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DRAFT FINAL

SUPPLEMENTAL ECOLOGICAL ASSESSMENT

**NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

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Prepared by:

**BAKER ENVIRONMENTAL, INC.
*Coraopolis, Pennsylvania***

TABLE OF CONTENTS

Page

LIST OF ACRONYMS AND ABBREVIATIONS v

EXECUTIVE SUMMARY

1.0 INTRODUCTION 1-1

1.1 Objective of Study 1-2

1.1.1 Compilation of Existing Data 1-2

1.1.2 Ecological Risk Assessment 1-2

1.1.3 Little Creek Harbor Environmental Perspective 1-3

1.2 Site Characterization 1-3

1.2.1 General Site Characteristics 1-3

1.2.2 Site-Specific Characteristics 1-4

2.0 METHODOLOGY OF DATA COLLECTION 2-1

2.1 Interviews 2-1

2.1.1 NAB Little Creek 2-1

2.1.2 Virginia Department of Environmental Quality 2-1

2.1.3 Chesapeake Bay Program 2-2

2.1.4 Environmental Monitoring and Assessment Program 2-2

2.1.5 Old Dominion University 2-3

2.2 Summary of Previous Investigations Reviewed 2-3

2.2.1 Non-IR Data 2-3

2.2.2 IR-Related Data 2-14

3.0 REGIONAL CONDITIONS 3-1

3.1 Regional Water Quality Characteristics 3-1

3.2 Regional Geology/Hydrogeology 3-3

4.0 ECOLOGICAL RISK ASSESSMENT 4-1

4.1 Objectives, Scope, and Organization of the Ecological Risk Assessment 4-1

4.2 Problem Formulation 4-2

4.2.1 Stressor Characteristics 4-3

4.2.2 Ecological Contaminants of Concern 4-3

4.2.3 Aquatic Ecosystems Potentially at Risk 4-10

4.2.4 Ecological Endpoints 4-15

4.2.5 Conceptual Model 4-16

4.3 Exposure Assessment 4-18

4.4 Ecological Effects Characterization 4-18

4.4.1 Surface Water 4-18

4.4.2 Sediment 4-19

4.5 Risk Characterization 4-20

4.5.1 Surface Water 4-21

4.5.2 Sediment 4-22

4.6 Ecological Significance 4-23

4.6.1 Aquatic Assessment Endpoint 4-24

TABLE OF CONTENTS
(Continued)

	<u>Page</u>
4.7	Uncertainty Analysis 4-28
4.7.1	Sampling Area 4-28
4.7.2	Reference Stations 4-28
4.7.3	Data Gaps 4-28
4.7.4	Sampling Method 4-29
4.7.5	Screening Levels 4-29
5.0	LITTLE CREEK HARBOR ENVIRONMENTAL PERSPECTIVES 5-1
5.1	Site 7 5-1
5.2	Site 12 5-2
5.3	Little Creek Harbor Benthic Macroinvertebrate Data 5-3
5.4	Little Creek Harbor Fish and Shellfish Data 5-6
5.5	Perspectives Conclusion 5-6
6.0	CONCLUSIONS 6-1
7.0	REFERENCES 7-1

APPENDICES

A	Miscellaneous Figures
A.1	EMAP Data Maps
A.2	Wetlands Map for Little Creek Harbor
B	Regulated Stormwater Outfall Map and Identification Tables
B.1	Stormwater Outfall Map
B.2	Stormwater Outfall Description Tables
C	Ecological Toxicological Profiles
D	IR-Related Surface Water and Sediment Data for Sites 7 and 12
D.1	Remedial Investigation Data
D.2	Round 1 Verification Step Data
D.3	Interim Remedial Investigation Data
D.4	Sediment Sampling and Analysis Data for Canal Adjacent to IR Site 12

LIST OF TABLES

1	List of Contacts
2	Ecological Contaminants of Concern Per Media Per Site
3	Frequency and Range of Detection Compared to Estuarine Surface Water Screening Levels - Site 7
4	Frequency and Range of Detection Compared to Sediment Screening Levels - Site 7
5	Frequency and Range of Detection Compared to Estuarine Surface Water Screening Levels - Site 12
6	Frequency and Range of Detection Compared to Sediment Screening Levels - Site 12
7	Physical/Chemical Characteristics of the Ecological Contaminants of Concern
8	Surface Water Quotient Index Per Station - Site 7
9	Surface Water Quotient Index Per Ecological Contaminant of Concern - Site 7
10	Surface Water Quotient Index Per Station - Site 12
11	Surface Water Quotient Index Per Ecological Contaminant of Concern - Site 12
12	Sediment Quotient Index Per Station - Site 7
13	Sediment Quotient Index Per Ecological Contaminant of Concern - Site 7
14	Sediment Quotient Index Per Station - Site 12
15	Sediment Quotient Index Per Ecological Contaminant of Concern - Site 12
16	Comparison of Remedial Investigation Surface Water Data to Reference Station Data - Site 7
17	Comparison of Remedial Investigation Sediment Data to Reference Station Data - Site 7
18	Comparison of Remedial Investigation Surface Water Data to Reference Station Data - Site 12
19	Comparison of Remedial Investigation Sediment Data to Reference Station Data - Site 12
20	Comparison of Remedial Investigation Surface Water Data to Previous Remedial Investigation Data - Site 7
21	Comparison of Remedial Investigation Sediment Data to Previous Remedial Investigation Data - Site 7
22	Comparison of Remedial Investigation Surface Water Data to Previous Remedial Investigation Data - Site 12
23	Comparison of Remedial Investigation Sediment Data to Previous Remedial Investigation Data - Site 12
24	Comparison of Remedial Investigation Surface Water Data to Non-Related Remedial Investigation Surface Water Data - Site 7
25	Comparison of Remedial Investigation Sediment Data to Non-Related Remedial Investigation Data - Site 7
26	Comparison of Remedial Investigation Surface Water Data to Non-Related Remedial Investigation Data - Site 12
27	Comparison of Remedial Investigation Sediment Data to Non-Related Remedial Investigation Data - Site 12
28	Benthic Macroinvertebrate Density Comparison - Little Creek Harbor
29	Benthic Macroinvertebrate Restoration Goals - Little Creek Harbor
30	Fish Tissue Detection Summary - Base Studies

LIST OF FIGURES

- 1 Regional Location Map
- 2 Little Creek Harbor Site Map
- 3 Little Creek Harbor Previous Investigation Sample Locations - includes the following studies:
 - Round One Verification Study Sample Locations (CH2M Hill, 1986)
 - AMRL Benthic Sample Locations (Ewing *et. al.*, 1988)
 - Dredging Sample Locations 1989 (Department of Army, 1995)
 - Dredging Sample Locations 1991 (J.R. Reed and Associates, 1991)
 - Interim Remedial Investigation Sample Locations (Ebasco Environmental, 1991)
 - AMRL Sample Locations 1992 (Ewing *et. al.*, 1992)
 - Remedial Investigation/Feasibility Study Sample Locations (Foster Wheeler, 1994a)
 - Naval Amphibious Base Little Creek Base Study 1995 Sample Locations (NAB, 1995a)
 - Naval Amphibious Base Little Creek Base Study 1994 Sample Locations (NAB, 1994)
 - Naval Amphibious Base Little Creek Study 1995 Biota Sample Locations (NAB, 1995a)
 - Sediment Sample Locations 1995 for IR Site 12 (Foster Wheeler, 1995)
- 4 Cape Charles Harbor STORET Sampling Location
- 5 Lynnhaven STORET Sampling Locations
- 6 Conceptual Model - Potential Exposure Pathways and Ecological Receptors
- 7 Conceptual Model - Potential ECOC Sources to Little Creek Harbor

LIST OF ACRONYMS AND ABBREVIATIONS

AET	Apparent Effect Threshold
AMRL	Applied Marine Research Laboratory
ANOVA	Analysis of Variance
AQUIRE	Aquatic Information Retrieval Database
BCF	Bioconcentration Factor
BSL	BTAG Screening Level
BOD	Biological Oxygen Demand
BTAG	Biological Technical Assistance Group
CAX	Cheatham Annex
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DO	Dissolved Oxygen
ECOC	Ecological Contaminants of Concern
EMAP	Environmental Monitoring and Assessment Program
ER-L	Effects Range-Low
ER-M	Effects Range-Median
ERA	Ecological Risk Assessment
ERE	Ecological Risk Evaluation
FS	Feasibility Study
Harbor	Little Creek Harbor
IAS	Initial Assessment Study
IR	Installation Restoration Program
K_{oc}	Organic Carbon Partition Coefficient
K_{ow}	Octanol Water Partition Coefficient
MANOVA	Multi Variate Analysis of Variance
mlw	Mean Low Water
NAB	Naval Amphibious Base
NEX	Naval Exchange
NH_4	Ammonium
NO_2	Nitrite
NO_3	Nitrate
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NWI	National Wetland Inventory
NWS	Naval Weapons Station
ODU	Old Dominion University

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
RGI	Benthic Macroinvertebrate Restoration Goal Index
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
SEA	Supplemental Ecological Assessment
SSL	Sediment Screening Level
STORET	USEPA Computer System for the Storage and Retrieval of Water Quality Data
SVOC	Semivolatile Organic Compound
SWSL	Surface Water Screening Level
TAL	Target Analyte List
TCL	Target Compound List
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOX	Total Organic Halogen
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
VADEQ	Virginia Department of Environmental Quality
VOC	Volatile Organic Compound
WQS	Water Quality Standards

EXECUTIVE SUMMARY

INTRODUCTION

Naval Amphibious Base (NAB) Little Creek provides on-base logistic facilities and support services to local commands, organizations, and other United States and allied units, home-ported ships, and commands of the operating forces to meet the amphibious training requirements of the Armed Forces of the United States. This Supplemental Ecological Assessment (SEA) has been performed to address the concerns of the United States Environmental Protection Agency (USEPA) Biological Technical Assistance Group (BTAG) regarding the impact of NAB Little Creek IR sites on the ecological resources of Little Creek Harbor (Harbor).

A Final Remedial Investigation/Feasibility Study (RI/FS) report included an Ecological Risk Evaluation that qualified risks to aquatic wildlife receptors within the reaches of Little Creek that were adjacent to Installation Restoration Program (IR) Sites 7 and 12. The BTAG requested further work be conducted to address the threat posed to aquatic life by these sites. The SEA of Little Creek Harbor consisted of the following components: 1) the compilation of all existing IR and non-IR data pertaining to Little Creek Harbor, 2) the conduct of a Phase One Ecological Risk Assessment (ERA) on the available Little Creek Harbor aquatic data, and 3) a perspective overview of the ecological condition of Little Creek Harbor as related to the condition of ecologically similar water bodies located within the southern region of the Chesapeake Bay.

COMPILATION OF EXISTING DATA

A review of existing environmental data was conducted for Little Creek Harbor for the ERA. Sources of this data included IR studies, Virginia Department of Environmental Quality (VADEQ) outfall reports, various NAB Little Creek water quality studies, NAB Little Creek Natural Resources Program Management reports, NAB Little Creek hydrological studies, and NAB Little Creek dredging program reports. To evaluate the relative potential impacts to Little Creek Harbor from the IR sites versus impacts from non-IR site point and non-point contaminant sources, an environmental perspective was developed from the information obtained. Information sources for Little Creek Harbor environmental perspective data include the USEPA's Chesapeake Bay Program, Old Dominion University (ODU), Virginia government agencies, and special regional programs.

This information also was used to establish reference stations for the ERA. Selected data from these reviews were compiled into a single electronic database to be used for the ERA.

ECOLOGICAL RISK ASSESSMENT

Based on the results of the compilation of the Little Creek Harbor data, a Phase One ERA was conducted using the Interim Ecological Risk Assessment Guidelines developed by USEPA Region III BTAG for addressing risks to aquatic receptors in the Harbor. In addition, Screening Levels developed by BTAG were used to determine the Ecological Contaminants of Concern (ECOCs). The IR data from the RI/FS report was used to conduct the ERA for NAB Little Creek Harbor. The non-IR data was used to determine impacts to Harbor from sources other than the IR sites. Surface Water Screening Levels (SWSLs) and Sediment Screening Levels (SSLs) were used in the risk characterization portion of the ERA to evaluate the likelihood of adverse effects occurring as a result of exposure to an ECOC. This evaluation used the quotient index (QI) approach with ratios calculated for each sampling station that exceeded screening levels. A ratio of one indicates a possibility for adverse effects to aquatic life.

The surface water and sediment data collected during the RI investigation were compared to surface water and sediment data collected from regional reference stations. Regional surface water and sediment data were obtained from USEPA's computer system for storage and retrieval of water quality data (STORET) from the years 1990 through 1995 for Cape Charles Harbor and Lynnhaven Harbor (including monitoring stations in the mainstem, eastern branch, western branch, and Broad Bay). Cape Charles was chosen as an ecologically similar reference water body because it is periodically dredged like Little Creek Harbor. Lynnhaven Harbor (and associated waterways) is a much larger water body than Little Creek Harbor. However, it was chosen because of its close proximity to Little Creek Harbor and the lack of surrounding industrial land use.

The aquatic assessment endpoint for NAB Little Creek is the decrease in the survival, growth, and/or reproduction of the aquatic receptor population or subpopulation that is attributable to site-related contaminants. The measurement endpoint for the aquatic assessment endpoint is the exceedance of contaminant-specific surface water and sediment effect concentrations. It is noted that no benthic macroinvertebrates or fish were collected at NAB Little Creek during the remedial investigation.

Site 7

The following ECOC concentrations in the surface water collected at Site 7 may potentially adversely impact the aquatic environment based on exceedance of acute and chronic SWSLs: copper, lead, and manganese.

Site 7 surface water ECOCs were compared to reference concentrations. Site 7 ECOCs including aluminum, barium, and cobalt were not analyzed in reference water bodies; therefore, they could not be compared to Site 7 concentrations. Copper in the reference surface water was detected at higher concentrations than in Site 7 surface water. Whereas, iron and manganese were detected at higher concentrations in Site 7 surface water than in reference surface water. Lead was only detected at one reference station (Cape Charles Harbor) at a concentration greater than Site 7 surface water concentrations.

Therefore, although three ECOCs may potentially adversely impact the aquatic environment, only manganese appears to be elevated above regional reference levels and is site-related. It is noted that manganese was detected in the groundwater at Site 7 and is found highly dissolved in the groundwater. However, the source of the SWSL of 10µg/l is believed to be based on a study of decreased growth in the pacific oyster *Crassostrea gigas*. This study did not meet the criteria for reliability in the Aquatic Information Retrieval Database (AQUIRE). Other studies in AQUIRE listed adverse effects at 20,000 µg/l to mollusk species, which is higher than the RI data. It also is noted that there was no clear spatial relationship established for the groundwater chemical data for Site 7. Therefore, isoconcentration maps were not constructed to determine the groundwater pathway to surface water.

Sediment collected from Site 7 at NAB Little Creek contained levels of arsenic, beryllium, cadmium, cobalt, copper, silver, and zinc that may affect the benthic community based on QIs calculated greater than one.

The following Site 7 sediment ECOCs were not analyzed for in the reference water bodies: acetone, 2-butanone, carbon disulfide, and cobalt. Aluminum and arsenic were detected at higher concentrations in the reference station in Broad Bay and at lower concentrations in the reference station in Cape Charles Harbor, as compared to Site 7. Beryllium, cadmium, copper, silver, and zinc

were detected at higher concentrations in the sediment at Site 7 than in reference sediment samples. Based on the station-specific QI evaluation, these inorganics may be potentially impacting the benthic community at Site 7. However, it is noted that the average of the detected concentrations of beryllium, copper, silver, and zinc were all less than the Effects Range-Low (ER-L), indicating no impact.

Although this Phase One ERA focused on the surface water and sediment data from the RI, information was available from previous IR reports to establish any trends in the data for Site 7. For Site 7, manganese surface water concentrations have generally decreased from the Interim RI to the RI. For the sediments at Site 7, cadmium (the only ECOC with an average concentration greater than the ER-L) increased from the Round I Verification Study to the RI Study. Of the other ECOCs with station-specific concentrations greater than the ER-Ls, in general, beryllium and copper decreased and silver and zinc increased.

Site 12

The following ECOC concentrations in the surface water collected at Site 12 at NAB Little Creek may potentially adversely impact the aquatic environment based on exceedance of acute and chronic SWSLs: arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc. The greatest exceedances (greater than 100 times) of SWSLs were demonstrated by copper and manganese at Site 12. Lead, mercury, nickel, and zinc had exceedances greater than 10 times the SWSLs at Site 12.

Site 12 surface water ECOCs were compared to reference surface water data. Site 12 ECOCs 2-butanone, aluminum, barium, cobalt, and mercury were not analyzed in the reference studies. Arsenic, chromium, copper, iron, lead, manganese, nickel, and zinc were detected at higher concentrations in Site 12 surface water than in reference water bodies. Beryllium was detected at lower concentrations at Site 12 than in several of the reference stations. However, beryllium surface water concentrations were higher at Site 12 than in the reference surface water collected from Cape Charles Harbor. The exceedances of SWSLs by concentrations of arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc at Site 12, as evaluated on a station-specific basis, may be impacting the aquatic environment. However, it is noted that arsenic and chromium average

concentrations across all stations were less than their respective SWSLs and the manganese SWSL may not be a valid effect level.

It has been determined that groundwater from Site 12 discharges to the drainage canal. However, based on the existing IR studies, groundwater from Site 12 is not believed to be the source of the metals that are found in the drainage canal. These investigations have focused on volatile organic compounds (VOCs) that may be transported from Site 12 to the drainage canal. There were no VOCs that exceeded SWSLs

It is noted that although the water and sediment at Site 12 may impact aquatic receptors, the impact to receptors in the Harbor may not be as severe. Site 12 RI samples were collected in the drainage canal adjacent to Site 12. The canal is located approximately 3,000 feet from the Harbor. The surface water flows through wetlands before discharging into the Harbor. Wetlands provide an effective treatment for many types of water pollution. Therefore, the contaminants detected in the surface water at Site 12 may be mitigated by the wetlands prior to discharge into the Harbor.

Based on the station-specific concentration evaluation, sediment collected from Site 12 contained levels of cadmium, cobalt, copper, lead, mercury, and zinc that may affect the benthic community based on exceedances of the QI ER-Ls calculated greater than one. All QI ER-Ls calculated at NAB Little Creek were less than 10, and there were no QI Effects Range-Median (ER-M) exceedances greater than one for any of the ECOCs at Site 12.

The Site 12 ECOCs acetone, cobalt, and mercury were not analyzed for in any of the reference studies. Cadmium, copper, lead, and zinc were detected at higher concentrations in the sediment collected at Site 12 than in the sediment collected from reference stations. Based on the exceedances of the ER-L on a station-specific basis, the sediment concentrations of cadmium, cobalt, copper, lead, mercury, and zinc at Site 12 may be impacting the aquatic community at NAB Little Creek. However, it is noted that the average concentrations of copper and mercury at these stations were below the ER-Ls.

Although this Phase One ERA focused on the surface water and sediment data from the RI, information was available from previous IR reports to establish any trends in the data for Site 12. At Site 12, surface water and sediment inorganics were not analyzed in the Interim RI or the Round

I Verification Study. However, sediment data was collected in 1995 from an IR-related study conducted in the canal adjacent to Site 12. Concentrations of acetone, copper, lead, and mercury were detected in the sediment study at higher concentrations in the RI than in the sediment study and concentrations of aluminum and cobalt were detected at about the same concentrations in both studies. In the canal study, acetone and aluminum concentrations were higher upstream of Site 12. Whereas, concentrations of lead, mercury, and zinc in the canal study were higher at stations downstream and adjacent to the site. Cobalt and copper were detected at varying concentrations both upstream and downstream of Site 12.

ENVIRONMENTAL PERSPECTIVE

The ERA indicated that ECOCs possibly attributed to IR Sites 7 and 12 are presenting a risk to the aquatic receptors in Little Creek Harbor. However, it was noted that there may be a variety of ECOC sources in Little Creek Harbor. In addition, the frequent disturbance of the Harbor's waters and sediments by 1) NAB's logistic and support operations and amphibious training requirements, 2) the periodic dredging operations, and 3) the natural ebb and flow of the tidal waters will tend to resuspend and redistribute ECOCs throughout the Harbor and overshadow any apparent fate and transport relationship to the various sources in the Harbor.

Site 7

At Site 7, manganese in the surface water may be adversely impacting the aquatic environment. Non-IR related studies conducted by ODU and NAB in Little Creek Harbor analyzed for various metals in the surface water. However, manganese was not analyzed in the ODU study or the two NAB studies.

Beryllium, cadmium, copper, silver, and zinc detected in the sediment at Site 7 may potentially impact the aquatic environment. The sediment analyzed in the ODU study demonstrated higher concentrations of arsenic, beryllium, cadmium, copper, silver, and zinc than the sediment collected in the RI study. In the two NAB studies, only cadmium was analyzed for in the sediment. Cadmium concentrations detected in the NAB studies were below concentrations detected in the RI study. Dredging data demonstrates that beryllium, copper, silver, and zinc were detected at higher concentrations during the 1989/90 dredging event than concentrations detected during the RI. It is

noted that the highest concentration of silver from the 1989/90 dredging event was detected in Little Creek Cove. Dredging data collected from the Harbor in 1991 demonstrated higher sediment concentrations of copper and zinc than detected in the RI study.

Site 12

At Site 12, arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc concentrations detected in the surface water may be adversely impacting the ecological ecosystem of Little Creek Harbor. A non-RI related study conducted by ODU in the Harbor found surface water concentrations of arsenic, chromium, copper, lead, mercury, and zinc lower than concentrations detected in the RI study. Manganese was not analyzed for in ODU study. All of the concentrations were below SWSL indicating minimal impacts in the main channel and coves of the Harbor. This study also indicates that the high level of zinc detected in the groundwater from the IR Sites is not impacting the Harbor.

Sediment collected from Site 12 contained levels of cadmium, cobalt, copper, lead, mercury, and zinc that may affect the benthic community. A non-IR related study conducted in the Harbor found sediment concentrations of cadmium, copper, and mercury higher than the sediment concentrations detected in the RI study. In addition, two dredging events detected higher concentrations of acetone, cadmium, copper, lead, mercury, and zinc than concentrations detected in the RI study. However, two other non-IR related studies detected sediment concentrations at lower levels than the RI study for cadmium and mercury.

Comparison of Site 12 data collected during the RI to non-IR Little Creek data indicates that the surface water concentrations of arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc may be causing an impact to aquatic receptors in the drainage canal. However, the ODU Applied Marine Research Laboratory (AMRL) data indicates that these impacts are localized and do not extend into the Harbor. For the sediments, the RI levels are below those found in the AMRL data and dredging data but above those found in the NAB data, indicating other potential sources of these ECOCs and variability in the concentrations of these ECOCs in the sediments for cadmium and mercury. Due to the significant travel distance from Site 12 to the Harbor and the existence of wetlands in the lower reaches of the drainage canal, the impacts of the metals may be mitigated by the wetlands.

It has been determined that groundwater from Site 12 discharges to the drainage canal. However, based on the existing IR studies, groundwater from Site 12 is not believed to be the source of the metals that are found in the drainage canal. These investigations have focused on VOCs that may be transported from Site 12 to the drainage canal. There were no VOCs that exceeded SWSLs. It is noted that the drainage canal adjacent to Site 12 collects surface water runoff from both on-site and off-site sources including Lake Bradford, Chubb Lake, a heavily used commercial area, and extensive surface transportation routes. Both Lake Bradford and Chubb Lake receive surface drainage flows via unlined canals and may receive significant amounts of salt water from the Chesapeake Bay during storm events. These non-IR related potential sources of ECOCs would contribute to the levels found in the RI study at Site 12.

Little Creek Harbor

A benthic macroinvertebrate study conducted by ODU indicates that the benthic species in Little Creek Harbor appear to be representative species for the salinity habitat of the Harbor compared to reference stations and restoration goal management objectives. These restoration goals for Chesapeake Bay benthic infaunal communities are evaluated using the Restoration Goal Index (RGI) based on several different monitoring programs.

The RGI calculated for Little Creek indicated that the benthic macroinvertebrate community is meeting benthic restoration goal requirements. The Shannon-Wiener Diversity and percent opportunistic species abundance for the Little Creek station were greater than the lower recommended RGI values. The species abundance and biomass values from the Little Creek sample were greater than the higher RGI value. The average RGI value calculated for Little Creek was four, indicating that the benthic community is within the set restoration goals.

The NAB studies found total mercury in blue crabs (97.4-225 $\mu\text{g}/\text{kg}$) and fish (132-148 $\mu\text{g}/\text{kg}$) collected from the Harbor. Mercury was an identified ECOC at Site 12 that may be impacting aquatic receptors via the sediment exposure pathway. Mercury bioaccumulates in biota. However, due to the high levels detected in the Harbor sediments during the AMRL study, the relative contribution of the source of the total mercury in the sediments from Site 12 cannot be determined.

There are many impacts to the ecological condition of the Harbor. Besides Sites 7 and 12, other IR sites also directly or indirectly drain into Little Creek Harbor. In addition, base activities, such as drills conducted on the mudflats, fueling, salvage and ship maintenance also impact the Harbor. Barges loading and unloading, railroad ferry activities, U.S. Coast Guard activities and other industrial uses of the Harbor also are influencing the aquatic environment.

The ERA indicates that there are ECOCs at Sites 7 and 12 at levels that may impact the ecological receptors of the Harbor. However, based on the surface water and benthic macroinvertebrate data from the AMRL studies, the ecological receptors of the Harbor are not being adversely impacted. The sediment data from the AMRL studies indicate that levels are elevated and may be impacting the ecological receptors, but the source of these elevated levels cannot be determined.

CONCLUSIONS

It was the purpose of this SEA to address the concerns of the USEPA BTAG regarding the impact of NAB Little Creek on the ecological resources of Little Creek Harbor. The following are the conclusions of the three components of the study - compilation of existing data, ERA, and Little Creek Environmental Perspective:

- Limited existing environmental data were available to address sources of ECOCs from non-IR and non-Navy sources.
- IR surface water and sediment data were limited to Sites 7 and 12 and were primarily volatile organic and inorganic data.
- The Phase One aquatic ERA conducted on surface water and sediment data collected from Sites 7 and 12 during the RI indicated that several inorganic compounds may potentially adversely impact the overall ecological condition of the Harbor.
- Based on the comparison of concentrations of ECOCs from the RI and concentrations of ECOCs from several water quality studies conducted in Little

Creek Harbor, there may be a variety of sources for the ECOCs detected in the Harbor.

- The overall water quality in Little Creek Harbor based on the water quality study by AMRL is meeting surface water screening levels for the metals analyzed with the exception of mercury. However, mercury was detected in only one station in the AMRL study. This station was located in the western portion of Little Creek Harbor and not in Little Creek Cove, which is adjacent to Site 7 and immediately downstream of Site 12. Mercury was not detected in the surface water and sediments at Site 7 and was detected in only one surface water and sediment sample at Site 12. For the sediments, many of the metals exceeding sediment screening levels for Sites 7 and 12 also exceeded these screening levels in the AMRL study. However, it is noted that the relative ranges of Sites 7 and 12 metal concentrations (with the exception of lead and zinc) were less than the ranges of metal concentrations found in the AMRL study.
- The surface water and sediment within the Harbor are frequently disturbed by 1) the natural influence of the tidal flux, 2) NAB's logistic and support operations, and amphibious training requirements, including boat traffic, and 3) the periodic dredging operations. These disturbances will impact the ecological resources of Little Creek Harbor and will tend to resuspend and redistribute ECOCs throughout the Harbor and overshadow any apparent fate and transport relationship to the various sources in the Harbor.
- The Restoration Goal Index calculated for Little Creek Harbor indicated that the benthic macroinvertebrate community is meeting benthic restoration goal requirements.

Although there may be some localized impacts from ECOCs related to Sites 7 and 12, there does not appear to be a significant impact on the ecological resources of Little Creek Harbor from the IR sites. Information collected in this SEA indicates limited toxicological impact and the absence of severe environmental media contamination. However, there is evidence of elevated heavy metal concentrations in the Harbor. These elevated concentrations are consistent with a chronic exposure

scenario with the contamination originating from a variety of sources within and outside of the Harbor.

1.0 INTRODUCTION

Naval Amphibious Base (NAB) Little Creek is a 2,147-acre base located in the Tidewater region of southeastern Virginia. Figure 1 presents a general overview of the region. NAB Little Creek provides on-base logistic facilities and support services to local commands, organizations, and other United States and allied units, home-ported ships, and commands of the operating forces to meet the amphibious training requirements of the Armed Forces of the United States (Foster Wheeler, 1994a). Figure 2 provides a site map of NAB Little Creek.

This Supplemental Ecological Assessment (SEA) has been performed to address the concerns of the United States Environmental Protection Agency (USEPA) Biological Technical Assistance Group (BTAG) regarding the impact of NAB Little Creek on the ecological resources of Little Creek Harbor. A Final Remedial Investigation/Feasibility Study (RI/FS) report (Foster Wheeler, 1994a) included an Ecological Risk Evaluation (ERE) that qualitatively defined risks to aquatic wildlife receptors within the reaches of Little Creek Harbor adjacent to Installation Restoration Program (IR) Sites 7 and 12. The BTAG requested that further work be conducted to address the threat posed to aquatic life by these sites.

Little Creek is not on the National Priority List (NPL), but the Navy is conducting proactive IR action. For this reason, the ERE was not designed to be a comprehensive assessment of risks like those required for NPL site ecological risk assessments (ERA) by the BTAG. The ERE determined that a quantitative study (i.e., ERA) may be necessary to further evaluate the impact of NAB Little Creek IR sites on the ecological environment.

The SEA of Little Creek Harbor (the Harbor) consisted of the following components: 1) the compilation of all existing IR and non-IR data pertaining to Little Creek Harbor, 2) the conduct of a Phase One ERA on the available Little Creek Harbor aquatic data, and 3) a perspective overview of the ecological condition of Little Creek Harbor as related to the condition of ecologically similar water bodies located within the southern region of the Chesapeake Bay.

1.1 Objective of Study

The objective of this study was to assess the impact of IR and non-IR sites on the aquatic ecology of Little Creek Harbor. The study was conducted in the following phases:

- Compilation of Existing Data
- Ecological Risk Assessment
- Little Creek Harbor Environmental Perspective

1.1.1 Compilation of Existing Data

A review of existing environmental data was conducted for Little Creek Harbor. Sources of this data included IR studies, Virginia Department of Environmental Quality (VADEQ) outfall reports, various NAB Little Creek water quality studies, NAB Little Creek Resources Management Program reports, NAB Little Creek hydrological studies, and NAB Little Creek dredging program reports. Selected data from this review was compiled into a single electronic database to be used for the ERA.

1.1.2 Ecological Risk Assessment

Based on the results of the compilation of the Little Creek Harbor data, an ERA was conducted using the Interim Ecological Risk Assessment Guidelines developed by USEPA Region III BTAG (USEPA, 1994a) for addressing risks to aquatic receptors in the Little Creek Harbor. In addition, Screening Levels developed by BTAG (USEPA, 1995) were used to determine the Ecological Contaminants of Concern (ECOCs).

Exposure point concentrations of ECOCs in the environmental media were calculated based on the Little Creek Harbor database. These ECOC concentrations represent the contribution of contaminants to the Little Creek Harbor that are a result of discharge from IR and non-IR sources. As part of the exposure characterization, the potential aquatic receptors in Little Creek Harbor were identified using available existing sources of information. In addition, the known endangered species were identified. Finally, the ecological effects of each ECOC were summarized in an ecological toxicological profile that includes available reproductive and growth effect endpoints.

Potential risks were characterized based on a Phase One ERA as per Region III BTAG guidance, which uses the hazard quotient methodology. A hazard quotient was calculated for each sample that exceeded screening values. Exceedance of unity in the hazard quotient index indicates the potential for risk to exposed aquatic receptors. The potential for bioaccumulation of ECOCs in the food chain is discussed qualitatively. An uncertainty analysis is provided that discusses the various assumptions and exposure parameters that may affect the risks that are characterized. The ecological significance of any potential risk to aquatic receptors in Little Creek Harbor is discussed based on the risks as compared to reference data and whether the risks are related to site-specific ECOCs.

1.1.3 Little Creek Harbor Environmental Perspective

To evaluate the potential impacts to Little Creek Harbor from the IR sites versus impacts from non-IR site point and non-point contaminant sources, an environmental perspective was developed from the information obtained. Information sources for Little Creek Harbor environmental perspective data include the USEPA's Chesapeake Bay Program, Old Dominion University (ODU), Virginia government agencies, and special regional programs.

1.2 Site Characterization

The following sections detail general NAB Little Creek characteristics, as well as site-specific characteristics of the IR sites potentially impacting the aquatic receptors of Little Creek Harbor.

1.2.1 General Site Characteristics

NAB Little Creek is located in the Atlantic Coastal Plain physiographic province (Tidewater Area). The base is bound on the north by the Chesapeake Bay, on the South by Shore Drive, on the east by Lake Bradford, and on the west by the Norfolk-Virginia Beach boundary. The central portion of the base is made of Little Creek Cove, Desert Cove, and the Little Creek channel that adjoins with the Chesapeake Bay (Foster Wheeler, 1994a). The land use at the base is primarily industrial, while the land use of the surrounding areas is suburban and industrial in nature (Foster Wheeler, 1994a).

Due to the extensive development of the region, wildlife populations in the vicinity of NAB Little Creek are quite limited and poorly representative of the general area. Widespread commercial and

residential development along with highway construction have eliminated most natural areas, and the few remaining areas are highly impacted by encroaching urbanization.

1.2.2 Site-Specific Characteristics

It is acknowledged that the runoff from several IR Sites drain into Little Creek Harbor and therefore, potentially may impact the ecological condition of the Harbor. Specifically, groundwater flows: from Sites 7 and 12 (via the drainage canal), and 13 toward Little Creek Cove; from Site 9 toward the Chesapeake Bay shoreline; and, from Sites 10 and 11 toward Desert Cove. It should be noted that because of the distance between Sites 11 and 13 and the Harbor, it is unlikely that surface runoff or groundwater from these sites would impact conditions within the Harbor.

Sites 7 and 12 are the only IR sites with surface water and sediment data available from the RI to assess potential impacts to the aquatic environment of the Harbor. The following sections present a description of only the IR Sites at NAB Little Creek that potentially may impact the aquatic environment of Little Creek Harbor.

1.2.2.1 Site 7 - Amphibious Base Landfill

The Amphibious Base Landfill is located in the south-central portion of the installation. The area is bounded on the north by the southeast shoreline of Little Creek Cove, on the east by Helicopter Road, on the south by the Hampton Roads Sanitation District treatment plant, and on the west by an undeveloped area that was used as an ordnance storage area. The landfill covers approximately 38 acres. The precise boundaries of the fill area have not been delineated. This area was originally an arm of Little Creek Cove that was filled with dredge spoils prior to its use as a landfill.

The landfill is well-vegetated, with the exception of the central and eastern portions that are mostly exposed unvegetated soil. Materials to be recycled, reused or transported off-base were often staged in the unvegetated area of the landfill. The area bordering Little Creek Cove is well vegetated with numerous trees and tall grasses. The landfill was constructed so that the central portion consists of a broad flat area bounded by gentle slopes on all sides.

The landfill operated from 1962 to 1979 (Foster Wheeler, 1994a). Before its use as a landfill, the site was used for the disposal of spoils from the dredging of Little Creek Cove. The landfill was initially operated as a trench-type landfill with open burning of refuse in the trenches. The trenches were excavated to the depth at which groundwater filled the trench as fast as it could be excavated. Standing water was common in the trenches. The landfill was later operated as an area landfill, i.e., refuse was spread over the ground surface and covered on a regular basis.

It is estimated that the landfill contains approximately 500,000 cubic yards of waste (Foster Wheeler, 1994a). A significant amount of this waste is most likely consisting of nonhazardous solid waste from base housing and other residential activities at the base. Specific records concerning the types and quantities of waste placed in the landfill are not available. However, because the landfill was the recipient of all the wastes produced at NAB Little Creek, it is probable that the landfill received potentially hazardous materials. The types of material believed to have been disposed in the landfill include: pesticides, paints, solvents, inorganics, heavy metals, acids, bases, PCBs, mixed municipal wastes, and unknowns. After its closure in 1979, the landfill area continued to be used as a metal collection and transfer site, a temporary storage area for wastes, and a burn area for scrap wood and trees (Foster Wheeler, 1994a).

1.2.2.2 Site 10 - Sewage Treatment Plant Landfill

The Sewage Treatment Plant Landfill is located in the north central portion of NAB Little Creek approximately 500 feet south of the Chesapeake Bay and west of the Driving Range Landfill. The landfill is bounded on the north and partially on the east by sand dunes, on the west by 11th Street, and on the south by recreational facilities which extend onto the landfill area. The landfill covers approximately 18 acres.

The Sewage Treatment Plant Landfill began operations in 1941 and was the first landfill to be used at NAB Little Creek. Landfill operations began in the southern portion of the area, which included an extension of Desert Cove and associated lowlands. Disposal in this area was reportedly directly into the water and resulted in the filling of approximately five acres of the cove. Disposal activities then moved northward into an area of marshy lowlands, and eventually encompassed an area of approximately 18 acres. According to the Initial Assessment Study (IAS), approximately 46,500 cubic yards of wastes have been disposed in this landfill.

The types of waste placed in the Sewage Treatment Plant Landfill were predominantly solid wastes until 1952. Most of the waste was then diverted to an incinerator adjacent to the site and the Driving Range Landfill. Disposal of sewage sludge from the on-site sewage treatment plant continued until 1968, the year in which the treatment plant closed. Between 1941 and 1952, this facility was the only operational landfill on NAB Little Creek and received all of the household and industrial wastes generated on base. A large quantity of demolition debris also was disposed in the landfill. Historical data concerning the types and quantities disposed at this landfill were not available. It is believed that the following types of waste could have been disposed at this landfill: pesticides, paints, solvents, inorganics, heavy metals, acids, bases, PCBs, mixed municipal wastes, and unknowns (Foster Wheeler, 1994a).

1.2.2.4 Site 11 - School of Music Plating Shop

The School of Music Plating Shop was located in Building 3651. This building was located in the eastern portion of NAB Little Creek, near the intersection of 7th and E Streets. The School of Music is located in Building 3602, which is southwest of the former plating shop. The actual site consisted of an in ground, concrete tank and its associated piping.

The neutralization tank for the plating shop was approximately 5 feet in diameter and 11 feet deep. Approximately 2.5 cubic yards of crushed limestone were placed in the pit to neutralize the acidic plating bath wastes. Waste water entered the tank via an acid-resistant drain pipe that originated in a sink in Building 3651 and terminated as an outfall on the western side of the tank. According to the Interim Remedial Investigation (Ebasco Environmental, 1991), neutralized waste water was discharged from the unit into the storm sewer via an outlet and drain from the northeast side of the tank. Flow through the unit was controlled by the standpipe and drain elevations, so that all waste water has to pass through the limestone before it could enter the discharge pipe connecting with the sewer.

Plating wastes were discharged into the neutralization tank during a ten-year period beginning in 1964. During its period of operation, the plating shop reportedly used silver cyanide, copper cyanide, chromic acid, nickel plating baths, and various acids. Also, lacquer strippers and lacquer were used (Foster Wheeler, 1994a).

1.2.2.5 Site 12 - Exchange Laundry Waste Disposal Area

The Exchange Laundry/Dry Cleaning Facility was located in Building 3323, near the intersection of 3rd and B Streets, in the eastern portion of the installation. Building 3323 was torn down in 1987 for construction of the existing commissary. A catch basin and a portion of a storm sewer line were also removed at that time. The sewer line received dry-cleaning wastes from the former Naval Exchange (NEX) laundry and drained to a canal that flows between Lake Bradford and Little Creek Cove. Wastes dumped into the storm sewer would flow north along B Street then west along the north side of Building 3329 before flowing into the canal. The site now consists of the remains of the sewer line, near the canal, and the former location of this line.

It has been reported that wastes dumped into the storm sewer and canal included tetrachloroethane sludges, soap, sizing, and dyes. The period of operation and disposal lasted from 1973 until 1978, during which an estimated 1,320 gallons of waste were dumped into the storm sewer drain (Foster Wheeler, 1994a).

1.2.2.6 Site 13 - Public Works PCP Dip Tank and Wash Rack

The pentachlorophenol (PCP) Dip Tank and Wash Rack is located near the intersection of 7th and F Streets in the eastern portion of NAB Little Creek, approximately one block west of Site 11. The site consists of the dip tank formerly used to treat wood with PCP, an adjacent area that had drying racks for the PCP-treated wood, a concrete wash rack, and an open area used by the Public Works Department for storage of supplies and equipment (Foster Wheeler, 1994a).

The PCP Dip Tank was located behind Building 3165E, and operated from the early 1960s until 1974. The dimensions of the tank are unknown, but it reportedly contained 300 to 400 gallons of PCP. Wood was dipped into the tank and set on racks for drying. The area formerly containing the PCP tank and the drying racks has been paved with asphalt, fenced, and converted into a Public Works Department storage area. A second area apparently used for drying and storage of PCP-treated wood was located northwest of Site 13, however, further details on the area are unavailable. The dip tank was cleaned out approximately every six months. Approximately 55 gallons of PCP sludge generated was removed each time the tank was cleaned. All remaining

PCP solution and associated sludges were removed from the tank in 1975. The tank was dismantled in 1982 (Foster Wheeler, 1994a).

2.0 METHODOLOGY OF DATA COLLECTION

This SEA was conducted using readily available existing information for NAB Little Creek Harbor and the surrounding environment. The existing information was obtained via interviews and document reviews. To identify the existing information, the SEA was initiated by developing a core set of contacts consisting of government agencies, Chesapeake Bay Program employees, and other technical experts. As contact calls were conducted, the original contact list was expanded into a network of contacts. Interviews were conducted either by phone or in person and the identified documents and databases were obtained. Table 1 presents the contact list developed during this investigation.

2.1 Interviews

The majority of the information collected for this SEA was obtained from NAB Little Creek, the VADEQ, the Chesapeake Bay Program, the Environmental Monitoring and Assessment Program (EMAP), and ODU. The following sections describe the types of documents and environmental data provided by the above-mentioned groups.

2.1.1 NAB Little Creek

NAB Little Creek provided both IR and non-IR reports and reference information. The Base also provided information on previous, present-day, and future management practices for the Harbor.

2.1.2 Virginia Department of Environmental Quality

The VADEQ provided water quality assessment [305(b)] reports and STORET data for Little Creek and regional reference areas. The VADEQ also was an identified source for Discharge Monitoring Reports and bioassay reports.

The Water Quality Assessment [305(b)] Report describes the water quality conditions during the time period of July 1, 1991 through June 30, 1993. The analysis of surface water quality conducted for this report was based on two different categories of information: monitored data and evaluated data. Monitoring data came primarily from the analysis of water column samples, fish tissue, and

sediment samples. Where monitoring data were not available, an evaluation was made, where possible, of the attainment of the individual support uses. These evaluations were based on data describing land use, point source discharges, non-point source pollution, fishery information, staff knowledge, and other relevant water quality information.

As part of the Surface Ambient Water Quality Monitoring Program, stations in the waters of Virginia are monitored to determine water quality trends and conditions in the state, for identification and ranking of Virginia's priority water bodies, and for reporting purposes in the 305(b) Water Quality Assessment Report. Stations are located to gather information from industrial, urban, rural, and undeveloped areas of the state. The monitoring network includes ambient water quality, benthic core, Chesapeake Bay tributary, and fish tissue monitoring stations, as well as stations identified specifically for special studies. All chemical and physical data collected at the monitoring stations are entered into USEPA's STORET database.

Information from twelve stations in the Little Creek Harbor area, Lynnhaven Bay, and the Cape Charles Harbor area were collected for this investigation. Lynnhaven Bay and Cape Charles Harbor surface water and sediment data were used as regional reference data to compare to Sites 7 and 12 NAB Little Creek RI data.

2.1.3 Chesapeake Bay Program

The Chesapeake Bay Program was a source for obtaining many of the documents identified in the interviews including regional and reference information on natural resources, surface water and sediment quality, and restoration goals. In addition, staff provided discussions on these documents.

2.1.4 Environmental Monitoring and Assessment Program

The EMAP provided environmental data for regional and reference areas in the Virginian Province: 1990 - 1993, Stations in the Chesapeake Bay - Maryland Region. The Virginian Province includes the wide expanse of irregular coastline from Cape Cod, Massachusetts to the mouth of the Chesapeake Bay (Cape Henry, Virginia). The Virginian Province includes USEPA Regions I, II, and III and the following states: Connecticut, Delaware, Massachusetts, Maryland, New Jersey, Pennsylvania, Rhode Island, and Virginia, including the District of Columbia.

Information available on the above stations included the following: benthic summaries, sediment chemistry, sediment toxicity test, sediment grain size characterization, benthic replicate abundance and biomass, vertical profile water quality, fish species composition, fish species abundance, and fish tissue chemistry data. The specific stations in the Virginian Province are provided in Appendix A.

It should be noted that the EMAP data requested for the southern portion of the Chesapeake Bay (no EMAP stations are located in Little Creek Harbor) is available in electronic format.

2.1.5 Old Dominion University

The ODU library was a source for obtaining many of the documents identified in the interviews including regional and reference environmental information.

2.2 Summary of Previous Investigations Reviewed

Two types of NAB Little Creek Harbor data were used in this investigation: IR related data and non-IR data. The IR data from the Final Remedial Investigation/Feasibility Study report (Foster Wheeler, 1994a) was used to conduct a Phase One ERA for NAB Little Creek Harbor. The non-IR data was used to determine impacts to Little Creek Harbor from sources other than the IR sites. The following sections present the two types of data reviewed for the study.

2.2.1 Non-IR Data

Surface water, sediment, and/or biota data were reviewed from the following non-IR related investigations:

- Water Quality and Living Resources Assessment of Five Sites in Little Creek Harbor (Ewing et al., 1992)
- Water, Sediment and Bioconcentration Study, Naval Amphibious Base, Little Creek, Virginia (NAB, 1994)

- A Study of Sediment and Water Quality in Little Creek Harbor (NAB, 1995a)
- Comparison of five benthic sampling devices (Ewing et al., 1988)
- STORET (VADEQ, 1995a)
- Environmental Monitoring and Assessment Program (EMAP, 1995)
- Discharge Monitoring Reports (VADEQ, 1995b)
- Results of Water-Effect Ratios for Metals (Internal Draft) (CH2M HILL, 1995)
- Fate and Transport of Landfill Contaminants Naval Amphibious Base Little Creek, Virginia (Conroy, 1993)
- Phase I Report. Stormwater Discharge Study, Naval Amphibious Base, Little Creek, Virginia Beach, Virginia. Summary Report (Gannett Fleming, Inc., 1993)
- Long-Term Management Strategy for Dredged Material Disposal for the Naval Weapons Station, Yorktown, Yorktown, Virginia; Naval Supply Center, Cheatham Annex, Williamsburg, Virginia; and Naval Amphibious Base, Little Creek, Norfolk, Virginia; Phase I: Evaluation of Existing Management Options and Data (Zappi et al., 1990)
- Long-Term Management Strategy for Dredged Material Disposal for the Naval Weapons Station, Yorktown, Yorktown, Virginia; Naval Supply Center, Cheatham Annex, Williamsburg, Virginia; and Naval Amphibious Base, Little Creek, Norfolk, Virginia; Phase I: Evaluation of Existing Management Options and Data (Palermo et al., 1993)
- Dredging Data, 1991 (J.R. Reed and Associates, 1991)

The following sections provide further detail on the non-IR related data that was reviewed and was used in conducting the ERA for Little Creek Harbor. It is noted that the summaries provided below include additional information on current conditions at NAB Little Creek as provided by Base personnel (NAB, 1995b).

Water Quality and Living Resources Assessment of Five Sites in Little Creek Harbor (Ewing et al., 1992)

Surface water and sediment samples were collected at five sites within Little Creek Harbor for chemical evaluation. Zooplankton and phytoplankton samples also were collected at each site. In addition, surrogate sampling devices were deployed in the water column at each site. These devices, developed by Applied Marine Research Laboratory (AMRL) of ODU, contained sorbet resins for concentrating dissolved organic contaminants from the water. Finally, temperature, dissolved oxygen (DO), pH, conductivity, and salinity were collected at each station at different depths. A second sampling event was associated with this investigation to collect sediments for bacterial community characterizations. Sampling locations are presented on Figure 3.

Surface water quality parameters analyzed at each station included: chlorophyll-*a*, biological oxygen demand (BOD), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), total phosphate-P, orthophosphate-P, nitrate (NO₃), nitrite (NO₂), ammonium (NH₄), total organic carbon (TOC), phenol, and cyanide. In addition, surface water samples were analyzed for the following analytical parameters: arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, zinc, tributyl-tin, and dibutyl-tin. The sorbet containing devices were analyzed for priority pollutants. Sediment samples were analyzed for: TOC, phenols, cyanide, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, zinc, semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), tributyl-tin, dibutyl-tin, oil and grease, and culturable bacterial count.

Arsenic, cadmium, chromium, copper, lead, and zinc were detected in all surface water samples, while mercury and selenium were detected in only one surface water sample. All other inorganic constituents were not detected. Total tributyl-tin was detected in one surface water sample, while total dibutyl-tin was detected in four surface water samples. Priority pollutant organic compounds

were detected at low levels in all surrogate sampling devices. Inorganic and total dibutyl-tin were detected in all sediment samples at varying concentrations. Limited base neutral acids, phthalates and polynuclear aromatic hydrocarbons (PAHs) also were detected in the sediment samples.

Bacterial numbers (total and culturable) in the Little Creek Harbor sediments were found to be within the normal, expected range for near-surface estuarine sediments. The types of bacteria identified were among those commonly isolated from estuarine sediments.

The phytoplankton that characterized the NAB Little Creek sites consisted mainly of a diverse representation of neritic species, common to the lower Chesapeake Bay and smaller estuaries in this region. Phytoplankton concentrations and biovolume were mainly a product of the growth of diatoms and dinoflagellates. The maximum concentrations of the phytoplankton and picoplankton components were within the ranges for late summer for this region. However, differences in phytoplankton and picoplankton development occurred at the sampling sites. Sites 3 and 5 (located within Little Creek Cove and Desert Cove, respectively) were recognized as the least productive, and these populations appeared suppressed in their growth and development. The most productive sites were located along the western edge of Little Creek Harbor (Sites 2 and 4). (See Figure 3)

The zooplankton communities at all of the Little Creek Harbor sites were dominated by the copepoda *Acartia tonsa*. This species dominates most mesohaline and polyhaline (5-30 parts per thousand salinity) areas of the lower Chesapeake Bay during the summer months. Zooplankton diversity ranged from 36 to 43 taxa per site, all of these values were determined to be within the range lower Chesapeake Bay sites in August. Overall, nothing unusual was detected in the zooplankton composition, abundance, or diversity at any of the Little Creek Harbor sites.

Water, Sediment and Bioconcentration Study, Naval Amphibious Base, Little Creek, Virginia.
(NAB, 1994)

Sampling activities included the collection of bottom sediment samples, mid-depth surface water samples, and the collection of biological samples (fish and crab) at one station (Site#4-w/s) in Little Creek Harbor. Sediment samples were collected with a Ponar dredge. Surface water samples were collected with a horizontal liquid sampler. Fish were collected with a rod and reel. Finally, crabs

were collected by crab pots and nets. Samples were collected twice at one sample location (See Figure 3) on July 7 and 14, 1994.

The sampling location was approximately 75 feet straight off the end of Pier 2. Edible muscle tissue was analyzed in both fish and crab samples. Two surface water samples were analyzed for TSS, depth, pH, temperature, salinity, DO, and conductivity. Two sediment samples were analyzed for heavy metals (mercury, cadmium, and selenium), pesticides, PAHs, PCBs, and tributyl-tin. Two crab samples and two fish samples (croaker and spot) were analyzed for pesticides, PAHs, PCBs, tributyl-tin, cadmium, mercury, and selenium.

Total mercury, anthracene, benzo(a)anthracene, benzo(b)anthracene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene were detected in the sediment sample collected on July 7, 1994. Total mercury, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene were detected in the sediment sample collected on July 14, 1994. Total mercury was the only constituent detected in the crab tissue samples collected during both sampling rounds. Total mercury was the only constituent detected in both the croaker and spot tissue samples.

A Study of Sediment and Water Quality and Biota Tissue in Little Creek Harbor (NAB, 1995a)

During January 1995, sediment samples were collected from two stations in Little Creek Harbor (See Figure 3). A measurement of the physical parameters of water (pH, temperature, DO, specific conductance, and salinity) was made at each site prior to sediment collection. Tributyl-tin was the only constituent detected in the sediment sample Site#4-S. Total mercury, total cadmium, and tributyl-tin were detected in the water sample Site#5-W. One fish (croaker) and one crab (blue crab) sample were collected on August 2, 1995 at a station out from Pier 58 at NAB Little Creek. Tissue samples were analyzed for tributyl-tin, total mercury, total cadmium, total selenium, SVOCs, pesticides and PCBs. Tributyl-tin and total mercury were the only constituents detected in the fish and crab samples.

Comparison of Five Benthic Sampling Devices (Ewing et al., 1988)

This study was a comparison of benthic macroinvertebrate sampling results obtained from five different samplers: the Ponar, Shipek, Smith-McIntyre, and Van Veen grab samplers and a spade-type box corer. Two benthic macroinvertebrate stations were sampled: one mud station in Little Creek Harbor and one sand station adjacent to the Thimble Shoal Channel located in the Chesapeake Bay. The Little Creek sampling location is presented on Figure 3. The sand site was located in a polyhaline portion of the lower Chesapeake Bay and deep-dwelling benthic macrofauna dominated the sample collected. The mud site was located in an upper mesohaline/lower polyhaline region of Little Creek Harbor and near-surface benthic macrofauna dominated the samples.

In addition to collecting benthic macroinvertebrates, bottom salinity, temperature, and DO were measured at each site prior to, and after sample collection. Benthic statistics calculated with the collection results included: community density, community biomass, density of each species collected, and biomass of each species collected, species diversity, species evenness, and mean species per replicate. Statistical comparisons between sampling devices were calculated by using univariate comparisons (Analysis of Variance [ANOVA] with Duncan's multiple range test) and multivariate comparisons (Multivariate Analysis of Variance [MANOVA]).

A total of 84 infaunal benthic taxa were identified in this study. Polychaetes comprised 46.5% of the individuals collected, crustaceans 23.8%, bivalves 13.1%, gastropods 8.3%, and other taxonomic groups 8.3%. Univariate comparisons between sampling gear indicate that community density and biomass were significantly different between gears. Multivariate comparisons between sampling gear did not demonstrate a significant difference in density or biomass between sampling gears.

The benthic results obtained from the Little Creek Harbor station (the mud site) collected with the Ponar sampler were used in the Environmental Perspective (Section 6) to assess the benthic community within Little Creek Harbor. The Chesapeake Bay - Benthic Macroinvertebrate Restoration Goal Index (RGI) was utilized to determine the overall condition of the benthic community at one station within Little Creek Harbor. In addition, the dominant species collected in Little Creek Harbor were compared to dominant species collected from an ecologically similar reference harbor. It is noted that only the data collected with the Ponar sampler from this study was used because the RGI data was collected with a Ponar sampler.

STORET Data (VADEQ, 1995)

STORET is the USEPA computer system for the storage and retrieval of water quality data. Data are entered into the STORET system by various Federal, state, and interstate agencies responsible for monitoring water quality. Funding for the collection and entry into the STORET database is provided by various sections of the Clean Water Act.

Surface water and sediment STORET data collected from Lynnhaven Harbor and Cape Charles Harbor were used as reference data to compare against surface water and sediment data collected in Little Creek Harbor (See Figures 4 and 5).

Long-Term Management Strategy for Dredged Material Disposal for Naval Weapons Station, Yorktown, Yorktown, Virginia; Naval Supply Center, Cheatham Annex, Williamsburg, Virginia; and Naval Amphibious Base, Little Creek, Norfolk, Virginia; Phase II: Formulation of Alternatives (Palermo *et al.*, 1993)

Fifteen locations in Little Creek Inlet and NAB Little Creek Channel north of the jetties were sampled on two separate occasions (November 1989 and January 1990). Dredged sediment samples also were collected in April 1990.

Sediment was collected from four different sites in the southern Chesapeake Bay; two sites situated adjacently to NAB Little Creek, one site in the York River near NWS Yorktown, and one site near Cheatham Annex (CAX). Sediment also was collected at two reference stations for performance of benthic bioassay testing.

Analysis of the test sediments and comparisons with the two reference sediments indicated that cadmium, chromium, copper, lead, mercury, nickel, and zinc levels in the test sediments exceeded the levels for those same metals at two reference stations. NAB Little Creek tributaries' sediment caused clams to bioaccumulate a level of mercury that exceeded both bay and ocean reference sediment bioaccumulation values, but this exceedance was not statistically significant. Clams exposed to NAB Little Creek tributary sediments, as well as clams exposed to both bay and ocean

reference sediments, were analyzed for PAHs. The results of residue determinations indicated that there was no evidence of bioaccumulation in the samples.

In a single case, lead was significantly bioaccumulated in NAB Little Creek tributary sediment as compared to ocean reference sediments, but this exceedance was not considered to have toxicological significance.

Dredging Data, 1991 (J.R. Reed and Associates, 1991)

Dredged sediment from 14 stations was collected from Little Creek Harbor during 1989 and 1990. Concentrations of cadmium, copper, lead, mercury, and zinc were detected in the dredged sediment samples collected in the Harbor. The dredging data were used qualitatively in this ERA for Sites 7 and 12.

The following non-IR reports pertaining to Little Creek Harbor were reviewed, but were not used in this study for various reasons as detailed below.

Environmental Monitoring and Assessment Program Data (EMAP, 1995)

The EMAP does not have any stations located within Little Creek Harbor or the reference sites. Therefore, they were not used in the SEA.

Discharge Monitoring Reports (VADEQ, 1995b)

Discharge Monitoring Reports contain primarily conventional parameters (pH, DO, flow, etc.). These reports did not contain the analytical parameters necessary to be used in this study.

Results of Water-Effect Ratios for Metals (Internal Draft) (CH2M HILL, 1995)

One surface water sample was collected in Little Creek Harbor. The surface water was analyzed for salinity, alkalinity, pH, TSS, TOC, and dissolved organic carbon. This is an ongoing program and the data have not been validated. Therefore, the data was not used in the ERA for Little Creek Harbor.

Fate and Transport of Landfill Contaminants, Naval Amphibious Base Little Creek, Virginia
(Conroy, 1993)

This report was a Master of Science in Engineering paper conducted on the Site 7 landfill at NAB Little Creek. This report considers only landfill contaminant migration through groundwater. This investigation reviews the history and development of the base and landfill to determine the types and quantities of wastes generated by base operations. Groundwater models were used to determine the potential migration patterns of contaminants from the landfill. Based on the hypothetical nature of this report and the lack of any additional data generated in this study, the information could not be used in this ERA.

Phase I Report, Stormwater Discharge Study, Naval Amphibious Base, Little Creek, Virginia Beach, Virginia. Summary Report (Gannett Fleming, Inc., 1993)

The stormwater discharge study provided for the collection and analysis of information needed to complete a National Pollutant Discharge Elimination System (NPDES) Permit Application for Stormwater Discharges at Little Creek. This report presented a summary of the information collected.

Facilities identified in the stormwater regulations as associated with industrial activity have been inventoried through field reconnaissance at NAB Little Creek and located on base mapping of the storm drainage systems (mapping provided in Appendix B). Twenty-eight outfalls subject to regulation (whether on the basis of SIC Code or material exposure to stormwater) have been identified on the mapping. Outfalls located in the industrial areas of NAB Little Creek, not subject to regulation, have also been identified separately on the mapping. A number of areas throughout the base drain to surface waters by sheet flow, rather than through a point-source conveyance. These areas have been identified separately on the mapping, as well as several isolated stormwater outfalls that do not outlet to surface waters. Tables describing the regulated stormwater outfalls also are presented in Appendix B.

The following summarizes the stormwater drainage systems that are related to Sites 7 and 12. Stormwater drainage systems related to the other sites can be identified in Appendix B.

Regulated outfall 003 has been identified in the vicinity of Site 7. One non-regulated outfall and five sheet flow discharges have been identified at Site 7. Also, the following material storage areas were previously in operation at Site 7: Asphalt/Sand/Aggregate Storage (3), Wood/Lumber Storage (1), Miscellaneous Construction Material Storage (1), Miscellaneous Metal Storage (1), Open Top Dumpster (1), Tire Storage (1), and Aboveground Fuel Tank (1). One Best Management Practice (vegetative filters) has also been identified in the vicinity of Site 7.

One sheet flow discharge and no regulated stormwater outfalls or non-regulated outfalls have been identified in the area of Site 12. One material storage area (an aboveground fuel tank) has been identified in the area of Site 12. Two exposed industrial activity areas: a Marine/Land Vehicle Maintenance area (one) and a Washdown area (one car wash), have been identified in the area of Site 12. Five Loading/Unloading areas have also been identified in the area of Site 12. The matrices studied in this report were primarily analyzed for physical parameters only; therefore, this data was not used in this ERA.

Long-Term Management Strategy for Dredged Material Disposal for the Naval Weapons Station, Yorktown, Virginia; Naval Supply Center, Cheatham Annex, Williamsburg, Virginia; and Naval Amphibious Base, Little Creek, Norfolk, Virginia; Phase I: Evaluation of Existing Management Options and Data (Zappi et al., 1990)

Dredged material from these facilities had been placed at the U.S. Army Corps of Engineers, Craney Island Dredge Disposal Area in past years. The Atlantic Division, Naval Facilities Engineering Command, the U.S. Army Corps of Engineers, Norfolk District, and the U.S. Army Corps of Engineers Waterways Experiment Station discussed the need for developing a long-range dredged material management strategy for Naval Weapons Station (NWS) Yorktown, CAX, and NAB Little Creek. The purpose of this report was to document an evaluation of existing management options and data for disposal of dredged material for these three facilities. This evaluation included a review of dredging volumes and frequencies, dredging and disposal equipment and techniques, environmental resources, and management options presently available.

Little Creek Inlet provides a sheltered harbor for military commercial, and private vessels. It is used primarily by NAB Little Creek; however, a rail ferry, the US Coast Guard, private marinas, and several industrial companies make use of the inlet.

Dredging in Little Creek Inlet is required to maintain navigable depths in the inlet. Norfolk District maintains the main Little Creek Channel from the Chesapeake Bay to one mile into Little Creek Inlet. In 1984, the main Little Creek Channel was dredged to a depth of 22 feet below mean low water (mlw), in addition to a 1-foot over depth, and a channel width of 500 to 550 feet, in addition to a turning basin.

Desert Cove was dredged to a depth of 10 feet below mlw in 1953. The flotilla pier was dredged to a depth ranging from 5 to 20 feet below mlw in 1961. In 1965, Piers 1 - 8 were dredged to a depth of 18 feet below mlw, in addition to a 2-foot over depth, and Pier 9 was dredged to a depth of 10 feet below mlw, in addition to a 2-foot over depth. In 1975, Piers 56 - 59 and 14 - 19 were dredged to a depth of 20 feet below mlw, and AFDL was dredged to a depth of 30 feet below mlw. In 1976, Piers 11 - 14 were dredged to a depth of 25 feet below mlw, and Pier 59 and the quaywall were dredged to a depth of 10 feet below mlw, and a 1-foot over depth. In 1982, the Chubb Lake Training Area was dredged to a depth of 6 feet below mlw in the channel and 4 feet below mlw at the boathouse. In 1984, Little Creek Cove, west of Pier 56, was dredged to a depth of 22 feet below mlw, in addition to a one-foot over depth.

Dredged sediments from NAB Little Creek have been sampled on four occasions. Twenty-four borings were taken in April 1974 at various locations in the main Little Creek Channel. These borings were associated with the widening of Little Creek Channel; therefore, the majority of the samples were taken along the sides of the old channel.

In January 1978, three sediment borings were taken in the southwest part of Little Creek Cove. These borings were associated with the proposed construction of an ammunition handling wharf. In November 1979, two shallow borings were taken adjacent to Piers 16 and 17 in southwest Little Creek Channel. In August 1982, 26 sediment borings were taken at various locations in the Little Creek Channel and Little Creek Cove.

This data was not available to use in this ERA.

2.2.2 IR-Related Data

Surface water, sediment, and/or biota samples were collected in the following IR-related investigations:

- Round 1 Verification Step (CH2M HILL, 1986)
- Interim Remedial Investigation (Ebasco Environmental, 1991)
- Remedial Investigation/Feasibility Study (Foster Wheeler, 1994a)
- Draft Report for Sediment Sampling and Analysis for Canal Adjacent to IR Site 12 (Foster Wheeler, 1995)

The following sections present a summary of the sampling and results of the IR-related reports reviewed for this study.

Round 1 Verification Step (CH2M HILL, 1986)

Surface water and sediment samples were collected from Sites 7 and 12 during this investigation. Sediment samples were collected with a hand auger, shovel, or a stainless steel scoop. Sediment samples were collected between 0 and 0.5 feet. Surface water samples were collected directly into the sample container. Sample locations are presented on Figure 3.

Five surface water and sediment samples were collected at Site 7. These samples were analyzed for priority pollutants, oil and grease, ethylene dibromide, base-neutral extractable organic compounds, acid extractable organic compounds, pesticides, PCBs, phenols, and metals.

Volatile organic compounds (VOCs) were not detected in any of the surface water samples, but low levels were detected in all of the sediment samples. Base-neutral extractable organic compounds were detected in two sediment samples, while acid extractable organic compounds were detected in two surface water samples. Pesticides and PCBs were detected in two sediment samples. Low levels of metals were detected in all of the surface water and sediment samples except LC7-SW1. Oil and grease also were detected in all surface water and sediment samples at levels ranging from 297 µg/L to 20,000 µg/L.

It was recommended, based on the results of this study, that three additional surface water samples be collected at locations farther from the landfill shoreline and one surface water sample from the drainage east of the landfill to assist in determining the source of surface water contamination. It was recommended that these samples be analyzed for priority pollutant metals and major ions.

Six surface water and sediment samples were collected at Site 12. These samples were analyzed for priority pollutants. VOCs were detected in four of the surface water and all of the sediment samples. Concentrations of most constituents in the samples were generally below or near the detection limits. VOC concentrations in the surface water ranged from not detected to 43.3 µg/L. VOC concentrations in the sediment ranged from 11 µg/L to 598 µg/L.

It was recommended, based on the results of this investigation, that a second round of samples, including six surface water samples and two sediment samples be collected. It was further recommended that both sediment samples should be collected near the outlet of the drainage pipe at a depth of 0.5 to 1.0-foot, and that all samples should be analyzed for VOCs.

Interim Remedial Investigation (Ebasco Environmental, 1991)

The Interim RI was conducted to determine whether further characterization activities or remedial actions were warranted at Sites 7, 9, 10, 11, 12, or 13. Surface water samples were collected at Site 7 and surface water and sediment samples were collected at Site 12. Sample locations are presented on Figure 3.

Eleven surface water samples (nine samples and two duplicate samples) were collected at Site 7. Surface water samples were collected from the canal on the site's west side, the small creek (northeast of the site), and from Little Creek Cove. All of the surface water samples were analyzed for unfiltered target analyte list (TAL) metals and ions (sulfate, chloride and alkalinity). Six of the surface water samples were analyzed for target compound list (TCL) VOCs, TCL SVOCs, TCL pesticides/PCBs, ethylene dibromide, total petroleum hydrocarbons (TPH), and hexavalent chromium. Five of the surface water samples were analyzed for TOC and total organic halogen (TOX).

Phenols were the only organic compounds detected in the surface water samples. TOC and TOX were detected in five of the surface water samples. Anions, including chloride, sulfate, and alkalinity, were detected in all of the surface water samples. Unfiltered samples for metals analyses were collected from all the surface water locations, and filtered samples were collected from two of the surface water locations. Metals were detected in all of the unfiltered and filtered surface water samples.

Eight surface water samples (seven samples and one duplicate sample) and four sediment samples (three samples and one duplicate sample) were collected in the canal which forms the northwestern edge of Site 12. Samples LC12-SED1 and LC12-SED2 were collected directly adjacent to the discharge pipe from depths of 0 - 6 inches and 6 - 12 inches, respectively. Only TCL VOC analysis was conducted on the surface water and sediment samples. No VOCs were detected in any of the surface water or sediment samples.

Remedial Investigation/Feasibility Study (Foster Wheeler, 1994a)

Results from the Round One Verification Study (CH2M HILL, 1986) and the Interim RI (Ebasco Environmental, 1991) indicated that little or no contamination was leaving any of the landfill sites (Foster Wheeler, 1994b). Therefore, the surface water and sediment samples collected during the RI were analyzed only for TCL volatile organic compounds and TAL inorganic compounds. Figure 3 presents sampling locations for the RI.

Site 7

Six surface water and six sediment samples (and one duplicate sample) were collected at Site 7 during the RI. These samples were collected during low tide conditions, based on information collected during the tidal survey, to minimize the effect of tidal surface water inflow and dilution. Three of the sampling locations were at upstream locations, and two sampling locations were downstream of the landfill in the west canal. One surface water and one sediment sample were also collected from the east canal.

The surface water and sediment sampling were conducted sequentially. Sampling progressed from downstream locations to upstream locations, and surface water samples were collected before the

sediment samples. Sampling personnel were careful not to disturb the bottom sediment or create any unnecessary agitation at the sampling location. Both the surface water and sediment samples were collected near the shoreline, with the sediment sample being collected from the uppermost six inches of sediment using a stainless steel spoon. The volatile sample for the sediment was collected first, and the remaining sample was homogenized in a decontaminated stainless steel bowl before being placed into the laboratory supplied containers. The surface water and sediment samples were analyzed for TCL VOCs, TAL metals, and anions. In addition, the sediment samples were analyzed for TOC.

Site 12

Four surface water and four sediment samples were collected at Site 12. The surface water and sediment sampling was conducted sequentially. Sampling progressed from downstream locations to upstream locations, and the surface water samples were collected first. Sampling personnel were careful not to disturb the bottom sediment or create any unnecessary agitation at the sampling location. Both the surface water and sediment samples were collected near the shoreline, with the sediment sample being collected from the uppermost 6 inches of sediment using a stainless steel spoon. The surface water and sediment samples were analyzed for TCL VOCs and TAL metals. In addition, the sediment samples were analyzed for TOC.

Draft Report for Sediment Sampling and Analysis for Canal Adjacent to IR Site 12 (Foster Wheeler, 1995)

It has been determined that drainage flow from Lake Bradford is restricted at various locations in the canal adjacent to Site 12 due to sedimentation and debris accumulation. Sediments in the canal will possibly be dredged and disposed; therefore, sampling and analysis of the canal sediment was conducted.

Ten sediment samples and four QA/QC samples were collected from the canal. Sediment was collected with a hand auger approximately to a depth two feet below the surface of the sediment. The samples were analyzed for TCL VOCs and TCL inorganic compounds. VOCs were detected at low concentrations in the sediment samples. Inorganic compounds were detected at varying concentrations in all of the sediment samples.

3.0 REGIONAL CONDITIONS

The following sections present regional conditions of the environment of the NAB Little Creek and the surrounding areas.

3.1 Regional Water Quality Characteristics

All waters of Virginia are classified and managed for recreational use, and for the propagation and growth of a balanced, indigenous population of fish, shellfish, and wildlife. These two uses are consistent with the goals of the Clean Water Act for swimmable and fishable waters. Many waters, such as cold water trout fisheries, are managed to maintain water quality substantially higher than the minimum required by the Clean Water Act (VADEQ, 1994).

Estuaries were impacted by nutrients (1,468 miles), with the Chesapeake Bay being the largest contributor. The entire Chesapeake Bay is categorized as fully supporting but threatened for aquatic life because it is nutrient enriched. This means that the nutrients have a potential for causing problems. Organic enrichment was the second leading cause of impairment of estuaries. Nutrients in the Chesapeake Bay caused algal blooms, which reduced the amount of light penetration, leading to the reduction of submerged aquatic vegetation. Agriculture and runoff were the primary sources of pollution in rivers, while municipal and industrial point sources (both in-state and out-of-state), agriculture, runoff, and atmospheric deposition were major sources of pollutants to estuaries (VADEQ, 1994).

The Virginia Department of Health has condemned 97,192 acres of productive shellfish areas in Virginia. These areas are all located in the Chesapeake Bay and Tidewater areas of the state. The harvesting of shellfish is prohibited in three bodies of water in Virginia: the Elizabeth and Lafayette Rivers, both within the lower James River subbasins; and Little Creek in the Small Coastal and Chesapeake Bay Basin. The following presents a listing of shellfish condemnation areas in the vicinity of Little Creek (VADEQ, 1994):

- Linkhorn Bay, Virginia Beach - Restricted October 15, 1930. Canceled March 24, 1975.

- Little Creek, Norfolk, Virginia Beach - Restricted April 16, 1935. Revised August 1, 1940. Revised August 25, 1987. Reissued April 27, 1989. Revised August 24, 1990.
- Lynnhaven, Broad and Linkhorn Bays, Virginia Beach - Restricted September 27, 1937. Revised February 24, 1974. Revised March 24, 1975. Conditionally approved November 26, 1976. Revised September 14, 1977. Revised October 29, 1980. Revised August 30, 1985. Revised February 10, 1986. Revised June 24, 1986. Revised May 12, 1987. Reissued April 27, 1989. Revised July 19, 1991. Revised November 16, 1992. Revised December 30, 1992. Revised January 4, 1994. Revised February 8, 1994.
- Lynnhaven Bay, Virginia Beach - Restricted September 9, 1941. Canceled February 20, 1974.
- Lynnhaven Bay, Virginia Beach - Condemned December 30, 1964. Canceled February 1974.
- Lynnhaven Bay, Western Branch, Virginia Beach - Condemned October 13, 1959. Canceled February 20, 1974.
- Chesapeake Bay, Adjoining Little Creek, Norfolk, Virginia Beach - Condemned March 28, 1969. Reissued April 27, 1989. Revised October 12, 1993.
- Lynnhaven Bay, Entire Western Branch, Virginia Beach - Condemned June 28, 1971. Rescinded December 15, 1971.
- Lynnhaven Bay: Brock Cove, Virginia Beach - Condemned March 7, 1972. Canceled February 20, 1974.
- Broad Bay: Dey Cove and Mill Dam Creek, Virginia Beach - Condemned April 11, 1972. Canceled March 24, 1975.

- Old Plantation Creek (Cape Charles), Northampton County - Condemned March 26, 1975. Rescinded November 28, 1977. Condemned September 24, 1991. Revised August 31, 1992. Revised November 16, 1992. Revised November 16, 1993.

The Pollution Response Program with the VADEQ responds to pollution incidents affecting State waters. This program maintains a database on these incidents and included information on where fish kills are known to have occurred. One fish kill in Little Creek Harbor, September 14, 1992, was located in this database. The fish kill occurred due to a low dissolved oxygen condition (red tide).

In 1976, Congress directed the USEPA to jointly conduct, with the Chesapeake Bay area states, a study on the condition of the Bay. The study, which was completed in 1983, revealed declines in submerged aquatic vegetation, productive oyster grounds, and landings of freshwater spawning fish. The study showed increases in nutrient levels, the volume of Chesapeake Bay waters containing low or no dissolved oxygen, and areas with elevated levels of heavy metals and toxic organic compounds in the water column and sediment (VADEQ, 1994).

3.2 Regional Geology/Hydrogeology

The following presents a summary of the regional geology/hydrogeology as presented in the RI Report (Foster Wheeler, 1994a). The NAB Little Creek area is located within the Atlantic Coastal Plain Physiographic Province. The region is underlain by several thousand feet of unconsolidated deposits of gravel, sand, and clay ranging in age from Lower Cretaceous to Holocene. These sediments overlie a bedrock basement of Precambrian and Triassic/Jurassic age. The natural surficial geologic units at NAB Little Creek are an unnamed Holocene sand, which forms the coastal barrier islands and beach-dune ridges bordering the Chesapeake Bay, and the Lynnhaven Member of the Upper Pleistocene Age Tabb Formation (Mixon *et al.*, 1989). Sites 7 and 12 are located in the Lynnhaven Member of the Upper Pleistocene Age Tabb Formation. This unit is a "pebbly and cobbly, fine to coarse gray sand grading upward into clayey and silty fine sand and sandy silt" (Mixon *et al.*, 1989).

The natural soils at NAB Little Creek have been largely disturbed by construction activities. The IAS estimated that 90 percent of the surface sediment at the base is either urban or dredged from the surrounding waterways, and other soils have been imported. It was also estimated that only 14 acres

of undisturbed marsh land remain at NAB Little Creek out of a total of 2,147 acres present at the base.

The uppermost water table aquifer, known as the Columbia Aquifer, is the primary unit of concern at NAB Little Creek. The Columbia Aquifer extends from the ground surface to a depth of 20 feet below mean sea level in the area of the base and is underlain by the upper unit of the Yorktown Formation. Recharge for the Columbia Aquifer comes primarily through infiltration of precipitation. The IAS estimated that approximately 50 percent of the precipitation which falls in the area infiltrates, and 78 percent of that water will reach the water table.

NAB Little Creek is located adjacent to the Chesapeake Bay. According to the RI Report, based on topographic mapping of the site, most surface drainage will flow into the Little Creek Tidal Inlet, which consists of Little Creek, Desert Cove, Little Creek Channel, and Little Creek Cove, and then into the Chesapeake Bay through the inlet. On the eastern part of the base, surface drainage flows via unlined canals into five lakes, of which Lake Bradford and Chubb Lake are the largest. These lakes do not have surface outlets into the Chesapeake Bay.

Chubb Lake and Lake Bradford are interconnected, freshwater lakes, not directly connected with other surface water bodies. The water level in these two lakes is regulated by the release of the overflow into a canal which drains to the southwest and eventually into Little Creek Cove. This canal was the subject of the RI sampling at Site 12. The IAS states that Chubb Lake and Lake Bradford may receive significant amounts of salt water from the Chesapeake Bay during extreme storm events.

As described in the IAS, NAB Little Creek is influenced by tidal fluctuations. Little Creek and Little Creek Cove experience a semidiurnal tide of approximately 2.5 feet, but because of the limited areal extent of the harbor, tidal currents are limited. Effects of the tidal fluctuations on the groundwater flow and contaminant migration at the base are unknown. Therefore, tidal surveys were conducted during the RI.

A narrow east-west trending canal, located south of NAB Little Creek, carries the outflow from the freshwater Lake Whitehurst Reservoir and Little Creek Reservoir/Lake Smith to Little Creek Cove. The 4,000-foot long drainage canal originates from Little Creek Reservoir and passes through the western portion of Site 7. Lake Smith is designated as an emergency source of potable water.

4.0 ECOLOGICAL RISK ASSESSMENT

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by Superfund Amendments and Reauthorization Act (SARA) of 1986, directs the USEPA to protect human health and the environment with respect to releases or potential releases of contaminants from abandoned hazardous waste sites (USEPA, 1989a). This section presents the focused ERA conducted for NAB Little Creek that assesses the potential impacts to aquatic ecological receptors from contaminants detected at the selected IR sites.

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

The objective of this Phase One aquatic ERA is to evaluate the potential that past IR site operations at NAB Little Creek have adversely affected the ecological integrity of the aquatic community of Little Creek Harbor. Specifically, this ERA of NAB Little Creek will evaluate the risk associated with two sites identified in the RI/FS conducted by Foster Wheeler (1994a) that had surface water and sediment samples analyzed. These sites include Site 7 - Amphibious Base Landfill and Site 12 - Exchange Laundry Waste Disposal Area. The conclusions of the ERA will be used to evaluate the appropriate remedial action for the IR sites for overall protection of the environment.

This Phase One aquatic ERA evaluated and analyzed the results from the RI including sampling and chemical analysis of the surface water and sediment. Fish and benthic macroinvertebrate samples were not collected during the RI at NAB Little Creek.

Information used to evaluate sensitive environments was obtained from An Inventory of Rare, Threatened, and Endangered Species of the Little Creek Naval Amphibious Base conducted by the Virginia Department of Conservation and Recreation (VADCR, 1990) and the Endangered, Threatened and Candidate Species on Navy and Marine Corps Lands: A Base Specific Handbook, developed by the Department of the Navy (1994).

The risk assessment methodologies used in this evaluation were consistent with those outlined in the Region III Interim Ecological Risk Assessment Guidelines (USEPA, 1994a). In addition, information found in the following documents was used to supplement the USEPA guidance document:

- Ecological Risk Assessment Guidance for Superfund (USEPA, 1994b)
- Framework for Ecological Risk Assessment (USEPA, 1992a)
- USEPA Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (USEPA, 1989b)
- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989c)

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

4.2 Problem Formulation

Problem formulation is the first step of an ERA and includes a preliminary characterization of exposure and effects. The presence and concentrations of any contaminants detected at least once were evaluated in order to determine the ECOCs. Ecological surveys were not conducted as part of the field activities during the RI. However, surveys were conducted during the evaluation of rare, threatened, and endangered species. Based on these observations and evaluation of habitats in the vicinity of the site, potential ecological receptors were identified. Finally, toxicological information

for the ECOCs detected in the media was obtained from available references and literature and used to evaluate the potential adverse ecological effects to the ecological receptors.

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

4.2.1 Stressor Characteristics

One of the initial steps in the problem formulation stage of an ERA is identifying the stressors and their potential ecological effects. A stressor is defined as any physical, chemical, or biological entity that can induce an adverse response. Identification of stressor characteristics for this ERA included the examination of results from the RI.

For this ERA, the stressors evaluated were the contaminants detected in the surface water and sediment collected during the RI. Contaminants in the soil and groundwater were not evaluated in this focused ERA. Only data from media directly affecting the aquatic environment were evaluated.

4.2.2 Ecological Contaminants of Concern

During the problem formulation stage, the chemical stressors to the site are identified. For this focused ERA, the stressors that were evaluated include the ECOCs detected in the surface water and sediment. Data from Sites 7 and 12 were evaluated separately in this focused ERA due to the distance between the two sites and the proposed sediment dredging and widening of the channel scheduled to occur at Site 12.

4.2.2.1 Criteria for Selecting Ecological Contaminants of Concern

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

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

- Historical information
- Prevalence
- Toxicity
- Comparison to regional screening levels and other appropriate criteria
- Comparison to associated field and laboratory blank data

Historical Information

Using historical information to assess contaminants' site-related activities, when combined with the following selection procedures, assists in the determination of ECOCs. The historical information for NAB Little Creek was presented in Section 1.0 of this report. To be conservative, contaminants that may have been historically used at the sites were retained as ECOCs to evaluate risk.

Prevalence

The frequency of positive detections in sample sets and the level at which a contaminant is detected in a given medium are factors that determine a chemical's prevalence. Contaminants that were detected in 5 percent or less of the samples were not retained as ECOCs.

Toxicity

The potential toxicity of a contaminant is an important consideration when selecting ECOCs for further evaluation in the ERA. Several of the contaminants detected in the media at NAB Little Creek are prevalent. However, the inherent toxicities to ecological receptors for some of the contaminants are low and, therefore, were not retained as ECOCs (i.e., calcium, magnesium, potassium, and sodium). In addition, several of the contaminants have not been adequately studied to develop screening values, or accepted toxicological data does not exist with which to assess the contaminants. To be conservative, contaminants that fell into this category were retained as ECOCs (if they were not eliminated due to other criteria). Information used to support ECOC selection is included in the Ecological Toxicological Profiles found in Appendix C.

Comparison to Screening Levels

BTAG Screening Levels (BSLs) developed by USEPA Region III (1995) were the primary source of surface water and sediment screening levels used in this ERA. Secondary sources of screening levels for surface water were obtained from the Commonwealth of Virginia's Water Quality Standards (VSWCB, 1992) and the USEPA Ambient Water Quality Criteria (USEPA, 1992b). These water quality screening levels will be herein referred to as Surface Water Screening Levels (SWSLs).

Secondary sources of screening levels for the sediment were obtained from: Long et al. (1995); Long and Morgan (1991); Apparent Effect Threshold (AET) values (TetraTech, 1986), and, the Wisconsin Department of Natural Resources interim guidance criteria for in-water disposal of dredged sediment (Sullivan et al., 1985). If sediment screening levels were not available from these sources, surface soil screening levels developed by BTAG (BSLs) were used as surrogate sediment screening levels. The sediment screening values will be referred to as Sediment Screening Levels (SSLs).

The SWSLs and SSLs are used for comparative purposes to infer potential ecological risks. Compounds that were detected at concentrations less than these screening levels are not retained as ECOCs as they are not expected to pose a significant risk to the ecological population. It is noted that some nondetect levels may be above their corresponding SWSLs and SSLs. However, these compounds are not retained as ECOCs because they were qualified as nondetects. A brief description of the screening levels used in the ECOC selection is presented in Section 4.4 Ecological Effects Characterization.

Comparison to Field and Laboratory Blank Data

In addition to the media samples, samples were collected for QA/QC analysis. These samples included equipment rinsate blanks and trip blanks. Common laboratory contaminants that were detected at concentrations of less than ten times the concentration in the blank sample, or other constituents that were detected at concentrations of less than five times the concentration in a blank sample were not retained as ECOCs.

4.2.2.2 Selection of Ecological Contaminants of Concern

Appendix D presents a summary of the surface water and sediment analytical data from surface water and sediment sampled during the RI. It is noted that Appendix D also contains data summaries from the other IR-related reports. The following sections present the selection of the ECOCs in each of the media using the aforementioned selection criteria. A summary of the ECOCs in each of the media for NAB Little Creek is presented on Table 2.

Surface water and sediment were collected from both Sites 7 and 12. The following sections present a discussion of the ECOCs selected in each of these media.

Site 7

One VOC and several inorganic contaminants were detected in the surface water at Site 7. However, only inorganic compounds were retained as ECOCs. The VOC acetone was detected at concentrations within ten times the concentration detected in the blank (18 ug/L); therefore, acetone was not retained as a surface water ECOC. Frequency, range of positive detection, and selection criteria are summarized on Table 3. Compounds retained as surface water ECOCs also are identified and the rationales for excluding those that were not retained are presented.

VOCs and inorganic compounds were retained as sediment ECOCs at Site 7. Frequency, range of positive detection, and selection criteria are summarized in Table 4 for those compounds detected in the sediment. Compounds retained as sediment ECOCs also are identified and the rationales for excluding those that were not retained are presented.

Site 12

VOCs and inorganic compounds were detected in and retained as ECOCs in the surface water collected from Site 12. The VOC acetone was detected at concentrations within ten times the concentration detected in the blank (18 ug/L); therefore, acetone was not retained as a surface water ECOC. Table 5 presents the surface water ECOCs selected and the rational for exclusion of the chemicals that were not retained.

A VOC and several inorganic compounds were retained as sediment ECOCs at Site 12. Frequency, range of positive detection, and selection criteria are summarized in Table 6 for those compounds detected in the sediment. Compounds that were not retained as sediment ECOCs also are identified, and the rationales for exclusion are presented.

4.2.2.3 Physical/Chemical Characteristics of Ecological Contaminants of Concern

Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include bioconcentration factors (BCFs), organic carbon partition coefficient (K_{oc}), and octanol water partition coefficient (K_{ow}). Table 7 summarizes these values for the ECOCs detected in the surface water and sediment at NAB Little Creek. Information from these tables was used in the risk characterization to assess the fate and transport of the constituents and the potential risks to the environmental receptors at the sites. The following paragraphs discuss the significance of each parameter included in the table.

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

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

The octanol/water partition coefficient (K_{ow}) is the ratio of a chemical concentration in octanol divided by the concentration in water. The K_{ow} has been shown to correlate well with bioconcentration factors in aquatic organisms and with adsorption to soil or sediment. The K_{ow} is used to calculate a bioaccumulation factor for plant uptake to estimate ECOCs concentration in plants.

4.2.2.4 Fate and Transport of ECOCs in Estuarine Systems

Estuaries and estuarine-like environments are transition zones between freshwater and marine aquatic systems. An estuary is defined as a semi-enclosed coastal body of water that has a free connection with the open sea and within which seawater is measurably diluted with fresh water from land drainage (Kennish, 1992).

The physical and chemical form of a metal in the aquatic environment is controlled by environmental variables such as pH, redox potential, DO, ionic strength, salinity, alkalinity, hardness, the presence of organic and particulate matter, and biological activity. For example, the lowering of pH will cause a release of metals from complexes and particulate matter.

Increasing salinity and microbial activity in a water body may result in the salting out of the large molecular weight organic portion (e.g., humic acids of fresh water and flocculation of inorganic matter). The salting out of the large molecular weight organic portion will result in an increased particle size that will remove metals from the water column. The metals removed from the water column will eventually settle in the sediment. Also, increased salinity and microbial activity may result in the disassociation of suspended organic matter by chlorine ions, chelating substances, and microbial decomposition. The disassociation of suspended organic matter will result in increased availability of the organics to biota (Kennish, 1992).

Reactions which take place during estuarine mixing have a significant effect on the partitioning of an element between dissolved and particulate phases. Trace metal removal during estuarine mixing is partly due to the relative affinities of trace metals for anions in salt water (and for humic acids and hydrous iron oxides, in the presence of salt water cations). The desorption of certain elements from suspended particulate matter can be caused by increasing salinity and the rise in the concentrations of the major seawater cations. The exchange of trace metals between dissolved and particulate phases is a regular phenomenon in estuarine systems.

The floor of the estuary serves as both a sink for trace metals as well as a source of the metals for the overlying water. The largest amount of heavy metals will initially accumulate in middle and upper estuary regions. Erosion and transport often carry heavy metals to the outer estuary or to areas

on the continental shelf beyond the estuarine mouth. Desorption and diagenetic remobilization (the release of contaminants back to the water column during the conversion of sediment into rock) of particle-bound trace elements down estuary, together with an influx of clean marine sediments through the estuarine mouth, will account for the typical gradual seaward decline of the heavy metal content of most estuarine sediments.

Trace metals carried in solution into an estuary may be removed from the solution upon contact with saline estuarine water. As salinity rises, particle-bound heavy metals sorbed to particulate organic matter, oxide coatings, and clays can be desorbed. Organic complexation will affect the speciation of the metals. Knowledge of estuarine trace element chemical speciation, however, is limited.

4.2.2.5 Fate and Transport of ECOCs in Wetlands

The Clean Water Act defines wetlands as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. The major components of wetlands that have an influence on the treatment process in wetlands include the plants, soils, bacteria, and animals that are found in wetland areas. The function and system performance of wetlands are influenced by water depth, temperature, pH, and DO concentrations.

Wetland systems can reduce high levels of BOD, suspended solids, and nitrogen, as well as significant levels of metals, trace organics, and pathogens. The basic treatment mechanisms can include sedimentation, chemical precipitation and adsorption, and microbial interactions with BOD, suspended solids, and nitrogen, as well as some uptake by the vegetation. Currently, there are limited data available on the metal removal capability of free-water-surface wetlands. However, the removal mechanisms are thought to be similar to those described for phosphorus removal. Phosphorus removal in natural systems can occur as a result of adsorption, complexation, and precipitation and is effective in soil-based land treatment systems. Phosphorous removal in many wetland systems is not very effective because of the limited contact opportunities between the wastewater and the soil. A significant clay content and the presence of iron and aluminum will enhance the potential for phosphorus removal. There is greater opportunity for contact and adsorption in subsurface flow wetlands, and metals removal can be very effective in these systems.

Soils in areas such as these typically receive seepage and runoff from higher lying areas. These soils can serve as sources, sinks, or transformers of chemicals depending on the soil type and hydrologic conditions. Soils such as these have been shown, under favorable conditions, to remove organic and inorganic constituents (and toxic materials) from water that flows across them (Mitsch, 1986). This removal can be attributed to many factors including, but not limited to: a reduction in velocity as water enters these areas causing some chemicals to “drop into” the soils; a variety of anaerobic and aerobic processes such as chemical precipitation, that remove certain chemicals from the water; and, a high contact rate between water and soils leading to significant exchange of nutrients.

It is noted that a wetland area is located between Site 12 and the Harbor. The surface water flows through this wetland area prior to discharging into the Harbor. Therefore, any contaminants detected in the surface water at Site 12 may be mitigated by the wetlands before release into the Harbor.

4.2.3 Aquatic Ecosystems Potentially at Risk

The aquatic ecosystems potentially at risk were identified in previously conducted habitat studies at NAB Little Creek. The following sections present the ecosystems potentially at risk from contaminants associated with Sites 7 and 12.

4.2.3.1 Habitat and Aquatic Biota

Little Creek Harbor is a saltwater, tidal ecosystem that is open to the Chesapeake Bay. The following presents a summary of the habitat and aquatic biota from Zappi *et. al.* (1990). In general, the sediments in Little Creek Channel and in the southern portion of Little Creek Cove are predominantly fine-grained, while the sediments near the mouth of Little Creek Channel out into the Chesapeake Bay a distance of approximately 10,000 feet are predominantly sands.

The beach habitat in the vicinity of Little Creek Inlet is typical of coastal beach-dune systems, grading from an initial community of beach grasses and herbaceous vegetation through increasingly dense stands of shrubs and small trees to stands of scrub live oak, wax-myrtle, and other shrubs. A large proportion of these communities are wetlands or transitional areas. Intertidal marshes also are present in the area of Little Creek.

The shoreline extending eastward from the Little Creek entrance jetties is characterized by a wide sandy foreshore and seashore with an extensive system of primary and secondary dunes. The dunes nearest the jetties have been modified with paths and other structures and have sparse stands of sea oats (*Uniola paniculata*), American beach grass (*Ammophila breviligulata*), seaside golden rod (*Solidago graminifolia*), groundsel bush (*Baccharis halimifolia*), and loblolly pine (*Pinus taeda*).

The phytoplankton is dominated by diatoms in winter and early spring and flagellates in summer. The zooplankton is dominated by copepoda *Acartia tonsa* and *Eurytemora affinis*, mysid shrimp (*Neomysis americana*), and the amphipods *Monoculodes edwardii* and *Gammarus* sp.

The benthic assemblages within Little Creek itself are composed of polychaetes and molluscs that are representative of the estuarine ecosystem, but have been described as depauperate, limited to the most tolerant species. The heavy use of the channel within the Little Creek area disturbs the bottom muds and associated organisms. The area of Chesapeake Bay lying offshore of Little Creek Inlet is a wintering area for blue crab (*Callinectes sapidus*) and supports the hard clam (*Mercenaria mercenaria*).

The fish assemblage in the vicinity of Little Creek Harbor is characterized by estuarine-dependant species. The commonly encountered species include the hogchoker (*Trinectes maculatus*), white perch (*Morone americana*), spot (*Leiostomus xanthurus*), oyster toadfish (*Opsanus tau*), striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), bay anchovy (*Anchoa mitchilli*), and Atlantic croaker (*Micropogonias undulatus*). Other species typical of more saline conditions that can be found include bluefish (*Pomatomus saltatrix*), flounder (*Paralichthys* spp.), speckled trout (*Cynoscion nebulosus*), menhaden (*Brevoortia tyrannus*), American eel (*Anguilla rostrata*), and sea mullet (*Mugil cephalus*). Finally, this area can have seasonally occurring anadromous species including blueback herring (*Alosa aestivalis*), alewife (*A. pseudoharengus*), hickory shad (*A. medocris*), and American shad (*A. sapidissima*).

4.2.3.2 Threatened and/or Endangered Species

An inventory of the rare, threatened and endangered species at NAB Little Creek was conducted in 1990 by the Virginia Department of Conservation and Recreation's Division of Natural Heritage (VADCR, 1990). This survey for the presence of rare vertebrates and plants was requested by the

Department of Navy. This inventory was conducted to allow NAB Little Creek to make land use decisions in compliance with the Endangered Species Act of 1973, and other laws, regulations, and policies that encourage the conservation and perpetuation of rare species. No Federal or State-listed threatened or endangered plant or animal species had been reported previously at the base, and no threatened or endangered plant or animal species were encountered during the 1990 survey.

Three species of plants considered rare by the State were identified at NAB Little Creek, they were identified as follows: Virginian Beach Pinweed (*Leachea maritima var virginica*), blue jack oak (*Quercus incana*), and the Spanish Moss (*Tillandsia usneoides*). The Virginia Beach Pinweed was found on the foredune and secondary dunes in the open herbaceous and scrub zones between the maritime forest and the beach (along the Chesapeake Bay shoreline). The blue jack oak was observed in the maritime forest community behind the open dunes, the species was concentrated in the eastern portion of the forest. A large population of Spanish moss trees was found on portions of the eastern end of Scout Island. Scout Island is located in between Chubb Lake and Bradford Lake in the north eastern portion of the base.

Suitable habitats for the following rare animal species were identified on site as follows: pungo mouse (*Peromyscus leucopus easti*) and least tern (*Sterna antillarum*). Sixteen pungo mice were captured during the inventory. The habitat within and just inland from the dune system is suitable for this species. Least terns were observed nesting on a sandy, Chesapeake Bay beach immediately east of Little Creek Channel by NAB Little Creek personnel.

Based on the results of the inventory, it was concluded that the potential for rare animal species at NAB Little Creek was low since the natural habitat, forested wetlands, and interdunal swales had been drastically altered. Much of the landscape of NAB Little Creek was found to be no longer in a natural state, and only a few sites were found to be relatively undisturbed (Department of Navy, 1994).

An Endangered, Threatened and Candidate Species on Navy and Marine Corps Lands Handbook (Department of Navy, 1994) provides information on plants and animals that are federally listed, or are candidates for federal listing, that occur or potentially occur on the installations listed in the handbook. The base-specific handbook includes candidates for federal listing, specific occurrences

mapped by the Natural Heritage Programs, more detailed and up-to-date information on taxonomy, statuses, life history, threats, and management, and a bibliography for each species.

The United States Department of the Interior, Fish and Wildlife Service noted the following at NAB Little Creek for the planning period 1988-1993: There are three Federally listed threatened or endangered species that might occur on Little Creek property at least temporarily during the year; these are the loggerhead turtle (*Caretta caretta*), peregrine falcon (*Falco peregrinus*) and piping plover (*Charadrius melodus*); several other species migrate along the Atlantic coast and might be found on or near the base as transients. These include six species of whales, four other species of sea turtles, the bald eagle and the shortnose sturgeon.

On October 1, 1987, the Virginia Department of Game and Inland Fisheries initiated a State Endangered Species Program which includes not only the Federal threatened and endangered species, but also those species considered rare within the State of Virginia. In addition to the Federal species listed above, there are five state endangered species which might occur in the vicinity of Little Creek. They are as follows: eastern tiger salamander (*Ambystoma tigrinum tigrinum*), chicken turtle (*Deirochelys reticularia*), Wilson's plover (*Charadrius wilsonia*), loggerhead shrike (*Lanius ludovicianus ludovicianus*), and eastern big-eared bat (*Plecotus rafinesquii macrotis*).

4.2.3.3 Wetlands

Typical wetland vegetation in the area of NAB Little Creek includes rushes, sedges, ferns, marsh hibiscus (*Hibiscus moscheutos*), smartweeds (*Polygonum* spp.), bayberry, wax myrtle, poison ivy (*Toxicodendron radicans*), beach plum (*Prunus maritima*), groundseltree, winged sumac (*Rhus copallinum*), red bay (*Persea borbonia*), and holly. Wetland trees include loblolly pine, live oak (*Quercus virginiana*), red maple, and sweetgum. Disturbed wetland areas may be dominated by common reed (Ebasco Environmental, 1991).

Site-specific wetland delineations were not conducted at NAB Little Creek during the RI. A wetland survey was conducted by the United States Department of Interior, Fish and Wildlife Service as a part of the National Wetland Inventory. Emergent wetlands totaling almost 14 acres were identified south and east of Little Creek Cove. The southern edge of Little Creek Cove is lined with a wetland dominated by saltmarsh cordgrass (*Spartina alterniflora*). The National Wetland Inventory

designation for this type of wetland (E2EM5N) indicates a regularly flooded, estuarine, intertidal, emergent wetland dominated by narrow-leaved, persistent vegetation. Tidal guts extending from the southeast corner of the Cove form similar estuarine emergent wetlands along Helicopter Road.

Reed grass (*Phragmites communis*) dominated the wetland located west of Helicopter Road. The NWI designation (E2EM1P) indicates an irregularly flooded, estuarine, emergent wetland dominated by narrow-leaved, persistent vegetation. Wildlife use of reed grass marshes is often restricted to escape cover and occasional nesting.

An emergent wetland located east of Helicopter Road supports saltmarsh cordgrass, salt meadow cordgrass (*Spartina patens*), reed grass, and groundsel tree (*Baccharis halimifolia*). The margins of the cordgrass marsh are vegetated with marsh elder (*Iva frutescens*), northern bayberry (*Myrica pensylvanica*), common waxmyrtle (*Myrica cerifera*), sweetgum (*Liquidambar styracflua*), red maple (*Acer rubrum*), sassafras (*Sassafras albidum*), holly (*Ilex* spp.), black willow (*Salix nigra*), and loblolly pine. Cordgrass marshes are much more productive than reed grass stands. Periodic tidal inundation flushes this nutrient-laden detritus out of the wetlands and into the aquatic ecosystem, providing a valuable contribution to the food chain.

Two tracts of wetlands were identified during the inventory of rare, threatened and endangered species by the Department of Conservation and Recreation (VADCR, 1990). The first wetland was identified as an emergent wetland fringe dominated by saltwater cordgrass. This wetland is located south of Little Creek Cove. This area has been designated by the U.S. Fish and Wildlife Service as a regularly flooded, estuarine, intertidal, emergent wetland dominated by narrow-leaved, persistent vegetation. Most of this wetland is within Site 7. A small portion of another wetland was found to be within the boundary of Site 7. This wetland is east of Helicopter Road and southeast of Little Creek Cove. This wetland was described as an irregularly flooded, estuarine, intertidal, emergent wetland dominated by narrow-leaved, persistent vegetation.

A wetland map for NAB Little Creek was developed from information compiled for the ongoing Hampton Roads Crossing environmental impact assessment project. This wetland map is presented in Appendix A (Michael Baker Jr. Inc., 1995).

4.2.3.4 Other Sensitive Environments

The inventory of rare, threatened, and endangered species conducted by the Department of Natural Heritage reported that the aquatic systems at NAB Little Creek serve as a winter haven for waterfowl and some wading birds, and considered the Base's wetlands to be a significant wildlife habitat (Ebasco Environmental, 1991).

In 1990, least terns, a state-recommended threatened species, were observed nesting on the Chesapeake Bay Beach immediately east of the Little Creek Channel. The Department of Natural Heritage recommended this area for conservation (VADCR, 1990) and recommended consultation with the Virginia Department of Game and Inland Fisheries to develop a management plan (Ebasco Environmental, 1991).

Sensitive environments within 15 miles upstream and downstream (because this area is tidally influenced) were evaluated during the Hazard Ranking System process. Seashore State Park, which is a State Park Natural Area, was the only sensitive area identified within a 15-mile radius of NAB Little Creek.

4.2.4 Ecological Endpoints

The information compiled on stressor characteristics, ecosystems potentially at risk, and ecological effects was used to select the ecological endpoints for this ERA. There are two primary types of ecological endpoints: assessment endpoints and measurement endpoints. Assessment endpoints are environmental characteristics, which, if they were found to be significantly affected, would indicate a need for remediation (e.g., decrease in sports fisheries). Measurement endpoints are quantitative expressions of an observed or measured effect of the ECOCs. Measurement endpoints may be identical to assessment endpoints (e.g., measurement of abundance of fish), or they may be used as surrogates for assessment endpoints (e.g., toxicity test endpoints). Both types of endpoints are used in the ecological risk evaluation and are defined below.

The assessment endpoint for this Phase One aquatic ERA is the potential decrease in survival, growth, and/or reproduction of the aquatic receptor population or subpopulation that is attributable to site-related contaminants. The measurement endpoint for this assessment endpoint is the

exceedance of contaminant-specific surface water and sediment effect concentrations. Section 4.4 Ecological Effects Characterization discusses the contaminant-specific surface water and sediment effect concentrations that were used and Section 4.7 Uncertainty Analysis discusses the limitations in their use in the ERA.

4.2.5 Conceptual Model

The site-specific conceptual model discusses the routes by which stressors might affect ecological components of the natural environment. The potential exposure pathways and ecological receptors for this Phase One aquatic ERA include the surface water/sediment exposure transport pathway and the groundwater exposure transport pathway with exposure to the benthic and pelagic flora and fauna of Little Creek Harbor. Figure 6 presents the flowchart of potential exposure pathways and ecological receptors. The exposure pathways and ecological receptors will be presented in more detail in the following section. Figure 7 presents the flowchart of potential ECOC sources to Little Creek Harbor.

To determine if ecological exposure via these pathways may occur in the absence of remedial actions, an analysis is conducted including the identification and characterization of the exposure pathways. The following four elements are examined to determine if a complete exposure pathway is present:

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

The following sections discuss the potential exposure scenarios for NAB Little Creek surface water and sediment.

4.2.5.1 Surface Water/Sediment Exposure Transport Pathway

Potential release sources to be considered in evaluating the surface water and sediment pathways are contaminated surface soil and groundwater. The release mechanisms to be considered are

groundwater seepage and surface runoff. The potential routes to be considered for ecological exposure to the contaminated surface water and sediments are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the surface water and sediment receiving surface water runoff or groundwater discharges from the site.

ECOCs were detected in the surface water and sediment, demonstrating a release from a source to the surface water-sediment transport medium. Potential receptors that may be exposed to contaminants in surface water and sediment include benthic and pelagic flora and fauna of Little Creek Harbor.

Aquatic receptors are exposed to contaminants in the surface water by ingesting water while feeding and by direct contact while feeding or swimming. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioconcentrated chemicals from the surface water and sediment.

4.2.5.2 Groundwater Exposure Transport Pathway

The potential release source to be considered in evaluating the groundwater pathway is contaminated soils. The release mechanism to be considered is leaching. The routes to be considered for ecological exposure to the contaminated groundwater are ingestion and dermal contact. ECOCs were detected in the groundwater, demonstrating a release from a source to the groundwater transport medium. Therefore, groundwater to area surface water and sediments may represent a pathway for contaminant migration.

Sub-surface biota (i.e., microorganisms) are the only ecological receptors expected to be directly exposed to groundwater and will not be assessed. However, at the groundwater to surface water/sediment interface, both wetlands and aquatic species may be exposed to the groundwater. However, it is noted that groundwater to surface water/sediment discharge cannot be quantified by using the existing data. This exposure pathway does not represent a complete pathway. The groundwater pathway in this assessment is accounted for in the surface water and sediment exposure pathway.

4.3 Exposure Assessment

The exposure assessment evaluates the interaction of the stressor with the ecological environment. The Remedial Investigation involved collecting samples from four media; soil, groundwater, surface water, and sediment. However, only surface water and sediment were evaluated in this Phase One aquatic ERA.

Exposure point concentrations of contaminants in the surface water and sediment for aquatic receptors were assumed to be equal to the contaminant concentration in the surface water and sediment. It is noted in the uncertainty section (Section 4.7 Uncertainty Analysis) of this ERA that all the contaminants in the surface water may not be bioavailable to the aquatic flora and fauna.

4.4 Ecological Effects Characterization

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

4.4.1 Surface Water

Potential risks to aquatic receptors from contaminants detected in the surface water were evaluated by comparisons to SWSLs. USEPA Region III has compiled a list of SWSLs that are non-enforceable regulatory guidelines and are of primary utility in assessing the acute and chronic toxic effects in aquatic systems. SWSLs are provided for marine aquatic systems, and are reported as acute and/or chronic values (USEPA, 1995). In addition to the SWSLs, USEPA has promulgated Water Quality Standards (WQS) for states that have not developed their own standards. These WQS are based primarily on the USEPA Ambient Water Quality Criteria, with some of the values updated with more recent information. It is noted that the Ambient Water Quality Criteria were developed to protect only 95 percent of the exposed species. Therefore, there may be some sensitive species that are not protected by these criteria. In addition, Virginia Water Quality Standards (surface water) also were used. These water quality standards are the concentrations of toxic substances that will

not result in chronic or acute toxicity to aquatic life (VSWCB, 1992). Virginia WQS and USEPA criteria were used for contaminants that did not have BSLs.

4.4.1.1 Site 7

Table 3 summarizes the SWSLs used to evaluate the surface water quality at Site 7. The following inorganics were retained as surface water ECOCs at Site 7 because they were detected above the SWSLs or there were no established reference values in which to evaluate the concentrations: aluminum, barium, cobalt, copper, iron, lead, and manganese.

4.4.1.2 Site 12

Table 5 summarizes the SWSLs used to evaluate the surface water quality at Site 12. 2-Butanone was the only VOC retained as an ECOC at Site 12 because sample concentrations were detected above blank sample concentrations and there are no established screening levels in which to evaluate the detected concentrations. The following inorganics were retained as surface water ECOCs at Site 12 because concentrations were detected above SWSLs or there were no established reference values in which to evaluate the concentrations: aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, and zinc.

4.4.2 **Sediment**

Potential risks to aquatic receptors from contaminants detected in the sediment were evaluated by comparisons to SSLs. USEPA Region III has compiled a list of SSLs that are non-enforceable regulatory guidelines and are of primary utility in assessing toxic effects in aquatic systems. In addition, SSLs have been compiled for evaluating the potential for chemical contaminants in sediment to cause adverse biological effects (Long *et al.*, 1995; Long and Morgan, 1991, and USEPA, 1995a). The lower ten percentiles (Effects Range-Low [ER-L]) and the median percentiles (Effects Range-Median [ER-M]) of biological effects have been developed for various contaminants. The concentrations below the ER-L represent a minimal-effects range (adverse effects would be rarely observed). The concentrations above the ER-L, but below the ER-M represent a possible-effects range (adverse effects would occasionally occur). Finally, the concentrations above

the ER-M represent a probable-effects range (adverse effects would probably occur) (Long *et al.*, 1995). It is noted that the SSLs developed by the USEPA Region III are primarily ER-L values.

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

4.4.2.1 Site 7

Table 4 summarizes the SSLs used to evaluate the sediment quality at Site 7. VOCs acetone, 2-butanone, and carbon disulfide were retained as sediment ECOCs because there were no established reference values in which to evaluate the detected concentrations. The following inorganics were retained as sediment ECOCs at Site 7 because they were detected at concentrations above SSLs or there were no established reference values in which to evaluate the detected concentrations: aluminum, arsenic, beryllium, cadmium, cobalt, copper, silver, and zinc.

4.4.2.2 Site 12

Table 6 summarizes the SSLs used to evaluate the sediment quality at Site 12. One VOC (acetone) was retained as a sediment ECOC at Site 12 because there were no established reference values in which to evaluate the detected concentrations. The following inorganics were retained as sediment ECOCs at Site 12 because they were detected at concentrations above SSLs or there were no established reference values in which to evaluate the detected concentrations: aluminum, cadmium, cobalt, copper, lead, mercury, and zinc.

4.5 **Risk Characterization**

The risk characterization is the final phase of a risk assessment. In risk characterization, the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. This section

evaluates the potential adverse effects on the ecological receptors at NAB Little Creek from contaminants identified at the sites.

4.5.1 Surface Water

The surface water data collected from Sites 7 and 12 were compared to SWSLs. Quotient index ratios were calculated for each sampling station that exceeded screening levels. In addition, cumulative QIs for the average detected concentration of each surface water ECOC were calculated. It is noted that 95-percent upper confidence limit concentrations could not be used in this ERA due to the small surface water sample sizes at Sites 7 and 12. A QI ratio greater than one indicates a possibility for adverse effects to aquatic life. The QI ratios calculated for the SWSLs were calculated for each ECOC at Sites 7 and 12 as follows:

$$QI = \frac{\text{station-specific concentration} / \text{average detected concentration}}{SWSL}$$

where: QI = Quotient Index
 SWSL = Surface Water Screening Level, µg/L

4.5.1.1 Site 7

As displayed on Table 8, surface water QIs per sample calculated at Site 7 were greater than ten for chronic manganese. Surface water QIs were greater than one, but less than ten for acute and chronic copper and chronic lead. All other surface water ECOCs identified at Site 7 (aluminum, barium, cobalt, and iron) did not have corresponding SWSLs in which to evaluate effects to aquatic life.

Table 9 presents a cumulative ecological risk calculated with average concentrations of surface water ECOCs. The average QI values calculated were greater than ten for chronic manganese. Total QIs calculated for the surface water were 2.92 for the acute and 27.88 for the chronic. Based on the cumulative QIs calculated, the surface water at Site 7 potentially poses a risk to the aquatic environment.

4.5.1.2 Site 12

As shown on Table 10, surface water QIs per sample calculated at Site 12 were greater than ten for acute and chronic copper, chronic lead, chronic manganese, chronic mercury, chronic nickel, and acute and chronic zinc. Surface water QIs were greater than one, but less than ten for chronic arsenic, chronic chromium, acute lead, and acute nickel. All other surface water ECOCs identified at Site 12 (2-butanone, aluminum, barium, beryllium, cobalt, and iron) did not have corresponding SWSLs in which to evaluate effects to aquatic life.

Table 11 presents cumulative ecological risks calculated with average surface water ECOC concentrations. The average QI values were greater than ten for acute and chronic copper, chronic lead, chronic manganese, chronic mercury, chronic nickel, and acute and chronic zinc. An average acute nickel QI was calculated greater than one, but less than five. Total QIs calculated for the surface water at Site 12 were 43.29 for the acute and 181.49 for the chronic. Based on the cumulative QIs, the surface water at Site 12 potentially poses a risk to the aquatic environment.

4.5.2 **Sediment**

The sediment collected at Sites 7 and 12 were compared to SSLs. QI ratios of the detected values at each sampling location and the BSLs/ER-Ls, ER-Ms, or AETs were calculated for each ECOC at Sites 7 and 12 exceeding SSLs. In addition, cumulative sediment QIs were calculated at each site using the average detected concentrations of the ECOCs. Average concentrations were used because there were not enough sediment samples collected at each site to determine the 95-percent upper confidence limit for each sediment ECOC. A QI greater than one for the ER-Ls indicates a possibility for adverse effects to aquatic life. A QI greater than one for the ER-Ms indicates a probable adverse effect to aquatic life (Long et al., 1995). The formula presented below was used to calculate the QI ratios.

$$QI = \frac{\text{station-specific concentration} / \text{average detected concentration}}{SSL}$$

where: QI = Quotient Index

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

4.5.2.1 Site 7

Table 12 presents QI ratios of the detected ECOCs at each sampling location at Site 7. QI ratios of greater than one but less than five upon comparison of the BSL/ER-L were calculated for the following contaminants: arsenic, cadmium, cobalt, copper, silver, and zinc. All ER-M QI ratios were below one for the ECOCs identified at Site 7, with the exception of beryllium that had an ER-M (AET) QI slightly greater than one. There are no SSLs established for acetone, 2-butanone, carbon disulfide, and aluminum to determine QI ratios.

Table 13 displays total QIs calculated for the sediment collected from Site 7. QIs were calculated greater than one for cadmium, cobalt, and silver. Total sediment QIs were calculated at 7.14 for ER-Ls and 1.70 for ER-Ms, indicating only a slight potential that the sediment at Site 7 is posing a risk to the benthic environment in the Harbor.

4.5.2.2 Site 12

Table 14 presents QI ratios of each sample detected above ECOC screening levels at Site 12. QI ratios of greater than one but less than five upon comparison of the BSL/ER-L were calculated for the following contaminants: cadmium, cobalt, copper, lead, mercury, and zinc. All ER-M QI ratios were below one for the ECOCs identified at Site 12. It is noted that acetone and aluminum do not have SSLs established to evaluate impacts to the aquatic environment.

Table 15 demonstrates average QIs calculated per ECOC identified in the sediment at Site 12. Average ER-L QIs were calculated greater than one, but less than two for cadmium, cobalt, lead, and zinc. Total site QIs were calculated at 8.10 for ER-Ls and 1.24 for ER-Ms, indicating a slight potential for the sediment at Site 12 to adversely impact the aquatic environment in the Harbor.

4.6 Ecological Significance

This section summarizes the overall risks to the aquatic environment within NAB Little Creek Harbor. This information supports the evaluation of remedial action(s) for Sites 7 and 12 that are protective of the aquatic environment.

The surface water and sediment data collected during the RI investigation were compared to surface water and sediment data collected from regional reference stations. Regional surface water and sediment data were obtained from STORET for the years 1990 through 1995 for Cape Charles Harbor (See Figure 4) and Lynnhaven Harbor (including monitoring stations in the mainstem, eastern branch, western branch, and Broad Bay) (See Figure 5). Cape Charles was chosen as an ecologically similar reference water body because it is periodically dredged like Little Creek Harbor. Lynnhaven Harbor and its associated waterways are a much larger water body than Little Creek Harbor. However, it was chosen because of its close proximity to Little Creek Harbor and the lack of surrounding industrial land use.

4.6.1 Aquatic Assessment Endpoint

The aquatic assessment endpoint for NAB Little Creek is the decrease in the survival, growth, and/or reproduction of the aquatic receptor population or subpopulation that is attributable to site-related contaminants. The measurement endpoint for the aquatic assessment endpoint is the exceedance of contaminant-specific surface water and sediment effect concentrations. It is noted that no benthic macroinvertebrates or fish were collected at NAB Little Creek during the remedial investigation.

4.6.1.1 Site 7

The following ECOC concentrations in the surface water collected at Site 7 may potentially adversely impact the aquatic environment based on exceedance of acute and chronic SWSLs: copper, lead, and manganese.

Table 16 presents Site 7 surface water ECOCs compared to reference concentrations. Site 7 ECOCs including aluminum, barium, and cobalt were not analyzed in reference water bodies; therefore, they could not be compared to Site 7 concentrations. Copper in the reference surface water was detected at higher concentrations than in Site 7 surface water. Whereas, iron and manganese were detected at higher concentrations in Site 7 surface water than in reference surface water. Lead was only detected at one reference station (Cape Charles Harbor) at a concentration greater than Site 7 surface water concentrations.

Therefore, although three ECOCs may potentially adversely impact the aquatic environment, only manganese appears to be elevated above regional reference levels and is site-related. It is noted that manganese was detected highly dissolved in the groundwater at Site 7. However, the source of the SWSL of 10µg/l is believed to be based on a study of decreased growth in the pacific oyster *Crassostrea gigas*. This study did not meet the criteria for reliability in the Aquatic Information Retrieval Database (AQUIRE). Other studies in AQUIRE listed adverse effects at 20,000 µg/L to mollusk species. It also is noted that there was no clear spatial relationship established for the groundwater chemical data for Site 7. Therefore, isoconcentration maps were not constructed to determine the groundwater pathway to surface water.

Sediment collected from Site 7 at NAB Little Creek contained levels of arsenic, beryllium, cadmium, cobalt, copper, silver, and zinc that may affect the benthic community based on QIs calculated greater than one.

As depicted on Table 17, the following Site 7 sediment ECOCs were not analyzed for in the reference water bodies: acetone, 2-butanone, carbon disulfide, and cobalt. Aluminum and arsenic were detected at higher concentrations in the reference station in Broad Bay and at lower concentrations in the reference station in Cape Charles Harbor, as compared to Site 7. Beryllium, cadmium, copper, silver, and zinc were detected at higher concentrations in the sediment at Site 7 than in reference sediment samples. Based on the station-specific QI evaluation, these inorganics may potentially impact the benthic community at Site 7. However, it is noted that the average of the detected concentrations of beryllium, copper, silver, and zinc were all less than the ER-L, indicating no impact.

Although this Phase One ERA focused on the surface water and sediment data from the RI, information was available from previous IR reports to establish any trends in the data for Site 7. For Site 7, manganese surface water concentrations have generally decreased from the Interim RI to the RI as shown in Table 20. For the sediment collected at Site 7, cadmium (the only ECOC with an average concentration greater than the ER-L) increased from the Round I Verification Study to the RI Study as shown in Table 21. Of the other ECOCs with station-specific concentrations greater than the ER-Ls, in general, beryllium and copper decreased and silver and zinc increased.

4.6.1.2 Site 12

The following ECOC concentrations in the surface water collected at Site 12 at NAB Little Creek may potentially adversely impact the aquatic environment based on exceedance of acute and chronic SWSLs: arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc. The greatest exceedances (greater than 100 times) of SWSLs were demonstrated by copper and manganese at Site 12. Lead, mercury, nickel, and zinc had exceedances greater than 10 times the SWSLs at Site 12.

Table 18 displays Site 12 surface water ECOCs compared to reference surface water data. Site 12 ECOCs 2-butanone, aluminum, barium, cobalt, and mercury were not analyzed in the reference studies. Arsenic, chromium, copper, iron, lead, manganese, nickel, and zinc were detected at higher concentrations in Site 12 surface water than in reference water bodies. Beryllium was detected at higher concentrations at Site 12 than in several of the reference locations. However, beryllium surface water concentrations were lower at Site 12 than in the reference surface water collected from Cape Charles Harbor. The exceedances of SWSLs by concentrations of arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc at Site 12, as evaluated on a station-specific basis, may be impacting the aquatic environment. However, it is noted that arsenic and chromium average concentrations across all stations were less than their respective SWSLs and the manganese SWSL may not be a valid effect level (see previous discussion).

It has been determined that groundwater from Site 12 discharges to the drainage canal. However, based on the existing IR studies, groundwater from Site 12 is not believed to be the source of the metals that are found in the drainage canal. These investigations have focused on VOCs that may be transported from Site 12 to the drainage canal. There were no VOCs that exceeded SWSLs.

It is noted that although the surface water and sediment may be impacting aquatic receptors, the impact to receptors in the Harbor may not be as severe. Site 12 RI samples were collected in the drainage canal adjacent to Site 12. The canal is located approximately 3,000 feet from the Harbor. The surface water flows through wetlands before discharging into the Harbor. Wetlands provide an effective treatment for many types of water pollution. Wetlands can remove or convert large quantities of contaminants, including organic matter, suspended solids, metals, and excess nutrients. Water quality is improved in wetland areas by natural filtration, sedimentation, and other processes

(Hammer, 1989). Therefore, the contaminants detected in the surface water at Site 12 may be mitigated by the wetlands prior to discharge into the Harbor (see discussion in Sections 4.2.2.4 and 4.2.2.5).

Based on the station-specific concentration evaluation, sediment collected from Site 12 contained levels of cadmium, cobalt, copper, lead, mercury, and zinc that may affect the benthic community based on exceedances of the QI ER-Ls calculated greater than one. All QI ER-Ls calculated at NAB Little Creek were less than 10, and there were no QI ER-M exceedances greater than one for any of the ECOCs at Site 12.

As displayed on Table 19, the Site 12 ECOCs acetone, cobalt, and mercury were not analyzed for in any of the reference studies. Cadmium, copper, lead, and zinc were detected at higher concentrations in the sediment collected at Site 12 than in the sediment collected from reference stations. Based on the exceedances of ER-L on a station-specific basis, the sediment concentrations of cadmium, cobalt, copper, lead, mercury, and zinc at Site 12 may be impacting the aquatic community at NAB Little Creek. However, it is noted that the average concentrations of copper and mercury at these stations were below the ER-Ls.

Although this Phase One ERA focused on the surface water and sediment data from the RI, information was available from previous IR reports to establish any trends in the data for Site 12. At Site 12, surface water and sediment inorganics were not analyzed in the Interim RI or the Round I Verification Study (Tables 22 and 23). However, sediment data was collected from an IR-related study conducted in the canal adjacent to Site 12 (Foster and Wheeler, 1995). Concentrations of acetone, copper, lead, and mercury were detected in the sediment study at higher concentrations than the RI concentrations. Concentrations of cadmium and zinc were detected at higher concentrations in the RI than in the sediment study and concentrations of aluminum and cobalt were detected at about the same concentrations in both studies. In the canal study, acetone and aluminum concentrations were higher upstream of Site 12. Whereas, concentrations of lead, mercury, and zinc in the canal study were higher at stations downstream and adjacent to the site. Cobalt and copper were detected at varying concentrations both upstream and downstream of Site 12.

4.7 Uncertainty Analysis

The procedures used in this evaluation to assess risks to ecological receptors, as in all such assessments, are subject to uncertainties. The following discusses the uncertainty in this ERA associated with the sampling area, reference stations, data gaps, sampling method, screening levels, and the QI calculations.

4.7.1 Sampling Area

There is uncertainty in attributing detected contaminants in the Little Creek Harbor specifically to Sites 7 and 12. Little Creek Harbor receives runoff from other RI sites on base, which may influence the surface water and sediment quality of the Harbor. However, surface water and sediment data were only sampled at Sites 7 and 12 during the RI.

4.7.2 Reference Stations

There is uncertainty associated with the use of the reference stations in the Ecological Significance (Section 4.6) of this ERA. Lynnhaven Harbor has a much larger drainage area compared to Little Creek Harbor. Cape Charles Harbor is situated on the eastern shore of the Chesapeake Bay; whereas, Little Creek Harbor is located on the southern shore. The surrounding land use of Little Creek Harbor was different from both Cape Charles Harbor and Lynnhaven Harbor. Little Creek Harbor has more surrounding industrial land use; whereas, Cape Charles Harbor and Lynnhaven Harbor have more surrounding residential land use. However, this alternative land use was by design to evaluate any effects of the ERA's ECOCs to this type of alternative land use. In addition, Lynnhaven, Cape Charles, and Little Creek Harbors may not have similar salinity grades.

4.7.3 Data Gaps

There is a limited amount of aquatic data available for Little Creek Harbor. Therefore, the ERA was conducted on a small number of surface water and sediment samples for each site (Sites 7 and 12) and does not completely represent the ecological condition of the entire Harbor. In addition, there is uncertainty in the data available for Little Creek Harbor. The parameters analyzed for in the RI study were not the same parameters analyzed for in the regional reference studies (STORET) or in

the non-RI studies. The analytical methods, QA/QC procedures, and detection limits used between the RI studies, non-RI studies, and STORET data are not necessarily comparable.

4.7.4 Sampling Method

The ecological investigation consisted of the evaluation of one sampling effort - the RI study. The results of this sampling only will provide a "snapshot in time" of the ecological environment. The Harbor is a fluctuating environment due to base activities, site activities, dredging operations, barge and railroad activities, and tidal influences. Therefore, the "snapshot in time" may not be an accurate representation of actual Little Creek Harbor aquatic conditions.

4.7.5 Screening Levels

There is uncertainty in the ecological endpoint comparison. The surface water screening levels are established to be protective of a majority of the potential receptors. However, there will be some species not protected by the values because of their increased sensitivity to the chemicals. For example, the Ambient Water Quality Criteria developed by USEPA in theory only protects 95 percent of the exposed species. Therefore, there may be some sensitive species present that may not be protected by the use of these criteria. In addition, most of the values are established using laboratory tests, where the concentrations of certain water quality parameters (pH, total organic carbon) that may influence toxicity are most likely at different concentrations in the site water.

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

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

In addition, there is uncertainty associated with the detection limits used for the parameters tested in the RI. Some of the screening levels used for analytical constituents in this ERA were lower than the associated detection limit. Therefore, there is uncertainty in the ECOC selection process. Nondetected chemicals may actually be impacting the aquatic environment.

4.7.6 Quotient Index Calculation

There is uncertainty in the calculation of the cumulative QI ratios. There is uncertainty in the use of the arithmetic average of the detected concentrations. The use of the detected average biases the QI calculation on the conservative side because the nondetected samples are not accounted for in the calculation.

5.0 LITTLE CREEK HARBOR ENVIRONMENTAL PERSPECTIVES

The ERA conducted in Section 4 indicated that contaminants possibly attributed to IR Sites 7 and 12 are presenting a risk to the aquatic receptors in Little Creek Harbor. However, as presented in the following subsections, there may be a variety of ECOC sources in Little Creek Harbor. In addition, the frequent disturbance of the Harbor's waters and sediments by 1) NAB's logistic and support operations and amphibious training requirements, 2) the periodic dredging operations, and 3) the natural ebb and flow of the tidal waters will tend to resuspend and redistribute ECOCs throughout the Harbor and overshadow any apparent fate and transport relationship to the various sources in the Harbor. The following subsections provide a perspective on the overall condition of Little Creek Harbor with respect to other sources of ECOCs.

5.1 Site 7

At Site 7, manganese in the surface water may be adversely impacting the aquatic environment. Non-IR related studies conducted by ODU (Ewing *et al.*, 1992) and NAB (1994,1995a) in Little Creek Harbor analyzed for various metals in the surface water. However, as depicted on Table 24, manganese was not analyzed in the ODU study or the two NAB studies.

Beryllium, cadmium, copper, silver, and zinc detected in the sediment at Site 7 may potentially impact the aquatic environment. As displayed on Table 25, the sediment analyzed in the ODU study (Ewing *et al.*, 1992) demonstrated higher concentrations of arsenic, beryllium, cadmium, copper, silver, and zinc than the sediment collected in the RI study. In the two NAB studies (1994,1995a), only cadmium was analyzed for in the sediment. Cadmium concentrations detected in the NAB studies were below concentrations detected in the RI Study. Dredging data demonstrates that beryllium, copper, silver, and zinc were detected at higher concentrations during the 1989/90 dredging event (Department of Army, 1995) than concentrations detected during the RI. It is noted that the highest concentration of silver from the 1989/90 dredging event was detected in Little Creek Cove. Dredging data collected from the Harbor in 1991 (J.R. Reed and Associates, 1991) demonstrate higher sediment concentrations of copper and zinc than concentrations detected in the RI study.

Comparison of Site 7 data collected during the RI to non-IR Little Creek data indicates that the surface water manganese concentrations at Site 7 may be causing an impact. It is noted that manganese was detected highly dissolved in the groundwater at Site 7. However, the source of the SWSL of 10µg/L is believed to be based on a study of decreased growth in the pacific oyster *Crassostrea gigas*. This study did not meet the criteria for reliability in the AQUIRE database. Other studies in AQUIRE listed adverse effects at 20,000 µg/L to mollusk species. It also is noted that there was no clear spatial relationship established for the groundwater chemical data for Site 7. Therefore, isoconcentration maps were not constructed to determine the groundwater pathway to surface water. Also, there are no non-IR data to determine the relative contribution from the site. For the sediments, the RI levels are below those found in the Ewing *et al.* (1992) and the dredging (J.R. Reed and Associates, 1991 and Department of Army, 1995) data indicating other potential sources of these ECOCs than Site 7.

5.2 Site 12

At Site 12, arsenic, beryllium, chromium, copper, lead, manganese, mercury, nickel, and zinc concentrations detected in the surface water may be adversely impacting the ecological ecosystem of Little Creek Harbor. As depicted on Table 26, a non-IR related study conducted by ODU in Little Creek (Ewing *et al.*, 1992) found surface water concentrations of arsenic, beryllium, chromium, copper, lead, mercury, nickel, and zinc lower than concentrations detected in the RI study. Manganese was not analyzed for in the ODU study. All of the Ewing study concentrations were below SWSLs indicating minimal impacts in the main channel and coves of the Harbor. This study also indicates that the high level of zinc detected in the groundwater from the IR Sites is not impacting the Harbor. This is supported by the analysis of the benthic macroinvertebrate data (see Section 5.3, Little Creek Harbor Benthic Macroinvertebrate Data).

As displayed on Table 27, sediment collected from Site 12 contained levels of cadmium, cobalt, copper, lead, mercury, and zinc that may affect the benthic community. A non-IR related study conducted in the Harbor (Ewing *et al.*, 1992) found sediment concentrations of cadmium, copper, and mercury higher than the sediment concentrations detected in the RI study. In addition, two dredging events (1989/90 and 1991) detected higher concentrations of acetone (1989/90 event only), cadmium, copper, lead (1991 event only), mercury, and zinc than concentrations detected in the RI

study. However, two other non-IR related studies (NAB, 1994 and 1995a) detected sediment concentrations at lower levels than the RI study for cadmium and mercury.

Comparison of Site 12 data collected during the RI to non-IR Little Creek data indicates that the surface water concentrations of arsenic, chromium, copper, lead, manganese, mercury, and zinc may be causing an impact to aquatic receptors in the drainage canal. However, the Ewing *et al.* (1992) data indicates that these impacts are localized and do not extend into the Harbor. For the sediments, the RI levels are below those found in the Ewing *et al.* (1992) data and dredging data (J.R. Reed and Associates, 1991 and Department of Army, 1995) but above those found in the NAB (1994,1995a) data, indicating other potential sources of these ECOCs and variability in the concentrations of these ECOCs in the sediments for cadmium and mercury. Due to the significant travel distance from Site 12 to the Harbor and the existence of wetlands in the lower reaches of the drainage canal, the impacts of the metals may be mitigated by the wetlands.

It has been determined that groundwater from Site 12 discharges to the drainage canal. However, based on the existing IR studies, groundwater from Site 12 is not believed to be the source of the metals that are found in the drainage canal. These investigations have focused on VOCs that may be transported from Site 12 to the drainage canal. There were no VOCs that exceeded SWSLs. It is noted that the drainage canal adjacent to Site 12 collects surface water runoff from both on-site and off-site sources including Lake Bradford, Chubb Lake, a heavily used commercial area, and extensive surface transportation routes. Both Lake Bradford and Chubb Lake receive surface drainage flows via unlined canals and may receive significant amounts of salt water from the Chesapeake Bay during storm events. These potential sources of ECOCs would contribute to the levels found in the RI study at Site 12.

5.3 Little Creek Harbor Benthic Macroinvertebrate Data

The comparison of the RI data for Sites 7 and 12 to non-IR Little Creek Harbor data and regional reference data indicates that Sites 7 and 12 may be adversely impacting the Harbor. However, a benthic macroinvertebrate study conducted by ODU in Little Creek Harbor (Ewing *et al.*, 1988) indicates that the benthic species in Little Creek Harbor appear to be representative species for the salinity habitat of the Harbor compared to reference stations and restoration goal management objectives.

Benthic macroinvertebrate samples were collected from one station located within Little Creek Harbor in the spring of 1987. See Figure 3 for the benthic sample location. The densities of the dominant taxa collected from Little Creek Harbor are presented on Table 28. The dominant species collected was the polychaete *Polydora ligni*. In addition, the following polychaetes also composed a majority of the benthic sample: *Streblospio benedicti* (opportunistic species), *Cirratulidae* spp., *Capitella capitata*, and *Mediomastus ambiseta* (opportunistic species) (Ewing et al., 1988).

Benthic sampling conducted in Lynnhaven Bay and its tidal tributaries found that the opportunistic species *Streblospio benedicti* was the most commonly collected species (Tourtellotte and Dauer, 1993). The benthic community in Lynnhaven Bay also was dominated by the following species: *Mediomastus ambiseta* (opportunistic species), *Hetermoastus filiformis* (opportunistic species), *Polydora ligni*, *Nereis succinea*, *Glycinde solitaria* (equilibrium species), *Eteone heteropoda*, *Capitella* spp., and *Paraprionospio pinnata* (opportunistic species) (Tourtellotte and Dauer, 1983).

The benthic species *Streblospio benedicti* is commonly the most abundant species collected in silt-clay substrates along the east coast and is possibly the most dominant species through the year. The abundance of *Streblospio benedicti* in silt-clay sediments is due to the life history and the species ability to function both as a surface deposit feeder and a suspension-feeder. The life history characteristics and versatility in the feeding modes give *Streblospio benedicti* resistance to and resilience from disturbances and sediment instability associated with muddy sediments (Tourtellotte and Dauer, 1983).

Restoration goals for Chesapeake Bay benthic infaunal communities have been developed by the USEPA - Chesapeake Bay Program Office and Maryland Governor's Council on Chesapeake Bay Research Fund (Ranasinghe et al., 1993). The benthic macroinvertebrate species collected in the tidal water of Little Creek Harbor were evaluated against these restoration goals. The Restoration Goal Index (RGI) was developed by standardizing benthic macroinvertebrate data from several different monitoring programs to allow integration into a single, coherent database. From this database, the RGI was developed to describe characteristics of benthic assemblages expected at sites having little evidence of environmental stress or disturbance. These goals could then be used to determine whether conditions at a site met, were above, or were below expectations defined for reference sites in similar habitats.

The RGI is calculated as the average score of a set of metrics. Each metric is scored as a five, three, or one, depending on whether its value at a site approximated, deviated slightly, or deviated greatly from its value at the best reference sites in the Chesapeake Bay. Values calculated at or below the first number (see the table below) for a RGI parameter represent a RGI value of one, values calculated between the two numbers are given a value of three, and values calculated above the second number represent a RGI of five (Ranasinghe *et al.*, 1993). A RGI value of three represents the minimum restoration goal. A value of less than three indicates an unacceptable benthic community status. RGI values of three or greater indicate habitats that meet or exceed the restoration goals. It should be noted that the sample collection methods may impact the RGI value. Thus, only the Ponar data was used for the calculation of the RGI for the Ewing (1988) data. The following RGI metrics were applicable to Little Creek Harbor benthic data:

RGI Parameters	High Mesohaline Mud Values
Shannon-Wiener Diversity Index	2 - 3
Abundance (#/m ²)	500 - 1000
Biomass (g/m ²)	0.5 - 8.0
%Opportunistic Biomass	0 - 15

RGI values for mesohaline habitats have not been established for all of the RGI input parameters. The parameters for the RGI calculation include the following: Shannon-Wiener Diversity Index, abundance, biomass, percent opportunistic biomass, percent carnivore/omnivore abundance, percent of taxa less than five centimeters from the sediment surface, percent biomass greater than five centimeters from the sediment surface, and percent carnivore/omnivore species abundance.

The following three validation tests of the RGI study were conducted by Ranasinghe *et al.* (1993) in conjunction with the establishment of the RGI: 1) calculation of the RGI for all samples taken at each reference site to determine the degree of correct classification of the reference sites, 2) calculation of the RGI values for known degraded habitats, and 3) for sites that were sampled more than once during the summer, an RGI was calculated for each site.

The types of species represented also were considered in evaluating the benthic macroinvertebrate community. The life history of the species inhabiting a site is an indication of the ecological health

of the benthic environment. Unsuitable, ecologically stressed benthic habitats tend to be dominated by opportunistic species; whereas, suitable benthic habitats tend to be dominated by equilibrium species. As mentioned above, opportunistic or unknown life history species dominated the benthic community collected in Little Creek Harbor. However, Lynnhaven Bay species also contained a majority of opportunistic or unknown life history species.

The RGI calculated for Little Creek indicated that the benthic macroinvertebrate community is meeting benthic restoration goal requirements. The Shannon-Wiener Diversity and percent opportunistic species abundance for the Little Creek station were greater than the lower recommended RGI values. The species abundance and biomass values from the Little Creek sample were greater than the higher RGI value. The average RGI value calculated for Little Creek was four, indicating that the benthic community is within the set restoration goals.

5.4 Little Creek Harbor Fish and Shellfish Data

The NAB (1994,1995) studies found total mercury in blue crabs (97.4-225 µg/kg) and fish (132-148 µg/kg) collected from the Harbor (see Table 30). Mercury was an identified ECOG at Site 12 that may be impacting aquatic receptors via the sediment exposure pathway. It is noted that mercury was not detected in the surface water and sediment samples at Site 7 and was detected in only one surface water and sediment sample at Site 12. Mercury bioaccumulates in biota. However, due to the high levels of mercury detected in the Harbor sediments during the Ewing *et al.* (1992) study, the relative contribution of total mercury to the Harbor from Site 12 cannot be determined.

5.5 Perspectives Conclusion

There are many impacts to the ecological condition of Little Creek Harbor. Besides Sites 7 and 12, other IR sites also directly or indirectly drain into Little Creek Harbor. In addition, base activities such as drills conducted on the mudflats, fueling, salvage and ship maintenance also impact the Harbor. Barges loading and unloading, railroad ferry activities, U.S. Coast Guard activities and other industrial uses of the Harbor also are influencing the aquatic environment.

The ERA indicated that there are ECOGs at Sites 7 and 12 at levels that may impact the ecological receptors of the Harbor. However, based on the surface water and benthic macroinvertebrate data

from the Ewing *et al.* (1988,1992) studies, the ecological receptors of the Harbor are not being adversely impacted. The sediment data from Ewing *et al.* (1992) do indicate that levels are elevated and may be impacting the ecological receptors, but the source of these elevated levels cannot be determined.

6.0 CONCLUSIONS

It was the purpose of this SEA to address the concerns of the USEPA BTAG regarding the impact of NAB Little Creek on the ecological resources of Little Creek Harbor. The following are the conclusions of the three components of the study - compilation of existing data, ERA, and Little Creek Environmental Perspective:

- Limited existing environmental data were available to address sources of ECOCs from non-IR and non-Navy sources.
- IR surface water and sediment data were limited to Sites 7 and 12 and were primarily volatile organic and inorganic data.
- The Phase One aquatic ERA conducted on surface water and sediment data collected from Sites 7 and 12 during the RI indicate that several inorganic compounds potentially adversely impact the overall ecological condition of the Harbor.
- Based on the comparison of IR ECOC concentrations and concentrations of ECOCs from several water quality studies conducted in Little Creek Harbor, there may be a variety of sources for the ECOCs detected in the Harbor.
- The overall water quality in Little Creek Harbor based on the study by Ewing *et al.* (1992) is meeting current screening levels metals analyzed with the exception of mercury. However, mercury only was detected in one station in the Ewing study. This station was located in the western portion of Little Creek Harbor and not in Little Creek Cove, which is adjacent to Site 7 and immediately downstream of Site 12. Mercury was not detected in the surface water and sediments at Site 7 and was detected in only one surface water and sediment sample at Site 12. For the sediment, many of the metals exceeding sediment benchmarks for Sites 7 and 12 also exceeded these benchmarks in the Ewing study. However, it is noted that the relative range of Sites 7 and 12 metal concentrations (with the exception of lead and zinc) were less than the range of metal concentrations found in the Ewing study.

- The Harbor's waters and sediments are frequently disturbed by 1) the natural influence of the tidal flux, 2) NAB's logistic and support operations, and amphibious training requirements, including boat traffic, and 3) the periodic dredging operations. These disturbances will impact the ecological resources of Little Creek Harbor and will tend to resuspend and redistribute ECOCs throughout the Harbor and overshadow any apparent fate and transport relationship to the various sources in the Harbor.
- The Restoration Goal Index calculated for Little Creek Harbor indicated that the benthic macroinvertebrate community is meeting benthic restoration goal requirements.

Although there may be some localized impacts from ECOCs related to Sites 7 and 12, there does not appear to be a significant impact on the ecological resources of Little Creek Harbor from the IR sites. Information collected in this SEA indicates limited toxicological impact and the absence of severe environmental media contamination. However, there is evidence of elevated heavy metal concentrations in the Harbor. These elevated concentrations are consistent with a chronic exposure scenario with the contamination originating from a variety of sources within and outside of the Harbor.

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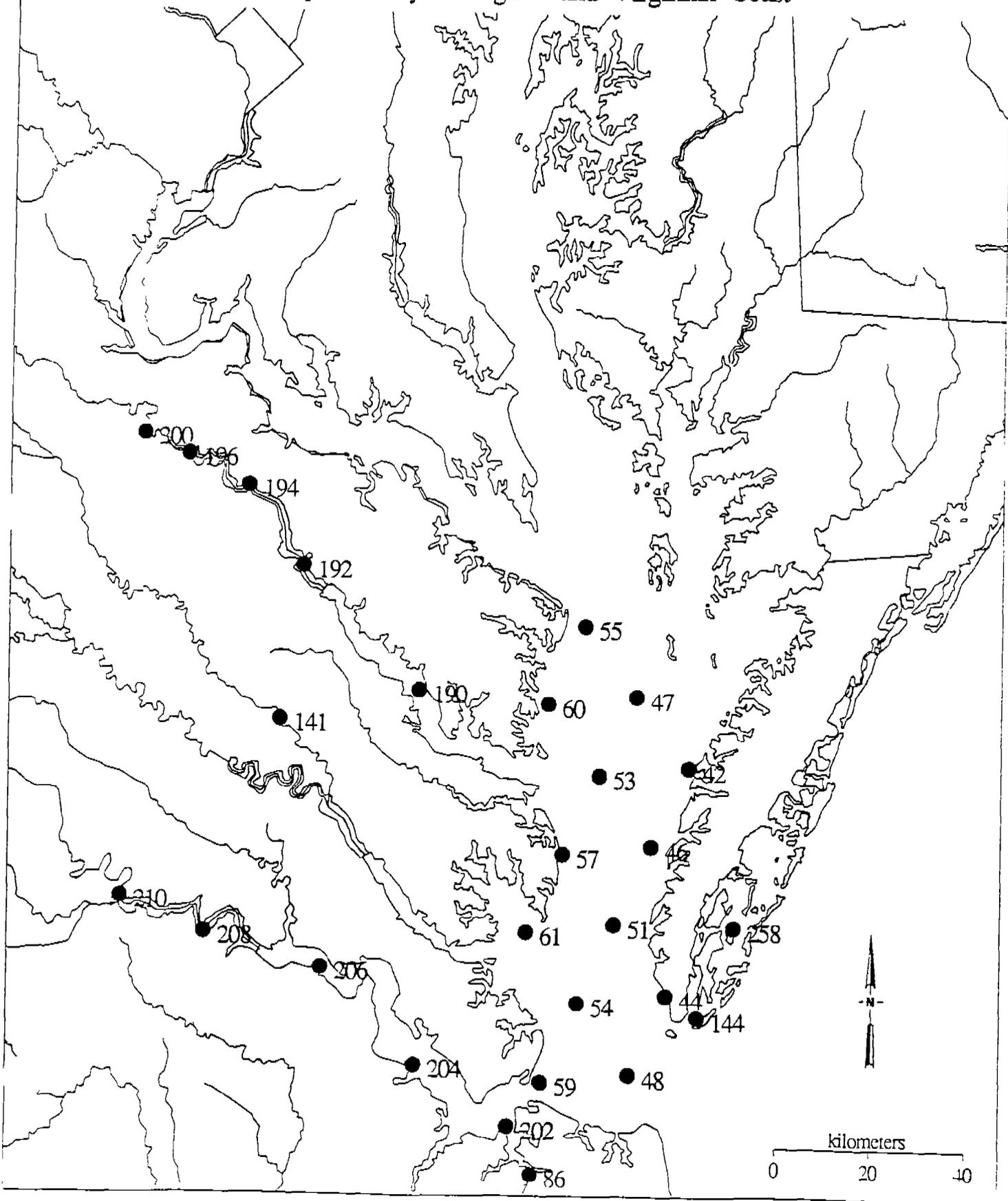
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APPENDIX A
MISCELLANEOUS FIGURES

APPENDIX A.1
EMAP DATA MAPS

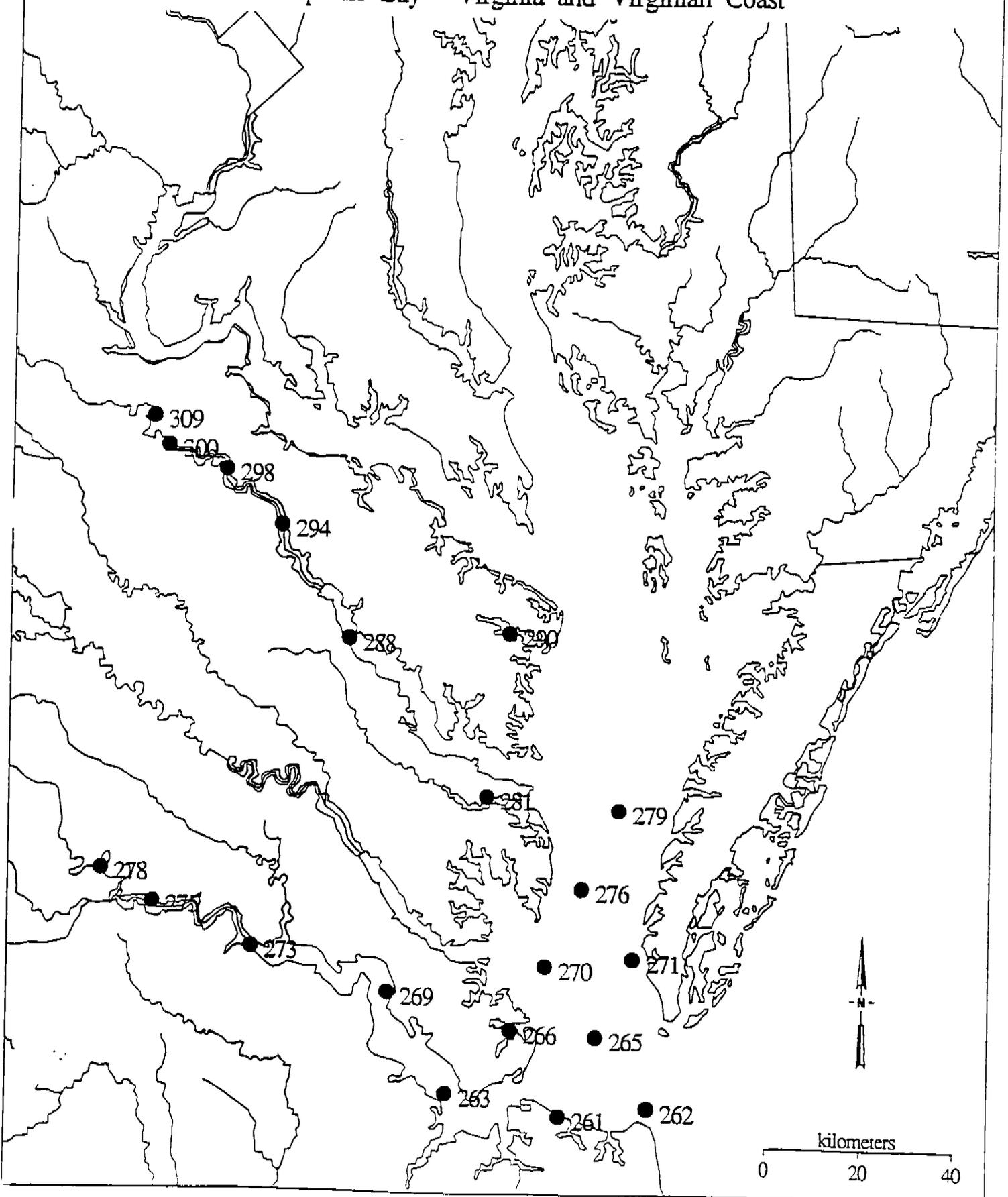
EMAP - ESTUARIES VIRGINIAN PROVINCE 1990 BASE STATIONS

Chesapeake Bay - Virginia and Virginian Coast



EMAP - ESTUARIES VIRGINIAN PROVINCE 1991 BASE STATIONS

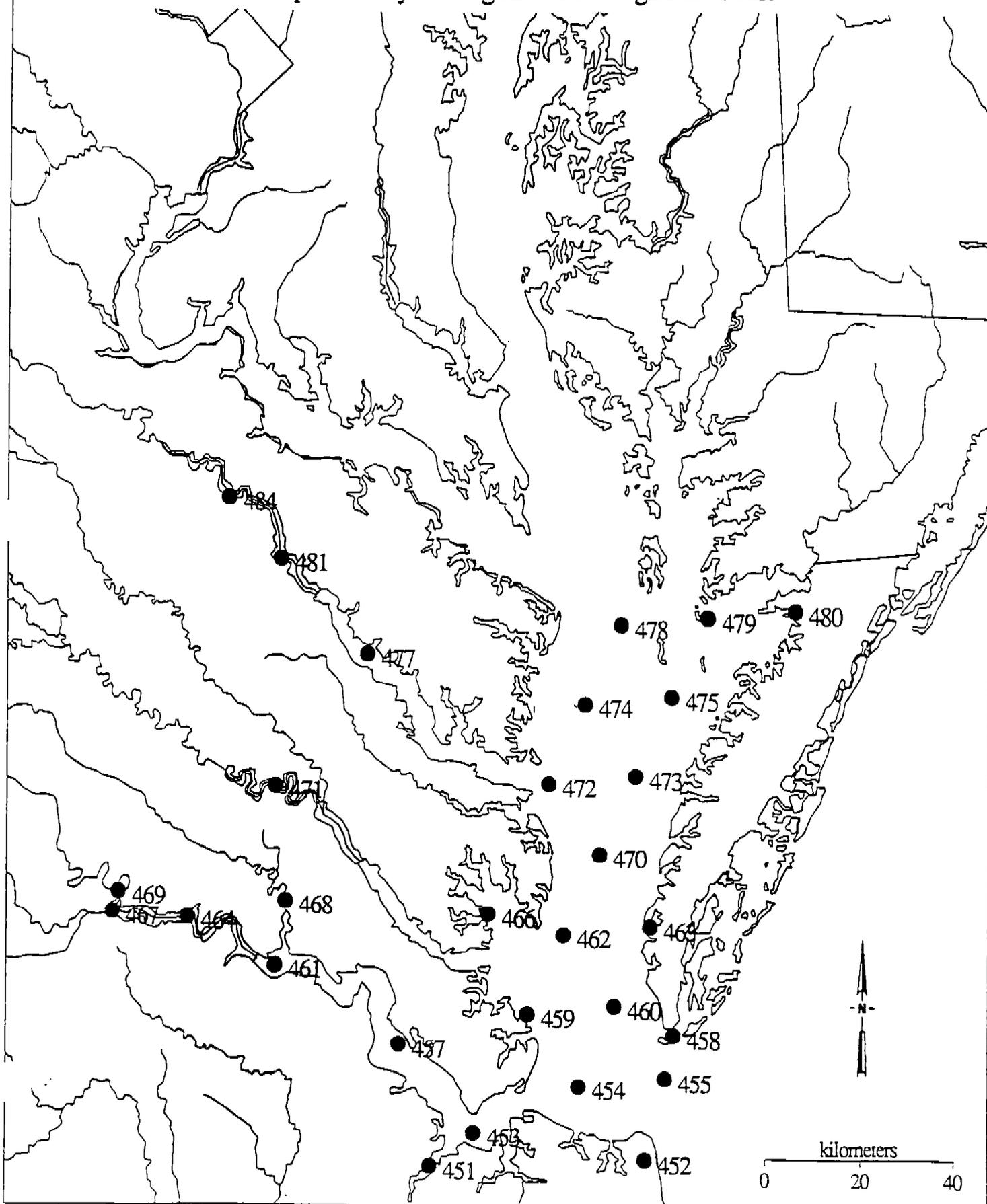
Chesapeake Bay - Virginia and Virginian Coast



EMAP – ESTUARIES VIRGINIAN PROVINCE

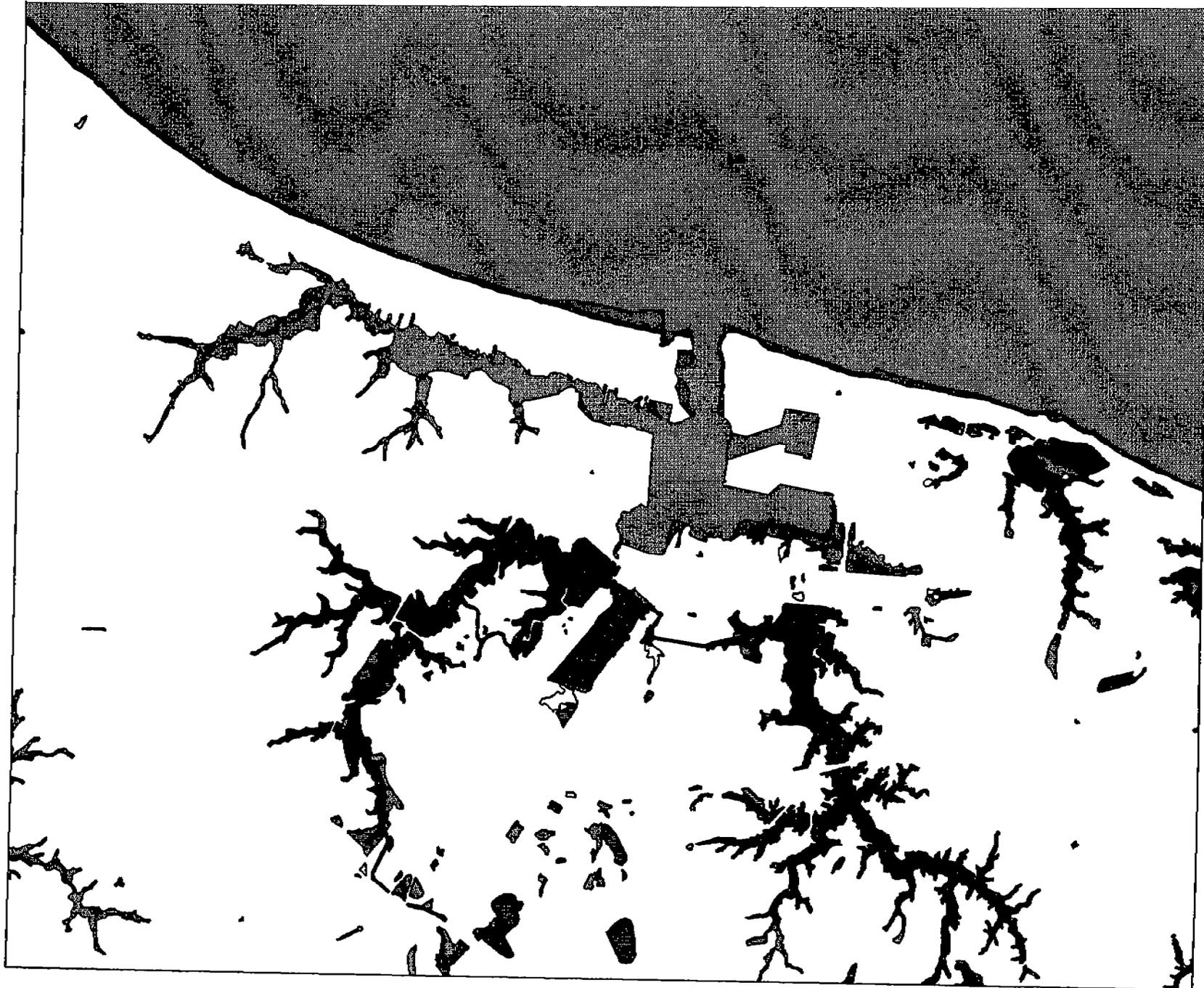
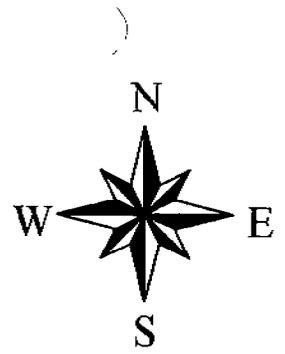
1992 BASE STATIONS

Chesapeake Bay – Virginia and Virginian Coast



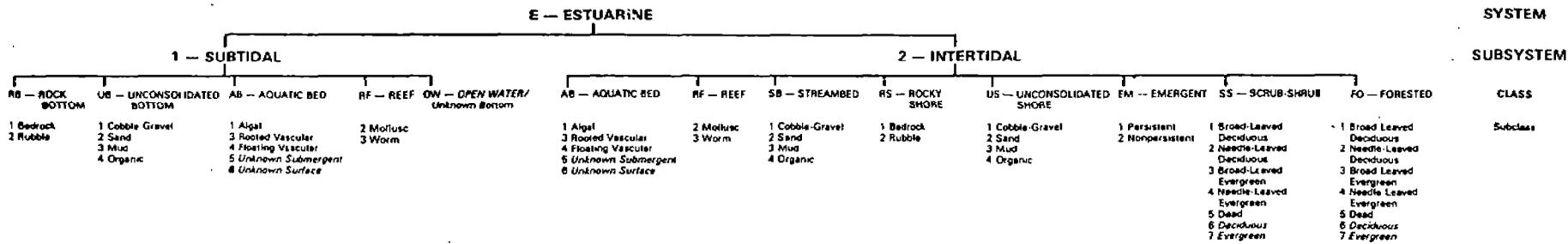
APPENDIX A.2
WETLANDS MAP FOR LITTLE CREEK HARBOR

Little Creek

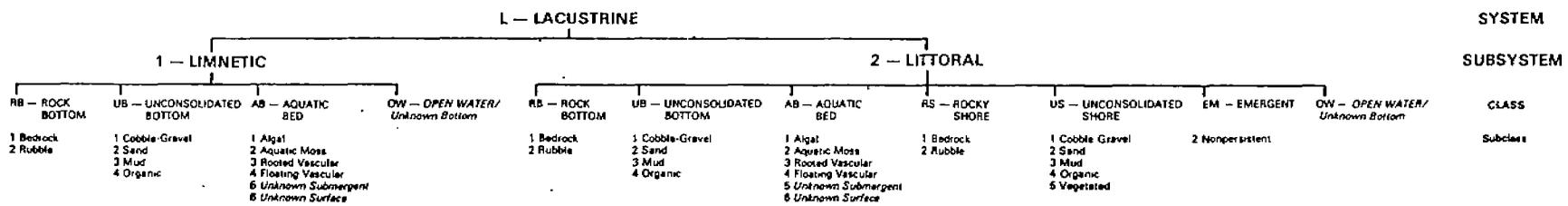


Lcreek

-  E1U
-  E2E
-  E2U
-  L1U
-  L2A
-  L2E
-  PAB
-  PEM
-  PFO
-  PSS
-  PUB
-  U

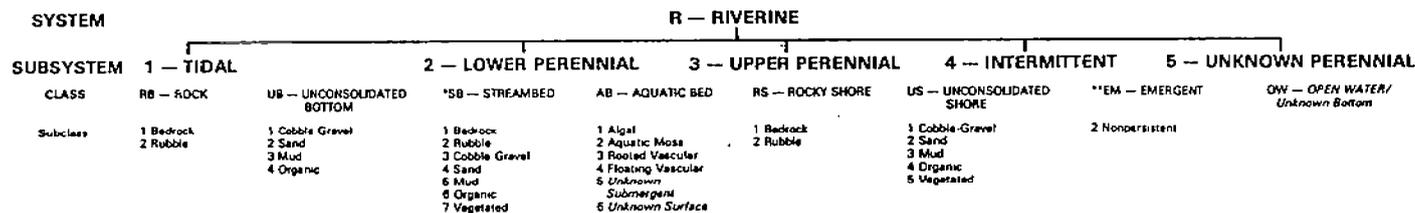
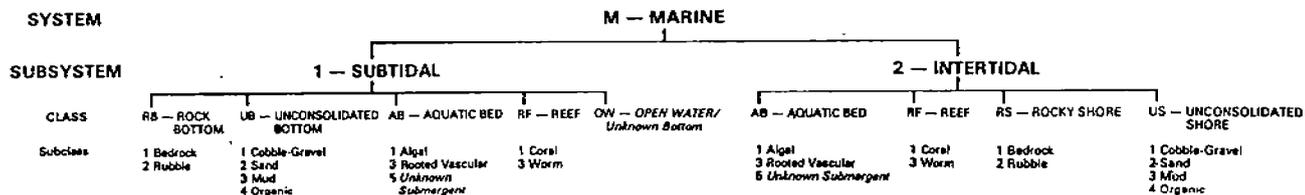


SYSTEM
SUBSYSTEM
CLASS
Subclass

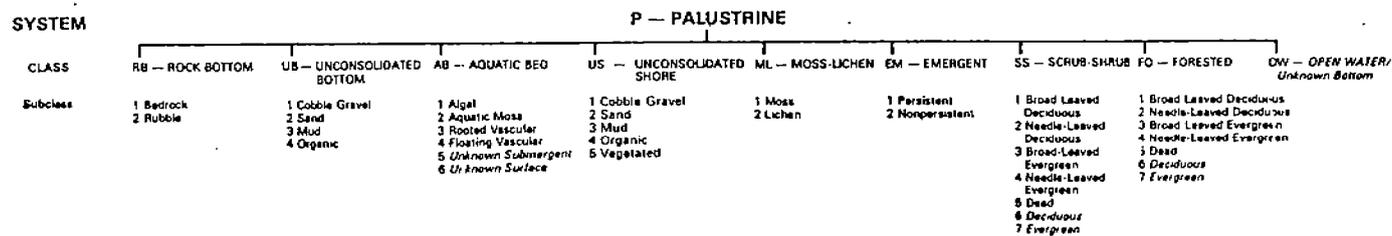


SYSTEM
SUBSYSTEM
CLASS
Subclass

MODIFIERS											
In order to more adequately describe wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The named modifier may also be applied to the ecological system.											
WATER REGIME	WATER CHEMISTRY	SOIL	SPECIAL MODIFIERS								
<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> Non-Tidal A. Temporarily Flooded B. Saturated C. Seasonally Flooded D. Seasonally Flooded/ Well Drained E. Seasonally Flooded/ Saturated F. Sempermanently Flooded G. Intermittently Exposed </td> <td style="width: 50%; vertical-align: top;"> Tidal H. Permanently Flooded J. Intermittently Flooded K. Artificially Flooded W. Intermittently Flooded/Temporary Y. Saturated, semipermanent/ Seasonal Z. Intermittently Exposed/Permanent U. Unknown </td> </tr> </table>	Non-Tidal A. Temporarily Flooded B. Saturated C. Seasonally Flooded D. Seasonally Flooded/ Well Drained E. Seasonally Flooded/ Saturated F. Sempermanently Flooded G. Intermittently Exposed	Tidal H. Permanently Flooded J. Intermittently Flooded K. Artificially Flooded W. Intermittently Flooded/Temporary Y. Saturated, semipermanent/ Seasonal Z. Intermittently Exposed/Permanent U. Unknown	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> Coastal Salinity 1. Hypersaline 2. Euhaline 3. Microhaline (Brackish) 4. Polyhaline 5. Mesohaline 9. Oligohaline 0. Fresh </td> <td style="width: 50%; vertical-align: top;"> Inland Salinity 7. Hypersaline 8. Eusaline 9. Mesosaline 0. Fresh </td> </tr> </table> <p style="font-size: small; text-align: center;">*These water regimes are only used in tidally influenced, freshwater systems</p>	Coastal Salinity 1. Hypersaline 2. Euhaline 3. Microhaline (Brackish) 4. Polyhaline 5. Mesohaline 9. Oligohaline 0. Fresh	Inland Salinity 7. Hypersaline 8. Eusaline 9. Mesosaline 0. Fresh	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> pH Modifiers for all Fresh Water a. Acid i. Circumneutral r. Alkaline </td> <td style="width: 50%; vertical-align: top;"> SOIL g. Organic n. Mineral </td> </tr> </table>	pH Modifiers for all Fresh Water a. Acid i. Circumneutral r. Alkaline	SOIL g. Organic n. Mineral	<table border="0" style="width: 100%;"> <tr> <td style="width: 33%; vertical-align: top;"> SPECIAL MODIFIERS b. Beaver d. Partially Drained/Ditched f. Farmed </td> <td style="width: 33%; vertical-align: top;"> h. Diked/Impounded r. Artificial Substrate s. Spot x. Excavated </td> </tr> </table>	SPECIAL MODIFIERS b. Beaver d. Partially Drained/Ditched f. Farmed	h. Diked/Impounded r. Artificial Substrate s. Spot x. Excavated
Non-Tidal A. Temporarily Flooded B. Saturated C. Seasonally Flooded D. Seasonally Flooded/ Well Drained E. Seasonally Flooded/ Saturated F. Sempermanently Flooded G. Intermittently Exposed	Tidal H. Permanently Flooded J. Intermittently Flooded K. Artificially Flooded W. Intermittently Flooded/Temporary Y. Saturated, semipermanent/ Seasonal Z. Intermittently Exposed/Permanent U. Unknown										
Coastal Salinity 1. Hypersaline 2. Euhaline 3. Microhaline (Brackish) 4. Polyhaline 5. Mesohaline 9. Oligohaline 0. Fresh	Inland Salinity 7. Hypersaline 8. Eusaline 9. Mesosaline 0. Fresh										
pH Modifiers for all Fresh Water a. Acid i. Circumneutral r. Alkaline	SOIL g. Organic n. Mineral										
SPECIAL MODIFIERS b. Beaver d. Partially Drained/Ditched f. Farmed	h. Diked/Impounded r. Artificial Substrate s. Spot x. Excavated										

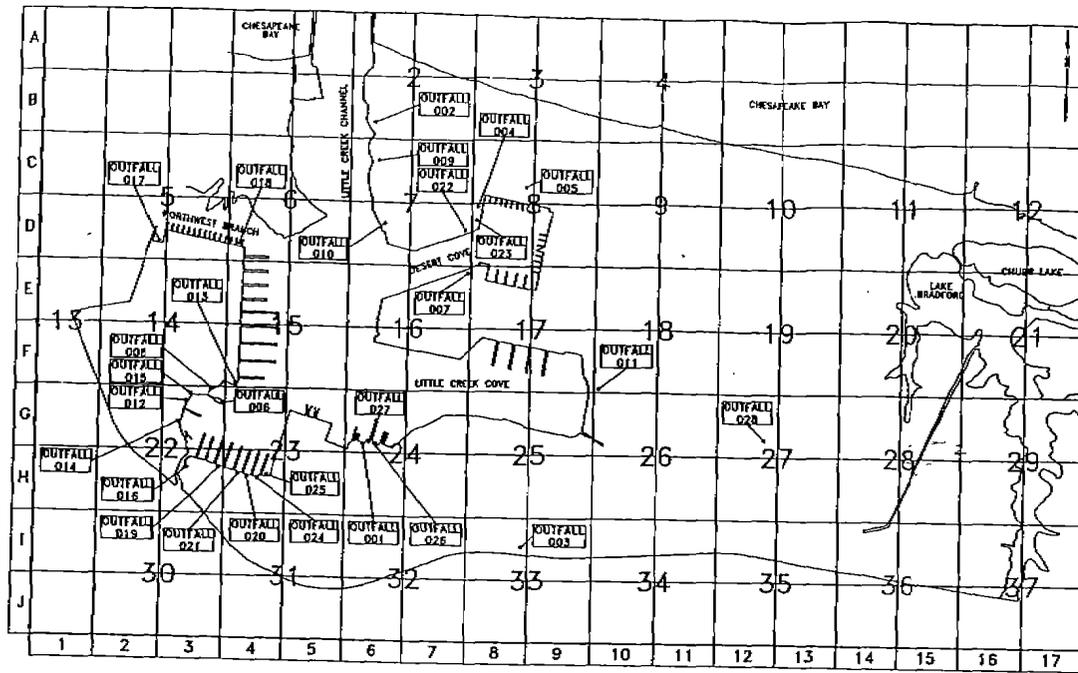


*STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS, and comprises the only CLASS in the INTERMITTENT SUBSYSTEM
 **EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS. The remaining CLASSES are found in all SUBSYSTEMS



APPENDIX B
REGULATED STORMWATER OUTFALL MAP AND
IDENTIFICATION TABLES

APPENDIX B.1
STORMWATER OUTFALL MAP



LEGEND

- 12" — PIPE
- ==== PAVED DITCH
- UNPAVED DITCH
- - - - DRAINAGE BOUNDARY
- CURB INLET (C.I.)
- BROF INLET (O.I.)
- MANHOLE (M.N.)
- OUTFALL XXX REGULATED OUTFALL
- OUTFALL NR-XXX NON-REGULATED OUTFALL
- OUTFALL ND-XXX NON-DISCHARGE OUTFALL
- SHEET FLOW SF-XXX SHEET FLOW DISCHARGE

Outfall	Total Area (acres)	Impervious Area (acres)	Pervious Area (acres)
001	20.64	5.73	14.91
002	20.13	18.78	1.35
003	10.27	1.72	8.55
004	1.68	0.19	1.49
005	0	0	0
006	0.09	0.09	0
007	3.52	0.93	2.59
008	0.77	0.77	0
009	10.99	10.04	0.95
010	9.52	8.01	1.51
011	42.14	28.78	13.36
012	24.01	8.32	15.69
013	8.85	6.99	1.86
014	8.46	7.4	1.06
015	4.22	3.78	0.44
016	4.25	2.37	1.88
017	11.59	4.18	7.41
018	1.6	0.71	0.89
019	0.15	0.15	0
020	0.53	0.22	0.31
021	0.11	0.11	0
022	0.08	0.06	0.02
023	0.19	0.18	0.01
024	0.25	0.25	0
025	1.63	1.00	0.63
026	0.64	0.64	0
027	0.77	0.77	0
028	28.76	9.87	18.89

1. ODF OUTFALL 013A (M.D.-8 SINGRIST AREA)
 2. ODFALL NUMBERING MODIFICATIONS

PROJECT: NS2470-92-0-7488
 ACTIVITY: SUBSTANTIATION TO

ATLANTIC DIVISION
 NAB LITTLE CREEK
 STORMWATER DISCHARGE STUDY
 VIRGINIA BEACH, VIRGINIA

SHEET NO. 4284112
 DATE: 11/7/94

REVISIONS
 NO. DATE BY

APPENDIX B.2
STORMWATER OUTFALL DESCRIPTION TABLES

REGULATED STORMWATER OUTFALLS

OUTFALL NO.	LATITUDE	LONGITUDE	REGULATED ACTIVITIES	ASSOCIATED BUILDINGS
001	N36°54'45"	W76°10'30"	This outfall is presently regulated under a VPDES Permit. SIC Code 4212 - Solid Waste Transfer Station > 90-Day Hazardous Waste Storage Area	New Solid Waste Transfer Station > 90-Day Hazardous Waste Transfer Storage Area.
002	N36°55'30"	W76°10'30"	This outfall is presently regulated under a VPDES Permit.	LCAC Parking Area No. 1.
003	N36°54'30"	W76°10'15"	This outfall is presently regulated under a VPDES Permit. SIC Code 5171 - Bulk Petroleum Storage	Bulk oil tanks NAB 759 and NAB 760. Demin Pond
004	N36°55'15"	W76°10'15"	This outfall is presently regulated under a VPDES Permit. SIC Code 5171 - Bulk Petroleum Storage	Fuel Tank Farm including tanks 3862-3866.
005	N36°55'30"	W76°10'15"	This outfall is presently regulated under a VPDES Permit; however, the discharge has been routed to the sanitary sewer system since July 1990.	Refueling area adjacent to the Fuel Tank Farm and the LCAC complex.
006	N36°55'00"	W76°11'00"	This outfall is presently regulated under a VPDES Permit. SIC Code 373 - Shipbuilding and Repair	Auxiliary Floating Drydock Light Six (AFDL-6) at Pier 10.
007	N36°55'15"	W76°10'15"	This outfall is presently regulated under a VPDES Permit. SIC Code 3471 - Sandblasting	Sandblasting area adjacent to Desert Cove.
008	N36°55'00"	W76°09'00"	This outfall is presently regulated under a VPDES Permit, because of dry weather steam condensate flow. There are no stormwater discharges associated with industrial activity.	Bldg's 3603, 3604, 3605, and 3015.
009	N36°55'30"	W76°10'30"	LANTDIV has requested that this outfall be included under the current VPDES permit.	LCAC Parking Area No. 2.
010	N36°55'15"	W76°10'30"	LANTDIV has requested that this outfall be included under the current VPDES permit.	LCAC Parking Area No. 3.

REGULATED STORMWATER OUTFALL DRAINAGE AREAS

OUTFALL NO.	TOTAL AREA (ACRES)	IMPERVIOUS AREA (ACRES)	RECEIVING STREAM
001	20.64	5.73	Little Creek Cove
002	20.13	18.78	Little Creek Channel
003	10.27	1.72	Unnamed Tributary of Little Creek Cove
004	1.68	0.19	Desert Cove
005	0	0	Not Applicable
006	0.09	0.09	Little Creek Channel
007	3.52	0.93	Desert Cove
008	0.77	0.77	Gulf Course Lake 1
009	10.99	10.04	Little Creek Channel
010	9.52	8.01	Little Creek Channel
011	42.14	28.78	Little Creek Cove
012	24.01	8.32	Little Creek Channel
013	8.85	6.99	Little Creek Channel
014	8.46	7.4	Little Creek Channel
015	4.22	3.78	Little Creek Channel
016	4.25	2.37	Unnamed Tributary of Little Creek Channel
017	11.59	4.18	Northwest Branch of Little Creek
018	1.6	0.71	Northwest Branch of Little Creek
019	0.15	0.15	Little Creek Channel
020	0.53	0.22	Little Creek Channel
021	0.11	0.11	Little Creek Channel
022	0.08	0.06	Little Creek Channel
023	0.19	0.18	Little Creek Channel
024	0.25	0.25	Little Creek Channel

REGULATED STORMWATER OUTFALL DRAINAGE AREAS

OUTFALL NO.	TOTAL AREA (ACRES)	IMPERVIOUS AREA (ACRES)	RECEIVING STREAM
025	1.63	1.00	Little Creek Channel
026	0.64	0.64	Little Creek Cove
027	0.77	0.77	Little Creek Cove
028	28.76	9.87	Unnamed Tributary of Little Creek Cove

APPENDIX C
ECOLOGICAL TOXICOLOGICAL PROFILES

Acetone tox
11/15/95
j.golden

ACETONE

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Acetone

CAS Number: 67-64-1

Synonyms: Dimethylketone; 2-propanone

Acetone is a colorless, volatile liquid that has a sweetish odor⁽¹⁾. It is considered the least toxic solvent in the industry. Acetone can be naturally occurring or manufactured artificially⁽²⁾. Acetone is used as a solvent in the production of lubricating oils, and as a chemical intermediate in the manufacturing of chloroform, pharmaceuticals, and pesticides. Acetone also is used to produce paints, varnishes, and lacquers⁽³⁾.

Acetone may be released into the environment as stack emissions, fugitive emissions, and in wastewater in its production and use as a chemical intermediate and solvent. In addition to industrial releases, acetone is the product of the photodioxidation of some alkanes and alkenes found in urban air, and in releases from volcanos and forest fires⁽²⁾.

If released into water, acetone will most likely biodegrade. Acetone will also volatilize. As a result of acetone's volatile characteristics, bioconcentration in aquatic organisms and adsorption to sediment should not be significant⁽²⁾.

Released on soil, acetone will volatilize with some leaching into soil. Acetone rapidly biodegrades in soils⁽²⁾.

Because of acetone's ability to volatilize, released into the atmosphere is the ultimate fate of acetone. In the atmosphere, acetone will undergo photolysis and react with photochemically produced hydroxyl radicals. The half-life of acetone ranges between 13 and 22 days with the longer half-life occurring in the winter months. This relatively long half-life allows for atmospheric dispersion of acetone. The primary removal process is wash out by rain⁽²⁾

Acetone.tox
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FATE IN THE ENVIRONMENT

Parameter	Values	Reference
Log K _{ow}	-0.24	4
Solubility	Infinite	3
K _{oc}	2.2	2
Vapor Pressure	231mm @25deg. C	2
Bioconcentration Factor	0.69 (fish)	5

TERRESTRIAL EFFECTS

Soil Flora and Fauna

No levels have been established for acetone in earthworms, plants, invertebrates or microbial populations.

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference.
Rat	100	NOEL	systemic	6

NOEL - No Observed Effect Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁽⁷⁾	NE	NE
USEPA Region III ⁽⁵⁾ Marine Fauna Freshwater Fauna	NE 9,000,000	NE NE
USEPA AWQC ⁽⁸⁾	NE	NE

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Standards
 NE - Not Established

Aquatic Life - Sediment

Sediment Screening Values	ER-L (ug/kg)	ER-M (ug/kg)
USEPA Region III ⁽⁵⁾	NE	NE
Long et al. ⁽⁹⁾	NE	NE

NE - Not Established

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- (4) United States Environmental Protection Agency. 1986. Superfund Public Health Evaluation Manual. EPA/540/1-86/060. Office of Emergency and Remedial Response. Washington, DC. October, 1986.
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- (8) United States Environmental Protection Agency. 1991 and 1992. Surface Water Quality Criteria. Federal Register. Volume 57, No. 246. May 1991 and December 1992..
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C-DISULF.TOX
7/20/95
A.Bernhardt

CARBON DISULFIDE

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Carbon Disulfide
CAS Number: 75-15-0
Synonyms: Dithiocarbonic anhydride

Carbon disulfide is a natural product of anaerobic biodegradation and is released to the atmosphere from oceans and land masses⁽¹⁾. It may also be released as emissions and in wastewater during its production and use. Carbon disulfide is used in the production of viscous rayon, cellophane, carbon tetrachloride, and as a solvent and fumigant⁽¹⁾.

If released to soil, carbon disulfide will be primarily lost by volatilization⁽¹⁾. Carbon disulfide also will rapidly volatilize from water with an estimated 2.6 hr half-life based on a river model⁽¹⁾. Adsorption to the sediment will not be significant⁽¹⁾. Carbon disulfide is not expected to significantly bioconcentrate in aquatic organisms⁽¹⁾.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	2.2	1
Water Solubility	2,100 mg/L @ 20°C	1
Log K _{oc}	2.16	2
Vapor Pressure	297 mm Hg @ 20°C	1
Bioconcentration Factor	NA	NA

NA - Not Available

C-DISULF.TOX
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TERRESTRIAL FATE

Soil Flora and Fauna

Species	Concentration (mg/kg)	Endpoint	Reference
Plant	NA	NA	NA
Flora	NA	NA	NA
Earthworm	NA	NA	NA
Microorganisms	NA	NA	NA

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
rabbit	11	subchronic NOAEL	Reproductive	3

NA - Not Applicable
NOAEL - No Observed Adverse Effect Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS (As III) ⁽⁶⁾ Marine Freshwater	NE NE	NE NE
USEPA Region III ⁽²⁾ Marine Flora Marine Fauna Freshwater Fauna Freshwater Flora	NE NE NE NE	NE NE NE NE
USEPA AWQC ⁽⁷⁾ Marine Freshwater	NE NE	NE NE
ORNL Benchmarks ⁽⁴⁾ Freshwater	159	8.89

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

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Aquatic Life - Sediment

Sediment Screening Values	ER-L	ER-M
USEPA Region III ⁽²⁾	NE	NE
Long et al., ⁽⁸⁾	NE	NE

NE - Not Established

AET - Apparent Effects Threshold

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C-DISULF.TOX

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- (8) Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." Environmental Management, 19:81-97.

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MEK.tox
4/12/95
r.san pedro

Methyl Ethyl Ketone

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Methyl Ethyl Ketone

CAS Number: 78-93-3

Synonyms: 2-Butanone; ethyl methyl ketone; MEK; methyl acetone

Methyl ethyl ketone (MEK) is used primarily as an industrial solvent. It is mainly used to manufacture gums, resins, nitrocellulose, cements and adhesives. Its production and use has lead to its presence in the atmosphere. In general, the ketones are naturally occurring components of food⁽¹⁾.

MEK is expected to be fairly mobile in the soil/groundwater system when present at low concentrations or as a separate organic phase (e.g., a significant spill). Portions of MEK associated with the water and air phases of soil have higher mobility than the adsorbed portion. Volatilization from near surface soils may occur. However, vapor concentrations in soil are expected to be very low whenever water is present. Biodegradation of MEK has been demonstrated. Persistence in environments with active microbial populations is not expected⁽¹⁾.

The primary pathway of concern is the migration of MEK from soil to groundwater. Volatilization is another primary exposure pathway. Bioaccumulation is not considered to be an important exposure pathway. Any pathways related to the uptake by aquatic organisms or domestic animals from surface waters are likely to be less significant other than other sources of exposure due to the low bioaccumulation factor for MEK⁽¹⁾.

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FATE IN THE ENVIRONMENT

Parameter	Values	Reference
Log K _{ow}	0.29	2
Solubility	2.68x10 ⁵ mg/L in water	3
Log K _{oc}	0.65	3
Vapor Pressure	77.5 mm Hg	3
Bioconcentration Factor	NA	

NA - Not Available

TERRESTRIAL EFFECTS

Soil Flora and Fauna

No levels have been established for MEK in earthworms, plants, invertebrates or microbial populations.

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference.
Rat	1,771	chronic NOAEL	reproductive	4

NOAEL - No Observed Adverse Effect Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁽⁵⁾	NE	NE
USEPA Region III ⁽⁶⁾ Marine Fauna Freshwater Fauna	NE 3,220,000	NE NE
USEPA AWQC ⁽⁷⁾	NE	NE

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Standards
 NE - Not Established

Aquatic Life - Sediment

Sediment Screening Values	ER-L (ug/kg)	ER-M (ug/kg)
USEPA Region III ⁽⁶⁾	NE	NE
Long et al. ⁽⁸⁾	NE	NE

NE - Not Established

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AL.tox
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M.Suminski

ALUMINUM

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Aluminum
CAS Number: 7429905

Pure aluminum is a light ductile metal which has a density of approximately one third that of iron. Aluminum is a good conductor of both heat and electricity, and it is easy to weld. When aluminum is exposed to air, a thin film of oxide forms on the surface, creating a protective coating which is resistant to corrosion. Aluminum is used in alloys together with copper, zinc, manganese, and magnesium.⁽¹⁾

Aluminum is one of the most abundant metals in the earth's crust, and it is ubiquitous in air and water, as well as soil. The toxicity of aluminum may be divided into three major categories (1) the effect of aluminum compounds on the gastrointestinal tract; (2) the effect of inhalation of aluminum compounds; and (3) systemic toxicity of aluminum.⁽²⁾

Aluminum is an extremely versatile metal with a wide variety of uses, e.g. packaging materials, several types of containers, kitchen utensils, auto-bodies and components, airplanes and building panels. Certain aluminum compounds are used in paint pigment, insulating materials, abrasives, cosmetics and even food additives. Aluminum sulfate is used in the treatment of drinking water and sewage.⁽¹⁾

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	NA	
Log K _{oc}	NA	
Vapor Pressure	NA	
Bioconcentration Factor	231(fish)	8
Density	2.7	1

NA- Information not available

TERRESTRIAL FATE

Soil Flora and Fauna

Species	Concentration (mg/kg)	Endpoint	Reference
Plant	50	Benchmark	3,4
Microorganisms	600	Benchmark	3,4

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Dog	600	subchronic NOAEL	diet	5
Mouse	19.3	chronic LOAEL	reproductive	6
Cattle	5	MTL	mortality	5
Poultry	10	MTL	diet	5
Rabbit	11.61	MTL	diet	5

MTL - Mineral Tolerance Level

NOAEL - No Observed Adverse Effects Level

LOAEL - Lowest Observed Adverse Effects Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS (As III) ⁽⁷⁾	NE	NE
USEPA Region III ⁽⁸⁾ Freshwater Flora Freshwater Fauna	460 200	NE NE
USEPA AWQC ⁽⁹⁾ Freshwater	750	87

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁽⁸⁾	NE	NE
Long et al. ⁽¹⁰⁾	NE	NE

NE - Not Established

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AS.TOX
4/4/95
M.Suminski

ARSENIC

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Arsenic
CAS Number: 7440-38-2
Synonyms: Arsenic inorganic, gray-arsenic

Arsenic is a naturally occurring element in the earth's crust. Pure arsenic is a gray-colored metal, but this form is not common in the environment. Arsenic is usually found combined with one or more other elements such as oxygen, chlorine, and sulfur. Arsenic combined with these elements is referred to as inorganic arsenic. Arsenic combined with carbon and hydrogen is referred to as organic arsenic¹¹.

Arsenic enters the environment both as the result of natural forces (volcanos and weathering of arsenic-containing rocks) and human activity (metal smelting, glass manufacturing, pesticide production and application, and fossil-fuel burning)¹¹.

Arsenic in the environment may undergo a complex cycle of chemical interconversions and transfers between media. Atmospheric emission, which are usually adsorbed to particulate matter, may undergo oxidation before being returned to the surface by wet or dry deposition. Arsenic in water may undergo either reduction or oxidation, depending on pH, the electrochemical oxidation-reduction potential (Eh), and other ions present. Soluble forms of arsenic tend to be quite mobile in water, while less soluble species adsorb to clay or soil particles¹¹.

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	NA
Solubility	1.000 E-06 mg/L @25 C	1
Log K _{oc}	4.97	1
Vapor Pressure	NA	NA
Bioconcentration Factor	3 (invertebrates) 4 (fish)	2

NA - Not Available

TERRESTRIAL FATE

Soil Flora and Fauna

Species	Concentration (mg/kg)	Endpoint	Reference
Plant	10	Benchmark	3
Flora	5	Screening Level	2
Earthworm	60	Benchmark	4
Microorganisms	100	Benchmark	4

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Poultry (Mallard Duck)	5.1	chronic NOAEL	mortality	5
Mouse	0.13	chronic LOAEL	reproductive	6
Cattle	0.25	MTL	NA	7
Rabbit	2.9	MTL	NA	7

NA - Not Applicable

MTL - Mineral Tolerance Level

NOAEL - No Observed Adverse Effect Level

LOAEL - Lowest Observed Adverse Effect Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS (As III) ⁽⁶⁾ Marine Freshwater	690 360	36 190
USEPA Region III ⁽²⁾ Marine Flora (As III) Marine Flora (As IV) Marine Fauna (As III) Freshwater Fauna (As) Freshwater Flora (As IV) Freshwater Fauna (As III)	NE NE NE NE 48 NE	19 13 36 874 NE 190
USEPA AWQC ⁽⁹⁾ Marine Freshwater	69 360	190 36

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁽²⁾ total As As III	8,200 (fauna)* 57 (AET)	NE NE
Long et al. ⁽¹⁰⁾	8.2	70

NE - Not Established
 AET - Apparent Effects Threshold
 * Screening Level

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Ba.tox
4/13/95
M.Suminski

BARIUM

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Barium
CAS Number: 7440-39-3

Barium is the heaviest of the stable alkaline earths (Group IIa of the Periodic Table). The free element is a silver-grey soft metal. It oxidizes readily in moist air, and it reacts with water or with dilute acids under evolution of hydrogen gas⁽¹⁾.

In its compounds, barium is a colorless divalent positive ion. The chloride and nitrate are soluble in water. The carbonate is much less soluble in water, but is soluble in dilute acids, and the sulfate is one of the least soluble compounds in any medium⁽¹⁾.

Barium is used in various alloys, in paints, soap, paper, and rubber, and in the manufacture of ceramics and glass. Barium fluorosilicate and carbonate have been used as insecticides. Barium is relatively abundant in nature and is found in plant and animal tissue. Plants accumulate barium from the soil⁽²⁾.

The toxicity of barium compounds depends on their solubility. The free ion is readily absorbed from the lung or gastrointestinal tract, but barium sulfate remains essentially unabsorbed. After absorption, barium accumulates in the skeleton. An accumulation also takes place in the pigmented parts of the eye⁽¹⁾.

Barium occurs chiefly as the mineral barite (BaSO_4). In recent years, about 80% of ground and crushed barite solid was used directly as a weighting agent in oil- and gas-well drilling muds. The remainder of barite is used in the manufacture of glass, ceramics, television picture tubes, brick and tile refractories, vinyl stabilizers, railroad flares, fireworks, fine chemicals, lubricating oil additives, permanent magnets, as well as in sugar refining, paper coating, steel hardening, and as pigment in paint⁽¹⁾.

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	NA	
Log K _{oc}	NA	
Vapor Pressure	NA	
Bioconcentration Factor	17,000(plants) 900(invertebrates) 8(fish)	3

NA - Not Available

TERRESTRIAL EFFECTS

Soil Flora and Fauna

Test Species	Screening Value (mg/kg)	Impact	Reference
Plant	500	Benchmark	5
Earthworm	440	Screening Level	3
Invertebrate	440	Screening Level	3
Microorganisms and Microbial Processes	3,000	Benchmark	4

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Rat	0.25	chronic NOAEL	observed effects	6,7
Cattle	0.1	MTL		8
Poultry	1	MTL		8
Rabbit	1.16	MTL		8

NOAEL - No Observed Adverse Effect Level
 MTL - Mineral Tolerance Level

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁽⁹⁾	NE	NE
USEPA Region III ⁽³⁾		
Freshwater Fauna	10,000	NE
Freshwaer Flora	NE	NE
Marine Fauna	NE	NE
Marine Flora	NE	NE
USEPA AWQC ⁽¹⁰⁾	NE	NE

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁽³⁾	NE	NE
Long et al. ⁽¹¹⁾	NE	NE
WDNR-Interim Criteria ⁽¹²⁾	500	NE

NE - Not Established

WDNR - Wisconsin Department of Natural Resources

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BE.TOX
7/20/95
A.Bernhardt

BERYLLIUM

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Beryllium
CAS Number: 7440-41-7
Synonyms: Beryllium-9, glucinium; glucinum; beryllium metallic

Beryllium occurs as a chemical component of certain rocks, soils, and volcanic dust. Beryllium is naturally emitted to the atmosphere by windblown dust and volcanic particles⁽¹⁾. The major emission source to the environment is the combustion of coal and fuel oil, which releases particulates and fly ash that contain beryllium into the atmosphere.

Sediment is the ultimate sink for beryllium in water, and its association with sediment would decrease the mobility in water. Beryllium does not bioconcentrate to high levels in aquatic animals, although the bioconcentration in bottom dwelling animals may be higher than nonbottom-dwelling animals. There is no evidence of biomagnification of beryllium within terrestrial or aquatic food chains⁽²⁾.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K_{ow}	NA	NA
Solubility	Insoluble in water, soluble in dilute acid and alkali	1
Log K_{oc}	NA	NA
Vapor Pressure	NA	NA
Bioconcentration Factor	100 (invertebrates, plants) 19 (fish)	2

NA - Not Available

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TERRESTRIAL FATE

Soil Flora and Fauna

Species	Concentration (mg/kg)	Endpoint	Reference
Plant	10	Benchmark	3
Flora	0.02	Screening Level	2
Earthworm	NA	NA	NA
Microorganisms	NA	NA	NA

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
rat	0.54	chronic NOAEL	Systemic	4,5

NA - Not Applicable
 NOAEL - No Observed Adverse Effect Level

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS (As III) ⁽⁶⁾ Marine Freshwater	NE NE	NE NE
USEPA Region III ⁽²⁾ Marine Flora Marine Fauna Freshwater Fauna Freshwater Flora	NE NE NE 100,000	NE NE 5.3 NE
USEPA AWQC ⁽⁷⁾ Marine Freshwater	NE 130 (LOEL)	NE 5.3 (LOEL)

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 LOEL - Insufficient data to develop criteria. Value presented is the Lowest Observed Effect Level
 NE - Not Established

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁽²⁾	NE	NE
Long <u>et.al.</u> , ⁽⁶⁾	NE	NE
Tetra Tech, 1986 ⁽⁹⁾	0.36 (AET)	NE

NE - Not Established
 AET - Apparent Effects Threshold

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Cd.tox
2/28/95
j.golden

CADMIUM

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Cadmium
CAS Number: 7440-43-9
Synonyms: C.I. 77180; Colloidal Cadmium

Cadmium is a soft, blue-white, malleable metal or gray-blue powder. Cadmium is used for electroplating, in pigment production, and in the manufacturing of plastic stabilizers and batteries. Sources of cadmium include smelter fumes and dusts, incineration products from cadmium-containing materials, fertilizer, and municipal wastewater and sludge discharges. It also is an industrial byproduct of the manufacturing of zinc, copper, and lead¹.

Cadmium compounds have varying degrees of solubility ranging from very soluble (cadmium salts) to nearly insoluble (cadmium metal). The solubility affects cadmium adsorption and toxicity¹. Cadmium may exist in water as a hydrated ion or as metal inorganic complexes. Adsorption and desorption processes are the most likely processes controlling the concentrations of cadmium released into natural waters. Cadmium is more mobile in aquatic environments than most heavy metals².

Adsorption and desorption rates of cadmium are rapid on mud solids and particles of clay, silica, humic material, and other naturally occurring solids. Changes in the physical chemistry of a waterbody (especially pH and redox potential) influence the suspension of cadmium from the sediments into the water column. During anaerobic conditions, cadmium is more likely to release from the sediments into the water column. Cadmium is not likely to partition from the water into the atmosphere because cadmium does not form volatile compounds¹.

Aquatic and terrestrial organisms bioaccumulate cadmium up the food chain. Bioconcentration in fish is dependent upon the pH and the organic content of the water¹. Cadmium may adversely impact the reproduction success of fish³.

Cadmium exists in soil as free cadmium compounds. Cadmium released to soils may leach into water, especially under acidic conditions. The transformation of cadmium in soil is dependent on sorption and desorption from water, and includes precipitation, dissolution, complexation, and ion exchange. Factors affecting transformation in soil include cation exchange capacity; pH; and the content of clay minerals, carbonate minerals, oxides, organic matter, and oxygen¹.

Cadmium is readily taken up by plant roots and translocates through the plant and accumulated.

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Cadmium depresses the uptake of iron, manganese, and probably calcium, magnesium, and nitrogen. Symptoms of plant toxicity include necrosis, wilting, reduced zinc levels, and reduction in growth. Agronomic crops are more sensitive to cadmium toxicity than trees⁴.

Cadmium can exist in the atmosphere as suspended particulate matter derived from sea spray, industrial emissions, combustion of fossil fuels, or the erosion of soils. Cadmium in the atmosphere will remain for approximately one to ten days before deposition occurs. Cadmium in the atmosphere usually takes the form of oxides, sulfates, sulfides, and chlorides. These complexes are stable and do not readily undergo photochemical reactions. Transformation of cadmium compounds in the air is mainly through dissolution in water or dilute acids¹.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K_{ow}	NA	
Solubility	Insoluble	1
Log K_{oc}	4.97	5
Vapor Pressure	0	5
Bioconcentration Factor	64 (fish)	6
	10,000 (invertebrates)	7
	4,900 (fish)	7

NA - Not Available

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TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Concentration (mg/kg)	Endpoint	Reference
earthworm	20	Benchmark	8
microorganisms	20	Benchmark	8
plants	3	Benchmark	4
flora	0.0025	Screening Level	7

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	0.5	MTL	NA	9
Mallard Duck	1.45	chronic NOAEL	reproductive	14
Rabbit	0.03	MTL	NA	9
Dog	0.75	subchronic NOAEL	reproductive	10
Rat	0.004	chronic NOAEL	systemic	15

NA - Not Applicable

MTL - Mineral Tolerance Level

NOAEL - No Observed Adverse Effects Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ¹¹ freshwater marine	$e^{(1.128[\ln(\text{hardness}^*)]-3.828)}$ 43	$e^{(0.7852[\ln(\text{hardness}^*)]-3.490)}$ 9.3
USEPA Region III ⁷ Freshwater Fauna Freshwater Flora Marine Fauna Marine Fauna	NE NE NE NE	0.15** 1.1** 9.3 NE
USEPA AWQC ¹² freshwater marine	$e^{(1.128[\ln(\text{hardness}^*)]-3.828)}$ 43	$e^{(0.7852[\ln(\text{hardness}^*)]-3.490)}$ 9.3

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established
 * Hardness based on calcium carbonate (mg/L)
 ** Value based on hardness and/or pH

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁷	0.676*(flora)	NE
Long et al. ¹³	1.2	9.6

NE - Not Established
 * Threshold Effects Level

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COBALT

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Cobalt
CAS Number: 7440-48-4
Synonyms: Aquacat; NCI-C60311

Cobalt is a steel-gray, shiny, hard, ductile ferromagnetic metal¹. It is a relatively rare metal produced primarily as a byproduct of other metals². The principal ores of cobalt are smaltite, cobaltite, chloanthite, and linnaeite. Cobalt is used in chemical agents, electroplating, ceramics, lamp filaments, catalysts, drier in printing inks, paints and varnishes, and in high temperature alloys¹. Cobalt salts are used as paint driers, catalysts, and in the production of numerous pigments³.

Cobalt released into water is expected to take a soluble form. The mobility of cobalt is controlled by its characteristic of adsorbing to the clay minerals and hydrous oxides of iron, manganese, and aluminum available in sediments and soils. Chelation of cobalt is possible in sediments and soil. Small amounts of cobalt may be solubilized by bacteriological activity. The effects of cobalt in the terrestrial environment is associated with nitrogen-fixation; however, excessive amounts can be toxic to plants. Vegetation is differentially susceptible to cobalt depending on the species. Grasses tend to be more susceptible to cobalt toxicity than broad leafed species⁴.

Although atmospheric transport of cobalt and cobalt compounds occurs, photolysis, volatilization, and biotransformation are important fate processes for cobalt³.

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	Insoluble	1
Log K _{oc}	NA	
Vapor Pressure	NA	
Bioconcentration Factor	40 (fish)	5

NA - Not Available

TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Microorganisms	1,000	Benchmark	6
Fauna	0.1	Screening Level	5
Plants	20	Benchmark	7
Flora	1.5	Screening Level	5

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Reference
Cattle	0.05	MTL	8
Poultry	0.5	MTL	8
Rabbit	0.58	MTL	8

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁹	NE	NE
USEPA Region III ⁵	NE	NE
USEPA AWQC ¹⁰	NE	NE

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁵	NE	NE
Long, et.al. ¹¹	NE	NE

NE - Not Established

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CHROMIUM

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Chromium

CAS Number: Chromium (III) 16065-83-1; Chromium (VI) 18540-29-9

Synonyms: Chromic Ion; Chromium Hexavalent Ion

Chromium is a semi-gray, heavy metal that exists in either a trivalent (III) or hexavalent (VI) state. Chromium (III) occurs naturally in the environment; whereas, chromium (VI) is produced by industrial processes. The metal chromium, is used for making steel and other alloys. Chromium (III) is used as brick lining for high-temperature, industrial furnaces. Chromium compounds (III and VI) are used for chrome plating, manufacture of dyes pigments, leather, wood preserves, and cooling tower water treatment¹.

The majority of chromium released into water will settle into the sediment; however, a small portion of chromium may dissolve into the water column. Soluble chromium compounds dissolved in the water column can remain in the water for years before settling into the bottom sediments. Chromium does not volatilize from the water surface. Chromium (VI) in the water column will eventually be reduced to Chromium (III) by organic matter in the water column¹.

Fish do not readily accumulated chromium from the water column. Chromium is not expected to biomagnify in the aquatic food chain. The bioavailability of chromium (III) to freshwater invertebrates decreases with the addition of humic acid. The decrease in bioavailability of the free form of chromium is due to its complexation with humic acid¹.

Chromium released into soil is mainly water-insoluble or is bound to the soil. However, a small fraction of chromium in soil will dissolve and may be transported deeper in the soil to groundwater. The transport of chromium in soil is dependent on the type and condition of the soil. Chromium is present in most soils in the form of chromium (III)¹. Chromium (III), as an insoluble salt, tends to strongly adhere to clay particles and organic matter; whereas, soluble chromium (VI) is not strongly adsorbed to soil². The fate of chromium in soil is dependent on the redox potential and the pH of the soil¹.

Plants growing in chromium-containing soil will uptake the chromium into its roots, but only a small fraction of the chromium will translocate in the above-ground, edible portions of the plants. There is no evidence that chromium will bioaccumulate in plants. In addition, there is no evidence that chromium will biomagnify along the terrestrial food chain¹.

The toxicity of chromium (III) to mammals is low because of its membrane permeability is poor and it is noncorrosive. In addition, there is an unlikelihood that chromium (III) will biomagnify in food chains. Chromium (VI) is considered more toxic to wildlife because of its high oxidizing potential and it easily penetrates biological membranes¹.

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Chromium is present in the air primarily in particulate form which results from surface soil dispersion or particulate emission from industrial sources². Naturally occurring gaseous forms of chromium are rare. Chromium compounds released into the air will remain in the air for less than ten days. The transport and partitioning of particulate matter in the atmosphere is dependent of the particle size and density. Chromium (VI) can be rapidly reduced in the atmosphere to chromium (III)¹.

FATE IN THE ENVIRONMENT

Parameter	Value		Reference
	Chromium (III)	Chromium (VI)	
Log K _{ow}	No Data	No Data	1
Water Solubility	Insoluble	Insoluble	1
Log K _{oc}	No Data	No Data	1
Vapor Pressure	No Data	No Data	1
Bioconcentration Factor	16 (fish)	16 (fish)	3
	192 (invertebrates)	192 (invertebrates)	4
		3.4 (fish)	4
	1,000,000 (invertebrates) (Cr total)	1,000 (plants) (Cr total)	4

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TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Earthworm	0.4	Benchmark	5
Fauna	0.0075	Screening Level	4
Microorganisms	10	Benchmark	5
Plants	1	Benchmark	6
Flora	0.02	Screening Level	4

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	5	MTL	NA	7
Poultry	50	MTL	NA	7
Rabbit	58	MTL	NA	7
Rat	2.41	chronic NOAEL	growth/food consumption	8

MTL - Mineral Tolerance Level

NOAEL - No Observed Adverse Effects Level

NA - Not Applicable

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁹ Chromium III freshwater marine	$e^{(0.8190[\ln(\text{hardness}^*)]+3.688)}$ NE	$e^{(0.8190[\ln(\text{hardness}^*)]+1.561)}$ NE
Chromium VI freshwater marine	16 1100	11 50
USEPA Region III ⁴ Chromium III freshwater fauna marine fauna	NE 10,300	NE 210**
Chromium VI freshwater fauna freshwater flora marine fauna	NE NE NE	1 2 50
USEPA AWQC ¹⁰ Chromium III freshwater marine	$e^{(0.8190[\ln(\text{hardness}^*)]+3.688)}$ NE	$e^{(0.8190[\ln(\text{hardness}^*)]+1.561)}$ NE
Chromium VI freshwater marine	16 1,100	11 50

WQS - Water Quality Standards

AWQC - Ambient Water Quality Criteria

NE - Not Established

* Hardness based on calcium carbonate concentration (mg/L)

** Value based on hardness and/or pH

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁴		
Total Chromium	260 (fauna)*; 5 (flora)	NE
Chromium III	81 (fauna)	NE
Chromium VI	<81 (fauna)	NE
Long et al. ¹¹	81	370

* Apparent Effect Threshold
NE - Not Established

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COPPER

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Copper
CAS Number: 7440-50-8
Synonyms: 1721 gold; ANAC 110

Copper is a reddish colored metal that occurs naturally in rock, soil, water, sediment and air. Copper also occurs naturally in plants and animals. Copper is used primarily as a metal or alloy in the manufacture of wire, sheet metals, pipe, and other metal products. Copper compounds are used in agriculture to treat plant diseases, for water treatment, and as preservatives for wood, leather, and fabrics¹.

The physicochemical form of copper released to the environment determines the impact of the element to the environment. Copper is released to water through natural weathering of soil and discharges from industries and sewage treatment plants. Copper released into water will most likely take the form of copper (II). Most copper in water is bound to organic matter; little is present in the free or readily exchangeable form. The concentration of dissolved copper in water is dependent on such factors as pH, the oxidation-reduction potential of the water, the presence of competing cations and anions of soluble cupric salts, and the presence of organic/inorganic complexing agents¹.

The process of complexation, adsorption, and precipitation control the amount of copper (II) released into water. Copper released into water tends to bind to the bottom sediments. Organics and iron oxides are the most important contributors to binding of copper by aerobic sediments. However, copper is typically associated with carbonates. In an anaerobic sediment, copper (II) will be reduced to copper (I) and insoluble cuprous salts will form¹.

Copper released to soil will be strongly adsorbed and remain in the upper few centimeters of soil. In most soils, the pH, organic matter, and ionic strength of the soil solutions are the key factors affecting adsorption. Copper will adsorb to organic matter, carbonate minerals, clay minerals, or hydrous iron and manganese oxides. Sandy soils with low pH have the greatest potential for leaching¹.

Copper released into the air will most likely take the form of particulate matter as an oxide, sulfate, or carbonate. Copper is removed from the atmosphere by gravitational settling, dry deposition, and washout by rain and clouds¹.

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NE	
Solubility	0.2	1
Log K _{oc}	4.26	1
Vapor Pressure	0	1
Bioconcentration Factor	36 (fish) 51.2 (fish) 23.53 (plant)	2 3 3

TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Earthworm	50	Benchmark	4
Microorganisms	100	Benchmark	4
Fauna	0.04	Screening Level	3
Plants	100	Benchmark	5

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	0.5	MTL	NA	6
Poultry	15	MTL	NA	6
Rabbit	11.61	MTL	NA	6
Mink	12.9	chronic NOAEL	reproductive	7

NA - Not Applicable
 MTL - Mineral Tolerance Level
 NOAEL - No Observed Adverse Effect Level

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁸ freshwater marine	$e^{(0.9422[\ln(\text{hardness}^*)] - 1.464)}$ 2.9	$e^{(0.8545[\ln(\text{hardness}^*)] - 1.465)}$ 2.9
Region III BTAG-Fauna ³ freshwater marine	6.5* 2.9	NE NE
USEPA AWQC ⁹ freshwater marine	$e^{(0.9422[\ln(\text{hardness}^*)] - 1.464)}$ 2.9	$e^{(0.8545[\ln(\text{hardness}^*)] - 1.465)}$ 2.9

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established
 * Hardness based on calcium carbonate concentration (mg/L)
 ** Value based on hardness and/or pH

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ³	34*	NE
Long et al. ¹⁰	34	270

* Screening Level
NE - Not Evaluated

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IRON

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Iron
CAS Number: 7439-89-6

Iron is a silvery white, malleable metal. It is the fourth most abundant (by weight) of the elements that compose the earth's crust and is a major constituent of clay soils¹

Iron in water may be present in varying quantities dependent upon the geology of the area and other chemical components of the water body^{1,2}. The bivalent and trivalent irons are the primary forms of concern in the aquatic environment. The ferrous or bivalent form can persist in waters void of dissolved oxygen and typically originate from groundwater of mines where these are pumped or drained. The ferric or trivalent form is insoluble. Iron can exist in natural organometallic or humic compounds and colloidal forms. Black or brown swamp waters may contain iron concentrations of several milligrams per liter in the presence or absence of dissolved oxygen, but this iron form has little effect on aquatic life¹. The majority of iron entering water bodies is likely to partition into the bottom sediments².

Iron released into soil has relatively low mobility potential. However, iron can be transported through the atmosphere².

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	0.000001	3
Log K _{oc}	4.97	3
Vapor Pressure	0	3
Bioconcentration Factor Freshwater Marine	NA NA	
LC ₅₀ fish (hours)	1,486	3
EC ₅₀ benthos (growth)	3,616	3
zooplankton (growth)	341	3
plants (growth)	2,371	3

NA - Not Available

TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Invertebrates	3,515	NOEC	4
Microorganisms	200	Benchmark	4
Flora	100	Screening Value	5

NE - Not Established

NOEC - No Observed Effects Concentration

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	5	MTL	NA	6
Poultry	50	MTL	NA	6
Rabbit	29	MTL	NA	6

MTL - Mineral Tolerance Level
 NA - Not Applicable

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁷ freshwater marine	NE NE	NE NE
USEPA Region III - Fauna ⁵ freshwater marine	NE NE	320 NE
USEPA AWQC ⁸ freshwater marine	1,000 NE	NE NE

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
Tetra Tech AET ⁹	27,000 (amphipod)	NE

AET - Apparent Effects Threshold

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Pb.tox
3/20/95
j.golden

LEAD

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Lead
CAS Number: 7439-92-1
Synonyms: Lead flake; Lead S 2; PB-S 100

Lead is ubiquitous and is a characteristic trace constituent in rocks, soils, water, plants, animals, and air. Lead is used in the manufacture of storage batteries, gasoline additives, pigments, alloys, and ammunition¹.

Lead compounds are extremely persistent in water and soil. Natural lead compounds are not mobile in surface and groundwater because lead leached from ore is adsorbed by ferric hydroxide. Lead also readily combines with hydroxide, carbonate, and sulfate ions to form insoluble compounds. These compounds precipitate and settle in the bottom sediment. Lead is not volatile, therefore, volatilization is not an important transport process from the aquatic environment².

In water, lead is most soluble and bioavailable under conditions of low pH, low organic content; low concentrations of suspended sediments; and low concentrations of the salts of calcium, cadmium, iron, manganese, and zinc. Lead tends to concentrate in the water surface microlayer (the upper 0.3 mm of water), especially when surface organic matter is present in thin films. However, most lead entering natural waters will precipitate to the sediment bottom as carbonates or hydroxides. Migration and speciation of lead in water is influenced by the water flow rate, increased flow rate results in increased concentrations of particulate and labile lead and a decrease in bound forms. At low stream flow, lead is rapidly removed from the water column by sedimentation¹.

Lead in sediment is mobilized and released when the pH decreases suddenly or ionic composition changes. Methylation of lead occurs in the sediments and is positively correlated to increasing temperature, reduced pH, and high microbial activities³.

Sorption is a dominant effect on the distribution of lead in soil. Lead readily adsorbs to inorganic solids, organic material and hydrous iron and manganese oxides. Because of its affinity for other materials, and its solubility characteristics, the mobility of lead in soil is low². Most lead is retained in soil and not transported via leaching or runoff to surface water⁴.

Lead is not readily taken up by plants. Therefore, its availability to terrestrial life forms also is limited². However, excessive amounts of lead can cause growth inhibition, as well as reduced photosynthesis, mitosis, and water absorption¹. Inorganic and organic lead compound disperse in the atmosphere as particulate matter. Lead is removed from the atmosphere by wet or dry deposition. Photolysis of atmospheric organic lead compounds occurs rapidly². The average residence time of atmospheric lead is seven to thirty days⁴.

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Lead does not appear to significantly bioaccumulated in most fish⁴. Microcosm studies indicate that lead is not biomagnified through the food chain². Lead concentrations tended to decrease markedly with increasing trophic level in both detritus-based and grazing aquatic food chains. However, lead is toxic to all phyla of aquatic biota, though effects are modified significantly by various biological and abiotic conditions¹.

Lead adversely impacts survival, growth, development, and metabolism of most terrestrial species. The organic forms of lead tend to be more toxic to wildlife than the inorganic lead compounds, but the inorganic forms are easily converted into organic lead forms by microorganisms³.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	NA	
Log K _{oc}	4.97	5
Vapor Pressure	0	5
Bioconcentration Factor	17.5 (invertebrates)	6
	726 (fish)	6
	49 (fish)	7

NA - Not Available

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TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Earthworm	500	Benchmark	8
Invertebrates	300	NOEC	8
Microorganisms	900	Benchmark	8
Fauna	0.01	Screening Level	6
Plants	50	Benchmark	9
Flora	0.0125	Screening Level	6

NOEC - No Observed Effects Concentration

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	0.15	MTL	NA	10
American Kestrel	3.85	chronic NOAEL	reproductive	11
Rabbit	1.74	MTL	NA	10
Rat	8	chronic NOAEL	reproductive	12

MTL - Mineral Tolerance Level

NOAEL - No Observed Adverse Effects Level

NA - Not Applicable

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ¹³ freshwater marine	$e^{(1.273[\ln(\text{hardness}^*)]-1.460)}$ 220	$e^{(1.273[\ln(\text{hardness}^*)]-4.705)}$ 8.5
USEPA Region III ⁶ freshwater flora freshwater fauna marine flora marine fauna	NE NE NE NE	NE 1** 5.1** NE
USEPA AWQC ¹⁴ freshwater marine	$e^{(1.273[\ln(\text{hardness}^*)]-1.460)}$ 220	$e^{(1.273[\ln(\text{hardness}^*)]-4.705)}$ 8.5

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established
 * Hardness based on calcium carbonate (mg/L)
 ** Value based on hardness and/or pH

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁶	46.7 (fauna)*	NE
Long et al. ¹⁵	46.7	218

* Screening Level
 NE - Not Established

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SILVER

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Silver
CAS Number: 7440-22-4
Synonyms: ARGENTUM CREDE, COLLARGOL

Silver is a naturally occurring metal. It is acquired as a by-product during the retrieval of copper, lead, zinc, and gold ores. Silver has been used for surgical prostheses, splints, fungicides, and coinage. Silver is currently being used in photographic materials, electrical products, paints, and batteries¹.

Silver in water will exist as a monovalent ion in the forms of sulfate, bicarbonate, or sulfate salts or adsorbed to particulate matter. In freshwater, silver may form complex ions with chlorides, ammonium, and sulfates; form soluble organic compounds; become adsorbed onto humic complexes and suspended particulates; or become incorporated into, or adsorbed onto aquatic biota. Sorption is the primary process causing silver partitioning in sediments. The majority of silver released into water will be sorbed by manganese dioxide which is affected by pH and oxidation-reduction conditions.¹

The transportation of silver released to soils is dependent on the drainage (silver tends to be removed from well-drained soils), oxidation-reduction potential, pH conditions, and the presence of organic matter. Silver tends to form complexes with inorganic chemicals and humic substances in soils. Silver is not likely to biotransform due to its toxicity to soil microorganisms and inhibition of bacterial biodegradative enzymes¹.

The major forms of silver in the atmosphere include metallic silver, silver sulfide, silver sulfate, silver carbonate, and silver halides. Silver released into the atmosphere is likely to travel long distances as fine particles¹

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	No Data	
Solubility	1.000 E-06 mg/L	2
Log K _{oc}	4.97	2
Vapor Pressure	2.947 E-08 @25 C	2
Bioconcentration Factor	34,000 (plants) 150 (fish) 0.5 (fish)	3 3 4

TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Microorganisms	50	Benchmark	5
Plants	2	Benchmark	6
Flora	0.0000098	Screening Level	3

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Poultry	5	MTL	NA	7
Mouse	18.1	subchronic NOAEL	systemic	8

MTL - Mineral Tolerance Level
NOAEL - No Observed Adverse Effects Level

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁹ freshwater marine	$e^{(1.72[\ln(\text{hardness}^*)]-6.52)}$ 2.3	NE NE
USEPA Region III ³ freshwater-flora freshwater-fauna marine-flora marine-fauna	1.9 NE 1.9 NE	NE 0.0001 NE 0.0001
USEPA AWQC ¹⁰ freshwater marine	$e^{(1.72[\ln(\text{hardness}^*)]-6.52)}$ 2.3	NE NE

WQS - Water Quality Standards
AWQC - Ambient Water Quality Criteria
NE - Not Established
* Hardness based on calcium carbonate (mg/L)

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ³	733*	NE
Long et al. ¹¹	1	2.2

NE - Not Established

* Screening Level

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MERCURY

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Mercury

CAS Number: 7439-97-6

Synonyms: hydragyrum; quicksilver; liquid silver; colloidal mercury

Mercury is a silvery, heavy liquid with valences of +1 and +2. Mercury exists as insoluble elemental mercury, organic species, and inorganic species. Solubility depends upon the reduction-oxidation potential, and the pH of the environment¹. Mercury is commonly used for amalgams, catalysts, electrical apparatuses, instruments such as thermometers and barometers, and neutron absorbers in nuclear power plants².

Mercury released to the environment will remain there indefinitely. The form that mercury exists in (organic or inorganic) may change with time. Chemical speciation is probably the most important variable influencing the ecotoxicology of mercury³. Inorganic mercury can be methylated by microorganisms indigenous to soils, freshwater, and salt water. This process is mediated by various microbial populations under both aerobic and anaerobic conditions. Methyl mercury is the most hazardous mercury species due to its high stability, its lipid solubility, and its possession of ionic properties that create a high ability to penetrate membranes in living organisms. Methylmercury in surface waters is rapidly accumulated by aquatic organisms. The top-level predator species usually contain the highest concentrations of methyl mercury³.

Freshwater plants exhibit a wide range of sensitivity to mercury; however, the most sensitive aquatic plant is less sensitive than the most sensitive freshwater animal. Fish tend to be more resistant to mercury than mollusks and crustaceans.

Mercury released into soils or surface water will exist in the mercuric state (Hg^{++}) and mercurous (H^+) states as a number of complex ions with varying water solubilities. Mercuric mercury, present as complexes and chelates with ligands, is probably the most predominant form of mercury present in surface waters⁴.

Volatile forms of mercury present in surface water is expected to evaporate into the air; whereas, solid forms of mercury partition to particulates or are transported in the water column, depending on their solubility. The two most important transformation processes in the fate of mercury in surface waters are biotransformation and bioaccumulation. Photolysis of organomercurials also may occur in surface waters⁴.

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Mercury released into soils may undergo the same chemical and biological transformations as mercury released into surface waters. Mercuric mercury usually forms complexes with chloride and hydroxide ions in soils, the specific compounds form are dependent on pH, salt content, and composition of the soil solution⁴.

Mercury released into the atmosphere will most likely undergo photolysis or organomercurials. Metallic mercury vapor may also be oxidized to other forms in the removal of the compound from the atmosphere by precipitation. Mercury vapor can be transported long distances before wet and dry deposition process return the element to the earth. The atmosphere is the smallest environmental reservoir of mercury⁴.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	5.6E-03	4
Log K _{oc}	2.43	5
Vapor Pressure	0.002	4
Bioconcentration Factor	23,661 (invertebrates)	6
	7,000 (fish)	6
	5,500 (fish)	7
	3,760 (estuarine organisms)	7
	9,000 (open ocean organisms)	7

NA - Not Applicable

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TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Earthworm	0.1	Benchmark	8
Invertebrates	300	NOEC	8
Microorganisms	30	Benchmark	8
Fauna	0.058	Screening Level	6
Plants	0.3	Benchmark	9

NOEC - No Observed Effects Concentration

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	0.01	MTL	NA	10
Poultry	0.1	MTL	NA	10
Rabbit	0.12	MTL	NA	10
Rat	0.32	chronic NOAEL	systemic	11

MTL - Mineral Tolerance Level

NOAEL - No Observed Adverse Effects Level

NA - Not Applicable

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ¹² freshwater marine	2.4 2.1	0.012 0.025
USEPA Region III ⁶ freshwater flora freshwater fauna marine flora marine fauna	NE NE NE NE	NE 0.012 NE 0.025
USEPA AWQC ¹³ freshwater marine	2.4 2.1	0.012 0.025

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁶	0.15 (fauna)*	NE
Long et al. ¹⁴	0.15	0.71

NE - Not Established
 * Screening Level

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MANGANESE

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Manganese

CAS Number: 7439-96-5

Synonyms: COLLOIDAL MANGANESE, MAGNACAT, MANGAN

Manganese is a brittle silvery metal which usually occurs as a complex with other metals such as iron. Manganese and its compounds are used in the making of steel alloys, dry-cell batteries, electrical coils, and other metallic fabrication applications. Other uses of manganese include as an oxidizing agent and as a food additive^(1,2).

Manganese can occur in soil, water, or air. Because it is an element, manganese cannot be degraded by environmental processes. However, it may transform from one manganese compound to another. While manganese can be transported in dusts or in water, the main source of routine manganese exposure is through ingestion of food. Vegetables, the germinal portions of grains, fruits, nuts, tea, and some spices are rich in manganese⁽¹⁾.

In the soil, the concentrations and chemical form in which manganese can occur is affected by pH, cation exchange capacity, drainage, and other factors. Lower pH and reducing conditions tend to favor solubility and hence, the mobility of manganese. Manganese often occurs at higher concentrations in the bottom of stratified lakes as a result of its release from bottom sediments as manganous ion under reducing conditions⁽³⁾.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	NA	
Log K _{oc}	NA	
Vapor Pressure	NA	
Bioconcentration Factor	35 (fish) 300 (plant)	4

NA - Not Available

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TERRESTRIAL FATE

Soil Flora and Fauna

Species	Concentration (mg/kg)	Endpoint	Reference
Plant	500	Benchmark	5
Earthworm	330	Screening Level	4
Invertebrate	330	Screening Level	4
Microorganisms and Microbial Processes	100	Benchmark	6

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	10	subchronic NOEL	not reported	13
Poultry	2,000	chronic	MTL	7
Rabbit	400	chronic	MTL	7
Rat	8.8	chronic NOAEL	reproductive	8

MTL - Mineral Tolerance Level
NOEL - No Observed Effect Level
NOAEL - No Observed Adverse Effect Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ⁽⁹⁾	NE	NE
USEPA Region III ⁽⁴⁾ Marine Flora Marine Fauna	NE NE	200 10
USEPA AWQC ⁽¹⁰⁾	NE	NE

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁽⁴⁾	NE	NE
Long, et al. ⁽¹¹⁾	NE	NE
Tetra Tech AET ⁽¹²⁾	700 (amphipod) 660 (oyster) 300 (benthic) 530 (microtox)	NE NE NE NE

NE - Not Established
 AET - Apparent Effects Threshold

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NICKEL

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Nickel
CAS Number: 7440-02-0
Synonyms: NP 2; HCA 1; Raney alloy; Raney Nickel

Nickel is a naturally occurring silvery metal that is found in the earth's crust. Nickel and its compounds are found in all parts of the environment, including plants and animals. Primary nickel is recovered from mined ore and nickel matte, and secondary nickel is recovered from scrap metal¹.

Nickel released into water will exist in both soluble and insoluble forms depending on the chemical and physical properties of the water. Nickel has not been shown to volatilize from the water surface. Nickel is significantly bioaccumulated in some, but not all aquatic species¹. Nickel adversely influences cell membranes with increasing water hardness².

Nickel is extremely persistent in soil; however, it still has the potential to leach through soil into groundwater. The average residence time of nickel in soil is estimated to be 2,400 to 3,500 years. The sorption of nickel into soils has found to correlate with suspension pH, total iron, and surface area. Organic complexing agents in soil tend to restrict the movement and availability of nickel in soil by forming organo-nickel complexes. Nickel is not expected to volatilize from soils¹. Nickel is not essential to plants in some instances it produces toxic effects².

Nickel released into the atmosphere will exist primarily in aerosol form. Airborne nickel will remain in the atmosphere for varying periods of time depending upon factors such as concentration, density and particle size, and precipitation. The average residence time of nickel in the atmosphere is seven days, with typical residence time ranging from one to twenty-one days. The predominant nickel species in air tend to be nickel oxide, nickel sulfate, complex oxides of nickel and other metals, and to a lesser extent, metallic nickel, and nickel subsulfide¹.

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FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	Insoluble	1
Log K _{oc}	4.97	3
Vapor Pressure	0.0	3
Bioconcentration Factor	40,000 (plant)	4
	100 (fish)	4
	47 (fish)	5

NA - Not Available

TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Earthworm	200	Benchmark	6
Microorganisms	90	Benchmark	6
Plants	30	Benchmark	7
Flora	2.5	Screening Level	4

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Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Effect	Reference
Cattle	0.25	MTL	NA	8
Poultry	15	MTL	NA	8
Rabbit	2.9	MTL	NA	8
Dog	25	chronic NOAEL	growth	9
Rat	5	chronic NOAEL	growth	9

MTL - Mineral Tolerance Level
 NOAEL - No Observed Adverse Effects Level
 NA - Not Applicable

REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ¹⁰ freshwater marine	$e^{(0.8460[\ln(\text{hardness}^*)+3.3612]}$ 75	$e^{(0.8460[\ln(\text{hardness}^*)+1.1645]}$ 8.3
USEPA Region III ⁴ freshwater flora freshwater fauna marine flora marine fauna	NE NE NE NE	NE 14.77** NE 8.3**
USEPA AWQC ¹¹ freshwater marine	$e^{(0.8460[\ln(\text{hardness}^*)+3.3612]}$ 75	$e^{(0.8460[\ln(\text{hardness}^*)+1.1645]}$ 8.3

WQS - Water Quality Standards
 AWQC - Ambient Water Quality Criteria
 NE - Not Established
 * Hardness based on calcium carbonate (mg/L)
 ** Value based on hardness and/or pH

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Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁴	20.9 (fauna)*	NE
Long et al. ¹²	20.9	51.6

NE - Not Established

* Screening Level

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ZINC

Ecological Toxicological Profile

INTRODUCTION

Chemical Name: Zinc
CAS Number: 7440-66-6
Synonyms: Blue Powder; JASAD; PASCO; LS 2

Zinc is bluish-white metal that dissolves readily in strong acids. Zinc compounds are found naturally in air, soil, and water, and are present in all foods. However, zinc is not found in nature in the free state. Zinc is commonly mined by underground and open pit mining. Zinc is commonly used as a protective coating for other metals. Zinc also is used in alloys such as bronze and brass, for electrical apparatus in many common goods, and in organic chemical extractions and reductions. Zinc chloride is used by the military to create smoke bombs. In pharmaceuticals, salts of zinc are used as solubilizing agents in many drugs. In addition, zinc is used with copper to make U.S. pennies¹.

Zinc released into surface water does not volatilize, but primarily settles into the bottom sediments. Zinc can be present in water as either suspended or dissolved compounds. Dissolved zinc may occur as the free (hydrated) zinc ion or as dissolved complexes and compounds with varying degrees of stability. Suspended (undissolved) zinc may be dissolved following minor changes in the water chemistry or may be sorbed to suspended matter. The sorption of zinc is affected by the nature of the zinc, the concentrations of the zinc, the pH, and the salinity of the water. Zinc tends to be more absorbed at higher pH concentration (>7). Desorption of zinc from sediments occurs as salinity increases¹.

Sorption of zinc is the dominant fate of zinc in the aquatic environment. Zinc partitions to sediments or suspended solids in surface water via sorption onto hydrous iron and manganese oxides, clay minerals, and organic matter. Transport of zinc in the aquatic environment is dependent upon the composition of suspended and bed sediments, dissolved and particulate iron and manganese concentrations, pH, salinity, concentrations of complexing ligands, and the concentration of zinc². In freshwater, zinc is the most soluble at low pH and low alkalinity concentrations. In natural waters, two reactions can occur: the competition for complexation sites between metal ions, and the competition between different ligands for the same metal ion¹.

Zinc is actively accumulated in aquatic systems. However, biota appear to represent a minor sink for zinc compared to the sediments¹. Zinc bioavailability and toxicity to aquatic organisms are highest under conditions of low pH, low alkalinity, low dissolved oxygen, and elevated temperatures. Soluble species of zinc are the most bioavailable and most toxic².

Zinc released onto soil is likely to be strongly absorbed. The mobility of zinc in soil is dependent

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upon the solubility of the speciated forms of the compound and on the soil properties (sorption potential, pH, salinity; anaerobic). Little land-disposed zinc is in a soluble form; therefore, mobility is limited by a slow dissolution. Consequently, zinc is not likely to migrate into groundwater¹.

Zinc released to the air is commonly found as a stable species such as zinc oxide. Chemical interaction of zinc compounds in the atmosphere may result in a change in the speciation of the compound. Atmospheric interactions are greatest for particles with smaller diameters. Zinc concentrations in the environment are relatively low. Volatilization does not appear to be an important process for zinc¹.

FATE IN THE ENVIRONMENT

Parameter	Value	Reference
Log K _{ow}	NA	
Solubility	Insoluble	1
Log K _{oc}	4.97	3
Vapor Pressure	0.0	3
Bioconcentration Factor	50,000 (plants)	4
	100,000 (invertebrates)	4
	2,000 (fish)	4
	47 (fish)	5

NA - Not Available

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TERRESTRIAL EFFECTS

Soil Flora and Fauna

Species	Effect Concentration (mg/kg)	Endpoint	Reference
Earthworm	200	Benchmark	6
Invertebrates	800	NOEC	6
Microorganisms	100	Benchmark	6
Plants	50	Benchmark	7
Flora	4.8	Screening Level	4

NOEC - No Observed Effects Level

Vertebrates

Test Species	Effect Dose (mg/kg/day)	Endpoint	Reference
Cattle	2.5	MTL	8
Poultry	50	MTL	8
Rabbit	29	MTL	8
Dog	1	subchronic (safe diet)	9

MTL - Mineral Tolerance Level

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REGULATORY LEVELS AND CRITERIA

Aquatic Life - Surface Water

State or Federal Standard/Criteria	Acute (ug/L)	Chronic (ug/L)
Virginia WQS ¹⁰ freshwater marine	$e^{(0.8473[\ln(\text{hardness}^*)]+0.8604)}$ 95	$e^{(0.8473[\ln(\text{hardness}^*)]+0.7614)}$ 86
USEPA Region III ⁴ freshwater flora freshwater fauna marine flora marine fauna	NE NE NE NE	110** 110** 86 86
USEPA AWQC ¹¹ freshwater marine	$e^{(0.8473[\ln(\text{hardness}^*)]+0.8604)}$ 95	$e^{(0.8473[\ln(\text{hardness}^*)]+0.7614)}$ 86

WQS - Water Quality Standards

AWQC - Ambient Water Quality Criteria

NE - Not Established

* Hardness is based on calcium carbonate (mg/L)

** Value is based on hardness and/or pH

Aquatic Life - Sediment

Sediment Screening Values	ER-L (mg/kg)	ER-M (mg/kg)
USEPA Region III ⁴	150 (fauna)*	NE
Long et al. ¹²	150	410

NE - Not Established

* Screening Value

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APPENDIX D
IR-RELATED SURFACE WATER AND SEDIMENT DATA FOR
SITES 7 AND 12

APPENDIX D.1
REMEDIAL INVESTIGATION DATA

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS
 DETECTED IN SURFACE WATER SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 12 – EXCHANGE LAUNDRY WASTE DISPOSAL AREA
 NAVAL AMPHIBIOUS BASE – LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE MATRIX UNITS	12-SW-101 Water ug/L	12-SW-102 Water ug/L	12-SW-103 Water ug/L	12-SW-104 Water ug/L
VOLATILE ORGANIC COMPOUNDS (VOCs):				
Acetone	ND	50 B	31 B	20 B
1,2-Dichloroethene (total)	ND	ND	11	ND
2-Butanone	ND	36	ND	ND
Trichloroethene	ND	ND	3 J	ND
Tetrachloroethene	ND	ND	3 J	ND
Toluene	4 J	58	2 J	ND
TOTAL VOCs:	4 J	144	50 J	20
TOTAL TICs:	ND	7 J	ND	ND

NOTES:

- ND indicates compound was not detected
- ug/L indicates micrograms per liter
- J indicates an estimated value
- B indicates compound detected in lab blank
- TICs indicates tentatively identified compounds
- Equipment rinsate, field blank, and trip blank shared with Background Well samples
- Matrix spike/matrix spike duplicate (MS/MSD) shared with Site 10

**SUMMARY OF TAL METALS
 DETECTED IN SURFACE WATER SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 12 – EXCHANGE LAUNDRY WASTE DISPOSAL AREA
 NAVAL AMPHIBIOUS BASE – LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE MATRIX UNITS	12-SW-101 Water ug/L	12-SW-102 Water ug/L	12-SW-103 Water ug/L	12-SW-104 Water ug/L
METALS:				
Aluminum	4,320 J	81,800 J	ND	ND
Arsenic	2.8 J	23.4 J	ND	2.2 J
Barium	50.4 J	669 J	25.6 J	25.3 J
Beryllium	ND	3.1 J	ND	ND
Cadmium	ND	7.5 J	ND	ND
Calcium	15,700 J	84,500 J	16,400 J	15,600 J
Chromium	ND	148 J	ND	ND
Cobalt	ND	64.0 J	ND	ND
Copper	21.5 J	305 J	10.1 J	4.7 J
Iron	10,300 J	94,800 J	3,930 J	2,900 J
Lead	25.2 J	312 J	2.0 J	3.0 J
Magnesium	5,300 J	26,600 J	5,150 J	6,160 J
Manganese	547 J	1,240 J	507 J	529 J
Mercury	ND	0.79 J	ND	ND
Nickel	ND	143 J	ND	ND
Potassium	3,880 J	21,300 J	3,600 J	2,800 J
Sodium	13,700 J	26,200 J	13,300 J	13,400 J
Vanadium	11.8 J	162 J	ND	ND
Zinc	204 J	3,800 J	153 J	39.1 J

NOTES:

ND indicates compound was not detected

ug/L indicates micrograms per liter

J indicates an estimated value

Equipment Rinsate and Field Blank shared with Background Well samples

Matrix spike/matrix spike duplicate (MS/MSD) shared with Site 10

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE DEPTH SAMPLE MATRIX UNITS	12-SED-102-00 0 - 6 inches Sediment ug/kg	12-SED-102-06 6 - 12 inches Sediment ug/kg	12-SED-103-00 0 - 6 inches Sediment ug/kg	12-SED-103-06 6 - 12 inches Sediment ug/kg
VOLATILE ORGANIC COMPOUNDS (VOCs):				
Acetone	30 J	82 J	ND	8 J
1,2-Dichloroethene (total)	14 J	ND	2 J	ND
Trichloroethene	19 J	ND	3 J	ND
Tetrachloroethene	15 J	ND	6 J	ND
Toluene	ND	ND	ND	5 J
Xylene (total)	ND	ND	ND	4 J
TOTAL VOCs:	78 J	82 J	11 J	17 J
TOTAL TICs:	131 J	ND	100 J	228 J

NOTES:

ND indicates compound was not detected
 ug/kg indicates micrograms per kilogram

J indicates an estimated value

TICs indicates tentatively identified compounds

Equipment rinsate, trip blank, matrix spike/matrix spike duplicate, and duplicate sample shared with Site 13

**SUMMARY OF TAL METALS
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 12 – EXCHANGE LAUNDRY WASTE DISPOSAL AREA
 NAVAL AMPHIBIOUS BASE – LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE DEPTH SAMPLE MATRIX UNITS	12-SED-102-00 0 – 6 inches Sediment mg/kg	12-SED-102-06 6 – 12 inches Sediment mg/kg	12-SED-103-00 0 – 6 inches Sediment mg/kg	12-SED-103-06 6 – 12 inches Sediment mg/kg
TAL METALS:				
Aluminum	11,700 J	4,180 J	2,690 J	1,130 J
Arsenic	5.6 J	3.8 J	2.1 J	0.64 J
Barium	72.0 J	30.1 J	12.5 J	3.4 J
Cadmium	ND	1.2 J	ND	ND
Calcium	2,970 J	793 J	217 J	72.5 J
Chromium	20.6 J	8.4 J	3.0 J	1.3 J
Cobalt	4.8 J	1.5 J	1.3 J	ND
Copper	36.0 J	18.0 J	7.5 J	2.3 J
Iron	12,900	4,940 J	2,560 J	1,220 J
Lead	66.3	38.3 J	110 J	8.7 J
Magnesium	1,990 J	541 J	274 J	83.6 J
Manganese	144 J	35.2 J	11.7 J	3.7 J
Mercury	ND	ND	0.28 J	ND
Nickel	13.8 J	5.1 J	2.9 J	ND
Potassium	1,350 J	340 J	115 J	45.8 J
Sodium	346 J	ND	ND	ND
Vanadium	26.9 J	11.9 J	8.1 J	1.9 J
Zinc	383 J	233 J	30.1 J	6.1 J

NOTES:

ND indicates compound was not detected

mg/kg indicates milligrams per kilogram

J indicates an estimated value

Equipment rinsate, matrix spike/matrix spike duplicate, and duplicate sample shared with Site 13

**SUMMARY OF TOTAL ORGANIC CARBON
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 12 – EXCHANGE LAUNDRY WASTE DISPOSAL AREA
 NAVAL AMPHIBIOUS BASE – LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE DEPTH SAMPLE MATRIX UNITS	12-SED-102-00 0 – 6 inches Sediment mg/kg	12-SED-102-06 6 – 12 inches Sediment mg/kg	12-SED-103-00 0 – 6 inches Sediment mg/kg	12-SED-103-06 6 – 12 inches Sediment mg/kg
TOTAL ORGANIC CARBON:	77,000	52,500	5,940	488

NOTES:

mg/kg indicates milligrams per kilogram

Equipment rinsate, matrix spike/matrix spike duplicate, and duplicate sample shared with Site 13

SUMMARY OF VOLATILE ORGANIC COMPOUNDS
 DETECTED IN SURFACE WATER SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 7 - AMPHIBIOUS BASE LANDFILL
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JULY 1, 1993

SAMPLE LOCATION/NUMBER	07-SW-101	07-SW-102	07-SW-103	07-SW-107 ⁽¹⁾ (Duplicate 07-SW-103)	07-SW-104	07-SW-105	07-SW-106	07-TB-P2-104
SAMPLE MATRIX UNITS	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L
VOLATILE ORGANIC COMPOUNDS (VOCs):								
Acetone	ND	17	15	17	ND	31	ND	18
TOTAL VOCs:	ND	17	15	17	ND	31	ND	18
TOTAL TICs:	ND	ND	ND	ND	ND	ND	ND	ND

NOTES:

- ND indicates compound was not detected
- ug/L indicates micrograms per liter
- TICs indicates tentatively identified compounds
- (1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.
- TB indicates trip blank

SUMMARY OF TAL TOTAL METALS
DETECTED IN SURFACE WATER SAMPLES
AND ASSOCIATED QUALITY CONTROL SAMPLE
SITE 7 - AMPHIBIOUS BASE LANDFILL
NAVAL AMPHIBIOUS BASE - LITTLE CREEK
VIRGINIA BEACH, VIRGINIA
JULY 1, 1993

SAMPLE LOCATION/NUMBER	07-SW-101	07-SW-102	07-SW-103	07-SW-107 ⁽¹⁾ (Duplicate 07-SW-03)	07-SW-104	07-SW-105	07-SW-106
SAMPLE MATRIX UNITS	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L
TAL TOTAL METALS:							
Aluminum	417 J	1,690 J	388 J	1,080 J	735 J	1,210 J	ND
Arsenic	2.4 B	10.3	ND	ND	9 B	7 B	9.9 B
Barium	17.5 B	36.8 B	28.3 B	34.5 B	24.1 B	34.9 B	20.2 B
Calcium	125,000	86,500	159,000	182,000	51,100	80,500	22,300
Cobalt	ND	4.7 B	3.4 B	3.4 B	5.6 B	5.1 B	ND
Copper	ND	14.1 B	5.3 B	6.3 B	8.5 B	6.8 B	ND
Iron	1,820 J	6,890 J	1,010 J	1,600 J	5,210 J	5,510 J	3,020 J
Lead	ND	5.1 J	ND	ND	50 J	3.2 J	ND
Magnesium	298,000	190,000	403,000	457,000	37,400	146,000	28,000
Manganese	156	306	83.9	91.6	322	193	334
Potassium	109,000 J	72,800 J	155,000 J	181,000 J	15,900 J	54,100 J	8,800 J
Sodium	2,530,000	1,630,000	3,710,000	4,250,000	235,000	1,210,000	184,000
Thallium	R	R	R	R	R	R	R
Zinc	ND	55.3	ND	ND	30.8	70.5	ND

NOTES:

ND indicates compound was not detected

ug/L indicates micrograms per liter

B indicates compound detected in lab blank

J indicates an estimated value.

R indicates data rejected and unusable.

(1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

SUMMARY OF ANIONS
DETECTED IN SURFACE WATER SAMPLES
AND ASSOCIATED QUALITY CONTROL SAMPLES
SITE 7 - AMPHIBIOUS BASE LANDFILL
NAVAL AMPHIBIOUS BASE - LITTLE CREEK
VIRGINIA BEACH, VIRGINIA
JULY 1, 1993

SAMPLE LOCATION/NUMBER	07-SW-101	07-SW-102	07-SW-103	07-SW-107 ⁽¹⁾ (Duplicate 07-SW-103)	07-SW-104	07-SW-105	07-SW-106
SAMPLE MATRIX UNITS	Water mg/L	Water mg/L	Water mg/L	Water mg/L	Water mg/L	Water mg/L	Water mg/L
ANIONS:							
Alkalinity	113	117	85.5	101	134	131	78.5
Bicarbonate Alkalinity	113	117	85.5	101	134	131	78.5
Chloride	21,000	7,820	19,700	10,000	1,050	6,250	700
Sulfate	1,010	585	1,380	1,400	177	695	118

NOTES:

ND indicates compound was not detected

mg/L indicates milligrams per liter

(1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

SUMMARY OF VOLATILE ORGANIC COMPOUNDS
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 7 - AMPHIBIOUS BASE LANDFILL
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JULY 1, 1983

SAMPLE LOCATION/NUMBER	07-SED-101 ⁽¹⁾	07-SED-102	07-SED-103	07-SED-107 (Duplicate 06-SED-103)	07-SED-104
SAMPLE MATRIX UNITS	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg
VOLATILE ORGANIC COMPOUNDS (VOCs):					
Methylene Chloride	ND	7 J	ND	ND	ND
Acetone	ND	370 J	ND	ND	ND
Carbon Disulfide	ND	4 J	ND	ND	ND
2-Butanone	ND	65	ND	19	12 J
Toluene	ND	5 J	ND	ND	1 J
TOTAL VOCs:	ND	451 J	ND	19	13 J
TOTAL TICs:	ND	33 J	ND	ND	ND

SAMPLE LOCATION/NUMBER	07-SED-105	07-SED-106	07-SED-RB101	07-TB-P2-104
SAMPLE MATRIX UNITS	Soil ug/kg	Soil ug/kg	Water ug/L	Water ug/L
VOLATILE ORGANIC COMPOUNDS (VOCs):				
Methylene Chloride	ND	ND	ND	ND
Acetone	ND	ND	ND	18
Carbon Disulfide	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND
Toluene	ND	ND	ND	ND
TOTAL VOCs:	ND	ND	ND	18
TOTAL TICs:	ND	ND	ND	ND

NOTES:

- ND indicates compound was not detected
- ug/kg indicates micrograms per kilogram
- ug/L indicates micrograms per liter
- J indicates an estimated value.
- TICs indicates tentatively identified compounds.
- (1) indicates a matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.
- RB indicates equipment rinse blank
- TB indicates trip blank.

SUMMARY OF TAL METALS AND CYANIDE
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 7 - AMPHIBIOUS BASE LANDFILL
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JULY 1, 1993

SAMPLE LOCATION/NUMBER	07-SED-101 ⁽¹⁾	07-SED-102	07-SED-103	07-SED-107 (Duplicate 07-SED-103)	07-SED-104	07-SED-105	07-SED-106	07-SED-RB101
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Water ug/L
TAL METALS AND CYANIDE:								
Aluminum	3,290	6,520	2,670	2,060	638	1,360	221	ND
Arsenic	3.9	8.6	2.7	1.8 B	2.9	1.8 B	1.2 B	ND
Barium	10.0 B	23.8 B	8.4 B	7.0 B	4.3 B	6.3 B	1.6 B	ND
Beryllium	0.28 B	ND	ND	ND	0.42 B	ND	ND	ND
Cadmium	2.4	3.1	ND	ND	2.3	ND	ND	ND
Calcium	479 B	1,120 B	1,500	385 B	214 B	394 B	ND	ND
Chromium	8.4 J	10.1 J	5.7 J	7.4 J	5.6 J	3.9 J	1.5 J	5.4 B
Cobalt	2.5 J	3.4 J	ND	0.94 J	ND	0.95 J	ND	ND
Copper	12.3	42.9	11.7	10.1	7.3	17.5	0.89 B	4.9 B
Iron	7,860	14,200	4,850	3,760	10,100	4,030	1,060	ND
Lead	9.1 J	31.1	9.3 J	7.8 J	4.7 J	12.6 J	1.7 J	ND
Magnesium	1,240 B	2,680	866 B	867 B	261 B	504 B	78.7 B	ND
Manganese	30.6	67.2	21.4	17.1	8.9	16.6	2.7 B	2.0 B
Nickel	4.7 B	7.6 B	3.6 B	4.6 B	3.3 B	4.0 B	ND	ND
Potassium	674 B	1,350 B	487 B	465 B	140 B	274 B	45.3 B	ND
Silver	0.75 J	ND	ND	ND	ND	ND	ND	ND
Sodium	2,340	5,160	1,340	2,700	399 B	628 B	299 B	ND
Vanadium	9.0 B	23.2	5.8 B	5.4 B	10.2	9.1 B	ND	ND
Zinc	36.8	213	41.2	35.5	29.5	37.2	ND	ND
Cyanide	ND	ND	ND	ND	ND	ND	ND	ND

NOTES:

- ND indicates compound was not detected
- mg/kg indicates milligrams per kilogram
- ug/L indicates micrograms per liter
- B indicates compound detected in lab blank
- J indicates an estimated value.
- (1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.
- RB indicates equipment rinseate blank

**SUMMARY OF ANIONS
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 7 - AMPHIBIOUS BASE LANDFILL
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JULY 1, 1993**

SAMPLE LOCATION/NUMBER	07-SED-101 ⁽¹⁾	07-SED-102	07-SED-103	07-SED-107 (Duplicate 07-SED-103)	07-SED-104
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg
ANIONS:					
Alkalinity	ND	ND	102	631	ND
Bicarbonate Alkalinity	ND	ND	102	631	ND
Chloride	3,050	7,530	1,870	3,810	634
Sulfate	722	1,160	893	810	140

SAMPLE LOCATION/NUMBER	07-SED-105	07-SED-106	07-SED-RB101
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Water mg/L
ANIONS:			
Alkalinity	ND	ND	ND
Bicarbonate Alkalinity	ND	ND	ND
Chloride	1,060	552	2.8
Sulfate	177	ND	ND

NOTES:

ND indicates compound was not detected

mg/kg indicates milligrams per kilogram

mg/L indicates milligrams per liter

(1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

RB indicates equipment rinse blank

**SUMMARY OF TOTAL ORGANIC CARBON
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 7 - AMPHIBIOUS BASE LANDFILL
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JULY 1, 1993**

SAMPLE LOCATION/NUMBER	07-SED-101 ⁽¹⁾	07-SED-102	07-SED-103	07-SED-107 (Duplicate 07-SED-103)	07-SED-104
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg
TOTAL ORGANIC CARBON:	5,140	21,400	7,100	6,020	983

SAMPLE LOCATION/NUMBER	07-SED-105	07-SED-106	07-SED-RB101
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Water mg/L
TOTAL ORGANIC CARBON:	906	373	NA

NOTES:

ND indicates compound was not detected

NA indicates sample was not analyzed

mg/kg indicates milligrams per kilogram

mg/L indicates milligrams per liter

(1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

RB indicates equipment rinsate blank

**SUMMARY OF TOTAL ORGANIC CARBON
 DETECTED IN SEDIMENT SAMPLES
 AND ASSOCIATED QUALITY CONTROL SAMPLES
 SITE 7 – AMPHIBIOUS BASE LANDFILL
 NAVAL AMPHIBIOUS BASE – LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 JULY 1, 1993**

SAMPLE LOCATION/NUMBER	07-SED-101 ⁽¹⁾	07-SED-102	07-SED-103	07-SED-107 (Duplicate 07-SED-103)	07-SED-104
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg
TOTAL ORGANIC CARBON:	5,140	21,400	7,100	6,020	983

SAMPLE LOCATION/NUMBER	07-SED-105	07-SED-106	07-SED-RB101
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Water mg/L
TOTAL ORGANIC CARBON:	906	373	NA

NOTES:

ND indicates compound was not detected

NA indicates sample was not analyzed

mg/kg indicates milligrams per kilogram

mg/L indicates milligrams per liter

(1) indicates matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

RB indicates equipment rinsate blank

APPENDIX D.2
ROUND 1 VERIFICATION STEP DATA

ANALYTICAL RESULTS--SITE 7, AMPHIBIOUS BASE LANDFILL

	GROUNDWATER (ppb)									SURFACE WATER (ppb)					SEDIMENT (ppm)				
	LC7 GM1	LC7 GM2	LC7 GM3	LC7 GM4	LC7 GM5	LC7 GM6	LC7 GM7	LC7 GM8	LC7 GM9	LC7 SM1	LC7 SM2	LC7 SM3	LC7 SM4	LC7 SM5	LC7 SED1	LC7 SED2	LC7 SED3	LC7 SED4	LC7 SED5
Antimony	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	30	<20	<20	<2	<2	<2	<2	<2
Arsenic	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	24	7	<5	<8	19.6	4.8	30.7	34	15.6
Beryllium	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<0.3	<0.3	0.6	0.7	0.3
Cadmium	<4	<4	<4	<4	<4	<4	<4	<4	7	<4	<4	<4	<4	<4	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium (Total)	<5	<5	<5	<5	<5	<5	<5	<5	9	<5	<5	9	6	5	12.2	5	14.4	19.9	8.2
Chromium (Hex.)	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	--	--	--	--	--
Copper	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	50	50	<30	<30	5.2	11.6	33.9	11.6	11.5
Lead	<3	<3	<3	<3	<3	<3	<3	<3	<3	<2	4	31*	26*	22*	4.3	12.7	39.3	20.7	16.4
Mercury	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.15	<0.15	<0.15	<0.15	<0.15
Nickel	<90	<90	<90	<90	<90	<90	<90	<90	<90	<90	<90	200*	<90	<90	6.3	5	19.9	19	10
Selenium	<4	<4	<4	<4	<4	<4	23*	21*	27*	<4	<4	40*	95*	53*	<0.8	<0.8	<0.8	<0.8	<0.8
Silver	<1	<1	1	1	3	4	10	9	14	<1	2	20	31	31	<5	<5	<5	<5	<5
Thallium	<50	<50	<50	<50	<50	<50	83	<50	<50	<50	<50	130	128	111	0.37	0.64	0.64	1.4	1.6
Zinc	10	20	90	410	30	40	50	80	260	<20	30	110	60	30	12.4	28.2	135	53	56
EDS	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	NR	BMDL	BMDL
Oil and Grease	6,000	8,000	6,000	8,000	3,000	10,000	35,000	25,000	47,000	20,000	8,000	5,000	9,000	9,000	297	567	2,206	536	1,306
VOC ^a																			
Methylene Chloride	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	23	73	21	96	43
Acetone	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	18	16	27	16	BMDL
Carbon Disulfide	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	2.2	2.2	BMDL
Chloroform	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	4.6	13	BMDL	3.2	1.9
Bromodichloromethane	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	1.1	2.7	BMDL	BMDL	BMDL
Toluene	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	2.6	BMDL

	GROUNDWATER (ppb)									SURFACE WATER (ppb)					SEDIMENT (ppm)				
	LC7 GW1	LC7 GW2	LC7 GW3	LC7 GW4	LC7 GW5	LC7 GW6	LC7 GW7	LC7 GW8	LC7 GW9	LC7 SW1	LC7 SW2	LC7 SW3	LC7 SW4	LC7 SW5	LC7 SED1	LC7 SED2	LC7 SED3	LC7 SED4	LC7 SED5
Base/Neutrals^a																			
Total Saturated Hydrocarbons	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	330	250	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	45	130
Acenaphthene	BMDL	BMDL	BMDL	16	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL
Bis (2-ethylhexyl) phthalate	BMDL	BMDL	BMDL	19	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL
Pesticides + PCBs^(a)																			
Chlordane	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	0.018	BMDL	BMDL	0.012
DOD	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	0.0028	BMDL	BMDL	0.0041
DDE	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	0.0024	BMDL	BMDL	0.0029
PCB 1260	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	0.033	BMDL	BMDL	BMDL
Acids^a																			
Phenols	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	1.8	2.0	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL

^a Compounds in this group that are not shown in this table were below detection limits.

BMDL--All compounds in this group were below method detection limits. Values for detection limits are given in Table 13.

<--Below detection limit shown.

NR--Value not reported, insufficient sample volume.

(--)--Unable to report useable data due to matrix interference.

*--Concentration exceeds a regulatory standard, guideline, or criterion (Table 11).

ANALYTICAL RESULTS--SITE 12, EXCHANGE LAUNDRY WASTE DISPOSAL AREA

	<i>SUB-SURFACE WATER</i> GROUNDWATER (ppb)						SEDIMENT (ppb)					
	LC12 SH1	LC12 SH2	LC12 SH3	LC12 SH4	LC12 SH5	LC12 SH6	LC12 SED1	LC12 SED2	LC12 SED3	LC12 SED4	LC12 SED5	LC12 SED6
VOC ^a												
Trichloroethene	BMDL	BMDL	BMDL	7.3*	4.1*	3.1*	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL
Tetrachloroethene	BMDL	BMDL	BMDL	17*	6.7*	5.3*	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL
Trans-1,2 Dichloroethene	BMDL	BMDL	BMDL	BMDL	26	19	BMDL	BMDL	BMDL	BMDL	BMDL	2.5
Vinyl Chloride	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	2.9
Toluene	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	9.1
Methylene Chloride	BMDL	BMDL	BMDL	19	BMDL	BMDL	280	22	11	7.9	37	5.5
Acetone	BMDL	BMDL	BMDL	BMDL	BMDL	BMDL	230	BMDL	BMDL	18	BMDL	BMDL
Chloroform	2.1	BMDL	BMDL	BMDL	1.6	BMDL	BMDL	4.6	BMDL	BMDL	2.4	2.7
Trichloro Trifluoroethane	NR	NR	NR	NR	NR	NR	71	NR	NR	NR	NR	NR
3-Methyl Pentane	NR	NR	NR	NR	NR	NR	17	NR	NR	NR	NR	NR

^aCompounds in this group that are not shown in this table were below detection limits.

BMDL--All compounds in this group were below method detection limits. Values for detection limits are given in Table 13.

<--Below detection limit shown.

NR--Value not reported routinely, reported only if observed.

*--Concentration exceeds a regulatory standard, guideline, or criterion (Table 11).

WDR185/032

APPENDIX D.3
INTERIM REMEDIAL INVESTIGATION DATA

SUMMARY OF 1986 AND 1990 SURFACE WATER DATA
ANALYTICAL RESULTS
AMPHIBIOUS BASK LANDFILL (SITE 7)
LITTLE CREEK - RI (CONTRACT #: W62470-90-D-7646)

Sample No/ Date	7-SW1		7-SW2		7-SW3			7-SW4		7-SW5		7-SW6		
	1986	1990	1986	1990	1986	1990	1990DUP	1986	1990	1986	1990	1986	1990	1990DUP

UNITS (UG/L)

VOLATILE FRACTION

	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Methylene chloride	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Acetone	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	10B	BMDL	ND	NA	NA	NA
Carbon disulfide	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Chloroform	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Bromodichloromethane	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Toluene	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA

UNITS (MG/L)

TOTAL PETROLEUM HYDROCARBONS	NA	1.0U	NA	1.0U	NA	1.0U	NA	NA	1.0U	NA	1.0U	NA	NA	NA
------------------------------	----	------	----	------	----	------	----	----	------	----	------	----	----	----

UNITS (UG/L)

ETHYLENE DIBROMIDE	NA	0.018U	NA	0.018U	NA	0.018U	NA	NA	0.018U	NA	0.018U	NA	NA	NA
--------------------	----	--------	----	--------	----	--------	----	----	--------	----	--------	----	----	----

UNITS (UG/L)

BASE/NEUTRAL/ACID FRACTIONS

	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Acenaphthene	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Bis(1-ethylhexyl)phthalate	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Phenols	1.8	ND	2	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA

UNITS (MG/L)

TOC	NA	4.44	NA	3.99	NA	3.9	NA	NA	2.44	NA	2.9	NA	NA	NA
-----	----	------	----	------	----	-----	----	----	------	----	-----	----	----	----

UNITS (UG/L)

TOX	NA	111	NA	53.3	NA	89.9	NA	NA	80	NA	59.1	NA	NA	NA
-----	----	-----	----	------	----	------	----	----	----	----	------	----	----	----

UNITS (UG/L)

PESTICIDES/PCBs FRACTION

	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
Chlordane	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
DDD	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
DDP	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA
PCB 1260	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	NA	NA	NA

UNITS (MG/L)

IONS

	NA	20	NA	74	NA	3570	NA	NA	4770	NA	4030	NA	8430	8070
Chloride	NA	27	NA	55	NA	549	NA	NA	590	NA	613	NA	1240	1110
sulfate	NA	41	NA	78	NA	51	NA	NA	46	NA	68	NA	69	76
Alkalinity														

BMDL = BELOW METHOD DETECTION LIMIT

NA = NOT ANALYZED

ND = NOT DETECTED

U = Sample Quantitation Limit

B = Blank Contamination

SUMMARY OF 1986 AND 1990 GROUNDWATER DATA
ANALYTICAL RESULTS
AMPHIBIOUS BASE LANDFILL (SITE 7)
LITTLE CREEK - RI (CONTRACT #: W62470-90-D-7646)

Sample No:	7-SW7		7-SW8		7-SW9	
	1986	1990	1986	1990	1986	1990

UNITS (UG/L)

VOLATILE FRACTION						
Methylene chloride	NA	NA	NA	NA	NA	NA
Acetone	NA	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA

UNITS (MG/L)

TOTAL PETROLEUM HYDROCARBONS	NA	NA	NA	NA	NA	NA
------------------------------	----	----	----	----	----	----

UNITS (UG/L)

ETHYLENE DIBROMIDE	NA	NA	NA	NA	NA	NA
--------------------	----	----	----	----	----	----

UNITS (UG/L)

BASE/NEUTRAL/ACID FRACTIONS						
Acenaphthene	NA	NA	NA	NA	NA	NA
Bis(2-ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA
Phenols	NA	NA	NA	NA	NA	NA

UNITS (MG/L)

TOC	NA	NA	NA	NA	NA	NA
-----	----	----	----	----	----	----

UNITS (UG/L)

TOX	NA	NA	NA	NA	NA	NA
-----	----	----	----	----	----	----

UNITS (UG/L)

PESTICIDES/PCBs FRACTION						
Chlordane	NA	NA	NA	NA	NA	NA
DDD	NA	NA	NA	NA	NA	NA
DDE	NA	NA	NA	NA	NA	NA
PCB 1260	NA	NA	NA	NA	NA	NA

UNITS (MG/L)

IONS						
Chloride	NA	5710	NA	8820	NA	3340
Sulfate	NA	1300	NA	1300	NA	525
Alkalinity	NA	78	NA	74	NA	78

BMDL = BELOW METHOD DETECTION LIMIT
 NA = NOT ANALYZED
 ND = NOT DETECTED
 U = Sample Quantitation Limit
 B = Blank Contamination

SUMMARY OF 1986 AND 1990 SURFACE WATER DATA
 INORGANIC ANALYTICAL RESULTS (UG/L)
 AMPHIBIOUS BASE LANDFILL (SITE 7)
 LITTLE CREEK - RI (CONTRACT #: W62470-90-D-7646)

Sample No:	7-SW1		7-SW2		7-SW3			7-SW4		7-SW5	
	1986	1990 Q	1986	1990 Q	1986	1990 Q	P. DUP 1990 Q	1986	1990 Q	1986	1990 Q
Antimony	20 U	3.4 U	20 U	3.4 U	3 U	3.4 U	3.4 U	20 U	3.4 U	20 U	3.4 U
Arsenic	5 U	3 U	24	13	7	3 U	3 U	5 U	3 U	8 U	3 U
Beryllium	3 U	1.6 U	3 U	1.6 U	3 U	1.6 U	1.6 U	3 U	1.6 U	3 U	1.6 U
Cadmium	4 U	5 U	4 U	5 U	4 U	5 U	5 U	4 U	5 U	4 U	5 U
Chromium-To	5 U	0.98 U	5 U	0.98 U	9	0.98 U	0.98 U	6	1 B	5	1 B
Chromium-Re	40 U	10 U	40 U	10 U	40 U	10 U	NA	40 U	10 U	40 U	10 U
Copper	30 U	11 U	50 U	11 U	50	13 B	11 U	30 U	11 U	30 U	11 U
Lead	2 U	3.2 U	4 U	3.2 U	31	3.2 U	3.2 U	26	3.2 U	22	3.2 U
Mercury	0.3 U	0.2 U	0.3 U	0.2 U	0.3 U	0.2 U	0.2 U	0.3 U	0.2 U	0.3 U	0.2 U
Nickel	90 U	22 U	90 U	22 U	200	22 U	22 U	90 U	22 U	90 U	22 U
Selenium	4 U	3.3 U	4 U	3.3 U	40	4.5 B	3.3 U	35	4.5 B	31	4.5 B
Silver	1 U	65 U	2	2.5 U	20	2.5 U	2.5 U	31	2.5 U	111	2.5 U
Thallium	50 U	2.4 U	50 U	2.4 U	130	2.4	2.4 U	128	2.4 U	30	2.4 U
Zinc	20 U	4.6 U	30	4.6 U	110	19 B	4.6 B	60	15 B	NA	10 B
Aluminum	NA	117 B	NA	97 U	NA	286 B	97 U	NA	483 B	NA	149 B
Barium	NA	3.2 U	NA	3.2 U	NA	3.2 U	3.2 U	NA	3.2 U	NA	3.2 U
Calcium	NA	16200	NA	25700	NA	102000	104000	NA	86500	NA	167000
Cobalt	NA	8.7 U	NA	8.7 U	NA	8.7 U	8.7 U	NA	8.7 U	NA	8.7 U
Iron	NA	121 B	NA	6000	NA	589	601	NA	533	NA	294
Magnesium	NA	4700	NA	13200	NA	306000	311000	NA	256000	NA	45200
Manganese	NA	33	NA	33	NA	33	33	NA	31	NA	16
Potassium	NA	2900	NA	3670	NA	446000	88000	NA	69000	NA	98700
Sodium	NA	10900	NA	49300	NA	1203700	2050000	NA	1850000	NA	28100
Vanadium	NA	9.2 U	NA	9.2 U	NA	9.2 U	9.2 U	NA	15 B	NA	9.2 U
Cyanide	NA	10 U	NA	10 U	NA	10 U	10 U	NA	10 U	NA	10 U

NA = Not Analyzed

R = Unusable

J/UJ = Estimated Result

SUMMARY OF 1986 AND 1990 SURFACE WATER DATA
 INORGANIC ANALYTICAL RESULTS (UG/L)
 AMPHIBIOUS BASE LANDFILL (SITE 7)
 LITTLE CREEK - RI (CONTRACT #: M62470-90-D-7466)

Sample No:	7-BW6				7-BW7		7-BW8		7-BW9	
	1986	1990	F. DUP		1986	1990	1986	1990	1986	1990
Date		Q	Q	Q		Q		Q		Q
Antimony	NA	3.4 UR	3.4 UR	3.4 UR	NA	3.4 U	NA	3.4 U	NA	3.4 U
Arsenic	NA	3 U	3 U	3 U	NA	3 U	NA	3 U	NA	3 U
Beryllium	NA	1.6 UJ	1.6 UJ	1.6 UJ	NA	1.6 U	NA	1.6 U	NA	1.6 U
Cadmium	NA	5 UJ	5 UJ	5 UJ	NA	5 U	NA	5 U	NA	5 U
Chromium-To	NA	0.98 U	0.98 U	0.98 U	NA	0.98 U	NA	0.98 U	NA	0.98 U
Chromium-Ba	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	NA	11 U	11 U	11 U	NA	11 U	NA	11 U	NA	11 U
Lead	NA	3.2 U	3.2 U	3.2 U	NA	3.2 U	NA	3.2 U	NA	3.2 U
Mercury	NA	0.2 U	0.2 U	0.2 U	NA	0.2 U	NA	0.2 U	NA	0.2 U
Nickel	NA	22 UJ	22 UJ	22 UJ	NA	22 U	NA	22 U	NA	22 U
Selenium	NA	3.3 B	3.3 B	3.3 B	NA	3.3 U	NA	3.3 U	NA	3.3 U
Silver	NA	2.5 U	2.5 U	2.5 U	NA	2.5 U	NA	2.5 U	NA	2.5 U
Thallium	NA	2.4 U	2.4 U	2.4 U	NA	2.4 B	NA	2.4 B	NA	2.4 U
Zinc	NA	4.6 UJ	4.6 UJ	4.6 UJ	NA	4.6 U	NA	4.6 U	NA	25 B
Aluminum	NA	245 B	215 B	215 B	NA	130 B	NA	127 B	NA	601 B
Barium	NA	3.2 U	3.2 U	3.2 U	NA	3.2 U	NA	3.2 U	NA	3.2 U
Calcium	NA	182000	182000	182000	NA	197000	NA	167000	NA	81900
Cobalt	NA	8.7 U	8.7 U	8.7 U	NA	8.7 U	NA	8.7 U	NA	8.7 U
Iron	NA	228 B	227 B	227 B	NA	210 B	NA	208 B	NA	915
Magnesium	NA	552000 J	554000 J	554000 J	NA	590000	NA	497000	NA	226000
Manganese	NA	7	6	6	NA	6	NA	8	NA	62
Potassium	NA	109000	128000	128000	NA	129000	NA	125000	NA	61500
Sodium	NA	3710000	3890000	3890000	NA	4000000	NA	3840000	NA	3840000
Vanadium	NA	9.2 U	9.2 U	9.2 U	NA	9.2 U	NA	9.2 U	NA	9.2 U
Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = Not Analyzed

R = Unusable

J/UJ = Estimated Result

SUMMARY OF 1986 AND 1990 SURFACE WATER DATA
ANALYTICAL RESULTS
EXCHANGE LAUNDRY WASTE DISPOSAL AREA (SITE 12)
LITTLE CREEK RI - (CONTRACT #: K62470-90-D-7646)

Sample Nos	12-BW1		12-BW2			12-BW3		12-BW4		12-BW5		12-BW6		12-BW7	
Date	1986	1990	1986	1990	1990DUP	1986	1990	1986	1990	1986	1990	1986	1990	1986	1990

UNITS (UG/L)	1986		1990			1986		1990		1986		1990		1986		1990	
VOLATILE FRACTION	1986	1990	1986	1990	1990DUP	1986	1990	1986	1990	1986	1990	1986	1990	1986	1990		
Trichloroethene	BMDL	SU	BMDL	SU	SU	BMDL	SU	7.3	SU	4.1	SU	3.1	SU	NA	SU		
Tetrachloroethene	BMDL	SU	BMDL	SU	SU	BMDL	SU	17	SU	6.7	SU	5.3	SU	NA	SU		
Trans-1,2-Dichloroethene	BMDL	SU	BMDL	SU	SU	BMDL	SU	BMDL	SU	26	SU	19	SU	NA	SU		
Vinyl chloride	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	BMDL	ND	BMDL	ND	NA	ND		
Toulene	BMDL	ND	BMDL	ND	ND	BMDL	ND	BMDL	ND	BMDL	ND	BMDL	ND	NA	ND		
Methylene chloride	BMDL	ND	BMDL	ND	ND	BMDL	ND	19B	ND	BMDL	ND	BMDL	ND	NA	ND		
Acetone	BMDL	31B	BMDL	ND	16B	BMDL	51B	BMDL	ND	BMDL	ND	BMDL	ND	NA	ND		
Chloroform	2.1	SU	BMDL	SU	SU	BMDL	SU	BMDL	SU	1.6	SU	BMDL	SU	NA	SU		

BMDL = Below Method Detection Limit
 NA = Not Analyzed
 ND = Not Detected
 B = Blank Contamination
 U = Sample Quantitation Limit

SUMMARY OF 1986 AND 1990 SEDIMENT DATA
ANALYTICAL RESULTS
EXCHANGE LAUNDRY WASTE DISPOSAL AREA (SITE 12)
LITTLE CREEK RI - (CONTRACT #: W62470-90-D-7646)

Sample No:	12-SED1		12-SED2		12-SED3			12-SED4		12-SED5		12-SED6	
	1986	1990	1986	1990	1986	1990	1990	1986	1990	1986	1990	1986	1990

UNITS (UG/KG)

VOLATILE FRACTION													
Trichloroethene	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	NA	BMDL	NA	BMDL	NA
Tetrachloroethene	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	NA	BMDL	NA	BMDL	NA
Trans-1,2-Dichloroethene	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	NA	BMDL	NA	2.5	NA
Vinyl chloride	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	NA	BMDL	NA	2.9	NA
Toluene	BMDL	ND	BMDL	ND	BMDL	ND	ND	BMDL	NA	BMDL	NA	9.1	NA
Methylene chloride	280	6U	22	4B	11	9U	6U	0.79	NA	37	NA	5.5	NA
Acetone	270	19U	BMDL	92B	BMDL	150B	160B	18	NA	BMDL	NA	BMDL	NA
Chloroform	BMDL	ND	6.6	ND	BMDL	ND	ND	BMDL	NA	2.4	NA	2.7	NA
Trichloro-trifluoroethane	71	NA	NR	NA	NR	ND	NA	NR	NA	NR	NA	NR	NA
1-Methyl pentane	17	NA	NR	NA	NR	ND	NA	NR	NA	NR	NA	NR	NA

BMDL = Below Method Detection Limit

NA = Not Analyzed

ND = Not Detected

NR = Not Required

B = Blank Contamination

U = Sample Quantitation Limit

APPENDIX D.4
SEDIMENT SAMPLING AND ANALYSIS DATA FOR CANAL
ADJACENT TO IR SITE 12

TCL VOLATILE ORGANIC COMPOUNDS IN SEDIMENT SAMPLES
 IR SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 FEBRUARY 26, 1995

SAMPLE NUMBER SAMPLE TYPE SAMPLE DATE UNITS	12-SED-01 SEDIMENT 2/26/95 ug/kg	12-SED-02 SEDIMENT 2/26/95 ug/kg	12-SED-03 SEDIMENT 2/26/95 ug/kg	12-SED-11 * SEDIMENT 2/26/95 ug/kg	12-SED-04 SEDIMENT 2/26/95 ug/kg	12-SED-05 SEDIMENT 2/26/95 ug/kg	12-SED-06 SEDIMENT 2/26/95 ug/kg	12-SED-06MS SEDIMENT 2/26/95 ug/kg	12-SED-06MSD SEDIMENT 2/26/95 ug/kg	12-SED-07 SEDIMENT 2/26/95 ug/kg	RISK-BASED CONCENTRATIONS	
											SOIL - INDUSTRIAL ug/kg	SOIL - RESIDENTIAL ug/kg
PARAMETER												
Chloromethane												
Bromomethane												
Vinyl Chloride												
Chloroethane												
Methylene Chloride	9 B		4 B		14 B	14 B				9 B	780,000	85,000
Acetone	100	350	7 J		180	120		73 J	86 J		200,000,000	7,800,000
Carbon Disulfide										12 J		
1,1-Dichloroethane								130	140		9,500	1,100
1,1-Dichloroethane												
1,2-Dichloroethane (Total)					3 J						18,000,000	700,000
Chloroform												
1,2-Dichloroethane												
2-Butanone	23	43			20	18	100 J	20	22	74	1,000,000,000	47,000,000
1,1,1-Trichloroethane												
Carbon Tetrachloride												
Vinyl Acetate												
Bromodichloromethane												
1,2-Dichloropropane												
trans-1,3-Dichloropropane												
Trichloroethane								69	76		520,000	58,000
Dibromochloromethane												
1,1,2-Trichloroethane												
Benzene								87	85		200,000	22,000
cis-1,3-Dichloropropane												
Bromoforn												
4-Methyl-2-Pentanone												
2-Hexanone												
Tetrachloroethane												
1,1,2,2-Tetrachloroethane												
Toluene	3 J							85	92		410,000,000	18,000,000
Chlorobenzene								73	80		41,000,000	1,600,000
Ethylbenzene												
Styrene												
Xylenes (Total)												
TOTAL VOLATILE ORGANICS	135	393	11		217	150	100	537	593	95		

NOTES:

- 1) TCL INDICATES TARGET COMPOUND LIST
- 2) RISK-BASED CONCENTRATIONS LISTED ONLY FOR DETECTED COMPOUNDS
- 3) BLANK INDICATES COMPOUND WAS NOT DETECTED.
- 4) B INDICATES COMPOUND WAS DETECTED IN LABORATORY BLANK.
- 5) J INDICATES AN ESTIMATED CONCENTRATION.

TABLE 4-1 (CONTINUED)
 TCL VOLATILE ORGANIC COMPOUNDS IN SEDIMENT SAMPLES
 IR SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 FEBRUARY 28, 1995

SAMPLE NUMBER SAMPLE TYPE SAMPLE DATE UNITS	12-SED-08 SEDIMENT 2/28/95 ug/kg	12-SED-09 SEDIMENT 2/28/95 ug/kg	12-SED-10 SEDIMENT 2/28/95 ug/kg	12-SED-DC-01 DECON WATER 2/28/95 ug/L	12-SED-FB-01 EQUIPMENT RINSATE 2/28/95 ug/L	12-SED-FB-01 FIELD BLANK 2/28/95 ug/L	12-SED-TB-01 TRIP BLANK 2/28/95 ug/L	RISK-BASED CONCENTRATIONS		
								SOIL - INDUSTRIAL ug/kg	SOIL - RESIDENTIAL ug/kg	TAP WATER ug/L
PARAMETER										
Chloromethane										
Bromomethane										
Vinyl Chloride										
Chloroethane										
Methylene Chloride	18 B	25 B	5 B				3 J	760,000	65,000	4.1
Acetone	90	65 J		36 J				200,000,000	7,600,000	3,700
Carbon Disulfide								200,000,000	7,800,000	
1,1-Dichloroethane										
1,1-Dichloroethane										
1,2-Dichloroethane (Total)										
Chloroform							3 J			
1,2-Dichloroethane										
2-Butanone	15							1,000,000,000	47,000,000	
1,1,1-Trichloroethane										
Carbon Tetrachloride										
Vinyl Acetate										
Bromodichloromethane										
1,2-Dichloropropane										
trans-1,3-Dichloropropene										
Trichloroethene										
Dibromochloromethane										
1,1,2-Trichloroethane										
Benzene										
cis-1,3-Dichloropropene										
Bromoform										
4-Methyl-2-Pentanone										
2-Hexanone										
Tetrachloroethene										
1,1,2,2-Tetrachloroethane										
Toluene										
Chlorobenzene										
Ethylbenzene										
Styrene										
Xylene (Total)										
TOTAL VOLATILE ORGANICS	123	90	5	36			6			

NOTES:

- 1) TCL INDICATES TARGET COMPOUND LIST.
- 2) RISK-BASED CONCENTRATIONS LISTED ONLY FOR DETECTED COMPOUNDS
- 3) BLANK INDICATES COMPOUND WAS NOT DETECTED.
- 4) B INDICATES COMPOUND WAS DETECTED IN LABORATORY BLANK
- 5) J INDICATES AN ESTIMATED CONCENTRATION.

TARGET ANALYTE LIST INORGANICS IN SEDIMENT SAMPLES
 IR SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 FEBRUARY 28, 1995

SAMPLE NUMBER	12-SED-01 SEDIMENT	12-SED-02 SEDIMENT	12-SED-03 SEDIMENT	12-SED-11 * SEDIMENT	12-SED-04 SEDIMENT	12-SED-05 SEDIMENT	12-SED-06 SEDIMENT	12-SED-07 SEDIMENT	RISK-BASED CONCENTRATIONS	
									INDUSTRIAL	RESIDENTIAL
SAMPLE TYPE	2/28/95	2/28/95	2/28/95	2/28/95	2/28/95	2/28/95	2/28/95	2/28/95	mg/kg	mg/kg
SAMPLE DATE	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
UNITS	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PARAMETER										
Aluminum	2,110	11,100	1,290	1,020	7,750	6,480	11,600	10,600	1,000,000	78,000
Antimony									820	31
Arsenic	2.5 J	9.0 J	1.7 J	1.3 J	4.0 J	3.2 J	6.0 J	5.1 J	33	0.37
Barium	13.9 J	64.9 J	13.5 J	8.2 J	31.7 J	25.8 J	57.8 J	53.6 J	140,000	5,500
Beryllium									13	0.15
Cadmium									1,000	39
Calcium	565 J	1,330 J	557 J	374 J	344 J	484 J	801 J	1,200 J	NL	NL
Chromium	5.0 J	13.3	2.9 J	3.3 J	9.5 J	8.3 J	14.6	16.9	10,000	390
Cobalt	1.8 J	5.0 J			3.0 J	1.2 J	3.6 J	4.4 J	120,000	4,700
Copper	7.2 J	54.1 J	7.0 J	7.3 J	13.5 J	9.3 J	27.0 J	31.9 J	76,000	2,900
Iron	3,250	13,600	2,010	1,590	6,720	5,600	13,500	11,700	NL	NL
Lead	20.0	71.4	36.0	22.1	25.2	27.2	57.4	129	0.2	0070
Magnesium	231 J	922 J	225 J	201 J	551 J	407 J	912 J	1,060 J	NL	NL
Manganese	23.9	88.7	16.1	14.0	26.4	25.1	63.1	83.8	10,000	390
Mercury				0.19 J			0.20 J		610	23
Nickel		7.4 J			6.3 J		5.1 J	8.3 J	41,000	1,600
Potassium								972 J	NL	NL
Selenium							0.41 J	0.77 J	10,000	390
Silver									NL	NL
Sodium	32.5 J	67.0 J	38.9 J	20.3 J	50.7 J	32.2 J	81.5 J	90.3 J	NL	NL
Thallium		0.47 J							NL	NL
Vanadium	6.0 J	18.5 J	4.7 J	4.0 J	13.1 J	11.8 J	22.2	25.1	14,000	550
Zinc	54.6	233	135	94.5	55.0	40.3	124	267	610,000	23,000

NOTES:

- 1) BLANK INDICATES NOT DETECTED.
- 2) ARSENIC RBC CONCENTRATION LISTED IS THAT OF ARSENIC (as carcinogen)
- 3) J INDICATES AN ESTIMATED CONCENTRATION.

TARGET ANALYTE LIST INORGANICS IN SEDIMENT SAMPLES
 IN SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA
 FEBRUARY 28, 1995

SAMPLE NUMBER	12-SED-08 SEDIMENT	12-SED-09 SEDIMENT	12-SED-10 SEDIMENT	12-SED-DC-01 DECON WATER	12-SED-RB-01 EQUIPMENT RINSATE	12-SED-FB-01 FIELD BLANK	RISK-BASED CONCENTRATIONS		
							SOIL - INDUSTRIAL	SOIL - RESIDENTIAL	Tap Water
SAMPLE TYPE	2/28/95	2/28/95	2/28/95	2/28/95	2/28/95	2/28/95	mg/kg	mg/kg	ug/L
SAMPLE DATE	mg/kg	mg/kg	mg/kg	ug/L	ug/L	ug/L			
UNITS									
PARAMETER									
Aluminum	4,940	6,410	1,840	25,000 J	351 J		1,000,000	78,000	37,000
Antimony							820	31	15
Arsenic	1.6 J	6.8 J		30.4 J			3.3	0.37	0.038
Barium	17.6 J	43.8 J	24.6 J	82.8 J			140,000	5,500	2,600
Beryllium							1.3	0.15	0.016
Cadmium				11.3			1,000	39	18
Calcium	222 J	641 J	2,200	9,640	150 J	24.7 J	NL	NL	NL
Chromium	6.1 J	9.4 J	16.8	45.6 J			10,000	390	180
Cobalt		2.8 J	1.7 J				120,000	4,700	2,200
Copper	2.9 J	23.7 J	7.1 J	32.3			76,000	2,900	1,400
Iron	4,250	8,350	2,920	17,700 J	20.4 J		NL	NL	NL
Lead	6.8	64.4	105	50.7 J	3.7 J	1.4 J	0.2	0.076	0.0037
Magnesium	353 J	620 J	1,180 J	7,240 J			NL	NL	NL
Manganese	14.5	44.7	95.9	139 J			10,000	390	180
Mercury		0.35 J	0.30 J				610	23	11
Nickel	2.8 J	2.8 J	4.2 J	85.0			41,000	1,600	730
Potassium				19,500			NL	NL	NL
Selenium		0.90 J		1.0 J			10,000	390	180
Silver							NL	NL	180
Sodium	28.1 J	62.3 J	49.6 J	959,000			NL	NL	NL
Thallium							NL	NL	NL
Vanadium	8.9 J	14.3 J	14.9	37.9 J			14,000	550	260
Zinc	15.9	104	135	293	2.4 J	5.5 J	610,000	23,000	11,000

NOTES:

- 1) BLANK INDICATES NOT DETECTED.
- 2) ARSENIC RBC CONCENTRATION LISTED IS THAT OF ARSENIC (as carcinogen)
- 3) B INDICATES COMPOUND WAS DETECTED IN LABORATORY BLANK.

TABLES

TABLE 1
LIST OF CONTACTS
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Organization/Agency/Institution	Contact	Area of Expertise
Chesapeake Bay Program Office - Annapolis, MD	William Matuszeski	Program Director
	Karen Bisland	Natural Resources
	Joe Macknis	Monitoring Program Coordinator
	Peter Marx	Public Relations
	Kent Mountford	Environmental Indicators
Old Dominion University - Norfolk, VA	Daniel Dauer	Department of Biological Sciences
	Anthony Rodi	Department of Biological Sciences
Virginia Department of Environmental Quality - Tidewater Regional Office	Debra Thompson	Regulatory Services
	Traycie West	Water Resources Development
EMAP - Virginia Province	Charlie Strobel	Environmental Data
	John Paul, Ph.D.	Research Environmental Scientist
Virginia Department of Health - Division of Shellfish Sanitation	Tim Fearington	Shellfish Closures
NAB Little Creek	Kelly Greaser	IR Program
	Ann Nelson	Environmental Quality
	Maureen Conners	Permits
	Catherine Zielske	Natural Resources
	John VanName	Water Quality
	John Chamberlin	Water Quality
Hampton Roads Sanitation	Dave Cooley	Plant Operator
U.S. Fish and Wildlife Service - White Marsh, VA	Kim Marbain	Threatened & Endangered Species
Virginia Department of Environmental Quality - Chesapeake Bay Program Office	Mark Bushing	Water Quality
Virginia Marine Resource Commission	Tony Watkinson	Wetlands/Shellfish
	Sonya Davis	Fish Statistics
Tidewater Community College	Fred Stemple	Biology Department

TABLE 1 (Continued)

**LIST OF CONTACTS
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Organization/Agency/Institution	Contact	Area of Expertise
LANTDIV	Jim Haluska	Dredging
U.S. Army Corps of Engineers	Ken Kemety	Dredging
COMNAVBASE	Steve Olson	Chesapeake Bay Program

TABLE 2

ECOLOGICAL CONTAMINANTS OF CONCERN PER MEDIA PER SITE
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Parameter	Site 7		Site 12	
	Surface Water	Sediment	Surface Water	Sediment
Volatile Organic Compounds:				
Acetone		X		X
2-Butanone		X	X	
Carbon Disulfide		X		
Inorganic Compounds:				
Aluminum	X	X	X	X
Arsenic		X	X	
Barium	X		X	
Beryllium		X	X	
Cadmium		X		X
Chromium			X	
Cobalt	X	X	X	X
Copper	X	X	X	X
Iron	X		X	
Lead	X		X	X
Manganese	X		X	
Mercury			X	X
Nickel			X	
Silver		X		
Zinc		X	X	X

TABLE 3

**FREQUENCY AND RANGE OF DETECTION COMPARED TO ESTUARINE SURFACE WATER SCREENING LEVELS
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Analyte	Surface Water Screening Levels (SWSLs)		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Ecological Contaminant of Concern ?	Reason for Exclusion
			No. of Positive Detects/No. of Samples	Range of Positive Detects				
	Acute	Chronic			Acute	Chronic		
Volatiles (µg/L):								
Acetone	NE	NE	4/7	15 - 31	NA	NA	No	Below Blank Concentration
Inorganics (µg/L):								
Aluminum	NE	NE	6/7	388J - 1,690J	NA	NA	Yes	
Arsenic	69 ⁽¹⁾	13 ⁽²⁾	5/7	2.4B - 10.3	0	0	No	Below SWSL
Barium	NE	NE	7/7	17.5B - 36.8B	NA	NA	Yes	
Calcium	NE	NE	7/7	22,300 - 182,000	NA	NA	No	Low Toxicity
Cobalt	NE	NE	5/7	3.4B - 5.6B	NA	NA	Yes	
Copper	2.9	2.9 ⁽¹⁾	5/7	5.3B - 14.1B	5	5	Yes	
Iron	NE	NE	7/7	1,010J - 6,890J	NA	NA	Yes	
Lead*	220 ⁽¹⁾	5.1	3/7	3.2J - 50J	0	1	Yes	
Magnesium	NE	NE	7/7	28,000 - 457,000	NA	NA	No	Low Toxicity
Manganese	NE	10	7/7	83.9 - 334	NA	7	Yes	
Mercury**	2.1 ⁽¹⁾	0.025	ND	0.134U	NA	NA	No	Not Detected
Nickel**	75 ⁽¹⁾	8.3	ND	10U	NA	NA	No	Not Detected

TABLE 3 (Continued)

FREQUENCY AND RANGE OF DETECTION COMPARED TO ESTUARINE SURFACE WATER SCREENING LEVELS
 SITE 7
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Surface Water Screening Levels (SWSLs)		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Ecological Contaminant of Concern ?	Reason for Exclusion
			No. of Positive Detects/No. of Samples	Range of Positive Detects				
	Acute	Chronic			Acute	Chronic		
Inorganics (µg/L) continued:								
Potassium	NE	NE	7/7	8,800J - 181,000J	NA	NA	No	Low Toxicity
Sodium	NE	NE	7/7	184,000 - 4,250,000	NA	NA	No	Low Toxicity
Zinc	95	86	3/7	30.8 - 70.5	0	0	No	Below SWSL

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

- * Detection limit is greater than the corresponding screening level; therefore, samples qualified as not detected may actually exceed screening levels
- ** Detection limit is greater than the corresponding screening level and the constituent is not detected; therefore, samples qualified as "non detects" may actually exceed screening levels
- NE Not Established
- NA Not Applicable
- µg/L micrograms per liter
- B Compound Detected in Blank
- J Estimated value
- ND Not Detected
- (1) USEPA, 1992
- (2) Value for Arsenic V

TABLE 4
FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING LEVELS
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Analyte	Sediment Screening Levels (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Ecological Contaminant of Concern?	Reason for Exclusion
	BSLs/ER-Ls	ER-MS ⁽²⁾	No. of Positive Detects/No. of Samples	Range of Positive Detections			
Volatile Organics (µg/kg):							
Acetone	NE	NE	1/7	370J	NA	Yes	
2-Butanone	NE	NE	2/7	12J - 65	NA	Yes	
Carbon Disulfide	NE	NE	1/7	4J	NA	Yes	
Methylene Chloride	<300 ⁽¹⁾	NE	1/7	7J	0	No	Below SSL
Toluene	100 ⁽¹⁾	NE	2/7	1J - 5J	0	No	Below SSL
Inorganics (mg/kg):							
Aluminum	NE	NE	7/7	221 - 6,520	NA	Yes	
Arsenic	8.2	70	7/7	1.2B - 8.6	1	Yes	
Barium	500 ⁽⁴⁾	NE	7/7	1.6B - 23.8B	0	No	Below SSL
Beryllium	NE	0.36 ⁽³⁾	2/7	0.28B - 0.42B	1	Yes	
Cadmium*	0.676	9.6	3/7	2.3 - 3.1	3	Yes	
Calcium	NE	NE	6/7	214B - 1,500	NA	No	Low Toxicity
Chromium	81	370	7/7	1.5J - 10.1J	0	No	Below SSL
Cobalt	1.5 ⁽¹⁾	NE	4/7	0.94J - 3.4J	2	Yes	
Copper	34	270	7/7	0.89B - 42.9	1	Yes	

TABLE 4 (Continued)

FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING LEVELS
 SITE 7
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Sediment Screening Levels (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Ecological Contaminant of Concern?	Reason for Exclusion
	BSLs/ER-Ls	ER-Ms ⁽²⁾	No. of Positive Detects/No. of Samples	Range of Positive Detections			
Inorganics (mg/kg) continued:							
Iron	NE	27,000 ⁽³⁾	7/7	1,060 - 14,200	0	No	Below SSL
Lead	46.7	218	7/7	1.7J - 31.1	0	No	Below SSL
Magnesium	NE	NE	7/7	78.7B - 2,680	NA	No	Low Toxicity
Manganese	230 ⁽⁵⁾	NE	7/7	2.7B - 67.2	0	No	Below SSL
Nickel	20.9	51.6	6/7	3.3B - 7.6B	0	No	Below SSL
Potassium	NE	NE	7/7	45.3B - 1,350B	NA	No	Low Toxicity
Silver*	0.733	3.7	1/7	0.75J	1	Yes	
Sodium	NE	NE	7/7	299B - 5,160	NA	No	Low Toxicity
Vanadium	58 ⁽¹⁾	NE	6/7	5.4B - 23.2	0	No	Below SSL
Zinc	150	410	6/7	29.5 - 213	1	Yes	

* Detection limit is greater than ER-L screening levels

BSL USEPA Region III BTAG Screening Level

ER-L Effects Range - Low

ER-M Effects Range - Median

NE Not Established

NA Not Applicable

µg/kg microgram per kilogram

mg/kg milligram per kilogram

J Estimated Value

B Compound Detected in Blank

⁽¹⁾ USEPA Region III screening level for soil-fauna

⁽²⁾ Long *et al.*, 1995.

⁽³⁾ Tetra Tech, Inc. 1986.

⁽⁴⁾ Sullivan *et al.*, 1985.

⁽⁵⁾ Long and Morgan, 1990.

TABLE 5
FREQUENCY AND RANGE OF DETECTION COMPARED TO ESTUARINE SURFACE WATER SCREENING LEVELS
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Analyte	Surface Water Screening Levels (SWSLs)		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Ecological Contaminant of Concern ?	Reason for Exclusion
	Acute	Chronic	No. of Positive Detects/No. of Samples	Range of Positive Detects	Acute	Chronic		
Volatiles (µg/L):								
Acetone	NE	NE	3/4	20B - 50B	NA	NA	No	Below Blank Concentration
1,2-Dichloroethene(total)	224,000	NE	1/4	1I	0	NA	No	Below SWSL
2-Butanone	NE	NE	1/4	36	NA	NA	Yes	
Trichloroethene	2,000	NE	1/4	3J	0	NA	No	Below SWSL
Tetrachloroethene	NE	450	1/4	3J	0	0	No	Below SWSL
Toluene	1,050	NE	3/4	2J - 58	0	0	No	Below SWSL
Inorganics (µg/L):								
Aluminum	NE	NE	2/4	4,320J - 81,800J	NA	NA	Yes	
Arsenic	69 ⁽¹⁾	13 ⁽²⁾	3/4	2.2J - 23.4J	0	1	Yes	
Barium	NE	NE	4/4	25.3J - 669J	NA	NA	Yes	
Beryllium	NE	NE	1/4	3.1J	NA	NA	Yes	
Cadmium	43 ⁽¹⁾	9.3	1/4	7.5J	0	0	No	Below SWSL

TABLE 5 (Continued)

**FREQUENCY AND RANGE OF DETECTION COMPARED TO ESTUARINE SURFACE WATER SCREENING LEVELS
SITE 12
NAVAL AMPHIBIOUS BASE - LITTLE CREEK
VIRGINIA BEACH, VIRGINIA**

Analyte	Surface Water Screening Levels (SWSLs)		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Ecological Contaminant of Concern ?	Reason for Exclusion
	Acute	Chronic	No. of Positive Detects/No. of Samples	Range of Positive Detects	Acute	Chronic		
Inorganics (µg/L) (continued):								
Calcium	NE	NE	4/4	15,600J - 84,500J	NA	NA	No	Low Toxicity
Chromium	10,300 ⁽¹⁾	50 ⁽⁴⁾	1/4	148J	0	1	Yes	
Cobalt	NE	NE	1/4	64J	NA	NA	Yes	
Copper	2.9	2.9 ⁽¹⁾	4/4	4.7J - 305J	4	4	Yes	
Iron	NE	NE	4/4	2,900J - 94,800J	NA	NA	Yes	
Lead	220 ⁽¹⁾	5.1	4/4	2J - 312J	1	2	Yes	
Magnesium	NE	NE	4/4	5,150J - 26,600J	NA	NA	No	Low Toxicity
Manganese	NE	10	4/4	507J - 1,240J	NA	4	Yes	
Mercury*	2.1 ⁽¹⁾	0.025	1/4	0.79J	0	1	Yes	
Nickel*	75 ⁽¹⁾	8.3	1/4	143J	1	1	Yes	
Potassium	NE	NE	4/4	2,800J - 21,300J	NA	NA	No	Low Toxicity
Sodium	NE	NE	11/11	13,300J - 26,200J	NA	NA	No	Low Toxicity

TABLE 5 (Continued)

FREQUENCY AND RANGE OF DETECTION COMPARED TO ESTUARINE SURFACE WATER SCREENING LEVELS
 SITE 12
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK
 VIRGINIA BEACH, VIRGINIA

Analyte	Surface Water Screening Levels (SWSLs)		Contaminant Frequency/Range		No. of Positive Detects Above SWSLs		Ecological Contaminant of Concern ?	Reason for Exclusion
	Acute	Chronic	No. of Positive Detects/No. of Samples	Range of Positive Detects	Acute	Chronic		
Inorganics (µg/L) (continued):								
Vanadium	<10,000	NE	2/4	11.8J - 162J	0	NA	No	Below SWSL
Zinc	95	86	4/4	39.1 - 3,800J	3	3	Yes	

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

* Detection limit is greater than the corresponding screening level; therefore, samples qualified as "non detects" may actually exceed the screening level

NE Not Established

NA Not Applicable

B Compound Detected in Blank

J Estimated value

µg/L microgram per liter

ND Not Detected

⁽¹⁾ USEPA, 1992

⁽²⁾ Value for Arsenic V

⁽³⁾ Value for Chromium III

⁽⁴⁾ Value for Chromium VI

TABLE 6
FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING LEVELS
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Analyte	Sediment Screening Levels (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Ecological Contaminant of Concern?	Reason for Exclusion
	BSLs/ER-Ls	ER-Ms ⁽²⁾	No. of Positive Detects/No. of Samples	Range of Positive Detections			
Volatile Organics (µg/kg):							
Acetone	NE	NE	3/4	8J - 82J	NA	Yes	
1,2-Dichloroethene(total)	<300 ⁽¹⁾	NE	2/4	2J - 14J	0	No	Below SSL
Trichloroethene	<300 ⁽¹⁾	NE	2/4	3J - 19J	0	No	Below SSL
Tetrachloroethene	<300 ⁽¹⁾	NE	2/4	6J - 15J	0	No	Below SSL
Toluene	100 ⁽¹⁾	NE	1/4	5J	0	No	Below SSL
Xylene(total)	NE	100 ⁽³⁾	1/4	4J	0	No	Below SSL
Inorganics (mg/kg):							
Aluminum	NE	NE	4/4	1,130J - 11,700J	NA	Yes	
Arsenic	8.2	70	4/4	0.64J - 5.6	0	No	Below SSL
Barium	500 ⁽⁴⁾	NE	4/4	3.4J - 72J	0	No	Below SSL
Cadmium	0.676	9.6	1/4	1.2J	1	Yes	
Calcium	NE	NE	4/4	72.5J - 2,970J	NA	No	Low Toxicity
Chromium	81	370	4/4	1.3J - 20.6J	0	No	Below SSL
Cobalt	1.5 ⁽¹⁾	NE	3/4	1.3J - 4.8J	1	Yes	

TABLE 6 (Continued)

FREQUENCY AND RANGE OF DETECTION COMPARED TO SEDIMENT SCREENING LEVELS
 SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Sediment Screening Levels (SSLs)		Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSL	Ecological Contaminant of Concern?	Reason for Exclusion
	BSLs/ER-Ls	ER-Ms ⁽²⁾	No. of Positive Detects/No. of Samples	Range of Positive Detects			
Inorganics (mg/kg) (continued):							
Copper	34	270	4/4	2.3J - 36J	1	Yes	
Iron	NE	27,000 ⁽³⁾	4/4	1,220J - 12,900	0	No	Below SSL
Lead	46.7	218	4/4	8.7J - 110J	2	Yes	
Magnesium	NE	NE	4/4	83.6J - 1,990J	NA	No	Low Toxicity
Manganese	230 ⁽⁵⁾	NE	4/4	3.7J - 144J	0	No	Below SSL
Mercury	0.15	0.71	1/4	0.28J	1	Yes	
Nickel	20.9	51.6	3/4	2.9J - 13.8J	0	No	Below SSL
Potassium	NE	NE	4/4	45.8J - 1,350J	NA	No	Low Toxicity
Sodium	NE	NE	1/4	346J	NA	No	Low Toxicity
Vanadium	58 ⁽¹⁾	NE	4/4	1.9J - 26.9J	0	No	Below SSL
Zinc	150	410	4/4	6.1J - 383J	2	Yes	

BSL USEPA Region III BTAG Screening Level
 ER-L Effects Range - Low
 ER-M Effects Range - Median
 µg/kg microgram per kilogram
 mg/kg milligram per kilogram
 NE Not Established
 NA Not Applicable
 J Estimated Value

⁽¹⁾ USEPA Region III screening level for soil-fauna
⁽²⁾ Long et al., 1995.
⁽³⁾ Tetra Tech, Inc. 1986.
⁽⁴⁾ Sullivan et al., 1985.
⁽⁵⁾ Long and Morgan, 1990.

TABLE 7

**PHYSICAL/CHEMICAL CHARACTERISTICS
OF THE ECOLOGICAL CONTAMINANTS OF CONCERN
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Ecological Contaminant of Concern	BCF	Organic Carbon Partition Coefficient (mL/g)	Log Octanol/Water Coefficient
Volatiles:			
2-Butanone	ND	4.5 ⁽¹⁾	0.29 ⁽²⁾
Acetone	0.69 ⁽³⁾	2.2 ⁽¹⁾	0.24 ⁽²⁾
Carbon Disulfide	ND	54 ⁽¹⁾	0 ⁽²⁾
Inorganics:			
Aluminum	231 ⁽³⁾	ND	ND
Arsenic	4 ⁽³⁾	ND	ND
Barium	8 ⁽³⁾	ND	ND
Beryllium	19 ⁽³⁾	ND	ND
Cadmium	4,900 ⁽³⁾	ND	ND
Chromium	3.4 ⁽³⁾	ND	ND
Cobalt	40 ⁽³⁾	ND	ND
Copper	51.2 ⁽³⁾	ND	ND
Iron	ND	ND	ND
Lead	726 ⁽³⁾	ND	ND
Manganese	35 ⁽³⁾	ND	ND
Mercury	7,000 ⁽³⁾	ND	ND
Nickel	100 ⁽³⁾	ND	ND
Silver	150 ⁽³⁾	ND	ND
Zinc	2,000 ⁽³⁾	ND	ND

BCF Bioconcentration Factor

ND No Data

⁽¹⁾ USEPA, 1986.

⁽²⁾ SCDM, 1991.

⁽³⁾ USEPA, 1995.

TABLE 8
SURFACE WATER QUOTIENT INDEX PER STATION
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Analyte	Sample Number	Sample Concentration	Surface Water Quotient Index	
			Acute	Chronic
Inorganics (µg/L):				
Aluminum	NA	NA	NA	NA
Barium	NA	NA	NA	NA
Cobalt	NA	NA	NA	NA
Copper	07-SW-102	14.1B	4.86	4.86
	07-SW-103	5.3B	1.83	1.83
	07-SW-107	6.3B	2.17	2.17
	07-SW-104	8.5B	2.93	2.93
	07-SW-105	6.8B	2.34	2.34
Lead	07-SW-104	50J	0.23	9.80
Iron	NA	NA	NA	NA
Manganese	07-SW-101	156	NA	15.60
	07-SW-102	306	NA	30.60
	07-SW-103	83.9	NA	8.39
	07-SW-107	91.6	NA	9.16
	07-SW-104	322	NA	32.20
	07-SW-105	193	NA	19.30
	07-SW-106	334	NA	33.40

NA Not Applicable

TABLE 9

SURFACE WATER QUOTIENT INDEX PER ECOLOGICAL CONTAMINANT OF CONCERN
 SITE 7
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Average Concentration	Surface Water Quotient Index	
		Acute	Chronic
Inorganics (µg/L):			
Aluminum	NA	NA	NA
Barium	NA	NA	NA
Cobalt	NA	NA	NA
Copper	8.20	2.83	2.83
Iron	NA	NA	NA
Lead	19.43	0.09	3.81
Manganese	212.36	NA	21.24
Total QI		2.92	27.88

NA Not Applicable
 QI Quotient Index
 µg/L micrograms per liter

TABLE 10

**SURFACE WATER QUOTIENT INDEX PER STATION
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Analyte	Sample Number	Sample Concentration	Surface Water Quotient Index	
			Acute	Chronic
Organics (µg/L):				
2-Butanone	NA	NA	NA	NA
Inorganics (µg/L):				
Aluminum	NA	NA	NA	NA
Arsenic	12-SW-102	23.4	0.34	1.80
Barium	NA	NA	NA	NA
Beryllium	NA	NA	NA	NA
Chromium	12-SW-102	148	0.01	2.96
Cobalt	NA	NA	NA	NA
Copper	12-SW-101	21.5	7.41	7.41
	12-SW-102	305	105.17	105.17
	12-SW-103	10.1	3.48	3.48
	12-SW-104	4.7	1.62	1.62
Iron	NA	NA	NA	NA
Lead	12-SW-101	25.2	0.11	4.94
	12-SW-102	312	1.42	61.18
Manganese	12-SW-101	547	NA	54.70
	12-SW-102	1,240	NA	124.00
	12-SW-103	507	NA	50.70
	12-SW-104	529	NA	52.90
Mercury	12-SW-102	0.79	0.38	31.6
Nickel	12-SW-102	143	1.91	17.23
Zinc	12-SW-101	204	2.15	2.37
	12-SW-102	3,800	40.00	44.19
	12-SW-103	153	1.61	1.78

NA Not Applicable
µg/L microgram per kilogram

TABLE 11

SURFACE WATER QUOTIENT INDEX PER ECOLOGICAL CONTAMINANT OF CONCERN
 SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Average Concentration	Surface Water Quotient Index	
		Acute	Chronic
Organics (µg/L):			
2-Butanone	NA	NA	NA
Inorganics (µg/L):			
Aluminum	NA	NA	NA
Arsenic	9.47	0.14	0.73
Barium	NA	NA	NA
Beryllium	NA	NA	NA
Chromium	148*	0.01	2.96
Cobalt	NA	NA	NA
Copper	85.33	29.42	29.42
Iron	NA	NA	NA
Lead	85.55	0.39	16.77
Manganese	705.75	NA	70.58
Mercury	0.79*	0.38	31.60
Nickel	143	1.91	17.23
Zinc	1,049.03	11.04	12.20
Total QI		43.29	181.49

NA Not Applicable
 QI Quotient Index
 * Maximum Value
 µg/L microgram per liter

TABLE 12

**SEDIMENT QUOTIENT INDEX PER STATION
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Analyte	Sample Number	Sample Concentration	Sediment Quotient Index	
			BSL/ER-L	ER-M
Volatile Organics (µg/kg):				
Acetone	NA	NA	NA	NA
2-Butanone	NA	NA	NA	NA
Carbon Disulfide	NA	NA	NA	NA
Inorganics (mg/kg):				
Aluminum	NA	NA	NA	NA
Arsenic	07-SED-102	8.6	1.05	0.12
Beryllium	07-SED-104	0.42	NA	1.17
Cadmium	07-SED-101	2.4	3.55	0.25
	07-SED-102	3.1	4.59	0.32
	07-SED-104	2.3	3.40	0.24
Cobalt	07-SED-101	2.5	1.67	NA
	07-SED-102	3.4	2.27	NA
Copper	07-SED-102	42.9	1.26	0.16
Silver	07-SED-101	0.75	1.02	0.20
Zinc	07-SED-102	213	1.42	0.52

BSL USEPA Region III BTAG Screening Level
ER-M Effects Range - Median
ER-L Effects Range - Low
NA Not Applicable
µg/kg microgram per kilogram
mg/kg milligram per kilogram

TABLE 13

**SEDIMENT QUOTIENT INDEX PER ECOLOGICAL CONTAMINANT OF CONCERN
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Analyte	Average Concentration	Sediment Quotient Index	
		BSL/ER-L	ER-M
Volatile Organics (µg/kg):			
Acetone	NA	NA	NA
2-Butanone	NA	NA	NA
Carbon Disulfide	NA	NA	NA
Inorganics (mg/kg):			
Aluminum	NA	NA	NA
Arsenic	3.27	0.40	0.05
Beryllium	0.35	NA	0.97
Cadmium	2.60	3.85	0.27
Cobalt	1.95	1.30	NA
Copper	14.67	0.13	0.05
Silver	0.75*	1.02	0.20
Zinc	65.53	0.44	0.16
Total QI		7.14	1.70

BSL USEPA Region III BTAG Screening Level

ER-L Effects Range - Low

ER-M Effects Range - Median

NA Not Applicable

* Maximum Value

QI Quotient Index

µg/kg microgram per kilogram

mg/kg milligram per kilogram

TABLE 14

SEDIMENT QUOTIENT INDEX PER STATION
 SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Sample Number	Sample Concentration	Sediment Quotient Index	
			BSL/ER-L	ER-M
Volatile Organics (µg/kg):				
Acetone	NA	NA	NA	NA
Inorganics (mg/kg):				
Aluminum	NA	NA	NA	NA
Cadmium	12-SED-102-06	1.2	1.78	0.13
Cobalt	12-SED-102-00	4.8	3.20	NA
Copper	12-SED-102-00	36	1.06	0.13
Lead	12-SED-102-00	66.3	1.42	0.30
	12-SED-103-00	110	2.36	0.50
Mercury	12-SED-103-00	0.28	1.87	0.39
Zinc	12-SED-102-00	383	2.55	0.93
	12-SED-102-06	233	1.55	0.57

BSL USEPA Region III BTAG Screening Level
 ER-L Effects Range - Low
 ER-M Effects Range - Median
 NA Not Applicable
 µg/kg microgram per kilogram
 mg/kg milligram per kilogram

TABLE 15

SEDIMENT QUOTIENT INDEX PER ECOLOGICAL CONTAMINANT OF CONCERN
 SITE 12
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte	Average Concentration	Sediment Quotient Index	
		BSL/ER-L	ER-M
Volatile Organics (µg/kg):			
Acetone	NA	NA	NA
Inorganics (mg/kg):			
Aluminum	NA	NA	NA
Cadmium	1.2*	1.78	0.13
Cobalt	2.53	1.69	NA
Copper	15.95	0.47	0.06
Lead	55.83	1.20	0.26
Mercury	0.28*	1.87	0.39
Zinc	163.05	1.09	0.40
Total QI		8.10	1.24

NA Not Applicable
 BSL USEPA Region III BTAG Screening Level
 ER-L Effects Range - Low
 ER-M Effects Range - Median
 QI Quotient Index
 * Maximum Value
 µg/kg microgram per kilogram
 mg/kg milligram per kilogram

TABLE 16

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Aluminum	388J - 1,690J	NE	NE	NE
Barium	17.5B - 36.8B	NE	NE	NE
Cobalt	3.4 - 5.6B	NE	NE	NE
Copper	5.3B - 14.1B	7-EBL000.01	40	91/06/25
			50U	92/04/28
			10U	94/04/12
			50	95/06/22
		7-BBY002.88	40	91/06/25
			10U	92/04/28
			50	95/06/22
		7-CCH000.00	11	90/05/24
			50	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
		7-LYN000.03	50	91/06/25
			50U	92/04/28
			10U	94/04/12
			68	95/06/22
		7-WES000.62	40	91/06/25
			50U	92/04/28
			10U	94/04/12
			50	95/06/22

TABLE 16 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Iron	1,010J - 6,890J	7-EBL000.01	NA	91/06/25
			82	92/04/28
			97	94/04/12
			440	95/06/22
		7-BBY002.88	NE	91/06/25
			111	92/04/28
			270	95/06/22
		7-CCH000.00	NE	90/05/24
			NE	91/06/19
			NE	92/04/23
			857	93/05/13
			152	94/04/27
			190	95/05/23
		7-LYN000.03	NE	91/06/25
			50U	92/04/28
			123	94/04/12
			340	95/06/22
		7-WES000.62	NE	91/06/25
			490	92/04/28
			160	94/04/12
710	95/06/22			

TABLE 16 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Lead	3.2J - 50J	7-EBL0000.01	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			5U	95/06/22
		7-BBY002.88	10U	91/06/25
			10U	92/04/28
			5U	95/06/22
		7-CCH000.00	100K	90/05/24
			10U	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
			NE	95/05/23
		7-LYN000.03	10U	91/06/25
			50U	92/04/12
			10U	94/04/12
			5U	95/06/22
		7-WES000.62	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
5U	95/06/22			

TABLE 16 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Manganese	83.9 - 334	7-EBL000.01	50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-BBY002.88	38	92/04/28
			50U	95/06/22
		7-CCH000.00	37.3	93/05/13
			14.2	94/04/27
			50U	95/05/23
		7-LYN000.03	50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-WES000.62	50U	92/04/28
			17.9	94/04/12
			50U	95/06/22

- NE Not Evaluated
- J Estimated value
- K Actual value is known to be less than value given
- B Compound Detected in Blank
- U Not Detected
- EBL Eastern Branch of Lynnhaven River
- BBY Broad Bay
- CCH Cape Charles Harbor
- LYN Mouth of Lynnhaven River
- WES Western Branch of Lynnhaven River
- µg/L microgram per kilogram

TABLE 17

**COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO REFERENCE STATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Parameter	Remedial Investigation Range of Positive Detects (mg/kg)	Reference Stations		
		STORET Station Location	STORET Concentration (mg/kg)	Date of Sample Collection
Acetone	0.37J	NE	NE	NE
2-Butanone	0.012J - 0.065	NE	NE	NE
Carbon Disulfide	0.004J	NE	NE	NE
Aluminum	221 - 6,520	7-BBY002.88	NE	93/06/08
			NE	94/04/12
			11,900	95/06/22
		7-CCH000.00	281	95/05/23
Arsenic	1.2B - 8.6	7-BBY002.88	13	93/06/08
			10	94/04/12
			10	95/06/22
		7-CCH000.00	5U	95/05/23
Beryllium	0.28B-0.42B	7-BBY002.88	5U	93/06/08
			5U	94/04/12
			5U	95/06/22
		7-CCH000.00	5U	95/05/23
Cadmium	2.3 - 3.1	7-EBL000.01	NA	NE
		7-BBY002.88	5U	93/06/08
			5U	94/04/12
			5U	95/06/22
7-CCH000.00	5U	95/05/23		
Cobalt	0.94J - 3.4J	NE	NE	NE
Copper	0.89B - 42.9	7-BBY002.88	29	93/06/08
			29	94/04/12
			8	95/06/22
		7-CCH000.00	5U	95/05/23

TABLE 17 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO REFERENCE STATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (mg/kg)	Reference Stations		
		STORET Station Location	STORET Concentration (mg/kg)	Date of Sample Collection
Silver	0.75J	7-BBY002.88	5U	93/06/08
			5U	94/04/12
			5U	95/06/22
		7-CCH000.00	5U	95/05/23
Zinc	29.5 - 213	7-BBY002.88	110	93/06/08
			130	94/04/12
			91	95/06/22
		7-CCH000.00	5U	95/05/23

- NE Not Evaluated
- B Compound Detected in Blank
- J Estimated value
- K Actual value is known to be less than value given
- U Note Detected
- BBY Broad Bay
- CCH Cape Charles Harbor
- EBL Eastern Branch of Lynnhaven River
- mg/kg milligram per kilogram

TABLE 18

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA

SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
2-Butanone	36	NE	NE	NE
Aluminum	4,320J - 81,800J	NE	NE	NE
Arsenic	2.2J - 23.4J	7-EBL000.01	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			13	95/06/22
		7-BBY002.88	10U	91/06/25
			10U	92/04/28
			14	95/06/22
		7-CCH000.00	10K	90/05/24
			10U	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
		7-LYN000.03	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			12	95/06/22
		7-WES000.62	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			13	95/06/22

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA

SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Barium	25.3J - 669J	NE	NE	NE
Beryllium	3.1J	7-EBL000.01	10U	91/06/25
			NE	92/04/28
			NE	94/04/12
			NE	95/06/22
		7-BBY002.88	10U	91/06/25
			NE	92/04/28
			NE	95/06/22
		7-CCH000.00	100K	90/05/24
			10U	91/06/19
			10U	92/04/23
			NE	93/05/13
			NE	94/04/27
		7-LYN000.03	10U	91/06/25
			NE	92/04/28
			NE	94/04/12
			NE	95/06/22
		7-WES000.62	10U	91/06/25
			NE	92/04/28
			NE	94/04/12
			NE	95/06/22

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Chromium	148J	7-EBL000.01	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-BBY002.88	10U	91/06/25
			10U	92/04/28
			50U	95/06/22
		7-CCH000.00	10K	90/05/24
			50U	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
		7-LYN000.03	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-WES000.62	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22
Cobalt	64J	NE	NE	NE

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Copper	4.7J - 305J	7-EBL000.01	40	91/06/25
			50U	92/04/28
			10U	94/04/12
			50	95/06/22
		7-BBY002.88	40	91/06/25
			10U	92/04/28
			50	95/06/22
		7-CCH000.00	11	90/05/24
			50	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
		7-LYN000.03	50	91/06/25
			50U	92/04/28
			10U	94/04/12
			68	95/06/22
		7-WES000.62	40	91/06/25
			50U	92/04/28
			10U	94/04/12
			50	95/06/22

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Iron	2,900J - 94,800J	7-EBL000.01	NE	91/06/25
			82	92/04/28
			97	94/04/12
			440	95/06/22
		7-BBY002.88	NE	91/06/25
			111	92/04/28
			270	95/06/22
		7-CCH000.00	NE	90/05/24
			NE	91/06/19
			NE	92/04/23
			857	93/05/13
			152	94/04/27
			190	95/05/23
		7-LYN000.03	NE	91/06/25
			50U	92/04/28
			123	94/04/12
			340	95/06/22
		7-WES000.62	NE	91/06/25
			490	92/04/28
			160	94/04/12
710	95/06/22			

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Lead	2J - 312J	7-EBL000.01	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			5U	95/06/22
		7-BBY002.88	10U	91/06/25
			10U	92/04/28
			5U	95/06/22
		7-CCH000.00	100K	90/05/24
			10U	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
			NE	95/05/23
		7-LYN000.03	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			5U	95/06/22
		7-WES000.62	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
5U	95/06/22			

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA

SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Manganese	507J - 1,240J	7-EBL000.01	50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-BBY002.88	38	92/04/28
			50U	95/06/22
		7-CCH000.00	37.3	93/05/13
			14.2	94/04/27
			50U	95/05/23
		7-LYN000.03	50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-WES000.62	50U	92/04/28
			17.9	94/04/12
			50U	95/06/22
		Mercury	0.79J	NE

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Nickel	143J	7-EBL000.01	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-BBY002.88	10U	91/06/25
			10U	92/04/28
			50U	95/06/22
		7-CCH000.00	10K	90/05/24
			10U	91/06/19
			10U	92/04/23
			10U	93/05/13
			10U	94/04/27
		7-LYN000.03	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22
		7-WES000.62	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22

TABLE 18 (Continued)

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (µg/L)	Reference Stations		
		STORET Station Location	STORET Concentration (µg/L)	Date of Sample Collection
Zinc	39.1 - 3,800J	7-EBL000.01	10U	91/06/25
			50U	92/04/28
			10	94/04/12
			50U	95/06/22
		7-BBY002.88	10U	91/06/25
			14	92/04/28
			50U	95/06/22
		7-CCH000.00	5K	90/05/24
			10U	91/06/19
			10U	92/04/23
			30	93/05/13
			10U	94/04/27
		7-LYN000.03	10	91/06/25
			50U	92/04/28
			16	94/04/12
			50U	95/06/22
		7-WES000.62	10U	91/06/25
			50U	92/04/28
			10U	94/04/12
			50U	95/06/22

TABLE 18 (Continued)

**COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO REFERENCE STATION DATA**

SITE 12

**NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

NE	Not Evaluated
J	Estimate value
K	Actual value is known to be less than value given
U	Not detected
EBL	Eastern Branch of Lynnhaven River
BBY	Broad Bay
CCH	Cape Charles Harbor
LYN	Mouth of Lynnhaven River
WES	Western Branch of Lynnhaven River
µg/L	microgram per liter

TABLE 19

COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO REFERENCE STATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter	Remedial Investigation Range of Positive Detects (mg/kg)	Reference Stations		
		STORET Station Location	STORET Concentration (mg/kg)	Date of Sample Collection
Acetone	0.008J - 0.082J	NE	NE	NE
Aluminum	1,130J - 11,700J	7-BBY002.88	NE	93/06/08
			NE	94/04/12
			11,900	95/06/22
		7-CCH000.00	281	95/05/23
Cadmium	1.2J	7-BBY002.88	5U	93/06/08
			5U	94/04/12
			5U	95/06/22
		7-CCH000.00	5U	95/05/23
Cobalt	1.3J - 4.8J	NE	NE	NE
Copper	2.3J - 36J	7-BBY002.88	29	93/06/08
			29	94/04/12
			8	95/06/22
		7-CCH000.00	5U	95/05/23
Lead	8.7J - 110J	7-BBY002.88	27	93/06/08
			22	94/04/12
			22	95/06/22
		7-CCH000.00	5U	95/05/23
Mercury	0.28J	NE	NE	NE
Zinc	6.1J - 383J	7-BBY002.88	110	93/06/08
			130	94/04/12
			91	95/06/22
		7-CCH000.00	5U	95/05/23

NE Not Evaluated
 J Estimate value
 U Not Detected
 BBY Broad Bay
 CCH Cape Charles Harbor
 mg/kg milligram per kilogram

TABLE 20

**COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO PREVIOUS REMEDIAL INVESTIGATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Parameter ⁽¹⁾	Remedial Investigation Site 7 (µg/L)	Round 1 Verification Study Site 7 (µg/L)	Interim Remedial Investigation Site 7 (µg/L)
Aluminum	388J - 1,690J	NA	117B - 601B
Barium	17.5B - 36.8B	NA	ND
Cobalt	3.4 - 5.6B	NA	ND
Copper	5.3B - 14.1B	50	13B
Iron	1,010J - 6,890J	NA	121B - 6,000
Manganese	83.9 - 334	NA	4 - 533

- (1) Parameters are ECOCs identified during the ecological RA
 B Compound Detected in Blank
 J Estimate Value
 U Not Detected
 NA Not Analyzed
 ND Not Detected
 µg/L microgram per kilogram

TABLE 21

**COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO PREVIOUS REMEDIAL INVESTIGATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Parameter ⁽¹⁾	Remedial Investigation Site 7 (mg/kg)	Round 1 Verification Study Site 7 (mg/kg)
Acetone	0.37J	16 - 27
2-Butanone	0.012J - 0.065	NA
Carbon Disulfide	0.004J	2.2
Aluminum	221 - 6,520	NA
Arsenic	1.2B - 8.6	4.8 - 34
Beryllium	0.28B - 0.42B	0.3 - 0.7
Cadmium	2.3 - 3.1	ND
Cobalt	0.94J - 3.4J	NA
Copper	0.89B - 42.9	5.2 - 33.9
Silver	0.75J	ND
Zinc	29.5 - 213	12.4 - 135

- (1) Parameters are ECOCs identified during the ecological RA
 J Estimate Value
 B Compound Detected in Blank
 NA Not Analyzed
 ND Not Detected
 mg/kg milligram per kilogram

TABLE 22

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO PREVIOUS REMEDIAL INVESTIGATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter ⁽¹⁾	Remedial Investigation Site 12 (µg/L)	Round 1 Verification Study Site 12 (µg/L)	Interim Remedial Investigation Site 12 (µg/L)
2-Butanone	36	NA	ND
Aluminum	4,320J - 81,800J	NA	NA
Arsenic	2.2J - 23.4J	NA	NA
Barium	25.3J - 669J	NA	NA
Beryllium	3.1J	NA	NA
Chromium	148J	NA	NA
Cobalt	64J	NA	NA
Copper	4.7J - 305J	NA	NA
Iron	2,900J - 94,800J	NA	NA
Lead	2J - 312J	NA	NA
Manganese	507J - 1,240J	NA	NA
Mercury	0.79J	NA	NA
Nickel	143J	NA	NA
Zinc	39.1 - 3,800J	NA	NA

- ⁽¹⁾ Parameters are ECOCs identified during the ecological RA
J Estimated Value
NA Not Analyzed
ND Not Detected
µg/L microgram per liter

TABLE 23

**COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO PREVIOUS REMEDIAL INVESTIGATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Parameter ⁽¹⁾	Remedial Investigation Site 12 (mg/kg)	Round 1 Verification Study Site 12 (mg/kg)	Interim Remedial Investigation Site 12 (mg/kg)	Canal Sediment Study Site 12 (mg/kg)
Acetone	0.008J - 0.082J	18 - 230	92B - 160B	0.007J - 0.35
Aluminum	1,130J - 11,700J	NA	NA	1,020 - 11,600
Cadmium	1.2J	NA	NA	ND
Cobalt	1.3J - 4.8J	NA	NA	1.2J - 5J
Copper	2.3J - 36J	NA	NA	2.9J - 54.1J
Lead	8.7J - 110J	NA	NA	6.8 - 129
Mercury	0.28J	NA	NA	0.19J - 0.35J
Zinc	6.1J - 383J	NA	NA	15.9 - 267

- (1) Parameters are ECOCs identified during the ecological RA
- J Estimate value
- B Estimate value biased low
- NA Not Analyzed
- ND Not Detected
- mg/kg milligram per killigram

TABLE 24

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
 TO NON-RELATED REMEDIAL INVESTIGATION SURFACE WATER DATA
 SITE 7
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Parameter ⁽¹⁾	Remedial Investigation Site 7 (µg/L)	Ewing <i>et. al.</i> , 1992 (µg/L)	Base Study, 1994 (µg/L)	Base Study, 1995 (µg/L)
Aluminum	388J - 1,690J	NA	NA	NA
Barium	17.5B - 36.8B	NA	NA	NA
Cobalt	3.4 - 5.6B	NA	NA	NA
Copper	5.3B - 14.1B	0.42 - 0.97	NA	NA
Iron	1,010J - 6,890J	NA	NA	NA
Manganese	83.9 - 334	NA	NA	NA

- (1) Parameters are ECOCs identified during the ecological RA
 J Estimate Value
 B Compound Detected in Blank
 NA Not Analyzed
 ND Not Detected
 µg/L microgram per liter

TABLE 25

COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO NON-RELATED REMEDIAL INVESTIGATION DATA
SITE 7
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter ⁽¹⁾	Remedial Investigation Site 7 (mg/kg)	AMRL, 1992 (mg/kg)	Base Study, 1994 (mg/kg)	Base Study, 1995 (mg/kg)	Dredging Data, 1989/90 (mg/kg)	Dredging Data, 1991 (mg/kg)
Acetone	0.37J	NA	NA	NA	0.19J - 0.22J	NA
2-Butanone	0.012J - 0.065	NA	NA	NA	<0.5	NA
Carbon Disulfide	0.004J	NA	NA	NA	<0.025	NA
Aluminum	221 - 6,520	NA	NA	NA	NA	NA
Arsenic	1.2B - 8.6	8.74 - 12.88	NA	NA	0.7 - 7.5	NA
Beryllium	0.28B - 0.42B	0.48 - 0.82	NA	NA	<0.5 - 1.1	NA
Cadmium	2.3 - 3.1	4 - 6.6	ND	1.14	<0.01 - 1.44	0.39 - 2.58
Cobalt	0.94J - 3.4J	NA	NA	NA	NA	NA
Copper	0.89B - 42.9	18.98 - 115.27	NA	NA	0.6 - 195	3.82 - 242
Silver	0.75J	0.92 - 3.29	NA	NA	<0.1 - 1.1	NA
Zinc	29.5 - 213	75.24 - 293.81	NA	NA	11.3 - 1,010	13.6 - 499

⁽¹⁾ Parameters are ECOCs identified during the ecological RA
J Estimate Value
B Compound Detected in Blank
NA Not Analyzed
ND Not Detected
AMRL Old Dominion University, Applied Marine Research Laboratory
mg/kg milligram per kilogram

TABLE 26

COMPARISON OF REMEDIAL INVESTIGATION SURFACE WATER DATA
TO NON-RELATED REMEDIAL INVESTIGATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter ⁽¹⁾	Remedial Investigation Site 12 (µg/L)	AMRL, 1992 (µg/L)	Base Study, 1994 (µg/L)	Base Study, 1995 (µg/L)
2-Butanone	36	NA	NA	NA
Aluminum	4,320J - 81,800J	NA	NA	NA
Arsenic	2.2J - 23.4J	0.3 - 0.7	NA	NA
Barium	25.3J - 669J	NA	NA	NA
Beryllium	3.1J	ND	NA	NA
Chromium	148J	2 - 6	NA	NA
Cobalt	64J	NA	NA	NA
Copper	4.7J - 305J	0.42 - 0.97	NA	NA
Iron	2,900J - 94,800J	NA	NA	NA
Lead	2J - 312J	0.2 - 1.5	NA	NA
Manganese	507J - 1,240J	NA	NA	NA
Mercury	0.79J	0.26	NA	NA
Nickel	143J	ND	NA	NA
Zinc	39.1 - 3,800J	5 - 16	NA	NA

- ⁽¹⁾ Parameters are ECOCs identified during the ecological RA
 J Estimate Value
 NA Not Analyzed
 ND Not Detected
 AMRL Old Dominion University, Applied Marine Research Laboratory
 µg/L microgram per liter

TABLE 27

COMPARISON OF REMEDIAL INVESTIGATION SEDIMENT DATA
TO NON-RELATED REMEDIAL INVESTIGATION DATA
SITE 12
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

Parameter ⁽¹⁾	Remedial Investigation Site 12 (mg/kg)	Ewing et. al., 1992 (mg/kg)	Base Study, 1994 (mg/kg)	Base Study, 1995 (mg/kg)	Dredging Data, 1989/90 (mg/kg)	Dredging Data, 1991 (mg/kg)
Acetone	0.008J - 0.082J	NA	NA	NA	0.019J - 0.22J	NA
Aluminum	1,130J - 11,700J	NA	NA	NA	NA	NA
Cadmium	1.2J	4 - 6.6	ND	1.14	<0.01 - 1.44	0.39 - 2.58
Cobalt	1.3J - 4.8J	NA	NA	NA	NA	NA
Copper	2.3J - 36J	18.98 - 115.27	NA	NA	0.6 - 195	3.82 - 242
Lead	8.7J - 110J	10 - 47	NA	NA	5.4 - 105	7.64 - 137
Mercury	0.28J	0.89 - 9.99	0.0445 - 0.0518	0.0987	<0.1 - 1.14	0.12 - 0.61
Zinc	6.1J - 383J	75.24 - 293.81	NA	NA	11.3 - 1,010	13.6 - 499

⁽¹⁾ Parameters are ECOCs identified during the ecological RA

J Estimate Value

NA Not Analyzed

ND Not Detected

mg/kg milligram per kilogram

TABLE 28

**BENTHIC MACROINVERTEBRATE DENSITY COMPARISON
LITTLE CREEK HARBOR
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

Species	Density (individuals/m ²)				
	Little Creek Site ⁽¹⁾	Tidal Creek Mud Sites ⁽²⁾	Lynnhaven Roads Sites ⁽²⁾	Inlet-Shoal Sites ⁽²⁾	Narrows Site ⁽²⁾
<i>Polydora ligni</i> (P)	6,291				552
<i>Parapionosyllis longicirrata</i> (P)				3,850	
<i>Streblospio benedicti</i> (P)	2,644	1,409	83		1,850
<i>Clymenella torquata</i> (P)					2,430
<i>Cirratulidae</i> spp. (P)	2,233				
<i>Capitella capitata</i> (P)	1,944				
<i>Mediomastus ambiseta</i> (P)	1,812	98	968		836
<i>Ophelia bicornis</i> (P)				1,042	
<i>Tellina agilis</i> (B)			610	316	
<i>Tubificoides</i> sp. (O)		356	641		
<i>Listriella clymenellae</i> (A)					303
<i>Cautleriella</i> sp. (P)			261		
<i>Eteone heteropoda</i> (P)	218	18			128
<i>Microphthalmus similis</i> (P)				195	
<i>Paraprionospio pinnata</i> (P)	136	79	235		
<i>Molgulia manhattensis</i> (AS)					197
<i>Streptosyllis</i> sp. (P)				181	
<i>Paraonis fulgens</i> (P)				127	
Nemertean sp. (N)		24	121	89	
<i>Ilyanassa obsoleta</i> (G)					115
<i>Corophium tuberculatum</i> (A)			114		
<i>Spiophanes bombyx</i> (P)			99		
<i>Gemma gemma</i> (B)				89	
<i>Tubificoides gabriellae</i> (O)	85				
<i>Capitellid</i> spp. (P)		67			
<i>Polycladida</i> sp. (F)				55	
<i>Sphaerosyllis hystrix</i> (P)				51	
<i>Leitoscoloplos fragilis</i> (P)	42				
<i>Glycinde solitaria</i> (P)		40	113		153

P Polychaete
B Bivalve
O Oligochaete
A Amphipod
AS Ascidiacea

N Nemertean
F Flatworm
(¹) Ewing *et al.*, 1988.
(²) Tourtellotte and Dauer, 1983.

TABLE 29

**BENTHIC MACROINVERTEBRATE RESTORATION GOALS
LITTLE CREEK HARBOR
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA**

RGI Parameters	RGI Values ⁽¹⁾	Little Creek Harbor Values	RGI Rating
Shannon-Weiner Diversity	2, 3	2.33	3
Abundance (#/m ²)	500, 1000	22967	5
Biomass (g/m ²)	0.5, 0.8	3.59	5
% Opportunistic Biomass	50, 15	18.07	3
% Opportunistic Abundance	--	NE	NA
% Equilibrium Biomass	--	3.7	NA
% Equilibrium Abundance	--	NE	NA
% of Taxa >5cm below sed. surface	10, 40	NE	NA
% of Biomass >5cm below sed. surface	10, 50	NE	NA
% Carnivore and Omnivore Abundance	10, 30	NE	NA
RGI			4

RGI Benthic Macroinvertebrate Restoration Goals Index

NA Not Applicable

NE Not Analyzed

Sediment Type: Mud

Salinity Grade: High Mesohaline

⁽¹⁾ Ranasinghe *et al.*, 1993.

TABLE 30

FISH TISSUE DETECTION SUMMARY - BASE STUDIES
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Analyte (µg/kg)	Base Study 1994 ⁽¹⁾				Base Study 1995 ⁽²⁾	
	Crabs 1-8	Crabs 1-7	Croaker #1	Spot 1-3	Canal-Crabs	Pier58-Croaker
Total Mercury	225	193	134	132	97.4	148
Tributyl-Tin	ND	ND	ND	ND	28	6

ND Not Detected

⁽¹⁾ NAB, 1994

⁽²⁾ NAB, 1995a

µg/kg microgram per kilogram

FIGURES

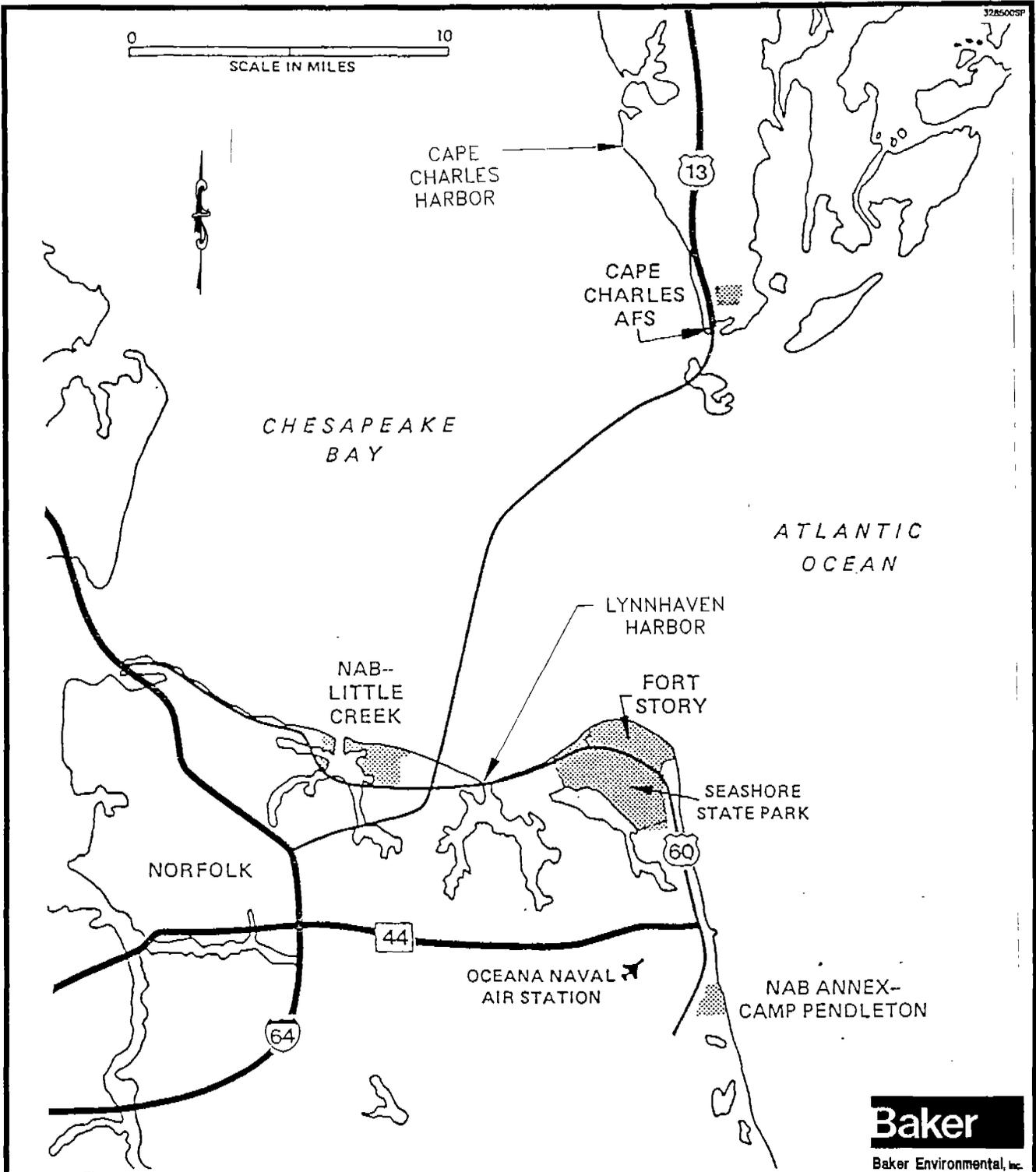


FIGURE 1
REGIONAL LOCATION MAP

NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA

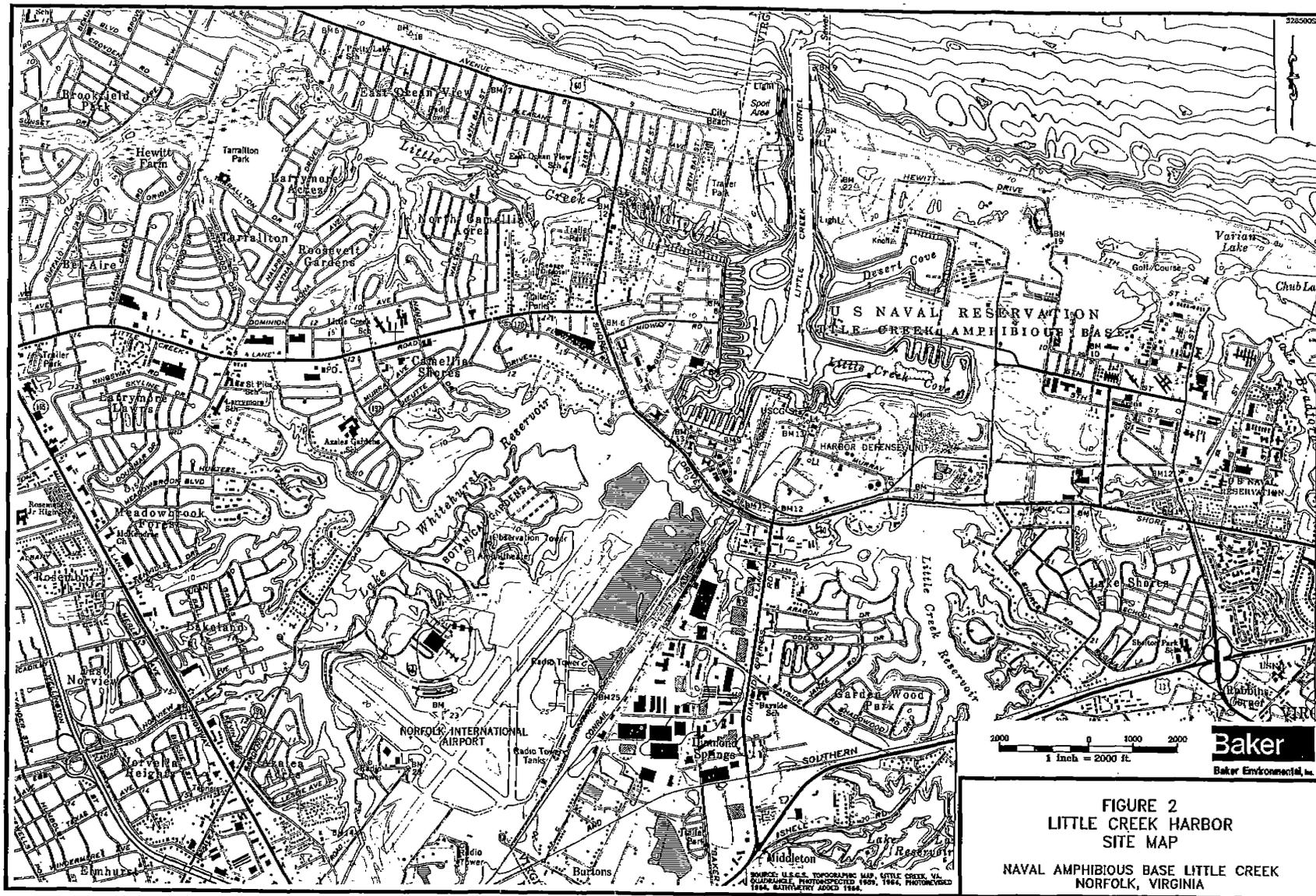
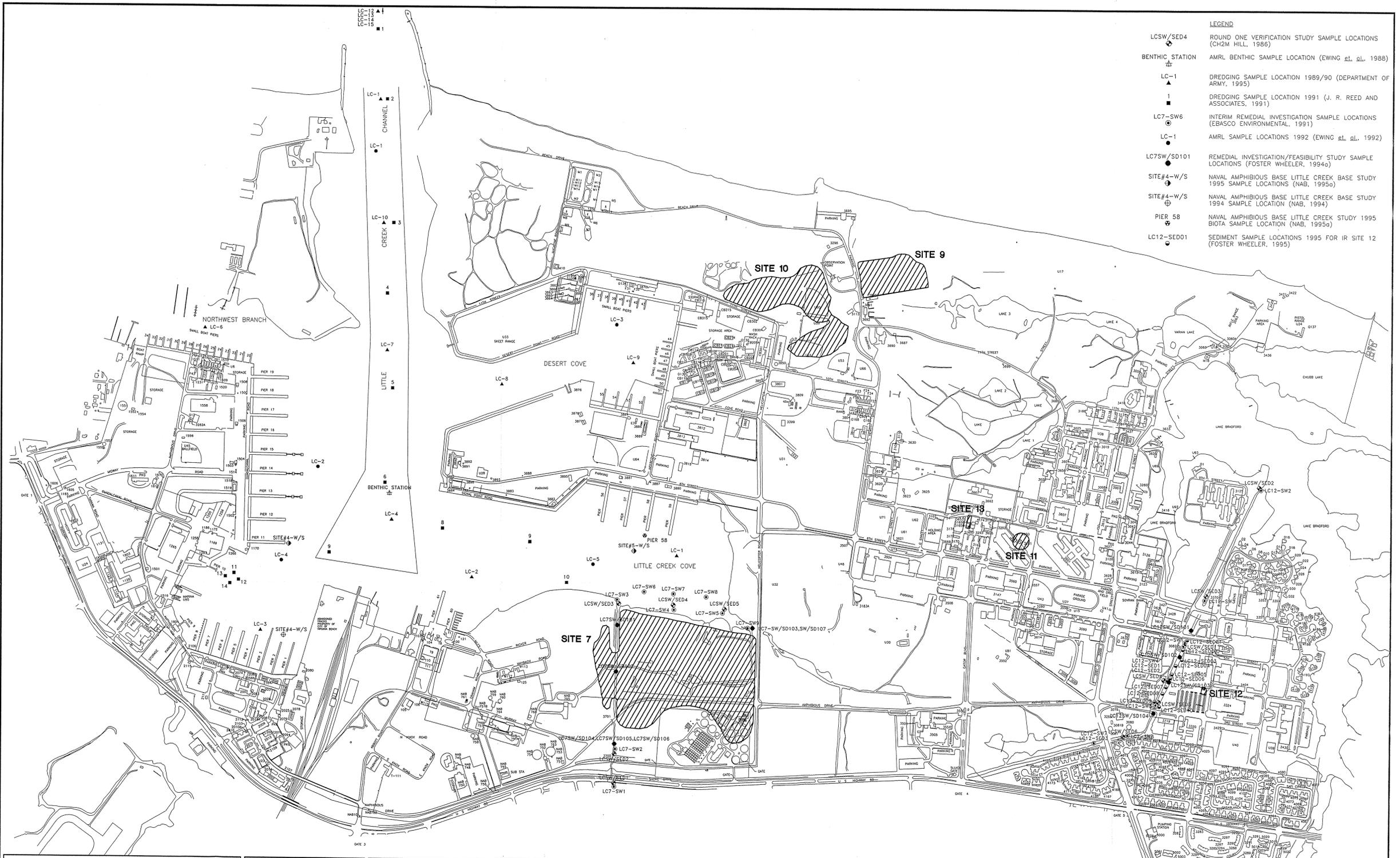


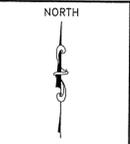
FIGURE 2
LITTLE CREEK HARBOR
SITE MAP
NAVAL AMPHIBIOUS BASE LITTLE CREEK
NORFOLK, VIRGINIA



- LEGEND**
- LC7SW/SED4 ROUND ONE VERIFICATION STUDY SAMPLE LOCATIONS (CH2M HILL, 1986)
 - BENTHIC STATION AMRL BENTHIC SAMPLE LOCATION (EWING et al., 1988)
 - LC-1 DREDGING SAMPLE LOCATION 1989/90 (DEPARTMENT OF ARMY, 1995)
 - 1 DREDGING SAMPLE LOCATION 1991 (J. R. REED AND ASSOCIATES, 1991)
 - LC7-SW6 INTERIM REMEDIAL INVESTIGATION SAMPLE LOCATIONS (EBASCO ENVIRONMENTAL, 1991)
 - LC-1 AMRL SAMPLE LOCATIONS 1992 (EWING et al., 1992)
 - LC7SW/SD101 REMEDIAL INVESTIGATION/FEASIBILITY STUDY SAMPLE LOCATIONS (FOSTER WHEELER, 1994a)
 - SITE#4-W/S NAVAL AMPHIBIOUS BASE LITTLE CREEK BASE STUDY 1995 SAMPLE LOCATIONS (NAB, 1995a)
 - SITE#4-W/S NAVAL AMPHIBIOUS BASE LITTLE CREEK BASE STUDY 1994 SAMPLE LOCATION (NAB, 1994)
 - PIER 58 NAVAL AMPHIBIOUS BASE LITTLE CREEK STUDY 1995 BIOTA SAMPLE LOCATION (NAB, 1995a)
 - LC12-SED01 SEDIMENT SAMPLE LOCATIONS 1995 FOR IR SITE 12 (FOSTER WHEELER, 1995)

REVISIONS	

DRAWN	WJH
REVIEWED	JAG
S.O.#	62470-328-0000-07000
CADD#	328501SP



LITTLE CREEK PREVIOUS INVESTIGATION SAMPLE LOCATIONS
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

Baker
 Baker Environmental, Inc.
 Coraopolis, Pennsylvania

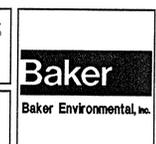
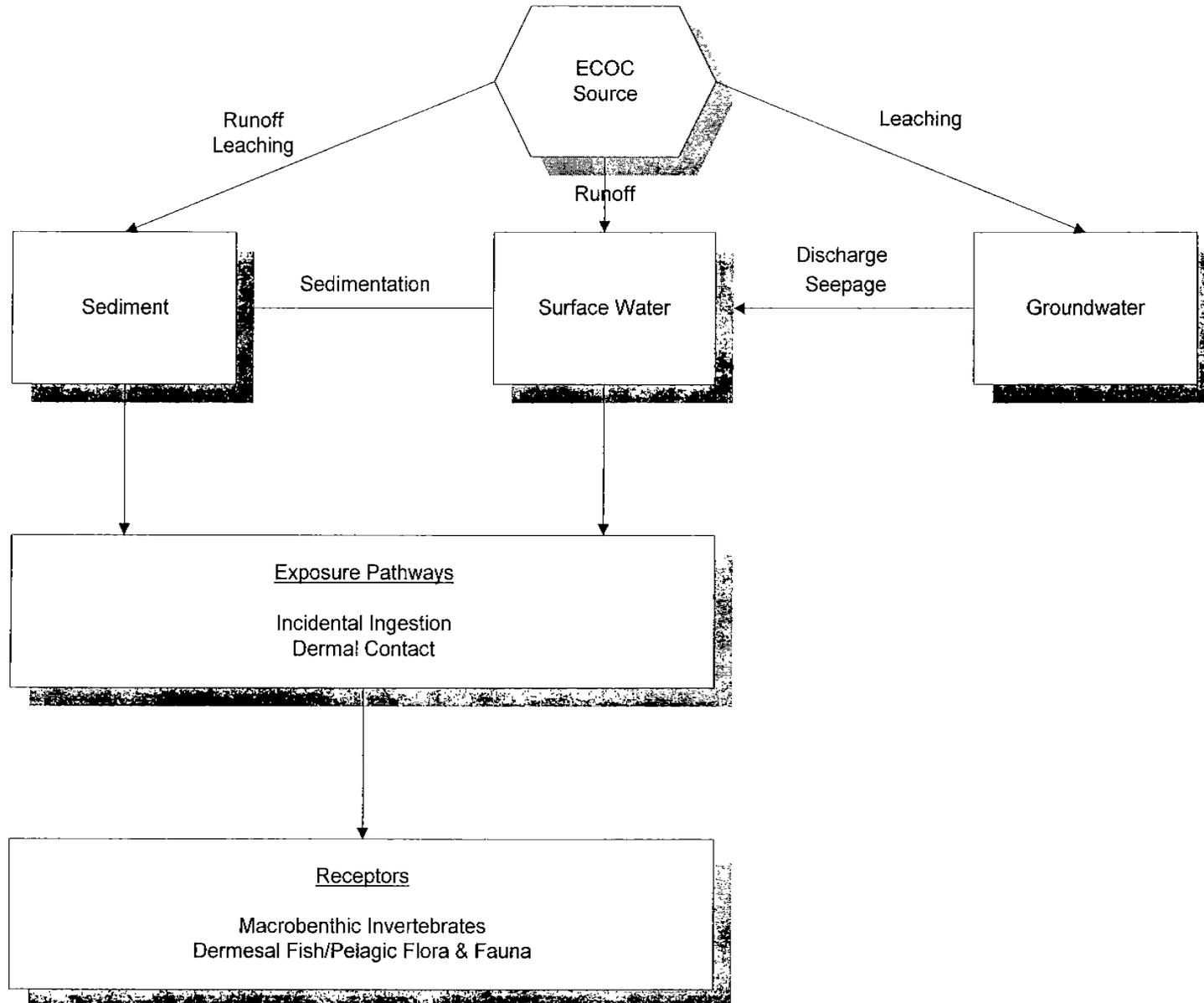


FIGURE 3
 LITTLE CREEK HARBOR PREVIOUS INVESTIGATION
 SAMPLE LOCATIONS
 NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

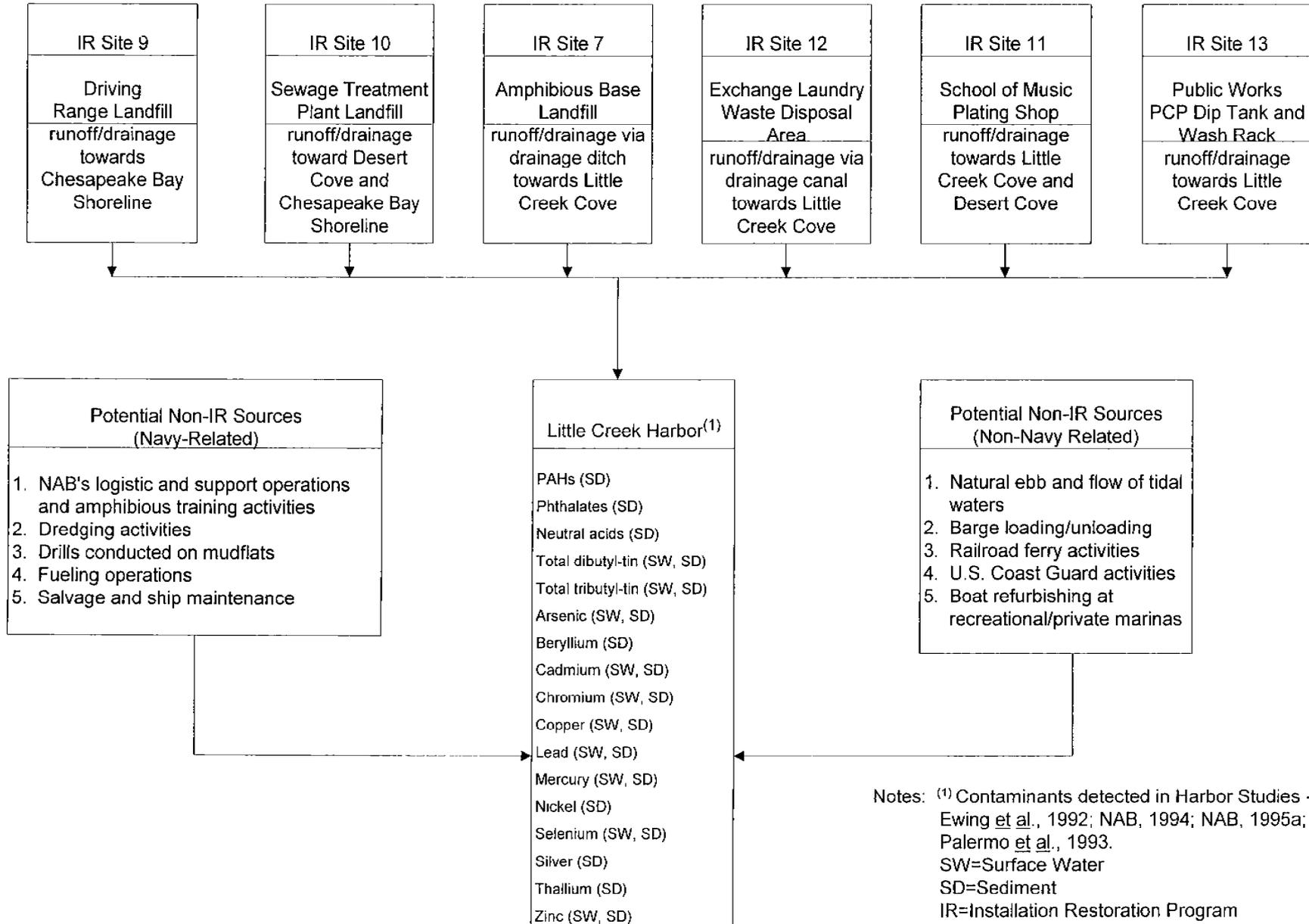
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 DATE APRIL, 1996

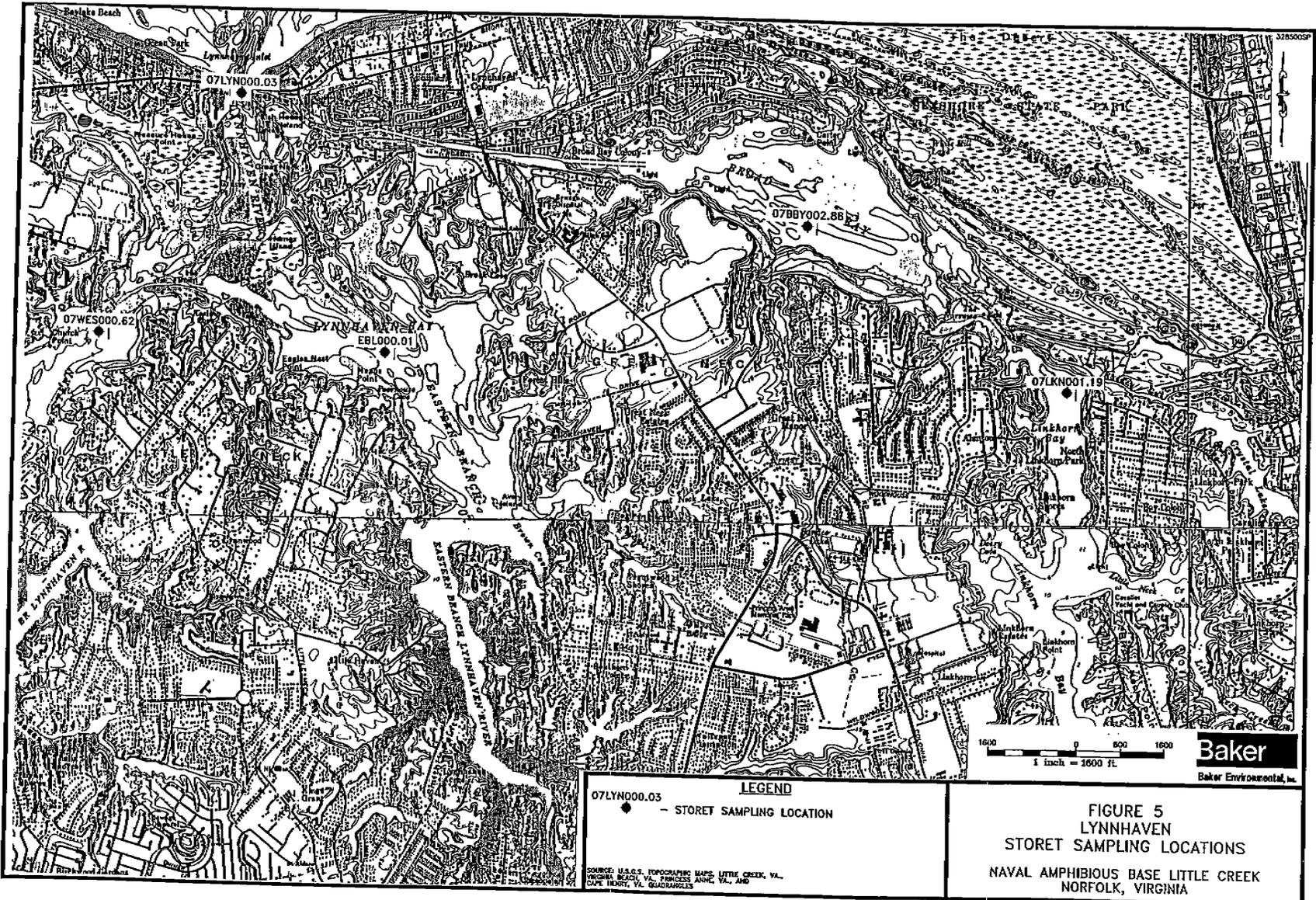
FIGURE NO.
7

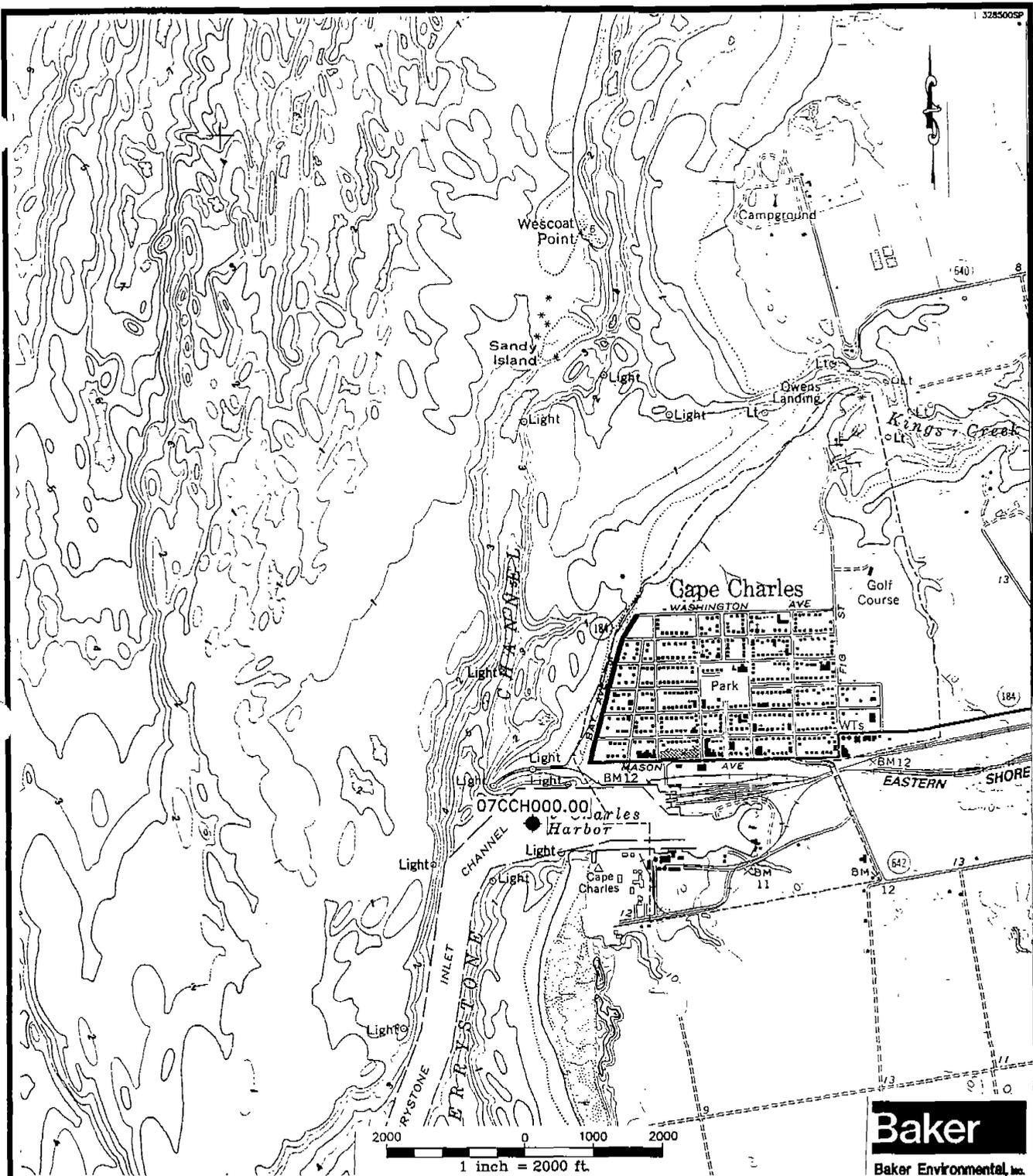
Figure 6
Conceptual Model
Potential Exposure Pathways and Ecological Receptors
Naval Amphibious Base Little Creek



**FIGURE 7
CONCEPTUAL MODEL
POTENTIAL ECOC SOURCES TO LITTLE CREEK HARBOR
NAVAL AMPHIBIOUS BASE LITTLE CREEK**







LEGEND
 07CCH000.00 - STORET SAMPLING LOCATION

FIGURE 4
CAPE CHARLES HARBOR
STORET SAMPLING LOCATION

NAVAL AMPHIBIOUS BASE LITTLE CREEK
 NORFOLK, VIRGINIA

SOURCE: U.S.G.S. TOPOGRAPHIC MAP, CAPE CHARLES QUADRANGLE, 1988, PHOTOREVISED 1986, BATHYMETRY ADDED 1986.