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RCRA Facilities Investigation/ Remedial Investigation

for

Site/SWMU 3 – Causeway Landfill

Marine Corps Recruit Depot

Parris Island, South Carolina

Volume I - Text

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MARINE CORPS RECRUIT DEPOT PARRIS ISLAND, SOUTH CAROLINA

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29406

Submitted by:
Tetra Tech, NUS, Inc.
661 Andersen Drive
Foster Plaza 7
Pittsburgh, Pennsylvania 15220

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PREPARED UNDER THE SUPERVISION OF:

DAVID D. BRAYACK, P.E.
TASK ORDER MANAGER
TETRA TECH NUS, INC.
PITTSBURGH, PENNSYLVANIA

APPROVED FOR SUBMITTAL BY:

DEBBIE WROBLEWSKI
PROGRAM MANAGER
TETRA TECH NUS, INC.
PITTSBURGH, PENNSYLVANIA

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ACRONYM LIST

ABB-ES	ABB Environmental Services
AOC	Area of Concern
AVS	Acid Volatile Solids
AWQC	Ambient Water Quality Criteria
ASTDR	Agency for Toxic Substances and Disease Registry
B&R Environmental	Brown & Root Environmental
BAF	Bioaccumulation Factors
BCF	Bioconcentration Factor
BEHP	bis(2-ethylhexyl)phthalate
BSAF	Biota Sediment Accumulation Factor
bgs	below ground surface
CAMP	Corrective Action Management Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
cm/s	centimeters per second
CMS	Corrective Measures Study
COC	Contaminant of Concern
COE	U.S. Army Corps of Engineers
COPC	Contaminant of Potential Concern
CSF	Cancer Slope Factor
CTO	Contract Task Order
CWA	Clean Water Act
DEHP	diethylexyl phthalate
DDTR	Sum of the concentrations of DDD, DDE, and DDT isomers
DQO	Data Quality Objective
ERA	Ecological Risk Assessment
ER-L	Effects Range Low
ER-M	Effects Range Medium
ERT	Environmental Response Team
ESI	Extended Site Inspection
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
gpd/ft	gallons per day per foot
gpm	gallons per minute

HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
IAS	Initial Assessment Study
ICV	Initial calibration verification
ID	Inside Diameter
IDW	Investigation Derived Waste
IEUBK Model	Integrated Exposure Uptake Biokinetic Model
ILCR	Incremental Lifetime Cancer Risk
IR	Installation Restoration
IRIS	Integrated Risk Information System
LOAEL	Lowest Observed Adverse Effect Level
MCLs	Maximum Contaminant Levels
MCRD	Marine Corps Recruit Depot
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mS/cm	milliSiemens per centimeter
msl	mean sea level
NACIP	Naval Assessment and Control of Installation Pollutants
NAVFAC	Naval Facilities Engineering Command
Navy	United States Navy
NCEA	National Center for Environmental Assessment
NEESA	Naval Energy and Environmental Support Activitiy
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NPL	National Priorities List
NTU	Nephelometric Turbidity Units
OC	Organic Carbon
PAHs	Polycyclic Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Completeness, and Comparability
PCBs	Polychlorinated Biphenyls
PCE	Tetrachloroethene
PEL	Probable Effects Level
PID	Photo-Ionization Detector
PR	Preliminary Review
psi	pounds per square inch
PVC	Polyvinyl Chloride

QAP	Quality Assurance Plan
QA/QC	Quality Assurance/Quality Control
RBC	Risk-based Concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facilities Assessment
RfC	Reference Concentration
RfD	Reference Dose
RFI	RCRA Facilities Investigation
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RPD	Relative percent difference
SARA	Superfund Amendments and Reauthorization Act
SCDHEC	South Carolina Department of Health & Environmental Control
SCDNR	South Carolina Department of Natural Resources
SMDP	Scientific/Management Decision Point
SOUTHDIV	Southern Division
SOUTHNAVFAC	Southern Division Naval Facilities
SSL	Soil Screening Level
SVOCs	Semivolatile Organic Compounds
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TCE	Trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total dissolved solids
TEF	Toxicity Equivalence Factor
TEL	Threshold Effects Level
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
TSS	Total suspended solids
TtNUS	Tetra Tech, NUS, Inc.
UCL	Upper Confidence Limit
µg/kg	micrograms per kilogram
µg/l	micrograms per liter
U.S. EPA	United States Environmental Protection Agency
USFWS	United States Fish & Wildlife Service
VOCs	Volatile Organic Compounds
VS	Verification Step

WQC	Water Quality Criteria
WQS	Water Quality Standard

EXECUTIVE SUMMARY

PURPOSE AND OBJECTIVES OF REPORT

This Remedial Investigation (RI)/RCRA Facility Investigation (RFI) report summarizes the 1998 and 1999 field activities and results for the Causeway Landfill (Site 3/Solid Waste Management Unit [SWMU] 3) located at the Marine Corps Recruit Depot (MCRD) Parris Island, South Carolina. The report encompasses the RI/RFI activities and also references previous investigations, as relevant. The historical activities include an Initial Assessment Study in 1986, a Verification Step in 1990, an Interim RCRA Facility Assessment in 1990, and an Extended Site Inspection in 1993. This RI/RFI report describes the collection of soil, sediment, surface water, and groundwater samples in accordance with the RI/RFI Work Plan, evaluates the analytical data, assesses human health and ecological risks, and provides recommendations.

HISTORICAL INFORMATION

MCRD Parris Island is located along the southern coast of South Carolina, approximately 1 mile south of the city of Port Royal and 3 miles south of the city of Beaufort within Beaufort County. MCRD Parris Island covers approximately 8,047 acres that consist of dry land, salt marshes, saltwater creeks, and ponds. MCRD Parris Island is the reception and recruit training facility for the Marine Corps for enlisted men from states east of the Mississippi River and for enlisted women nationwide.

Site 3 is an integral part of a causeway connecting Horse Island and Parris Island, in the north section of MCRD Parris Island. The causeway is a gravel, two-lane road consisting of alternate layers of solid waste and fill dirt constructed along a tidal marsh of the Broad River (across Ribbon Creek). Pipes are buried beneath the causeway to allow tidal movement between the surface water bodies separated by the unit.

The Causeway Landfill (Site 3) functioned as the major disposal area for trash and other materials discarded in dumpsters around the MCRD during most of the period between 1960 and 1972. The solid waste disposed at the site included empty pesticide containers, oily rags, spent absorbent, petroleum and chlorinated solvent sludge, perchloroethylene (PCE) still bottoms, mercury amalgam and beryllium waste, polychlorinated-biphenyl (PCB)-contaminated oil, and metal shavings. The causeway was also constructed with fill dirt taken from the borrow pits.

The causeway is approximately 10 acres in size, 4,000 feet long, 100 feet wide, and 10 feet high (above the water surface), with a gravel road surface and rip-rap sides overgrown with vegetation.

The RI/RFI field investigation was conducted from May 1998 to September 1998 and August 1999 and included sampling of soils, surface water, sediment, and groundwater, and establishment of background conditions. The purpose of these activities was to characterize the nature and extent of contamination at Site 3 where the potential for off-site migration exists. Both human health and ecological risk assessments are included in this report to support site decisions.

Data collected during the investigation have been entered into a database. The database was used in this report to support the risk assessments, including the comparison of analytical results to state and federal standards and to background levels. Data evaluation and recommendations for Site 3 are included herein. Data validation on these data consisted of either a data review or a full data validation. The full data validation was performed on approximately 10 percent of the data packages received from a laboratory. All analytes were covered by at least one full data validation. A data review was performed on the remaining data packages for the purposes of identifying false positive and negative results.

INVESTIGATION SUMMARY

During the 1998 RI/RFI investigation, groundwater, surface soils, sediment, and surface water samples were collected and analyzed for TCL/TAL and other selected parameters (e.g. geotechnical properties). Select samples were analyzed for Appendix IX constituents. 1998 field activities include the following:

- 4 groundwater monitoring wells were installed and developed (3 shallow and 1 deep)
- 4 groundwater samples were collected (one from each well) using low flow sample techniques
  a tidal influence study was conducted using the monitoring wells and surface water bodies
- slug tests were conducted on each well to determine hydraulic parameters
- 20 surface water were collected
- 21 sediment samples were collected
- 17 surface soil samples were collected
- sample locations were surveyed to establish horizontal and vertical control

In August 1999, 12 sediment samples were collected to better define detections of organics observed in the 1998 sediment samples.

SITE GEOLOGY/HYDROGEOLOGY RESULTS

Surface soils collected from the causeway landfill during the 1998 field event consisted of fine to medium sands with a varying silt content. Riprap consisting of concrete fragments was observed along the flanks

of the causeway. Sediment samples collected from the marsh and pond along the causeway consisted of silts and clays, with a varying sand content.

Generally, the shallow subsurface geology of the study area consists of fill material and a heterogeneous mixture of tidal and storm-deposited clay and sand. In the center of the causeway, fill material was encountered to depths of at least 10.5 to 18 feet bgs. The fill soils consisted of sand with a varying amount of silt. The observed refuse within the soil boring samples consisted of a large amount of wood fragments along with metal fragments (cans), paper, plastics, and fragments of concrete and brick.

The boundary between fill and natural material is fairly distinct. Beneath the fill, the sediment consists of tidal sands with a varying silt content to a depth of 28 feet bgs. From the depth of 28 feet bgs to termination of the boring at 40 feet bgs, clay was encountered. A falling head permeability test performed on an undisturbed resulted in an estimated vertical hydraulic conductivity of 4.4×10^{-8} cm/s. This indicates that the clay the likely acts as a confining unit.

In general, a surficial groundwater table exists at the site. The underlying clay is thick enough to act as a confining unit to the overlying sands of the upper surficial aquifer. The upper surficial aquifer across the site is approximately 18 to 20 feet thick, based on the depth of the clay unit encountered. Based on slug test data, the geometric average hydraulic conductivity for the three shallow surficial aquifer wells was 1.28 feet per day (4.53×10^{-4} cm/sec) and the deep surficial well was 0.65 feet per day (2.30×10^{-4} cm/sec). The values for the shallow and deep wells are within the typical range of hydraulic conductivity for clayey, silty sands, silts, and sandy silts.

The upper surficial is general divided from the lower Floridan Aquifer by the Hawthorn Formation, which acts as a confining unit. The Hawthorn Formation is a phosphatic sand and clay unit with a reported thickness of approximately 2 to 40 feet in the study area.

The Floridan Aquifer, which underlies the site, extends continuously from South Carolina into Florida. Groundwater of this aquifer occurs mainly under artesian conditions at MCRD Parris Island. The Floridan aquifer is the most important source of groundwater in the Low Country area, and wells generally less than 250 feet deep tap this aquifer system. The aquifer is the only source of potable groundwater west, north, and east of MCRD Parris Island.

NATURE AND EXTENT OF CONTAMINATION

Surface soils were found to contain several polynuclear aromatic hydrocarbons (PAHs), PCBs, pesticides, lead, arsenic, aluminum, iron, mercury, vanadium, and zinc at concentrations greater than present in background soils and in exceedance of the most stringent human health risk-based concentrations

(RBCs) (residential) or ecological screening values. Because of the presence of asphalt at the site and the common application of pesticides at the base, PAHs and pesticides may or may not result from waste disposal activities.

Benzene, chlorobenzene, 1,4-dichlorobenzene, arsenic, iron, thallium, and alpha-BHC were detected in the site groundwater at concentrations that exceed the most stringent human health criteria (drinking water standards). The presence of a salt-water marsh surrounding the site and the measured salinity of the groundwater restricts the use of site groundwater as a potable water supply. Chlorobenzene was the only groundwater analyte that exceeded ecological screening values for surface water. This VOC was not detected in surface water or sediment samples indicating that migration from the fill area was not significant.

Fluoranthene, mercury, and silver were detected in surface water at concentrations in excess of the most stringent human health RBCs or ecological screening values. Each chemical exceeded the criteria in 1 of 20 samples.

Sediments were found to contain several PAHs, PCBs, pesticides, lead, arsenic, aluminum, copper, iron, mercury, and zinc at concentrations greater than present in background sediments and in exceedance of the most stringent human health RBCs (residential) or ecological screening values. Because of the presence of asphalt at the site and the common application of pesticides at the base, the PAHs and pesticides may or may not be from site-related waste disposal activities.

HUMAN HEALTH RISK ASSESSMENT SUMMARY

The human health risk assessment considered site media exposure to construction workers and maintenance workers. The estimated incremental cancer risk to construction workers and maintenance workers exceeded $1x10^{-6}$, but was less than $1x10^{-4}$. These risks are within the acceptable U.S. Environmental Protection Agency (U.S. EPA) target risk range. The noncarcinogenic risk estimates for both the construction worker and the maintenance worker was less than 1.0, indicating that toxic effects are not anticipated.

The human health risk assessment also considered environmental exposure from recreational fishing at the site. These risk calculations were based on current (1998) surface water and sediment data, as well as biota data collected in 1991.

Based on 1991 biota results and U.S. Food and Drug Administration criteria, consumption of fin fish and shellfish at the site do not represent a threat to human health.

The 1991 biota results were also used to calculate risks to human health under a frequent consumer (daily – default) and occasional consumer (once per week) of fish from the site. Using this data and these scenarios for non carcinogenic risks, a potentially significant risk to human health was possible for the hypothetical frequent fish consumer, but not for the occasional consumer. Incremental cancer risk estimates under both scenarios were within the acceptable U.S. EPA risk range of $1x10^{-4}$ to $1x10^{-6}$.

The 1998 surface water and sediment data were also used to estimate risk to human health through theoretical partitioning of contaminants to fish and human consumption of the fish. Under the most stringent scenario (frequent fish consumer and maximum concentrations), incremental cancers risks exceeded $1x10^{-4}$ and non carcinogenic risks were greater than 1.0. These risk estimates are higher than acceptable U.S. EPA risk criteria. PAHs, pesticides, PCBs, and arsenic were the main contributors to risk. However, under more typical site conditions, (average concentrations and occasional fish consumption), incremental cancer risk estimates were within the acceptable U.S. EPA risk range of $1x10^{-4}$ to $1x10^{-6}$ and the non carcinogenic risk estimate was less than 1.0.

ECOLOGICAL RISK ASSESSMENT SUMMARY

The initial ecological risk screening determined that the maximum concentrations of several metals, pesticides, PCBs, and PAHs at the site exceed U.S. EPA Region IV screening values, indicating a potential ecological risk. In addition, several other chemicals were identified as COPCs because of the lack of screening criteria.

The food chain modeling evaluated nine representative receptors and found that the majority of the initial chemicals of potential concern (COPCs) do not represent a threat to site receptors even under a worst case scenario (organisms constantly exposed to maximum concentrations). Chemicals that pose potential risks under this scenario consist of PCBs, pesticides, and several metals.

The food chain modeling found that under more realistic conditions which consider mean chemical concentrations, the list of chemicals in which hazard quotients (HQ) for NOAELs exceed 1.0 were reduced to the following:

- DDT(maximum HQ is 8)
- DDE (maximum HQ is 36)
- DDD (maximum HQ is 2)
- aluminum (maximum HQ is 1,450)
- arsenic (maximum HQ is 11)
- iron (maximum HQ is 54)

- lead (maximum HQ is 5)
- mercury (maximum HQ is 6)
- thallium (maximum HQ is 6)
- vanadium (maximum HQ is 30)
- zinc (maximum HQ is 3).

In evaluating this data the following factors should be considered.

- Except for lead, mercury and zinc, the maximum detected metal concentrations were within a factor of two of background concentrations and the mean concentrations were normally within the range of surface soil or sediment background results.

- The maximum hazard quotients for lead, mercury, and zinc were associated with the robin and to a lesser extent the heron and eagle.

- For the heron and eagle, when home ranges (of thousands of acres) and the size of potential forage areas at Site 3 (40 acres) are considered, hazard quotients presented above would be reduced by a factor of at least 60 (See Appendix F). Based on this consideration, COPCs would not present a significant potential risk for these two receptors. Similar home range considerations for the other receptors would also result in lower hazard quotients.

- Because of base wide application, pesticides may or may not be site related. The concentrations detected at Site 3 were similar to normal concentrations found at the base. In addition, based on foodchain modeling using actual tissue concentrations measured in finfish and shellfish collected in 1991, the potential risk to representative aquatic receptors were less than predicted by foodchain modeling based on surface water and sediment data.

RECOMMENDATIONS

The surface soil data is adequate to proceed to a feasibility study/corrective measures study (FS/CMS) to evaluate capping/covering options for this landfill. Protection of ecological receptors (direct contact and erosion into the sediment) is the primary concern.

Based on site groundwater not being considered as a viable drinking water source, the finding of only relatively minor groundwater criteria exceedances, and the absence of a threat to surrounding surface water and sediment through groundwater migration, groundwater does not need to be considered in a FS/CMS.

Because of the transient nature of surface water, water quality concerns would be better addressed through management of sediment and soil. As such, surface water does not need to be considered directly in a FS/CMS.

Sediment data are adequate to proceed to a feasibility FS/CMS. Even though the data does not suggest the presence of significant widespread sediment contamination, potential contamination at some locations should be evaluated.

1.0 INTRODUCTION

1.1 PURPOSE OF REPORT

Tetra Tech NUS, Inc. (TtNUS) has prepared this remedial investigation (RI)/RCRA Facility Investigation (RFI) report summarizing field activities conducted at the Causeway Landfill [Site 3/Solid Waste Management Unit (SWMU) 3], located at the Marine Corps Recruit Depot (MCRD) Parris Island, South Carolina. This report was prepared for the United States Navy (Navy) Southern Division (SOUTHDIV) Naval Facilities Engineering Command (NAVFAC) under Contract Task Order (CTO) 0020, for the Comprehensive Long-Term Environmental Action Navy (CLEAN) III Contract Number N62467-94-D-0888.

1.2 REGULATORY SETTING

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act of 1986 (SARA) established a program for the cleanup of hazardous waste disposal and spill sites nationwide. This program contains provisions for the cleanup of contamination from past hazardous waste operations and past hazardous material spills and is the framework for installation restoration (IR) programs at Navy and Marine Corps installations. The Resource Conservation and Recovery Act (RCRA), as amended, also establishes a cleanup program that provides for current and future hazardous waste management practices, as well as clean-up of past disposal sites at permitted or interim status Navy/Marine Corps installations. SOUTHNAVFAC has the responsibility for implementing the Navy's IR Program at MCRD Parris Island.

Because of the past hazardous waste activities conducted at the MCRD Parris Island, South Carolina, the MCRD meets criteria for conducting IR activities under the CERCLA regulatory framework. To date, the MCRD has completed steps equivalent to the preliminary assessment/site inspection phases of the CERCLA remedial action process at Site/SWMU 3. The MCRD also meets the criteria for conducting IR activities under the authority of RCRA because, in the late 1980s, the MCRD submitted a RCRA Part A application. Per RCRA, this action required the MCRD to conduct corrective action for the release of hazardous waste or hazardous constituents from SWMUs. An interim RCRA Facility Assessment (RFA) was conducted in 1990 as part of this requirement. Since this time, the MCRD has withdrawn its Part A application.

Because of the circumstances surrounding the MCRD's IR program history, discussions have been held among representatives from the U.S. Marine Corps, U.S. Navy, South Carolina Department of Health and Environmental Control (SCDHEC), and the U.S. Environmental Protection Agency (U.S. EPA), Region IV to determine the appropriate regulatory framework for conducting IR activities at the MCRD. From these

discussions, it has been decided that this report will encompass both CERCLA and RCRA requirements and the title, RI/RFI, reflects this decision. For ease of reading and clarity, Site/SWMU 3 will be referred to as Site 3 for the remainder of this document.

1.3 SCOPE OF RFI/RI

The RI/RFI field investigation was conducted in May 1998 to September 1998 and August 1999 and included sampling of soils, surface water, and sediment, as well as an overall investigation of site groundwater and establishment of background conditions. The purpose of these activities was to characterize the nature and extent of contamination at Site 3 where the potential for off-site migration exists. Both human health and ecological risk assessments are included in this report to support site decisions.

Data collected during the investigation have been entered into a database. The database was used in this report to support the risk assessments, including the comparison of analytical results to state and federal standards and to background levels. Data evaluation and recommendations for Site 3 are included herein. Data validation on these data consisted of either a data review or a full data validation. The full data validation was performed on approximately 10 percent of the data packages received from a laboratory. All analytes were covered by at least one full data validation. A data review was performed on the remaining data packages for the purposes of identifying false positive and negative results.

1.4 HISTORICAL INFORMATION

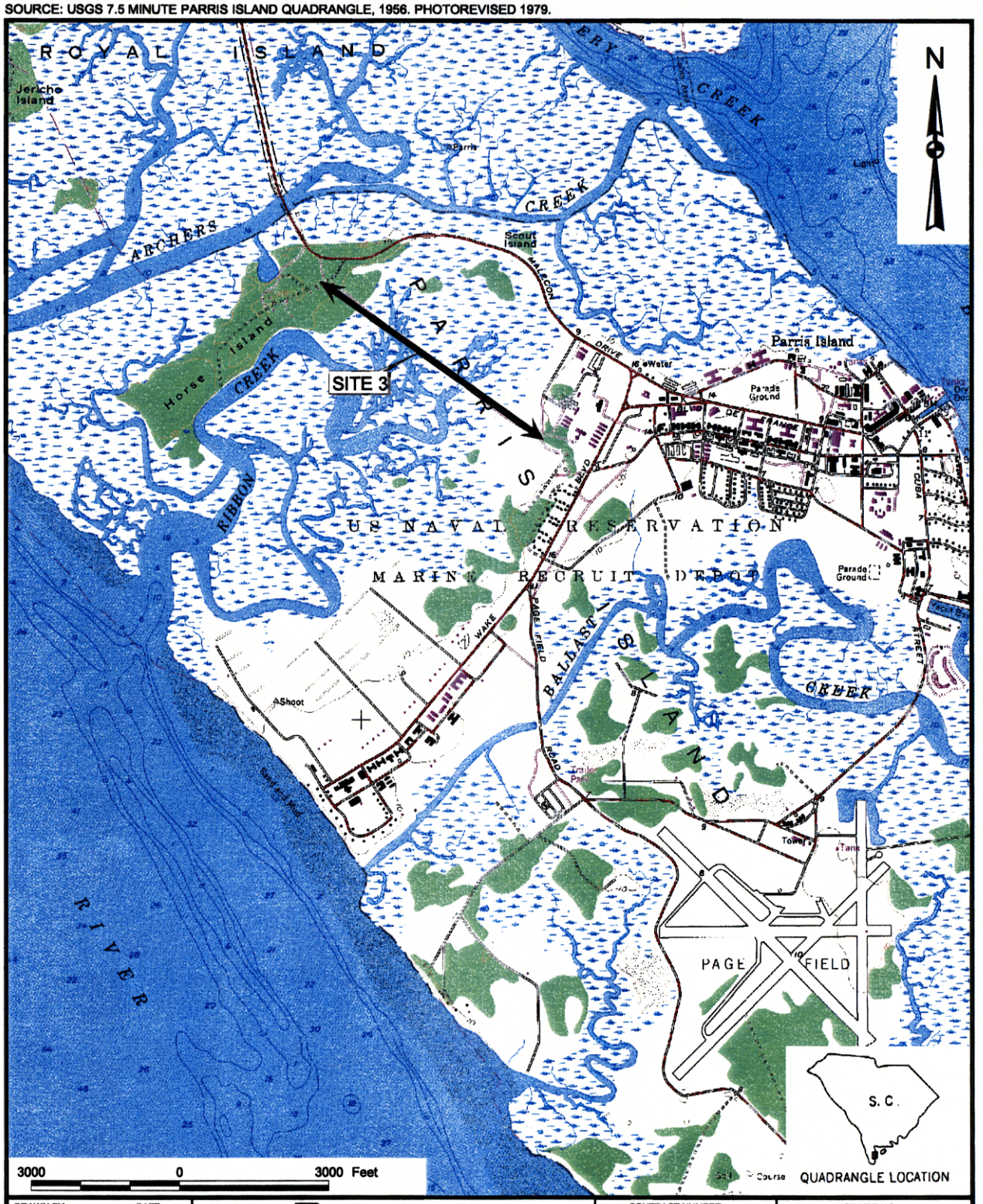
1.4.1 Facility Background

MCRD Parris Island is located along the southern coast of South Carolina, approximately 1 mile south of the city of Port Royal and 3 miles south of the city of Beaufort within Beaufort County. MCRD Parris Island covers approximately 8,047 acres that consist of dry land, salt marshes, saltwater creeks, and ponds, as shown in Figure 1-1. MCRD Parris Island is the reception and recruit training facility for the Marine Corps for enlisted men from states east of the Mississippi River and for enlisted women nationwide.

1.4.2 Site 3 Background and History

Site 3 is an integral part of a causeway connecting Horse Island and Parris Island, in the north section of MCRD Parris Island, as shown in Figure 1-2. The causeway is primarily a gravel, two-lane road consisting of alternate layers of solid waste and fill dirt constructed along a tidal marsh of the Broad River (across Ribbon Creek). Portions of the roadway are covered with asphalt. At two locations along the causeway, three concrete pipes are buried beneath the causeway to allow tidal movement between the surface water bodies separated by the unit.

SOURCE: USGS 7.5 MINUTE PARRIS ISLAND QUADRANGLE, 1956. PHOTOREVISED 1979.



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P:\GIS\MCRD_PARRISISLAND\PARRIS.APR 25-JAN-99 DNP DEPOT LOCATION - SITE 3 LAYOUT

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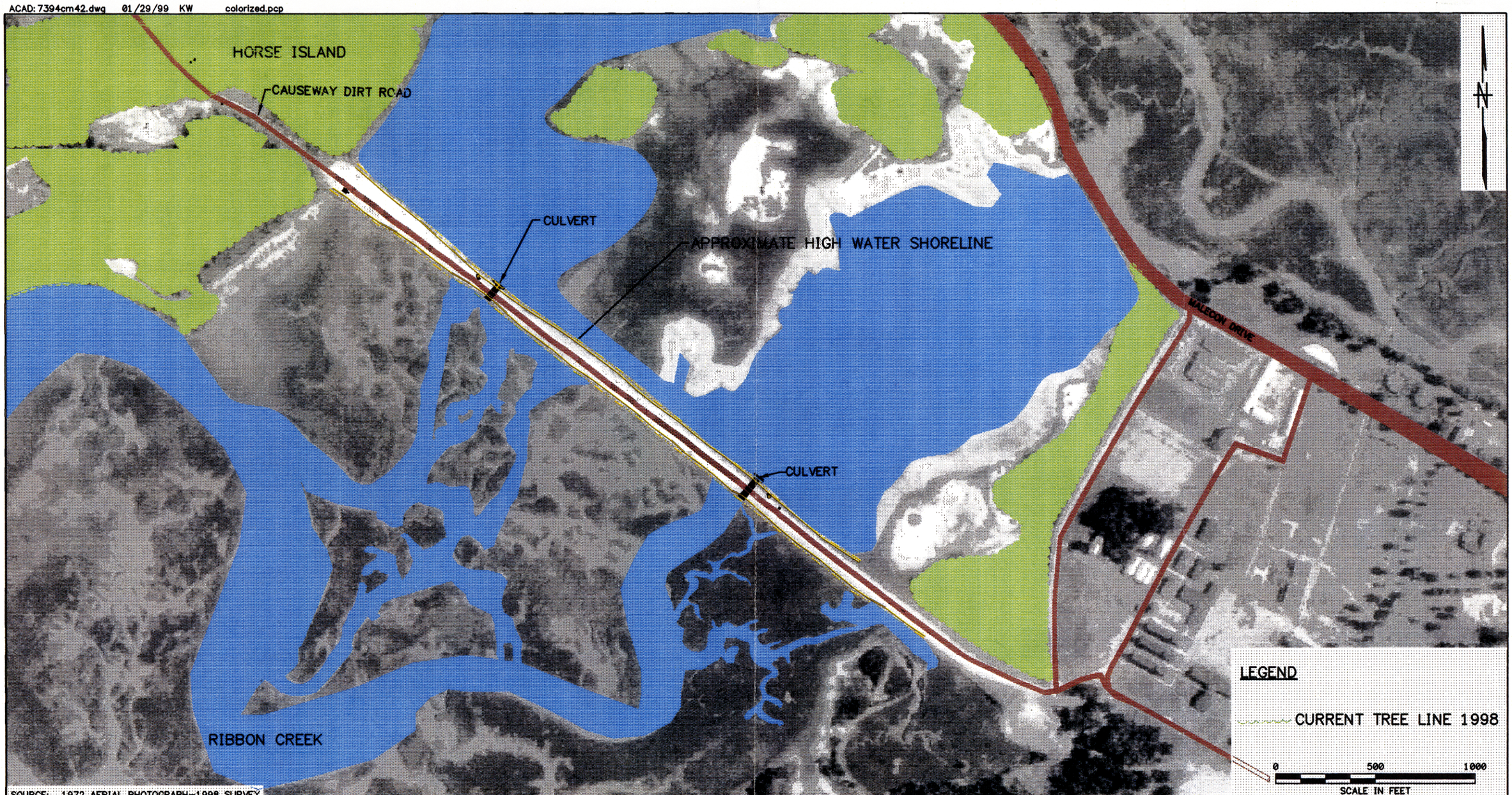

SOURCE: 1972 AERIAL PHOTOGRAPH-1998 SURVEY

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJP DATE 11/19/98
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COST/SCHED-AREA
SCALE AS NOTED

SITE LAYOUT
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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The Causeway Landfill (Site 3) functioned as the major disposal area for trash and other materials discarded in dumpsters around the MCRD during most of the period between 1960 and 1972. Between 1960 and 1965, this landfill received approximately 75 percent of the solid waste generated by the Depot. The site was inactive between 1966 and 1968. Between 1969 and 1972, the site received all of the Depot's solid waste. The solid waste disposed at the site included empty pesticide containers, oily rags, spent absorbent, petroleum and chlorinated solvent sludge, perchloroethylene (PCE) still bottoms, mercury amalgam and beryllium waste, polychlorinated-biphenyl (PCB)-contaminated oil, and metal shavings. In 1972, landfilling operations ceased at Site 3.

The causeway was constructed in two separate sections across a tidal marsh of the Broad River. One section began from the northeast edge of Horse Island and was built primarily with fill dirt taken from the borrow pits on Horse Island. Some solid wastes were also reportedly placed in this section of the causeway. The other section started near the southern end of Talasesa Street on Parris Island and was built with the solid waste mentioned in the previous paragraph and with fill dirt. Aerial photos taken in 1951, 1965, and 1972 illustrate that the two sections of causeway gradually extended into the marsh until they met in 1972. At its completion in 1972, the causeway was approximately 10 acres in size, 4,000 feet long, 100 feet wide, and 10 feet high (above the water surface), with a gravel road surface and rip-rap sides overgrown with vegetation. Limited information is available concerning the presence and areal extent of fill material used to cover the landfill after disposal activities were discontinued in 1972. No landfill activity has taken place at Site 3 since 1972.

1.4.3 Previous Site 3 Investigations

Several investigations conducted at MCRD Parris Island have included Site 3. Based on the results of past investigations, it was determined that further evaluation was needed and a recommendation was made to conduct an RFI/RI. These earlier investigations are as follows.

Initial Assessment Study

In 1986, the Naval Energy and Environmental Support Activity (NEESA) conducted an initial assessment study (IAS) (NEESA, 1986) under the Naval Assessment and Control of Installation Pollutants (NACIP) Program. The IAS is equivalent to the preliminary assessment phase of the CERCLA process. The purpose of the IAS (Phase I of the NACIP Program) was to identify potentially contaminated sites at MCRD Parris Island that may pose a threat to human health or the environment. In the IAS, NEESA identified Site 3 as a site requiring further investigation for the purposes of assessing potential long-term impacts to human health and the environment. The study recommended NACIP Phase II (Verification

Step) actions be conducted at the site. These actions included the sampling of groundwater and surface water at seepage points along the causeway and the sampling of the soil and sediment at these locations.

Verification Step

Based on the recommendations of the IAS, McClelland Consultants conducted a verification step (VS) at Site 3 (McClelland, 1990). The VS is equivalent to the site inspection phase of the CERCLA process. McClelland collected eight shallow soil/sediment samples and eight surface water samples along the flanks of the causeway.

The VS samples were analyzed for volatile organic compounds (VOCs), acid and base/neutral extractable organics, PCBs and pesticides, total metals (arsenic, barium, beryllium, cadmium, chromium, selenium, and silver), and Extended Procedure toxicity metals (arsenic, cadmium, chromium, lead, and mercury).

No organic compounds were detected in the soil/sediment or surface water samples at the causeway landfill. Cadmium, lead, and mercury were detected at levels that exceeded the current U.S. EPA Region IV Waste Management Division Saltwater and Sediment Screening Values.

The VS concluded that, based on the presence of inorganics in the sediment and surface water, advanced sampling and assessment were recommended at Site 3 to address potential concerns regarding the harvesting of shellfish and fish species in the vicinity of the causeway landfill.

Interim RCRA Facility Assessment

Per the requirements of the MCRD's application for a RCRA permit, an Interim RFA was performed from January 1990 to March 1990. The RFA (Kearney, 1990) indicated there was documented disposal of waste containing hazardous constituents in an unlined unit in the immediate vicinity of surface waters and that an RFI was necessary for Site 3.

Extended Site Inspection Report, Causeway Landfill

An extended site inspection was conducted to evaluate whether the consumption of fish and shellfish caught in the vicinity of the Causeway Landfill posed a risk to human health (ABB Environmental Services, Inc., 1993). Fish and shellfish commonly harvested in the area were sampled and analyzed to determine whether tissue levels exceeded action levels established by the United States Food and Drug Administration. Biological tissues were analyzed for mercury, organic polynuclear aromatic hydrocarbons (PAHs), PCBs, and pesticides. The results of the screening indicated elevated levels of pesticides and PCBs in tissues from the pond side of the causeway and raised concerns over ecological issues. Mercury

amalgam was identified as having been disposed in the landfill. Mercury amalgam could have an ecological impact if detected in site media.

1.5 REPORT ORGANIZATION

This report is divided into eight sections. Section 1.0, Introduction, provides historic information about MCRD Parris Island and Site 3 in particular. Section 2.0, Environmental Setting, provides geological and geographical information about MCRD Parris Island and the surrounding areas. Section 3.0, Investigation Summary, summarizes the sampling program and presents the Site 3 geology and hydrogeology based on the field results. Section 4.0, Nature and Extent of Contamination, addresses the nature and extent of site contamination for all media investigated. Section 5.0, Contaminant Fate and Transport, is a reference-like section describing the chemical and physical properties of the analytes positively detected at Site 3. Section 6.0, Human Health Risk Assessment, and Section 7.0, Ecological Risk Assessment, present the methodology and results of the human health and ecological risk assessments, respectively. Section 8.0, Conclusions and Recommendations, focuses on the magnitude of site-related risks and remedies, if any, to address those risks. Appendices A through F provide support documentation for the field investigation and supplemental information for the evaluation of results.

2.0 ENVIRONMENTAL SETTING

This section contains general information relative to the environmental setting common to all the sites currently under investigation at MCRD Parris Island. The following is a list of the topics and the subsections in which they are discussed.

- Section 2.1 – Climate
- Section 2.2 – Topography
- Section 2.3 – Surface Water Drainage
- Section 2.4 – Soils
- Section 2.5 – Geology
- Section 2.6 – Hydrogeology
- Section 2.7 – Ecology

2.1 CLIMATE

The following section was summarized from the IAS (NEESA, 1986). MCRD Parris Island is in the southernmost region of South Carolina, where the climate is milder than elsewhere in the state. This low-lying coastal area has numerous islands, inlets, streams, and marshes and a temperature regime that clearly reflects the influences of its maritime and southerly location. The climate is subtropical, with long and hot summers followed by short and mild winters. Precipitation is abundant, averaging about 49 inches per year and remaining within the range of 40 to 58 inches during most years. Precipitation in the amount of 0.1 inches or more falls on an average of about 77 days per year. The annual distribution shows a major monthly maximum of about 7 inches in July and a major monthly minimum of about 2 inches in November. The period from April through October, which includes the growing season for most crops in this area, receives an average of about 34 inches of rain, about 70 percent of the annual total.

Spring is a season of transition between a rather uniform winter and a rather uniform summer. March is typically a month of heavy rains and warming temperatures. April tends to be dry, but scattered thunderstorm activity begins as summer begins. April and May are the months of greatest tornado hazard, during the March-through-October tornado season.

Summers are warm and humid. Maximum daily temperatures are near or above 90º Fahrenheit (F), and minimum daily temperatures are 65 to 70º F. Temperatures in excess of 100º F are usually recorded on 2 to 5 days each year. Maritime tropical air persists in the area for extended periods during summer. The abundant supply of warm, moist, relatively unstable air produces frequent scattered showers and thunderstorms. About 54 thunderstorms occur in an average year; 16 occur in an average July.

Hailstorms are infrequent, occurring one to five times per year, and are usually of little consequence. The tropical storm season is generally considered to be the period from June through October. Hurricanes are rare to the area, but tropical storms occur on an average of about once every 2 or 3 years.

Autumn begins warm, humid, and showery but changes to a warm, relatively dry, and pleasant Indian summer, which tends to take place in October and continue into November. The first freezing temperatures in the area can be expected in the middle of November, but the onset of frost tends to be quite variable from year to year and from place to place. Tropical storms or hurricanes occasionally bring heavy rains and strong winds to the area during this season.

The winter season is short and mild. It is also relatively dry, accounting for only about 20 percent of the average annual precipitation. Average daily maximum and minimum temperatures are 63º F and 38º F, respectively. The average winter temperature is about 50º F. Freezing temperatures occur about 27 days per year. Winter precipitation normally comes in the form of rain associated with fronts. Measurable snowfall seldom occurs. Freezing rain occurs some winters, but damaging ice storms are rare (Stuck, 1980).

2.2 TOPOGRAPHY

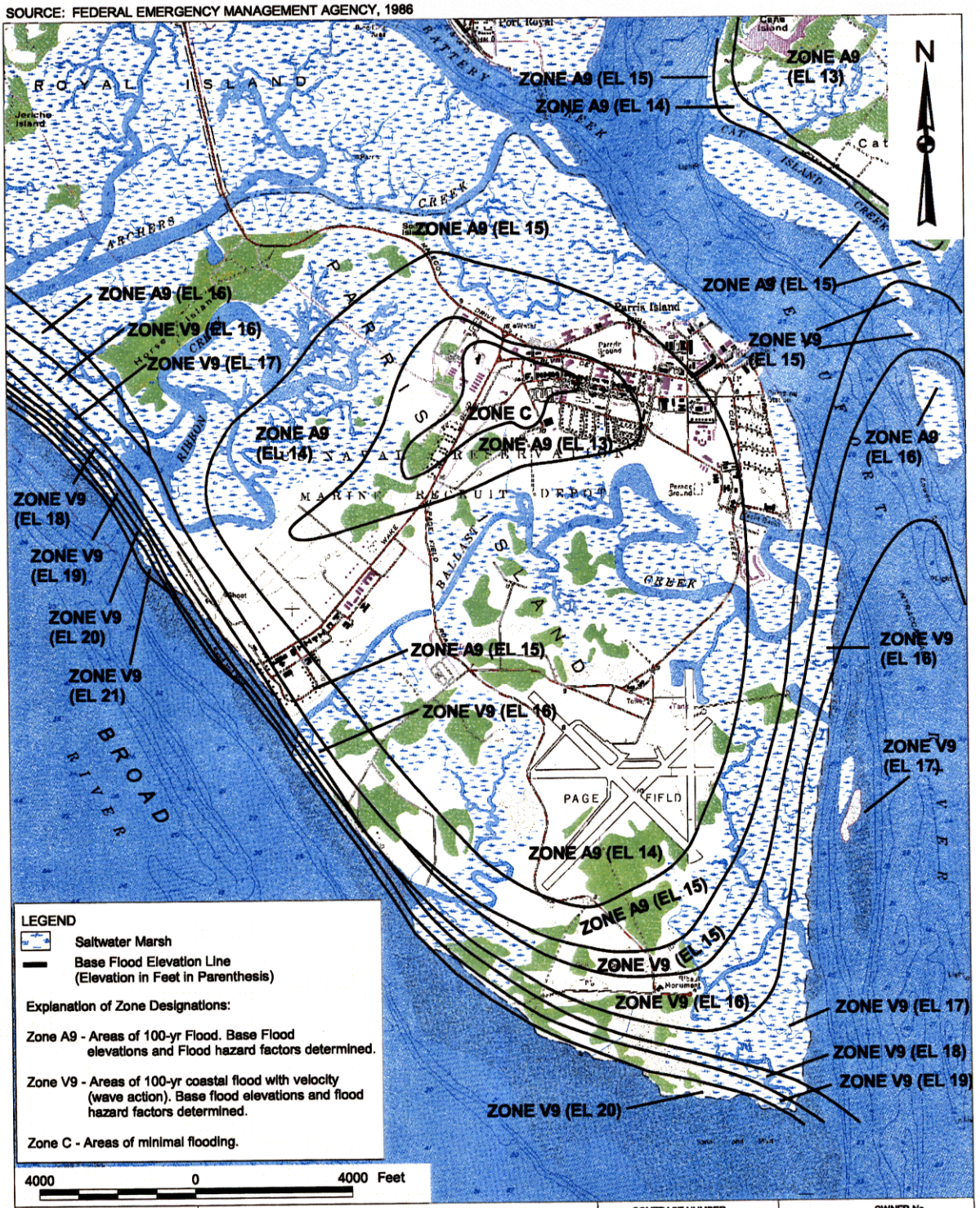
MCRD Parris Island lies in the Lower Coastal Plain physiographic province. Elevations range from sea level to 22 feet above mean sea level (msl). The Depot consists of Parris Island (the largest and most developed island), seven smaller, named islands, many small unnamed islands, salt marshes, and related tidal creeks (Figure 2-1). Because of the low elevation, most of the Depot is within the 100-year flood plain. The majority of the area of Parris Island north of Ballast Creek, the east central area of Page Field, and the central part of Horse Island are the only surfaces above the 100-year flood plain (NEESA, 1986).

The Depot covers 8,047 acres: 1,502 acres are devoted to forest management; 744 acres are grass and facilities; 4,344 acres are saltwater marsh; and the remainder consists of creeks, ponds, and causeways. Dry land makes up 3,274 acres (NEESA, 1986).

2.3 SURFACE WATER DRAINAGE

Drainage off the land surface is to the nearest surface water body. Three generally east-west creeks drain much of the Depot. Archers Creek is at the northern boundary of the Depot and connects Battery Creek to the north with the Broad River to the west of Parris Island (see Figure 1-1). Ribbon Creek drains the area between Horse and Parris Islands and flows westward into the Broad River. Ballast Creek

SOURCE: FEDERAL EMERGENCY MANAGEMENT AGENCY, 1986



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enters the Beaufort River and drains central Parris Island. Smaller unnamed creeks drain the areas west and east of Page Field.

The Beaufort and Broad Rivers meet at the southern end of Parris Island to form Port Royal Sound, which extends about 4 miles southeastward to the Atlantic Ocean.

2.4 SOILS

Soils at MCRD Parris Island have been mapped by the U.S. Soil Conservation Service as both individual soils and groupings of soils (units). The Depot has been mapped as having 15 individual soil types, but only eight types are present beneath the identified sites. Three soil units have been mapped for the Depot (Figure 2-2); these will be described below and the eight individual soil types will be explained in detail. The physical properties of the individual soil types are tabulated in Table 2-1.

2.4.1 Wando-Seabrook-Seewee Soil Unit

Excessively drained, moderately well-drained, and somewhat poorly drained soils that are sandy throughout make up this unit. Horse Island is made of this soil unit. This soil unit constitutes about 31 percent of Beaufort County. The unit is about 24 percent Wando soils, 18 percent Seabrook soils, 11 percent Seewee soil, and 47 percent minor soils.

Wando soils are in the higher areas of the soil unit and are excessively drained. Seabrook soils are in intermediate areas and are moderately well drained. Seewee soils are commonly in slightly lower areas than Seabrook soils and are somewhat poorly drained. All of these soils are sandy throughout and differ primarily in drainage. The minor soils in this soil unit are the somewhat poorly drained Ridgeland soils, the poorly drained Baratari soils, and the very poorly drained Polawana and Rosedhu soils. In Jasper and Beaufort Counties, about 60 percent of the soils contained within this soil unit are woodland, 20 percent have been developed for urban and recreational uses, and 20 percent are used for cultivated crops, truck crops, or pasture. With the exception of the soils in the higher areas, wetness is the main limitation to use of these soils. Dryness is a limitation to the excessively drained soils in the higher areas. There is rapid leaching in all these soils. All soils in this unit, except the excessively drained Wando soils, have a seasonally high water table.

2.4.2 Coosaw-Williman-Ridgeland Soil Unit

Somewhat poorly drained and poorly drained soils that have a thick sandy surface layer and a loamy subsoil and somewhat poorly drained soils that are sandy throughout make up this soil unit. This soil unit

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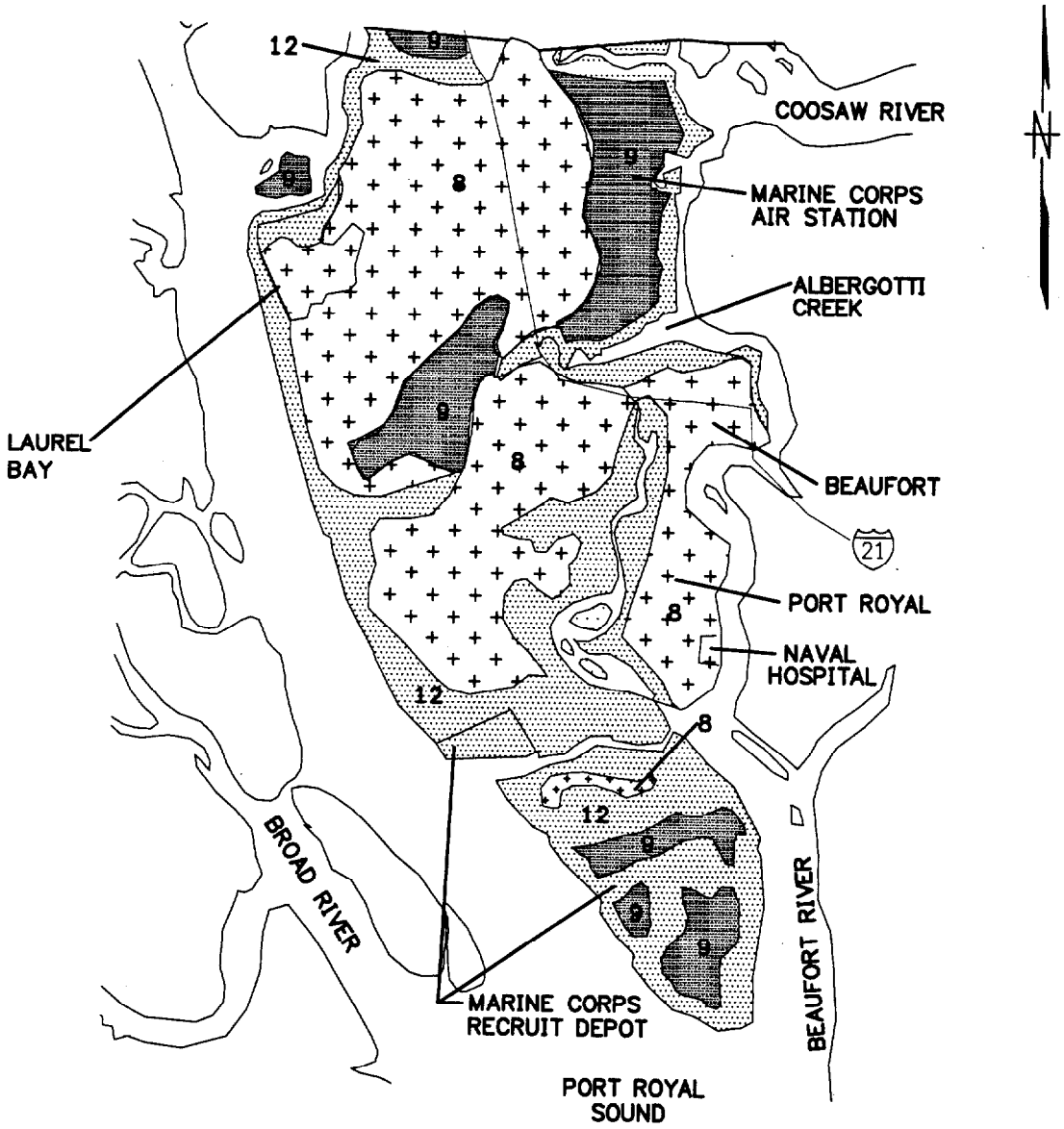

0 3 6
APPROXIMATE SCALE IN MILES

SOURCE: ADAPTED FROM STUCK, 1980

LEGEND
8 WANDO–SEABROOK–SEEWEE SOIL UNIT
9 COOSAW–WILLIMAN–RIDGELAND SOIL UNIT
12 BOHICKET–CAPERS–HANDSBORO SOIL UNIT

DRAWN BY HJP DATE 10/23/98			CONTRACT NO. 7394
CHECKED BY DATE		SOIL UNIT MAP MCRD PARRIS ISLAND	APPROVED BY DATE
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FORM CADD NO. SDIV_AV.DWG – REV 0 – 1/20/98

TABLE 2-1

SOIL PROPERTIES
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Soil Symbol - Soil Name	Depth (in.)	USDA Texture	United Soil Classification	Percent Clay &	Liquid Limit (%)	Plasticity Index	Corrosion Risk Steel/Concrete	Sites Affected(1)
Bk - Bohicket Unit 12	0-10 10-40 49-80	Silty clay loam Silty clay, clay Variable	CH, MH CH, MH ----	90-100 70-95 ----	60-100 50-100 ----	30-60 19-60 ----	High/High High/High ----	Sites 1 (1), 5 (5), 12 (10), 14 (14), 19 (19), 20 (20), 22 (22), 23 (23), 24 (24), 25 (25), 28 (28), 29 (29), 30 (30), 31 (31), 32 (32), 33 (33), 34 (34), 38 (38), 39 (39), 40 (40), 43 (43), 45 (45)
CE - Capers Association Unit 12	0-22 22-68	Silty clay loam Clay, silty clay	MH MH	70-100 75-100	50-80 60-80	15-40 18-40	High/High High/High	Site 3 (3), 21 (21), 41 (41)
Cs - Coosaw Unit 9	0-27 27-31 31-77	Loamy fine sand Sandy loam, fine sandy loam Sandy clay loam, fine sandy loam, sand loam	SM SM, SM-SC SM, SC, SM-SC	15-30 20-40 25-50	--- 30 15-35	NP NP-7 2-15	Moderate/High Moderate/High Moderate/High	Sites 4 (4), 6 (6), 11 (9), 13 (11-13) Site 15 (15)
Mu - Murad Unit 9	0-49 49-60 60-80	Fine sand Sandy loam, fine sandy loam, sandy clay loam Fine sandy loam, sandy clay loam, sandy clay	SM, SP-SM SM, SM-SC, SC SM, SC, CL, SM-SC	10-25 25-50 36-65	--- 40 25-50	NP NP-15 5-25	Moderate/High Moderate/High Moderate/High	Sites 7 (7), 8 (AOC A and B), 17 (17), 18 (18) Site 15 (15)
Sw - Seewee	0-25 25-45 45-80	Fine sand Fine sand, sand Fine sand, sand	SP-SP, SM SP, SP-SM, SM SP, SP-SM, SM	5-20 2-15 1-15	--- --- ---	NP NP NP	Low/High Low/High Low/High	Site 15 (15)
Wa - Wahee Unit 9	0-13 13-40 40-62	Fine sandy loam Clay, clay loam, silty clay Sandy clay loam, clay loam, silty clay loam	SM, SM-SC CL, CH CL	30-50 70-90 36-65	30 41-60 30-50	NP-7 18-32 11-25	Moderate/High High/High High/High	Site 13 (11-13)
Wd - Wando Units 8 and 9	0-52 52-85	Fine sand Sand, fine sand	SP-SM, SM SP, SP-SM, SM	5-25 2-20	--- ---	NP NP	Low/Moderate Low/Moderate	Sites 2 (2), 8 (AOC A and B), 27 (27), 35 (35), 36 (36), 37 (37) Sites 9 (8), 10 (AOC C), 13 (11-13), 16 (16), 26 (26)
Wn - Williman Unit 9	0-26 26-80	Loamy fine sand Sandy loam, fine sandy loam, sandy clay loam	SM SM-SC, CL-ML, SC, CL	15-35 30-65	25 15-35	NP-3 3-15	High/High High/High	Site 13 (11-13) Site 15 (15)

TABLE 2-1

SOIL PROPERTIES
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Soil Symbol - Soil Name	Depth (in.)	Permeability (in/hr)	Available Water Capacity (in/in)	Shrink-Swell Potential	Erosion Hazard	Hydrologic Group	High Water Table Depth (ft)/Kind	Sites Affected(1)
Bk - Bohicket Unit 12	0-10 10-49 49-80	0.6-0.2 0.06 ---	0.14-0.18 0.12-0.16 ---	High High ---	---	D	+3-0/Apparent	Sites 1 (1), 5(5), 12 (10), 14 (14), 19 (19), 20 (20), 22 (22), 23 (23), 24 (24), 25 (25), 28 (28), 29 (29), 30 (30), 31 (31), 32 (32), 33 (33), 34 (34), 38 (38), 39 (39), 40 (40), 43 (43), 45 (45)
CE - Capers Association Unit 12	0-22 22-68	0.06-0.2 0.06	0.01-0.03 0.01-0.03	Very High Very High	---	D	+1-1.0/Marsh	Site 3 (3), 21 (21), 41 (41)
Cs - Coosaw Unit 9	0-27 27-31 31-77	6.0-20 2.0-6.0 0.6-2.0	0.06-0.11 0.08-0.13 0.08-0.16	Low Low Low	Slight	D	1.0-2.0/Apparent	Sites 4 (4), 6 (6), 11 (9), 13 (11-13) Site 15 (15)
Mu - Murad Unit 9	0-49 49-60 60-80	6.0-20 0.6-2.0 0.6-2.0	0.05-0.11 0.1-0.17 0.11-0.18	Very Low Very Low Very Low	Slight	C	1.5-3.0/Apparent	Sites 7 (7), 8 (AOC A and B), 17 (17), 18 (18) Site 15 (15)
Sw - Seewee	0-25 25-45 45-80	6.0-2.0 0.6-6.0 6.0-2.0	0.05-0.08 0.04-0.07 0.04-0.07	Very Low Very Low Very Low	Slight	B	1.0-2.0/Apparent	Site 15 (15)
Wa - Wahee Unit 9	0-13 13-40 40-62	0.6-2.0 0.06-0.2 0.2-0.6	0.10-0.15 0.12-0.20 0.12-0.20	Low Moderate Moderate	Slight	D	0-1.0/Apparent	Site 13 (11-13)
Wd - Wando Units 8 and 9	0-52 52-85	6.0-20 6.0-20	0.05-0.08 0.03-0.07	Very Low Very Low	Slight	A	6.0/--	Sites 2 (2), 8 (AOC A and B), 27 (27), 35 (35), 36 (36), 37 (37) Sites 9 (8), 10 (AOC C), 13 (11-13), 16 (16), 26 (26)
Wn - Williman Unit 9	0-26 26-80	2.0-6.0 0.6-2.0	0.05-0.11 0.10-0.16	Very Low Low	Slight	D	0-1.0/Apparent	Site 13 (11-13) Site 15 (15)

1 A site's respective SWMU number is listed in parenthesis.

comprises about 13 percent of Beaufort County. The unit is about 21 percent Coosaw soils, 20 percent Williman soils, 13 percent Ridgeland soils, and 46 percent minor soils.

Coosaw soils are predominant in the higher areas and are somewhat poorly drained. Williman soils are in low areas and are poorly drained. Both of these soils have a sandy surface layer that is 20 to 40 inches thick and a loamy subsoil. Ridgeland soils commonly occupy intermediate areas, are sandy throughout, and are somewhat poorly drained. All these soils have a seasonal high water table. Among the minor soils in this soil unit are the excessively drained Wando soils, the moderately well-drained Seabrook soils, the somewhat poorly drained Murad soils, and the very poorly drained Deloss and Polawana soils. About 50 percent of this unit is woodland, 15 percent has been developed for urban and recreational uses, and 35 percent is used for truck crops, other crops, and pasture. Wetness is the main limitation to use of these soils.

2.4.3 Bohicket-Capers-Handsboro Soil Unit

Very poorly drained mineral and organic soils that are flooded daily or occasionally by saltwater and adjacent upstream areas that are flooded occasionally by freshwater comprise this unit.

This soil unit consists of about 53 percent Bohicket soils, 17 percent Capers soils, 7 percent Handsboro soils, and 23 percent minor soils. Bohicket soils are commonly found in slightly lower areas than Capers and Handsboro soils. Frequently adjacent to tidal streams, they are flooded by saltwater to a depth of 6 to 36 inches twice daily. Capers soils are commonly in areas a few inches higher than Bohicket soils and are not as highly dissected by small tidal streams. Both Capers and Bohicket soils have a silty clay loam surface layer and are underlain by clay and clay loam. Handsboro soils are very poorly drained, organic soils that are flooded daily or occasionally by saltwater. Among the minor soils in this soil unit are small islands of the excessively drained Wando soils, the moderately well-drained Seabrook soils, the poorly drained Argent soils, and the very poorly drained Santee soils. Most of the soils in this map unit are associated with marsh grasses. The hazard of flooding, excessive salt and sulfur, and low bearing strength are some of the limitations to use of these soils.

2.5 GEOLOGY

The regional subsurface geology of MCRD Parris Island is described in the following two subsections: descriptive geology and structural geology. This text has been completed and modified from the following sources: Hayes, 1979; Glowacz, and others, 1980; and Hassen, 1985.

2.5.1 Descriptive Geology

Figure 2-3 shows a generalized lithological section that identifies the geological and hydrogeological units of the Beaufort-Jasper County Area, widely referred to as the Low Country. The following text describes the geological units from the oldest (Eocene age) to the youngest (Pleistocene age): The Santee Limestone, Cooper Marl, Hawthorn Formation, and Pleistocene sands and clays.

Santee Limestone

The Santee Limestone of Eocene age is primarily composed of limestones that vary from relatively pure to impure limestone containing clay or shale to relatively thick marls. In the Low Country area, the Santee Limestone is divided into three main lithologic units (Hayes, 1979), which are summarized as follows. The uppermost unit consists of white, cream-colored, or light gray fossiliferous limestone and, in places, is composed almost entirely of fossil remains; this unit ranges in thickness from essentially 0 to more than 200 feet. The middle unit consists of sandy or clayey limestone and ranges from 200 to 600 feet thick. The lower unit is indurated, siliceous, glauconitic, light gray to creamy yellow limestone that averages about 30 feet in thickness. The Santee Limestone corresponds to the Floridan aquifer, which is considered to be a high-quality aquifer in the upper to middle units. Water quality in the lower unit is high in mineral content (including chloride).

Cooper Marl

In the area near MCRD Parris Island, the Cooper Marl of Oligocene age consists of phosphatic, greenish-gray clay and fine-grained sand with a moderate to very abundant amount of shells. In several areas of South Carolina, the Cooper Marl contains sections of argillaceous to clean limestone, which may yield large amounts of good water. However, the Cooper Marl in the Parris Island area serves as a confining unit to the underlying Santee Limestone. The thickness of the Cooper Marl ranges from 0 to 15 feet, reflecting the amount of erosion prior to deposition of the overlying Hawthorn Formation. Within the region of the Depot, the top of the unit is 20 to 120 feet below land surface (Hassen, 1985).

Hawthorn Formation

The Hawthorn Formation of Miocene age primarily consists of a thin (5 to 15 feet thick) Lower Miocene limestone known as the Tampa Limestone. The Tampa Limestone is composed of phosphatic sand, sandy marl, or sandy clay in eastern Chatham County and southwestern Beaufort County. Wells that are open to the Tampa Limestone have a noticeably high content of hydrogen sulfide, which imparts a rotten-egg odor to the water. The Hawthorn Formation also consists of sandy, clayey materials that are frequently eroded and therefore locally discontinuous in coastal Beaufort County. The Hawthorn Formation was not encountered in the northwest portion of Parris Island during the 1998 field event.

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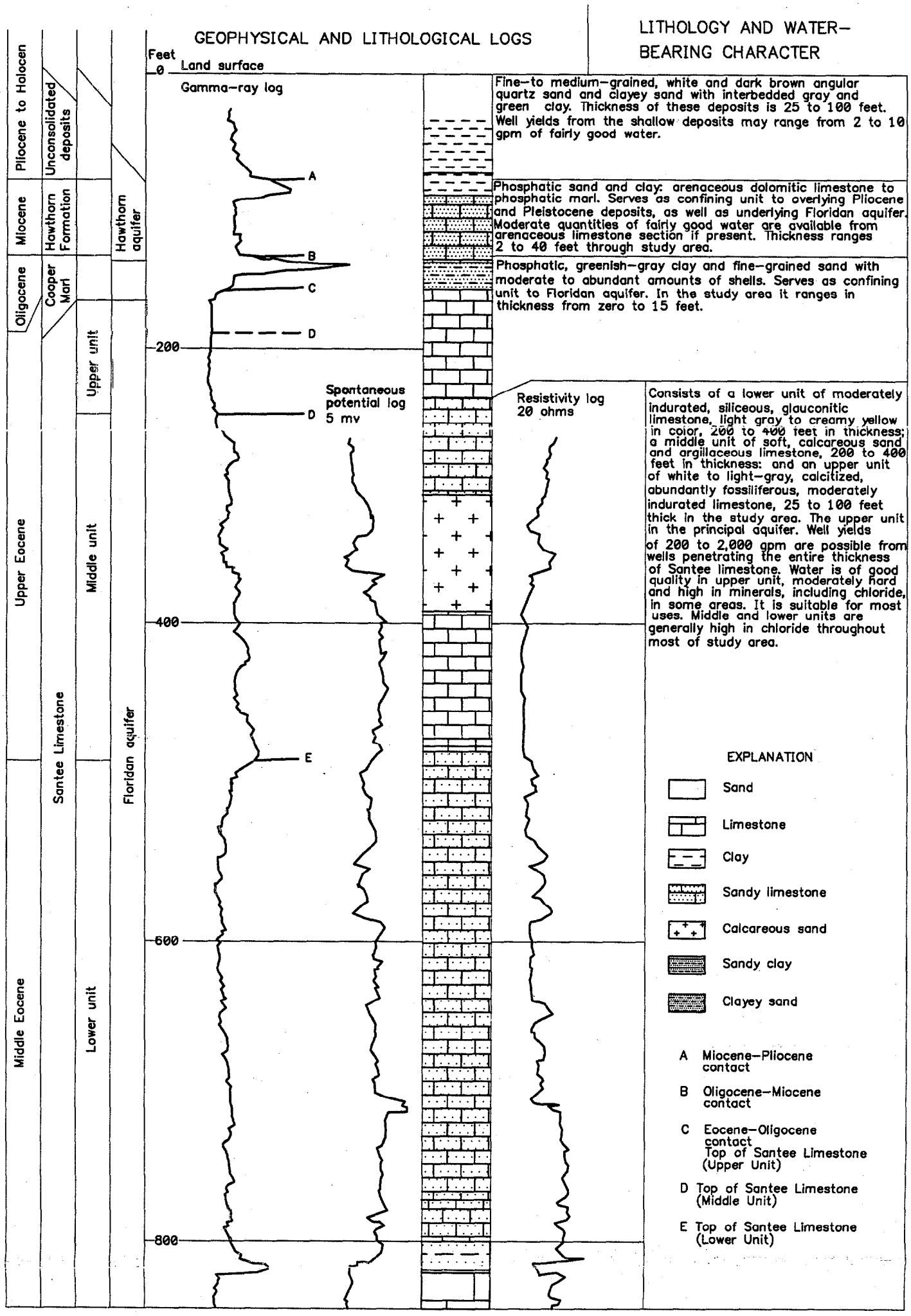

SOURCE: HASSEN, 1985

DRAWN BY HJP DATE 10/21/97		CONTRACT NO. 7394	
CHECKED BY DATE	GENERALIZED LITHOLOGICAL SECTION MCRD PARRIS ISLAND	APPROVED BY DATE	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE AS NOTED		DRAWING NO. FIGURE 2-3	REV. 0

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The potential of the Hawthorn Formation as an aquifer in the study area is doubtful, owing to its thinness and general lithology; little is known about its water-bearing characteristics. In the areas of Jasper, Hampton, and Colleton Counties (Hayes, 1979), yields of 50 to 200 gallons per minute (gpm) of potable water are reported from this formation (Hassen, 1985). However, when present in the study area, the Hawthorn (in conjunction with the Cooper Marl Formation) serves as a confining unit to the overlying Pleistocene deposits, as well as to the underlying Santee Limestone.

Pleistocene Sediments

The Pleistocene Epoch was marked by sea-level fluctuations that are recorded in the sediment depositional record as land emergence and submergence cycles. As a result of the sea-level fluctuations, the Pleistocene sediments are in many cases reworked, deposited as barrier islands, cut by erosional channels, and interbedded with alluvium. Geomorphologically, the "cycles" are reflected as four terrace formations, which are, from oldest to youngest, the Pamplico, Princess Anne, Silver Bluff, and Recent (Glowacz, and others, 1980); the Princess Anne, Silver Bluff, and Recent deposits are present on Parris Island.

The Princess Anne and Silver Bluff Formations occur near the surface in the area as high-permeability beach-ridge deposits and low-permeability clays (marsh deposits) located between the beach-ridge deposits. The permeable beach-ridges of these formations are generally vegetated with hardwoods and have erosional scarp faces that tend to trend somewhat parallel to the Atlantic Ocean. Approximate elevations for the terrace formations are Princess Anne, 16 to 8 feet above mean sea level (msl), and Silver Bluff, 8 to 0 feet above msl.

Water tables tend to be very shallow in the swampy, topographically lower elevations and range from surface grade to approximately 3 feet deep. In the topographically higher portion of the formations, consisting of older beach-ridges and bar deposits, the water table ranges from surface grade to a maximum of about 10 feet deep. Ironstone deposits are commonly found in this barrier island deposit, are low in permeability, and range from reddish brown to black in color (depending on the iron and manganese content). The iron-manganese-cemented sands range in thickness from 10 feet to sand-size concretions. These ironstone features are thought to represent past and present geochemical changes-of-state of iron and manganese due to seasonal fluctuations of the near-surface water table. In typical vertical soil profiles, the near-surface mottled zones caused by iron-manganese staining can be considered an indicator of the local, seasonal, high water-table elevation. The more massive concretions may represent a biogenic precipitate in Pleistocene marsh (backbarrier) environments. The sandy dune and beach faces of the barrier islands have deeper water than the marshy backbarrier deposits (Glowacz, and others, 1980).

Recent deposits occur as thin surficial veneers near the present coastline. Examples of these deposits are Fripp Island and the seaward side of Hilton Head Island. The recent deposits consist of beaches, sand dunes, and alluvium. Most of the Recent alluvium consists of silt and clays of very low permeability (Glowacz, and others, 1980).

2.5.2 Structural Geology

Geologic structure has an important influence on the hydrogeology of the Tertiary Limestone Aquifer in the Beaufort-Jasper County area, widely referred to as the Low Country. A generalized regional geological profile in the area of the MCRD showing the surficial sands, the low-permeability Hawthorn Formation, and the Santee Limestone, comprising the Tertiary Limestone Aquifer, is presented in Figure 2-4. Figure 2-5 shows the structure contour map of the top of the Santee Limestone.

The regional structural setting of the Santee Limestone influences the occurrence and extent of saltwater intrusion into the corresponding Floridan aquifer, the thickness (or absence) of confining beds over the aquifer, and the distribution of permeability, particularly in the upper part of the aquifer. The upper surface of the aquifer has a regional dip (or slope) generally trending toward the southeast. This surface is locally highly irregular, with structural highs (arches) and lows (troughs) present.

The most conspicuous and hydrogeologically important structural feature in the Low Country is the Beaufort Arch, a structural high with a northeast-trending axis. The Beaufort Arch is located in central Beaufort County. Over the axis of the Beaufort Arch, the top of the Santee Limestone ranges from about 40 to 20 feet below msl and is occasionally less than 20 feet below msl. Because of this shallow depth, tidal rivers and estuaries that are more than 20 feet deep actually penetrate the upper surface of the Santee Limestone. During the Pleistocene, when sea level was much lower than it is at present, the top of the Santee Limestone in the Beaufort area was scoured by rivers flowing into the sea. Confining units such as the Cooper Marl and Hawthorn Formation were removed in some areas by the scouring. Mining of river phosphate and channel dredging may have also been responsible for removing confining beds in the Beaufort River.

A structural low, the Ridgeland Trough, has a northeast-trending axis extending from just northwest of Hardeeville in Jasper County to the vicinity of Highway 21 in northern Beaufort County. Along the axis of this structural basin, the top of the Santee Limestone occurs at an elevation of greater than 100 feet below msl, and in southwestern Jasper County, the top of the unit occurs at an elevation of more than 200 feet below msl.

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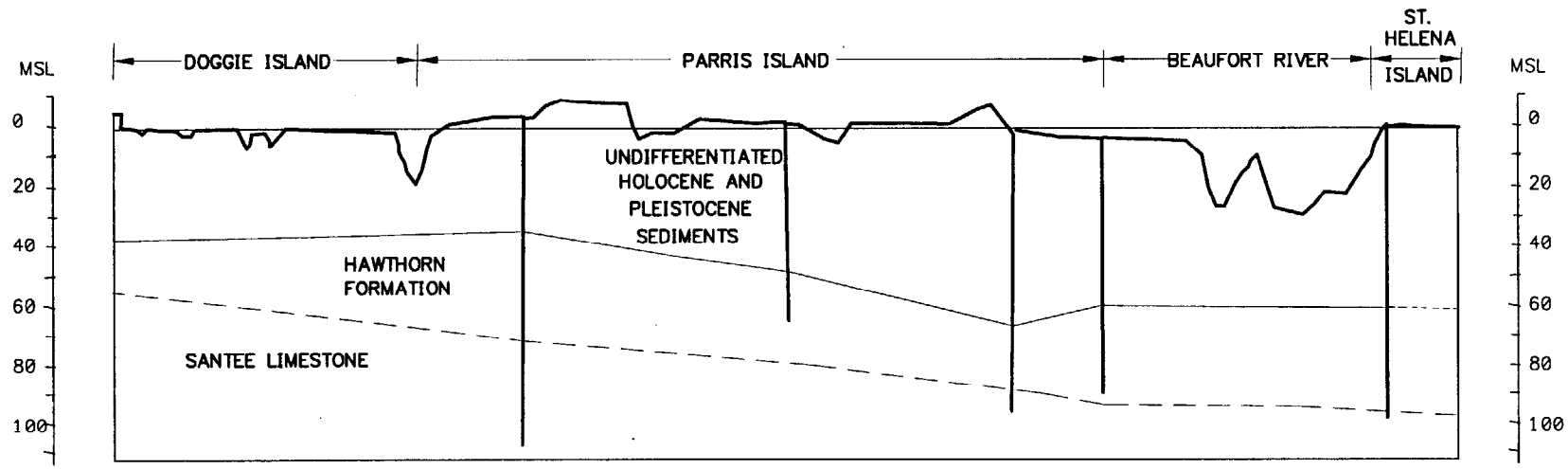


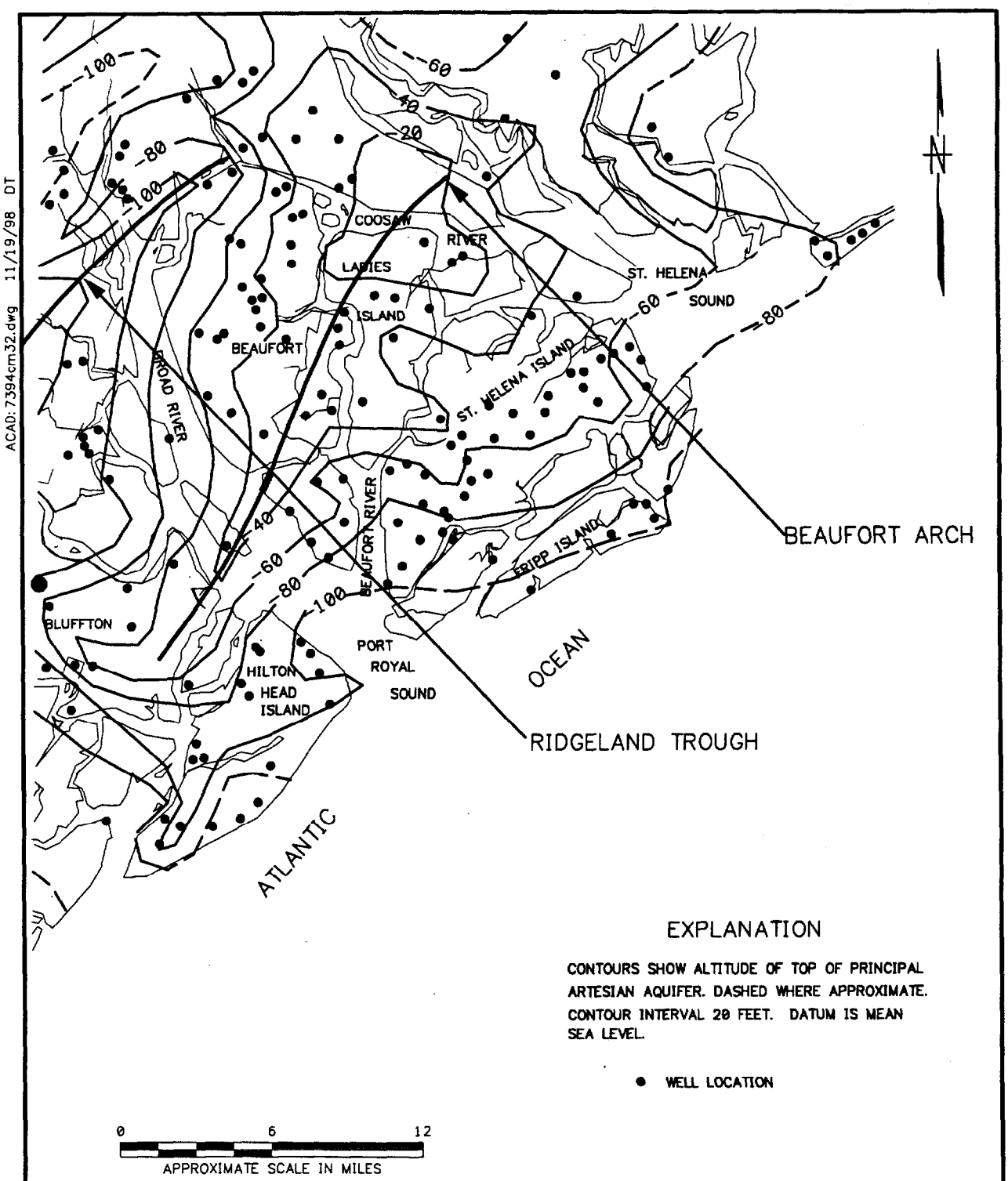
NOTE:
TIDAL RIVERS AND ESTUARIES THAT ARE MORE THAN 20 FEET DEEP MAY PENETRATE THE UPPER SURFACE OF THE SANTEE LIMESTONE

0 6000 12000
SCALE IN FEET

SOURCE: DAMES & MOORE, 1986

DRAWN BY HJP DATE 10/21/97	DEPARTMENT OF THE NAVY ★ SOUTHERN DIV FACILITIES ENGINEERING COMD ★	GENERALIZED GEOLOGICAL PROFILE IN THE AREA OF MCRD PARRIS ISLAND	CONTRACT NO. 7394
CHECKED BY DATE			APPROVED BY DATE
COST/SCHED-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 2-4 REV. 0

FORM CADD NO. SDIV_AH.DWG - REV 0 - 1/20/98



EXPLANATION

CONTOURS SHOW ALTITUDE OF TOP OF PRINCIPAL ARTESIAN AQUIFER. DASHED WHERE APPROXIMATE. CONTOUR INTERVAL 20 FEET. DATUM IS MEAN SEA LEVEL.

● WELL LOCATION

0 6 12
APPROXIMATE SCALE IN MILES

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CHECKED BY DATE			APPROVED BY DATE
COST/SCHED-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 2-5 / REV. 0

FORM CADD NO. SDIV_AV.DWG - REV 0 - 1/20/98

In reference to groundwater hydrology, these geologic structures are important with respect to the depth of the Floridan Aquifer below salty surface water bodies. The structures are also important because confining beds overlying the aquifer are thick in structural troughs but are thin over structural highs.

2.6 HYDROGEOLOGY

The following sections describe the regional hydrogeology of MCRD Parris Island as delineated on Figure 2-3. There are two primary aquifers: the surficial aquifer and the Floridan Aquifer. These aquifers are generally separated by the Hawthorn Formation and Cooper Marl, which act as confining units to the underlying Floridan Aquifer.

2.6.1 Hydrogeology of the Surficial Aquifer

In the MCRD Parris Island area, the shallow, unconfined aquifer generally consists of permeable, fine to medium, Pleistocene age sands. These sands are primarily subangular and quartzitic, containing carbonate shell fragments, heavy minerals, glauconite, and finely disseminated organics. Holocene age sediments generally consist of coarser, more angular, and less indurated (compacted) sands than the Pleistocene age soils. River alluvium consists of silty, micaceous, fine to medium sand. Lenticular bodies of iron-cemented sand occur throughout the Pleistocene sediments.

Surface relief is relatively low. The area is drained by fresh and brackish water streams inland and by tidal streams along the coast. The water table in the MCRD Parris Island area usually ranges from 0 to 10 feet below ground surface (bgs) and is most commonly found at a depth of 3 feet bgs. Water-table fluctuations are a function of recharge, evaporation, and transpiration and have been observed to be as great as 6.5 feet at some locations (Glowacz, and others, 1980). Groundwater-table fluctuations due to tidal action have been measured to occur as far as 1,800 feet inland from the marsh edge (SCWRC, unpublished field data). The water-table elevation drops near drainage ditches to reflect discharge into the ditches.

The hydraulic conductivity of clean fine Holocene sands of the surficial aquifer at the southwestern end of Hilton Head Island was estimated as 13 ft/day [5×10^{-3} centimeters per second (cm/s)]. Pleistocene sands on Hilton Head Island had a hydraulic conductivity of 0.1 to 1.0 ft/day (4×10^{-5} cm/s to 4×10^{-4} cm/s) (Glowacz and others, 1980). Hydraulic conductivity at the Depot was calculated to be 0.8 ft/day (3×10^{-4} cm/s) (Glowacz and others, 1980).

The direction of groundwater flow in the upper portion of the shallow surficial aquifer is generally toward the nearest surface water body, such as a pond, river, tidal creek, or the ocean (refer to Figure 2-6 for general groundwater flow direction across the Depot). The hydraulic gradients are usually low and are

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SOURCE: DAMES & MOORE, 1986

DRAWN BY D. PERRY / DATE 13-NOV-97	Tetra Tech NUS, Inc.	CONTRACT NUMBER —	OWNER No. —
CHECKED BY / DATE	SHALLOW AQUIFER GROUNDWATER FLOW MAP MCRD PARRIS ISLAND	APPROVED BY — / DATE —	
COST/SCHEDULE-AREA		APPROVED BY — / DATE —	
SCALE AS NOTED		DRAWING No. FIGURE 2-6	REV 0

P:\GIS\APR\PARRIS.APR 13-NOV-97 DNP GROUNDWATER FLOW LAYOUT

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nearly flat; they are always less than 1 percent, except near ditches that dewater small areas. The rate of groundwater flow in the shallow aquifer is generally less than 2 feet per day, typically in the range of 0.2 to 1.2 ft/day (SCDHEC, 1982).

2.6.2 Hydrogeology and Water Quality of the Floridan Limestone Aquifer

The Floridan Aquifer, also referred to as the Tertiary Limestone aquifer, extends continuously from South Carolina into Florida. In the central Coastal Plain, this aquifer occurs at or near land surface and is tapped by many small-diameter wells less than 100 feet deep. In many locations throughout the central Coastal Plain, groundwater in the aquifer occurs largely under unconfined conditions, although artesian (confined) conditions are common. Toward the south and southeast, the aquifer is capped by confining beds of the Cooper Marl, and artesian conditions predominate (refer to Figure 2-7 for the potentiometric surface of the Floridan Aquifer). In the Low Country (including the Beaufort area north of MCRD Parris Island), the aquifer system again occurs near land surface, and confining beds vary from essentially 0 to more than 150 feet in thickness. Groundwater of this aquifer occurs mainly under artesian conditions at MCRD Parris Island.

The Floridan aquifer is the most important source of groundwater in the Low Country area, and wells generally less than 250 feet deep tap this aquifer system. The aquifer is the only source of potable groundwater west, north, and east of MCRD Parris Island. It is conservatively estimated that over 4,000 wells tap this aquifer in the Low Country and that this aquifer system probably supplies over 80 percent of the groundwater used in this area. The Depot is served by the Beaufort, Jasper, and Colleton County Water Districts.

Groundwater in the Floridan aquifer occurs in solutionally enlarged openings or cavities in the limestone. In general, groundwater occurs in a series of broadly defined water-bearing (permeable) zones that serve as aquifers and are separated by less permeable rocks. Two hydrogeologic zones within the Floridan aquifer lie beneath the MCRD Parris Island area. They dip toward Savannah, Georgia and are parallel to the geologic unit (or formation) boundaries. These two hydrogeologic units consist of a 200-foot-thick Upper Hydrogeologic Unit that contains an upper permeable zone and an 800-foot-thick Lower Hydrogeologic Unit that has a somewhat lower permeability compared to the Upper Unit.

Upper Hydrogeologic Unit

The Upper Hydrogeologic Unit below MCRD Parris Island consists of the uppermost permeable zone of the Floridan aquifer. This upper permeable zone occurs throughout most of Beaufort County. However, it thins over the Beaufort Arch and has been completely eroded approximately 20 miles north of MCRD Parris Island.

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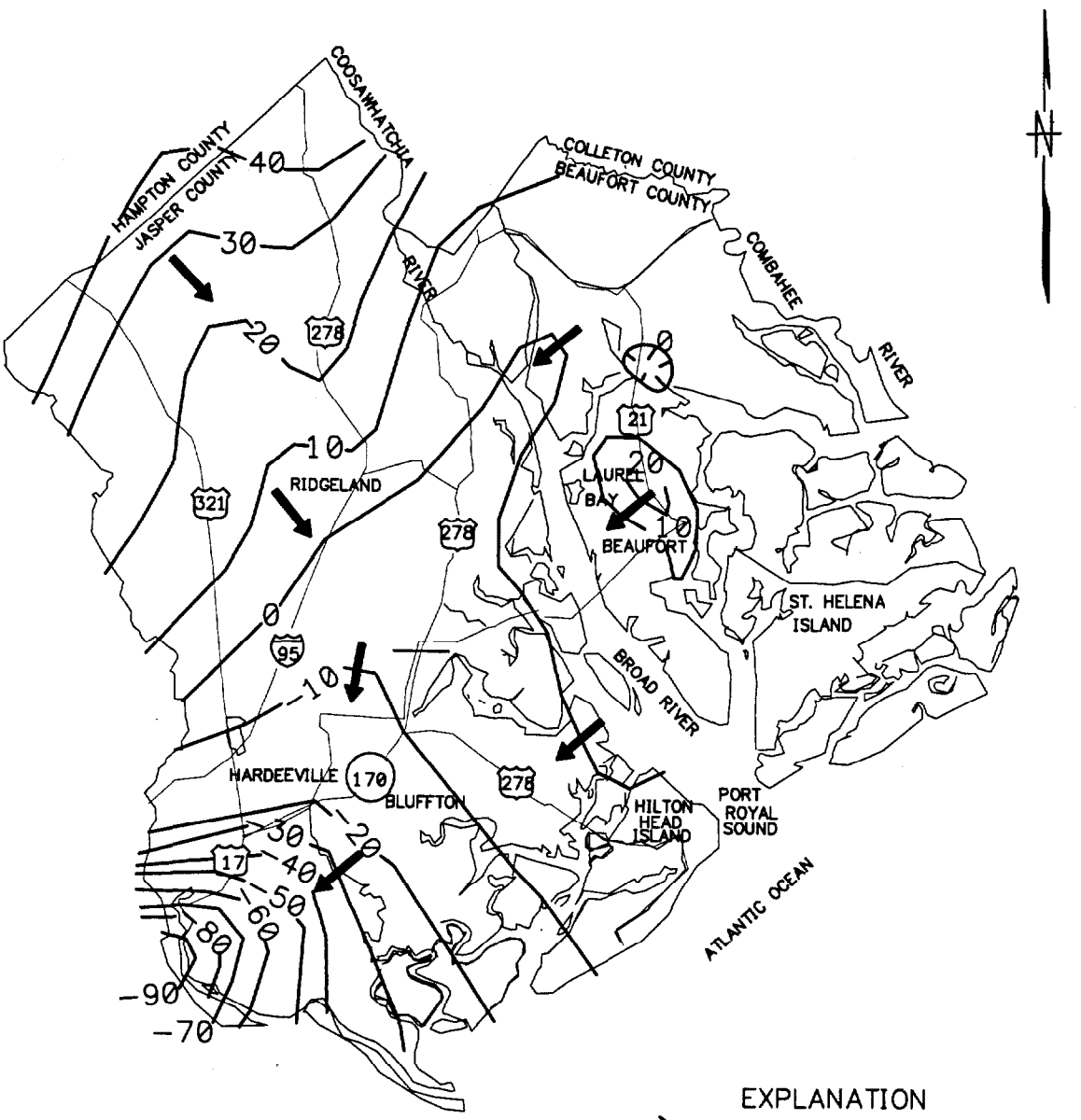

EXPLANATION

10 POTENTIOMETRIC CONTOUR, IN FEET ABOVE OR BELOW (-) SEA LEVEL.

GROUNDWATER FLOW DIRECTION

0 10 20
APPROXIMATE SCALE IN MILES

SOURCE: HASSEN, 1985

DRAWN BY HJP DATE 10/23/97	DEPARTMENT OF THE NAVY SOUTHERN DIV FACILITIES ENGINEERING COMD	POTENTIOMETRIC SURFACE OF THE FLORIDAN AQUIFER (DEEP AQUIFER) MCRD PARRIS ISLAND	CONTRACT NO. 7394
CHECKED BY DATE			APPROVED BY DATE
COST/SCHED-AREA			APPROVED BY DATE
SCALE AS NOTED			DRAWING NO. FIGURE 2-7 REV. 0

FORM CADD NO. SDIV_AV.DWG - REV 0 - 1/20/98

Recharge of the Upper Unit in South Carolina occurs over most of Beaufort County east of the Broad River and over a 30-mile-wide zone trending northwest of the city of Beaufort along the South Carolina-Georgia border. Areas west of the Depot are not recharge zones because of the thick, low-permeability formations within the Ridgeland Trough. A 30-mile-wide, east-west-trending recharge zone is present from 60 to 90 miles north of MCRD Parris Island. These zones delineate potential effective porosity at the ground surface; actual recharge is affected by the thickness and vertical permeability of overlying soils and rock formations.

The Upper Hydrogeologic Unit supplies most of the groundwater used from the Floridan aquifer in the Low Country. In some areas of the coastal parts of the Low Country, including Parris Island, water-bearing zones contain salt water. The average transmissivity of the Upper Unit of the Floridan aquifer in western Beaufort County (i.e., all of Beaufort County west of the Broad River) and southern Jasper County is about 370,000 gallons per day per foot (gpd/ft) and in eastern Beaufort County is notably less than 75,000 gpd/ft. The transmissivity of the Upper Unit in northern Jasper County and southwestern and southeastern Hampton County is estimated to range from 75,000 gpd/ft to 220,000 gpd/ft, transmissivities in the western and southwestern parts of the area are due to increased thickness of the upper permeable zone (Hayes, 1979).

The average hydraulic conductivity of the Upper Unit (determined by dividing the average transmissivity by average thickness) is estimated to be 400 feet per day (ft/d) (1.4×10^{-1} cm/s) in western Beaufort County, Jasper County, and southeastern and southwestern Hampton County. The upper permeability zone in eastern Beaufort County is estimated to have an average hydraulic conductivity of 175 ft/d (6.2×10^{-2} cm/s) (Hayes, 1979).

Lower Hydrogeologic Unit

The water-bearing properties of the Lower Hydrogeologic Unit are not well known in much of the Low Country. Wells that are drilled into the Lower Hydrogeologic Unit are usually also open to the Upper Unit.

The Lower Unit is not a single unit but is a thick, complex unit that is composed of both aquifers and confining beds. Prolific aquifers do not occur in the Lower Unit because these rocks are primarily impure limestone or marl. Aquifers in the Lower Unit contain saline formation water in the coastal parts of the Low Country, such as below MCRD Parris Island. Chloride and dissolved solids generally increase with depth in these zones.

The transmissivity of the Lower Unit in northern Colleton County and northeastern Hampton County is estimated to range from 37,000 gpd/ft to as low as 3,700 gpd/ft, with transmissivity decreasing to the north and northeast. The average transmissivity of the Lower Unit in southern Colleton County is

estimated to be 30,000 gpd/ft. The hydraulic conductivity of the Lower Unit is estimated to vary between 75 and 100 ft/d (10^{-2} cm/sec) in eastern Beaufort County, Colleton County, and northeastern Hampton County (Hayes, 1979).

2.7 ECOLOGY

2.7.1 Ecosystems

2.7.1.1 Wetlands

Eight types of wetlands and deepwater habitats are found on MCRD Parris Island, according to the National Wetlands Inventory (1989). Five of these are estuarine (saltwater) habitats and three are palustrine (freshwater). The estuarine communities occupy the vast majority of the wetland and deepwater habitats at MCRD Parris Island. The most common estuarine community is estuarine, intertidal, emergent (E2EM). Other estuarine communities are the estuarine, subtidal, unconsolidated bottom (E1UB); estuarine, intertidal, scrub-shrub (E2SS); estuarine, intertidal, unconsolidated shore (E2US); and estuarine, intertidal, streambed (E2SB). The three palustrine community types occupy a very small portion of MCRD Parris Island and are found in the vicinity of the airfield and around the obstacle course. These three types are palustrine, emergent (PEM); palustrine, scrub-shrub (PSS); and palustrine, forested (PFO).

In South Carolina, three agencies have regulatory control over dredge and fill operations in jurisdictional wetlands and deepwater habitats. They are the U.S. Army Corps of Engineers (COE), U.S. EPA Region IV, and the South Carolina Department of Health and Environmental Control (SCDHEC). The South Carolina Department of Natural Resources (SCDNR) does not have regulatory authority over such operations; however, this agency reviews and comments on permit applications for such activities.

COE, which exercises the broadest jurisdiction, requires permits for the discharge of dredge or fill materials into waters of the United States, pursuant to Section 404 of the Clean Water Act (CWA). COE also regulates construction of certain structures of work in or affecting navigable waters of the United States, pursuant to Section 10 of the Rivers and Harbors Act of 1899. South Carolina requires permits for any dredging, filling, construction, or alteration activity in, on, or over any navigable waterway of the state. SCDHEC requires water quality certification for dredge, fill, and construction projects in the state's "coastal zone" and requires permits in accordance with the Coastal Zone Management Plan. Without SCDHEC's Office of Ocean and Coastal Resource Management's certification, a permit for a dredge, fill, or construction project in the "coastal zone" cannot be issued by the permitting agency.

The largest natural vegetation community found on MCRD Parris Island is the saltwater marsh. Saltwater marshes occupy expansive areas that are alternately flooded and drained by changing tides. The most common plant found in this community is smooth cordgrass (*Spartina alterniflora*). Other plants found in saltwater marshes on Parris Island are black needlerush (*Juncus roemerianus*), seashore saltgrass (*Distichlis spicata*), and glasswort (*Salicornia virginica*).

The saltwater marshes and adjacent estuarine waters support a diverse assemblage of fauna, particularly fish and crustaceans. Fish, mollusks, and crustaceans, such as blue crabs (*Callinectes sapidus*), stone crabs (*Menippe* sp.), shrimps (*Penaeus* and *Palaemonetes* spp.), American oysters (*Crassostrea virginica*), Atlantic ribbed mussels (*Geukensis demissus*), killifish, and mummichogs *(Fundulus spp.)* live in the marshes in large numbers. Marshes also support large numbers of animals that prey upon the fish and crustaceans. These predators include mammals such as raccoons (*Procyon lotor*), mink (*Mustela vison*), and river otter (*Lutra canadensis*); wading birds such as tricolored herons (*Egretta tricolor*) and snowy egrets (*Egretta thula*); various shorebirds and gulls; brown pelicans (*Pelecanus occidentalis*); and large numbers of wintering water fowl, such as lesser scaup (*Aythya affinis*), ring-necked ducks (*Aythya collaris*), and common mergansers (*Mergus merganser*); and fish, such as red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), summer flounder (*Paralichthys dentatus*), and southern flounder (*Paralichthys lethostigma*).

2.7.1.2 Uplands

Upland vegetation communities include forested and open (field and lawn) areas. MCRD Parris Island contains approximately 1,502 acres of forest land, most of which is dominated by slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*). These forest lands are managed for "multiple-use" such as wildlife habitat, aesthetics, soil erosion control, threatened and endangered species habitat, outdoor recreation, and timber production. The managed pine forests support a number of wildlife species, including white-tailed deer (*Odocoileus virginianus*) and bobwhite (*Colinus virginianus*).

The upland plant communities also include temperate evergreen forest and maritime forest. Areas of the island that have never been filled or excavated tend to support the temperate evergreen forest. The extreme southern tip of the island (south of the golf course) is maritime forest with many large live oaks (*Quercus virginiana*). Jericho and Doggie Islands are temperate evergreen forest, surrounded by salt marsh. Horse Island is covered with both pine forest (in the fill and borrow areas) and temperate evergreen forest (in relatively undisturbed areas) and is surrounded by salt marsh.

The temperate evergreen forest is characterized by evergreen oaks, such as the live oak and laurel oak (*Quercus laurifolia*), and other evergreen trees and shrubs, such as the bull bay or southern magnolia (*Magnolia grandiflora*), red bay (*Peresa borbonia*), sweet bay (*Magnolia virginiana*), and yaupon (*Ilex*

vomitoria). The understory includes many runner or vine species, such as poison ivy (*Rhus radicans*), Virginia creeper (*Parthenocissus quinquefolia*), muscadine grape (*Vitis rotundifolia*), and greenbriar (*Smilax rotundifolia*).

The maritime forest is a temperate evergreen forest that has been modified by salt spray and constant sea breezes. As a result, salt-tolerant species dominate. These species include trees and shrubs such as the live oak, yaupon, wax myrtle (*Myrica cerifera*), and cabbage palmetto (*Sabal palmetto*). Typically, these species are stratified in bands along the ocean-facing beaches of islands. The band of vegetation nearest the ocean is composed of the most salt-tolerant species, wax myrtle followed by the yaupon, and then a live oak-cabbage palmetto association. Undergrowth is typically sparse in maritime forest, although greenbriar vines are common in areas that do not support significant populations of large herbivores, such as white-tailed deer.

The common mammalian herbivores of the area include the white-tailed deer, the eastern cottontail (*Sylvilagus floridanus*), the marsh rabbit (*Sylvilagus palustris*), the gray squirrel (*Sciurus carolinensis*), the fox squirrel (*Sciurus niger*), the cotton rat (*Sigmodon hispidus*), and the cotton mouse (*Peromyscus gossypinus*). Carnivores include the red fox (*Vulpes vulpes*), mink (*Mustela vison*), striped skunk (*Mephitus mephitus*), and river otter (*Lutra canadensis*). Common bird species include the bobwhite (*Colinus virginianus*), the barred owl (*Strix varia*), chuck-wills-widow (*Caprimulgus carolinesis*), blue jay (*Cyanocitta cristata*), common crow (*Corvus brachyrhynchos*), fish crow (*Corvus ossifragus*), mockingbird (*Mimus polyglottos*), osprey (*Pandion haliaetus*), red-tailed hawk (*Buteo jamaicensis*), mourning dove (*Zenaida marcroura*), and numerous others.

Common reptiles and amphibians include the yellow rat snake (*Elaphe obsoleta quadrivittata*), black racer (*Coiluber constrictor*), red-bellied water snake (*Nerodia erythrogaster*), eastern cottonmouth (*Agkistrodon piscivorus*), narrow-mouthed toad (*Gastrophryne carolinensis*), southern toad (*Buffo terrestris*), squirrel treefrog (*Hyla squirella*), bullfrog (*Rana catesbeina*), diamondback terrapin (*Malaclemys terrapin*), eastern glass lizard (*Ophisaurus ventralis*), and the broad-headed skink (*Eumeces laticeps*). Freshwater fishes include largemouth bass (*Micropterus salmoides*) sunfishes (*Lepomis spp.),* the brown bullhead (*Ameiurus nebulosus*), and eastern mosquitofish (*Gambusia holbrooki*).

2.7.2 Threatened or Endangered Species

A study conducted by SOUTHDIV NAVFAC identified threatened and endangered plants and animals that occur or potentially occur on MCRD Parris Island. Section 7 of the Endangered Species Act states "each Federal Agency shall, in consultation with and with the assistance of the Secretary [of the Department of the Interior], insure any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species." South

Carolina also provides protection to threatened or endangered animal species but presently does not have any regulations that protect threatened or endangered plant species.

No threatened or endangered plant species are known to occur on MCRD Parris Island. Five threatened or endangered animal species are known to occur in or around the Depot. They are the American alligator, bald eagle, wood stork, least tern, and the West Indian manatee. The American alligator (*Alligator mississippiensis*) is occasionally observed in the large pond adjacent to the Causeway Landfill in the northwestern portion of MCRD Parris Island and could utilize freshwater ponds and ditches on the Depot. Formerly an endangered species, the alligator has recovered in many portions of its range. The species is still federally listed as threatened because it is similar in appearance to the endangered American crocodile. Bald eagles are occasional visitors, and one pair of nesting bald eagles was discovered at MCRD Parris Island in January 1998. Wood storks are also known to use the estuarine environment in and around the Depot, but there are no known rookeries on MCRD Parris Island. Least terns (state-listed as threatened) have been observed feeding in the Third Battalion Pond. Their preferred nesting habitat of beaches is limited on the installation, and their nesting status is not known. Manatees have been recorded in the estuaries around MCRD Parris Island but are transient species in the area and occur rarely. Table 2-2 provides a list of endangered, threatened, and candidate species known to occur or possibly occurring in Beaufort County, based on records maintained by the U.S. Fish and Wildlife Service and current as of December 29, 1997. Table 2-2 does not include the American alligator and least tern, but as mentioned above, these two species are known to occur, at least occasionally, at MCRD Parris Island. The following sea turtles may occur in the area: Kemp's ridley, green, hawksbill, leatherback, and loggerhead. These turtles are known to enter Port Royal Sound; however, there is no evidence of nesting. A complete listing of rare, threatened, and endangered species of South Carolina is provided in Volume I of the MCRD Parris Island Master Work Plan (B & R Environmental, 1998a).

TABLE 2-2

BEAUFORT COUNTY DISTRIBUTION RECORDS OF ENDANGERED, THREATENED, AND CANDIDATE SPECIES MCRD PARRIS ISLAND, SOUTH CAROLINA

Species	Status	Certainty of Occurrence[a]
West Indian manatee (*Trichechus manatus*)	E	Known
Finback whale (*Balaenoptera physalus*)	E	Known
Humpback whale (*Megaptera novaeanqliae*)	E	Known
Northern right whale (*Eubaleana glacialis*)	E	Known
Sei whale (*Balacnoptera borealis*)	E	Known
Sperm whale (*Physeter catodon*)	E	Known
Peregrine falcon (*Falco peregrinus*)	E (S/A)	Known
Bald eagle (*Haliaeetus leucocephalus*)	T	Known
Wood stork (*Mycteria americana*)	E	Known
Red-cockaded woodpecker (*Picoides borealis*)	E	Known
Piping plover (*Charadrius melodus*)	T	Known
Kemp's ridley sea turtle (*Lepidochelys kempi*)	E	Known
Leatherback sea turtle (*Dermochelys coriacea*)	E	Known
Loggerhead sea turtle (*Caretta caretta*)	T	Known
Green sea turtle (*Chelonia mydas*)	T	Known
Flatwoods salamander (*Ambystoma cingulatum*)	PT	Known
Shortnose sturgeon (*Acipenser brevirostrum*)	E	Known
Pondberry (*Lindera melissifolia*)	E	Known
Canby's dropwort (*Oxypolis canbyi*)	E	Possible
Chaff-seed (*Schwalbea americana*)	E	Known
Dusky shark (*Carcharhinus obscurus*)	C	Possible
Sand tiger shark (*Odontaspis taurus*)	C	Possible
Night shark (*Carcharinus signatus*)	C	Possible
Speckled hind (*Epinephelus drummondbayl*)	C	Possible
Jewfish (*E. itijara*)	C	Possible
Warsaw grouper (*E. nigritus*)	C	Possible
Nassau grouper (*E. striatus*)	C	Possible

a Occurrence in Beaufort County based on records maintained by U.S. Fish and Wildlife Service. Current as of December 29, 1997.
E Endangered
T Threatened
S/A Due to similarity of appearance
PT Proposed to be listed as threatened
C U.S. Fish and Wildlife Service or National Marine Fisheries Service has on file sufficient information on biological vulnerability and threat(s) to support proposals to list this species.

3.0 INVESTIGATION SUMMARY

The field investigation for Site/SWMU 3 (Site 3) was performed from May to September 1998 and August 1999. During the field investigation, monitoring wells were installed, groundwater, soil, sediment, and surface water samples were collected, a tidal study was performed, and aquifer tests were conducted. Information collected during the investigation was used to supplement existing geologic and hydrogeologic information at Site 3. The following sections discuss deviations from the work plan, the field activities that were conducted, and the site-specific geologic and hydrogeologic setting at Site 3. A summary of the RFI/RI sampling activities is provided in Tables 3-1 to 3-10. The site layout for Site 3 is shown in Figure 3-1.

3.1 DEVIATIONS FROM THE WORK PLAN

Several deviations to the approved work plan for Site 3 (B&R Environmental, 1998b) were made during the field effort:

- The method of well installation was changed from the approved work plan method of mud rotary drilling to the use of 4-1/4-inch inner direction hollow-stem augers after consultation SCDHEC.

- Well PAI-03-MW-02(D) was not installed to the top of the Hawthorn Formation as proposed in the work plan. During the drilling of soil boring PAI-03-SB-01, the Hawthorn Formation was not encountered to the termination of the boring at a depth of 40 feet. A clay unit was encountered from a depth of 28 to 40 feet. Based on the color, texture, and penetration resistance of the clay encountered from 28 to 36 feet bgs, this material is not believed to be part of the Hawthorn formation. However, clay encountered from 36 to 40 feet bgs does correspond to characteristics of the Hawthorn Formation. This unit, if continuous across the area, would act as a confining unit to the overlying formations by restricting the downward migration of any possible contaminants. The proposed well was installed to the top of this clay unit.

- The locations of the four monitoring wells were altered from those proposed in the work plan (B&R Environmental, 1998b) based on a partnering team decision made in June 1998. Monitoring well cluster PAI-03-MW-01(S) and PAI-03-MW-02(D) was installed at a location near PAI-03-SW-01, PAI-03-SW-13, and PAI-03-SW-14 due to detections of cadmium, mercury, lead, sliver, and fluoranthene at these surface water sample locations. Similarly, monitoring well PAI-03-MW-04(S) was installed at a location near PAI-03-SW-04, PAI-03-SW-09, and PAI-03-SW-21 due to detections of lead and copper at these surface water sample locations. It should be noted that these detections were below

TABLE 3-1

SAMPLING RATIONALE
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Sample Location	Sampling Rationale
GROUNDWATER	
PAI-03-MW-01(S)	Collected to provide analytical data from the shallow surficial aquifer. Located near PAI-03-SW-01, PAI-03-SW-13, and PAI-03-SW-14 due to detections of cadmium, mercury, lead, sliver, and fluoranthene at these surface water sample locations. It should be noted that detections were below screening criteria.
PAI-02-MW-02(D)	Collected to provide analytical data from the deep surficial aquifer. Located near PAI-03-SW-01, PAI-03-SW-13, and PAI-03-SW-14 due to detections of cadmium, mercury, lead, sliver, and fluoranthene at these surface water sample locations. It should be noted that detections were below screening criteria.
PAI-03-MW-03(S)	Collected to provide analytical data from the shallow surficial aquifer. Located between PAI-03-MW-01(S) and PAI-03-MW-04(S) to provide spatial distribution of analytical data along the causeway.
PAI-03-MW-04(S)	Collected to provide analytical data from the shallow surficial aquifer. Located near PAI-03-SW-04, PAI-03-SW-09, and PAI-03-SW-21 due to detections of lead and copper at these surface water sample locations. It should be noted that detections were below screening criteria.
SURFACE WATER	
PAI-03-SW-09 to PAI-03-SW-22, PAI-03-SW-27 and PAI-03-SW-28	Collected to assess potential migration and accumulation of chemicals from the causeway landfill to the surface water adjacent to the landfill. Sampling locations were chosen to span the length of both sides of the causeway.
PAI-03-SW-23	Collected to assess potential contaminant migration of chemicals from the causeway landfill to the pond located northeast of the causeway.
PAI-03-SW-24, PAI-03-SW-25, and PAI-03-SW-26	Collected to assess potential contaminant migration of chemicals from the causeway landfill to Ribbon Creek.
SEDIMENT	
PAI-03-SD-09 to PAI-03-SD-22, PAI-01-SD-27 and PAI-01-SD-28	Collected to assess potential contaminant migration and accumulation of chemicals from the causeway landfill to the sediment adjacent to the landfill. Sampling locations were chosen to span the length of both sides of the causeway.
PAI-03-SD-23	Collected to assess potential contaminant migration of chemicals from the causeway landfill to the pond located northeast of the causeway.
PAI-03-SD-24, PAI-03-SD-25, and PAI-03-SD-26	Collected to assess potential contaminant migration of chemicals from the causeway landfill to Ribbon Creek.
PAI-03-SD-29 through PAI-03-SD-31	Collected to better delineate PAHs detections observed in PAI-03-SD-22.
PAI-03-SD-32 through PAI-03-SD-34	Collected to better delineate PCB detections observed in PAI-03-SD-20.
PAI-03-SD-35 through PAI-03-SD-37	Collected to better delineate pesticide detections observed in PAI-03-SD-14
PAI-03-SD-38 through PAI-03-SD-40	Collected to better delineate pesticide detections observed in PAI-03-SD-28

TABLE 3-1

SAMPLING RATIONALE
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Sample Location	Sampling Rationale
SURFACE SOIL	
PAI-03-SS-01 to PAI-03-SS-16	Collected to characterize the nature and extent of contamination of the surface soil atop the causeway landfill. Sampling locations were chosen to span the length of the causeway.
SUBSURFACE SOIL	
PAI-03-SB-01 through PAI-03-SB-04	Samples collected during monitoring well installations to provide geotechnical data.

TABLE 3-2

MONITORING WELL CONSTRUCTION DETAILS
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Well Monitoring ID	Installation Date	Ground Elevation (ft. msl)	Measuring Point Elevation (ft. msl)	Total Depth (feet bgs)	Depth to Water (feet TPVC)	Screened Interval (feet bgs)
PAI-03-MW-01(S)	1998	10.0	9.77	16	7.2	6-16
PAI-03-MW-02(D)	1998	9.9	9.82	28	7.57	23-28
PAI-03-MW-03(S)	1998	13.2	12.99	18	10.02	8-18
PAI-03-MW-04(S)	1998	13.2	12.75	18	10.28	8-18

PAI-03-MW-01(S) – well installed in shallow surficial aquifer.
PAI-03-MW-02(D) – well installed in deep surficial aquifer.
Depths to groundwater measured before wells were sampled.
TPVC -Top of PVC casing
bgs -below ground surface
ft. msl -feet above mean sea level

TABLE 3-3

SUMMARY OF SUBSURFACE SOIL SAMPLES
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Sample ID	Date Collected	Media	Depth Collected (Feet)	Analysis
PAI-03-SB-02-04*	1998	Subsurface soil	4-6	(2)
PAI-03-SB-02-24*	1998	Subsurface soil	24-26	(1), (2), (4)
PAI-03-SB-02-28*	1998	Subsurface soil	28-30	(3)
PAI-03-SB-03-10*	1998	Subsurface soil	10-12	(2)
PAI-03-SB-03-12*	1998	Subsurface soil	12-14	(1), (2), (4)

* Denotes top of sample interval

1 TOC, pH.
2 Natural moisture content, grain-size analysis and Atterberg Limits.
3 Shelby tube (for Vertical Hydraulic Conductivity).
4 Porosity, bulk density, and specific gravity.

TABLE 3-4

SUMMARY OF SURFACE WATER SAMPLES COLLECTED
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Sample ID	Date Collected	Media	Depth Collected	Analysis
PAI-03-SW-09-00	1998	Surface water	Surface	(1), (3), (4)
PAI-03-SW-10-00	1998	Surface water	Surface	(2), (3), (4)
PAI-03-SW-11-00	1998	Surface water	Surface	(1), (3), (4)
PAI-03-SW-12-00	1998	Surface water	Surface	(1), (3), (4)
PAI-03-SW-13-00	1998	Surface water	Surface	(1), (3), (4)
PAI-03-SW-14-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-15-00	1998	Surface water	Surface	(1), (2), (3), (4)
PAI-03-SW-16-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-17-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-18-00	1998	Surface water	Surface	(1), (2), (3), (4)
PAI-03-SW-19-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-20-00	1998	Surface water	Surface	(1), (3), (4)
PAI-03-SW-21-00 PAI-03-SW-21-00-D	1998 1998	Surface water Surface water	Surface Surface	(3), (4) (3), (4)
PAI-03-SW-22-00	1998	Surface water	Surface	(1), (3), (4)
PAI-03-SW-23-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-24-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-25-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-26-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-27-00	1998	Surface water	Surface	(3), (4)
PAI-03-SW-28-00	1998	Surface water	Surface	(3), (4)

PAI-03-SW-021-00D - duplicate
TCL - Target Compound List
TOC - Total Organic Carbon
TAL - Target Analyte List
PCBs - Polychlorinated biphenyls

1 TOC, Hardness ($CaCO_3$).
2 Hexavalent Chromium.
3 TCL volatiles, semivolatiles, pesticides, PCBs, TAL Metals (Totals), TAL Metals (Dissolved) cyanide.
4 Dissolved oxygen, salinity, temperature, pH, and turbidity.

TABLE 3-5

SUMMARY OF SURFACE WATER QUALITY PARAMETERS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Sample ID	Temperature (°C)	pH	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	Salinity (%)	Turbidity (NTU)	Secchi Disk (FT)
PAI-03-SW-09-00	37.2	7.30	37.2	6.43	2.38	18	(1)
PAI-03-SW-10-00	31.0	6.40	37	4.6	2.4	6	(1)
PAI-03-SW-11-00	26.5	7.36	36.9	7.32	2.38	20	(1)
PAI-03-SW-12-00	26.1	7.82	33.7	8.60	2.18	75	(1)
PAI-03-SW-13-00	29.1	7.68	36.1	7.20	2.32	20	(1)
PAI-03-SW-14-00	29.7	8.06	32.8	10.34	2.05	5	(1)
PAI-03-SW-15-00	33.8	7.73	33.8	10.25	2.06	7	(1)
PAI-03-SW-16-00	33.7	7.94	33.7	2.02	2.16	22	(1)
PAI-03-SW-17-00	34.2	8.17	34.2	12.25	2.18	12	(1)
PAI-03-SW-18-00	30.4	7.50	33.5	7.87	2.09	6	(1)
PAI-03-SW-19-00	29.7	6.3	34.6	7.59	2.20	8	(1)
PAI-03-SW-20-00	30.0	7.28	33.8	8.21	2.13	2	(1)
PAI-03-SW-21-00	30.1	7.40	37.5	5.80	2.41	3	(1)
PAI-03-SW-21-00-D	30.1	7.40	37.5	5.80	2.41	3	(1)
PAI-03-SW-22-00	28.6	7.45	36.4	6.10	2.35	9	(1)
PAI-03-SW-23-00	34.7	7.01	37.7	8.01	2.40	14	(1)
PAI-03-SW-24-00	NM	NM	NM	NM	NM	NM	NM
PAI-03-SW-25-00	NM	NM	NM	NM	NM	NM	NM
PAI-03-SW-26-00	NM	NM	NM	NM	NM	NM	NM
PAI-03-SW-27-00	32.9	7.34	20.6	2.53	1.24	>999	(1)
PAI-03-SW-28-00	28.5	7.22	13.6	3.53	0.81	43	(1)

1 Surface water too shallow to obtain Secchi Disk readings.
PAI-03-SW-21-00-D - duplicate
mS/cm - milliSiemens per centimeter
mg/L - milligram per Liter
NTU - Nephlometric Turbidity Units
NM - Not measured

TABLE 3-6

SUMMARY OF SEDIMENT SAMPLES COLLECTED
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Sample ID	Date Collected	Media	Depth Collected (Feet)	Analysis
PAI-03-SD-09-01	1998	Sediment	0-0.5	(1), (2), (4)
PAI-03-SD-10-01	1998	Sediment	0-0.5	(1), (3)
PAI-03-SD-11-01	1998	Sediment	0-0.5	(1), (2), (4)
PAI-03-SD-12-01 PAI-03-SD-12-02	1998 1998	Sediment Sediment	0-0.5 0.5-1	(1), (2), (4) (1)
PAI-03-SD-13-01 PAI-03-SD-13-01-D	1998 1998	Sediment Sediment	0-0.5 0-0.5	(1) (1)
PAI-03-SD-14-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-15-01	1998	Sediment	0-0.5	(1), (2), (3), (4)
PAI-03-SD-16-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-17-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-18-01	1998	Sediment	0-0.5	(1), (2), (3), (4)
PAI-03-SD-19-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-20-01	1998	Sediment	0-0.5	(1), (2), (4)
PAI-03-SD-21-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-22-01	1998	Sediment	0-0.5	(1), (2), (4)
PAI-03-SD-23-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-24-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-25-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-26-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-27-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-28-01	1998	Sediment	0-0.5	(1)
PAI-03-SD-29-01 PAI-03-SD-29-01-DU	1999 1999	Sediment Sediment	0-0.5 0-0.5	(5) (5)
PAI-03-SD-30-01	1999	Sediment	0-0.5	(5)
PAI-03-SD-31-01	1999	Sediment	0-0.5	(5)
PAI-03-SD-32-01	1999	Sediment	0-0.5	(6)
PAI-03-SD-33-01	1999	Sediment	0-0.5	(6)
PAI-03-SD-34-01 PAI-03-SD-34-01DU	1999 1999	Sediment Sediment	0-0.5 0-0.5	(6) (6)
PAI-03-SD-35-01	1999	Sediment	0-0.5	(7)
PAI-03-SD-36-01	1999	Sediment	0-0.5	(7)
PAI-03-SD-37-01	1999	Sediment	0-0.5	(7)
PAI-03-SD-38-01	1999	Sediment	0-0.5	(7)

TABLE 3-6

**SUMMARY OF SEDIMENT SAMPLES COLLECTED
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2**

Sample ID	Date Collected	Media	Depth Collected (Feet)	Analysis
PAI-03-SD-39-01	1999	Sediment	0-0.5	(7)
PAI-03-SD-40-01 PAI-03-SD-4-01DU	1999 1999	Sediment Sediment	0-0.5 0-0.5	(7) (7)

PAI-03-SD-29-01DU - duplicate
PAI-03-SD-13-01-D - duplicate
TCL- Target Compound List
TOC - Total Organic Carbon
TAL - Target Analyte List
PCBs - Polychlorinated biphenyls
PAHs - Polynuclear Aromatic Hydrocarbons

1 TCL volatiles, semivolatiles, pesticides, PCBs, TAL Metals (Total), cyanide.
2 TOC, pH.
3 Hexavalent Chromium.
4 Grain –size analysis and bulk density.
5 PAHs
6 TCL PCBs
7 TCL Pesticides

TABLE 3-7

SUMMARY OF SURFACE SOIL SAMPLES COLLECTED
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Sample ID	Date Collected	Media	Depth Collected (Feet)	Analysis
PAI-03-SS-01-01	1998	Soil	0-1	(1)
PAI-03-SS-02-01	1998	Soil	0-1	(1)
PAI-03-SS-03-01	1998	Soil	0-1	(1)
PAI-03-SS-04-01	1998	Soil	0-1	(1)
PAI-03-SS-05-01	1998	Soil	0-1	(1), (2)
PAI-03-SS-06-01	1998	Soil	0-1	(1)
PAI-03-SS-07-01	1998	Soil	0-1	(1), (2)
PAI-03-SS-08-01	1998	Soil	0-1	(1)
PAI-03-SS-09-01	1998	Soil	0-1	(1)
PAI-03-SS-10-01	1998	Soil	0-1	(1), (2)
PAI-03-SS-11-01	1998	Soil	0-1	(1)
PAI-03-SS-12-01	1998	Soil	0-1	(1)
PAI-03-SS-13-01	1998	Soil	0-1	(1)
PAI-03-SS-14-01 PAI-03-SS-14-01-D	1998 1998	Soil Soil	0-1 0-1	(1) (1)
PAI-03-SS-15-01	1998	Soil	0-1	(1)
PAI-03-SS-16-01	1998	Soil	0-1	(1)

PAI-03-SS-14-01-D - Duplicate
TAL - Target Analyte List
TCL- Target Compound List
PCBs - Polychlorinated biphenyls

1 TCL volatiles, semivolatiles, pesticides, PCBs, TAL Metals (Total), cyanide.
2 Hexavalent Chromium.

TABLE 3-8

**SUMMARY OF GROUNDWATER SAMPLES COLLECTED
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Sample ID	Date Collected	Media	Depth Collected	Analysis
PAI-03-GW-01-01	1998	Groundwater	Shallow surficial	(1), (2), (3), (5), (6)
PAI-03-GW-02-01	1998	Groundwater	Deep Surficial	(1), (4), (5), (6)
PAI-03-GW-03-01	1998	Groundwater	Shallow surficial	(1), (2), (3), (5), (6)
PAI-03-GW-04-01	1998	Groundwater	Shallow surficial	(1), (2), (3), (5), (6)

TAL - Target Analyte List
TCL- Target Compound List
TOC- Total Organic Carbon
PCBs- Polychlorinated biphenyls
TDS- Total dissolved solids
TSS- Total suspended solids

1 TOC, Hardness ($CaCO_3$).
2 Hexavalent Chromium.
3 TCL volatiles, semivolatiles, pesticides, PCBs, TAL Metals (Totals), TAL Metals (Dissolved) cyanide.
4 RCRA Appendix IX Organics (including volatile organics, semivolatile organics, pesticides/PCBs, pesticides and chlorinated herbicides), RCRA Appendix IX inorganics, cyanide.
5 TDS, TSS, chloride, fluoride nitrate/nitrite, sulfate.
6 Dissolved oxygen, salinity, temperature, pH, and turbidity.

TABLE 3-9

**SUMMARY OF GROUNDWATER QUALITY PARAMETERS
COLLECTED DURING PURGING
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Sample Number	Temperature (°C)	pH	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	Salinity (%)	Turbidity (NTU)
PAI-03-GW-01-01	24.2	6.47	4.27	1.42	0.25	9
PAI-03-GW-02-01	21.9	6.18	29.9	1.67	1.87	3
PAI-03-GW-03-01	24.3	7.14	6.61	0.68	0.35	2
PAI-03-GW-04-01	24.5	6.62	29.4	1.38	1.83	<10

mS/cm - milliSiemens per centimeter
mg/L - milligram per Liter
NTU - Nephlometric Turbidity Units

TABLE 3-10

WATER LEVEL MEASUREMENTS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Well Monitoring ID	Date Measured	Measuring Point Elevation (ft. msl)	Depth to Water (ft. from TPVC)	Groundwater Elevation (ft. msl)	Rising Hydraulic Conductivity (ft/day)	Falling Hydraulic Conductivity (ft/day)
PAI-03-MW-01(S)	08/05/98	9.77	7.20	2.57	0.901	N/A
PAI-03-MW-02(D)	08/05/98	9.82	7.57	2.25	0.615	1.41
PAI-03-MW-03(S)	08/06/98	12.99	10.02	2.97	2.76	N/A
PAI-03-MW-04(S)	08/06/98	12.75	10.28	2.47	0.852	N/A

Depth to groundwater measured during well sampling event.
PAI-03-MW-01(S) - well installed in shallow surficial aquifer.
PAI-03-MW-02(D) - well installed in shallow surficial aquifer.
ft msl - feet above mean sea level
TPVC - top of polyvinyl chloride (PVC)

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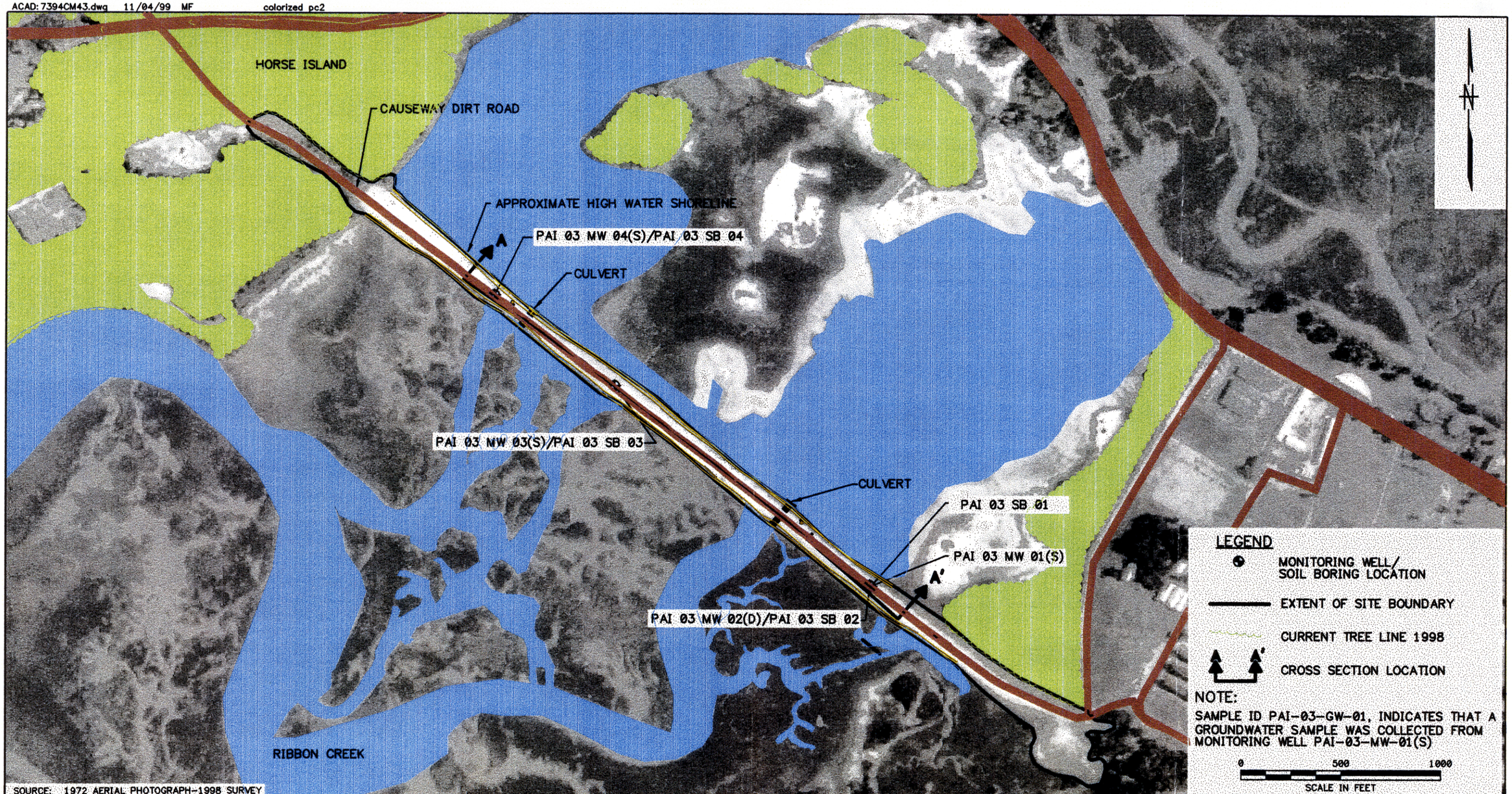

SOURCE: 1972 AERIAL PHOTOGRAPH-1998 SURVEY

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DRAWN BY HJP DATE 11/30/98
CHECKED BY DATE
COST/SCHED-AREA
SCALE AS NOTED

MONITORING WELL AND SOIL BORING SAMPLE LOCATION MAP
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 7394
APPROVED BY DATE
APPROVED BY DATE
DRAWING NO. FIGURE 3-1
REV. 0

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screening criteria. Monitoring well PAI-03-MW-03(S) was installed at a location between PAI-03-MW-01(S) and PAI-03-MW-04(S) to provide spatial distribution of analytical data along the causeway.

- Soil boring sample designations PAI-03-SB-01-01, PAI-03-SB-02-01, PAI-03-SB-03-01, PAI-03-SB-04-01 were changed to PAI-03-SS-13-01, PAI-03-SS-14-01, PAI-03-SS-15-01, and PAI-03-SS-16-01, respectively.

- The approved work plan stated that surface water samples would be collected at low tide; however, if the samples had been collected at low tide as proposed, the sample locations would have been collected as far as 500 to 700 feet from the causeway. Because these samples were collected to assess the potential migration of chemicals from the landfill to surface water adjacent to the causeway, surface water samples were collected on the receding tide, approximately 50 feet from the causeway.

- Field parameters (temperature, pH, specific conductance, dissolved oxygen, salinity, turbidity) were not collected from surface water samples PAI-03-SW-24, PAI-03-SW-25, and PAI-03-SW-26 as proposed. At the time of sample collection, the field meter was not functioning. Because the samples were located in the Rifle Range Impact Area and access to this area was limited, a remobilization to the area to collect these parameters was not done. If needed, this data can be collected in the future.

- Two additional sediment (PAI-03-SD-27-01 and PAI-03-SD-28-01) and surface water (PAI-03-SW-27-00 and PAI-03-SW-28-00) sample locations were added to obtain information along the southeastern end of the causeway.

- Due to the shallowness of the surface water at the proposed locations at the time of sampling, Secchi Disk readings were not obtained.

- Per correspondence on August 20, 1999, the MCRD Parris Island partnering team agreed to forgo 100 percent data validation of analytical packages. Instead, the partnering team agreed that data validation would consist of either a data review or a full data validation. The full data validation would be performed on approximately 10 percent of the data packages received from a laboratory and all analytes would be covered by at least one full data validation. A data review would be performed on the remaining data packages for the purposes of identifying false positive and negative results.

- The monitoring wells were installed as flushmounts. It was originally anticipated to install the wells as stickups on the side of the road, however, the presence of utilities in the area prevented this location. As a result, the wells were installed as flushmounts in the roadway.

3.2 FIELD INVESTIGATION

The following sections discuss the activities conducted during the field investigation at Site 3. First, a history of investigative activities at Site 3 is presented. Next, the specific field activities conducted during the investigation are discussed. These activities include monitoring well installation; subsurface soil, surface water, sediment, surface soil, and groundwater sampling; the performance of slug tests and a tidal influence study; and investigation-derived waste management. Lastly, a discussion of quality assurance/quality control samples and sample analysis is presented.

3.2.1 Sampling History

Previous investigations conducted at the MCRD Parris Island that have included Site 3 consist of an initial assessment study (NEESA, 1986) and subsequent Verification Step (McClelland, 1990) to identify potentially contaminated sites at MCRD Parris Island that may pose a threat to human health or the environment. Also, an Interim RFA (Kearny, 1990) was performed per RCRA permitting requirements. Lastly, an ESI (ABB, 1993) was conducted to evaluate whether the consumption of fish and shellfish caught in the vicinity of the causeway landfill posed a risk to human health. A description of these investigations is provided in Section 1.4.3.

3.2.2 Monitoring Well Installation

Four monitoring wells were installed during the 1998 RFI/RI field investigation at the locations indicated on Figure 3-1. Of the four new wells, three shallow surficial aquifer wells were installed to depths of 18 feet or less below ground surface (bgs) and one deep surficial aquifer well was installed to a depth of 28 feet bgs. The well permit authorization is provided in Appendix A.

The monitoring wells were installed through the ID of 8-inch outside diameter augers to help ensure a proper sand pack. The wells were installed in accordance with SCDHEC regulations. The surficial aquifer monitoring wells were constructed with 10-foot screen sections with 0.010-inch slot openings and No. 1 sand due to the fines encountered at shallow depths. The deep surficial well were constructed using five-foot screen sections with 0.020-inch slot screens and No. 2 sand. Boring logs and monitoring well construction sheets were completed for each soil boring and monitoring well location. Copies of these forms are provided in Appendix A.

A licensed South Carolina driller employed by Parratt Wolff, of Hillsborough, North Carolina, installed the monitoring wells. All monitoring wells were developed after construction using a surge block and a

submersible pump. Well development logs were completed during development and are provided in Appendix A. Construction details of the monitoring wells are provided in Table 3-2.

As indicated in Table 3-2, three wells [PAI-03-MW-01(S), PAI-03-MW-03(S), and PAI-03-MW-04(S)] were installed as shallow monitoring wells and screened in the upper part of the surficial aquifer. The wells were installed so that the well screen intercepted the water table. The fourth well, PAI-03-MW-02(D) was installed in the deeper portion of the surficial aquifer and screened immediately above a confining unit encountered at 28 feet bgs.

3.2.3 Subsurface Soil Sampling

Subsurface soil samples (Figure 3-1) were collected from each of three soil boring locations using split-spoon sampling techniques. Soil boring PAI-03-SB-01 was performed at the well nest location as an exploratory boring attempt to locate the Hawthorn Formation and to obtain lithologic samples. Subsurface sample PAI-03-SB-02-04 was collected from a depth of 4 to 6 bgs within the vadose zone for ecological analysis for TOC and pH. Subsurface sample PAI-03-SB-02-24 was collected from a depth of 24 to 26 feet bgs within the screened interval of the deep surficial well [PAI-03-MW-02(D)] for ecological and geotechnical evaluation, including TOC, pH, natural moisture content, grain size analysis, Atterberg Limits, porosity, bulk density, and specific gravity. A Shelby tube sample (PAI-03-SB-02-28) was also collected and analyzed for vertical hydraulic conductivity. Soil sample PAI-03-SB-03-10, collected from a depth of 10 to 12 feet bgs from the vadose zone, was analyzed for natural moisture content, grain size analysis, and Atterberg Limits. Sample PAI-03-SB-03-12, collected from a depth of 12 to 14 feet bgs just beneath the water table, was analyzed for TOC, pH, natural moisture content, grain size, Atterberg Limits, porosity, bulk density, and specific gravity. The results of the ecological/geotechnical sampling are presented in Appendix A. All collected split-spoon samples were screened in the field using a photoionization detector (PID). Several samples had elevated PID readings; however, there were no visual signs of contamination. Copies of the soil sample log sheets are provided in Appendix A. A summary of the subsurface soil samples collected is presented in Table 3-3.

3.2.4 Surface Water Sampling

Twenty-one surface water samples (PAI-03-SW-09-00 through PAI-03-SW-28-00 and one duplicate sample) were collected adjacent to the causeway from the pond, tidal flats, and streams during the field investigation for Site 3. All surface water samples were sampled during the receding tide. The samples were obtained by dipping the appropriate containers in the water to collect the samples. The samples were analyzed for Target Compound List (TCL) VOCs, SVOCs, pesticides, PCBs, Target Analyte List (TAL) metals (totals and dissolved), and cyanide. The analytical parameters on the samples are

summarized in Table 3-4. Surface water quality parameters collected during sampling are listed in Table 3-5, and the sample locations are shown on Figure 3-2.

Three of the surface water samples (PAI-03-SW-10-00, PAI-03-SW-15-00, and PAI-03-SW-18-00) were also analyzed for hexavalent chromium. The three hexavalent chromium samples were collected from across the site at representative locations. The purpose of this supplemental analysis was to support the risk assessment by determining the speciation of total chromium. Eight of the surface water samples were analyzed for TOC and hardness ($CaCO_3$). Surface water sampling was performed in accordance with the RFI/RI work plan (B&R Environmental, 1998b) with the exceptions listed in Section 3.1. Copies of the surface water sample log sheets are provided in Appendix A.

The surface water quality parameters indicate that, at the time of sampling, the water temperature ranged from 26.1° to 37.2° C. The pH readings varied from 6.3 to 8.17. The specific conductance varied between 13.6 to 37.7 mS/cm. Dissolved oxygen measurements ranged from 2.02 to 12.25 mg/L. Salinity remained fairly constant, ranging only from 0.81 to 2.41 percent. Turbidity of the samples varied widely from 2 to >999 NTUs. The elevated turbidity can be attributed to the unavoidable disturbance of the sediment while the sampler walked to the sample locations.

3.2.5 Sediment Sampling

A total of 22 sediment samples (PAI-03-SD-09-01 through PAI-03-SD-28-01, PAI-03-SD-12-02, and one duplicate sample) were collected north and south of the causeway landfill during the 1998 field investigation. Site 3 sediment sample locations are shown on Figure 3-2. Sediment sampling was performed in accordance with the RFI/RI work plan (B&R Environmental, 1998b) with the exceptions listed in Section 3.1. A pre-cleaned plastic or stainless-steel trowel was used to collect the sample to the appropriate depth. The sample material for all the analytical parameters except TCL VOCs was placed directly in the appropriate containers and then on ice. The volatile samples were collected using Encore® samplers. The samplers were then capped and placed on ice. Copies of the sediment sample log sheets are provided in Appendix A.

The 1998 sediment samples were analyzed for TCL volatiles, semivolatiles, pesticides, PCBs, TAL metals (Total), and cyanide. Samples PAI-03-SD-09-01, PAI-03-SD-11-01, PAI-03-SD-12-01, PAI-03-SD-15-01, PAI-03-SD-18-01, PAI-03-SD-20-01, and PAI-03-SD-22-01 were analyzed for TOC and pH. In addition, samples PAI-03-SD-10-01, PAI-03-SD-15-01, and PAI-03-SD-18-01 were analyzed for hexavalent chromium. The three hexavalent chromium samples were collected from across the site at respective locations. Samples PAI-03-SD-09-01, PAI-03-SD-11-01, PAI-03-SD-12-01, PAI-03-SD-20-01, and PAI-03-SD-23-01 were also tested for grain size and bulk density. The laboratory analyses for the samples

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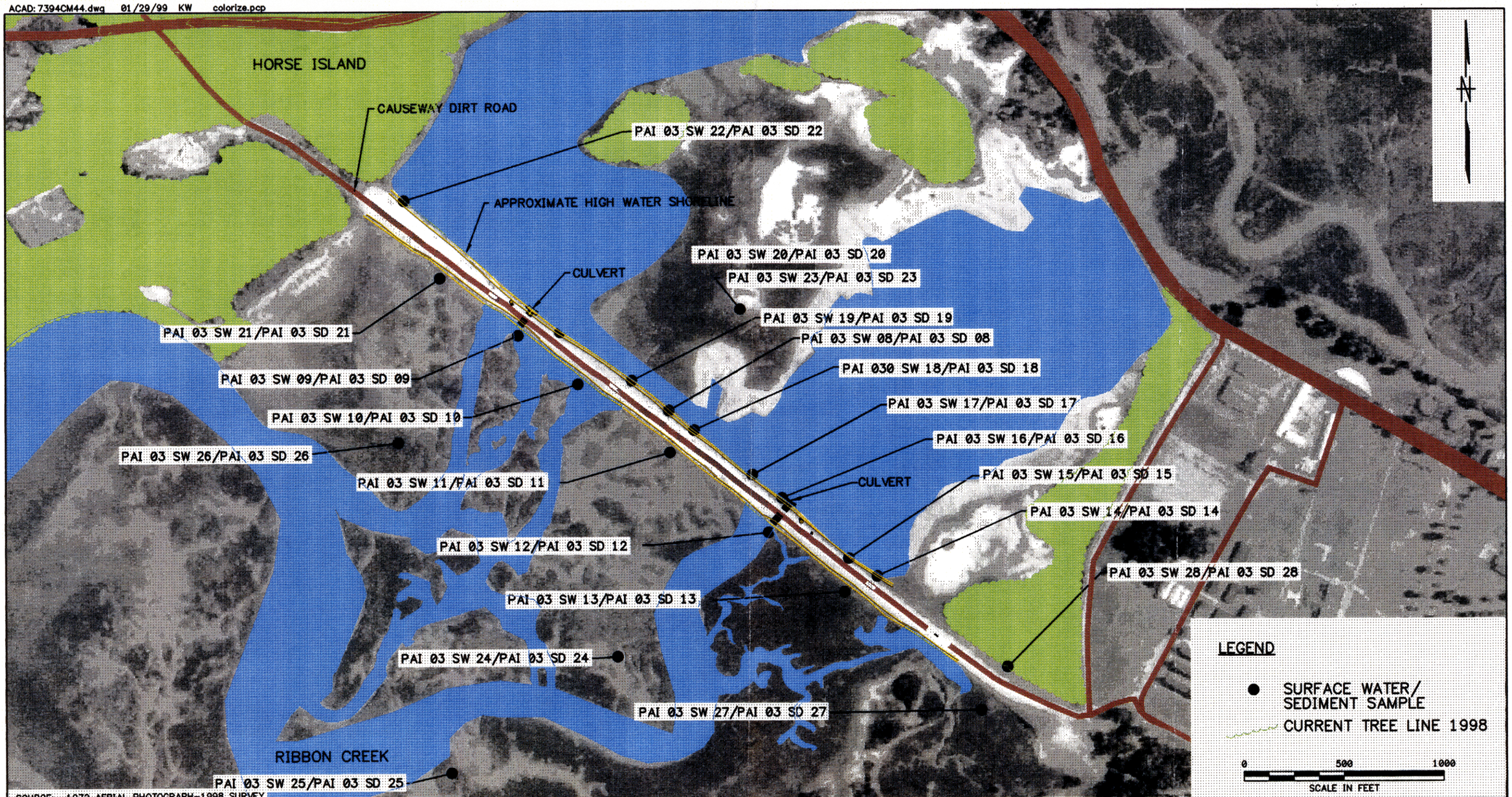

SOURCE: 1972 AERIAL PHOTOGRAPH-1998 SURVEY

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DRAWN BY HJP DATE 11/30/98
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COST/SCHED-AREA
SCALE AS NOTED

SURFACE WATER AND SEDIMENT SAMPLE LOCATION MAP
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 7394
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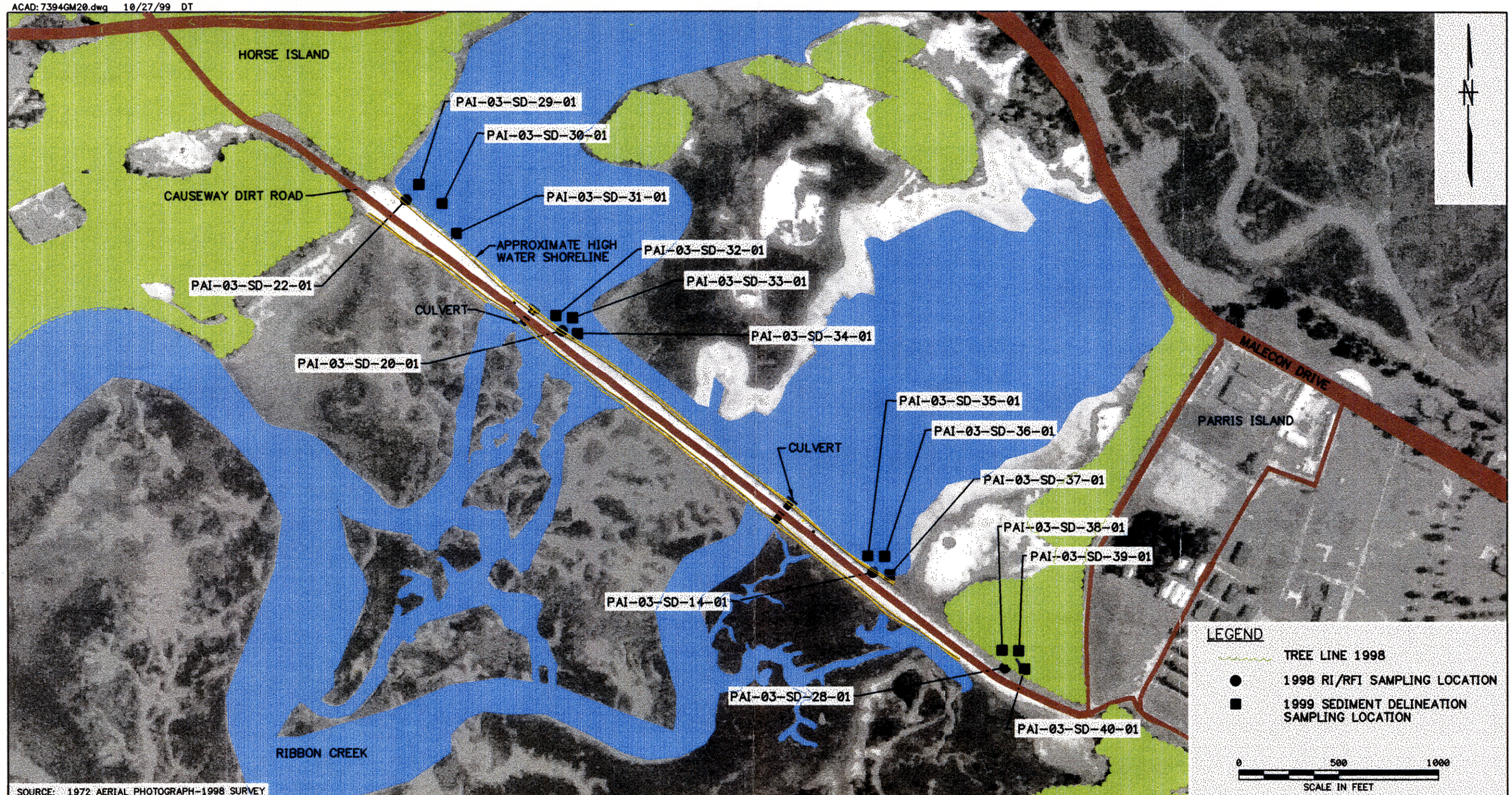

SOURCE: 1972 AERIAL PHOTOGRAPH-1998 SURVEY

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SCALE AS NOTED

SEDIMENT LOCATION MAP
(1999 DELINEATION SAMPLES)
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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are summarized in Table 3-6. The results of the ecological/geotechnical sampling are presented in Appendix A.

Based on the results obtained from the 1998 field event, 15 additional samples (PAI-03-SD-29-01 through PAI-03-SD-40-01, and three duplicate samples) were collected during the August 1999 field event at the locations shown on Figure 3-3. The additional samples were collected from the Pond on the north side of the causeway landfill. At 7 of the 12 sample locations sediment grab samples were collected by hand in one to 1-1/2 feet of water. At the remaining four sample locations, a Ponar sampler was used to collect the samples in 2 to 4.5 feet of water. The Ponar sampler was cleaned between samples using a distilled water and soap wash and a distilled water rinse.

Sediment samples PAI-03-SD-29-01, PAI-03-SD-30-01, and PAI-03-SD-31-01 were analyzed for polynuclear aromatic hydrocarbons (PAHs). Samples PAI-03-SD-32-01, PAI-03-SD-33-01, and PAI-03-SD-34-01 were analyzed for TCL PCBs. Samples PAI-03-SD-35-01 through PAI-03-SD-40-01 were analyzed for TCL pesticides.

The laboratory analyses for the samples are summarized in Table 3-6. Copies of the sediment sample log sheets are provided in Appendix A.

3.2.6 Surface Soil Sampling

A total of 17 surface soil samples (PAI-03-SS-01-01 through PAI-03-SS-16-01 and one duplicate sample) were collected during the field investigation. This total included the four soil boring surficial samples converted to surface soil samples (PAI-03-SS-13-01 through PAI-03-SS-16-01). The soil samples were collected from a depth of 0 to 1 foot bgs. Surface soil sample locations are shown on Figure 3-4. The sample locations were moved from the proposed locations in the road to a grid system located along both sides of the road. The analytical methods performed on the samples are summarized in Table 3-7. Sample log sheets for soils are presented in Appendix A. Surface materials consisting of grasses and other organic material were removed before the sample was obtained. A pre-cleaned plastic or stainless-steel trowel was used to collect the sample to a depth of 1 foot. The sample material for all the analytical parameters except for TCL VOCs was placed directly in the appropriate containers and then on ice. Sample material for TCL VOC analysis was collected using Encore® samplers. Soil was collected in the samplers, and the samplers were capped and placed on ice. All the surface soil samples were analyzed for TCL VOCs, SVOCs, pesticides, PCBs, TAL metals (Total), and cyanide. In addition to these samples, PAI-03-SS-05-01, PAI-03-SS-07-01, and PAI-03-SS-10-01 were analyzed for hexavalent chromium. The three hexavalent chromium samples were collected from across the site at representative locations. Surface soil sampling was performed in accordance with the RFI/RI work plan (B&R Environmental, 1998b).

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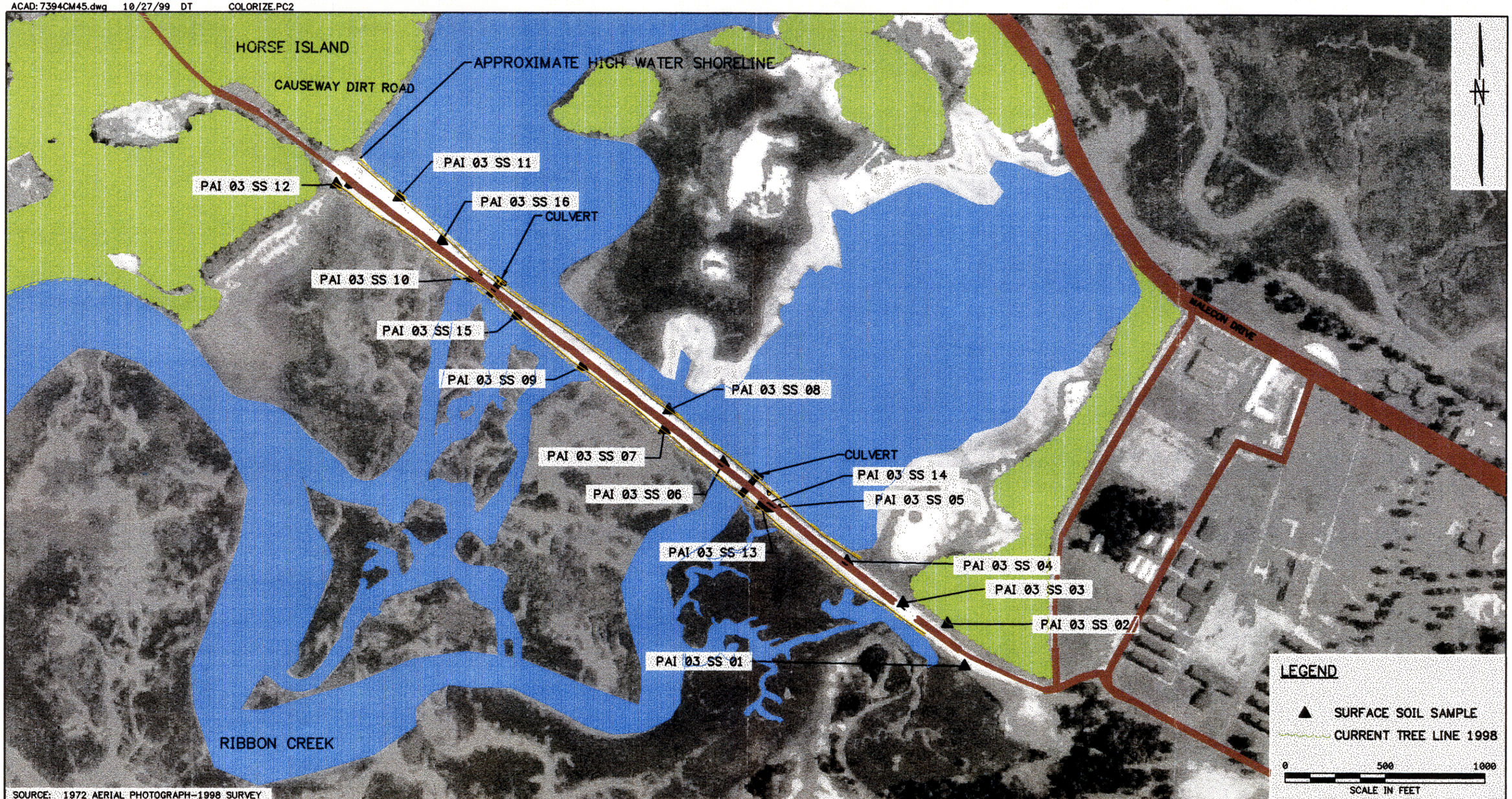

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SURFACE SOIL
SAMPLE LOCATION MAP
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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3.2.7 Groundwater Sampling

Groundwater sampling was performed using a peristaltic pump and pre-cleaned disposable tubing. The tubing was lowered in the wells to approximately the midpoint of the well screens. The wells were then purged in accordance with the low-flow sampling techniques specified in the approved work plan (B&R Environmental, 1998b). Water-level data and water-quality parameters, such as temperature, pH, specific conductance, turbidity, dissolved oxygen, and salinity, were collected during purging of the monitoring wells and recorded on low-flow purge data sheets and groundwater sample log sheets (included in Appendix A). The groundwater sample from each well, with the exception of the TCL VOCs, was collected by reducing the flow to minimize volatilization of the sample and collecting the sample in the appropriate containers directly from the tubing after it passed through the peristaltic pump. The TCL VOCs samples were collected by removing the tubing from the well and allowing the water in the tubing to flow under gravity backward through the tubing. The water was then collected in the appropriate containers.

Groundwater samples PAI-03-GW-01-01[1], PAI-03-GW-03-01, and PAI-03-GW-04-01 were analyzed for TOC, hardness, TCL VOCs, SVOCs, pesticides, PCBs, TAL metals (Total), TAL metals (Dissolved), cyanide, hexavalent chromium, total dissolved solids (TDS), total suspended solids (TSS), chloride, fluoride, nitrate/nitrite, and sulfate. Groundwater sample PAI-03-GW-02-01 was analyzed for TOC, hardness, RCRA Appendix IX organics (including volatile organics, semivolatile organics, pesticides/PCBs, and chlorinated herbicides), and RCRA Appendix IX inorganics and cyanide. Appendix IX analysis was conducted at one groundwater monitoring well to satisfy SCHEC requirements under the State RCRA program. The groundwater analytical parameters are summarized in Table 3-8. The groundwater quality information (including dissolved oxygen, salinity, temperature, pH, and turbidity) was also collected and is summarized in Table 3-9. The depth-to-water measurements shown on Table 3-10 were collected before the wells were purged. The groundwater sample locations are indicated on Figure 3-1.

As observed from Table 3-9, the pH of the groundwater at Site 3 varied between 6.18 (PAI-03-GW-02-01) and 7.14 (PAI-03-GW-03-01). The temperature readings varied from 21.9 °C (PAI-03-GW-02-01) to 24.5 °C (PAI-03-GW-04-01). The specific conductance varied from 4.27 mS/cm (PAI-03-GW-01-01) to 29.9 mS/cm PAI-03-GW-02-01). Salinity readings ranged from 0.25 to 1.87 percent. The salinity readings indicate that all the groundwater samples are considered to be brackish to saline (fresh water is less than 0.048 percent as identified by SCDHEC, 1998). The groundwater samples from wells installed in the

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1 Sample identification number PAI-03-GW-01-01 indicates the groundwater sample was collected from monitoring well PAI-03-MW(S)-01.

shallow surficial aquifer generally exhibited lower salinity readings than the well installed in the deeper portion of the surficial aquifer. Dissolved oxygen readings varied from 0.68 to 1.67 mg/L. The wells were purged in an effort to reduce the turbidity to less than the benchmark of 5 Nephelometric Turbidity Units (NTUs). Turbidity of the samples collected ranged from 2 to <10 NTUs.

3.2.8 Slug Tests

Slug tests were performed on the four new monitoring wells. Rising and falling head slug tests were performed at each of the monitoring wells. The procedure for performing the rising-head slug test consisted of injecting a slug of known volume below the water level within the well. After the water level re-stabilized, the slug was suddenly removed to create a drop of water level within the well. A 20 pounds per square inch (psi) pressure transducer and a data logger were used to record the rate of water-level recovery. The procedure for performing the falling-head slug test consisted of rapidly injecting a slug of known volume into the well below the water surface, so that the water level within the well rose. The subsequent rate of water-level recovery to the original static water level (time versus recovery) was measured. The data were analyzed using the Hvorslev Method (Hvorslev, 1951). Slug test results are discussed in Section 3.4.

3.2.9 Tidal Influence Study

A tidal influence study was performed in September 1998. The results of this study indicate that the wells installed at Site 3 are tidally influenced. The tidal fluctuation that was observed in the deep surficial monitoring well PAI-03-MW-02(D) was 0.90 feet. The shallow surficial monitoring wells exhibited tidal fluctuations of 0.036 feet in well PAI-03-MW-03(S) to 0.5 feet in well PAI-03-MW-01(S). A control point set up in the pond on the north side of the causeway indicated the water level within the pond varied 0.13 feet during the period of the tidal study. Well PAI-01-MW-06(D) at Site/SWMU 1 and a control point at Archer Creek Bridge were also monitored during the same time as the Site 3 wells.

3.2.10 Surveying

All monitoring well, soil boring, sediment, surface water, and surface soil sample locations were surveyed for horizontal and vertical control by Donaldson, Garrett & Associates, Inc., of Macon, Georgia (South Carolina licensed) in accordance with the RFI/RI work plan (B&R Environmental, 1998b). A permanent concrete monument was installed at Site 3 to establish site control. The concrete monument has a plaque containing the northing, easting, and ground surface elevation at that point. The northing and easting coordinates are tied into the South Carolina State Plane Coordinate System, North American Datum 1983 (NAD83).

3.2.11 Investigative Derived Waste (IDW)

During the investigation, 55-gallon drums of water (decontamination, development, and purge waters) and soil IDW were generated and stored within the Depot's waste storage facility pending final disposition of the IDW. All IDW was handled in accordance with the Master Work plan (B&R Environmental, 1998a) and the work plan for Site 3 (B&R Environmental, 1998b).

A composite sample was collected from the drummed decontamination waters and analyzed for TCL VOCs, SVOCs, PCBs, pesticides and TAL inorganics. Additionally, a composite sample was collected from the drummed soils and analyzed for the previously mentioned parameters plus Toxicity Characteristic Leaching Procedure (TCLP) inorganics. Analytical results from groundwater samples collected during the field investigation were used to characterize development and purge waters.

Site 3 soil IDW was found to be nonhazardous; however, this IDW was observed to contain soil waste (paper and plastic, etc) and was considered inherently waste-like. In April 1999, Site 3 drummed soils were disposed at an approved solid waste landfill.

Decontamination, development, and purge waters were also found to be non-hazardous. All liquid IDW was discharged to the Depot's wastewater treatment facility for treatment. Fenn-Vac, the IDW subcontractor, conducted the discharge of waters and the off-site disposal of drummed soils.

3.2.12 Quality Assurance/Quality Control (QA/QC) Samples

Quality assurance (QA) objectives are evaluated by assessing the PARCC parameters, as defined in the Master Quality Assurance Plan (QAP). The PARCC parameters are precision, accuracy, representativeness, comparability, and completeness. QA/QC samples were collected to provide information pertaining to these key quality characteristics. The QA/QC sample results from this investigation are summarized in the following subsections.

The following QA/QC samples were collected during this investigation: 2 source water blanks, 14 trip blanks, 10 temperature blanks, 4 equipment rinse blanks (these samples are limited, because disposable sampling equipment was used), and 3 duplicate samples from surface water, sediment, and surface soil.

QA/QC sample log sheets are provided in Appendix A. Appendix D contains a detailed PARCC discussion and the data validation summaries. The sample chain-of-custody (COC) forms can be found in Appendix A.

Precision

Precision is a measure of the degree to which two or more measurements are in agreement. Field sampling precision was assessed through the collection and analysis of field duplicate samples. The precision of the laboratory's analytical program was assessed through the calculation of relative percent difference (RPD) for the matrix spike/matrix spike duplicate (MS/MSD) samples. According to the QAP, field duplicate results are considered to be precise if the RPD is less than 50 percent for solid samples and less than 30 percent for aqueous samples. Laboratory duplicates for solid and aqueous matrices are considered to be precise if the RPD is less than 35 percent and 20 percent, respectively. No results were qualified for RPD noncompliance. Based on the validation results, the data appear to be precise.

Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference value. Accuracy in the field is assessed through the use of field equipment rinsate blanks, trip blanks, and source water blanks and also through adherence to sample handling, preservation, and holding times. Laboratory accuracy is assessed through the analysis of matrix spike, standard reference materials, and the determination of percent recoveries. Spike recoveries (e.g., blank, surrogate, and matrix spikes) are compared to acceptance limits statistically derived by the laboratory in accordance with established practices identified in the analytical method followed and further defined in the laboratory QAP.

Percent Recovery

Two sediment sample results (PAI-03-SD-12 and PAI-03-SD-15) indicated that matrix spike (MS) percent recoveries for hexavalent chromium were less than 10 percent. As a result, non-detects were qualified with "UR" or rejected. The laboratory control sample (LCS) percent recoveries for hexavalent chromium were also below quality control limits.

In the surface water samples, the initial calibration verification (ICV) percent recoveries for hexavalent chromium were less than the 90 percent quality control limit. As a result, non-detects for this parameter were qualified with "UJ" or estimated.

The MS percent recovery was less than the 75 percent quality control limit for selenium. As a result, positive selenium results in groundwater were qualified with "J" and non-detects with "UJ" or estimated.

The continuing calibration verification (CCV) percent recovery for thallium was less than the 90 percent quality control limit. Therefore, the non-detect results for thallium in the source water samples were qualified as "UJ" or estimated.

Surrogate recoveries in soil samples were below quality control limits. As a result, scope of the non-detected SVOC results were rejected and qualified as "UR."

Heptachlor epoxide, detected in sample PAI-03-SS-01, was rejected (qualified as "R") due to a percent difference between columns that exceeded 100 percent.

Holding Times

The holding times for hexavalent chromium for the source water samples were exceeded by 8 hours due to the delivery time. As a result, the detected results were qualified with "J" and non-detected results for this metal were qualified as "UJ" or estimated. Cyanide holding times were exceeded by 1 to 3 days, resulting in estimated ("UJ") non-detect results in some sediment and surface water samples. The holding time variance resulted from delayed shipment of the samples (because of weekend collection of sample in restricted areas) and late analysis at the laboratory.

Laboratory and Field Blanks

Several VOCs and SVOCs were found in the field/trip blanks. One VOC and two SVOCs were found in the laboratory blank. Various inorganics were found in the laboratory/preparation blank. Positive sample results less than 5 times the maximum blank concentration (or 10 times for typical laboratory contaminants) were qualified as "U" or non-detect due to blank contamination. Details are presented in Appendix D.

Representativeness

Representativeness was qualified through the field sampling procedures and evaluation of laboratory analytical data. The site data accurately and precisely depict the actual characteristics of the environmental conditions that exist at Site 3. EPA-approved work plans and standardized sampling, handling, analytical, and reported procedures were followed to ensure that the final data accurately represent actual site conditions. Validated results support this finding.

Comparability

Comparability, the confidence of comparing one data set to another, was satisfied through the strict adherence of field sampling and laboratory analysis to their respective SOPs. Both programs (field and laboratory) adhered to their respective SOPs and were reviewed by third parties. Also, the majority of sampling for this investigation occurred during the spring/summer 1998. Historical surface water and sediment data from 1988 and biota data from 1992 were explained separately from the 1998 data. In

addition, standardized sampling and analysis methods and data reporting formats (including use of consistent units of measure and reporting of solid matrix sample results on a dry-weight basis) were used. As a result, data collected for this site are comparable and usable.

Completeness

Completeness is the percentage of analyses with valid results as compared to the total number of analyses for each analytical method in a given matrix. For this project, 90 percent completeness is acceptable for meeting the data completeness objective. For Site 3, only one pesticide, heptachlor epoxide, (detected in sample PAI-03-SS-01), was rejected. In other cases, the non-detected results of several parameters, e.g., acetone, 2-butanone, 2-methylnaphthalene, 4-methylphenol, bis(2-ethylhexyl) phthalate, carbazole, dibenzofuran) were rejected. The amount of rejected data was approximately 2 percent. As a result, the amount of usable and valid data available was 98 percent, which meets the project objective for completeness. Appendix D presents the details of the validation reports.

Detection Limits

Sediment samples analyzed for pesticides (PAI-03-SD-24 to PAI-03-SD-28) were diluted by a factor of 10 due to matrix interference, which elevated the pesticide detection limits for these samples. Sample PAI-03-SD-23, analyzed for PAHs, was diluted by a factor of 10 due to matrix interferences, which accounts for elevated PAH detection limits. This same sample was analyzed for pesticides and diluted by a factor of 5 to account for matrix interferences thereby, elevating the pesticide detection limits.

PAHs and pesticides in soil samples were detected at levels greater than the instrument's linear range. As a result, samples were diluted by a factor of 2 to 50, which accounts for elevated detection limits. One sample, PAI-03-SS-01, was re-analyzed at a dilution factor of 200 due to the presence of fluoranthene, chyrsene, and benzo(b)fluoranthene above the instrument linear range.

In both sediment and soil samples, some elevated detection limits are attributed to the high moisture content of the samples (see Appendix D, validation report for SDG U05699, for the specific samples).

3.2.13 Sample Analysis

Chemical analysis of 1998 environmental samples was conducted at two laboratories. 1998 soils, sediment, and surface water samples were analyzed for chemical parameters at RECRA Environmental, Inc in Chicago, Illinois. 1998 groundwater samples were analyzed at Laucks Testings Laboratory, Seattle, Washington. Both laboratories are certified by South Carolina. 1999 sediment samples were analyzed for chemical parameters at Severn Trent Laboratories, University Park, Illinois. Results are

presented in Appendix C. All analytical results are presented in the appendix including positive detections and detection limits for non-detected parameters. The appendix is divided into background results and Site 3 sample results. In addition, Appendix C is divided into soils, sediments, surface water, and groundwater data.

Kiber Environmental Services of Norcross, Georgia performed the geotechnical analysis. Results are presented in Appendix A.

3.3 SITE-SPECIFIC GEOLOGY

The site-specific geology at Site 3 was interpreted by classifying subsurface materials collected during drilling activities in 1998. A cross-section along the Site 3 causeway was developed from the data collected during the field investigation. Information from the Soil Survey of Beaufort and Jasper Counties, South Carolina, 1980 (U.S. Department of Agriculture, Soil Conservation Service) was used for the correlation of soil types.

The Soil Survey of Beaufort and Jasper Counties indicates that the Wando-Seabrook-Seewee Soil Unit is present on Horse Island, located at the northwestern end of the causeway. Also present on Horse Island in the area of the causeway are borrow pit soils. The causeway extends southeast from Horse Island across the tidal flats and creeks and connects to Parris Island. The predominant soils adjacent to the causeway are the Bohicket Association and the Capers Association.

The borrow pit soils located along the causeway adjacent to Horse Island and adjacent to Parris Island represent areas where soil has been removed by man for use as fill material. The soils removed may include surface soil, subsoil, and in some instances substratum.

The Bohicket Association soils consist of dark gray to greenish-gray, poorly drained, nearly level soils that are tidally flooded. These soils vary from marine silty and clay loam to silty clays and clays. Bohicket soils have low permeability and high water capacity. When continuously saturated, the soils range from slightly acidic to moderately alkaline. If allowed to dry for 30 days, the soils become extremely acidic. The Capers Association soils are similar to the Bohicket soil in nature, are found at only slightly higher elevations, and consist of gray to dark gray to gray-green clays and sandy clays. Acidity ranges from neutral to moderately alkaline. When, dried the soils are extremely acidic. Most of the association is in marsh vegetation, consisting of smooth cordgrass, needlegrass, and big cordgrass. The rest is bare.

Surface soils collected from the causeway landfill during the 1998 field event consisted of fine to medium sands with a varying silt content, as confirmed by the lithologic descriptions during the sampling event. Riprap consisting of concrete fragments was observed along the flanks of the causeway during the field

event. Fill material was encountered to depths of at least 18 feet bgs along the causeway. Sediment samples collected from the marsh and pond along the causeway consisted of silts and clays, with a varying sand content.

Subsurface materials at Site 3 were classified from the performance of four soil test borings drilled during the TtNUS field investigation. Three of the borings (PAI-03-SB-01, PAI-03-SB-03, and PAI-03-SB-04) were sampled continuously to the termination of the borings using split-spoon sampling techniques. Boring PAI-03-SB-02 was sampled the first 8 feet to collect a vadose zone sample for analysis and at depth to verify the subsurface lithology observed in boring PAI-03-SB-01 before samples were collected for geotechnical/ecological evaluation. The site-specific geology at the unit has been affected by human activities. Refuse and construction debris were buried in the tidal marsh to a depth of at least 18 feet to create the causeway.

Figure 3-5 shows Cross-section A-A' that was developed from the soil boring data collected during the current investigation. The location of Cross-section A-A' is shown on Figure 3-1. Generally, the shallow subsurface geology of the study area consists of fill material and a heterogeneous mixture of tidal and storm-deposited clay and sand, with clay prevalent from 28 feet bgs to a depth of at least 40 feet bgs as observed at the deepest soil boring, PAI-03-SB-01. The boundary between fill and natural material is fairly distinct at the boring locations. Fill material was observed to a depth of 10.5 feet bgs in boring PAI-03-SB-01 and to a depth of at least 18 feet bgs in boring PAI-03-SB-04. The fill soils consisted of sand with a varying amount of silt. The observed refuse within the soil boring samples consisted of a large amount of wood fragments along with metal fragments (cans), paper, plastics, and fragments of concrete and brick.

Beneath the fill, the sediment, as observed in boring PAI-03-SB-01, consists of tidal sands with a varying silt content to a depth of 28 feet bgs. From the depth of 28 feet bgs to termination of the boring at 40 feet bgs, clay was encountered. Subsurface soil and sediment samples analyzed for ecological/geotechnical parameters confirm the geology encountered. Details of the results of the ecological/geotechnical sampling are presented in Appendix A. The clays encountered beneath Site 3 do not correspond to the Hawthorn Formation as observed during field events at Site 1. A falling head permeability test performed on an undisturbed Shelby tube sample PAI-03-SB-02-28 (sample depth 28 to 30 feet bgs) collected within this unit resulted in an estimated vertical hydraulic conductivity of 4.4×10^{-8} cm/s. This indicates that the clay the likely acts as a confining unit. If the clay unit exists across the site, the confining unit is at least 12 feet thick.

3.4 SITE-SPECIFIC HYDROGEOLOGY

The hydrogeologic conditions at Site 3 were interpreted from data obtained during the subsurface investigation activities at the site, groundwater-level measurements collected, and slug tests performed during the 1998 investigation.

In general, a surficial groundwater table (7.43 to 10.73 feet bgs) exists at the site where the new monitoring wells were installed. Twelve feet of clay (28 to 40 feet bgs) was encountered in boring PAI-03-SB-01. The boring was terminated at this depth without encountering the Hawthorn Formation. The 12 feet of clay encountered is thick enough to act as a confining unit to the overlying sands of the upper surficial aquifer. The upper surficial aquifer across the site is approximately 18 to 20 feet thick, based on the depth of the clay unit encountered. Recharge of the shallow aquifer beneath the causeway is likely to occur primarily through infiltration of surface water from the pond located on the northern side of the causeway at low tide and from the tidal streams and tidal flats located south of the causeway at high tide. At the causeway, shallow groundwater is expected to flow to the south a majority of the time except during the few tides around spring tide where the shallow groundwater flows to the north. During high tide, shallow groundwater flow is expected to reverse flow and move from south to north. Site 3 is located within the 100-year flood plain. This was determined by reviewing the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (1986). Based on the groundwater elevation data collected during this field event, the vertical gradient within the surficial aquifer is downward.

Rising-head slug tests were performed in the shallow surficial aquifer monitoring wells at Site 3. A rising- and falling-head slug test was performed in the deep surficial aquifer monitoring well, PAI-03-MW-02. The geometric average hydraulic conductivity for the three shallow surficial aquifer wells was calculated to be 1.28 feet per day (4.53×10^{-4} cm/sec). The hydraulic conductivity of the deep surficial well was determined by averaging the rising- and falling-head tests, and the result was 1.01 feet per day (3.57×10^{-4} cm/sec). The values for the shallow and deep wells are within the typical range of hydraulic conductivity for clayey, silty sands, silts, and sandy silts (Fetter, 1980). Hydraulic conductivity curves and calculations based on the slug tests are included in Appendix B. The result of a falling-head permeability test performed on an undisturbed sample collected from boring location PAI-03-SB-02 (well PAI-03-MW-02) at a depth of 28 to 30 feet bgs indicates the material encountered has a vertical hydraulic conductivity of 4.4×10^{-8} cm/sec and is consistent with clays (Fetter, 1980).

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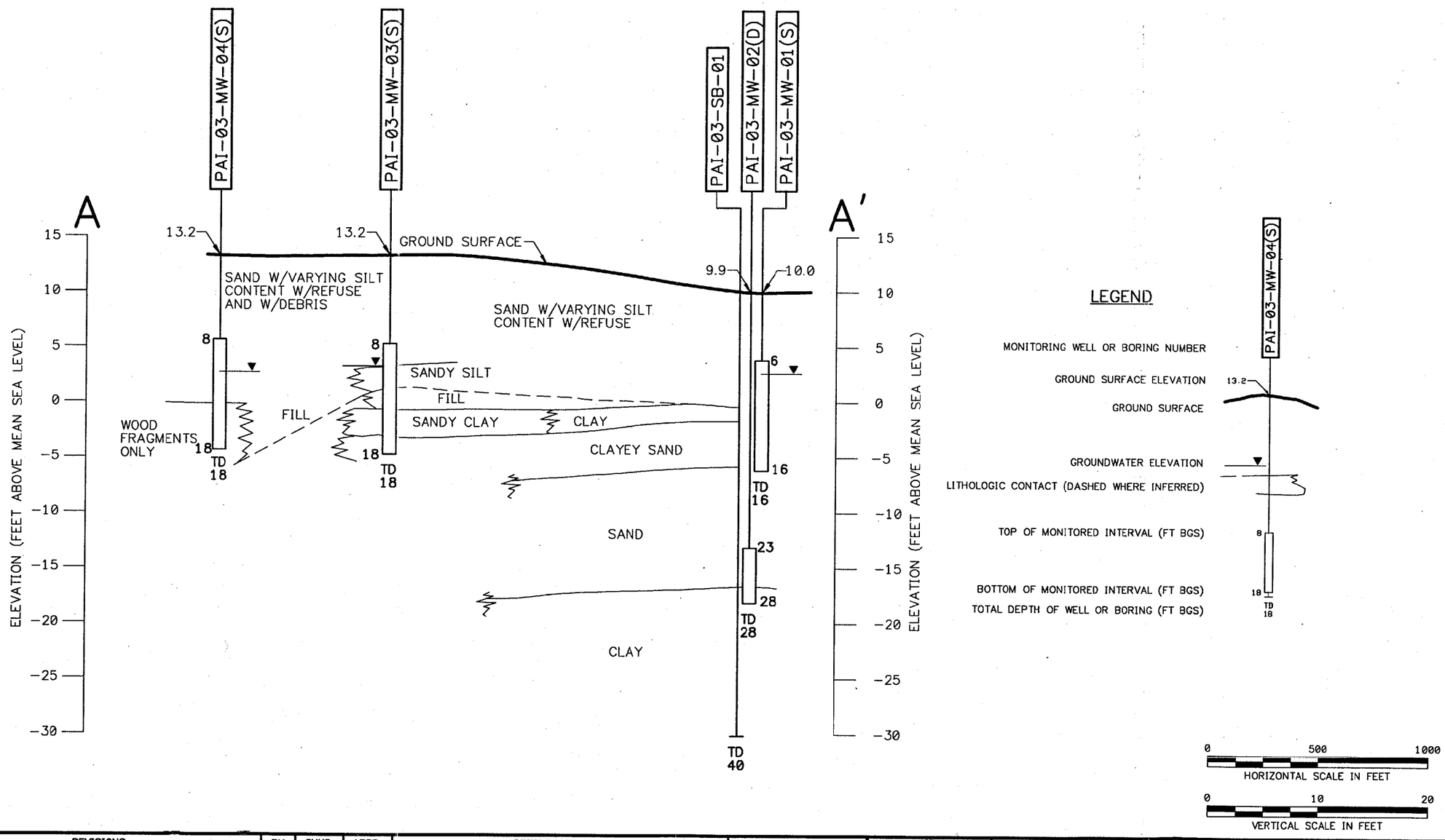

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY MF DATE 2/4/99
CHECKED BY DATE
COST/SCHED-AREA
SCALE AS NOTED

CROSS SECTION A-A'
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 7394
APPROVED BY DATE
APPROVED BY DATE
DRAWING NO. FIGURE 3-5
REV. 0

FORM CADD NO. SDIV_BH.DWG - REV 0 - 1/20/98

4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the analytical results of the 1998 and 1999 field investigation sampling conducted at Site/SWMU 3 (Site 3). Site 3 is the Causeway Landfill. This landfill was the major disposal area for trash and other waste materials discarded in dumpsters located around the base from 1960 to 1972. Approximately 75 percent of the solid waste originated from the Depot. This solid waste reportedly included empty pesticide containers, oily rags, spent adsorbent, petroleum, and chlorinated solvent sludge, perchloroethylene still bottoms, mercury amalgram and beryllium waste, PCB-contaminated oil, and metal shavings.

In 1988, eight surface water and sediment samples were collected and analyzed for priority pollutants. The 1988 sample results were reported in the 1990 Verification Report and were also included in the current Work Plan for Site 3 (B&R Environmental, 1998b). Exceedances of screening criteria were noted for several metals. These results are discussed and compared to the 1998 surface water and sediment results (see Sections 4.1.3 and 4.1.4). In 1992, biota samples were collected from the area. Detected concentrations were at concentrations less than U.S. Food and Drug Administration (USFDA) action levels. Additional discussion is presented in Section 4.5.

Samples were collected from Site 3 in the spring and summer of 1998. Additional sediment samples were collected in August 1999 to better delineate results obtained during the 1998 testing. A summary of the analytical program is provided in Tables 3-1 and 3-2. Sample locations are shown on Figures 3-1, 3-2, and 3-3. During the field investigation sampling, 16 surface soil samples, four filtered and non-filtered groundwater samples, 20 filtered and non-filtered surface water samples, and 20 sediment samples were collected and analyzed. In 1999, 12 additional sediment samples were collected. A complete set of analytical results is presented in Appendix C.

Analytical results were also compared to human health and ecological criteria on a preliminary basis. Data presented in Section 4.0 figures exceeds background plus Human Health RBCs or ecological screening values. A detailed discussion pertaining to the comparison of analytical results to EPA human health and ecological criteria is provided in the human health and ecological risk assessments presented in Sections 6.0 and 7.0, respectively. Inorganic background levels are based on samples collected from areas that are remote from the investigative sites and other waste management activities at Parris Island. For each background area, sample locations were visually located in the field to confirm the absence of waste management activities and represent a range of undisturbed soil and sediment types. The two locations selected for background samples consist of Pickney Island and an undeveloped area on the southern portion of Parris Island. See Appendix A for sample locations. Six background samples were collected for all media of concern, except groundwater. Positive detections were noted for most

TABLE 4-1

SUMMARY OF DETECTED BACKGROUND CONCENTRATIONS
MCRD PARRIS ISLAND, SOUTH CAROLINA

Parameter	Surface Soil	Sediment	Surface Water Filtered	Surface Water Unfiltered
Organics	**(µg/kg)**	**(µg/kg)**	**(µg/l)**	**(µg/l)**
4-Methyl-2-pentanone	7.3	26		
2-Butanone		22		
Acetone	267			
Chloromethane				0.68
Carbon Disulfide		9.2		
Toluene	5.7	9.7		
Xylenes				1
Bis(2-Ethylhexyl)phthalate		421		45
Fluorene	646			
Indeno(1,2,3-cd)pyrene		518		2.6
Beta-BHC		7.1		
Inorganics	**(mg/kg)**	**(mg/kg)**	**(µg/l)**	**(µg/l)**
Aluminum	7270	24200		3100
Arsenic	1.4	12	4.3	5.1
Barium	24	28	256	38
Beryllium	0.095	0.98		
Cadmium		0.28		
Calcium	766	4000	650000	637000
Chromium	6.2	35.2	20	22.5
Cobalt	0.36	2.6		
Copper	1.5	10	13	7
Iron	3920	21500	48	2090
Lead	12.5	21	11	
Magnesium	515	6400	1900000	1900000
Manganese	129	186	18	53
Mercury	0.11	0.09		
Nickel	1.8	6		
Potassium	313	3200	890000	830000
Selenium	0.29			
Sodium	241	19000	15900000	16000000
Thallium	0.098	0.41		
Vanadium	9.5	50	15	18
Zinc	9.7	45	66	11

Background concentration is calculated as 2 times the average background concentration.

For chemicals in which at least one detection was noted, the average was calculated using 1/2 the detection limit for non detected chemicals.

Blank: Indicates that the chemical was not detected in any sample, and therefore an average could not be calculated.

Chemicals not detected in the background data set were not presented in this table. They include antimony, silver, and most organic compounds.

parameters (see Table 4-1). The values presented in Table 4-1 are based on EPA Region 4 protocol and equal 2 times the mean value. A complete set of analytical results is presented in Appendix C.

Data was validated in accordance with U.S. EPA National Functional Guidance for Organic and Inorganic Data Review (U.S. EPA, 1994a,b). The analytical results for the sampled media are summarized in the following sections.

4.1 SURFACE SOIL

Summary statistics of positive results for the 1998 surface soil sampling at Site 3 are provided in Table 4-2. Positive detections of organics and inorganics for surface soil at Site 3 that exceed background levels and human health or ecological criteria are shown on Figure 4-1. The human health criteria consist of the soil concentration equal to the lower of a 1E-06 incremental lifetime cancer risk or a hazard quotient equal to 1.0 under the residential use scenario (EPA Region III RBCs). The ecological criteria is based on EPA Region IV guidance. See Sections 6.0 and 7.0 for a more detailed evaluation.

Organic compounds detected in surface soil at Site 3 include the VOCs, acetone, chloroform, and 2-butanone. The detected SVOCs are 2-methylnaphthalene, 4-methylphenol, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl) phthalate, carbazole, chrysene, dibenzofuran, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene. Detected pesticides and PCBs include 4,4'-DDE, 4,4'-DDT, alpha-chlordane, gamma-chlordane, Aroclor 1254, and Aroclor 1260.

Acetone and 2-butanone were detected in 2 and 1 instances, respectively. The detected maximum levels were generally low, ranging from 240 µg/kg to 360 µg/kg (2-butanone). Chloroform (4/16) was detected at a maximum level of 2 µg/kg. VOCs were detected generally at low levels, with the exception of acetone at one location. VOCs were not detected at concentrations exceeding human health or ecological screening values (see Figure 4-1).

The following SVOCs were detected the most: benzo(b)fluoranthene (15/16), fluoranthene (14/16), phenanthrene (14/16), benzo(k)fluoranthene (11/16), benzo(a)anthracene (10/16), benzo(a)pyrene (10/16), indeno(1,2,3-cd)pyrene (10/16), and pyrene (10/16). Anthracene (6/16) and benzo(g,h,i)perylene (5/16) were detected less frequently. The remaining SVOCs were detected infrequently (i.e., frequency of 3 or less out of 16): 2-methylnapthalene, 4-methylphenol, acenaphthene, acenaphthylene, bis(2-ethylhexyl) phthalate, carbazole, and dibenzofuran. The range of maximum detections for the more frequently detected SVOCs was 1,200 µg/kg (phenanthrene) to 5,100 µg/kg (fluoranthene). The detections of SVOCs were relatively low. Nearly all the detected maximum levels were located at sample

TABLE 4-2

SUMMARY OF STATISTICS - SURFACE SOIL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Positive Detect	Average of Positive Detects	Average All[1]	Background	Maximum Exceed Backgrd.
Volatiles (ug/kg)								
2-Butanone	1/16	360	5 - 10	PAI-03-SS-008-01	360	26	NA	NA
Acetone	2/6	120 - 240	14 - 900	PAI-03-SS-008-01	180	169	NA	NA
Chloroform	4/16	1 - 2	5 - 10	PAI-03-SS-011-01	1.5	2.8	NA	NA
Semivolatiles (ug/kg)								
2-Methylnaphthalene	1/15	300	340 - 380	PAI-03-SS-001-01	300	187	NA	NA
4-Methylphenol	1/15	120	340 - 380	PAI-03-SS-001-01	120	175	NA	NA
Acenaphthene	1/16	4000	94 - 4600	PAI-03-SS-001-01	4,000	726	NA	NA
Acenaphthylene	1/16	1800	47 - 2300	PAI-03-SS-001-01	1,800	350	NA	NA
Anthracene	6/16	1.7 - 340	1.9 - 93	PAI-03-SS-001-01	66	33	NA	NA
Benzo(a)anthracene	10/16	3 - 3000	8.6 - 230	PAI-03-SS-001-01	335	225	NA	NA
Benzo(a)pyrene	10/16	4.1 - 4000	8.6 - 230	PAI-03-SS-001-01	438	290	NA	NA
Benzo(b)fluoranthene	15/16	2.2 - 3400	3.6	PAI-03-SS-001-01	263	247	NA	NA
Benzo(g,h,i)perylene	5/16	9.3 - 2500	7.5 - 370	PAI-03-SS-001-01	527	198	NA	NA
Benzo(k)fluoranthene	11/16	1.7 - 1300	3.6 - 93	PAI-03-SS-001-01	130	97	NA	NA
Bis(2-Ethylhexyl)phthalate	1/15	2300	340 - 370	PAI-03-SS-015-01	2,300	320	NA	NA
Carbazole	3/15	48 - 670	340 - 380	PAI-03-SS-001-01	256	194	NA	NA
Chrysene	13/16	3.6 - 2900	9.1 - 230	PAI-03-SS-001-01	274	230	NA	NA
Dibenzofuran	1/15	340	340 - 380	PAI-03-SS-001-01	340	190	NA	NA
Fluoranthene	14/16	6.4 - 5100	5.5 - 22	PAI-03-SS-001-01	472	414	NA	NA
Indeno(1,2,3-cd)pyrene	10/16	2.6 - 2600	8.6 - 230	PAI-03-SS-001-01	279	193	NA	NA
Phenanthrene	14/16	2.2 - 1200	7.2 - 190	PAI-03-SS-001-01	129	119	NA	NA
Pyrene	10/16	13 - 4500	9.4 - 460	PAI-03-SS-001-01	527	360	NA	NA
Pesticides/PCBs (ug/kg)								
4,4'-DDE	1/16	4.1	1.7 - 190	PAI-03-SS-012-01	4.1	12	NA	NA
4,4'-DDT	2/16	1.8 - 4.5	1.8 - 190	PAI-03-SS-012-01	3.2	12	NA	NA
Alpha-Chlordane	1/16	96	0.87 - 1900	PAI-03-SS-001-01	96	96	NA	NA
Aroclor-1254	1/16	56	8.6 - 9.4	PAI-03-SS-009-01	56	7.7	NA	NA
Aroclor-1260	4/16	11 - 100	8.6 - 9.4	PAI-03-SS-013-01	41	14	NA	NA
Gamma-Chlordane	1/16	53	0.87 - 1900	PAI-03-SS-001-01	53	93	NA	NA
Inorganics (mg/kg)								
Aluminum	16/16	2370 - 10800	0	PAI-03-SS-010-01	5,745	5,745	7,270	Yes
Antimony	2/16	0.17 - 0.33	0.15 - 0.23	PAI-03-SS-015-01	0.25	0.10	ND	Yes
Arsenic	16/16	0.44 - 11.8	0	PAI-03-SS-003-01	1.7	1.7	1.4	Yes
Barium	16/16	5.8 - 81.2	0	PAI-03-SS-001-01	16	16	24	Yes
Beryllium	3/16	0.11 - 0.58	0.02 - 0.38	PAI-03-SS-004-01	0.38	0.12	0.10	Yes
Cadmium	6/16	0.04 - 0.53	0.02 - 0.03	PAI-03-SS-001-01	0.21	0.09	ND	Yes
Calcium	16/16	461 - 56100	0	PAI-03-SS-015-01	11,082	11,082	766	Yes
Chromium	16/16	3.5 - 15.9	0	PAI-03-SS-004-01	8.4	8.4	6.2	Yes
Cobalt	16/16	0.14 - 1.7	0	PAI-03-SS-004-01	0.61	0.61	0.36	Yes
Copper	13/16	1.3 - 10.7	0.46 - 1.6	PAI-03-SS-004-01	3.9	3.3	1.5	Yes
Iron	16/16	2180 - 7370	0	PAI-03-SS-004-01	4,788	4,788	3,920	Yes
Lead	16/16	5.5 - 264	0	PAI-03-SS-001-01	31	31	13	Yes
Magnesium	16/16	150 - 2250	0	PAI-03-SS-004-01	646	646	515	Yes
Manganese	16/16	8.1 - 66.9	0	PAI-03-SS-015-01	28	28	129	No
Mercury	6/16	0.0375 - 0.43	0.02 - 0.03	PAI-03-SS-009-01	0.13	0.06	0.11	Yes
Nickel	16/16	0.39 - 6.1	0	PAI-03-SS-002-01	2.0	2.0	1.8	Yes
Potassium	16/16	115 - 1380	0	PAI-03-SS-004-01	370	370	313	Yes
Selenium	2/16	0.28 - 0.41	0.14 - 0.5	PAI-03-SS-010-01	0.35	0.15	0.29	Yes
Silver	1/16	0.09	0.05 - 0.06	PAI-03-SS-015-01	0.09	0.03	ND	Yes
Sodium	6/16	192 - 5480	164 - 441	PAI-03-SS-004-01	1,854	801	241	Yes
Vanadium	16/16	4.7 - 21.4	0	PAI-03-SS-004-01	10	10	10	Yes
Zinc	16/16	5.7 - 205	0	PAI-03-SS-001-01	27	27	10	Yes

NA = Not Applicable

ND = Non-Detect

Average All is the arithmetic average where 1/2 of the detection limit was used for ND results when calculating the average.

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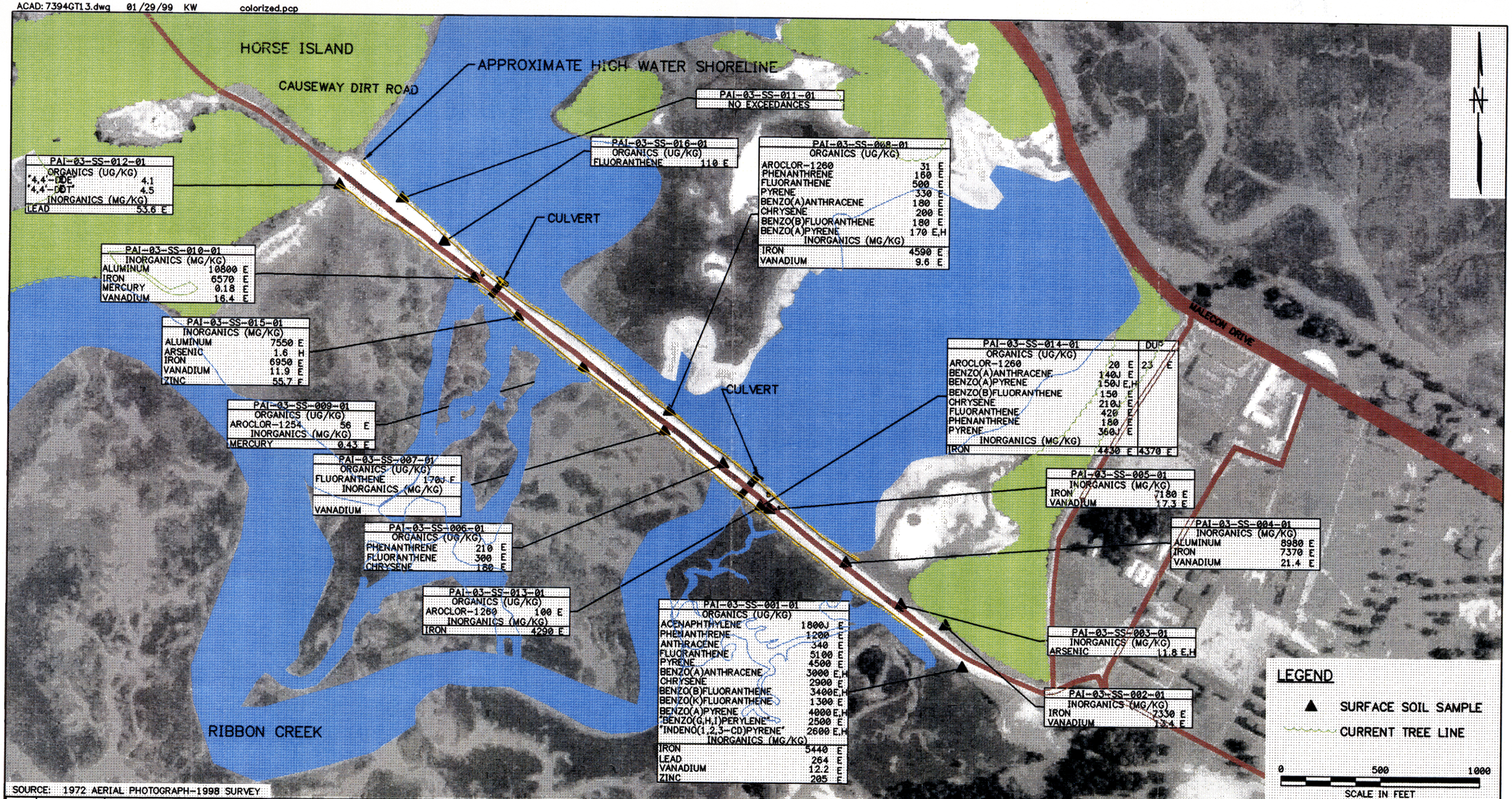

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COST/SCHED-AREA
SCALE AS NOTED

SURFACE SOIL SAMPLE RESULTS
THAT EXCEED BACKGROUND, HUMAN HEALTH
RBCs, AND/OR ECOLOGICAL SCREENING VALUES
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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REV. 0

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location PAI-03-SS-01. SVOCs and 6 PAHs were detected at concentrations exceeding human health and ecological screening criteria at 6 of 16 sample locations (see Figure 4-1).

Pesticides were detected at a frequency of 1 or 2 out of 16. The range of maximum levels was 4.1 µg/kg (4-4'-DDE) to 96 µg/kg (alpha-chlordane). This maximum detection was found at sample location PAI-03-SS-01. Of the PCB compounds, Aroclor 1260 was detected the most (4/16). The range of maximum PCB levels was 56 µg/kg (Aroclor 1254) to 100 µg/kg (Aroclor 1260). This maximum level was located at sample location PAI-03-SS-13. Detected pesticide and PCB levels were generally low, but, in general, a positive detection also resulted in an exceedance of ecological screening criteria (see Figure 4-1).

Inorganics were also detected throughout the surface soil samples collected at Site 3. They included the following metals: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc. Essential nutrients like calcium, magnesium, potassium, and sodium were also detected.

The following metals were detected in all samples, unless otherwise noted: aluminum, arsenic, barium, chromium, cobalt, copper (13/16), iron, lead, manganese, nickel, vanadium, and zinc. The other metals were found less frequently: antimony (2/16), beryllium (3/16), cadmium (6/16), mercury (6/16), selenium (2/16), and silver (1/16). Aluminum and iron were detected at maximum levels of 10,800 mg/kg and 7,370 mg/kg, respectively. Lead and zinc were detected at maximum concentrations of 264 mg/kg and 205 mg/kg, respectively. The range of maximum detections for the remaining metals (excluding the essential nutrients) was 0.09 mg/kg (silver) to 81.2 mg/kg (barium). Most maximum detections were found at sample location PAI-03-SS-04.

With the exception of manganese, detected metals exceeded background levels in one or more locations. Copper, iron, lead, and zinc were detected at levels that exceed the corresponding background levels by an order of magnitude or greater. However, only aluminum, arsenic, iron, lead, mercury, vanadium, and zinc exceeded an ecological or human health criterion (see Figure 4-1).

4.2 GROUNDWATER

Summary statistics of positive results for the 1998 groundwater sampling at Site 3 are provided in Table 4-3. Positive detections of organics and inorganics for groundwater at Site 3 that exceeded human health or ecological criteria are shown on Figure 4-2. The human health criteria consist of the groundwater concentration equal to the lower of 1E-06 incremental lifetime cancer risk or a hazard quotient equal to 1.0 under the potable water use scenario (EPA Region III RBCs). The ecological criteria is based on the assumption that groundwater would become surface water. The lower of the EPA Region 4 fresh water

TABLE 4-3

SUMMARY STATISTICS - GROUNDWATER
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Positive Detect	Average of Positive Detects	Average All[1]
Volatiles (µg/L)						
Benzene	2/4	0.3 - 21	1	PAI-03-GW-001-01	11	5.6
Carbon Disulfide	1/4	0.3	1	PAI-03-GW-002-01	0.30	0.45
Chlorobenzene	2/4	0.6 - 130	1	PAI-03-GW-001-01	65	33
Chloroform	1/4	0.3	1	PAI-03-GW-004-01	0.30	0.45
Ethylbenzene	1/4	0.3	1	PAI-03-GW-001-01	0.30	0.45
Toluene	2/4	0.3	1	PAI-03-GW-002-01	0.30	0.40
Xylenes, Total	1/4	0.3	1	PAI-03-GW-001-01	0.30	0.45
Semivolatiles (µg/L)						
1,4-Dichlorobenzene	1/4	10	5	PAI-03-GW-001-01	10	4.4
2-Methylnaphthalene	1/4	1	5	PAI-03-GW-003-01	1.0	2.1
4-Methylphenol	1/4	73	5	PAI-03-GW-003-01	73	20
Acenaphthene	1/4	2	5	PAI-03-GW-003-01	2.0	2.4
Anthracene	1/4	1	5	PAI-03-GW-003-01	1.0	2.1
Bis(2-Ethylhexyl)phthalate	3/4	1	5	PAI-03-GW-001-01	1.0	1.4
Fluorene	1/4	1	5	PAI-03-GW-003-01	1.0	2.1
N-Nitrosodiphenylamine	1/4	1	5	PAI-03-GW-001-01	1.0	2.1
Naphthalene	2/4	1	5	PAI-03-GW-001-01	1.0	1.8
Phenanthrene	1/4	1	5	PAI-03-GW-003-01	1.0	2.1
Pesticides/PCBs (µg/L)						
alpha-BHC	1/4	0.12	0.05	PAI-03-GW-002-01	0.12	0.05
Inorganics - Unfiltered (µg/L)						
Arsenic	4/4	2.2 - 34.5	0	PAI-03-GW-001-01	11	11
Barium	4/4	93.5 - 854	0	PAI-03-GW-004-01	357	357
Calcium	3/3	60600 - 474000	0	PAI-03-GW-004-01	203,033	203,033
Chromium	2/4	7.6 - 27	6.4	PAI-03-GW-004-01	17	10
Iron	3/3	14600 - 32600	0	PAI-03-GW-004-01	23,633	23,633
Magnesium	3/3	76400 - 508000	0	PAI-03-GW-004-01	235,133	235,133
Manganese	3/3	112 - 708	0	PAI-03-GW-004-01	391	391
Potassium	3/3	63600 - 209000	0	PAI-03-GW-004-01	128,533	128,533
Sodium	3/3	588000 - 4610000	0	PAI-03-GW-004-01	2,119,333	2,119,333
Thallium	1/4	2.6	1.8 - 9	PAI-03-GW-004-01	2.6	2.2
Inorganics - Filtered (µg/L)						
Arsenic	4/4	1.2 - 31.1	0	PAI-03-GW-001-01-F	9.3	9.3
Barium	4/4	93.3 - 901	0	PAI-03-GW-004-01-F	373	373
Calcium	3/3	63400 - 492000	0	PAI-03-GW-004-01-F	210,500	210,500
Chromium	1/4	24.8	6.4	PAI-03-GW-004-01-F	25	8.6
Iron	3/3	14600 - 31500	0	PAI-03-GW-004-01-F	23,500	23,500
Magnesium	3/3	75400 - 543000	0	PAI-03-GW-004-01-F	247,800	247,800
Manganese	3/3	113 - 711	0	PAI-03-GW-004-01-F	395	395
Potassium	3/3	64800 - 223000	0	PAI-03-GW-004-01-F	134,933	134,933
Sodium	3/3	576000 - 5130000	0	PAI-03-GW-004-01-F	2,295,333	2,295,333
Thallium	1/4	3.8	1.8 - 9	PAI-03-GW-004-01-F	3.8	2.5

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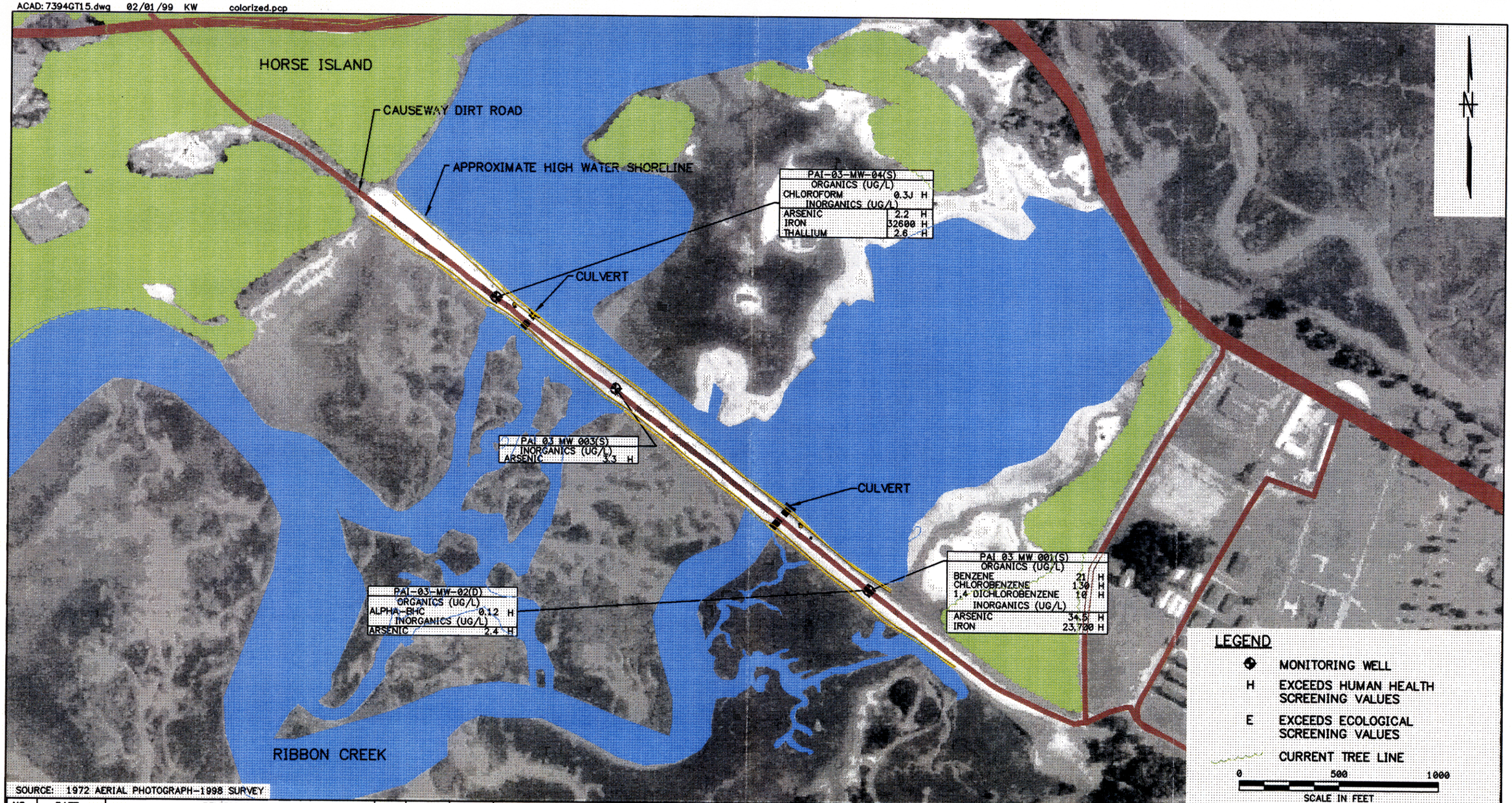

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GROUNDWATER SAMPLE RESULTS
THAT EXCEED HUMAN HEALTH RBC's OR
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SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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and brackish water screening levels is then used. See Sections 6.0 and 7.0 for a more detailed evaluation.

Organic compounds detected in groundwater at Site 3 included the following VOCs: benzene, carbon disulfide, chlorobenzene, chloroform, ethylbenzene, toluene, and xylenes. Detected SVOCs included 1,4-dichlorobenzene, 2-methylnaphthalene, 4-methylphenol, acenaphthene, anthracene, bis(2-ethylhexyl) phthalate, fluorene, n-nitrosodiphenylamine, naphthalene, and phenanthrene. The only detected pesticide in Site 3 groundwater was alpha-BHC.

VOCs were detected at a frequency of 1 to 2 out of the 4 samples. Chlorobenzene was detected at a maximum level of 130 µg/L [PAI-03-MW-03(S)]. Benzene was detected at a maximum level of 21 µg/L [PAI-03-MW-03(S)]. The remaining VOCs were detected at the maximum level of 0.3 µg/L. Of the VOCs, only chloroform, at 0.3 J µg/L, exceeded a human health criterion (see Figure 4-2).

Bis(2-ethylhexyl) phthalate and naphthalene were detected at frequencies of 3 and 2 out of 4, respectively. The other SVOCs were detected once or twice. The maximum level of 4-methylphenol was 73 µg/L [PAI-03-MW-03(S)]. The maximum concentration of 1,4-dichlorobenzene was 10 µg/L [PAI-03-MW-03(S)]. The remaining SVOCs were detected at maximum levels of 1 µg/L and 2 µg/L. The detected levels of SVOCs were generally low, and SVOCs were not detected at concentrations that exceeded human health or ecological criteria.

Alpha-BHC was detected once at a level of 0.12 µg/L. Pesticides were infrequently detected at low levels. However, this concentration would exceed human health criteria if this area were used as a drinking water supply (see Figure 4-2).

The following inorganics were detected in the filtered and non-filtered groundwater samples collected from Site 3: arsenic, barium, chromium, iron, manganese, and thallium. Essential nutrients like calcium, magnesium, potassium, and sodium were also detected. Iron (total) was detected at a maximum level of 32,600 µg/L. Barium (total) and manganese (total) were detected at slightly lower levels, i.e., 854 µg/L and 708 µg/L, respectively. The remaining metals (excluding essential nutrients) were detected at maximum levels ranging from 2.6 µg/L (thallium, total) to 34.5 µg/L (arsenic, total). Maximum detections of total metals were primarily found at sample location PAI-03-MW-04(S).

Filtered results were relatively similar to total results. Iron was detected at a maximum level of 31,500 µg/L. Barium and manganese were detected at slightly lower levels, i.e., 901 µg/L and 711 µg/L, respectively. The remaining metals (excluding essential nutrients) were detected at maximum levels

ranging from 3.8 µg/L (thallium) to 31.1 µg/L (arsenic). Maximum detections were primarily found at sample location PAI-03-MW-04(S) (filtered).

For the inorganics, if the area groundwater were used for potable water, then arsenic, iron, or thallium would exceed human health screening criteria (Figure 4-2).

4.3 SURFACE WATER

4.3.1 1998 Analytical Data

Summary statistics of positive results for the 1998 surface water sampling at Site 3 are provided in Table 4-4. Positive detections of organics and inorganics for surface water at Site 3 that exceeded background levels and/or human health or ecological criteria are shown on Figure 4-3. The human health criteria consists of the surface water concentration equal to the lower of 1E-06 incremental lifetime cancer risk or a hazard quotient equal to 1.0 for consumption of surface water and organisms (EPA water quality standards). The EPA Region 4 brackish water screening levels is then used. See Sections 6.0 and 7.0 for a more detailed evaluation.

Organic compounds detected in surface water at Site 3 included acetone and the following detected SVOCs: anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl) phthalate, butylbenzyl phthalate, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene. No pesticides or PCBs were detected in surface water.

Acetone was detected once at a concentration of 3 µg/L. The SVOCs were also detected infrequently, i.e., 3 or less out of 20 samples. Bis(2-ethylhexyl) phthalate (BEHP) was detected the most at a frequency of 6 out of 20. The maximum detections of SVOCs ranged from 0.25 µg/L to 7 µg/L (BEHP). For the organic detections, only fluoranthene exceeded a human health or ecological screening value.

The following inorganics were detected in the non-filtered surface water sampled collected from Site 3: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, vanadium, and zinc. Essential nutrients like calcium, magnesium, potassium, and sodium were also detected. Filtered metals results included aluminum, antimony, arsenic, barium, copper, iron, lead, manganese, silver, vanadium, and zinc. Essential nutrients like calcium, magnesium, potassium, and sodium were also detected.

The following metals were detected in nearly all the unfiltered samples, i.e., 18 or more out of 20 samples, at the following maximum levels: aluminum (88,600 µg/L), iron (110,000 µg/L), and manganese

TABLE 4-4

SUMMARY STATISTICS - SURFACE WATER
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Positive Detect	Average of Positive Detects	Average All[1]	Background	Maximum Level Exceed Backgrd.
Volatiles (ug/L)								
Acetone	1/1	3	0	PAI-03-SW-023	3.0	3.0	NA	NA
Semivolatiles (ug/L)								
Anthracene	1/20	0.38	0.048 - 0.054	PAI-03-SW-014	0.38	0.04	NA	NA
Benzo(a)anthracene	1/20	0.66	0.12 - 0.14	PAI-03-SW-014	0.66	0.09	NA	NA
Benzo(a)pyrene	2/20	0.075 - 0.72	0.12 - 0.14	PAI-03-SW-014	0.40	0.10	NA	NA
Benzo(b)fluoranthene	2/20	0.06 - 0.67	0.048 - 0.49	PAI-03-SW-014	0.37	0.07	NA	NA
Benzo(g,h,i)perylene	1/20	0.89	0.19 - 0.22	PAI-03-SW-014	0.89	0.14	NA	NA
Benzo(k)fluoranthene	2/20	0.025 - 0.25	0.048 - 0.49	PAI-03-SW-014	0.14	0.05	NA	NA
Bis(2-Ethylhexyl)phthalate	6/20	2 - 7	10	PAI-03-SW-025	4.5	4.9	NA	NA
Butylbenzyl Phthalate	1/20	5	10 - 10.5	PAI-03-SW-028	5.0	5.0	NA	NA
Chrysene	2/20	0.09 - 1.2	0.12 - 0.14	PAI-03-SW-014	0.65	0.12	NA	NA
Fluoranthene	3/20	0.1 - 1.9	0.12 - 0.14	PAI-03-SW-014	0.71	0.16	NA	NA
Indeno(1,2,3-cd)pyrene	2/20	0.075 - 0.39	0.12 - 0.14	PAI-03-SW-014	0.23	0.08	NA	NA
Phenanthrene	3/20	0.05 - 1.4	0.0955 - 0.11	PAI-03-SW-014	0.50	0.12	NA	NA
Pyrene	1/20	1.3	0.24 - 0.27	PAI-03-SW-014	1.30	0.19	NA	NA
Inorganics - Non-filtered (ug/L)								
Aluminum	18/20	242 - 88600	44.5 - 90.8	PAI-03-SW-027	5,951	5,360	3,113	Yes
Antimony	4/20	1.8 - 3.2	1.7 - 3.7	PAI-03-SW-014	2.5	1.3	ND	Yes
Arsenic	1/20	96.1	1.5 - 3.5	PAI-03-SW-027	96	6	5	Yes
Barium	13/20	13 - 227	12.4 - 15.9	PAI-03-SW-025	41	29	38	Yes
Beryllium	1/20	4.4	0.2	PAI-03-SW-027	4.4	0.32	ND	Yes
Cadmium	1/20	2	0.3	PAI-03-SW-027	2.0	0.24	ND	Yes
Calcium	20/20	126000 - 274000	0	PAI-03-SW-013	245,325	245,325	637,000	No
Chromium	3/20	0.79 - 164	0.7 - 0.8	PAI-03-SW-027	55	9	23	Yes
Cobalt	1/20	21.1	0.6	PAI-03-SW-027	21	1.3	ND	Yes
Copper	8/20	1.4 - 152	1.2 - 3.2	PAI-03-SW-027	23	10	7.0	Yes
Iron	18/20	163 - 110000	16.6 - 91.7	PAI-03-SW-027	6,783	6,107	2,091	Yes
Lead	1/20	132	1 - 17	PAI-03-SW-027	132	9.1	ND	Yes
Magnesium	20/20	230000 - 841000	0	PAI-03-SW-025	727,250	727,250	1,918,667	No
Manganese	19/20	5.3 - 840	0.4	PAI-03-SW-027	80	76	53	Yes
Mercury	1/20	0.15	0.1	PAI-03-SW-027	0.15	0.06	ND	Yes
Nickel	1/20	39.8	1	PAI-03-SW-027	40	2	ND	Yes
Potassium	20/20	146000 - 478000	0	PAI-03-SW-014	400,675	400,675	831,333	No
Silver	4/20	0.68 - 2.1	0.6 - 0.7	PAI-03-SW-021-AVG	1.12	0.48	ND	Yes
Sodium	20/20	1950000 - 6820000	0	PAI-03-SW-025	5,947,500	5,947,500	16,226,667	No
Vanadium	1/20	269	0.5 - 6.1	PAI-03-SW-027	269	15	18	Yes
Zinc	4/20	12.7 - 294	1.9 - 8.3	PAI-03-SW-027	97	22	11	Yes
Inorganics - Filtered (ug/L)								
Aluminum	2/20	323 - 650	22.7 - 120	PAI-03-SW-025-F	487	82	ND	Yes
Antimony	4/20	1.8 - 4.2	1.7 - 4.9	PAI-03-SW-019-F	2.8	1.5	ND	Yes
Arsenic	2/20	2.3 - 12.9	1.5 - 3.5	PAI-03-SW-027-F	7.6	1.7	4.3	Yes
Barium	20/20	15 - 279	0	PAI-03-SW-028-F	227	227	256	Yes
Calcium	20/20	137000 - 282000	0	PAI-03-SW-025-F	244,275	244,275	645,333	No
Copper	3/20	1 - 1.7	1.2 - 7.5	PAI-03-SW-011-F	1.3	1.2	13	No
Iron	2/20	175 - 549	16.6 - 93.8	PAI-03-SW-025-F	362	46	18	Yes
Magnesium	20/20	249000 - 843000	0	PAI-03-SW-025-F	721,500	721,500	1,918,000	No
Manganese	15/20	7.4 - 156	0.4 - 1.9	PAI-03-SW-028-F	42	32	18	Yes
Potassium	20/20	159000 - 495000	0	PAI-03-SW-009-F	444,625	444,625	890,667	No
Silver	1/20	0.71	0.6 - 0.7	PAI-03-SW-013-F	0.71	0.33	ND	Yes
Sodium	20/20	2110000 - 6970000	0	PAI-03-SW-022-F	5,968,250	5,968,250	15,986,667	No
Vanadium	1/20	11	0.5 - 1.9	PAI-03-SW-027-F	11	0.92	15	No
Zinc	18/20	25.2 - 84.8	3.5 - 15.4	PAI-03-SW-012-F	55	50	66	Yes

NA = Not Applicable

ND = Non-Detect

[1]Average All is the arithmetic average where 1/2 of the detection limit was used for ND results when calculating the average.

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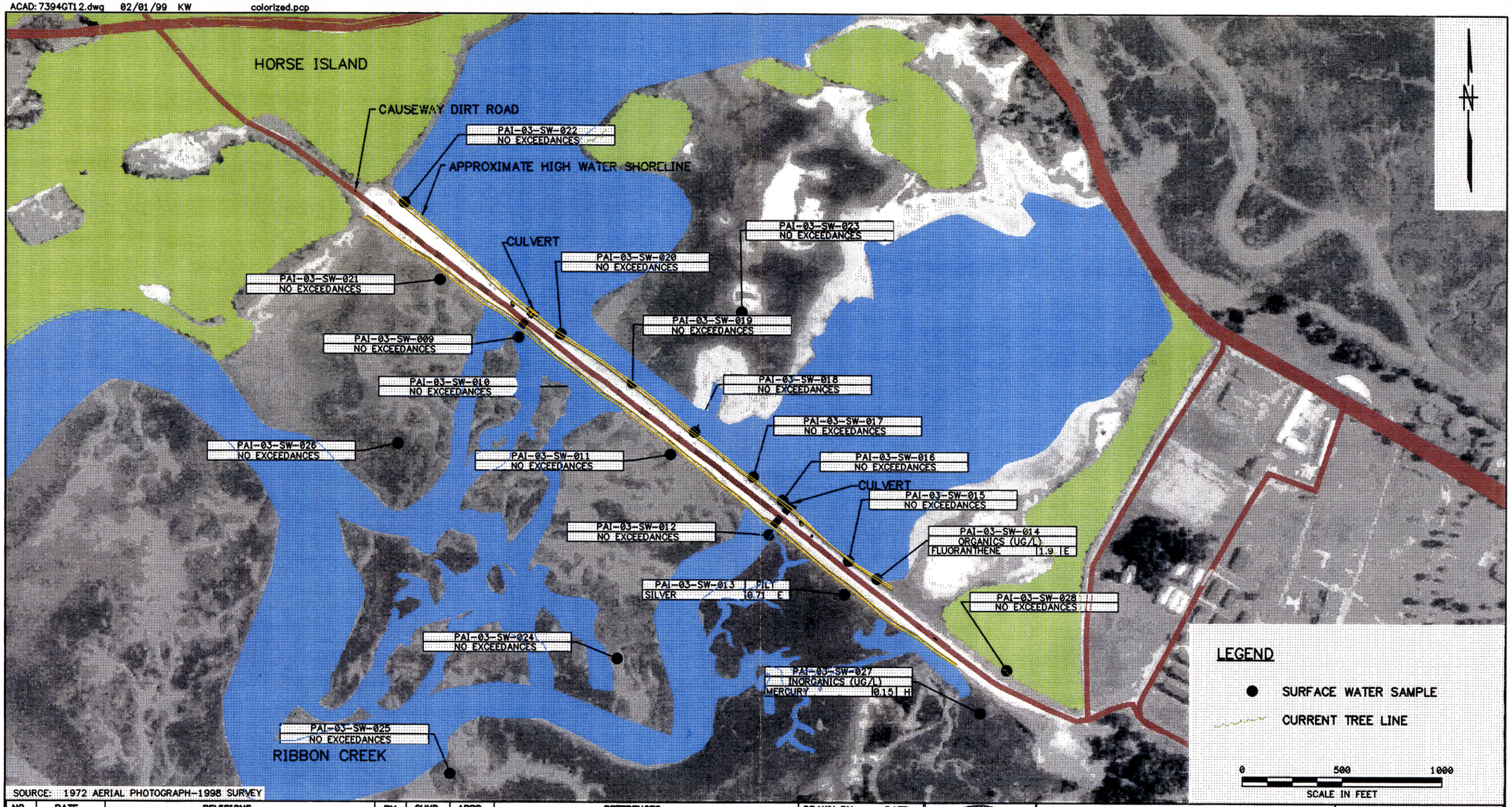

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SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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(840 µg/L). Barium was detected in 13 samples at a maximum level of 227 µg/L. Copper was detected in eight samples with a maximum concentration of 152 µg/L. The remaining detected metals were found in only 4 or less of the samples. The range of maximum detections of the other metals was 0.15 µg/L to 294 µg/L (zinc). Most maximum levels were detected at sample location PAI-03-SW-27. For the unfiltered results, only mercury at one location exceeded a human health criterion (see Figure 4-3).

Filtered results indicated that barium, manganese, and zinc were detected in most of the samples. Maximum levels ranged from 84.8 µg/L (zinc) to 279 µg/L (barium). The range of the other detected metals was 0.71 µg/L (silver) to 650 µg/L (aluminum). Most maximum levels were detected at sample location PAI-03-SW-25. For the filtered results, only silver at one location exceeded an ecological screening value (see Figure 4-3).

The following total metals exceeded background values: aluminum, arsenic, barium, chromium, copper, iron, manganese, vanadium, and zinc. The filtered metals results that exceeded background levels were arsenic, barium, iron, manganese, and zinc. The following total metals were detected at levels that exceeded the background levels by at least an order of magnitude: aluminum, iron, manganese, and zinc. The following filtered metals results exceeded background levels by at least one order of magnitude: iron and manganese.

4.3.2 Comparison of 1998 and 1988 Analytical Data

Surface water data from the 1988 and 1998 sample events are presented in Table 4-5. Included in the table are the individual results from 1988 and the average and maximum surface water concentrations detected in 1998. An evaluation of each chemical is presented below.

Lead: Lead was detected in the surface waters in both 1988 and 1998. The maximum concentration detected in 1998 is higher than detected in 1988, but the average concentration is consistent with historic data. Therefore, the use of only the current data will not affect the results of risk calculations for lead.

Cadmium and Mercury: Cadmium and mercury was detected in two of eight surface water samples in 1988 at concentrations in excess of surface water screening values. For the 1998 data set, there were no cadmium exceedances and one mercury exceedance for surface water screening criteria. As a result, use of only the 1998 data would eliminate cadmium as a COPC but would still retain mercury as a COPC.

For the 1988 mercury data, there were also potential concerns with the quality of the mercury results for the surface water samples. For SW-1, mercury was detected at a concentration of 1.6 µg/L in the original sample. However, the duplicate of the sample found no detectable mercury (at 0.5 µg/L). The second mercury detection was just at the detection limit of 0.5 µg/L. Also, even one half of the detection limit for

TABLE 4-5

COMPARISON OF SURFACE WATER DATA FROM 1988 WITH 1998 (UG/L)
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

PARAMETER	1988 TEST RESULTS								MAXIMUM SW CONC. 1988	AVERAGE SW CONC. 1998	MAXIMUM SW CONC. 1998
	SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07	SW-08			
Cadmium	10					13			13	0.24	2
Lead	22	12	9	13	5	11	6	7	22	9.1	132
Mercury	1.6	0.5							1.6	0.055	0.15

Blank indicates that the chemical was not detected.

Mercury result for SW-01 duplicate was none detected at 0.5 ug/l.

mercury in 1988 samples exceeds the surface water screening values, thereby limiting the usability of the data.

4.4 SEDIMENT

4.4.1 1998 Analytical Data

Summary statistics of positive results for the 1998 sediment sampling at Site 3 are provided in Table 4-6. Positive detections of organics and inorganics for sediment at Site 3 that exceeded background levels and human health or ecological criteria are shown on Figure 4-4. The human health criteria consist of the soil concentration equal to the lower of 1E-06 incremental lifetime cancer risk or a hazard quotient equal to 1.0 under the residential use scenario (EPA Region III RBCs) assuming that the sediment is the same as surface soils. The ecological criteria consist of the EPA Region 4 Screening Values. See Sections 6.0 and 7.0 for a more detailed evaluation.

Organic compounds detected in sediment at Site 3 included the following VOCs: acetone, 2-butanone, carbon disulfide, and chloroform. The detected SVOCs included anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, carbazole, chrysene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene. The following pesticides and PCBs were detected: 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-chlordane, gamma-chlordane, Aroclor 1254, and Aroclor 1260.

Maximum VOC detections ranged from 1 µg/kg (chloroform) to 170 µg/kg (acetone). Concentrations were generally low, and VOCs were detected at low frequencies, i.e., 6 samples or less out of 20 samples total. As shown on Figure 4-4, VOCs did not exceed ecological or human health screening criteria.

Benzo(b)fluoranthene and chrysene were detected in 13 samples at maximum levels of 990 µg/kg and 1,900 µg/kg, respectively. Fluoranthene, phenanthrene, and pyrene were detected in fewer samples, i.e., 8 or 9 samples, with a range of maximum concentrations of 2,400 µg/kg to 3,500 µg/kg (fluoranthene). The remaining SVOCs were detected in fewer samples, i.e., 6 samples or less. The range of maximum detections was 13 µg/kg to 1,200 µg/kg [benzo(a)anthracene and benzo(a)pyrene]. Most maximum detections occurred at sample location PAI-03-SD-22 (asphalt is present at the surface). Sample location PA1-03-SD-22 was visually inspected in March 1999. Pieces of asphalt ranging in size from sand to several inches in diameter were noted in the sediments and on the adjacent hillside. Asphalt is known to contain moderate concentrations of PAHs. PAHs exceeded ecological or human health screening criteria in 2 of the 20 samples (see Figure 4-4).

TABLE 4-6

SUMMARY STATISTICS - SEDIMENT
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Positive Detects	Average of Positive Results	Average All[1]	Background	Maximum Exceed Backgrd.
Volatiles (ug/kg)								
2-Butanone	6/17	8 - 61	6 - 37	PAI-03-SD-014-01	24	14	NA	NA
Acetone	2/6	150 - 170	39 - 100	PAI-03-SD-026-01	160	75	NA	NA
Carbon Disulfide	6/21	3 - 40	6 - 37	PAI-03-SD-014-01	21	12	NA	NA
Chloroform	2/21	1	8 - 38	PAI-03-SD-016-01	1.0	9.2	NA	NA
Semivolatiles (ug/kg)								
Anthracene	4/21	3.7 - 770	2.3 - 260	PAI-03-SD-022-01	197	55	NA	NA
Benzo(a)anthracene	6/21	5.1 - 1200	5.7 - 650	PAI-03-SD-022-01	222	105	NA	NA
Benzo(a)pyrene	6/21	8.1 - 1200	5.7 - 650	PAI-03-SD-022-01	227	106	NA	NA
Benzo(b)fluoranthene	13/21	1.8 - 990	23 - 260	PAI-03-SD-022-01	96	73	NA	NA
Benzo(g,h,i)perylene	2/21	24 - 570	9.2 - 1000	PAI-03-SD-022-01	297	99	NA	NA
Benzo(k)fluoranthene	5/21	3 - 420	2.3 - 260	PAI-03-SD-022-01	95	39	NA	NA
Carbazole	1/21	570	440 - 1600	PAI-03-SD-022-01	570	409	NA	NA
Chrysene	13/21	3.2 - 1900	60 - 650	PAI-03-SD-022-01	183	148	NA	NA
Dibenzofuran	1/21	190	440 - 1600	PAI-03-SD-022-01	190	391	NA	NA
Fluoranthene	9/21	15 - 3500	5.7 - 650	PAI-03-SD-022-01	437	225	NA	NA
Fluorene	1/21	13	11 - 1300	PAI-03-SD-027-01	13	105	NA	NA
Indeno(1,2,3-cd)pyrene	6/21	5.8 - 660	5.7 - 650	PAI-03-SD-022-01	128	78	NA	NA
Phenanthrene	9/21	5.8 - 2400	4.6 - 520	PAI-03-SD-022-01	282	153	NA	NA
Pyrene	8/21	11 - 2700	11 - 1300	PAI-03-SD-022-01	375	225	NA	NA
Pesticides/PCBs (ug/kg)								
4,4'-DDD	2/21	40 - 290	2.3 - 140	PAI-03-SD-014-01	165	41	NA	NA
4,4'-DDE	1/21	45	2.3 - 140	PAI-03-SD-014-01	45	29	NA	NA
4,4'-DDT	1/21	34	2.3 - 140	PAI-03-SD-021-01	34	29	NA	NA
Alpha-Chlordane	1/21	28	1.1 - 1400	PAI-03-SD-028-01	28	146	NA	NA
Aroclor-1254	3/21	65 - 250	11 - 40	PAI-03-SD-020-01	137	28	NA	NA
Aroclor-1260	2/21	45 - 70	11 - 40	PAI-03-SD-015-01	58	15	NA	NA
Gamma-Chlordane	1/21	28	1.1 - 1400	PAI-03-SD-028-01	28	146	NA	NA
Inorganics (mg/kg)								
Aluminum	21/21	1510 - 29700	0	PAI-03-SD-026-01	13,060	13,060	24,284	Yes
Antimony	3/21	0.34 - 0.74	0.19 - 0.66	PAI-03-SD-014-01	0.48	0.22	ND	Yes
Arsenic	16/21	2.3 - 19.8	0.22 - 0.97	PAI-03-SD-024-01	8	6	12	Yes
Barium	16/21	3.6 - 53.8	17 - 36.2	PAI-03-SD-022-01	18	17	28	Yes
Beryllium	11/21	0.29 - 1.4	0.02 - 0.46	PAI-03-SD-026-01	0.82	0.48	0.98	Yes
Cadmium	10/21	0.12 - 0.44	0.03 - 0.12	PAI-03-SD-010-01	0.27	0.15	0.28	No
Calcium	21/21	408 - 32800	0	PAI-03-SD-010-01	3,849	3,849	4,002	Yes
Chromium	21/21	3.3 - 50.3	0	PAI-03-SD-026-01	22	22	35	Yes
Cobalt	19/21	0.11 - 5.6	0.07	PAI-03-SD-026-01	2.2	2.0	2.6	Yes
Copper	21/21	1.8 - 46.9	0	PAI-03-SD-020-01	15	15	10	Yes
Iron	21/21	1100 - 28000	0	PAI-03-SD-024-01	12,745	12,745	21,450	Yes
Lead	21/21	6.4 - 105	0	PAI-03-SD-017-01	30	30	21	Yes
Magnesium	21/21	267 - 6710	0	PAI-03-SD-023-01	3,222	3,222	6,437	Yes
Manganese	21/21	9.7 - 205	0	PAI-03-SD-026-01	70	70	186	Yes
Mercury	6/21	0.05 - 0.35	0.02 - 0.09	PAI-03-SD-028-01	0.14	0.06	0.09	Yes
Nickel	19/21	0.42 - 13.9	0.12 - 0.81	PAI-03-SD-020-01	6.0	5.5	6.0	Yes
Potassium	21/21	170 - 4570	0	PAI-03-SD-026-01	2,028	2,028	3,190	Yes
Selenium	7/21	0.32 - 1.1	0.19 - 1	PAI-03-SD-028-01	0.62	0.34	ND	Yes
Silver	1/21	0.13	0.07 - 0.23	PAI-03-SD-020-01	0.13	0.07	ND	Yes
Sodium	20/21	377 - 26600	1960	PAI-03-SD-023-01	9,706	9,290	19,110	Yes
Thallium	1/21	0.62	0.18 - 0.89	PAI-03-SD-027-01	0.62	0.21	0.41	Yes
Vanadium	21/21	2.6 - 63.7	0	PAI-03-SD-026-01	29	29	50	Yes
Zinc	21/21	5.2 - 159	0	PAI-03-SD-020-01	43	43	45	Yes
Cyanide	1/21	0.71	0.44 - 1.8	PAI-03-SD-018-01	0.71	0.48	ND	Yes

NA = Not Applicable
ND = Non-Detect
1 Average All is the arithmetic average where 1/2 of the detection limit was used for ND results when calculating the average.

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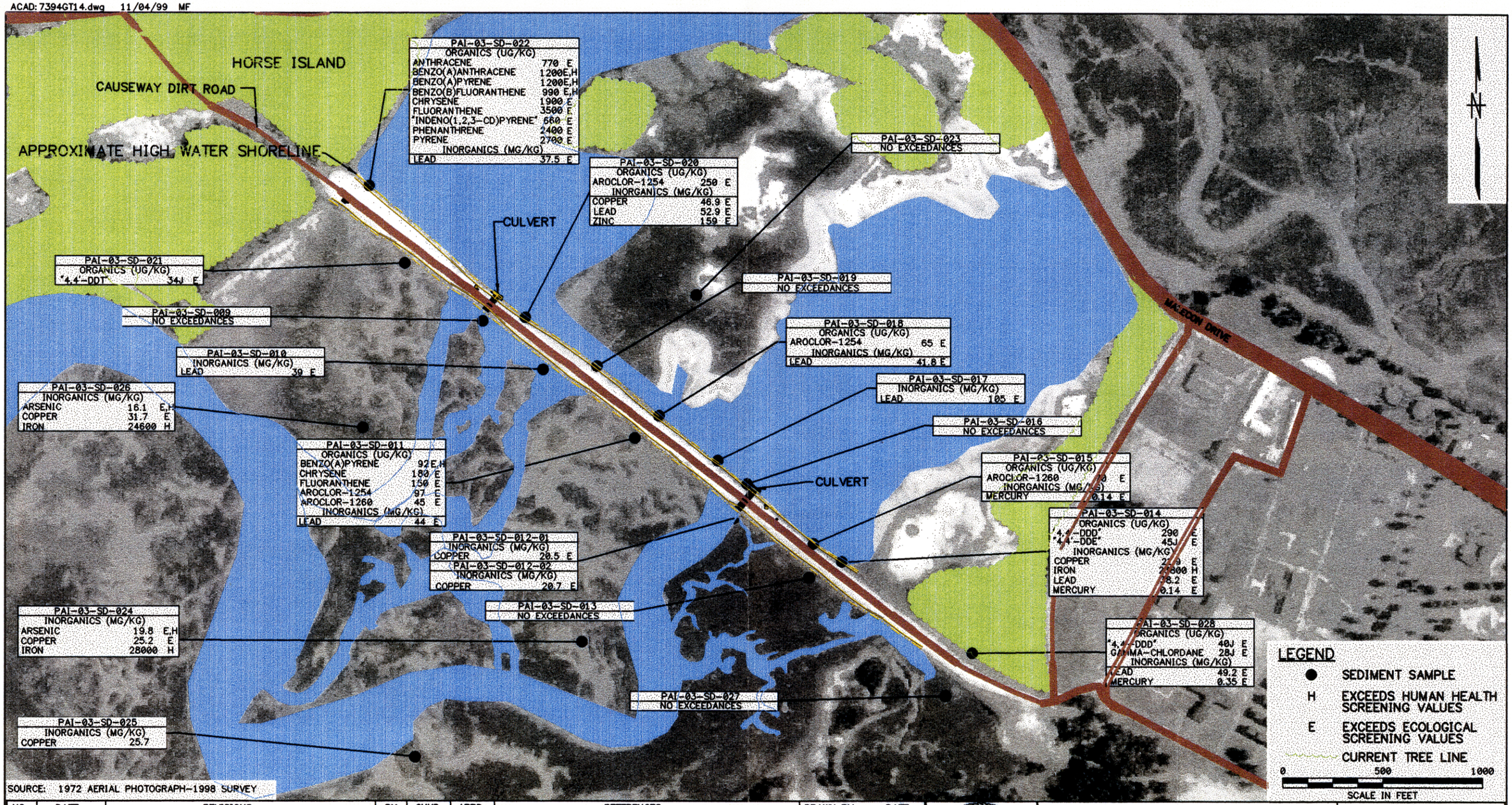

SOURCE: 1972 AERIAL PHOTOGRAPH-1998 SURVEY

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJP DATE 11/19/98
CHECKED BY DATE
COST/SCHED-AREA
SCALE AS NOTED

SEDIMENT SAMPLE RESULTS
THAT EXCEED BACKGROUND, HUMAN HEALTH
RBC's AND/OR ECOLOGICAL SCREENING VALUES
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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REV. 0

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Pesticides and PCBs were detected infrequently, i.e., 3 or less samples out of 21 total samples. Pesticide maximum detections ranged from 28 µg/kg (chlordanes) to 290 µg/kg (4,4'-DDD). Pesticides or PCBs exceeded ecological or human health screening values in 7 of the 20 samples (see Figure 4-4).

The following inorganics were detected in the sediment at Site 3: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Essential nutrients like calcium, magnesium, potassium, and sodium were also detected. Aluminum, arsenic, barium, chromium, cobalt, copper, iron, lead, manganese, nickel, vanadium, and zinc were detected in most of the samples, i.e., the number detected was greater than 16. The range of maximum detections was 5.6 mg/kg (cobalt) to 29,700 mg/kg (aluminum). Antimony, beryllium, cadmium, cyanide, mercury, selenium, silver, and thallium were detected in fewer samples. Maximum levels ranged from 0.13 mg/kg (silver) to 1.4 mg/kg (beryllium).

The following metals were detected at maximum concentrations greater than background values: aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, thallium, vanadium, and zinc. Detected levels of these chemicals were within an order of magnitude of background levels.

Sediment grain size and TOC data for 1998 samples are presented in Table 4-7. A more complete description of sample characteristics is provided in Appendix A (sample log sheets). General field observations indicate that sediments samples collected in 1998 are predominately black, to green, to dark brown fine sands and silts. Roots, clays, and/or gravel were observed in some of the samples. The sediments on the pond side immediately adjacent to the causeway are predominately a fine grained sand typical of soil covering the causeway. These sediments were likely deposited during construction of the causeway or from ongoing erosion. The TOC of these sediments are relatively low for a marsh ranging from 0.26% to 1.0%. At a distance of 10 to 30 feet from the pond side of the causeway, the sediments were noted to be finer grained silts and clays. The sediments on the marsh side vary from silt and clays on the flats to a fine grained sand and silt in the tidal channels. The TOC results for the marsh sediment side vary from 1.3% to 2.3%.

4.4.2 Comparison of 1998 and 1988 Analytical Results

Sediment data from the 1988 and 1998 sample events are presented in Table 4-8. Included in the table are the individual results from 1998 and the average and maximum sediment concentrations detected in 1998. An evaluation of each chemical is presented below.

Barium, Chromium, Lead, and Selenium: Barium, chromium, and lead were all detected at higher concentrations in the sediments in 1998 than in samples collected in 1988. Therefore, the use of only the

TABLE 4-7

SEDIMENT GRAIN SIZE AND TOC
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

SAMPLE ID	TOC %	GRAIN SIZE				FIELD	LOCATION
		% GRAVEL	% SAND	% SILT	% CLAY	DESCRIPTION	
PAI-03-SD-009-01	1.8	5.5	60.6	19.6	14.3	Black/green, fine grained sand, silt, roots	Marsh, adjacent to causeway
PAI-03-SD-010-01						Black/green, silt, fine grained sand, roots	Marsh, adjacent to causeway
PAI-03-SD-011-01	2.3	2.2	67.2	11.9	18.7	Black/green, fine grained sand silt, roots	Marsh, adjacent to causeway
PAI-03-SD-012-01	1.3	0.1	85.5	7.0	7.4	Dark brown, black, fine grained sand, silt, and gravel	Marsh, adjacent to causeway
PAI-03-SD-013-01						Black, silt, fine grained sand	Marsh, adjacent to causeway
PAI-03-SD-014-01						Black, dark, brown, silt, fine gained sand	Pond, adjacent to causeway
PAI-03-SD-015-01	0.38	0.5	88.8	5.3	5.4	Black, silt, fine grained sand, gravel, roots	Pond, adjacent to causeway
PAI-03-SD-016-01						Black, dark brown, silt, fine grained sand, gravel, roots	Pond, adjacent to causeway
PAI-03-SD-017-01						Black, fine grained sand, roots	Pond, adjacent to causeway
PAI-03-SD-018-01	1.0	2.3	70.9	12.2	14.6	---	Pond, adjacent to causeway
PAI-03-SD-019-01						---	Pond, adjacent to causeway
PAI-03-SD-020-01	0.26	3.9	88.8	2.4	4.9	---	Pond, adjacent to causeway
PAI-03-SD-021-01						Black/green, fine sand, silt, roots	Marsh, adjacent to causeway
PAI-03-SD-022-01	0.42	19.0	68.1	6.0	6.9	---	Pond, adjacent to causeway
PAI-03-SD-023-01						Grey black, silt and fine sand	Pond, away from causeway
PAI-03-SD-024-01						Black, clay, silt	March, away from causeway

TABLE 4-7

SEDIMENT GRAIN SIZE AND TOC
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

SAMPLE ID	TOC %	GRAIN SIZE				FIELD	LOCATION
		% GRAVEL	% SAND	% SILT	% CLAY	DESCRIPTION	
PAI-03-SD-025-01						Black, clay, silty sand	March, away from causeway
PAI-03-SD-026-01						Black, clay, silty sand	March, away from causeway
PAI-03-SD-027-01						Black/grey clayey, silty fine sand.	March, away from causeway
PAI-03-SD-028-01						Black/grey clayey, silty fine sand.	Pond, adjacent to causeway

TABLE 4-8

COMPARISON OF SEDIMENT DATA FROM 1988 WITH 1998 (MG/KG)
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

PARAMETER	1988 TEST RESULTS								MAXIMUM SEDIMENT CONC.1988	AVERAGE SEDIMENT CONC. 1998	MAXIMUM SEDIMENT CONC. 1998
	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8			
Barium	1.45	2.53	5.88	2.71	3.74	2.38	1.86	3.45	5.88	17	36.2
Chromium			2.58	2.21	2.43		1.76	1.8	2.58	22	50.3
Lead	0.48	0.98	8.08	6.8	18.8	0.52	4.32	23.9	23.9	30	105
Mercury	0.45	0.6	0.4	0.3	0.55	0.35	0.35	0.45	0.6	0.055	0.35
Hex Cr				0.01			0.01		0.01		ND
Selenium					0.16		0.15		0.16	0.34	1.1

A blank indicates that the chemical was not detected.

1998 data in the risk evaluation and calculations will result in a slightly higher risk estimate than if both data sets were used.

Mercury: Mercury was detected at a relatively consistent concentration of 0.3 to 0.6 mg/kg in 8 of 8 samples collected in 1988. The finding of a uniform concentration of a chemical over a wide area is not consistent with a normal highly variable chemical releases at a waste site and indicates possible concerns with the quality of the older data. A review of the 1988 database did not find obvious quality concerns; however, several QA samples needed to validate the data were not collected in 1988.

In 1998, mercury was detected in 6 of 21 samples with an average and maximum concentration of 0.055 mg/kg and 0.35 mg/kg, respectively. The use of the current data only would still identify mercury as a COPC; however, average risk calculation results would be less.

Hexavalent Chromium: Hexavalent chromium was detected in two of 8 samples from 1988 at a concentration of 0.01 mg/kg (which is the detection limit). Hexavalent chromium was not detected in any of the current samples, indicating that hexavalent chromium is not currently present at the site. The minimum screening level of hexavalent chromium in sediments would not be exceeded in either case.

4.4.3 1999 Analytical Results

Additional sediment samples were collected at Site 3 in August 1999 and analyzed for PAHs, pesticides, and PCBs in order to better delineate areas of impacted sediments for the feasibility study. Summary statistics of positive results for the 1999 sediment sampling at Site 3 are provided in Table 4-9. Positive detections of PAHs, pesticides, and PCBs for sediment that exceeded background levels and human health or ecological criteria re shown on Figure 4-5.

PAHs detected in the 1999 sediment samples collected from Site 3 included acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene. Pesticides were detected in sediment and included 4,4'-DDD and 4,4'-DDE. Aroclor-1254 was the only PCB detected in sediment samples collected in 1999.

PAHs were detected in all three samples that were analyzed for PAHs. Maximum concentrations ranged from 4 µg/kg (anthracene) to 98 J µg/kg (acenaphthene). Concentrations of PAHs were less than the human health and ecological screening criteria (Figure 4-5).

Pesticides were detected in two samples (Figure 4-5). Maximum concentrations ranged from 60 µg/kg (4,4'-DDE) to 75 µg/kg (4,4'-DDE). Concentrations of 4,4'-DDE and 4,4'-DDD exceeded ecological screening criteria at two of six sampling locations (Figure 4-5).

TABLE 4-9

SUMARRY STATISTICS - SEDIMENT DATA
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Positive Detect	Average of Positive Detects	Average All[1]	Background	Maximum Exceed Backgrd.
Semivolatile Organics (ug/kg)								
Acenaphthene	1/3	98	120 - 330	PAI-03-SD-29-01-AVG	98.0	108	NA	NA
Anthracene	1/3	4	2.4 - 6.6	PAI-03-SD-29-01-AVG	4.00	2.83	NA	NA
Benzo(a)anthracene	2/3	8.9 - 18	16	PAI-03-SD-29-01-AVG	13.5	11.6	NA	NA
Benzo(a)pyrene	3/3	8.2 - 22	ND	PAI-03-SD-30-01	16.7	16.7	NA	NA
Benzo(b)fluoranthene	3/3	7.8 - 19	ND	PAI-03-SD-30-01	14.8	14.8	NA	NA
Benzo(k)fluoranthene	3/3	4.5 - 10.25	ND	PAI-03-SD-29-01-AVG	7.78	7.78	NA	NA
Chrysene	2/3	6.1 - 13.25	16	PAI-03-SD-29-01-AVG	9.68	9.12	NA	NA
Fluoranthene	3/3	13 - 39	ND	PAI-03-SD-29-01-AVG	24.3	24.3	NA	NA
Indeno(1,2,3-cd)pyrene	2/3	9.9 - 14	59	PAI-03-SD-29-01-AVG	12.0	17.8	NA	NA
Pyrene	2/3	13 - 35.5	33	PAI-03-SD-29-01-AVG	24.3	21.7	NA	NA
Pesticides/PCBs (ug/Kg)								
4,4'-DDD	2/6	62 - 70	24 - 28	PAI-03-SD-38-01	66.0	30.7	NA	NA
4,4'-DDE	2/6	60 - 75	24 - 28	PAI-03-SD-36-01	67.5	31.2	NA	NA
Aroclor-1254	2/3	76 - 250	18	PAI-03-SD-34-01-AVG	163	112	NA	NA

ND - Non-Detect.
NA - Not Applicable
1 Average All is the arithmetic average where 1/2 of the detection limit was used for the ND results when calculating the average.

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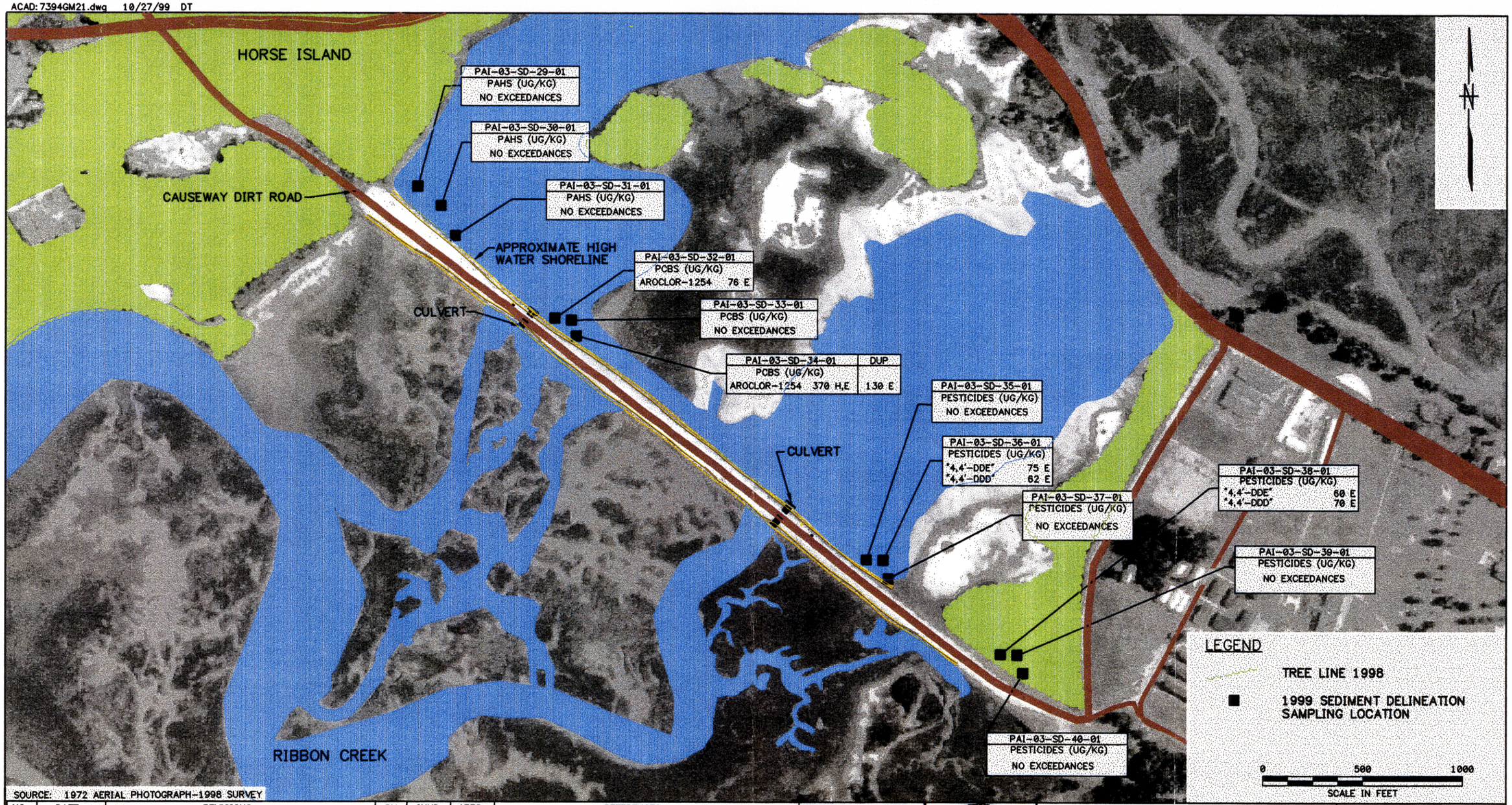

SOURCE: 1972 AERIAL PHOTOGRAPH-1998 SURVEY

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

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CHECKED BY DATE
COST/SCHED-AREA
SCALE AS NOTED

1999 SEDIMENT DELINEATION SAMPLING
ANALYTICAL RESULTS
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

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DRAWING NO. FIGURE 4-5
REV. 0

FORM CADD NO. SDIV_BH.DWG - REV 0 - 1/20/98

Aroclor-1254 was detected in two of these sediment samples at concentrations ranging from 76 µg/kg to 370 µg/kg, although the concentration of Aroclor-1254 in the duplicate to this sample was 130 J µg/kg. Concentrations of Aroclor-1254 exceeded human health screening criteria at one location and ecological screening criteria at two locations (Figure 4-5).

4.4.4 Comparison of the 1998 and 1999 Analytical Results

As summarized on Table 4-10, the maximum concentrations of the two data sets were compared. Several different PAHs were detected in the sediment samples collected in 1998 in comparison to the 1999 results. Benzo(g,h,i)perylene, fluorene, and phenanthrene were detected in sediment samples collected in 1998 but were not detected in sediment samples collected in 1999. Acenaphthene was detected in one sediment sample collected in 1999 but not in sediment samples collected in 1998. PAH concentrations in the 1999 samples were one or more orders of magnitude lower than those in the 1998 sediment samples.

Fewer pesticides were detected in the 1999 samples. Alpha-chlordane, gamma-chlordane, and 4,4'-DDT were detected in sediment samples collected in 1998 but not in sediment samples collected in 1999. Concentrations of 4,4'-DDD were lower in the 1999 samples as compared to those in the 1998 sediment samples. Concentrations of 4,4'-DDE were higher in the 1999 samples as compared to those in the 1998 sediment samples.

Aroclor-1254 and -1260 were detected in the 1998 sediments samples whereas only Aroclor-1254 was detected in the 1999 sediment samples. The maximum detected concentration of Aroclor-1254 was slightly higher in the 1999 samples (370 J µg/kg) as compared to the 1998 samples (250 J µg/kg).

Based on this comparison, the detected results from the 1999 sediment investigation are similar to that found in 1998. As a result, even though they effect the areas of consideration, they would not significantly effect the results of the human health ecological risk assessments.

4.5 BIOTA

An ESI was conducted to evaluate fish and shellfish commonly harvested in the area (ABB, 1993). Mullet, flounder, crab, clam, and oyster species were assessed. Tissue samples were collected and analyzed for mercury, PAHs, PCBs, and pesticides. The analytical results were compared to USFDA action levels (see Table 6-6, located in Section 6.0). Results indicated the presence of PCBs and pesticides in samples collected from the pond side of the causeway. However, the results of this

TABLE 4-10

COMPARISON OF 1998 AND 1999 SEDIMENT SAMPLING RESULTS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

PARAMETER	1998 Maximum	1999 Maximum	Change (+/-)
PAHs (ug/kg)			
Acenaphthene	ND	98	+
Anthracene	770	4	-
Benzo(a)anthracene	1200	18	-
Benzo(a)pyrene	1200	22	-
Benzo(b)fluoranthene	990	19	-
Benzo(k)fluoranthene	420	10.25	-
Chrysene	1900	16	-
Fluoranthene	3500	39	-
Indeno(1,2,3-cd)pyrene	660	59	-
Pyrene	2700	33	-
Pesticides (ug/kg)			
4,4'-DDD	290	70	-
4,4'-DDE	45	75	+
PCBs (ug/kg)			
Aroclor-1254	250	250	+

ND - Not detected.

investigation indicate that maximum chemical tissue concentrations for the five species sampled are below USFDA action levels for samples collected on both the pond and tidal creek side of the causeway.

5.0 CHEMICAL FATE AND TRANSPORT ANALYSIS

This section contains information on contaminant fate and transport and the chemical properties affecting contaminant migration at Site/SWMU 3 (Site 3). Section 5.1 contains a discussion of the chemical and physical properties of the analytes detected in all media. Section 5.2 presents brief discussions of contaminant persistence, and Section 5.3 presents a summary of contaminant migration.

5.1 CHEMICAL AND PHYSICAL PROPERTIES

Chemical and physical properties of the compounds detected on site are presented and discussed in this section. These parameters are used to estimate the environmental behavior of site chemicals. Physical and chemical properties of the organic chemicals detected at MCRD Parris Island Site 3 are provided in Table 5-1. Physical and chemical properties for inorganics are provided in Table 5-2.

Empirically determined literature values of the water solubility, octanol/water partition coefficient, organic carbon partition coefficient, vapor pressure, Henry's Law constant, bioconcentration factor, and specific gravity are presented, when available. Calculated values, which were obtained using approximation methods, are presented when literature values are not available.

5.2 CHEMICAL PERSISTENCE

The persistence of various classes of chemicals is discussed in this section. Several transformation mechanisms affect chemical persistence, such as hydrolysis, biodegradation, photolysis, and oxidation/reduction reactions. The following general classes of compounds are discussed:

- Ketones
- Monocyclic aromatics
- Miscellaneous Volatile Organic Compounds (VOCs)
- Polynuclear aromatic hydrocarbons (PAHs)
- Phthalate esters
- Miscellaneous Semivolatile Organic Compounds (SVOCs)
- Pesticides
- Polychlorinated biphenyls (PCBs)
- Metals

TABLE 5-1

FATE AND TRANSPORT PHYSICAL AND CHEMICAL CHARACTERISTICS FOR ORGANICS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Chemical	Specific Gravity (@ 20/4°C)[1]	Vapor Pressure (mm Hg @ 20°C)[1]	Solubility (mg/L @ 20°C)[1]	Octanol/ Water Partition Coefficient (K_{ow}) [1]	Organic Carbon Partition Coefficient (K_{oc}) [2]	Henry's Law Constant (atm-m3/mole)[1]	Bioconcentration Factor (mg/L/mg/kg) (BCF) [2]
KETONES							
Acetone	0.7899	2.66E+02 (25°C)	Miscible	5.75E-01	7.8E+03[3]	4.276E-05 (25°C)	3.81E-01[4]
2-Butanone	0.8054	1.0E+02 (25°C)	2.75E+05	1.82E+00	4.44E+0[5]	4.66E-05 (25°C)	9.3E-01[4]
MONOCYCLIC AROMATICS							
4-Methylphenol	1.0178	1.1E-01 (25°C)	2.4E+04 (40°C)	8.32E+01	9.0E-01[6]	3.92E-07	1.7E+01[4]
Benzene	0.8786	76	1,780	135	31-143	5.43E-03	3.4-24
Toluene	0.8669	2.8E+01 (25°C)	5.15E+02	4.90E+02	1.82E+02[3]	5.92E-03 (25°C)	1.48E+02
Xylenes (Total)	0.86104 - 0.8801	1E+01 (27.3 - 32.1°C)	1.6E+02 - 1.75E+02[7]	5.89E+02 - 1.58E+03	3.63E+02 - 4.07E+02[3]	4.184E-03 - 6.662E-03 (25°C)	7.5E+01 - 1.59E+02[4]
VOLATILE ORGANICS							
Carbon disulfide	1.2632	2.98E+02	2.90E+03	1.45E+02	4.57E+01[3]	1.921E-02 (25°C)	2.6E+01[4]
Chlorobenzene	1.1066	11.9	471.7	2.84	83-389	3.45E-03	10-100, 2.65
Chloroform	1.5	1.51E+02	8.2E+03	9.33E+02	31	2.87E-03	3.75
1,4-Dichlorobenzene	NA	1.76	87	3.52	273-1,833	1.5E-03	370-720
Ethylbenzene	0.867	9.53	161	1.41E+03	1,100	8.44E-03	37.5
POLYNUCLEAR AROMATIC HYDROCARBONS (PAHs)							
Acenaphthene	1.0242 (90/4°C)	1E+01 (131°C)	3.42E+0 (25°C)	8.32E+03	7.08E+03[3]	2.41E-04 (25°C)	1.80E+03
Acenaphthylene	0.899	NA	3.93	NA	NA	NA	NA
Anthracene	1.283 (25/4°C)	1.95E-04 (25°C)	1.29E+0 (25°C)	2.82E+04	2.95E+04[3]	8.6E-05 (25°C)	4.70E+03
Benzo(a)anthracene	1.274	5.00E-09	1E-02 (24°C)	4.07E+05	3.98E+05[3]	6.60E-07	5.30E+04
Benzo(b)fluoranthene	NA	5.00E-07	1.2E-03 (25°C)	3.72E+06	1.23E+06[3]	1.20E-05	1.40E+05
Benzo(k)fluoranthene	NA	9.59E-11	5.5E-04 (25°C)	6.92E+06	1.23E+06[3]	1.04E-03	1.40E+05
Benzo(g,h,i)perylene	NA	1.00E-10	2.6E-04 (25°C)	1.70E+07	1.60E+06	1.4E-07 (25°C)	3.50E+05
Benzo(a)pyrene	1.351	5.00E-09	3.8E-03 (25°C)	9.55E+05	1.02E+06[3]	4.9E-07 (25°C)	1.40E+05
Chrysene	1.274 (20°C)	6.3E-09 (25°C)	6E-03 (25°C)	4.07E+05	3.98E+05[3]	1.05E-06 (25°C)	5.30E+04
Dibenzo(a,h)anthracene	1.282	1.00E-10	5E-04 (25°C)	9.33E+05	3.80E+06[3]	7.3E-08 (25°C)	6.90E+05
Dibenzofuran	4.22	2.48E-03	3.11	1.32E+04	-	2.13E-04	3.13
Fluoranthene	1.252	5.0E-06 (25°C)	2.65E-01 (25°C)	2.14E+05	1.07E+05[3]	6.5E-06 (25°C)	1.20E+04
Fluorene	1.202	1E+01 (146°C)	1.9E+0 (25°C)	1.51E+04	1.38E+04[3]	1.17E-04 (25°C)	3.80E+03
Indeno(1,2,3-cd)pyrene	NA	1E-010 (25°C)	6.20E-02	4.57E+07	3.47E+06[3]	6.95E-08 (25°C)	3.50E+05
2-Methylnaphthalene	1.0058	1E+01 (105°C)	2.6E+01 (25°C)	7.24E+03	7.27E+02[5]	4.99E-04 (25°C)	5.1E+02[4]
Naphthalene	1.162	8.2E-02 (25°C)	3E+01 (25°C)	2.34E+03	2.00E+03[3]	4.83E-04 (25°C)	4.20E+02
Phenanthrene	0.980 (4°C)	1E+0 (118.2°C)	8.16E-01 (21°C)	2.88E+04	1.40E+04	3.93E-05 (25°C)	4.70E+03
Pyrene	1.271 (23/4°C)	2.5E+0 (200°C)	1.6E-01 (26°C)	1.51E+05	1.05E+05[3]	5.1E-06 (25°C)	1.20E+04

TABLE 5-1

FATE AND TRANSPORT PHYSICAL AND CHEMICAL CHARACTERISTICS FOR ORGANICS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Chemical	Specific Gravity (@ 20/4°C)[1]	Vapor Pressure (mm Hg @ 20°C)[1]	Solubility (mg/L @ 20°C)[1]	Octanol/ Water Partition Coefficient (K_{ow}) [1]	Organic Carbon Partition Coefficient (K_{oc}) [2]	Henry's Law Constant (atm-m3/mole)[1]	Bioconcentration Factor (mg/L/mg/kg) (BCF) [2]
PHTHALATE ESTERS							
Bis(2-ethylhexyl)phthalate	0.99 (20/20°C)	1.2E+0 (200°C)	4E-01 (25°C)	2.00E+05	1.51E+07[3]	3.00E-07	2.30E+08
Butylbenzylpthalate	NA	8.6E-06	2.69	8.123E+04	68-350	1.3E-06	663
SEMIVOLATILE ORGANICS							
Carbazole	1.1 (18°C/4°C)	4.0E+02 (323°C)	NA	1.95E+03[8]	3.39E+03[3]	NA	1.86E+02[4]
n-Nitrosodiphenylamine	NA	0.1	40	372-1,349	832-1,820	6.6E-04	NA
PESTICIDES							
Alpha-BHC	NA	1.6E-04	7.8	7.94E+03	1,080	7.85E-06	500
Chlordane	1.61 (25°C)	1E-05 (25°C)	5.60E-02	6.03E+02	1.20E+05[8]	4.79E-05 (25°C)	4.00E+04
4,4'-DDD	1.476	1E-06 (30°C)	1.6E-01 (24°C)	9.77E+05	1.00E+06[3]	2.16E-05	1.80E+05
4,4'-DDE	NA	6.50E-06	4.00E-02	4.90E+05	4.47E+06[3]	2.34E-05	8.90E+05
4,4'-DDT	1.5 (15/4°C)	1.50E-07	3.1E-03 (25°C)	1.55E+06	2.63E+06[3]	3.89E-05 (25°C)	8.00E+06
PCBs							
Aroclor-1254	NA	7.71E-05	0.012-0.057	3.2E+06	NA	2E-03	26,000-660,000
Aroclor-1260	1.58 (25°C)[2]	4.05E-05[2]	2.7E-03[2]	1.4E+07[2]	6.70E+06	7.4E-01[2]	1.30E+06

1 USEPA, September 1992, Handbook of RCRA Groundwater Monitoring Constituents: Chemical and Physical Properties.
2 USEPA, December 1982, Aquatic Fate Process Data for Organic Priority Pollutants.
3 USEPA, July 1996, Soil Screening Guidance.
4 Lyman et at., 1990, Eq. 5-2.
5 Lyman et al., 1990; Equation 4-5
6 Howard, 1989, Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume 1.
7 ATSDR, October 1989, Toxicity Profile for Xylenes.
8 Verschueren, 1983, Handbook of Environmental Data of Organic Chemicals.

NA - Not Available

TABLE 5-2

FATE AND TRANSPORT PHYSICAL AND CHEMICAL CONSTANTS FOR INORGANICS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Molecular Weight (g/mol)[1]	Specific Gravity (20/4 C)[1]	Vapor Pressure (25 C) (mm Hg)[1]	Solubility (25 C) (mg/L)[1]	Henry's Law Constant (25 C) (atm-m^3/mol)[1]	Bioconcentration Factor (L/kg)[2]
Inorganics						
Aluminum	26.98[3]	2.708 (20 C)[3]	NA	NA	NA	NA
Antimony	121.75	6.684 (25 C)	1 (886 C)	insoluble	NA	NA
Arsenic	74.9216	5.727 (14 C)	1 (372 C)	insoluble	NA	NA
Barium	137.33	3.51 (20 C)	10 (1049 C)	hydrolyzes	NA	NA
Beryllium	9.01218	1.85 (20 C)	1 (1520 C)	insoluble	NA	NA
Cadmium	112.41	8.642 (UT)	NA	insoluble	NA	NA
Chromium	51.996	7.2 (28 C)	1 (1616 C)	insoluble	NA	NA
Cobalt	58.9332	8.9 (UT)	30 (2375 C)	insoluble	NA	NA
Copper	63.546	8.92 (UT)	1 (1628 C)	insoluble	NA	NA
Cyanide		0.6884 g/cm^3	630	soluble	0.051	NA
Lead	207.2	11.2960 (16 C)	1 (970 C)	insoluble	NA	NA
Manganese	54.938[4]	7.2[4]	NA	NA	NA	NA
Mercury	200.59	13.5939	100 (260 C)	0.056	1.14E-02 (UT)	3133[5]
Nickel	58.69	8.9 (UT)	1 (1800 C)	insoluble	NA	NA
Selenium	78.96	4.81 (20/4+1 C)	NA	NA	NA	NA
Silver	107.8682	10.5 (20 C)	1 (1310 C)	insoluble	NA	NA
Thallium	204.383	11.85 (UT)	1 (825 C)	insoluble	NA	NA
Tin	118.69	5.75 - 7.28	1 (1492 C)	insoluble	NA	NA
Vanadium	50.9415	5.96 (UT)	NA	insoluble	NA	NA
Zinc	65.38	7.14 (UT)	1 (487 C)	insoluble	NA	NA

1 Handbook of RCRA Ground-Water Monitoring Constituents: Chemical and Physical Properties, September 1992. Solubility of metals in water is dependent on other parameters, such as pH and temperature.
2 Aquatic Fate Process Data for Organic Priority Pollutants, December 1982.
3 The Condensed Chemical Dictionary, Van Nostrand Reinhold Company, New York, 1971.
4 Chemical, Physical, and Biological Properties of Compounds Present at Hazardous Waste Sites, Clement Associates, September 1985.
5 Lyman, W., Reehl, W., and Rosenblatt, D., 1990. Handbook of Chemical Property Estimation Methods.

5.2.1 Ketones

Ketones are highly volatile in the pure form and water soluble, and two processes dominate the fate of these compounds in the environment. Hydrolysis is generally not a significant fate process for this class of chemicals, nor is bioconcentration significant, based on the low K_{ow}s (Howard, 1990).

Methyl ethyl ketone (MEK) biodegrades anaerobically. In groundwater, this ketone may degrade slowly following a long acclimation period. The half-life of MEK in groundwater is estimated to be between 3 and 12 days. In air, the half-life of this compound is 2.3 days or less (Howard, 1990).

Acetone is completely miscible in water and is unlikely to adsorb to soil or sediments or bioaccumulate. It has a high vapor pressure in the pure form and, once released to the air, photolysis and reaction with hydroxyl radicals result in an average half-life of 22 days. It biodegrades upon release to soil, groundwater, and surface water. The estimated half-life in a model river from volatilization is 20 hours (Howard, 1990).

2-Butanone will partially evaporate into the atmosphere if released to the soil and may also leach into the groundwater. Once in the groundwater, 2-butanone may slowly degrade. In surface water, 2-butanone has a half-life of approximately 3 to 12 days. Hydrolysis, photolysis, bioconcentration, and adsorption are not significant fate processes for this chemical (Howard, 1990).

5.2.2 Monocyclic Aromatics

Monocyclic aromatic compounds, such as benzene, toluene, ethylbenzene, chlorobenzene, and xylenes, are not considered to be persistent in the environment, particularly in comparison to chemicals such as PCBs and pesticides. Monocyclic aromatics are subject to degradation via the action of both soil and aquatic microorganisms. The biodegradation of these compounds in the soil matrix is dependent on the abundance of microflora, macronutrient availability, soil reaction (pH), temperature, etc.

In the event that these compounds discharge to surface water bodies, volatilization and biodegradation may occur relatively rapidly. For example, a reported biodegradation rate constant for benzene is 0.11 day^{-1} in aquatic systems (Lyman et al., 1990). This corresponds to an aquatic half-life of approximately 6 days. Other monocyclic aromatics are subject to similar degradation processes in aquatic environments (U.S. EPA, 1982). However, chlorinated monocyclic aromatics such as chlorobenzene are not expected to be as susceptible to microbial degradation. For example, a reported first-order biodegradation rate constant for chlorobenzene is 0.0045 day^{-1} in aquatic systems (Lyman et al., 1990), which corresponds to an aquatic half-life of approximately 150 days.

Benzene in groundwater is significantly reduced by the action of aerobic bacteria. A biodegradation rate of 0.95 percent per day has been reported (Chiang et al., 1989). The amount of benzene, toluene, and xylenes in the groundwater was reported to be directly proportional to the availability of dissolved oxygen. Chlorobenzene will percolate into groundwater, especially if the soil overlying the groundwater is sandy with minimal organic content (Howard, 1990).

Additional environmental degradation processes, such as hydrolysis and photolysis, are considered to be insignificant fate mechanisms for monocyclic aromatics in aquatic systems (U.S. EPA, 1982). However, some monocyclic aromatics, such as benzene and toluene, have been shown to undergo clay-, mineral-, and soil-catalyzed oxidation (Dragun, 1988).

Miscellaneous VOCs

Chloroform, 1,4-dichlorobenzene, ethylbenzene, and carbon disulfide were also detected. These VOCs tend to volatilize and degrade in the atmosphere via reaction with photochemically produced hydroxyl radicals. In air, the half-life of carbon disulfide is 9 days. 1,4-dichlorobenzene will adsorb more readily to soils than chloroform or ethylbenzene. Soil is a natural sink for carbon disulfide via adsorption and biodegradation. Chloroform and ethylbenzene tend to leach into the underlying groundwater. Carbon disulfide will also leach into groundwater where it biodegrades. In water, 1,4-dichlorobenzene will adsorb to sediment and bioconcentrate in aquatic organisms. Chloroform and ethylbenzene do not readily bioconcentrate in aquatic organisms. Carbon disulfide will volatilize upon release to surface water (half-life of 2.6 hours estimated from a model river) (Howard, 1990).

At this site, carbon disulfide was also detected in site background, suggesting that detections of this VOC at the site are no different from levels detected in natural background areas.

5.2.3 Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs have very low water solubilities, vapor pressures, and Henry's Law constants, and high organic carbon coefficients (K_{oc}s) and octanol water coefficients (K_{ow}s). The low-molecular-weight PAHs (e.g., acenaphthene, anthracene, fluorene, phenanthrene) may volatilize from surface waters, whereas the high-molecular-weight PAHs (e.g., benzo(a)pyrene, benzo(a)anthracene, chrysene, etc.) are less likely to volatilize. PAHs in soil are much more likely to bind to soil and be transported via mass transport mechanisms than to go into solution.

Bioconcentration of PAHs in aquatic organisms is greater for the higher-molecular-weight compounds than the lower-molecular-weight compounds. PAHs can be bioaccumulated from water, sediments, or lower organisms in the food chain.

Land-spreading applications have indicated that PAHs are highly amenable to microbial degradation in soil. Temperature, pH, oxygen concentrations, initial chemical concentrations, and moisture influence the rate of degradation. Photolysis, hydrolysis, and oxidation are not important fate processes for the degradation of PAHs in soil (ATSDR, 1989). Half-lives available for PAHs are summarized in Table 5-3.

The most important fates of PAHs in water are photo-oxidation, chemical oxidation, and biodegradation. PAHs do not contain functional groups that are susceptible to hydrolytic action; therefore, hydrolysis is considered to be an insignificant degradation mechanism. Water depth, turbidity, and temperature influence the rate of photodegradation. Benzo(a)pyrene, chrysene, fluorene, and pyrene are reported to be resistant to photodegradation. PAHs may also be oxidized by chlorination and ozonation, and may be metabolized by microbes under oxygenated conditions (ATSDR, 1989).

5.2.4 Phthalate Esters

Phthalate esters are considered to be relatively persistent chemicals in the environment. Although numerous studies have demonstrated that phthalate esters undergo biodegradation, it appears that this is a slow process in both soils and surface waters. Certain microorganisms have been shown to excrete products that increase the solubility of phthalate esters and enhance their biodegradation (Gibbons and Alexander, 1989).

Biodegradation of bis(2-ethylhexyl)phthalate and other phthalates in water is an important fate mechanism, with a half-life of 2 to 3 weeks reported for bis(2-ethylhexyl)phthalate (Howard, 1989). Bioaccumulation is also a significant fate process. Hydrolysis of phthalate esters is very slow, with calculated half-lives of 3 years (dimethyl phthalate) to 2000 years [bis(2-ethylhexyl)phthalate] (U.S. EPA, 1979). Similarly, photolysis and volatilization are considered to be insignificant degradation mechanisms (U.S. EPA, 1979; Howard, 1989). Diethyl phthalate and di-n-octyl phthalate were also detected. These compounds will adsorb to particulates and sediment. Di-n-octyl phthalate will also bioconcentrate in aquatic organisms.

5.2.5 Pesticides

Whether pesticides are sprayed, dusted, or applied directly to the soil, the soil is the ultimate sink for these chemicals. Runoff may carry pesticides to adjacent surface water bodies. Bioconcentration of

TABLE 5-3
SUMMARY OF PAH HALF-LIFE VALUES
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

PAHs	Half-Life				
	Air	S. Water	Groundwater	Sediment	Soil
2-Methylnaphthalene	NA	54 h	NA	NA	NA
Acenaphthene	0.9-9 h	3-300 h	590-4,896 h	NA	295-2,448 h
Acenaphthylene	0.2-1.3 h	1,020-1,440 h	2,040-2,880 h	NA	1,020-1,440 h
Anthracene	0.6-1.7 h	0.6-1.7 h	2,400-22,080 h	NA	3.3-175 days
Benzo(a)anthracene	1-3 h	1-3 h	4,896-32,640 h	NA	4-6,250 days
Benzo(a)pyrene	0.4-1.1 h	2 h	2,736-25,440 h	NA	2 days
Benzo(b)fluoranthene	1.4-14.3 h	8.7-720 h	17,280-29,280 h	NA	8,640-14640 h
Benzo(g,h,i)perylene	0.32-3.21 h	14,160-15,600 h	28,320-31,200 h	NA	14,160-15,600 h
Benzo(k)fluoranthene	1.1-11 h	4-499 h	42,860-102,720 h	NA	21,840-51,360 h
Chrysene	0.8-8 h	4.4-13 h	17,808-48,000 h	NA	8,904-24,000 h
Fluoranthene	2-20 h	21-63 h	6,720-21,120 h	NA	44-182 days
Indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	NA
Naphthalene	< 1 day	16 h	0.6 years	4.9 h	3.6 months
Phenanthrene	2-20 h	3-25 h	768-9,600 h	NA	2.5-26 d
Pyrene	0.7-2 h	0.7-2 h	10,080-91,200 h	NA	3-35 h

Source: Mackay, D., Shiu, W.Y., & Ma, K.C. *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals - PAHs, Polychlorinated Dioxins, and Dibenzofurans*. 1992.
NA = Not Available
h = hours
d = days

pesticides in the food chain is another important fate mechanism. Hydrolysis, oxidation, and photolysis are not generally important fate mechanisms for pesticides in soil or water. Hydrolysis half-lives for several pesticides are reported in periods of months to years (U.S. EPA, 1979).

4,4'-DDT and its metabolites are considered to be persistent chemicals. They undergo extensive adsorption to soil and are not highly soluble. Biodegradation may occur under both aerobic and anaerobic conditions in the presence of certain soil microorganisms. Under aerobic conditions, DDT may be transformed to DDE, whereas under anaerobic conditions, DDD may result. These compounds are, however, somewhat volatile, with a reported half-life of 100 days for DDT in soil. These compounds are highly lipophilic and therefore readily bioaccumulate (ATSDR, 1992). DDT is no longer in production in the United States.

Chlordane is persistent in soil (mean half-life of 3.3 years). It can also leach to groundwater. Chlordane released to soil will volatilize from the surface. It is very slowly biotransformed in the environment. The half-life of chlordane in surface water is estimated at 8 hours (a river). Adsorption to sediment is a major fate process for this pesticide. It is very persistent in the aquatic environment. The BCF is greater than 3,200.

α-BHC was detected. Lindane (γ-BHC) is not expected to volatilize or hydrolyze in water. When released to soil, it is slow to volatilize and does not readily leach to groundwater. Lindane binds tightly to soil particles. It can biodegrade more readily under aerobic conditions vs. anaerobic conditions. It will degrade in the atmosphere via reaction with hydroxyl radicals. Lindane bioconcentrates slightly in aquatic organisms.

5.2.6 Polychlorinated Biphenyls (PCBs)

PCBs are considered to be very persistent organic chemicals. Biodegradation is the only process known to transform PCBs under environmental conditions, and only the lighter compounds are measurably biodegraded (U.S. EPA, 1979). Although some microorganisms (e.g., Phanaerochaete chrysosporium) may biodegrade PCBs, such fungi may not exist in local soil. There is experimental evidence to suggest that heavier PCBs (five or more chlorine atoms per molecule) can undergo photolytic degradation, but there are no data to suggest that this process operates under environmental conditions (U.S. EPA, 1979). Base-, acid-, and neutral-promoted hydrolysis are considered to be inconsequential degradation mechanisms for PCBs (U.S. EPA, 1982).

5.2.7 Metals

Metals are highly persistent environmental contaminants. They do not biodegrade, photolyze, hydrolyze, etc. The major fate mechanisms for metals are adsorption to the soil matrix (as compared to being part of the soil structure) and bioaccumulation.

The mobility of metals is influenced primarily by their physical and chemical properties in combination with the physical and chemical characteristics of the soil matrix. Factors that assist in predicting the mobility of inorganic species are the soil/pore water pH, soil/pore water Eh, and cation exchange capacity. The mobility of metals generally increases with decreasing soil pH and cation exchange capacity.

5.3 CHEMICAL MIGRATION

This section presents a brief overview of contaminant fate and transport issues for several major chemical classes detected at Site 3.

5.3.1 Volatile Organics

Volatile organic chemicals are typically considered to be fairly soluble and have a low capacity for retention by soil organic carbon; therefore, these are the organic compounds most frequently detected in groundwater. These types of chemicals may migrate through the soil column after being released by a spill event or by subsurface waste burial as infiltrating precipitation solubilizes them. A fraction of these chemicals is retained by the soil, but most will continue migrating downward to the water table. At that time, migration occurs primarily laterally with the hydraulic gradient. Again, some portion of the chemical may be retained by the saturated soil.

Several of these compounds have specific gravities less than that of water (e.g., benzene, toluene). These compounds are typically found in fuels, and if a large enough fuel spill occurs, these compounds may move through the soil column as a bulk liquid, until they reach the water table. There, instead of going into solution, the majority of the release may remain as a discrete fuel layer on the water-table surface, with some of the material going into solution at the water/fuel interface.

Similarly, compounds with specific gravities greater than that of water (e.g.,TCE) are often used in various industrial applications such as degreasing. If a large enough spill of these solvents occurs, these chemicals may also migrate as a bulk liquid but will not stop at the water table (i.e., these chemicals will mix/sink into the aquifer).

5.3.2 Polycyclic Aromatic Hydrocarbons

PAHs are generally considered to be fairly immobile chemicals in the environment. They are large molecules with high organic carbon partition coefficients and low solubilities when compared to the volatile organics. These compounds, when found in the soil, generally do not migrate vertically to a great extent. Instead, they are more likely to adhere to soil particles and be removed from the site via surface runoff and erosional processes.

5.3.3 Pesticides

Pesticides were used at this installation. Many of the detected compounds are no longer licensed for general sale and use in the United States. Therefore, it is assumed that much of what was detected in the soil and sediments is representative of past application for insect control.

Like the PAHs, pesticides as a class of compounds are not considered to be very mobile in the environment. These chemicals, upon application or disposal, tend to remain affixed to soil particles. Migration of pesticides occurs primarily by erosion via the action of wind or water.

5.3.4 Inorganics

Because metals are frequently incorporated into the soil matrix and remain bound to particulate matter, they also migrate from the source areas via bulk movement processes (erosion). The larger particles (greater than 0.45 microns, which are removed via the filtration step prior to water analysis) are not generally considered to be mobile in groundwater. The metals detected in unfiltered groundwater samples are often representative of suspended soil material in the samples.

There are some instances, however, where these metals are found at such concentrations or in such form as to be able to migrate in solution. It is possible that industrial activities could saturate all available exchange sites in soil and hence a metal may be mobilized. Metals are also more mobile under acidic conditions, which may exist in areas where plating-type activities have occurred. Finally, a metal solution may be utilized in some industrial applications. In these cases, it is possible for metals to migrate vertically through the soil column and reach the groundwater.

6.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

The baseline human health risk assessment contained in this section was performed to characterize and quantify potential health risks at Site/SWMU 3, the Causeway Landfill (Site 3), in the absence of remedial action. The results of the baseline risk assessment are also used to focus the evaluation of remedial action alternatives, if action is required. The baseline risk assessment consists of five major components:

- Data evaluation
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis

Methods for selection of chemicals of potential concern (COPCs) to be evaluated quantitatively in the baseline human health risk assessment, as well as those chemicals identified as COPCs for Site 3, are described in Section 6.1, Data Evaluation. The data evaluation section is primarily concerned with the selection of COPCs that are representative of the type and magnitude of potential human health effects. The COPC screening process involves the comparison of maximum site concentrations to risk-based screening levels and other health-based standards. Recent and historical data available for the site are considered during the selection process. A brief discussion of data usability is also provided.

Section 6.2, Exposure Assessment, identifies potential receptor populations and exposure pathways by which receptors may come in contact with contaminants at the site. Potential exposure routes under current and future land uses are developed from information on source area, chemical concentrations, chemical release mechanisms, patterns of human activity, and other pertinent information. A concise conceptual site model illustrates the potential receptors and exposure pathways evaluated in the baseline risk assessment. The exposure assessment also includes the calculation of quantitative estimates of chemical intake for each identified receptor, pathway, and route of exposure under the reasonable maximum exposure (RME) scenario. Equations and relevant exposure input parameters used in estimating chemical intakes are provided.

Section 6.3, Toxicity Assessment, presents the chemical-specific toxicity criteria for the identified COPCs that are used in the quantification of potential human health risks. These toxicity criteria, when integrated with the estimated chemical intakes developed in the exposure assessment, provide the basis for quantifying potential human health risks.

Methods used for characterizing risks associated with noncarcinogenic and carcinogenic effects for exposure to COPCs are provided in Section 6.4, Risk Characterization. Actual numerical results of the baseline human health risk assessment for Site 3 are summarized.

Because the quantitative risk estimates developed in the risk characterization are based on a number of assumptions (concerning exposure, land use, toxicity, etc.), various uncertainties are associated with the risk assessment process. A brief discussion of the uncertainties associated with the risk evaluation for Site 3 is contained in Section 6.5, Uncertainty Analysis.

To assess potential public health risks, four major aspects of chemical contamination and exposure must be considered: contaminants with toxic characteristics must be found in environmental media; the contaminants must be released by either natural processes or by human action; potential exposure points must exist; and human receptors must be present at the point of exposure. Risk is a function of both toxicity and exposure; without one of the factors listed above, there is no risk.

An illustration of the baseline human health risk assessment process is provided in Figure 6-1.

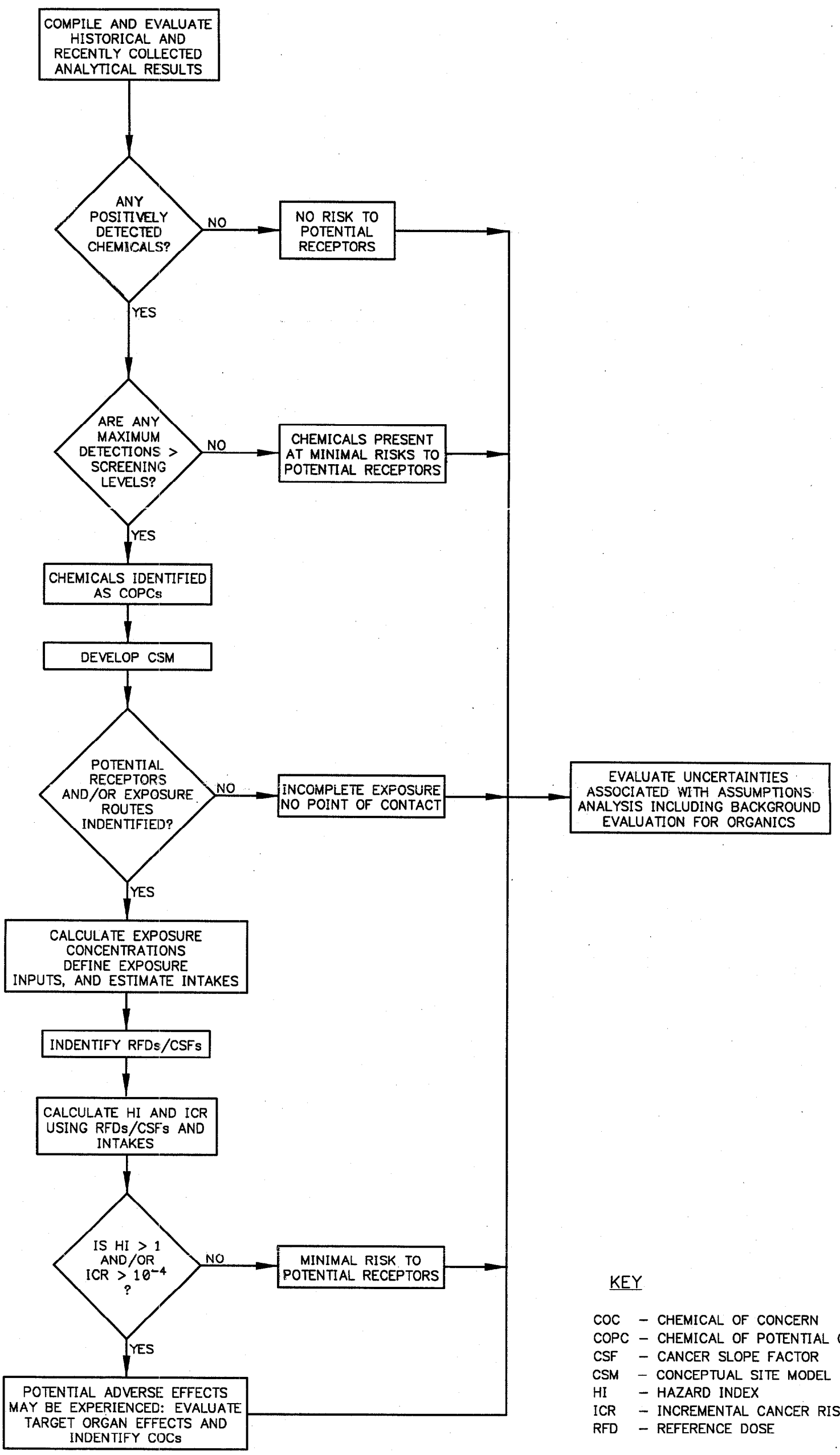
The baseline human health risk assessment for Site 3 was conducted using the most recent guidance from the U.S. EPA (U.S. EPA, 1989 and 1992a), including Regional supplemental guidance (U.S. EPA Region IV, 1995a). To maintain consistency among risk assessments performed at various sites at the Base, methodologies presented in the *Master Workplan for MCRD, Parris Island, South Carolina* (B&R Environmental, 1998b) were also used to develop the baseline risk assessment for this site.

6.1 DATA EVALUATION

Data evaluation is a site-specific task that uses a variety of information to determine which of the detected chemicals at a site are most likely to present a risk to potential human receptors. The end result of this qualitative selection process is a list of COPCs for each environmental medium under consideration. Section 6.1.1 provides a brief summary of data usability as it pertains to the baseline human health risk assessment. The selection of COPCs for the site is contained in Section 6.1.2.

6.1.1 Data Usability

This section addresses the usability of data collected as part of the 1998 RI/RFI field investigation. The use of approved work plans for the 1998 RI/RFI promotes quality by identifying appropriate sample locations, analytical parameters, analytical methods, and data quality objectives (DQOs). The results of



KEY

COC – CHEMICAL OF CONCERN
COPC – CHEMICAL OF POTENTIAL CONCERN
CSF – CANCER SLOPE FACTOR
CSM – CONCEPTUAL SITE MODEL
HI – HAZARD INDEX
ICR – INCREMENTAL CANCER RISK
RFD – REFERENCE DOSE

DRAWN BY KW 1/21/99 DATE	SUMMARY OF HUMAN HEALTH RISK ASSESSMENT PROCESS SITE 3 – CAUSEWAY LANDFILL MCRD PARRIS ISLAND, SOUTH CAROLINA	CONTRACT NO. 7394	
CHECKED BY DATE		APPROVED BY DATE	
COST/SCHED--AREA		APPROVED BY DATE	
SCALE N.T.S.		DRAWING NO. FIGURE 6–1	REV. 0

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measures (field and laboratory quality control, data validation, etc.) taken to ensure the quality of data collected during the 1998 RI/RFI field investigation are summarized in Appendix D of this report.

All sample data collected for Site 3 were used to assess potential human health risks. The qualification of data during the formal data validation process is not expected to compromise the results of the baseline human health risk assessment. Analytical data qualified as estimated were utilized, even though the reported positive concentrations or sample-specific quantitation limits may be somewhat imprecise. The use of estimated data adds to the uncertainty associated with the risk assessment; however, the associated uncertainty is expected to be negligible compared to the other uncertainties inherent in the risk evaluation process (i.e., uncertainties with land uses, exposure scenarios, toxicological criteria, etc.).

6.1.2 Selection of COPCs

The overall goal of the baseline human health risk assessment is to quantify risks associated with those chemicals that represent a potentially significant human health hazard on the basis of toxicity, environmental concentration, and mobility. U.S. EPA guidance (U.S. EPA, 1989 and U.S. EPA, Region IV, 1995a) recommends focusing the baseline risk assessment by quantifying risk only for a select list of COPCs at a site. These chemicals, which are a subset of all detected chemicals in a given medium, are defined as those chemicals likely to dominate the overall potential risks for a site.

For the purposes of this baseline risk assessment, COPCs for a particular medium are limited to those chemicals that exceed a selection criterion. The maximum concentration of a chemical detected in soil, sediment, and groundwater was compared to the risk-based concentrations (RBCs) screening criteria for that chemical. RBCs have been determined for cancer risk levels of 1×10^{-6} and noncancer (hazard quotient) levels of 1.0 and are presented in the most recent version of the U.S. EPA Region III Risk-Based Concentration Table. The screening values in the report Tables were divided by 10 for noncarcinogens to screen to the more conservative hazard quotient of 0.1. Chemicals detected in groundwater were retained as COPCs if the maximum detected concentration exceeded the screening criteria for tap water. The maximum concentrations of chemicals detected in soil or sediment were compared to Region III residential screening criteria for soil ingestion. U.S. EPA soil screening levels for transfer to air or groundwater were used to evaluate the inhalation pathway and the potential for chemicals to migrate from soil to groundwater. Chemicals with concentrations exceeding these screening criteria will be retained as COPCs.

Concentrations (maximum) of chemicals detected in surface water were compared to the Water Quality Standard (WQS) for human health (consumption of water and organisms), and the chemicals were retained as COPCs whenever the standards were exceeded. If WQSs were not available for detected chemicals, comparisons were made to the U.S. EPA Region III tap water screening criteria.

Fish tissue samples were not collected as part of the current site investigation. Finfish and shellfish samples were collected as part of the ESI (ABB Environmental Services, Inc., 1993) and the results were compared to action levels established by the United States Food and Drug Administration (USFDA). The ESI results will also be compared to the U.S. EPA Region III RBCs for the ingestion of fish. In addition, chemical concentrations in fish tissue will be estimated as part of the ecological screening risk assessment discussed in Section 7.0 of this report, the resulting fish tissue concentrations will be used in the human health risk assessment. The estimated fish tissue concentrations will be compared to the U.S. EPA Region III RBCs for the ingestion of fish and USDFA action levels.

Inorganic COPCs were also selected based on a comparison of site-specific chemical concentrations to background chemical concentrations. Comparisons were made between the maximum concentration of the site-specific chemical and twice the mean of the background chemical concentration. If the maximum detected concentration was less than twice the mean of the background chemical concentrations, then that chemical was not retained as a COPC.

Samples were analyzed for both total chromium and hexavalent chromium. Since hexavalent chromium was not detected, criteria for trivalent chromium were used to evaluated concentrations of total chromium.

The initial list of COPCs for an area under investigation includes any chemical detected at least once in validated environmental samples from the area. Essential human nutrients (magnesium, potassium, calcium, and sodium) present at relatively low concentrations are then eliminated from the initial list of COPCs. They can be eliminated because they are only toxic at high doses.

Maximum detected concentrations (in a single sample) in each sample medium for Site 3 were compared to the risk-based and health-based screening criteria. If the maximum concentration exceeded any of the screening criteria, that chemical was retained as a COPC for all significant exposures involving that medium. For example, if arsenic was retained for soil, this chemical was evaluated as a COPC for both ingestion and dermal exposure routes. If none of the chemicals detected in a medium exceeded criteria, that medium was dropped from further consideration and the potential risks associated with exposure to that medium are regarded as relatively insignificant.

Table 6-1 lists the screening criteria used in the selection of COPCs. A medium-specific discussion of the specific criteria used for COPC selection and the results for the selection process is provided in the remainder of this section. A copy of all the screening criteria is included in Appendix E.3.

TABLE 6-1

SCREENING CRITERIA USED IN SELECTION OF COPCS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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CAS Number	Chemical	EPA Region III RBC[1] Residential (µg/kg)		EPA SSL[2] Soil to Air (µg/kg)		EPA SSL[2] Soil to Groundwater (µg/kg)		EPA Region III RBC[1] Tap Water (µg/L)		EPA MCL[3] (µg/L)	EPA AWQC[4] (µg/L)	EPA Region III RBC[1] Fish (µg/kg)	
VOLATILE ORGANIC COMPOUNDS													
78-93-3	2-Butanone	47000000	N	N/A		N/A		1900	N	N/A	N/A	810	N
67-64-1	Acetone	7800000	N	1000000	N	16000	N	3700	N	N/A	N/A	140	N
71-43-2	Benzene	22000	C	800	C	30		0.36	C	5	1.2	0.11	C
75-15-0	Carbon Disulfide	7800000	N	720000	N	32000	N	1000	N	N/A	N/A	140	N
108-90-7	Chlorobenzene	1600000	N	130000	N	1000		35	N	N/A	680	27	N
67-66-3	Chloroform	100000	C	300	C	600	C	0.15	C	100/80	5.7	0.52	C
100-41-4	Ethylbenzene	7800000	N	400000	N	13000		1300	N	700	3100	140	N
108-88-3	Toluene	16000000	N	650000	N	12000		750	N	1000	6800	270	N
1330-20-7	Xylenes, Total	160000000	N	410000	N	190000		12000	N	10000	N/A	2700	N
SEMIVOLATILE ORGANIC COMPOUNDS													
106-46-7	1,4-Dichlorobenzene	27000	C	N/A		2000		0.47	C	N/A	400	0.13	C
91-57-6	2-Methylnaphthalene	1600000	N	N/A		N/A		120	N	N/A	N/A	54	N
106-44-5	4-Methylphenol	390000	N	N/A		N/A		180	N	N/A	N/A	6.8	N
83-32-9	Acenaphthene	4700000	N	N/A		570000	N	2200	N	N/A	1200	81	N
208-96-8	Acenaphthylene	1600000 (5)	N	N/A		N/A		1500 (5)	N	N/A	N/A	54 (5)	N
120-12-7	Anthracene	23000000	N	N/A		12000000	N	11000	N	N/A	9600	410	N
56-55-3	Benzo(a)anthracene	870	C	N/A		2000	C	0.092	C	N/A	0.0044	0.0043	C
50-32-8	Benzo(a)pyrene	87	C	N/A		8000	C	0.0092	C	0.002	0.0044	0.00043	C
205-99-2	Benzo(b)fluoranthene	870	C	N/A		5000	C	0.092	C	N/A	0.0044	0.0043	C
191-24-2	Benzo(g,h,i)perylene	1600000 (5)	N	N/A		N/A		1500 (5)	N	N/A	N/A	54 (5)	N
207-08-9	Benzo(k)fluoranthene	8700	C	N/A		49000	C	0.92	C	N/A	0.0044	0.043	C
117-81-7	Bis(2-ethylhexyl)phthalate	46000	C	3100000	N	3600000	C	4.8	C	N/A	1.8	0.23	C
85-68-7	Butylbenzyl Phthalate	16000000	N	930000	sat	930000	sat	7300	N	N/A	3000	270	N
86-74-8	Carbazole	32000	C	N/A		600	C	3.3	C	N/A	N/A	0.16	C
218-01-9	Chrysene	87000	C	N/A		160000	C	9.2	C	N/A	0.0044	0.43	C
132-64-9	Dibenzofuran	310000	N	N/A		N/A		24	N	N/A	N/A	5.4	N
206-44-0	Fluoranthene	3100000	N	N/A		4300000	N	1500	N	N/A	300	54	N
86-73-7	Fluorene	3100000	N	N/A		560000	N	1500	N	N/A	1300	54	N
193-39-5	Indeno(1,2,3-cd)pyrene	870	C	N/A		14000	C	0.092	C	N/A	0.0044	0.0043	C
86-30-6	N-Nitrosodiphenylamine	130000	C	N/A		1000	C	14	C	N/A	5	0.64	C
91-20-3	Naphthalene	1600000	N	N/A		84000		730	N	N/A	N/A	54	N
85-01-8	Phenanthrene	3100000 (5)	N	N/A		N/A		1500 (5)	N	N/A	N/A	54 (5)	N
129-00-0	Pyrene	2300000	N	N/A		4200000	N	1100	N	N/A	960	41	N

TABLE 6-1

SCREENING CRITERIA USED IN SELECTION OF COPCS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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CAS Number	Chemical	EPA Region III RBC[1] Residential (µg/kg)		EPA SSL[2] Soil to Air (µg/kg)		EPA SSL[2] Soil to Groundwater (µg/kg)		EPA Region III RBC[1] Tap Water (µg/L)		EPA MCL[3] (µg/L)	EPA AWQC[4] (µg/L)	EPA Region III RBC[1] Fish (µg/kg)	
PESTICIDES/PCBs													
72-54-8	4,4'-DDD	2700	C	N/A		16000		0.28	C	N/A	0.00083	0.013	C
72-55-9	4,4'-DDE	1900	C	N/A		16000	C	0.2	C	N/A	0.00059	0.0093	C
50-29-3	4,4'-DDT	1900	C	N/A		32000	C	0.2	C	N/A	0.00059	0.0093	C
319-84-6	alpha-BHC	100	C	N/A		3	C	0.011	C	N/A	0.0039	0.0005	C
5103-71-9	alpha-Chlordane	1800	C	20000	C	10000	C	0.19	C	2	0.0021 (10)	0.009	C
11097-69-1	Aroclor-1254	320	C	N/A		N/A		0.033	C	0.5 (10)	0.00017 (10)	0.0016	C
11096-82-5	Aroclor-1260	320	C	N/A		N/A		0.033	C	0.5 (10)	0.00017 (10)	0.0016	C
57-74-9	Gamma-Chlordane	1800	C	20000	C	10000	C	0.19	C	2	0.0021 (10)	0.009	C
INORGANICS													
7429-90-5	Aluminum	78000000	N	N/A		N/A		37000	N	50 To 200 (11)	N/A	1400	N
7440-36-0	Antimony	31000	N	N/A		5000	N	15	N	6	14	0.54	N
7440-38-2	Arsenic	430	C	750000	C	29000	C	0.045	C	50	0.018	0.0021	C
7440-39-3	Barium	5500000	N	69000000	N	1600000	N	2600	N	2000	1000 (13)	95	N
7440-41-7	Beryllium	160000	N	1300000	C	63000	C	73	N	4	0.0037 (13)	2.7	N
7440-43-9	Cadmium	39000	N	1800000	C	8000	N	18	N	5	10 (13)	0.68	N
7440-70-2	Calcium	N/A		N/A		N/A		N/A		N/A	N/A	N/A	
7440-47-3	Chromium	120000000	N	270000	C	38000	C	55000	N	100	170000 (13)	2000000	N
7440-48-4	Cobalt	4700000	N	N/A		N/A		2200	N	N/A	N/A	81	N
7440-50-8	Copper	3100000	N	N/A		N/A		1500	N	1000 (11)	1300	54	N
7439-89-6	Iron	23000000	N	N/A		N/A		11000	N	300 (11)	300 (13)	410	N
7439-92-1	Lead	400000 (7)		N/A		N/A		N/A		15 (12)	50 (13)	N/A	
7439-95-4	Magnesium	N/A		N/A		N/A		N/A		N/A	N/A	N/A	
7439-96-5	Manganese	1600000	N	N/A		N/A		730	N	50 (11)	50 (13)	27	N
7487-94-7	Mercury	23000 (8)	N	N/A		N/A		11	N	2	0.05	0.41 (14)	N
7440-02-0	Nickel	1600000	N	13000000	C	130000	N	730	N	100	610	27	N
	Potassium	N/A		N/A		N/A		N/A		N/A	N/A	N/A	
7782-49-2	Selenium	390000	N	N/A		5000	N	180	N	50	N/A	6.8	N
7440-22-4	Silver	390000	N	N/A		34000	N	180	N	100 (11)	N/A	6.8	N
7440-23-5	Sodium	N/A		N/A		N/A		N/A		N/A	N/A	N/A	
7440-28-0	Thallium	5500	N	N/A		700		2.6	N	2	1.7	0.095	N
7440-62-2	Vanadium	550000	N	N/A		6000000	N	260	N	N/A	1100 (13)	9.5	N
7440-66-6	Zinc	23000000	N	N/A		12000000	N	11000	N	5000 (11)	9100	410	N
57-12-5	Cyanide	1600000 (9)	N	N/A		40000 (9)		730 (9)	N	200	700	27 (9)	N

TABLE 6-1

SCREENING CRITERIA USED IN SELECTION OF COPCS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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CAS Number	Chemical	EPA Region III RBC[1] Residential (µg/kg)	EPA SSL[2] Soil to Air (µg/kg)	EPA SSL[2] Soil to Groundwater (µg/kg)	EPA Region III RBC[1] Tap Water (µg/L)	EPA MCL[3] (µg/L)	EPA AWQC[4] (µg/L)	EPA Region III RBC[1] Fish (µg/kg)

Notes:

1 USEPA Region III Risk-Based Concentration Table, April 12, 1999. (Cancer benchmark value = 1E-06, HI = 1.0)
2 USEPA Soil Screening Level Guidance: Technical Background Document. May 1996.
3 USEPA Drinking Water Regulations and Health Advisories, October 1996.
4 Federal Register 68354-68364, December, 1998.
5 Value is for naphthalene.
6 Value is for hexavalent chromium.
7 OSWER Screening level.
8 Value is for mercuric chloride
9 Value is for free cyanide.
10 Value is for PCBs
11 Secondary MCLs
12 Action level.
13 Published criteria values in "Water Quality Criteria Summary Concentrations", 12/96.
14 Value is for methyl mercury.

Definitions: N/A = Not Applicable
C = Carcinogenic
N = Non-Carcinogenic
sat = saturation concentration
MCL = Maximum Contaminant Level
SMCL = Secondary Maximum Contaminant Level
RBC = Risk-Based Concentration
SSL = Soil Screening Level.
AWQC = Ambient Water Quality Criteria.

6.1.2.1 Surface Soil

Sixteen surface soil samples were collected at Site 3 and analyzed for VOCs, SVOCs, pesticides/PCBs, and inorganics. A comparison of the maximum detected concentrations to the risk-based screening levels is presented in Table 6-2. The following chemicals were detected at maximum concentrations in surface soil that exceeded the risk-based COPC screening levels.

- SVOCs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene]
- Inorganics (aluminum, arsenic, and iron)

In accordance with U.S. EPA Region IV guidance, since several carcinogenic PAHs have maximum concentrations exceeding the screening criteria, all carcinogenic PAHs will be retained as COPCs for soil.

Concentrations of all chemicals detected in surface soil were less than the U.S. EPA soil screening levels (SSLs) for soil to air; therefore, exposures through inhalation of fugitive dust were not retained for evaluation in the risk assessment.

Maximum detected concentrations in surface soil were also compared to U.S. EPA soil screening levels for migration to groundwater. Maximum concentrations of benzo(a)anthracene and carbazole exceeded the SSLs, indicating the potential for these chemicals to migrate to groundwater and potentially impact the quality of groundwater. However, benzo(a)anthracene and carbazole were not detected in groundwater samples collected at Site 3. Consequently, benzo(a)anthracene and carbazole were not retained as COPCs for the migration from soil to groundwater.

6.1.2.2 Groundwater

Four groundwater samples were collected at Site 3 and analyzed for VOCs, SVOCs, pesticides/PCBs, and inorganics. A comparison of the maximum detected concentrations to the risk-based screening levels is presented in Table 6-3. The following chemicals were detected at maximum concentrations in groundwater that exceeded the risk-based COPC screening levels.

- VOCs (benzene, chlorobenzene, and chloroform)
- SVOCs (1,4-dichlorobenzene and 4-methylphenol)
- Pesticides (alpha-BHC)
- Inorganics (arsenic, barium, iron, manganese, and thallium)

TABLE 6-2

OCCURRENC, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH SOIL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	EPA[3] Region III Screening Values		Screening[4] Toxicity Value		Screening[5] Toxicity Value		COPC Flag	Rationale for[6] Contaminant Deletion or Selection
	VOCs																		
78-93-3	2-Butanone	360		360		µg/kg	PAI-03-SS-008-01	1/16	5 - 10	360	N/A	4700000	N	N/A		N/A		No	BSL
67-64-1	Acetone	120	J	240	J	µg/kg	PAI-03-SS-008-01	2/6	14 - 900	240	N/A	780000	N	1000000	N	16000	N	No	BSL
67-66-3	Chloroform	1	J	2	J	µg/kg	PAI-03-SS-011-01	4/16	5 - 10	2	N/A	100000	C	300	C	600	C	No	BSL
	SVOCs																		
91-57-6	2-Methylnaphthalene	300	J	300	J	µg/kg	PAI-03-SS-001-01	1/15	340 - 380	300	N/A	160000	N	N/A		N/A		No	BSL
106-44-5	4-Methylphenol	120	J	120	J	µg/kg	PAI-03-SS-001-01	1/15	340 - 380	120	N/A	39000	N	N/A		N/A		No	BSL
83-32-9	Acenaphthene	4000	J	4000	J	µg/kg	PAI-03-SS-001-01	1/16	94 - 4600	4000	N/A	470000	N	N/A		570000	Sat	No	BSL
208-96-8	Acenaphthylene	1800	J	1800	J	µg/kg	PAI-03-SS-001-01	1/16	47 - 2300	1800	N/A	160000 (7)	N	N/A		N/A		No	BSL
120-12-7	Anthracene	1.7	J	340		µg/kg	PAI-03-SS-001-01	6/16	1.9 - 93	340	N/A	2300000	N	N/A		12000000	N	No	BSL
56-55-3	Benzo(a)anthracene	3	J	3000		µg/kg	PAI-03-SS-001-01	10/16	8.6 - 230	3000	N/A	870	C	N/A		2000	C	Yes	ASL
50-32-8	Benzo(a)pyrene	4.1	J	4000		µg/kg	PAI-03-SS-001-01	10/16	8.6 - 230	4000	N/A	87	C	N/A		8000	C	Yes	ASL
205-99-2	Benzo(b)fluoranthene	2.2	J	3400		µg/kg	PAI-03-SS-001-01	15/16	3.6	3400	N/A	870	C	N/A		5000	C	Yes	ASL
191-24-2	Benzo(g,h,i)perylene	9.3	J	2500		µg/kg	PAI-03-SS-001-01	5/16	7.5 - 370	2500	N/A	160000 (7)	N	N/A		N/A		No	BSL
207-08-9	Benzo(k)fluoranthene	1.7	J	1300		µg/kg	PAI-03-SS-001-01	11/16	3.6 - 93	1300	N/A	8700	C	N/A		49000	C	Yes	cPAH
117-81-7	Bis(2 ethylhexyl)phthalate	2300		2300		µg/kg	PAI-03-SS-015-01	1/15	340 - 370	2300	N/A	46000	C	3100000	N	3600000	C	No	BSL
86-74-8	Carbazole	48	J	670		µg/kg	PAI-03-SS-001-01	3/15	340 - 380	670	N/A	32000	C	N/A		600	C	No	ASL
218-01-9	Chrysene	3.6		2900		µg/kg	PAI-03-SS-001-01	13/16	9.1 - 230	2900	N/A	87000	C	N/A		160000	C	Yes	cPAH
132-64-9	Dibenzofuran	340	J	340	J	µg/kg	PAI-03-SS-001-01	1/15	340 - 380	340	N/A	31000	N	N/A		N/A		No	BSL
206-44-0	Fluoranthene	6.4	J	5100		µg/kg	PAI-03-SS-001-01	14/16	5.5 - 22	5100	N/A	310000	N	N/A		4300000	N	No	BSL
193-39-5	Indeno(1,2,3-cd)pyrene	2.6	J	2600		µg/kg	PAI-03-SS-001-01	10/16	8.6 - 230	2600	N/A	870	C	N/A		14000	C	Yes	ASL
85-01-8	Phenanthrene	2.2	J	1200		µg/kg	PAI-03-SS-001-01	14/16	7.2 - 190	1200	N/A	160000 (7)	N	N/A		N/A		No	BSL
129-00-0	Pyrene	13	J	4500		µg/kg	PAI-03-SS-001-01	10/16	9.4 - 460	4500	N/A	230000	N	N/A		4200000	N	No	BSL
	PESTICIDES/PCBs																		
72-55-9	4,4'-DDE	4.1		4.1		µg/kg	PAI-03-SS-012-01	1/16	1.7 - 190	4.1	N/A	1900	C	N/A		16000	C	No	BSL
50-29-3	4,4'-DDT	1.8		4.5		µg/kg	PAI-03-SS-012-01	2/16	1.8 - 190	4.5	N/A	1900	C	N/A		32000	C	No	BSL
5103-71-9	alpha-Chlordane	96		96		µg/kg	PAI-03-SS-001-01	1/16	0.87 - 1900	96	N/A	1800	C	20000	C	10000	C	No	BSL
11097-69-1	Aroclor-1254	56		56		µg/kg	PAI-03-SS-009-01	1/16	8.6 - 9.4	56	N/A	320	C	N/A		N/A		No	BSL
11096-82-5	Aroclor-1260	11		100		µg/kg	PAI-03-SS-013-01	4/16	8.6 - 9.4	100	N/A	320	C	N/A		N/A		No	BSL
57-74-9	Gamma-Chlordane	53		53		µg/kg	PAI-03-SS-001-01	1/16	0.87 - 1900	53	N/A	1800	C	20000	C	10000	C	No	BSL
	INORGANICS																		
7429-90-5	Aluminum	2370		10800		mg/kg	PAI-03-SS-010-01	16/16	NA	10800	7270	7800	N	N/A		N/A		Yes	ASL
7440-36-0	Antimony	0.17	J	0.33	J	mg/kg	PAI-03-SS-015-01	2/16	0.15 - 0.23	0.33	ND	3.1	N	N/A		5	N	No	BSL
7440-38-2	Arsenic	0.44		11.8		mg/kg	PAI-03-SS-003-01	16/16	NA	12	1.44	0.43	C	750	C	29	C	Yes	ASL
7440-39-3	Barium	5.8		81.2		mg/kg	PAI-03-SS-001-01	16/16	NA	81.2	23.6	550	N	69000	N	1600	N	No	BSL
7440-41-7	Beryllium	0.11		0.58		mg/kg	PAI-03-SS-004-01	3/16	0.02 - 0.38	0.58	0.095	16	N	1300	C	63	C	No	BSL
7440-43-9	Cadmium	0.04		0.53		mg/kg	PAI-03-SS-001-01	6/16	0.02 - 0.03	0.53	ND	7.8	N	1800	C	8	N	No	BSL
7440-70-2	Calcium	461		56100		mg/kg	PAI-03-SS-015-01	16/16	NA	56100	766	N/A		N/A		N/A		No	NUT
7440-47-3	Chromium	3.5		15.9		mg/kg	PAI-03-SS-004-01	16/16	NA	15.9	6.23	12000 (8)	N	270	C	38	C	No	BSL
7440-48-4	Cobalt	0.14		1.7		mg/kg	PAI-03-SS-004-01	16/16	NA	1.7	0.363	470	N	N/A		N/A		No	BSL

TABLE 6-2

OCCURRENC, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH SOIL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	EPA[3] Region III Screening Values		Screening[4] Toxicity Value		Screening[5] Toxicity Value		COPC Flag	Rationale for[6] Contaminant Deletion or Selection
7440-50-8	Copper	1.3		10.7		mg/kg	PAI-03-SS-004-01	13/16	0.46 - 1.6	10.7	1.52	310	N	N/A		N/A		No	BSL
7439-89-6	Iron	2180		7370		mg/kg	PAI-03-SS-004-01	16/16	NA	7370	3920	2300	N	N/A		N/A		Yes	ASL
7439-92-1	Lead	5.5		264		mg/kg	PAI-03-SS-001-01	16/16	NA	264	12.5	400 (9)		N/A		N/A		No	BSL
7439-96-5	Magnesium	150		2250		mg/kg	PAI-03-SS-004-01	16/16	NA	2250	515	N/A		N/A		N/A		No	NUT
7439-96-5	Manganese	8.1		66.9		mg/kg	PAI-03-SS-015-01	16/16	NA	66.9	129	1100	N	N/A		N/A		No	BSL
7487-94-7	Mercury	0.0375		0.43		mg/kg	PAI-03-SS-009-01	6/16	0.02 - 0.03	0.43	0.11	2.3 (10)	N	N/A		N/A		No	BSL
7440-02-0	Nickel	0.39		6.1		mg/kg	PAI-03-SS-002-01	16/16	NA	6.1	1.8	160	N	13000	C	130	N	No	BSL
	Potassium	115		1380		mg/kg	PAI-03-SS-004-01	16/16	NA	1380	313	N/A		N/A		N/A		No	NUT
7782-49-2	Selenium	0.28		0.41		mg/kg	PAI-03-SS-010-01	2/16	0.14 - 0.5	0.41	0.285	39	N	N/A		5	N	No	BSL
7440-22-4	Silver	0.09		0.09		mg/kg	PAI-03-SS-015-01	1/16	0.05 - 0.06	0.09	ND	39	N	N/A		34	N	No	BSL
7440-23-5	Sodium	192		5480		mg/kg	PAI-03-SS-004-01	6/16	164 - 441	5480	241	N/A		N/A		N/A		No	NUT
7440-62-2	Vanadium	4.7		21.4		mg/kg	PAI-03-SS-004-01	16/16	NA	21.4	9.5	55	N	N/A		6000	N	No	BSL
7440-66-6	Zinc	5.7		205		mg/kg	PAI-03-SS-001-01	16/16	NA	205	9.7	2300	N	N/A		12000	N	No	BSL

Notes:

1 Minimum/maximum detected concentration.

2 N/A - Refer to supporting information for background discussion.
Background values derived from statistical analysis. Follow Regional guidance and provide supporting information.

3 USEPA Region III Risk-Based Concentration Table, April 12, 1999. (Cancer benchmark value = 1E-06, HI = 0.1)

4 USEPA Soil Screening Level Guidance: Technical Background Document. May 1996.

5 USEPA Soil Screening Level Guidance: Technical Background Document. May 1996. (Based on a DAF [Dilutional Attenuation Factor] of 20)

6 Rationale Codes Selection Reason: Above Screening Levels (ASL)
Retained because other carcinogenic PAHs exceed screenig criteria (cPAH)
Deletion Reason: Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

7 No RBC available for chemical. Naphthalene is used as a surrogate based on similar chemical structure.

8 Hexavalent chromium was not detected in surface soil, therefore chromium is evaluated as trivalent chromium.

9 OSWER screening level.

10 Value for mercuric chloride.

Chemicals retained as COPCs are shaded.

Definitions:
N/A = Not Applicable
SQL = Sample Quantitation Limit
COPC = Chemical of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

TABLE 6-3

OCCURRENCE, DISTRIBUTION AND SELECTIONOF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH GROUNDWATER
SITE 3- CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	Screening[3] Toxicity Value		Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	VOCs																
71-43-2	Benzene	0.3	J	21		µg/L	PAI-03-GW-001-01	2/4	1	21	N/A	0.36	C	5	MCL	Yes	ASL
75-15-0	Carbon Disulfide	0.3	J	0.3	J	µg/L	PAI-03-GW-002-01	1/4	1	0.3	N/A	100	N	N/A	N/A	No	BSL
108-90-7	Chlorobenzene	0.6	J	130		µg/L	PAI-03-GW-001-01	2/4	1	130	N/A	3.5	N	N/A	N/A	Yes	ASL
67-66-3	Chloroform	0.3		0.3		µg/L	PAI-03-GW-004-01	1/4	1	0.3	N/A	0.15	C	100/80	MCL	Yes	ASL
100-41-4	Ethylbenzene	0.3	J	0.3	J	µg/L	PAI-03-GW-001-01	1/4	1	0.3	N/A	130	N	700	MCL	No	BSL
108-88-3	Toluene	0.3	J	0.3	J	µg/L	PAI-03-GW-002-01	2/4	1	0.3	N/A	75	N	1000	MCL	No	BSL
1330-20-7	Xylenes, Total	0.3	J	0.3	J	µg/L	PAI-03-GW-001-01	1/4	1	0.3	N/A	1200	N	10000	MCL	No	BSL
	SVOCs																
106-46-7	1,4-Dichlorobenzene	10		10		µg/L	PAI-03-GW-001-01	1/4	5	10	N/A	0.47	C	N/A	N/A	Yes	ASL
91-57-6	2-Methylnaphthalene	1	J	1	J	µg/L	PAI-03-GW-003-01	1/4	5	1	N/A	120	N	N/A	N/A	No	BSL
106-44-5	4-Methylphenol	73		73		µg/L	PAI-03-GW-003-01	1/4	5	73	N/A	18	N	N/A	N/A	Yes	ASL
83-32-9	Acenaphthene	2	J	2	J	µg/L	PAI-03-GW-003-01	1/4	5	2	N/A	220	N	N/A	N/A	No	BSL
120-12-7	Anthracene	1	J	1	J	µg/L	PAI-03-GW-003-01	1/4	5	1	N/A	1100	N	N/A	N/A	No	BSL
117-81-7	Bis(2-ethylhexyl)phthalate	1	J	1	J	µg/L	PAI-03-GW-001-01	3/4	5	1	N/A	4.8	C	N/A	N/A	No	BSL
86-73-7	Fluorene	1	J	1	J	µg/L	PAI-03-GW-003-01	1/4	5	1	N/A	150	N	N/A	N/A	No	BSL
86-30-6	N-Nitrosodiphenylamine	1	J	1	J	µg/L	PAI-03-GW-001-01	1/4	5	1	N/A	14	C	N/A	N/A	No	BSL
91-20-3	Naphthalene	1	J	1	J	µg/L	PAI-03-GW-001-01	2/4	5	1	N/A	73	N	N/A	N/A	No	BSL
85-01-8	Phenanthrene	1	J	1	J	µg/L	PAI-03-GW-003-01	1/4	5	1	N/A	73 (5)	N	N/A	N/A	No	BSL
	PESTICIDES/PCBs																
319-84-6	alpha-BHC	0.12		0.12		µg/L	PAI-03-GW-002-01	1/4	0.05	0.12	N/A	0.011	C	N/A	N/A	Yes	ASL
	INORGANICS (UNFILTERED)																
7440-38-2	Arsenic	2.2		34.5		µg/L	PAI-03-GW-001-01	4/4	NA	34.5	N/A	0.045	C	50	MCL	Yes	ASL
7440-39-3	Barium	93.5		854		µg/L	PAI-03-GW-004-01	4/4	NA	854	N/A	260	N	2000	MCL	Yes	ASL
7440-70-2	Calcium	60600		474000		µg/L	PAI-03-GW-004-01	3/3	NA	474000	N/A	NA		N/A	N/A	No	NUT
7440-47-3	Chromium	7.6		27		µg/L	PAI-03-GW-004-01	2/4	6.4	27	N/A	5500 (6)	N	100	MCL	No	BSL
7439-89-6	Iron	14600		32600		µg/L	PAI-03-GW-004-01	3/3	NA	32600	N/A	1100	N	300	SMCL	Yes	ASL
7439-95-4	Magnesium	76400		508000		µg/L	PAI-03-GW-004-01	3/3	NA	508000	N/A	NA		N/A	N/A	No	NUT
7439-96-5	Manganese	112		708		µg/L	PAI-03-GW-004-01	3/3	NA	708	N/A	73	N	50	SMCL	Yes	ASL
	Potassium	63600		209000		µg/L	PAI-03-GW-004-01	3/3	NA	209000	N/A	NA		N/A	N/A	No	NUT
7440-23-5	Sodium	588000		4610000		µg/L	PAI-03-GW-004-01	3/3	NA	4610000	N/A	NA		N/A	N/A	No	NUT
	Thallium	2.6		2.6		µg/L	PAI-03-GW-004-01	1/4	1.8 - 9	2.6	N/A	0.26	N	2	MCL	Yes	ASL
	INORGANICS (FILTERED)																
7440-38-2	Arsenic	1.2		31.1		µg/L	PAI-03-GW-001-01-F	4/4	NA	31.1	N/A	0.045	C	50	MCL	Yes	ASL
7440-39-3	Barium	93.3		901		µg/L	PAI-03-GW-004-01-F	4/4	NA	901	N/A	260	N	2000	MCL	Yes	ASL
7440-70-2	Calcium	63400		492000		µg/L	PAI-03-GW-004-01-F	3/3	NA	492000	N/A	N/A		N/A	N/A	No	NUT
7440-47-3	Chromium	24.8		24.8		µg/L	PAI-03-GW-004-01-F	1/4	6.4	24.8	N/A	5500 (6)	N	100	MCL	No	BSL
7439-89-6	Iron	14600		31500		µg/L	PAI-03-GW-004-01-F	3/3	NA	31500	N/A	1100	N	300	SMCL	Yes	ASL
7439-95-4	Magnesium	75400		543000		µg/L	PAI-03-GW-004-01-F	3/3	NA	543000	N/A	N/A		N/A	N/A	No	NTX

TABLE 6-3

OCCURRENCE, DISTRIBUTION AND SELECTIONOF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH GROUNDWATER
SITE 3- CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	Screening[3] Toxicity Value		Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
7439-96-5	Manganese	113		711		µg/L	PAI-03-GW-004-01-F	3/3	NA	711	N/A	73	N	50	SMCL	Yes	ASL
	Potassium	64800		223000		µg/L	PAI-03-GW-004-01-F	3/3	NA	223000	N/A	N/A		N/A	N/A	No	NUT
7440-23-5	Sodium	576000		5130000		µg/L	PAI-03-GW-004-01-F	3/3	NA	5130000	N/A	N/A		N/A	N/A	No	NTX
7440-28-0	Thallium	3.8		3.8		µg/L	PAI-03-GW-004-01-F	1/4	1.8 - 9	3.8	N/A	0.26	N	2	MCL	Yes	ASL

1 Minimum/maximum detected concentration.

2 N/A - Refer to supporting information for background discussion.
Background values derived from statistical analysis. Follow Regional guidance and provide supporting information.

3 USEPA Region III Risk-Based Concentration Table, April 12, 1999. (Cancer benchmark value = 1E-06, HI = 0.1)

4 Rationale Codes Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Infrequent Detection (IFD)
No Toxicity Information (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

5 Value for naphthalene.

6 Hexavalent chromium was not detected in groundwater therefore chromium is evaluated as trivalent chromium.

Chemicals retained as COPCs are shaded.

Definitions:
N/A = Not Applicable
SQL = Sample Quantitation Limit
COPC = Chemical of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
MCL = Federal Maximum Contaminant Level
SMCL = Secondary Maximum Contaminant Level
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

Maximum detected concentrations of inorganics exceeded the screening criteria in both unfiltered and filtered groundwater samples.

6.1.2.4 Surface Water

Twenty surface water samples were collected at Site 3 and analyzed for VOCs, SVOCs, pesticides/PCBs, and inorganics. A comparison of the maximum detected concentrations to the risk-based screening levels is presented in Table 6-4. The following chemicals were detected at maximum concentrations in surface water that exceeded the risk-based COPC screening levels.

- SVOCs [benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, and indeno(1,2,3-cd)pyrene]
- Inorganics (aluminum, arsenic, iron, and manganese)

In accordance with U.S. EPA Region IV guidance, since several carcinogenic PAHs have maximum concentrations exceeding the screening criteria, all carcinogenic PAHs were retained as COPCs for surface water.

Arsenic was detected in one of 20 unfiltered surface water samples and two of 20 filtered surface water samples. Arsenic concentrations were below the screening criteria in unfiltered surface water samples but exceeded the screening criteria in filtered surface water samples. Iron and manganese exceeded the screening criteria in both unfiltered and filtered surface water samples.

Concentrations of lead, mercury, and vanadium exceeded the screening criteria, but these compounds were only detected in one of 20 unfiltered surface water samples. Consequently, these compounds were not retained as COPCs due to their low frequency of detection (less than 5 percent). These compounds were not detected in filtered surface water samples.

6.1.2.5 Sediment

Twenty-one sediment samples were collected at Site 3 and analyzed for VOCs, SVOCs, pesticides/PCBs, and inorganics. A comparison of the maximum detected concentrations to the risk-based screening levels is presented in Table 6-5. The following chemicals were detected at maximum concentrations in sediment that exceeded the risk-based COPC screening levels.

- SVOCs [benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene]
- Inorganics (aluminum, arsenic, iron, and vanadium)

TABLE 6-4

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH SURFACE WATER
SITE 3- CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	Screening[3] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	VOCs															
67-64-1	Acetone	3	J	3	J	µg/L	PAI-03-SW-023	1/1	NA	3	N/A	370 (5)	N/A	N/A	No	BSL
	SVOCs															
120-12-7	Anthracene	0.38		0.38		µg/L	PAI-03-SW-014	1/20	0.048 - 0.054	0.38	N/A	9600	N/A	N/A	No	BSL, IFD
56-55-3	Benzo(a)anthracene	0.66		0.66		µg/L	PAI-03-SW-014	1/20	0.12 - 0.14	0.66	N/A	0.0028	N/A	N/A	Yes	ASL, IFD
50-32-8	Benzo(a)pyrene	0.075	J	0.72		µg/L	PAI-03-SW-014	2/20	0.12 - 0.14	0.72	N/A	0.0044	N/A	N/A	Yes	ASL
205-99-2	Benzo(b)fluoranthene	0.06		0.67		µg/L	PAI-03-SW-014	2/20	0.048 - 0.49	0.67	N/A	0.0044	N/A	N/A	Yes	ASL
191-24-2	Benzo(g,h,i)perylene	0.89		0.89		µg/L	PAI-03-SW-014	1/20	0.19 - 0.22	0.89	N/A	73 (5)(6)	N/A	N/A	No	IFD
207-08-9	Benzo(k)fluoranthene	0.025		0.25		µg/L	PAI-03-SW-014	2/20	0.048 - 0.49	0.25	N/A	0.0044	N/A	N/A	Yes	ASL
117-81-7	Bis(2-ethylhexyl)phthalate	2	J	7	J	µg/L	PAI-03-SW-025	6/20	10	7	N/A	1.8	N/A	N/A	Yes	ASL
85-68-7	Butylbenzyl Phthalate	5	J	5	J	µg/L	PAI-03-SW-028	1/20	10 - 10.5	5	N/A	3000	N/A	N/A	No	BSL, IFD
218-01-9	Chrysene	0.09	J	1.2		µg/L	PAI-03-SW-014	2/20	0.12 - 0.14	1.2	N/A	0.0044	N/A	N/A	Yes	ASL
206-44-0	Fluoranthene	0.1	J	1.9		µg/L	PAI-03-SW-014	3/20	0.12 - 0.14	1.9	N/A	300	N/A	N/A	No	BSL
193-39-5	Indeno(1,2,3-cd)pyrene	0.075	J	0.39		µg/L	PAI-03-SW-014	2/20	0.12 - 0.14	0.39	N/A	0.0044	N/A	N/A	Yes	ASL
85-01-8	Phenanthrene	0.05	J	1.4		µg/L	PAI-03-SW-014	3/20	0.0955 - 0.11	1.4	N/A	73 (5)(6)	N/A	N/A	No	BSL
129-00-0	Pyrene	1.3		1.3		µg/L	PAI-03-SW-014	1/20	0.24 - 0.27	1.3	N/A	960	N/A	N/A	No	BSL, IFD
	INORGANICS (NON-FILTERED)															
7429-90-5	Aluminum	242		88600		µg/L	PAI-03-SW-027	18/20	44.5 - 90.8	88600	3113	3700 (5)	N/A	N/A	Yes	ASL
7440-36-0	Antimony	1.8		3.2		µg/L	PAI-03-SW-014	4/20	1.7 - 3.7	3.2	ND	14	N/A	N/A	No	BSL
7440-38-2	Arsenic	96.1		96.1		µg/L	PAI-03-SW-027	1/20	1.5 - 3.5	96.1	5.13	0.018	N/A	N/A	No	IFD
7440-39-3	Barium	13		227		µg/L	PAI-03-SW-025	13/20	12.4 - 15.9	227	38.4	1000 (7)	N/A	N/A	No	BSL
7440-41-7	Beryllium	4.4		4.4		µg/L	PAI-03-SW-027	1/20	0.2	4.4	ND	0.0037 (7)	N/A	N/A	No	IFD
7440-43-9	Cadmium	2		2		µg/L	PAI-03-SW-027	1/20	0.3	2	ND	10 (7)	N/A	N/A	No	BSL, IFD
7440-70-2	Calcium	126000		274000		µg/L	PAI-03-SW-013	20/20	NA	274000	637000	N/A	N/A	N/A	No	NUT, BKG
7440-47-3	Chromium	0.79		164		µg/L	PAI-03-SW-027	3/20	0.7 - 0.8	164	22.5	170000 (7)	N/A	N/A	No	BSL
7440-48-4	Cobalt	21.1		21.1		µg/L	PAI-03-SW-027	1/20	0.6	21.1	ND	220 (5)	N/A	N/A	No	BSL, IFD
7440-50-8	Copper	1.4		152		µg/L	PAI-03-SW-027	8/20	1.2 - 3.2	152	6.97	1300	N/A	N/A	No	BSL
7439-89-6	Iron	163		110000		µg/L	PAI-03-SW-027	18/20	16.6 - 91.7	110000	2091	300 (7)	N/A	N/A	Yes	ASL
7439-92-1	Lead	132		132		µg/L	PAI-03-SW-027	1/20	1 - 17	132	ND	50 (7)	N/A	N/A	No	IFD
7439-95-4	Magnesium	230000		841000		µg/L	PAI-03-SW-025	20/20	NA	841000	1918667	N/A	N/A	N/A	No	NUT, BKG
7439-96-5	Manganese	5.3		840		µg/L	PAI-03-SW-027	19/20	0.4	840	53.1	50 (7)	N/A	N/A	Yes	ASL
7487-94-7	Mercury	0.15		0.15		µg/L	PAI-03-SW-027	1/20	0.1	0.15	ND	0.05	N/A	N/A	No	IFD
7440-02-0	Nickel	39.8		39.8		µg/L	PAI-03-SW-027	1/20	1	39.8	ND	610	N/A	N/A	No	BSL, IFD
	Potassium	146000		478000		µg/L	PAI-03-SW-014	20/20	NA	478000	831333	N/A	N/A	N/A	No	NUT, BKG
7440-22-4	Silver	0.68		2.1		µg/L	PAI-03-SW-021-AVG	4/20	0.6 - 0.7	2.1	ND	18 (5)	N/A	N/A	No	BSL
7440-23-5	Sodium	1950000		6820000		µg/L	PAI-03-SW-025	20/20	NA	6820000	16226667	N/A	N/A	N/A	No	NUT, BKG
7440-62-2	Vanadium	269		269		µg/L	PAI-03-SW-027	1/20	0.5 - 6.1	269	18.2	26 (5)	N/A	N/A	No	IFD
7440-66-6	Zinc	12.7		294		µg/L	PAI-03-SW-027	4/20	1.9 - 8.3	294	10.6	9100	N/A	N/A	No	BSL

TABLE 6-4

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH SURFACE WATER
SITE 3- CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	Screening[3] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	INORGANICS (FILTERED)															
7429-90-5	Aluminum	323		650		µg/L	PAI-03-SW-025-F	2/20	22.7 - 120	650	ND	3700 (5)	N/A	N/A	No	BSL
7440-36-0	Antimony	1.8		4.2		µg/L	PAI-03-SW-019-F	4/20	1.7 - 4.9	4.2	ND	14	N/A	N/A	No	BSL
7440-38-2	Arsenic	2.3		12.9		µg/L	PAI-03-SW-027-F	2/20	1.5 - 3.5	12.9	4.27	0.018	N/A	N/A	Yes	ASL
7440-39-3	Barium	15		279		µg/L	PAI-03-SW-028-F	20/20	NA	279	256	1000 (7)	N/A	N/A	No	BSL
7440-70-2	Calcium	137000		282000		µg/L	PAI-03-SW-025-F	20/20	NA	282000	645334	N/A	N/A	N/A	No	NUT, BKG
7440-50-8	Copper	1		1.7		µg/L	PAI-03-SW-011-F	3/20	1.2 - 7.5	1.7	13.1	1300	N/A	N/A	No	BSL, BKG
7439-89-6	Iron	175		549		µg/L	PAI-03-SW-025-F	2/20	16.6 - 93.8	549	18.3	300 (7)	N/A	N/A	Yes	ASL
7439-95-4	Magnesium	249000		843000		µg/L	PAI-03-SW-025-F	20/20	NA	843000	1918000	N/A	N/A	N/A	No	NUT, BKG
7439-96-5	Manganese	7.4		156		µg/L	PAI-03-SW-028-F	15/20	0.4 - 1.9	156	18.5	50 (7)	N/A	N/A	Yes	ASL
	Potassium	159000		495000		µg/L	PAI-03-SW-009-F	20/20	NA	495000	890667	N/A	N/A	N/A	No	NUT, BKG
7440-22-4	Silver	0.71		0.71		µg/L	PAI-03-SW-013-F	1/20	0.6 - 0.7	0.71	ND	18 (5)	N/A	N/A	No	BSL
7440-23-5	Sodium	2110000		6970000		µg/L	PAI-03-SW-022-F	20/20	NA	6970000	15986667	N/A	N/A	N/A	No	NUT, BKG
7440-62-2	Vanadium	11		11		µg/L	PAI-03-SW-027-F	1/20	0.5 - 1.9	11	14.7	26 (5)	N/A	N/A	No	BSL, BKG, IFD
7440-66-6	Zinc	25.2		84.8		µg/L	PAI-03-SW-012-F	18/20	3.5 - 15.4	84.8	67.7	9100	N/A	N/A	No	BSL

Notes:

1 Minimum/maximum detected concentration.

2 N/A - Refer to supporting information for background discussion.
Background values derived from statistical analysis. Follow Regional guidance and provide supporting information.

3 Criteria as published in 40CFR 131.36 unless otherwise noted.

4 Rationale Codes Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Infrequent Detection (IFD)
No Toxicity Information (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

5 Water quality criteria not available EPA Region III RBC for tap water ingestion used (Cancere benchmark value = 1E-6, HI = 0.1).

6 Value is for naphthalene.

7 Recalculated values in "Water Quality Criteria Summary Concentrations", 12/96.

Chemicals retained as COPCs are shaded.

Definitions:
N/A = Not Applicable
SQL = Sample Quantitation Limit
COPC = Chemical of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
MCL = Federal Maximum Contaminant Level
SMCL = Secondary Maximum Contaminant Level
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

TABLE 6-5

OCCURRENCE, DISTRIBUTION AND SELECTIONOF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH SEDIMENT
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	EPA[3] Region III Value		Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	VOCs																
78-93-3	2-Butanone	8		61		ug/kg	PAI-03-SD-014-01	6/17	6 - 37	61	N/A	4700000	N	N/A	N/A	No	BSL
67-64-1	Acetone	150	J	170	J	ug/kg	PAI-03-SD-026-01	2/6	39 - 100	170	N/A	780000	N	N/A	N/A	No	BSL
75-15-0	Carbon Disulfide	3	J	40	J	ug/kg	PAI-03-SD-014-01	6/21	6 - 37	40	N/A	780000	N	N/A	N/A	No	BSL
67-66-3	Chloroform	1	J	1	J	ug/kg	PAI-03-SD-016-01	2/21	8 - 38	1	N/A	100000	C	N/A	N/A	No	BSL
	SVOCs																
120-12-7	Anthracene	3.7		770		ug/kg	PAI-03-SD-022-01	4/21	2.3 - 260	770	N/A	2300000	N	N/A	N/A	No	BSL
56-55-3	Benzo(a)anthracene	5.1	J	1200		ug/kg	PAI-03-SD-022-01	6/21	5.7 - 650	1200	N/A	870	C	N/A	N/A	Yes	ASL
50-32-8	Benzo(a)pyrene	8.1		1200		ug/kg	PAI-03-SD-022-01	6/21	5.7 - 650	1200	N/A	87	C	N/A	N/A	Yes	ASL
205-99-2	Benzo(b)fluoranthene	1.8	J	990		ug/kg	PAI-03-SD-022-01	13/21	23 - 260	990	N/A	870	C	N/A	N/A	Yes	ASL
191-24-2	Benzo(g,h,i)perylene	24		570		ug/kg	PAI-03-SD-022-01	2/21	9.2 - 1000	570	N/A	160000 (5)	N	N/A	N/A	No	BSL
207-08-9	Benzo(k)fluoranthene	3		420		ug/kg	PAI-03-SD-022-01	5/21	2.3 - 260	420	N/A	8700	C	N/A	N/A	Yes	cPAH
86-74-8	Carbazole	570		570		ug/kg	PAI-03-SD-022-01	1/21	440 - 1600	570	N/A	32000	C	N/A	N/A	No	BSL, IFD
218-01-9	Chrysene	3.2	J	1900		ug/kg	PAI-03-SD-022-01	13/21	60 - 650	1900	N/A	87000	C	N/A	N/A	Yes	cPAH
132-64-9	Dibenzofuran	190	J	190	J	ug/kg	PAI-03-SD-022-01	1/21	440 - 1600	190	N/A	31000	N	N/A	N/A	No	BSL, IFD
206-44-0	Fluoranthene	15		3500		ug/kg	PAI-03-SD-022-01	9/21	5.7 - 650	3500	N/A	310000	N	N/A	N/A	No	BSL
86-73-7	Fluorene	13		13		ug/kg	PAI-03-SD-027-01	1/21	11 - 1300	13	N/A	310000	N	N/A	N/A	No	BSL, IFD
193-39-5	Indeno(1,2,3-cd)pyrene	5.8	J	660		ug/kg	PAI-03-SD-022-01	6/21	5.7 - 650	660	N/A	870	C	N/A	N/A	Yes	cPAH
85-01-8	Phenanthrene	5.8		2400		ug/kg	PAI-03-SD-022-01	9/21	4.6 - 520	2400	N/A	160000 (5)	N	N/A	N/A	No	BSL
129-00-0	Pyrene	11	J	2700		ug/kg	PAI-03-SD-022-01	8/21	11 - 1300	2700	N/A	230000	N	N/A	N/A	No	BSL
	PESTICIDES/PCBs																
72-54-8	4,4'-DDD	40	J	290		ug/kg	PAI-03-SD-014-01	2/21	2.3 - 140	290	N/A	2700	C	N/A	N/A	No	BSL
72-55-9	4,4'-DDE	45	J	45	J	ug/kg	PAI-03-SD-014-01	1/21	2.3 - 140	45	N/A	1900	C	N/A	N/A	No	BSL, IFD
50-29-3	4,4'-DDT	34	J	34	J	ug/kg	PAI-03-SD-021-01	1/21	2.3 - 140	34	N/A	1900	C	N/A	N/A	No	BSL, IFD
5103-71-9	alpha-Chlordane	28	J	28	J	ug/kg	PAI-03-SD-028-01	1/21	1.1 - 1400	28	N/A	1800	C	N/A	N/A	No	BSL, IFD
11097-69-1	Aroclor-1254	65		250		ug/kg	PAI-03-SD-020-01	3/21	11 - 40	250	N/A	320	C	N/A	N/A	No	BSL
11096-82-5	Aroclor-1260	45		70		ug/kg	PAI-03-SD-015-01	2/21	11 - 40	70	N/A	320	C	N/A	N/A	No	BSL
	Gamma-Chlordane	28	J	28	J	ug/kg	PAI-03-SD-028-01	1/21	1.1 - 1400	28	N/A	1800	C	N/A	N/A	No	BSL, IFD
	INORGANICS																
7429-90-5	Aluminum	1510		29700		mg/kg	PAI-03-SD-026-01	21/21	NA	29700	24284	7800	N	N/A	N/A	Yes	ASL
7440-36-0	Antimony	0.34	J	0.74	J	mg/kg	PAI-03-SD-014-01	3/21	0.19 - 0.66	0.74	ND	3.1	N	N/A	N/A	No	BSL
7440-38-2	Arsenic	2.3		19.8		mg/kg	PAI-03-SD-024-01	16/21	0.22 - 0.97	19.8	12.2	0.43	C	N/A	N/A	Yes	ASL
7440-39-3	Barium	3.6		53.8		mg/kg	PAI-03-SD-022-01	16/21	17 - 36.2	53.8	28.0	550	N	N/A	N/A	No	BSL
7440-41-7	Beryllium	0.29		1.4		mg/kg	PAI-03-SD-026-01	11/21	0.02 - 0.46	1.4	0.977	16	N	N/A	N/A	No	BSL
7440-43-9	Cadmium	0.12		0.44		mg/kg	PAI-03-SD-010-01	10/21	0.03 - 0.12	0.44	0.278	7.8	N	N/A	N/A	No	BSL
	Calcium	408		32800		mg/kg	PAI-03-SD-010-01	21/21	NA	32800	4002	N/A		N/A	N/A	No	NUT
7440-47-3	Chromium	3.3		50.3		mg/kg	PAI-03-SD-026-01	21/21	NA	50.3	35.2	12000 (6)	N	N/A	N/A	No	BSL
7440-48-4	Cobalt	0.11		5.6		mg/kg	PAI-03-SD-026-01	19/21	0.07	5.6	2.63	470	N	N/A	N/A	No	BSL
7440-50-8	Copper	1.8		46.9		mg/kg	PAI-03-SD-020-01	21/21	NA	46.9	10.1	310	N	N/A	N/A	No	BSL

TABLE 6-5

OCCURRENCE, DISTRIBUTION AND SELECTIONOF CHEMICALS OF POTENTIAL CONCERN
DIRECT CONTACT WITH SEDIMENT
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

CAS Number	Chemical	Minimum[1] Concentration	Minimum Qualifier	Maximum[1] Concentration	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background[2] Value	EPA[3] Region III Value		Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
7439-89-6	Iron	1100		28000		mg/kg	PAI-03-SD-024-01	21/21	NA	28000	21450	2300	N	N/A	N/A	Yes	ASL
7439-92-1	Lead	6.4		105		mg/kg	PAI-03-SD-017-01	21/21	NA	105	20.6	400 (7)		N/A	N/A	No	BSL
7439-95-4	Magnesium	267		6710		mg/kg	PAI-03-SD-023-01	21/21	NA	6710	6437	N/A		N/A	N/A	No	NUT
7439-96-5	Manganese	9.7		205		mg/kg	PAI-03-SD-026-01	21/21	NA	205	186	1100	N	N/A	N/A	No	BSL
7487-94-7	Mercury	0.05		0.35		mg/kg	PAI-03-SD-028-01	6/21	0.02 - 0.09	0.35	0.09	2.3 (8)	N	N/A	N/A	No	BSL
7440-02-0	Nickel	0.42		13.9		mg/kg	PAI-03-SD-020-01	19/21	0.12 - 0.81	13.9	5.95	160	N	N/A	N/A	No	BSL
	Potassium	170		4570		mg/kg	PAI-03-SD-026-01	21/21	NA	4570	3190	N/A		N/A	N/A	No	NUT
7782-49-2	Selenium	0.32		1.1		mg/kg	PAI-03-SD-028-01	7/21	0.19 - 1	1.1	ND	39	N	N/A	N/A	No	BSL
7440-22-4	Silver	0.13		0.13		mg/kg	PAI-03-SD-020-01	1/21	0.07 - 0.23	0.13	ND	39	N	N/A	N/A	No	BSL, IFD
7440-23-5	Sodium	377		26600		mg/kg	PAI-03-SD-023-01	20/21	1960	26600	19110	N/A		N/A	N/A	No	NUT
7440-28-0	Thallium	0.62		0.62		mg/kg	PAI-03-SD-027-01	1/21	0.18 - 0.89	0.62	0.405	0.55	N	N/A	N/A	No	IFD
7440-62-2	Vanadium	2.6		63.7		mg/kg	PAI-03-SD-026-01	21/21	NA	63.7	49.6	55	N	N/A	N/A	Yes	ASL
7440-66-6	Zinc	5.2		159		mg/kg	PAI-03-SD-020-01	21/21	NA	159	45.0	2300	N	N/A	N/A	No	BSL
57-12-5	Cyanide	0.71		0.71		mg/kg	PAI-03-SD-018-01	1/21	0.44 - 1.8	0.71	N/A	160	N	N/A	N/A	No	BSL, IFD

1 Minimum/maximum detected concentration.

2 N/A - Refer to supporting information for background discussion.
Background values derived from statistical analysis. Follow Regional guidance and provide supporting information.

3 USEPA Region III Risk-Based Concentration Table, April 12, 1999. (Cancer benchmark value = 1E-06, HI = 0.1)

4 Rationale Codes Selection Reason:
- Above Screening Levels (ASL)
- Retained because other carcinogenic PAHs exceed screenig criteria (cPAH)

Deletion Reason:
- Infrequent Detection (IFD)
- No Toxicity Information (NTX)
- Essential Nutrient (NUT)
- Below Screening Level (BSL)

5 No RBC available, naphthalene is used as a surrogate based on similar chemical structures.

6 Hexavalent chromium was not detected in sediment therefore chromium is evaluated as trivalent chromium.

7 OSWER screening level.

8 Value for mercuric chloride.

Chemicals retained as COPCs are shaded.

Definitions:
- N/A = Not Applicable
- SQL = Sample Quantitation Limit
- COPC = Chemical of Potential Concern
- ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
- J = Estimated Value
- C = Carcinogenic
- N = Non-Carcinogenic

In accordance with U.S. EPA Region IV guidance, since several carcinogenic PAHs have maximum concentrations exceeding the screening criteria, all carcinogenic PAHS will be retained as COPCs for sediment.

6.1.2.6 Fish Tissue

Finfish and shellfish commonly harvested in the area at Site 3 were sampled as part of the 1991 EIS, and the results were compared to USFDA action levels and U.S. EPA Region III RBCs for ingestion of fish (Table 6-6). All detected concentrations were below USFDA action levels. However, concentrations of dieldrin in mullets and crabs, DDE in flounders, heptachlor expoxide in crabs, mercury in flounders and crabs, and Aroclor 1254 in flounders, mullets, and oysters exceeded the screening criteria for ingestion of fish. Therefore, dieldrin, DDE, heptachlor expoxide, mercury, and Aroclor 1254 were retained as COPCs.

As part of the ecological risk assessment presented in Section 7.0 of this report, concentrations of chemicals in fish tissue were also estimated from sediment and surface water samples collected during the 1998 field investigation. A comparison of the estimated fish tissue concentrations with USFDA action levels and U.S. EPA Region III RBCs is presented in Table 6-7. All estimated fish tissue concentrations were below USFDA action levels. However, the following chemicals had calculated concentrations in fish tissue that exceeded the risk-based COPC screening levels.

- PAHs [benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene]
- SVOCs (carbazole)
- Pesticides/PCBs (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, alpha-chlordane, gamma-chlordane, Aroclor 1254, and Aroclor 1260)
- Inorganics (arsenic, copper, and mercury)

In accordance with U.S. EPA Region IV guidance, since several carcinogenic PAHs have estimated fish tissue concentrations exceeding the screening criteria, all carcinogenic PAHs will be retained as COPCs for fish tissue.

Table 6-8 presents a summary of the chemicals retained as COPCs in surface soil, groundwater, sediment, surface water, and fish at Site 3.

6.2 EXPOSURE ASSESSMENT

The exposure assessment defines and evaluates the exposures experienced by likely receptor populations at a site. In order to have an exposure, several factors must be present: a source and mechanism of release; a route of contaminant transport through an environmental medium; a contact

TABLE 6-6

1991 DATA COMPARISON WITH USFDA ACTION LEVELS AND EPA REGION III SCREENING LEVELS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Concentration in Species[1,2]										USFDA Action Level	EPA Region III Screening Levels[3] Fish	COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	Flounder		Mullet		Crab		Clam		Oyster					
	Pond	Tidal	Pond	Tidal	Pond	Tidal	Pond	Tidal	Pond	Tidal				
Aldrin	-	-	0.17	0.17	-	-	-	-	-	-	300	0.19 C	No	BSL
Dieldrin	-	-	0.43	0.57	0.43	0.98	-	0.094	-	-	300	**0.2** C	**Yes**	ASL
Chlordane	0.53	-	1.2	1.3	0.57	0.52	-	0.18	0.99	0.4	300	9 C	No	BSL
DDT (2,4)	-	-	0.21	0.21	-	-	-	0.0696	0.29	-	5000	9.3 C	No	BSL
DDT (4,4)	-	-	0.98	1.1	-	-	-	0.32	-	-	5000	9.3 C	No	BSL
DDE (2,4)	0.53	-	0.095	0.31	0.2	-	-	0.11	0.565	0.29	5000	9.3 C	No	BSL
DDE (4,4)	24	1.3	45	25	18	14	-	0.41	15.7	3.1	5000	**9.3** C	**Yes**	ASL
DDD (2,4)	-	-	0.26	0.27	-	-	-	0.088	-	-	5000	13 C	No	BSL
DDD (4,4)	7.4	0.25	7.1	6.6	8.5	2.5	-	0.0936	7.5	0.97	5000	13 C	No	BSL
Endrin	-	-	0.88	0.89	-	-	-	-	-	-	300	41 N	No	BSL
Heptachlor	-	-	0.38	0.38	-	-	-	-	-	-	300	0.7 C	No	BSL
Heptachlor epoxide	-	-	0.14	0.14	0.38	0.95	-	-	-	-	300	**0.35** C	**Yes**	ASL
Mercury	66	58	5.6	7.8	28	59	-	8.2	13	9.6	1000	**41 (5)** N	**Yes**	ASL
Mirex	1.5	0.4	2.3	1.1	1.4	1.1	-	-	0.469	0.14	100	27 N	No	BSL
Aroclor 1254	54	2.1	59	47	-	-	-	-	58	-	2000	**1.6** C	**Yes**	ASL

Notes
All units in ug/kg
1 - Data from Extended Site Inspection (ABB Environmental Services, Inc. August 1993).
2 - Concentrations are reported as mean wet weight plus one standard error.
3 - USEPA Region III Risk-Based Concentration Table, October 1, 1998. (Cancer benchmark value = 1E-06, HI = 0.1)
4 - Rationale Codes Selection Reason: Above Screening Levels (ASL)
Deletion Reason: Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)
5 - Value for mercuric chloride.

Chemicals retained as COPCs are shaded.

Definitions: USFDA - U.S. Food and Drug Administration
DDT - dichlorophenyl trichloroethane
DDE - dichlorophenyl dichloroethylene
DDD - dichlorophenyl dichloroethane
C - carcinogenic
N - noncarcinogenic
RBC - Risk-Based Concentration

TABLE 6-7

COMPARISON OF CALCULATED FISH TISSUE CONCENTRATIONS (1998) USFDA ACTION LEVELS AND EPA REGION III SCREENING LEVELS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Chemical Concentration	Sediment/Surface Water Concentration[1]		Calculated Fish Tissue Concentration[2]		USFDA Action Level	EPA Region III Screening Level[3] Fish		COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	Maximum Concentration	Average Concentration	Maximum Concentration	Average Concentration					
SEMIVOLATILE ORGANIC COMPOUNDS (mg/kg)									
Anthracene	0.77	0.055	0.160	0.011	N/A	41	N	No	BSL
Benzo(a)anthracene	1.2	0.141	0.249	0.029	N/A	**0.0043**	C	**Yes**	ASL
Benzo(a)pyrene	1.2	0.106	0.249	0.022	N/A	**0.00043**	C	**Yes**	ASL
Benzo(b)fluoranthene	0.99	0.073	0.205	0.015	N/A	**0.0043**	C	**Yes**	ASL
Carbazole	0.57	0.409	0.407	0.292	N/A	**0.16**	C	**Yes**	ASL
Chrysene	1.9	0.148	0.394	0.031	N/A	**0.43**	C	**Yes**	cPAH
Dibenzofuran	0.19	0.391	0.136	0.279	N/A	0.54	N	No	BSL
Fluoranthene	3.5	0.225	0.725	0.047	N/A	5.4	N	No	BSL
Indeno(1,2,3-cd)pyrene	0.66	0.078	0.137	0.016	N/A	**0.0043**	C	**Yes**	ASL
Phenanthrene	2.4	0.153	1.71	0.109	N/A	2.7 (5)	N	No	BSL
Pyrene	2.7	0.225	0.559	0.047	N/A	4.1	N	No	BSL
PESTICIDES/PCBs (mg/kg)									
4,4'-DDD	0.29	0.041	0.058	0.008	5	**0.013**	C	**Yes**	ASL
4,4'-DDE	0.045	0.029	0.248	0.161	5	**0.0093**	C	**Yes**	ASL
4,4'-DDT	0.034	0.029	0.041	0.035	5	**0.0093**	C	**Yes**	ASL
alpha-chlordane	0.028	0.146	0.095	0.497	0.3	**0.009 (6)**	C	**Yes**	ASL
gamma-chlordane	0.028	0.146	0.044	0.231	0.3	**0.009 (6)**	C	**Yes**	ASL
Aroclor-1254	0.25	0.028	0.330	0.038	2	**0.0016**	C	**Yes**	ASL
Aroclor-1260	0.07	0.015	0.093	0.019	2	**0.0016**	C	**Yes**	ASL
INORGANICS (mg/kg)									
Aluminum	88.6	5.36	NC	NC	N/A	140	N	No	BSL
Arsenic	0.096	0.006	1.634	0.098	76	**0.0021**	C	**Yes**	ASL
Barium	0.279	0.029	NC	NC	N/A	9.5	N	No	BSL
Beryllium	0.004	0.0003	0.084	0.006	N/A	0.27	N	No	BSL
Chromium	0.164	0.009	2.62	0.138	12	200	N	No	BSL
Cobalt	0.021	0.001	NC	NC	N/A	8.1	N	No	BSL
Copper	0.152	0.010	5.47	0.347	N/A	**5.4**	N	**Yes**	ASL
Iron	110	6.11	NC	NC	N/A	41	N	No	BSL
Lead	0.132	0.009	0.528	0.036	1.5	N/A		No	NTX
Manganese	0.84	0.076	NC	NC	N/A	2.7	N	No	BSL
Mercury	0.00015	0.0001	0.564	0.207	N/A	**0.041(7)**	N	**Yes**	ASL
Nickel	0.040	0.002	1.87	0.116	70	2.7	N	No	BSL

TABLE 6-7

COMPARISON OF CALCULATED FISH TISSUE CONCENTRATIONS (1998) USFDA ACTION LEVELS AND EPA REGION III SCREENING LEVELS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Chemical Concentration	Sediment/Surface Water Concentration[1]		Calculated Fish Tissue Concentration[2]		USFDA Action Level	EPA Region III Screening Level[3] Fish		COPC Flag	Rationale for[4] Contaminant Deletion or Selection
	Maximum Concentration	Average Concentration	Maximum Concentration	Average Concentration					
Vanadium	0.269	0.015	NC	NC	N/A	0.95	N	No	BSL
Zinc	0.294	0.022	13.8	1.019	N/A	41	N	No	BSL
Antimony	0.004	0.001	0.004	0.001	N/A	0.54	N	No	BSL
Silver	0.002	0.0005	0.001	0.0002	N/A	0.68	N	No	BSL

Notes:

1 - Sediment concentrations used for organics, pesticides, surface water concentrations used for inorganics.
2 - See Section 7 for calculation of fish tissue concentrations.
3 - USEPA Region III Risk-Based Concentration Table, April 12, 1999. (Cancer benchmark value = 1E-06, HI = 0.1)
4 - Rationale Codes Selection Reason: Above Screening Levels (ASL)
Retained because other carcinogenic PAHs exceed screenig criteria (cPAH)
Deletion Reason: No Toxicity Information (NTX)
Below Screening Level (BSL)
5 - Value for naphthalene.
6 - Value for chlorodane.
7 - Value is for methyl mercury.
NC - Not calculated, no BCF available.
N/A - No USFDA or EPA Region III RBC available.

Chemicals retained as COPCs are shaded.

TABLE 6-8

CHEMICALS RETAINED AS HUMAN HEALTH COPCs
SITE 3- CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Surface Soil	Soil to Air	Soil to Groundwater	Groundwater	Sediment	Surface Water	Fish Tissue(1)	Fish Tissue(2)
VOCs								
Benzene				X				
Chlorobenzene				X				
Chloroform				X				
SVOCs								
1,4-Dichlorobenzene				X				
4-Methylphenol				X				
Benzo(a)anthracene	X		X		X			X
Benzo(a)pyrene	X				X	X		X
Benzo(b)fluoranthene	X				X	X		X
Benzo(k)fluoranthene						X		
Bis(2-ethylhexyl)phthalate						X		
Carbazole			X					X
Chrysene						X		
Indeno(1,2,3-cd)pyrene	X					X		X
PESTICIDES/PCBS								
alpha-BHC				X				
alpha-chlordane								X
gamma-chlordance								X
Aroclor-1254							X	X
Aroclor-1260								X
Dieldrin							X	
DDD								X
DDE							X	X
DDT								X
Heptachlor Epoxide							X	
INORGANICS								
Aluminum	X				X	X		
Arsenic	X			X	X	X		X
Barium				X				
Coppper								X
Iron	X			X	X	X		
Manganese				X		X		
Mercury							X	X
Thallium				X				
Vanadium					X			

Notes
X - Indicates chemical was retained as a COPC.
1 - Based on fish tissue samples from Extended Site Inspection (ABB Environmental Services, Inc., August, 1993).
2 - Based on calculated concentrations of chemicals in fish tissue from ecological risk assessment.

point for a human receptor; and an exposure route at the point of contact. All four components must be present for the exposures to occur.

The exposure assessment presented in this section of the report consists of several subsections that characterize the physical site setting and the potential receptors of concern, identify the potential contaminant migration and exposure pathways, define the contaminant concentrations at the point of exposure, and present the equations used to quantify exposure in terms of contaminant intake (dose). Appendix E-1 of this report contains sample calculations for the quantification of contaminant intakes, as well as the chemical-specific intakes for Site 3.

6.2.1 Exposure Setting

There is no development in close proximity to MCRD Parris Island, because it is an island. The surrounding areas are estuarine, however, and support considerable commercial and recreational fishing, boating, and water recreation. The mainland closest to Parris Island is developed as a residential area. Hilton Head, a major recreational area, is located approximately 3 miles southwest of Parris Island, across Port Royal Sound.

Because it is an island, MCRD Parris Island has a single point of access for vehicular traffic. Military police stationed at the entrance currently monitor incoming traffic, stopping those without official stickers.

Site 3 is an integral part of a causeway connecting Horse Island and Parris Island, in the north section of MCRD Parris Island. The causeway is a gravel, two-lane road, consisting of alternate layers of solid waste and fill dirt constructed along a tidal marsh of the Broad River. At two locations along the causeway, three concrete pipes are buried beneath the causeway to allow tidal movement between the surface water bodies separated by the unit.

6.2.2 Conceptual Site Model

This section discusses the conceptual site model for Site 3. A conceptual site model facilitates consistent and comprehensive evaluation of the potential risks to human health by creating a framework for identifying the pathways by which human receptors may come in contact with contaminated media resulting from the source area. A conceptual site model depicts the relationships among the following elements that are necessary for defining complete exposure pathways:

- Site sources of contamination
- COPCs in environmental media
- Contaminant release mechanisms

- Contaminant transport pathways
- Exposure mechanisms and exposure routes
- Potential receptors

The conceptual site model for Site 3 is provided in Figure 6-2. The sources of contamination at the site are the wastes disposed within the causeway. Contaminants may be released from the causeway by mechanisms such as stormwater runoff and subsequent erosion of surface soil; leaching of COPCs from soil via infiltrating water to subsurface soil and subsequent migration through the subsurface soil to the water table; wind erosion of surface soil (fugitive dust); and volatilization of chemicals from soil (volatile emissions).

Storms generate runoff, which is directed toward the surrounding surface water. Initially, this water may move across the causeway as sheet flow, which can entrain loose soil material. This soil is moved from the site as a sediment and will be deposited where the flow velocity diminishes below that needed to carry a particular grain size.

Soluble chemicals may also migrate downward through the soil column via infiltrating precipitation. The migration of these chemicals may be somewhat impeded by the chemical's tendency to bind to soil organic material. However, these soluble chemicals may eventually reach the water table. Once in the groundwater, these chemicals continue to migrate via dispersion and advection.

Chemicals adsorbed to surface soil may also be released from a site via wind erosion of loose soil material. These particulates are carried downwind and potentially off site if the grain size is small enough and the wind velocity is great enough. Additionally, chemicals may also be released from soil via volatilization.

Once released from the source, contaminants are transported in media such as soil, groundwater, surface water, sediment, or air. Potential receptors may be exposed either directly or indirectly to contaminants in these media by a variety of exposure mechanisms, such as direct contact and immersion. Typically, several exposure routes (ingestion, dermal contact, inhalation, etc.) are associated with a particular exposure mechanism.

The conceptual site model presented in Figure 6-2 also indicates those exposure routes that are carried through the quantitative risk assessment for each potential receptor. An objective of the development of the conceptual site model, as well as the baseline human health risk assessment, is to focus attention on those pathways that contribute the most to the potential impacts on human health and the environment

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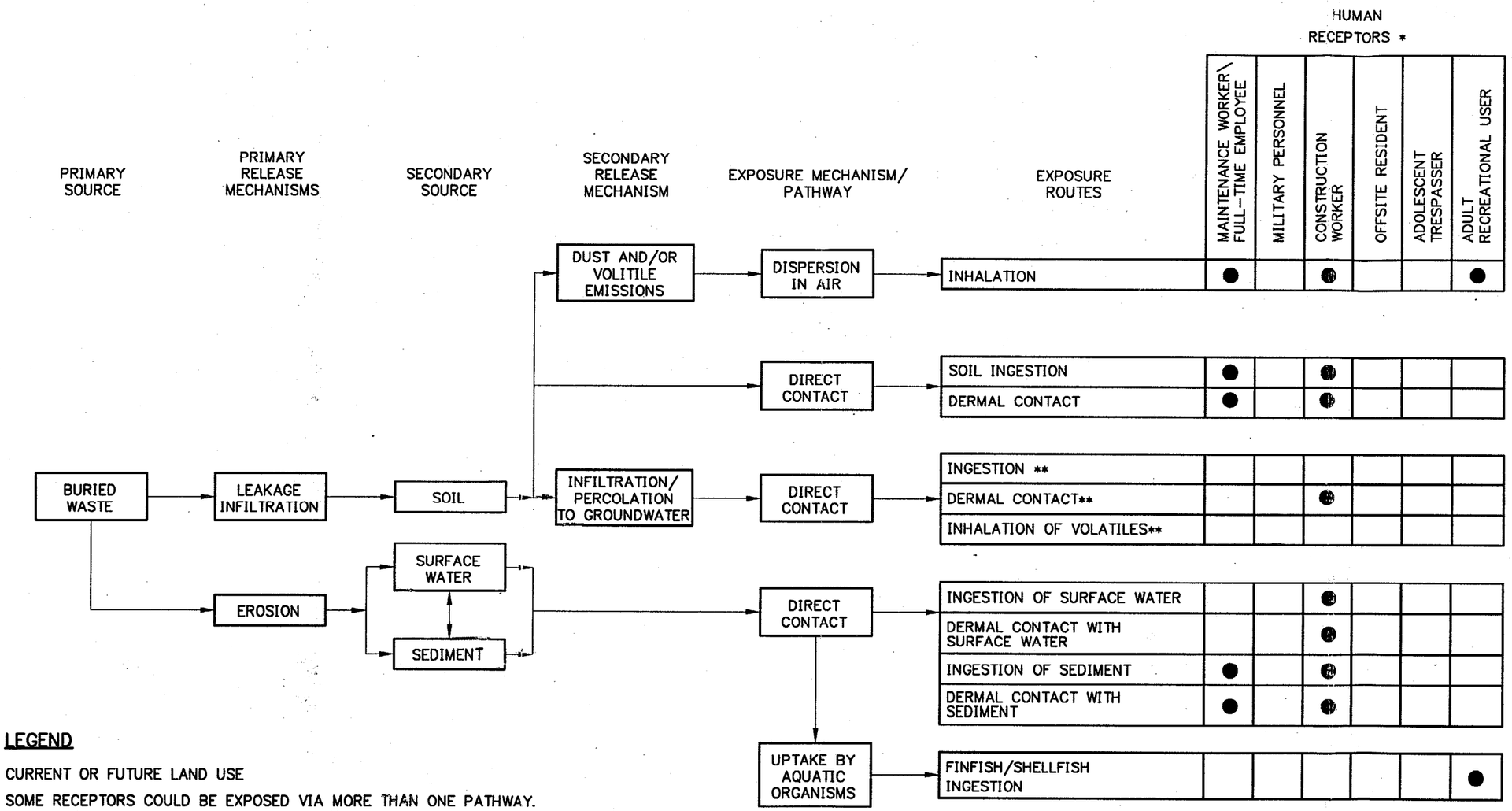

LEGEND

● CURRENT OR FUTURE LAND USE

* SOME RECEPTORS COULD BE EXPOSED VIA MORE THAN ONE PATHWAY.

** THE ONLY CURRENT ANTICIPATED EXPOSURE TO GROUNDWATER IS DURING EXCAVATION. INTENTIONAL USE OF GROUNDWATER IS ASSUMED AS A POTENTIAL PATHWAY TO RESIDENTS UNLESS SUSPECTED POOR QUALITY AND LIMITED MIGRATION IS CONFIRMED DURING SAMPLING.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY KW DATE 1/21/99
CHECKED BY DATE
COST/SCHED-AREA
SCALE N.T.S.

CONCEPTUAL SITE MODEL
SITE 3-CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 7394
APPROVED BY DATE
APPROVED BY DATE
DRAWING NO. FIGURE 6-2
REV. 0

FORM CADD NO. SDV_BH12.DGN - REV 0 - 1/20/98

and to provide the rationale for eliminating other exposure pathways that are considered to be minor components of the overall risk.

6.2.3 Potential Exposure Pathways

Potential receptors can come into contact with contaminants in a variety of ways, which are generally the result of interactions between a receptor's behavior or lifestyle and an exposure medium. This assessment defines an exposure route as a stylized description of the behavior that brings a receptor into contact with a contaminated medium.

6.2.3.1 Air

This pathway is based on the scenario that a receptor is immersed in air that contains suspended particulates and/or volatile organic vapors originating from the source area. Subsequent exposure of the receptor occurs upon inhalation of the ambient air.

A qualitative comparison of maximum detected concentrations in surface soil at Site 3 to U.S. EPA SSLs, based on intermedia transfer (from soil to air), was performed to determine if additional quantitative analysis of this potential exposure pathway was warranted. The SSLs are based on residential land use and lifetime exposure scenarios and are, therefore, conservative values for potential receptors under current and future land use conditions. Exposures to fugitive dust and VOCs released from soil were found to be relatively insignificant, based on the qualitative screening. This screening is summarized in Table 6-2. Maximum detections of all chemicals in surface soil were less than the SSLs; therefore, exposure via the inhalation pathway is considered to be minimal and was not considered for further evaluation.

6.2.3.2 Direct Contact with Soil and Sediment

Potential receptors may come into direct contact with surface soil and sediment, which may be affected by the release of chemicals from the source area. During the receptor's period of contact, the individual may be exposed via incidental ingestion of a surface soil and sediment or via dermal absorption of contaminants from surface soil and sediment.

Dermal contact with chemicals detected in the site surface soil and sediment may or may not result in a significant exposure. For these chemicals to be percutaneously absorbed, they must first desorb from soil and diffuse through the skin. Various factors affect the rate of dermal absorption, including the amount of soil on the skin surface, soil characteristics (moisture, pH, organic carbon content, etc.), skin characteristics (thickness, temperature, hydration, etc.), volatilization losses, and chemical-specific

properties. Dermal exposures to chemicals in soil and sediment are evaluated quantitatively in the baseline risk assessment.

Potential exposure to sediment is expected to be less than potential exposure to surface soil. Receptors may come into direct contact with sediment in the marshy areas of the site, although this is not considered likely because of the presence of alligators in the area.

6.2.3.3 Direct Contact with Groundwater

Human receptors using groundwater as a potable water supply may be exposed to groundwater via ingestion, dermal contact, and inhalation. Groundwater is not currently used as a potable water supply at the site nor is it expected to be used in the future as a potable water supply. This scenario is based on the configuration of the site, the high TDS of the groundwater, and the current and future use of the site as a landfill, and the relative absence of toxic constituents. The site is approximately 5,000 feet long and 100 feet wide, with a 20-foot wide road running down the middle. In addition, above ground and underground utilities are located on the sides of the road. As a result, these features would effectively preclude the installation of potable water supply wells. Secondly, the TDS of the groundwater averages greater than 10,000 mg/l. The high TDS results from a salt-water pond on one side, a salt-water marsh on the other side, and a limited precipitation infiltration area. Attempts to pump water from this area would be more likely to draw from the abundant supply of salt water from either side of the causeway than from accumulated precipitation infiltration. Thirdly the causeway is a landfill. Under future scenario's considered for the causeway, restrictions would be placed to prevent the installation of wells for this purpose. Finally, with the exception of minor exceedances of benzene, chlorobenzene, and thallium in one well each, Federal and state MCLs are not exceeded in the site groundwater. In addition, there are no off-site residents located downgradient in the immediate vicinity of the site who might use groundwater as a potable water supply. Construction workers may have dermal contact groundwater if excavation below the water table occurs.

6.2.3.4 Direct Contact with Surface Water

Receptors may come into direct contact with surface water in the pond or marshy areas of the site. These surface waters may contain contaminants in a dissolved phase. Individuals may be exposed via dermal contact and/or incidental ingestion. Exposure to surface water at Site 3 is expected to be limited due to the presence of alligators in area.

6.2.3.5 Ingestion of Fish

Military personnel stationed at Parris Island harvest fin and shell fish at Site 3. Receptors ingesting fish caught in the area may be exposed to COPCs that have bioaccumulated in fish tissue.

6.2.4 Potential Receptors

Potential receptors were identified for both current and future land use conditions. The receptors were identified by analyzing the interaction of current land use practices and the identified sources of contamination. These receptors are as follows:

- Individuals (**construction workers**) who may contact surface and subsurface soils while excavating will be evaluated for exposure to surface soil and surface water/sediment. Dermal exposure to shallow groundwater may also be possible for this receptor. It will be assumed that the construction worker is exposed to surface soil 6 months over a 1-year period and would be engaged in activities where there could be exposure to groundwater, surface water, and sediment 1 month out of the year.

- **Maintenance workers** may be exposed to site media while performing maintenance activities (e.g., mowing, landscaping). The maintenance worker is assumed to be different receptor than the military personnel receptor. The maintenance worker is assumed to be a long-term, civilian employee at the site who is engaged exclusively in maintenance activities, whereas the military personnel is assumed to be an instructor or a trainee. The U.S. EPA default value is used for the exposure duration for the maintenance worker. Although it is possible for military personnel to perform maintenance activities, the exposure duration for military personnel (three to six years) is less than the exposure duration for the maintenance worker (25 years), therefore the maintenance worker is a more conservative scenario. The maintenance worker will be evaluated for exposure to surface soil and sediment. Exposure to groundwater will not be evaluated for these receptors because shallow groundwater at Site 3 is not used as a potable water supply under current conditions. Exposure to surface water is expected to be minimal because of the presence of alligators in the area. It will be assumed that maintenance workers are engaged in activities at the site where they may be exposed to surface soil 1 day a week and exposed to sediment 1/2 day a week.

- Access to Site 3 is restricted, so there are no off-site recreational users/trespassers at Site 3. Site 3 is part of the causeway that connects Horse Island and Paris Island. The residential area and parade grounds are not located in the vicinity of the causeway. The sides of the causeway are steep making direct contact with surface water and sediment difficult. In addition warnings are posted on the causeway prohibiting swimming/wadding in the surface water adjacent to the causeway due to the presence of alligators in the area. Fishing is possible at the causeway due to the presence of fishing

platforms. On-site recreational users consisting of military personnel stationed at the base and who fish off of the fishing platforms may be exposed to potentially contaminated finfish/shellfish at site 3.

Cancer risks and hazard indices for construction workers and maintenance workers were within the U.S. EPA acceptable levels. As a result, potential risks to other receptor groups with lower exposure frequencies (e.g., recreational users) would also be within acceptable levels.

A summary of the rationale used for the selection or elimination of a potential receptor group is provided in Table 6-9.

6.2.6 Exposure Point Concentrations

According to U.S. EPA guidance (U.S. EPA 1989 and 1992b), risk assessments are conducted using a representative exposure point concentration for each COPC. The exposure point concentration is typically defined as the upper 95 percent confidence limit (UCL), which is based on the distribution of a data set. However, when small data sets (i.e., less than 11 samples) are available for a site and/or medium, the 95 percent UCL is not considered to be a good estimate of the sample mean. In those cases, the maximum detected concentration is used as the exposure point concentration. It should be noted that a sample and its duplicate sample were averaged prior to the determination of the exposure point concentration.

For normally distributed data, the calculation of the exposure point concentration (UCL) is a two-step process. First the standard deviation of the sample set must be determined, as follows:

$$S = \left[\frac{\Sigma(X_i - \overline{X})^2}{(n-1)}\right]^{1/2}$$

where: S = standard deviation
X_i = individual sample value
n = number of samples
$\overline{X}$ = mean sample value

The one-sided UCL on the mean is then calculated as follows:

$$UCL = \overline{X} + t\left(\frac{S}{n^{1/2}}\right)$$

TABLE 6-9

SELECTIONOF EXPOSURE PATHWAYS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Surface Soil	Surface Soil	Surface Soil	Construction Workers	Adult	Ingestion	On-Site	Quant	Construction workers may have contact with soil during excavation activities.
						Dermal	On-Site	Quant	Construction workers may have contact with soil during excavation activities.
				Full-time Employees	Adult	Ingestion	On-Site	None	No full-time employees at site.
						Dermal	On-Site	None	No full-time employees at site.
				Maintenance Workers	Adult	Ingestion	On-Site	Quant	Maintenance workers may have contact with soil during normal work activities.
						Dermal	On-Site	Quant	Maintenance workers may have contact with soil during normal work activities.
				Military Personnel	Adult	Ingestion	On-Site	None	No military personnel at site.
						Dermal	On-Site	None	No military personnel at site.
				Trespassers	Adolescents	Ingestion	On-Site	None	Access to site is restricted
						Dermal	On-Site	None	Access to site is restricted
				Residents	Child	Ingestion	Off-Site	None	No off-site residents in vicinity of site.
						Dermal	Off-Site	None	No off-site residents in vicinity of site.
					Adult	Ingestion	Off-Site	None	No off-site residents in vicinity of site.
						Dermal	Off-Site	None	No off-site residents in vicinity of site.
				Recreational User	Adult	Ingestion	On-Site	None	Recreational users are not exposed to soil.
						Dermal	On-Site	None	Recreational users are not exposed to soil.
		Air		Construction Workers	Adult	Inhalation	On-site	Qual	Construction workers may be exposed to fugitive dust and volatile emissions during construction activities.
				Full-time Employees	Adult	Inhalation	On-site	None	No full-time employees at site.
				Maintenance Workers	Adult	Inhalation	On-site	Qual	Maintenance workers may be exposed to fugitive dust and volatile emissions during construction activities.
				Military Personnel	Adult	Inhalation	On-site	None	No full-time military personnel at site.
				Trespassers	Adolescents	Inhalation	On-site	None	Access to site is restricted.
				Residents	Child	Inhalation	Off-Site	None	No off-site residents in vicinity of site.
					Adult	Inhalation	Off-Site	None	No off-site residents in vicinity of site.
				Recreational User	Adult	Inhalation	On-site	Qual	Recreational users may be exposed to fugitive dust and volatile emissions while at site.
	Groundwater	Groundwater	Shallow Aquifer	Construction Workers	Adult	Ingestion	On-Site	None	Groundwater is not used as a potable water supply at the site.
						Dermal	On-Site	Quant	Construction workers may contact groundwater during excavation activities.
				Full-time Employees	Adult	Ingestion	On-Site	None	No full-time employees at site.
						Dermal	On-Site	None	No full-time employees at site.
				Maintenance Workers	Adult	Ingestion	On-Site	None	Groundwater is not used as a potable water supply at the site.
						Dermal	On-Site	None	Groundwater is not used as a potable water supply at the site.
				Military Personnel	Adult	Ingestion	On-Site	None	Site is not used by military personnel.
						Dermal	On-Site	None	Site is not used by military personnel.
				Trespassers	Adolescents	Ingestion	On-Site	None	Access to site is restricted.
						Dermal	On-Site	None	Access to site is restricted.
				Residents	Child	Ingestion	Off-Site	None	No off-site residents in the vicinity of the site.
						Dermal	Off-Site	None	No off-site residents in the vicinity of the site.
					Adult	Ingestion	Off-Site	None	No off-site residents in the vicinity of the site.
						Dermal	Off-Site	None	No off-site residents in the vicinity of the site.
	Groundwater	Air	Shallow Aquifer	Construction Workers	Adult	Inhalation	On-site	None	Groundwater is not used as a potable water supply at the site.
				Full-time Employees	Adult	Inhalation	On-site	None	No full-time employees at site.

TABLE 6-9

SELECTIONOF EXPOSURE PATHWAYS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
	Groundwater (Continued)	Air (Continued)	Shallow Aquifer (Continued)	Maintenance Workers	Adult	Inhalation	On-site	None	Groundwater is not used as a potable water supply at the site.
				Military Personnel	Adult	Inhalation	On-Site	None	Site is not used by military personnel.
				Trespassers	Adolescents	Inhalation	On-Site	None	Access to site is restricted.
				Residents	Child	Inhalation	Off-Site	None	No off-site residents in the vicinity of the site.
					Adult	Inhalation	Off-Site	None	No off-site residents in the vicinity of the site.
				Recreational User	Adult	Inhalation	On-Site	None	Recreational users do not come into contact with groundwater.
	Sediment	Sediment	Sediment	Construction Workers	Adult	Ingestion	On-Site	Quant	Construction workers may contact sediment during construction activities.
						Dermal	On-Site	Quant	Construction workers may contact sediment during construction activities.
				Full-time Employees	Adult	Ingestion	On-Site	None	No full-time employees at site.
						Dermal	On-Site	None	No full-time employees at site.
				Maintenance Workers	Adult	Ingestion	On-Site	Quant	Maintenance workers may contact sediment during normal work activities.
						Dermal	On-Site	Quant	Maintenance workers may contact sediment during normal work activities.
				Military Personnel	Adult	Ingestion	On-Site	None	Site is not used by military personnel.
						Dermal	On-Site	None	Site is not used by military personnel.
				Trespassers	Adolescents	Ingestion	On-Site	None	Access to site is restricted.
						Dermal	On-Site	None	Access to site is restricted.
				Residents	Child	Ingestion	Off-Site	None	No off-site residents in the vicinity of the site.
						Dermal	Off-Site	None	No off-site residents in the vicinity of the site.
					Adult	Ingestion	Off-Site	None	No off-site residents in the vicinity of the site.
						Dermal	Off-Site	None	No off-site residents in the vicinity of the site.
				Recreational Users	Adult	Ingestion	On-Site	None	Recreational users do not contact sediment.
						Dermal	On-Site	None	Recreational users do not contact sediment.
	Surface Water	Surface Water	Surface Water	Construction Workers	Adult	Ingestion	On-Site	Quant	Construction workers may contact surface water during construction activities.
						Dermal	On-Site	Quant	Construction workers may contact surface water during construction activities.
				Full-time Employees	Adult	Ingestion	On-Site	None	No full-time employees at site.
						Dermal	On-Site	None	No full-time employees at site.
				Maintenance Workers	Adult	Ingestion	On-Site	None	Maintenance workers do not contact surface water.
						Dermal	On-Site	None	Maintenance workers do not contact surface water.
	Surface Water	Surface Water	Surface Water	Military Personnel	Adult	Ingestion	On-Site	None	Site is not used by military personnel.
						Dermal	On-Site	None	Site is not used by military personnel.
				Trespassers	Adolescents	Ingestion	On-Site	None	Access to site is restricted.
						Dermal	On-Site	None	Access to site is restricted.
				Residents	Child	Ingestion	Off-Site	None	No off-site residents in the vicinity of the site.
						Dermal	Off-Site	None	No off-site residents in the vicinity of the site.
					Adult	Ingestion	Off-Site	None	No off-site residents in the vicinity of the site.
						Dermal	Off-Site	None	No off-site residents in the vicinity of the site.
				Recreational User	Adult	Ingestion	On-Site	None	Limited exposure due to presence of alligators in vicinity of site.
						Dermal	On-Site	None	Limited exposure due to presence of alligators in vicinity of site.
		Fish	Fish	Recreational User	Adult	Ingestion	On-Site	Quant	Recreational user may eat fish caught from on-site ponds.

where: UCL = 95% Upper confidence limit of the mean

$\overline{X}$ = Arithmetic average

t = One-sided t distribution factor ($t_{0.95}$)

S = standard deviation

n = number of samples

For log-normally distributed data sets, the exposure concentration is calculated using the following equation:

$$UCL = \exp\left(\overline{X} + 0.5S^2 + \frac{HS}{(n-1)^{1/2}}\right)$$

where: UCL = 95% Upper confidence limit of the mean

exp = Constant (base of the natural log, e)

$\overline{X}$ = Mean of the transformed data

S = standard deviation of the transformed data

H = H-statistic (from Gilbert, 1987; $H_{0.95}$)

n = Number of samples

This equation uses individual sample results that have been transformed using the natural logarithm function. If the data set had an undefined distribution, then the maximum detected concentration was used as the exposure point concentration.

U.S. EPA Region IV has adopted a Toxicity Equivalence Factor (TEF) approach to evaluate potentially carcinogenic PAHs. These TEFs are based on the relative potency of each compound relative to that of benzo(a)pyrene. TEFs for the individual carcinogenic PAHs are as follows:

Compound	TEF
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenzo(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

The TEFs are used to convert each individual carcinogenic PAH concentration into an equivalent concentration of benzo(a)pyrene.

Estimation of chemical concentrations in fish tissue is discussed in the ecological risk assessment present in Section 7.0.

Exposure point concentrations for COPCs for surface soil, surface water, sediment, and fish tissue are summarized in Tables 6-10 and 6-11. Only four groundwater samples were collected, so the maximum detected concentration in groundwater was used as the exposure point concentration.

6.2.7 Quantification of Exposure

Estimates of exposure are based on the contaminant concentrations at the exposure points and on scenario-specific assumptions and intake parameters. The models and equations used to quantify intakes are described in this section and have been obtained from a variety of U.S. EPA guidance documents, which are cited in the specific intake estimation sections below.

Exposure model parameters for all receptors are presented in Tables 6-12 to 6-18. The parameters are based on those presented in the Master Workplan for MCRD, Parris Island, South Carolina (B&R Environmental, 1998b) and standard U.S. EPA Region IV default values. Rationale is provided below for those parameters that are non-standard values or values other than those presented in the master work plan. The parameters are used in the equations presented in this section, along with the exposure point concentrations previously defined to estimate contaminant intakes, which will be used to determine potential risks. Individual chemical intakes for each receptor/exposure route combination are presented in Appendix E.

6.2.7.1 Incidental Ingestion of Soil/Sediment

Direct physical contact with soil (and sediment) may result in the incidental ingestion of chemicals. Construction workers may be exposed to surface soil and sediment during excavation activities. Maintenance workers may be exposed to surface soil and sediment while mowing or landscaping. Exposure associated with the oral route is estimated in the following manner (U.S. EPA, 1989):

$$\text{Intake}_{si} = \frac{(C_{si})(IR_s)(FI)(EF)(ED)(CF)}{(BW)(AT)}$$

TABLE 6-10

EXPOSURE POINT CONCENTRATIONS
SITE 3 CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Soil (mg/kg)	Groundwater (µg/L)	Sediment (mg/kg)	Surface Water (µg/L)
VOLATILE ORGANIC COMPOUNDS				
Benzene	NA	21[1]	NA	NA
Chlorobenzene	NA	130[1]	NA	NA
Chloroform	NA	0.3[1]	NA	NA
SEMIVOLATILE ORGANIC COMPOUNDS				
1,4-Dichlorobenzene	NA	10[1]	NA	NA
4-Methylphenol	NA	18[1]	NA	NA
Benzo(a)pyrene equivalents	4.92[1]	NA	1.49[1]	0.896[1]
Bis(2-ethylhexyl)phthalate	NA	NA	NA	7[1]
PESTICIDES/PCBs				
alpha-BHC	NA	0.12[1]	NA	NA
Metals				
Aluminum	7137[2]	NA	29700[1]	88600[1]
Arsenic	11.8[1]	34.5[1]	8.45[3]	96.1[1]
Barium	NA	854[1]	NA	NA
Iron	5916[2]	32600[1]	15948[3]	110,000[1]
Manganese	NA	708[1]	NA	840[1]
Thallium	NA	2.6[1]	NA	100000[1]
Vanadium	NA	NA	63.7[1]	NA

Notes
1 - Maximum detected concentration.
2 - 95% UCL on mean of a lognormal data distribution.
3 - 95% UCL on mean of a normal data distribution.
NA - Not applicable

TABLE 6-11

EXPOSURE POINT CONCENTRATIONS FOR INGESTION OF FISH
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Measured Fish Tissue Concentration(1) (mg/kg)	Calculated Average Concentration(2) (mg/kg)	Calculated Maximum Concentration(2) (mg/kg)
Benzo(a)pyrene equivalents	N/A	0.007	0.308
Carbazole	N/A	0.292	0.407
4,4'-DDD	N/A	0.008	0.058
4,4'-DDE	N/A	0.161	0.248
4,4'-DDT	N/A	0.035	0.041
alpha-chlordane	N/A	0.497	0.095
gamma-chlordane	N/A	0.231	0.044
Aroclor-1254	0.059	0.038	0.330
Aroclor-1260	N/A	0.019	0.093
Arsenic	N/A	0.098	1.630
Dieldrin	0.00098	N/A	N/A
DDE	0.045	N/A	N/A
Heptachor Expoxide	0.00095	N/A	N/A
Copper	N/A	0.347	5.470
Mercury	0.066	0.207	0.564

Notes:

1 - Maximum measured concentration from Extended Site Inspection, (ABB Environmental Services, 1993).

2 - Calculated using surface water/sediment results from 1998 field investigation, See Section 7.0.

N/A - Not applicable.

TABLE 6-12

VALUES USED FOR DAILY INTAKE CALCULATIONS
CONSTRUCTION WORKER EXPOSED TO SURFACE SOIL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	CT Value	CT Rationale/ Reference	Intake Equation/ Model Name
Ingestion	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Intake (mg/kg/day) =
	IR-S	Ingestion Rate	mg/day	480	EPA, 1995	N/A	N/A	$\frac{Cs \times IRS \times CF3 \times FI \times EF \times ED}{BW \times AT}$
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	
	FI	Fraction Ingested	unitless	1	EPA, 1995	N/A	N/A	
	EF	Exposure Frequency	days/year	125	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	
Dermal	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Dermally Absorbed Dose (mg/kg/day) =
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	$\frac{Cs \times CF3 \times SA \times SSAF \times DABS \times EF \times ED}{BW \times AT}$
	SA	Skin Surface Available for Contact	cm2	4100	(1)	N/A	N/A	
	SSAF	Soil to Skin Adherence Factor	mg/cm2/event	1	EPA, 1995	N/A	N/A	
	DABS	Absorption Factor	unitless	See Text	(2)	N/A	N/A	
	EF	Exposure Frequency	days/year	125	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	

Notes:

1 - Professional judgement.

2 - Refer to supporting text.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol : Human Health Evaluation Manual, Part A OERR EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

EPA Region 4, 1995: Supplement Guidance to RAGS: Region 4 Bulletins. Exposure Assessment Human Health Risk Assessment Bulletiin No. 3.

TABLE 6-13

VALUES USED FOR DAILY INTAKE CALCULATIONS
CONSTRUCTION WORKER EXPOSED TO SEDIMENT
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	CT Value	CT Rationale/ Reference	Intake Equation/ Model Name
Ingestion	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Intake (mg/kg/day) =
	IR-S	Ingestion Rate	mg/day	480	EPA, 1995	N/A	N/A	$\frac{Cs \times IRS \times CF3 \times FI \times EF \times ED}{BW \times AT}$
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	
	FI	Fraction Ingested	unitless	1	EPA, 1995	N/A	N/A	
	EF	Exposure Frequency	days/year	21	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	
Dermal	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Dermally Absorbed Dose (mg/kg/day) =
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	$\frac{Cs \times CF3 \times SA \times SSAF \times DABS \times EF \times ED}{BW \times AT}$
	SA	Skin Surface Available for Contact	cm2	4100	(1)	N/A	N/A	
	SSAF	Soil to Skin Adherence Factor	mg/cm2/event	1	EPA, 1995	N/A	N/A	
	DABS	Absorption Factor	unitless		(2)	N/A	N/A	
	EF	Exposure Frequency	days/year	21	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	

Notes:

1 - Professional judgement.

2 - Refer to supporting text.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

EPA Region 4, 1995: Supplement Guidance to RAGS: Region 4 Bulletins. Exposure Assessment Human Health Risk Assessment Bulletin No. 3.

TABLE 6-14

VALUES USED FOR DAILY INTAKE CALCULATIONS
CONSTRUCTION WORKER EXPOSED TO GROUNDWATER
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	CT Value	CT Rationale/ Reference	Intake Equation/ Model Name
Dermal	DAevent	Absorbed dose per event	mg/cm2-event	See Table 6-10	See Table 6-10	N/A	N/A	Dermally Absorbed Dose (mg/kg/day)
	SA	Skin Surface Available for Contact	cm2	2490	(1)	N/A	N/A	$= \frac{DAevent \times EV \times EF \times ED \times SA}{BW \times AT}$
	EV	Event Frequency.	events/day	1	(1)	N/A	N/A	
	ET	Exposure Time	hours/event	8	(1)	N/A	N/A	
	EF	Exposure Frequency	days/year	21	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	See text for calculation of DAevent.
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	

Notes:

1 - Professional judgement.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

EPA Region 4, 1995: Supplement Guidance to RAGS: Region 4 Bulletins. Exposure Assessment Human Health Risk Assessment Bulletiin No. 3.

TABLE 6-15

VALUES USED FOR DAILY INTAKE CALCULATIONS
CONSTRUCTION WORKER EXPOSED TO SURFACE WATER
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	CT Value	CT Rationale/ Reference	Intake Equation/ Model Name
Ingestion	CW	Chemical Concentration in Water	ug/L	See Table 6-10	See Table 6-10	N/A	N/A	Intake (mg/kg/day) =
	CR	Contact Rate	L/hour	0.01	EPA, 1995	N/A	N/A	$\frac{CW \times CR \times CF \times ET \times EF \times ED}{BW \times AT}$
		Conversion factor	ug/mg	0.001	- -	N/A	N/A	
	ET	Exposure Time	hours/event	8	(1)	N/A	N/A	
	EF	Exposure Frequency	events/year	21	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	
Dermal	DAevent	Absorbed dose per event	mg/cm2-event	See Text	(2)	N/A	N/A	Dermally Absorbed Dose (mg/kg/day)
	SA	Skin Surface Available for Contact	cm2	2490	(1)	N/A	N/A	$= \frac{DAevent \times EV \times EF \times ED \times SA}{BW \times AT}$
	EV	Event Frequency	events/day	1	(1)	N/A	N/A	
	ET	Exposure Time	hours/event	8	EPA, 1989	N/A	N/A	
	EF	Exposure Frequency	days/year	21	EPA, 1995	N/A	N/A	
	ED	Exposure Duration	years	1	(1)	N/A	N/A	See text for calculation of DAevent.
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	365	EPA, 1989	N/A	N/A	

Notes:

1 - Professional judgement.

2 - Refer to supporting text.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

EPA Region 4, 1995: Supplement Guidance to RAGS: Region 4 Bulletins. Exposure Assessment Human Health Risk Assessment Bulletiin No. 3.

TABLE 6-16

VALUES USED FOR DAILY INTAKE CALCULATIONS
MAINTENANCE WORKER EXPOSED TO SOIL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	CT Value	CT Rationale/ Reference	Intake Equation/ Model Name
Ingestion	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Intake (mg/kg/day) =
	IR-S	Ingestion Rate	mg/day	100	EPA, 1995	N/A	N/A	$\frac{Cs \times IRS \times CF3 \times FI \times EF \times ED}{BW \times AT}$
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	
	FI	Fraction Ingested	unitless	1	EPA, 1995	N/A	N/A	
	EF	Exposure Frequency	days/year	50	(1)	N/A	N/A	
	ED	Exposure Duration	years	25	EPA, 1995	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	9125	EPA, 1989	N/A	N/A	
Dermal	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Dermally Absorbed Dose (mg/kg/day) =
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	$\frac{Cs \times CF3 \times SA \times SSAF \times DABS \times EF \times ED}{BW \times AT}$
	SA	Skin Surface Available for Contact	cm2	4100	(1)	N/A	N/A	
	SSAF	Soil to Skin Adherence Factor	mg/cm2/event	1	EPA, 1995	N/A	N/A	
	DABS	Absorption Factor	unitless	See Text	(2)	N/A	N/A	
	EF	Exposure Frequency	days/year	50	(1)	N/A	N/A	
	ED	Exposure Duration	years	25	EPA, 1995	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	9125	EPA, 1989	N/A	N/A	

Notes:

1 - Professional judgement.

2 - Refer to supporting text.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

EPA Region 4, 1995: Supplement Guidance to RAGS: Region 4 Bulletins. Exposure Assessment Human Health Risk Assessment Bulletiin No. 3.

TABLE 6-17

VALUES USED FOR DAILY INTAKE CALCULATIONS
MAINTENANCE WORKER EXPOSED TO SEDIMENT
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	RME Value	RME Rationale/ Reference	CT Value	CT Rationale/ Reference	Intake Equation/ Model Name
Ingestion	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Intake (mg/kg/day) =
	IR-S	Ingestion Rate	mg/day	100	EPA, 1995	N/A	N/A	$\frac{Cs \times IRS \times CF3 \times FI \times EF \times ED}{BW \times AT}$
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	
	FI	Fraction Ingested	unitless	1	EPA, 1995	N/A	N/A	
	EF	Exposure Frequency	days/year	25	(1)	N/A	N/A	
	ED	Exposure Duration	years	25	EPA, 1995	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	9125	EPA, 1989	N/A	N/A	
Dermal	CS	Chemical concentration in soil	mg/kg	See Table 6-10	See Table 6-10	N/A	N/A	Dermally Absorbed Dose (mg/kg/day) =
	CF3	Conversion Factor 3	kg/mg	1.0E-06	- -	N/A	N/A	$\frac{Cs \times CF3 \times SA \times SSAF \times DABS \times EF \times ED}{BW \times AT}$
	SA	Skin Surface Available for Contact	cm2	4100	(1)	N/A	N/A	
	SSAF	Soil to Skin Adherence Factor	mg/cm2/event	1	EPA, 1995	N/A	N/A	
	DABS	Absorption Factor	unitless	See Text	(2)	N/A	N/A	
	EF	Exposure Frequency	days/year	25	(1)	N/A	N/A	
	ED	Exposure Duration	years	25	EPA, 1995	N/A	N/A	
	BW	Body Weight	kg	70	EPA, 1993	N/A	N/A	
	AT-C	Averaging Time (Cancer)	days	25,550	EPA, 1989	N/A	N/A	
	AT-N	Averaging Time (Non-Cancer)	days	9,125	EPA, 1989	N/A	N/A	

Notes:

1 - Professional judgement.

2 - Refer to supporting text.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

EPA Region 4, 1995: Supplement Guidance to RAGS: Region 4 Bulletins. Exposure Assessment Human Health Risk Assessment Bulletiin No. 3.

TABLE 6-18

VALUES USED FOR DAILY INTAKE CALCULATIONS
ADULT RECREATIONAL USER EXPOSED TO FINFISH/SHELL FISH
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Exposure Route	Parameter Code	Parameter Definition	Units	Default Value	Default Rationale/ Reference	Site-Specific Value	Site-Specific Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Cfish	Chemical Concentration in fish	mg/kg	See Table 6-11	See Text	See Table 6-11	See Text	Intake (mg/kg/day) =
	IR	Fish/shellfish ingestion rate	kg/day	0.054	EPA, 1995	0.145	EPA, 1995	$\frac{Cfish \times IR \times FI \times EF \times ED}{BW \times AT}$
	FI	Fraction ingested from source	unitless	1	EPA, 1995	1	EPA, 1995	
	EF	Exposure Frequency	day/year	350	EPA, 1995	45	EPA, 1995	
	ED	Exposure Duration	years	30	EPA, 1995	6	EPA, 1995	
	BW	Body Weight	kg	70	EPA, 1993	70	EPA, 1993	
	AT-C	Averaging Time (Cancer)	days	25550	EPA, 1989	25550	EPA, 1989	
	AT-N	Averaging Time (Non-Cancer)	days	10950	EPA, 1989	2190	EPA, 1989	

Notes:

1 - Professional judgement.

2 - Refer to supporting text.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1993: Superfund Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure..

where: $Intake_i$ = intake of contaminant "i" from soil or sediment (mg/kg/day)
C_{si} = concentration of contaminant "i" in soil or sediment (mg/kg)
IR = incidental ingestion rate (mg/day)
FI = fraction ingested from contaminated source (decimal fraction)
EF = exposure frequency (days/year)
ED = exposure duration (years)
CF = conversion factor (10^{-6} kg/mg)
BW = body weight (kg)
AT = averaging time (days);
for noncarcinogens, AT = ED x 365 days/year;
for carcinogens, AT = 70 years x 365 days/year

Since Site 3 is relatively small in size, it was assumed that a construction worker would be engaged in construction-related activities 6 work months or 125 days per year (EF_{Soil}) over a 1-year period (ED). It was further assumed that a construction worker would be exposed to sediment for one work month or 21 days per year ($EF_{Sediment}$) while at the site. For maintenance workers, it was assumed that they would be at the site for 1 day a week or 50 days per year (EF_{Soil}). It was also assumed that, while at the site, the maintenance worker would be exposed to sediment for 1/2 day a week or 25 days per year ($EF_{Sediment}$). The maintenance worker is assumed to be a civilian employee, consequently, the EPA default value of 25 years is used for the exposure duration (ED). All other exposure parameters for incidental ingestion of soil and sediment are standard U.S. EPA default values.

6.2.7.2 Dermal Contact with Soil/Sediment

During direct contact, construction workers and maintenance workers may get contaminated soil and sediment on their skin. Dermal absorption from potentially contaminated soil and sediment is calculated using the following equation:

$$Intake_{si} = \frac{(C_{si})(SA)(AF)(ABS)(CF)(EF)(ED)}{(BW)(AT)}$$

where: $Intake_{si}$ = amount of chemical "i" absorbed during contact with soil or sediment (mg/kg/day)
C_{si} = concentration of chemical "i" in soil or sediment (mg/kg)
SA = skin surface area available for contact (cm^2/day)
AF = skin adherence factor (mg/cm^2)
ABS = absorption factor (decimal fraction)
CF = conversion factor (10^{-6} kg/mg)
EF = exposure frequency (days/year)

ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED x 365 days/year;
		for carcinogens, AT = 70 years x 365 days/year

The same exposure frequencies and durations used in the estimation of incidental ingestion intakes of soil/sediment are used to estimate exposure via dermal contact. Current guidance (U.S. EPA, 1992a) is used to develop the following default assumptions concerning the amount of skin surface area available for contact for a receptor: For construction workers and maintenance workers, the exposed skin surface area was assumed to be 4,100 cm^2. This value represents the hands, forearms, and head being exposed to soil (U.S. EPA, 1992a). The upper limit of the published range (U.S. EPA, 1992a), 1.0 mg/cm^2, is employed for the soil/sediment skin adherence factor. Absorption factors of 0.13 and 0.03 were used to assess dermal exposure to benzo(a)pyrene and arsenic, respectively (U.S. EPA, 1997a). Region IV default values of 0.01 for organics and 0.001 for inorganics were used for those chemicals for which chemical-specific absorption factors were not available (U.S. EPA Region IV, 1995a). All other exposure parameters for dermal contact with soil and sediment are standard U.S. EPA default values.

6.2.7.3 Incidental Ingestion of Surface Water

Construction workers may incidentally ingest surface water during construction activities. Intakes associated with ingestion of water are evaluated using the following equations (U.S. EPA, 1989):

$$\text{Intake}_{swi} = \frac{(C_{swi})(CR)(ET)(EF)(ED)}{(BW)(AT)}$$

where:	Intake_{swi}	=	intake of chemical "i" from water (mg/kg/day)
	C_{sw}	=	concentration of chemical "i" in water (mg/L)
	CR	=	contact rate for surface water (L/hour)
	ET	=	exposure time for surface water (hours/day)
	EF	=	exposure frequency (days/year)
	ED	=	exposure duration (years)
	BW	=	body weight (kg)
	AT	=	averaging time (days);
			for noncarcinogens, AT = ED x 365 days/year;
			for carcinogens, AT = 70 years x 365 days/year

It is assumed that construction workers may incidentally ingest (CR) 0.01 L/hr (similar to wading) while at the site (U.S. EPA, 1995a). As with exposure to sediment, it was assumed that a construction worker would be exposed to surface water for 1 work month or 21 days per year ($EF_{Surface\ Water}$) while at the site. The exposure time (ET) for construction workers is 8 hours per day, the length of a typical work day. All other exposure parameters for incidental ingestion of surface water are standard U.S. EPA default values.

6.2.7.4 Dermal Contact with Groundwater/Surface Water

Construction workers may contact groundwater during construction activities if excavation occurs below the water table. In addition, construction workers may come into contact with surface water during construction activities. The following equation is used to assess exposures resulting from dermal contact with water (U.S. EPA, 1992a):

$$DAD_{wi} = \frac{(DA_{event})(EV)(ED)(EF)(A)}{(BW)(AT)}$$

where: DAD_{wi} = dermally absorbed dose of chemical "i" from water (mg/kg/day)
DA_{event} = absorbed dose per event (mg/cm^2/event)
EV = event frequency (events/day)
ED = exposure duration (years)
EF = exposure frequency (days/year)
A = skin surface area available for contact (cm^2)
BW = body weight (kg)
AT = averaging time (days);
for noncarcinogens, AT = ED x 365 days/year;
for carcinogens, AT = 70years x 365 days/year

The absorbed dose per event (DA_{event}) is estimated using a nonsteady-state approach for organic compounds and a more traditional steady-state approach for inorganics. For organics, the following equations apply:

$$\text{If } t_{event} < t^*, \text{ then: } DA_{event} = (2K_p)(C_{sw})(CF)\left(\sqrt{\frac{6\tau t_{event}}{\pi}}\right)$$

$$\text{If } t_{event} > t^*, \text{ then: } DA_{event} = (K_p)(C_{sw})(CF)\left(\frac{t_{event}}{1+B} + 2\tau\left(\frac{1+3B}{1+B}\right)\right)$$

where: t_{event} = duration of event (hour/event)
t^* = time it takes to reach steady-state conditions (hours)
K_p = permeability coefficient from water through skin (cm/hour)

C_{sw}	=	concentration of chemical "i" in water (mg/L)
τ	=	lag time (hour)
π	=	constant (unitless; equal to 3.141592654)
CF	=	conversion factor (10^{-3} L/cm^3)
B	=	partitioning constant derived by Bunge Model (dimensionless)

For organic COPCs for groundwater and surface, values for the chemical-specific parameters (t_{event}, t^*, K_p, τ, and B) are obtained from the current dermal guidance (U.S. EPA, 1992a) and are included in Appendix E.

The following nonsteady-state equation is used to estimate DA_{event} for inorganics:

$$DA_{event} = (K_p)\,(C_{sw})\,(t_{event})$$

The recommended default value of 0.001 cm/hour was used for the inorganic selected as COPCs.

Current guidance (U.S. EPA, 1992a) is used to develop the following default assumptions concerning the amount of skin surface area available for contact: For construction workers and maintenance workers, the exposed skin surface area was assumed to be 2,490 cm^2. This value represents the hands and forearms being exposed to groundwater/surface water (U.S. EPA, 1992a). As with exposures to surface water and sediment, it was assumed that a construction worker would be exposed to groundwater and surface water for one work month or 21 days per year ($EF_{Groundwater}$) while at the site. The exposure time (ET) for construction workers is 8 hours per day, the length of a typical work day. All other exposure parameters for dermal contact with groundwater and surface water are standard U.S. EPA default values.

6.2.7.5 Ingestion of Fish

Recreational users who consume fin and shall fish caught in the area may be exposed to COPCs in fish tissue. Intakes associated with ingestion of fish are evaluated using the following equation (U.S. EPA, 1989):

$$Intake_{fishi} = \frac{(C_{fishi})(IR)(FI)(EF)(ED)}{(BW)(AT)}$$

where:	$Intake_{fishi}$	=	intake of contaminant "i" from ingestion of fish (mg/kg/day)
	C_{fishi}	=	concentration of contaminant "i" in fish tissue (mg/kg)
	IR	=	fish ingestion rate (kg/day or kg/meals)
	FI	=	fraction ingested from contaminated source (decimal fraction)

EF	=	exposure frequency (days/year or meals/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days); for noncarcinogens, AT = ED x 365 days/year; for carcinogens, AT = 70 years x 365 days/year

Two scenarios will be evaluated for the recreational user. The first scenario will use U.S. EPA standard default values, which assume that an individual ingests 0.054 kg-fish per meal (IR) for 350 meals per year (EF) over a 30 year period (ED). The second scenario will be based on site-specific considerations. It will be assumed that the recreational user fishes at the site 45 days per year, which is approximately 1 day a week. It will also be assumed that the fish a recreational user catches at the site supplies one meal a week, for a total of 45 meals per year (EF). The U.S. EPA Region IV suggested default value of 0.145 kg-fish/meal for site-specific evaluations will be used for the fish ingestion rate (IR). It will be assumed that the recreational user is military personnel stationed at the base who spend two 3-year tours of duty or 6 years (ED) at the site. All other exposure parameters for ingestion of fish tissue are standard U.S. EPA default values.

6.3 TOXICITY ASSESSMENT

The toxicity assessment examines information concerning the potential human health effects associated with exposure to COPCs. The goal of the toxicity assessment is to provide, for each COPC, a quantitative estimate of the relationship between the magnitude and type of exposure and the severity or probability of human health effects. The toxicity values presented in this section are integrated with the outputs of the exposure assessment to characterize the potential for the occurrence of adverse health effects.

The toxicological evaluation involves a critical review and interpretation of toxicity data from epidemiological, clinical, animal, and in vitro studies. This review of the data ideally determines both the nature of the health effects associated with a particular chemical and the probability that a given quantity of a chemical could result in the referenced effect. This analysis defines the relationship between the dose received and the incidence of an adverse effect for the COPC.

The entire toxicological database is used to guide the derivation of cancer slope factors (CSFs) for carcinogenic effects and reference doses (RfDs) for noncarcinogenic effects. These data may include epidemiological studies, long-term animal bioassays, short-term tests, and comparisons of molecular structure. Data from these sources are reviewed to determine if a chemical is likely to be toxic to humans. Because of the lack of available human studies, however, the majority of toxicity data used to derive CSFs and RfDs come from animal studies.

For noncarcinogenic effects, the most appropriate animal model (i.e., the species most biologically similar to the human) is identified. Pharmacokinetic data often enter into this determination. In the absence of sufficient data to identify the most appropriate animal model, the most sensitive species is chosen. The RfD is generally derived from the most comprehensive toxicology study that characterizes the dose-response relationship for the critical effect of the chemical. Preference is given to studies using the exposure route of concern; in the absence of such data, however, an RfD for one route of exposure may be extrapolated from data from a study that used a different route of exposure. Such extrapolation must take into account pharmacokinetic and toxicological differences between the routes of exposure. Uncertainty factors are applied to the highest no-observed-adverse-effect-level (NOAEL) to adjust for inter- and intraspecies variation, deficiencies in the toxicological database, and use of subchronic rather than chronic animal studies. Additional uncertainty factors may be applied to estimate a NOAEL from a lowest-observed-adverse-effect-level (LOAEL) if the key study failed to determine a NOAEL.

CSFs for weights-of-evidence of Group A or B chemicals are generally derived from positive cancer studies that adequately identify the target organ in the test animal data and characterize the dose-response relationship. CSFs are derived for Group C compounds for which the data are sufficient but are not derived for Group D or E chemicals. No consideration is given to similarity in the animal and human target organ(s) because a chemical capable of inducing cancer in any animal tissue is considered potentially carcinogenic to humans. Preference is given to studies using the route of exposure of concern, in which normal physiologic function was not impaired, and in which exposure occurred during most of the animal's lifetime. Exposure and pharmacokinetic considerations are used to estimate equivalent human doses for computation of the CSF. When a number of studies of similar quality are available, the data may be combined in the derivation of the CSF.

Toxicological profiles for each of the COPCs are presented in Appendix E. These profiles present a summary of the available literature on carcinogenic and noncarcinogenic effects associated with human exposure to the chemical.

6.3.1 Carcinogenic Effects

The toxicity information considered in the assessment of potential carcinogenic risks includes a weight-of-evidence classification and a slope factor. The weight-of-evidence classification qualitatively describes the likelihood that a chemical is a human carcinogen and is based on an evaluation of the available data from human and animal studies. A chemical may be placed in one of three groups in U.S. EPA's classification system to denote its potential for carcinogenic effects:

- Group A - known human carcinogen
- Group B1 or B2 - probable human carcinogen

- Group C - possible human carcinogen

Chemicals that cannot be classified as a human carcinogen because of a lack of data are placed in Group D, and those for which there is evidence of noncarcinogenicity in humans are in Group E.

The CSF is the toxicity value used to quantitatively express the carcinogenic hazard of cancer-causing chemicals. It is defined as the upper-bound estimate of the probability of cancer incidence per unit dose averaged over a lifetime. Slope factors are derived from studies of carcinogenicity in humans and/or laboratory animals and are typically calculated for compounds in Groups A, B1, and B2, although some Group C carcinogens also have slope factors and some B2 carcinogens have none (e.g., lead). Slope factors are specific to a chemical and route of exposure and are expressed in units of $(mg/kg/day)^{-1}$ for both oral and inhalation routes. Inhalation cancer toxicity values are usually expressed as inhalation unit risks in units of reciprocal $\mu g/m^3$ ($1/\mu g/m^3$). Because cancer risk characterization requires an estimate of reciprocal dose in units of 1/mg/kg/day, the inhalation unit risk must be converted to the mathematical equivalent of an inhalation cancer slope factor, or risk per unit dose (mg/kg/day). This is done by assuming that humans weigh 70 kilograms and inhale 20 m^3 of air per day [i.e., the inhalation unit risk ($1/\mu g/m^3$) is divided by 20 m^3, multiplied by 70 kg, and multiplied by 1,000 µg/mg to yield the mathematical equivalent of an inhalation slope factor (1/mg/kg/day)].

CSFs for COPCs at Site 3 are presented in Table 6-19. The primary sources of information for these values are U.S. EPA's Integrated Risk Information System (IRIS). The U.S. EPA intends that IRIS supersede all other sources of toxicity information for risk assessment. If values were not available in IRIS, the annual Health Effects Assessment Summary Tables (HEAST) were consulted. U.S. EPA Region III Risk-Based Concentration Tables (U.S. EPA, 1998) are also used as a quick tabulated reference for available CSFs. If no CSF is available from any of these sources, carcinogenic risks are not quantified and potential exposures are addressed in Section 6.5, Uncertainty Analysis.

CSFs also exist for several (but not all) Class C compounds, which are identified as "possible" human carcinogens. These compounds typically exhibit inadequate evidence of carcinogenicity in humans and limited evidence in animals. In this human health risk assessment, Class C compounds are evaluated the same as Class A, B1, and B2 compounds. The uncertainty associated with this approach is discussed in Section 6.5.

TABLE 6-19

CANCER TOXICITY DATA - ORAL/DERMAL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor[1]	Adjusted Dermal Cancer Slope Factor[2]	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date[3] (MM/DD/YY)
VOCs							
Benzene	2.9E-02	97%	3.0E-02	(mg/kg/day) $^{-1}$	A	IRIS	11/01/99
Chlorobenzene	N/A	31%	N/A	(mg/kg/day) $^{-1}$	D	N/A	11/01/99
Chloroform	6.1E-03	20%	3.1E-02	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
SVOCs							
1,4-Dichlorobenzene	2.4E-02	90%	2.7E-02	(mg/kg/day) $^{-1}$	C	HEAST	07/97
4-Methylphenol	N/A	65%	N/A	(mg/kg/day) $^{-1}$	C	N/A	N/A
Benzo(a)anthracene	N/A	31%	N/A	(mg/kg/day) $^{-1}$	B2	N/A	N/A
Benzo(b)fluoranthene	N/A	31%	N/A	(mg/kg/day) $^{-1}$	B2	N/A	N/A
Benzo(k)fluoranthene	N/A	31%	N/A	(mg/kg/day) $^{-1}$	B2	N/A	N/A
Benzo(a)pyrene	7.3E+00	31%	2.4E+01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
Bis(2-ethylhexyl)phthalate	1.4E-02	19%	7.4E-02	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
Carbazole	2.0E-02	31%	6.5E-02	(mg/kg/day) $^{-1}$		HEAST	07/97
Chrysene	N/A	31%	N/A	(mg/kg/day) $^{-1}$	B2	N/A	N/A
Indeno(1,2,3-cd)pyrene	N/A	31%	N/A	(mg/kg/day) $^{-1}$	B2	N/A	N/A
PESTICIDES/PCBs							
alpha-BHC	6.3E+00	97%	6.5E+00	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
4,4'-DDD	2.4E-01	70%	3.4E-01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
4,4'-DDE	3.4E-01	70%	4.9E-01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
4,4'-DDT	3.4E-01	70%	4.9E-01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
alpha-chlordane	3.5E-01	50%	7.0E-01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
gamma-chlordane	3.5E-01	50%	7.0E-01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
Aroclor-1254	2.0E+00	90%	2.2E+00	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
Aroclor-1260	2.0E+00	90%	2.2E+00	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
Dieldrin	1.6E+01	50%	3.2E+01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
Heptachlor expoxide	9.1E+00	72%	1.3E+01	(mg/kg/day) $^{-1}$	B2	IRIS	11/01/99
INORGANICS							
Aluminum	N/A	10%	N/A	(mg/kg/day) $^{-1}$	N/A	N/A	N/A
Arsenic	1.5E+00	41%	3.7E+00	(mg/kg/day) $^{-1}$	A	IRIS	11/01/99
Barium	N/A	7%	N/A	(mg/kg/day) $^{-1}$	D	N/A	N/A
Copper	N/A	30%	N/A	(mg/kg/day) $^{-1}$	N/A	N/A	N/A

TABLE 6-19

CANCER TOXICITY DATA - ORAL/DERMAL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor[1]	Adjusted Dermal Cancer Slope Factor[2]	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date[3] (MM/DD/YY)
Iron	N/A	15%	N/A	$(mg/kg/day)^{-1}$	N/A	N/A	N/A
Manganese	N/A	4%	N/A	$(mg/kg/day)^{-1}$	D	N/A	N/A
Mercury	N/A	1%	N/A	$(mg/kg/day)^{-1}$	C	IRIS	11/01/99
Thallium	N/A	15%	N/A	$(mg/kg/day)^{-1}$	N/A	N/A	N/A
Vanadium	N/A	1%	N/A	$(mg/kg/day)^{-1}$	N/A	N/A	N/A

Notes:

IRIS = Integrated Risk Information System

HEAST= Health Effects Assessment Summary Tables

1 - USEPA Region IV, February 26, 1996.

2 - CSFdermal = CSForal/Oral to Dermal Adjustment Factor.

3 - For IRIS values, provide the date IRIS was searched.
For HEAST values, provide the date of HEAST.

EPA Group:

A - Human carcinogen

B1 - Probable human carcinogen - indicates that limited human data are available

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

C - Possible human carcinogen

D - Not classifiable as a human carcinogen

E - Evidence of noncarcinogenicity

Weight of Evidence:

Known/Likely

Cannot be Determined

Not Likely

Dermal CSFs are derived from the corresponding oral values. Regional guidance (U.S. EPA, Region IV, 1996b) is used as a basis for determining the dermal CSFs. In the derivation of a dermal CSF, the oral CSF is divided by the gastrointestinal absorption efficiency to determine a CSF based on an absorbed dose rather than an administered dose, as follows:

$$CSF_{dermal} = (CSF_{oral}) / (ABS_{GI})$$

The oral CSF is divided by the absorption efficiency because CSFs are expressed as reciprocal doses. Dermal CSFs and the absorption efficiencies used in their determination are also included in Table 6-19.

As discussed in Section 6.2.6, U.S. EPA Region IV has adopted a Toxicity Equivalence Factor (TEF) approach to evaluate potentially carcinogenic PAHs. These TEFs are based on the relative potency of each compound relative to that of benzo(a)pyrene. U.S. EPA Region IV also requires that dermal exposures to PAHs be evaluated using the TEF approach. Consequently, the oral and dermal CSF for benzo(a)pyrene is used to evaluated exposures to all carcinogenic PAHs in terms of benzo(a)pyrene equivalents.

6.3.2 Noncarcinogenic Effects

For noncarcinogens, it is assumed that there exists a dose below which no adverse health effects will be seen. Below this "threshold" dose, exposure to a chemical can be tolerated without adverse effects. For noncarcinogens, a range of exposure exists that can be tolerated. Toxic effects are manifested only when physiologic protective mechanisms are overcome by exposures to a chemical above its threshold level. Maternal and developmental endpoints are considered systemic toxicity.

The potential for noncarcinogenic health effects resulting from exposure to chemicals is assessed by comparing an exposure estimate (intake or dose) to an RfD. The RfD is expressed in units of mg/kg/day and represents a daily intake of contaminant per kilogram of body weight that is not sufficient to cause the threshold effect of concern. An RfD is specific to the chemical, the route of exposure, and the duration over which the exposure occurs. Separate RfDs are presented for ingestion and inhalation pathways. In particular, reference concentrations (RfCs) in units of mg/m^3 are typically presented for the inhalation pathway. Because characterization of noncarcinogenic effects requires an estimate of dose in units of mg/kg/day, the inhalation RfC must be converted to an inhalation RfD. This is done by assuming that humans weigh 70 kg and inhale 20 m^3 of air per day [i.e., the inhalation RfC (mg/m^3) is multiplied by 20 m^3/day and divided by 70 kg to yield an inhalation RfD (mg/kg/day)].

To derive an RfD, the U.S. EPA reviews all relevant human and animal studies for each compound and selects the study (studies) pertinent to the derivation of the specific RfD. Each study is evaluated to determine the NOAEL or, if the data are inadequate for such a determination, the LOAEL. The NOAEL corresponds to the dose (in mg/kg/day) that can be administered over a lifetime without inducing observable adverse effects. The LOAEL corresponds to the lowest daily dose that induces an observable adverse effect. The toxic effect characterized by the LOAEL is referred to as the "critical effect." To derive an RfD, the NOAEL (or LOAEL) is divided by uncertainty factors to ensure that the RfD will be protective of human health. Uncertainty factors are applied to account for extrapolation of data from laboratory animals to humans (interspecies extrapolation), variation in human sensitivity to the toxic effects of a compound (intraspecies differences), derivation of a chronic RfD based on a subchronic rather than a chronic study, and/or derivation of an RfD from the LOAEL rather than the NOAEL. In addition to these uncertainty factors, modifying factors between 1 and 10 may be applied to reflect additional qualitative considerations in evaluating the data. For most compounds, the modifying factor is 1.

A dermal RfD is developed from an oral RfD by multiplying by the gastrointestinal tract absorption factor as follows:

$$RfD_{dermal} = (RfD_{oral})(ABS_{GI})$$

The resulting dermal RfD is, therefore, based on absorbed dose, which is what is calculated by the dermal exposure algorithms.

RfDs for the COPCs at Site 3 are presented in Table 6-20. The primary source of these values is the IRIS database (U.S. EPA, 1999), followed by other U.S. EPA sources described for the carcinogens. Table 6-20 also includes the primary target organs affected by a particular chemical. This information may be used in the risk characterization section to segregate risks by target organ effects, unless the total Hazard Index is below unity. This ensures that "risks" are not overestimated when different compounds affect different target organs.

6.4 RISK CHARACTERIZATION

This section provides a characterization of the potential human health risks associated with the potential exposure to COPCs at Site 3. Section 6.4.1 outlines the methods used to quantitatively estimate the type and magnitude of potential risks for human receptors. A summary of the risk characterization for Site 3 is provided in Section 6.4.2.

TABLE 6-20

NON-CANCER TOXICITY DATA - ORAL/DERMAL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor[1]	Adjusted Dermal RfD[2]	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ[3] (MM/DD/YY)
VOCs										
Benzene	Chronic	3.0E-03	mg/kg/day	97%	2.9E-03	mg/kg/day	Blood		EPAIII	04/12/99
Chlorobenzene	Chronic	2.0E-02	mg/kg/day	31%	6.2E-03	mg/kg/day	Liver	1000	IRIS	11/01/99
Chloroform	Chronic	1.0E-02	mg/kg/day	20%	2.0E-03	mg/kg/day	Liver	1000	IRIS	11/01/99
SVOCs										
1,4-Dichlorobenzene	Chronic	3.0E-02	mg/kg/day	90%	2.7E-02	mg/kg/day	Liver	30	EPAIII	04/12/99
4-Methylphenol	Chronic	5.0E-03	mg/kg/day	65%	3.3E-03	mg/kg/day	CNS	1000	HEAST	07/97
Benzo(a)anthracene	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Benzo(b)fluoranthene	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Benzo(k)fluoranthene	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Bis(2-ethylhexyl)phthalate	Chronic	2.0E-02	mg/kg/day	19%	3.8E-03	mg/kg/day	Liver	1000	IRIS	11/01/99
Carbazole	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Chrysene	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Indeno(1,2,3-cd)pyrene	N/A	N/A	mg/kg/day	31%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Heptachor expoxide	Chronic	1.30E-05	mg/kg/day	72%	9.40E-06	mg/kg/day	Liver	1000	IRIS	11/1/99
PESTICIDES/PCBs										
alpha-BHC	N/A	N/A	mg/kg/day	97%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
4,4'-DDD	N/A	N/A	mg/kg/day	70%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
4,4'-DDE	N/A	N/A	mg/kg/day	70%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
4,4'-DDT	Chronic	5.00E-04	mg/kg/day	70%	3.5E-04	mg/kg/day	N/A	N/A	N/A	N/A
alpha-chlordane	N/A	N/A	mg/kg/day	50%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
gamma-chlordane	N/A	N/A	mg/kg/day	50%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Aroclor-1254	Chronic	2E-05	mg/kg/day	90%	1.8E-05	mg/kg/day	Immune, CNS	300	IRIS	11/01/99
Aroclor-1260	N/A	N/A	mg/kg/day	90%	N/A	mg/kg/day	N/A	N/A	N/A	N/A
Dieldrin	Chronic	5E-05	mg/kg/day	50%	2.5E-05	mg/kg/day	Liver	100	IRIS	11/01/99
Heptachlor Epoxide	Chronic	1.3E-05	mg/kg/day	72%	9.4E-06	mg/kg/day	Liver	1000	IRIS	11/01/99
INORGANICS										
Aluminum	Chronic	1.0E+00	mg/kg/day	10%	1.0E-01	mg/kg/day	CNS	N/A	EPAIII	04/12/99
Arsenic	Chronic	3.0E-04	mg/kg/day	41%	1.2E-04	mg/kg/day	Skin	3	IRIS	11/01/99
Barium	Chronic	7.0E-02	mg/kg/day	7%	4.9E-03	mg/kg/day	CVS	3	IRIS	11/01/99
Copper	Chronic	4.0E-02	mg/kg/day	30%	1.2E-02	mg/kg/day	GI Tract	N/A	HEAST	07/97
Iron	Chronic	3.0E-01	mg/kg/day	15%	4.5E-02	mg/kg/day	Liver	N/A	EPAIII	04/12/99
Manganese	Chronic	2.0E-02	mg/kg/day	4%	8.0E-04	mg/kg/day	CNS	1	IRIS	11/01/99

TABLE 6-20

NON-CANCER TOXICITY DATA - ORAL/DERMAL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor[1]	Adjusted Dermal RfD[2]	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ[3] (MM/DD/YY)
Mercury	Chronic	3.0E-04	mg/kg/day	0.01%	3.0E-08	mg/kg/day	CNS	1000	IRIS	11/01/99
Thallium	Chronic	7.0E-05	mg/kg/day	15%	1.1E-05	mg/kg/day	Liver, Blood	N/A	EPAIII	N/A
Vanadium	Chronic	7.0E-03	mg/kg/day	1.0%	7.0E-05	mg/kg/day	None reported	100	HEAST	07/97

Notes;

1 - USEPA Region IV, February 26, 1996.

2 - RfDdermal = RfDoral x Oral to Dermal Adjustment Factor

3 - For IRIS values date that IRIS was searched.
For HEAST values, provide the date of HEAST.
FOR EPAIII, date of RBC Table.

N/A = Not Applicable

IRIS = Integrated Risk Information System

HEAST= Health Effects Assessment Summary Tables

EPAIII = USEPA Region III Risk-Based Concentration Table, October 1, 1998.

6.4.1 Methodology for Estimation of Quantitative Risks

Potential human health risks resulting from exposure to COPCs are estimated using algorithms established by the U.S. EPA (U.S. EPA, 1989). The methods described by the U.S. EPA are protective of human health and are likely to overestimate (rather than underestimate) risk. The methodology uses specific algorithms to calculate risk as a function of chemical concentration, human exposure parameters, and toxicity.

Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also exhibit noncarcinogenic effects. Potential impacts are then characterized for both types of health effects.

6.4.1.1 Carcinogenic Effects

Risks attributable to exposure to carcinogens COPCs are estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. At low doses, the incremental lifetime cancer risk (ILCR) is determined as follows (U.S. EPA, 1989):

$$ILCR_i = (Intake_i)(CSF_i)$$

where: $ILCR_i$ = Incremental Lifetime Cancer Risk for chemical "i", expressed as a unitless probability

$Intake_i$ = Intake of chemical "i" (mg/kg/day)

CSF_i = Cancer slope factor of chemical "i" (kg/day/mg)

Estimated ILCRs are compared to the U.S. EPA target risk range, 10^{-4} to 10^{-6}. Risks below 1×10^{-6} (1/1,000,000, or a risk less than 1 in 1 million) are generally considered to be "acceptable" by the U.S. EPA, whereas risks greater than 1×10^{-4} (1 in 10,000) are generally considered to be "unacceptable" by the agency. Depending on the risk management goals for the site, risks within 10^{-4} to 10^{-6} are also typically regarded as "acceptable."

When carcinogenic risks exceed 1×10^{-2} using the above methodology, the U.S. EPA (U.S. EPA, 1989) specifies that the one-hit model be used, as follows:

$$ILCR_i = 1 - \exp(-Intake_i)(CSF_i)$$

Risks are estimated for all carcinogenic compounds regardless of the class designation (A, B, or C).

6.4.1.2 Noncarcinogenic Effects

The hazards associated with the effects of noncarcinogenic COPCs are evaluated by comparing an exposure level or intake to an RfD. The ratio of the intake to the RfD is called the Hazard Quotient (HQ) and is defined as follows (U.S. EPA, 1989):

$$HQ_i = \frac{Intake}{RfD_i}$$

where: HQ_i = Hazard Quotient for chemical "i" (unitless)
$Intake_i$ = Intake of chemical "i" (mg/kg/day)
RfD_i = Reference Dose of chemical "i" (mg/kg/day)

A Hazard Index (HI) is generated by summing the individual HQs for all the COPCs. If the HI exceeds unity, there exists a potential for noncarcinogenic (toxic) effects to occur. When the HI exceeds unity, it is necessary to segregate the HQs by target organ effects since the HQs for all noncarcinogens are not considered to be truly additive unless similar target organs are affected.

The estimation of noncarcinogenic effects (i.e., the calculation of HQs/HIs) should not be construed as a probability in the manner of the ILCR, but rather a numerical indicator of the extent to which a predicted intake exceeds, or is less than, an RfD.

6.4.2 Results of the Risk Characterization

This section contains a summary of the results of the risk characterization for Site 3. Potential cancer risks and hazard indices were calculated for construction workers, maintenance workers, recreational users and are summarized in Table 6-21. Sample calculations are presented in Appendix E-1. Results of the risk assessment in RAGS Part D format is included in Appendix E.2.

Construction Workers

All estimated cancer risks for construction workers were within U.S. EPA's target risk range of 10^{-4} to 10^{-6}. The estimated cancer risk for construction workers was 6.5×10^{-6} for exposure to surface soil, 4.0×10^{-8} for exposure to groundwater, 4.0×10^{-7} for exposure to sediment, and 1.0×10^{-5} for exposure to surface water. The total cancer risk across all media was 1.7×10^{-5}.

All estimated HIs were less than the acceptable level of 1.0, indicating that adverse health effects are not anticipated for construction workers under the defined conditions. The estimated HIs for construction

TABLE 6-21

SUMMARY OF HUMAN HEALTH CANCER RISKS AND HAZARD INDICES
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks >10^{-4}	Chemicals with Cancer Risks >10^{-5}	Chemicals with Cancer Risks >10^{-6}	Hazard Index	Chemicals with HI > 1
Construction Worker	Soil	Ingestion	1.8E-06	--	--	cPAHs	0.16	--
		Dermal Contact	4.7E-06	--	--	cPAHs	0.06	--
		Total	6.5E-06	--	--	cPAHs	0.22	--
	Groundwater	Dermal Contact	4.0E-08	--	--	--	0.06	--
	Sediment	Ingestion	1.3E-07	--	--	--	0.05	--
		Dermal Contact	2.6E-07	--	--	--	0.01	--
		Total	4.0E-07	--	--	--	0.06	--
	Surface Water	Ingestion	1.4E-07	--	--	--	0.05	--
		Dermal Contact	1.0E-05	--	--	cPAHs	0.09	--
		Total	1.0E-05	--	cPAHs	--	0.14	--
		Total All Media	1.7E-05			Total All Media	0.47	
Maintenance Worker	Soil	Ingestion	3.7E-06	--	--	cPAHs, Arsenic	0.01	--
		Dermal Contact	4.7E-05	--	cPAHs	Arsenic	0.02	--
		Total	5.1E-05	--	cPAHs	Arsenic	0.04	--
	Sediment	Ingestion	8.2E-07	--	--	--	0.01	--
		Dermal Contact	7.9E-06	--	--	cPAHs, Arsenic	0.01	--
		Total	8.7E-06	--	--	cPAHs, Arsenic	0.03	--
		Total All Media	5.9E-05			Total All Media	0.06	
Recreational Users	Fish (Measured Tissue)	Conservative	5.0E-05	--	Aroclor 1254	Dieldrin, DDE	2.4	Aroclor 1254
		Site-Specific	3.5E-06	--		Aroclor 1254	0.83	--
	Fish (Calculated Sediment/Surface Water - Maximum Concentration)	Conservative	1.8E-03	cPAHs, Aroclor 1254, Arsenic	DDE, alpha-chlordane, Aroclor 1260	Carbazole, DDD, DDT, gamma-chlordane	18	Aroclor 1254, Arsenic, Mercury
		Site-Specific	1.3E-04	--	cPAHs, Aroclor 1254, Arsenic	DDE, Aroclor 1260	6.1	Aroclor 1254, Arsenic, Mercury
	Fish (Calculated Sediment/Surface Water - Average Concentration)	Conservative	2.0E-04	--	cPAHs, DDE, alpha-chlordane, gamma-chlordane, Aroclor 1254, Aroclor 1260, Arsenic	Carbazole, DDT	2.2	Aroclor 1254
		Site-Specific	1.4E-05	--	--	cPAHs, DDE, alpha-chlordane, gamma-chlordane, Aroclor 1254, Arsenic	0.76	--

CPAHs: Carcinogenic polynuclear aromatic hydrocarbons
Conservative: U.S. EPA Region IV default parameters (see Table 6-18)
Site-Specific: Values based on site specific conditions (see Table 6-18)

workers were 0.22 for exposure to soil, 0.06 for exposure to groundwater, 0.06 for exposure to sediment, and 0.14 for exposure to surface water. The cumulative HI across all media was 0.47.

Maintenance Workers

All estimated cancer risks for maintenance workers were within U.S. EPA's target risk range of 10^{-4} to 10^{-6}. The estimated cancer risks for maintenance workers were 5.1×10^{-5} for exposures to soil and 8.7×10^{-6} for exposures to sediment. The total cancer risk across all media was 5.9×10^{-5}.

All estimated HIs were less than the acceptable level of 1.0. The HIs for a maintenance worker were 0.04 for exposure to soil and 0.03 for exposure to sediment, indicating that no adverse health effects anticipated for maintenance workers exposed to soil and sediment under the defined conditions.

Recreational Users

Cancer risks and hazard indices were estimated for recreational users ingesting fin and shell fish caught at the site using fish tissue samples collected during the ESI in 1991 and using calculated concentrations of chemicals in fish tissue based on the 1998 surface water and sediment sampling investigation results. In addition, cancer risks and HIs were estimated using U.S. EPA Region IV default exposure assumptions and also using site-specific considerations.

Cancer risks from exposures by recreational users ingesting fish based on the 1991 fish tissue samples were within the U.S. EPA target risk range of 10^{-4} to 10^{-6} for both scenarios evaluated. The estimated cancer risks for recreational users were 5.0×10^{-5} using the U.S. EPA Region IV default exposure assumptions and 3.5×10^{-6} using exposure assumptions based on site-specific considerations.

The estimated HI from exposures by recreational users ingesting fish based on the 1991 fish tissue samples and using the U.S. EPA Region IV default exposure assumptions was 2.4, which exceeds the acceptable level of 1.0. Aroclor 1254 (HI = 2.2) was the main contributor to the HI. The estimated HI using exposure assumptions based on site-specific considerations was 0.83, which is less than 1.0.

Concentrations of chemicals in surface water and sediment samples from the 1998 investigation were also used to calculate chemical concentrations in fish tissue. Estimated cancer risks based on maximum surface water/sediment concentrations exceeded U.S. EPA's target risk range of 10^{-4} to 10^{-6}. Cancer risks from exposures by recreational users ingesting fish based on the estimated chemical concentrations in fish tissue using the maximum surface water/sediment concentrations were 1.8×10^{-3} based on U.S. EPA Region IV default exposure assumptions and 1.3×10^{-4} based on site-specific exposure assumptions. Carcinogenic PAHs, pesticides, and arsenic were the main contributors to the cancer risk.

Estimated HIs based on maximum surface water/sediment concentrations exceeded the acceptable level of 1.0. The estimated HIs from exposures by recreational users ingesting fish based on the estimated chemical concentrations in fish tissue using the maximum surface water/sediment concentrations were 18 based on U.S. EPA Region IV default exposure assumptions and 6.1 using site-specific exposure assumptions; these HIs exceed the acceptable level of 1.0. Aroclor 1254 (HI_{max} = 12, HI_{avg} = 1.4) arsenic (HI_{max} = 4.0, HI_{avg} = 1.4), and mercury (HI_{max} = 1.4, HI_{avg} = 0.5) were the main contributors to the HIs.

Cancer risks from exposures by recreational users ingesting fish based on the estimated chemical concentrations in fish tissue using the average surface water/sediment concentrations and U.S. EPA Region IV default exposure assumptions were 2.0×10^{-4}, which exceeds U.S. EPA's target risk range of 10^{-4} to 10^{-6}. Carcinogenic PAHs, pesticides, and arsenic were the main contributors to the cancer risk. The cancer risk from ingestion of fish by recreational users based on site-specific assumptions was 1.4×10^{-5}, which is within U.S. EPA's target risk range.

The estimated HI from exposures by recreational users ingesting fish based on the estimated chemical concentrations in fish tissue using the average surface water/sediment concentrations and U.S. EPA Region IV default exposure assumptions was 2.2, which exceeds the acceptable level of 1.0. Aroclor 1254 (HI = 1.4) was the main contributor to the HI. The estimated HI based on site-specific assumptions was 0.76, which is less than 1.0.

6.5 UNCERTAINTY ANALYSIS

There is uncertainty associated with all aspects of the baseline human health risk assessment presented in this section. A summary of the uncertainties, including a discussion of how they may affect the final risk numbers, is provided in this section.

Uncertainty in the selection of COPCs is related to the current status of the predictive databases, the grouping of samples, and the procedures used to include or exclude constituents as COPCs. Uncertainty associated with the exposure assessment includes the values used as input variables for a given intake route/scenario, the assumptions made to determine exposure point concentrations, and the predictions regarding future land use and population characteristics. Uncertainty in the toxicity assessment includes the quality of the existing toxicity data needed to support dose-response relationships and the weight-of-evidence used for determining the carcinogenicity of COPC. Uncertainty in risk characterization includes that associated with exposure to multiple chemicals and the cumulative uncertainty from combining conservative assumptions made in earlier activities.

While there are various sources of uncertainty, as described above, the direction of uncertainty can be influenced by the assumptions made throughout the risk assessment, including selection of COPCs and selection of values for dose-response relationships. Throughout the entire risk assessment, assumptions that consider safety factors are made so that the final calculated risks are overestimated.

Generally, risk assessments carry two types of uncertainty: measurement and informational uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements. For example, this type of uncertainty is associated with analytical data collected for each site. The risk assessment reflects the accumulated variances of the individual values used.

Informational uncertainty stems from inadequate availability of information needed to complete the toxicity and exposure assessments. Often, this gap is significant, such as the absence of information on the effects of human exposure to low doses of a chemical, on the biological mechanism of action of a chemical, or on the behavior of a chemical in soil.

Once the risk assessment is complete, the results must be reviewed and evaluated to identify the type and magnitude of uncertainty involved. Reliance on results from a risk assessment without consideration of uncertainties, limitations, and assumptions inherent in the process can be misleading. For example, to account for uncertainties in the development of exposure assumptions, conservative estimates must be made to ensure that the particular assumptions made are protective of sensitive subpopulations or the maximum exposed individuals. If a number of conservative assumptions are combined in an exposure model, the resulting calculations can propagate the uncertainties associated with those assumptions, thereby producing a much larger uncertainty for the final results. This uncertainty is biased toward over predicting both carcinogenic and noncarcinogenic risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered when making risk management decisions.

This interpretation is especially relevant when the risks exceed the point-of-departure for defining "acceptable" risk. For example, when risks calculated using a high degree of uncertainty are below an "acceptable" risk level (i.e., 1×10^{-6}), the interpretation of no significant risk is typically straightforward. However, when risks calculated using a high degree of uncertainty are above an "acceptable" risk level (i.e., 1×10^{-4}), a conclusion can be difficult unless uncertainty is considered.

6.5.1 Uncertainty in Data Evaluation

There is a minor amount of uncertainty associated with the data evaluation that may impact the numerical risk estimates presented in Section 6.4, Risk Characterization. The most significant issues related to uncertainty in the data evaluation for Site 3 are the screening levels used, the absence of screening levels

for a few chemicals detected in the site media, and the exclusion of the 1999 sediment data from the human health risk assessment. A brief discussion of each of these issues is provided below.

6.5.1.1 COPC Screening Levels

The use of predetermined screening values based on conservative land use scenarios (i.e., residential land use for soil and sediment and ingestion/inhalation for groundwater/surface water), in combination with the use of risk-based screening values corresponding to a 1 x 10^{-6} ILCR and a 0.1 HI, should ensure that the significant contributors to risk from a site are evaluated. The elimination of chemicals that are present at concentrations that correspond to a less than 1 x 10^{-6} ILCR and less than 0.1 HI should not affect the final conclusions of the risk assessment since these chemicals are not expected to cause a potential health concern.

6.5.1.2 Absence of COPC Screening Levels

There are several chemicals [acenaphthylene, benzo(g,h,i)perylene, and phenanthrene] for which there are no available health criteria and for which no risk-based COPC screening criteria could be developed. The screening criterion for naphthalene was used as a surrogate for these chemicals since the chemical structures of these chemicals are similar to that of naphthalene. Therefore, there is some uncertainty associated with screening these chemicals using the screening criterion for naphthalene. The maximum detected concentrations of acenaphthylene, benzo(g,h,i)perylene, and phenanthrene are approximately two or more orders of magnitude lower than the screening criteria for naphthalene. Consequently, the absence of screening criteria for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene and the use of naphthalene as a surrogate for these chemicals does not affect the conclusions of the risk assessment.

6.5.1.3 Exclusion of 1999 Sediment Data

Only sediment analytical data collected in 1998 was used in the human health risk assessment. Additional sediment samples were collected at Site 3 in August 1999 in order to delineate areas of impacted sediments for the feasibility study. A comparison of the 1998 results to the 1999 results was presented in Section 4.4.3. As discussed in Section 4.4.3 concentrations of PAHs and 4,4'-DDD wee lower in the 1999 samples as compared to the 1998 samples and concentration of 4,4'-DDE and Aroclor-1254 were slightly higher (less than an order of magnitude) in the 1999 samples as compared to the 1998 samples. Concentrations of PAHs and pesticides in the 1999 sediment samples were less than the human health screening criteria. Aroclor-1254 was detected at a maximum concentration of 370 J µg/kg, although the concentration of Aroclor-1254 in the duplicate to this sample was 130 J µg/kg. The maximum detected Aroclor-1254 concentration of 370 J µg/kg exceeded the EPA Region III RBC of 320 µg/kg for residential exposures but was less than the EPA Region III RBC of 2,900 µg/kg for industrial exposures. Only

exposures to industrial receptors were evaluated at Site 3. Consequently, the exclusion of the 1999 sediment data from the human health risk assessment does not significantly impact the results of the human health risk assessment.

6.5.2 Uncertainty in the Exposure Assessment

Uncertainty in the exposure assessment arises because of the methods used to calculate exposure point concentrations, the determination of land use conditions, the selection of receptors and scenarios, and the selection of exposure parameters. Each of these is discussed below.

6.5.2.1 Land Use

The current land use patterns at the site are well established, thereby reducing the uncertainty associated with land use assumptions. Land use at the site is currently limited and is expected to be limited in the future.

6.5.2.2 Exposure Point Concentrations

For some chemicals in surface soil, surface water, and sediment, the distribution of the chemical was not defined and the maximum detected concentration was used as the exposure point concentration. As a result, the estimations of risk, where the maximum concentrations were used as the exposure point concentration, are most likely to be overstated because it is unlikely that potential receptors would be exposed to the maximum concentration over the entire exposure period.

Concentrations of chemicals in fish tissue were estimated using the surface water and sediment results from the 1998 field investigation and bioconcentration factors. Bioconcentration factors only estimate the uptake for chemicals from surface water and sediment and do not consider what happens to the chemical after uptake by fish. Most aquatic animals can degrade PAHs to more polar metabolites and excrete them rapidly. Even species lacking PAH-metabolizing ability can release accumulated PAHs rapidly when they are returned to a PAH-free environment. Thus, food chain biomagnification of PAHs occurs to a very limited extent, if at all (Rand and Petrocelli, 1985). The ability of fish to metabolize PAHs probably explains why benzo(a)pyrene frequently is not detected or is found only at very low concentrations in fish from areas heavily contaminated with PAHs (Varanasi and Gmur, 1980, 1981). Consequently, the use of bioconcentration factors to estimate PAHs concentration in fish tissue most likely overestimates the actual PAH concentration in fish tissue and subsequently results in an overestimation of risk.

Concentrations of inorganics in fish tissue were estimated using unfiltered surface water samples, but also could have been estimated using filtered surface water samples. Arsenic was identified as one of the major

contributors to the cancer risk and hazard indices for ingestion of fish by adult recreational users. The maximum detected concentration of arsenic was 96.1 µg/L in unfiltered samples versus 12.9 µg/L in filtered samples. The average detected concentration of arsenic was 6 µg/L in unfiltered samples versus 1.7 µg/L in filtered samples. The total cancer risk for ingestion of fish based on unfiltered surface water samples and maximum concentrations was 1.8×10^{-3} (Arsenic - 7.8×10^{-4}) for RME exposures and 1.3×10^{-4} (arsenic = 5.4×10^{-5}) for site-specific exposures. The total cancer risk for ingestion of fish based on filtered surface water samples and maximum concentrations was 1.1×10^{-3} (Arsenic = 1.0×10^{-4}) for RME exposures and 7.0×10^{-5} (arsenic = 7.2×10^{-6}) for site-specific exposures. The total cancer risk for ingestion of fish based on unfiltered surface water samples and average concentrations was 2.0×10^{-4} (Arsenic - 4.7×10^{-5}) for RME exposures and 1.4×10^{-5} (arsenic - 3.2×10^{-6}) for site-specific exposures. The total cancer risk for ingestion of fish based on filtered surface water samples and average concentrations was 1.7×10^{-4} (Arsenic = 1.4×10^{-5}) for RME exposures and 1.2×10^{-5} (arsenic = 9.6×10^{-7}) for site-specific exposures. The use of filtered samples for arsenic would have resulted in slightly lower risks but the overall conclusions of the risk assessment would not change. Therefore, the use of unfiltered surface water samples, while conservative, does not result in significant uncertainty in the risk assessment.

6.5.2.3 Exposure Routes and Receptor Identification

Site 3 is part of the causeway, a two-lane gravel road that connects Horse Island and Parris Island. Because Site 3 is a road, very little activity occurs there. Receptors evaluated in the human health risk assessment included construction workers, maintenance workers, and recreational users. Construction workers were assumed to be exposed to all media, maintenance workers were assumed to be exposed to soil and sediment, and recreational users were assumed to be exposed via the ingestion of potentially contaminated fish. Given that Site 3 is a road, it is very unlikely that any type of major construction activity would occur in this area, e.g., building construction. Consequently, there is uncertainty associated with the selection of a construction worker as a receptor at Site 3. The sides of the road are vegetated so periodic maintenance in the form of mowing grass is possible. Therefore, a maintenance worker is a likely receptor at Site 3. Fishing also occurs at Site 3, so there is very little uncertainty with the selection of a recreational user as a receptor at Site 3.

6.5.2.4 Exposure Parameters

Each exposure factor selected for use in the risk assessment has some associated uncertainty. Generally, exposure factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid underestimation of exposure, the U.S. EPA guidelines on the RME receptor were used, which generally consist of the 95th percentile for most parameters. Therefore, the selected values for the RME receptor represent the upper bound of the observed or expected habits of the majority of the population.

Generally, the uncertainty can be assessed quantitatively for a number of assumptions made in determining factors for calculating exposures and intakes. Many of these parameters were determined from statistical analyses on human population characteristics. Often, the database used to summarize a particular exposure parameter (i.e., body weight) is quite large. Consequently, the values chosen for such variables in the RME scenario have low uncertainty. For many parameters for which limited information exists (i.e., dermal absorption of organic chemicals from soil), there is greater uncertainty. However, there are often sufficient data to estimate these parameters with low uncertainty.

Many of the quantities used to calculate exposures and risks in this report are selected from a distribution of possible values. For the RME scenario, the value representing the 95th percentile is generally selected for each parameter to ensure that the assessment bounds the actual risks from a postulated exposure. This risk number is used in risk management decisions but does not indicate what a more average or typical exposure might be or what risk range might be expected for individuals in the exposed population.

6.5.3 Uncertainty in the Toxicological Evaluation

Uncertainties associated with the toxicity assessment (determination of RfDs and CSFs and use of available criteria) are presented in this section.

6.5.3.1 Derivation of Toxicity Criteria

Uncertainty associated with the toxicity assessment is associated with hazard assessment and dose-response evaluations for the COPCs. The hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will also induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using the U.S. EPA methods. Positive animal cancer test data suggest that humans contain tissue(s) that may also manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of noncancer effects, however, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans.

Uncertainty in hazard assessment arises from the nature and quality of the animal and human data. Uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose related; when pharmacokinetic data indicate a similar fate in humans and animals; when postulated mechanisms of toxicity are similar for humans and animals; and when the chemical of concern is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainty in the dose-response evaluation includes the determination of a CSF for the carcinogenic assessment and derivation of an RfD for the noncarcinogenic assessment. Uncertainty is introduced from interspecies (animal to human) extrapolation, which, in the absence of quantitative pharmacokinetic or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Uncertainty also results from intraspecies variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so that intragroup biological variation is minimal, but the human population of concern may reflect a great deal of heterogeneity including unusual sensitivity or tolerance to the COPC. Even toxicity data from human occupational exposure reflect a bias, because only those individuals sufficiently healthy to attend work regularly (the "healthy worker effect") and those not unusually sensitive to the chemical are likely to be occupationally exposed. Finally, uncertainty arises from the quality of the key study from which the quantitative estimate is derived and the database. For cancer effects, the uncertainty associated with dose-response factors is mitigated by assuming the 95 percent upper bound for the slope factor. Another source of uncertainty in carcinogenic assessment is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from animal data, is based on a nonthreshold assumption of carcinogenesis. There is evidence to suggest, however, that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic (Williams and Weisburger, 1991); therefore, the use of the linearized multistage model is conservative for chemicals that exhibit a threshold for carcinogenicity.

For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD to mitigate poor quality of the key study or gaps in the database. Additional uncertainty for noncancer effects arises from the use of an effect level in the estimation of an RfD, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises in estimation of an RfD for chronic exposure from less-than-chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the less-than-chronic study. Uncertainty in the derivation of RfDs is mitigated by the use of uncertainty and modifying factors that normally range between 3 and 10. The resulting combination of uncertainty and modifying factors may reach 1,000 or more.

The derivation of dermal RfDs and CSFs from oral values may cause uncertainty. This is particularly the case when no gastrointestinal absorption rates are available in the literature or when only qualitative statements regarding absorption are available. Whenever possible, gastrointestinal absorption rates from U.S. EPA Region IV were used for all chemicals in the human health risk assessment. U.S. EPA is currently revising the dermal guidance and has interim gastrointestinal absorption rates that differ from

those recommended by U.S. EPA Region IV. For example, U.S. EPA Region IV recommends a gastrointestinal absorption rate of 31 percent for PAHs. The draft U.S. EPA dermal guidance lists a gastrointestinal absorption rate of 89 percent for PAHs and recommends that the oral CSF be used as the dermal CSF. Consequently, risks from dermal exposures evaluated using the draft U.S. EPA guidance will be lower than those evaluated using the U.S. EPA Region IV guidance. Therefore, dermal exposures based on the U.S. EPA Region IV guidance may overestimate cancer risks.

6.5.3.2 Use of PAH Toxicity Criteria

Uncertainty also arises in the dose-response assessment for values derived for several PAHs by using studies with limitations. These criteria are used to not only calculate risks for COPCs but also to determine risk-based COPC screening levels for PAHs. PAHs for which no toxicity data are available are evaluated using benzo(a)pyrene toxicity data with estimated orders of potential potency for the average and RME receptors. This may either underestimate or overestimate the carcinogenic risks associated with PAHs.

6.5.3.3 Use of Arsenic Toxicity Criteria

The carcinogenicity of arsenic via ingestion is not confirmed by the available data. However, the U.S. EPA has proposed an oral unit risk factor that was used for all oral and dermal exposures to arsenic at this site. Since arsenic is selected as a COPC for various media at Site 3, the risks associated with this chemical may be overstated. Although the more restrictive basis for evaluating risk associated with exposure to arsenic is to assume it is a carcinogen, carcinogenic effects are not the primary health effects expected to be manifested upon exposure to arsenic. The preponderance of scientific information indicates that humans are capable of metabolizing arsenic to expedite its elimination from the body (ATSDR, 1988). Its elimination from the body obviously mitigates the possibility for arsenic to manifest carcinogenic effects. Therefore, evaluating arsenic as a noncarcinogen would be more appropriate.

6.5.3.5 Use of Toxicity Criteria From NCEA

National Center for Environmental Assessment (NCEA) provisional RfDs are used to evaluate noncarcinogenic effects from exposure to benzene, 1,4-dichlorobenzene, aluminum, iron, and thallium. The provisional RfDs for aluminum and iron are based on allowable intakes rather than adverse effect levels. Therefore, there is some degree of uncertainty associated with the use of the RfDs.

The degree of uncertainty associated with the use of the provisional values for these chemicals has a potentially significant impact on the results of the risk assessment, especially since aluminum and iron are identified as major contributors to the estimated HI for the construction worker exposed to surface soil,

sediment, and surface water. Since the RfDs are not based on adverse effect levels, like the other toxicity criteria used in the risk assessment, the potential significance of the estimated HIs are diminished when this is taken into consideration.

6.5.4 Uncertainty in the Risk Characterization

Uncertainty in risk characterization results primarily from assumptions made regarding additivity of effects from exposure to multiple COPCs from various exposure routes. High uncertainty exists when summing cancer risks for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Often compounds affect different organs, have different mechanisms of action, and differ in their fate in the body, so additivity may not be an appropriate assumption. However, the assumption of additivity is made to provide a conservative estimate of risk.

Finally, the risk characterization does not consider antagonistic or synergistic effects. Little or no information is available to determine the potential for antagonism or synergism for the COPCs. Therefore, this uncertainty cannot be discussed for its impact on the risk assessment, since it may either underestimate or overestimate potential human health risk.

7.0 ECOLOGICAL RISK ASSESSMENT

The RFI process requires an assessment of the potential adverse effects of site contamination on the environment. Ecological receptors that utilize Site/SWMU 3 (Site 3) and nearby areas could potentially be at risk from environmental contamination associated with Site 3. Accordingly, an ecological risk assessment (ERA) was performed to characterize the potential risks from site-related contaminants to ecological receptors.

7.1 OVERVIEW OF METHODS

This section provides an outline of the general approach that was taken to assess the impacts of site contamination on ecological receptors. This assessment generally followed a two-step process, as follows:

Step 1: Preliminary Problem Formulation (Section 7.2) and Ecological Effects Evaluation (Section 7.3)

- Preliminary Problem Formulation - This first phase of an ERA discusses the goals, breadth, and focus of the assessment. It includes general descriptions of the site, with emphasis on the habitats and ecological receptors that are present. This phase also involves characterization of contaminant sources and migration pathways, evaluation of routes of contaminant exposure, and selection of analytes to be assessed. Assessment and measurement endpoints are also selected in this phase, and a conceptual model is developed that describes how contaminants associated with Site 3 may come into contact with ecological receptors.

- Preliminary Ecological Effects Evaluation - In this phase, medium-specific ecological screening guidelines for each analyte (i.e., concentrations of each contaminant above which adverse effects to ecological receptors may occur) are identified. Contaminant doses associated with toxicity to representative ecological receptors are also identified. This step is undertaken concurrently with the exposure assessment described below.

Step 2: Preliminary Exposure Assessment (Section 7.4) and Risk Calculation (Section 7.5)

- Preliminary Exposure Estimate - This portion of the ERA includes the identification of data used to represent concentrations of contaminants to which ecological receptors may be exposed in various media and the selection of exposure point contaminant concentrations from those data. Contaminant doses for representative receptors are also calculated.

- Preliminary Risk Calculation - In this step, exposure point concentrations are compared to guidelines in order to characterize potential risk to ecological receptors. Contaminant doses associated with toxicity are compared to calculated doses for representative receptors. Analytes that are found to pose potential risk after these comparisons are selected as ecological contaminants of potential concern (COPCs).

When these two steps are completed, the results are interpreted, ecological contaminants of concern (COCs) are selected, and the uncertainties associated with the ERA are addressed. COCs are COPCs that are shown to present unacceptable risks to ecological receptors based on their concentrations, distributions, and modes of toxicity. The above process, described in further detail below, represents the general approach recommended in the most recent U.S. EPA guidance for performing ERAs (U.S. EPA, 1997b, U.S. EPA, 1998b), which served as the basis for the ERA methodology. Furthermore, the ERA was conducted in accordance with Navy policy (DON, 1999) and other available guidance documents (U.S. EPA, 1995b; Wentsel et al., 1996) and publications (Ingersoll et al., 1997; Suter, 1993; Calabrese and Baldwin, 1993). The methods used in this ERA and discussed below were summarized in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998b). Revisions to the Master Work Plan have been discussed with the MCRD Parris Island partnering team.

Due to the potential complexity of ERAs, they are often conducted using a tiered approach and punctuated with Scientific/Management Decision Points (SMDPs). SMDPs are meetings involving the risk managers and risk assessment team and are conducted to evaluate the work up to that point and ensure that the ERA is proceeding in an efficient manner. Information analyzed in one tier is evaluated to determine whether the objectives of the study have been met. The results are then used to identify the data required for the next tier, if necessary. The Tier 1 ERA is also known as a Screening Risk Assessment. The Screening Risk Assessment uses conservative (i.e. stringent) assumptions to evaluate site data and determine whether additional ecological risk assessment or accelerated site cleanup may be warranted, or that the site poses negligible ecological risks.

The second tier is a baseline ERA (BERA), which is conducted if the results of the screening-level ERA indicate that additional study is warranted. The BERA is a more focused study of the initial COPCs, and comprises Steps 3 through 7 of the 8-step ERA process. The BERA begins with a more balanced evaluation of the conservativeness inherent in the first two steps of the ERA process (U.S. EPA, 1997b; DON, 1999).

7.2 PRELIMINARY PROBLEM FORMULATION

7.2.1 Habitat Types and Ecological Receptors

Site 3 consists of a causeway constructed across a tidal marsh in the northern portion of MCRD Parris island. A 30-foot wide gravel road extends along the length of the causeway. A 10- to 40-foot wide strip of mowed grass exists on each side of the gravel road. Scattered hackberry trees (*Celtis laevigata*) and a variety of weedy plants are located along the banks of the causeway. Common plant species include Eastern baccharis (*Baccharis halimifolia*), ragweed (*Ambrosia artemisiifolia*), and amaranth (*Amaranthus* spp). The marsh on the north side of the causeway is primarily a ponded area of open water. The marsh south of the causeway is a vast expanse of thickly vegetated cordgrass (*Spartina alterniflora*), intersected by several tidal channels.

The frequently mowed portions of the causeway provide only marginal wildlife habitat, and few terrestrial wildlife species are expected to utilize those areas. Some portions of the banks of the causeway, however, are thickly vegetated and provide habitat for small mammals such as the Eastern mole (*Scalopus aquaticus*), short-tailed shrew (*Blarina carolinensis*), cotton rat (*Sigmodon hispidus*), and cotton mouse (*Peromyscus gossypinus*). Raccoons (*Procyon lotor*) and opossums (*Didelphis virginiana*) are expected to forage along the water's edge. Based on the existence of only marginal terrestrial wildlife habitat, and the absence of evidence such as tracks and scat, the use of the site by larger mammals is probably minimal. Some bird species forage on the causeway, especially along the edges of the vegetated areas.

The saltwater marsh provides habitat for a diverse assemblage of fauna, particularly fish and crustaceans. Several species of animals probably prey upon these fish and crustaceans. These include wading birds such as the tricolored heron (*Egretta tricolor*), great blue heron (*Ardea herodias*), green heron (*Butorides striatus)*, and snowy egret (*Egretta thula*). Various shorebirds and wintering waterfowl forage in the marsh.

The ponded area north of the site occasionally receives tidal inflow via two sets of three culverts beneath the causeway. This tidal flow results in saline conditions in the pond, thereby limiting aquatic organisms in the pond to marine species. Fish such as red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), southern flounder (*Paralichthys lethostigma*), summer flounder (*Paralichthys dentatus*), whiting (*Menticirrhus americanus*), and striped mullet (*Mugil cephalus)*, as well as a variety of mollusks and crustaceans, are known to occur in the marsh on both sides of the causeway.

Endangered and threatened species that utilize the site consist of the bald eagle (*Haliaeetus leucocephalus*), wood stork (*Mycteria americana*), and American alligator (*Alligator mississippiensis*). An

active bald eagle nest is located near the southeastern end of the causeway, and the associated pair of eagles is known to frequently forage in the vicinity of the site. The bald eagle is state and federally listed as threatened. Wood storks (state and federally listed as endangered) forage in various locations throughout the Depot, and they could occasionally forage near the site. Two alligators are frequently observed in the ponded area north of the causeway. Although common in some parts of its range, the alligator is federally listed as threatened due to its similarity in appearance to the endangered American crocodile (*Crocodylus acutus*).

Although other endangered and threatened species occur in Beaufort County (Table 2-2 of Volume I, Master Work Plan), the site provides poor habitats for these species. For example, the manatee (*Trichechus manatus*), shortnose sturgeon (*Acipenser brevirostrum*), and various sea turtles have been seen, at least occasionally, in the Broad River, Beaufort River, and Port Royal Sound. However, these species usually are not associated with shallow marsh areas present at Site 3. With the exception of the bald eagle, wood stork, and alligator, the likelihood of endangered and threatened species in the vicinity of the site is remote.

7.2.2 Contaminant Sources and Migration Pathways

The contaminant source at Site 3 is buried material from historical landfilling activities at the site. The contaminant migration pathways that were evaluated for the site include volatilization, wind erosion, overland runoff, and infiltration of contaminants. Constituents in the site soil could volatilize from surficial material or become airborne via resuspension. Contaminated fugitive dust could also be generated during ground-disturbing activities, such as construction or excavation. These contaminants could be dispersed in the surrounding environment and transported to downwind locations where they could become deposited in surface soil, surface water, or sediment. Precipitation runoff could carry constituents to nearby surface water and sediment in the marsh. Infiltrating precipitation could cause the contamination of subsurface soil and groundwater. Groundwater from the site could possibly discharge to surface water in the marsh, where groundwater contaminants could be subsequently deposited in sediment or in the tissues of aquatic organisms.

7.2.3 Exposure Routes

Aquatic and semi-aquatic organisms in the marsh adjacent to the site could be exposed to contaminants through direct contact with surface water and sediments, incidental ingestion of surface water and sediments, and consumption of contaminated food items. Aquatic and semi-aquatic organisms could also be exposed to constituents from contaminated groundwater that discharges to surface water in the marsh.

Terrestrial animals could be exposed to soil contaminants through ingestion of contaminated food items. Animals can incidentally ingest soil while grooming fur, preening feathers, digging, grazing close to the soil, or feeding on items to which soil has adhered (such as roots and tubers). Terrestrial vegetation can be exposed to contaminants via direct aerial deposition and root translocation. Aerial deposition was not investigated, primarily because the contaminant sources at the site are largely covered by vegetation, reducing the amount of bare soil and fugitive dust. Terrestrial animal receptors could also come into contact with contaminants in surface water through drinking, although the salinity of the surface water in the marsh precludes its use as drinking water. In addition, this exposure route represents a negligible portion of total exposure for most receptors (Sample et al., 1996). Nevertheless, organisms that prey on aquatic species could incidentally ingest surface water when consuming food items. Therefore, this exposure route was investigated for wading birds and the raccoon.

Exposure to contaminants in the soil via dermal contact may occur but is unlikely to represent a major exposure pathway because fur, feathers, and chitinous exoskeletons probably minimize transfer of contaminants across dermal tissue. In addition, little information is available (e.g., absorption factors) to evaluate dermal exposures to wildlife. Volatile constituents are present in soil, soil-bound contaminant resuspension could occur, and combustion could release contaminants into the air. However, inhalation does not represent a significant exposure pathway because air contaminant concentrations are assumed to be quite low, even for burrowing wildlife. In addition, inhalation ecotoxicity data for chronic exposure are lacking. Therefore, the air pathway was not considered for ecological receptors.

7.2.4 Selection of Analytes to be Investigated

Analytes initially included for quantitative analysis in the ERA were all analytes detected in surface water, sediment, surface soil, and groundwater samples collected in 1998 sampling activities. However, calcium, magnesium, potassium, and sodium were excluded since they are essential nutrients that are toxic only at extremely high concentrations. Due to the scarcity of data for these essential nutrients, it was not possible to develop ranges of toxicity for them even at high concentrations. The limited toxicity data available indicate that high dietary intake of these nutrients is well tolerated. The process that was used to select COPCs from the detected analytes is described in Section 7.5. Profiles describing the environmental fate, transport, and toxicity of COPCs are presented in Appendix F.

7.2.5 Assessment and Measurement Endpoints

As discussed in U.S. EPA (1997b) and Wentsel et al. (1996), one of the major tasks in preliminary problem formulation is the selection of assessment and measurement endpoints. An assessment endpoint is "an explicit expression of actual environmental values that are to be protected" and measurement endpoints are "measurable ecological characteristics that are related to the valued

characteristic chosen as the assessment endpoint" (U.S. EPA, 1997b). The assessment endpoints selected for this ERA were based on the environmental setting, contaminants known to exist at the site, contaminant fate and transport mechanisms, exposure pathways, mechanisms of ecotoxicity, and likely categories of receptors that could be affected by site-related contaminants. The assessment endpoints consist of the protection of the following groups of receptors from adverse effects of site-related contaminants on growth, survival, and reproduction:

- benthic invertebrate communities
- fish communities (forage fish and higher trophic level fish)
- piscivorous birds
- omnivorous birds
- carnivorous birds
- omnivorous mammals
- herbivorous mammals
- mammals that feed on soil invertebrates
- terrestrial and aquatic vegetation

As discussed in Section 7.2.1, most of the site consists of a gravel road and frequently mowed areas. Therefore, the site provides only marginal habitat for terrestrial organisms, and the diversity and abundance of terrestrial wildlife species are expected to be low. Consequently, carnivorous mammals and birds that feed exclusively on soil invertebrates were not included as assessment endpoints since the use of the site by these two groups of receptors is probably infrequent and insignificant. Amphibians and reptiles were not included as assessment endpoints since toxicity data for amphibians and reptiles are sparse, resulting in a small, sporadic toxicity database. In addition, relatively few amphibians and reptiles are expected to utilize the terrestrial portions of the site.

Measurement endpoints serve as surrogates for assessment endpoints, since they are more easily quantified or observed than assessment endpoints. Measurement endpoints consisted of contaminant concentrations associated with adverse effects on growth, survival, and reproduction of aquatic organisms (surface water screening levels), benthic organisms (sediment screening levels), and terrestrial vegetation and soil invertebrates (surface soil screening levels). In addition, measurement endpoints for representative receptor groups were contaminant doses associated with adverse effects on growth, survival, and reproduction of these receptors. Taken together, the measurement endpoints address all of the groups of receptors chosen as assessment endpoints.

7.2.6 Conceptual Site Model

The conceptual model is designed to diagram the potentially exposed receptor populations and applicable exposure pathways, based on the physical nature of the site and the potential contaminant source areas. Actual or potential exposures of ecological receptors associated with Site 3 were determined by identifying the most likely pathways of contaminant release and transport. A complete exposure pathway has three components: a source of contaminants that can be released to the environment; a route of contaminant transport through an environmental medium; and an exposure route or contact point for an ecological receptor. A preliminary conceptual model for Site 3 is presented in Figure 7-1. Dermal (direct contact) and inhalation exposure routes are included in the conceptual model since they are theoretically possible, but as mentioned earlier, they represent minor exposure routes and were not investigated.

7.3 PRELIMINARY ECOLOGICAL EFFECTS EVALUATION

For this ERA, exposure-point concentrations of detected analytes in surface water, groundwater, sediment, and surface soil were compared to ecologically based guidelines to determine if the analytes should be selected as COPCs. In addition, toxic doses of contaminants were compared to modeled doses for representative receptors. The methods used for the selection of ecological screening levels are discussed below.

7.3.1 Ecological Screening Values

The initial ecological screening value comparison consisted of the comparison of maximum concentrations of chemicals detected in Site 3 media to Region IV approved ecological screening values (ESVs) (U.S. EPA, 1995b). If the maximum concentration was less than the ESV, the chemical was eliminated from further consideration. If the maximum concentration equaled or exceeded the ESV, or if an ESV was not available, the chemical was considered to be an ecological COPC and was retained for further study in the ecological risk assessment.

The ESVs used for the initial screening of ground water, surface water, sediment, and surface soil were those established by U.S. EPA Region IV (EPA, 1995b; 1998b). Since Site 3 borders a tidal marsh, the surface water samples were saline (average salinity = 18 ppt). Therefore, salt water ESVs were used for the surface water screening value comparison in accordance with U.S. EPA (1996a) and SCDHEC (1998) guidance. Ground water samples were also saline (average salinity = 10 ppt), and thus, chemical concentrations were compared to surface water ESVs for salt water in accordance with U.S. EPA Region IV policy (U.S. EPA, 1995b).

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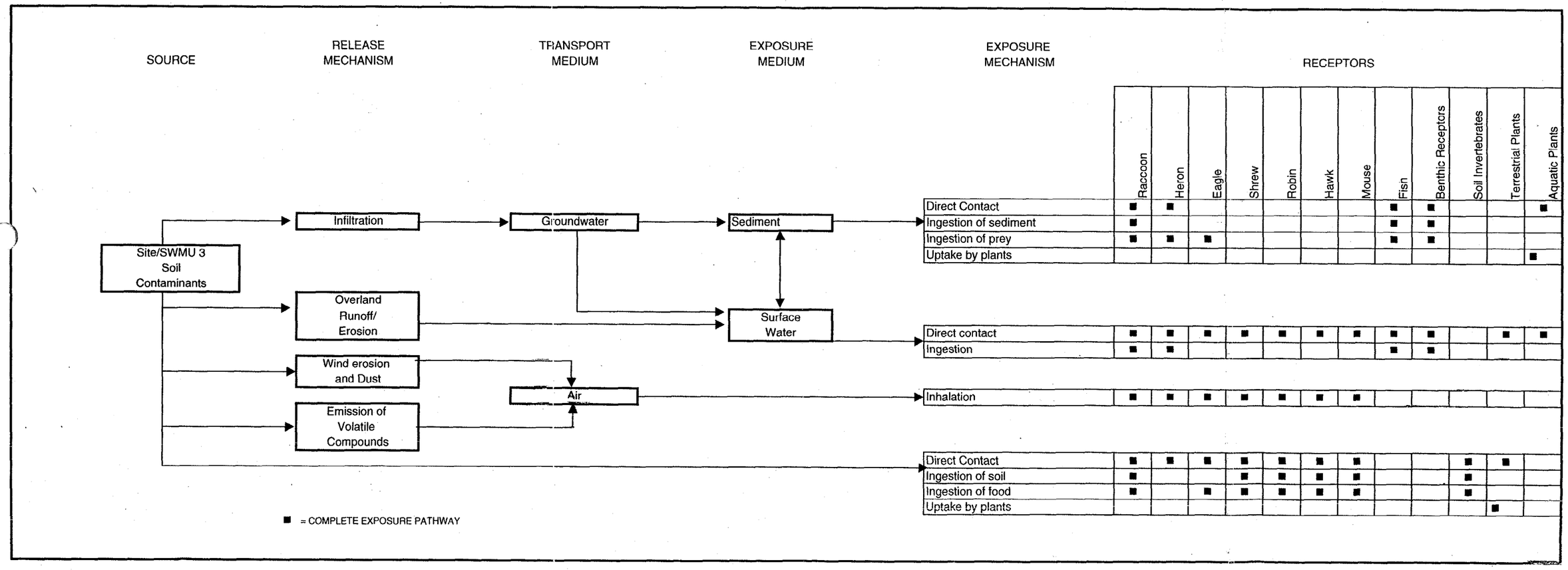
FIGURE 7-1

CONCEPTUAL SITE MODEL
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA



Following recent discussions with U.S. EPA Region IV (ABB, 1997), the ESV for benzo(a)pyrene was used as a surrogate for high molecular weight PAHs, the ESV for naphthalene was used as a surrogate for low molecular weight PAHs when ESVs were not available for those compounds, and the ESV for diethylhexyl phthalate (DEHP) was used when ESVs were not available for phthalates. With one exception, the ESV for the most toxic form of metals was used. The exception was for chromium in surface soil. Selected soil samples were analyzed for hexavalent chromium, and all soil samples were analyzed for total chromium. Therefore, an ESV of 0.4 ppm was used for screening the hexavalent chromium data (Efroymson, 1997a), and an ESV of 64 ppm (CCME, 1997) was used for screening the total chromium data.

7.3.2 Toxicity Reference Values

Modeling of contaminant exposure via the food chain was performed to investigate potential risks to representative receptors. Toxicity reference values (TRVs), which are contaminant doses associated with adverse effects on growth, survival, and reproduction, were obtained for comparison to doses that the receptors may receive in the environment. TRVs were preferentially selected that represent a threshold for sublethal effects such as impairment of reproduction or growth and were obtained for each type of receptor (e.g., avian carnivore), as discussed below.

Since toxicity data for the specific receptors chosen herein were usually not available, toxicity data from laboratory species were extrapolated to receptor species. Most of the toxicity data were obtained from ORNL wildlife toxicity data (Sample et al., 1996). Data were also obtained from an U.S. EPA Environmental Response Team (ERT, 1997) report, the Integrated Risk Information System (IRIS) and the Agency for Toxic Substances and Disease Registry (ATSDR) toxicity profiles. No-observed-adverse-effects-levels (NOAELs) and lowest-observed-adverse-effects-levels (LOAELs) were used in the models. Following U.S. EPA Region IV guidance, LOAELs were divided by a factor of 10 to obtain NOAELs if NOAELS were not available for a contaminant. Following discussions with U.S. EPA Region IV, VOCs were not included in food chain modeling, since analytes with log K_{ow} values less than 3.5 (VOCs) generally do not accumulate in animal tissue (Suter, 1993). TRVs used in this ERA and their sources are presented in Tables 7-1 (mammals) and 7-2 (birds and fish).

7.3.3 Representative Receptors

Species used in the food chain modeling (Table 7-3) were chosen to represent the groups of receptors most likely to be exposed to the highest contaminant concentrations because of their position in the food web, diet (ingestion rate and food type), home range (contained within the area of contamination), and body size. The socio-cultural nature of the receptor species (e.g., threatened or endangered species) was also considered. The selected species are assumed to be representative of other species within the

TABLE 7-1

TOXICITY REFERENCE VALUES (TRVs) FOR MAMMAL RECEPTORS
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
VOLATILE ORGANIC COMPOUNDS						
2-Butanone	Rat	Neurological effects	173	1730	ATSDR (1991a)	NOAEL*10
Acetone	Rat	Liver and Kidney	10	50	Sample et al. (1996)	Sample et al. (1996)
Carbon Disulfide	Rabbit	Offspring malformations	11	110	IRIS (1991)	NOAEL*10
Chloroform			NA	NA		
SEMIVOLATILE ORGANIC COMPOUNDS						
2-Methylnapthalene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
4-Methylphenol			175	450	ATSDR (1997)	ATSDR (1997)
Acenaphthylene	Mouse	Tumors	1.3	2.6	ERT (1997)	ERT (1997)
Anthracene	Mouse	Tumors	1.3	2.6	ERT (1997)	ERT (1997)
Benzo(a)anthracene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Benzo(a)pyrene	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Benzo(b)fluoranthene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Benzo(g,h,i)perylene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Benzo(k)fluoranthene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Bis(2-ethylhexyl)phthalate	Mouse	Reproduction	18.3	183	Sample et al. (1996)	Sample et al. (1996)
Butylbenzlphthalate[2]	Mouse	Reproduction	18.3	183	Sample et al. (1996)	Sample et al. (1996)
Carbazole	Mouse	Tumors	1.3	2.6	ERT (1997)	ERT (1997)
Chrysene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Dibenzofuran	Mouse	Multinuclear hepatocyte	60	125	ATSDR (1991b)	ATSDR (1991b)
Fluoranthene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
Indeno(1,2,3-cd)pyrene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)

TABLE 7-1

TOXICITY REFERENCE VALUES (TRVs) FOR MAMMAL RECEPTORS
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
Phenanthrene	Mouse	Tumors	1.3	2.6	ERT (1997)	ERT (1997)
Pyrene[1]	Mouse	Reproduction	1	10	Sample et al. (1996)	Sample et al. (1996)
PESTICIDES/PCBs						
4,4'-DDD[3]	Rat	Reproduction	0.8	4	Sample et al. (1996)	Sample et al. (1996)
4,4'-DDE	Hamster	Systemic	20	41.5	ATSDR 1988	ATSDR 1988
4,4'-DDT	Rat	Reproduction	0.8	4	Sample et al. (1996)	Sample et al. (1996)
Aroclor-1254	Mouse	Reproduction	0.068	0.68	Sample et al. (1996)	Sample et al. (1996)
Aroclor-1260[4]	Mouse	Reproduction	0.068	0.68	Sample et al. (1996)	Sample et al. (1996)
Alpha-Chlordane[5]	Mouse	Reproduction	4.6	9.2	Sample et al. (1996)	Sample et al. (1996)
Gamma-Chlordane[5]	Mouse	Reproduction	4.6	9.2	Sample et al. (1996)	Sample et al. (1996)
METALS AND INORGANIC COMPOUNDS						
Aluminum	Mouse	Reproduction	1.93	19.3	Sample et al. (1996)	Sample et al. (1996)
Arsenic	Mouse	Reproduction	0.126	1.26	Sample et al. (1996)	Sample et al. (1996)
Barium	Rat	Growth, hypertension	5.1	51	Sample et al. (1996)	NOAEL*10
Beryllium	Rat	Longevity, weight loss	0.66	6.6	Sample et al. (1996)	NOAEL*10
Cobalt			1	10	ERT (1997)	NOAEL*10
Copper	Mink	Reproduction	11.7	15.14	Sample et al. (1996)	Sample et al. (1996)
Cyanide	Rat	Reproduction	68.7	687	Sample et al. (1996)	NOAEL*10
Iron	Rabbit		50	500	ERT (1997)	NOAEL*10
Lead	Rat	Reproduction	8	80	Sample et al. (1996)	Sample et al. (1996)
Manganese	Rat	Reproduction	88	284	Sample et al. (1996)	Sample et al. (1996)
Mercury	Mink	Reproduction	0.015	0.025	Sample et al. (1996)	Sample et al. (1996)
Selenium	Rat	Reproduction	0.2	0.33	Sample et al. (1996)	Sample et al. (1996)

TABLE 7-1

TOXICITY REFERENCE VALUES (TRVs) FOR MAMMAL RECEPTORS
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
Thallium	Rat	Reproduction	0.0074	0.074	Sample et al. (1996)	Sample et al. (1996)
Vanadium	Rat	Reproduction	0.21	2.1	Sample et al. (1996)	Sample et al. (1996)
Zinc	Rat	Reproduction	160	320	Sample et al. (1996)	Sample et al. (1996)

1 Benzo(a)pyrene TRV used as a surrogate for high molecular weight PAHs.
2 Bis(2-ethylhexyl)phthalate TRV used as a surrogate for butylbenzlphthalate.
3 4,4'–DDT TRV used as a surrogate for 4,4'-DDD.
4 Aroclor 1254 used as a surrogate for Aroclor 1260.
5 Chlordane used as a surrogate for alpha-chlordane and gamma-chlordane.

TABLE 7-2

TOXICITY REFERENCE VALUES (TRVs) FOR BIRDS AND FISH
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 4

Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
VOLATILE ORGANIC COMPOUNDS						
2-Butanone			NA	NA		
Acetone			NA	NA		
Carbon Disulfide			NA	NA		
Chloroform			NA	NA		
SEMIVOLATILE ORGANIC COMPOUNDS						
2-Methylnapthalene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
4-Methylphenol			NA	NA		
Acenaphthylene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Anthracene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Benzo(a)anthracene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Benzo(a)pyrene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Benzo(b)fluoranthene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Benzo(g,h,i)perylene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Benzo(k)fluoranthene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)

TABLE 7-2

TOXICITY REFERENCE VALUES (TRVs) FOR BIRDS AND FISH
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
Bis(2-ethylhexyl)phthalate	Ringed dove	Reproduction	1.1	11	Sample et al. (1996)	NOAEL*10
Carbazole	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Chrysene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Dibenzofuran			NA	NA		
Fluoranthene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Indeno(1,2,3-cd)pyrene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Phenanthrene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
Pyrene	European Starlings	Body weight, hemoglobin	10	100	ERT (1997)	NOAEL*10
	Channel Catfish	Mortality	0.3	3	ERT (1997)	ERT (1997)
PESTICIDES/PCBs						
Aroclor-1254	Ring-necked Pheasant	Reproduction	0.18	1.8	Sample et al. (1996)	Sample et al. (1996)
Aroclor-1260[1]	Ring-necked Pheasant	Reproduction	0.18	1.8	Sample et al. (1996)	Sample et al. (1996)
Alpha-Chlordane[2]	Red-winged Blackbird	Mortality	2.14	10.7	Sample et al. (1996)	Sample et al. (1996)
Gamma-Chlordane[2]	Red-winged Blackbird	Mortality	2.14	10.7	Sample et al. (1996)	Sample et al. (1996)
4,4'-DDD[3]	Brown Pelican	Reproduction	0.0028	0.028	ERT (1997)	NOAEL*10

TABLE 7-2

TOXICITY REFERENCE VALUES (TRVs) FOR BIRDS AND FISH
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
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Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
4,4'-DDE[3]	Brown Pelican	Reproduction	0.0028	0.028	ERT (1997)	NOAEL*10
4,4'-DDT	Brown Pelican	Reproduction	0.0028	0.028	ERT (1997)	NOAEL*10
METALS AND INORGANIC COMPOUNDS						
Aluminum	Ringed Dove	Reproduction	109.7	1097	Sample et al. (1996)	NOAEL*10
Antimony			NA	NA		
Arsenic	Mallard duck	Mortality	5.14	12.84	Sample et al. (1996)	Sample et al. (1996)
	Rainbow Trout	Body Weight, Growth	0.59	7.1	ERT (1997)	ERT (1997)
Barium	1-day old chicks	Mortality	20.8	41.7	Sample et al. (1996)	Sample et al. (1996)
Beryllium			NA	NA		
Chromium	Black Duck	Reproduction	1	5	Sample et al. (1996)	Sample et al. (1996)
	Rainbow Trout	Body Weight, Growth	0.02	0.12	ERT (1997)	ERT (1997)
Cobalt			1	10	ERT (1997)	NOAEL*10
Copper	1-day old chicks	Growth, Mortality	47	61.7	Sample et al. (1996)	Sample et al. (1996)
Cyanide, total	Chicken		4.5	45	ERT (1997)	NOAEL*10
Iron	Chicken		100	1000	ERT (1997)	NOAEL*10
Lead	Japanese Quail	Reproduction	1.13	11.3	Sample et al. (1996)	Sample et al. (1996)
Manganese	Japanese Quail	Growth,Behavior	977	9770	Sample et al. (1996)	NOAEL*10
Mercury	Mallard Duck	Reproduction	0.0064	0.064	Sample et al. (1996)	Sample et al. (1996)
	Rainbow Trout	Growth	0.008	0.94	ERT (1997)	ERT (1997)
Nickel	Mallard duckling	Growth, Mortality	77.4	107	Sample et al. (1996)	Sample et al. (1996)
Selenium	Mallard duck	Reproduction	0.4	0.8	Sample et al. (1996)	Sample et al. (1996)
Silver			NA	NA		

TABLE 7-2

TOXICITY REFERENCE VALUES (TRVs) FOR BIRDS AND FISH
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 4 OF 4

Chemical	Test Species	Endpoint	NOAEL Derived TRV (mg/kg/day)	LOAEL Derived TRV (mg/kg/day)	NOAEL Source of TRV	LOAEL Source of TRV
Thallium	Pheasant	Mortality	0.47	4.7	LOAEL/10	LD_{50}/5; Hudson et al. (1984)
Vanadium	Mallard duck	Mortality	11.4	114	Sample et al. (1996)	NOAEL*10
Zinc	White leghorn hens	Reproduction	14.5	131	Sample et al. (1996)	Sample et al. (1996)

1 TRV for Aroclor 1254
2 TRV for total chlordane
3 TRV for DDT

TABLE 7-3

EXPOSURE PARAMETERS FOR REPRESENTATIVE ECOLOGICAL RECEPTORS
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Receptor	Representative Group	Body Weight[1] (grams)	Food Ingestion[1,2] (grams/day)	Assumed Diet for Exposure Assessment[1]	Home Range[1] (acres)
Short-tailed shrew (*Blarina carolinensis*)	Insectivorous mammal	9.73[3]	5.2	90% invertebrates 10% soil	0.96[1] to 2.4[3]
Cotton mouse (*Peromyscus gossypnius*)	Herbivorous Mammal	31[4]	8.6	98% vegetation 2% soil[5]	0.05 to 0.3[5]
Raccoon (*Procyon lotor*)	Omnivorous Mammal	3990	856	90.6% aquatic invertebrates 9.4% sediment	96 to 161
American robin (*Turdus migratorius*)	Omnivorous Bird	77.3	69	35% invertebrates 60% vegetation 5% soil[6]	0.5 to 2.1 (nesting season)
Great Blue Heron (*Ardea herodias*)	Piscivorous Bird	2229	401	100% fish soil, sediment: none[6]	1.5 to 20 (feeding territory)[13]
Bald Eagle (*Haliaeetus leucocephalus*)	Piscivorous Bird	3750	450	100% fish soil, sediment: none[6]	2500-3700[7]
Red-tailed hawk (*Buteo jamaicensis*)	Carnivorous Bird	1126	126	100% prey soil, sediment: none[6]	940 to 2440
Mummichog (*Fundulus heteroclitus*)	Forage fish	3.0[8]	0.174[8]	N/A; exposure assumed equal to sediment concentrations	40-400 yds. in tidal creeks[9]
Red drum (*Sciaenops ocellatus*)	Upper trophic level fish	1400[10]	28[11]	85% prey, 15% sediment[12]	not available

1 Exposure parameters are from EPA (1993) unless otherwise noted.
2 Food ingestion includes intended food items and incidentally ingested soil or sediment. For example, a shrew would be expected to consume 4.7 g invertebrates plus 0.5 g soil per day. See section 7.4.2.1 of text for ingestion formulas.
3 Cothran et al (1991)
4 Lowery (1974)
5 Based on deer mouse (*Peromyscus maniculatus*)
6 Sample and Suter (1994)
7 Stalmaster (1987)
8 Iannuzzi et al (1996)
9 Abraham (1985)
10 Wenner (1992)
11 Evans and Engel (1994)
12 Gerking (1994). See section 7.3.3.9 of text.
13 Actual home range is much greater.

same trophic group or guild and represent the groups of organisms specified in the assessment endpoints. For each of the representative species, information on life history was collected, including diet, average body weight, food ingestion rates, and home range. A discussion of the representative receptors chosen for this ERA is presented below.

7.3.3.1 Short-tailed shrew (*Blarina carolinensis*)

The short-tailed shrew was selected as a representative insectivorous small mammal. It can be found in forested areas, brushy areas, and near marshes. It feeds primarily on insects but will prey on earthworms, snails, centipedes, slugs, and even small vertebrates (Burt and Grossenheider, 1980). The short-tailed shrew has a voracious appetite for its body size, and as a result, may receive high doses of contaminants relative to other small mammals. Its home range is approximately 0.5 to 2.4 acres (U.S. EPA, 1993), allowing it to potentially spend all or much of its time on Site 3.

7.3.3.2 Cotton mouse (*Peromyscus gossypinus*)

The cotton mouse was chosen as a representative herbivorous small mammal. It is frequently associated with forested areas and moist habitats along the wetland/upland interface (Burt and Grossenheider, 1980). It is common in the Southeast and feeds on grasses, sedges, seeds, fruits, grains, and bark. Since its home range is usually less than 1 acre (U.S. EPA, 1993), it could reside permanently at Site 3.

7.3.3.3 Raccoon (*Procyon lotor*)

The raccoon was selected as a representative mammalian omnivore. The raccoon is found in a variety of habitats and particularly in swamps, floodplain forests, and marshes. The raccoon is an opportunistic feeder that will consume terrestrial and aquatic plants and animals. Crustaceans are common forage items for raccoons in marine and estuarine environments, and fish usually comprise less than 3 percent of the diet (U.S. EPA, 1993). The raccoon is the primary mammalian predator of the blue crab (Darnell, 1959). A common but false belief regarding the raccoon's food habits is that a raccoon always washes its food before eating it. When foraging in shallow water, however, a raccoon will sometimes dip a food item in water prior to eating it (Brown, 1997; Lowery, 1974). The size of a raccoon's home range depends on factors such as age, sex, habitat, food sources, and season. A literature review of several studies reported home ranges of up to 6,000 acres, although values of 200 to 600 acres were most common (U.S. EPA, 1993). Raccoon home ranges during a 1-year period on a Georgia coastal island were 161 acres for adult males and 96 acres for adult females (Lotze, 1979).

7.3.3.4 American robin (*Turdus migratorius*)

The American robin was chosen as a representative omnivorous bird. Common winter food items include seeds and fruit. Insects and invertebrates, especially earthworms, are eaten more frequently in the spring and summer. The robin is common in South Carolina and the entire eastern United States in a variety of habitats. The home range of the robin during breeding season is approximately 0.5 to 2.0 acres (U.S. EPA, 1993). Therefore, a robin might forage exclusively at the site only during nesting. Robins in South Carolina are joined by migratory individuals from the northern United States during the winter. During the non-breeding seasons, robins generally roam over large areas and usually form communal roosts within 1 to 2 miles of foraging areas (U.S. EPA, 1993).

7.3.3.5 Great blue heron (*Ardea herodias*)

The great blue heron was selected as a representative avian piscivore. The species is common in South Carolina and the entire eastern United States. It forages primarily in marshes and along gently sloping shorelines, particularly where small fish are plentiful in shallow areas. Fish are the preferred prey, commonly comprising about 90 to 98 percent of the diet, and are usually less than 25 cm in length. Great blue herons will also consume reptiles, amphibians, and crustaceans (U.S. EPA, 1993). Breeding populations in South Carolina are non-migratory. The distance between foraging areas and communal nesting/roosting areas ranges from 0 to 12 miles (U.S. EPA, 1993). Parnell and Soots (1978) found that the average distance between foraging areas and nesting/roosting areas along the North Carolina Coast was 4 to 5 miles. While feeding, individual herons defend areas averaging 1.5 to 20 acres (U.S. EPA, 1993).

7.3.3.6 Bald Eagle (*Haliaeetus leucocephus*)

In addition to the great blue heron, the bald eagle was selected as a representative avian piscivore. Bald eagles are generally restricted to coastal areas, lakes, and rivers. They prey on fish near the surface but will eat dead fish or other carrion, as well as birds and mammals. The bald eagle preys on larger food item than the great blue heron. As with other predators, the home range is variable. The average foraging distance from roosts or nests is generally 2 to 4 miles (U.S. EPA, 1993). Home ranges are usually greater than 2,500 acres (Stalmaster, 1987). As mentioned in Section 7.2.1, an active bald eagle nest is located near the southeastern end of the causeway at Site 3, and the pair of eagles associated with this nest is known to frequently forage in the vicinity of the site, as well as elsewhere at MCRD Parris Island. Some bald eagles in the southern United States migrate northward in mid-summer (after the nesting season) and return in early autumn. For this ERA, it was conservatively assumed that the eagles near Site 3 are non-migratory, remaining in the vicinity year-round.

7.3.3.7 Red-tailed hawk (*Buteo jamaicensis*)

The red-tailed hawk was selected as a representative avian carnivore. This hawk is common in South Carolina and the entire eastern United States, and it forages in a variety of habitats. The red-tailed hawk feeds primarily on small mammals but will also consume small birds, lizards, snakes, and insects (U.S. EPA, 1993). Breeding populations in South Carolina are non-migratory. The home range size is highly variable, depending on the available habitat. Mean home ranges varied from 150 to over 4,300 acres in several studies summarized by U.S. EPA (1993). The home range shown in Table 7-3 (940-2,440 acres) represents the data from habitats most similar to those at MCRD Parris Island (U.S. EPA, 1993). Although red-tailed hawks could forage year-round at Site 3, the terrestrial habitat at the site would constitute a minor portion of the hawk's foraging area.

7.3.3.8 Mummichog (Fundulus heteroclitus)

The mummichog represents a forage fish, i.e., a fish that is a food source of other organisms. The mummichog is one of the most abundant and productive fish species in coastal areas from the Gulf of St. Lawrence to Texas. It inhabits brackish coves, inlets, tidal creeks, and salt marshes. The mummichog feeds primarily on crustaceans, polychaetes, insects, algae, and detritus and is an important food source for many predators. It is one of the most stationary estuarine fish, with a summer home range of approximately 40 yards along tidal creeks; however, some may move as much as 400 yards (Abraham, 1985).

7.3.3.9 Red drum (Sciaenops ocellatus)

The red drum represents upper trophic level fish. This fish is distributed in coastal and estuarine waters from Massachusetts to Mexico. It uses sight and touch to forage primarily on bottom-dwelling animals. Crabs, shrimps, and fish compose the bulk of the diet for adults, and juveniles feed on copepods, amphipods, and small shrimp (Manooch and Raver, 1984; Pattillo et al, 1997). Red drum become sexually mature at 3 years of age. Eggs are spawned in nearshore and inshore waters close to barrier island passes and channels (Pattillo et al., 1997). Red drum are known to occur in the ponded area adjacent to Site 3, and probably occur in the tidal channels of the marsh south and west of the causeway.

The body weight of red drum shown in Table 7-3 (1400 g) and used as representative of red drum in the food chain modeling calculations is the approximate maximum weight of a fish that ospreys and the southern sub-species of bald eagles normally prey upon (Henny, 1988; Stalmaster 1987). A sediment ingestion rate could not be located for red drum. However, approximately 15 percent of an adult red drum's diet is composed of detritus (Gerking, 1994). It is assumed that this material is composed entirely of sediment as conservative estimate.

7.3.3.10 Other Potential Receptors

Potential risks to species such as shellfish or other aquatic invertebrates cannot be determined using the food chain model since ingestion toxicity data for these receptors do not exist or are not available. For example, body burdens associated with adverse effects on aquatic invertebrates can be found in the literature, but NOAELs for oral ingestion are sparse. It should be noted that ambient water quality criteria (AWQC) for most contaminants are based, in part, on sensitive aquatic species. Also, sediment guidelines are based on potential risks to sediment invertebrates. Thus, the surface water and sediment screening assessment accounts for the aquatic invertebrate species excluded from the food chain modeling.

7.4 PRELIMINARY EXPOSURE ESTIMATE

7.4 1 Exposure Point Concentrations

Data used to obtain exposure point contaminant concentrations in this ERA were gathered primarily from 1998 RFI sampling. Raw data from samples collected in 1998 are presented in Appendix C. The maximum detected concentrations of analytes in surface water (filtered and unfiltered samples), sediment, and surface soil were used as exposure point concentrations and were compared to ecological screening levels. Sampling conducted prior to 1998 is discussed below.

Eight surface water and eight sediment samples were collected in 1988. The 1988 samples were analyzed for priority pollutants, and the results were reported in the 1990 Verification Report (McClelland, 1990). However, the older data are probably not representative of current site conditions. In addition, the quality of the older data is uncertain, and the analytical methods and sample collection techniques were not the same in 1988 as in 1998. As a result, and with the concurrence of the MCRD Parris Island partnering team, the 1990 data were not included in the database for Site 3.

An ESI was previously conducted to evaluate whether the consumption of fish and shellfish caught by recreational fisherman in the vicinity of Site 3 poses a risk to human health (ABB, 1993). Striped mullet, summer flounder, blue crab (*Callinectes sapidus*), clams (Mercenaria mercenaria), and oysters (*Crassostrea virginica*) were collected from both sides of the causeway in November 1991 and analyzed for PAHs, PCBs, pesticides, and mercury. The mullet and flounder samples consisted liver tissue and filleted muscle tissue samples. Crabs were processed whole. Clams and oysters were shucked, with subsequent analyses of soft tissue. The use of the ESI tissue data in this ERA is discussed in Section 7.4.2.3.

The maximum detected concentrations in filtered and unfiltered groundwater were used as exposure point contaminants in that medium. Although aquatic and semi-aquatic organisms will not be directly exposed to groundwater contaminants, they could be exposed via groundwater discharge to aquatic environments. Comparing groundwater concentrations to Region IV surface water screening levels is a conservative measure of potential impacts to aquatic media from contaminated groundwater discharge. This measure does not take into account dilution at the discharge point(s), the amount of discharge, location of the point(s) of discharge, direction of groundwater flow, or bioavailability of groundwater contaminants.

U.S. EPA Region IV considers 0- to 1-foot soil samples to be representative of surface soils. Surface soil samples collected during 1998 RFI sampling were collected from this depth.

7.4.2 Contaminant Doses for Representative Receptors

Contaminants with maximum concentrations less than Region IV approved ESVs were dropped from further consideration, and those with concentrations that equaled or exceeded ecological screening levels were retained as preliminary COPCs. A simple food chain model was then used to predict dietary exposures of preliminary COPCs for representative receptor species. The predicted exposures were compared to TRVs in the risk calculation step. Both the maximum and mean concentrations of contaminants were used in the model. Means were calculated using one-half the detection limit for "nondetects". Mean concentrations were presented in Tables 4-2 (surface soil), 4-4 (surface water), and 4-6 (sediment). Mean concentrations were used to provide balance to the assessment. The actual dose a receptor species receives as the result of indirect or direct exposure is dependent upon the habits of the species and other factors.

7.4.2.1 Dose Equation

Food chain modeling utilized the following equation to estimate contaminant intake from the ingestion of food and water and incidental ingestion of soil or sediment:

$$PD = [(C_{soil}\ FI * SA * F) + (C_{water} * W * FI) + (C_{food} * F * FA * FI)]/WR$$

where:

PD	=	predicted dose from the ingestion of food, water, and the incidental ingestion of soil or sediment (mg/kg/day)
C_{soil}	=	concentration in soil or sediment (mg/kg)
FI	=	fractional intake (% of home range that overlaps affected area; assumed to be 100%)
SA	=	percent of diet that equals soil or sediment

F	=	food consumed (kg/day)
C_{water}	=	concentration in water (mg/L)
W	=	water consumed (L/day)
WR	=	weight of receptor (kg)
FA	=	animals/vegetation as a percentage of diet
C_{food}	=	contaminant concentration (vegetation or prey; mg/kg)

The contaminant concentration in food (C_{food} in the equation shown above) was calculated using bioaccumulation factors (BAFs), bioconcentration factors (BCFs), and biota sediment accumulation factors (BSAFs) from published sources (see Appendix F). Values of 1.0 were assumed where BAFs, BCFs, and BSAFs were not available.

Surface soil data were used in the food chain modeling to calculate doses to the shrew, mouse, robin, and hawk as follows. Chemical concentrations in terrestrial invertebrates (food items of the shrew and robin) were estimated by multiplying each chemical's surface soil concentration by its associated soil-to-invertebrate BAF. Chemical concentrations in vegetation (food items of the mouse and robin) were estimated by multiplying each chemical's surface soil concentration by its associated soil-to-plant BAF. The resulting estimated concentrations in invertebrates and plants were multiplied by the associated food-to-mammal BAF to derive estimated concentrations in the shrew and mouse, respectively. The estimated mammal concentrations were then used to derive an estimated dose to the red-tailed hawk. The hawk's diet was assumed to consist of equal amounts of shrews and mice. Incidental ingestion of surface soil was also included in the dose equations for the shrew, mouse, and robin. Incidental ingestion of surface soil is negligible for birds of prey (Sample and Suter, 1994) and thus, was not included in the dose equations for the hawk and eagle.

Sediment data were used to calculate doses to the raccoon, heron, eagle, mummichog, and red drum. Since BSAFs do not exist for inorganic compounds, concentrations of inorganic compounds (i.e., metals) in food items of the raccoon, heron, eagle, and red drum were assumed to be equal to sediment concentrations. This is a conservative assumption since transfer through the food chain does not occur for most metals.

The following equation (U.S. EPA, 1997c) was used to estimate tissue concentrations (i.e., the theoretical bioaccumulation potential) of organic compounds in food items of the raccoon, heron, eagle and red drum:

$$TBP = BSAF(C_s/f_{oc})f_l$$

where TBP = theoretical bioaccumulation potential (mg/kg)

C_s = chemical concentration in sediment (mg/kg)

BSAF = biota-sediment accumulation factor (ratio of the concentration of a chemical in tissue, normalized to lipid, to the concentration of the chemical in surface sediment, normalized to organic carbon)

f_{oc} = total organic carbon (TOC) content of sediment expressed as a decimal fraction

f_l = organism lipid content expressed as a decimal fraction

The average TOC in sediment samples at Site 3 was 1.4 percent. Thus, the f_{oc} used herein was 0.014. Lipid content values were assumed to be 3.5 percent for the mummichog (Iannuzzi et al 1996) and 1.0 percent for the red drum (Sullivan and Otwell, 1992). Prey items of the raccoon, heron, and red drum were assumed to consist exclusively of mummichogs, and the eagle was assumed to forage exclusively on red drum. Incidental ingestion of sediment was also included in the dose equations for the raccoon and red drum, but was assumed to be negligible for the heron and eagle (Sample and Suter, 1994). Incidental ingestion of surface water was included in the dose equations for the raccoon and heron, as discussed in Section 7.4.2.2.

The use of sediment data rather than surface water to calculate doses for aquatic and semi-aquatic receptors provided a conservative assessment of exposure since contaminant concentrations were generally greater in sediment than in surface water samples. However, BSAFs have not been generated for inorganic chemicals. Therefore, a subsequent food chain modeling iteration was also conducted using filtered surface water data. In this iteration, concentrations in prey items of the raccoon, heron, red drum, and eagle were calculated by multiplying fish BCFs by surface water concentrations.

The TBP formula described above was not used to calculate doses to the mummichog. Food items of the mummichog consist of a variety of crustaceans, polychaetes, insects, algae, and detritus (Abraham, 1985). Estimations of chemical concentrations in these food items were beyond the scope of this ERA. Instead, chemical concentrations in food items of the mummichog were assumed to be equal to measured sediment concentrations.

Most input parameters shown in Table 7-3 for representative receptors were obtained from U.S. EPA's Wildlife Exposure Factors Handbook: Volumes I and II (1993). In general, the values used for the input parameters were the most conservative (e.g., upper bound food ingestion rate) presented in the U.S. EPA publication. Wet weight food ingestion rates were calculated as follows:

- shrew: 0.541 grams food/gram body weight/day (g/g bw/day) (U.S. EPA, 1993)
- cotton mouse: calculated using rodent equation for food ingestion (g/day): $0.621 \times wt^{0.564}$ (U.S. EPA, 1993); converted to wet weight assuming 50 percent water content in food items (vegetation)
- raccoon: calculated using mammal equation for food ingestion (g/day): $0.235 \times wt^{0.822}$ (U.S. EPA, 1993); converted to wet weight assuming 75 percent water content in food items (aquatic organisms)
- robin: 0.89 g/g bw/day (U.S. EPA, 1993)
- heron: 0.18 g/g bw/day (U.S. EPA, 1993)
- eagle: 0.12 g/g bw/day (U.S. EPA, 1993)
- hawk: 0.112 g/g bw/day (U.S. EPA, 1993)
- mummichog: 0.058g/g bw/day (Iannuzzi et al., 1996)
- red drum: 0.02 g/g bw/day (Evans and Engel, 1994)

7.4.2.2 Ingestion of Surface Water

Since water in the marsh is saline (17 to 19 ppt), surface water at the site was not considered to be a source of drinking water. However, some organisms that prey on aquatic species could incidentally ingest surface water while consuming food items. For example, a wading bird or raccoon would probably ingest a small amount of surface water when ingesting aquatic prey. Therefore, the incidental ingestion of unfiltered surface water was investigated for the great blue heron and raccoon. The incidental ingestion of surface water was assumed to be negligible for the other representative receptors listed in Table 7-3, due to their feeding habits. The bald eagle, for example, usually consumes prey items after carrying them to a perch (e.g., tree or nest) and would not incidentally ingest surface water with the prey item.

A literature review was conducted for data on the amount of surface water incidentally ingested while consuming aquatic prey items. No helpful information was found. Instead, a value was experimentally derived as follows. A euthanized shrimp (11.6 g wet weight) and minnow (0.3 g wet weight), each held by forceps, were submersed in water then allowed to drip onto a tared, electronic balance. After 60 trials, the average mass of water that dripped from the shrimp was 0.46 g, which equates to 0.0397 g water per gram shrimp (0.46/11.6). After 190 trials, the average mass of water that dripped from the minnow was 0.0484 g, which equates to 0.161 g water per gram minnow (0.0484/0.3). Based on these results, an organism consuming shrimp immediately removed from the water would incidentally ingest an amount of surface water equal to 3.97 percent of the shrimp's body weight. Similarly, consumption of minnows would result in the ingestion of surface water at a ratio of 16.1 percent of the minnow's body weight. The greater of these two values was chosen and conservatively rounded to 20 percent. Thus, daily water consumption in the dose equation for the raccoon and great blue heron was assumed to be 20 percent of the respective food consumption.

7.4.2.3 Tissue Data

Tissue data from fish, crabs, clams, and oysters collected in 1991 during the ESI (ABB, 1993) were also used in the food chain model to assess potential risks posed by COPCs to receptors that prey on these organisms. Potential risks to the bald eagle were assessed using striped mullet and summer flounder tissue data, with separate calculations using liver tissue and fillet (muscle) tissue. Potential risks to the raccoon were assessed using crab, clam, and oyster tissue data.

Both the maximum and average concentrations of contaminants were utilized in the food chain model using the 1991 tissue data. Flounder data were compared to mullet data and the highest value from the two (for each analyte) was used in the maximum contaminant scenario for the eagle. The mean of flounder and mullet concentrations was used in the mean contaminant scenario for the eagle. Similarly, doses to the raccoon utilized the maximum concentration from among crabs, clams, and oysters and the mean of means from crab, clam, and oyster data. Food chain modeling using the tissue data does not include the incidental ingestion of sediment or surface water. The uncertainty resulting from the omission of incidental ingestion of surface water and sediment is discussed in Section 7.5.7.5.

Tissue data from fish, crabs, clams, and oysters collected for the ESI were also compared to tissue concentrations considered to be protective of the organisms and to fish and wildlife consumers of those organisms.

7.5 PRELIMINARY RISK CALCULATION

The preliminary risk calculation step in the ERA process compared contaminant doses for representative receptors to doses associated with toxic effects (U.S. EPA, 1997b). Prior to this step, the maximum concentrations of contaminants in each medium were compared to Region IV ESVs. The ratio of the exposure point contaminant concentration to the ESV or the modeled dose to the TRV is called the Hazard Quotient (HQ), defined as follows:

$$HQ_i = EPC_i/ESV_i \text{ or } ID_i/TRV$$

where:

HQ_i	=	Hazard Quotient for analyte "i" (unitless)
EPC_i	=	Exposure Point Concentration for analyte "i" (µg/L or µg/kg or mg/kg)
ESV_i	=	Ecological Screening Value for analyte "i" (µg/L or µg/kg or mg/kg)
ID_i	=	Intake Dose for analyte "i" (mg/kg/day)
TRV_i	=	Toxicity Reference Value for analyte "i" (mg/kg/day)

When the ratio of the exposure point concentration or intake dose to its respective guideline exceeded 1.0, adverse impacts were considered possible, and the contaminant was retained as a COPC. The HQ value should not be construed as being probabilistic; rather, it is a numerical indicator of the extent to which an exposure point concentration or intake dose exceeds or is less than a guideline. When an HQ value exceeds 1.0, it is an indication that ecological receptors are potentially at risk; additional evaluation or data may be necessary to confirm with greater certainty whether ecological receptors are actually at risk, especially since most guidelines are conservatively derived.

The use of HQs is probably the most common method used for risk characterization in ERAs. Advantages of this method include the following (Barnthouse et al., 1986):

- The HQ method is relatively easy to use, is generally accepted, and can be applied to any data.
- The method is useful when a large number of contaminants must be screened

This method of risk characterization has some inherent limitations. One primary limitation is that it is a "no/maybe" method for relating toxicity to exposure. That is, it uses single values for exposure concentrations and guidelines. The HQ method does not account for the variability in both these parameters.

The results of the comparison of maximum contaminant concentrations in each medium to Region IV screening levels are presented in screening tables. The screening tables include the frequency of detection for each analyte, the maximum exposure point concentration, and contaminant-specific Region IV screening level. Tables were also generated that present the HQ values for each representative receptor used in the food chain modeling using maximum contaminant concentrations. Separate tables are provided for average concentrations.

In summary, the COPC selection process was as follows:

1. The maximum concentrations of detected chemicals in Site 3 surface water, groundwater, sediment, and surface soil were compared to Region IV screening levels (ESVs), with the exception of the essential nutrients mentioned earlier. If the maximum concentration was less than the Region IV ESV, the chemical was dropped from further consideration; if it equaled or exceeded the Region IV ESV, the chemical was selected as a COPC. If no Region IV ESV was available, the chemical was selected as a COPC.

2. All COPCs identified in surface water, sediment, and surface soil were used in the food chain modeling.

3. Groundwater data were not used in the food chain modeling. Aquatic and semi-aquatic organisms will not be directly exposed to groundwater contaminants. It is assumed that potential groundwater discharge to aquatic environments is taken into account through the evaluation of surface water and sediment COPCs.

7.6 SCREENING RESULTS

7.6.1 Surface Water

Twenty-seven analytes in surface water samples were retained as COPCs (Table 7-4). Acetone, a VOC, was a COPC since no Region IV screening value was available. Ten SVOCs were COPCs, nine of them because no Region IV screening value was available. Fluoranthene was retained as a COPC with an HQ of 1.2. Sixteen metals were retained as COPCs, eight of which had no Region IV screening levels. The maximum HQ among the metal COPCs was 52.4 for copper. Other HQ values were 15.5 for lead, 9.1 for silver, 6.0 for mercury, 4.8 for nickel, 3.4 for zinc, 2.7 for arsenic, and 1.6 for chromium.

7.6.2 Sediment

There were 37 sediment COPCs (Table 7-5). Four VOCs were detected in sediment, and all were retained as COPCs since none had Region IV screening values. Eleven SVOCs were retained as COPCs; two of these 11 had no Region IV screening values. The highest HQ for the SVOCs was 31.0 (fluoranthene). Five pesticides and two PCB compounds were detected in sediment; all had HQs greater than 1.0 and were thus retained as COPCs. The pesticides consisted of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT (hereafter referred to as DDD, DDE, and DDT, or collectively as DDTR), alpha-chlordane, and gamma-chlordane. The PCB compounds consisted of Aroclor 1254 (HQ = 11.6) and Aroclor 1260 (HQ = 3.2). Although infrequently detected, some pesticides had high HQs, with values ranging from 21.7 (DDE) to 237.7 (DDD). Fifteen metals were COPCs in sediment; 10 had no Region IV ESVs.

7.6.3 Surface Soil

Thirty-three analytes in surface soil were retained as COPCs (Table 7-6). Two VOCs and five SVOCs were retained as COPCs since no screening values were available. HQ values for the VOC and SVOC COPCs ranged from 2.0 (chloroform) to 51.0 (fluoranthene). Four pesticide and two PCB compounds were detected in surface soil; all were retained as COPCs. Screening values were not available for alpha- and gamma-chlordane. HQ values for the pesticide and PCB compounds ranged from 1.6 (DDE) to 5.0 (Aroclor 1260). Seven metals were retained as COPCs, with HQs ranging from 1.2 (arsenic) to 216 (aluminum).

TABLE 7-4

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SURFACE WATER
PARRIS ISLAND, SOUTH CAROLINA
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Analyte	Frequency of Detection	Range of Detection		Location of Maximum	EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum				
VOLATILE ORGANIC COMPOUNDS (µg/L)							
Acetone	1/1	3	3	PAI-03-SW-023	NA	NA	Yes
SEMIVOLATILE ORGANIC COMPOUNDS (µg/L)							
Anthracene	1/20	0.38	0.38	PAI-03-SW-014	23.5	0.02	No
Benzo(a)anthracene	1/20	0.66	0.66	PAI-03-SW-014	NA	NA	Yes
Benzo(a)pyrene	2/20	0.075	0.72	PAI-03-SW-014	NA	NA	Yes
Benzo(b)fluoranthene	2/20	0.06	0.67	PAI-03-SW-014	NA	NA	Yes
Benzo(g,h,i)perylene	1/20	0.89	0.89	PAI-03-SW-014	NA	NA	Yes
Benzo(k)fluoranthene	2/20	0.025	0.25	PAI-03-SW-014	NA	NA	Yes
Bis(2-Ethylhexyl)phthalate	6/20	2	7	PAI-03-SW-025	NA	NA	Yes
Butylbenzyl Phthalate	1/20	5	5	PAI-03-SW-028	29.4	0.17	No
Chrysene	2/20	0.09	1.2	PAI-03-SW-014	NA	NA	Yes
Fluoranthene	3/20	0.1	1.9	PAI-03-SW-014	1.6	1.2	Yes
Indeno(1,2,3-cd)pyrene	2/20	0.075	0.39	PAI-03-SW-014	NA	NA	Yes
Phenanthrene	3/20	0.05	1.4	PAI-03-SW-014	23.5	0.06	No
Pyrene	1/20	1.3	1.3	PAI-03-SW-014	NA	NA	Yes
METALS/INORGANICS (µg/L)							
Aluminum	18/20	242	88600	PAI-03-SW-027	NA	NA	Yes
Antimony	4/20	1.8	4.2	PAI-03-SW-019-F	NA	NA	Yes
Arsenic	2/20	2.3	96.1	PAI-03-SW-027	36	2.7	Yes
Barium	20/20	13	279	PAI-03-SW-028-F	NA	NA	Yes
Beryllium	1/20	4.4	4.4	PAI-03-SW-027	NA	NA	Yes
Cadmium	1/20	2	2	PAI-03-SW-027	9.3	0.2	No
Chromium	3/20	0.79	164	PAI-03-SW-027	103	1.6	Yes
Cobalt	1/20	21.1	21.1	PAI-03-SW-027	NA	NA	Yes
Copper	8/20	1	152	PAI-03-SW-027	2.9	52.4	Yes
Iron	18/20	163	110000	PAI-03-SW-027	NA	NA	Yes
Lead	1/20	132	132	PAI-03-SW-027	8.5	15.5	Yes
Manganese	19/20	5.3	840	PAI-03-SW-027	NA	NA	Yes

TABLE 7-4

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SURFACE WATER
PARRIS ISLAND, SOUTH CAROLINA
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Analyte	Frequency of Detection	Range of Detection		Location of Maximum	EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum				
Mercury	1/20	0.15	0.15	PAI-03-SW-027	0.025	6.0	Yes
Nickel	1/20	39.8	39.8	PAI-03-SW-027	8.3	4.8	Yes
Silver	4/20	0.68	2.1	PAI-03-SW-021	0.23	9.1	Yes
Vanadium	1/20	269	269	PAI-03-SW-027	NA	NA	Yes
Zinc	18/20	12.7	294	PAI-03-SW-027	86	3.4	Yes

NA = Not Available.

TABLE 7-5

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SEDIMENT
PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 3

Analyte	Frequency of Detection	Range of Detection		Location of Maximum	EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum				
VOLATILE ORGANIC COMPOUNDS (µg/kg)							
2-Butanone	6/17	8	61	PAI-03-SD-014-01	NA	NA	Yes
Acetone	2/6	150	170	PAI-03-SD-026-01	NA	NA	Yes
Carbon Disulfide	6/21	3	40	PAI-03-SD-014-01	NA	NA	Yes
Chloroform	2/21	1	1	PAI-03-SD-015-01, PAI-03-SD-016-01	NA	NA	Yes
SEMIVOLATILE ORGANIC COMPOUNDS (µg/kg)							
Anthracene	4/21	3.7	770	PAI-03-SD-022-01	46.9	16.4	Yes
Benzo(a)anthracene	6/21	5.1	1200	PAI-03-SD-022-01	74.8	16.0	Yes
Benzo(a)pyrene	6/21	8.1	1200	PAI-03-SD-022-01	88.8	13.5	Yes
Benzo(b)fluoranthene	13/21	1.8	990	PAI-03-SD-022-01	655.0	1.5	Yes
Benzo(g,h,i)perylene	2/21	24	570	PAI-03-SD-022-01	655.0	0.9	No
Benzo(k)fluoranthene	5/21	3	420	PAI-03-SD-022-01	655.0	0.6	No
Carbazole	1/21	570	570	PAI-03-SD-022-01	NA	NA	Yes
Chrysene	13/21	3.2	1900	PAI-03-SD-022-01	108.0	17.6	Yes
Dibenzofuran	1/21	190	190	PAI-03-SD-022-01	NA	NA	Yes
Fluoranthene	9/21	15	3500	PAI-03-SD-022-01	113.0	31.0	Yes
Fluorene	1/21	13	13	PAI-03-SD-027-01	21.2	0.6	No
Indeno(1,2,3-cd)pyrene	6/21	5.8	660	PAI-03-SD-022-01	655.0	1.0	Yes
Phenanthrene	9/21	5.8	2400	PAI-03-SD-022-01	86.7	27.7	Yes
Pyrene	8/21	11	2700	PAI-03-SD-022-01	153.0	17.6	Yes

TABLE 7-5

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SEDIMENT
PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 3

Analyte	Frequency of Detection	Range of Detection		Location of Maximum	EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum				
PESTICIDES AND PCBs (µg/kg)							
4,4'-DDD	2/21	40	290	PAI-03-SD-014-01	1.22	237.7	Yes
4,4'-DDE	1/21	45	45	PAI-03-SD-014-01	2.07	21.7	Yes
4,4'-DDT	1/21	34	34	PAI-03-SD-021-01	1.19	28.6	Yes
Alpha-Chlordane	1/21	28	28	PAI-03-SD-028-01	0.5[a]	56	Yes
Aroclor-1254	3/21	65	250	PAI-03-SD-020-01	21.6[b]	11.6	Yes
Aroclor-1260	2/21	45	70	PAI-03-SD-015-01	21.6[b]	3.2	Yes
Gamma-Chlordane	1/21	28	28	PAI-03-SD-028-01	0.5[a]	56	Yes
METALS AND INORGANIC COMPOUNDS (mg/kg)							
Aluminum	21/21	1510	29700	PAI-03-SD-026-01	NA	NA	Yes
Antimony	3/21	0.34	0.74	PAI-03-SD-014-01	2.0	0.4	No
Arsenic	16/21	2.3	19.8	PAI-03-SD-024-01	7.24	2.7	Yes
Barium	16/21	3.6	53.8	PAI-03-SD-022-01	NA	NA	Yes
Beryllium	11/21	0.29	1.4	PAI-03-SD-026-01	NA	NA	Yes
Cadmium	10/21	0.12	0.44	PAI-03-SD-010-01	0.676	0.7	No
Chromium	21/21	3.3	50.3	PAI-03-SD-026-01	52.3	0.96	No
Cobalt	19/21	0.11	5.6	PAI-03-SD-026-01	NA	NA	Yes
Copper	21/21	1.8	46.9	PAI-03-SD-020-01	18.7	2.5	Yes
Cyanide	1/21	0.71	0.71	PAI-03-SD-018-01	NA	NA	Yes
Iron	21/21	1100	28000	PAI-03-SD-024-01	NA	NA	Yes
Lead	21/21	6.4	105	PAI-03-SD-017-01	30.2	3.5	Yes
Manganese	21/21	9.7	205	PAI-03-SD-026-01	NA	NA	Yes

TABLE 7-5

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SEDIMENT
PARRIS ISLAND, SOUTH CAROLINA
PAGE 3 OF 3

Analyte	Frequency of Detection	Range of Detection		Location of Maximum	EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum				
Mercury	6/21	0.05	0.35	PAI-03-SD-028-01	0.13	2.7	Yes
Nickel	19/21	0.42	13.9	PAI-03-SD-020-01	15.9	0.9	No
Selenium	7/21	0.32	1.1	PAI-03-SD-028-01	NA	NA	Yes
Silver	1/21	0.13	0.13	PAI-03-SD-020-01	0.733	0.2	No
Thallium	1/21	0.62	0.62	PAI-03-SD-027-01	NA	NA	Yes
Vanadium	21/21	2.6	63.7	PAI-03-SD-026-01	NA	NA	Yes
Zinc	21/21	5.2	159	PAI-03-SD-020-01	124.0	1.3	Yes

NA = Not Available.
a ESV for total chlordane
b ESV for total PCBs

TABLE 7-6

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SURFACE SOIL
PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 3

Analyte	Frequency of Detection	Range of Detection		EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum			
VOLATILE ORGANIC COMPOUNDS (µg/kg)						
2-Butanone	1/16	360	360	NA	NA	Yes
Acetone	2/6	120	240	NA	NA	Yes
Chloroform	4/16	1	2	1.0	2	Yes
SEMIVOLATILE ORGANIC COMPOUNDS (µg/kg)						
2-Methylnaphthalene	1/15	300	300	NA	NA	Yes
4-Methylphenol	1/15	120	120	NA	NA	Yes
Acenaphthene	1/16	4000	4000	20000	0.2	No
Acenaphthylene	1/16	1800	1800	100	18	Yes
Anthracene	6/16	1.7	340	100	3.4	Yes
Benzo(a)anthracene	10/16	3	3000	100	30	Yes
Benzo(a)pyrene	10/16	4.1	4000	100	40	Yes
Benzo(b)fluoranthene	15/16	2.2	3400	100	34	Yes
Benzo(g,h,i)perylene	5/16	9.3	2500	100	25	Yes
Benzo(k)fluoranthene	11/16	1.7	1300	100	13	Yes
Bis(2-Ethylhexyl)phthalate	1/15	2300	2300	NA	NA	Yes
Carbazole	3/15	48	670	NA	NA	Yes
Chrysene	13/16	3.6	2900	100	29	Yes
Dibenzofuran	1/15	340	340	NA	NA	Yes
Fluoranthene	14/16	6.4	5100	100	51	Yes
Indeno(1,2,3-cd)pyrene	10/16	2.6	2600	100	26	Yes
Phenanthrene	14/16	2.2	1200	100	12	Yes
Pyrene	10/16	13	4500	100	45	Yes

TABLE 7-6

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SURFACE SOIL
PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 3

Analyte	Frequency of Detection	Range of Detection		EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum			
PESTICIDES/PCBs (µg/kg)						
4,4'-DDE	1/16	4.1	4.1	2.5	1.6	Yes
4,4'-DDT	2/16	1.8	4.5	2.5	1.8	Yes
Alpha-Chlordane	1/16	96	96	NA	NA	Yes
Aroclor-1254	1/16	56	56	20	2.8	Yes
Aroclor-1260	4/16	11	100	20	5	Yes
Gamma-Chlordane	1/16	53	53	NA	NA	Yes
METALS AND INORGANIC COMPOUNDS (mg/kg)						
Aluminum	16/16	2370	10800	50	216	Yes
Antimony	2/16	0.17	0.33	3.5	0.09	No
Arsenic	16/16	0.44	11.8	10	1.2	Yes
Barium	16/16	5.8	81.2	165	0.5	No
Beryllium	3/16	0.11	0.58	1.1	0.5	No
Cadmium	6/16	0.04	0.53	1.6	0.3	No
Chromium	16/16	3.5	15.9	64	0.2	No
Cobalt	16/16	0.14	1.7	20	0.09	No
Copper	13/16	1.3	10.7	40	0.3	No
Iron	16/16	2180	7370	200	36.9	Yes
Lead	16/16	5.5	264	50	5.3	Yes
Manganese	16/16	8.1	66.9	100	0.7	No
Mercury	6/16	0.0375	0.43	0.1	4.3	Yes
Nickel	16/16	0.39	6.1	30	0.2	No
Selenium	2/16	0.28	0.41	0.81	0.5	No

TABLE 7-6

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – SURFACE SOIL
PARRIS ISLAND, SOUTH CAROLINA
PAGE 3 OF 3

Analyte	Frequency of Detection	Range of Detection		EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum			
Silver	1/16	0.09	0.09	2.0	0.05	No
Vanadium	16/16	4.7	21.4	2.0	10.7	Yes
Zinc	16/16	5.7	205	50	4.1	Yes

NA = Not Available.

7.6.4 Groundwater

Nine analytes in groundwater samples were retained as COPCs (Table 7-7). These consisted of three VOCs, three SVOCs, and three metals. The HQ for chlorobenzene was 1.2. The remaining COPCs had no available screening levels.

7.6.5 Tissue Data

All tissue concentrations of PAHs, pesticides, and PCBs in 1991 samples were less than their respective protective tissue guidelines, shown in Table 7-8. Mercury concentrations in one flounder liver sample and one mullet liver sample from the pond side of the causeway exceeded the 0.1 mg/kg criterion proposed by Eisler (1987a) as protective of piscivorous birds (Table 7-8). The maximum concentration of mercury in flounder livers was 0.42 mg/kg, and the maximum concentration of mercury in mullet livers was 0.15 mg/kg. Mercury concentrations were less than 0.1 mg/kg in all other flounder and mullet muscle samples and in all crab, clam, and oyster samples.

Concentrations of PAHs, pesticides, and PCBs in tissue tended to be higher in the pond than on the opposite side of the causeway, and PAH concentrations in crabs tended to be greater than in clams or oysters (ABB, 1993). Trends regarding mercury were not as clear, except that concentrations in mullet and flounder livers tended to be higher in the pond than on the opposite side of the causeway.

7.6.6 Food Chain Modeling

Based on surface soil data, aluminum, arsenic, iron, lead, mercury, vanadium, and zinc had at least one HQ greater than 1.0 for the terrestrial food chain modeling using maximum concentrations (Table 7-9). Aroclor 1254 and Aroclor 1260 had HQs greater than 1.0 using the maximum concentrations but no HQs greater than 1.0 using mean concentrations (Table 7-10). The HQ for DDE slightly exceeded 1.0 for the robin using mean concentrations but was less than 1.0 using maximum concentrations. This anomaly resulted from this pesticide being detected in only one of 16 soil samples, and its single detected value was less than the mean calculated using one-half the detection limit for each non-detect.

Based on the aquatic food chain modeling using sediment and surface water data, DDD, DDE, DDT, aluminum, arsenic, iron, lead, mercury, thallium, and vanadium had at least one HQ greater than 1.0 using maximum and mean concentrations (Tables 7-11 and 7-12). Aroclor 1254, barium, selenium, zinc, and cobalt had HQs greater than 1.0 using the maximum concentrations but no HQs greater than 1.0 using mean concentrations (Table 7-12).

TABLE 7-7

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – GROUNDWATER
PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Analyte	Frequency of Detection	Range of Detection		EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum			
VOLATILE ORGANIC COMPOUNDS (µg/L)						
Benzene	2/4	0.3	21	109	0.2	No
Carbon Disulfide	1/4	0.3	0.3	NA	NA	Yes
Chlorobenzene	2/4	0.6	130	105	1.2	Yes
Chloroform	1/4	0.3	0.3	815	0.0004	No
Ethylbenzene	1/4	0.3	0.3	4.3	0.07	No
Toluene	2/4	0.3	0.3	37	0.008	No
Xylenes, Total	1/4	0.3	0.3	NA	NA	Yes
1,4-Dichlorobenzene	1/4	10	10	19.9	0.5	No
2-Methylnaphthalene	1/4	1	1	NA	NA	Yes
4-Methylphenol	1/4	73	73	NA	NA	Yes
Acenaphthene	1/4	2	2	9.7	0.2	No
Anthracene	1/4	1	1	23.5	0.04	No
Bis(2-Ethylhexyl)phthalate	3/4	1	1	NA	NA	Yes
Fluorene	1/4	1	1	23.5	0.04	No
N-Nitrosodiphenylamine	1/4	1	1	33,000	3.0E-05	No
Naphthalene	2/4	1	1	23.5	0.04	No
Phenanthrene	1/4	1	1	23.5	0.04	No
PESTICIDES/PCBs (µg/L)						
alpha-BHC	1/4	0.12	0.12	1400	8.6E-05	No

TABLE 7-7

SELECTION OF CHEMICALS OF POTENTIAL CONCERN
SITE 3 – GROUNDWATER
PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Analyte	Frequency of Detection	Range of Detection		EPA Region 4 Screening Level	Maximum Hazard Quotient	Selected as COPC (Yes/No?)
		Minimum	Maximum			
METALS AND INORGANIC COMPOUNDS (µg/L)						
Arsenic	4/4	1.2	34.5	36	0.96	No
Barium	4/4	93.3	901	NA	NA	Yes
Chromium	2/4	7.6	27	103	0.3	No
Iron	3/3	14600	32600	NA	NA	Yes
Manganese	3/3	112	711	NA	NA	Yes
Thallium	1/4	3.8	3.8	21.3	0.2	No

NA = Not Available.

TABLE 7-8

CHEMICAL CONCENTRATIONS IN FISH TISSUE PROTECTIVE OF FISH AND PISCIVOROUS RECEPTORS MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical[a]	Chemical Concentration	Notes
INORGANICS (mg/kg WET WEIGHT)		
Mercury	0.1	Fish concentration protective of piscivorous birds (Eisler, 1987a)
	0.3	Fish concentration protective of piscivorous birds (Scheuhammer and Blancher, 1994)
	1.1	Fish concentration protective of piscivorous mammals (Eisler, 1987a)
	3.0	Adult fish protection criterion (Weiner and Spry, 1996)
ORGANIC COMPOUNDS (µg/kg WET WEIGHT)		
DDT, DDD, DDE	200[b]	Non-carcinogenic criterion for protection of sensitive piscivorous wildlife (Newell et al., 1987)
	266[b]	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
Aldrin	120	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	22	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
cis-Chlordane, trans-Nonachlor	500	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	370	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
	300	Fish concentration protective of piscivorous wildlife (Eisler, 1990)
Dieldrin	120	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	22	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
Endrin	25	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
Heptachlor	200	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	210	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
Heptachlor epoxide	200	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	210	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
Hexachlorobenzene	330	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	200	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
Lindane (gamma BHC)	100	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987
	510	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
Mirex	10	Fish concentration protective of fish & piscivorous wildlife (Eisler, 1985)
	330	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	373	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
PAHs (total)	300	Fish protection criterion (Eisler, 1987b)
PCBs	130	Non-carcinogenic piscivorous wildlife criterion (Newell et al., 1987)
	110	1 in 100 cancer risk level for piscivorous wildlife (Newell et al., 1987)
	400	Fish protection criterion (Eisler, 1986)
	3000	Fish concentration protective of piscivorous birds (Eisler, 1986)

a Detected in at least one fish, crab, clam, or oyster tissue sample collected at Site 3 during ESI (ABB, 1993)
b Criterion for DDT and metabolites
c More detailed data is presented in Appendix F.

TABLE 7-9

RESULTS OF FOOD CHAIN MODELING
TERRESTRIAL RECEPTORS
MAXIMUM CONCENTRATIONS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Shrew		Mouse		Robin		Hawk	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
SEMIVOLATILE ORGANIC COMPOUNDS								
2-Methylnaphthalene	3.12E-02	3.12E-03	2.21E-03	2.21E-04	2.43E-03	2.43E-04	5.61E-05	5.61E-06
4-Methylphenol	3.68E-04	1.43E-04	1.90E-04	7.40E-05	NA	NA	NA	NA
Acenaphthylene	1.44E-01	7.21E-02	1.02E-02	5.10E-03	1.46E-02	1.46E-03	3.37E-04	3.37E-05
Anthracene	1.53E-02	7.65E-03	1.93E-03	9.64E-04	1.75E-03	1.75E-04	9.65E-06	9.65E-07
Benzo(a)anthracene	1.97E-01	1.97E-02	2.21E-02	2.21E-03	1.68E-02	1.68E-03	1.60E-04	1.60E-05
Benzo(a)pyrene	3.46E-01	3.46E-02	2.95E-02	2.95E-03	2.78E-02	2.78E-03	5.04E-04	5.04E-05
Benzo(b)fluoranthene	2.87E-01	2.87E-02	2.51E-02	2.51E-03	2.32E-02	2.32E-03	4.03E-04	4.03E-05
Benzo(g,h,i)perylene	1.93E-01	1.93E-02	1.84E-02	1.84E-03	1.59E-02	1.59E-03	2.33E-04	2.33E-05
Benzo(k)fluoranthene	1.01E-01	1.01E-02	9.58E-03	9.58E-04	8.33E-03	8.33E-04	1.25E-04	1.25E-05
Bis(2-ethylhexyl)phthalate	1.28E-02	1.28E-03	1.82E-03	1.82E-04	1.96E-01	1.96E-02	2.33E-03	2.33E-04
Carbazole	5.37E-02	2.68E-02	1.01E-02	5.07E-03	7.05E-03	7.05E-04	8.81E-05	8.81E-06
Chrysene	2.04E-01	2.04E-02	2.14E-02	2.14E-03	1.72E-02	1.72E-03	2.03E-04	2.03E-05
Dibenzofuran	5.77E-04	2.77E-04	8.23E-05	3.95E-05	NA	NA	NA	NA
Fluoranthene	3.12E-01	3.12E-02	3.76E-02	3.76E-03	2.71E-02	2.71E-03	1.93E-04	1.93E-05
Indeno(1,2,3-cd)pyrene	2.45E-01	2.45E-02	1.92E-02	1.92E-03	1.93E-02	1.93E-03	3.95E-04	3.95E-05
Phenanthrene	6.03E-02	3.02E-02	6.80E-03	3.40E-03	6.70E-03	6.70E-04	6.25E-05	6.25E-06
Pyrene	2.81E-01	2.81E-02	3.32E-02	3.32E-03	2.43E-02	2.43E-03	1.90E-04	1.90E-05
PESTICIDES/PCBs								
4,4'-DDE	4.48E-03	8.96E-04	4.24E-05	8.47E-06	8.51E-01	8.51E-02	1.68E-01	1.68E-02
4,4'-DDT	1.85E-03	3.70E-04	4.65E-05	9.30E-06	3.67E-01	3.67E-02	6.26E-02	6.26E-03
alpha-chlordane	1.72E-02	8.61E-03	1.65E-04	8.23E-05	2.46E-02	4.93E-03	2.22E-03	4.44E-04
gamma-chlordane	9.51E-03	4.76E-03	9.09E-05	4.54E-05	1.36E-02	2.72E-03	1.23E-03	2.45E-04
Aroclor-1254	**2.35E+00**	2.35E-01	3.14E-02	3.14E-03	5.98E-01	5.98E-02	3.92E-01	3.92E-02
Aroclor-1260	**4.19E+00**	4.19E-01	5.61E-02	5.61E-03	**1.07E+00**	1.07E-01	6.99E-01	6.99E-02
METALS AND INORGANICS								
Aluminum	**4.43E+02**	**4.43E+01**	**3.23E+01**	**3.23E+00**	**6.07E+00**	6.07E-01	2.22E-02	2.22E-03
Arsenic	**1.51E+01**	**1.51E+00**	**3.01E+00**	3.01E-01	3.84E-01	1.54E-01	4.13E-03	1.66E-03
Iron	**1.06E+01**	**1.06E+00**	**4.09E+01**	**4.09E+00**	**4.36E+01**	**4.36E+00**	**4.28E+00**	4.28E-01
Lead	**6.00E+00**	6.00E-01	**1.10E+00**	1.10E-01	**4.26E+01**	**4.26E+00**	7.22E-02	7.22E-03
Mercury	**2.50E+01**	**1.50E+01**	**1.56E+00**	9.37E-01	**4.50E+01**	**4.50E+00**	7.04E-02	7.04E-03
Vanadium	**7.40E+00**	7.40E-01	5.96E-01	5.96E-02	1.08E-01	1.08E-02	5.52E-04	5.52E-05
Zinc	**2.05E+00**	**1.02E+00**	2.20E-01	1.10E-01	**1.94E+01**	**2.15E+00**	**6.33E+00**	7.01E-01

NA = NOAEL/LOAEL not available

TABLE 7-10

**RESULTS OF FOOD CHAIN MODELING
TERRESTRIAL RECEPTORS
MEAN CONCENTRATIONS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Ecological Contaminant of Potential Concern	Shrew		Mouse		Robin		Hawk	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
SEMIVOLATILE ORGANIC COMPOUNDS								
2-Methylnaphthalene	1.95E-02	1.95E-03	1.38E-03	1.38E-04	1.51E-03	1.51E-04	3.50E-05	3.50E-06
4-Methylphenol	5.36E-04	2.08E-04	2.77E-04	1.08E-04	NA	NA	NA	NA
Acenaphthylene	2.81E-02	1.40E-02	1.99E-03	9.93E-04	2.84E-03	2.84E-04	6.55E-05	6.55E-06
Anthracene	1.50E-03	7.48E-04	1.88E-04	9.42E-05	1.71E-04	1.71E-05	9.44E-07	9.44E-08
Benzo(a)anthracene	1.48E-02	1.48E-03	1.66E-03	1.66E-04	1.26E-03	1.26E-04	1.20E-05	1.20E-06
Benzo(a)pyrene	2.51E-02	2.51E-03	2.13E-03	2.13E-04	2.01E-03	2.01E-04	3.65E-05	3.65E-06
Benzo(b)fluoranthene	2.08E-02	2.08E-03	1.82E-03	1.82E-04	1.68E-03	1.68E-04	2.92E-05	2.92E-06
Benzo(g,h,i)perylene	1.53E-02	1.53E-03	1.46E-03	1.46E-04	1.26E-03	1.26E-04	1.85E-05	1.85E-06
Benzo(k)fluoranthene	7.55E-03	7.55E-04	7.13E-04	7.13E-05	6.19E-04	6.19E-05	9.31E-06	9.31E-07
Bis(2-ethylhexyl)phthalate	1.78E-03	1.78E-04	2.54E-04	2.54E-05	2.72E-02	2.72E-03	3.24E-04	3.24E-05
Carbazole	1.56E-02	7.79E-03	2.94E-03	1.47E-03	2.05E-03	2.05E-04	2.56E-05	2.56E-06
Chrysene	1.62E-02	1.62E-03	1.70E-03	1.70E-04	1.36E-03	1.36E-04	1.61E-05	1.61E-06
Dibenzofuran	3.22E-04	1.55E-04	4.59E-05	2.20E-05	NA	NA	NA	NA
Fluoranthene	2.53E-02	2.53E-03	3.05E-03	3.05E-04	2.20E-03	2.20E-04	1.56E-05	1.56E-06
Indeno(1,2,3-cd)pyrene	1.82E-02	1.82E-03	1.43E-03	1.43E-04	1.44E-03	1.44E-04	2.94E-05	2.94E-06
Phenanthrene	5.98E-03	2.99E-03	6.75E-04	3.37E-04	6.65E-04	6.65E-05	6.20E-06	6.20E-07
Pyrene	2.25E-02	2.25E-03	2.65E-03	2.65E-04	1.94E-03	1.94E-04	1.52E-05	1.52E-06
PESTICIDES/PCBs								
4,4'-DDE	1.27E-02	2.53E-03	1.20E-04	2.40E-05	**2.41E+00**	2.41E-01	4.76E-01	4.76E-02
4,4'-DDT	4.80E-03	9.60E-04	1.21E-04	2.42E-05	9.52E-01	9.52E-02	1.63E-01	1.63E-02
alpha-chlordane	1.72E-02	8.61E-03	1.65E-04	8.23E-05	2.46E-02	4.92E-03	2.22E-03	4.44E-04
gamma-chlordane	1.67E-02	8.37E-03	1.60E-04	8.00E-05	2.39E-02	4.79E-03	2.16E-03	4.31E-04
Aroclor-1254	3.24E-01	3.24E-02	4.34E-03	4.34E-04	8.25E-02	8.25E-03	5.41E-02	5.41E-03
Aroclor-1260	5.71E-01	5.71E-02	7.64E-03	7.64E-04	1.45E-01	1.45E-02	9.52E-02	9.52E-03
METALS AND INORGANICS								
Aluminum	**2.36E+02**	**2.36E+01**	**1.72E+01**	**1.72E+00**	**3.23E+00**	3.23E-01	1.18E-02	1.18E-03
Arsenic	**2.14E+00**	2.14E-01	4.25E-01	4.25E-02	5.41E-02	2.17E-02	5.83E-04	2.34E-04
Iron	**6.89E+00**	6.89E-01	**2.66E+01**	**2.66E+00**	**2.83E+01**	**2.83E+00**	**2.78E+00**	2.78E-01
Lead	7.04E-01	7.04E-02	1.29E-01	1.29E-02	**5.00E+00**	5.00E-01	8.47E-03	8.47E-04
Mercury	**3.33E+00**	**2.00E+00**	2.08E-01	1.25E-01	**6.00E+00**	6.00E-01	9.39E-03	9.39E-04
Vanadium	**3.61E+00**	3.61E-01	2.91E-01	2.91E-02	5.27E-02	5.27E-03	2.69E-04	2.69E-05
Zinc	2.73E-01	1.36E-01	2.92E-02	1.46E-02	**2.58E+00**	2.86E-01	8.43E-01	9.33E-02

NA = NOAEL/LOAEL not available

TABLE 7-11

RESULTS OF FOOD CHAIN MODELING
AQUATIC RECEPTORS
MAXIMUM CONCENTRATIONS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Raccoon		Heron		Mummichog		Red Drum		Eagle	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
SEMIVOLATILE ORGANIC COMPOUNDS										
Anthracene	9.45E-02	4.77E-02	1.00E-02	1.00E-03	1.49E-01	1.49E-02	3.93E-02	3.93E-03	1.91E-03	1.91E-04
Benzo(a)anthracene	1.93E-01	1.93E-02	1.57E-02	1.57E-03	2.32E-01	2.32E-02	6.13E-02	6.13E-03	2.98E-03	2.98E-04
Benzo(a)pyrene	1.93E-01	1.93E-02	1.57E-02	1.57E-03	2.32E-01	2.32E-02	6.13E-02	6.13E-03	2.98E-03	2.98E-04
Benzo(b)fluoranthene	1.60E-01	1.60E-02	1.29E-02	1.29E-03	1.91E-01	1.91E-02	5.06E-02	5.06E-03	2.46E-03	2.46E-04
Carbazole	2.22E-01	1.11E-01	2.56E-02	2.56E-03	1.10E-01	1.10E-02	8.65E-02	8.65E-03	4.89E-03	4.89E-04
Chrysene	3.06E-01	3.06E-02	2.48E-02	2.48E-03	3.67E-01	3.67E-02	9.71E-02	9.71E-03	4.72E-03	4.72E-04
Dibenzofuran	1.60E-03	7.69E-04	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	5.64E-01	5.64E-02	4.57E-02	4.57E-03	6.77E-01	6.77E-02	1.79E-01	1.79E-02	8.70E-03	8.70E-04
Indeno(1,2,3-cd)pyrene	1.06E-01	1.06E-02	8.61E-03	8.61E-04	1.28E-01	1.28E-02	3.37E-02	3.37E-03	1.64E-03	1.64E-04
Phenanthrene	6.20E-01	3.10E-01	7.01E-02	7.01E-03	4.64E-01	4.64E-02	2.45E-01	2.45E-02	1.34E-02	1.34E-03
Pyrene	4.35E-01	4.35E-02	3.52E-02	3.52E-03	5.22E-01	5.22E-02	1.38E-01	1.38E-02	6.71E-03	6.71E-04
PESTICIDES/PCBs										
4,4'-DDD	5.66E-02	1.13E-02	**1.30E+01**	**1.30E+00**	NA	NA	NA	NA	**2.49E+00**	2.49E-01
4,4'-DDE	2.12E-01	4.23E-02	**5.57E+01**	**5.57E+00**	NA	NA	NA	NA	**1.06E+01**	**1.06E+00**
4,4'-DDT	3.53E-02	7.07E-03	**9.12E+00**	9.12E-01	NA	NA	NA	NA	**1.74E+00**	1.74E-01
Alpha-Chlordane	1.42E-02	7.12E-03	2.81E-02	5.61E-03	NA	NA	NA	NA	5.35E-03	1.07E-03
Aroclor-1254	**3.38E+00**	3.38E-01	**1.16E+00**	1.16E-01	NA	NA	NA	NA	2.20E-01	2.20E-02
Aroclor-1260	9.46E-01	9.46E-02	3.24E-01	3.24E-02	NA	NA	NA	NA	6.17E-02	6.17E-03
Gamma-Chlordane	6.69E-03	3.34E-03	1.31E-02	2.61E-03	NA	NA	NA	NA	2.49E-03	4.98E-04
INORGANICS										
Aluminum	**3.30E+03**	**3.30E+02**	**4.87E+01**	**4.87E+00**	NA	NA	NA	NA	**3.25E+01**	**3.25E+00**
Arsenic	**3.37E+01**	**3.37E+00**	6.94E-01	2.78E-01	**1.95E+00**	1.62E-01	6.71E-01	5.58E-02	4.62E-01	1.85E-01
Barium	**2.27E+00**	2.27E-01	4.66E-01	2.32E-01	NA	NA	NA	NA	3.10E-01	1.55E-01
Beryllium	4.55E-01	4.55E-02	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	**1.20E+00**	1.20E-01	**1.01E+00**	1.01E-01	NA	NA	NA	NA	6.72E-01	6.72E-02
Copper	8.61E-01	6.65E-01	1.80E-01	1.37E-01	NA	NA	NA	NA	1.20E-01	9.12E-02
Cyanide	2.22E-03	2.22E-04	2.84E-02	2.84E-03	NA	NA	NA	NA	1.89E-02	1.89E-03
Iron	**1.20E+02**	**1.20E+01**	**5.04E+01**	**5.04E+00**	NA	NA	NA	NA	**3.36E+01**	**3.36E+00**
Lead	**2.82E+00**	2.82E-01	**1.67E+01**	**1.67E+00**	NA	NA	NA	NA	**1.12E+01**	**1.12E+00**
Manganese	5.00E-01	1.55E-01	3.78E-02	3.78E-03	NA	NA	NA	NA	2.52E-02	2.52E-03
Mercury	**5.01E+00**	**3.00E+00**	**9.84E+00**	9.84E-01	**2.54E+00**	2.16E-02	8.75E-01	7.45E-03	**6.56E+00**	6.56E-01
Selenium	**1.18E+00**	7.15E-01	4.95E-01	2.47E-01	NA	NA	NA	NA	3.30E-01	1.65E-01
Thallium	**1.80E+01**	**1.80E+00**	2.37E-01	2.37E-02	NA	NA	NA	NA	1.58E-01	1.58E-02
Vanadium	**6.61E+01**	**6.51E+00**	**1.01E+00**	1.01E-01	NA	NA	NA	NA	6.71E-01	6.71E-02
Zinc	2.13E-01	1.07E-01	**1.97E+00**	2.18E-01	NA	NA	NA	NA	**1.32E+00**	1.46E-01

NA = NOAEL/LOAEL not available

TABLE 7-12

RESULTS OF FOOD CHAIN MODELING
AQUATIC RECEPTORS
MEAN CONCENTRATIONS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Raccoon		Heron		Mummichog		Red Drum		Eagle	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
SEMIVOLATILE ORGANIC COMPOUNDS										
Anthracene	6.82E-03	3.41E-03	7.18E-04	7.18E-05	1.06E-02	1.06E-03	2.81E-03	2.81E-04	1.37E-04	1.37E-05
Benzo(a)anthracene	2.27E-02	2.27E-03	1.83E-03	1.83E-04	2.72E-02	2.72E-03	7.19E-03	7.19E-04	3.50E-04	3.50E-05
Benzo(a)pyrene	1.71E-02	1.71E-03	1.38E-03	1.38E-04	2.05E-02	2.05E-03	5.42E-03	5.42E-04	2.64E-04	2.64E-05
Benzo(b)fluoranthene	1.18E-02	1.18E-03	9.52E-04	9.52E-05	1.41E-02	1.41E-03	3.73E-03	3.73E-04	1.81E-04	1.81E-05
Carbazole	1.59E-01	7.96E-02	1.84E-02	1.84E-03	7.91E-02	7.91E-03	6.21E-02	6.21E-03	3.51E-03	3.51E-04
Chrysene	2.39E-02	2.39E-03	1.93E-03	1.93E-04	2.87E-02	2.87E-03	7.58E-03	7.58E-04	3.69E-04	3.69E-05
Dibenzofuran	3.30E-03	1.58E-03	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	3.62E-02	3.62E-03	2.93E-03	2.93E-04	4.35E-02	4.35E-03	1.15E-02	1.15E-03	5.59E-04	5.59E-05
Indeno(1,2,3-cd)pyrene	1.25E-02	1.25E-03	1.02E-03	1.02E-04	1.50E-02	1.50E-03	3.98E-03	3.98E-04	1.93E-04	1.93E-05
Phenanthrene	3.95E-02	1.97E-02	4.47E-03	4.47E-04	2.96E-02	2.96E-03	1.56E-02	1.56E-03	8.51E-04	8.51E-05
Pyrene	3.62E-02	3.62E-03	2.93E-03	2.93E-04	4.34E-02	4.34E-03	1.15E-02	1.15E-03	5.58E-04	5.58E-05
PESTICIDES/PCBs										
4,4'-DDD	8.07E-03	1.61E-03	**1.86E+00**	1.86E-01	NA	NA	NA	NA	3.54E-01	3.54E-02
4,4'-DDE	1.37E-01	2.75E-02	**3.61E+01**	**3.61E+00**	NA	NA	NA	NA	**6.88E+00**	6.88E-01
4,4'-DDT	3.02E-02	6.05E-03	**7.80E+00**	7.80E-01	NA	NA	NA	NA	**1.49E+00**	1.49E-01
Alpha-Chlordane	7.41E-02	3.70E-02	1.46E-01	2.92E-02	NA	NA	NA	NA	2.78E-02	5.57E-03
Aroclor-1254	3.84E-01	3.84E-02	1.31E-01	1.31E-02	NA	NA	NA	NA	2.51E-02	2.51E-03
Aroclor-1260	1.98E-01	1.98E-02	6.76E-02	6.76E-03	NA	NA	NA	NA	1.29E-02	1.29E-03
Gamma-Chlordane	3.48E-02	1.74E-02	6.80E-02	1.36E-02	NA	NA	NA	NA	1.30E-02	2.59E-03
INORGANICS										
Aluminum	**1.45E+03**	**1.45E+02**	**2.14E+01**	**2.14E+00**	NA	NA	NA	NA	**1.43E+01**	**1.43E+00**
Arsenic	**1.10E+01**	1.10E+00	2.25E-01	9.02E-02	6.33E-01	5.26E-02	2.18E-01	1.81E-02	1.50E-01	6.02E-02
Barium	7.25E-01	7.25E-02	1.49E-01	7.44E-02	NA	NA	NA	NA	9.95E-02	4.96E-02
Beryllium	1.56E-01	1.56E-02	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	4.36E-01	4.36E-02	3.65E-01	3.65E-02	NA	NA	NA	NA	2.44E-01	2.44E-02
Copper	2.18E-01	2.18E-01	5.88E-02	4.48E-02	NA	NA	NA	NA	3.92E-02	2.98E-02
Cyanide	1.49E-03	1.49E-04	1.91E-02	1.91E-03	NA	NA	NA	NA	1.27E-02	1.27E-03
Iron	**5.47E+01**	**5.47E+00**	**2.29E+01**	**2.29E+00**	NA	NA	NA	NA	**1.53E+01**	**1.53E+00**
Lead	8.02E-01	8.02E-02	**4.76E+00**	4.76E-01	NA	NA	NA	NA	**3.18E+00**	3.18E-01
Manganese	1.70E-01	5.27E-02	1.28E-02	1.28E-03	NA	NA	NA	NA	8.57E-03	8.57E-04
Mercury	8.00E-01	4.80E-01	**1.57E+00**	1.57E-01	4.06E-01	3.45E-03	1.40E-01	1.19E-03	**1.05E+00**	1.05E-01
Selenium	3.66E-01	2.22E-01	1.53E-01	7.66E-02	NA	NA	NA	NA	1.02E-01	5.11E-02
Thallium	**6.22E+00**	6.22E-01	8.21E-02	8.21E-03	NA	NA	NA	NA	5.47E-02	5.47E-03
Vanadium	**2.97E+01**	**2.97E+00**	4.59E-01	4.59E-02	NA	NA	NA	NA	3.06E-01	3.06E-02
Zinc	5.81E-02	2.90E-02	5.37E-01	5.95E-02	NA	NA	NA	NA	3.58E-01	3.97E-02

NA = NOAEL/LOAEL not available

The results of the food chain modeling using maximum concentrations of filtered surface water indicated that aluminum, arsenic, iron, and vanadium had HQs greater than 1.0 (Table 7-13). Using mean concentrations, aluminum, iron, and vanadium had HQs greater than 1.0 (Table 7-14).

Based on the use of the 1991 tissue data in food chain modeling, DDD, DDE, and mercury had at least one HQ greater than 1.0 using maximum and mean concentrations (Tables 7-15 and 7-16).

7.7 STEP 3A: REFINEMENT OF CONTAMINANTS OF POTENTIAL CONCERN

7.7.1 Other Risk Characterization Considerations

The ERA, up to this point, can be considered to be a "screening-level" assessment, or "Tier 1" assessment, since it is based primarily on a conservative initial screening of contaminant concentrations against contaminant-specific screening levels. As noted in Section 7.6, maximum concentrations of several analytes exceed conservative ecological screening levels. The use of conservative guidelines and maximum detected concentrations in the screening-level assessment is necessary to ensure that potential risks are not underestimated. However, if the hazard quotients derived from comparisons of maximum concentrations to conservative screening levels are used as the single factor for including a COPC in a baseline ERA without consideration of other relevant information, additional ecological studies such as toxicity testing or tissue analyses could be undertaken for COPCs that do not actually pose significant risks. For this reason, refinement of COPCs, the first sub-step within Step 3, was incorporated into this ERA. Step 3a involves the consideration of factors such as background data (mainly for inorganics), toxicological evaluation of COPCs, frequency of detection, and comparisons of COPCs to alternate guidelines (U.S. EPA, 1997b; DON, 1999).

Some factors to be considered that are outside the boundaries of the simple concentration-ESV comparisons have already been presented, such as the use of average contaminant concentrations and LOAELs in the food chain modeling. The frequency of detection and spatial analysis of exceedances were also evaluated during Step 3a to determine whether potential risks are widespread or limited to a small area. The magnitude of the HQs was also considered. As described earlier, the relationship between the magnitude of a HQ and toxicity is not necessarily linear. However, the magnitude of an HQ can be used as rough approximation of the extent of potential risks, especially if there is sufficient confidence in the guideline used.

The use of less conservative guidelines provides balance to the conservative screening-level assessment. For example, some Region IV sediment ESVs are based on Effects Range-Low (ER-L) values obtained from Long et al. (1995). However, an ER-L is defined as the concentration below which adverse ecological "effects would rarely be observed," and the Effects Range-Median (ER-M) is the point

TABLE 7-13

RESULTS OF FOOD CHAIN MODELING
AQUATIC RECEPTORS
MAXIMUM CONCENTRATIONS - FILTERED SURFACE WATER
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Raccoon		Heron		Red Drum		Eagle	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
INORGANICS								
Aluminum	**3.19E+02**	**3.19E+01**	1.30E-01	1.30E-02	NA	NA	6.75E-02	6.75E-03
Antimony	ND	ND	NA	NA	ND	ND	NA	NA
Arsenic	**3.54E+00**	3.54E-01	8.35E-03	3.34E-03	1.07E-01	8.89E-03	5.12E-03	2.05E-03
Barium	2.58E-01	2.58E-02	1.01E-02	5.05E-03	NA	NA	6.44E-03	3.21E-03
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND
Copper	8.24E-02	6.37E-02	3.50E-04	2.67E-04	NA	NA	1.56E-04	1.19E-04
Iron	**1.71E+01**	**1.71E+00**	**2.71E+00**	2.71E-01	NA	NA	**1.78E+00**	1.78E-01
Lead	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	1.76E-01	5.45E-02	1.07E-02	1.07E-03	NA	NA	7.15E-03	7.15E-04
Mercury	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	NA	NA	ND	ND	NA	NA
Thallium	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	**6.17E+00**	6.17E-01	8.49E-04	8.49E-05	NA	NA	1.16E-06	1.16E-07
Zinc	2.50E-02	1.25E-02	5.02E-02	5.55E-03	NA	NA	3.30E-02	3.65E-03

NA = NOAEL/LOAEL not available

ND = Not Detected

TABLE 7-14

RESULTS OF FOOD CHAIN MODELING
AQUATIC RECEPTORS
MEAN CONCENTRATIONS - FILTERED SURFACE WATER
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Raccoon		Heron		Red Drum		Eagle	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
INORGANICS								
Aluminum	**1.37E+02**	**1.37E+01**	1.45E-02	1.45E-03	NA	NA	8.53E-03	8.53E-04
Antimony	ND	ND	NA	NA	ND	ND	NA	NA
Arsenic	1.08E+00	1.08E-01	1.07E-03	4.28E-04	3.36E-02	2.79E-03	6.86E-04	2.75E-04
Barium	1.03E-01	1.03E-02	7.89E-03	3.94E-03	NA	NA	5.23E-03	2.61E-03
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND
Copper	2.72E-02	2.10E-02	1.78E-04	1.36E-04	NA	NA	1.14E-04	8.68E-05
Iron	**5.62E+00**	5.62E-01	2.24E-01	2.24E-02	NA	NA	1.48E-01	1.48E-02
Lead	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	4.23E-02	1.31E-02	2.19E-03	2.19E-04	NA	NA	1.46E-03	1.46E-04
Mercury	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	NA	NA	ND	ND	NA	NA
Thallium	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	**2.80E+00**	2.80E-01	4.59E-05	4.59E-06	NA	NA	9.72E-08	9.72E-09
Zinc	8.29E-03	4.15E-03	2.89E-02	3.20E-03	NA	NA	1.93E-02	2.13E-03

NA = NOAEL/LOAEL not available
ND = Not Detected

TABLE 7-15

RESULTS OF FOOD CHAIN MODELING USING TISSUE DATA
MAXIMUM CONCENTRATIONS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Raccoon		Eagle (fish muscle)		Eagle (fish liver)	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
SEMIVOLATILE ORGANIC COMPOUNDS						
2-Methylnaphthalene	2.72E-04	2.72E-05	3.84E-05	3.84E-06	1.06E-03	1.06E-04
Acenaphthylene	3.74E-04	1.87E-04	2.28E-05	2.28E-06	3.96E-05	3.96E-06
Acenaphthene	2.69E-04	1.35E-04	1.92E-05	1.92E-06	2.40E-04	2.40E-05
Fluorene	4.04E-05	2.02E-05	1.56E-05	1.56E-06	1.44E-04	1.44E-05
Phenanthrene	3.29E-04	1.64E-04	2.28E-05	2.28E-06	5.88E-04	5.88E-05
Anthracene	2.39E-04	1.20E-04	1.92E-05	1.92E-06	7.20E-05	7.20E-06
Fluoranthene	2.33E-04	2.33E-05	7.44E-06	7.44E-07	9.72E-04	9.72E-05
Pyrene	1.21E-03	1.21E-04	3.60E-05	3.60E-06	6.24E-03	6.24E-04
Benzo(a)anthracene	ND	ND	ND	ND	6.48E-05	6.48E-06
Chrysene	6.22E-04	6.22E-05	3.84E-05	3.84E-06	7.80E-05	7.80E-06
Benzo(b)fluoranthene	1.34E-03	1.34E-04	6.96E-05	6.96E-06	1.68E-04	1.68E-05
Benzo(k)fluoranthene	9.14E-04	9.14E-05	4.56E-05	4.56E-06	1.20E-04	1.20E-05
Benzo(a)pyrene	7.97E-04	7.97E-05	3.24E-05	3.24E-06	6.24E-05	6.24E-06
Indeno(1,2,3-cd)pyrene	3.89E-04	3.89E-05	1.80E-05	1.80E-06	ND	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	7.19E-04	7.19E-05	3.24E-05	3.24E-06	3.84E-04	3.84E-05
PESTICIDE/PCBs						
Aroclor-1254	1.69E-01	1.69E-02	4.87E-02	4.87E-03	5.93E-01	5.93E-02
Aroclor-1260	ND	ND	1.67E-03	1.67E-04	ND	ND
4,4'-DDD	5.10E-04	1.02E-04	4.71E-01	4.71E-02	**1.50E+01**	**1.50E+00**
4,4'-DDE	2.14E-04	1.03E-04	**2.40E+00**	2.40E-01	**3.21E+01**	**3.21E+00**
4,4'-DDT	ND	ND	4.29E-02	4.29E-03	ND	ND
cis-Chlordane	5.07E-05	2.54E-05	1.12E-04	2.24E-05	8.97E-04	1.79E-04
INORGANIC COMPOUNDS						
Mercury	1.43E-01	8.55E-02	**1.29E+00**	1.29E-01	**2.06E+00**	2.06E-01

ND = For raccoon, not detected in crab, clam, or oyster tissue. For eagle, not detected in mullet or flounder tissue.

TABLE 7-16

RESULTS OF FOOD CHAIN MODELING USING TISSUE DATA
MEAN CONCENTRATIONS
SITE 3 - CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA

Ecological Contaminant of Potential Concern	Raccoon		Eagle (fish muscle)		Eagle (fish liver)	
	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ	NOAEL HQ	LOAEL HQ
SEMIVOLATILE ORGANIC COMPOUNDS						
2-Methylnaphthalene	2.14E-04	2.14E-05	1.22E-05	1.22E-06	1.99E-04	1.99E-05
Acenaphthylene	1.79E-04	8.97E-05	1.62E-05	1.62E-06	2.88E-05	2.88E-06
Acenaphthene	2.39E-05	1.20E-05	6.90E-06	6.90E-07	4.20E-05	4.20E-06
Fluorene	2.84E-05	1.42E-05	5.31E-06	5.31E-07	5.73E-05	5.73E-06
Phenanthrene	2.69E-04	1.35E-04	7.92E-06	7.92E-07	1.66E-04	1.66E-05
Anthracene	2.09E-05	1.05E-05	6.52E-06	6.52E-07	3.15E-05	3.15E-06
Fluoranthene	1.01E-03	1.01E-04	3.03E-06	3.03E-07	1.01E-04	1.01E-05
Pyrene	5.25E-04	5.25E-05	2.93E-06	2.93E-07	3.41E-04	3.41E-05
Benzo(a)anthracene	7.00E-04	7.00E-05	3.33E-05	3.33E-06	4.50E-05	4.50E-06
Chrysene	2.92E-04	2.92E-05	2.22E-05	2.22E-06	3.87E-05	3.87E-06
Benzo(b)fluoranthene	2.92E-04	2.92E-05	5.10E-05	5.10E-06	6.33E-05	6.33E-06
Benzo(k)fluoranthene	1.94E-04	1.94E-05	3.45E-05	3.45E-06	4.21E-05	4.21E-06
Benzo(a)pyrene	5.25E-04	5.25E-05	3.09E-05	3.09E-06	4.38E-05	4.38E-06
Indeno(1,2,3-cd)pyrene	2.92E-04	2.92E-05	1.53E-05	1.53E-06	2.43E-05	2.43E-06
Dibenzo(a,h)anthracene	3.59E-04	1.79E-04	2.25E-05	2.25E-06	3.39E-05	3.39E-06
Benzo(g,h,i)perylene	5.44E-04	5.44E-05	2.31E-05	2.31E-06	6.48E-05	6.48E-06
PESTICIDE/PCBs						
Aroclor-1254	1.40E-01	1.40E-02	1.50E-02	1.50E-03	1.01E-01	1.01E-02
Aroclor-1260	ND	ND	1.50E-03	1.50E-04	ND	ND
4,4'-DDD	1.29E-03	2.58E-04	1.32E-01	1.32E-02	**1.60E+00**	1.60E-01
4,4'-DDE	1.26E-04	6.09E-05	5.39E-01	5.39E-02	**4.08E+00**	4.08E-01
4,4'-DDT	ND	ND	3.17E-02	3.17E-03	ND	ND
cis-Chlordane	1.06E-05	5.28E-06	2.86E-05	5.72E-06	3.25E-04	6.50E-05
INORGANIC COMPOUNDS						
Mercury	1.43E-01	8.55E-02	5.69E-01	5.69E-02	**1.49E+00**	1.49E-01

ND = Not Detected

below which adverse effects "would occasionally occur" (Long et al., 1995). Therefore, ascribing risk to a sediment contaminant detected at a concentration that exceeds the ER-L but is below the ER-M can be misleading. For this reason, when contaminant concentrations exceed Region IV ESVs, or no Region IV ESV was available, less conservative guidelines are presented for sediment and surface soils (Tables 7-17 and 7-18).

Alternative sediment guidelines include Probable Effects Levels (PELs) established by the Florida Department of Environmental Protection (FDEP, 1994). The PELs are loosely analogous to ER-Ms, which are also presented. The data set used by Long et al. (1995) to develop ER-Ls and ER-Ms was also used by FDEP. However, unlike the ER-Ls and ER-Ms, the TELs and PELs also incorporate chemical concentrations observed or predicted to be associated with no adverse biological effects (no effects data). The PEL is the geometric mean of the 50th percentile in the effects data set and 85th percentile in the no effects data set. The PEL represents the lower limit of the range of contaminant concentrations that are usually or always associated with adverse biological effects (FDEP, 1994).

For surface soils, Dutch values from Beyer (1990) are presented, as well as surface soil guidelines from Oak Ridge National Laboratory indicative of toxicity to soil invertebrates and terrestrial plants (Efroymson et al., 1997a, 1997b). In addition, newer Dutch values are presented (MHSP&E, 1994). These include target values and intervention values. Target values represent the "soil quality required for the full restoration of the soil's functionality for human, animal and plant life," or "soil quality ultimately aimed for." The intervention values replace the 1990 C values and represent "the concentration levels of the contaminants in the soil ... above which the functionality of the soil for human, plant, and animal life is seriously impaired or threatened." The 1994 intervention values also take into account ecotoxicological considerations.

Few sources of ESVs other than Region IV values are available for surface water. However, U.S. EPA Region III BTAG (1995c) has a few ESVs for analytes in surface water for which U.S. EPA Region IV has no values. These were considered after the initial screening.

Background samples have been collected and analyzed as part of current RFI/RI activities at MCRD Parris Island. As a result, soil, sediment, and surface water background data are available for use in assessing the extent to which Site 3 chemical concentrations are due to site-related activities. Background data are provided in Table 4-1.

A "weight-of-evidence" approach (U.S. EPA, 1997b) was used to determine the extent of potential risks when HQ values exceeded 1.0, although analytes were automatically selected as COPCs if their maximum concentration HQ exceeded 1.0 after screening against Region IV ESVs. Conclusions

TABLE 7-17

COMPARISON OF ECOLOGICAL COPCs IN SEDIMENT TO VARIOUS GUIDELINES SITE 3 – CAUSEWAY LANDFILL MCRD PARRIS ISLAND, SOUTH CAROLINA PAGE 1 OF 2

COPC	Maximum	Mean	Region 4 ESV	ER-M	PEL	Other
VOLATILE ORGANIC COMPOUNDS (µg/kg)						
2-Butanone	61	13.7	NA	NA	NA	NA
Acetone	170	75.1	NA	NA	NA	NA
Carbon Disulfide	40	11.7	NA	NA	NA	NA
Chloroform	1	9.2	NA	NA	NA	NA
SEMIVOLATILE ORGANIC COMPOUNDS (µg/kg)						
Anthracene	770	55.0	46.9	1100	245	85.3[a]
Benzo(a)anthracene	1200	104.7	74.8	1600	693	261[a]
Benzo(a)pyrene	1200	106.1	88.8	1600	763	430[a]
Benzo(b)fluoranthene	990	73.0	NA	NA	NA	3,200[a]
Carbazole	570	409.2	NA	NA	NA	NA
Chrysene	1900	148.3	108	2800	846	384[a]
Dibenzofuran	190	391.1	NA	NA	NA	540[a]
Fluoranthene	3500	224.8	113	5100	1494	8,680[b]
Indeno(1,2,3-cd)pyrene	660	77.8	NA	NA	NA	600[a]
Phenanthrene	2400	152.9	86.7	1500	544	2,520[b]
Pyrene	2700	224.6	153	2600	1398	665[a]
PESTICIDES/PCBs (µg/kg)						
4,4'-DDD	290	41.4	1.22	NA	7.81	16[a]
4,4'-DDE	45	29.2	2.07	27	374	2.2[a]
4,4'-DDT	34	29.1	1.19	NA	4.77	12[f]
DDTR[g]	335	99.7	1.58	46.1	51.7	11[f]
Aroclor-1254	250	28.4	21.6[d]	180	189	22.7[a]
Aroclor-1260	70	14.6	21.6[d]	180	189	22.7[a]
Alpha-Chlordane	28	145.8	0.5[e]	NA	NA	NA
Gamma-Chlordane	28	145.8	0.5[e]	NA	NA	NA
METALS AND INORGANIC COMPOUNDS (mg/kg)						
Aluminum	29700	13060.5	NA	NA	NA	NA
Arsenic	19.8	6.4	7.24	70	41.6	8.2[a]
Barium	53.8	17.2	NA	NA	NA	NA
Beryllium	1.4	0.5	NA	NA	NA	NA
Cobalt	5.6	2.0	NA	NA	NA	NA
Copper	46.9	15.3	18.7	270	108	34[a]

TABLE 7-17

**COMPARISON OF ECOLOGICAL COPCs IN SEDIMENT
TO VARIOUS GUIDELINES
SITE 3 – CAUSEWAY LANDFILL
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2**

COPC	Maximum	Mean	Region 4 ESV	ER-M	PEL	Other
Cyanide	0.71	0.5	NA	NA	NA	NA
Iron	28000	12744.8	NA	NA	NA	NA
Lead	105	29.9	30.2	218	112	46.7[a]
Manganese	205	69.7	NA	NA	NA	NA
Mercury	0.35	0.06	0.13	0.71	0.7	0.15[a]
Selenium	1.1	0.3	NA	NA	NA	NA
Thallium	0.62	0.2	NA	NA	NA	NA
Vanadium	63.7	29.1	NA	NA	NA	NA
Zinc	159	43.3	124	410	271	150[a]

NA Not Available
ER-M Effects Range Medium (Long et al., 1995)
PEL Probable Effects Level (FDEP, 1994)
a EPA Region 3 BTAG Ecological Screening Value (EPA, 1995c)
b Sediment Quality Advisory Level based on site specific organic carbon content (EPA, 1997c)
c ER-M value for total DDT
d ESV for total PCBs
e ESV for total chlordane
f Apparent Effects Threshold (Buchman, 1999)
g DDTR is the sum of the concentrations of DDD, DDE, and DDT isomers.

TABLE 7-18

COMPARISON OF SURFACE SOIL CHEMICALS OF POTENTIAL CONCERN (COPCs)
TO OTHER GUIDELINES – SITE 3
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

COPC	Maximum	Mean	ORNL Earthworms/ microorganisms	ORNL Soil Phytotoxicity	BTAG Region III Fauna	BTAG Region III Flora	Beyer (1990) "A" Value	Beyer (1990) "B" Value	Dutch (1994) Target	Dutch (1994) Intervention
VOLATILE ORGANIC COMPOUNDS (µg/kg)										
2-Butanone	360	25.5	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	240	169.2	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	2	2.8	NA	NA	300	300	NA	NA	NA	NA
SEMIVOLATILE ORGANIC COMPOUNDS (µg/kg)										
2-Methylnapthanlene	300	187	NA	NA	NA	NA	NA	NA	NA	NA
4-Methylphenol	120	175	NA	NA	100	100	NA	NA	NA	5000
Acenaphthylene	1800	350.4	NA	NA	100	100	NA	NA	NA	NA
Anthracene	340	33.2	NA	NA	100	100	100	10000	NA	NA
Benzo(a)anthracene	3000	224.9	NA	NA	100	100	NA	NA	NA	NA
Benzo(a)pyrene	4000	289.5	NA	NA	100	NA	100	1000	NA	NA
Benzo(b)fluoranthene	3400	247	NA	NA	100	100	NA	NA	NA	NA
Benzo(g,h,i)perylene	3500	198.2	NA	NA	100	100	NA	NA	NA	NA
Benzo(k)fluoranthene	1300	96.7	NA	NA	100	100	NA	NA	NA	NA
Bis(2-ethylhexyl)phthalate	2300	319.7	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole	670	194.5	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	2900	230.4	NA	NA	100	100	NA	NA	NA	NA
Dibenzofuran	340	189.7	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	5100	413.7	NA	NA	100	100	100	10000	NA	NA
Indeno(1,2,3-cd)pyrene	3600	193.4	NA	NA	100	100	NA	NA	NA	NA
Phenanthrene	1200	119.0	NA	NA	100	100	100	5000	NA	NA
Pyrene	4500	359.9	NA	NA	100	100	100	10000	NA	NA

TABLE 7-18

COMPARISON OF SURFACE SOIL CHEMICALS OF POTENTIAL CONCERN (COPCs)
TO OTHER GUIDELINES – SITE 3
MCRD PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

COPC	Maximum	Mean	ORNL Earthworms/ microorganisms	ORNL Soil Phytotoxicity	BTAG Region III Fauna	BTAG Region III Flora	Beyer (1990) "A" Value	Beyer (1990) "B" Value	Dutch (1994) Target	Dutch (1994) Intervention
PESTICIDES/PCBs (µg/kg)										
4,4'-DDE	4.1	11.6	NA	NA	100	100	NA	NA	2.5	4000
4,4'-DDT	4.5	11.7	NA	NA	100	100	NA	NA	2.5	4000
Aroclor-1254	56	7.7	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1260	100	13.6	NA	NA	NA	NA	NA	NA	NA	NA
Alpha-Chlordane	96	95.9	NA	NA	100	100	NA	NA	NA	NA
Gamma-Chlordane	53	93.3	NA	NA	100	100	NA	NA	NA	NA
METALS AND INORGANIC COMPOUNDS (mg/kg)										
Aluminum	10800	5745.3	600	50	NA	1	NA	NA	NA	NA
Arsenic	11.8	1.7	60	10	NA	328	20	30	29	55
Iron	7370	4788.1	200	NA	12	3,260	NA	NA	NA	NA
Lead	264	31.0	500	50	0.01	2	50	150	85	530
Mercury	0.43	0.06	0.1	0.3	0.058	0.058	0.5	2.0	0.3	10
Vanadium	21.4	10.5	20	2.0	58	0.5	NA	NA	NA	NA
Zinc	205	27.3	100	50	NA	10	200	500	140	720

NA – Not Available

regarding the potential risks associated with Site 3 and recommendations for additional ecological study or remedial considerations are presented in Section 8.0.

7.8 STEP 3A DISCUSSION

7.8.1 Surface Water

Acetone was the only VOC detected in surface water. No Region IV ESVs or alternate screening values were available for acetone. The concentration of acetone (3 µg/L) does not appear to be high, although a definitive conclusion regarding its ecological significance cannot be made without adequate toxicity data. However, acetone is a common laboratory contaminant, and in general, VOCs do not bioaccumulate or biomagnify.

Ten SVOCs were COPCs in surface water, nine of them because Region IV screening values were not available (Table 7-4). The maximum concentration of fluoranthene only slightly exceeded its ESV, with an HQ of 1.2. Only one of these 10 surface water COPCs [bis(2-ethylhexyl)phthalate] was a COPC in groundwater, and none of the 10 COPCs were detected in shallow or deep groundwater samples collected from monitoring well PAI-03-MW-03(S), which is located adjacent to the location where most of the highest surface water concentrations of SVOCs were detected (PA1-03-SW-14). If groundwater was the contaminant source, this would not be expected. The maximum concentration of bis(2-ethylhexyl) phthalate was 7 µg/L, which is much less than the U.S. EPA Region III BTAG ESV of 360 µg/L (U.S. EPA, 1995c). None of the SVOCs had HQ values greater than 1.0 in the food chain modeling.

Sixteen metals were retained as surface water COPCs; eight had no Region IV ESVs. Sample PA1-03-SW-27 tended to have the highest concentrations of metals. HQ values exceeded 1.0 for arsenic, copper, chromium, lead, mercury, nickel, silver, and zinc. However, chromium, lead, mercury, and nickel were not detected in filtered water samples (Table 4-4), and the maximum concentrations of arsenic, copper, and zinc in filtered samples were less than Region IV ESVs. As discussed by U.S. EPA (1996a), concentrations of dissolved metals, rather than total metals, more closely approximate the bioavailable fraction of metals in the water column. Silver was detected in 1 of 20 filtered samples; the concentration in this sample (SW-013F) was 0.71 µg/L, which exceeded the Region IV ESV of 0.23 µg/L. Silver was not detected in groundwater. Of the eight COPCs with no Region IV ESVs, beryllium and cobalt were not detected in filtered samples, and aluminum, antimony, iron, and vanadium were infrequently detected (1 to 4 of 20 samples). Manganese was detected in 15 of 20 filtered samples, and barium was detected in all 20 filtered samples. Manganese concentrations in most samples exceeded background values, and most barium concentrations were near the upper end of the range of background values. Results of the food chain modeling using maximum concentrations of filtered surface water samples indicated that only aluminum, arsenic, iron, and vanadium had HQ values greater than 1.0.

Surface water is often a poor indicator of potential contaminant release and environmental conditions in dynamic systems such as the marsh adjacent to Site 3 due to the "snapshot" effect. Surface water conditions at the site are heavily influenced by several factors. The concentrations of analytes in surface water near Site 3 will change in relation to the amount of tidal influence and the related amount of water near the site at any given time. For example, tides may bring in analytes from other areas. Tides and tidal movement can also influence the physical chemistry of the surface water, thereby potentially altering the bioavailability of surface water contaminants. To illustrate, incoming tides can increase the amount of suspended particulates, which can bind to analytes in solution and reduce their bioavailability. The amount of groundwater discharge can also influence the concentrations of analytes in surface water. If the surface water samples were collected at seeps, representative concentrations may be overestimated if groundwater is contaminated or vice versa at seeps with little contamination.

7.8.2 Groundwater

Chlorobenzene was the only VOC with a maximum value greater than the Region IV ESV, but the HQ was relatively low (1.2). Xylene and carbon disulfide were retained as groundwater COPCs since Region IV ESVs were not available. However, the single detected xylene value of 0.3 µg/L is much less than the U.S. EPA Region III BTAG ESV of 6,000 µg/L, and the single detected carbon disulfide value of 0.3 µg/L is less than the U.S. EPA Region III BTAG ESV of 2.0 µg/L (U.S. EPA, 1995c). Chlorobenzene and xylene were not detected in any other medium, and carbon disulfide was detected in 6 of 21 sediment samples.

Three SVOCs [2-methylnaphthalene, 4-methylphenol, and bis(2-ethylhexyl) phthalate] were retained as groundwater COPCs since Region IV ESVs were not available. The single detected 2-methylnaphthalene value of 1.0 µg/L is much less than the U.S. EPA Region III BTAG ESV of 300 µg/L, and the maximum concentration of bis(2-ethylhexyl) phthalate (1.0 µg/L) is much less than the U.S. EPA Region III BTAG ESV of 360 µg/L (U.S. EPA, 1995c). An alternative ESV for 4-methylphenol was not available, but this SVOC was not detected in surface water or sediment and was detected in only 1 of 15 surface soil samples.

No inorganics in groundwater exceeded Region IV ESVs, but barium, iron, and manganese were retained as groundwater COPCs since Region IV ESVs were not available.

As stated in Section 7.4.1, groundwater contaminant concentrations are compared to surface water ESVs as a conservative measure to determine if potential risks to aquatic biota may be possible via discharge of contaminated groundwater. Since dilution will occur upon discharge, groundwater concentrations

must, for the most part, significantly exceed surface water concentrations to be of concern. None of the organic or inorganic contaminants in Site 3 groundwater, with the exception of chlorobenzene, exceeded Region IV-ESVs, and chlorobenzene's exceedance was slight (HQ=1.2).

7.8.3 Sediment

No Region IV ESVs were available for the VOCs 2-butanone, acetone, carbon disulfide, and chloroform. In addition, no alternate guidelines were available for these VOCs. Qualitatively, the maximum concentrations of these organics do not appear to be high (170 µg/kg or less), although definitive conclusions regarding their ecological significance cannot be made without adequate toxicity data. Their frequencies of detection ranged from 2 of 21 to 6 of 17 samples. Acetone is a common laboratory contaminant, and carbon disulfide occurs naturally in sediments. In general, VOCs do not bioaccumulate or biomagnify.

Eleven SVOCs (primarily PAH compounds) were retained as COPCs. The maximum concentrations of all SVOC COPCs were in sample PAI-03-SD-022, located at the northwestern end of the causeway. A comparison of SVOC concentrations to alternate guidelines shows that most detected values were less than their respective ER-M values (Table 7-17). Furthermore, no SVOCs had HQ values greater than 1.0 in the food chain modeling, indicating that SVOCs pose no risks to terrestrial or aquatic receptors. In addition, concentrations of PAH compounds detected in fish, crabs, clams, and oysters in 1991 were considerably less than 300 µg/kg, the value identified by Eisler (1987b) as a fish-protection criterion. (Table 7-8).

Five pesticides (DDD, DDE, DDT, alpha-chlordane, and gamma-chlordane) and two PCB compounds (Aroclor 1254 and Aroclor 1260) were detected in sediment; all had HQs greater than 1.0. All seven analytes were infrequently detected; however, the detection limits in most samples exceeded the Region IV ESVs. The uncertainty inherent in this is somewhat mitigated by using a value of one-half the detection limit for these samples in the food chain modeling using average concentrations. For example, the detection limits in some samples where DDTR was not detected were as high as 140 µg/kg (compared to ESVs of approximately 1 to 2 µg/kg); the assumed concentration in such samples was 70 µg/kg. Since the DDTR detection limits were less than 61 µg/kg in 16 of 21 sediment samples (see Appendix C-2), it seems likely that the actual concentrations in the remaining five "non-detect" samples were less than 70 µg/kg. If so, using a value of 70 µg/kg contributes to a conservative assessment when the actual value may have been considerably less. However, the actual concentrations in the remaining five "non-detect" samples could have been considerably more than one-half the detection limit. Alpha-chlordane and gamma-chlordane had no HQ values greater than 1.0 in the food chain modeling, indicating that these two COPCs pose no risks to terrestrial or aquatic representative receptors. The

NOAEL HQ for Aroclor 1254 in the maximum sediment scenario slightly exceeded 1.0 for the heron and raccoon and was less than 1.0 for the other receptors (Table 7-11). Some HQ values for DDTR exceeded 1.0 in the food chain modeling.

Fifteen inorganics were COPCs in sediment; 10 had no Region IV ESVs. Of these COPCs, barium, beryllium, cobalt, copper, cyanide, manganese, and selenium were not COPCs in surface soil, indicating that erosion of Site 3 surface soils might not be contributing them to the marsh. As indicated in Figure 4-4, concentrations of inorganics exceeded background values in only a few sediment samples, except that lead tended to exceed its ESV and background value in most samples. Lead was detected in all sediment samples, but lead concentrations in most samples were in the 10 to 30 mg/kg range, and the mean concentration was 29.9 mg/kg. The highest lead concentration was 105 mg/kg in sample SD-017. Mercury was detected in 6 of 21 samples (all detection limits were less than the ESV) and exceeded its ESV in three samples, all of which were near the southeastern end of the causeway. The maximum sediment concentrations of arsenic, copper, lead, mercury, and zinc were much less than their respective ER-M values (Table 7-17).

No Region IV or alternate sediment ESVs were available for aluminum, barium, beryllium, cobalt, iron, manganese, selenium, and vanadium. Aluminum and iron are two of the most common elements in the earth's crust. Iron and manganese are essential nutrients and common elements. Selenium is an essential nutrient but is harmful at higher concentrations (Eisler, 1985). It was detected in 7 of 21 samples. Vanadium is generally not considered to be toxic in the environment (Mailman, 1980).

7.8.4 Soil

Three VOCs were COPCs in surface soil: acetone, 2-butanone, and chloroform. All were infrequently detected, and the maximum concentration of chloroform (2 µg/kg) was much less than the alternate ESV of 300 µg/kg (U.S. EPA, 1995c). Acetone was detected in 2 of 6 samples, and its maximum concentration (240 µg/kg) was less than the value in background samples of 267 µg/kg. Acetone's presence in background samples lends credence to the assumption that acetone was a laboratory contaminant. As stated previously, VOCs do not generally bioaccumulate or biomagnify.

Several SVOCs (primarily PAH compounds) were COPCs in surface soil. Most of the highest concentrations of SVOCs were in sample PAI-03-SS-001, located at the southeastern end of the causeway. Concentrations of SVOCs also tended to exceed Region IV ESVs in samples PAI-03-SS-014 and PAI-03-SS-008. PAHs have a strong affinity for soil organic carbon and are therefore unlikely to migrate as solutes or be appreciably bioavailable. Although the site-specific bioavailabilty of PAHs and other analytes in Site 3 surface soils is unknown, contaminants at most waste sites are typically in poorly available forms (Efroymson et al., 1997a). As mentioned earlier, no SVOCs had HQ values greater than

1.0 in the food chain modeling, indicating that SVOCs pose no significant risks to representative receptors.

Four pesticide and two PCB compounds were detected in surface soil; all were retained as COPCs. HQ values in the terrestrial food chain modeling slightly exceeded 1.0 for Aroclor 1254 (shrew) and Aroclor 1260 (shrew and robin) in the maximum contaminant scenario. In the mean terrestrial contaminant scenario, DDE had an HQ greater than 1.0. The apparent discrepancy here (i.e., a higher HQ using mean rather than maximum concentrations) was due to the detection limits in the DDE analyses. DDE was detected in only 1 of 16 samples; using a value of one-half the detection limit in "non-detects" to calculate a mean resulted in a mean that exceeded the maximum detected value. It should also be noted that the detection limits for DDE and DDT exceeded the ESV in some samples. However, the detection limits in all but two of the "non-detects" were less than 20 µg/kg, which is less than concentrations typically found in soils at MCRD Parris Island (Appendix F). Thus, with the possible exception of two samples in which the detection limit was 190 µg/kg, the DDTR concentrations in soil samples from Site 3 fall within the range of DDTR values that appear to represent widespread historical use of the pesticide DDT.

Seven metals were retained as COPCs: aluminum, arsenic, iron, lead, mercury, vanadium, and zinc. HQs ranged from 1.5 (arsenic) to 443 (aluminum). Maximum concentrations of arsenic and mercury, however, were less than Dutch (Beyer, 1990) "A" ESVs. The maximum concentration of zinc (205 mg/kg) only slightly exceeded the Dutch (Beyer, 1990) "A" ESV of 200 mg/kg. All seven COPCs had at least one HQ value greater than 1.0 in the terrestrial food chain modeling using maximum contaminant concentrations (Table 7-9). Aluminum and iron are two of the most common elements in the earth's crust. Iron and zinc are essential nutrients, although they can be toxic at high concentrations. Soil ecotoxicity data for aluminum, iron, and vanadium are scarce, limiting interpretation of toxic concentrations.

7.8.5 Food Chain Modeling Considerations

Several conservative assumptions were used in the food chain modeling. For example, the receptors were assumed to spend 100 percent of their life on the site. While this may be plausible for smaller receptors (e.g., short-tailed shrew and cotton mouse), Site 3 comprises a very small portion of the home range of other receptors. Ingestion rates were obtained from captive studies, which may overestimate the amount of food ingested relative to wild animals that may have limited food resources. These conservative assumptions tend to overestimate risks.

Typical home ranges for the robin and red-tailed hawk (terrestrial receptors) and the great blue heron, raccoon, and bald eagle (semi-aquatic receptors) are much larger than Site 3. U.S. EPA (1993) presents typical home ranges of 940 to 2,440 acres for the red-tailed hawk and 96 to 161 acres for the raccoon,

and the robin, great blue heron, and eagle roam over areas of several square miles in extent. If these area-use factors (overlap of site size with home range and time per year potentially on site) were used in the modeling, HQ values would drop significantly.

Food chain modeling using the tissue data collected in 1991 for the ESI (ABB, 1993) did not include the incidental ingestion of sediment or surface water. Surface water and sediment samples were not collected for the ESI, and combining tissue data collected in 1991 with sediment and surface water data collected in 1998 is not desirable. Therefore, the HQ values shown in Tables 7-15 and 7-16 should be assessed with this in mind. However, the extent to which incidental ingestion of surface water contributes to the total dose is usually minor.

Furthermore, whole-body analyses of fish collected for the ESI were not conducted. Instead, fish (mullet and flounder) samples consisted of filleted muscle and liver samples. Potential risks to the eagle were assessed separately using each data set. The relationship of liver and muscle to whole-body concentrations is uncertain for most contaminants, but some contaminants (e.g., chlorinated insecticides) are known to concentrate more in tissues other than muscle. For example, Forbis (1986) reported that the BCF of lindane in whole body samples of bluegill sunfish was approximately 1.8 times higher than in muscle fillets. Mercury concentrations, on the other hand, are usually higher in fish muscle than in whole-body samples. Lange et al. (1998) found a strong correlation (r^2 = 0.9915) between whole-body and muscle tissue mercury concentrations in 177 samples of largemouth bass. Specifically, whole-body mercury concentrations averaged 69.5 percent of the fillet concentration across all sizes of largemouth bass. Therefore, assuming the relationship is similar for red drum and mullet, the use of HQs generated for mercury using fillet concentrations probably slightly over-estimates risk, and the use of HQs generated for DDTR using fillet concentrations probably slightly under-estimates risk. The use of livers as a substitute for whole-body tissues probably approximates the HQ that would result from the use of whole-body data.

Crabs were processed whole, and clams and oysters were shucked with subsequent analyses of soft tissue (ABB, 1993). This procedure approximates the consumption patterns of most ecological receptors. In other words, raccoons or wading birds often consume whole crabs (especially juvenile crabs or small species). On the other hand, raccoons and other consumers of clams and oysters ordinarily consume only the soft tissues and discard the outer shell.

7.9 SCREENING LEVEL AND STEP 3A UNCERTAINTY ANALYSIS

Uncertainty is associated with all aspects of the ERA process. This section provides a summary of the general uncertainties involved in this ERA, with a discussion of how they may affect the final risk values and conclusions.

The results of an ERA must be reviewed and evaluated to identify the types and magnitudes of uncertainties involved. Relying on results from a risk assessment without consideration of uncertainties, limitations, and assumptions inherent in the process can be misleading. If numerous conservative assumptions are combined in the ERA process, the resulting calculations will propagate the uncertainties associated with each of those assumptions. The resulting bias is toward overpredicting risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered.

Generally, risk assessments carry two types of uncertainty: measurement and informational. Measurement uncertainty refers to the variability inherent in measured data. The risk assessment reflects the accumulated variances of the individual values used for several different parameters. Informational uncertainty stems from the limited availability of necessary information. Often the gap between what is needed and what is available is significant. As examples, information is often absent regarding the effects of some contaminants on wildlife receptors, the biological mechanisms of contaminants, and the impacts of physiological differences on exposure pathways.

- Uncertainty is associated with each of the steps of the risk assessment process:

- Uncertainty in preliminary problem formulation can result from limited information regarding contaminant sources, release mechanisms, and exposure routes.

- Uncertainty in the ecological effects characterization arises from the quality of the existing screening values and toxicity data to support a determination of potential adverse impacts to ecological receptors.

- Uncertainty associated with the exposure assessment includes the methods used and the assumptions made to determine exposure point concentrations or calculate contaminant doses

7.9.1 Uncertainty in the Preliminary Problem Formulation

The marsh at Site 3 could receive contaminant inputs from more than one source, although, initially, contaminants are conservatively assumed to stem directly from activities related to the site. Since contaminant concentrations may reflect inputs from many sources, including non-MCRD sources, uncertainties exist regarding whether risk characterized at the site stems from site-related contaminants.

7.9.2 Uncertainty in the Ecological Effects Characterization

Uncertainty in this risk assessment also arises from the nature and quality of the available toxicity data used to derive guidelines. This uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose related; and when mechanisms of toxicity are similar for laboratory and wildlife species. Most guidelines are based on conservative assumptions. Although an inherent level of conservatism is needed in a screening-level ecological risk assessment to ensure that the most sensitive receptors are protected, conservative guidelines may heavily overestimate potential risks and the resulting HQ values may be misleading. Region IV screening levels and the NOAELs and LOAELs used in this assessment are based on laboratory studies that do not take into account mitigating or ameliorating physical and chemical conditions in the environment. That is, the most bioavailable (i.e., toxic) form of the contaminant is usually applied to the exposure medium. In reality, bioavailability is rarely, if ever, 100 percent. Conversely, laboratory studies frequently ignore potentially exacerbating conditions such as the possibility of synergistic effects of complex mixtures of chemicals and altered sediment chemistry due to periodic hypoxia and resultant pH depression. Ecological guidelines may underestimate potential risks when these factors are inadequately determined.

Conservative guidelines for surface water are set to protect the majority of aquatic organisms from adverse effects on growth, survival, and reproduction. The laboratory testing that is used for the development of guidelines generally uses the most toxic form of the element (ionic species derived from a metal salt such as $AgNO_3$ or CuCl). These guidelines overestimate toxicity by not taking into account the speciation of the metal in a natural water system. U.S. EPA has begun to recognize that other factors such as hardness and organic carbon (OC) concentrations have an effect on the toxicity of a metal. U.S. EPA has incorporated hardness coefficients into the freshwater guidelines for many metals, but coefficients for OC have yet to be proposed.

As mentioned earlier, few data are available for investigating dietary exposures and related risks to reptiles and amphibians. The absence of toxicity data for these organisms precludes modeling of potential risks to them. As a result, direct conclusions about the potential risks to reptiles and amphibians cannot be made, and only qualitative inferences can be drawn. Considering the lack of elevated concentrations of inorganics in filtered surface water samples, the potential risks to amphibians and aquatic reptiles appear to be insignificant.

ERAs, unlike human health risk assessments, must consider risks to many different species. Calculation of risks for every potential receptor species is not possible. For this ERA, conservative guidelines protective of a wide range of ecological receptors were sought. The underlying assumption associated with the use of these guidelines is that contaminant concentrations in excess of these values are

indicative of potential impacts to actual receptors inhabiting the area. However, species-specific physiological differences that may influence an organism's response to a contaminant or subtle behavioral differences that may increase/decrease a receptor's contact with a contaminant are seldom known. Also, some contaminants were present for which no suitable guidelines were available, and as a result, they could not be quantitatively assessed. The use of guidelines, while necessary, will introduce error into the results of an assessment.

7.9.3 Uncertainty in the Exposure Assessment

Uncertainty in the exposure assessment arises mainly in the methods used to obtain exposure-point concentrations. The maximum detected contaminant concentrations were generally used to represent the highest contaminant concentrations to which ecological receptors might be exposed. If the samples evaluated in this ERA are representative of contaminant concentrations associated with the sites, then this approach is conservative and should overestimate potential risks to ecological receptors. The maximum concentration of a contaminant in a given medium may have been collected in a "hot spot" of contamination and may be much higher than the remaining values in the data set. Although use of maximum values is appropriate for screening in an ERA, maximum values may grossly over predict potential risks. To somewhat mitigate these uncertainties, average concentrations were also used, but they do not fully account for the uncertainties involved in selecting exposure point contaminant concentrations.

Contaminant concentrations in a given medium may under-predict potential risks if sample locations are not properly selected. For example, sediment samples should be collected from areas where sediment deposition is expected to be maximal. Otherwise, sediment data may not be adequate for conservatively estimating ecological risks. For this ERA, sediment samples were collected along the both sides of the causeway, and from tidal flats south of the causeway. Sediment grain size and percent total organic carbon (TOC) data are available for some of these samples (Table 4-7). The high sand content (>85 percent) in some of the samples could lead to an assumption that the samples were not collected from depositional areas of fine grained silts and clays. However, the majority of the causeway materials are a fine grained sand like that observed in these sediments. Also, because of the shallow depth of the pond and active flow patterns in the channels, sandy rather than silty sediments could be present to a greater extent than is normally associated with depositional areas. Furthermore, the spacing of sample locations indicates that the sample locations selected are probably representative of the sediments at the site. Nevertheless, some degree of uncertainty remains.

Dermal and inhalation exposures were not evaluated in this ERA. As discussed in Section 7.2.3, these exposure routes are usually miniscule, but since they cannot be quantitatively assessed, only limited, qualitative conclusions regarding their significance can be drawn and uncertainties remain. Dermal

exposure is usually limited by the outer coverings of most receptors. Nonetheless, certain portions of some receptors, such as food pads, eyes, and nose do not contain fur or feathers, for example, and may have a higher chance of exposure. However, these areas generally constitute a small portion of the total surface area of most receptors. Although some of the concentrations of contaminants in surface soils and sediments are elevated, they do not appear to be high enough qualitatively to warrant concern over dermal exposure. Surface water can reach the dermis regardless of outer coverings such as fur and feathers, but interpretability of the surface water data is low.

Inhalation of contaminants is assumed to be miniscule. Airborne aerosols, particulates, and vapors are not assumed to be applicable for aquatic media. As mentioned earlier, bare soil is minimal at the site. As a result, airborne particles would be expected to be minimal. Concentrations of VOCs in surface soils at Site 3 were low. The PAHs, phthalates, and pesticides at the site have low Henry's Law constants and hence do not volatilize easily. They also have high affinities for organic carbon, which would preclude significant volatilization. Burrowing wildlife (e.g., moles) would be expected to have a higher probability of inhalation exposure, but data regarding inhalation exposure and toxicity for wildlife were not available. The factors discussed above would be expected to reduce the chances of exposure for burrowers.

Uncertainty is also associated with the use of literature-based BAFs, BCFs, and BSAFs used in the screening-level food chain modeling. These values often vary considerably between species and sites. This can lead to both over-and underestimation of potential risks.

7.9.4 Uncertainty in the Risk Characterization

Uncertainty in the risk characterization is affected by all aspects of the ERA process described in the above sections. Uncertainty in risk characterization also stems, in part, from combining different components of the ERA in this step. Each of those components already contains uncertainty. Thus, uncertainties may be propagated when these components are combined. To try to reduce the overall uncertainty in the risk assessment, the weight of evidence approach is used to make risk decisions. This approach takes the results of all aspects of the assessment into account, including the uncertainties, to make determinations of potential risk/no risk.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions developed during the Site/SWMU 3 RI/RFI are summarized as follows.

1.0 Surface soils were found to contain several polynuclear aromatic hydrocarbons (PAHs), PCBs, pesticides, lead, arsenic, aluminum, iron, mercury, vanadium, and zinc at concentrations greater than present in background soils and in exceedance of the most stringent human health RBCs (residential) or ecological screening values. Because of the presence of asphalt at the site and the common application of pesticides at the base, PAHs and pesticides may or may not result from waste disposal activities.

2.0 Benzene, chlorobenzene, 1,4-dichlorobenzene, arsenic, iron, thallium, and alpha-BHC were detected in the site groundwater at concentrations that exceed the most stringent human health criteria (drinking water standards). The presence of a salt water marsh surrounding the site and the measured salinity of the groundwater restricts the use of site groundwater as a potable water supply. Chlorobenzene was the only groundwater analyte that exceeded ecological screening values for surface water. This VOC was not detected in surface water or sediment samples indicating that migration from the fill area was not significant.

3.0 Fluoranthene, mercury, and silver were detected in surface water at concentrations in excess of background and the most stringent human health RBCs or ecological screening values. Each chemical exceeded the criteria in 1 of 20 samples.

4.0 Sediments were found to contain several PAHs, PCBs, pesticides, lead, arsenic, aluminum, copper, iron, mercury, and zinc at concentrations greater than present in background sediments and in exceedance of the most stringent human health RBCs (residential) or ecological screening values. Because of the presence of asphalt at the site and the common application of pesticides at the base, the PAHs and pesticides may or may not be from site related waste disposal activities.

5.0 The human health risk assessment considered site media exposure to construction workers and maintenance workers. The estimated incremental cancer risk to construction workers and maintenance workers exceeded $1x10^{-6}$, but was less than $1x10^{-4}$. These risks are within the acceptable U.S. EPA target risk range. The noncarcinogenic risk estimates for both the construction worker and the maintenance worker was less than 1.0, indicating that toxic effects are not anticipated.

6.0 The human health risk assessment also considered environmental exposure from recreational fishing at the site. These risk calculations were based on current (1998) surface water and sediment data, as well as biota data collected in 1991.

- Based on 1991 biota results and U.S. Food and Drug Administration critieria, consumption of fin fish and shellfish at the site do not represent a threat to human health.

- The 1991 biota results were also used to calculate risks to human health under a frequent consumer (daily – default) and occasional consumer (once per week) of fish from the site. Using this data and these scenarios for non carcinogenic risks, a potentially significant risk to human health was possible for the hypothetical frequent fish consumer, but not for the occasional consumer. Incremental cancer risk estimates under both scenarios were within the acceptable U.S. EPA risk range of $1x10^{-4}$ to $1x10^{-6}$.

- The 1998 surface water and sediment data were also used to estimate risk to human health through theoretical partitioning of contaminants to fish and human consumption of the fish. Under the most stringent scenario (frequent fish consumer and maximum concentrations), incremental cancers risks exceeded $1x10^{-4}$ and non carcinogenic risks were greater than 1.0. These risk estimates are higher than acceptable U.S. EPA risk criteria. PAHs, pesticides, PCBs, and arsenic were the main contributors to risk. However, under more typical site conditions, (average concentrations and occasional fish consumption), incremental cancer risk estimates were within the acceptable U.S. EPA risk range of $1x10^{-4}$ to $1x10^{-6}$ and the non carcinogenic risk estimate was less than 1.0.

7.0 The initial ecological risk screening determined that the maximum concentrations of several metals, pesticides, PCBs, and PAHs at the site exceed U.S. EPA Region IV screening values, indicating a potential ecological risk. In addition, several other chemicals were identified as COPCs because of the lack of screening criteria.

8.0 The food chain modeling evaluated nine representative receptors and found that the majority of the initial COPCs do not represent a threat to site receptors even under a worst case scenario (organisms constantly exposed to maximum concentrations). Chemicals that pose potential risks under this scenario consist of PCBs, pesticides, and several metals.

9.0 The food chain modeling found that under more realistic conditions which consider mean chemical concentrations, the list of chemicals in which hazard quotients (HQ) for NOAELs exceed 1.0 were reduced to the following:

- DDT(maximum HQ is 8)
- DDE (maximum HQ is 36)
- DDD (maximum HQ is 2)
- aluminum (maximum HQ is 1,450)
- arsenic (maximum HQ is 11)
- iron (maximum HQ is 54)
- lead (maximum HQ is 5)
- mercury (maximum HQ is 6)
- thallium (maximum HQ is 6)
- vanadium (maximum HQ is 30)
- zinc (maximum HQ is 3).

In evaluating this data the following factors should be considered.

- Except for lead, mercury and zinc, the maximum detected metal concentrations were within a factor of two of background concentrations and the mean concentrations were normally within the range of surface soil or sediment background results.

- The maximum hazard quotients for lead, mercury, and zinc were associated with the robin and to a lesser extent the heron and eagle.

- For the heron and eagle, when home ranges (of thousands of acres) and the size of potential forage areas at Site 3 (40 acres) are considered, hazard quotients presented above would be reduced by a factor of at least 60 (see Appendix F). Based on this consideration, COPCs would not present a significant potential risk for these two receptors. Similar home range considerations for the other receptors would also result in lower hazard quotients.

- Because of base wide application, pesticides may or may not be site related. The concentrations detected at Site 3 were similar to normal concentrations found at the base. In addition, based on foodchain modeling using actual tissue concentrations measured in FinFish and shellfish collected in 1991, the potential risk to representative aquatic receptors were less than predicted by foodchain modeling based on surface water and sediment data.

10.0 The surface soil data is adequate to proceed to a feasibility study/corrective measures study to evaluate capping/covering options for this landfill. Protection of ecological receptors (direct contact and erosion into the sediment) is the primary concern.

11.0 Based on site groundwater not being considered as a viable drinking water source, the finding of only relatively minor groundwater criteria exceedances, and the absence of a threat to surrounding surface water and sediment through groundwater migration, groundwater does not need to be remediated; however, reducing precipitation infiltration and restrictions on groundwater use would be considered under each of the soil alternatives.

12.0 Because of the transient nature of surface water, water quality concerns would be better addressed through management of sediment and soil.

13.0 The sediment data is adequate to proceed to a feasibility study/corrective measures study. Even though the data does not suggest the presence of significant widespread sediment contamination, potential contamination at some locations should be evaluated.

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