Hydrogeology
Rick Richter, Trident EQC
Tony Hunt, SOUTHNAVFACENGCOM
Reece Batten, SOUTHNAVFACENGCOM
Dann Spariosu, EPA Region IV

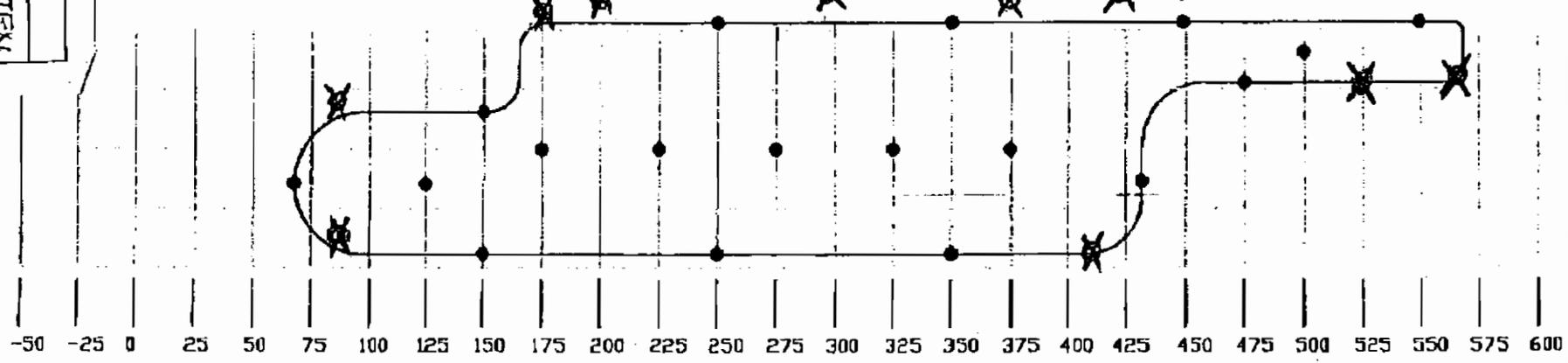
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To	JOHNNY TAPIA	From	REECE BATTEN
Co.	DHEC	Co.	g/18 SDIV
Digital	896-4179	Phone #	(843) 820-5528

✱ - NEW SAMPLES PER PIONECON 7/17/98
 BETWEEN JOHNNY TAPIA, DHEC
 AND REECE BATTEN, SDIV



HOBSON AVENUE



BLGD.
641

LEGEND

● - PROPOSED CONFIRMATORY SAMPLE



SPORTENVDETCHASN
 1889 North Hobson Ave.
 North Charleston, SC
 29405-2106
 Ph. (803) 743-8777

Confirmatory Sampling Map
 Zone "G" - PCBs
 Charleston Naval Base
 Charleston, SC

DWG DATE: 27 JAN 98 DWG NAME: Zone G_1

07/17/98 11:45 803 743 0563 SPECIAL PROG 823 743 0563 001



DEPARTMENT OF THE NAVY

SOUTHERN DIVISION

NAVAL FACILITIES ENGINEERING COMMAND

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20 February, 1998

Mr. John Litton, P.E.
Director, Division of Hazardous and Infectious Waste Management
Bureau of Land and Waste Management
South Carolina Department of Health and Environmental Control
2600 Bull Street, Columbia, SC 29201

Subj: TRANSFER OF FUEL DISTRIBUTION SYSTEM CORRECTIVE ACTION AND
NOTIFICATION OF AOC 709

Ref: (a) SOUTHNAVFACENGCOM letter, Hunt to Litton, dated 20 August 1997

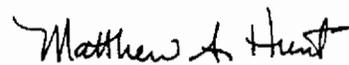
Dear Mr. Litton:

The purpose of this letter is to request formal approval of the transfer of corrective action for the Fuel Distribution System (AOC 626) and associated facilities (Enclosure (1)). Formal approval has been requested previously in reference (a) however after further discussion between Department representatives and the Navy, it was determined that SWMU 24, AOC 631 and three other areas identified during initial sampling require further investigation under the Naval Base RCRA Part B permit. Enclosure (1) lists those sites which will be transferred to the UST Program. Enclosure (2) is a site map which identifies the approximate location of the site assessment samples and the approximate location of each of these sites. Based on the initial results of field work conducted at the sites in Enclosure (1) it has been determined that the site contaminants are petroleum products that most likely originated from virgin petroleum releases and therefore corrective action is appropriate under Subtitle I of RCRA, the Underground Storage Tank Program. Enclosure (3) is a site map which provides the approximate site boundaries and location of proposed shallow groundwater monitoring locations for the three areas identified during this discussion.

This issue has been discussed with and concurred on by representatives from the S.C. Department of Health and Environmental Control and U.S. Environmental Protection Agency. We request that the Department and the EPA provide approval for transfer of the Fuel Distribution System (AOC 626) and associated facilities listed in Enclosure (1). Included in this correspondence we provide notification of AOC 709 as a new site to be added to the Naval Base RCRA Part B permit. The Navy will initiate permit revisions as required. If you should have any questions, please contact Gabe Magwood or myself at (803) 820-7307 or 820-5525 respectively.

Subj: TRANSFER OF FUEL DISTRIBUTION SYSTEM CORRECTIVE ACTION AND
NOTIFICATION OF AOC 709 (continued)

Sincerely,



MATTHEW A. HUNT
Environmental Engineer
Installation Restoration III

Encl: (1) Sites Recommended for Transfer to the UST Program
(2) Sampling Locations, Fuel Distribution System
(3) Proposed FDS Shallow Groundwater Monitoring Locations

Copy to:

SCDHEC (Paul Bergstrand, Johnny Tapia, Paul Bristol), USEPA (Dann Spariousu)
SOUTHDIIV (Gabe Magwood), CSO Naval Base Charleston (Billy Drawdy, Daryle Fontenot),
SPORTENVDETHASN (Dearhart), Ensafe (Todd Haverkost)

Enclosure (1)
Sites Recommended for Transfer to the UST Program

SWMU/AOC C Number	SWMU/AOC Name	SWMU/AOC Location	Study Zone
AOC 626	Fuel Farm	Corner of Hobson and Viaduct Roads	G
AOC 622	Ballast Water Treatment Facility	Within Fuel Farm	G
AOC 623	Concrete Tank	Building 96	G
AOC 624	Fuel Oil Booster Pumphouse	Building 98	G
AOC 625	Sludge Pumphouse	Building 3901B	G
AOC 627	Oil Spill Area at Hobson Avenue	Intersection of Hobson and Viaduct Road	G
AOC 629	Unloading Facility	Building 3913	G
AOC 641	Stripper Pumphouse	Building 336	G

**ZONE G
RCRA FACILITY
INVESTIGATION REPORT
NAVBASE CHARLESTON**

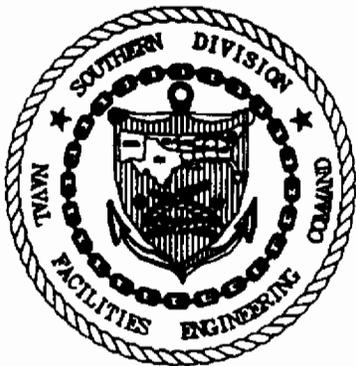


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Table of Contents

ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR NAVBASE	a.1
1.0 INTRODUCTION	1.1
1.1 NAVBASE Description and Background	1.1
1.2 Base Closure Process for Environmental Cleanup	1.1
1.3 Investigative Zone Delineation	1.2
1.4 Current Investigation	1.2
1.5 Previous Investigations	1.7
1.6 RFI Report Organization	1.7
2.0 PHYSICAL SETTING	2.1
2.1 Regional Setting	2.1
2.1.1 Regional Physiographic and Geologic Description	2.1
2.1.2 Regional Hydrologic and Hydrogeologic Background	2.1
2.1.3 Regional Climate	2.1
2.2 Zone G Geologic Investigation	2.1
2.2.1 Monitoring Wells	2.1
2.2.2 Geotechnical Analyses	2.3
2.2.3 Zone G Geology	2.3
2.3 Zone G Hydrogeology	2.16
2.3.1 Surficial Aquifer	2.17
2.3.2 Groundwater Flow Direction	2.18
2.3.3 Horizontal Hydraulic Gradient	2.23
2.3.4 Horizontal Groundwater Conductivity	2.23
2.3.5 Horizontal Groundwater Velocity	2.28
2.3.6 Tidal Influence	2.29
2.3.7 Vertical Hydraulic Gradient	2.31
2.3.8 Lithologic Unit Summary	2.32
3.0 FIELD INVESTIGATION	3.1
3.1 Investigation Objectives	3.1
3.2 Sampling Procedures, Protocols, and Analyses	3.1
3.2.1 Sample Identification	3.3
3.2.2 Soil Sampling	3.4
3.2.3 Monitoring Well Installation and Development	3.7
3.2.4 Groundwater Sampling	3.10
3.2.5 Sediment/Surface Water Sampling	3.11
3.2.6 DPT Screening Surveys	3.12
3.2.7 Vertical and Horizontal Surveying	3.13
3.2.8 Aquifer Characterization	3.13
3.2.9 Decontamination Procedures	3.13

4.0	DATA VALIDATION	4.1
4.1	Introduction	4.1
4.2	Validation Summary	4.1
	4.2.1 Organic Evaluation Criteria	4.2
	4.2.2 Inorganic Evaluation Criteria	4.3
4.3	Zone G Data Validation Reports	4.7
	4.3.1 Soil Blanks	4.8
	4.3.2 Groundwater Blanks	4.14
4.4	Method Detection Limits	4.17
5.0	DATA EVALUATION AND BACKGROUND COMPARISON	5.1
5.1	Organic Compound Analytical Results Evaluation	5.1
5.2	Inorganic Analytical Results Evaluation	5.2
	5.2.1 Grid-Based Background Dataset	5.3
	5.2.2 Nondetect Data	5.4
	5.2.3 Developing Datasets for Sites	5.4
	5.2.4 Comparing Site Values to Background	5.4
	5.2.5 Reference Concentration Test	5.4
	5.2.6 Wilcoxon Rank Sum Test	5.5
	5.2.7 Summary of Techniques Used	5.5
	5.2.8 Combined Results of the Reference Concentration and Wilcoxon Rank Sum Tests	5.6
	5.2.9 Conclusion	5.6
	5.2.10 Background Values	5.7
6.0	FATE AND TRANSPORT	6.1
6.1	Properties Affecting Fate and Transport	6.2
	6.1.1 Contaminant Properties Affecting Fate and Transport	6.3
	6.1.2 Media Properties Affecting Fate and Transport	6.4
6.2	Fate and Transport Approach for Zone G	6.9
	6.2.1 Soil-to-Groundwater Cross-Media Transport	6.9
	6.2.2 Groundwater-to-Surface Water Cross-Media Transport	6.17
	6.2.3 Surface Soil-to-Sediment Cross-Media Transport	6.19
	6.2.4 Soil-to-Air Cross-Media Transport	6.20
6.3	Fate and Transport Screening Assumptions Versus Site Conditions	6.21
7.0	HUMAN HEALTH RISK ASSESSMENT	7.1
7.1	Introduction	7.1
7.2	Objectives	7.1
7.3	Human Health Risk Assessment Methods	7.3
	7.3.1 Data Sources	7.3
	7.3.2 Data Validation	7.4
	7.3.3 Management of Site-Related Data	7.4
	7.3.4 Selection of Chemicals of Potential Concern	7.6
	7.3.5 Calculation of Risk and Hazard	7.10

7.3.6	Exposure Assessment	7.11
7.3.7	Toxicity Assessment	7.11
7.3.8	Risk Characterization	7.11
7.3.9	Risk Uncertainty	7.11
7.3.10	Risk Summary	7.20
7.3.11	RGOs	7.20
8.0	ECOLOGICAL RISK ASSESSMENT	8.1
8.1	ERA Rationale	8.1
8.2	Environmental Setting	8.3
8.3	Conceptual Model	8.7
8.4	Selection of Ecological Chemicals of Potential Concern	8.12
8.5	Contaminant Fate and Transport	8.19
8.6	Exposure Pathways and Assessment	8.20
8.7	Ecological Effects Assessment	8.22
8.8	Risk Characterization	8.32
8.9	Uncertainty	8.40
8.10	Risk Summary	8.41
9.0	CORRECTIVE MEASURES	9.1
9.1	Introduction	9.1
9.2	Remedy Selection Approach	9.6
9.3	Proposed Remedy	9.7
9.4	Development of Target Media Cleanup Goals	9.7
9.5	Identification, Screening, and Development of Corrective Measures Technologies	9.7
9.5.1	Identification of Corrective Measure Technologies	9.7
9.5.2	Description of Prescreened Technologies	9.10
9.5.3	Screening Criteria	9.14
9.6	Identification of Corrective Measures Alternatives	9.15
9.7	Evaluation of Corrective Measures Alternatives	9.16
9.8	Ranking the Corrective Measures Alternatives	9.16
10.0	SITE-SPECIFIC EVALUATIONS	10.1
10.1	AOC 628, Sandblasting Area, Southeast of Building 68	10.1.1
10.1.1	Site Geology	10.1.1
10.1.2	Field Investigation Approach	10.1.1
10.1.3	Soil Sampling and Analysis	10.1.3
10.1.4	Fate and Transport Assessment	10.1.21
10.1.5	Human Health Risk Assessment	10.1.27
10.1.6	Corrective Measures Considerations	10.1.53
10.2	AOC 633, Substation, Building 451C	10.2.1
10.2.1	Site Geology	10.2.1
10.2.2	Field Investigation Approach	10.2.1
10.2.3	Soil Sampling and Analysis	10.2.3

	10.2.4	Sediment Sampling and Analysis	10.2.10
	10.2.5	Fate and Transport Assessment	10.2.28
	10.2.6	Human Health Risk Assessment	10.2.43
	10.2.7	Corrective Measures Considerations	10.2.62
10.3		AOC 634, Flammable Material Storage, Building 1814	10.3.1
	10.3.1	Site Geology	10.3.1
	10.3.2	Field Investigation Approach	10.3.1
	10.3.3	Soil Sampling and Analysis	10.3.3
	10.3.4	Fate and Transport Assessment	10.3.4
	10.3.5	Human Health Risk Assessment	10.3.14
	10.3.6	Corrective Measures Considerations	10.3.17
10.4		AOC 638, Former Torpedo Workshop, Building 132	10.4.1
	10.4.1	Site Geology and Hydrogeology	10.4.1
	10.4.2	Field Investigation Approach	10.4.5
	10.4.3	Soil Sampling and Analyzes	10.4.5
	10.4.4	Groundwater Sampling and Analysis	10.4.23
	10.4.5	Fate and Transport Assessment	10.4.27
	10.4.6	Human Health Risk Assessment	10.4.30
	10.4.7	Corrective Measures Considerations	10.4.52
10.5		AOC 642, Former Pistol Range, Present Parking Lot	10.5.1
	10.5.1	Site Geology	10.5.1
	10.5.2	Field Investigation Approach	10.5.1
	10.5.3	Soil Sampling and Analyses	10.5.3
	10.5.4	Fate and Transport Assessment	10.5.19
	10.5.5	Human Health Risk Assessment	10.5.26
	10.5.6	Corrective Measures Considerations	10.5.54
10.6		SWMU 8, Oil Sludge Pit; AOC 636, Torpedo Magazine, Building 161 Area	10.6.1
	10.6.1	Site Geology and Hydrogeology	10.6.1
	10.6.2	Field Investigation Approach	10.6.4
	10.6.3	Soil Sampling and Analysis	10.6.7
	10.6.4	Groundwater Sampling and Analysis	10.6.109
	10.6.5	Fate and Transport Assessment	10.6.124
	10.6.6	Human Health Risk Assessment	10.6.136
	10.6.7	Corrective Measures Considerations	10.6.201
10.7		AOC 637, Dump Area, Building 161 Area	10.7.1
	10.7.1	Site Geology and Hydrogeology	10.7.1
	10.7.2	Field Investigation Approach	10.7.5
	10.7.3	Soil Sampling and Analysis	10.7.5
	10.7.4	Sediment Sampling and Analysis	10.7.32
	10.7.5	Groundwater Sampling and Analysis	10.7.48
	10.7.6	Surface Water Sampling and Analysis	10.7.76
	10.7.7	Fate and Transport Assessment	10.7.97
	10.7.8	Human Health Risk Assessment	10.7.105
	10.7.9	Corrective Measures Considerations	10.7.154

10.8	SWMU 11, Caustic Pond	10.8.1
	10.8.1 Site Geology and Hydrogeology	10.8.1
	10.8.2 Field Investigation Approach	10.8.5
	10.8.3 DPT Sampling and Analysis	10.8.5
	10.8.4 Soil Sampling and Analysis	10.8.7
	10.8.5 Sediment Sampling and Analysis	10.8.18
	10.8.6 Groundwater Sampling and Analysis	10.8.23
	10.8.7 Fate and Transport Assessment	10.8.25
	10.8.8 Human Health Risk Assessment	10.8.36
	10.8.9 Corrective Measures Considerations	10.8.48
10.9	SWMU 120, Pier M Laydown	10.9.1
	10.9.1 Site Geology and Hydrogeology	10.9.1
	10.9.2 Field Investigation Approach	10.9.5
	10.9.3 Soil Sampling and Analysis	10.9.5
	10.9.4 Sediment Sampling and Analysis	10.9.21
	10.9.5 Groundwater Sampling and Analysis	10.9.30
	10.9.6 Fate and Transport Assessment	10.9.37
	10.9.7 Human Health Risk Assessment	10.9.43
	10.9.8 Corrective Measures Considerations	10.9.78
10.10	AOC 643, Substation, Building 125	10.10.1
	10.10.1 Site Geology	10.10.1
	10.10.2 Field Investigation Approach	10.10.1
	10.10.3 Soil Sampling and Analysis	10.10.3
	10.10.4 Sediment Sampling and Analysis	10.10.27
	10.10.5 Fate and Transport Assessment	10.10.35
	10.10.6 Human Health Risk Assessment	10.10.42
	10.10.7 Corrective Measures Considerations	10.10.74
10.11	SWMU 3, Pesticide Mixing Area	10.11.1
	10.11.1 Site Geology and Hydrogeology	10.11.1
	10.11.2 Field Investigation Approach	10.11.5
	10.11.3 Soil Sampling and Analysis	10.11.5
	10.11.4 Groundwater Sampling and Analysis	10.11.29
	10.11.5 Fate and Transport Assessment	10.11.37
	10.11.6 Human Health Risk Assessment	10.11.48
	10.11.7 Corrective Measures Considerations	10.11.88
10.12	SWMU 6, Public Works Storage Yard; SWMU 7, PCB Transformer Storage Yard; and AOC 635, Paint and Oil Storehouse, Building 3902	10.12.1
	10.12.1 Site Geology and Hydrogeology	10.12.1
	10.12.2 Field Investigation Approach	10.12.3
	10.12.3 Soil Sampling and Analysis	10.12.3
	10.12.4 Groundwater Sampling and Analysis	10.12.121
	10.12.5 Fate and Transport Assessment	10.12.150
	10.12.6 Human Health Risk Assessment	10.12.157
	10.12.7 Corrective Measures Considerations	10.12.237

10.13	AOC 646, Operational Storage, Building 3906Q	10.13.1
	10.13.1 Site Geology	10.13.1
	10.13.2 Field Investigation Approach	10.13.1
	10.13.3 Soil Sampling and Analysis	10.13.3
	10.13.4 Fate and Transport Assessment	10.13.19
	10.13.5 Human Health Risk Assessment	10.13.22
	10.13.6 Corrective Measures Considerations	10.13.41
10.14	AOC 706, Area Behind Building 246	10.14.1
	10.14.1 Site Geology and Hydrogeology	10.14.1
	10.14.2 Field Investigation Approach	10.14.5
	10.14.3 Soil Sampling and Analyses	10.14.5
	10.14.4 Groundwater Sampling and Analysis	10.14.35
	10.14.5 Fate and Transport Assessment	10.14.51
	10.14.6 Human Health Risk Assessment	10.14.57
	10.14.7 Corrective Measures Considerations	10.14.87
10.15	SWMU 24, Waste Oil Reclamation Facility	10.15.1
	10.15.1 Site Geology	10.15.1
	10.15.2 Field Investigation Approach	10.15.5
	10.15.3 Soil Sampling and Analysis	10.15.5
	10.15.4 Groundwater Sampling and Analysis	10.15.22
	10.15.5 Fate and Transport Assessment	10.15.32
	10.15.6 Soil-to-Groundwater Cross Media Transport	10.15.32
	10.15.7 Groundwater Migration and Surface Water Cross-Media Transport	10.15.32
	10.15.8 Soil-to-Air Cross-Media Transport	10.15.34
	10.15.9 SWMU 24 Fate and Transport Summary	10.15.34
	10.15.10 Human Health Risk Assessment	10.15.36
	10.15.11 Corrective Measures Considerations	10.15.69
11.0	CONCLUSIONS AND PRELIMINARY RECOMMENDATIONS	11.1
11.1	AOC 628, Sandblasting Area, Southeast of Building 68	11.3
11.2	AOC 633, Substation, Building 451C	11.3
11.3	AOC 634, Flammable Material Storage, Building 1814	11.4
11.4	AOC 638, Former Torpedo Workshop, Building 132	11.5
11.5	AOC 642, Former Pistol Range, Present Parking Lot	11.5
11.6	SWMU 8, Oil Sludge Pit; AOC 636, Torpedo Magazine, Building 161 Area	11.6
11.7	AOC 637, Dump Area, Building 161 Area	11.7
11.8	SWMU 11, Caustic Pond	11.14
11.9	SWMU 120, Pier M Laydown	11.15
11.10	AOC 643, Substation, Building 125	11.16
11.11	SWMU 3, Pesticide Mixing Area	11.16
11.12	SWMU 6, Public Works Storage Yard; SWMU 7, PCB Transformer Storage Yard; and AOC 635, Paint and Oil Storehouse, Building 3902	11.17
11.13	AOC 646, Operational Storage, Building 3906Q	11.18
11.14	AOC 706, Area Behind Building 246	11.19

11.15	SWMU 24, Waste Oil Reclamation Facility	11.20
11.16	Ecological Risk Summary	11.21
11.16.1	Aquatic Wildlife	11.22
11.16.2	Terrestrial Wildlife	11.22
11.16.3	Vegetation	11.23
12.0	REFERENCES	12.1
13.0	SIGNATORY REQUIREMENT	13.1

List of Figures

Figure 1-1	Investigative Zone Boundaries	1.3
Figure 1-2	Zone G AOC and SWMU Location Map	1.6
Figure 2-1	Zone G Monitoring Well Location Map	2.2
Figure 2-2	Lithologic Cross Sections A-A', C-C', D-D', E-E'	2.9
Figure 2-3	Lithologic Cross Section B-B'	2.10
Figure 2-4	Topographic Map of the Top of the Ashley Formation	2.11
Figure 2-5	Zone G Shallow Groundwater Low-Tide Elevation Map	2.19
Figure 2-6	Zone G Shallow Groundwater High-Tide Elevation Map	2.20
Figure 2-7	Zone G Deep Groundwater Low-Tide Elevation Map	2.21
Figure 2-8	Zone G Deep Groundwater High-Tide Elevation Map	2.22
Figure 2-9	Surficial Aquifer Aerial Distribution of Hydraulic Conductivity	2.27
Figure 2-10	Zone G Shallow Groundwater Tidal Variation	2.30
Figure 2-11	Zone G Vertical Hydraulic Gradients	2.33
Figure 3-1	Zone G Grid-Based Soil Sample Location Map	3.5
Figure 3-2	Zone G Grid-Based Groundwater Sample Location Map	3.8
Figure 8-1	Ecological Study Areas	8.2
Figure 8-2	Ecological Subzones within Zone G	8.4
Figure 8-3	Contaminant Pathway Model for Ecological Receptors, Zone G	8.11
Figure 8-4	Subzone G-1 Sample Locations	8.33
Figure 10.1-1	Sampling Locations, 628	10.1.2
Figure 10.1-2	Methylene Chloride in Subsurface Soil, AOC 628	10.1.19
Figure 10.1-3	BEQs in Surface Soil, AOC 628	10.1.20
Figure 10.1-4	Arsenic in Surface Soil, AOC 628	10.1.22
Figure 10.1-5	Chromium in Surface Soil, AOC 628	10.1.23
Figure 10.1-6	Point Risk Estimates for Surface Soil Residential Scenario, AOC 628	10.1.47
Figure 10.1-7	Point Hazard Estimates for Surface Soil Residential Scenario, AOC 628	10.1.48
Figure 10.1-8	Point Risk Estimates for Surface Soil Industrial	10.1.51
Figure 10.2-1	Sampling Locations, AOC 633	10.2.2
Figure 10.2-2	Aroclor-1260 in Surface Soil	10.2.8
Figure 10.2-3	Aroclor-1260 in Subsurface Soil	10.2.9

Figure 10.2-4	Bis(2-ethylhexyl)phthalate in Sediment, AOC 633	10.2.20
Figure 10.2-5	Fluoranthene in Sediment, AOC 633	10.2.21
Figure 10.2-6	Pyrene in Sediment, AOC 633	10.2.22
Figure 10.2-7	alpha-Chlordane in Sediment, AOC 633	10.2.23
Figure 10.2-8	gamma-Chlordane in Sediment, AOC 633	10.2.24
Figure 10.2-9	4,4'-DDD in Sediment, AOC 633	10.2.25
Figure 10.2-10	4,4'-DDE in Sediment, AOC 633	10.2.26
Figure 10.2-11	4,4'-DDT in Sediment, AOC 633	10.2.27
Figure 10.2-12	Aroclor-1260 in Sediment, AOC 633	10.2.29
Figure 10.2-13	Antimony in Sediment, AOC 633	10.2.30
Figure 10.2-14	Arsenic in Sediment, AOC 633	10.2.31
Figure 10.2-15	Cadmium in Sediment, AOC 633	10.2.32
Figure 10.2-16	Chromium in Sediment, AOC 633	10.2.33
Figure 10.2-17	Copper in Sediment, AOC 633	10.2.34
Figure 10.2-18	Lead in Sediment, AOC 633	10.2.35
Figure 10.2-19	Mercury in Sediment, AOC 633	10.2.36
Figure 10.2-20	Nickel in Sediment, AOC 633	10.2.37
Figure 10.2-21	Zinc in Sediment, AOC 633	10.2.38
Figure 10.2-22	Point Risk Estimates for Surface Soil Residential Scenario, AOC 633	10.2.61
Figure 10.3-1	Sampling Locations, AOC 634	10.3.2
Figure 10.4-1	Sampling Locations, AOC 638	10.4.2
Figure 10.4-2	Shallow Groundwater Low-Tide Potentiometric Map, AOC 638	10.4.3
Figure 10.4-3	Shallow Groundwater High-Tide Potentiometric Map, AOC 638	10.4.4
Figure 10.4-4	BEQs in Surface Soil, AOC 638	10.4.22
Figure 10.4-5	Point Risk Estimates for Surface Soil Residential Scenario, AOC 638	10.4.50
Figure 10.5-1	Sampling Locations, AOC 642	10.5.2
Figure 10.5-2	Arsenic in Surface Soil, AOC 642	10.5.20
Figure 10.5-3	Manganese in Surface Soil, AOC 642	10.5.21
Figure 10.5-4	Nickel in Surface Soil, AOC 642	10.5.22
Figure 10.5-5	Thallium in Surface Soil, AOC 642	10.5.23
Figure 10.5-6	Point Risk Estimates for Surface Soil Residential Scenario, AOC 642	10.5.48
Figure 10.5-7	Point Hazard Estimates for Surface Soil Residential Scenario, AOC 642	10.5.51
Figure 10.5-8	Point Risk Estimates for Surface Soil Industrial Scenario, AOC 642	10.5.52
Figure 10.6-1	Soil Sampling Location Map, SWMU 8 and AOC 636	10.6.2
Figure 10.6-2	Groundwater Sampling Locations, SWMU 8 and AOC 636	10.6.3
Figure 10.6-3	Shallow Groundwater Low-Tide Potentiometric Map, SWMU 8 and AOC 636	10.6.5
Figure 10.6-4	Shallow Groundwater High-tide Potentiometric Map, SWMU 8 and AOC 636	10.6.6
Figure 10.6-5	1,1,2,2-Tetrachloroethane in Subsurface Soil, SWMU 8 and AOC 636	10.6.88

Figure 10.6-6	1,1,2-Trichloroethane in Subsurface Soil, SWMU 8 and AOC 636 . . .	10.6.89
Figure 10.6-7	BEQs in Surface Soil, SWMU 8 and AOC 636	10.6.90
Figure 10.6-8	Benzo(a)anthracene in Subsurface Soil, SWMU 8 and AOC 636 . . .	10.6.91
Figure 10.6-9	Dieldrin in Surface Soil, SWMU 8 and AOC 636	10.6.92
Figure 10.6-10	Aroclor-1260 in Surface Soil, SWMU 8 and AOC 636	10.6.93
Figure 10.6-11	Dieldrin in Subsurface Soil, SWMU 8 and AOC 636	10.6.95
Figure 10.6-12	Hydrazine in Surface Soil, SWMU 8 and AOC 636	10.6.96
Figure 10.6-13	Hydrazine in Subsurface Soil, SWMU 8 and AOC 636	10.6.97
Figure 10.6-14	Antimony in Surface Soil, SWMU 8 and AOC 636	10.6.98
Figure 10.6-15	Arsenic in Surface Soil, SWMU 8 and AOC 636	10.6.99
Figure 10.6-16	Chromium in Surface Soil, SWMU 8 and AOC 636	10.6.100
Figure 10.6-17	Lead in Surface Soil, SWMU 8 and AOC 636	10.6.101
Figure 10.6-18	Thallium in Surface Soil, SWMU 8 and AOC 636	10.6.102
Figure 10.6-19	Antimony in Subsurface Soil, SWMU 8 and AOC 636	10.6.103
Figure 10.6-20	Copper in Subsurface Soil, SWMU 8 and AOC 636	10.6.104
Figure 10.6-21	Lead in Subsurface Soil, SWMU 8 and AOC 636	10.6.105
Figure 10.6-22	Manganese in Subsurface Soil, SWMU 8 and AOC 636	10.6.106
Figure 10.6-23	Mercury in Subsurface Soil, SWMU 8 and AOC 636	10.6.107
Figure 10.6-24	Thallium in Subsurface Soil, SWMU 8 and AOC 636	10.6.108
Figure 10.6-25	Bis(2-ethylhexyl)phthalate, SWMU 8 and AOC 636	10.6.123
Figure 10.6-26	Hydrazine in Shallow Groundwater, SWMU 8 and AOC 636	10.6.125
Figure 10.6-27	Antimony in Shallow Groundwater, SWMU 8 and AOC 636	10.6.126
Figure 10.6-28	Barium in Shallow Groundwater, SWMU 8 and AOC 636	10.6.127
Figure 10.6-29	Thallium in Shallow Groundwater, SWMU 8 and AOC 636	10.6.128
Figure 10.6-30	Vanadium in Shallow Groundwater, SWMU 8 and AOC 636	10.6.129
Figure 10.6-31	Point Risk Estimates for Surface Soil Residential Scenario, SWMU 8 and AOC 636	10.6.178
Figure 10.6-32	Point Hazard Estimates for Surface Soil Residential Scenario, SWMU 8 and AOC 636	10.6.179
Figure 10.6-33	Point Risk Estimates for Surface Soil Industrial Scenario, SWMU 8 and AOC 636	10.6.190
Figure 10.6-34	Point Risk Estimates for Groundwater Residential Scenario, SWMU 8 and AOC 636	10.6.197
Figure 10.6-35	Point Hazard Estimates for Groundwater Residential Scenario, SWMU 8 and AOC 636	10.6.198
Figure 10.7.1	Sampling Locations, AOC 637	10.7.2
Figure 10.7-2	Shallow Groundwater Low-Tide Potentiometric Map, AOC 637	10.7.3
Figure 10.7-3	Shallow Groundwater High-Tide Potentiometric Map, AOC 637	10.7.4
Figure 10.7-4	BEQs in Surface Soil, AOC 637	10.7.29
Figure 10.7-5	Hydrazine in Surface Soil, AOC 637	10.7.30
Figure 10.7-6	Hydrazine in Subsurface Soil, AOC 637	10.7.31
Figure 10.7-7	Arsenic in Surface Soil, AOC 637	10.7.33
Figure 10.7-8	Thallium in Surface Soil, AOC 637	10.7.34
Figure 10.7-9	Bis(2-ethylhexyl)phthalate in Sediment, AOC 637	10.7.43
Figure 10.7-10	gamma-Chlordane in Sediment, AOC 637	10.7.44

Figure 10.7-11	Dieldrin in Sediment, AOC 637	10.7.45
Figure 10.7-12	Aroclor-1016 in Sediment, AOC 637	10.7.46
Figure 10.7-13	Aroclor-1260 in Sediment, AOC 637	10.7.47
Figure 10.7-14	Copper in Sediment, AOC 637	10.7.49
Figure 10.7-15	Lead in Sediment, AOC 637	10.7.50
Figure 10.7-16	Mercury in Sediment, AOC 637	10.7.51
Figure 10.7-17	Nickel in Sediment, AOC 637	10.7.52
Figure 10.7-18	Zinc in Sediment, AOC 637	10.7.53
Figure 10.7-19	Benzene in Shallow Groundwater, AOC 637	10.7.66
Figure 10.7-20	Chlorobenzene in Shallow Groundwater, AOC 637	10.7.67
Figure 10.7-21	Ethylbenzene in Shallow Groundwater, AOC 637	10.7.68
Figure 10.7-22	Toluene in Shallow Groundwater, AOC 637	10.7.69
Figure 10.7-23	Xylene in Shallow Groundwater, AOC 637	10.7.70
Figure 10.7-24	1,4-Dichlorobenzene in Shallow Groundwater, AOC 637	10.7.71
Figure 10.7-25	4-Methylphenol in Shallow Groundwater, AOC 637	10.7.72
Figure 10.7-26	Naphthalene in Shallow Groundwater, AOC 637	10.7.73
Figure 10.7-27	Tetryl in Shallow Groundwater, AOC 637	10.7.74
Figure 10.7-28	Hydrazine in Shallow Groundwater, AOC 637	10.7.75
Figure 10.7-29	Antimony in Shallow Groundwater, AOC 637	10.7.77
Figure 10.7-30	Barium in Shallow Groundwater, AOC 637	10.7.78
Figure 10.7-31	Chromium in Shallow Groundwater, AOC 637	10.7.79
Figure 10.7-32	Lead in Shallow Groundwater, AOC 637	10.7.80
Figure 10.7-33	Thallium in Shallow Groundwater, AOC 637	10.7.81
Figure 10.7-34	Bis(2-ethylhexyl)phthalate in Surface Water, AOC 637	10.7.87
Figure 10.7-35	Aluminum in Surface Water, AOC 637	10.7.88
Figure 10.7-36	Beryllium in Surface Water, AOC 637	10.7.89
Figure 10.7-37	Cadmium in Surface Water, AOC 637	10.7.90
Figure 10.7-38	Chromium in Surface Water, AOC 637	10.7.91
Figure 10.7-39	Copper in Surface Water, AOC 637	10.7.92
Figure 10.7-40	Iron in Surface Water, AOC 637	10.7.93
Figure 10.7-41	Lead in Surface Water, AOC 637	10.7.94
Figure 10.7-42	Mercury in Surface Water, AOC 637	10.7.95
Figure 10.7-43	Zinc in Surface Water, AOC 637	10.7.96
Figure 10.7-44	Probability Percentage of Blood Lead Level for Child 0-7 Years, AOC 637	10.7.135
Figure 10.7-45	Point Risk Estimates for Surface Soil Residential Scenario, AOC 637	10.7.145
Figure 10.7-46	Point Hazard Estimates for Surface Soil Residential Scenario, AOC 637	10.7.146
Figure 10.7-47	Point Risk Estimates for Surface Soil Industrial Scenario, AOC 637	10.7.149
Figure 10.7-48	Point Risk Estimates for Groundwater Residential Scenario, AOC 637	10.7.151
Figure 10.7-49	Point Hazard Estimates for Groundwater Residential Scenario, AOC 637	10.7.152

Figure 10.8-1	Sampling Locations, SWMU 11	10.8.2
Figure 10.8-2	Shallow Groundwater Low-Tide Potentiometric Map, SWMU 11 . .	10.8.3
Figure 10.8-3	Shallow Groundwater High-Tide Potentiometric Map, SWMU 11 . .	10.8.4
Figure 10.8-4	Lead in Surface Soil, SWMU 11	10.8.19
Figure 10.8-6	Probability Percentage of blood Lead Levels For Child 0-7 Years - Surface Soil, SWMU 11	10.8.42
Figure 10.8-7	Probability Percentage of Blood Lead Levels for Child 5-6 Years - Surface Soil, SWMU 11	10.8.46
Figure 10.9-1	Sampling Locations, SWMU 120	10.9.2
Figure 10.9-2	Shallow Groundwater Low-Tide Potentiometric Map, SWMU 120 .	10.9.3
Figure 10.9-3	Shallow Groundwater High-Tide Potentiometric Map, SWMU 120 .	10.9.4
Figure 10.9-4	BEQs in Surface Soil, SWMU 120	10.9.22
Figure 10.9-5	Antimony in Surface Soil, SWMU 120	10.9.23
Figure 10.9-6	Chromium in Surface Soil, SWMU 120	10.9.24
Figure 10.9-7	Arsenic in Shallow Groundwater, SWMU 120	10.9.38
Figure 10.9-8	Point Risk Estimates for Surface Soil Residential Scenario, SWMU 120	10.9.70
Figure 10.9-9	Point Risk Estimates for Groundwater Residential Scenario, SWMU 120	10.9.74
Figure 10.9-10	Point Hazard Estimates for Groundwater Residential Scenario, SWMU 120	10.9.75
Figure 10.10-1	Sampling Locations, AOC 643	10.10.2
Figure 10.10-2	BEQs in Surface Soil, AOC 643	10.10.24
Figure 10.10-3	Aroclor-1260 in Surface Soil, AOC 643	10.10.25
Figure 10.10-4	Dieldrin in Subsurface Soil, AOC 643	10.10.26
Figure 10.10-5	Arsenic in Surface Soil AOC 643	10.10.28
Figure 10.10-6	Chromium in Surface Soil AOC 643	10.10.29
Figure 10.10-7	Vanadium in Surface Soil, AOC 643	10.10.30
Figure 10.10-8	Point Risk Estimates for Surface Soil Residential Scenario, AOC 643	10.10.66
Figure 10.10-9	Point Hazard Estimates for Surface Soil Residential Scenario, AOC 643	10.10.67
Figure 10.10-10	Point Risk Estimates for Surface Soil Industrial Scenario, AOC 643	10.10.71
Figure 10.11-1	Sampling Locations, SWMU 3	10.11.2
Figure 10.11-2	Shallow Groundwater Low-Tide Potentiometric Map, SWMU 3	10.11.3
Figure 10.11-3	Shallow Groundwater High-Tide Potentiometric Map, SWMU 3	10.11.4
Figure 10.11-4	Alpha-Chlordane in Surface Soil; SWMU 3	10.11.24
Figure 10.11-5	Gamma-Chlordane in Surface Soil, SWMU 3	10.11.25
Figure 10.11-6	4,4'-DDE in Surface Soil, SWMU 3	10.11.26
Figure 10.11-7	Heptachlor in Surface Soil, SWMU 3	10.11.27
Figure 10.11-8	Aroclor-1260 in Surface Soil, SWMU 3	10.11.28
Figure 10.11-9	Manganese in Surface Soil, SWMU 3	10.11.30

Figure 10.11-10	Aluminum in Shallow Groundwater, SWMU 3	10.11.38
Figure 10.11-11	Beryllium in Shallow Groundwater, SWMU 3	10.11.39
Figure 10.11-12	Chromium in Shallow Groundwater, SWMU 3	10.11.40
Figure 10.11-13	Thallium in Shallow Groundwater, SWMU 3	10.11.41
Figure 10.11-14	Vanadium in Shallow Groundwater, SWMU 3	10.11.42
Figure 10.11-15	Point Risk Estimates for Surface Soil Residential Scenario, SWMU 3	10.11.80
Figure 10.11-16	Point Hazard Estimates for Surface Soil Residential Scenario, SWMU 3	10.11.81
Figure 10.11-17	Point Risk Estimates for Surface Soil Industrial Scenario, SWMU 3	10.11.85
Figure 10.11-18	Point Risk Estimates for Groundwater Residential Scenario, SWMU 3	10.11.90
Figure 10.11-19	Point Hazard Estimates for Groundwater Residential Scenario, SWMU 3	10.11.91
Figure 10.12-1	Sampling Location SWMUs 6, 7 and AOC 635	10.12.2
Figure 10.12-2	Shallow Groundwater Potentiometric Map, SWMUs 6, 7 and AOC 635	10.12.4
Figure 10.12-3	Shallow Groundwater High-Tide Potentiometric Map SWMU 6 Public Works Storage Yard, SWMU 7 PCB Transformer Storage, Building 3902, AOC 635 Paint and Oil Storehouse	10.12.5
Figure 10.12-4	BEQs in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.105
Figure 10.12-5	Benzo(a)anthracene in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.106
Figure 10.12-6	Carbazole in Subsurface Soil, SWMUs 6, 7 and AOC 635	10.12.107
Figure 10.12-7	4,4'-DDE in Surface Soil, SWMUs 6,7 and AOC 635	10.12.108
Figure 10.12-8	4,4'-DDD in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.109
Figure 10.12-9	4,4'-DDT in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.110
Figure 10.12-10	alpha-BHC in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.111
Figure 10.12-11	beta-BHC in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.112
Figure 10.12-12	delta-BHC in Surface Soil, SWMUs 6,7 and AOC 635	10.12.113
Figure 10.12-13	gamma-BHC in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.114
Figure 10.12-14	alpha-Chlordane in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.115
Figure 10.12-15	gamma-Chlordane in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.116
Figure 10.12-16	Heptachlor in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.117
Figure 10.12-17	Aroclor-1254 in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.118
Figure 10.12-18	Aroclor-1260 in Surface Soil, SWMUs 6, 7 and Aoc 635	10.12.119
Figure 10.12-19	delta-BHC in Subsurface Soil, SWMUs 6, 7 and AOC 635	10.12.120
Figure 10.12-20	Dioxin in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.122
Figure 10.12-21	Antimony in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.123
Figure 10.12-22	Arsenic in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.124
Figure 10.12-23	Chromium in Surface Soil, SWMUs 6, 7 and Aoc 635	10.12.125
Figure 10.12-24	Lead in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.126

Figure 10.12-25	Manganese in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.127
Figure 10.12-26	Thallium in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.128
Figure 10.12-27	Vanadium in Surface Soil, SWMUs 6, 7 and AOC 635	10.12.129
Figure 10.12-28	Arsenic in Subsurface Soil, SWMUs 6, 7 and AOC 635	10.12.130
Figure 10.12-29	Mercury in Subsurface Soil, SWMUs 6, 7 and AOC 635	10.12.131
Figure 10.12-30	Pentachlorophenol in Shallow Groundwater, SWMUs 6, 7 and AOC 635	10.12.146
Figure 10.12-31	Arsenic in Shallow Groundwater, SWMUs 6, 7 and AOC 635	10.12.147
Figure 10.12-32	Barium in Shallow Groundwater, SWMUs 6, 7 and AOC 635	10.12.148
Figure 10.12-33	Beryllium in Shallow Groundwater, SWMUs 6, 7 and AOC 635	10.12.149
Figure 10.12-34	Point Risk Estimates for Surface Soil Residential Scenario, SWMUs 6, 7 and AOC 635	10.12.203
Figure 10.12-35	Point Hazard Estimates for Surface Soil Residential Scenario, SWMUs 6, 7 and AOC 635	10.12.204
Figure 10.12-36	Point Risk Estimates for Surface Soil Residential Scenario	10.12.222
Figure 10.12-37	Point Risk Estimates for Groundwater Residential Scenario	10.12.232
Figure 10.12-38	Point Hazard Estimates for Groundwater Residential Scenario	10.12.233
Figure 10.13-1	Sampling Locations, AOC 646	10.13.2
Figure 10.13-2	BEQs in Surface Soil, AOC 646	10.13.18
Figure 10.13-3	Point Risk Estimates for Surface Soil Residential Scenario, AOC 646	10.13.40
Figure 10.14-1	Sampling Locations, AOC 706	10.14.2
Figure 10.14-2	Shallow Groundwater Low Tide Potentiometric Map, AOC 706	10.14.3
Figure 10.14-3	Shallow Groundwater High Tide Potentiometric Map, AOC 706	10.14.4
Figure 10.14-4	Pentachlorophenol in Surface Soil, AOC 706	10.14.33
Figure 10.14-5	Aroclor-1260 in Subsurface Soil, AOC 706	10.14.34
Figure 10.14-6	Antimony in Surface Soil, AOC 706	10.14.36
Figure 10.14-7	Cadmium in Surface Soil, AOC 706	10.14.37
Figure 10.14-8	Antimony in Subsurface Soil, AOC 706	10.14.38
Figure 10.14-9	Copper in Subsurface Soil, AOC 706	10.14.39
Figure 10.14-10	Lead in Subsurface Soil, AOC 706	10.14.40
Figure 10.14-11	Mercury in Subsurface Soil, AOC 706	10.14.41
Figure 10.14-12	Thallium in Subsurface Soil, AOC 706	10.14.42
Figure 10.14-13	Barium in Shallow Groundwater, AOC 706	10.14.49
Figure 10.14-14	Thallium in Shallow Groundwater, AOC 706	10.14.50
Figure 10.14-15	Point Hazard Estimates for Surface Soil Residential Scenario, AOC 706	10.14.83
Figure 10.14-16	Point Hazard Estimates for Groundwater Residential Scenario, AOC 706	10.14.86

Figure 10.15-1	Soil and Groundwater Sampling Locations, SWMU 24	10.15.2
Figure 10.15-2	Shallow Groundwater Low-Tide Potentiometric Map, SWMU 24	10.15.3
Figure 10.15-3	Shallow Groundwater High-Tide Potentiometric Map, SWMU 24	10.15.4
Figure 10.15-4	BEQs in Surface Soil, SWMU 24.	10.15.21
Figure 10.15-5	Arsenic in Shallow Groundwater, SWMU 24	10.15.31
Figure 10.15-6	Point Risk Estimates for Surface Soil Residential Scenario	10.15.61
Figure 10.15-7	Point Risk Estimates for Surface Soil Industrial Scenario	10.15.64
Figure 10.15-8	Point Risk Estimates for Groundwater Residential Scenario	10.15.66
Figure 10.15-9	Point Hazard Estimates for Groundwater Residential Scenario	10.15.67
Figure 11-1	Benzene in Shallow Groundwater	11.8
Figure 11-2	Antimony in Shallow Groundwater	11.9
Figure 11-3	Arsenic in Shallow Groundwater	11.10
Figure 11-4	Barium in Shallow Groundwater	11.11
Figure 11-5	Beryllium in Shallow Groundwater	11.12
Figure 11-6	Thallium in Shallow Groundwater	11.13

List of Tables

Table 1.1	Zone G AOCs and SWMUs	1.5
Table 2.1	Zone G Monitoring Well Construction Data	2.4
Table 2.2	Zone G Geotechnical Sample Data	2.7
Table 2.3	Zone G Horizontal Hydraulic Gradients	2.24
Table 2.4	Zone G Horizontal Hydraulic Conductivities	2.24
Table 2.5	Zone G Groundwater Velocity Results	2.29
Table 2.6	Zone G Vertical Hydraulic Gradients	2.32
Table 4.1	Diluted Soil Samples	4.4
Table 4.2	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Dioxins	4.18
Table 4.3	Southwest Laboratory of Oklahoma's Method Detection Limit Study for VOCs	4.20
Table 4.4	Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs	4.22
Table 4.5	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Pesticides/PCB	4.25
Table 4.6	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Organophosphorus Pesticides	4.27
Table 4.7	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Herbicides	4.28
Table 4.8	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by Low-Level ICAP Method	4.29

Table 4.9	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by ICAP Method	4.30
Table 4.10	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Mercury by Cold Vapors	4.32
Table 4.11	Southwest Laboratory of Oklahoma's Method Detection Limit Study for Miscellaneous Inorganics	4.32
Table 5.1	Background Values	5.8
Table 6.1	Constituent Characteristics Based On Chemical and Physical Properties	6.3
Table 6.2	Soil and Aquifer Parameters Used to Evaluate Fate and Transport	6.7
Table 6.3	Groundwater Travel Time Analysis	6.8
Table 6.4	Calculation of Soil-to-Groundwater Soil Screening Levels	6.12
Table 8.1	Associated With Ecological Subzones AOC/SWMUs	8.5
Table 8.2	Federal and State Listed Threatened, Endangered and Candidate Species Which Reside or Potentially Occur on NAVBASE	8.8
Table 8.3	Subzone G-1 Organic Constituents in Sediment	8.14
Table 8.4	Subzone G-1 Inorganic Constituents in Sediment	8.15
Table 8.5	Subzone G-2 Organic Constituents in Surface Soil	8.16
Table 8.6	Subzone G-2 Inorganic Constituents in Soil	8.18
Table 8.7	Wildlife Contaminant Exposure Model for Surface Soil	8.23
Table 8.8	Chemical Effects Studies on Terrestrial Infaunal Invertebrates	8.29
Table 8.9	Hazard Quotients for Potential LETHAL Effects for Wildlife Species Associated with Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2	8.43
Table 8.10	Hazard Quotients for Potential SUB-LETHAL Effects for Wildlife Species Associated with Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2	8.47
Table 8.11	Bioaccumulation Data ¹ Ecological Risk Assessment	8.51
Table 8.12	Exposure Parameters and Assumptions for Representative Wildlife Species at SubZone G-2	8.54
Table 8.13	Summary of Chemical Effects Studies on Vegetation	8.55
Table 9.1	Removal/Containment/Disposal Options	9.9
Table 9.2	Treatment Technology Options	9.9
Table 10.1.1	Soil Samples and Analyses AOC 628	10.1.3
Table 10.1.2	Organic Compound Analytical Results for Soil AOC 628	10.1.5
Table 10.1.3	Inorganic Compound Analytical Results for Soil AOC 628	10.1.8
Table 10.1.4	Analytes Detected in Surface and Subsurface Soil AOC 628	10.1.11
Table 10.1.5	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 628	10.1.24
Table 10.1.6	Soil-to-Air Volatilization Screening Analysis AOC628	10.1.26
Table 10.1.7	Chemicals Present in Site Samples, AOC 628 - Surface Soil	10.1.28
Table 10.1.8	Exposure Pathways Summary AOC 628	10.1.30

Table 10.1.9	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 628	10.1.32
Table 10.1.10	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 628	10.1.33
Table 10.1.11	Toxicological Reference Information for Chemicals of Potential Concern, AOC 628	10.1.34
Table 10.1.12	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 628	10.1.39
Table 10.1.13	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 628	10.1.40
Table 10.1.14	Summary of Risks and Hazard-based COCs, AOC 628	10.1.42
Table 10.1.15	Summary of Risk and Hazard, AOC 628	10.1.46
Table 10.1.16	Point Estimates of Risk and Hazard - Soil Pathways Residential Scenario, AOC 628	10.1.50
Table 10.1.17	Point Estimates of Risk and Hazard - Surface Soil Pathways Industrial Scenario, AOC 628	10.1.52
Table 10.1.18	Remedial Goal Options Surface Soil, AOC 628	10.1.54
Table 10.1.19	Cumulative and Chemical-Specific Exposure Risks and Hazard AOC 628	10.1.56
Table 10.1.20	Potential Corrective Measures AOC 628	10.1.56
Table 10.2.1	Soil Samples and Analyses, AOC 633	10.2.4
Table 10.2.2	Organic Compound Analytical Results for Soil, AOC 633	10.2.5
Table 10.2.3	Analytes Detected in Surface and Subsurface Soil, AOC 633	10.2.6
Table 10.2.4	Sediment Samples and Analyses, AOC 633	10.2.10
Table 10.2.5	Organic Analytical Results for Sediment, AOC 633	10.2.11
Table 10.2.6	Inorganics Analytical Results for Sediment, AOC 633	10.2.13
Table 10.2.7	Analytes Detected in Sediment Samples, AOC 633	10.2.15
Table 10.2.8	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 633	10.2.39
Table 10.2.9	Chemicals Present in Site Samples AOC 633 - Surface Soil	10.2.44
Table 10.2.10	Exposure Pathways Summary, AOC 633	10.2.46
Table 10.2.11	Summary of Statistical Analysis Surface Soil COPCs, AOC 633	10.2.47
Table 10.2.12	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 633	10.2.48
Table 10.2.13	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 633	10.2.49
Table 10.2.14	Toxicological Reference Information for Chemicals of Potential Concern, AOC 633	10.2.51
Table 10.2.15	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 633	10.2.53
Table 10.2.16	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 633	10.2.54

Table 10.2.17	Summary of Risk and Hazard-based COCs, AOC 633	10.2.55
Table 10.2.18	Summary of Risk and Hazard, AOC 633	10.2.59
Table 10.2.19	Point Estimates of Risk and Hazard - Surface Soil Pathways Residential Scenario, AOC 633	10.2.60
Table 10.3.1	Soil Samples and Analyses, AOC 634	10.3.3
Table 10.3.2	Organic Compound Analytical Results for Soil, AOC 634	10.3.5
Table 10.3.3	Inorganic Analytical Results for Soil, AOC 634	10.3.6
Table 10.3.4	Analytes Detected in Surface and Subsurface Soil, AOC 634	10.3.9
Table 10.3.5	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 634	10.3.13
Table 10.3.6	Chemicals Present in Site Samples, AOC 634 — Surface Soil	10.3.16
Table 10.4.1	Soil Samples and Analyzes AOC 638	10.4.6
Table 10.4.2	Organic Compound Analytical Results for Soil AOC 638	10.4.7
Table 10.4.3	Inorganic Analytical Results for Soil AOC 638	10.4.11
Table 10.4.4	Analytes Detected in Surface and Subsurface Soil AOC 638	10.4.14
Table 10.4.5	Groundwater Samples and Analyzes AOC 638	10.4.23
Table 10.4.6	Inorganic Analytical Results for Groundwater AOC 638	10.4.24
Table 10.4.7	Analytes Detected in Shallow Groundwater AOC 638	10.4.25
Table 10.4.8	Chemicals Detected in Surface Soil, Subsurface Soil and Shallow Groundwater; Comparison to SSLs, Tap Water RBCs, Saltwater Surface Water Chronic Screening Levels, and Background Concentrations, AOC 638	10.4.28
Table 10.4.9	Chemicals Present in Site Samples, AOC 638 — Surface Soil	10.4.31
Table 10.4.10	Chemicals Present in Site Samples, AOC 638 — Groundwater	10.4.33
Table 10.4.11	Exposure Pathways Summary, AOC 638	10.4.35
Table 10.4.12	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 638	10.4.36
Table 10.4.13	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 638	10.4.37
Table 10.4.14	Toxicological Reference Information for Chemicals of Potential Concern, AOC 638	10.4.38
Table 10.4.15	Hazard Quotients and Incremental Lifetime Cancer Risk Incidental Surface Soil Ingestion, AOC 638	10.4.42
Table 10.4.16	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 638	10.4.43
Table 10.4.17	Summary of Risk and Hazard-based COCs, AOC 638	10.4.45
Table 10.4.18	Summary of Risk and Hazard, AOC 638	10.4.49
Table 10.4.19	Point Estimates of Risked Hazard - Surface Soil Pathway	10.4.51
Table 10.4.20	Remedial Goal Options for Soil, AOC 638	10.4.53
Table 10.4.21	Cumulative and Chemical-Specific Exposure Risks and Hazard AOC 638	10.4.55
Table 10.4.22	Potential Corrective Measures AOC 638	10.4.55

Table 10.5.1	Soil Samples, AOC 642	10.5.4
Table 10.5.2	Organic Compound Analytical Results for Soil, AOC 642	10.5.5
Table 10.5.3	Inorganic Analytical Results for Soil, AOC 642	10.5.6
Table 10.5.4	Analytes Detected in Surface and Subsurface Soil, AOC 642	10.5.9
Table 10.5.5	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 642	10.5.24
Table 10.5.6	Chemicals Present in Site Samples, AOC 642 — Surface Soil	10.5.28
Table 10.5.7	Exposure Pathways Summary, AOC 642	10.5.30
Table 10.5.8	Summary of Statistical Analysis Surface Soil COPCs, AOC 642	10.5.32
Table 10.5.9	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 642	10.5.33
Table 10.5.10	Chronic Daily Intakes Dermal Contact with Surface Soil	10.5.34
Table 10.5.11	Toxicological Reference Information for Chemicals of Potential Concern	10.5.35
Table 10.5.12	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 642	10.5.39
Table 10.5.13	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 642	10.5.40
Table 10.5.14	Summary of Risk and Hazard-Based COCs, AOC 642	10.5.43
Table 10.5.15	Summary of Risk and Hazard, AOC 642	10.5.47
Table 10.5.16	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, AOC 642	10.5.49
Table 10.5.17	Point Estimates of Risk and Hazard - Surface Soil Pathways Industrial Scenario, AOC 642	10.5.53
Table 10.5.18	Remedial Goal Options Surface Soil, AOC 642	10.5.55
Table 10.5.19	Cumulative and Chemical-Specific Exposure Risks and Hazard, AOC 642	10.5.56
Table 10.5.20	Potential Corrective Measures, AOC 642	10.5.56
Table 10.6.1	1993 Soil Samples and Analyses (Pre-RFI Samples) SWMU 8 and AOC 636	10.6.8
Table 10.6.2	Soil Samples and Analyses (RFI Samples) SWMU 8 and AOC 636	10.6.10
Table 10.6.3	Organic Compound Analytical Results for Soil SWMU 8, AOC 636	10.6.12
Table 10.6.4	Inorganic Analytical Results for Soil SWMU 8, AOC 636	10.6.18
Table 10.6.5	Analytes Detected in Surface and Subsurface Soil SWMU 8 and AOC 636	10.6.21
Table 10.6.6	1993 Groundwater Samples and Analyses SWMU 8 and AOC 636	10.6.110
Table 10.6.7	Groundwater Samples and Analyses SWMU 8 and AOC 636	10.6.110
Table 10.6.8	Organic Analytical Results for Groundwater SWMU 8, AOC 636	10.6.111

Table 10.6.9	Inorganic Analytical Results for Groundwater SWMU 8, AOC 636	10.6.112
Table 10.6.10	Analytes Detected in Groundwater SWMU 8, AOC 636	10.6.114
Table 10.6.11	Chemicals Present in Surface Soil, Subsurface Soil, and Shallow Groundwater Comparison to SSLs, Tap Water RBCs, Surface Water Screening Levels, and Background Concentration, SWMU 8 and AOC 636.	10.6.131
Table 10.6.12	Soil-to-Air Volatilization Screening Analysis, SWMU 8 and AOC 636	10.6.135
Table 10.6.13	Chemicals Present in Site Samples, SWMU 8 and AOC 636. . .	10.6.138
Table 10.6.14	Chemicals Present in Site Samples - 93 Data, SWMU 8 and AOC 635	10.6.140
Table 10.6.15	Chemicals Present in Site Samples, SWMU 8 and AOC 636, Groundwater	10.6.141
Table 10.6.16	Exposure Pathways Summary, Combined SWMU 8	10.6.143
Table 10.6.17	Summary of Statistical Analysis Surface Soil COPCs, SWMU 8 and AOC 636	10.6.145
Table 10.6.18	Chronic Daily Intakes Incidental Ingestion of Surface Soil, SWMU 8 and AOC 636	10.6.146
Table 10.6.19	Chronic Daily Intakes Dermal Contact with Surface Soil, SWMU 8 and AOC 636.	10.6.147
Table 10.6.20	Chronic Daily Intakes Inhalation of Surface Soil COPCs Resulting from Dust Emission, SWMU 8 and AOC 636	10.6.148
Table 10.6.21	Chronic Daily Intake Ingestion of COPCs in Groundwater . . .	10.6.151
Table 10.6.22	Toxicological Reference Information for Chemicals of Potential Concern	10.6.152
Table 10.6.23	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, SWMU 8 and AOC 636 . . .	10.6.160
Table 10.6.24	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, SWMU 8 and AOC 636 . . .	10.6.161
Table 10.6.25	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Surface Soil COPCs Resulting from Dust Emission	10.6.162
Table 10.6.26	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, SWMU 8 and AOC 636	10.6.165
Table 10.6.27	Summary of Risk and Hazard-based COCs, SWMU 8 and AOC 636	10.6.167
Table 10.6.28	Summary of Risk and Hazard, SWMU 8 and AOC 636	10.6.177
Table 10.6.29	Point Estimates of Risk and Hazard - Surface Soil Pathways Residential Scenario, SWMU 8 and AOC 636	10.6.180
Table 10.6.30	Point Estimates of Risk and Hazard Surface Soil Pathways Industrial Scenario, SWMU 8 and AOC 636	10.6.191
Table 10.6.31	Point Estimates of Risk and Hazard Groundwater Pathways Residential Scenario, SWMU 8 and AOC 636	10.6.196

Table 10.6.32	Remedial Goal Options Surface Soil, SWMU 8 and AOC 636 .	10.6.199
Table 10.6.33	Remedial Goal Options Groundwater, SWMU 8 and AOC 636	10.6.200
Table 10.6.34	Cumulative and Chemical-Specific Exposure Risks and Hazard	10.6.201
Table 10.6.35	Potential Corrective Measures for SMWU 8 and AOC 636 . . .	10.6.202
Table 10.7.1	AOC 637 Soil Samples and Analyses	10.7.6
Table 10.7.2	AOC 637 Organic Compound Analytical Results for Soil	10.7.7
Table 10.7.3	AOC 637 Inorganic Analytical Results for Soil	10.7.12
Table 10.7.4	AOC 637 Analytes Detected in Surface and Subsurface Soil	10.7.15
Table 10.7.5	AOC 637 Sediment Sample and Analyzes	10.7.32
Table 10.7.6	AOC 637 Organic Analytical Results for Sediment	10.7.36
Table 10.7.7	AOC 637 Inorganics Analytical Results for Sediment	10.7.38
Table 10.7.8	AOC 637 Analytes Detected in Sediment Samples	10.7.40
Table 10.7.9	AOC 637 Groundwater Samples and Analyzes	10.7.48
Table 10.7.10	AOC 637 Organic Compound Analytical Results for Groundwater	10.7.55
Table 10.7.11	AOC 637 Inorganic Analytical Results for Groundwater	10.7.58
Table 10.7.12	AOC 637 Analytes Detected in Shallow Groundwater	10.7.60
Table 10.7.13	AOC 637 Surface Water Sample and Analyses	10.7.76
Table 10.7.14	AOC 637 Organic Analytical Results for Surface Water	10.7.82
Table 10.7.15	AOC 637 Inorganic Analytical Results for Surface Water	10.7.83
Table 10.7.16	AOC 637 Analytes Detected in Surface Water Samples	10.7.85
Table 10.7.17	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 637	10.7.98
Table 10.7.18	Soil-to-Air Volatilization Screening Analysis, AOC 637	10.7.103
Table 10.7.19	Chemicals Present in Site Samples, AOC 637 — Surface Soil .	10.7.106
Table 10.7.20	Chemicals Present in Site Samples, AOC 637 — Groundwater	10.7.109
Table 10.7.21	AOC 637 Exposure Pathways Summary	10.7.110
Table 10.7.22	Chronic Daily Intakes Incidental Ingestion of Surface Soil . . .	10.7.113
Table 10.7.23	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 637	10.7.114
Table 10.7.24	Chronic Daily Intakes Ingestion of COPCs in Groundwater . . .	10.7.115
Table 10.7.25	Toxicological Reference Information for Chemicals of Potential Concern, AOC 637	10.7.116
Table 10.7.26	Hazard Quotient and Incremental Lifetime Cancer Risks Incidental Surface	10.7.127
Table 10.7.27	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 637	10.7.128
Table 10.7.28	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, AOC 637	10.7.130
Table 10.7.29	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Inhalation, AOC 637	10.7.131

Table 10.7.30	Lead Model Results - AOC 637 Future Residential Scenario . . .	10.7.134
Table 10.7.31	Summary of Risk and Hazard-based COCs, AOC 637	10.7.137
Table 10.7.32	Summary of Risk and Hazard, AOC 637	10.7.144
Table 10.7.33	Point Estimates of Risk and Hazard — Surface Soil Pathways Residential Scenario, AOC 637	10.7.147
Table 10.7.34	Point Estimates of Risk and Hazard — Surface Soil Pathways Industrial Scenario, AOC 637	10.7.150
Table 10.7.35	Point Estimates of Risk and Hazard — Groundwater Pathways Residential Scenario, AOC 637	10.7.153
Table 10.7.36	Remedial Goal Options Surface Soil, AOC 637	10.7.155
Table 10.7.37	Remedial Goal Options Groundwater, AOC 637	10.7.156
Table 10.7.38	AOC 637 Cumulative and Chemical-Specific Exposure Risks and Hazard	10.7.157
Table 10.7.39	AOC 637 Potential Corrective Measures	10.7.158
Table 10.8.1	DPT Samples SWMU 11	10.8.6
Table 10.8.2	Soil Samples and Analyses SWMU 11	10.8.7
Table 10.8.3	Organic Compound Analytical Results for Soil SWMU 11	10.8.9
Table 10.8.4	Inorganic Analytical Results for Soil SWMU 11	10.8.10
Table 10.8.5	Analytes Detected in Surface and Subsurface Soil SWMU 11	10.8.13
Table 10.8.6	Sediment Samples and Analyses SWMU 11	10.8.20
Table 10.8.7	Analytical Results for Sediment SWMU 11	10.8.20
Table 10.8.8	Analytes Detected in Sediment Samples SWMU 11	10.8.22
Table 10.8.9	Groundwater Samples SWMU 11	10.8.23
Table 10.8.10	Analytical Results for Groundwater SWMU 11	10.8.26
Table 10.8.11	Analytes Detected in Shallow Groundwater SWMU 11	10.8.28
Table 10.8.12	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, SWMU 11	10.8.31
Table 10.8.13	Soil-to-Air Volatilization Screening Analysis, SWMU 11	10.8.33
Table 10.8.14	Chemicals Present in Site Samples - Surface Soil, SWMU 11	10.8.37
Table 10.8.15	Chemicals Present in Site Samples - Groundwater, SWMU 11	10.8.38
Table 10.8.16	Lead Model Results Future Residential Scenario SWMU 11	10.8.41
Table 10.8.17	Lead Model Results Industrial Scenario SWMU 11	10.8.44
Table 10.8.18	Potential Corrective Measures for SWMU 11	10.8.49
Table 10.9.1	Soil Samples and Analyses SWMU 120	10.9.6
Table 10.9.2	Organic Compound Analytical Results for Soil SWMU 120	10.9.7
Table 10.9.3	Inorganic Analytical Results for Soil SWMU 120	10.9.10
Table 10.9.4	Analytes Detected in Surface and Subsurface Soil SWMU 120	10.9.13
Table 10.9.5	Sediment Samples and Analyses SWMU 120	10.9.25
Table 10.9.6	Organic Analytical Results for Sediment SWMU 120	10.9.26
Table 10.9.7	Inorganics Analytical Results for Sediment SWMU 120	10.9.27
Table 10.9.8	Analytes Detected in Sediment Samples SWMU 120	10.9.28
Table 10.9.9	Groundwater Samples and Analyses SWMU 120	10.9.31

Table 10.9.10	Inorganic Analytical Results for Groundwater SWMU 120 . . .	10.9.32
Table 10.9.11	Analytes Detected in Shallow Groundwater SWMU 120	10.9.34
Table 10.9.12	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, SWMU 120	10.9.39
Table 10.9.13	Chemicals Present in Site Samples, SWMU 120 — Surface Soil	10.9.45
Table 10.9.14	Chemicals Present in Site Samples, SWMU 120 — Groundwater	10.9.46
Table 10.9.15	Exposure Pathways Summary SWMU 120	10.9.48
Table 10.9.16	Chronic Daily Intakes Incidental Ingestion of Surface Soil, SWMU 120	10.9.50
Table 10.9.17	Chronic Daily Intakes Dermal Contact with Surface Soil, SWMU 120	10.9.51
Table 10.9.18	Chronic Daily Intakes Ingestion of COPCs in Groundwater, SWMU 120	10.9.52
Table 10.9.19	Toxicological Reference Information for Chemicals of Potential Concern, SWMU 120	10.9.53
Table 10.9.20	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, SWMU 120	10.9.58
Table 10.9.21	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, SWMU 120	10.9.59
Table 10.9.22	Hazard Quotients and Incremental Lifetime Cancer Risks Shallow Groundwater Ingestion, SWMU 120	10.9.61
Table 10.9.23	Summary of Risk and Hazard-based COCs, SWMU 120	10.9.63
Table 10.9.24	Summary of Risk and Hazard, SWMU 120	10.9.69
Table 10.9.25	Point Estimates of Risk and Hazard — Surface Soil Pathways Residential Scenario, SWMU 120	10.9.71
Table 10.9.26	Point Estimates of Risk and Hazard — Groundwater Pathways Residential Scenario, SWMU 120	10.9.73
Table 10.9.27	Remedial Goal Options for Soil, SWMU 120	10.9.76
Table 10.9.28	Remedial Goal Options Shallow Groundwater, SWMU 120 . . .	10.9.77
Table 10.9.29	Cumulative and Chemical-Specific Exposure Risks and Hazard SWMU 120	10.9.79
Table 10.9.30	Potential Corrective Measures SWMU 120	10.9.79
Table 10.10.1	Soil Samples AOC 643	10.10.4
Table 10.10.2	Organic Compound Analytical Results for Soil AOC 643	10.10.5
Table 10.10.3	Inorganic Analytical Results for Soil AOC 643	10.10.9
Table 10.10.4	Analytes Detected in Surface and Subsurface Soil AOC 643 . .	10.10.12
Table 10.10.5	Sediment Sample and Analyses AOC 643	10.10.27
Table 10.10.6	Organic Analytical Results for Sediment AOC 643	10.10.32
Table 10.10.7	Analytes Detected in Sediment Samples	10.10.34

Table 10.10.8	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 643	10.10.36
Table 10.10.9	Soil to Air Volatilization Screening Analysis	10.10.40
Table 10.10.10	Chemicals Present in Site Samples, AOC 643 — Surface Soil	10.10.43
Table 10.10.11	Exposure Pathways Summary AOC 643	10.10.46
Table 10.10.12	Summary of Statistical Analysis Surface Soil COPCs, AOC 643	10.10.48
Table 10.10.13	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 643	10.10.49
Table 10.10.14	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 643	10.10.50
Table 10.10.15	Toxicological Reference Information for Chemicals of Potential Concern, AOC 643	10.10.51
Table 10.10.16	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 643	10.10.56
Table 10.10.17	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 643	10.10.57
Table 10.10.18	Summary of Risk and Hazard-based COCs, AOC 643	10.10.59
Table 10.10.19	Summary of Risk and Hazard, AOC 643	10.10.65
Table 10.10.20	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, AOC 643	10.10.68
Table 10.10.21	Point Estimates of Risk and Hazard — Surface Soil Pathways Industrial Scenario, AOC 643	10.10.72
Table 10.10.22	Remedial Goal Options Surface Soil, AOC 643	10.10.73
Table 10.10.23	Cumulative and Chemical-Specific Exposure Risks and Hazard	10.10.75
Table 10.10.24	Potential Corrective Measures AOC 643	10.10.75
Table 10.11.1	Soil Samples and Analyses SWMU 3	10.11.6
Table 10.11.2	Organic Compound Analytical Results for Soil SWMU 3	10.11.8
Table 10.11.3	Inorganic Analytical Results for Soil SWMU 3	10.11.11
Table 10.11.4	Analytes Detected in Surface and Subsurface Soil SWMU 3	10.11.14
Table 10.11.5	Groundwater Samples and Analyses SWMU 3	10.11.31
Table 10.11.6	Inorganic Analytical Results for Groundwater SWMU 3	10.11.32
Table 10.11.7	Analytes Detected in Shallow Groundwater SWMU 3	10.11.34
Table 10.11.8	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, SWMU 3	10.11.43
Table 10.11.9	Soil-to-Air Volatilization Screening Analysis, SWMU 3	10.11.46
Table 10.11.10	Chemicals Present in Site Samples, SWMU 3	10.11.50
Table 10.11.11	Chemicals Present in Site Samples SWMU 3 — Surface Soil	10.11.51
Table 10.11.12	Exposure Pathways Summary SWMU 3	10.11.52

Table 10.11.13	Summary of Statistical Analysis Surface Soil COPCs, SWMU 3	10.11.54
Table 10.11.14	Chronic Daily Intakes Incidental Ingestion of Surface Soil, SWMU 3	10.11.56
Table 10.11.15	Chronic Daily Intakes Dermal Contact with Surface Soil, SWMU 3	10.11.57
Table 10.11.16	Chronic Daily Intakes Ingestion of COPCs in Groundwater . . .	10.11.58
Table 10.11.17	Toxicological Reference Information for Chemicals of Potential Concern, SWMU 3	10.11.59
Table 10.11.18	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, SWMU 3	10.11.65
Table 10.11.19	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soils, SWMU 3	10.11.66
Table 10.11.20	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, SWMU 3	10.11.68
Table 10.11.21	Summary of Risk and Hazard-based COCs, SWMU 3	10.11.71
Table 10.11.22	Summary of Risk and Hazard, SWMU 3	10.11.79
Table 10.11.23	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, SWMU 3	10.11.82
Table 10.11.24	Point Estimates of Risk and Hazard — Surface Soil Pathways Industrial Scenario, SWMU 3	10.11.86
Table 10.11.25	Point Estimates of Risk and Hazard — Groundwater Pathways Residential Scenario, SWMU 3	10.11.89
Table 10.11.26	Remedial Goal Options for Surface Soil, SWMU 3	10.11.92
Table 10.11.27	Remedial Goal Options for Shallow Groundwater, SWMU 3 . .	10.11.93
Table 10.11.28	Cumulative and Chemical-Specific Exposure Risks and Hazard SWMU 3	10.11.94
Table 10.11.29	Potential Corrective Measures SWMU 3	10.11.95
Table 10.12.1	1933 Soil Samples and Analyses (Pre-RFI Samples) SWMU 6,7 and AOC 635	10.12.6
Table 10.12.2	Soil Samples and Analyses SWMUs 6, 7 and AOC 635	10.12.8
Table 10.12.3	Organic Compound Analytical Results for Soil SWMU 6, SWMU 7, AOC 635	10.12.10
Table 10.12.4	Inorganic Analytical Results for Soil (1993) SWMU 6, SWMU 7, AOC 635	10.12.16
Table 10.12.5	Organic Compound Analytical Results for Soil SWMU 6, SWMU 7, AOC 635	10.12.19
Table 10.12.6	Inorganic Analytical Results for Soil SWMU 6, SWMU 7, AOC 635	10.12.24
Table 10.12.7	Analytes Detected in Surface and Subsurface Soil SWMU 6, SWMU 7, AOC 635	10.12.27
Table 10.12.8	1993 Groundwater Samples and Analyses (Pre-RFI Samples) SWMU 6, 7 and AOC 635	10.12.132

Table 10.12.9	SWMUs 6, 7 and AOC 635 Groundwater Samples and Analyses	10.12.132
Table 10.12.10	Organic Analytical Results for Groundwater SWMU 6, SWMU 7, AOC 635	10.12.134
Table 10.12.11	Inorganic Analytical Results for Groundwater SWMU 6, SWMU 7, AOC 635	10.12.135
Table 10.12.12	Analytes Detected in Shallow Groundwater SWMU 6, SWMU 7, AOC 635	10.12.137
Table 10.12.13	Chemicals Detected in Surface Soil, and Shallow Groundwater. Comparison to SSLs, Tap Water RBCs, Saltwater Surface Water Chronic Screening Levels, and Background Concentrations, SWMUs 6, 7 and AOC 635.	10.12.151
Table 10.12.14	Soil-to-Air Volatilization Screening Analysis, SWMUs 6, 7 and AOC 635	10.12.154
Table 10.12.15	Chemicals Present in Site Samples - Surface Soil, SWMUs 6, 7 and AOC 635	10.12.160
Table 10.12.16	Chemicals Present in Site Samples - 1993 Surface Soil	10.12.162
Table 10.12.17	Chemicals Present in Site Samples - Groundwater	10.12.163
Table 10.12.18	Exposure Pathways Summary — Combined SWMU 6	10.12.164
Table 10.12.19	Summary of Statistical Analysis Surface Soil COPCs	10.12.166
Table 10.12.20	Chronic Daily Intakes Incidental Ingestion of Surface Soil	10.12.167
Table 10.12.21	Chronic Daily Intakes Dermal Contact with Surface Soil	10.12.168
Table 10.12.22	Chronic Daily Intakes Inhalation of Surface Soil COPCs Resulting from Dust Emission	10.12.170
Table 10.12.23	Chronic Daily Intakes Ingestion of COPCs in Groundwater	10.12.172
Table 10.12.24	Toxicological Reference Information for Chemicals of Potential Concern	10.12.173
Table 10.12.25	HCH Isomer Information SWMU 6, SWMU 7, AOC 635	10.12.178
Table 10.12.26	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion	10.12.187
Table 10.12.27	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Dermal Contact with Surface Soil	10.12.188
Table 10.12.28	Hazard Quotients and Incremental Lifetime Cancer Risks Inhalation of Surface Soil COPCs Resulting from Dust Emission	10.12.189
Table 10.12.29	Hazard Quotients and Incremental Lifetime Cancer Risks Ingestion	10.12.192
Table 10.12.30	Summary of Risk and Hazard-based COCs	10.12.194
Table 10.12.31	Summary of Risk and Hazard	10.12.202
Table 10.12.32	Point Estimates of Risk and Hazard - Surface Soil Pathways Residential Scenario	10.12.205
Table 10.12.33	Points Estimates of Risk and Hazard - Surface Sol Pathways Industrial Scenario	10.12.223
Table 10.12.34	Point Estimates of Risk and Hazard - Groundwater Pathways Residential Scenario	10.12.235

Table 10.12.35	Remedial Goal Options Surface Soil	10.12.236
Table 10.12.36	Remedial Goal Options Groundwater	10.12.238
Table 10.12.37	Cumulative and Chemical-Specific Exposure Risks and Hazard SWMUs 6, 7 and AOC 635	10.12.239
Table 10.12.38	Potential Corrective Measures SWMUs 6, 7 and AOC 635 . .	10.12.240
Table 10.13.1	Soil Samples and Analyses AOC 646	10.13.4
Table 10.13.2	Organic Analytical Results for Soil AOC 646	10.13.5
Table 10.13.3	Inorganic Analytical Results for Soil AOC 646	10.13.8
Table 10.13.4	Analytes Detected in Surface and Subsurface Soil AOC 646 . .	10.13.11
Table 10.13.5	Chemicals Detected in Surface Soil, Subsurface Soil, and Shallow Groundwater. Comparison to SSLs, Tap Water RBCs, Saltwater Surface Water Chronic Screening Levels, and Background Concentrations, AOC 646	10.13.20
Table 10.13.6	Soil-to-Air Volatilization Screening Analysis, AOC 646	10.13.21
Table 10.13.7	Chemicals Present in Site Samples - Surface Soil, AOC 646 . .	10.13.24
Table 10.13.8	Exposure Pathways Summary — AOC 646	10.13.25
Table 10.13.9	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 646	10.13.28
Table 10.13.10	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 646	10.13.29
Table 10.13.11	Toxicological Reference Information for Chemicals of Potential Concern, AOC 646	10.13.30
Table 10.13.12	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 646	10.13.33
Table 10.13.13	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 646	10.13.34
Table 10.13.14	Summary of Risk and Hazard-based COCs, AOC 646	10.13.36
Table 10.13.15	Summary of Risk and Hazard, AOC 646	10.13.39
Table 10.13.16	Point Estimate of Risk and Hazard - Surface Soil Pathways Residential Scenario, AOC 646	10.13.42
Table 10.13.17	Remedial Goal Options Surface Soil, AOC 646	10.13.43
Table 10.13.18	Cumulative and Chemical-Specific Exposure Risks and Hazard AOC 646	10.13.44
Table 10.13.19	Potential Corrective Measures AOC 646	10.13.45
Table 10.14.1	Soil Samples and Analyses, AOC 706	10.14.6
Table 10.14.2	Organic Compound Analytical Results for Soil, AOC 706	10.14.8
Table 10.14.3	Inorganic Analytical Results for Soil, AOC 706	10.14.13
Table 10.14.4	Analytes Detected in Surface and Subsurface Soil, AOC 706	10.14.16
Table 10.14.5	Groundwater Samples and Analyses, AOC 706	10.14.43
Table 10.14.6	Organic Compound Analytical Results for Groundwater, AOC 706	10.14.44
Table 10.14.7	Inorganic Analytical Results for Groundwater, AOC 706	10.14.45
Table 10.14.8	Analytes Detected in Shallow Groundwater, AOC 706	10.14.47

Table 10.14.9	Chemicals Detected in Surface Soil, Subsurface Soil, Shallow Groundwater, and Deep Groundwater Comparison to SSLs, Tap Water RBCs, Salt Water Surface Water Chronic Screening Levels, and Background Concentrations, AOC 706	10.14.52
Table 10.14.10	Soil-to-Air Volatilization Screening Analysis, AOC 706	10.14.55
Table 10.14.11	Chemicals Present in Site Samples, AOC 706 — Surface Soil	10.14.58
Table 10.14.12	Chemicals Present in Site Samples, AOC 706 — Groundwater	10.14.60
Table 10.14.13	Exposure Pathways Summary, AOC 706	10.14.62
Table 10.14.14	Summary of Statistical Analysis Surface Soil COPCs, AOC 706	10.14.64
Table 10.14.15	Chronic Daily Intakes Incidental Ingestion of Surface Soil, AOC 706	10.14.65
Table 10.14.16	Chronic Daily Intakes Dermal Contact with Surface Soil, AOC 706	10.14.66
Table 10.14.17	Chronic Daily Intakes Ingestion of COPCs in Groundwater, AOC 706	10.14.67
Table 10.14.18	Toxicological Reference Information for Chemicals of Potential Concern,	10.14.69
Table 10.14.19	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion, AOC 706	10.14.72
Table 10.14.20	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil, AOC 706	10.14.73
Table 10.14.21	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion, AOC 706	10.14.75
Table 10.14.22	Summary of Risk and Hazard-based COCs, AOC 706	10.14.77
Table 10.14.23	Summary of Risk and Hazard, AOC 706	10.14.82
Table 10.14.24	Point Estimates of Risk and Hazard — Soil Pathways Residential Scenario, AOC 706	10.14.84
Table 10.14.25	Point Estimates of Risk and Hazard — Groundwater Pathways Residential	10.14.85
Table 10.14.26	Remedial Goal Options Groundwater, AOC 706	10.14.88
Table 10.14.27	Cumulative and Chemical-Specific Exposure Risks and Hazard, AOC 706	10.14.89
Table 10.14.28	Potential Corrective Measures, AOC 706	10.14.89
Table 10.15.1	Zone G SWMU 24 Soil Samples and Analyses	10.15.6
Table 10.15.2	Zone G SWMU 24 Organic Compound Analytical Results for Soil	10.15.9
Table 10.15.3	Zone G SWMU 24 Inorganic Compound Analytical Results for Soil	10.15.13
Table 10.15.4	Zone G SWMU 24 Analytes Detected in Surface and Subsurface Soil	10.15.16
Table 10.15.5	Zone G SWMU 24 Groundwater Samples and Analyses	10.15.23
Table 10.15.6	Zone G SWMU 24 Organic Analytical Results for Groundwater	10.15.24
Table 10.15.7	Zone G SWMU 24 Inorganic Analytical Results for Groundwater	10.15.25
Table 10.15.8	Zone G SWMU 24 Analytes Detected in Shallow Groundwater	10.15.27

Table 10.15.9	Chemicals Detected in Surface Soil and Shallow Groundwater, SWMU 24	10.15.33
Table 10.15.10	Soil-to-Air Volatilization Screening Analysis, SWMU 24	10.15.35
Table 10.15.11	Chemicals Present in Site Samples, SWMU 24, Surface Soil	10.15.38
Table 10.15.12	Chemicals Present in Site Samples, SWMU 24, Groundwater	10.15.39
Table 10.15.13	Exposure Pathways Summary — SWMU 24 Charleston Naval Complex — Zone G Charleston, South Carolina	10.15.40
Table 10.15.14	Chronic Daily Intakes (CDI) Incidental Ingestion of Surface Soil	10.15.43
Table 10.15.15	Chronic Daily Intakes (CDI) Dermal Contact with Surface Soil	10.15.44
Table 10.15.16	Chronic Daily Intakes (CDI) Ingestion of COPCs in Groundwater	10.15.45
Table 10.15.17	Toxicological Reference Information for Chemicals of Potential Concern	10.15.46
Table 10.15.18	Hazard Quotients and Incremental Lifetime Cancer Risks Incidental Surface Soil Ingestion	10.15.49
Table 10.15.19	Hazard Quotients and Incremental Lifetime Cancer Risks Dermal Contact with Surface Soil	10.15.50
Table 10.15.20	Hazard Quotients and Incremental Lifetime Cancer Risks Groundwater Ingestion	10.15.52
Table 10.15.21	Summary of Risk an Hazard-based COCs	10.15.54
Table 10.15.22	Summary of Risk and Hazard	10.15.60
Table 10.15.23	Point Estimates of Risk - Surface Soil Pathways	10.15.62
Table 10.15.24	Point Estimates of Risk - Surface Soil Pathways Site Worker Scenario	10.15.65
Table 10.15.25	Point Estimates of Risk and Hazard - Groundwater Pathways Residential Scenario	10.15.68
Table 10.15.26	Remedial Goal Options Surface Soil	10.15.70
Table 10.15.27	Remedial Goal Options Groundwater	10.15.71
Table 10.15.28	Zone G SWMU 24 Cumulative and Chemical-Specific Exposure Risks and Hazard	10.15.72
Table 10.15.29	Zone G SWMU 24 Potential Corrective Measures	10.15.72
Table 11.1	Site Conclusions and Zone G Preliminary Recommendations	11.2
Table 11.2	AOC 628 Conclusion Summary	11.3
Table 11.3	AOC 633 Conclusion Summary	11.4
Table 11.4	AOC 638 Conclusion Summary	11.5
Table 11.5	AOC 642 Conclusion Summary	11.6
Table 11.6	SWMU 8 and AOC 636 Conclusion Summary	11.7
Table 11.7	AOC 637 Conclusion Summary	11.14
Table 11.8	SWMU 11 Conclusion Summary	11.15
Table 11.9	SWMU 120 Conclusion Summary	11.16
Table 11.10	AOC 643 Conclusion Summary	11.16
Table 11.11	SWMU 3 Conclusion Summary	11.17

Table 11.12	SWMUs 6, 7 and AOC 635 Conclusion Summary	11.18
Table 11.13	AOC 646 Conclusion Summary	11.19
Table 11.14	AOC 706 Conclusion Summary	11.20
Table 11.15	SWMU 24 Conclusion Summary	11.21
Table 11.16	Zone G AOC/SWMUs Associated With Ecological Subzones	11.22

List of Appendices

Appendix A	Monitoring Well Construction Diagrams
Appendix B	Geotechnical Summary
Appendix C	AQTESOLV Results
Appendix D	Analytical Data Summary
Appendix E	Data Validation Reports

ABBREVIATIONS, ACRONYMS, AND SYMBOLS FOR NAVBASE ZONE G

The following abbreviations, acronyms, and units of measurement are used in this report.

atm-m ³ /mole	Atmospheric cubic meters per mole
AL	Action Level
AOC	Area of Concern
AQTESOLV	Aquifer Test Solver
AA	Atomic Absorption
AEC	Area of Ecological Concern
AWQC	Ambient Water Quality Criteria
b	Aquifer Thickness
BAF	Bioaccumulation Factor
BEQ	Benzo(a)pyrene Equivalent
BEHP	bis(2-ethylhexyl)phthalate
BEST	Building Economic Solutions Together
bgs	Below ground surface
BOS	Bottom of screen
BOW	Bottom of well
BRA	Baseline Risk Assessment
BRAC	Base Realignment and Closure Act of 1988 and Defense Base Closure and Realignment Act of 1990, collectively
BW	Receptor body weight (kg)
C-2	Candidate species for federal listing, Category 2
CCC	Calibration Check compound
CAMU	Corrective Action Management Unit
CDD	Chlorinated dibenzo-p-dioxin
CDF	Chlorinated dibenzofuran
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
cm/sec	Centimeter per second
CMS	Corrective Measures Study
CNSY	Charleston Naval Shipyard
COC	Chemical of Concern
cPAH	Carcinogenic Polynuclear Aromatic Hydrocarbon
COPC	Chemical of Potential Concern
CPSS	Chemical Present in Site Samples
CR	Confirmed Resident
CRAVE	Carcinogenic Risk Assessment Verification Endeavor

Abbreviations, Acronyms, And Symbols For NAVBASE Zone G (Continued)

CrIII	Trivalent chromium
CrVI	Hexavalent chromium
CSAP	Comprehensive Sampling and Analysis Plan
CSI	Confirmatory Sampling Investigation
CT	Central Tendency
D	Density/Diluted Sample
DAF	Dilution Attenuation Factor
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyl-trichloroethane
DPT	Direct Push Technology
DQO	Data Quality Objectives
E	Endangered
ED	Exposure Duration
E/A&H	EnSafe/Allen & Hoshall
ECPC	Ecological Chemical of Potential Concern
EPC	Exposure Point Concentration
ERA	Environmental Risk Assessment
ESA	Ecological Study Area
ESDSOPQAM	Environmental Services Division Standard Operating Procedures and Quality Assurance Manual
FC	Fraction contacted
FCC	Food Contaminant Concentration
FDS	Fuel Distribution System
FI	Fraction Ingested/Food Ingested
ft bgs	Feet below ground surface
ft/day	Feet per day
ft msl	Feet above mean sea level
F _{oc}	Fraction Organic Carbon
g/cm ³	gram per cubic centimeter
g/mole	gram per mole
GW	Ground Water
HEAST	Health Effects Assessment Summary Table
HHRA	Human Health Risk Assessment
HI	Hazard Index
HL	Henry's Law Constant
HpCDD	Heptachlorodibenzo-p-dioxin

Abbreviations, Acronyms, And Symbols For NAVBASE Zone G (Continued)

HpCDF	Heptachlorodibenzofuran
HxCDD	Hexachlorodibenzo-p-dioxin
HxCDF	Hexachlorodibenzofuran
HQ	Hazard Quotient
HR	Home Range (acres)
HSWA	Hazardous and Solid Waste Amendments
HTTD	High-Temperature Thermal Desorption
HxCDD	Hexachlorodibenzo-p-dioxin
HxCDF	Hexachlorodibenzofuran
<i>i</i>	Horizontal Hydraulic Gradient
ICAP	Inductively Coupled Argon Plasma
ICM	Interim Corrective Measure
ILCR	Incremental Lifetime Excess Cancer Risk
IR _{diet}	Food ingestion rate of receptor (kg of food per day)
IRIS	Integrated Risk Information System
K	Hydraulic Conductivity
K _d	Normalized Partitioning Coefficient
K _h	Hydraulic Conductivity
Kg/L	Kilogram per liter
K _{oc}	Organic Carbon/Water Partitioning Coefficient
K _v	Vertical Permeability
k _{goc} /L _{water}	Kilogram of organic carbon per liter of water
log K _{ow}	Octanol/Water Partitioning Coefficient
LCS	Laboratory Control Sample
LC ₅₀	Lethal Concentration to 50 percent of test population
LD ₅₀	Lethal Dose to 50 percent of test population
LM	Likely Migrant
LN	Natural Logarithm
LOAEL	Lowest Observed Adverse Effect Level
LTDD	Low-Temperature Thermal Desorption
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
meq/L	milliequivalent per liter
meg/100g	milliequivalent per 100 grams
mg/kg	Miligram per kilogram
mg/kg-BW	Miligram per kilogram of bodyweight
mg/kg-BW-day	Miligram per kilogram of bodyweight per day
mg/kg-day	Milligram per kilogram per day

Abbreviations, Acronyms, And Symbols For NAVBASE Zone G (Continued)

mg/L	Miligram per liter
MW	Molecular Weight
mm Hg	millimeters of mercury
n	Soil total porosity/Number of samples collected
<i>ne</i>	Effective porosity
NA	Not Available/Not Applicable
NAVBASE	Naval Base Charleston
NC	Species of Concern, National/Not able to calculate value
ND	Not Detected
NFI	No Further Investigation
NM	Not Measured
NOAEL	No Observed Adverse Effects Level
NPDES	National Pollutant Discharge Elimination System
NRCC	National Research Council of Canada
NTU	Nephelometric Turbidity Units
OCDD	Octachlorodibenzo-p-dioxin
OCDF	Octachlorodibenzofuran
OP	Organophosphorous
P _n	Percent of diet composed of food item N
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PDE	Potential Dietary Exposure
PeCDD	Pentachlorodibenzo-p-dioxin
PeCDF	Pentachlorodibenzofuran
PM	Possibly Migrant
POTW	Publicly Owned Treatment Works
POV	Privately Owned Vehicle
PR	Possible Resident
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
Qc	Quaternary Clay
Qm	Quaternary Marsh Clay
Qs	Quaternary Sand

Abbreviations, Acronyms, And Symbols For NAVBASE Zone G (Continued)

RAB	Restoration Advisory Board
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RC	Species of Concern, Regional/Reference Concentration
RCRA	Resource Conservation and Recovery Act
RDA	Charleston Naval Complex Redevelopment Authority
R	Retardation Factor
RFA	RCRA Facility Assessment
RfD	Reference Dose
RFI	RCRA Facility Investigation
RGO	Remedial Goal Option
RME	Reasonable Maximum Exposure
RRF	Relative Response Factor
S	Aquifer Storativity
SC	Species of Concern, State
SCDHEC	South Carolina Department of Health and Environmental Control
SCWMRD	South Carolina Wildlife and Marine Resources Department
SE	Soil Exposure
SF	Slope Factor
SFF	Site Foraging Factor
SL	State Listed
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SPCC	System Performance Check Compounds
SR	Status Review
SQL	Sample Quantitation Limit
SSL	Soil Screening Levels
SSV	Sediment Screening Value
SVE	Soil Vapor Extraction
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
T	Aquifer Transmissivity/Threatened
Ta	Ashley Formation
T _{1/2}	Half Life
T _n	Tissue concentration in food item N
TCDD	Tetrachlorodibenzo-p-dioxin
TCDF	Tetrachlorodibenzofuran
TDS	Total Dissolved Solids
TEF	Toxic Equivalency Factor
TEQ	TCDD Equivalency Quotient
THQ	Target Hazard Quotient

Abbreviations, Acronyms, And Symbols For NAVBASE Zone G (Continued)

TOC	Top of Casing/Total Organic Carbon
TOS	Top of Screened Interval
TPH	Total Petroleum Hydrocarbons
TRV	Toxicity Reference Value
T/SA	Threatened due to similarity of appearance
Tu	Tertiary Undifferentiated Unit
UCL	Upper Confidence Limit
UM	Unlikely Migrant
UR	Unlikely Resident
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
UTL	Upper Tolerance Limit
UV	Ultraviolet
V	Horizontal Groundwater Velocity
VOC	Volatile Organic Compound
VP	Vapor Pressure
Δx	Distance Between Points
Δh	Hydraulic Head
ρ_b	Dry soil bulk density
$\mu\text{g}/\text{cm}^2$	Microgram per square centimeter
$\mu\text{g}/\text{kg}$	Microgram per kilogram
$\mu\text{g}/\text{L}$	Microgram per liter
$\mu\text{g}/\text{m}^3$	Microgram per cubic meter
ng/kg	Nanogram per kilogram
pg/L	Picogram per liter
%D	Percent Difference
%RSD	Percent Relative Standard Deviation

FILING INSTRUCTIONS

The following is a list of the pages in the *Draft Zone G RCRA Facility Investigation Report*, dated February 20, 1998 that have been revised. The obsolete pages presently in your binders are listed in the column headed "Remove." New and replacement pages are listed in the column headed "Replace."

If you have any questions, please call 843-884-0029.

List of Changes/Revisions	<u>Remove</u> <u>Pages</u>	<u>Replace</u> <u>Pages</u>
Table of Contents - updated.	i - xiv	i - xvi
Volume IV of VI – Sections 10.13 to 13 and Appendix A to C		
SWMU 24 Section 10.15	-	10.15.1 to 10.15.72
Section 11.0	Remove all pages except for the figures	11.1 to 11.23
Appendix A	-	Add to the back
Volume V of VI – Appendix D to Part of E		
Appendix D	-	Add to the back
Volume VI of VI – Appendix E		
Appendix E	-	Add to the back

1.0 INTRODUCTION

The environmental investigation and remediation at Naval Base Charleston (NAVBASE) are required by the Hazardous and Solid Waste Amendments (HSWA) portion of the Resource Conservation and Recovery Act (RCRA) Part B permit (permit number: SCO 170 022 560) (South Carolina Department of Health and Environmental Control [SCDHEC], May 4, 1990). These conditions are consistent with the RCRA Corrective Action Program, whose objectives are to evaluate the nature and extent of any hazardous waste or constituent releases, and to identify, develop, and implement appropriate corrective measures to protect human health and the environment. The scope of the RCRA Facility Investigation (RFI) includes the entire naval base, which has been divided into Zones A through L to accelerate the RFI process. This Zone G RFI Report, prepared by EnSafe, is submitted to satisfy condition IV.C.6 of the HSWA portion of the Part B permit (SCDHEC, May 4, 1990).

1.1 NAVBASE Description and Background

Section 1.1 of the *Draft Zone A RCRA Facility Investigation Report* (EnSafe/Allen & Hoshall [E/A&H], 1996a) details the description and background of NAVBASE. Several facilities within Zone G are currently being leased to private industrial clients.

1.2 Base Closure Process for Environmental Cleanup

Section 1.2 of the *Draft Zone A RFI Report* details the base closure process for environmental cleanup. Where appropriate in this document, Areas of Concern (AOCs) and Solid Waste Management Units (SWMUs) are collectively referred to as *sites*. Due to their proximity and similarity in materials, many sites in Zone G have been grouped for investigative purposes and share data from sample locations to define nature and extent of contamination along site boundaries.

1.3 Investigative Zone Delineation

Due to the size of the base and the level of detail required for investigations, NAVBASE has been divided into 12 investigative zones, identified as Zones A through L, and as shown in Figure 1-1. The Restoration Advisory Board (RAB) and the Building Economic Solutions Together (BEST) committees ranked the investigation and cleanup priority of the zones. In 1994, BEST was replaced by the Charleston Naval Complex Redevelopment Authority (RDA), which has authority to establish leases for the transferred property. Zone G is bordered by Zone F along Wood Street and Hobson Avenue to the northwest, the controlled industrial area (Zone E) along Thirteenth Street to the northwest; the Cooper River to the north; Bainbridge Avenue (Zone H) and the base property boundary to the south; and Halsey Street (Zones H and I) to the east. The NAVBASE property boundary is to the south and west. The zone also includes the Chicora Tank Farm to the southwest.

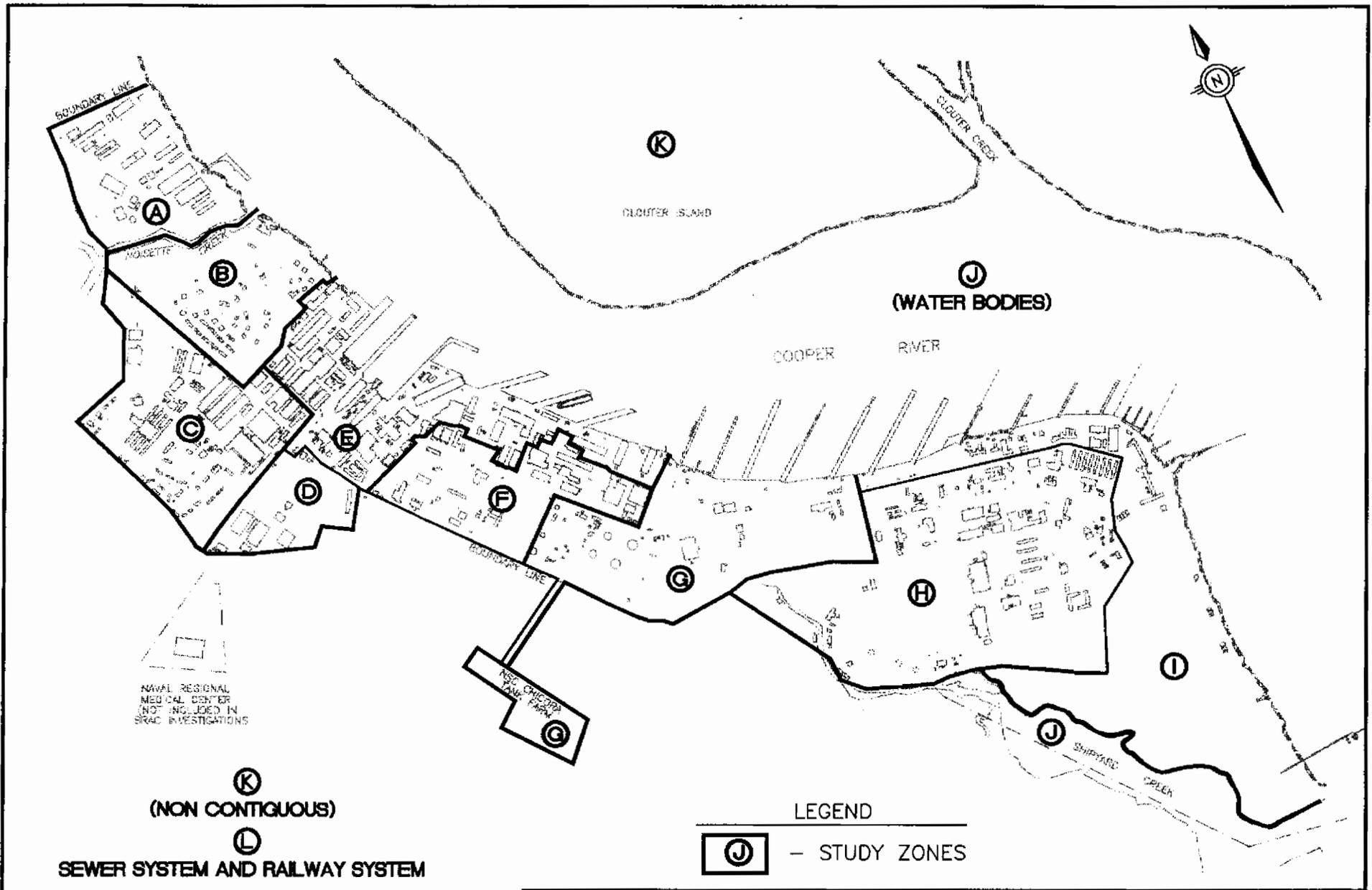
1.4 Current Investigation

Objective

The objectives of the RFI are to characterize the nature and extent of contaminants associated with releases from AOCs and SWMUs, to evaluate contaminant migration pathways, and to identify both actual and potential receptors. The ultimate goal is to determine the need for interim corrective measures (ICMs) or a corrective measures study (CMS). This need will be evaluated by conducting a baseline risk assessment (BRA) to assess the excess risks posed to human health and the environment by individual and/or groups of sites within a zone.

Field Investigation Scope

Twenty-seven sites were identified in Zone G through the RCRA Facility Assessment (RFA) process. Ten of these sites are associated with the NAVBASE Fuel Distribution System (FDS) and will be reported on separately. Each site in Zone G is detailed in the *Final RCRA Facility Assessment for Naval Base Charleston* (E/A&H, June 6, 1995), and the *Final Zones D, F, and G*

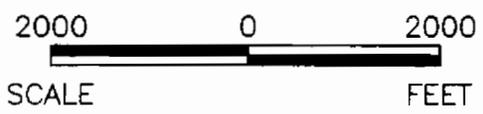


NAVAL REGIONAL
MEDICAL CENTER
(NOT INCLUDED IN
SRAC INVESTIGATIONS)

(K)
(NON CONTIGUOUS)

(L)

SEWER SYSTEM AND RAILWAY SYSTEM



LEGEND

(J) - STUDY ZONES



ZONE G
RCRA FACILITY
INVESTIGATION REPORT
NAVAL BASE CHARLESTON
CHARLESTON, S.C.

FIGURE 1-1
INVESTIGATIVE
ZONE BOUNDARIES

RFI Work Plan (E/A&H, 1996b). Investigative approaches for each site were developed and proposed based on the best available information at that time and were subject to modification based on additional site information availability and/or site conditions. The RCRA investigatory designations used are defined below:

- *No Further Investigation (NFI)* — This designation was applied to AOCs or SWMUs with sufficient data to thoroughly assess the potential hazards associated with the site and to determine that it does not pose a threat to human health or the environment.
- *Confirmatory Sampling Investigation (CSI)* — This designation was applied to AOCs or SWMUs for which insufficient data were available to thoroughly assess the potential site hazards. Generally, a limited amount of "confirmatory" samples were needed to determine whether a hazard exists. The result of the CSI determines whether NFI is appropriate or a full-scale RFI is warranted.
- *RFI* — This designation was applied to AOCs or SWMUs if visual evidence, historical information such as spill reports, or analytical data indicated that a release of hazardous substances to the environment has occurred. A complete characterization of the site is needed to determine the nature and extent of contamination, to identify migration pathways, to identify actual and potential receptors, and to evaluate the ecological and human health risks posed by the site.

The approved final RFI work plan outlined an investigative strategy for each of the 17 Zone G sites reported on herein and the ten sites included in the FDS. The FDS sites will be presented in a separate report. Table 1.1 summarizes each Zone G AOC and SWMU requiring investigation. Figure 1-2 identifies each site's location.

Table 1.1
 Zone G
 AOCs and SWMUs

AOCs and SWMUs	Site Description	Investigative Approach	Previous Investigations	Investigation Grouping
AOC 628	Sandblasting Area, Southeast of Building 68	CSI	None	Investigated independently
AOC 633	Substation, Building 451C	CSI	None	Investigated independently
AOC 634	Flammable Material Storage Building 1814	CSI	None	Investigated independently
AOC 638	Torpedo Workshop, Building 132	CSI	None	Investigated independently
AOC 642	Former Pistol Range, Present Parking Lot	CSI	None	Investigated independently
SWMU 8	Oil Sludge Pit	RFI	1982 Confirmation Study; 1993 Soil and Groundwater Sampling	Investigated together due to site proximity
AOC 636	Torpedo Magazine, Building 161 Area	CSI	None	
AOC 637	Dump Area, Building 161 Area	CSI	None	Investigated independently
SWMU 11	Caustic Pond	RFI	Initial Assessment; 1982 Confirmation Study	Investigated independently
SWMU 120	Pier M Laydown	CSI	None	Investigated independently
AOC 643	Substation, Building 125	CSI	None	Investigated independently
SWMU 3	Pesticide Mixing Area	RFI	1982 Confirmation Study	Investigated independently
SWMU 6	Public Works Storage Yard (Old Corral)	RFI	1988 closure of Interim Status HW Facilities; 1993 soil and groundwater sampling	Investigated together due to site proximity
SWMU 7	PCB Transformer Storage Yard	RFI	1982 confirmation study; 1993 soil sampling	
AOC 635	Paint and Oil Storehouse, Building 3902	RFI	None	
AOC 646	Operational Storage, Building 3906-Q	CSI	None	Investigated independently
AOC 706	Area Behind Building 246	RFI	1987 Interim RFA; 1996 Closure Activities Report	Investigated independently

1.5 Previous Investigations 1

In addition to data generated during this investigation, pertinent data from previous investigations of Zone G sites have been incorporated, along with other historical information. 2
3

1.6 RFI Report Organization 4

To facilitate review, the RFI Report has been formatted to discuss zone-wide information, overall technical approach, and evaluation methods first. Following this are the AOC and SWMU specific evaluations and conclusions. These general sections are sequenced according to the natural progression of an RFI investigation. The zone-wide sections are: 5
6
7
8

- 1.0 Introduction 9
- 2.0 Physical Setting 10
- 3.0 Field Investigation 11
- 4.0 Data Validation 12
- 5.0 Data Evaluation and Background Comparison 13
- 6.0 Fate and Transport 14
- 7.0 Human Health Risk Assessment 15
- 8.0 Ecological Risk Assessment 16
- 9.0 Corrective Measures 17

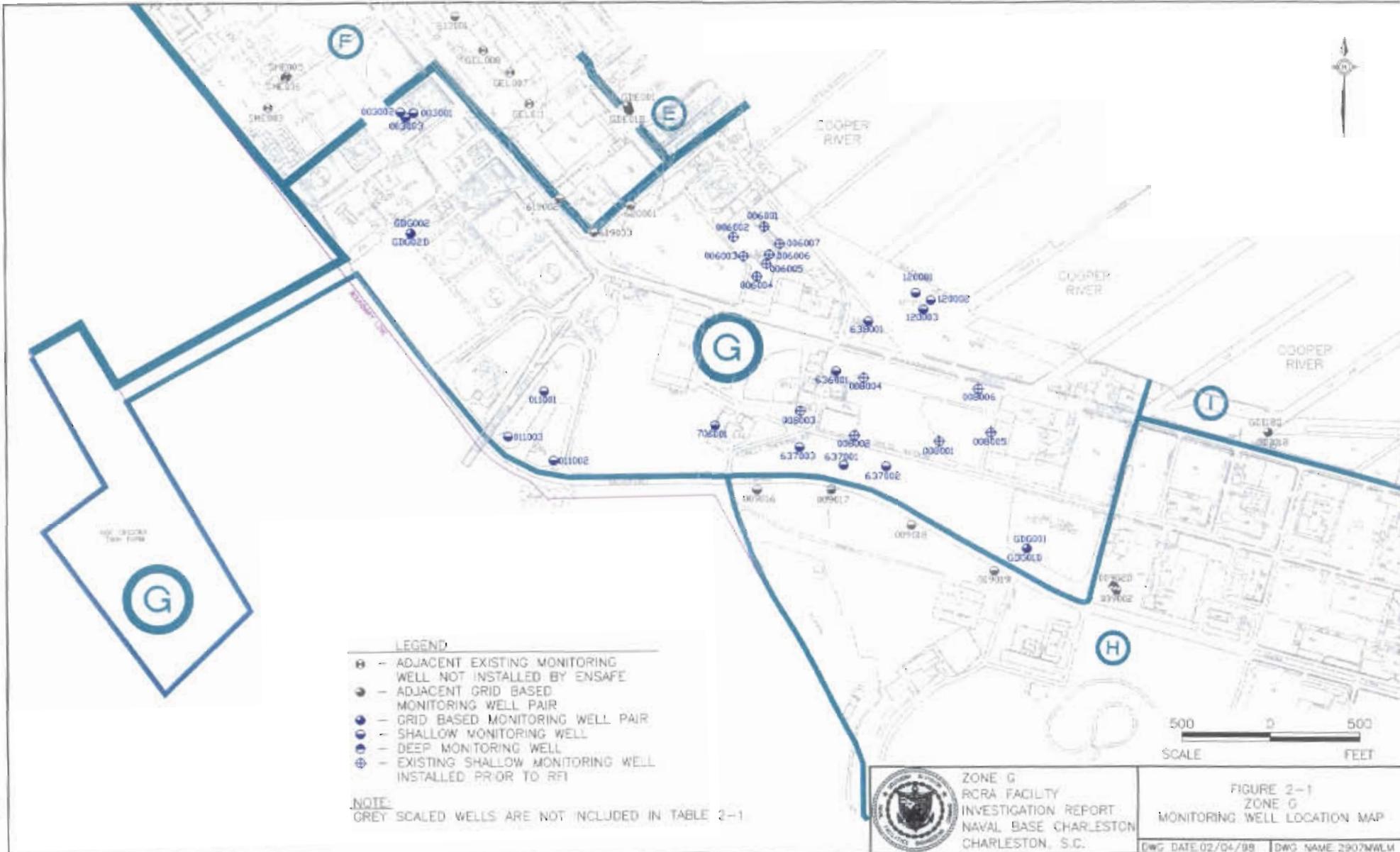
The site-specific sections are: 18

- 10.0 Site-Specific Evaluations 19
- 11.0 Conclusions and Preliminary Recommendations 20
- 12.0 References 21
- 13.0 Signatory Requirement 22

Section 8 of the RFI addresses zonewide ecological risk. Where applicable, surface soil and sediment data from AOCs/SWMUs which have the potential to impact Zone G ecological receptors (subzones) are presented to determine overall ecological risk.

Section 10 of the RFI follows the same zone-wide outline as Sections 1 through 9, but on a site-specific (per AOC and SWMU) basis. The section is subdivided by specific AOCs or SWMUs, or site groupings, and includes the actual data summaries, risk calculations, and corrective measures evaluations specific to each area. In this manner, the entire investigation sequence, is contained within a site-specific section for easy reference.

2.0	PHYSICAL SETTING	1
2.1	Regional Setting	2
2.1.1	Regional Physiographic and Geologic Description	3
	The NAVBASE area regional physiographic and geologic settings are described in Section 2.1.1 of the <i>Draft Zone A RFI Report</i> .	4 5
2.1.2	Regional Hydrologic and Hydrogeologic Background	6
	Regional hydrology and hydrogeology for the NAVBASE area are described in Section 2.2.1 of the <i>Draft Zone A RFI Report</i> .	7 8
2.1.3	Regional Climate	9
	Regional climate is discussed in Section 2.3 of the <i>Draft Zone A RFI Report</i> .	10
2.2	Zone G Geologic Investigation	11
	Geologic and stratigraphic information was obtained from samples collected during soil and monitoring well boring advancement. The borings were advanced using hollow-stem auger and rotasonic drilling methods. Soil samples were collected with a two-foot split-spoon sampler, or continuous sampler depending on the drilling method in use. The stratigraphy was logged by an EnSafe geologist in accordance with the approved <i>Final Comprehensive Sampling and Analysis Plan (CSAP) RCRA Facility Investigation (Revision No: 02)</i> (E/A&H 1996c).	12 13 14 15 16 17
2.2.1	Monitoring Wells	18
	Nineteen monitoring wells (17 shallow and two deep) were installed at Zone G between August 1996 and April 1997 for the groundwater investigation of the Zone G sites. In addition, 13 shallow wells, installed in 1993 at SWMUs 6, 7 and 8 were also used in the RFI. The Zone G	19 20 21



LEGEND

- ⊕ - ADJACENT EXISTING MONITORING WELL NOT INSTALLED BY ENSAFE
- - ADJACENT GRID BASED MONITORING WELL PAIR
- ⊙ - GRID BASED MONITORING WELL PAIR
- - SHALLOW MONITORING WELL
- ⊖ - DEEP MONITORING WELL
- ⊕ - EXISTING SHALLOW MONITORING WELL INSTALLED PRIOR TO RFI

NOTE:
GREY SCALED WELLS ARE NOT INCLUDED IN TABLE 2-1


ZONE G
 RCRA FACILITY
 INVESTIGATION REPORT
 NAVAL BASE CHARLESTON
 CHARLESTON, S.C.

500 0 500
 SCALE FEET

FIGURE 2-1
 ZONE G
 MONITORING WELL LOCATION MAP

DWG DATE: 02/04/98 DWG NAME: 2907MWM

well locations are illustrated in Figure 2-1. The deep wells were installed at two non-biased (grid-based) locations, each paired with a shallow well. Lithologic boring logs and well construction diagrams are contained in Appendix A. Table 2.1 lists the monitoring wells used for the Zone G RFI, along with pertinent information regarding well construction.

2.2.2 Geotechnical Analyses

Shelby tube soil samples were collected to characterize physical properties of Zone G soils during the RFI. These samples were analyzed for porosity, bulk density, grain-size distribution, specific gravity, percent moisture, and vertical permeability. Shelby tube sample intervals were selected for geotechnical analysis based upon areal distribution and lithology. Additional geotechnical information was obtained from borings advanced at AOCs 628, 633, 637, 642 and 643. Samples were collected from the additional locations to provide supplemental moisture content and grain-size data in specific areas of interest. Zone G geotechnical results are summarized in Table 2.2. Laboratory analyses of Shelby tube samples are in Appendix B.

2.2.3 Zone G Geology

Only Quaternary and Tertiary age sediments were encountered during the Zone G RFI. The lowermost stratigraphic unit identified in Zone G is the Ashley Formation member of the Mid-Tertiary age Cooper Group. Overlying the Ashley are younger Upper-Tertiary and Quaternary- age stratigraphic units. Stratigraphic units encountered during the RFI are presented in the following sections in ascending order. Lithologic cross sections for Zone G are presented in Figures 2-2 and 2-3. The deepest borehole in Zone G (GDG01D) limited available stratigraphic information to the upper 68-feet of unconsolidated sediments. Figure 2-4 presents the topography of the top of the Ashley Formation in Zones F and G. Zone G geologic maps and cross sections were developed from split-spoon and rotasonic core lithologic sample data.

Table 2.1
Zone G
Monitoring Well Construction Data

Well Identifier	Date Installed	TOC Elevation (ft msl)	Ground Elevation (ft msl)	Construction Depths (ft bgs)			GW Elev.* Low Tide (ft msl)	GW Elev.* High Tide (ft msl)
				TOS	BOS	BOW		
RFI Wells								
003001	10/30/96	12.91	13.1	4.0	13.4	14.0	5.41*	5.53*
003002	10/31/96	12.86	13.0	4.0	13.4	14.0	5.01*	5.14*
003003	10/31/96	12.71	12.9	4.0	13.4	14.0	6.07*	6.24*
011001	9/9/96	10.14	10.4	2.5	11.9	12.5	5.22	5.33
011002	9/12/96	11.45	8.7	2.4	11.8	12.4	5.96	5.86
011003	9/9/96	11.83	9.5	2.3	11.7	12.3	6.46	6.53
120001	8/30/96	6.05	6.2	2.5	11.9	12.5	3.79	4.29
120002	8/30/96	7.01	7.2	2.5	11.9	12.5	4.20	4.22
120003	9/3/96	6.34	6.4	2.6	12.0	12.6	4.32	4.30
636001	9/11/96	5.41	5.5	2.3	11.7	12.3	1.44	2.70
637001	9/11/96	8.15	3.1	2.5	11.9	12.5	3.83	4.58
637002	4/17/97	5.43	5.6	2.0	11.5	12.0	3.98	3.82
637003	4/17/97	7.10	4.2	2.0	11.5	13.0	4.48	4.44
638001	9/11/96	9.87	7.4	2.4	11.8	12.4	4.22	4.13
706001	4/17/97	5.90	6.1	4.0	13.5	14.0	4.36	4.40
GDG001	8/28/96	8.49	6.0	2.6	12.0	12.6	4.69	4.72

**Table 2.1
 Zone G
 Monitoring Well Construction Data**

Well Identifier	Date Installed	TOC Elevation (ft msl)	Ground Elevation (ft msl)	Construction Depths (ft bgs)			GW Elev.* Low Tide (ft msl)	GW Elev.* High Tide (ft msl)
				TOS	BOS	BOW		
GDG01D	9/15/96	8.71	6.0	46.7	55.7	56.5	5.43	5.43
GDG002	8/28/96	10.96	8.5	2.8	12.2	12.8	7.08	8.54
GDG02D	8/30/96	10.37	8.4	21.7	25.7	26.5	6.27	6.38
Previously Constructed Wells								
006001	9/23/93	8.49	5.6	5.5	15.5	15.5	3.17	3.32
006002	9/21/93	7.83	4.8	4.0	14.0	14.0	3.05	3.11
006003	9/21/93	8.06	5.3	3.5	13.5	13.5	3.40	3.53
006004	9/22/93	8.20	5.3	4.5	14.5	14.5	2.93	3.02
006005	9/22/93	9.11	6.2	5.0	15.0	15.5	2.72	2.99
006006	9/22/93	9.41	6.4	4.5	14.5	14.5	2.71	3.02
006007	9/23/93	8.49	5.9	5.0	15.0	15.0	0.78	3.10
008001	9/24/93	7.37	4.5	10.2	20.2	20.2	3.45	3.66
008002	9/25/93	8.62	5.8	4.3	14.3	14.3	3.82	4.03
008003	9/25/93	8.33	5.4	10.3	20.3	20.3	4.91	4.93
008004	9/27/93	8.63	5.8	3.3	13.3	13.3	0.94	3.34
008005	9/29/93	8.52	5.8	3.8	13.8	13.8	4.60	5.22
008006	9/30/93	6.87	6.5	5.4	15.4	15.4	3.52	3.41

Notes:

TOC = Top of well casing
TOS = Top of screened interval
BOS = Bottom of screened interval
BOW = Bottom of well (end cap)
GW = Groundwater
ft = Feet
msl = Mean sea level
bgs = Below ground surface
* = Data collected 4/29/97
a = Data collected 6/6/97

Table 2.2
Zone G
Geotechnical Sample Data

Sample Identifier	Sample Depth (ft bgs)	Lith Type	Moisture Content (%)	Bulk Dry Density (g/cm ³)	Bulk Wet Density (g/cm ³)	Specific Gravity (g/cm ³)	Percent Porosity	Vertical Permeability		Grain-Size Distribution		
								cm/sec	ft/day	Percent Sand	Percent Silt	Percent Clay
003002	2-4	Fill	9.6	—	1.94	2.62	33.1	7.70E-04	2.18	78	6	16
003002	6-8	Qs	18.7	—	1.90	2.62	41.0	3.20E-04	0.907	85	4	11
003002	8-10	Qc	20.1	—	—	2.76	37.4	2.22E-06	6.29E-03	55	15	30
003002	10-12	Qs	26.2	—	1.78	2.71	51.5	1.34E-03	3.80	92	2	6
011001	6-8	Qc	19.6	—	—	2.66	35.5	6.36E-07	1.80E-03	56	15	29
011001	8-10	Qs	20.4	1.54	—	2.69	43.0	4.60E-05	1.30E-01	74	10	16
011002	2-4	Fill	10.0	—	1.53	2.67	48.3	6.70E-03	19.0	96	1	3
011003	8-10	Qc	19.2	1.69	—	2.69	34.9	1.17E-06	3.32E-03	57	15	28
120001	6-8	Qm	79.8	0.82	—	2.69	80.1	8.24E-08	2.34E-04	2	33	65
120002	4-6	Fill	40.8	—	—	2.60	59.7	1.08E-06	3.06E-03	68	14	18
120002	8-10	Qs	32.0	1.18	—	2.73	56.6	8.30E-04	2.35	87	6	7
636001	9-11	Qm	56.4	1.04	—	2.63	73.8	6.70E-08	1.90E-04	46	16	38
638001	8-10	Qm	83.4	0.85	—	2.71	80.5	1.29E-07	3.66E-04	4	37	59
GDG01D	65-67.5	Ta	44.8	1.25	—	2.69	56.6	8.69E-06	2.46E-02	34	41	25
628002	—	—	41.3	—	—	2.63	—	—	—	47	24	29
633009	—	—	15.1	—	—	2.69	—	—	—	88	6	6
637007	—	—	25.7	—	—	2.63	—	—	—	76	9	15

Table 2.2
 Zone G
 Geotechnical Sample Data

Sample Identifier	Sample Depth (ft bgs)	Lith Type	Moisture Content (%)	Bulk Dry Density (g/cm ³)	Bulk Wet Density (g/cm ³)	Specific Gravity (g/cm ³)	Percent Porosity	Vertical Permeability		Grain-Size Distribution		
								cm/sec	ft/day	Percent Sand	Percent Silt	Percent Clay
642004	—	—	17.7	—	—	2.74	—	—	—	92	3	5
643007	—	—	15.4	—	—	2.69	—	—	—	86	5	9

Notes:

- ft bgs = feet below ground surface
- g/cm³ = grams per cubic centimeter
- cm/sec = centimeters per second
- ft/day = feet per day
- Qs = Quaternary sand
- Qc = Quaternary clay
- Qm = Quaternary marsh clay
- Ta = Ashley Formation
- = Parameter not measured

2.2.3.1 Tertiary-Age Sediments

Ashley Formation

The oldest sediment encountered during the Zone G RFI was the Ashley Formation (Ta), the youngest member of the Eocene-Oligocene age Cooper Group. The Ta was deposited in an open-marine shelf environment during a rise in sea level in the late Oligocene (Weems and Lemon, 1993).

The Ta was encountered throughout Zone G at elevations ranging from -16.6 feet mean sea level (ft msl) at location GDG02D to -49 feet msl at location GDG01D (Figure 2-3). Figure 2-4 shows that the Ta is higher in the eastern portion of Zone G than in the western and southern portions and that the Ta contact with overlying Zone G sediments is undulatory due to its scoured nature.

The Ta is an olive-yellow to olive-brown, tight, slightly calcareous, clayey silt with varying amounts of very fine to fine grained sand that decrease rapidly with depth. It is firm to stiff, low in plasticity, and moist to wet. Laboratory analysis of a Shelby tube sample taken from 65 to 67.5 feet bgs at GDG01D of Ta sediment resulted in a grain-size distribution of 34% fine sand, 41% silt, and 25% clay, and a porosity of 56.6%. This laboratory analysis compares favorably to those presented in the *Zone F RFI Report* (EnSafe, December, 1997) and *Zone H RFI Report* (E/A&H, July, 1996).

Tertiary Undifferentiated Unit

According to Weems and Lemon (1993) four Tertiary age units are placed stratigraphically above the Ta. These units are (in ascending order) the Chandler Bridge, Edisto, Marks Head, and Goose Creek Limestone formations. Upper-Tertiary marine regression-transgression sequences have resulted in considerable erosion before subsequent deposition. This erosion has resulted in typically unconformable contacts, where many of the intervening stratigraphic units are no longer

present. These stratigraphic units are quite difficult to identify in the field and have not been identified. For this report, these units have been grouped as undifferentiated Upper Tertiary (Tu).

The Tu is likely present in the western portion of Zone G near the boundary of Zone F (Figure 2-2); however, no boreholes in the western portions of Zone G were advanced greater than 20 ft below ground surface (bgs) to substantiate the presence of Tu. Geotechnical data on Tu sediments were unobtainable elsewhere in Zone G as this unit was not encountered at either deep monitoring well locations (GDG01D and GDG02D). Tu sediment data are, however, available from zones adjacent to Zone G. Immediately north of Zone G in the southeastern portion of Zone E (location GDE01D), Tu occurs at 11 ft bgs and is 23 feet thick (EnSafe, November, 1997).

The Tu is characterized as an olive-gray to green silt with varying amounts of clay, and very fine to fine quartz and phosphate sand. It is slightly plastic, soft, and intermixed with phosphate pebbles, shell hash, and oyster shells. Tu geotechnical data, available from samples collected in the adjacent portion of Zone F, revealed an average grain size distribution of 58% sand, 19% silt, and 23% clay, with an average porosity of 48% (EnSafe, December, 1997). Also in adjacent Zone E, the average grain size distribution for four Tu sediment samples was 57% sand, 43% silt and clay, with an average porosity of 42% (EnSafe, November, 1997).

2.2.3.2 Quaternary-Age Sediments

The Quaternary Period began with the Pleistocene Epoch and continues with the Holocene (Recent) Epoch. During the Quaternary, several marine transgression-regression sequences occurred which resulted in a complex network of terraces composed of coastal depositional environments such as barrier islands, back-barrier lagoons, tidal inlets, and shallow-marine shelf systems. During the Quaternary, regional crustal uplift in the Charleston region preserved many barrier and back-barrier lagoon deposits as terraces. Succeeding transgressions reworked the

shallow-marine shelf deposits on the seaward side of each older barrier ridge or island. This activity resulted in a younger sequence of sediments on the seaward side, laterally adjacent to the previous (older) coastal deposit (Weems and Lemon, 1993). Weems and Lemon (1993) have identified and correlated several formations of Quaternary age sediments. However, field identification of these formational units is difficult since many characteristics may be evident only at the microscopic level.

Throughout Zone G, Quaternary-age sediments were observed from the top of Tertiary-age sediments to the surface. These sediments range from 25 feet thick at GDG02D to 55 feet thick at GDG01D, including fill and other anthropogenic deposits. These sediments comprise the Pleistocene-age Wando Formation, which is overlain by Holocene-age sand and clay deposits.

According to Weems and Lemon (1993), the Wando depositional period encompasses three distinct high sea-level stands in the late Pleistocene. As a result, Wando composition consists of vertically and sometimes laterally repeating sequences of clayey sand and clay deposits overlying barrier sand deposits which, in turn, overlie fossiliferous shelf-sand deposits.

During the Holocene, rivers and streams have down cut these sediment sequences, leaving scours that have become filled with clay and silty sand deposits typical of low energy environments. These younger deposits may resemble Wando-age deposits and further complicate the interpretation of local geology. Various distinct Quaternary-age litho-stratigraphic units have been identified and correlated in the geologic cross sections prepared for the Zone G RFI report. The following three Zone G Quaternary-age units are described below: Quaternary Clay (Qc), Quaternary Marsh Clay (Qm), and Quaternary Sand (Qs).

Quaternary Clay

The Qc deposits consist of a stiff, brown to brownish red to gray, very fine to fine grained sandy and silty clay. This unit is often interbedded with brown sandy nodular laminae. The clay ranges from low to high plasticity with low organic content. The Qc unit is most often found in the upper 10 to 15 feet of the shallow subsurface.

Three Shelby tube samples of the Qc unit were obtained from locations within Zone G. These sample locations were 003002 (8 to 10 feet bgs), 011001 (6 to 8 feet bgs), and 011003 (8 to 10 feet bgs) and revealed an average grain size distribution of 29% clay, 15% silt, and 56% sand. The average porosity value was 35.9%.

Quaternary Marsh Clay

The Qm is a dark gray to black, soft, sticky clay, occasionally laminated with sand, silt, and shelly lenses. It is typified by a high organic content, often intermixed with grass and wood fragments. The Qm has low plasticity and a distinctive hydrogen sulfide odor.

Data gathered during previous RFIs suggest that the thickness of the Qm unit varies throughout NAVBASE. Well borings in Zone G support this observation. In the southeastern portion of Zone G, the Qm is approximately 45 feet thick at location GDG01D, while it decreases to approximately 7 feet thick at GDG02D in the western portion of Zone G (Figures 2-2 and 2-3).

Three Shelby tube samples of Qm in Zone G were collected. The average grain size distribution, based on the samples from 120001 (6 to 8 ft bgs), 636001 (9 to 11 ft bgs), and 638001 (8 to 10 ft bgs), was found to be 17% sand, 29% silt, and 54% clay. The average porosity was 78%. Similarly, Qm samples from Zone F exhibited an average grain size distribution of 8% sand, 41% silt, and 51% clay, with a porosity of 68% (EnSafe, December, 1997).

Quaternary Sand

The Qs unit is typically gray, orange, and brown, very fine to medium silty sand, well to moderately well sorted and loose. Grain size tends to increase with depth to medium sand. Occasional laminae of brown to black silt, as well as small shell fragments, are often present. This unit lacks the clay content associated with the Qc unit.

The Qs deposits in Zone G range from thin lenticular bodies ranging from 0.5 to 1.7 feet thick at GDG01D to thicker lenses about four-feet thick at GDG02D (Figure 2-2). Four Shelby tube samples of Qs were collected at Zone G. The average grain-size distribution exhibited by this unit is 85% sand, 6% silt, and 9% clay with an average porosity of 48%.

2.2.3.3 Soil

Due to extensive surface soil disturbance at NAVBASE during its operational history, approximately the upper five-feet of the subsurface are typically a mixture of fill and native sediments. However, the extent of fill placement varies throughout NAVBASE. Areas of extensive excavations or areas where native soils may have been unsuitable for foundation support may have undergone more extensive fill placement. The fill includes materials dredged from the Cooper River and Shipyard Creek, which are an unsorted mixture of sands, silts, and clays.

Three Shelby tube samples of fill material were collected from borings 003002, 120002, and 011002. The average grain-size distribution of these samples was 81% sand, 7% silt, and 12% clay. Sample porosities averaged 47%.

2.3 Zone G Hydrogeology

Hydrogeological information was obtained from slug test analyses and water-level measurements conducted during the Zone G RFI. Grain-size analysis, porosity data, and estimates of vertical

permeability (K_v), were determined from laboratory analysis of Zone G Shelby tube samples collected during the RFI.

2.3.1 Surficial Aquifer

The surficial aquifer extends from the water table to the top of the Ta, which serves as a regional confining unit. Aquifer thickness varies throughout Zone G, based upon the water table, the surface elevation, and elevation of the top of the Ta (Figure 2-4). Based on two deep well borings in Zone G, the surficial aquifer ranges from 25 to 55 feet thick. Figures 2-2 and 2-3 exhibit the variable thickness and lithology of the surficial aquifer.

In the western portion of Zone G, the boring log for GDG02D shows that the surficial aquifer is 25 feet thick and, from the bottom to top, consists of three feet of Qs overlain by 13 feet of Qc. The Qc is overlain by seven feet of Qm followed by 2 feet of fill to ground surface. The upper portions of the surficial aquifer in this region of Zone G are probably unconfined to semiconfined depending upon the nature of the fill materials, while the Qs at the bottom of the aquifer is confined by the 13 feet of Qc above it.

Aquifer characteristics differ somewhat in the southeastern portion of Zone G, near deep boring GDG01D. At this location, the aquifer is 55 feet thick and is composed of two feet of Qs, which is overlain by 48 feet of Qm. The Qm becomes interbedded with Qs lenses between 10 and 13.5 feet bgs. At the top of the surficial aquifer, the Qm is overlain by five feet of fill. Similar to GDG02D, the Qs at the base of the aquifer is confined by the thick sequence of Qm above it. Water levels in shallow well GDG001 during this study have resided within the interval of fill material overlying the Qm. This suggests unconfined to perched water table conditions or possibly semi-confined conditions for near surface material overlying the Qm, depending upon the permeability of the fill deposits.

2.3.2 Groundwater Flow Direction

Water levels in the shallow and deep wells in Zone G and selected wells from surrounding zones were generally measured during low and high tides on April 29, 1997. Water level data were recorded by well depth and tidal stage.

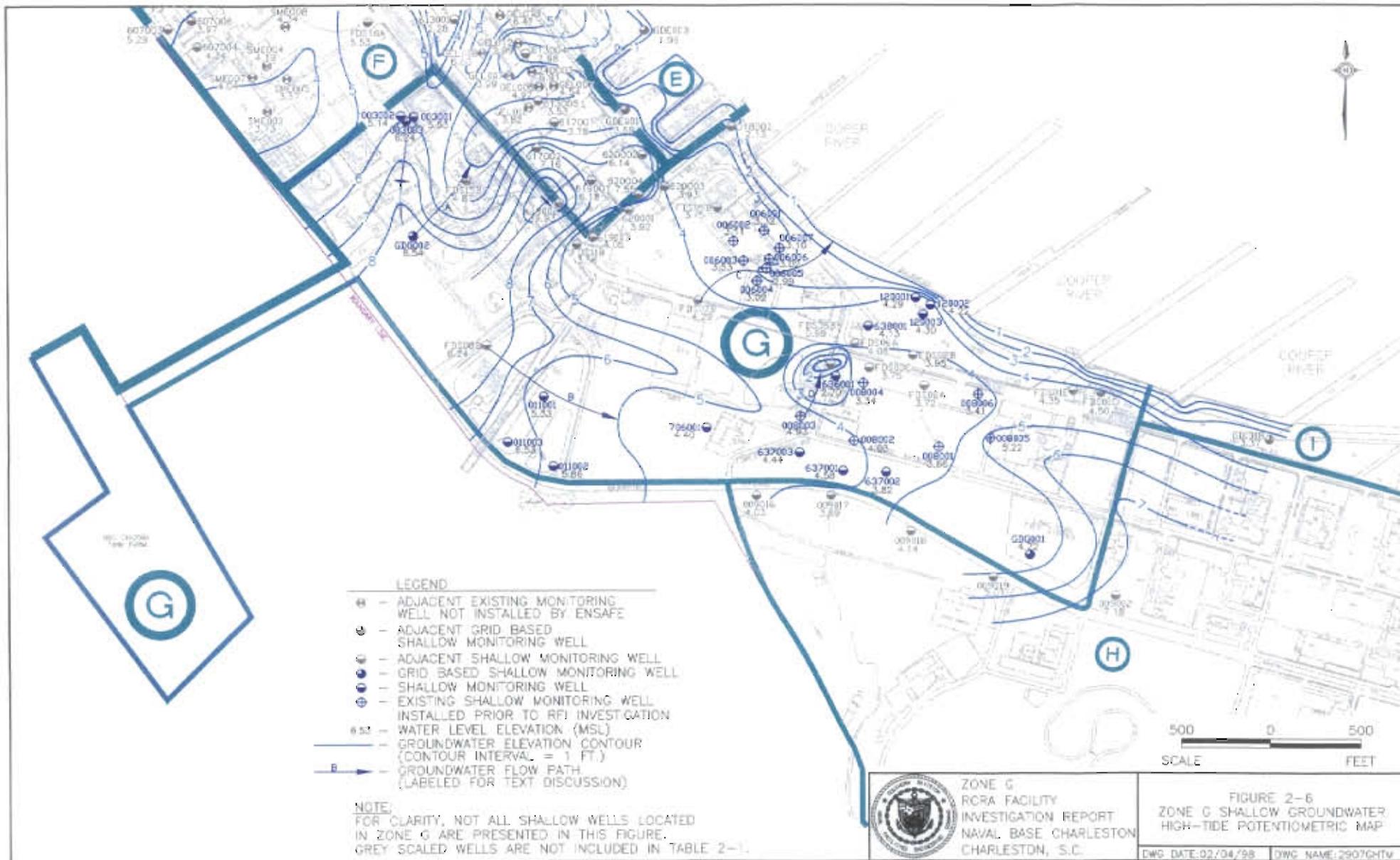
Shallow Wells

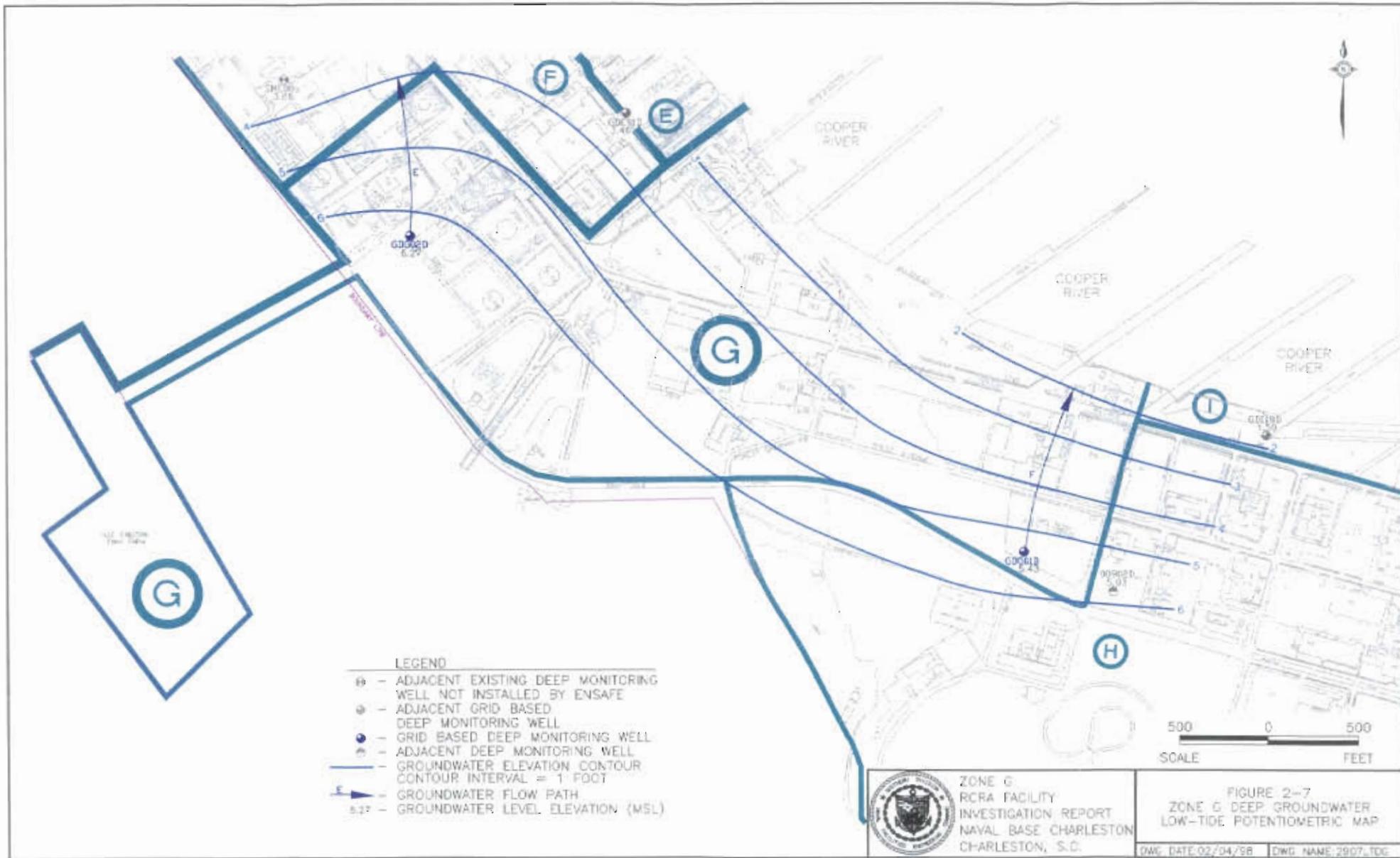
Figures 2-5 and 2-6 depict groundwater elevation contours in selected shallow wells at low and high tide, respectively. These figures represent the potentiometer groundwater surface. Both maps indicate that shallow groundwater flow in the surficial aquifer is highly variable in gradient and direction. Throughout the zone, groundwater flow is governed by the locations and orientation of groundwater elevational highs and lows.

In the western portion of Zone G, high groundwater elevations at GDG002 and FDS08B, and 619002 in Zone F define a groundwater mound that directs flow towards the northwest, north, northeast, and east. From Hobson Avenue north, groundwater flows toward the Cooper River as expected, except for the area nearest SWMU 8. A groundwater depression is near AOC 636; the lowest groundwater elevation occurs at FDS05B during both tidal events. In the southeastern portion of Zone G, groundwater flow is west and north from a groundwater high in Zone H. Groundwater generally flows either to the Cooper River or the depression at SWMU 8 from these higher elevations.

Deep Wells

Figures 2-7 and 2-8 are contour maps of groundwater elevation data from the deep wells during low and high tide, respectively. These figures depict the potentiometric surface of the water bearing unit at the base of surficial aquifer. A comparison of these maps indicates no significant change in groundwater flow direction from low to high tide. Groundwater generally flows north

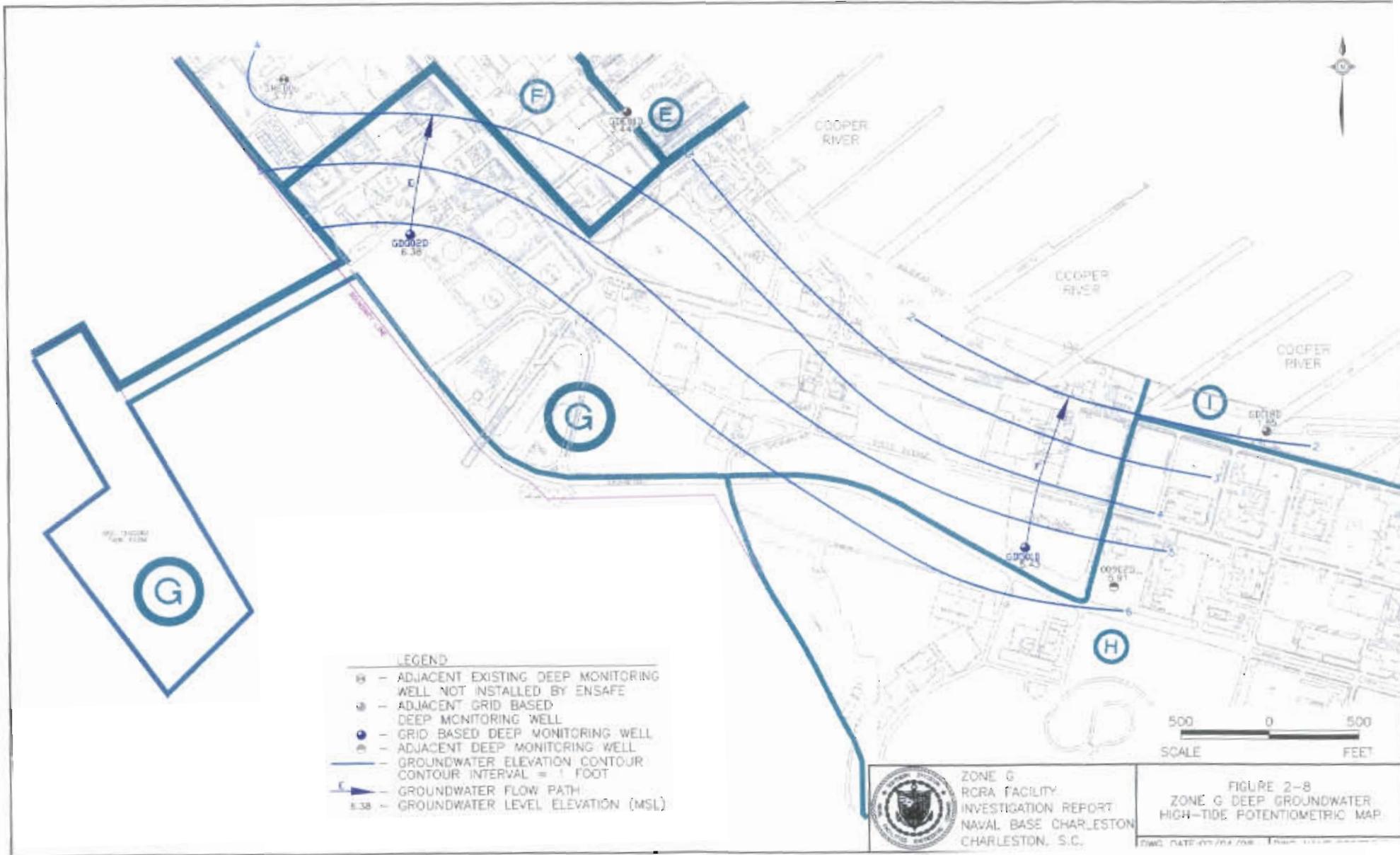




- LEGEND**
- ⊕ - ADJACENT EXISTING DEEP MONITORING WELL NOT INSTALLED BY ENSAFE
 - ⊙ - ADJACENT GRID BASED DEEP MONITORING WELL
 - - GRID BASED DEEP MONITORING WELL
 - ⊗ - ADJACENT DEEP MONITORING WELL
 - - GROUNDWATER ELEVATION CONTOUR CONTOUR INTERVAL = 1 FOOT
 - - GROUNDWATER FLOW PATH
 - E.29 - GROUNDWATER LEVEL ELEVATION (MSL)


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FIGURE 2-7
 ZONE G DEEP GROUNDWATER
 LOW-TIDE POTENTIOMETRIC MAP
 DWG. DATE: 02/04/98 | DWG. NAME: 2907.TOC



- LEGEND**
- ⊗ - ADJACENT EXISTING DEEP MONITORING WELL NOT INSTALLED BY ENSAFE
 - ⊙ - ADJACENT GRID BASED DEEP MONITORING WELL
 - - GRID BASED DEEP MONITORING WELL
 - ⊙ - ADJACENT DEEP MONITORING WELL
 - - GROUNDWATER ELEVATION CONTOUR CONTOUR INTERVAL = 1 FOOT
 - - GROUNDWATER FLOW PATH
 - 6.36 - GROUNDWATER LEVEL ELEVATION (MSL)


 ZONE G
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 CHARLESTON, S.C.

500 0 500
 SCALE FEET

FIGURE 2-8
 ZONE G DEEP GROUNDWATER
 HIGH-TIDE POTENTIOMETRIC MAP

DWG. DATE: 07/24/08. TYPED: 11/11/08

in the western section of Zone G. Throughout the central and eastern portions, groundwater flows northeast and north, respectively. The Cooper River is the ultimate receptor for deep groundwater originating in Zone G.

2.3.3 Horizontal Hydraulic Gradient

The horizontal hydraulic gradient (i) measures the difference in hydraulic head (Δh) (i.e., change in groundwater elevation) between two points divided by the distance between the points (Δx). It is a unitless value used to quantitatively determine the magnitude of potential groundwater flow. Groundwater elevation contour maps for shallow wells (Figures 2-5 and 2-6) and deep wells (Figures 2-7 and 2-8) were examined to find representative ranges in horizontal hydraulic gradient at both low and high tide for the shallow and deep wells. Locations used to determine these gradients were taken along groundwater flow lines labeled "A" through "D" in Figures 2-5 and 2-6 for shallow groundwater flow and "E" and "F" in Figures 2-7 and 2-8 for deep groundwater flow. The calculated horizontal hydraulic gradients for Zone G are presented in Table 2.3.

2.3.4 Horizontal Groundwater Conductivity

Slug test data were used to evaluate the horizontal hydraulic conductivity of an aquifer at a single point. The resulting horizontal hydraulic conductivity (K_h) values from these slug tests are presented in Table 2.4 for shallow, and deep wells. Because hydraulic conductivity data are lognormally distributed, the geometric mean is the best measure of central tendency. Therefore, the representative hydraulic conductivity for each well is presented as the geometric mean of the falling and rising head values.

Data from the slug tests were compiled using the computer program AQTESOLV (Aquifer Test Solver) by the Geraghty and Miller Modeling Group (1989). AQTESOLV has several widely published and accepted analytical solutions for many different kinds of aquifer tests. Rising and falling head slug test data from shallow wells were plotted using an unconfined aquifer solution.

Table 2.3
Zone G
Horizontal Hydraulic Gradients

Measurement Points	Tide	Δh (ft)	Δx (ft)	i
Shallow Groundwater				
A	Low	3.08	695	0.0044
	High	4.54	500	0.0090
B	Low	2.88	780	0.0037
	High	3.24	820	0.0040
C	Low	3.02	530	0.0057
	High	3.29	825	0.0040
D	Low	3.91	310	0.0126
	High	3.93	275	0.0143
Deep Groundwater				
E	Low	2.27	900	0.0025
	High	2.38	690	0.0034
F	Low	3.43	970	0.0035
	High	3.43	900	0.0038

Notes:

Water level measurements from 4/29/97 used for calculations.

Δh (ft) = Hydraulic head difference

Δx (ft) = Distance between points

i = Horizontal hydraulic gradient

Table 2.4
Zone G
Horizontal Hydraulic Conductivities

Well	Falling Head Hydraulic Conductivity ^a	Rising Head Hydraulic Conductivity ^a	Geometric Mean ^b
Shallow Wells			
GDG001	1.1	1.9	1.4
GDG002	0.30	0.34	0.32
011001	4.3	3.6	3.9
011002	NM	3.1	3.1
636001	0.41	0.34	0.37
637001	3.2	3.3	3.3
008004	6.4	5.8	6.1
008006	8.0	7.4	7.7

Table 2.4
Zone G
Horizontal Hydraulic Conductivities

Well	Falling Head Hydraulic Conductivity ^a	Rising Head Hydraulic Conductivity ^a	Geometric Mean ^b
Deep Wells			
GDG01D	31	20	25
GDG02D	0.51	0.42	0.46

Notes:

- a = Slug test results in ft/day.
- b = Calculated using the falling and rising head values.
- NM = Not measured, well recovery was too slow to evaluate conductivity.

For this solution, time (elapsed) versus displacement (change in water level) was plotted on semi-logarithmic graph paper. Hydraulic conductivity (K) was computed by the program using an equation developed by Bouwer and Rice (1976) for unconfined aquifers. Slug test results and program printouts are included in Appendix C.

Data from deep wells were analyzed using a confined solution by Cooper, Bredehoeft, and Papadopulos (1967). This solution uses time (elapsed) plotted against changes in head on semi-logarithmic graph paper to calculate aquifer transmissivity (T) and storativity (S). Again, results and printouts are included in Appendix C.

The Bower and Rice and Cooper et al. methods assume the following conditions:

- A homogeneous, isotropic aquifer of uniform thickness
- Horizontal water table/potentiometric surface prior to test
- Instantaneous change in head
- Negligible well losses

- Well storage is not negligible and is accounted for 1
- Fully or partially penetrating wells 2
- Steady state flow 3

A line of best fit was matched to the plotted data that was thought to best represent the “true” aquifer response. Given all the above qualifiers, hydraulic conductivity data from these tests are presented only to two significant figures. 4
5
6

Transmissivities from the Cooper et al. confined solution were converted to hydraulic conductivity values with the following relationship: 7
8

$$K = \frac{T}{b}$$

where: 9

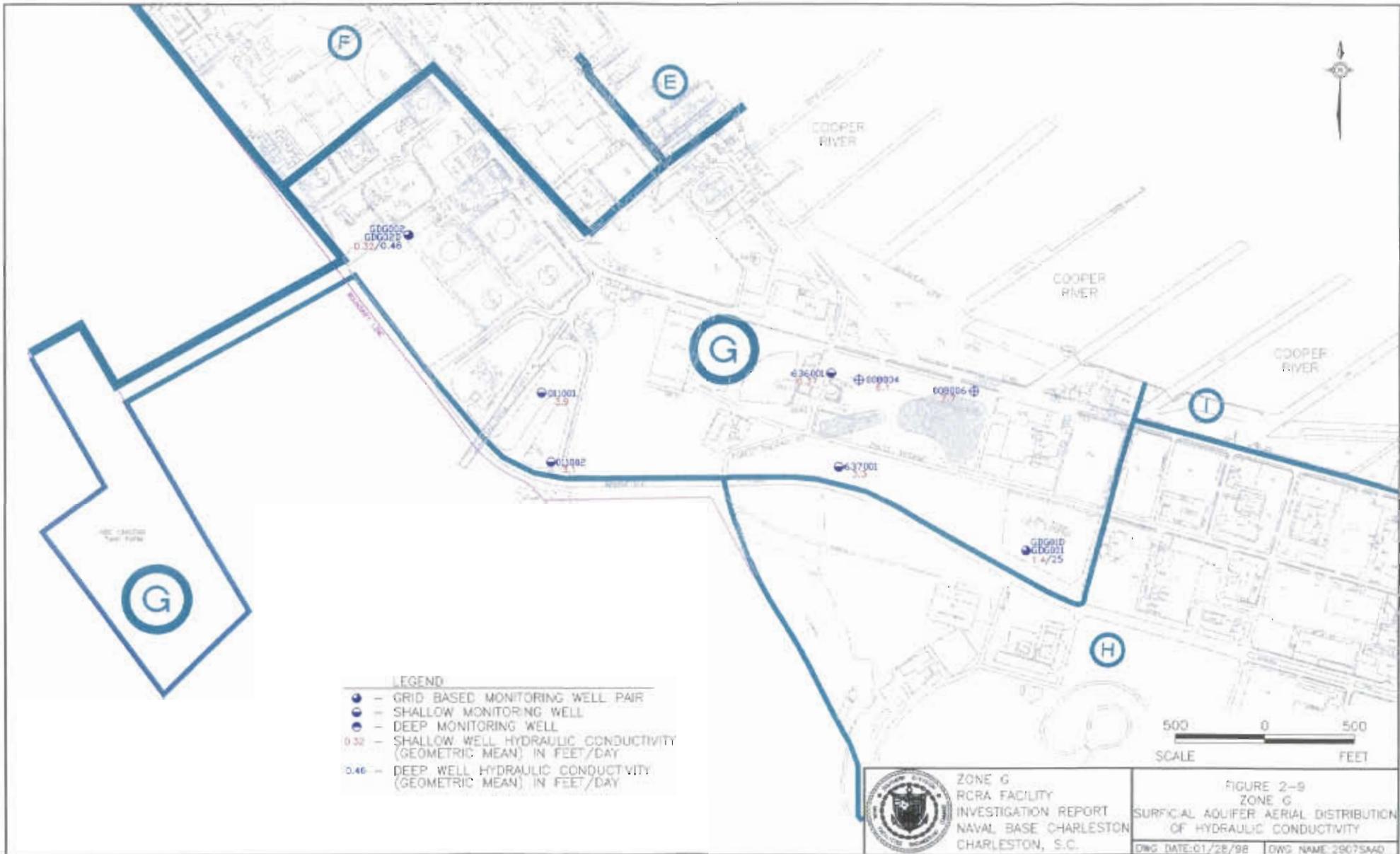
K = hydraulic conductivity 10

T = transmissivity 11

b = aquifer thickness 12

The aquifer thickness (b) at each tested well was obtained from the well boring log by summing the thicknesses of suspected water producing layers that intersect the well filterpack. 13
14

Figure 2-9 presents the aerial distribution of hydraulic conductivity (shallow wells/deep wells) in the surficial aquifer using values from Table 2.4. Hydraulic conductivities in the shallow portion of the aquifer range from 0.32 to 7.7 ft/day with a geometric mean of 2.1 ft/day. The two deep wells exhibited horizontal hydraulic conductivities ranging from 0.46 to 25 ft/day and a geometric mean of 3.4 ft/day. 15
16
17
18
19



- LEGEND**
- - GRID-BASED MONITORING WELL PAIR
 - - SHALLOW MONITORING WELL
 - - DEEP MONITORING WELL
 - 0.32 - SHALLOW WELL HYDRAULIC CONDUCTIVITY (GEOMETRIC MEAN) IN FEET/DAY
 - 0.46 - DEEP WELL HYDRAULIC CONDUCTIVITY (GEOMETRIC MEAN) IN FEET/DAY

500 0 500
SCALE FEET


ZONE G
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FIGURE 2-9
 ZONE G
 SURFICIAL AQUIFER AERIAL DISTRIBUTION
 OF HYDRAULIC CONDUCTIVITY
 DWG DATE: 01/28/98 DWG NAME: 29075M40

2.3.5 Horizontal Groundwater Velocity

Horizontal groundwater velocity was calculated using the following formula:

$$V = \frac{K * i}{n_e}$$

where:

- V = horizontal groundwater velocity
- K = hydraulic conductivity
- i = horizontal hydraulic gradient
- n_e = effective porosity

Horizontal hydraulic velocities were calculated for the horizontal gradients presented in Table 2.3. Shallow wells GDG001, 011001, 011002, 008004, and 008006 were completed in Quaternary sand and represent the highest K values in the shallow subsurface of Zone G. A geometric mean of the K values at each of these wells was used to calculate shallow groundwater velocities.

To determine the most conservative (highest) shallow groundwater velocities, the lowest porosity from laboratory data is desirable. Using the Shelby tube data analyses, the lowest porosity from Qs deposits was found to be 41 % from the 6 to 8 foot bgs interval at location 003002. This value was used as effective porosity in the velocity calculations.

Limited hydraulic and laboratory data is available from deep well locations in Zone G. However, assuming the 41 % porosity for deeper Qs deposits and using the two geometric mean K_h values from the Zone G deep wells, an estimate of two possible groundwater velocity estimates may be made.

Table 2.5 presents the calculated groundwater flow velocity estimates.

**Table 2.5
 Zone G
 Groundwater Velocity Results**

Aquifer Location	Tide	n_e	K (ft/day)		Gradient (i)	Estimated Velocity (ft/day)	
Shallow Groundwater							
A	Low	0.41	3.8		0.0044	0.04	
	High				0.0090	0.08	
B	Low	0.41	3.8		0.0037	0.03	
	High				0.0040	0.04	
C	Low	0.41	3.8		0.0057	0.05	
	High				0.0040	0.04	
D	Low	0.41	3.8		0.0126	0.12	
	High				0.0143	0.13	
Deep Groundwater							
			K_1	K_2		V_1	V_2
E	Low	0.41	0.46	25	0.0025	0.003	0.15
	High				0.0034	0.004	0.20
F	Low	0.41	0.46	25	0.0035	0.004	0.21
	High				0.0038	0.004	0.23

Notes:

- ft/day = Feet per day
- i = Horizontal hydraulic gradient
- n_e = Effective porosity

2.3.6 Tidal Influence

The numerical difference in groundwater elevation from low to high tide for shallow wells is shown in Figure 2-10. Static water level elevations for high and low tide are presented in Table 2.1. Wells with larger tidal difference values are more highly influenced by tidal fluctuations than wells with lower values. A negative tidal variation value indicates a decrease in water level elevation from low to high tide. Conversely, a positive tidal variation indicates an

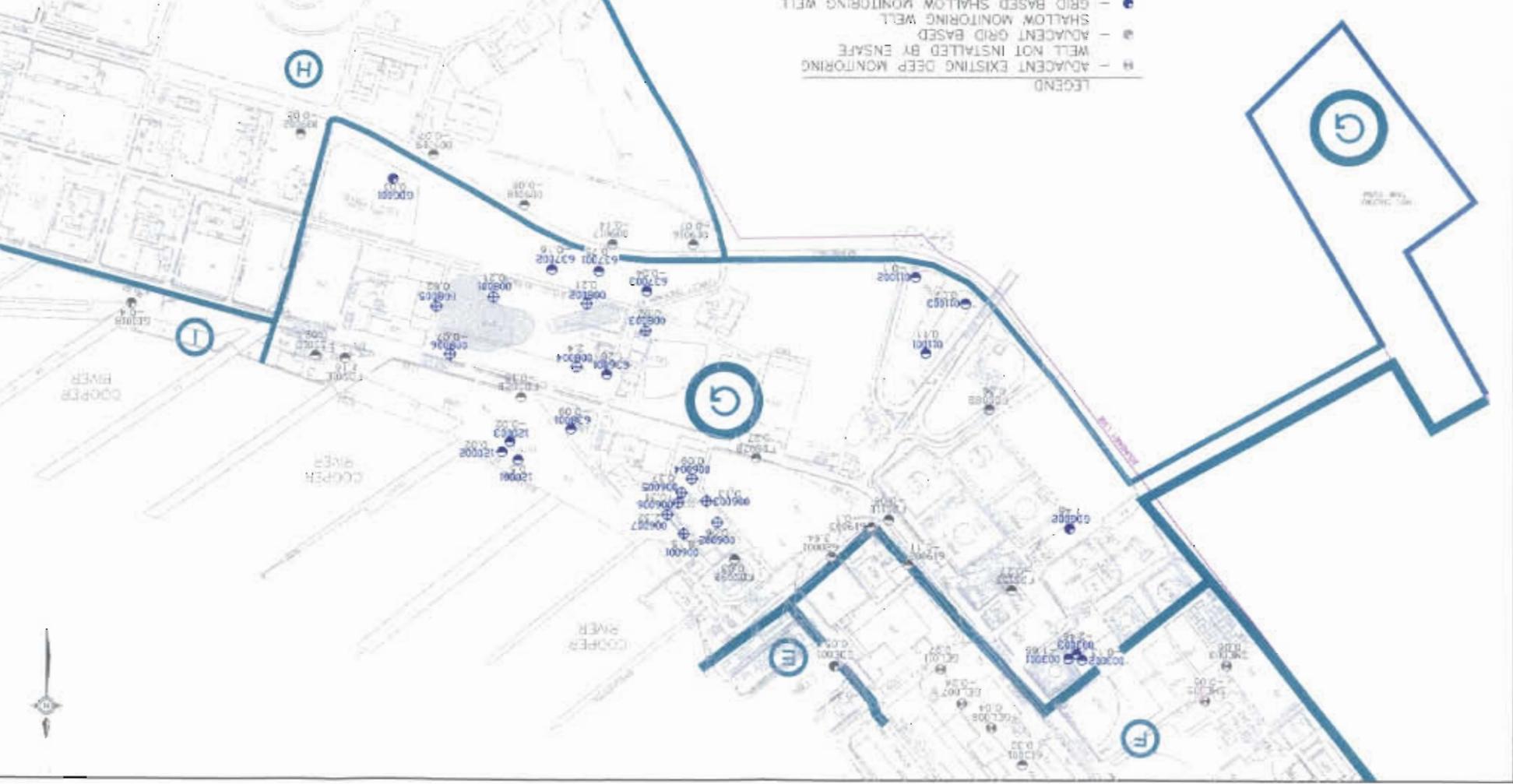
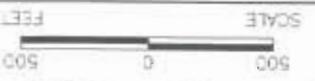
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 RORA FACILITY
 ZONE G



FIGURE 2-10
 ZONE G SHALLOW GROUNDWATER
 TIDAL VARIATION
 DWG DATE: 02/04/98
 DWG NAME: 2902LHV

NOTE
 FOR CLARITY, NOT ALL SHALLOW WELLS LOCATED
 IN ZONE G ARE PRESENTED IN THIS FIGURE
 GREY SCALED WELLS ARE NOT INCLUDED IN TABLE 2-1

LEGEND
 H - ADJACENT EXISTING DEEP MONITORING
 WELL NOT INSTALLED BY ENSAFE
 a - ADJACENT GRID BASED
 SHALLOW MONITORING WELL
 ● - GRID BASED SHALLOW MONITORING WELL
 ● - SHALLOW MONITORING WELL
 ⊕ - EXISTING SHALLOW MONITORING WELL
 INSTALLED PRIOR TO RFI
 - - - EXISTING SHALLOW MONITORING WELL
 - - - LEVEL DECREASE FROM LOW TO HIGH TIDE



increase in water level from low to high tide. Wells with low or negative tidal differences may have higher tidal lag times than wells with high values. High lag times often occur in wells that have limited hydrologic connection with or are at great distances from tidal water bodies (Cooper River).

A comparison of the low and high tide groundwater elevation maps indicates that subtle, local changes in groundwater flow direction occur in response to tidal changes in the surficial aquifer. For example, the sizes and shapes of the groundwater high in the western portion and the depression in the central portion of the zone have been slightly altered.

From Figure 2-10 the distribution and magnitude of tidal change exhibits no regular pattern and little or no consistency throughout most of Zone G. Negative changes were more easily grouped than positive changes. The negative changes were confined to the southern extent of Zone G along Bainbridge Avenue and two areas along Hobson Avenue — just north of SWMU 8 and the other southeast of SWMU 3. Positive changes were isolated and less widespread aerially.

2.3.7 Vertical Hydraulic Gradient

Water levels were measured in the two shallow/deep well pairs (GDG001/GDG01D and GDG002/GDG02D) on April 29, 1997. Table 2.6 presents the calculated vertical hydraulic gradients between these well pairs during that event. The vertical gradients were calculated by dividing the difference between water levels at each well pair by the vertical distance between the bottom of each well screen in the pair. Positive values indicate downward vertical gradients whereas negative values indicate an upward vertical gradient.

Table 2.6
Zone G
Vertical Hydraulic Gradients

Well Pair	Vertical Distance (ft)	Date	Low Tide		High Tide	
			Groundwater Elevation Difference (ft)	Vertical Hydraulic gradient	Groundwater Elevation Difference (ft)	Vertical Hydraulic gradient
GDG001/01D	43.9	4/29/97	-0.74	-0.017	-0.71	-0.016
GDG002/2D	13.7	4/29/97	0.81	0.059	2.16	0.157

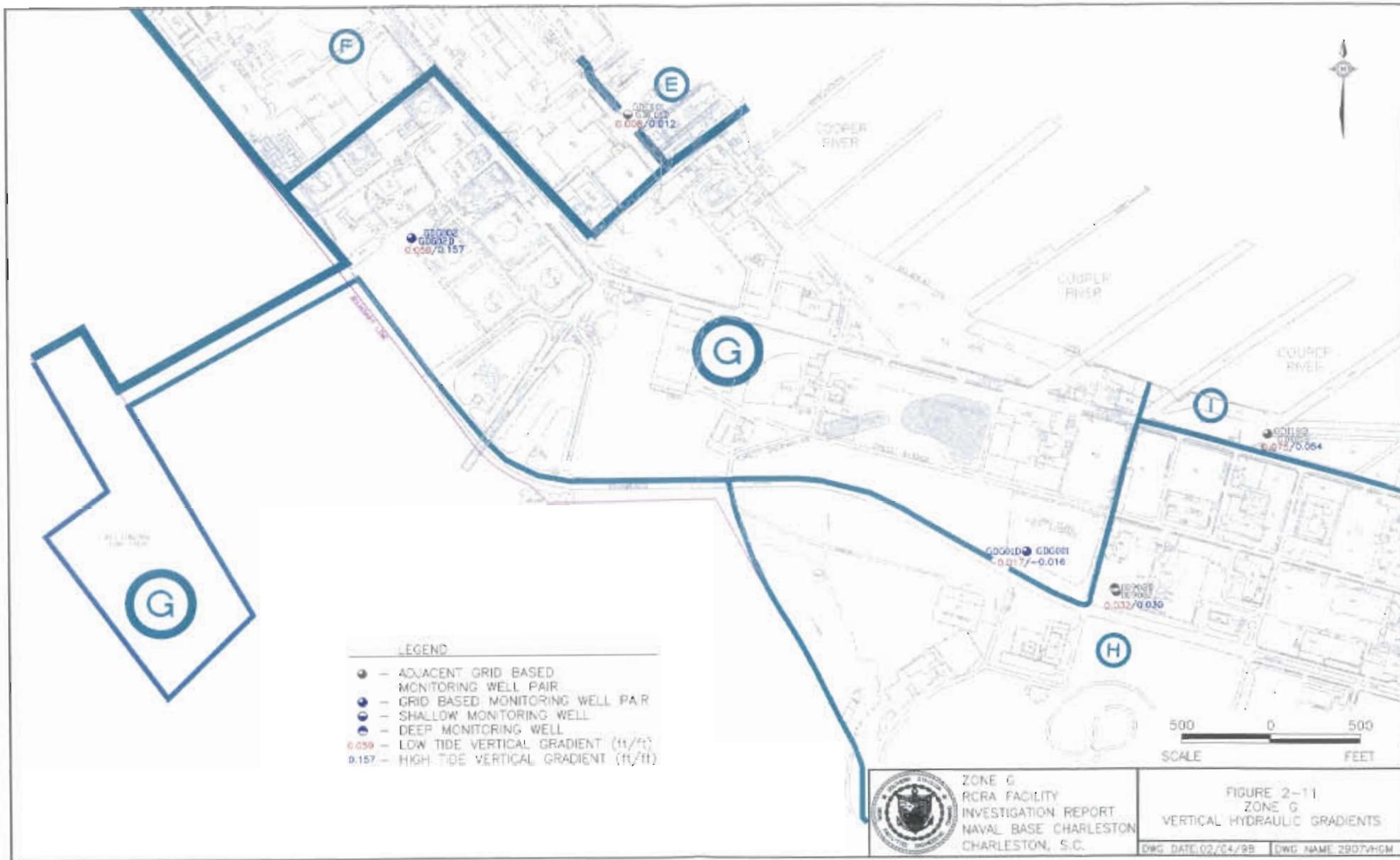
Areal distribution of vertical gradients from wells are graphically presented in Figure 2-11. This figure shows gradients measured between shallow and deep wells at low tide (red) and high tide (blue).

Well pair GDG001/01D exhibited an upward vertical gradient at low and high tides. This indicates an upward flow potential from the Qs layer at the bottom of the surficial aquifer to the interfingering Qm/Qs layers in the upper portion of the aquifer.

A downward vertical gradient was measured at well pair GDG002/02D during both low and high tide. The magnitude of this gradient was much greater during high tide.

2.3.8 Lithologic Unit Summary

The following sections discuss the hydrologic properties and role of the predominant lithologic units in the groundwater flow regime at Zone G.



LEGEND

- - ADJACENT GRID BASED MONITORING WELL PAIR
- - GRID BASED MONITORING WELL PAIR
- - SHALLOW MONITORING WELL
- - DEEP MONITORING WELL
- 0.039 - LOW TIDE VERTICAL GRADIENT (ft/ft)
- 0.157 - HIGH TIDE VERTICAL GRADIENT (ft/ft)


 ZONE G
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 CHARLESTON, S.C.

FIGURE 2-11
 ZONE G
 VERTICAL HYDRAULIC GRADIENTS
 DWG. DATE: 02/04/95 | DWG. NAME: 2907VHGM

2.3.8.1 Tertiary Age Units

Ashley Formation

The Ta is important because of its role as a confining unit between the lower members of the Cooper Group and the Eocene-age Santee Limestone and the overlying water-bearing strata of the Quaternary sediments (Park, 1985). Lithologic cross sections presented by Weems and Lemon (1993) show the Ta to have a laterally consistent overall thickness. Samples collected from this unit at NAVBASE have shown high clay and silt contents and varying sand contents, depending greatly upon depth.

One Shelby tube sample collected from the Ta at GDG01D exhibited a vertical permeability of $8.7E-06$ centimeters per second (cm/sec) (0.025 ft/day). Zone G Ta permeability is comparable with that of adjoining zone Ta sediments. To the northwest in Zone F, the one Shelby tube sample collected from the Ta exhibited a vertical permeability of $4.5E-06$ cm/sec (0.013 ft/day) (EnSafe, December 1997). To the east in Zone E, seven Shelby tube samples exhibited a geometric mean vertical permeability of $1.7E-05$ cm/sec (0.048 ft/day) (EnSafe, November 1997). According to Fetter (1988), sediments with vertical permeabilities of $1E-05$ cm/sec (0.028 ft/day) or less can be considered confining units.

Upper Tertiary Undifferentiated

Though geotechnical data on Tu sediments was unobtainable in Zone G, this unit was encountered to the northwest in adjacent Zone F. The vertical hydraulic conductivity from sample 60704D in Zone F was $6.20E-05$ cm/sec (0.176 ft/day) (EnSafe, December 1997). Three Shelby tube samples collected from the Tu in Zone E revealed a significant range in vertical permeabilities, from $5.40E-06$ cm/sec (0.0153 ft/day) to $4.11E-04$ cm/sec (1.165 ft/day) (EnSafe, November 1997).

2.3.8.2 Quaternary Age Sediments

During the field investigation, Shelby tube samples were obtained from the Qc, Qs, and Qm deposits beneath Zone G. The results of laboratory vertical permeability testing were presented in Table 2.2. This section discusses the viability of these lithologic units as aquifers.

Quaternary Clay

For the Qc unit, the geometric mean vertical hydraulic conductivity calculated from three Shelby tube samples was 1.18E-06 cm/sec (3.35E-03 ft/day). This is approximately an order of magnitude greater than the geometric mean of 1.2E-07 cm/sec (3.5E-04 ft/day) from five samples collected in Zone F. Based upon K_v values, Qc should be an effective barrier to vertical groundwater flow. If Qc sediments are interbedded with sand, Qc may act as a leaky confining unit if the sand interbeds are connected vertically. Aquifer characterization during previous all zone-wide RFIs at NAVBASE have suggested that Qc sediments have K_h values less than 1 ft/day (EnSafe, November 1997). These low K_h values suggest very limited potential for horizontal groundwater movement through these sediments. However, Qc sediments are often interbedded with thin sand units which may act as preferential flow paths for lateral groundwater movement.

Quaternary Marsh Clay

Three Shelby tube samples of Qm from Zone G exhibited a geometric mean vertical hydraulic conductivity of 8.9E-08 cm/sec (2.5E-04 ft/day). This compares favorably with geometric means of 1.6E-07 cm/sec (4.5E-04 ft/day) and 1.2E-06 cm/sec (3.3E-03 ft/day) Zone F and Zone E Shelby tubes samples, respectively (EnSafe, December 1997; EnSafe, November 1997). Based on this data, Qm sediments would be expected to act as an aquitard to vertical groundwater migration. However, Qm may allow limited horizontal groundwater movement due to the increased conductivity of occasional thin interbedded sand units.

Quaternary Sand

Four Shelby tube samples of Qs from Zone G exhibited a vertical hydraulic conductivity geometric mean of 3.6E-04 cm/sec (1.0 ft/day). Two Shelby tube samples of Qs from Zone F exhibited a K_v geometric mean of 6.4E-07 cm/sec (1.8E-03 ft/day) (EnSafe, December 1997). To the east in Zone E, seven Qs Shelby tube samples had a geometric mean vertical hydraulic conductivity of 4.7E-04 cm/sec (1.3 ft/day) (EnSafe, November 1997).

Horizontal hydraulic conductivities for Qs deposits in Zone G ranged between 1.4 to 7.7 ft/day. Similarly, Qs deposits in Zone E were found to range from 3 to 20 ft/day in Zone E (EnSafe, November 1997). As a result, Qs deposits constitute the primary water-bearing and transmissive unit in Zone G. Vertical flow within the Qs may vary greatly depending upon the percentage of fines and interlaying of thin silty clay laminae, as shown in the K_v values from Zone F Shelby tube samples. Consequently, Qs deposits may act as a vertical aquitard in very limited local areas. However, heterogeneities in Qs sediment may provide intervals of preferential flow within the unit itself and as interbeds within low permeability Qm and Qc deposits. These intervals of preferential flow within the groundwater system may affect flow direction and velocity.

3.0 FIELD INVESTIGATION 1

The following section lists the field investigation objectives and describes the technical sampling methods, procedures, and protocols implemented during Zone G data collection. Fieldwork was conducted in accordance with the approved final CSAP and the United States Environmental Protection Agency (USEPA) Region IV Environmental Services Division, *Standard Operating Procedures and Quality Assurance Manual* (ESDSOPQAM) (USEPA, 1996a). Any deviations from the approved work plans, such as the number of samples collected, modified locations, or procedures, etc., were documented in the field logbooks and are detailed in Section 10, Site-Specific Evaluations. 2
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3.1 Investigation Objectives 10

The Zone G sampling strategy, as detailed in the approved final RFI work plan, was designed to collect sufficient environmental media data to: 11
12

- Characterize the facilities 13
- Define contaminant pathways and potential receptors (on and offsite, where applicable) 14
- Define the nature and extent of any contamination 15
- Assess human health and ecological excess risk 16
- Assess the need for corrective measures 17

3.2 Sampling Procedures, Protocols, and Analyses 18

The media sampled during the Zone G field investigation were soil, groundwater, sediment, and surface water. Sampling was generally conducted in accordance with the approved final RFI work plan. The media collected and the analyses varied between sites. The objective of the site-specific sampling and analyses was to provide sufficient data to meet the stated investigation objectives. 19
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Analytical Protocols

All screening and discrete site samples were analyzed per USEPA SW-846 methods at data quality objective (DQO) Level III unless otherwise noted. Analytical methods for soil, sediment, and groundwater samples were:

- Volatile organic compounds (VOCs) USEPA Method 8260
- Semivolatile organic compounds (SVOCs) USEPA Method 8270
- Pesticides/Polychlorinated Biphenyls (PCBs) USEPA Method 8080
- Cyanide USEPA Method 9010
- Metals/Mercury USEPA Method 6010/7470
- Herbicides USEPA Method 8150
- Organophosphorous (OP) pesticides USEPA Method 8140
- pH USEPA Method 9045
- Total Dissolved Solids (TDS) USEPA Method 160.1
- Chlorides USEPA Method 325.1
- Sulfates USEPA Method 375.1
- Propellants USEPA Method 8330
- Explosives USEPA Method 8330

Approximately 10% of the samples collected for each medium at Zone G were duplicated and submitted for Appendix IX analytical parameters at DQO Level IV. These additional samples were collected to fulfill quality assurance/quality control (QA/QC) standards while cost-effectively analyzing additional parameters. Besides analyses for VOC, SVOC, pesticide, OP pesticide, PCB, metal, and cyanide constituents, Appendix IX samples included:

• Hexavalent chromium	USEPA Method 7196	1
• Dioxins/Dibenzofurans	USEPA Method 8290	2
• Herbicides	USEPA Method 8150	3

To support corrective measures at NAVBASE, selected soil samples in Zone G were analyzed for the following engineering parameters: cation exchange capacity (CEC), total organic carbon (TOC), and pH. Additionally, thin-walled Shelby tube soil samples were collected for physical parameters, per the approved final RFI work plan, and as described in Section 4.6.2 of the approved final CSAP. Analysis of Shelby tube soil samples varied based on type of soil, recovery of tube sample, location, and depth of sample. Shelby tube results were detailed in Section 2.

3.2.1 Sample Identification

All samples collected during the RFI were identified using the 10-character scheme outlined in Section 11.4 of the approved final CSAP. This scheme identifies the samples by site, sample matrix, location, and sample depth. The first three characters identify the site where the sample was collected. The fourth and fifth characters identify the medium or sample QC code. Characters six through eight designate sampling location: boring or well number, sampling station, trench number, existing well identification, and others. The ninth and tenth characters represent sample-specific identification such as depth to the nearest foot, depth interval, sampling event for water samples, and others.

The following codes were used to identify specific media for sample identification during the Zone G RFI: (1) soil boring samples — SB; (2) groundwater samples — GW (GW is not used in well location identifiers on maps and in tables in this report); (3) sediment samples — M; (4) surface water samples — W; (5) Direct Push Technology (DPT) soil samples — SP; (6) DPT groundwater samples — GP.

Sample identification for soil samples collected as part of the 1993 confirmation study at SWMUs 6, 7, and 8 are comprised of eight characters. The first three identify the site. The fourth, fifth and sixth characters designate the specific soil boring location. The last two characters are used to identify the sample interval.

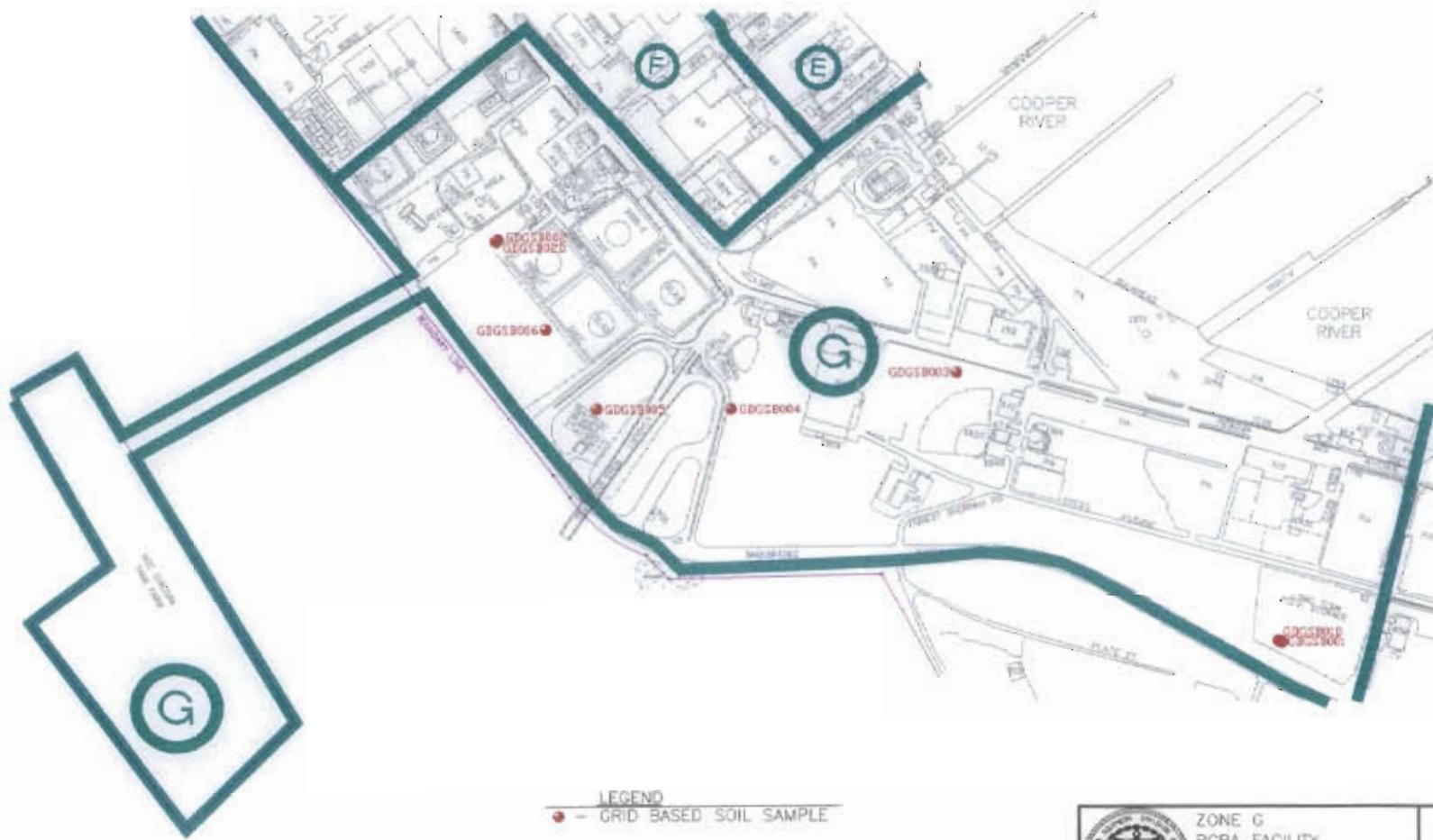
3.2.2 Soil Sampling

Section 4 of the approved final CSAP describes Zone G RFI soil sampling procedures and activities. The following subsections summarize these procedures.

In accordance with Section 3 of the final RFI work plan, a systematic grid-based sampling approach was selected to more fully characterize background conditions, and supplement the biased sampling locations. A total of nine grid-based soil borings were advanced at Zone G, as depicted in Figure 3-1. Upper and lower interval samples were collected as described in Section 3.2.2.2 of this report. Samples were analyzed for metals, cyanide, pesticides/PCBs, SVOCs, and VOCs, as described in Section 3.2, above.

3.2.2.1 Soil Sample Locations

Soil samples were generally collected as proposed in the approved final RFI work plan; the locations were based on the investigation strategy outlined in Section 1.2 of that document. Each AOC and SWMU primary sampling pattern is presented in Sections 2.11 through 2.23 of the approved final RFI work plan. Some proposed sample locations were modified slightly due to utility locations or because they were inaccessible. Additional samples were required to adequately characterize contaminant distribution at some sites. After the analytical data for the initial round of soil sampling were interpreted, a second sampling round was proposed for some sites to further delineate contaminants identified during the initial sampling. Typically, additional sample locations were justified due to relatively high contaminant concentrations identified on the



LEGEND
● - GRID BASED SOIL SAMPLE

500 0 500
SCALE FEET

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FIGURE 3-1
ZONE G
GRID BASE SOIL SAMPLING
LOCATION MAP
DWG DATE: 05/21/97 DWG NAME: 29C7G5B

previous sampling pattern's perimeter. Section 10 figures detail the site-specific soil sample locations.

3.2.2.2 Soil Sample Collection

Composite soil samples were generally collected for laboratory analysis from zero to one foot bgs and from three to five feet bgs. The zero to one foot bgs interval is referred to in this report as the first or upper-interval sample. At soil sample locations overlain by pavement, the upper interval was collected from the base of the pavement to one foot below the base of the pavement. The three to five feet bgs interval is referred to as the second or lower-interval sample. No other intervals were sampled due to the relatively shallow depth to groundwater in Zone G, typically from four to six feet bgs. No saturated soil samples were retained for laboratory analysis.

Stainless-steel hand augers were used to collect soil samples, as detailed in Section 4.5 of the approved final CSAP. At sodded locations, the sod (generally less than two-inches thick) overlying the soil sample at the upper interval was removed before augering to one foot bgs. A coring machine was used to gain access to soil covered by concrete and/or asphalt pavement. At SWMU 11, screening soil samples were collected using DPT. All DPT soil sampling was performed in accordance with Section 4.3.3 of the approved final CSAP.

3.2.2.3 Soil Sample Preparation, Packaging, and Shipment

Section 3.2.2.3 of the *Draft Zone A RFI Report* details soil sample preparation, packaging, and shipment as conducted for the Zone G RFI.

3.2.2.4 Soil Sample Analysis

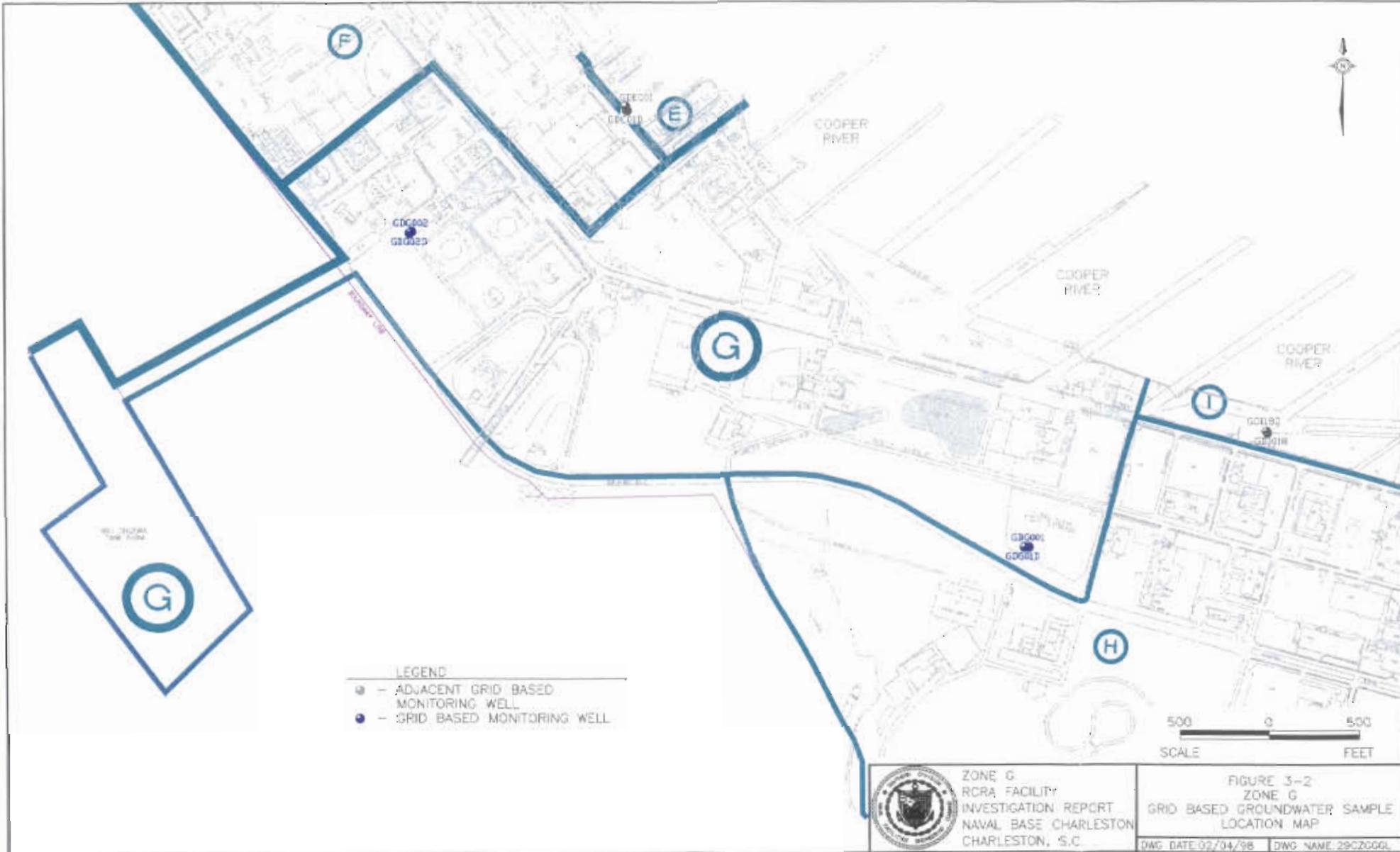
Section 3.2.2.4 of the *Draft Zone A RFI Report* details soil sample analysis as performed for the Zone G RFI. Analytical protocols specific to the Zone G RFI are described in Section 3.2 of this report.

3.2.3 Monitoring Well Installation and Development

At Zone G monitoring wells were generally installed and sampled in accordance with the approved final RFI work plan. Following analysis and interpretation of initial groundwater analytical data, additional wells and/or subsequent sampling were required at some sites to determine the extent of groundwater contamination. Typically, these additional samples were justified due to relatively high concentrations of contaminants on the perimeter of the previous sample pattern. Section 10 figures present the site-specific groundwater sample locations.

Additionally, per the approved final RFI work plan, a systematic grid-based groundwater sampling approach was selected to more fully characterize background conditions, and to supplement the biased sampling locations. For Zone G, two shallow/deep well pairs (GDG001/GDG01D and GDG002/GDG02D) were installed. Grid pair GDG001/GDG01D was located west of the 3900-F tank complex, while grid pair GDG002/GDG02D was located in the privately owned vehicle (POV) storage area northwest of the intersection of Bainbridge Avenue and Halsey Street. Zone G grid-based groundwater samples were analyzed for metals, cyanide, pesticides/PCBs, SVOCs, VOCs, sulfates, chlorides, and TDS as described in Section 3.2, above. Figure 3-2 presents the Zone G grid-based groundwater sample locations.

Section 5 of the approved final CSAP describes the methods used during monitoring well installation. All monitoring wells were permitted by the SCDHEC, and installed according to South Carolina Well Standards and Regulations (R.61-71.11). All shallow and deep monitoring wells were constructed of an appropriate length of two-inch inside diameter polyvinyl chloride (PVC) riser pipe attached to a 10-foot section of 0.010-inch slotted PVC well screen. The following subsections briefly describe Zone G site-specific methods. All identification numbers for monitoring wells installed during the Zone G investigation consist of six characters. The first three characters identify the site where the monitoring wells were installed. Characters four



- LEGEND
- - ADJACENT GRID BASED MONITORING WELL
 - - GRID BASED MONITORING WELL


 ZONE G
 RCRA FACILITY
 INVESTIGATION REPORT
 NAVAL BASE CHARLESTON
 CHARLESTON, S.C.

FIGURE 3-2
 ZONE G
 GRID BASED GROUNDWATER SAMPLE
 LOCATION MAP
 DWG DATE: 02/04/98 DWG NAME: 29C200GL

through six identify the individual well number. For Zone G grid-based monitoring wells, the first three characters are GDG. Appendix A includes the Zone G lithologic boring logs and monitoring well construction diagrams.

Sample identification for groundwater samples collected as part of the 1993 confirmation study at SWMUs 6, 7, and 8 are comprised of eight characters. The first three identify the site. The fourth, fifth, and sixth identify the well sampled. The last two identify the sampling event.

3.2.3.1 Shallow Monitoring Well Installation

Zone G shallow monitoring wells were installed to facilitate groundwater sampling in the upper water-bearing zone of the shallow aquifer. The total depth of the shallow wells depended primarily on depth to groundwater, because these wells were installed to bracket the water table surface at each location. Because groundwater is encountered at approximately four to six feet bgs across Zone G, the average shallow monitoring well depth was approximately 12 feet bgs. These monitoring wells were installed using hollow-stem auger drilling method, in accordance with procedures set forth in Section 5 of the approved final CSAP. Additionally, 13 shallow wells previously installed during the 1993 sampling event (SMWUs 6, 7 and AOC 635 — seven wells, and SWMU 8 — six wells) were redeveloped and sampled during the initial sampling phase at Zone G. Three shallow wells were installed subsequently (AOC 637 — two wells, AOC 706 — one well) to address concerns developed from earlier soil and groundwater sampling phases.

3.2.3.2 Deep Monitoring Well Installation

Two deep grid-based monitoring wells were installed at Zone G to facilitate groundwater sampling at the base of the shallow aquifer. No deep monitoring wells were installed at Zone G sites. Per Section 5.5 of the approved final CSAP, rotasonic drilling methods were used to install the deep monitoring wells, rotasonic drilling methods were used to install the deep monitoring wells. The deepest of the two wells was 56.5 feet bgs.

3.2.3.3 Monitoring Well Protector Construction

Section 3.2.3.4 of the *Draft Zone A RFI Report* details the monitoring well protector construction process as performed for the Zone G RFI. Monitoring wells were completed with either flush-mount, manhole type well protectors or above-grade protective casings, depending upon well location.

3.2.3.4 Monitoring Well Development

Section 3.2.3.5 of the *Draft Zone A RFI Report* details monitoring well development procedures as conducted for the Zone G RFI.

3.2.4 Groundwater Sampling

Section 3.2.4 of the *Draft Zone A RFI Report* details groundwater sampling as conducted for the Zone G RFI.

3.2.4.1 Groundwater Sampling Locations

At Zone G, installation of monitoring wells were based on the locations identified in the approved final RFI work plan. Some proposed locations were adjusted due to inaccessibility or obstructing utilities. Section 10 figures detail the site-specific soil sample locations. Supplementary wells were located to further define the extent of contaminants detected in the previously installed wells.

3.2.4.2 Groundwater Sample Collection

Section 3.2.4.2 of the *Draft Zone A RFI Report* details the groundwater sample collection process as conducted for the Zone G RFI. At Zone G, peristaltic pump procedures were used as set forth in Section 6 of the approved final CSAP.

3.2.4.3 Groundwater Sample Preparation, Packaging, and Shipment

Section 3.2.4.3 of the *Draft Zone A RFI Report* details groundwater sample preparation, packaging, and shipment as performed for the Zone G RFI.

3.2.4.4 Groundwater Sample Analysis

Section 3.2.4.4 of the *Draft Zone A RFI Report* details groundwater sample analysis as conducted for the Zone G RFI. Analytical protocols specific to the Zone G RFI are described in Section 3.2 of this report.

3.2.5 Sediment/Surface Water Sampling

Section 3.2.5 of the *Draft Zone A Report* details sediment sampling as conducted for the Zone G RFI. Section 7 of the approved final CSAP describes the procedures used for sediment and surface water sample collection at Zone G.

3.2.5.1 Sediment Sample Locations

The investigation strategy proposed in the approved final RFI work plan included the collection of sediment samples from four sites in Zone G (AOCs 633 and 643, SWMUs 11 and 120). The purpose was to determine the impact of contaminant transport via the surface water drainage pathways from these areas. Locations sampled included storm sewer manholes, drainage ditches, downgradient flow-paths from these sites, and adjacent wetlands. A total of 11 sediment samples from these sites were proposed in the RFI work plan. Due to a lack of sediment, sample 120M0002 was not collected. Ten sediment samples were collected during the first phase of the field investigation for Zone G. Later, an additional sediment and surface water sample were collected from a drainage ditch adjacent AOC 637. These subsequent samples near AOC 637 were not proposed in the approved final RFI work plan, and were collected to determine the impact of contaminant transport via the downgradient drainage pathway from the site. Section 10 contains maps detailing site-specific sediment sample locations.

3.2.5.2 Sediment/Surface Water Sample Collection

At Zone G, composite sediment samples were collected for laboratory analysis from zero- to six- inches bgs using the scoop sampling method outlined in Section 7.2.3 of the CSAP. Section 7.3 of the CSAP details procedures used to collect the surface water sample from AOC 637.

3.2.5.3 Sediment/Surface Water Sample Preparation, Packaging, and Shipment

Guidelines in Section 11 of the approved final CSAP were followed for the preparation, packaging, and shipment of sediment samples collected during the Zone G RFI.

3.2.5.4 Sediment Sample Analysis

Sediment samples were analyzed per USEPA SW-846 at DQO Level III unless otherwise noted. Analytical protocols specific to the Zone G RFI are described in Section 3.2 of this report.

3.2.6 DPT Screening Surveys

The approved final RFI work plan proposed for a DPT soil screening effort at one Zone G site (SWMU 11) to define the areal extent and thickness of residual sludge at this site, and to assess the pH of the unsaturated and saturated zones.

3.2.6.1 DPT Screening Locations

The approved final RFI work plan proposed a 100 foot sampling grid for the DPT effort at SWMU 11, with additional samples near the perimeter of the site, as needed. In all, eight push sample locations were collected at SWMU 11, including both surface and subsurface sampling intervals.

3.2.6.2 DPT Sample Collection

Soil was sampled using a DPT rig, as described in Sections 4.3.3 and 6.1.3 of the approved final CSAP.

3.2.6.3 DPT Sample Preparation, Packaging, and Shipment

Guidelines in Section 11 of the CSAP were followed for preparing, packaging, and shipping of DPT samples collected at SWMU 11. These samples were submitted to the contracted laboratory.

3.2.6.4 DPT Sample Analysis

DPT samples for SWMU 11 were submitted to the contracted laboratory for analysis for metals and pH. Analytical protocols specific to the Zone G RFI are described in Section 3.2 of this report.

3.2.7 Vertical and Horizontal Surveying

Section 3.2.7 of the *Draft Zone A RFI Report* discusses the procedures for vertical and horizontal surveying used for the Zone G RFI.

3.2.8 Aquifer Characterization

Section 3.2.8 of the *Draft Zone A RFI Report* details aquifer characterization procedures as conducted for the Zone G RFI.

3.2.9 Decontamination Procedures

Section 3.2.9 of the *Draft Zone A RFI Report* details decontamination procedures as conducted for the Zone G RFI.

3.2.9.1 Decontamination Area Setup

Section 3.2.9.1 of the *Draft Zone A RFI Report* details decontamination area setup as conducted for the Zone G RFI.

3.2.9.2 Cross-Contamination Prevention 1

Section 3.2.9.2 of the *Draft Zone A RFI Report* details cross-contamination prevention measures 2
as conducted for the Zone G RFI. 3

3.2.9.3 Nonsampling Equipment 4

Section 3.2.9.3 of the *Draft Zone A RFI Report* details decontamination procedures for 5
nonsampling equipment as conducted for the Zone G RFI. 6

3.2.9.4 Sampling Equipment 7

Section 3.2.9.4 of the *Draft Zone A RFI Report* details decontamination procedures for sampling 8
equipment as conducted for the Zone G RFI. 9

4.0 DATA VALIDATION

4.1 Introduction

Section 4.1 of the *Draft Zone A RFI Report* defines the DQOs used for the Zone G investigation. For Zone G, Level III analytical data with 10% analyses for Appendix IX at Level IV were deemed appropriate for the following data uses: (1) site screening, (2) site characterization, (3) risk assessment, and (4) determinations/design of corrective measures. Site screening data for Zone G were accomplished by obtaining environmental samples through the use of DPT collection techniques. Site screening samples from SWMU 11 were submitted to the contracted laboratory (Southwest Laboratories, Inc.) to be analyzed at Level III for metals and pH.

Appendix D includes the complete analytical dataset for Zone G.

4.2 Validation Summary

Section 4.2 of the *Draft Zone A RFI Report* discusses the NAVBASE analytical program, including the analytical methods used, as well as the QA/QC evaluation for the definitive data produced during the Zone G RFI.

Field samples were collected at Zone G from August 1996 to August 1997, in accordance with the approved work plan. All non-screening samples were analyzed by Southwest Laboratory of Oklahoma. In accordance with the approved final CSAP, sample analyses followed the guidance in *Test Methods for Evaluating Solid Waste*, SW-846 (USEPA, 1986a) and Title 40 CFR Part 264.

Third-party independent data validation of all analytical work performed under the CSAP was conducted by Heartland Environmental Services, Inc. of St. Charles, Missouri based on the QC criteria developed for the Contract Laboratory Program (CLP). The third-party validator's function was to assess and summarize the quality and reliability of the data to determine their

usability and to document any factors affecting data usability, such as compliance with methods, possible matrix interferences, and laboratory blank contamination.

4.2.1 Organic Evaluation Criteria

Section 4.2.1 of the *Draft Zone A RFI Report* discusses the organic evaluation criteria as they apply to the Zone G RFI. Appendix D includes the complete analytical dataset for Zone G.

4.2.1.1 Holding Times

Section 4.2.1.1 of the *Draft Zone A RFI Report* discusses organic sample holding times as they apply to the Zone G RFI.

4.2.1.2 GC/MS Instrument Performance Checks

Section 4.2.1.2 of the *Draft Zone A RFI Report* discusses performance standards for VOC and SVOC analyses as they apply to the Zone G RFI.

4.2.1.3 Surrogate Spike Recoveries

Section 4.2.1.3 of the *Draft Zone A RFI Report* discusses organic surrogate compounds as they apply to the Zone G RFI.

4.2.1.4 Instrument Calibration

Section 4.2.1.4 of the *Draft Zone A RFI Report* discusses instrument calibration as it applies to the organic data evaluation for the Zone G RFI.

4.2.1.5 Matrix Spike/Matrix Spike Duplicate

Section 4.2.1.5 of the *Draft Zone A RFI Report* discusses matrix spikes/duplicates as they apply to the organic data evaluation for the Zone G RFI.

4.2.1.6 Laboratory Control Samples and Laboratory Duplicates	1
Section 4.2.1.6 of the <i>Draft Zone A RFI Report</i> discusses laboratory control samples and laboratory duplicates as they apply to the organic data evaluation for the Zone G RFI.	2 3
4.2.1.7 Blank Analysis	4
Section 4.2.1.7 of the <i>Draft Zone A RFI Report</i> discusses blank analysis as it applies to the organic data evaluation for the Zone G RFI.	5 6
4.2.1.8 Field-Derived Blanks	7
Section 4.2.1.8 of the <i>Draft Zone A RFI Report</i> discusses field-derived blank analyses as they apply to the organic data evaluation for the Zone G RFI.	8 9
4.2.1.9 Internal Standard Performance	10
Section 4.2.1.9 of the <i>Draft Zone A RFI Report</i> discusses internal performance standards as they apply to the organic data evaluation for the Zone G RFI.	11 12
4.2.1.10 Diluted Samples	13
A special evaluation was performed for diluted samples to determine if method detection limits (MDLs) were low enough to be compared to reference concentrations (e.g., Maximum Contaminant Levels [MCLs], Risk-Based Concentrations [RBCs], etc.). Table 4.1 lists the diluted samples for Zone G.	14 15 16 17
4.2.2 Inorganic Evaluation Criteria	18
Section 4.2.2 of the <i>Draft Zone A RFI Report</i> discusses the inorganic evaluation criteria as they apply to the Zone G RFI. Appendix D includes the complete analytical dataset for Zone G.	19 20

Table 4.1
 Zone G
 Diluted Soil Samples

Method	Diluted Parameter	Sample ID	Result (µg/kg)	VQUAL
APX9 PEST	4,4'-DDD	006CB00201	21000	
SW846-PEST	4,4'-DDD	006SB00101	930	D
SW846-PEST	4,4'-DDD	006SB00201	19000	D
SW846-PEST	4,4'-DDD	120SB00101	560	D
SW846-PEST	4,4'-DDD	120SB00201	200	D
SW846-PEST	4,4'-DDD	120SB00202	7100	D
SW846-PEST	4,4'-DDD	120SB00601	68	D
APX9 PEST	4,4'-DDD	636CB00201	260	
SW846-PEST	4,4'-DDD	636SB00201	98	DJ
SW846-PEST	4,4'-DDD	636SB00402	180	D
SW846-PEST	4,4'-DDD	706SB00202	110	D
SW846-PEST	4,4'-DDD	706SB00602	98	D
SW846-PEST	4,4'-DDE	003SB00201	81	D
SW846-PEST	4,4'-DDE	003SB00901	200	D
SW846-PEST	4,4'-DDE	003SB00902	160	D
APX9 PEST	4,4'-DDE	006CB00201	5800	D
SW846-PEST	4,4'-DDE	006SB00101	1600	D
SW846-PEST	4,4'-DDE	006SB00102	84	D
SW846-PEST	4,4'-DDE	006SB00201	4000	D
SW846-PEST	4,4'-DDE	006SB00301	100	D
SW846-PEST	4,4'-DDE	120SB00601	56	
APX9 PEST	4,4'-DDE	636CB00201	160	DJ
SW846-PEST	4,4'-DDE	636SB00201	75	DJ
SW846-PEST	4,4'-DDE	636SB00402	120	D
APX9 PEST	4,4'-DDE	638CB00101	96	DJ
SW846-PEST	4,4'-DDE	638SB00101	56	DJ
APX9 PEST	4,4'-DDE	643CB00901	100	D
APX9 PEST	4,4'-DDE	643CB01001	59	D
SW846-PEST	4,4'-DDE	643SB00201	210	D
SW846-PEST	4,4'-DDE	643SB00401	54	D
SW846-PEST	4,4'-DDE	643SB00601	380	D
SW846-PEST	4,4'-DDE	643SB00801	100	D
SW846-PEST	4,4'-DDE	643SB00901	70	D
SW846-PEST	4,4'-DDE	643SB01001	64	D
APX9 PEST	4,4'-DDE	706CB00201	69	DJ
SW846-PEST	4,4'-DDE	706SB00102	130	D
SW846-PEST	4,4'-DDE	706SB00602	140	D
SW846-PEST	4,4'-DDE	GDGSB00701	57	D
APX9 PEST	4,4'-DDT	003CB00701	97	D
SW846-PEST	4,4'-DDT	003SB00201	65	D
SW846-PEST	4,4'-DDT	003SB00701	94	D
SW846-PEST	4,4'-DDT	003SB00901	180	D

Table 4.1
Zone G
Diluted Soil Samples

Method	Diluted Parameter	Sample ID	Result (µg/kg)	VQUAL
SW846-PEST	4,4'-DDT	003SB00902	250	D
APX9 PEST	4,4'-DDT	006CB00201	6600	D
SW846-PEST	4,4'-DDT	006SB00101	2200	D
SW846-PEST	4,4'-DDT	006SB00102	120	D
SW846-PEST	4,4'-DDT	006SB00201	4300	D
SW846-PEST	4,4'-DDT	006SB00301	60	D
SW846-PEST	4,4'-DDT	120SB00601	320	D
SW846-PEST	4,4'-DDT	643SB00201	55	D
SW846-PEST	4,4'-DDT	643SB00601	94	D
SW846-PEST	4,4'-DDT	643SB00701	110	D
SW846-PEST	4,4'-DDT	643SB01001	250	DJ
SW846-PEST	4,4'-DDT	706SB00602	140	D
SW846-PEST	4,4'-DDT	GDGSB00801	780	D
SW846-VOA	Acetone	006SB00102	540	D
SW846-VOA	Acetone	638SB00402	120	D
SW846-PEST	Aroclor-1260	006SB00101	8600	D
SW846-PEST	Aroclor-1260	633SB00702	25000	D
SW846-PEST	Aroclor-1260	643SB00701	1700	D
SW846-PEST	Aroclor-1260	643SB01001	2200	DJ
SW846-PEST	Aroclor-1260	GDGSB00301	3500	D
SW846-PEST	Aroclor-1260	GDGSB00701	1600	D
SW846-PEST	Aroclor-1260	GDGSB00801	1300	D
SW846-PEST	Endrin aldehyde	643M000101	110	D
SW846-PEST	Endrin aldehyde	643SB01001	120	DJ
SW846-PEST	Heptachlor	003SB00801	210	D
SW846-SVOA	Phenanthrene	643M000101	2100	D
SW846-PEST	alpha-Chlordane	003SB00301	16000	D
SW846-PEST	alpha-Chlordane	003SB00801	420	DJ
SW846-PEST	alpha-Chlordane	003SB00802	35	DJ
SW846-PEST	alpha-Chlordane	003SB00901	21	DJ
SW846-PEST	alpha-Chlordane	003SB00902	85	DJ
SW846-PEST	alpha-Chlordane	633SB01001	450	D
SW846-PEST	alpha-Chlordane	637SB00301	39	D
SW846-PEST	alpha-Chlordane	643M000101	45	DJ
SW846-SVOA	bis(2-Ethylhexyl)phthalate	643M000101	14000	D
SW846-PEST	gamma-Chlordane	003SB00301	22000	D
SW846-PEST	gamma-Chlordane	003SB00801	510	D
SW846-PEST	gamma-Chlordane	003SB00802	40	D
SW846-PEST	gamma-Chlordane	003SB00901	21	D
SW846-PEST	gamma-Chlordane	003SB00902	110	D
SW846-PEST	gamma-Chlordane	633SB01001	420	DJ
SW846-PEST	gamma-Chlordane	636SB00901	51	D
SW846-PEST	gamma-Chlordane	637SB00301	73	DJ

Table 4.1
 Zone G
 Diluted Soil Samples

Method	Diluted Parameter	Sample ID	Result (µg/kg)	VQUAL
APX9 PEST	gamma-Chlordane	638CB00101	46	D
SW846-PEST	gamma-Chlordane	638SB00101	35	DJ
SW846-PEST	gamma-Chlordane	643M000101	49	D
SW846-PEST	gamma-Chlordane	643SB00201	24	D

Notes:

All results are in µg/kg (microgram per kilogram)
 VQUAL = Validation Qualifier
 D = Diluted sample
 DJ = Diluted sample, results estimated

4.2.2.1 Holding Times

Section 4.2.2.1 of the *Draft Zone A RFI Report* discusses inorganic holding times as they apply to the Zone G RFI.

4.2.2.2 Instrument Calibration

Section 4.2.2.2 of the *Draft Zone A RFI Report* discusses instrument calibration as it applies to the Zone G RFI.

4.2.2.3 Blank Analysis

Section 4.2.2.3 of the *Draft Zone A RFI Report* discusses blank analysis as it applies to the Zone G RFI.

4.2.2.4 Inductively Coupled Argon Plasma Interference Check Samples

Section 4.2.2.4 of the *Draft Zone A RFI Report* discusses inductively coupled argon plasma (ICAP) interference check samples as they apply to the Zone G RFI.

4.2.2.5 Laboratory Control Samples

Section 4.2.2.5 of the *Draft Zone A RFI Report* discusses laboratory control samples (LCS) as they apply to the Zone G RFI.

4.2.2.6 Spike Sample Analysis

Section 4.2.2.6 of the *Draft Zone A RFI Report* discusses spike sample analyses as they apply to the Zone G RFI.

4.2.2.7 Laboratory Duplicates

Section 4.2.2.7 of the *Draft Zone A RFI Report* discusses laboratory duplicates as they apply to the Zone G RFI.

4.2.2.8 ICAP Serial Dilutions

Section 4.2.2.8 of the *Draft Zone A RFI Report* discusses ICAP serial dilutions as they apply to the Zone G RFI.

4.2.2.9 Atomic Absorption Duplicate Injections and Postdigestion Spike Recoveries

Section 4.2.2.9 of the *Draft Zone A RFI Report* discusses atomic absorption (AA) analysis, duplicate injections, and postdigestion spikes as they apply to the Zone G RFI.

4.3 Zone G Data Validation Reports

The complete Zone G data validation reports and a table of validation qualifiers, are included in Appendix E. These reports are the outcome of the evaluations described above and are specific to the analytical data collected during the Zone G RFI. During data validation review of Zone G soil and groundwater analyses, the following per-site deficiencies and/or problems were noted in the VOC, SVOC, and metals methods. Although field blanks were site specific, trip, equipment, and distilled water blanks were not necessarily specific to the site.

4.3.1 Soil Blanks	1
AOC 628 — Soil blanks numbered for AOC 628 for the VOC method contained detectable:	2
• Methylene chloride in the method blank	3
• 2-butanone in the trip blank	4
• Acetone in the method and trip blanks	5
Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the distilled water blank.	6 7
Blanks for the metals method contained detectable:	8
• Tin in the method blank	9
• Copper and sodium in the distilled water and equipment blanks	10
• Beryllium in the distilled water, equipment, and method blanks	11
AOC 634 — Soil blanks numbered for AOC 634 for the VOC method contained detectable: acetone, chloroform, and methylene chloride in the method and trip blanks. Blanks for the metals method contained detectable nickel, sodium, tin, and zinc in the method blank.	12 13 14
AOC 638 — Soil blanks numbered for AOC 638 for the VOC method contained detectable:	15
• 2-butanone in the method blank	16
• Acetone and methylene chloride in the distilled water, equipment, trip, and method blanks	17 18

Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the equipment and method blanks. 1
2

Blanks for the metals method contained detectable: 3

- Antimony in the method blank 4
- Cyanide and tin were in the method and equipment blanks 5
- Sodium in the distilled water and equipment blanks 6

AOC 642 — Soil blanks numbered for AOC 642 for the metals method contained detectable antimony, copper, nickel, potassium, sodium, and tin in the method blanks. 7
8

SWMU 8 — Soil blanks numbered for SWMU 8 for the VOC method contained detectable: 9

- Acetone in the method blank 10
- Methylene chloride in the distilled water, equipment, trip, and method blanks 11

Blanks for the SVOC method contained detectable bis (2-ethylhexyl)phthalate in the distilled water, equipment, and method blanks. 12
13

Blanks for the metals method contained detectable: 14

- Cobalt and tin in the method blank 15
- Sodium in the equipment blank 16
- Antimony and mercury in the distilled water and equipment blanks 17

AOC 636 — Soil blanks numbered for AOC 636 for the VOC method contained detectable 2-butanone, acetone, carbon disulfide, and methylene chloride in the method blank. Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable antimony, sodium, and tin in the method blank.

SWMU 11 — Soil blanks numbered for SWMU 11 for the VOC method contained detectable:

- 1,1-dichloroethene and methylene chloride in the trip blank
- Acetone in the method and trip blanks

Blanks for the metals method contained detectable:

- Selenium and tin in the method blank
- Sodium in the equipment blank
- Cyanide and silver in the equipment and method blanks

DPT Samples — Blanks numbered for the DPT samples collected at SWMU 11 for the metals method contained detectable cobalt and tin in the method blank.

SWMU 120 — Soil blanks numbered for SWMU 120 for the VOC method contained detectable:

- 2-butanone in the method blank
- Acetone in the distilled water, equipment, and method blanks
- Methylene chloride in the distilled water, equipment, method and trip blanks

Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the method blank.

Blanks for the metals method contained detectable:	1
• Beryllium, cyanide, tin, and zinc in the method blank	2
• Copper and sodium in the distilled water and equipment blanks	3
AOC 643 — Soil blanks numbered for AOC 643 for the VOC method contained detectable:	4
• 2-butanone in the trip blank	5
• Methylene chloride in the method blank	6
• Acetone in the trip and method blanks	7
Blanks for the SVOC method contained detectable butylbenzylphthalate and bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable beryllium, copper, nickel, sodium, tin and zinc in the method blank.	8 9 10
SWMU 3 — Soil blanks numbered for SWMU 3 for the VOC method contained detectable:	11
• Methylene chloride in the trip blank	12
• Acetone in the method and trip blanks	13
• Chloroform in the distilled water, equipment, trip, and method blanks	14
Blanks for the metals method contained detectable:	15
• Antimony, silver, tin, and zinc in the method blank	16
• Copper, nickel, and sodium in the distilled water and equipment blanks	17
• Beryllium and cyanide in the distilled water, equipment, and method blanks	18

SWMU 6 — Soil blanks numbered for SWMU 6 (associated with the SWMUs 6, 7 and AOC 635 investigation) for the VOC method contained detectable 2-butanone, acetone, and methylene chloride in the method blank. Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable antimony and sodium in the method blank.

SWMU 7 — Soil blanks numbered for SWMU 7 (associated with the SWMUs 6, 7 and AOC 635 investigation) for the VOC method contained detectable 2-butanone, acetone, chloroform, and methylene chloride in the method blank. Blanks for the metals method contained detectable copper, nickel, sodium, tin and zinc in the method blank.

AOC 635 — Soil blanks numbered for AOC 635 (associated with the SWMUs 6, 7 and AOC 635 investigation) for the VOC method contained detectable acetone, chloroform, and methylene chloride in the method blank. Blanks for the metals method contained detectable copper and tin in the method blank.

AOC 646 — Soil blanks numbered for AOC 646 for the VOC method contained detectable:

- 2-butanone and methylene chloride in the method blank
- Acetone in the method and trip blanks

Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the method blank.

Blanks for the metals method contained detectable beryllium and tin in the method blank.

AOC 706 — Soil blanks numbered for AOC 706 for the VOC method contained detectable:	1
• 2-butanone in the trip blank	2
• Acetone in the distilled water, method, and trip blanks	3
• Carbon disulfide in the distilled water, equipment, and trip blanks	4
• Methylene chloride in the distilled water, equipment, trip, and method blanks	5
 Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the distilled water, equipment, and method blanks.	 6 7
 Blanks for the metals method contained detectable:	 8
• Antimony and tin in the method blank	9
• Beryllium and sodium in the distilled water and equipment blanks	10
• Cyanide and mercury in the distilled water, equipment, and method blanks	11
 Soil Grid-Based Samples — Blanks numbered for the site soil grid-based samples for the VOC method contained detectable:	 12 13
• 2-butanone in the method blank	14
• Acetone and methylene chloride in the method and trip blanks	15
• Chloroform in the distilled water, equipment, trip, and method blanks	16
 Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the distilled water and equipment blanks.	 17 18

Blanks for the metals method contained detectable:	1
• Antimony selenium, thallium, and tin in the method blank	2
• Sodium and zinc in the distilled water and equipment blanks	3
• Cyanide in the distilled water and method blanks	4
• Beryllium and copper in the distilled water, equipment, and method blanks	5
4.3.2 Groundwater Blanks	6
AOC 638 — Groundwater blanks numbered for AOC 638 for the VOC method contained detectable acetone and methylene chloride in the method and trip blanks. Blanks for the metals method contained detectable tin and vanadium in the method blank.	7 8 9
SWMU 8 — Groundwater blanks numbered for SWMU 8 for the VOC method contained detectable:	10 11
• Carbon disulfide and methylene chloride the method blank	12
• Acetone and xylene in the trip blank	13
Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the field blank.	14
Blanks for the metals method contained detectable beryllium, chromium, and zinc in the method blank.	15 16
AOC 636 — Groundwater blanks numbered for AOC 636 for the VOC method contained detectable acetone and methylene chloride in the method blank. Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable beryllium, chromium, and mercury in the method blank.	17 18 19 20

AOC 637 – Groundwater blanks numbered for AOC 637 for the VOC method contained detectable acetone and methylene chloride in the method blank. Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the method blank. Blanks for the metals method contained detectable beryllium and mercury in the method blank.

SWMU 11 – Groundwater blanks numbered for SWMU 11 for the metals method contained detectable:

- Copper in the method blank
- Antimony and chromium in the equipment blank
- Nickel and tin in the distilled water, equipment, and field blanks

SWMU 120 – Groundwater blanks numbered for SWMU 120 for the VOC method contained detectable:

- Acetone in the field blank
- Methylene chloride in the field and trip blanks

Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the field blank.

Blanks for the metals method contained detectable:

- Chromium, copper, and cyanide in the method blank
- Beryllium and zinc in the field and method blanks

SWMU 3 – Groundwater blanks numbered for SWMU 3 for the VOC method contained detectable 1,2-dichloroethene detectable in the trip blank. Blanks for the metals method contained detectable antimony, copper, tin, vanadium and zinc in the method blank.

SWMU 6 – Groundwater blanks numbered for SWMU 6 (associated with the SWMUs 6, 7 and AOC 635 investigation) for the VOC method contained detectable acetone and methylene chloride in the distilled water, equipment, and trip blanks. Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the equipment and method blanks.

Blanks for the metals method contained detectable:

- Cyanide in the method blank
- Chromium in the distilled water blank
- Antimony, nickel, and tin in the distilled water and equipment blanks
- Thallium in the distilled water and method blanks
- Copper in the distilled water, equipment, and method blanks

Groundwater Grid-Based Samples

Groundwater blanks numbered for the grid-based samples for the VOC method contained detectable:

- Acetone in the method blank
- Methylene chloride in the field and trip blanks

Blanks for the SVOC method contained detectable bis(2-ethylhexyl)phthalate in the field blank.

Blanks for the metals method contained detectable:	1
• Beryllium, chromium, copper, cyanide, mercury, and tin in the method blank	2
• Zinc in the field and method blanks	3
Review of the analytical data showed no elevated detection limits.	4
4.4 Method Detection Limits	5
Tables 4.2 through 4.11 contain Southwest Laboratory of Oklahoma’s MDL study.	6

Table 4.2
 Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Dioxins

Compound	CAS Number	MDL	
		Water (pg/L)	Soil (ng/kg)
Tetra-Octa Dioxin/Furans-High Res Mass Spec			
Test Code:	MS790		
Method:	SW846/8290, High Resolution Method		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 10g		
Initial Calibration:	1.0/2.5/5 - 200/500/1000 ng/mL		
Continuing Calibration:	10/25/50 ng/mL		
2378-TCDD	1746-01-6	6.79	0.17
12378-PeCDD	40321-76-4	6.64	0.74
123478-HxCDD	39227-28-6	17.63	0.82
123678-HxCDD	57653-85-7	13.56	0.89
123789-HxCDD	19408-74-3	15.35	0.96
1234678-HpCDD	35822-39-4	14.44	0.41
OCDD	3268-87-9	21.46	0.59
2378-TCDF	51207-31-9	2.96	0.39
12378-PeCDF	57117-41-6	5.58	0.27
23478-PeCDF	57117-31-4	13.26	0.60
123478-HxCDF	70648-26-9	7.96	0.54
123678-HxCDF	57117-44-9	8.68	0.57
123789-Hx-CDF	72918-21-9	17.87	0.69
234678-HxCDF	60851-34-5	16.00	0.88
1234678-HpCDF	67562-39-4	10.99	0.26
1234789-HpCDF	5563-89-7	17.98	0.53
OCDF	39001-02-0	10.63	0.32

Notes:

MDL	=	Method detection limit
pg/L	=	picogram per liter
ng/kg	=	nanogram per kilogram
ng/mL	=	nanogram per milliliter
HpCDD	=	Heptachlorodibenzo-p-dioxin
HpCDF	=	Heptachlorodibenzofuran
HxCDD	=	Hexachlorodibenzo-p-dioxin
HxCDF	=	Hexachlorodibenzofuran
OCDD	=	Octachlorodibenzo-p-dioxin
OCDF	=	Octachlorodibenzofuran
PeCDD	=	Pentachlorodibenzo-p-dioxin
PeCDF	=	Pentachlorodibenzofuran
TCDD	=	Tetrachlorodibenzo-p-dioxin
TCDF	=	Tetrachlorodibenzofuran

Table 4.3
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for VOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Volatiles			
Test Code:	MS300		
Method:	SW846 8240, 3rd Edition, Nov. 1986/Sept. 1994		
Matrix:	Soil-Water		
Sample Volume:	5 g - 5 mL		
Initial Calibration:	5-20-50-100-200 ppb, %RSD < 30% for CCC compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100		
Continuing Calibration:	50 ppb, %D < 20% for CCC Compounds, SPCC RRF > 0.300, except for Bromoform RRF > 0.100		
Chloromethane	74-87-3	0.96	1.6
Vinyl Chloride	75-01-4	1.4	1.8
Bromomethane	74-83-9	1.8	2.0
Chloroethane	75-00-3	1.4	2.1
1,1-Dichloroethene	75-35-4	1.4	1.8
Acetone	67-64-1	1.6	2.6
Carbon Disulfide	75-15-0	1.5	2.0
Methylene Chloride	75-09-2	3.0	1.8
1,2-Dichloroethene (total)	540-59-0	0.97	2.1
trans-1,2-Dichloroethene	56-60-5	0.97	2.1
1,1-Dichloroethane	75-34-3	0.97	2.0
Vinyl Acetate	108-05-4	0.92	1.6
cis-1,2-Dichloroethene	156-59-2	0.93	1.9
2-Butanone	78-93-3	0.88	1.6
Chloroform	67-77-3	0.85	1.9
1,1,1-Trichloroethane	71-55-6	1.3	1.8
Carbon Tetrachloride	56-23-5	1.2	1.9
Benzene	71-43-2	1.5	1.7
1,2-Dichloroethane	107-06-2	0.44	2.0
Trichloroethene	79-01-6	1.0	1.9
1,2-Dichloropropane	78-87-5	0.76	1.9
Bromodichloromethane	75-27-4	0.68	1.9

Table 4.3
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for VOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
2-Chloroethyl Vinyl Ether	110-75-8	0.54	4.4
cis-1,3-Dichloropropene	10061-01-5	0.58	2.0
4-Methyl-2-Pentanone	108-10-1	1.8	1.9
Toluene	108-88-3	1.0	1.7
trans-1,2-Dichloropropene	10061-02-6	0.60	1.8
1,1,2-Trichloroethane	79-00-5	0.45	1.9
Tetrachloroethene	127-18-4	1.2	2.2
2-Hexanone	591-78-6	0.62	2.4
Dibromochloromethane	124-48-1	0.78	1.6
Chlorobenzene	108-90-7	0.83	1.9
Ethylbenzene	100-31-4	1.2	1.9
m,p-Xylene	13-302-07	2.2	3.9
Xylene (Total)	1330-20-7	2.2	3.9
o-Xylene	95-47-6	0.93	1.9
Styrene	100-42-5	0.8	2.1
Bromoform	75-25-2	1.0	1.7
1,1,1,2-Tetrachloroethane	79-34-5	1.3	1.7

Notes:

- CCC = Calibration Check Compounds
- %D = Percent difference
- RRF = Relative Response Factor
- %RSD = Percent Relative Standard Deviation
- SPCC = System Performance Check Compounds
- MDL = Method Detection Limit
- $\mu\text{g/L}$ = microgram per liter
- $\mu\text{g/kg}$ = microgram per kilogram

Table 4.4
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Semivolatiles			
Test Code:	MS500		
Method:	SW846 8270, 823rd Edition, Nov. 1986, PQL Table II, Rev.0, Sept. 1986		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	20-50-100-120-160 ng, %RSD for CCC compounds=30%, SPCC=RRF > 0.05		
Continuing Calibration:	50 ng, %D = 25% for CCC Compounds, SPCC = RRF > 0.05100		
Phenol	108-95-2	3.3	100
bis(2-chloroethyl)ether	111-44-4	3.4	100
2-Chlorophenol	95-57-8	3.3	97
1,3-Dichlorobenzene	541-73-1	2.6	100
1,4-Dichlorobenzene	106-46-7	2.8	120
Benzyl alcohol	100-51-6	3.6	82
1,2-Dichlorobenzene	95-50-1	3.0	100
2-Methylphenol	95-48-7	2.9	130
bis(2-chloroisopropyl)ether	108-60-1	3.5	89
4-Methylphenol	106-44-5	6.4	94
N-Nitroso-di-n-propylamine	621-64-7	2.8	87
Hexachloroethane	67-72-1	2.3	94
Isophorone	78-59-1	3.0	100
Nitrobenzene	98-95-3	3.5	100
2-Nitrophenol	88-75-5	3.4	99
2,4-Dimethylphenol	105-67-9	3.9	160
bis(2-chloroethoxy)methane	111-91-1	3.3	99
2,4-Dichlorophenol	120-83-2	2.6	110
Benzoic acid	65-85-0	9.2	150
1,2,4-Trichlorobenzene	120-82-1	2.9	94
Naphthalene	91-20-3	2.6	110
4-Chloroaniline	106-47-8	3.3	210

Table 4.4
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Hexachlorobutadiene	87-68-3	3.0	90
4-Chloro-3-methylphenol	59-50-7	2.6	90
2-Methylnaphthalene	91-57-6	2.4	85
Hexachlorocyclopentadiene	77-47-4	NA	75
2,4,6-Trichlorophenol	88-06-2	2.6	110
2,4,5-Trichlorophenol	95-95-4	2.7	110
2-Chloronaphthalene	91-58-7	2.1	110
2-Nitroaniline	88-74-4	2.8	110
Dimethylphthalate	131-11-3	0.8	120
Acenaphthylene	208-96-8	2.4	120
2,6-Dinitrotoluene	606-20-2	4.0	110
3-Nitroaniline	99-09-2	3.6	150
Acenaphthene	83-32-9	2.2	100
2,4-Dinitrophenol	51-28-5	2.9	100
4-Nitrophenol	100-02-7	2.6	93
Dibenzofuran	132-64-9	1.9	110
2,4-Dinitrotoluene	121-14-2	3.9	100
Diethylphthalate	84-66-2	1.2	120
Fluorene	86-73-7	1.8	100
4-Chlorophenyl-phenylether	7005-72-3	2.2	120
4-Nitroaniline	100-01-6	2.8	150
4,6-Dinitro-2-methylphenol	534-52-1	2.4	100
N-nitrosodiphenylamine	86-30-6	2.4	110
4-Bromophenyl-phenylether	101-55-3	2.3	86
Hexachlorobenzene	118-74-1	2.6	84
Pentachlorophenol	87-86-5	2.3	76

Table 4.4
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for SVOCs

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Phenanthrene	85-01-8	2.6	110
Anthracene	120-12-7	2.6	100
Di-n-butylphthalate	84-74-2	2.0	110
Fluoranthene	206-44-0	1.9	100
Pyrene	129-00-0	1.2	120
Butylbenzylphthalate	85-68-7	1.1	120
Benzo(a)anthracene	56-55-3	1.0	100
3,3'-Dichlorobenzidine	91-94-1	2.4	120
Chrysene	218-1-9	0.9	100
bis(2-ethylhexyl)phthalate	117-81-7	3.5	140
Di-n-octylphthalate	117-84-0	2.0	110
Benzo(b)fluoranthene	205-99-2	1.8	120
Benzo(k)fluoranthene	207-08-9	2.1	100
Benzo(a)pyrene	50-32-8	1.6	83
Indeno(1,2,3-cd)pyrene	193-39-5	1.6	110
Dibenz(a,h)anthracene	53-70-3	1.6	120
Benzo(g,h,i)perylene	191-24-2	1.6	130

Notes:

CCC	=	Calibration Check Compounds
%D	=	Percent difference
RRF	=	Relative Response Factor
%RSD	=	Percent Relative Standard Deviation
SPCC	=	System Performance Check Compounds
MDL	=	Method Detection Limit
$\mu\text{g/L}$	=	microgram per liter
$\mu\text{g/kg}$	=	microgram per kilogram
NA	=	Not applicable

Table 4.5
 Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Pesticides/PCB

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Pesticide/PCB			
Test Code:	GC800		
Method:	SW846 8080A, 3rd Edition, Nov. 1986		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	5 point calibration, %RSD=20%		
Continuing Calibration:	Single point calibration, %D = 15%		
alpha-BHC	319-84-6	2E-03	0.130
beta-BHC	319-85-7	1E-03	0.120
delta-BHC	319-86-8	6E-03	8.6E-02
gamma-BHC(Lindane)	58-89-9	2E-03	6.8E-02
Heptachlor	76-44-8	1.9E-02	9.5E-02
Aldrin	309-00-2	1E-03	6.2E-02
Heptachlor epoxide	1024-57-3	4E-03	5.1E-02
Endosulfan I	959-98-8	3E-03	9.8E-02
Dieldrin	60-57-1	4E-03	0.170
4,4-DDE	72-55-9	6E-03	0.150
Endrin	72-20-8	8E-03	0.120
Endosulfan II	33213-65-9	6E-03	0.110
4'4'-DDD	72-54-8	4E-03	0.100
Endosulfan sulfate	1031-07-8	2E-03	0.250
4'4'-DDT	50-29-3	9E-03	0.250
Methoxychlor	72-43-5	2.1E-02	0.390
Endrin ketone	53494-70-5	4E-03	0.110
Endrin aldehyde	7421-36-3	8E-03	0.220
alpha-Chlordane	5193-71-9	2E-03	0.250
gamma-Chlordane	5103-74-2	2E-03	0.130
Toxaphene	8001-35-2	1.6E-03	2.000
Aroclor-1016	12674-11-2	0.210	2.600

Table 4.5
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Pesticides/PCB

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Aroclor-1221	11104-28-2	6.2E-02	2.300
Aroclor-1232	11141-16-5	0.280	1.800
Aroclor-1242	53469-21-9	2.4E-02	1.600
Aroclor-1248	12672-29-6	9.6E-02	2.200
Aroclor-1254	11097-69-1	0.140	3.200
Aroclor-1260	11096-82-5	0.170	2.700

Notes:
 %D = Percent difference
 %RSD = Percent Relative Standard Deviation
 MDL = Method Detection Limit
 $\mu\text{g/L}$ = microgram per liter
 $\mu\text{g/kg}$ = microgram per kilogram

Table 4.6
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Organophosphorus Pesticides

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Pesticides, Organophosphorus			
Test Code:	GC880		
Method:	SW846-8140, EPA methodology		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	5 point calibration, %RSD=20%		
Continuing Calibration:	Single point calibration, %D = 15%		
Dichlorvos	62-73-7	0.29	17.0
Mevinphos	7786-34-7	0.47	30.0
Demeton S	8065-48-3	0.27	19.0
Ethoprop	13194-48-4	0.23	17.0
Naled	300-76-5	0.50	60.0
Phorate	298-02-2	0.18	11.0
Diazinon	333-41-5	0.33	19.0
Disulfoton	298-04-4	0.22	12.0
Parathion-methyl	298-00-0	0.04	3.5
Ronnel	299-84-3	0.41	22.0
Fenthion	55-38-9	0.20	6.9
Chlorpyrifos	2921-88-2	0.20	9.9
Trichloroanate	327-98-0	0.20	9.5
Stirophos	22248-79-9	0.57	79.0
Tokuthion	34643-46-4	0.34	16.0
Merphos	150-50-5	0.29	15.0
Fensulfothion	115-90-2	0.60	78.0
Boistar	35400-43-2	0.20	9.2
Azinphos-methyl	86-50-0	0.26	85.0
Coumaphos	56-72-4	0.41	100.0

Notes:
 %D = Percent difference
 %RSD = Percent Relative Standard Deviation
 MDL = Method Detection Limit
 $\mu\text{g/L}$ = microgram per liter
 $\mu\text{g/kg}$ = microgram per kilogram

Table 4.7
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Herbicides

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil ($\mu\text{g/kg}$)
Acid Herbicides			
Test Code:	GC570		
Method:	SW846-8150, EPA methodology		
Matrix:	Water-Soil		
Extract Volume:	1000 mL - 30g		
Initial Calibration:	5 point calibration, %RSD=20%		
Continuing Calibration:	Single point calibration, %D = 15%		
Dalapon	75-99-0	1.30	24
Dicamba	1918-00-9	0.11	4.89
MCPPP	93-65-2	7.4	535
MCPA	94-74-6	12.0	627
Dichloroprop	120-36-5	0.19	8.26
2,4-D	94-75-7	0.29	9.51
2,4,5-TP (Silvex)	93-72-1	8.8E-02	6.15
2,4,5-T	93-76-5	0.18	2.28
2,4-DB	94-82-6	0.70	12.46
Dinoseb	88-85-7	0.49	2.76

Notes:
 %D = Percent difference
 %RSD = Percent Relative Standard Deviation
 MDL = Method Detection Limit
 $\mu\text{g/L}$ = microgram per liter
 $\mu\text{g/kg}$ = microgram per kilogram

Table 4.8
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by Low-Level ICAP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Metals reporting limits by Low Level ICAP			
Method:	SW846 Third Edition, Nov. 1986, Method 6010A		
Matrix:	Water-Soil		
Extract Volume:	100mL - 1g		
Initial Calibration:	0-500ug/L - varies		
Continuing Calibration:	$\frac{1}{2}$ high std		
Aluminum	7429-90-5	8.0	1.30
Antimony	7440-36-0	1.6	0.27
Arsenic	7440-38-2	2.1	0.31
Barium	7440-39-3	0.3	6E-02
Beryllium	7440-41-7	0.2	3E-02
Boron	7440-42-8	11.0	2.60
Cadmium	7440-43-9	0.3	5.1E-02
Calcium	7440-70-2	43.0	1.90
Chromium	7440-47-3	1.0	7E-02
Cobalt	7440-48-4	0.8	6E-02
Copper	7440-50-8	1.4	0.26
Iron	7439-89-6	20.0	1.60
Lead	7439-92-1	0.9	0.18
Magnesium	7439-95-4	43.0	4.70
Manganese	7439-96-5	0.3	4E-02
Molybdenum	7439-98-7	0.9	0.18
Nickel	7440-02-0	0.7	0.12
Potassium	7440-09-7	55.0	7.00
Selenium	7782-49-2	3.4	0.24
Scandium	440-20-2	0.1	2E-02
Strontium	7440-24-6	0.2	7E-02
Silicon	7440-21-3	35.0	15.00
Silver	7440-22-4	1.0	0.17

Table 4.8
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by Low-Level ICAP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Sodium	7440-23-5	19.0	4.90
Thallium	7440-28-0	5.0	0.46
Tin	7440-31-5	14.0	0.45
Titanium	7440-32-6	0.7	0.05
Vanadium	7440-62-2	1.1	0.13
Zinc	744-66-6	5.8	1.10

Notes:
 $\mu\text{g/L}$ = microgram per liter
 mg/kg = milligram per kilogram
 ICAP = Inductively coupled argon plasma

Table 4.9
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by ICAP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Metals reporting limits by ICAP			
Method: SW846 Third Edition, Nov. 1986, Method 6010			
Matrix: Water-Soil			
Extract Volume: 100mL - 1g			
Initial Calibration: 0-1000 $\mu\text{g/L}$ -varies			
Continuing Calibration: $\frac{1}{2}$ high std			
Aluminum	7429-90-5	14	2.8
Antimony	7440-36-0	12	1.7
Arsenic	7440-38-2	32	3.1
Barium	7440-39-3	1.0	0.19
Beryllium	7440-41-7	1.0	0.10
Boron	7440-42-8	17	2.5
Cadmium	7440-43-9	1.3	0.11
Calcium	7440-70-2	39	23.0

Table 4.9
Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Metals by ICAP Method

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Chromium	7440-47-3	1.9	0.38
Cobalt	7440-48-4	2.8	0.46
Copper	7440-50-8	8.3	0.73
Iron	7439-89-6	18	1.7
Lead	7439-92-1	12	1.5
Magnesium	7439-95-4	25	6.1
Manganese	7439-96-5	1.2	0.10
Molybdenum	7439-98-7	5.7	25
Nickel	7440-02-0	6.5	5.9E-02
Potassium	7440-09-7	560	57.0
Selenium	7782-49-2	28	3.1
Silicon	7440-21-3	70	23.0
Silver	7440-22-4	1.4	0.25
Sodium	7440-23-5	27	50.0
Thallium	7440-28-0	48	4.6
Tin	7440-31-5	17	2.1
Titanium	7440-32-6	1.0	0.14
Vanadium	7440-62-2	2.2	0.27
Zinc	744-66-6	11	1.1

Notes:
 $\mu\text{g/L}$ = microgram per liter
 mg/kg = milligram per kilogram
 ICAP = Inductively coupled argon plasma

Table 4.10
 Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Mercury by Cold Vapors

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Mercury by Cold Vapors			
Test Code:	MT310		
Method:	SW846 Third Edition, Nov. 1986		
Matrix:	Water-Soil		
Extract Volume:	100mL - 0.6g		
Initial Calibration:	0 - 10.0 $\mu\text{g/L}$		
Continuing Calibration:	1/2 HIGH STD		
Mercury	7439-97-6	0.12	3E-02

Notes:
 $\mu\text{g/L}$ = microgram per liter
 mg/kg = milligram per kilogram

Table 4.11
 Zone G
 Southwest Laboratory of Oklahoma's Method Detection Limit Study for Miscellaneous Inorganics

Compound	CAS Number	MDL	
		Water ($\mu\text{g/L}$)	Soil (mg/kg)
Miscellaneous Inorganic Analyses			
Test Code:	Methods various		
Method:			
Matrix:	Water-Soil		
Extract Volume:			
Initial Calibration:			
Continuing Calibration:			
Chloride (IC)	EPA300.0	7E-02	0.7
Cyanide (Total)	SW846-9010	2.0	0.5
Hexavalent Chromium	SW846-7196	5E-03	0.20
Sulfate (IC)	EPA300.0	0.1	0.9
Total Dissolved Solids	EPA160.1	4	—

Notes:
 $\mu\text{g/L}$ = microgram per liter
 mg/kg = milligram per kilogram

5.0 DATA EVALUATION AND BACKGROUND COMPARISON

This section describes the approach and technical methods employed to determine the nature and extent of all chemicals present in site samples (CPSSs) in soil and groundwater at Zone G sites, and to compare concentrations of inorganics in site samples to naturally occurring background concentrations. Nature and extent were evaluated to determine the overall distribution of constituents detected on micro (site-specific), and macro (zonewide) scales. In addition, these data will be used to assess basewide conditions and the relationship of contaminants between zones across NAVBASE.

Types of analytes detected in Zone G included VOCs, SVOCs, herbicides, pesticides, PCBs, explosives, dioxins, and inorganics. Detected concentrations were compared to corresponding RBCs listed in the USEPA Region III *Risk-Based Concentration Table* (USEPA, October 22, 1997), to: (1) evaluate the significance of the detections; (2) determine the need for additional sampling for defining the extent of contamination; and (3) develop investigative endpoints. Detected inorganic concentrations were also compared to corresponding background concentrations specific to Zone G. The comparisons pertain only to the protection of human health and do not address protection of ecological receptors. Risk to the ecosystem from the contaminants onsite is assessed in Section 8.

Site-specific nature and extent evaluations for AOCs and SWMUs in Zone G are detailed in Section 10 of this report.

5.1 Organic Compound Analytical Results Evaluation

Organic compound concentrations in Zone G soil and groundwater samples were compared to RBCs. Information was also compiled on each compound's frequency of detection and its mean and range of detected concentrations (see Section 10).

For screening purposes, concentrations of dioxin congeners and carcinogenic polynuclear aromatic hydrocarbons (cPAHs) were converted to 2,3,7,8-TCDD equivalency quotients (TEQs) and benzo(a)pyrene equivalents (BEQs), respectively, in accordance with recent USEPA guidance. Section 5.1 of the Draft Zone A RFI Report details the guidance and procedures followed during the Zone G RFI.

5.2 Inorganic Analytical Results Evaluation

Inorganic sample analytical results are often difficult to evaluate because inorganics are naturally occurring in soil, ubiquitous, and frequently present in groundwater. Further, NAVBASE was predominantly built on artificially placed dredge/fill material, compounding the difficulty of assessing natural site conditions. The following describes the step-by-step procedures used to determine background for inorganics in soil and groundwater at Zone G and the approach for comparing background data to site data.

Many chemicals, particularly carcinogenic metals such as arsenic and beryllium, are typically detected at concentrations that are much higher than their corresponding risk-based screening levels. It is usually necessary to supplement site-specific sampling efforts with an attempt to determine the non-site-related concentrations of these chemicals. The problem is how to determine these background concentrations, and how much higher than background a specific site parameter must be before it is of concern. USEPA Region IV guidance recommends using twice the mean of the background data values as an upper bound, considering site-related values higher than this bound to represent contamination. Although more sophisticated statistical tests can be used when larger datasets are available, the smaller site and background datasets of Zone G mandated use of the “twice the mean” approach for comparing site values to background.

Where possible, EnSafe used a dual testing procedure to compare site-specific values for inorganics with results from a grid-based background dataset. Background values for surface soil,

subsurface soil, shallow groundwater, and deep groundwater were calculated as described above, 1
in accordance with established NAVBASE procedures, and approved by the project team technical 2
subcommittee. Where data supported use of the Wilcoxon rank sum test (see Section 5.2.6 3
below), approved background values were used in combination with Wilcoxon test results to make 4
background comparisons for soil. Because groundwater datasets supported use of the Wilcoxon 5
rank sum test at only two combined sites, background comparisons for groundwater at all but these 6
two sites were performed using reference concentrations only. 7

5.2.1 Grid-Based Background Dataset 8

The background datasets for Zone G soil were derived from nine upper and seven lower-interval 9
samples collected from nine grid-based soil borings (GDGSB001 to GDGSB009). The background 10
datasets for shallow and deep groundwater were derived from two sampling rounds from two grid- 11
based well pairs (GDG001/GDG01D and GDG002/GDG02D). Original first-round sample results 12
(GDG00101, collected on November 16, 1996) for shallow grid well GDG001 were thought to 13
be affected by elevated turbidity levels (132 nephelometric turbidity units (NTU) measured 14
immediately before sampling) and were not considered representative of groundwater constituent 15
concentrations at the well's location. A supplemental first-round sample (GDG001A1) was 16
collected from well GDG001 on January 29, 1997. Results from this sample appear in place of 17
the original first-round results in the background dataset. Figures 3-1 and 3-2 in Section 3 depict 18
the Zone G grid-based soil and groundwater sample locations. 19

Because of concerns about inadvertently including contaminated samples in the background 20
datasets, outliers were eliminated more readily than many standard statistical guidelines would 21
suggest. After consultation with the project team, outliers were removed on a chemical-by- 22
chemical basis, means were recalculated for each chemical's dataset, and the resulting modified 23
datasets were used for all further comparisons to background. 24

5.2.2 Nondetect Data

Following guidelines presented in various USEPA documents, one-half of the sample quantitation limit (SQL) was used to represent nondetect values in the datasets. In practice, this meant using one-half of the *U* values reported by the analytical laboratory and confirmed by the validator. Analytical results qualified *R* or *UR* were considered unusable and were not included in the datasets.

5.2.3 Developing Datasets for Sites

Results of laboratory analyses of soil and groundwater samples from the AOCs and SWMUs were assembled into datasets for each chemical of interest from upper and lower interval soils and from shallow groundwater, for comparison to background. No deep groundwater monitoring wells were installed at AOCs or SWMUs in Zone G.

5.2.4 Comparing Site Values to Background

Section 5.2.4 of the *Draft Zone A RFI Report* contains a discussion of statistical hypothesis testing for comparing site concentrations to background. It presents EPA’s suggested “twice the mean” approach and compares it to more powerful statistical approaches that can be used in its place. It also recommends a dual testing strategy to detect different types of site contamination, involving a reference concentration comparison and the Wilcoxon rank sum test.

5.2.5 Reference Concentration Test

As discussed above, background values were determined for each inorganic in each environmental medium by calculating twice the mean of the background sample concentrations. Analytical results for each site sample were then compared to the corresponding background concentrations to identify individual samples with concentrations significantly higher than background. If the results from the test were positive (i.e., significantly higher than background), sample values were

compared to the corresponding USEPA RBCs for soil and tap water and, where appropriate, carried forward into detailed human health risk assessment (HHRA).

5.2.6 Wilcoxon Rank Sum Test

To identify onsite contamination when the majority of a site's sample values are higher than the mean background value (but not dramatically higher), as a group, the site samples must be shown to be significantly higher than the group of background samples.

The most commonly prescribed method for comparing two populations is the Student's *t*-test, which determines whether the two population means differ significantly. The *t*-test was not used in this investigation to compare site values to background because it is parametric. A nonparametric counterpart to the *t*-test is the Wilcoxon rank sum test, also known as the Mann-Whitney U test. Since this test is nonparametric, the two datasets that are compared need not be drawn from normal or even symmetric distributions, and the test can accommodate a moderate number of nondetect values by treating them as ties (Gilbert, 1987). Each dataset (representing site samples or background samples) should contain at least four data values.

The Wilcoxon rank sum test was run on inorganic analytical results only when nondetects were no greater than 50% in both site and background datasets, and only when each dataset contained at least four values. Because of these restrictions, the test was run at 12 of the 14 Zone G sites for surface soil, at six sites for subsurface soil, and at only two sites (combined SWMU 6 and combined SWMU 8) for shallow groundwater. Section 5.2.6 of the *Draft Zone A RFI Report* contains an additional description of the Wilcoxon rank sum test and justification for its use.

5.2.7 Summary of Techniques Used

Methods used for soil sample results are capable of detecting situations where (a) individual site values are much higher than background, or (b) site values are generally higher than background.

For situation (a), site values were compared to zone background concentrations consisting of twice the mean of background sample values. To account for situation (b), the Wilcoxon rank sum test was applied to compare each group of site values to background. For datasets not meeting the criteria for the Wilcoxon test, site values were compared to background concentrations only. Loss of the Wilcoxon rank sum test results for some datasets was not considered detrimental to background comparisons because comparing individual sample results to twice the mean of the background samples is an arbitrary method that is inherently more conservative than using the statistical tests (upper tolerance limits) that are possible with larger datasets. The added conservatism of the “twice the mean” reference concentration test made up for the loss of the Wilcoxon rank sum test where the Wilcoxon test could not be run.

5.2.8 Combined Results of the Reference Concentration and Wilcoxon Rank Sum Tests

Methods described in Section 5.2.5 identify individual site samples with concentrations significantly higher than background, while the method in Section 5.2.6 identifies entire sites. If the outcome of either test was positive (i.e., significantly higher than background), sample values were compared to the corresponding USEPA RBCs for soil and tap water and, where appropriate, carried forward into detailed HHRA. Where background comparisons could not be carried out for a chemical due to lack of detections in background samples, site concentrations were screened against risk-based concentrations only.

5.2.9 Conclusion

The overall approach documented here is conservative for three reasons:

- Following procedures described in Section 5.2.1, high values were removed from the background datasets whether or not they were true outliers in the conventional sense, thereby lowering the total background concentrations to which the site values were compared;

- The use of two complementary tests for soil sample results increased the likelihood that any contamination would be identified and addressed further. A positive result from either test triggered a detailed HHRA whenever site concentrations exceeded corresponding USEPA RBC values; and

- The use of twice the mean of background sample concentrations generally results in lower background values than are justified by more sophisticated statistical tests. The effect of these factors is to increase the rate of false-positive test results while minimizing the rate of false negatives, as explained in Section 5.2.4 of the *Draft Zone A RFI Report*.

5.2.10 Background Values

Table 5.1 presents background values derived from grid-based soil and groundwater samples from Zone G.

Zone G RCRA Facility Investigation Report
 NAVBASE Charleston
 Section 5 — Data Evaluation and Background Comparison
 Revision: 0

Table 5.1
 Zone G
 Background Values

Inorganic Analyte	Surface Soil (mg/kg)(n = 9)	Subsurface Soil (mg/kg)(n = 7)	Shallow Groundwater (µg/L)(n = 4)	Deep Groundwater (µg/L)(n = 4)
Aluminum	18,700	23,600	692	23.5
Antimony	2.89	ND	4.85	3.9
Arsenic	17.2*	15.5*	17.8	5.4
Barium	109	64.5	31	316
Beryllium	1.20	1.63	ND	ND
Cadmium	1.07	0.48	0.53	ND
Chromium	42.8	43.4*	3.88	2.37
Cobalt	6.60	8.14	1.45	10.6
Copper	260	32.6	8.33	ND
Lead	181	66.3	4.6	ND
Manganese	325	291	2,906	537
Mercury	1.03	0.31	ND	ND
Nickel	20.6	18.3	4.08	21.7
Selenium	1.22	1.26	4.3	ND
Silver	ND	ND	1.65	2.9
Thallium	0.85	0.95	ND	ND
Tin	9.67	2.96	ND	ND
Vanadium	60.9	72.5	15.4	ND
Zinc	519	145	15.6	16.2
Cyanide	0.38	0.22	3.8	ND

Notes:
 n = Number of background samples analyzed
 ND = Not detected
 * = Reference value for non-clay samples
 mg/kg = Milligrams per kilogram.
 µg/kg = Micrograms per kilogram.
 µg/L = Micrograms per liter.

6.0 FATE AND TRANSPORT

Fate and transport assessment evaluates whether chemical constituents can become mobile or change in the environment, based on their chemical and physical properties and the processes governing their interaction with environmental media. Macroscopic physical characteristics of the site such as climate, hydrology, topography, and geology determine weathering and erosional transport processes. Microscopic characteristics of site soil, sediment, and water, as well as the chemical and physical properties of the constituents, govern the processes of infiltration, advection, diffusion, dispersion, erosion, and volatilization that move constituents between or within media. A discussion of fate and transport will help to identify potential receptors that may be impacted by constituent movement in the environment.

The AOCs and SWMUs at Zone G are mostly situated on flat, low-lying land, much of it covered with buildings and pavement. Precipitation falling on impervious surfaces drains into storm sewers, where it is transported to outfalls on the Cooper River. Rainwater that infiltrates the soil percolates into the upper, unconfined portion of the surficial aquifer, which is the uppermost unit of the regional Wando Formation. After evaluating Zone G for the characteristics discussed in the previous paragraph, four potential routes of constituent migration have been identified for further investigation:

- Leaching of constituents from soil-to-groundwater
- Migration of constituents from groundwater into surface water bodies
- Surface soil erosion and runoff of constituents into sediment and catch basins
- Air emissions resulting from VOCs released from surface soil

Definitions:

Infiltration is the movement of water into and through the soil under the influence of gravity and capillary attraction.

Advection is the process by which dissolved substances migrate with moving groundwater. 1
Hydraulic conductivity, effective porosity, and hydraulic gradient are some of the aquifer 2
characteristics that determine a chemical's rate of movement by advection. This process is 3
generally the most important transport mechanism for compounds associated with groundwater. 4

Diffusion is the random process by which solutes are transported from regions of high 5
concentration to regions of low concentration as a result of the concentration gradient. In very 6
fine sediments with very low hydraulic conductivities, diffusive transport may be the dominant 7
mode of migration. 8

Dispersion is the hydrodynamic process by which solutes are mixed with uncontaminated water, 9
diluted, and transported preferentially due to heterogeneous properties of the aquifer. 10
Longitudinal dispersion can cause an increase in contaminant concentration ahead of the advective 11
front. 12

Erosion is the process by which particles are suspended and subsequently moved by the physical 13
action of water and/or wind. Compounds adsorbed to particulate material are thereby moved 14
along with the particulate. 15

Volatilization is the process whereby contaminants dissolved in water or present as nonaqueous 16
phase liquids evaporate into soil gas in the vadose zone and/or into the atmosphere. Volatilization 17
of solutes is controlled by their vapor pressures and Henry's law constants (HLs). 18

6.1 Properties Affecting Fate and Transport 19

Numerous chemical and physical properties of both the constituent and the surrounding media are 20
used to evaluate fate and transport mechanisms. 21

6.1.1 Contaminant Properties Affecting Fate and Transport

Chemical and physical properties of constituents used to evaluate fate and transport include vapor pressure (VP), density (D), solubility, half-life ($T_{1/2}$), HL, organic carbon/water partitioning coefficient (K_{oc}), and molecular weight (MW). Table 6.1 provides an overview of chemical properties and expected behavior in environmental media based on these properties.

Table 6.1
Zone G
Constituent Characteristics Based On
Chemical and Physical Properties

Property	Critical Value ^a	High (>)	Low (<)
Vapor Pressure	10E-03 mm Hg	volatile	nonvolatile
Density	1.0 g/cm ³	sinks/falls	floats/rises
Solubility	0 to 100 mg/L	leaches from soil; mobile in water; does not readily volatilize from water	sorbs to soil; immobile in water; volatilizes from water
Henry's Law Constant	5E-06 to 5E-03 atm-m ³ /mole	resistance to mass transfer in the aqueous phase	resistance to mass transfer in the gas phase
Half-life	biologically dependent	does not degrade readily	degrades readily
Organic Carbon/Water Partitioning Coefficient (K_{oc})	10 to 10000 kg _{oc} /L _{water}	tends to sorb to organic material in soil; immobile in the soil matrix	tends not to sorb to organic material in soil; mobile in the soil matrix
Molecular Weight	400 g/mole	characteristics listed above may not hold true; more detailed evaluation necessary	all of the above generally hold true

Note:

- a = Critical values were based on literature review and professional judgment
- mm Hg = Millimeters of mercury
- atm-m³/mole = Atmosphere cubic meters per mole
- kg_{oc}/L_{water} = Kilograms of organic carbon per liter of water
- g/cm³ = Grams per cubic centimeter
- mg/L = Milligrams per liter
- g/mole = Gram per mole

Compounds with similar chemical and physical properties display similar fate and transport behavior. These relationships facilitate the grouping of contaminants into categories. Section 6.1.1 of the draft Zone A RFI Report details characteristics affecting fate and transport for the following groups of chemicals:

- VOCs
- SVOCs
- Pesticides/PCBs
- Chlorinated herbicides
- Chlorinated dibenzodioxins/dibenzofurans
- Inorganics

6.1.2 Media Properties Affecting Fate and Transport

The properties of environmental media used to evaluate fate and transport include TOC, normalized partitioning coefficient (K_d), CEC, redox conditions, pH, soil type, and retardation factor (R). The following briefly discusses these properties.

Total Organic Carbon

TOC indicates the soil's sorptive capabilities. The higher the TOC, the higher the potential for a given chemical to sorb to soil particles, particularly for organic compounds. TOC may also be expressed as fraction organic carbon content (f_{oc}) of the soil (e.g., grams of solid organic carbon per gram of dry soil).

Normalized Partitioning Coefficient

K_d is used to predict the capacity for a constituent to partition between soil and water; it is a function of both the constituent and the soil. To estimate K_d , the constituent's K_{oc} is adjusted by

the soil's TOC: $K_d = K_{oc} f_{oc}$. Soil/constituent combinations with higher K_d s have a higher potential to sorb.

Cation Exchange Capacity

CEC reflects the soil's capacity to adsorb ions, neutralizing ionic deficiencies on the surfaces of its particles. Generally, trivalent ions are preferentially adsorbed to soil over divalent ions, and divalent ions are preferentially adsorbed over monovalent ions. The amount of cation exchange also depends on soil pH. Soils with high CEC values have the potential to adsorb inorganic ions and organic compounds with dipole moments.

Redox Conditions

Redox is the process which includes oxidation (the loss of electrons), and reduction (the gain of electrons). The resultant change in oxidation state generates products that are different from the original reactants in their solubilities, toxicities, reactivities, and mobilities. Extreme redox conditions tend to mobilize chemicals, especially transition metals.

pH

The pH value is a negative inverse logarithmic measure of hydrogen ion concentration in the soil or groundwater, indicating the acidity or alkalinity of the medium. Chemicals react differently under changing pHs. Low pH conditions tend to mobilize chemicals, especially inorganics, while high pH conditions may lead to the formation of immobile metal hydroxides.

Soil Type

The mineralogical composition, particle size distribution, and organic content of soil affect chemical fate and transport. Soil characteristics influence or determine hydraulic conductivity, effective porosity, and hydraulic gradient which, in turn, dictate groundwater flow.

Retardation Factor

The retardation factor is a measure of the ability of an aquifer matrix to inhibit the movement of a chemical by preferentially binding contaminants with high K_{oc} . R is calculated as follows:

$$R = 1 + \frac{K_d \rho_b}{n}$$

Where:

R = Retardation factor

K_d = Soil/water partitioning coefficient (L/kg)

ρ_b = Dry soil bulk density (kg/L)

n = Soil total porosity

Table 6.2 summarizes the soil parameters used to evaluate fate and transport for Zone G. The geometric mean CEC for Zone G soil is 34.2 milliequivalents per 100 grams (meq/100g), with a range of CEC values from 24.0 to 46.5 meq/100g. The geometric mean pH for Zone G soil is 7.39, with a range of pH values from 4.93 to 8.24. Fifteen of the 19 soil pH values were greater than 7.0. These soil conditions indicate limited mobility for inorganics by the processes of advection, diffusion, and dispersion, except in localized areas of low pH. The geometric mean TOC concentration for Zone G soil samples is 12,400 mg/kg (the arithmetic mean is 16,600 mg/kg). The range of TOC values for Zone G soil is 2,980 to 42,800 mg/kg. TOC measurements indicate a relatively high organic content that will inhibit the movement of contaminants, particularly those with high K_{oc} values, due to increased soil adsorption.

The geometric mean of the total porosity from the vadose zone and surficial aquifer in Zone G is 50.0%, as determined through analysis of 14 Shelby tube samples collected from depths ranging

Table 6.2
Soil and Aquifer Parameters Used to Evaluate Fate and Transport

Parameter	Number of Soil Samples	Zone G Minimum Value	Zone G Maximum Value	Zone G Geometric Mean Value	Units
CEC ^a	7	24.0	46.5	34.2	meq/100g
TOC ^a	7	2,980	42,800	12,400	mg/kg
pH ^a	19	4.93	8.24	7.39	—
Total Porosity ^b	14	.331	.805	.500	—
Hydraulic Conductivity ^c					
Shallow Wells	8 Wells	0.32	7.7	2.1	ft/day
Deep Wells	2 Wells	0.46	25	3.4	ft/day

Notes:

- a = Values are from discrete soil sample data.
 - b = Values are from Zone G Shelby tube samples collected from the vadose zone and surficial aquifer.
 - c = Values are geometric means of rising head and falling head slug test results.
- ft/day = Feet per day.

from 2 ft to 67.5 ft bgs. The high total porosity values reflect the high clay content of many of these samples. Hydraulic conductivity values for individual wells are reported as the geometric means of the rising head and falling head slug test results, as shown in Table 2.4. The average (geometric mean) of the geometric mean hydraulic conductivities for Zone G shallow groundwater, as determined by slug test data analysis from eight shallow monitoring wells, is 2.1 ft/day. The average geometric mean hydraulic conductivity for Zone G deep groundwater, as determined by slug test data analysis from two deep grid wells, is 3.4 ft/day. The average for deep groundwater was affected by one particularly large value; for comparison, *arithmetic* means of the geometric mean hydraulic conductivities were 3.3 ft/day for shallow groundwater and 12.7 ft/day for deep groundwater.

Horizontal hydraulic gradients were calculated for shallow and deep groundwater at Zone G. For shallow groundwater, gradients varied from 3.7E-8 feet/feet to 1.4E-02 feet/feet. For deep groundwater, limited data indicated gradients ranging from 2.5E-03 feet/feet to 4.1E-03 feet/feet.

Table 6.3 lists the approximate time of travel for advective groundwater flow from various AOCs/SWMUs to the Cooper River or Shipyard Creek, depending on direction of flow and local groundwater gradient, hydraulic conductivity, and stratigraphy. Groundwater levels in Zone G are typically within 5 feet of the surface. A river gauging station at the Army Depot in North Charleston at mile 10.5 of the Cooper River, upstream from Zone G, reported a mean river stage of 1.06 feet for the year October 1992 - September 1993. Downstream from NAVBASE at the gauging station at Charleston Harbor (mile 0.6), mean river stage is roughly zero. Calculation of travel times was based on an assumption of 0.5 feet local elevation for water in the Cooper River and 1.0 feet in the headwaters of Shipyard Creek. Travel times presented in Table 6.3 are for advective groundwater flow only, and do not account for potential effects of diffusion, dispersion, and retardation that would variably increase time of transport for solutes depending on their physical and chemical properties.

Table 6.3
 Zone G
 Groundwater Travel Time Analysis

SWMU/AOC	Hydraulic Conductivity (ft/day) ^a	Vertical/ Horizontal Gradient (-)	Total Porosity (-) ^b	Horizontal Velocity (ft/year)	Horizontal Distance (ft) ^c	Travel Time (years)
SWMU 3	2.1	0.003	0.2	11	1600	139
SWMU 6, 7, AOC 635	3.4	0.005	0.2	31	550	18
SWMU 8, AOC 636	4.7	0.006	0.175	59	250	4
SWMU 11	3.4	0.005	0.2	31	1200	39
SWMU 120	2.1	0.008	0.175	35	500	14
AOC 637	3.3	0.020	0.3	80	200	2
AOC 643	2.1	0.015	0.2	57	250	4

Notes:

- a = Based on slug test data from adjacent monitoring wells
- b = Effective porosity is estimated based on soil textural classes in the upper sand as stated in *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities*, Interim Final Guidance (USEPA, 1989a).
- c = Horizontal distance is based on the potentiometric path of groundwater flow

6.2 Fate and Transport Approach for Zone G

As presented earlier in this section, four potential routes of constituent migration have been identified for Zone G. Each site area has been evaluated for site conditions that promote these migration pathways. In some cases, it is logical to evaluate fate and transport for a combination of sites based on their proximity.

Evaluation of an individual constituent's ability to migrate considers four cross-media transfer mechanisms: (1) soil-to-groundwater, (2) groundwater-to-surface water, (3) surface soil-to-air, and (4) surface soil-to-sediment. Cases can be made for each of these potential transfer mechanisms based on empirical data available for each environmental medium sampled. For example, if a constituent is found in soil as well as in groundwater, it is reasonable to conclude that the soil constituent may be leaching to the groundwater. In support of such conclusions, Zone G fate and transport phenomena were evaluated using constituent-specific chemical and physical properties, risk-based screening concentrations, and grid-based background values.

The following sections describe the methods used to evaluate the potential migration of constituents identified at each AOC/SWMU. Where a specific migration pathway could not be identified for a site, no screening or formal assessment was performed for that pathway. Fate and transport were not evaluated for essential nutrients (calcium, iron, magnesium, potassium, and sodium) or for chlorides or sulfates, which are abundant in shallow coastal/estuarine environments. Section 10 contains discussions of site-specific fate and transport, migration pathways and potential receptors.

6.2.1 Soil-to-Groundwater Cross-Media Transport

A phased screening approach was used to evaluate the potential for soil-to-groundwater migration of constituents, focusing attention on chemicals that have the greatest potential for impacting the surficial aquifer. Due to the nature and age of most AOC/SWMU operations, it might be assumed

that any compounds with the potential to migrate from soil into the surficial aquifer would have done so already. This assumption would also be appropriate in light of the thin, relatively permeable soil layer above the water table at Zone G. However, all soil constituents were evaluated for their potential threat to groundwater regardless of whether the constituent was detected in groundwater. The screening process may be summarized as follows:

Quantitative — Maximum soil constituent concentrations for each AOC/SWMU (or group thereof) were compared to the greater of:

1. Leachability-based generic soil-to-groundwater screening levels (SSLs) as presented in the USEPA *Soil Screening Guidance: Technical Background Document*, (USEPA, 1996b) (primary source) or USEPA Region III *Risk Based Concentration Table, January-June 1996* (USEPA, 1996c) (secondary source). Leachability-based SSLs were used directly from the *Technical Background Document* (USEPA, 1996b), modified from those in the RBC table, or calculated independently, as described below, assuming a dilution attenuation factor (DAF) of 20.
2. Soil background values for inorganics in Zone G, determined in consultation with the project team technical subcommittee; selected as described below.

Maximum groundwater constituent concentrations for each AOC/SWMU (or group thereof) were compared to the greater of:

1. Tap water risk-based screening concentrations as presented in USEPA Region III Risk Based Concentration Table (USEPA, October 22, 1997), assuming a total hazard quotient (THQ) of 1.0.

2. Groundwater background values for inorganics in Zone G, determined in consultation with the project team technical subcommittee; selected as described below.

Quantitative screening defines the list of chemicals to be considered for detailed fate and transport assessment. It reveals constituents in soil having the potential to impact the surficial aquifer, identifying areas where relatively recent releases or immobile constituents may not yet have impacted samples from existing monitoring wells. A conservative screening approach was employed using generic SSLs to provide the most comprehensive list of constituents with the potential to impact groundwater. It was assumed that if soil concentrations do not exceed conservative leachability-based screening levels or background, no significant migration potential exists. Likewise, if current groundwater concentrations do not exceed risk-based screening values or background, it was concluded that existing soil/groundwater equilibria are sufficiently protective of human health relative to potential groundwater ingestion exposure pathways.

The soil-to-groundwater migration pathway was assessed using generic SSLs that assume a DAF of 20, rather than site-specific SSLs. DAFs significantly higher than 20 would be justified for Zone G AOCs and SWMUs, based on site-specific values of hydraulic conductivity, hydraulic gradient, aquifer thickness, and estimated infiltration rate (to estimate dilution), as well as soil type and organic content (to estimate attenuation). Higher DAF values translate into higher SSLs. Section 6.3 compares assumptions underlying the fate and transport screening process with site-specific conditions. As a screening tool, generic SSLs are used to compile a list of potential fate and transport concerns; detailed fate and transport assessments evaluate the identified concerns to facilitate risk management decisions.

Table 6.4 contains physical site characteristics along with chemical and physical properties and regulatory standards for each constituent detected in Zone G soil and groundwater samples, enabling calculation of soil screening levels for protection of groundwater. Where generic SSLs

Table 6.4
 Calculation of Soil to Groundwater Soil Screening Levels
 NAVBASE Charleston: Zone G
 Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (--) :	0.002							
Dilution Factor (--) :	20							
Dry Soil Bulk Density (kg/L) :	1.5	Dimension-	Organic					
Water-filled Soil Porosity (--) :	0.3	less	Carbon					
Air-filled Soil Porosity (--) :	0.13	Henry's	Water	Tap	Unadjusted			
Soil Porosity (--) :	0.43	Law	Part.	Water	Target	Target	Soil to	
		Constant	Coeff.	RBC	Leachate	Leachate	Groundwater	
		(--)	(L/kg)	(mg/L)	Conc.	Conc.	SSL	
				(mg/L)	(mg/L)	(mg/L)	(mg/kg)	
Volatile Organic Compounds								
Acetone	1.59E-03	5.75E-01	3.7	NA	3.7	74	14.9	
Acrolein	1.80E-04	5.25E-01	0.73	NA	0.73	14.6	2.94	
Benzene	2.28E-01	5.89E+01	0.00036	0.005	0.005	0.1	0.0338	
2-Butanone (MEK)	1.90E-03	3.88E+00	1.9	NA	1.9	38	7.90	
Carbon disulfide	1.24E+00	4.57E+01	1	NA	1	20	7.98	
Chlorobenzene	1.52E-01	2.19E+02	0.039	NA	0.039	0.78	0.508	
Chloroform	1.50E-01	3.98E+01	0.15	0.1	0.1	2	0.585	
1,1-Dichloroethane	2.30E-01	3.16E+01	0.81	NA	0.81	16.2	4.59	
Ethylbenzene	3.23E-01	3.63E+02	1.3	0.7	0.7	14	13.4	
4-Methyl-2-pentanone (MIBK)	1.61E-04	6.17E+00	2.9	NA	2.9	58	12.3	
Methylene chloride	8.98E-02	1.17E+01	0.0041	NA	0.0041	0.082	0.0190	
Styrene	1.13E-01	7.76E+02	1.6	0.1	0.1	2	3.52	
1,1,2,2-Tetrachloroethane	1.41E-02	9.33E+01	5.2E-05	NA	5.2E-05	0.00104	0.000403	
Tetrachloroethene	7.54E-01	1.55E+02	0.0011	0.005	0.005	0.1	0.0575	
Toluene	2.72E-01	1.82E+02	0.75	1	1	20	11.8	
1,1,1-Trichloroethane	7.05E-01	1.10E+02	0.54	0.2	0.2	4	1.92	
1,1,2-Trichloroethane	3.74E-02	5.01E+01	0.00019	0.003	0.003	0.06	0.018	
Trichloroethene	4.22E-01	1.66E+02	0.0016	0.005	0.005	0.1	0.0569	
1,2,3-Trichloropropane	1.56E-02	3.89E+02	1.5E-06	NA	1.5E-06	3E-05	0.000029	
Vinyl acetate	2.10E-02	5.25E+00	37	NA	37	740	157	
Vinyl chloride	1.11E+00	1.86E+01	1.9E-05	0.002	0.002	0.04	0.0133	
Xylene (total)	2.91E-01	2.43E+02	12	10	10	200	142	
Semivolatile Organic Compounds								
Acenaphthene	6.36E-03	7.08E+03	2.2	NA	2.2	44	632	
Acenaphthylene	8.20E-03	4.79E+03	1.5	NA	1.5	30	293	
Aniline	5.74E-05	9.10E+00	0.01	NA	0.01	0.2	0.044	
Anthracene	2.67E-03	2.95E+04	11	NA	11	220	13024	
Benzo(g,h,i)perylene	5.74E-06	7.76E+06	1.5	NA	1.5	30	465606	
Benzo(a)pyrene equivalents								
Benzo(a)anthracene	1.37E-04	3.98E+05	9.2E-05	NA	9.2E-05	0.00184	1.47	
Benzo(a)pyrene	4.63E-05	1.02E+06	9.2E-06	0.0002	0.0002	0.004	8.16	
Benzo(b)fluoranthene	4.55E-03	1.23E+06	9.2E-05	NA	9.2E-05	0.00184	4.53	
Benzo(k)fluoranthene	3.40E-05	1.23E+06	0.00092	NA	0.00092	0.0184	45.3	
Chrysene	3.88E-03	3.98E+05	0.0092	NA	0.0092	0.184	147	
Dibenzo(a,h)anthracene	6.03E-07	3.80E+06	9.2E-06	NA	9.2E-06	0.000184	1.40	
Indeno(1,2,3-cd)pyrene	6.56E-05	3.47E+06	9.2E-05	NA	9.2E-05	0.00184	12.8	
Benzyl alcohol	9.35E-06	5.00E+00	11	NA	11	220	46.2	
Butylbenzylphthalate	5.17E-05	5.75E+04	7.3	NA	7.3	146	16819	
Carbazole	6.26E-07	3.39E+03	0.0034	NA	0.0034	0.068	0.475	
4-Chloroaniline	1.36E-05	6.61E+01	0.15	NA	0.15	3	1.00	
4-Chloro-3-methylphenol	7.30E-05	7.76E+02	0.18	NA	0.18	3.6	6.31	
2-Chlorophenol	1.60E-02	3.88E+02	0.18	NA	0.18	3.6	3.52	
Dibenzofuran	NDA	8.32E+03	0.15	NA	0.15	3	50.52	
Di-n-butylphthalate	3.85E-08	3.39E+04	3.7	NA	3.7	74	5032.0	
1,2-Dichlorobenzene (o-)	7.79E-02	6.17E+02	0.064	0.6	0.6	12	17.3	
1,4-Dichlorobenzene (p-)	9.96E-02	6.17E+02	0.00044	0.075	0.075	1.5	2.16	
3,3'-Dichlorobenzidine	1.64E-07	7.24E+02	0.00015	NA	0.00015	0.003	0.0049	
2,4-Dichlorophenol	1.30E-04	1.47E+02	0.11	NA	0.11	2.2	1.09	
Diethylphthalate	1.85E-05	2.88E+02	29	NA	29	580	450	
2,4-Dimethylphenol	8.20E-05	2.09E+02	0.73	NA	0.73	14.6	9.023	

Table 6.4
 Calculation of Soil to Groundwater Soil Screening Levels
 NAVBASE Charleston: Zone G
 Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (--) :	0.002							
Dilution Factor (--) :	20							
Dry Soil Bulk Density (kg/L) :	1.5	Dimension-	Organic					
Water-filled Soil Porosity (--) :	0.3	less	Carbon					
Air-filled Soil Porosity (--) :	0.13	Henry's	Water	Tap	Unadjusted			
Soil Porosity (--) :	0.43	Law	Part.	Water	Target	Target	Soil to	
		Constant	Coeff.	RBC	Leachate	Leachate	Groundwater	
		(--)	(L/kg)	(mg/L)	Conc.	Conc.	SSL	
				(mg/L)	(mg/L)	(mg/L)	(mg/kg)	
2,4-Dinitrotoluene		3.80E-06	9.55E+01	0.073	NA	0.073	1.46	0.571
Di-n-octylphthalate		2.74E-03	8.32E+07	0.73	NA	0.73	14.6	2.43E+06
bis(2-Ethylhexyl)phthalate (BEHP)		4.18E-06	1.51E+07	0.0048	0.006	0.006	0.12	3624
Fluoranthene		6.60E-04	1.07E+05	1.5	NA	1.5	30	6426
Fluorene		2.61E-03	1.38E+04	1.5	NA	1.5	30	834
2-Methylnaphthalene		1.98E-02	2.00E+03	1.5	NA	1.5	30	126
2-Methylphenol (o-cresol)		4.92E-05	9.12E+01	1.8	NA	1.8	36	13.8
4-Methylphenol (p-cresol)		4.92E-05	9.12E+01	0.18	NA	0.18	3.6	1.38
Naphthalene		1.98E-02	2.00E+03	1.5	NA	1.5	30	126
4-Nitrophenol		NDA	NDA	0.29	NA	0.29	5.8	NA
Pentachlorophenol		1.00E-06	5.92E+02	0.00056	0.001	0.001	0.02	0.028
Phenanthrene		1.60E-03	2.29E+04	1.5	NA	1.5	30	1381
Phenol		1.63E-05	2.88E+01	22	NA	22	440	113
Pyrene		4.51E-04	1.05E+05	1.1	NA	1.1	22	4624
2,3,4,6-Tetrachlorophenol		2.50E-04	1.05E+02	1.1	NA	1.1	22	9.01
1,2,4-Trichlorobenzene		5.82E-02	1.78E+03	0.19	0.07	0.07	1.4	5.27
Pesticide/PCB Compounds								
Aldrin		6.97E-03	2.45E+06	4E-06	NA	4E-06	8E-05	0.392
Aroclor-1248		NDA	3.09E+05	3.4E-05	0.0005	NA	NA	1.00
Aroclor-1254		NDA	3.09E+05	3.4E-05	0.0005	NA	NA	1.00
Aroclor 1260		NDA	3.09E+05	3.4E-05	0.0005	NA	NA	1.00
alpha-BHC		4.35E-04	1.23E+03	1.1E-05	NA	1.1E-05	0.00022	0.00059
beta-BHC		3.05E-05	1.26E+03	3.7E-05	NA	3.7E-05	0.00074	0.00201
delta-BHC		3.05E-05	1.26E+03	3.7E-05	NA	3.7E-05	0.00074	0.00201
gamma-BHC (Lindane)		5.74E-04	1.07E+03	5.2E-05	0.0002	0.0002	0.004	0.00936
alpha-Chlordane		1.99E-03	1.20E+05	0.00019	0.002	0.002	0.04	9.61
gamma-Chlordane		1.99E-03	1.20E+05	0.00019	0.002	0.002	0.04	9.61
4,4'-DDD		1.64E-04	1.00E+06	0.00028	NA	0.00028	0.0056	11.2
4,4'-DDE		8.61E-04	4.47E+06	0.0002	NA	0.0002	0.004	35.8
4,4'-DDT		3.32E-04	2.63E+06	0.0002	NA	0.0002	0.004	21.0
Dieldrin		6.19E-04	2.14E+04	4.2E-06	NA	4.2E-06	8.4E-05	0.00361
Endosulfan		4.59E-04	2.14E+03	0.22	NA	0.22	4.4	19.7
Endrin		3.08E-04	1.23E+04	0.011	0.002	0.002	0.04	0.992
Heptachlor		6.07E+01	1.41E+06	2.3E-06	0.0004	0.0004	0.008	22.6
Heptachlor epoxide		3.90E-04	8.32E+04	1.2E-06	0.0002	0.0002	0.004	0.666
Methoxychlor		6.48E-04	9.77E+04	0.18	0.04	0.04	0.8	156
Herbicides								
2,4-D		5.70E-09	8.91E+02	0.061	0.07	0.07	1.4	2.77
Polychlorinated dibenzodioxins/dibenzofurans								
TCDD Equivalents		1.31E-03	1.58E+06	4.5E-10	3E-08	3E-08	6E-07	0.00190
Hydrazine								
Hydrazine		1.73E-09	1.00E-01	2.2E-05	NA	2.2E-05	0.00044	0.000088
Explosives								
Tetryl		NDA	NDA	NA	NA	NA	NA	NA
Inorganic Compounds								
Aluminum		NA	<i>Kd (6.8 pH)</i> 1.50E+03	37	NA	37	740	1.11E+06

Table 6.4
Calculation of Soil to Groundwater Soil Screening Levels
NAVBASE Charleston: Zone G
Charleston, South Carolina

Site-Specific Parameters:								
Fraction Organic Carbon (--):	0.002							
Dilution Factor (--):	20							
Dry Soil Bulk Density (kg/L):	1.5	Dimension-	Organic			Unadjusted		
Water-filled Soil Porosity (--):	0.3	less	Carbon			Target		
Air-filled Soil Porosity (--):	0.13	Henry's	Water	Tap		Leachate	Target	Soil to
Soil Porosity (--):	0.43	Law	Part.	Water	MCL/	Conc.	Leachate	Groundwater
		Constant	Coeff.	RBC	MCLG		Conc.	SSL
		(--)	(L/kg)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/kg)
Antimony		NA	4.50E+01	0.015	0.006	0.006	0.12	5.42
Arsenic		NA	2.90E+01	4.5E-05	0.05	0.05	1	29.2
Barium		NA	4.10E+01	2.6	2	2	40	1648
Beryllium		NA	7.90E+02	1.6E-05	0.004	0.004	0.08	63.2
Cadmium		NA	7.50E+01	0.018	0.005	0.005	0.1	7.52
Chromium (total)		NA	1.80E+06	0.18	0.1	0.1	2	3.60E+06
Cobalt		NA	4.50E+01	2.2	NA	2.2	44	1989
Copper		NA	3.50E+01	130	1.3	1.3	26	915
Cyanide		NA	1.00E+01	0.73	0.2	0.2	4	40.8
Lead		NA	NA	0.015	NA	0.015	0.3	Background
Manganese		NA	6.50E+01	0.84	NA	0.84	16.8	1095
Mercury		4.67E-01	5.20E+01	0.011	0.002	0.002	0.04	2.09
Nickel		NA	6.50E+01	0.73	0.1	0.1	2	130
Selenium		NA	5.00E+00	0.18	0.05	0.05	1	5.20
Silver		NA	8.30E+00	0.18	NA	0.18	3.6	30.6
Thallium		NA	7.10E+01	0.0029	0.0005	0.0005	0.01	0.712
Tin		NA	2.50E+01	22	NA	22	440	11088
Vanadium		NA	1.00E+03	0.26	NA	0.26	5.2	5201
Zinc		NA	6.20E+01	11	NA	11	220	13684

Notes:

NA - Not applicable

NDA - No data available

L/kg - Liters per kilogram

mg/kg - Milligrams per kilogram

mg/L - Milligrams per liter

for organics were not listed in the *Technical Background Document* (USEPA, 1996b) or the January-June Region III RBC table (USEPA, 1996c), they were calculated using the values shown in Table 6.4. Values of Henry's law constant and K_{oc} not available in the *Technical Background Document* or the *USEPA Soil Screening Guidance: User's Guide* (USEPA, 1996d), were obtained from various standard references. Where calculated SSLs in Table 6.4 differed from USEPA's generic values, the USEPA values prevailed. Differences in the two versions of SSLs were generally due to USEPA's use of nonstandard target leachate concentrations as starting points for their calculations: rather than starting with listed RBCs or MCLs, USEPA sometimes rounds them off to one or two significant figures. USEPA's starting-point values are listed in Attachment D, "Regulatory and Human Health Benchmarks for SSL Development," of the *User's Guide*. Where no generic SSLs were listed for inorganics, generic SSLs were calculated based on default values for K_d taken from the TERRA model (Baes, C.S. III, et al., September 1984).

The SSL used for total chromium was 38 mg/kg, as recommended in the *Technical Background Document*. USEPA's prescribed value of 38 mg/kg is equal to the SSL for hexavalent chromium (CrVI), on the conservative assumption that any detected chromium may be CrVI. Because none of the 20 hand-augered soil samples, two DPT soil samples, or nine groundwater samples from Zone G that were analyzed for CrVI reported a detection, all detected total chromium concentrations were assumed to be trivalent (CrIII). According to the *Technical Background Document*, CrIII as a contaminant in soil is not considered a threat to groundwater at any concentration. This conclusion is supported by the calculated SSL value of $3.6E+06$ mg/kg for chromium in Table 6.4.

The greater of the background values for surface soil or subsurface soil was used as the screening alternative to SSLs for inorganics. Since constituent migration is from surface or near-surface soil downward through subsurface soil to the aquifer, and since the SSL method assumes zero attenuation of constituents during migration, the higher of the two background values is always

appropriate for comparison to SSLs. Similarly, the greater of the background values for shallow and deep groundwater was used as the screening alternative to tap water RBCs. The lithology of the surficial aquifer in Zone G is complex, with no apparent widespread aquitards. Over distances involved in migration from AOCs/SWMUs to surface water, aquifer units at all depths down to the confining unit (Ashley Formation) are assumed to be interconnected, so that the higher background value is always relevant. Thallium was the only inorganic with a background value for soil that was equal to its corresponding tabulated or calculated SSL, while arsenic and manganese were the only inorganics with groundwater background values higher than their corresponding tap water RBCs.

Detailed Assessment — Upon completion of the quantitative screening process, site constituent concentrations exceeding the screening values were examined to delineate the magnitude and areal extent of soil impacts potentially affecting groundwater. Maximum constituent concentrations in surface soil were compared to those in subsurface samples to estimate the extent of downward migration. The number and spatial distribution of exceedances were noted. Relative concentrations in soil and groundwater were compared. Corresponding exceedances in nearby AOCs/SWMUs were examined as possible sources or as indicators of lateral migration.

Detailed assessments helped determine the significance of soil impacts relative to the surficial aquifer. In some instances, isolated areas of soil contamination above leachability-based concentrations may have the potential for localized shallow groundwater impacts, but not of a magnitude that would pose a long-term or widespread threat to the aquifer. The detailed assessment was used to identify these cases and to decide which areas of soil contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

6.2.2 Groundwater-to-Surface Water Cross-Media Transport

Groundwater in the surficial aquifer in Zone G moves generally toward the Cooper River and the headwaters of Shipyard Creek. The principal focus of this evaluation was determining whether constituents identified in groundwater have the potential to extend their impacts to different locations within the surficial aquifer or to surface water in the Cooper River or Shipyard Creek. Aside from a single sample, collected from a drainage ditch at AOC 637, surface water was not sampled as part of the Zone G RFI. Therefore, potential impacts on surface water were evaluated by comparing groundwater constituent concentrations to surface water screening standards, as described below. The screening process may be summarized as follows:

Quantitative – Chemicals present in groundwater were compared to appropriate screening values. Relative to human health evaluation, maximum shallow groundwater analytical results for each AOC/SWMU (or group thereof) were compared to the greater of:

1. Tap water risk-based screening levels as presented in USEPA Region III RBC tables (USEPA, October 22, 1997), assuming THQ of 1.0.
2. Groundwater background values for inorganics in Zone G, determined in consultation with the project team technical subcommittee; selected as described above in Section 6.2.1.

To evaluate potential impact on ecological receptors, maximum shallow groundwater analytical results for each AOC/SWMU (or group thereof) were compared to USEPA saltwater surface water chronic screening values for hazardous waste sites, from Supplemental Guidance to RAGS: Region 4 Bulletins, *Ecological Risk Assessment, Bulletin 2* (USEPA, 1995a). Since surface water samples were not proposed or collected as part of the Zone G RFI, no background values for surface water constituents could be determined for use as alternatives to surface water screening standards.

The quantitative assessment identifies chemicals detected in groundwater having the potential to disperse within the aquifer, increasing the areal extent of groundwater concentrations that exceed human-health-based standards, or impacting surface water via groundwater migration and discharge. If groundwater concentrations do not exceed tap water risk-based screening levels or background concentrations, no significant threat relative to migration potential exists. If reported concentrations in groundwater do not exceed saltwater surface water chronic screening levels, no threat exists relative to ecological impacts resulting from groundwater discharge to surface water. This screening assessment purposely does not consider effects of dilution and attenuation on transport between the affected well and the surface water discharge point, or the dilutional capacity of the receiving water body. Omitting these factors from the quantitative screening ensures that a conservative list of potential groundwater-to-surface water concerns is developed.

Detailed Assessment — Upon completion of the quantitative screening process, detailed assessments were performed to delineate the magnitude and areal extent of groundwater impacts that may adversely affect human or ecological receptors. Maximum constituent concentrations in shallow groundwater were compared to those in deep groundwater if available to estimate the extent of downward migration. The number and spatial distribution of exceedances were noted. Corresponding exceedances in nearby AOCs/SWMUs were examined as possible sources or as indicators of lateral migration.

The detailed assessments helped to determine the significance of groundwater impacts and potential impacts. In addition, inferences were drawn about the potential for significant impacts on surface water. The Zone J RFI results will be used to confirm or refute preliminary conclusions. Detailed assessments were also used to determine which areas of groundwater contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

6.2.3 Surface Soil-to-Sediment Cross-Media Transport

To evaluate surface soil-to-sediment erosional migration, a phased screening approach identified chemicals with the potential to cause contamination in sediments following surface soil erosion. The screening process may be summarized as follows:

Qualitative – The CPSS lists (excluding essential nutrients) for surface soil and sediment were compared to determine which chemicals were present in both media.

Sediments are formed by surface soil erosion, with accumulation in depositional areas. Normally, site topography and ground cover are used to identify areas with erosional potential and the corresponding expected areas of deposition. Because erosional/depositional processes within Zone G are limited at most AOCs/SWMUs due to the presence of buildings, paved surfaces, and engineered drainage, evidence of constituent migration from surface soil-to-sediment is rare. Several Zone G sediment samples were collected from catch basins. Nevertheless, all sediment results were compared to data for proximate surface soil representing possible points of origin for sediment contaminants.

Semiquantitative – The maximum concentration in surface soil was compared to the maximum concentration in sediment for constituents present in both media. The purpose of the semiquantitative assessment was to provide additional evidence in support of this possible migration pathway.

Evaluation of fate and transport for sediments in Zone G was limited to sediments as contaminant receptors. Fate and transport for constituents originating in Zone G catch-basin sediments will be provided in the RFI report for Zone L; fate and transport for constituents originating in wetland or fluvial sediments will be provided in the RFI report for Zone J.

6.2.4 Soil-to-Air Cross-Media Transport

To evaluate the soil-to-air migration pathway for volatile contaminants, the screening approach focused on VOC which possess the greatest potential to create a human health threat in ambient air. The screening process may be summarized as follows:

Quantitative – The maximum concentrations of volatile organics detected in surface soil at each AOC/SWMU were compared to soil-to-air screening concentrations as presented in the USEPA *Soil Screening Guidance: Technical Background Document*, (primary source) or USEPA Region III RBC table, January-June 1996 (secondary source).

The quantitative assessment defines the list of chemicals under consideration for formal fate and transport evaluation. If soil concentrations do not exceed soil-to-air volatilization screening concentrations, no significant migration potential exists, and current soil conditions would be considered protective of human health relative to potential inhalation exposure pathways.

Detailed Assessment – Following the quantitative screening process, detailed assessments were performed to delineate the magnitude and areal extent of surface soil impacts potentially affecting ambient air. The number and spatial distribution of exceedances were noted, as were site-specific conditions possibly affecting release of volatiles into the air.

The outcome of the detailed assessments was used to determine the significance of soil impacts relative to ambient air. In some instances, isolated areas of soil contamination above soil-to-air volatilization-based concentrations could have the potential for localized ambient air impacts but not be of a magnitude to pose a long-term or widespread threat through inhalation pathways. The detailed assessment identified these cases and determined which areas of soil contamination may require supplemental investigation and/or modeling applications during the CMS as part of the remedial alternatives development process.

6.3 Fate and Transport Screening Assumptions Versus Site Conditions

The fate and transport screening procedure was designed as a conservative method to identify and evaluate soil and groundwater constituents with the potential to impact groundwater and surface water quality in the Cooper River or Shipyard Creek. The screening tables identify the constituents, while the detailed assessments evaluate their significance. The procedure depends heavily on USEPA's soil screening methodology, and makes many simplifying assumptions that come directly from the 1996 *Soil Screening Guidance*. This section compares some of the assumptions of the screening procedure with actual conditions encountered at SWMUs and AOCs in Zone G in an attempt to demonstrate the conservative nature of the method. The screening assumptions are shown in italics, followed by commentary.

1. *The contaminant source is infinite (i.e., steady-state concentrations are maintained during the exposure period).* At virtually every site, the original sources (process/spill) of soil and/or groundwater contamination, have been discontinued. As constituent molecules migrate through the system or degrade, they are generally not replaced from the original sources.
2. *Each soil contaminant is uniformly distributed from the surface to the top of the aquifer, at a concentration equal to the maximum value reported from any of the samples.* Site conditions vary greatly, as seen in sample analytical results. Most often, screening exceedances are reported from a relatively small percentage of samples, as presented in the detailed assessments.
3. *There is no contaminant attenuation (i.e., adsorption, biodegradation, chemical degradation) as leachate moves downward through soil.* In reality, dissolved organic compounds and metallic ions originating in the upper soil horizons are not particularly mobile, due to sorption. Because of their origins in back-barrier, lagoonal, and other

low-energy environments, many NAVBASE soils and lithologic units exhibit moderate to very high clay content. The average clay percentage of 19 Zone G Shelby tube samples, ranging in depth from 2 to 67.5 feet, was 22. The geometric mean CEC of seven Zone G soil samples was 34.2 meq/100g. For comparison, CEC for pure montmorillonite clay (smectite) ranges from 80 to 150 meq/100g. Other clays such as illite (10-40 meq/100g) and kaolinite (3-15 meq/100g) have lower values (Boulding, 1995). The relatively high clay content and corresponding high CEC values of Zone G soil should result in extensive attenuation of migrating site constituents, especially inorganics.

The geometric mean TOC of the same seven soil samples was 12,400 mg/kg ($f_{oc} = 1.2E-02$), while the arithmetic mean was 16,600 mg/kg ($f_{oc} = 1.7E-02$). The default value of f_{oc} used by USEPA to calculate generic SSLs is $2E-02$, indicating that Zone G soils have on average six to eight times the organic carbon available to bind contaminants to soil particles, versus the soils assumed in the generic model's partitioning equation for migration to groundwater.

USEPA's generic SSLs are based on reference values of K_{oc} for ionizing organics and K_d for inorganics. The listed reference values assume a soil pH of 6.8. For Zone G, the geometric mean pH for 19 soil samples was moderately higher at 7.39; 16 of the 19 measured pH values exceeded 6.8. Values of K_d for most metals would be higher in local areas with higher pHs and lower in areas with lower pHs. The effect of pH variations on the value of K_{oc} for ionizing organics is reversed, but is weaker than for inorganics.

4. *The generic SSLs used in the screening tables are based on a DAF of 20. Since USEPA's methodology unrealistically assumes zero attenuation for migration of leachate through the vadose zone and groundwater through the aquifer, the default DAF of 20 recommended in the 1996 Soil Screening Guidance is actually a dilution factor only. Using equations presented in the User's Guide, a site-specific dilution factor of 14.2 was calculated for*

leachate and shallow groundwater at combined SWMU 6. The calculation assumes a rainfall infiltration rate of 0.3 inches per year, equal to the rate assigned by the ongoing USGS groundwater modeling study to the semi-industrial areas of the base (Zones A, H, and I). Considering the relatively high clay content, CEC, and TOC of Zone G soil and aquifer sediments, a default DAF of 20 is suitably conservative for initial screening purposes.

5. *There is no contaminant attenuation as groundwater moves through the aquifer. Although Zone G aquifer sediments were not sampled for hydrogeochemical parameters, the lithology and the CEC and TOC values of the soil samples in the vadose zone indicate otherwise, as discussed above in item 3:*

- Substantial amounts of clay present
- Geometric mean CEC of seven samples similar to those of illite
- Geometric mean TOC of seven samples six to eight times higher than USEPA default values

6. *The contaminant concentration in the theoretical groundwater plume associated with each site is equal to (a) the concentration of leachate produced by the maximum detected soil concentration and diluted 20:1 by groundwater, or (b) maximum groundwater concentration. This assumption should be compared to analytical results from soil and groundwater samples collected at each AOC/SWMU and from groundwater samples collected downgradient from each site. High constituent concentrations in Zone G soil or groundwater samples were generally reported from a few isolated locations rather than across entire sites. The number and spatial distribution of screening exceedances is detailed in the assessments for each site.*

7. *An appropriate human health screen for groundwater is USEPA's Region III tap water RBCs (USEPA, October 22, 1997) using a THQ of 1.0. Since the focus of the fate and transport analysis was on individual chemical concentrations and behavior rather than risk, a THQ of 1.0 was considered appropriate. The many built-in conservatisms discussed above should more than make up for any possible compounding effects of multiple contaminants in environmental media.* 1
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8. *An appropriate ecological screen for surface water in the Cooper River and Shipyard Creek is USEPA's saltwater surface water chronic screening values for hazardous waste sites (USEPA, 1995a). Shipyard Creek and the portion of the Cooper River opposite NAVBASE are both tidally influenced streams containing brackish water. The screening values in the USEPA publication noted above include the "Criteria to Protect Aquatic Life" incorporated by reference into SCDHEC's Water Classifications and Standards (Regulation 61-68), plus additional values.* 7
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7.0 HUMAN HEALTH RISK ASSESSMENT

7.1 Introduction

Section 7.1 of the *Draft Zone A RFI Report* discusses the purpose of the HHRA as it applies to the Zone G RFI.

Chemical contamination at the site must be adequately characterized before a HHRA can determine whether detected concentrations are potentially toxic and cause increased cancer incidences, and before it becomes useful for making remedial decisions. Characterizing the study area includes determining the amount, type, and location of contaminant sources. Variables include exposure pathways such as media type and migration routes; and the type, sensitivities, exposure duration, and dynamics of the exposed populations (receptors); as well as the toxicological properties of identified contaminants.

7.2 Objectives

The objectives of the HHRA are to: (1) characterize the source media and determine the chemicals of potential concern (COPCs) for affected environmental media; (2) identify potential receptors, quantifying potential exposures under current and future conditions for all affected environmental media; (3) qualitatively and quantitatively evaluate the adverse effects associated with the site-specific COPCs in each medium; (4) characterize the potential baseline carcinogenic risk and noncarcinogenic hazards associated with exposure to impacted environmental media at Zone G under current and future conditions; (5) evaluate uncertainties related to exposure predictions, toxicological data, and resultant carcinogenic risk and noncarcinogenic hazard predictions; and (6) establish Remedial Goal Options (RGOs) for chemicals of concern (COCs) in each environmental medium based on risk/hazard for risk management decision-making.

The focus of each investigation is detailed in the field investigation approach section for each site. Comprehensive tables list the sample identification numbers and analytical methods applied to each

sample. At most AOCs and SWMUs, sampling activities consisted of collecting surface (upper interval) and subsurface (lower interval) soil samples, and groundwater samples from monitoring wells installed in the shallow and deep portions of the surficial aquifer underlying the zone. Analytical results from surface soils and groundwater were used to assess possible exposure to environmental contaminants.

Organization

A HHRA, as defined by Risk Assessment Guidance for Superfund (RAGS) Part A, includes the following steps:

- *Site characterization:* Evaluation of site geography, geology, hydrogeology, climate, and demographics.
- *Data collection:* Analysis of environmental media samples, including background/reference samples.
- *Data evaluation:* Statistical analysis of analytical data to identify the nature and extent of contamination and to establish a preliminary list of COPCs based on risk-based and background screening. This list will subsequently be refined to identify COCs.
- *Exposure assessment:* Identification of potential receptors under current and predicted conditions, visualization of potential exposure pathways, calculation of exposure point concentrations (EPCs), and quantification of chemical intakes.
- *Toxicity assessment:* Qualitative evaluation of the adverse effects of the COPCs, and quantitative estimate of the relationship between exposure and severity or probability of effect.

- *Risk characterization:* A combination of the outputs of the exposure assessment and the toxicity assessment to quantify the total cancer and noncancer risk to the hypothetical receptors. 1
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- *Uncertainty:* Discussion and evaluation of the areas of recognized uncertainty in human health risk assessments in addition to medium- and exposure pathway-specific influences. 4
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- *Risk/Hazard Summary:* Presentation and discussion of the results of the quantification of exposure (risk and hazard) for the potential receptors and their exposure pathways identified under current and future conditions. 6
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- *RGOs:* Computation of exposure concentrations corresponding to risk projections within the USEPA target risk range of 1E-06 to 1E-04 for carcinogenic COCs and Hazard Quotient (HQ) goals of 0.1, 1, and 3 for noncarcinogenic COCs. 9
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This general process was followed in preparing the HHRA for each Zone G AOC and SWMU or groups of sites at NAVBASE. 12
13

7.3 Human Health Risk Assessment Methods 14

Section 7.3 of the *Draft Zone A RFI Report* discusses HHRA methods as these apply to the Zone G RFI. 15
16

7.3.1 Data Sources 17

Section 7.3.1 of the *Draft Zone A RFI Report* discusses data sources as they apply to the Zone G RFI. 18
19

7.3.2 Data Validation

Section 7.3.2 of the *Draft Zone A RFI Report* discusses data validation as it applies to the Zone G RFI.

7.3.3 Management of Site-Related Data

All environmental sampling data were evaluated for suitability for use in the quantitative HHRA. Data obtained via the following methods were not appropriate for the quantitative HHRA: (1) analytical methods not specific for a particular chemical such as TOC or total organic halogen; and (2) field screening instruments, including total organic vapor monitoring units and organic vapor analyzers.

Because duplicate samples were collected for QA/QC, some sample locations had more than one analytical result. One objective of data management was to provide one result per sample location per analyte. Therefore, the mean of the duplicate and primary sample results were used as the applicable value, unless the analyte was detected in only the duplicate or primary sample. In such cases, the detected results were used.

In addition, the HHRA addressed limitations of analytical results by including estimated concentrations for nondetected parameters. A nondetect indicates that the analyte was not detected above the quantitation limit of the sample (*U*-qualified results), as is determined by the analytical method, the instrument used, and possible matrix interferences. However, an analyte could be nondetected and still be present at any concentration between zero and the quantitation limit. For this reason, one-half the *U* value could serve as an unbiased estimate of the nondetect. Because the estimated values of *J*-qualified hits were frequently much lower than the sample quantitation limits of *U*-qualified nondetects for organic compounds, one-half of each *U* value was compared to one-half of the lowest hit (normally *J*-qualified) at the same site. The lesser of these two values

was used as the best estimate of the concentration that was potentially present below the sample quantitation limit, and was inserted into the adjusted dataset.

For inorganic chemicals, the decision rule was less complex: one-half of each *U* value represented the concentration of the corresponding sample when compiling the adjusted dataset. If two nondetects were reported for any one location (a result of QA/QC samples), one-half the lesser of the *U* values was compared to the lowest hit at the site (for organics, as above) or applied directly (for inorganics) to estimate a concentration value to be used in the Zone G RFI risk calculations. If a parameter was not detected at an AOC/SWMU, neither data management method was applied, and the parameter was not considered in screening or formal assessment.

Once the dataset was complete (i.e., after elimination of faulty data, consolidation of duplicate data values, and quantification of censored values), statistical methods were used to evaluate the RFI analytical results to identify COPCs at potential receptor locations. The statistical methods used in data evaluation are discussed below. The rationale used to develop this methodology and the statistical techniques used to implement it are based on the following sources:

- *RAGS, Volume I -- Human Health Evaluation Manual (Part A)*, (USEPA, 1989b), (RAGS Part A).
- *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987).
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA, 1992a).

Microsoft FoxPro, Borland Quattro Pro, and SPlus for Windows¹ were used to manage data and calculate statistics. For each set of data describing the concentration of chemicals in a contaminated area, the following information was tabulated: frequency of detection, range of detected values, average of detected concentrations, and the calculated 95% upper confidence limit (UCL) for the mean of log transformed values of the concentration. In accordance with RAGS, either the maximum concentration detected or the UCL was used to quantify potential exposure, depending on which one was the lesser value.

7.3.4 Selection of Chemicals of Potential Concern

The objective of this step was to screen the available information on the CPSS at each AOC or SWMU to develop a list or group of COPCs. COPCs are chemicals selected by comparison with screening concentrations (risk-based and reference), intrinsic toxicological properties, persistence, fate and transport characteristics, and cross-media transport potential. For COPCs to be considered a COC and warrant assessment relative to corrective measures, it must meet two criteria. First, the COPC must contribute to an exposure pathway with an incremental lifetime excess cancer risk (ILCR) in excess of 1E-06 or a hazard index (HI) greater than 1 for any of the exposure scenarios evaluated in the risk assessment. Second, the COPC must have an individual risk projection greater than 1E-06 or an HQ greater than 0.1 ILCR.

Before evaluating the potential risks/hazards associated with site media, it was first necessary to delineate onsite contamination by noting the chemicals detected in environmental media. These chemicals represent the CPSS for each AOC or SWMU. The nature and general extent of CPSS at each site are detailed in Section 10 of the RFI. To reduce the list and focus the risk assessment on COPCs, site-related data were compared to RBCs and background concentrations.

¹ Reference to specific software products are not to be construed as an endorsement by the U.S. Navy or EnSafe Inc.

Comparison of Site-Related Data to Risk-Based Screening Concentrations

The maximum CPSS concentrations detected in samples were compared to risk-based screening values obtained from the *Risk-Based Concentration Table* (USEPA, October 22, 1997). According to this guidance, USEPA used a target HQ of 0.1 and a risk goal of 1E-06 to calculate screening concentrations for noncarcinogens and carcinogens, respectively. Noncarcinogenic chemical values were adjusted to equate to an HQ of 0.1.

Groundwater results were compared to tap water screening values, and reported soil (and sediment, where applicable) concentrations were compared to residential soil ingestion screening values. The soil screening value for lead was set equal to 400 mg/kg, consistent with current USEPA Office of Solid Waste and Emergency Response directives considering protection of a hypothetical child resident (USEPA, 1994a); the lead groundwater screening value used was the USEPA Office of Water treatment technique action level (AL) of 15 µg/L (USEPA, 1996e).

A soil screening value of 1,000 ng/kg (as 2,3,7,8-TCDD TEQs) was applied to chlorinated dibenzo-p-dioxin (CDDs) and dibenzofurans, based on a worker/industrial scenario and a target risk of 1E-04. USEPA Region IV has determined this value to be an appropriate cleanup level although normally a residential scenario and a target risk of 1E-06 serve as the basis for screening values. For dioxin, USEPA Region IV considers this target risk more appropriate because of the high level of uncertainty associated with dioxin exposure. For groundwater, the TEQ value computed for each sample was compared to the 2,3,7,8-TCDD tap water screening level of 4E-04 pg/L.

In accordance with recent cPAH guidance (USEPA, 1993), BEQs were computed, where appropriate, by multiplying the reported concentration of each cPAH by its corresponding toxicity equivalency factor (TEF). The BEQ values were then summed for each sample, and the total was compared to the benzo(a)pyrene RBC value during the screening process. Subsequent exposure

quantification and risk/hazard projections for cPAHs in soil and groundwater were performed using total BEQ values for each sampling location rather than individual compound concentrations.

CPSSs with maximum detected concentrations exceeding their corresponding concentrations, goals, levels, and/or standards were retained for further evaluation and reference screening in the risk assessment. Screening values based on surrogate compounds were used if no screening values were available in USEPA's table. The selection of surrogate compounds was based on structural, chemical, or toxicological similarities.

Because shallow and deep groundwater beneath most Zone G areas contain chlorides and/or TDS exceeding South Carolina potable source criteria, water from these aquifers is not appropriate for domestic use. Consequently, screening the concentrations of compounds detected in groundwater against tap water RBCs assesses the significance of groundwater impacts very conservatively.

For CPSS present in all depths of soil and shallow groundwater, an additional risk-based screening was part of the fate and transport assessment. Fate and transport methodology is explained in Section 6; site-specific discussions are in Section 10.

Comparison of Site-Related Data to Background Concentrations

Soil and groundwater background concentrations were determined for Zone G using results from the grid-based soil and groundwater background sampling. Surface soil, subsurface soil, shallow groundwater, and deep groundwater were all addressed separately for determining background concentrations. After risk- and hazard-based screening values were compared, CPSS were retained for further consideration as COPCs in the HHRA on an AOC- or SWMU-specific basis under the following conditions: if their maximum detected concentrations exceeded corresponding background concentrations, or if overall site concentrations were significantly greater than corresponding overall background concentrations as determined by Wilcoxon rank sum test

procedures. The two statistical background comparisons were conducted as parallel analyses. If either method suggested that site-specific concentrations deviated from naturally occurring levels, the chemical was retained for formal risk assessment. These comparisons help account for chemicals common in nature, such as aluminum, manganese, and arsenic. By virtue of this process, risk and/or hazard associated with naturally occurring chemicals is not addressed where concentrations do not exceed corresponding background values. The statistical methods used to determine background concentrations and the rationale used to compare site concentrations are discussed in Section 5 of this report.

The background concentration is a fixed value determined to represent the upper bound of naturally occurring levels for a chemical in a specific matrix. Comparisons using background concentrations are most effective in identifying “hot spots” or limited areas with pronounced impacts. Population tests, in this case performed using the Wilcoxon rank sum method, are used to determine whether values from one population (the site samples) are consistently higher or lower than those from another (the entire background dataset). Ideally, population tests identify general elevations in chemical concentrations, absent definable hot spots. Statistical methods, upper tolerance limit (UTL) calculations, Wilcoxon rank sum test outputs, and background sample information are discussed in Section 5. In the RFI, if the maximum concentration of a CPSS was determined to be less than either background (via background concentration comparison and population test) or the risk-based screening value, it was not considered further in the risk assessments unless deemed appropriate, based on chemical-specific characteristics (e.g., degradation product with greater toxicity).

Elimination of Essential Elements: Calcium, Iron, Magnesium, Potassium, and Sodium

In accordance with RAGS Part A, essential elements that are potentially toxic only at extremely high concentrations may be eliminated from further consideration as COPCs in a risk assessment. Specifically, an essential nutrient may be screened out of a risk assessment if it is present at

concentrations not associated with adverse health effects. Based on RAGS, the lack of risk-related data, and USEPA Region IV's recommendations, the following essential nutrients were eliminated from the human health risk assessment: (1) calcium, (2) iron, (3) magnesium, (4) potassium, and (5) sodium.

Summary of COPCs

Screening evaluation results are presented on a medium-specific basis in each HHRA in Section 10. In summary, the risk information obtained from the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) is necessary to calculate risk, hazard estimates, and risk-based screening values. This information is based on toxicological and epidemiological data critiqued and approved by the scientific and regulatory community (i.e., listed in IRIS and/or HEAST). Risk information was not available for some CPSS; therefore, it was not possible to calculate risk and/or hazard for those chemicals. For each environmental medium sampled at an AOC or SWMU, the data were screened using risk-based and background values. Screening process results are presented in tables in each HHRA. Those chemicals determined to be COPCs through the screening process are designated with an asterisk. Total isomer concentrations reported for CDDs and dibenzofurans (e.g., Total HxCDD) were not specifically used in formal assessment per USEPA protocol. No RBCs are available for the generic group total petroleum hydrocarbons (TPH). As a result, TPH assessment was consistent with the NAVBASE screening level of 100 mg/kg for soil. If no groundwater impacts were identified, the current soil concentrations were considered sufficiently protective of the underlying aquifer.

7.3.5 Calculation of Risk and Hazard

Section 7.3.5 of the *Draft Zone A RFI Report* discusses the calculation of risk and hazard as it applies to the Zone G RFI.

7.3.6 Exposure Assessment

Section 7.3.6 of the *Draft Zone A RFI Report* discusses exposure assessment for the Zone G RFI HHRA.

7.3.7 Toxicity Assessment

Section 7.3.7 of the *Draft Zone A RFI Report* discusses the toxicity assessment procedures for the Zone G RFI HHRA.

7.3.8 Risk Characterization

Section 7.3.8 of the *Draft Zone A RFI Report* discusses the risk characterization procedures used for the Zone G RFI.

7.3.9 Risk Uncertainty

This section of the HHRA discusses the uncertainty and/or variability inherent in the risk assessment process, along with medium and exposure pathway-specific influences. Risk assessment sections are discussed separately below; specific examples of uncertainty sources are included where appropriate.

General

Uncertainty factors into each step of the exposure and toxicity assessments summarized above. Combined with other uncertainties, initial uncertainties associated with the first stages of the risk assessment process become magnified. Using high-end estimates of potential exposure concentrations, frequencies, durations, and rates leads to conservative chronic daily intake (CDI) estimates. Toxicological values for chemicals derived from USEPA databases and other sources are generally derived from animal studies. To predict potential human responses, uncertainty and modifying factors are applied to extrapolate the results of these studies, and provide a margin of safety based upon confidence in the studies. During the risk characterization, individual chemical

risk is added to determine the incremental excess cancer risk for each exposure pathway. If calculations of individual exposure predictions were based on the upper limit estimates of exposure to each chemical, the margin of safety of the cumulative incremental risk is the sum of all the individual safety margins applied throughout the process. Use of these safety margins during all exposure and risk/hazard computations provides an extremely conservative means of predicting potential human health effects. The margins of safety or "conservatism" inherent in each step of the human health risk assessment are addressed in the risk uncertainty discussions. All uncertainties or potential variability cannot be eliminated from the risk assessment process. However, recognizing the influences of these factors is fundamental to understanding and subsequently using risk assessment results.

The risk uncertainty portion of the HHRA presents factors influencing the uncertainty of the calculated incremental excess cancer risks and HQs/HIs. It also discusses, the uncertainty and/or variability of site-specific and medium/pathway-specific factors introduced in the risk assessment process. Calculated risk/hazard levels reflect the underlying variability of the analytical results upon which they are based. These levels also embody uncertainty about potentially unsampled maxima and minima in the analytes. The exposure pathways considered in the exposure assessment section of the HHRA are extremely conservative.

During the risk assessment process, assumptions are based on population studies and USEPA guidance. This guidance divides the assumptions into two basic categories: (1) the upper bound (90 to 95th percentile), and (2) the mean or 50th percentile central tendency (CT) exposure assumptions. As discussed in the exposure assessment section, the reasonable maximum exposure (RME) is based on the upper-bound assumptions, while CT exposure is based on mean assumptions. Therefore, risks and hazards calculated using RME assumptions are generally over, rather than underestimates. The following paragraphs discuss sources of uncertainty and variability pertinent to each exposure pathway evaluated.

Quality of Data

Data collected during the Zone G investigation are presented in Section 10 of this RFI, which includes results from AOC and SWMU sites. The QA/QC of those data is addressed in Section 4. The purpose of the data evaluation is to verify that the QC requirements of the dataset have been met and to characterize questionable data.

Most analytical results for environmental samples have inherent uncertainty. This uncertainty is a function of: (1) the matrix characteristics and heterogeneity, (2) the precision and accuracy of sampling, and (3) preparation and analysis methods employed. Although data are typically considered to be exact values, they are in reality the laboratory's best estimate within a range defined by method control limits. As a result, reported concentrations for any chemical can actually be under or overestimates of actual concentrations.

Identification of COPCs

Rather than addressing risk/hazard for all chemicals detected, screening values were used to focus the HHRA on pathways of concern and COPCs that individually exceed 1E-06 risk or an HQ of 0.1.

Exposure Pathways and Contaminants

As discussed in Section 7.3.4 comparisons were made using the most conservative set of screening values (residential land use) provided by USEPA for each exposure medium. Many CPSS were eliminated from the formal assessment on this basis. Potential cumulative effects associated with multiple chemicals dismissed through this process are a valid concern. However, since maximum detected concentrations were used in the screening comparison with low range risk/hazard goals, much uncertainty is alleviated. A large number (i.e., greater than 10) of constituents would have to be present at near-RBC concentrations to substantiate cumulative effects concerns. Although conservative screening methods are used, inhalation and dermal exposure are not incorporated into

the soil screening values calculated by USEPA. If these pathways were the primary concern (as opposed to the ingestion pathway), the screening method could eliminate contaminants that should otherwise be considered COPCs. Zone G surface soil data are compared to soil-to-air cross-media transport via volatilization in the fate and transport discussion of this report. Constituents that can significantly contribute to risk via other exposure pathways, but were omitted based on comparison to residential RBCs, were added back to the list of COPCs.

Comparison to Background Concentrations

Because the HHRA estimates the excess cancer risk or health hazard posed by COPCs, individual sample data values for inorganic chemicals were compared to background concentrations in the Zone G RFI, after being compared to the risk-based screening values. As a corollary background screening method, the Wilcoxon rank sum test was used to compare site inorganic COPC data populations to corresponding reference data populations. The outcomes of the fixed point and Wilcoxon tests determined whether concentrations differed significantly between onsite and background locations, as detailed in Section 7.3.4. The dual approach to background screening reduces the probability for a COPC to be improperly dismissed from formal assessment.

Additional uncertainty is introduced by comparing site data to nonspecific screening reference data. Although the background concentrations are specific to Zone G, they are not specific to individual AOCs or SWMUs. The use of zone-specific background standards, however, decreases the uncertainty normally resulting from using a single set of standards for the entire base.

Elimination of Essential Nutrients

In accordance with RAGS, the following nutrients were eliminated from the Zone G HHRA: (1) calcium, (2) sodium, (3) potassium, (4) magnesium, and (5) iron. Toxicity from overexposure to these nutrients is only possible if human receptors are exposed to extremely high doses. USEPA recommends eliminating these compounds from formal risk assessment. Because no

USEPA recommends eliminating these compounds from formal risk assessment. Because no screening comparison was performed, the HIs calculated in the HHRA could be positively influenced by the nutrient concentrations detected onsite. Therefore, the HIs are possibly underestimates.

Characterization of Exposure Setting and Identification of Exposure Pathways

Because of the highly conservative assumptions (e.g., future residential use) recommended by USEPA Region IV, high bias potential is introduced through the exposure setting and pathway selection when assessing potential future and current exposure. The assumptions made in the site worker scenario are also conservative and tend to overestimate exposure. Current site workers are not exposed to site groundwater. They are infrequently exposed to surface soils when walking across the site, using commercial facilities, or mowing the grass. Site workers could not be expected to stay in contact with affected media for eight hours per day, 250 days per year, as assumed in the exposure assessment. Mowing grass 52 days per year would result in approximately one-fifth the projected risk/hazard for site workers.

Residential use of Zone G sites is not likely, based on uses, the nature of surrounding areas, and potential reuse plans. If this area ever became residential, most of the present buildings would be demolished and the surface soil conditions would likely change. The area could be covered with roads, paved driveways, landscaping soil, and/or houses, or parts of the property could be made into playgrounds. Consequently, exposure to current surface soil conditions would not be likely under a true future residential scenario. Exposure pathways assessed in the HHRA would generally overestimate the risk and hazard posed to current site workers and future site residents.

Groundwater is not currently used at any Zone G location as a source of potable or process water. A basewide potable water system provides drinking and process water to buildings throughout Zone G. This system is to remain in operation under the current base reuse plan. Accordingly,

use of shallow groundwater would not be expected under future use scenarios. Therefore, the projected risk/hazard scenario associated with shallow groundwater exposure is highly conservative, and associated pathways are not expected to be completed in the future.

Additionally, the shallow aquifer monitored during the RFI naturally contains significant concentrations of chlorides and TDS. As such, this water-bearing zone's potential as a potable water source is questionable. Absent potential potable uses, the applicability of tap water-based screening or remedial standards is questionable.

Determination of Exposure Point Concentrations

Based on the guidance provided by USEPA, EPCs are concentrations used to estimate CDI. The uncertainty associated with EPCs stems primarily from their statistical determination or the imposition of maximum concentrations, described below.

Statistical Estimation of Exposure Point Concentrations

USEPA's *Supplemental Guidance to RAGS: Calculating the Concentration Term* guidance outlines a statistical estimation of EPC. These calculated concentrations are 95% UCLs for the mean, which are based on certain assumptions. USEPA assumes that most (if not all) environmental data are lognormally distributed. This assumption can lead to over or underestimation of the concentration because many environmental data are neither normally nor lognormally distributed.

The UCL calculation method includes the *H*-statistic, which is based on the number of samples analyzed for each COPC and the standard deviation of the results. To obtain this number, a table must be referenced, and the value must be interpolated (estimated) from the table. The equation for the *H*-statistic has not been provided in the supplemental guidance, nor does the document referred to in the guidance provide the equation. Although the statistic appears to be nonlinear,

local linearity was assumed as a way to interpolate the statistic for each COPC addressed in the HHRAAs.

Linear interpolation provides a good estimate of the H-statistic; however, both the UCL formula and H are natural log values. The effect of multiplying natural log numbers is not equivalent to multiplying untransformed values. When data are log transformed, adding two numbers is the equivalent of multiplying the two numbers if they were not transformed. The effect of multiplying a number while in log form is exponential; and here, H is applied as a multiplier. In summary, using this method to calculate the UCL has the effect of overestimating, and often provides concentrations greater than the maximum detected onsite. For all datasets with fewer than 10 total samples for a specific medium, the maximum concentrations detected were used as EPCs. The limited number of soil and groundwater samples used to assess site conditions often resulted in considerable variability between data points, and thus relatively high standard deviations about the mean. The high standard deviation elevates UCL projections.

Although RAGS advocates using neither worst-case scenarios nor maximum concentrations as EPCs, the use of the H -statistic often necessitates using the reported maximum concentration as the EPC. In accordance with RAGS, the lesser of either the maximum concentration or the UCL is used as the EPC. As reviewed above, summation of risk based on maximum concentrations leads to overestimation of exposure, especially in the case of low detection frequency or spatially segregated COPCs. This concept is further discussed below.

Frequency of Detection and Spatial Distribution

Because of the influence of standard deviation on EPC, low frequency of detection can cause COPCs to be addressed inappropriately in the risk assessment. More specifically, COPCs detected only once or twice in all samples analyzed (having concentrations exceeding the RBCs and reference concentrations) would be expected to show relatively higher standard deviations as

concentration variability or range widens. A higher standard deviation results in a high *H*-statistic, typically leading to a UCL greater than the maximum concentration detected onsite. If that is the case, use of the UCL or maximum concentration detected as the EPC (or possibly the inclusion of the COPC in question a COC) may not be appropriate, if the EPC can be assumed to be widely distributed spatially. A receptor cannot feasibly be exposed simultaneously to maximum concentrations of different contaminants at several locations. The use of the maximum concentrations (or the UCL) is questionable for these contaminants, and the calculated risk/hazard could be skewed upward due to the low frequency of detection.

In some instances, hot spots can be defined within the investigation area. A hot spot is an isolated area of concentrated contamination, within a larger area not impacted, or much less so. Exposure quantification in the presence of a hot spot may be achieved by calculating a fraction ingested/fraction contacted (FI/FC) from a contaminated source factor. This calculation is based on the percentage of the total exposure area encompassed by the hot spot, modifying the maximum (or restricted area average) contaminant concentration to derive the EPC.

Toxicity Assessment Information

Uncertainty is generally recognized in developing human toxicological risk from experimental data. This is primarily due to uncertainty of data extrapolation in the areas of: (1) high- to low-dose exposure, and (2) animal data to human experience. The site-specific uncertainty occurs mainly in the degree of accuracy of the exposure assumptions. Most of these assumptions cannot be verified; for example, the degree of chemical absorption from the gut or through the skin, or the amount of soil contact is not known with certainty.

The uncertainty of toxicological values from the IRIS and HEAST databases provided by USEPA is summarized (where available) in each HHRA. Among other factors, the uncertainty assigned to these values account for: (1) acute to chronic dose extrapolation, (2) study inadequacies, and

(3) sensitive subpopulations. Although uncertainty factors for a specific compound may be 1,000 or higher, these safety factors are applied by USEPA to help guarantee a conservative overall assessment for risk/hazard, relative to human health concerns. The possibility of uncertainty obligates the USEPA and the risk assessor to make conservative assumptions to eliminate actual health risk to be greater than that determined via the risk assessment process. Alternatively, the process is not intended to be overly conservative so risk values have no basis in actual conditions. This balance was considered in developing exposure assumptions and pathways, and in interpreting data and guidance for Zone G site HHRAs.

Evaluation of Dioxin Congeners as 2,3,7,8-TCDD Equivalents

Where CDDs and dibenzofurans (dioxins) were detected in soil, TEQs were derived by multiplying the concentration of each dioxin congener by its corresponding USEPA TEF. The resulting TEQs were then summed for each sample, comparing the total to the 1,000 ng/kg AL. If the total TEQ value was less than 1,000 ng/kg, then soil dioxins do not pose an unacceptable risk. Groundwater exposure quantification used TEQ values computed for each monitoring point.

Evaluation of Chemicals for Which No Toxicity Values Are Available

Parameters not having corresponding RBCs due to the lack of approved toxicological values were not included in the CDI calculation data. However, this does not indicate that chemicals lacking approved toxicological values pose no risk/hazard. As stated previously, essential nutrients were eliminated based on their low potential for toxicity. Therefore, these chemicals were not assessed further in the HHRA.

Quantification of Risk/Hazard

This section of each HHRA discusses potential sources of uncertainty or variability not covered in preceding sections. Each exposure medium identified in the formal risk assessment process is discussed briefly.

Mapping Risk/Hazard

Risk and hazard maps presenting site-specific HHRA results are in Section 10. For selected sites, point maps were constructed showing the cumulative risk/hazard computed at specific locations. Location-specific data were summed and plotted to illustrate ranges of total risk and/or total hazard at sites where such presentations could be supported.

Risk and hazard point mapping is a useful risk assessment tool for determining whether hot spots (or isolated areas of gross contamination) are present in an otherwise unimpacted area. This is important because heterogeneous contaminant concentrations can affect how receptors are exposed to the affected media. It is sometimes appropriate to estimate the FI/FC from the contaminated source in computing CDI. Point maps allow for visual analysis of risk and hazard distributions, as well as easier estimation of the extent of hot spots relative to the overall site area. These maps also support preliminary scoping of remedial requirements and assessment of potential cleanup alternatives in the CMS.

7.3.10 Risk Summary

In each site-specific HHRA, this section summarizes the risk and hazard projected for each receptor group, exposure medium, and exposure pathway.

7.3.11 RGOs

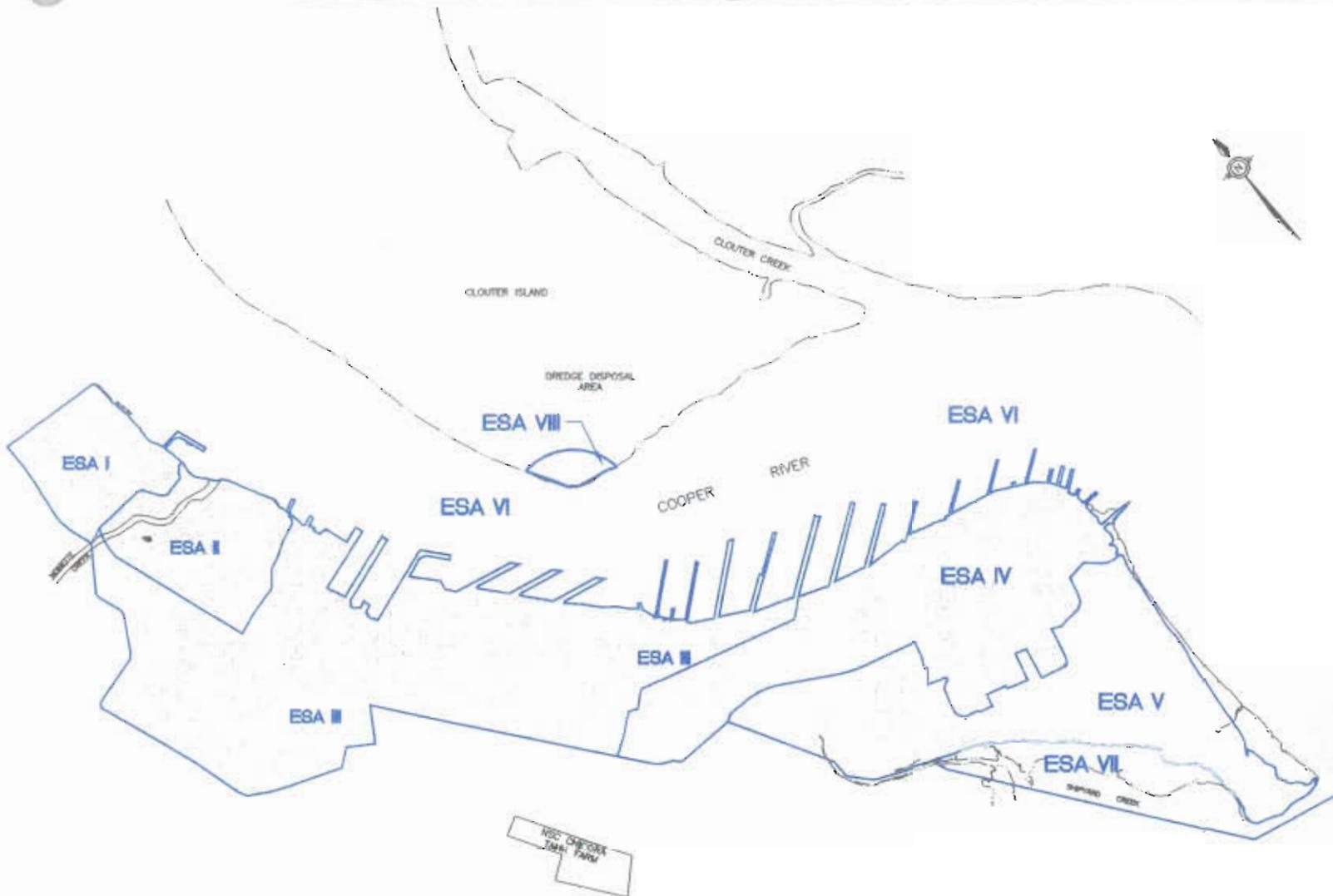
Section 7.3.11 of the *Draft Zone A RFI Report* discusses RGOs as they apply to the HHRA for Zone G RFI.

8.0 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment (ERA) is a key component of the BRA. Its purpose is to develop a qualitative and/or quantitative ecological appraisal of the actual or potential effects of Zone G contamination on the surrounding ecosystem. The assessment considers environmental media and exposure pathways that could result in unacceptable levels of exposure to flora and fauna now or in the foreseeable future. The approach to assessing risk components at Zone G was based on *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997), *Risk Assessment Guidance for Superfund, Volume II - Environmental Evaluation Manual* (USEPA, 1989c), and *Framework for Ecological Risk Assessment* (USEPA, 1992b).

8.1 ERA Rationale

Basewide, eight Ecological Study Areas (ESAs) were designated to assist in appropriately qualifying geographic boundaries of areas with contiguous habitats or similar ecosystem distributions (Figure 8-1). Within these ESAs, smaller areas of ecological concern (AECs) were specified to focus the ecological assessment relative to potential AOC/SWMU contribution and receptor exposure. Using an ecological survey form, all AECs underwent habitat and resident biota evaluations to obtain preliminary ecological information essential to the Zone G ERA. The completed forms are presented in Appendices A and B of the Zone J RFI Work Plan (E/A&H, November 22, 1995) and summarized below. This habitat survey method, which is used in conjunction with the Zone G RFI report, is also described in the Zone J RFI Work Plan. The purpose of the Zone G ERA is to address zonewide impacts to ecological subzones within AECs previously identified within Zone G. Where applicable, surface soil and sediment data from AOCs/SWMUs potentially impacting Zone G ecological subzones are used herein to determine overall ecological risk.



LEGEND

— ESA BOUNDARY



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FIGURE 8-1
ECOLOGICAL STUDY AREA
LOCATION MAP

DWG DATE: 12/30/97 | DWG NAME: 2907ESAL

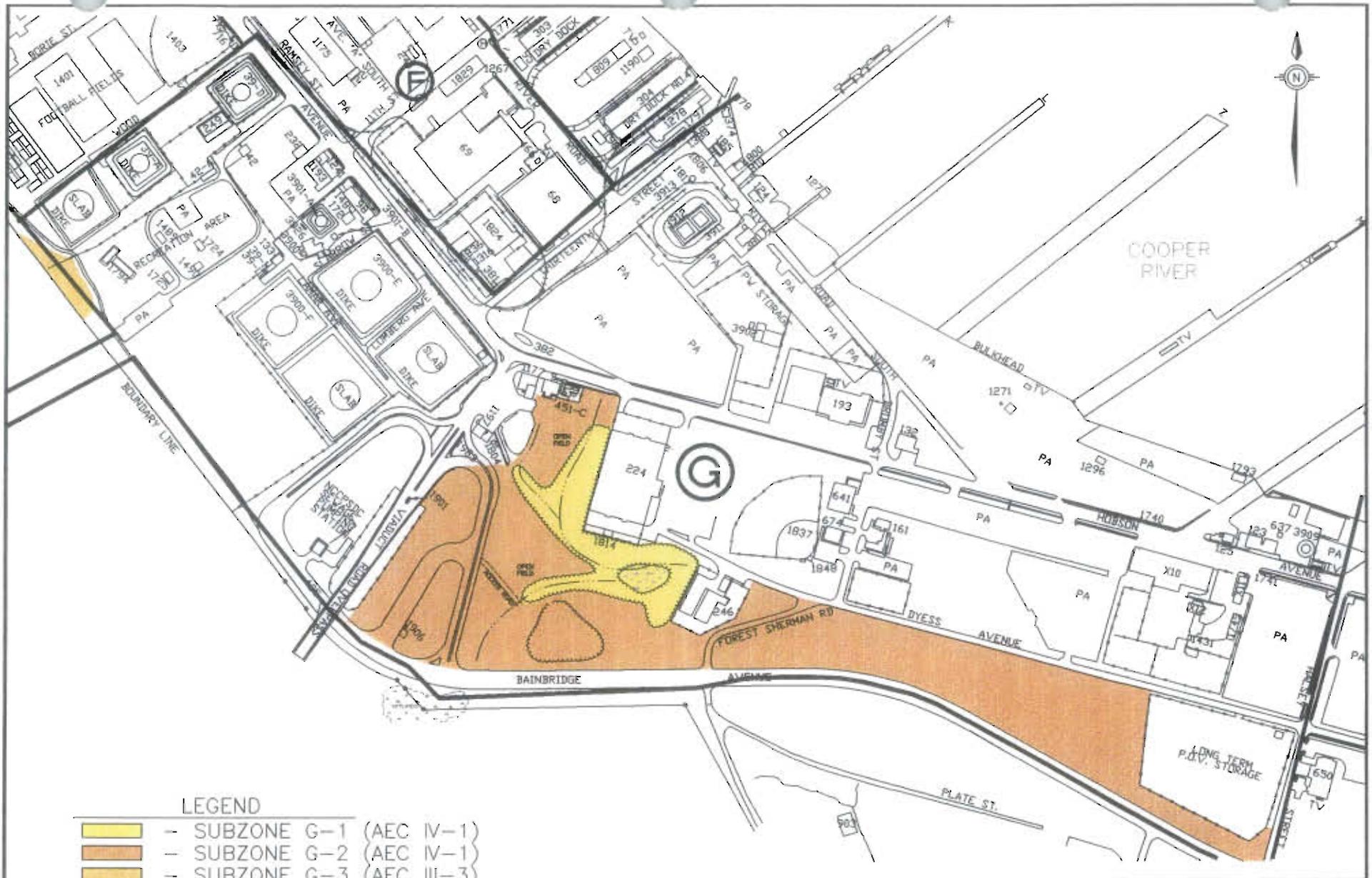
Two areas of ecological concern, AEC III-3 and AEC IV-1, occur within Zone G. These have been divided into three Zone G subzones, the boundaries of which were based on observed habitat type and are depicted in Figure 8-2. AEC IV-1 includes Subzones G-1 and G-2, while AEC III-3 includes Subzone G-3. These subzones are the units of the Zone G ERA and are discussed in the following section. If there is a potential for contaminant migration to aquatic areas beyond the Zone G perimeter, such as Shipyard Creek, risk to any applicable receptors will be evaluated during the Zone J investigation of the NAVBASE water bodies. Areas in Zone G which did not contain suitable habitat for ecological receptors, such as parking areas and buildings in the more developed areas, were not addressed for ecological risk. The subzones and non-ecological areas are shown in Figure 8-2. Specific endpoints and assessment techniques for each subzone are presented below. The AOC/SWMUs associated with each subzone are identified in Table 8.1 along with any ecological areas outside Zone G, yet still potentially impacted by releases associated with Zone G sites.

8.2 Environmental Setting

Habitat Descriptions

Subzone G-1 — This subzone is an approximately 4.5-acre palustrine scrub-shrub wetland located west and south of Building 224 and west of Building 246. This wetland community has developed around drainage ditches which conduct surface water runoff from several nearby sites identified during the Zone G investigation. These include: (1) AOC 633 - Substation, Building 451C; (2) AOC 634 - Flammable Material Storage, Building 1814; and (3) AOC 706 - Area Behind Building 246. These sites are discussed in detail in Section 10.

The outer perimeter of this subzone consists of a densely vegetated, infrequently-flooded thicket containing wax myrtle (*Myrica cerifera*), Chinese tallow-tree (*Sapium sebiferum*), groundsel-tree (*Bachcharis halimifolia*), southern hackberry (*Celtis laevigata*), red mulberry (*Morus rubra*),



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- SUBZONE G-1 (AEC IV-1)
- SUBZONE G-2 (AEC IV-1)
- SUBZONE G-3 (AEC III-3)
- NON ECOLOGICAL AREAS



ZONE G
RCRA FACILITY
INVESTIGATION REPORT
NAVAL BASE CHARLESTON
CHARLESTON, S.C.

FIGURE 8-2
ECOLOGICAL SUBZONES
WITHIN ZONE G

Table 8.1
Zone G
AOC/SWMUs Associated With Ecological Subzones

AOC/SWMU	Description	Potentially Impacted Ecological Areas Outside of Zone G
Subzone G-1		
AOCs 633, 634, and 706	Substation Bldg. 451C, Flammable Material Storage Bldg. 1814, and Area Behind Bldg. 246.	Shipyards Creek
Subzone G-2		
SWMU 11	Caustic Pond	Shipyards Creek
AOC 637	Dump Area, Bldg. 161 Area	Shipyards Creek
AOC 706	Area Behind Bldg. 246	Shipyards Creek
Subzone G-3		
None	Chicora Tank Farm	Chicora Marsh

Notes:

Chicora Tank Farm and marsh is being investigated as part of the petroleum UST investigations at NAVBASE

willow (*Salix nigra* and *Salix caroliniana*), and eastern red cedar (*Juniperus virginiana*). This 1
 vegetation forms a moderately dense canopy above the interior's network of channelized ditches, 2
 which conveys excess storm water to the headwaters of Shipyards Creek approximately 1,000 feet 3
 to the southeast. An area of open water approximately 0.5 to 1 foot deep exists near the eastern 4
 border of Subzone G-1 and contains both emergent (e.g., *Typha* spp.) and submergent aquatic 5
 vegetation, as well as several tallow-trees growing on a small island in the center of the pond. 6
 Small fish (i.e., *Gambusia* spp.) occur here as well as semi-aquatic species such as frogs, toads 7
 (Order Anura) and other amphibians, and aquatic and semi-aquatic insects. Avian species either 8
 observed or expected to be found here include red-winged blackbirds (*Agelaius phoeniceus*), 9
 northern mockingbirds (*Mimus polyglottis*), American robins (*Turdus migratorius*) European 10
 starlings (*Sturnus vulgaris*), boat-tailed grackles (*Quiscalus major*), and common grackles 11
 (*Quiscalus quiscula*). Small mammals such as the Eastern cottontail rabbit (*Sylvilagus floridanus*) 12
 may use the dryer edge-habitat of Subzone G-1, but arboreal mammals such as the eastern grey 13

squirrel (*Sciurus carolinensis*) likely use this area for only at temporary refuge, since foraging and access/egress opportunities are be limited. This and the fact that subzone is somewhat isolated from proximal woods by roads and industrial development, make it an unsuitable area for feeding or rearing of young. Subzone G-1 is surrounded by large grassy fields (Subzone G-2) to the north, west, and south, and by Buildings 224 and 246. Six sediment samples collected within the drainage ditches and open water area will be used to assess risk in this subzone.

Subzone G-2 — This elongated subzone consists of approximately 23.5-acres of grassy, low-lying fields bordered by Bainbridge and Dyess Avenues and Viaduct Road and contain a few mature mulberry, oak, and hackberry trees. Several small ditches which originate from the wetland in Subzone G-1 contain cattail (*Typha* spp.) and sedges (Family Cyperaceae) and transect this subzone. While able to sustain aquatic/hydrophytic vegetation, these ditches do not retain water long enough to support a viable aquatic faunal community. Considered more applicable to the terrestrial exposure pathways, the three sediment samples collected from these ditches will be used with the other soil samples collected in the subzone to assess risk to terrestrial receptors. Avian species observed or expected to be present in this subzone include American robin (*Turdus migratorius*), common grackle, boat-tailed grackle, and European starlings. Occasional foraging by red-tailed hawk, kestrel, and loggerhead shrike (Families Buteoninae, Falconidae, and Laniidae) is also expected due to the likely population of prey using this area, including Eastern cottontail rabbit, Eastern grey squirrel, and other small rodents.

Sites investigated in the Zone G RFI that may have impacted Subzone G-2 include (1) SWMU 11 – Caustic Pond, (2) AOC 637 – Dump Area, Building 161 Area, and (3) AOC 706 – Area behind Building 246.

Subzone G-3 – This subzone is a 0.63-acre vegetated drainage ditch/storm-water detention pond west of a recreational area (Facility Number 1794) at the base’s property boundary. Subzone G-3

is part of a larger offsite emergent wetland which leads to the Chicora Tank Farm, approximately 800 feet to the southwest of the subzone. On the base, the ditches/pond is surrounded by a small scrub/shrub community with vegetation including wax myrtle, black willow, red mulberry, and tallow trees. As previously discussed, no contaminant migration pathways from known AOCs/SWMUs to this site have been identified, thus no assessment of risk was performed. Furthermore, the Chicora Tank Farm and its associated impacts are being addressed as part of the investigation of the FDS. Impacts to Subzone G-3 will be presented with the formal discussion of the FDS.

Threatened and Endangered Species

Several threatened and endangered species, and species of concern could occur within the Zone G boundaries. Table 8.2 lists those species currently listed on state and federal registers that have been historically or recently identified at NAVBASE. Most notably, least terns (*Sterna antillarum*), a species listed by the South Carolina Department of Natural Resources as threatened in Charleston County, have repeatedly established a breeding colony on the roof of Building 224, which is bordered on the east and south by Subzone G-1. Risk to this species, however, will not be addressed in the Zone G investigation due to the lack of an exposure route. Least terns are a piscivorous species that nest on roofs containing pea-gravel when suitable sandy beaches are not available. The birds at this colony are expected to forage in the nearby Cooper River and Shipyard Creek and rear their young on the roof of Building 224 without ever contacting contaminated sources in the zone. The potential for exposure associated with foraging in the rivers will be addressed as part of the Zone J investigation.

8.3 Conceptual Model

Figure 8-3 presents a conceptual model of the potential contaminant pathways from source to ecological receptors for Zone G subzones. Due to the presence of standing water at Subzone G-1,

Table 8.2
Zone G
Federal and State Listed Threatened, Endangered and Candidate Species
Which Reside or Potentially Occur on NAVBASE

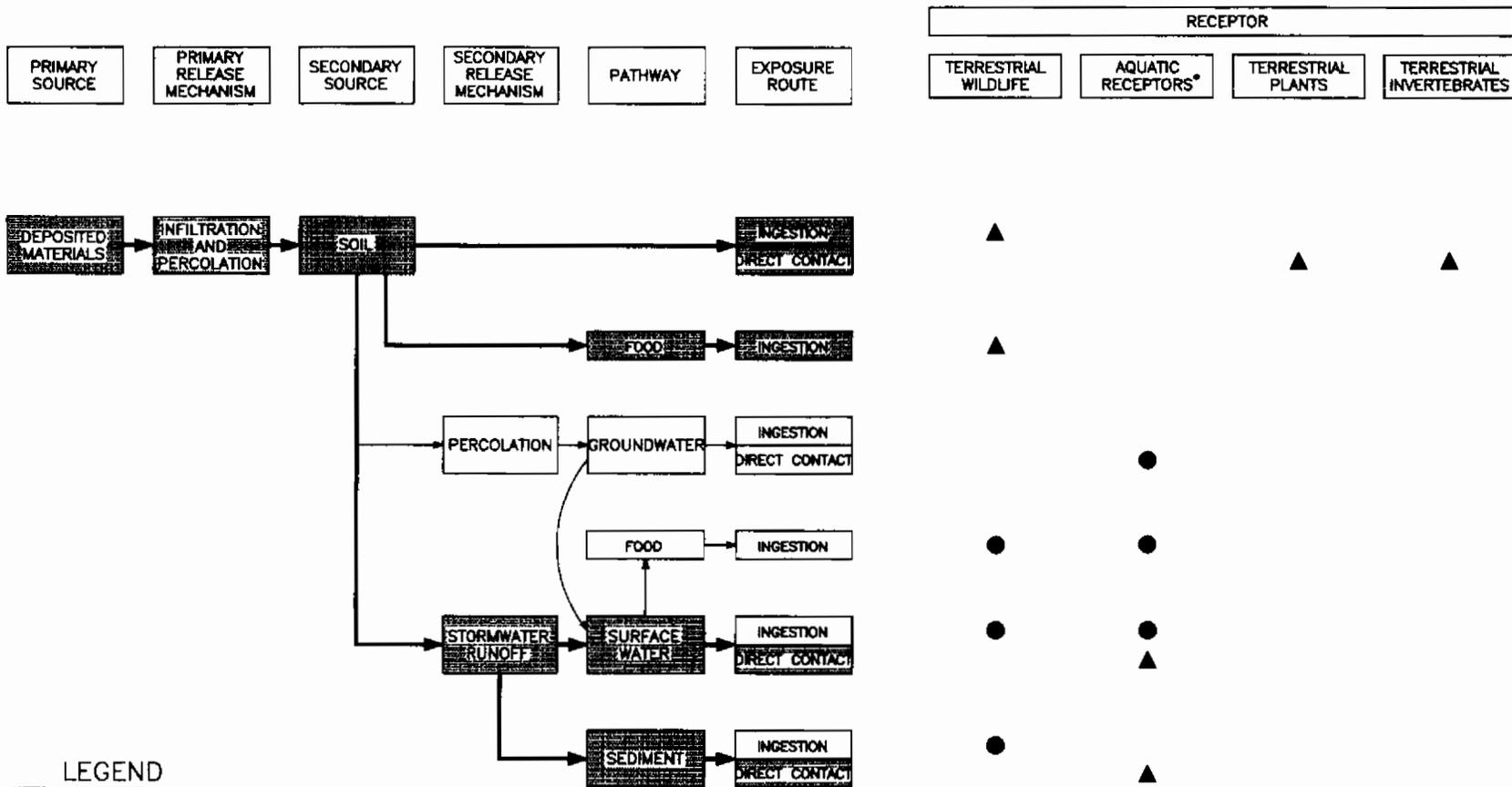
Common Name	Scientific Name	Residence Status	USFWS Listing	SCWMRD Listing
Reptiles and Amphibians				
American Alligator	<i>Alligator mississippiensis</i>	PR	T/SA	T/SA
Flatwoods Salamander	<i>Ambystoma cingulanum</i>	UR	C-2	SC
Eastern Tiger Salamander	<i>Ambystoma tigrinum tigrinum</i>	PR	—	SC
Broad-Striped Dwarf Siren	<i>Pseudobranchius striatus</i>	PR	—	SC
Crawfish Frog	<i>Rana areolata</i>	PR	—	SC
Loggerhead Turtle	<i>Caretta</i>	PM	T	T
Kemp's Ridley Sea Turtle	<i>Lepidochelys kempi</i>	PM	E	E
Island Glass Lizard	<i>Ophisaurus compressus</i>	UR	SR	SR
Birds				
Brown Pelican	<i>Pelecanus occidentalis</i>	LM	—	SC
Wood Stork	<i>Mycteria americana</i>	LM	E	E
Osprey	<i>Pandion haliaetus</i>	CR	—	SC
American Swallow-Tailed Kite	<i>Elanoides forficatus forficatus</i>	PM	SR	E
Bachman's Sparrow	<i>Aimophila aestivalis</i>	UR	SR	SR
Red-Cockaded Woodpecker	<i>Picoides borealis</i>	UR	E	E
Bachman's Warbler	<i>Vermivora bachmanii</i>	UR	E	E
Bald Eagle	<i>Haliaeetus leucocephalus</i>	LM	E	E
Arctic Peregrine Falcon	<i>Falco peregrinus tundrius</i>	PM	T	T
Piping Plover	<i>Charadrius melodus</i>	PM	T	T
Least Tern	<i>Sterna antillarum</i>	CR	—	T
Least Tern Breeding Colony		CR	—	SC
Wading Bird Breeding Colony		CR ^a	—	SC
Mammals				
Black Bear	<i>Ursus americanus</i>	UM	—	SC
West Indian Manatee	<i>Trichechus manatus</i>	PM	E	E

Table 8.2
Zone G
Federal and State Listed Threatened, Endangered and Candidate Species
Which Reside or Potentially Occur on NAVBASE

Common Name	Scientific Name	Residence Status	USFWS Listing	SCWMRD Listing
Fish				
Shortnose Sturgeon	<i>Acipenser brevirostrum</i>	LM	E	E
Plants				
Canby's Dropwort	<i>Oxypolis canbyi</i>	UR	E	E
Pondberry	<i>Lindera melissifolia</i>	UR	E	E
Incised Groovebur	<i>Agrimonia incisa</i>	UR	C-2	NC
Sea-Beach Pigweed	<i>Amaranthus pumilus</i>	UR	SR	NC
Cypress Knee Sedge	<i>Carex decomposita</i>	UR	SR	-
Chaff-Seed	<i>Schwalbea americana</i>	UR	SR	NC
Whisk Fern	<i>Psilotum nudum</i>	UR	-	SL
Climbing Fern	<i>Lygodium palmatum</i>	UR	-	SL
Piedmont Flatsedge	<i>Cyperus tetragonus</i>	PR	-	SL
Baldwin Nutrush	<i>Scleria baldwinii</i>	UR	-	SL
Nodding Pogonia	<i>Triphora trianthophora</i>	UR	-	SL
Savannah Milkweed	<i>Asclepias pedicellata</i>	UR	-	RC
Venus' Fly-Trap	<i>Dionaea muscipula</i>	UR	-	RC
Sweet Pinesap	<i>Monotropsis odorata</i>	UR	-	RC
Climbing Fetter-Bush	<i>Pieris phillyreifolia</i>	UR	-	SL
Sea Purslane	<i>Trianthema portulacastrum</i>	CR	-	SC

Notes:

a	=	Wading bird colony has been a confirmed resident at the base, but was not present during field studies in April 1994
CR	=	Confirmed resident
PR	=	Possible resident
UR	=	Unlikely resident
LM	=	Likely migrant or occasional visitor
PM	=	Possibly migrant or occasional visitor
UM	=	Unlikely migrant or occasional visitor
SC	=	Species of concern, state
SR	=	Status review
E	=	Endangered
T	=	Threatened
SL	=	State listed
RC	=	Species of concern, regional
NC	=	Species of concern, national
C-2	=	Candidate species for federal listing, Category 2
T/SA	=	Threatened due to similarity of appearance
USFWS	=	U.S. Fish and Wildlife Service
SCWMRD	=	South Carolina Wildlife and Marine Resources Department
Source:		<i>Final Environmental Impact Statement for Disposal and Reuse of the Charleston Naval Base</i> (Ecology and Environment, June 1995)



NOTE: SHADED BOXES, BOLD ARROWS, AND TRIANGLES INDICATE SELECTED PATHWAY



ZONE G
RCRA FACILITY
INVESTIGATION REPORT
NAVAL BASE CHARLESTON
CHARLESTON, S.C.

FIGURE 8-3
CONTAMINANT PATHWAY MODEL FOR
ECOLOGICAL RECEPTORS

DWG DATE: 01/28/98

DWG NAME: 2907CPMF

* - AQUATIC RECEPTORS - INVERTEBRATES, PLANTS, ALGAE, AMPHIBIANS, AND FISH

sediment-exposure pathways will be evaluated. Exposure pathways from soil to receptors are evaluated for Subzone G-2. Direct impacts to terrestrial plants are not included in this assessment but transfer mechanisms are considered in food chain transfer analyses. Information related to specific contaminant toxic mechanisms to vegetation are also discussed.

Although groundwater has been monitored, a water table depth (approximately 5 ft bgs) within Zone G precludes assessing ecological impacts from this medium to receptors within Zone G subzones. Subzone G-1, which is a semi-to-permanently flooded wetland, is not anticipated to affect or be affected by groundwater due to local hydrology, which indicates the presence of a shallow confining layer above the water table (see Section 2 for more details on site hydrology).

8.4 Selection of Ecological Chemicals of Potential Concern

Section 10 of this report discusses past activities at Zone G AOCs and SWMUs associated with the designated ecological subzones that may have impacted the surrounding ecosystem. COCs resulting from these activities have been identified and quantified according to USEPA methods and protocols for analyses of soil and sediment.

For the assessment of ecological risk, it was necessary to identify ecological contaminants of potential concern (ECPCs) using the following criteria:

- In surface soil, inorganic ECPCs were compounds which either exceeded twice the mean of, or were not detected in, reference (grid-based) samples.
- Any organic constituent detected in greater than 5% of the samples was considered an ECPC.

- Sediment ECPCs exceeded the USEPA Region IV sediment screening values, exceeded the most conservative effects level found in literature (HQs greater than 1), or an appropriate benchmark was unavailable.
- Any organic or inorganic constituent detected in less than 5% of the samples was not considered an ECPC.

Other ECPC Selection Criteria: Calcium, iron, magnesium, potassium, and sodium were not included in this assessment process as they are naturally occurring essential elements. Only the results from surficial soil (0 to 1 foot bgs) are addressed. It is presumed, even considering root development in the lower strata, that most biological effects will be limited to the upper zone. For the purposes of this document, all calculations were performed using the maximum concentration of each parameter detected in each subzone. Contaminant spatial distribution are discussed as necessary.

For compounds detected in both the primary and duplicate samples, concentrations for both detections were averaged and addressed as one concentration. For compounds that were detected in only one of the primary or duplicate samples, the detected value was used. Tables 8.3 and 8.4 present the sample results and screening values used to identify sediment ECPCs in Subzone G-1 for organic and inorganic compounds, respectively. For Subzone G-1, six sediment samples collected during the AOC 633 investigation will be used to evaluate the sediment exposure pathway described in Section 8.3. These samples were collected to determine impacts to Subzone G-1 from AOCs 633, 634, and 706. The range of concentrations presented in the following tables are derived from those samples collected within the specified subzone and therefore may not reflect the same concentration ranges discussed in other sections of this report. For the assessment of sediments, parameter-specific HQs were calculated to indicate the significance of detected concentrations relative to respective sediment screening values (HQ is the maximum concentration divided by its screening level). An HQ less than one indicates little or

Table 8.3
 Zone G
 Subzone G-1
 Organic Constituents in Sediment

Compound Name	Number of Detections	Range of Concentrations Detected ($\mu\text{g}/\text{kg}$)	Screening Value ($\mu\text{g}/\text{kg}$)	HQ	ECPC
Volatile Organic Compounds (n=6)					
2-Butanone	1	20	NA	NC	Yes
Carbon Disulfide	1	11	NA	NC	Yes
Semivolatile Organic Compounds (n=6)					
2-methylnaphthalene	1	92	330	0.279	Yes
Anthracene	1	60	330	0.18	Yes
Benzo(a)anthracene	3	60 - 180	330	0.55	Yes
Benzo(b)fluoranthene	3	78 - 310	NA	NC	Yes
Benzo(a)pyrene	1	130	330	0.39	Yes
Benzo(k)fluoranthene	2	77 - 200	NA	NC	Yes
Benzoic acid	1	79	NA	NC	Yes
Butylbenzylphthalate	1	63	NA	NC	Yes
Chrysene	3	91 - 260	330	0.79	Yes
Fluoranthene	3	100 - 410	330	1.24	Yes
Phenanthrene	2	100 - 270	330	0.82	Yes
Pyrene	3	120 - 650	330	1.97	Yes
Bis(2-ethylhexyl)phthalate	1	3,400	182	18.7	Yes
Pesticides/PCBs (n=6)					
Aroclor-1260	1	270	33	8.18	Yes
alpha-Chlordane	2	5.1 - 86	1.7	50.6	Yes
gamma-Chlordane	2	9.1 - 130	1.7	76.5	Yes
4,4-DDD	3	12 - 18	3.3	5.45	Yes
4,4'-DDE	4	8.1 - 34	3.3	10.3	Yes
4,4'-DDT	1	16	3.3	4.85	Yes

Notes:

n = Number of samples collected

Screening Value = Sediment Screening Values from *Ecological Risk Assessment, Bulletin 1* (USEPA, 1995b)

HQ = Hazard Quotient is maximum concentration / screening value

ECPC = Ecological Chemical of Potential Concern

NA = Data not available

NC = Cannot be calculated

DDD = Dichlorodiphenyldichloroethane

DDE = Dichlorodiphenyldichloroethylene

DDT = Dichlorodiphenyltrichloroethane

Table 8.4
 Zone G
 Subzone G-1
 Inorganic Constituents in Sediment

Inorganic Elements (n=6)	Number of Detections	Range of Concentrations Detected (mg/kg)	Screening Value (mg/kg)	HQ	ECPC
Aluminum	6	8,850 - 34,500	NA	NC	Yes
Antimony	2	0.95 - 23.50	12	1.96	Yes
Arsenic	6	4.90 - 25.30	7.24	3.49	Yes
Barium	6	19.30 - 317	NA	NC	Yes
Beryllium	5	0.53 - 1.60	NA	NC	Yes
Cadmium	4	0.39 - 4.90	1	4.9	Yes
Chromium	6	13 - 61.70	52.3	1.18	Yes
Cobalt	6	0.77 - 9.10	NA	NC	Yes
Copper	5	34.40 - 1,220	18.7	65.2	Yes
Lead	6	6.90 - 393	30.2	13.0	Yes
Manganese	6	16 - 710	NA	NC	Yes
Mercury	5	0.27 - 1.00	0.13	7.69	Yes
Nickel	5	17.10 - 47.60	15.9	2.99	Yes
Selenium	6	0.47 - 1.50	NA	NC	Yes
Silver	2	0.73 - 0.95	2	0.48	No
Tin	1	52.80	NA	NC	Yes
Vanadium	6	21.50 - 77	NA	NC	Yes
Zinc	5	140 - 3,260	124	26.3	Yes

Notes:

- n = Number of samples collected. Includes six sediment samples collected from Subzone G-1 area (633M0001 through 633M0006)
- Screening Value = Sediment Screening Values from *Ecological Risk Assessment; Bulletin No.1* (USEPA, 1995b)
- HQ = Hazard Quotient (maximum concentration /screening value)
- ECPC = Ecological Chemical of Potential Concern
- NA = Not available
- NC = Not calculated

no risk, less than 10 indicates moderate risk and an HQ over 100, extreme risk. Tables 8.5 and 1
 8.6 present the results and reference values used to identify soil ECPCs in Subzone G-2. The 2
 exposure pathway from soil to receptor in Subzone G-2 will be evaluated from 22 surface soil 3
 samples collected from AOCs 637, 706, and SWMU 11. Included also are the three dry sediment 4
 samples collected from drainage ditches (two from SWMU 11, one from AOC 637) in G-2. 5

Table 8.5
Zone G
Subzone G-2
Organic Constituents in Surface Soil

Compound Name	Number of Detections	Range of Concentrations ($\mu\text{g}/\text{kg}$)	ECPC
Volatile Organic Compounds (n=16)			
2-Butanone	1	7	Yes
1,2,3-Trichloropropane	1	6	Yes
Benzene	2	1.0 - 3.0	Yes
Carbon disulfide	2	1.0 - 2.0	Yes
Chlorobenzene	1	6.0	Yes
Trichloroethene	2	3.0 - 4.0	Yes
Semivolatile Organic Compounds (n = 18)			
2-Methylnaphthalene	4	55 - 120	Yes
4-Methylphenol (p-Cresol)	1	52	Yes
Acenaphthene	4	100 - 200	Yes
Acenaphthylene	1	45	Yes
Anthracene	4	240 - 410	Yes
Benzo(a)anthracene	7	50 - 1,000	Yes
Benzo(a)pyrene	8	56 - 890	Yes
Benzo(b)fluoranthene	8	49 - 1,400	Yes
Benzo(g,h,i)perylene	6	50 - 680	Yes
Benzo(k)fluoranthene	8	32 - 580	Yes
Benzoic Acid	2	83 - 170	Yes
Bis(2-ethylhexyl)phthalate	2	84 - 190	Yes
Chrysene	8	51 - 1,200	Yes
Dibenz(a,h)anthracene	3	160 - 320	Yes
Dibenzofuran	3	66 - 100	Yes
Fluoranthene	11	45 - 1,700	Yes
Fluorene	4	95 - 200	Yes
Indeno(1,2,3-cd)pyrene	6	169 - 560	Yes
Naphthalene	3	51 - 160	Yes
N-nitrosodiphenylamine	1	75	Yes

Table 8.5
Zone G
Subzone G-2
Organic Constituents in Surface Soil

Compound Name	Number of Detections	Range of Concentrations ($\mu\text{g}/\text{kg}$)	ECPC
Phenanthrene	7	82 - 2,400	Yes
Pyrene	11	46 - 2,600	Yes
Pesticide/PCBs (n = 18)			
4,4'-DDD	2	5.6 - 12	Yes
4,4'-DDE	6	4.1 - 58	Yes
4,4'-DDT	3	4.4 - 36	Yes
Aroclor-1016	1	210	Yes
Aroclor-1260	3	64 - 180	Yes
Dieldrin	1	5.6	Yes
Endosulfan II	1	3.3	Yes
Endrin	1	15	Yes
Endrin Aldehyde	2	5.5 - 9.4	Yes
Endrin ketone	1	11	Yes
Heptachlor	2	3.9 - 13	Yes
Heptachlor epoxide	1	2.8	Yes
alpha-Chlordane	3	2.6 - 39	Yes
gamma-Chlordane	10	1.4 - 73	Yes
Dioxins (n=4) (ng/kg)			
1234678-HpCDD	4	4.46 - 68.9	Yes
1234678-HpCDF	2	1.53 - 1.76	Yes
123478-HxCDF	2	0.57 - 9.36	Yes

Notes:

n = Number of Samples. Includes 22 surficial soil samples collected at AOCs 637, 706, and SWMU 11 and three dry sediment samples; two collected from drainage ditches at SWMU 11 and one from a drainage ditch adjacent to AOC 637

ECPC = Ecological Chemical of Potential Concern

HpCDD = Heptachlorodibenzo-p-dioxin

HpCDF = Heptachlorodibenzofuran

HxCDF = Hexachlorodibenzofuran

All results are in micrograms per kilogram ($\mu\text{g}/\text{kg}$) except for dioxins which are in nanograms per kilograms (ng/kg)

Table 8.6
Zone G
Subzone G-2
Inorganic Constituents in Soil

Inorganic Elements (n=25)	Number of Detections	Range of Concentrations (mg/kg)	Background Concentration (mg/kg)	ECPC
Aluminum	25	2,960 - 14,700	18,700	No
Antimony	5	0.47 - 4.2	2.89	Yes
Arsenic	25	0.49 - 19.0	17.2	Yes
Barium	25	4.6 - 172	109	Yes
Beryllium	21	0.11 - 0.79	1.2	No
Cadmium	21	0.07 - 5.1	1.07	Yes
Chromium	25	3.8 - 32.2	42.8	No
Cobalt	24	0.39 - 4.0	6.6	No
Copper	22	0.60 - 221	260	No
Lead	25	3.0 - 1,100	181	Yes
Manganese	25	7.7 - 159.5	325	No
Mercury	13	0.05 - 2.1	1.03	Yes
Nickel	23	1.0 - 46.4	20.6	Yes
Selenium	13	0.39 - 1.1	1.22	No
Silver	4	0.24 - 0.42	ND	Yes
Thallium	3	0.69 - 1.06	0.85	Yes
Tin	7	1.65 - 10.6	9.67	Yes
Vanadium	25	4.0 - 37.05	60.9	No
Zinc	23	6.7 - 238	519	No

Notes:

- n = Number of samples collected. Includes 22 surficial soil samples collected at AOCs 637, 706, and SWMU 11 and three dry sediment samples; two collected from drainage ditches at SWMU 11 and one from a drainage ditch adjacent to AOC 637
 - ECPC = Ecological Chemical of Potential Concern
- Background concentrations are derived for Zone G surface soil, as presented in Table 5.1

These will be compared to surface soil criteria, along with the Subzone G-2 surface soils, since there is more exposure potential for terrestrial species in G-2 rather than for aquatic (the drainage ditches of concern are only periodically inundated during rain events).

8.5 Contaminant Fate and Transport

Surface soil across the site consists of fine- to medium-grained sand with silt and some clay. Although this soil type is typically low in organic material with moderate permeability, surface soil samples in Zone G exhibited higher TOC values than anticipated. These factors allow for development of a microbial community, thereby increasing the likelihood of microbial decomposition of sorbed organic contaminants.

In addition, contaminants sorbed to surface soil conceivably could be transported via air or surface water runoff. However, both of these pathways are unlikely as major routes. Migration via air pathways could be significant only as it relates to dispersal of upper soil layer particles during high winds typical to coastal areas. Because sand particles are relatively large and heavy, extended migration through this route is not expected. Contaminants are also not expected to spread far via surface runoff due to the substrate's permeable nature. Most of the road-side storm drains and ditches in Zone G that are near AOCs/SWMUs function as detention basins rather than surface water conveyances. This inhibited transport of water-borne constituents from Zone G AOCs/SWMUs suggests that risks from surface water migration to the grassy fields of Subzone G-2 are likely to be negligible. The low-lying Subzone G-1, however, is under greater influence of localized runoff patterns and has apparently formed a wetland by detaining storm water runoff. All sites that could potentially contribute contamination to this subzone have been considered in this assessment. The physical adsorption of contaminants to soil particles and available organic material also limits horizontal migration. An exception, however, is the elevated soil bank behind AOC 706. This bank is sloped so that surface runoff drains a short distance

directly to the eastern-most portion of Subzone G-1. Fate and transport issues are discussed in Section 6.

8.6 Exposure Pathways and Assessment

After the ECPCs were identified for each subzone in Zone G, an assessment of the potential exposure pathways was performed. Lacking an identified migration pathway from any known contaminant source, exposure routes associated with Subzone G-3 were not evaluated. If the potential exposure of a Zone G ECPC to an ecological receptor in either Subzone G-1 or G-2 was indicated, the potential risk to that receptor (or group of receptors) was then evaluated. Based on the habitat types observed in each Zone G subzone, the exposure pathways to the following potential receptors were identified: aquatic wildlife, infaunal invertebrates (worms and insects living within the soil), terrestrial wildlife (birds/mammals), and vegetation.

Aquatic Wildlife

The primary exposure pathway evaluated for aquatic wildlife species in the standing water of Subzone G-1 is contact/interface with water and sediment. An assessment endpoint, evaluating the aquatic community health, has been selected with a measurement endpoint that predicts chronic effects to aquatic community species. The potential for adverse effects to benthic species will be measured by comparing observed sediment concentrations to those reported in the literature (USEPA, 1995b) known to cause changes or impairment in reproduction, growth, or survival.

Infaunal Invertebrates

The primary exposure pathway evaluated for infaunal invertebrates in Subzone G-2 will be via direct contact with surface soil. An assessment endpoint of a well-balanced soil infaunal community will be qualitatively measured by comparing literature data to detected soil concentrations.

Terrestrial Wildlife

For terrestrial wildlife species, exposure would include direct dermal contact, ingestion of soil particles, and food-chain transfer. Small mammals could contact contaminated soil if the area is a migratory corridor or if animals burrow into it. Contact time (exposure) will be limited when animals are crossing the area, but could be lengthy if burrows are established. Dermal contact by small reptiles and amphibians would be similar to that for small mammals. For insect populations, direct exposure to ground-dwelling species could provide a link for contaminant transfer to higher-level predators.

The assessment endpoint selected for terrestrial wildlife in Subzone G-2 is the maintenance of well-balanced terrestrial wildlife populations and communities. As a measure of the assessment endpoint selected, site concentrations were compared to the results of laboratory toxicity studies in literature that relate the oral dose of a contaminant with adverse response to growth, reproduction, or survival. Selected assessment endpoint species include: Eastern cottontail rabbit (*Sylvilagus floridanus*), short-tailed shrew (*Blarina brevicauda*), and American robin (*Turdus migratorius*) in G-2. All of these species (or an equivalent) are likely to occur within Subzone G-2.

To assess biotransfer of contaminants along food chains, the total potential dietary exposure (PDE) has been modeled for representative wildlife species within Subzone G-2. PDEs are calculated based on predicted concentrations of the ECPCs in food items that the species would consume, the amount of soil it would ingest, the relative amount of different food items in its diet, body weight, and food ingestion rate. The concentrations of ECPCs in food items are estimated based upon literature reported bioaccumulation factors (BAFs), which are a ratio of the ECPC concentration in dietary items to the concentration in soil. The BAFs reported for avian and mammalian species are reported ratios of ECPCs in the tissue of the animals to the concentrations of ECPCs in their diets.

The site foraging factor (SFF) allows the frequency of feeding in the area to be considered by estimating it relative to the receptor's feeding range and by considering the fraction of the year the receptor would be exposed to site contaminants. For a conservative assessment, a SFF of one was used to indicate that the chosen species is onsite year-round. The wildlife contaminant exposure model for surface soil at Zone G is shown in Table 8.7.

Vegetation

Woody and herbaceous vegetation in Subzone G-2 could incorporate certain detected constituents (primarily metals) through processes such as uptake/accumulation, translocation, adhesion, or biotransformation. These plant-borne constituents could also be ingested by terrestrial herbivores. No studies directed at accretion of ECPCs by plants through sediment were available. Therefore, effects to plants could not be assessed for Subzone G-1.

8.7 Ecological Effects Assessment

Stressor Characteristics

Inorganics

In general, heavy metals adversely affect survival, growth, reproduction, development, and metabolism of both terrestrial and aquatic invertebrate species, but effects are substantially modified by physical, chemical, and biological variables. Pascoe et al. (1994) observed that, in general, bioavailability of metals in soil to small mammals was limited. This study also suggests that metal intake for higher trophic species may be similarly limited. Most heavy metals do not biomagnify. In contact tests with terrestrial earthworms the order of toxicity for heavy metals from most toxic to least toxic was copper > zinc > nickel = cadmium > lead. Information on the toxicological effects associated with the inorganic ECPCs in Zone G soil and sediment are listed below. Toxicological information on the behavior of aluminum, barium, beryllium, cobalt, manganese, nickel, selenium, silver, thallium, tin, and vanadium was unavailable.

Table 8.7
Zone G
Wildlife Contaminant Exposure Model for Surface Soil

$$\begin{aligned}
 \text{Food Contaminant Concentration (FCC) (mg/kg)} &= \text{BAF} \times \text{Soil Contaminant Concentration(mg/kg)} \\
 \\
 \text{Soil Exposure (SE) (mg/kg)} &= (\% \text{ of diet as soil}) \times \text{Soil Contaminant Concentration(mg/kg)} \\
 \\
 \text{PDE (mg contaminant/kg/ BW/day)} &= \frac{[P_1 \times T_1 + P_2 \times T_2 + \dots P_n \times T_n + \text{SE}] \times \text{IR}_{\text{diet}} \times \text{SFF}}{\text{BW}}
 \end{aligned}$$

where:

- BAF = Bioaccumulation Factor from Table 8-11
- P_n = percent of diet composed of food item N
- T_n = tissue concentration in food item N (FCC in mg/kg)
- IR_{diet} = food ingestion rate of receptor (kg of food per day)
- SFF = site foraging factor (cannot exceed 1)
- BW = receptor body weight (kg)
- PDE = Potential Dietary Exposure

Antimony — Antimony was determined to be an ECPC in both Subzone G-1 sediment and Subzone G-2 soil. There are relatively little data on the behavior of antimony. Over a broad range of soil oxidation/reduction conditions (Eh -0.5 to 0.5), most soil antimony would be expected to exist in insoluble forms if pH is less than 7.5. As a result, antimony would be expected to have low mobility. This data is not available for this subzone.

Arsenic — While qualifying as an ECPC in both G-1 and G-2 sediments, arsenic is a naturally occurring compound and, with respect to cycling in the environment, is constantly changing. Many inorganic arsenicals are known teratogens and are more toxic than organic arsenicals

(Eisler, 1988). Soil biota appear to be capable of tolerating and metabolizing relatively high concentrations (microbiota to 1,600 mg/kg) of arsenic (Wang et al., 1984). Adverse effects to aquatic organisms have been reported at concentrations of 19 to 48 $\mu\text{g/L}$ in water. Arsenic in soil does not appear to magnify along the aquatic food chain.

Cadmium — Cadmium, an ECPC at both subzones G-1 and G-2, is a relatively rare heavy metal. It is a known teratogen and carcinogen and probably a mutagen, and has been implicated as the cause of severe deleterious effects on fish and wildlife (Eisler, 1985). Birds and mammals are comparatively resistant to the biocidal properties of cadmium. Freshwater organisms appear to be the most susceptible group to cadmium toxicity, which is modified significantly by water hardness. Adsorption and desorption processes are likely to be major factors in controlling cadmium concentrations in natural waters. Adsorption and desorption rates of cadmium are rapid on mud solids and particles of clay, silica, humic material, and other naturally occurring solids.

Chromium — Chromium, an ECPC in Subzone G-1 sediments, produces more adverse effects to biota in the hexavalent phase than the trivalent phase. In clayey sediments, trivalent chromium dominates and benthic invertebrate bioaccumulation is limited (Neff et al., 1978).

Copper — Copper, also an ECPC in Subzone G-1 sediments, is an essential micronutrient, and therefore, it is readily accumulated by aquatic organisms. It is a broad-spectrum biocide, which may be associated with both acute and chronic toxicity.

Lead — Lead is an ECPC in both subzones. In soil lead concentrates in organic-rich surface horizons in soil (National Research Council of Canada [NRCC], 1973). Lead's estimated residence time in soil is about 20 years (Nriagu, 1978). In sediments, lead is primarily found in association with iron and manganese hydroxides and may also form associations with clays and organic matter. Under oxidizing conditions, lead tends to remain tightly bound to sediments, but

is released into the water column under reducing conditions. Lead may accumulate to relatively high concentrations in aquatic biota.

Mercury – Mercury, also an ECPC in both subzones, is a known mutagen, teratogen, and carcinogen. It adversely affects reproduction, growth, development, motor coordination, and metabolism. Mercury has a high potential for bioaccumulation and biomagnification, and is slow to depurate. Organic mercury compounds produce more adverse effects than inorganic mercury compounds. Inorganic mercury can be biologically transformed to organic mercury compounds.

Zinc – Zinc is an ECPC in Subzone G-1 sediments. Most zinc introduced into aquatic environments is eventually partitioned into the sediments. In natural waters zinc speciates into the toxic aquo ion, other dissolved chemical species, various inorganic and organic complexes, and is readily transported. Reduced conditions enhance zinc's bioavailability.

Organics

With less than 20 samples collected at each of the Zone G subzones, a detection of an organic compound in a single sample meets the five percent ECPC selection criteria, classifying every organic detected as an ECPC. The available stressor characteristics are listed below.

Volatile Organic Compounds – Little information exists on the toxic effects to terrestrial organisms from VOCs in soil. Most information available are effects studies related to human health from inhalation of specific compounds by laboratory animals. Impact from the limited occurrence and relatively low concentrations of VOCs observed in soil is difficult to assess, but it is predicted that under such conditions measurable effects to terrestrial species would be difficult to determine.

Polynuclear Aromatic Hydrocarbons – PAHs vary by molecular weight and thus differ substantially in their behavior and distribution in the environment and in their biological effects. With increasing molecular weight, aqueous solubility decreases and the octanol-water partition coefficient ($\log K_{ow}$) increases, suggesting increased solubility in fats, a decrease in resistance to oxidation and reduction, and a decrease in vapor pressure (Eisler, 1987). In water, PAHs either evaporate, disperse into the water column, become incorporated into sediments, or undergo degradative processes such as photooxidation, chemical oxidation, and biological transformation by bacteria and animals (Neff, 1979).

Most environmental concern has focused on PAHs that range in molecular weight from 128.16 (naphthalene) to 300.36 (coronene). Generally, lower molecular weight PAH compounds, containing two or three aromatic rings, exhibit significant acute toxicity but are not carcinogenic. High molecular weight PAH compounds, four to seven rings, are significantly less toxic, but are demonstrably carcinogenic, mutagenic, or teratogenic to aquatic species. PAHs show little tendency to biomagnify in food chains because most are rapidly metabolized (Eisler, 1987). Very little information is available on food chain adverse effects as a result of soil PAH contamination.

Pesticide/PCBs – Samples collected from both subzones G-1 and G-2 contained pesticides and PCBs. Organochlorine pesticides have been used extensively in the United States since the 1940s and appear to be ubiquitous in the environment, being found in surface water, sediment, and biological tissues. They are readily absorbed by warm-blooded species and degradatory products are frequently more toxic than the parent form. Food chain biomagnification is usually low, except in some marine mammals. In soil invertebrates, organochlorine pesticides can accumulate to concentrations higher than those in the surrounding soil, and residues may in turn be ingested by birds and other animals feeding on earthworms (Beyer and Gish, 1980). Most environmental effects studies have been directed at mammals and birds.

PCBs are distributed worldwide with measurable concentrations recorded in fishery and wildlife resources from numerous locations (Eisler, 1986). They are known to bioaccumulate and to biomagnify within the food chain, and cause biological effects such as death, birth defects, tumors, and a wasting syndrome. In terrestrial environments, PCBs are rapidly metabolized from the soil into the terrestrial food chain (McKee, 1992). Subsoil-dwelling organisms may directly absorb PCBs and may transfer through the food chain to species.

Dioxins — Dioxins are trace compounds in some commercial herbicides and chlorophenols (Eisler, 1986). The most toxic and most extensively studied dioxin is 2,3,7,8-TCDD. Laboratory studies with birds, mammals, aquatic organisms, and other species have demonstrated that exposure to 2,3,7,8-TCDD can result in acute and delayed mortality as well as mutagenic and reproductive effects. In soil, microbial decomposition of TCDD is slow (Ramel, 1978) and uptake by vegetation is considered negligible (Blair, 1973).

Assessment of Potential Receptors

Aquatic Wildlife

Potential adverse ecological effects to aquatic species from identified ECPCs are predicted based on the most conservative benchmark available (i.e., chronic water quality criteria, sediment screening values, or effects information from literature). Effects are predicted using a preliminary screening approach. Maximum water and sediment concentrations for ECPCs are divided by the available benchmark to produce an HQ. Calculated HQs for ECPCs from each media will be summed to determine an HI. HQs with a result higher than one are considered to demonstrate a potential risk. Values higher than 10 are considered to be of moderately high potential risk and above 100, extreme risk.

Infaunal Invertebrates

Predicted potential adverse ecological effects to soil invertebrates from identified ECPCs are based on effects information in available literature. Table 8.8 summarizes chemical effects studies on terrestrial infaunal invertebrates. Because soil maximum contaminant levels are unavailable for effects levels, studies are used for comparative qualitative assessments only.

Terrestrial Wildlife

Potential adverse effects to bird and mammal species associated with the identified ECPCs are based on food uptake potential. Available toxicity reference values (TRVs) were determined for each measurement endpoint species selected. The TRV relates the dose of a respective ECPC in an oral exposure with an adverse effect. The lethal TRV has been determined to be one-fifth of the lowest reported lethal dose to 50 percent of test population (LD₅₀) value for the most closely related test species. One fifth of an oral LD₅₀ value is considered to be protective of lethal effects for 99.9% of individuals in a test population (USEPA, 1986b). It is assumed that this level of risk to individuals within terrestrial wildlife populations across Zone G is acceptable.

A sublethal TRV is also identified, representing the threshold for sublethal effects. Sublethal effects are defined as those that impair or prevent reproduction, growth, or survival. Therefore, sublethal TRVs are based on the lowest observed adverse effect level (LOAEL) for the most closely related test species. The sublethal TRV represents the measurement endpoint chosen as the basis for establishing risk.

Vegetation

Toxicity to terrestrial plants from soil contaminants detected within the subzones is qualitatively evaluated. Risk potentials are discussed relative to literature studies and general information on phytotoxic mechanisms by selected ECPCs.

Table 8.8
Zone G
Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Study	Organisms	Measured Parameter	Effects Level	Measured Response
Parmelee et al. (1993)	nematode/microarthropods	Copper	200 mg/kg	Significant decline in numbers
Neuhauser et al. (1986)	earthworm <i>Eisenia foetida</i>	Copper salts	643 mg/kg	LC ₅₀
		Zinc salts	662 mg/kg	LC ₅₀
		Nickel salts	757 mg/kg	LC ₅₀
		Cadmium salts	1,843 mg/kg	LC ₅₀
		Lead salts	6,000 mg/kg	LC ₅₀
		4-Nitrophenol	38 mg/kg	LC ₅₀
		Fluorene	173 mg/kg	LC ₅₀
		Phenol	401 mg/kg	LC ₅₀
Roberts and Dorrough (1984)	<i>Eisenia foetida</i>	Cadmium chloride	10 - 100 µg/cm ²	LC ₅₀
		Copper sulfate	10 - 100 µg/cm ²	LC ₅₀
		Lead nitrate	10 - 100 µg/cm ²	LC ₅₀
Malecki et al. (1982)*	<i>Eisenia foetida</i>	Cadmium	250 mg/kg	Growth difference to control
		Nickel	440 mg/kg	Growth difference to control
		Copper	1,320 mg/kg	Growth difference to control
		Zinc	2,800 mg/kg	Growth difference to control
		Lead	21,600 mg/kg	Growth difference to control
Strait (1984)	Mite <i>Platynothrus peltifer</i>	Copper	200 mg/kg	Population decrease
van Straalen et al. (1989)	Mites	Cadmium	> 128 mg/kg	Mortality
McKee (1992)	Terrestrial epigeic ³ Invertebrates	PCBs	120,000 mg/kg	No community structure effects

Table 8.8
Zone G
Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Study	Organisms	Measured Parameter	Effects Level	Measured Response
Callahan, et al. (1991)	earthworms <i>L. terrestris</i>	DDT	400 µg/kg	No detectable concentration in tissue from soil concentrations
		DDD	700 µg/kg	
		DDE	200 µg/kg	
Menzie et al. (1992)	<i>E. foetida</i>	DDT	1,000 (4,000) ^o µg/kg	Survival; no effect for LC ₅₀ test
		DDD	1,000 [12,000] ^o µg/kg	
		DDE	1,000 (2,000) ^o µg/kg	
Miller et al. (1985)	Earthworm	Copper	644 mg/kg	EC ₅₀
		Zinc	628 mg/kg	EC ₅₀
	Microtox (15 min.)	Copper	0.28 - 0.42 mg/kg	Photo reduction
		Zinc	1.6 mg/kg	Photo reduction
Paine et al. (1993)	Crickets <i>Acheta domesticus</i>	PCBs	1,200 mg/kg	LC ₅₀
Reinecke and Nash (1984)	Earthworms <i>Allolobophora caliginosa</i> <i>Lumbricus rubellus</i>	Dioxin	< 5 mg/kg	No mortality
			> 10 mg/kg	Lethality
Ma (1984)	<i>Lumbricus rubellus</i>	Copper	100 - 150 mg/kg	Cocoon production decrease
		Copper	300 mg/kg	Mortality
Beyer et al. (1985)	<i>Eisenia foetida</i>	Methyl Mercury	25 mg/kg	100% mortality
			5 mg/kg	21% mortality
Abbasi and Soni (1983)	Earthworm <i>Octochaetus pattoni</i>	Inorganic Mercury	0.79 mg/kg	50% mortality
			5 mg/kg	100% mortality
Rhett et al. (1988)	<i>Eisenia foetida</i>	PCBs	240 mg/kg	LC ₅₀

Table 8.8
Zone G
Chemical Effects Studies on Terrestrial Infaunal Invertebrates

Study	Organisms	Measured Parameter	Effects Level	Measured Response
Nielson (1951)	earthworms	Copper	150 mg/kg	Population reduced by 0.5
			260 mg/kg	Population eliminated
Van Rhee (1967)	earthworms	Copper	85 mg/kg	Gradual decline of population
Ma (1982)	<i>Lumbricus rubellus</i>	Copper chloride	1,000 mg/kg	6-wk LC ₅₀

Notes:

- a = Growth effects levels are average of at least five of six compounds: metal acetate; metal carbonate; metal chloride; metal nitrate; metal oxide, metal sulfate
- b = Aboveground species including Carabidae, Entobeyidae, Formicidae, Gryllidae and Staphylinidae
- c = Average soil concentration levels [maximum values]
- LC₅₀ = Lethal Concentration to 50 percent of test population
- EC₅₀ = Effect concentration to 50 percent of test population

8.8 Risk Characterization

Using the above described techniques to assess ecological effects, risk to potential receptors can be characterized by determining the likelihood that adverse effects will occur as a result of exposure to constituents in subzone soil or sediment.

Aquatic Wildlife

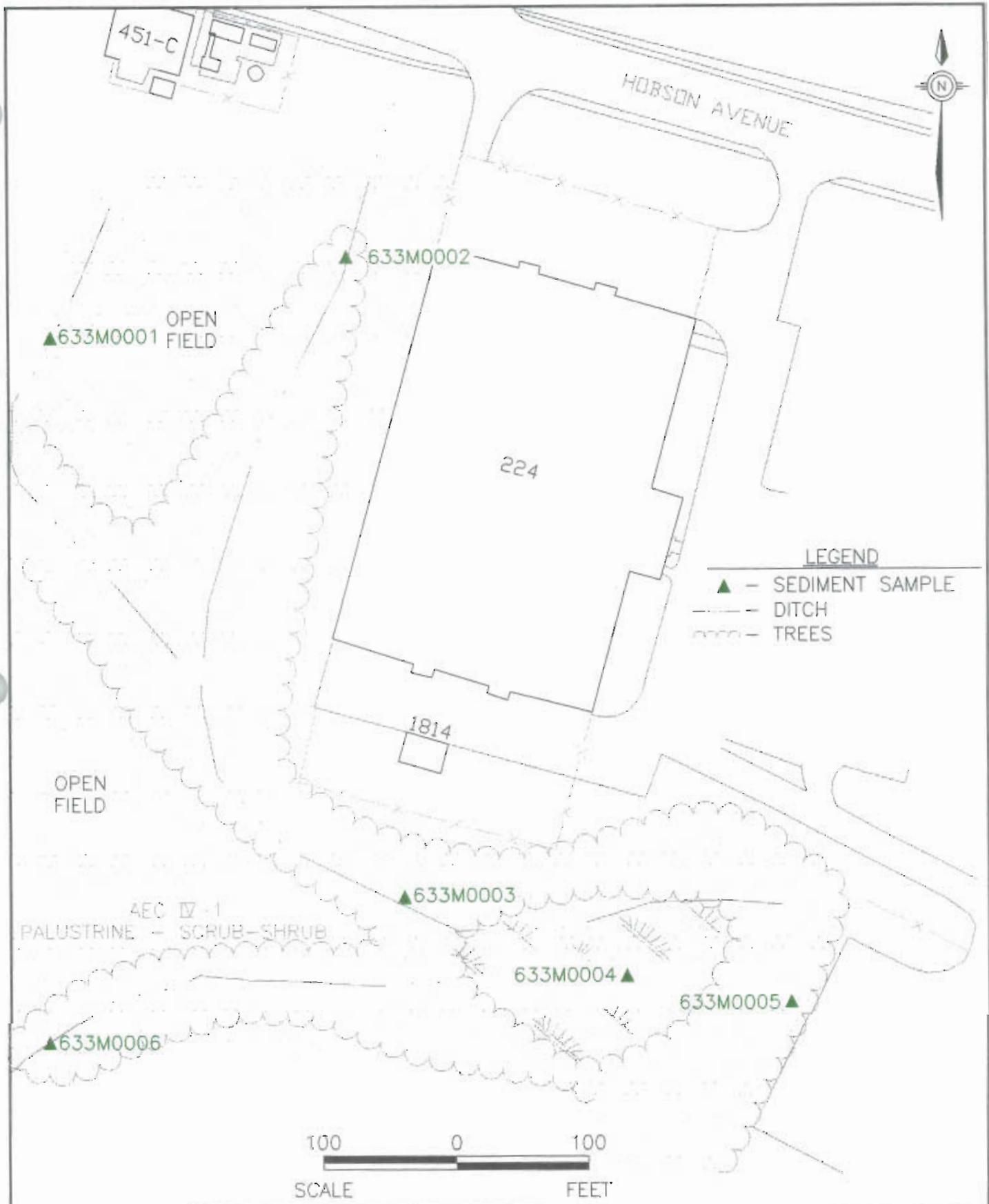
Within the standing water of Subzone G-1, a potential for risk to aquatic wildlife exists based on exceedances of USEPA Region IV Sediment Screening Values (SSVs), which are also represented by the resulting HQ calculations (refer to Tables 8.3 and 8.4). Sediment HQs greater than one, but less than 10, were calculated for antimony, arsenic, cadmium, chromium, mercury, nickel, fluoranthene, pyrene, Aroclor-1260, 4,4'-DDD, and 4,4'-DDT. HQs greater than 10, indicating moderate risk, were calculated for copper (65.2), lead (13.0) zinc (26.3), bis(2-ethylhexyl)phthalate (18.9), alpha-chlordane (50.6), gamma-chlordane (76.5), and 4,4'-DDE (10.3). These HQs were calculated using the maximum detected concentrations.

Inorganics – Elevated concentrations of inorganics in Subzone G-1 sediment appear to be present throughout the subzone. Subzone G-1 sample locations are depicted on Figure 8-4 and are the easternmost samples collected in the subzone. Actual impacts to the benthic organism at Subzone G-1 would require measurement of tissue concentrations or insitu bioaccumulation studies.

Infaunal Invertebrates

The risk characterization for terrestrial infaunal invertebrates was determined through the comparison of the detected concentrations to the effects levels presented in Table 8.8.

Most toxicological information reviewed for the subzone-specific infaunal invertebrates assessment dealt with earthworms and other infaunal species. It is important to note that soil found in both



ZONE G
RCRA FACILITY
INVESTIGATION REPORT
NAVAL BASE, CHARLESTON
CHARLESTON, S.C.

FIGURE 8-4
SUBZONE G-1
SAMPLE LOCATIONS

DWG DATE: 01/15/98

DWG NAME: 2907SGSL

subzones is predominantly sand and may not support these specific organisms. Although infaunal species found in the sandy environment may not be the same as those dealt with in the literature, the ecological niche which they occupy should be similar; therefore, comparison to toxicological concentrations should apply.

SVOCs — Although some soil-borne semivolatiles are considered carcinogenic to mammals, very few field studies exist on their toxicity to terrestrial infauna. Of those studies presented on Table 8.8, only one involved SVOCs and only one of the SVOCs studied (fluorene) was an ECPC for Zone G soil. The artificial soil tests conducted by Neuhauser et al. (1986) produced an LC₅₀ value for fluorene of 173 mg/kg which is slightly exceeded by the maximum concentration detected in Subzone G-2 surface soil (200 mg/kg). Fluorene is considered to be acutely toxic at certain concentrations but it is not considered a carcinogen. Generally, PAHs break down in natural systems via photodegradation and microbial transformation. Field variability and soil chemical matrices can greatly influence toxicological effects of PAH compounds.

Pesticides — Most toxicological studies on terrestrial infaunal organisms have been directed at measuring pesticide effects. Earthworm toxicology and response information is the most prevalent. Investigators agree that earthworms can accumulate pesticides to concentrations found in residence soil. Callahan also found that chlordane, as other pesticides, was taken up rapidly by earthworms and that total DDT concentrations over 1,000 µg/kg in soil, along with documented long half-life information (5.7 years for DDT), indicated a long-term significant risk to receptors. At Subzone G-2, the maximum concentration of DDT in surface soil was 36 µg/kg.

PCBs — Risk factors associated with PCBs are similar to those for pesticides. After acute mortality, food chain biomagnification and transfer are the most important issues considered when assessing long-term risk. Paine et al. (1993) suggested a benchmark value between 100 to 300 mg/kg PCB for mortality in terrestrial insects. Also, Rhett et al. (1988) observed LC₅₀ values

for earthworms treated with PCBs at 240 mg/kg. McKee (1992) reported that soil invertebrate community structure was not reduced by exposure to PCB-contaminated soil (maximum concentrations to 120,000 mg/kg wet weight) based on family level classification of invertebrates. The maximum PCB concentrations at Subzone G-2 was 180 $\mu\text{g}/\text{kg}$ of Aroclor-1260 and 210 $\mu\text{g}/\text{kg}$ of Aroclor-1016.

Dioxins — Reinecke and Nash (1984) studied the toxic effects of dioxin (2,3,7,8-TCDD) in soil to earthworms. For two species, *Allolobophora caliginosa* and *Lumbricus rubellus*, concentrations of 5 mg/kg or less had no acute effect, but concentrations of 10 mg/kg and above were lethal. Soil at Subzone G-2 contained several dioxin congeners, the maximum being 68.9 ng/kg 1,2,3,4,6,7,8-HpCDD) which is 0.000068.9 mg/kg.

Inorganics — Most studies on metals toxicity to terrestrial receptors have been directed at infaunal ecosystems or avian biology. Information on relative metal toxicities to earthworms was provided by Roberts and Dorough (1984) where, along with 90 other chemicals, three metal salts (cadmium chloride, copper sulfate, and lead nitrate) were tested. The results showed that these heavy metal salts fell into the "very toxic" category, with LC_{50} values in the 10 to 100 micrograms per square centimeter ($\mu\text{g}/\text{cm}^2$) range. Although these concentrations (more specifically, application doses) may be relative to earthworms, it is improper to apply them to upper-level trophic species. Studies indicate that some degradation products become increasingly more toxic to earthworms and less toxic to upper-level vertebrates.

Other studies on toxicities of metal salts to earthworms have been conducted by Neuhauser et al. (1986) and Malecki et al. (1982). In the former study, metal nitrate compounds were relatively toxic to earthworms in this order: copper > zinc > nickel > cadmium > lead. Mean LC_{50} values were 643, 662, 757, 1,843 and 6,000 mg/kg, respectively. In the latter study, six chemical forms of each metal were chosen to cover a broad range of solubility and to represent the forms

likely to be found in the soil. Overall, cadmium was most toxic, followed by nickel, copper, zinc, and lead. It appears obvious from the results of these two studies that the form of the metal in soil is a major consideration in judging effects of their concentrations on soil biota.

For copper, Ma (1984) investigated sublethal effects of copper in soil to growth, cocoon production, and litter breakdown activity for *Lumbricus rubellus*. Cocoon and litter breakdown activity were significantly reduced at 131 mg/kg of copper, and mortality was first observed at concentrations near 300 mg/kg. Parmelee et al. (1993) found that total nematode/microarthropod (mostly mites) numbers declined in soil having copper concentrations above 200 mg/kg; omnivore-predator nematodes and specific microarthropod groups were significantly reduced at 100 mg/kg copper.

The highest copper concentration in surface soil at Subzone G-2 is 221 mg/kg, which is below the background concentration of 260 mg/kg, but available effect levels in literature indicate a potential for adverse effects to terrestrial infauna. Based on the available information, no other inorganics are at concentrations that would indicate potential risk to infaunal species.

Terrestrial Wildlife

Risks for the representative wildlife species at the terrestrial Subzone G-2 are associated with ingestion of surface soil and food and are quantitatively evaluated using HQs and HIs. The HQs are calculated for each ECPC by dividing the PDE concentration by the TRV. When the estimated PDE is less than the TRV ($HQ < 1$), the contaminant exposure is assumed to fall below the range considered to be associated with adverse effects for growth, reproduction, and survival, and no risks to the wildlife populations are assumed. When the HQ is greater than one, the ecological significance is discussed and risk is assumed. To estimate cumulative risk for each species, the HQs calculated for each ECPC is summed, producing a HI.

PDEs were only generated for Zone G ECPCs. Using the model for prediction of contaminant exposure presented in Table 8.7, PDE values were obtained. HQs and HIs for both lethal and sublethal effects for ECPCs at Subzone G-2 were then determined and presented in Tables 8.9 and 8.10, respectively. For representative terrestrial wildlife species, PDEs were calculated using available bioaccumulation data presented in Table 8.11. Exposure parameters and assumptions for representative species in Subzone G-2 used to calculate food contaminant concentrations are presented in Table 8.12. To make this section more readable, Tables 8.9 through 8.12 are included at the end of this section.

The HQ and HI values calculated for lethal effects to selected species from soil contamination in Subzone G-2 were all less than one (see Table 8.9). As shown in this table, no potential for lethal effects to wildlife exist as a result of exposure to ECPCs in surface soil. Potential sub-lethal effects to wildlife species associated with maximum exposure concentrations of ECPCs in soil are indicated by HQ calculations (see Table 8.10).

Based on the model prediction, exposure to elevated arsenic concentration in soil at Subzone G-2 creates a potential sub-lethal effect to small mammals. The sub-lethal HQ calculated for the short-tailed shrew from arsenic in soil is 4.99. A potential sub-lethal effect to passerine birds from exposure to elevated mercury concentration in soil also exists at Subzone G-2. The sub-lethal HQ calculated for the American robin from mercury in soil is 1.63. This prediction of low sub-lethal risk to carnivorous mammals and birds appears to be accurate in relation to literature information. Uptake of metals by soil invertebrates, such as earthworms, to levels equal to soil concentrations has been shown (Neuhauser et al., 1985) and earthworms have been shown to be an important food item of the American robin (McDonald, 1983) and shrew (Whitaker and Ferraro, 1963). Based on the maximum mercury and arsenic concentration found in Subzone G-2, birds and mammals preying on soil infaunal species could be at risk. In situ bioaccumulation studies would help reduce any uncertainty inherent in the model prediction.

All sub-lethal HQ and HI values calculated for the cottontail rabbit for potential effects from soil contamination in Subzone G-2 were less than one.

Vegetation

Limited information exists on toxic effects of soil contamination to plants in natural environments. Most literature containing effects information deals with herbicide or fungicide application programs. Beyer, et al. (1985) demonstrated that only a small portion of all metals measured in soil became incorporated in plant foliage. In their study, the origin for plant metal residues was suggested to have come primarily from aerial deposition. Table 8.13 (also at the end of this section) presents phytotoxic effects levels for arsenic, copper, lead and zinc for several species. Of these four metals, only lead was identified as an ECPC for surface soil in Subzone G-2. The reported effect levels for copper and zinc were also exceeded. Effects levels vary depending on specific soil physico-chemical conditions such as pH, organic content, and cation-exchange-capacity.

Inorganics – Like other metals, the bioavailability of lead in soil to plants is enhanced by reduced soil pH, reduced organic matter, and reduced iron oxides and phosphorous content (NRCC, 1973). Studies have shown that there is no convincing evidence that terrestrial vegetation is important in food chain biomagnification of lead (USEPA, 1985a). The maximum concentration of lead detected at Subzone G-2 is 1,100 mg/kg, exceeding both effect levels found in literature for uptake of lead (500 mg/kg) and reduced germination rates (800 mg/kg) in test species.

The phytotoxic nature of copper to crop production has been studied relative to application rates (Hirst, et al., 1961). Although not a ECPC, copper's maximum concentration in Subzone G-2 surface soil was 221mg/kg, well above the 47 mg/kg effect level reported by Miller et al. (1985).

Since the background concentration for zinc is 519 mg/kg, the highest concentration of zinc detected in Subzone G-2 (238 mg/kg) did not warrant ECPC classification, but it did exceed the effect levels (53 mg/kg and 61 mg/kg) reported by Miller et al. (1985) to limit seed germination.

Organics — Specific vegetation effect levels for organics were not available, so a quantitative assessment could not be made. There have been studies conducted which offer some general information on the interactions of organic compounds with vegetation.

Studies by USEPA (1980), Lee and Grant (1981), Wang and Meresz (1982) and Edwards (1983) generally conclude the following characteristic of PAHs exposure to plants. Lower molecular weight compounds are absorbed more readily than higher molecular weight compounds. It was also observed that above-ground parts of plants have higher residue levels, which is most likely attributable to airborne deposition, but even with known exposure, PAH-induced phytotoxic effects are rare. It was also observed that higher plants can catabolize benzo(a)pyrene and possibly other PAH compounds. These and other conditions make biotransfer of PAHs from exposed plants to terrestrial herbivores an unlikely pathway.

For PCBs, Klekowski (1982) suggested that, after studying a PCB-contaminated site in Massachusetts, there was no evidence of genetic damage to terrestrial plants. Isensee and Jones (1971) indicated that dioxins were less readily taken up by terrestrial plants compared to aquatic plants, and studies by Blair (1973) and Ramel (1978) considered uptake of 2,3,7,8-TCDD from soils by vegetation to be negligible. Eisler (1990) noted that there was little information available on phytotoxicity of chlordane and that there was little evidence to indicate accumulation by crop plants. In soils, chlordane is mostly immobile and there is only a limited capacity for translocation into edible portions of food crops (NRCC, 1975).

8.9 Uncertainty

General uncertainties are associated with the ERA for Zone G. In order to provide a quantitative perspective to these, a plus (+) or minus (-) is associated with each uncertainty, suggesting whether the uncertainty most likely resulted in an over-estimation or underestimation of risk. When both signs are given, the uncertainty has the potential to either over- or underestimate risk.

- Degradation of chemicals has not been considered in the ECPC selection process (+)
- Specific effects to biota within the area are unknown (+/-)
- Acute and chronic effects data on some ECPCs were unavailable (-)
- Synergistic or antagonistic effects cannot be quantified (+/-)
- For some ECPCs, only assumptions relative to similar compounds or classes of elements can be made (+/-)
- Use of related species for risk determination may not correlate to risk for selected representative wildlife species (-)
- Dermal or inhalation exposure pathways were not evaluated (-)
- Maximum exposure scenarios and concentrations may tend to overestimate risk potentials (+)
- On occasion, BAFs were assumed due to lack of information (+/-)

- Actual occurrence of selected wildlife species within the contaminated area is uncertain, but was assumed at 100% (+) 1
2
- Ingestion rates in food chain analyses may be a source of uncertainty to exposure (+/-) 3
- Sediment screening values are obtained from laboratory studies and may not reflect field-based exposure scenarios (+) 4
5

8.10 Risk Summary 6

Risks to ecological receptors were evaluated for ECPCs in sediment at Subzone G-1 and in soil at Subzones G-2. Risk associated with exposure to ECPCs in Subzone G-2 surface soil was evaluated for terrestrial wildlife based on a model that predicts the contaminant exposure via diet and incidental ingestion of soil. The risk evaluation is based on a comparison of predicted doses for representative wildlife species representing thresholds for both lethal and sublethal effects (TRVs). Risks to soil invertebrates and plants were evaluated based on qualitative comparisons to literature effects levels for taxonomic groups similar to those potentially occurring at Zone G. Risks for aquatic wildlife were quantified by calculating HQs from benchmark values that are either promulgated or proposed by federal and state regulatory agencies. 7
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Aquatic Wildlife — Potential risk exists to the aquatic communities in throughout Subzone G-1 based on the sediment concentrations reported for antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, bis(2-ethylhexyl)phthalate, fluoranthene, pyrene, Aroclor-1260, alpha-chlordane, gamma-chlordane, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT. 16
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Terrestrial Wildlife — No risk potential for lethal effects to terrestrial wildlife exist based on soil ECPCs within Subzone G-2. All HQ and HI values calculated for each of the representative wildlife species were less than one. 20
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Potential sublethal effects exist for both small carnivorous mammals and passerine birds from exposure to arsenic and mercury in soil at G-2. Although literature information appears to be accurate and supportive of the model, insitu bioaccumulation studies at both sites would help reduce the uncertainty inherent in the model predictions.

Vegetation — A potential risk to woody seedlings and young herbaceous species exists from metal contamination observed in Subzone G-2 soil. Copper, lead, and zinc concentrations were above effects levels reported in literature. Effects from organic concentrations could not be assessed. The actual effects of site constituents to vegetation in G-1 can not be determined because of limited studies for accumulation of contaminants by aquatic plants growing in sediment.

Table 8.9
Zone G
Hazard Quotients for Potential LETHAL Effects for Wildlife Species Associated with
Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Volatile Organics Compounds										
2-Butanone	0.007	NC	NA	NC	NC	NA	NC	NC	NA	NC
1,2,3-Trichloropropane	0.006	NC	NA	NC	NC	NA	NC	NC	NA	NC
Benzene	0.003	NC	NA	NC	NC	NA	NC	NC	NA	NC
Carbon Disulfide	0.002	NC	NA	NC	NC	NA	NC	NC	NA	NC
Chlorobenzene	0.006	NC	NA	NC	NC	NA	NC	NC	NA	NC
Trichloroethene	0.004	NC	NA	NC	NC	NA	NC	NC	NA	NC
Semivolatile Organics Compounds										
2-Methylnaphthalene	0.120	NC	NA	NC	NC	NA	NC	NC	NA	NC
4-Methylphenol (<i>p</i> -Cresol)	0.052	NC	NA	NC	NC	NA	NC	NC	NA	NC
Acenaphthene	0.200	NC	NA	NC	NC	NA	NC	NC	NA	NC
Acenaphthylene	0.045	NC	NA	NC	NC	NA	NC	NC	NA	NC
Anthracene	0.410	NC	NA	NC	NC	NA	NC	NC	NA	NC
Benzo(a)anthracene	1.000	NC	NA	NC	NC	NA	NC	NA	NA	NC
Benzo(a)pyrene	0.890	1.47E -02	NA	NC	2.47E -03	1.00E	2.47E -04	1.58E -02	1.00E +01	1.58E -03
Benzo(b)fluoranthene	1.400	2.65E -02	NA	NC	3.52E -03	NA	NC	2.45E -02	NA	NC
Benzo(g,h,i)perylene	0.680	1.08E -02	NA	NC	1.49E -03	NA	NC	1.12E -02	NA	NC
Benzo(k)fluoranthene	0.580	1.50E -02	NA	NC	1.77E -03	NA	NC	1.20E -02	NA	NC
Benzoic Acid	0.170	NC	NA	NC	NC	NA	NC	NC	NA	NC
Bis(2-ethylhexyl)phthalate	0.190	2.72E -03	NA	NC	8.01E -05	6.80E	1.18E -08	3.69E -03	1.60E +02	2.31E -05
Chrysene	1.200	1.76E -02	NA	NC	3.87E -03	NA	NC	2.11E -02	NA	NC

Table 8.9
Zone G
Hazard Quotients for Potential LETHAL Effects for Wildlife Species Associated with
Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Dibenz(a,h)anthracene	0.320	NC	NA	NC	NC	NA	NC	NC	NA	NC
Dibenzofuran	0.100	NC	NA	NC	NC	NA	NC	NC	NA	NC
Fluoranthene	1.700	2.30E +02	NA	NC	7.36E -03	4.00E +02	1.84E -06	2.59E -02	NA	NC
Fluorene	0.200	NC	NA	NC	NC	NA	NC	NC	NA	NC
Indeno(1,2,3-cd)pyrene	0.560	NC	NA	NC	NC	NA	NC	NC	NA	NC
Naphthalene	0.160	NC	NA	NC	NC	NA	NC	NC	NA	NC
N-nitrosodiphenylamine	0.075	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenanthrene	2.400	NC	NA	NC	NC	NA	NC	NC	NA	NC
Pyrene	2.600	3.15E -02	NA	NC	1.26E -02	5.40E +02	2.33E -05	4.31E -02	1.60E +02	2.69 E-04
Pesticides/PCBs										
4,4'-DDD	0.012	NC	NA	NC	NC	NA	NC	NC	NA	NC
4,4'-DDE	0.058	1.95E -02	NA	NC	2.17E -04	1.60E +02	1.36E -06	6.99E -03	1.40E +02	4.99E -05
4,4'-DDT	0.036	1.21E -02	8.00E +02	1.51E -05	1.35E -04	5.00E +01	2.70E -06	4.34E -03	2.70E +01	1.61E -04
Aroclor-1016	0.210	NC	NA	NC	NC	NA	NC	NC	NA	NC
Aroclor-1260	0.180	1.58E -02	NA	NC	3.41E -04	1.00E +02	3.41E -06	1.73E -02	1.00E +02	1.73E -04
Dieldrin	0.0056	7.30E +04	9.60E +00	7.60E -05	2.95E -06	9.00E +00	3.28E -07	1.16E -03	7.60E +00	1.53E -04
Endosulfan II	0.0033	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin	0.015	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin Aldehyde	0.0094	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin Ketone	0.011	NC	NA	NC	NC	NA	NC	NC	NA	NC
Heptachlor	0.013	NC	NA	NC	NC	NA	NC	NC	NA	NC

Table 8.9
Zone G
Hazard Quotients for Potential LETHAL Effects for Wildlife Species Associated with
Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Heptachlor Epoxide	0.0028	NC	NA	NC	NC	NA	NC	NC	NA	NC
Alpha-chlordane	0.039	NC	NA	NC	NC	NA	NC	NC	NA	NC
Gamma-chlordane	0.073	NC	NA	NC	NC	NA	NC	NC	NA	NC
Dioxins										
1234678-HpCDD	0.0001	NC	NA	NC	NC	NA	NC	NC	NA	NC
1234678-HpCDF	0.000002	NC	NA	NC	NC	NA	NC	NC	NA	NC
123478-HxCDF	0.000009	NC	NA	NC	NC	NA	NC	NC	NA	NC
Inorganics										
Antimony	4.2	NC	NA	NC	NC	NA	NC	NC	NA	NC
Arsenic	19.0	1.70E +00	NA	NC	4.15E -02	1.53E +02	2.71E -04	2.89E +00	2.90E +01	9.98E -02
Barium	172	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cadmium	5.1	8.36E -01	NA	NC	1.09E +01	3.00E +01	3.63E -01	8.44E -01	1.78E -01	4.74E -03
Lead	1,100	4.14E +03	4.95E +03	8.16E -03	2.20E +00	NA	NC	4.15E +01	3.00E +02	1.38E -01
Mercury	2.1	1.04E -01	2.50E +00	4.17E -02	8.02E -02	3.60E +00	2.23E -02	1.07E -01	4.40E +00	2.42E -02
Nickel	46.4	NC	NA	NC	NC	NA	NC	NC	NA	NC
Silver	0.42	NC	NA	NC	NC	NA	NC	NC	NA	NC
Thallium	1.06	NC	NA	NC	NC	NA	NC	NC	NA	NC
Tin	10.6	NC	NA	NC	NC	NA	NC	NC	NA	NC
Hazard Index				5.00E +02			3.86E +01			2.69E -01

Notes:

- Max Conc = Maximum Concentration of Analyte
- NA = Data not available
- NC = Not able to calculate value
- PDE = Potential Dietary Exposure (mg/kg/BW) calculated based on equation in Table 8.6
- TRV = Reference Toxicity Value (mg/kg/BW/day) - 1/5 of the lowest reported LD₅₀ value from Appendix G for closest related species
- HQ = Hazard Quotient - PDE divided by the TRV
- HI = Hazard Index (HQ₁ + HQ₂ + ...Hq)

Table 8.10
Zone G
Hazard Quotients for Potential SUB-LETHAL Effects for Wildlife Species Associated with
Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Volatile Organics Compounds										
2-Butanone	0.007	NC	NA	NC	NC	NA	NC	NC	NA	NC
1,2,3-Trichloropropane	0.006	NC	NA	NC	NC	NA	NC	NC	NA	NC
Benzene	0.003	NC	NA	NC	NC	NA	NC	NC	NA	NC
Carbon Disulfide	0.002	NC	NA	NC	NC	NA	NC	NC	NA	NC
Chlorobenzene	0.006	NC	NA	NC	NC	NA	NC	NC	NA	NC
Trichloroethene	0.004	NC	NA	NC	NC	NA	NC	NC	NA	NC
Semivolatile Organics Compounds										
2-Methylnaphthalene	0.120	NC	NA	NC	NC	NA	NC	NC	NA	NC
4-Methylphenol (<i>p</i> -Cresol)	0.052	NC	NA	NC	NC	NA	NC	NC	NA	NC
Acenaphthene	0.200	NC	NA	NC	NC	NA	NC	NC	NA	NC
Acenaphthylene	0.045	NC	NA	NC	NC	NA	NC	NC	NA	NC
Anthracene	0.410	NC	NA	NC	NC	NA	NC	NC	NA	NC
Benzo(a)anthracene	1.000	NC	NA	NC	NC	NA	NC	NA	NA	NC
Benzo(a)pyrene	0.890	1.47E -02	NA	NC	2.47E -03	1.00E +01	2.47E -04	1.58E -02	4.00E +01	2.50E -01
Benzo(b)fluoranthene	1.400	2.65E -02	NA	NC	3.52E -03	NA	NC	2.45E -02	NA	NC
Benzo(g,h,i)perylene	0.680	1.08E -02	NA	NC	1.49E -03	NA	NC	1.12E -02	NA	NC
Benzo(k)fluoranthene	0.580	1.50E -02	NA	NC	1.77E -03	NA	NC	1.20E -02	NA	NC
Benzoic Acid	0.170	NC	NA	NC	NC	NA	NC	NC	NA	NC
Bis(2-ethylhexyl)phthalate	0.190	2.72E -03	NA	NC	8.01E -05	3.50E +01	2.29E -06	3.69E -03	5.00E +01	7.39E -05
Chrysene	1.200	1.76E -02	NA	NC	3.87E -03	NA	NC	2.11E -02	NA	NC

Table 8.10
Zone G
Hazard Quotients for Potential SUB-LETHAL Effects for Wildlife Species Associated with
Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Dibenz(a,h)anthracene	0.320	NC	NA	NC	NC	NA	NC	NC	NA	NC
Dibenzofuran	0.100	NC	NA	NC	NC	NA	NC	NC	NA	NC
Fluoranthene	1.700	2.30E -02	NA	NC	7.36E -03	4.00E +02	1.84E -06	2.59E -02	NA	NC
Fluorene	0.200	NC	NA	NC	NC	NA	NC	NC	NA	NC
Indeno(1,2,3-cd)pyrene	0.560	NC	NA	NC	NC	NA	NC	NC	NA	NC
Naphthalene	0.160	NC	NA	NC	NC	NA	NC	NC	NA	NC
N-nitrosodiphenylamine	0.075	NC	NA	NC	NC	NA	NC	NC	NA	NC
Phenanthrene	2.400	NC	NA	NC	NC	NA	NC	NC	NA	NC
Pyrene	2.600	3.15E -02	NA	NC	1.26E -02	NA	NC	4.31E -02	NA	NC
Pesticides/PCBs										
4,4'-DDD	0.012	NC	NA	NC	NC	NA	NC	NC	NA	NC
4,4'-DDE	0.058	1.95E -02	5.80E -01	3.36E -02	2.17E -04	NA	NC	6.99E -03	1.40E +02	4.99E -05
4,4'-DDT	0.036	1.21E -02	1.40E -02	8.63E -02	1.35E -04	1.50E +02	8.99E -07	4.34E -03	8.10E +01	5.36E -05
Aroclor-1016	0.210	NC	NA	NC	NC	NA	NC	NC	NA	NC
Aroclor-1260	0.180	1.58E -02	NA	NC	3.41E -04	6.40E +00	5.33E -05	1.73E -02	7.40E +01	2.34E -04
Dieldrin	0.0056	7.30E -04	NA	NC	2.95E -06	NA	NC	1.16E -03	3.30E -01	3.57E -03
Endosulfan II	0.0033	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin	0.015	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin Aldehyde	0.0094	NC	NA	NC	NC	NA	NC	NC	NA	NC
Endrin Ketone	0.011	NC	NA	NC	NC	NA	NC	NC	NA	NC
Heptachlor	0.013	NC	NA	NC	NC	NA	NC	NC	NA	NC

Table 8.10
Zone G
Hazard Quotients for Potential SUB-LETHAL Effects for Wildlife Species Associated with
Maximum Exposure Concentrations of ECPCs in Soil at Subzone G-2

Analyte	Max Conc (mg/kg)	American Robin			Eastern Cottontail Rabbit			Short-tailed Shrew		
		PDE	TRV	HQ	PDE	TRV	HQ	PDE	TRV	HQ
Heptachlor Epoxide	0.0028	NC	NA	NC	NC	NA	NC	NC	NA	NC
Alpha-chlordane	0.039	NC	NA	NC	NC	NA	NC	NC	NA	NC
Gamma-chlordane	0.073	NC	NA	NC	NC	NA	NC	NC	NA	NC
Dioxins										
1234678-HpCDD	0.0001	NC	NA	NC	NC	NA	NC	NC	NA	NC
1234678-HpCDF	0.000002	NC	NA	NC	NC	NA	NC	NC	NA	NC
123478-HxCDF	0.000009	NC	NA	NC	NC	NA	NC	NC	NA	NC
Inorganics										
Antimony	4.2	NC	NA	NC	NC	NA	NC	NC	NA	NC
Arsenic	19.0	1.71E +00	NA	NC	4.15E -02	NA	NC	2.89E +00	5.80E +01	4.99E +00
Barium	172	NC	NA	NC	NC	NA	NC	NC	NA	NC
Cadmium	5.1	8.36E -01	1.00E +01	8.36E -02	1.09E +01	2.20E +01	4.95E -01	8.44E -01	4.48E +02	1.88E -03
Lead	1,100	4.14E +03	1.30E +02	3.11E -01	2.20E +00	5.20E +02	4.23E -03	4.15E +01	3.00E +02	1.38E -01
Mercury	2.1	1.04E -01	6.40E -02	1.63E +00	8.02E -02	5.00E -01	1.60E -01	1.07E -01	5.00E -01	2.13E -01
Nickel	46.4	NC	NA	NC	NC	NA	NC	NC	NA	NC
Silver	0.42	NC	NA	NC	NC	NA	NC	NC	NA	NC
Thallium	1.06	NC	NA	NC	NC	NA	NC	NC	NA	NC
Tin	10.6	NC	NA	NC	NC	NA	NC	NC	NA	NC
Hazard Index				2.14E +01			6.60E -01			5.60E +00

Notes:

- Max Conc** = Maximum Concentration of Analyte
- NA** = Data not available
- NC** = Not able to calculate value
- PDE** = Potential Dietary Exposure (mg/kg/BW) calculated based on equation in Table 8.6
- TRV** = Reference Toxicity Value (mg/kg/BW/day) - lowest reported LOAEL value from Appendix G for closest related species
- HQ** = Hazard Quotient - PDE divided by the TRV
- HI** = Hazard Index ($HQ_1 + HQ_2 + \dots Hq$)
- Bold** = $HQ > 1$ and indicates potential risk

Table 8.11
Zone G
Bioaccumulation Data¹
Ecological Risk Assessment

Analyte	Log K_{ow}	Plant	Bioaccumulation Factors (BAFs)		
			Terrestrial Invertebrate	Mammal	Bird
Semivolatile Organic Compounds					
Anthracene	4.4 [c]	NA	0.005 [d]	6.30E-04 [a]	1 [ab]
Benzo(a)anthracene	5.74 [c]	0.019 [e]	0.0125 [d]	1.38E-02 [a]	1 [ab]
Benzo(a)pyrene	6.07 [c]	0.012 [e]	0.0342 [d]	2.95E-02 [a]	1 [ab]
Benzo(b)fluoranthene	6.32 [c]	0.008 [e]	0.032 [d]	5.25E-02 [a]	1 [ab]
Benzo(g,h,i)perylene	7 [c]	0.003 [e]	0.024 [d]	2.50E-01 [a]	1 [ab]
Benzo(k)fluoranthene	6.45 [c]	0.007 [e]	0.025 [d]	7.08E-02 [a]	1 [ab]
Bis(2-ethylhexyl)phthalate	5.3 [f]	0.033 [e]	0.022 [aj]	5.00E-03 [a]	1 [ab]
Butylbenzylphthalate	4.78 [g]	0.049 [e]	0.022 [aj]	1.50E-03 [a]	1 [ab]
Chrysene	5.71 [c]	0.019 [e]	0.031 [d]	1.29E-02 [a]	1 [ab]
Dibenzo(a,h)anthracene	6.42 [c]	0.008 [e]	0.022 [aj]	6.61E-02 [a]	1 [ab]
Di-n-butylphthalate	4.8 [h]	NA	0.022 [aj]	1.60E-03 [a]	1 [ab]
Fluoranthene	5.25 [c]	0.036 [e]	0.007 [d]	4.50E-03 [a]	1 [ab]
Indeno(1,2,3-cd)pyrene	7.7 [c]	0.0014 [e]	0.042 [d]	1.26E+00 [a]	1 [ab]
Phenanthrene	4.43 [c]	NA	0.012 [d]	6.70E-04 [a]	1 [ab]
Pyrene	5.09 [c]	0.044 [e]	0.018 [d]	3.10E-03 [a]	1 [ab]
Pesticides/PCBs/Dioxins					
Aroclor-1248	6 [c]	0.013 [e]	1.2 [i]	1.00E+00 [ak]	1 [ab]
Aroclor-1254	6.02 [c]	0.013 [e]	1.2 [i]	1.00E+00 [ak]	1 [ab]
Aroclor-1260	6 [c]	0.013 [e]	1.2 [ii]	1.00E+00 [ak]	1 [ab]

Table 8.11
 Zone G
 Bioaccumulation Data¹
 Ecological Risk Assessment

Analyte	Log K _{ow}	Plant	Bioaccumulation Factors (BAFs)		
			Terrestrial Invertebrate	Mammal	Bird
alpha-Chlordane	2.78 [f]	0.027 [ac]	0.8 [j]	7.10E-01 [ak]	0.71 [ai]
gamma-Chlordane	3.32 [f]	0.027 [ac]	0.8 [j]	7.10E-01 [ak]	0.71 [ai]
4,4'-DDE	5.69 [f]	0.02 [e]	0.98 [v]	2.91E+00 [ak]	2.91 [ll]
4,4'-DDT	4.48 [f]	0.027 [ac]	0.98 [v]	2.91E+00 [ak]	2.91 [ll]
Dieldrin	4.95 [f]	0.049 [e]	1.2 [m]	7.10E-01 [ak]	0.71 [n]
2,3,7,8 TCDD	6.80 [am]	0.005 [e]	5.0 [b]	8.40E-01 [an]	1 [ab]
Inorganics					
Arsenic	NA	0.3 [p]	0.77 [ae]	3.60E-01 [ag]	0.45 [ah]
Barium	NA	0.56 [ag]	0.77 [ae]	3.40E-01 [af]	0.45 [ah]
Cadmium	NA	33 [q]	1.4 [k]	2.06E+00 [r]	0.38 [s]
Copper	NA	0.78 [t]	0.16 [i]	6.00E-01 [q]	0.45 [ah]
Lead	NA	0 [q]	0.22 [u]	5.40E-01 [w]	0.45 [ah]
Manganese	NA	0.56 [ag]	0.77 [ae]	3.40E-01 [ag]	0.45 [ah]
Mercury	NA	0.56 [ag]	0.34 [x]	1.00E-02 [aa]	2.33 [ae]
Selenium	NA	0.009 [y]	0.77 [ae]	3.40E-01 [af]	0.51 [z]
Zinc	NA	0.61 [t]	1.77 [i]	2.06E+00 [w]	0.45 [ah]

- Notes:**
- [a] = Calculated using the following equation (Travis and Arms, 1988), unless otherwise noted: $\log \text{BAF} - \log K_{ow} - 7.6$; result multiplied by average of ingestion rates for non-lactating and lactating test animals. There is an uncertainty involved in using this equation for PAHs, because this study did not use any PAHs in the regression analysis
 - [b] = Reinecke and Nash (1984)
 - [c] = Geometric mean of values from USEPA (1986b)
 - [d] = Marquerie et al. (1987). Mean of values. Converted to wet weight assuming 90% body weight as water
 - [e] = Calculated using the following equation in Travis and Arms (1988) for analytes with $\log K_{ow} > 5$: $\log (\text{Plant Uptake Factor}) = 1.588 - 0.578 \log K_{ow}$
 - [f] = From USEPA (1986)
 - [g] = Value from Verschueren (1983)
 - [h] = Value from Howard (1990)
 - [i] = Bioconcentration factor for earthworms from Diercxsens, et al. (1985)
 - [j] = Value from Gish (1970)
 - [k] = Mean of values reported for soil invertebrates in Macfadyen (1980) converted from dry weight to wet weight
 - [l] = Whole body pheasant BAF for 4,4'-DDT, derived from Kenaga (1973)
 - [m] = Average of values reported for soil invertebrates in Edwards and Thompson (1973)
 - [n] = Jeffries and Davis (1968)
 - [o] = Value reported for endrin from Gish (1970)
 - [p] = Average of BAF values reported from Wang et al. (1984), Sheppard et al. (1985) and Merry et al. (1986)
 - [q] = Levine et al. (1989)
 - [r] = Mean of values reported for *Sorex araneus* in Macfadyen (1980)
 - [s] = Based on accumulation of cadmium in kidneys of European quail in Pimentel et al. (1984)
 - [t] = Median of values reported from Levine et al. (1989)
 - [u] = Geometric mean of BAF values (fresh wt. worm/dry wt. soil) for worms and woodlice (USEPA, 1985a). Fresh weight tissue concentrations calculated assuming 90% body water content
 - [v] = Beyer and Gish (1980) reported dry weight to wet weight ratio
 - [w] = Mean of values for *Microtus agrestis* and *Apodemus sylvaticus* in Macfadyen (1980)
 - [x] = Value from USEPA (1985b) sludge document
 - [y] = Based on reported ratio of selenium in plant tissue and iron fly ash amended soil (Stoewsand et al., 1978)
 - [z] = Based on average of reported ratio of selenium in diet to liver, kidney, and breast tissue of chickens (Ort and Latshaw, 1978)
 - [aa] = USEPA, 1985b
 - [ab] = Assumption
 - [ac] = Assumed value based on average of BAFs calculated for other pesticides and PCBs
 - [ad] = Assumed value based on average of BAFs for Aroclor-1260, alpha-chlordane, 4,4'-DDE, Dieldrin and endrin ketone
 - [ae] = Assumed value based on average of BAFs reported for other metals
 - [af] = Assumed value based on average of reported BAFs for Cd, Cu, Pb and Hg
 - [ag] = Assumed value based on average of reported BAFs for As, Cu, Hg and Zn
 - [ah] = Assumed value based on average of reported BAF values for Cd and Se
 - [ai] = Assumed value based on reported BAF for dieldrin
 - [aj] = Assumed value based on average of BAFs for semivolatiles
 - [ak] = Value for mammal unavailable. Bioaccumulation assumed to be the same as values reported for birds
 - [am] = Polder et al. (1995)
 - [an] = Rose et al. (1976)
 - [ao] = Travis and Arms (1988)
 - [ap] = van Gestel and Ma (1988)
 - NA = Not available
 - 1 = Table adapted from BRA, NAS Cecil Field, Jacksonville, Florida

Table 8.12
Zone G
 Exposure Parameters and Assumptions for Representative Wildlife Species at SubZone G-2

Representative Wildlife Species	Trophic Status	Prey in Diet (%)					Incidental Soil Ingestion (%)	HR (acres)	ED	Site Foraging Frequency	Ingestion Rate (kg/day)	Body Weight (kg)
		Inverts	Plants	Small Mammals	Herpeto-fauna	Small Birds						
American Robin ^a	Small Carnivorous Bird	83	7	0	0	0	10	1.04	1	9.13E-01	0.10	0.077
Eastern Cottontail ^b	Small Herbivorous Mammal	0	97	0	0	0	3	9.3	1	1.02E-01	0.08	1.2
Short-tailed Shrew ^c	Small Carnivorous Mammal	78	12	0	0	0	10	0.96	1	1.00E+00	0.0025	0.018

SITE AREA: 2.15 acres

Notes:

- a = Diet assumptions based on data from Hamilton (1943) and Wheelwright (1986)
 Food ingestion rate (FI) from formula: $FI(kg/day) = 0.0582 W^{0.651} (wg)$ (Nagy, 1987)
 Body weight from Clench and Leberman (1978)
 Home range reflects interpolated values from Howell (1942); and Weatherhead and McRae (1990)
 - b = Diet assumptions based on data from Dusi (1952); and Spencer and Chapman (1986)
 Food ingestion rate (FI) from formula: $FI(kg/day) = 0.0687 \times W^{0.822} (kg)$ (Nagy, 1987)
 Body weight reflects interpolated values from Chapman and Morgan (1973); Pelton and Jenkins (1970)
 Home range reflects interpolated values from Althoff and Storm (1989); and Dixon et al. (1981)
 - c = Diet assumption based on data from Whitaker and Ferraro (1963)
 Food ingestion rate (FI) from formula: $FI(kg/day) = 0.0687 \times w^{0.822} (kg)$ (Nagy, 1987)
 Body weight from Lomolino (1984)
 Home range value from Buckner (1966)
 - ED = Exposure Duration (percentage of year receptor is expected to be found at study area expressed as a factor, i.e., 100% = 1.0)
 - HR = Home Range (acres)
- Site Foraging Frequency is the site area (acres) times ED divided by HR; cannot exceed 1.0

Table 8.13
Zone G
Summary of Chemical Effects Studies on Vegetation

Study	Organisms	Measured Parameter	Effects Level	Measured Response
USEPA (1987)	<i>Acer rubrum</i> , Red Maple	Zinc	100 mg/kg	Lethal to seedlings
USEPA (1987)	<i>Quercus rubra</i> , Oak	Zinc	100 mg/kg	Lethal to seedlings
NRCC (1978)	Canadian crops	Arsenic	25-85 mg/kg	Depressed crop yield
	<i>Oryza sativum</i> , Rice	Arsenic (disodium methylarsenate)	50 mg/kg	75% decrease yield
Sadiq (1985)	Corn plant	Lead	800 mg/kg	No elevated concentration in plants
Krishnaya and Bedi (1986)	<i>Cassia</i> spp., Weeds	Lead	500 mg/kg	90% reduced pollen germination
Miller et al. (1985)	Radish (seed germination)	Copper	47 mg/kg	EC ₅₀
		Zinc	53 mg/kg	EC ₅₀
	Cucumber (see germination)	Copper	55 mg/kg	EC ₅₀
		Zinc	61 mg/kg	EC ₅₀

Notes:

mg/kg = Milligrams per kilogram

EC₅₀ = Effect concentration to 50 percent of test population

9.0 CORRECTIVE MEASURES

9.1 Introduction

According to condition IV.E.1 of the NAVBASE RCRA Part B Permit (SCDHEC, May 4, 1990), SCDHEC will review the final RFI report and notify NAVBASE of the need for further investigations, corrective actions, corrective action studies, or plans to meet the requirements of R.61-79.264.101, South Carolina Hazardous Waste Rules, which outline regulations for correction actions for SWMUs. This section of the RFI report is in response to SCDHEC’s comment that “the RFI report should discuss whether the extent of contamination has been defined, and proposed recommended actions for the AOCs and SWMUs, such as collection of additional samples, proceed into a CMS, or NFI, whichever is appropriate.” The NAVBASE project team established ALs to assess whether to conduct a CMS at 1E-06 residential risk. The following discusses the overall approach for evaluating a CMS, lists potential remedies, and outlines the steps to be conducted during a CMS. The sites that will require a CMS are discussed in Section 10, Site-Specific Evaluations.

Any CMS at NAVBASE will be conducted according to standard methods presented in the USEPA guidance document, *RCRA Corrective Action Plan* (USEPA, 1994b). The standard methods will be presented in a zone-specific CMS work plan for collecting necessary data, evaluating potential alternatives, and developing a final remedial alternative by establishing a set procedure for evaluation and assessment, as described in the comprehensive CMS work plan.

To establish this procedure, the zone-specific CMS work plan will outline the CMS report and discuss basic elements. The overall structure of the plan will be explained to illustrate the decision-making process. Briefly, the report outline is:

Report Outline	1
• Introduction/Purpose	2
• Description of Current Conditions	3
• Corrective Action Objectives	4
• Identification, Screening, and Development of Corrective Measures Alternatives	5
• Evaluation of a Final Corrective Measures Alternative	6
• Recommendation by a Permittee/Respondent for a Final Corrective Measures Alternative	7
• Public Involvement Plan	8

Each required element will be detailed in the CMS work plan to: 9

- Identify minimum requirements for CMS reports in each area 10
- Define the base pool of technologies to be evaluated for each medium 11
- Define the evaluation process 12
- Identify selection criteria for the final corrective measures alternative 13

Issues to be discussed under each element are: 14

- An activity-specific description of the overall purpose of the CMS for NAVBASE. 15

AOCs and SWMUs at NAVBASE will be discussed in the CMS Work Plan on a zone-wide basis. Activities, contaminants, and issues specific to each zone will be discussed. The CMS work plan will identify specific sites to be addressed in the CMS, any focused approach (such as naming a primary technology in lieu of the full screening), and the subsequent cleanup goals. 16
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- A description of the corrective action objectives for NAVBASE, including how target media cleanup standards, points of compliance, or risk assessments will be established and performed for each site, zone, and activity.

Cleanup standards will be developed for each site, zone, or activity using the designated exposure scenario (residential, commercial, or industrial) for that area. BRAs, conducted in conjunction with the RFI for each zone, will be used to identify areas with unacceptable risk/hazard as per the designated exposure scenario. During the CMS, areas with unacceptable risk will be evaluated according to media, primary contaminants contributing to risk, and the potential for groundwater contamination.

- Identification, screening, and development of corrective measures alternatives.

Tables similar to those presented in the NAVBASE RFI work plans will be used in the CMS work plan to present the pool of technologies initially evaluated in the CMS. These tables represent a range of technologies with different applications; each technology must be screened and evaluated before it is discarded from further consideration. The tables, therefore, preclude any bias toward a particular technology through full-scale screening techniques.

Technologies will be screened using site- and waste-specific characteristics. The CMS work plan will identify factors to be considered, including type of media, depth of contamination, areal extent of contamination, number and type of contaminants, remedial goals, future land-use scenarios, and adjacent remedial activities. In addition, the CMS work plan will present the requirements for implementing Corrective Action Management Units (CAMUs).

After technologies have been screened, they will be assembled into corrective action alternatives and evaluated according to criteria discussed below. 1
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- *A description of the general approach to investigating and evaluating potential corrective action measures.* 3
4

Corrective measures alternatives will be evaluated using four primary and five secondary criteria, listed below: 5
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Primary 7

1. *Protect human health and the environment* 8
2. *Attain media cleanup standards set by the implementing agency* 9
3. *Control the source of releases so as to reduce or eliminate, to the extent practical, further releases that may pose a threat to human health and the environment* 10
11
4. *Comply with any applicable waste management standards* 12

Secondary 13

1. *Long-term reliability and effectiveness* 14
2. *Reduction in the toxicity, mobility, or volume of waste* 15
3. *Short-term effectiveness* 16
4. *Implementability* 17
5. *Cost* 18

Alternatives will be discussed and compared according to these criteria, which are used to gauge their relative effectiveness and implementability. 19
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- A detailed description of how pilot, laboratory, and/or bench-scale studies will be selected, performed, evaluated, reported on, and transferred to full scale. 1
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Treatability studies will be implemented when more involved treatment units are being considered. For example, air stripping technologies usually do not require treatability studies to determine optimal processes for treating groundwater. However, ultraviolet (UV)/oxidation, an innovative technology, may require extensive treatability testing to determine oxidant dosages and retention times. 3
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The base structure and objectives of a treatability study will be discussed. Objectives may include dosages, percent reduction in contaminant(s), treatment cost per unit volume, and implementation constraints. Study results will be used to assess the alternatives presented in the CMS and determine the optimal remedial approach for each site, zone, or activity. 8
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- A description of how a statement of basis or response to comments or permit modifications will be processed. 12
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Statement of basis/response to comments will be handled through NAVBASE and Southern Division, Naval Facilities Engineering Command (SOUTHDIV). The Comprehensive Long-term Environmental Action Navy (CLEAN) contractor, EnSafe Inc., will assist the Navy in preparing the statement of basis or response to comments. Permit modifications will be managed through NAVBASE as the permit holder until the base is closed. Upon closure, SOUTHDIV and NAVBASE's caretaker will manage permit modifications. According to the RCRA permit issued May 4, 1990, Appendix C, Facility Submission Summary, a permit modification is required to prepare and conduct a Corrective Action Study/Plan. 14
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- A description of the overall project management approach, including levels of authority (i.e., organizational charts), lines of communication, project schedules, budgets, and personnel.

The overall project management is the responsibility of SOUTHDIV for NAVBASE. The lines of authority, communication, and project schedules have been developed and agreed upon and are provided in the Comprehensive Project Management Plan dated August 30, 1994, and its amendments (E/A&H, August 30, 1994). In general, NAVBASE is responsible for ensuring that conditions of the permit are satisfied with the ultimate responsibility held by the Commander of Charleston Naval Shipyard (CNSY). The budget for conducting a CMS is defined by SOUTHDIV and funds are provided by the U.S. Congress. Personnel to conduct the CMS will be assigned by EnSafe as needed for project-specific items. EnSafe will manage the CMS effort through its Charleston, South Carolina, office.

- Qualifications of personnel to direct or perform the work will be described.

EnSafe will use trained qualified and/or registered geologists and engineers of South Carolina, where required.

9.2 Remedy Selection Approach

As agreed in the *Final Comprehensive Project Management Plan* remedies will be selected in accordance with statutory and RCRA CMS criteria. Particular attention will be given to the following items when evaluating alternatives:

- Background concentrations, particularly of inorganic compounds
- Land use/risk assessment

- Basewide treatment facilities 1
- Presumptive remedies 2
- Remedies for petroleum, oils, lubricants, and other contaminants of this type 3

CAMUs and temporary units will be used, where necessary, to facilitate storage and treatment during remediation activities. 4
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9.3 Proposed Remedy 6

Section 9.3 of the *Draft Zone A RFI Report* discusses the proposed remedy process for NAVBASE Charleston. 7
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9.4 Development of Target Media Cleanup Goals 9

Section 9.4 of the *Draft Zone A RFI Report* discusses the development of target media cleanup goals for soil, groundwater, sediment, surface water, and air. 10
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9.5 Identification, Screening, and Development of Corrective Measures Technologies 12

The initial step in assembling corrective measures alternatives is to identify, screen, and develop corrective measures technologies that apply to the site. Technologies are typically screened using waste-, media-, and site-specific characteristics. This section addresses the range of technologies which may be assessed for each site, the screening process, and screening criteria. 13
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9.5.1 Identification of Corrective Measure Technologies 17

Each site will be assessed using the methodology described in Section 9.2. Impacted media and COCs were initially identified in the RFI. The site-specific BRAs in Section 10 identify soil and groundwater as the contaminated media of concern. 18
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For each site, the major contaminants present have been grouped into one or more of the following categories: 1
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- Chlorinated VOCs 3
- Nonchlorinated VOCs 4
- Chlorinated SVOCs 5
- Nonchlorinated SVOCs 6
- Pesticides/herbicides 7
- PCBs 8
- Dioxins 9
- Inorganic compounds (includes metals) 10
- Petroleum hydrocarbons 11

Table 9.1 lists nontreatment options for soil, groundwater/leachate, sediment, surface water, and air: removal, containment, and disposal. Table 9.2 lists contaminant types and the recommended types of treatment for each medium. These tables supply general waste management options for various situations. Remedial technologies are described in Section 9.5.2 of this document. 12
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Some sites may contain a combination of contaminants (i.e., inorganics, pesticides, and petroleum hydrocarbons). As a result, multiple technology types may be required to remove these contaminants. However, some sites may contain only one type of contaminant. 16
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The following example presents a common situation where more than one type of contaminant exists onsite. The site contains VOCs and SVOCs that have been identified as slightly exceeding risk-based remedial goals. A containment alternative in this situation may include fencing to restrict unauthorized access, aerating the contaminated area, adding fertilizer and enriched soil, seeding to maintain a vegetative cover to control runoff, and monitoring. This containment approach seeks to reduce health risks through land management and natural attenuation. 19
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**Table 9.1
 Zone G
 Removal/Containment/Disposal Options**

Action	Soil	Groundwater/ Leachate	Sediment	Surface Water	Air
Removal	Excavation	Groundwater extraction Leachate collection	Dredging	Diversion Pumping	NA
Containment	Institutional controls Capping Storm water controls Long-term monitoring Intrinsic (natural) bioremediation/attenuation	Slurry wall Gradient controls Long-term monitoring Intrinsic (natural) bioremediation/attenuation	Berms/diversion Storm water controls	Diversion	NA
Disposal	Landfill	POTW NPDES discharge Land application	Landfill	POTW NPDES discharge	Discharge via air permit

Notes:

- POTW = Publicly owned treatment works
- NPDES = National Pollutant Discharge Elimination System
- NA = Not Applicable

**Table 9.2
 Zone G
 Treatment Technology Options**

Contaminant Type	Soil	Groundwater/Leachate	Sediment	Air
Chlorinated VOCs	Soil washing Incineration Thermal desorption Bioremediation	Chemical oxidation Bioremediation Adsorption Air stripping UV/ozone oxidation	Same as soil	Oxidation
Nonchlorinated VOCs	Soil washing Incineration Thermal desorption Soil vapor extraction Bioremediation Steam extraction	Oxidation Bioremediation Adsorption Air stripping	Same as soil	Adsorption Oxidation
Chlorinated SVOCs	Soil washing Bioremediation Incineration Thermal desorption Solidification/stabilization	Oxidation Bioremediation Air stripping	Same as soil	Adsorption Oxidation
Nonchlorinated SVOCs	Soil washing Incineration Thermal desorption Bioremediation Solidification/stabilization	Oxidation Bioremediation Sorption	Same as soil	Oxidation Adsorption

Table 9.2
Zone G
Treatment Technology Options

Contaminant Type	Soil	Groundwater/Leachate	Sediment	Air
Pesticides/ Herbicides	Solidification/stabilization Soil washing Bioremediation Incineration Thermal desorption	Oxidation Bioremediation Sorption	Same as soil	Oxidation
PCBs	Solidification/stabilization Soil washing Dehalogenation Incineration Thermal desorption	Oxidation Dehalogenation Incineration Solidification	Solvent extraction Dehalogenation Solidification/stabilization	Oxidation
Dioxins	Incineration Solidification/stabilization	Oxidation		Oxidation
Inorganics	Solidification/stabilization Soil washing	Chemical precipitation Adsorption Sedimentation Filtration	Same as soil	Filtration Scrubbers Adsorption

As discussed in previous sections, COCs may vary between scenarios because each site may be evaluated under both residential and site worker scenarios. Two lists of applicable technologies may be developed for each site, one for each scenario.

9.5.2 Description of Prescreened Technologies

The following paragraphs describe technologies that appear to be the most feasible for the initial CMS. These technologies are divided into four categories: in-situ soil, ex-situ soil, in-situ groundwater, and ex-situ groundwater.

In-Situ Soil

Bioremediation

This technology uses microorganisms to biologically oxidize contaminants into harmless chemicals such as carbon dioxide and water. The organisms can be naturally occurring or they can be added

to the soil. In many circumstances, nutrients can be supplemented to enhance this process. Nitrate and phosphate are often the limiting nutrients at a site. However, insufficient electron acceptors are the greatest variable limiting bioremediation. The most common electron acceptor is oxygen for aerobic biodegradation. For these sites, bioremediation via natural attenuation is likely to be a good candidate for some compounds. Typically nonchlorinated VOCs and SVOCs are good candidates for this technology.

Solidification/Stabilization

This technology consists of mixing reagents with soil to prevent contaminants from leaching to the groundwater. This technology immobilizes contaminants, preventing migration. However, this technology does not remove the contaminant.

Ex-Situ Treatment of Soils

All ex-situ soil treatments require excavation to another location or at least bringing the material to the surface. Typically heavy equipment is used to move the soil. If contaminated soil is limited in volume and considered nonhazardous, it may be feasible to dispose of it in a landfill. If sites have a limited area of contaminated soil, it may be feasible to remove the soil with heavy equipment and treat it ex-situ. If nonhazardous, it could be disposed of in a landfill.

Soil Washing

Soil washing physically separates soil particles by size, then treats the smaller grains with solutions that desorb the contaminants. The resulting contaminated solution is then treated by another technology. In general, small soil particles such as clay and silt have a higher TOC content, which tends to absorb hydrophobic compounds such as chlorinated contaminants. Essentially the technology compacts contaminated soil, then washes it with a solvent to remove the contaminants.

Thermal Desorption

Thermal desorption technologies are performed at high or low temperatures, depending on the contaminant. Both of these technologies are used with incineration or some other type of offgas treatment. Soil is excavated and put in the treatment systems for both high- and low-temperature desorption to separate the contaminants from the soil, not to destroy the chemicals. The volatilized contaminants enter an airstream and travel to some type of gas treatment for the contaminant destruction. Low-temperature (200°F to 600°F) thermal desorption (LTTD) is used only for VOCs while high-temperature (600°F to 1,000 °F) thermal desorption (HTTD) is used for SVOCs, polynuclear aromatic hydrocarbons (PAHs), PCBs, and pesticides.

Thermal Destruction/Incineration

This technology is used with ex-situ soil technologies. Typically the contaminant is removed from the soil matrix and transferred to an airstream. The airstream is then treated with the thermal destruction on a catalyst or burned in an incinerator, or a combination of the two. High temperatures (1,800°F to 2,000°F) are required to destroy organics such as PCBs, dioxins, furans, pesticides, and others.

Solidification/Stabilization

This technology is similar to the in-situ methods; however, the soil is first excavated before being mixed with the chemical reagents or concrete.

In-Situ Groundwater Treatment

Bioremediation

Bioremediating contaminants in groundwater involves adding nutrients such as phosphate or nitrate and an electron acceptor such as oxygen or nitrate to the groundwater via injection wells. The most typical electron acceptor addition comes from either oxygen via air sparging, and/or nitrate with the addition of other nutrients.

Intrinsic Remediation

This technology, also called natural attenuation, simply allows naturally occurring bioremediation, oxidation, hydrolysis, dispersion, and advection to occur unassisted. No nutrients or electron acceptors are added to the site. The site may be monitored to observe the contaminant reduction. Many case studies have demonstrated this technology on TPH.

Ex-Situ Treatment of Groundwater

Any ex-situ treatment of groundwater requires a system of extraction wells and pumps to deliver the groundwater to the treatment location.

Chemical Precipitation

The solubility of many metals is a function of pH. As a result, chemical agents can be added to change the pH of the water, which results in the metals becoming insoluble. In other cases, a chemical can be added to chelate the metal and precipitate it out of the solution. Either way, the contaminants can then be removed by filtering.

Air Stripping

Groundwater can be extracted from the subsurface and pumped to a nearby publicly owned treatment works (POTW). While the contaminated groundwater is in the aeration basin of the water treatment plant, the volatile compounds (compounds with a high HL) will mass-transfer from the water to the air. Steam can also be used to heat the groundwater, causing organics to volatilize. These air vapors can be treated with an appropriate technology or can be permitted as an air emissions source.

Chemical Oxidation/UV-Ozone

Ozone, one of the strongest chemical oxidizers, can be generated with UV light sources. Almost any organic compound can be oxidized. When water passes through a flowstream surrounded by

UV lights, oxygen in the water is converted to ozone and the organics are oxidized into harmless by-products. Compounds that typically are recalcitrant to biological oxidation, such as chlorinated organics, can be easily oxidized with ozone. Good light transmission is essential; therefore, very turbid water is not a good candidate for UV ozonation.

Activated Sludge

Activated sludge treatment of wastes occurs in a wastewater treatment plant. The activated sludge process uses microorganisms to convert organic wastes to inorganic wastes and/or bacterial cell mass, carbon dioxide, and water.

9.5.3 Screening Criteria

When more than one technology applies to a specific site, it is necessary to evaluate the limitations to show why certain CMS technologies may not be feasible to implement waste- and site-specific conditions. Therefore, for each technology, the following criteria will be discussed:

- Site characteristics
- Waste characteristics
- Technology limitations

Site Characteristics

Site characteristics define the site and any constraints that may impact selecting and implementing remedial technologies. Primary characteristics to be considered include the current and future use of the AOC or SWMU. Other characteristics include the contaminated media, areal distribution of contamination, and depth to/of contamination. Current migration pathways and the potential for intrinsic remediation will also be considered. Each site may have one or two technology lists, which will be evaluated for residential and Base Closure and Realignment (BRAC)-specified future uses.

Waste Characteristics

Waste characteristics define the nature of contamination. The primary waste characteristic to be considered is the general type of contamination – VOCs, SVOCs, pesticides/herbicides, PCBs, dioxins, inorganic compounds, and TPH analysis. The presence of halogenated compounds, such as chlorinated benzenes or trichloroethylene, is also critical.

Where multiple types of contamination are present (such as PCBs and dioxins, or pesticides and VOCs), certain technologies may be eliminated from consideration due to their inability to effectively treat the wastes. For example, soil vapor extraction (SVE) typically is not used on pesticide sites, although it is very effective for most VOCs. If both contaminants must be treated concurrently, SVE would be eliminated from further evaluation. Where appropriate, contaminant concentrations will be considered to screen remedial technologies.

Technology Limitations

Technology limitations are used to assess the feasibility of implementing a particular technology. These limitations may include technical restrictions on application, including the presence of a shallow water table, depth to bedrock, etc. Additional limitations include minimum or maximum process volumes, such as technologies that are cost-effective only when contaminated soil volume exceeds 1,000 cubic yards. Other limitation to be assessed include effectiveness in meeting treatment goals and remedial time frame. Technologies meeting this screening criterion may differ from residential to BRAC-specified use scenarios due to the differences in cleanup goals for each scenario.

9.6 Identification of Corrective Measures Alternatives

Section 9.6 of the *Draft Zone A RFI Report* discusses identification of corrective measures alternatives as these apply to the Zone G RFI.

9.7 Evaluation of Corrective Measures Alternatives

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Section 9.7 of the *Draft Zone A RFI Report* discusses evaluation of corrective measures alternatives as they apply to the Zone G RFI.

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9.8 Ranking the Corrective Measures Alternatives

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Section 9.8 of the *Draft Zone A RFI Report* discusses ranking the corrective measures alternatives, as they apply to the Zone G RFI.

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