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FINAL

REMEDIAL INVESTIGATION REPORT
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY

TEXT

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0312

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/kg	microgram per kilogram
$\mu g/m^3$	microgram per cubic meter
µg/g	micrograms per gram
µg/L	microgram per Liter
ABS	adsorption factor
AF	soil to skin adherence factor
AMTRAC	amphibious tractor
AOC	area of concern
AQTESOLV	Aquifer Test Solver Program
AQUIRE	Aquatic Information Retrieval Database
ARARs	applicable or relevant and appropriate requirements
ARL	Aquatic Reference Level
AST	aboveground storage tank
ASTM	American Society for Testing Materials
AT	averaging time
ATc	averaging time carcinogen
ATnc	averaging time noncarcinogen
ATEC	ATEC Environmental Consultants, Inc.
AWQC	Ambient Water Quality Criteria
Baker	Baker Environmental, Inc.
BCF	biological concentration factor
bgs	below ground surface
BI	biotoxic index
BOD	biological oxygen demand
BRA	baseline risk assessment
BW	body weight
CADD	computer aided design drafting
CAMA	Coastal Area Management Act
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	conversion factor
CFR	Code of Federal Regulations
CIS-1,2-DCE	Cis-1,2-dichloroethlene
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

COC	contaminants of concern
COD	chemical oxygen demand
COPC	contaminant of potential concern
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limit
CRQL	Contract Required Quantitation Limit
CSF	carcinogenic slope factor
4,4'-DDD	dichloro-diphenyl-dichloroethane
4,4'-DDE	dichloro-diphenyl-dichloroethylene
4,4'-DDT	dichloro-diphenyl-trichloroethane
DEM	Division of Environmental Management
DoN	Department of the Navy
ED	exposure duration
EF	exposure frequency
Eh	oxidation reduction potential
EL	exposure level
EMD	Environmental Management Division
ER-L	Effects Range - Low
ER-M	Effects Range - Median
ERA	ecological risk assessment
ET	exposure time
FFA	Federal Facilities Agreement
F_i	fraction ingested from source
f_{oc}	sediment particle grain size
FS	Feasibility Study
FSAP	Field Sampling and Analysis Plan
gpm	gallons per minute
GSI	Groundwater Technology Government Services, Inc.
H	mean species diversity
HA	health advisory
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

HQW	high quality water
H AND HSSW	Headquarters and Headquarters Squadron Station Weather
IAS	Initial Assessment Study
ICR	incremental cancer risk
ID	inside diameter
IDW	investigative derived wastes
IR	ingestion rate
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
K	Hydraulic Conductivity
K_d	soil sorption coefficient
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LOAEL	lowest-observed-adverse -effect level
LAW	Law Environmental, Inc.
MBI	Macroinvertebrate Biotic Index
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
MF	Modifying Factor
MI	Mobility Index
msl	mean sea level
NC DEHNR	North Carolina Department of Environment, Health and Natural Resources
NCMFC	North Carolina Marine Fisheries Commission
NCSPCS	North Carolina State Plane Coordinate System
NCWQC	North Carolina Water Quality Criteria
NCWQS	North Carolina Water Quality Standards
NCWRC	North Carolina Wildlife Resources Commission
NEHC	Navy Environmental Health Center
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	No-Observed-Adverse-Effect-Level
NOEL	No-Observed-Effect-Level
NPL	National Priorities List

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NPS	National Park Service
NSW	nutrient sensitive waters
NTU	Nephelometric turbidity unit
NUS	NUS Corporation
NWI	National Wetlands Inventory
OU	Operable Unit
ORNL	Oak Ridge National Laboratory
PAH	polynuclear aromatic hydrocarbon
PC	permeability constant
PCBs	polychlorinated biphenyls
PEF	particulate emissions factor
PID	photoionization detector
POL	petroleum, oil, lubricants
ppb	parts per billion
ppm	parts per million
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QI	quotient index
RA	risk assessment
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	Remedial Investigation
ROD	Record of Decision
S	water solubility
SA	exposed skin surface area
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service
SI	Site Inspection
SMCL	Secondary Drinking Water Regulations
SOP	Standard Operating Procedures
SQC	Sediment Quality Criteria
SSV	Sediment Screening Value
SSSV	Surface Soil Screening Value

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

SVOC	semivolatile organic compound
SWSV	surface water screening value
TAL	Target Analyte List
TCL	Target Compound List
TCE	Trichloroethlene
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TEF	toxicity equivalency factor
TICs	tentatively identified compounds
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRACER	Tracer Research Coperation
TRVs	terrestrial reference values
TSS	total suspended solids
UCL	Upper Confidence Limit
UF	uncertainty factor
USCS	Unified Soil Classification System
USDA	Untied States Department of Agriculture
USDI	United States Department of Interior
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USMC	United States Marine Corps
UST	underground storage tank
VOC	volatile organic compound
WAR	Water and Air Research, Inc.
WQSV	water quality screening values
WS	Wilderness Society

EXECUTIVE SUMMARY

This document was prepared by Baker Environmental, Inc. (Baker) to document on the activities and findings of the Remedial Investigation (RI) conducted at Operable Unit No. 9, Site 73 - Amphibious Vehicle Maintenance Facility, MCB Camp Lejeune, North Carolina.

Purpose of the RI

The purpose of the RI is to evaluate the nature and extent of the threat to public health and the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants. The RI investigation consisted of the sampling surficial and subsurface soil, groundwater, sediment, surface water and benthic and aquatic species. The resultant analytical data was evaluated to characterize site conditions and to and perform a human health risk assessment (RA) and an ecological RA. Furthermore, this RI report provides information to perform a Feasibility Study (FS) and prepare a Record of Decision (ROD) for selecting a final remedial action.

Site Location

Site 73 is situated within the boundaries of the Amphibious Vehicle Maintenance Facility located in the Courthouse Bay area of MCB Camp Lejeune . Site 73 is roughly bounded by State Route 172 (Sneads Ferry Road) to the north, Courthouse Bay to the south, and unnamed tributaries of Courthouse Bay to the east and west. Courthouse Road, which bisects the study area, is used to enter the complex. The study area consists of numerous buildings, ASTs, USTs, vehicle wash racks, and oil/water separators. The terrain is primarily flat. Stormwater run-off tends to drain directly south to Courthouse Bay or to two small unnamed tributaries located east and west of the facility, ultimately discharging to Courthouse Bay. A broad marshy area is associated with the western tributary. Directly north of the site is another large marsh and a stream that discharges north into the New River. The latter marsh is separated from the site by State Route 172 which represents a local topographical high and surface water runoff divide.

Site History

The Amphibious Vehicle Maintenance Facility started operations in 1946 and is currently active. Based on an Initial Assessment Study (IAS) conducted in 1983, an estimated 400,000 gallons of waste oil was discharged directly onto the ground surface at this facility, primarily near Building A-47. In addition to the waste oil, approximately 20,000 gallons of waste battery acid was also reportedly disposed in the area northeast of Building A-47. The waste battery acid was poured into shallow hand-shoveled holes which were then backfilled. Neither area is visually apparent with respect to its history of waste disposal. Moreover, most of the area where waste disposal reportedly took place, is covered with concrete, buildings or roads. A previous report (Law-Catlin, 1993) indicated that solvents may have also been disposed at this site although no specific disposal locations or date were identified.

Previous Studies and Findings

Seven previous environmental investigations have been conducted at this site prior to this RI. These studies include an Initial Assessment Study by Water and Air Research, Inc. (WAR, 1983), Confirmation Study by Environmental Science and Engineering, Inc. (ESE, 1990) and five separate UST investigations.

The first UST investigation was conducted in 1991 by ATEC Environmental Consultants (ATEC) and focused on UST SA-21. In 1992 and 1993, Baker Environmental, Inc. (Baker) performed additional investigations on the same UST. UST A47/3 was investigated by Groundwater Technology Government Services, Inc. (GSI) in April 1993 and Law-Catlin in October 1993. Both USTs where reported to be leaking. UST SA-21 was a steel 30,000 gallon capacity tank which contained both gasoline and diesel fuel. This tank was installed in 1959 and subsequently removed in 1991. UST A47/3 was a steel 30,000 gallon capacity tank which contained diesel fuel. Available information indicates that this UST was installed in 1986. A hydrostatic test was performed on A47/3 in late 1992; this tank was subsequently replaced with a fiberglass tank.

Description of the RI

The RI field activities at Site 73 were conducted in two phases. The objective of first phase was to detail the extent of soil and groundwater contamination based on historical information and previous investigations. At the completion of the initial phase, the analytical data was evaluated to determine whether the extent of soil and groundwater contamination had been delineated. With the concurrence of LANTDIV, USEPA, NC DEHNR and MCB Camp Lejeune, it was concluded that an additional phase of field work was necessary to further define the vertical and horizontal extent of soil and groundwater contamination detected at the site.

The first phase was initiated in the field on April 3 and concluded May 25, 1995. Additional work associated with the first phase (primarily IDW management, surveying, and groundwater elevation measurements) was conducted between May 26 and August 21, 1995. The second phase of the field investigation commenced on February 16, and concluded March 27, 1996. IDW management, groundwater elevation measurements and a geophysical survey associated with the second phase of field work was conducted between May 13 and 16, 1996. The field programs consisted of soil and groundwater investigations, surface water and sediment investigations, an ecological investigation, a site survey, and investigative derived waste (IDW) handling.

Soil samples collected were analyzed for one or more of the following: Target Compound List (TCL) organics; Target Analyte List (TAL) metals; or Total Petroleum Hydrocarbons (TPH). Soil samples collected in the vicinity of the UST systems within the site may have had multiple analytical methods for volatile analyses as well as other analytical requirements stipulated by NC DEHNR regulations. In addition to the environmental samples collected at the site, a single soil sample was collected from soil boring 73-MW13 and submitted for analysis of engineering parameters.

Groundwater samples collected during the first phase of field work were analyzed for VOCs via Method 601/602, TCL SVOCs, pesticides and PCBs via CLP protocols. In addition, all monitoring wells were analyzed for TSS and TAL metals (total metals plus five percent of the samples for dissolved metals) via CLP protocols, and an additional sample was collected from monitoring wells 73-MW13 and A47/3-08 and analyzed for BOD, COD, TOC, total Kjeldahl nitrogen (TKN), TDS, total phosphorus, microbial count, and alkalinity. Samples collected in the vicinity of USTs were analyzed for parameters in accordance with requirements mandated by NC DEHNR.

An additional round of groundwater samples were collected during the second phase of field work. Samples collected during this phase were analyzed for TCL volatiles via CLP protocols, only. In addition, a sample was collected from monitoring well 73-GW01 for engineering parameters.

Surface water/sediment samples were analyzed for TCL organics, TAL metals and TOC. Additionally, the 0- to 6-inch samples were analyzed for grain size distribution. Fish and crab samples were analyzed for TCL organics and TAL metals, only.

Summary of Physical and Chemical Results

Soils

- The subsurface soils at the site consist of unconsolidated deposits of sand and silty sand separated by a discontinuous clay layer that thickens and thins across the site. The sands are fine to medium grained and contain varied amounts of silt and clay.

- Underlying the sands described in the previous paragraph is a loose to very dense, greenish-gray, fine sand containing varying amounts of silt and shell fragments, trace clay and cemented sand nodules. This soil unit constitutes the Belgrade Formation typically referred to as the semi-confining unit separating the surficial and Castle Hayne aquifers. It appears that this unit is not acting as a confining or semi-confining unit at Site 73. Based on hydraulic head differentials, it does not appear that this unit is restricting flow from the surficial to the Castle Hayne aquifer.

- Cross-sections indicate that a much larger tributary existed where the eastern unnamed tributary presently exists. This tributary may have connected the New River, north of the site, with Courthouse Bay. The evidence for this theory is the highly angular, geologically younger sands encountered at depths more typical of the River Bend Formation; the surficial clay (mentioned in the first paragraph) and the Belgrade and upper units of the River Bend Formations are missing; and topographical maps provided by the USGS indicate that wetlands/marshlands located north of NC State Route 172 have the same surficial topography as the area surrounding the unnamed tributary on the eastern portion of the site. The significance of this observation is that contamination has a potential pathway into deeper groundwater zones without impediment by less permeable geologic units.

- Eleven VOCs were detected in surface and subsurface soils collected at Site 73, however, none of the compounds exceeded the EPA's Soil Screening Levels protective of groundwater.

- High concentrations of SVOCs were detected in surface soil sample 73-AC2-MW07-00, and in subsurface soil samples collected from soil boring locations 73-MW15B, 73-MW14, 73-SB01 and 73-SB06. Soil sample 73-AC2-MW07-00 was collected from an area where evidence of waste disposal had been observed during field operations. Soil borings 73-MW15B, 73-MW14, 73-SB01 and 73-SB06 were drilled in areas located near to USTs or oil/water separators which may be the source of the elevated SVOCs. 2,4-Dinitrophenol and benzo(a)anthracene were detected in the soils at concentrations exceeding applicable soil screening levels for groundwater protection.

- Pesticides were detected in the surface and subsurface soils throughout the site. The most commonly detected compound was 4,4'-DDD. An equal number of compounds were detected in both the surface and subsurface samples. Pesticides detected in the subsurface soils were observed in areas where the soils have been either disturbed by excavation, construction, or training exercises and the reworked soil may have contained pesticide contamination. The scattered detections of pesticides and the relatively low concentrations observed in the samples provide evidence that the contamination is probably the result of surface pesticide application rather than disposal.

- PCBs were detected in the surface and subsurface soils. Detections were observed in a surface sample collected from 73-MW20 and a subsurface soil sample from boring 73-SB07. The frequency, location and concentration of PCB detections suggest that the contamination is the result of POL spills and releases.

- The distribution of detected inorganic analytes among both the surface and subsurface soils followed no pattern and were observed throughout the site at varying concentrations, suggesting that the former and current site operations have not resulted in noticeable inorganic contamination.

Groundwater

- Shallow groundwater flow is radial from a topographical high centered near Buildings A-8 through A-11. Flow patterns in the eastern portion of the site are controlled by the absence of the underlying clay allowing the surficial groundwater to combine with the underlying groundwater zones; thus causing change in the direction of surficial groundwater flow.

- Groundwater flow in the upper portion of the Castle Hayne aquifer is controlled by Courthouse Bay. A groundwater divide is present north of the site in the area of State Route 172. Flow direction in the mid to lower portion of the Castle Hayne aquifer is controlled by the New River.

- Groundwater elevations collected from the monitoring wells indicate that groundwater located on the southeastern side of the bay flows toward Courthouse Bay as does groundwater on the northwestern side.

- A pathline analysis was conducted as part of an overall modeling effort conducted at the site. The analysis indicated that as groundwater in the shallow aquifer begins to descend it changes course heading toward Courthouse Bay, however continuing its decent. As groundwater nears the bay, the vertical gradient reverses and both shallow and deep groundwater begin to recharge Courthouse Bay.

- Benzene contamination was detected in the shallow groundwater within the A-47 complex. It was defined horizontally by monitoring wells A47/3-09, A47/3-11, 73-MW27 and 73-MW29. A former UST, reportedly located in the vicinity of the A-47 complex, is the suspected source of this contamination. The contamination is, for the most part, restricted to the surficial aquifer which is consistent with the contaminants natural tendency to reside in the upper portions of any water-bearing zone.

- The highest concentration of TCE was detected in intermediate monitoring well 73-DW03 (screened from approximately -51.7 to -61.7 feet msl), located in the central portion of the Building A-47 complex. The horizontal extent of contamination is defined by monitoring wells 73-DW06, -DW07, and 73-DW08 to the west, 73-DW09 and -DW10 to the north, 73-DW13 to the east and Courthouse Bay to the south. The vertical extent lies between 63 feet and 146.5 feet msl based on the lack of VOCs detected in the mid to lower portions of the Castle Hayne aquifer.

- Inorganic contamination in the groundwater mainly consisted of iron and manganese; however, these analytes are commonly detected in groundwater at Camp Lejeune at levels exceeding the NCWQS values. Therefore, these inorganic constituents are not considered to be the result of past waste disposal practices at Site 73.

Surface Water/Sediment

- Courthouse Bay is unaffected by the volatiles detected in the groundwater at the site.

- PAHs detected in the sediments are suspected as the result of fossil fuel combustion due to the high amount of boat and amphibious traffic occurring in the bay on a daily basis.

- The concentrations and distribution of pesticides in sediments sampled in Courthouse Bay indicate that the occurrence of these compounds is probably the result of erosion and possible aerial pesticide application, and not from spills or disposal events.

Biota

- VOCs detected in the fish and crab samples were restricted to common laboratory contaminants and are suspected to be the result of sample preparation.

- Endrin (a pesticide) was detected in a fillet sample collected from sampling station F/C-02 located in Courthouse Bay. This same compound was detected in sediments and surface and subsurface soils and is suspected to have originated from Base-wide aerial application.

- A number of metals were detected in the fish and crab samples collected from Courthouse Bay. Three of the metals detected (mercury, molybdenum and selenium were not detected in any other media sampled at the site and are not considered to be related to past waste disposal activities at Site 73.

Human Health Risk Assessment

The following sections present a summary of the human health risk assessment.

Current Scenario

- Carcinogenic and noncarcinogenic risk values for the adult fisherman and child receptor exceeded USEPA's acceptable risk range for ingestion of both fish and crab tissue. The elevated ICR and HI values are due primarily to the presence of arsenic. The risk, in this instance, may not be site related because sediment was the only other media in which arsenic was detected and because the fish and crab are migratory by nature.

Future Scenario

- The Phase I groundwater exposure scenario indicated that the overall site noncarcinogenic risk exceeded unity for the adult and child residents. However, for the adult receptor, the individual media HI values were below unity (i.e., one), therefore making it unlikely that adverse systemic health effects would result in future adult receptors.

- Under the Phase II groundwater exposure scenario, the total site noncarcinogenic risk exceeded unity for the adult and child residents. Adverse systemic health effects are unlikely for the adult receptor since the exposure pathway HI values were below unity. The total site HI was 4 for the child receptor. The risk was again driven primarily by the ingestion of iron and manganese in the groundwater at the site.

- The Phase II groundwater exposure scenario indicated that a potential carcinogenic risk in excess of EPA's acceptable range from groundwater ingestion to the future residential child and adult. Vinyl chloride was the primary contributor to these elevated risk values.

Ecological Risk Assessment

The following sections present a summary of the ecological risk assessment.

Aquatic Ecosystem

- The benthic species at the sampling stations located in the tributaries to Courthouse Bay and several stations within the bay had lower indices than the background stations. This indicates that the benthic community at these locations may be adversely impacted by contaminants detected in the sediment.

- Several of the contaminants detected in the fish and crab tissues appeared to be elevated above background studies. Based on the relatively abundant and diverse fish population at the site, these contaminants do not appear to be significantly impacting the fish community.

- Tissue concentrations of arsenic, chromium, lead and zinc were below toxicity concentrations located in the literature for aquatic and piscivorous wildlife.

- The inorganics detected in the surface water and sediment appear to have a low potential to adversely impact the aquatic receptor population.

- The risk posed by the sediment is from pesticides detected at several stations within the bay. The compounds are not considered to be site-related contaminants, but they are most likely remnants of past Base-wide pesticide application.

Terrestrial Ecosystem

- Several inorganics such as aluminum, chromium, iron and vanadium detected in samples collected from the surface soils exceeded soil toxicity benchmark values. Most of the benchmark values exceeded were plant benchmark values, however, the flora community did not appear to be impacted.

- The CDI exceeded the TRV for all five terrestrial species evaluated at the site. The risks were driven by aluminum, antimony, arsenic and cadmium.

- Some potential impacts to soil invertebrates and plants may occur as a result of site-related contaminants. In addition, there is a potential for decrease in the terrestrial vertebrate population from site-related contaminants based on the terrestrial intake model. Aluminum concentrations in the surface soils exceed flora and fauna values, as well as contribute to risks in terrestrial models.

Conclusions

The scope of the RI focused on nine Area of Concern (AOCs). At the outset of the RI, the AOCs that appeared to be the most significant, based on available information, were AOCs 1, 5, and 6. Data obtained under the RI indicates the vertical and horizontal extent of contamination has been defined to within the vicinity of Site 73. There appears no significant surface or subsurface or subsurface soil contamination that presents a significant human health or ecological risk. The most significant contamination was encountered in groundwater at AOCs 1 and 6.

AOC 1 comprises the main portion of the site which includes the majority of the Building A-47 complex. Historical information indicated that 400,000 gallons of POL may have been disposed along with an undetermined volume of solvents. Few surface soil samples collected in this AOC possessed concentrations of metals in excess of base background. Less than 5 percent of the subsurface soil samples collected within AOC 1 contained organic or inorganic compound concentrations in excess of comparison criteria. Groundwater results indicate that most of the compounds whose concentration exceed NCWQS and/or federal MCLs were collected from wells installed inside the boundaries of AOC 1. The results of the RI indicated the presence of a BTEX plume in this area. However, the source of this plume is most likely to be a former UST reportedly located within the vicinity of the A-47 complex rather than the reported POL disposed at AOC 1. Data obtained for UST investigations at the site (see Appendix A) indicates the presence of elevated levels of total petroleum hydrocarbons (TPH) and oil and grease south of Building A-47 which could be remnants of the POL disposal in this area. Solvent contamination was also encountered in AOC 1 consistent with historical data. The detected levels of TCE , DCE, and vinyl chloride in AOC 1 were the highest encountered during the

RI at 320 µg/L, 120 µg/L, and 43 J µg/L, respectively. Groundwater modeling performed by Baker indicated that the natural tendencies of groundwater at the site is to recharge Courthouse Bay and limit the downward migration potential of the contamination. Vertically, the extent of contamination is defined to exist between 63 and 146.5 feet msl as evident by analytical results received from samples collected from deep monitoring wells.

AOC 6 is adjacent to the eastern border of AOC 5 and is the site of a former 30,000-gallon UST used to store diesel fuel (UST A47/3). Although soil sample results from this portion of the site indicate very few compounds exceeded comparison criteria, groundwater possessed contaminant concentrations exceeding NCWQS and/or federal MCLs. The results of the RI confirmed the results of previous studies indicating fuel and solvent-related groundwater contamination. The solvent contamination is likely related to the historical disposal activities that reportedly occurred at AOC 1.

AOC 5 was the general area north of Building A-47 where 20,000 gallons of waste battery acid and an undetermined volume of waste oil may have been disposed. The results of the investigation in this area did not indicate levels of inorganics indicative of a large volume of waste battery acid disposal. Evidence of waste oil disposal was primarily limited to two detections of PCBs in soil samples obtained at 73MW-20 (140 NJ and 170 J µg/kg). Soil screening levels protective of groundwater were not established for PCBs, therefore, neither concentration is in excess of screening criteria. Neither TPH or oil and grease were detected in soil samples obtained from this area.

Based on the results of surface water and sediment sampling in Courthouse Bay and the unnamed tributaries located to the east and west of Site 73, it appears that volatile organic contamination present in the groundwater is not impacting Courthouse Bay.

The results of the human health risk assessment indicated that current site conditions do not present an adverse risk to military personnel engaged in daily activities at the Amphibious Vehicle Maintenance Facility.

Adverse human health risks at this site are associated primarily with organic and inorganic contaminants in the groundwater and inorganic contaminants identified in fish and crab tissue. However, only the organic contaminants are clearly associated with past site activities.

The ecological risks associated with the terrestrial and aquatic ecosystems were primarily associated with inorganic contaminants in the surface soils, sediment and surface waters at the site.

1.0 INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) on October 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA) Region IV, North Carolina Department of the Environment, Health and Natural Resources (NC DEHNR), and the United States Department of the Navy (DoN) entered into a Federal Facilities Agreement (FFA) for MCB, Camp Lejeune. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at MCB Camp Lejeune were thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives were developed and implemented as necessary to protect the public health, welfare, and the environment (FFA, 1989).

The Fiscal Year 1997 Site Management Plan for MCB Camp Lejeune, a primary document referenced in the FFA, identifies 34 sites that require Remedial Investigation/Feasibility Study (RI/FS) activities. These 34 sites have been divided into 18 operable units to simplify proceeding with RI/FS activities. Operable Unit (OU) No. 9, comprised of Sites 65 and 73, is the general focus of this report. However, this report specifically addresses Site 73 and a separate remedial investigation (RI) report addresses Site 65. As part of the RI, seven underground storage tank (UST) systems located within the boundaries of the site were investigated. The data collected from each UST are included in Appendix A of this report. Figure 1-1 the MCB Camp Lejeune and the location of Site 73. Figure 1-2 presents a plan of Site 73 and Figure 1-3 depicts the approximate locations of the UST systems within Site 73. Note that tables and figures are provided in Volume II of this report.

The purpose of the RI is to evaluate the nature and extent of the threat to public health and the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants. The RI was conducted through the sampling of several media [soil (surficial and subsurface), groundwater, sediment, surface water and benthic and aquatic species], evaluating the resultant analytical data, and performing a human health risk assessment (RA) and ecological RA. Furthermore, the RI report provides information to support a Feasibility Study (FS) and Record of Decision (ROD) for a final remedial action.

This RI Report has been prepared by Baker Environmental, Inc. (Baker) for submittal to the Naval Facilities Engineering Command, Atlantic Division (LANTDIV), MCB Camp Lejeune Environmental Management Division (EMD), USEPA Region IV, the NC DEHNR, and the Navy Environmental Health Center (NEHC), for their review.

The following subsections describe the characteristics and history of OU No. 9, Site 73. In addition, Section 1.1 provides an overview of the RI Report Organization.

1.1 Report Organization

This RI Report for Site 73 is comprised of four volumes with text (Volume I), tables and figures (Volume II), and Appendices (Volumes III and IV). Volume I - Text is separated into the following sections:

Volume I: Text

- Introduction (includes site descriptions and history)
- Field Investigation
- Regional and Site Characteristics
- Nature and Extent of Contamination
- Contaminant Fate and Transport
- Baseline Human Health Risk Assessment
- Ecological Risk Assessment
- Conclusions and Recommendations

1.2 Operable Unit Description

Operable Units were formed as an incremental step toward addressing individual site concerns and to simplify the specific problems associated with a site or a group of sites. OU No. 9 includes the Courthouse Bay Liquids Disposal Area (Site 73) and Engineer and Dump (Site 65). Both sites are located in the Courthouse Bay area of MCB, Camp Lejeune. The area is accessible via Marine's Road and North Carolina Route 172. Site 73 is located within the confines of the Amphibious Vehicle Maintenance Facility. In fact, the Courthouse Bay Liquids Disposal Area is synonymous with the Amphibious Vehicle Training Facility. Within the Activity, the site is more commonly known as the latter and, consequently, this report refers to Site 73 as the Amphibious Vehicle Training Facility.

1.3 Site Description and History

In general, Site 73 refers to an area where waste oil and battery acid were reported disposed. The site encompasses the Amphibious Vehicle Maintenance Facility located in the Courthouse Bay Area of MCB Camp Lejeune (see Figure 1-2). Site 73 is roughly bounded by State Route 172 (Sneads Ferry Road) to the north, Courthouse Bay to the south, and unnamed tributaries to Courthouse Bay to the east and west. Courthouse Road, which bisects the study area, is used to enter the complex.

The study area consists of numerous buildings, aboveground storage tanks (ASTs), underground storage tanks (USTs), vehicle wash racks, and oil/water separators. Most of the USTs are or were located (some USTs have been removed) within the fenced area around Building A47. Non-petroleum type wastes are routinely handled at an active Hazmat Storage Area located near UST A47/3. Other USTs are or were located near Buildings A1, A2, and A10. The RI/FS Work Plan (Baker, 1995) contains profiles of the various USTs. Figure 1-3 depicts the approximate locations of the USTs.

The terrain at Site 73 is primarily flat. Stormwater runoff tends to drain directly south to Courthouse Bay or to two small unnamed tributaries located east and west of the facility which ultimately discharge to Courthouse Bay. A broad marshy area is associated with the western tributary. Directly north of the site is another large marshy area and a stream that discharges north into the New River. This marshy area is separated from the site by State Route 172 which represents a local topographic high and a surface water runoff divide.

The Amphibious Vehicle Maintenance Facility started operations in 1946 and is currently active. Available information indicates that an estimated 400,000 gallons of waste oil was discharged directly onto the ground surface at this facility, primarily near Building A47. In addition to the waste oil, approximately 20,000 gallons of waste battery acid was also reportedly disposed in the area northeast of A47. The waste battery acid was poured into shallow hand-shoveled holes which were then backfilled. Neither area is visually apparent with respect to its history of waste disposal. Moreover, most of the area where waste disposal reportedly took place, is covered with concrete, building and/or roads. A previous report (Law-Catlin, 1993) indicated that solvents may have also been disposed at this site although no specific disposal locations or dates were identified.

1.4 Summary of Previous Site Investigations

Seven previous environmental investigations have been conducted at this site to date including an Initial Assessment Study by Water and Air Research, Inc. (WAR, 1983), Confirmation Study by Environmental Science and Engineering, Inc. (ESE, 1990) and five UST investigations.

The first UST investigation was conducted in 1991 by ATEC Environmental Consultants (ATEC) of UST SA-21. In 1992 and 1993, Baker Environmental, Inc. (Baker) performed additional investigations on the same UST. UST A47/3 was investigated by Groundwater Technology Government Services, Inc. (GSI) in April 1993 and Law-Catlin in October 1993. Both USTs where reported to be leaking. UST SA-21 was a steel 30,000 gallon capacity tank which held gasoline and diesel fuel. This tank was installed in 1959 and subsequently removed in 1991. UST A47/3 was a steel 30,000 gallon capacity tank which held diesel fuel. Available information indicates that this UST was installed in 1986. A hydrostatic test was performed on A47/3 in late 1992. UST A47/3 was subsequently replaced with a fiberglass tank.

1.4.1 Confirmation Study (ESE, 1990)

During the Confirmation Study, ESE installed four shallow groundwater monitoring wells in 1984 and a fifth shallow monitoring well in 1986. Two rounds of groundwater samples were collected and analyzed for volume organics, cadmium, chromium, lead, antimony, oil and grease, and total phenols (analytical methods are not available). The first round was collected in 1984 from the four newly installed wells and the existing supply well (designated 73GW5 for the 1984 sampling effort). The second round was collected in 1987 from all five ESE wells including the newly installed 73MW5. The previous set of compounds were analyzed with the addition of xylene, methyl ethyl ketone, methyl isobutyl ketone, ethylene dibromide, and hexavalent chromium. Results from the groundwater sampling showed positive detections of organic and inorganic compounds. The most significant contaminants detected were benzene (17 µg/L; 73GW4), 1,1-dichloroethylene (2.3 µg/L; 73GW4), trans-1,2-dichloroethene (360 µg/L; 73GW3), toluene (4 µg/L; 73GW4), vinyl chloride (74 µg/L; 73GW4), cadmium (10 µg/L; 73GW2), chromium (95 µg/L; 73GW1), lead (109 µg/L; 73GW1), and oil and grease (2,000 µg/L, 73GW1 and 73GW2). Location of the groundwater monitoring wells and the surface water/sediment sampling stations are provided on Figure 1-4.

Surface water/sediment samples were collected from three locations offshore in Courthouse Bay as part of the study in 1986/87. The results of the sampling effort identified the presence of cadmium (0.69 mg/kg; 73SD3), chromium (11.8 to 53 mg/kg), lead 8.5 to 22.2 mg/kg), phenols (0.207 to 1.56 mg/kg) and oil and grease (314 to 1,510 mg/kg) in the sediment. Chromium was detected in the surface water but was reported that the levels were below the freshwater standard of 50 µg/L.

1.4.2 UST SA-21 Investigation (ATEC, 1991 and Baker, 1992 and 1993)

Investigations were conducted in the vicinity of UST SA-21 by ATEC (1991) and Baker (1992 and 1993). ATEC advanced eight subsurface soil borings for the purpose of collecting soil samples and investigating the shallow geology at the site. Upon completion of the borings, groundwater monitoring wells were installed and sampled for total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and total xylenes (BTEX). The locations of the ATEC monitoring wells are provided on Figure 1-5.

The highest levels of detectable concentrations in the soils were as follows: TPH (490 mg/kg), ethylbenzene (1,000 µg/kg), and total xylenes (4,000 µg/kg). Benzene and toluene were not detected above 50 µg/kg. The highest levels of detectable concentrations in the groundwater samples were as follows: TPH (0.39 mg/L; MW-3), benzene (45 µg/L; MW-7), toluene (56 µg/L; MW-7), ethylbenzene (9 µg/L; MW-3), and total xylenes (13 µg/L; MW-7). Based on the previously stated concentrations, ATEC recommended that additional soil sampling be conducted around the MW-3 location to determine the extent of soils contaminated by petroleum hydrocarbons and that an additional groundwater investigation be conducted in the vicinity of MW-3 and MW-7 to determine the extent of benzene contamination.

Baker conducted two investigations at the site. The first was conducted in 1992 and Baker drilled 13 boreholes, collected two samples form each soil boring and analyzed each sample for total petroleum hydrocarbons (TPH). Seven boreholes were converted to shallow Type II groundwater monitoring wells and sampled in order to investigate the shallow aquifer. Two borings were converted to deep Type III monitoring wells and sampled to investigate the upper portion of the Castle Hayne aquifer. Additionally, seven groundwater samples were collected via the hydropunch method. Groundwater samples were analyzed for BTEX and total VOCs. The locations of the soil borings, Type II and Type III monitoring wells, and the hydropunch samples are illustrated on Figure 1-6. The results are provided on Figures 1-7, 1-8, and 1-9. Figure 1-7 provides soil sample results for low to medium boiling point hydrocarbons. Figure 1-8 provides soil sample results for medium to high boiling point hydrocarbons. Figure 1-9 provides groundwater sample results for benzene and total VOC concentrations.

The second investigation was conducted in 1993 and Baker collected 36 subsurface soil samples from 18 soil borings for TPH analysis. Five of the boreholes were converted into shallow Type II groundwater monitoring wells and two were converted into deep Type III monitoring wells. One recovery well was installed for conducting a pump test and eventual remediation of the site. An eight-hour pump test yielded a pumping rate of approximately three gallons per minute (gpm). Groundwater samples for collected for analysis of BTEX and total VOCs. Groundwater contamination was not detected in the wells or hydropunches advanced during this investigation. Locations of all samples are provided on Figure 1-10 and soil sample results are provided on Figures 1-11 and 1-12.

1.4.3 UST A47/3 Investigation (GSI, 1993 and Law-Catlin, 1993)

UST A47/3 was formerly located southeast of Building A47 and was investigated by GSI and Law-Catlin in 1993. GSI advanced seven soil borings from which seven soil samples were collected for TPH analysis. The borings were later converted into shallow Type II groundwater monitoring wells and sampled for BTEX analysis. TPH was detected in the soils at a range of 440 to 3,000 mg/kg. The highest levels of detectable concentrations in the groundwater samples were as follows: benzene (1.7 µg/L), toluene (0.6 µg/L), ethylbenzene (3.8 µg/L) and total xylenes (3.0 µg/L).

Law-Catlin conducted an additional investigation of the site in which 48 subsurface soil samples were collected from 16 soil borings for TPH analysis. The soil borings were later converted into 12 shallow Type II groundwater monitoring wells, three deep Type III monitoring wells and one pumping well. In addition to the groundwater samples collected from the monitoring wells, ten samples were collected via hydropunch procedure. All groundwater samples were analyzed for BTEX. Locations of the hydropunch samples, subsurface soil samples and the groundwater monitoring wells are provided on Figure 1-13 and results are provided on Figures 1-14 and 1-15.

Richard Catlin & Associates subsequently obtained groundwater samples from shallow wells A47/3-8 and A47/3-9 and analyzed them for non-fuel specific compounds via EPA Method 502.2. The results, reported in a letter report dated March 22, 1994, revealed the presence of elevated levels of several chlorinated organic compounds (e.g., vinyl chloride, trichloroethylene); however, only benzene was detected in excess of State of North Carolina groundwater standards.

1.4.4 Aerial Photography Review

Aerial photographs of the site from 1962 through 1989 were reviewed by Baker staff at the base Forestry Department. Additionally, two photographs, dated 1964 and 1970, were obtained from the USEPA and five photos, dated 1956 through 1993, were provided by the USDA Aerial Photography Field Office. All were reviewed by Baker and specific observations were as follows:

- Aerial photographs from 1956 (see Figure 1-16) and 1970 (see Figure 1-17) appear essentially unchanged. Building A-3 is the primary building at the site as evident by the large number of amphibious vehicles surrounding it. The only difference in the two photos is the apparent deforestation in the vicinity of the Amphibious Vehicle Maintenance Facility. Evidence of the disposal of liquid waste does not appear in either of these photos.

- The photograph from 1983 (see Figure 1-18) appears to be virtually identical to the photo from 1970 indicating the lack of substantial modifications to the site. However, evidence of the surface disposal of liquid wastes is apparent as evident by the stained soils around the edge of the concrete pad. Building A-3 is still the focal point for operations at the site. The only modifications evident are the concrete pad constructed around Building A-3 and the oil/water separators located southeast between it and the bay.

- The aerial photographs from 1989 and 1993 (see Figure 1-19) are essentially unchanged and depict the new main Building A47. The construction of this structure represented a significant alteration to the site including paving a substantial portion of the northeast section of the site. The newly paved area includes a large portion of the area where waste oil disposal is suspected to have occurred.

1.4.5 Preliminary Investigation

A soil gas survey and groundwater sample screening program was conducted at Site 73 by Baker from June 7 through June 14, 1994. This preliminary investigation was performed to provide additional data regarding the presence or absence of organic contaminants across the site and to better define source areas of contamination prior to the preparation of project plans. Baker subcontracted Tracer Research Corporation (Tracer) of Monmouth, New Jersey to execute the program. A grid of sampling points was laid out across the site by a survey subcontractor, Colbert Associates (Colbert) of Baltimore, Maryland. In general, the sampling locations were located along a 200-foot by 200-foot grid across the site in areas where sampling was not concentrated under previous investigations. Additional sampling locations were concentrated around other suspected source areas such as oil/water separators, active and former USTs, and miscellaneous areas such as active and former vehicle washdown basins. Tracer obtained a shallow groundwater sample from each sampling location. An attempt was also made to obtain a soil gas sample from each sampling location; however, at some locations the close proximity of the shallow groundwater surface to the top of ground surface precluded the successful collection of soil gas samples. See Tables 1-1 and 1-2 for results of the soil gas survey.

Each soil gas and groundwater sample obtained was analyzed by Tracer in the field via mobile gas chromatograph for benzene, toluene, ethyl benzene, total xylenes, total volatile hydrocarbons (TVHC: C4 to C9 range and C10 to Cx range where C followed by a number indicates how many carbon atoms comprise the hydrocarbon compound), trichloroethane (TCA), trichloroethene (TCE), tetrachloroethylene (PCE), and methylene chloride. These parameters were selected to provide a broad range of petroleum hydrocarbons and solvents which comprise the two classes of organic contaminants of concern at this site. The results of the program are presented on Figures 1-20 and 1-21.

Using the results of the preliminary investigation and previous investigations, Baker subdivided Site 73 into nine distinct areas of concern (AOCs), in order to segregate potential sources of contamination and identify future ecological sampling zones (Figure 1-22). The total area encompassed by the AOCs measures approximately 48 acres. Each AOC was described in the RI Work Plan (Baker, 1995).

AOC #1	The general area identified in the Camp Lejeune Site Summary Report (ESE, 1990) where over 400,000 gallons of POL may have been disposed. A previous report also indicated that solvents may have been disposed in this area. USTs A-47/1, A-47/5, and A-47/4 are located within this AOC.
AOC #2	A vehicle roadway/ditch area at the extreme southwestern edge of the site which leads into Courthouse Bay. During a Pre-RI site visit, Baker observed two distinct areas of random discharge into the road/ditch from seeps located on both sides of the road/ditch. Although the seeps were brownish in appearance, samples obtained during the preliminary investigation indicated no detectable levels of volatile organic compounds were present.
AOC #3	Former location of UST SA-26, a 550-gallon waste oil. This UST was removed after it was determined to be leaking. Adjacent to this former UST is a vehicle washdown area that is connected to an oil/water separator.
AOC #4	UST SA-21 area that previously contained a 30,000-gallon UST for the storage of diesel fuel and gasoline. This area was previously investigated by ATEC and Baker.
AOC #5	The general area identified in the Camp Lejeune Site Summary Report (ESE, 1990) where over 20,000 gallons of waste battery acid may have been disposed. This area is also part of the area where waste oil may have been disposed.
AOC #6	UST A47/3 area that previously contained a 30,000-gallon UST used to store diesel fuel. This UST area was previously investigated by GSI and Law-Catlin.

AOC #7	Unnamed stream which borders Site 73 on the east. This surface water body may be a receptor of shallow groundwater and/or surface water run-off.
AOC #8	The area of Courthouse Bay which could be impacted by Site 73 shallow groundwater recharge and surface water run-off.
AOC #9	Unnamed stream which borders Site 73 on the west. This surface water may be a possible receptor of surface groundwater and/or surface soil run-off.

1.5 Data Limitations

Upon review of the previous investigation and the subsequent analytical findings, it was determined that data limitations existed for soils and groundwater at Site 73. The most significant data gap concerned the extent of contamination in soil and groundwater during previous investigations at Site 73. Specific data needs included the following:

- The nature and extent of surface soil contamination in the northern portion of the site.
- The nature and extent of surface soil contamination in the western portion of the site.
- The presence or absence of site-related contaminants in the surface and subsurface soil in order to conduct a human health risk assessment.
- The hydrogeologic parameters of the shallow and intermediate aquifer.
- Data to support the assessment of risks to human health posed by future potential exposure to the groundwater.

From these site-specific data needs, RI objectives were established to meet the data deficiencies for Site 73. RI objectives are presented in the following section.

1.6 Remedial Investigation Objectives

Table 1-3 presents the RI objectives that were included in the RI Work Plan (Baker, 1995).

1.7 References

ATEC Environmental Consultants. 1992. Underground Storage Tank Site Check Investigation Report. Building A-47, UST CA-21, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina.

Baker Environmental, Inc. 1992. Site Assessment Report, Building A-47, Amphibious Vehicle Maintenance Facility, Underground Storage Tank System SA-21, MCB Camp Lejeune, North Carolina. Contract Task Order 0109. Final. October 12, 1992.

Baker Environmental, Inc. 1993. Additional Assessment Activities, Underground Storage Tank System SA-21, Building A-47, Amphibious Vehicle Maintenance Facility, Camp Lejeune, North Carolina. Contract Task Order 0109. Draft. March 29, 1993.

Baker Environmental, Inc. 1995. Remedial Investigation/Feasibility Study Work Plan, Operable Unit No. 9). Final. Prepared for the Department of the Navy, Naval Facilities Engineering Command, Atlantic Division, Norfolk Virginia.

Camp Lejeune Federal Facility Agreement (FFA). December 6, 1989.

DON, 1988. Master Plan, Camp Lejeune Complex, North Carolina. COMNAVFACENGCOM, April 8, 1988.

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Law-Catlin Associates, Inc. 1993. Leaking Underground Storage Tanks, Comprehensive Site Assessment, Building A-47 Pumps, Marine Corps Base, Camp Lejeune, North Carolina. Draft. December 29, 1993. Volumes I and II.

Richard Catlin & Associates, Inc. 1994. "Leaking Underground Storage Tank, Additional Monitoring Well and Waste Composite Sampling, Building A-47 Pumps, Marine Corps Base, Camp Lejeune, North Carolina." Correspondence to Mark Barnes, LANTDIV. March 22, 1994.

Water and Air Research, Inc. (WAR). 1983. Initial Assessment Study of Marine Corps Base, Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity.

SECTION 1.0 TABLES

TABLE 1-1

ANALYTICAL RESULTS FROM SOIL GAS SURVEY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene ppm	Toluene ppm	Ethyl Benzene ppm	Xylenes ppm	C_4-C_9 TVHC ppm	C_{10}-C_x TVHC ppm	CH_2CL_2 ppm	TCA ppm	TCE ppm	PCE ppm
73-SGS-01S	ND	ND	ND	ND	4.68	3.12	ND	ND	ND	ND
73-SGS-02	ND	ND	ND	ND	ND	ND	ND	0.0004	ND	0.0006
73-SGS-05S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-06	ND	ND	ND	ND	ND	ND	ND	0.0005	ND	0.0008
73-SGS-07S	INT	ND	ND	ND	0.156	ND	ND	ND	ND	ND
73-SGS-08	ND	ND	ND	ND	ND	ND	ND	0.0002	ND	0.0006
73-SGS-09S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-10	ND	ND	ND	ND	ND	ND	ND	0.0002	ND	ND
73-SGS-11S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-13S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-14S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-15S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-16S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-18S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-21S	ND	1.08	ND	ND	1.82	ND	ND	ND	ND	ND
73-SGS-22S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-23S	0.128	0.135	ND	ND	0.52	ND	ND	ND	ND	ND
73-SGS-24S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 1-1 (Continued)

ANALYTICAL RESULTS FROM SOIL GAS SURVEY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene ppm	Toluene ppm	Ethyl Benzene ppm	Xylenes ppm	C_4-C_9 TVHC ppm	C_{10}-C_x TVHC ppm	CH_2CL_2 ppm	TCA ppm	TCE ppm	PCE ppm
73-SGS-25S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-27S	ND	INT	ND	ND	10.7	ND	ND	ND	ND	ND
73-SGS-30S	ND	1.08	ND	ND	21.8	5.20	ND	ND	ND	ND
73-SGS-31S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-32S	INT	INT	ND	ND	468	ND	ND	ND	ND	ND
73-SGS-33S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-34S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-35S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-36S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-37S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-38S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-39S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-40S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-41S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-42S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-43S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-44S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-45S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-46S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 1-1 (Continued)

ANALYTICAL RESULTS FROM SOIL GAS SURVEY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene ppm	Toluene ppm	Ethyl Benzene ppm	Xylenes ppm	C_4-C_9 TVHC ppm	C_{10}-C_x TVHC ppm	CH_2CL_2 ppm	TCA ppm	TCE ppm	PCE ppm
73-SGS-47S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-49S	ND	ND	ND	ND	ND	2.86	ND	ND	ND	ND
73-SGS-51S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-53S	INT	ND	ND	2.64	46.8	13.0	ND	ND	ND	ND
73-SGS-55S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-56S	ND	ND	ND	ND	ND	0.78	ND	ND	ND	ND
73-SGS-58S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-59S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-60S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-64S	ND	ND	ND	3.12	31.2	ND	ND	ND	ND	ND
73-SGS-65S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-66S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-68S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-70S	ND	ND	ND	ND	0.26	ND	ND	ND	ND	ND
73-SGS-72S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-73S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-74S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-76S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-78S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 1-1 (Continued)

ANALYTICAL RESULTS FROM SOIL GAS SURVEY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene ppm	Toluene ppm	Ethyl Benzene ppm	Xylenes ppm	C_4-C_9 TVHC ppm	C_{10}-C_x TVHC ppm	CH_2CL_2 ppm	TCA ppm	TCE ppm	PCE ppm
73-SGS-81S	ND	ND	ND	ND	ND	ND	ND	0.036	ND	0.001
73-SGS-82S	ND	ND	ND	ND	0.78	ND	ND	ND	ND	ND
73-SGS-84S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-88S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-89S	ND	ND	ND	ND	ND	ND	0.029	0.0054	0.0013	0.003
73-SGS-90S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-92S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-93S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-95S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-97S	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0015
73-SGS-98S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-99S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-101S	ND	INT	ND	ND	109.2	ND	ND	ND	ND	ND
73-SGS-103S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-104S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-105S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-106S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-107S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-109S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 1-1 (Continued)

ANALYTICAL RESULTS FROM SOIL GAS SURVEY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene ppm	Toluene ppm	Ethyl Benzene ppm	Xylenes ppm	C_4-C_9 TVHC ppm	C_{10}-C_x TVHC ppm	CH_2CL_2 ppm	TCA ppm	TCE ppm	PCE ppm
73-SGS-111S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-112S	ND	10.5	ND	ND	16.1	1.30	ND	ND	ND	ND
73-SGS-114S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-115S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-116S	ND	ND	ND	ND	ND	ND	ND	0.0036	ND	ND
73-SGS-117S	ND	ND	ND	ND	ND	0.78	ND	ND	ND	ND
73-SGS-118S	ND	ND	ND	ND	ND	2.86	ND	ND	ND	ND
73-SGS-119S	ND	ND	ND	ND	ND	0.52	ND	ND	ND	ND
73-SGS-120S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AIR - max []	<0.2	<0.4	<0.7	<0.8	<0.9	<0.9	<0.07	<0.003	<0.007	<0.009
AIR - min [ ]	<0.02	<0.04	<0.07	<0.08	<0.08	<0.08	<0.008	<0.0003	<0.0003	<0.0003

Notes:

TVHC = Total Volatile HydroCarbons
ND = Not Detected Above Detection Limits
INT = Interference

ppm = Parts Per Million
TCA = 1,1,2-Trichloroethane
TCE = Trichoroethene

PCE = Tetrachloroethene

TABLE 1-2

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene µg/L	Toluene µg/L	Ethyl Benzene µg/L	Xylenes µg/L	C_4-C_9 TVHC µg/L	C_{10}-C_x TVHC µg/L	CH_2CL_2 µg/L	TCA µg/L	TCE µg/L	PCE µg/L
73-SGS-01W	ND	ND	ND	190	240	930	ND	ND	ND	ND
73-SGS-03W	ND	ND	ND	ND	37	11	ND	ND	ND	ND
73-SGS-05W	ND	ND	ND	ND	ND	ND	ND	0.002	ND	ND
73-SGS-07W	ND	ND	ND	ND	ND	ND	ND	0.006	0.02	0.004
73-SGS-09W	ND	ND	ND	ND	ND	ND	ND	0.003	ND	ND
73-SGS-11W	0.2	2	ND	0.8	5	ND	ND	0.004	ND	ND
73-SGS-13W	0.08	0.3	0.2	ND	2	ND	ND	0.002	ND	ND
73-SGS-14W	0.2	0.7	ND	ND	0.9	ND	ND	0.002	ND	ND
73-SGS-15W	1	1	ND	1	10	ND	ND	0.002	ND	ND
73-SGS-16W	0.4	1	0.5	2	4	ND	ND	0.006	ND	0.008
73-SGS-17W	ND	ND	ND	ND	ND	3700	ND	0.002	ND	ND
73-SGS-18W	ND	1	ND	ND	1	ND	ND	0.004	ND	0.005
73-SGS-19W	ND	ND	ND	ND	ND	ND	ND	0.001	ND	ND
73-SGS-20W	0.2	1	1	2	6	ND	ND	0.006	ND	0.007
73-SGS-21W	ND	ND	ND	ND	2	ND	ND	0.001	ND	ND
73-SGS-22W	ND	ND	ND	ND	ND	ND	ND	0.002	ND	0.008
73-SGS-23W	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-24W	0.9	0.7	ND	1	3	ND	ND	0.002	ND	ND

TABLE 1-2 (Continued)

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene µg/L	Toluene µg/L	Ethyl Benzene µg/L	Xylenes µg/L	C_4-C_9 TVHC µg/L	C_{10}-C_x TVHC µg/L	CH_2CL_2 µg/L	TCA µg/L	TCE µg/L	PCE µg/L
73-SGS-25W	ND	ND	ND	ND	8	54	ND	0.002	ND	ND
73-SGS-26W	0.2	0.9	ND	ND	1	ND	ND	ND	ND	ND
73-SGS-27W	ND	2	ND	ND	55	ND	ND	ND	ND	ND
73-SGS-28W	ND	0.6	ND	ND	2	ND	ND	ND	ND	ND
73-SGS-29W	ND	2	ND	ND	2	ND	ND	ND	ND	ND
73-SGS-30W	13	ND	ND	ND	14	ND	ND	0.002	ND	ND
73-SGS-31W	INT	INT	ND	ND	490	75	ND	0.002	0.02	ND
73-SGS-32W	ND	ND	ND	ND	38	ND	ND	0.002	ND	ND
73-SGS-33W	0.8	0.8	ND	ND	2	ND	ND	0.001	ND	ND
73-SGS-34W	ND	0.5	ND	ND	0.7	ND	ND	ND	ND	ND
73-SGS-35W	16	ND	ND	ND	160	ND	ND	ND	ND	ND
73-SGS-36W	ND	0.5	ND	ND	120	ND	ND	ND	0.03	ND
73-SGS-37W	ND	0.9	ND	ND	1	ND	ND	ND	ND	ND
73-SGS-38W	0.2	0.8	ND	0.8	4	ND	ND	0.004	ND	0.005
73-SGS-39W	ND	1	ND	ND	2	ND	ND	ND	0.01	ND
73-SGS-40W	0.2	0.8	ND	0.4	1	ND	ND	0.002	0.005	ND
73-SGS-41W	0.3	1	ND	ND	21	ND	ND	ND	ND	ND
73-SGS-42W	0.3	0.9	ND	1	3	ND	ND	0.006	ND	0.005

TABLE 1-2 (Continued)

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene μg/L	Toluene μg/L	Ethyl Benzene μg/L	Xylenes μg/L	C_4-C_9 TVHC μg/L	C_{10}-C_x TVHC μg/L	CH_2CL_2 μg/L	TCA μg/L	TCE μg/L	PCE μg/L
73-SGS-43W	ND	2	ND	4	34	ND	ND	0.003	ND	ND
73-SGS-44W	0.2	1	ND	0.9	11	ND	ND	0.002	ND	ND
73-SGS-45W	ND	1	ND	0.9	14	ND	ND	ND	ND	ND
73-SGS-46W	ND	0.9	ND	0.9	5	ND	ND	ND	ND	ND
73-SGS-47W	0.2	0.9	ND	0.9	2	ND	ND	0.002	ND	ND
73-SGS-48W	0.6	1	ND	0.9	8	ND	ND	ND	ND	ND
73-SGS-49W	0.3	0.5	ND	ND	2	ND	ND	0.002	ND	ND
73-SGS-50W	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-51W	0.3	0.8	ND	ND	1	ND	ND	ND	ND	ND
73-SGS-52W	ND	0.5	ND	ND	11	ND	ND	ND	ND	ND
73-SGS-53W	ND	ND	ND	ND	270	810	ND	0.002	ND	ND
73-SGS-54W	ND	2	ND	2	13	ND	ND	ND	ND	ND
73-SGS-55W	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-56W	0.2	1	ND	ND	1	ND	ND	ND	ND	ND
73-SGS-57W	0.2	0.6	ND	ND	0.8	ND	ND	ND	ND	ND
73-SGS-58W	0.3	0.3	ND	ND	2	ND	ND	ND	ND	ND
73-SGS-59W	0.3	0.5	ND	ND	1	ND	ND	ND	ND	ND
73-SGS-60W	0.2	0.8	ND	ND	1	ND	ND	0.002	ND	ND

TABLE 1-2 (Continued)

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene µg/L	Toluene µg/L	Ethyl Benzene µg/L	Xylenes µg/L	C_4-C_9 TVHC µg/L	C_{10}-C_x TVHC µg/L	CH_2CL_2 µg/L	TCA µg/L	TCE µg/L	PCE µg/L
73-SGS-61W	0.2	0.7	ND	ND	1	ND	ND	0.003	ND	ND
73-SGS-62W	0.8	0.5	ND	ND	4	ND	ND	0.02	ND	ND
73-SGS-63W	0.1	0.8	ND	ND	2	ND	ND	ND	ND	ND
73-SGS-64W	ND	ND	ND	ND	58	ND	ND	0.002	ND	ND
73-SGS-65W	1	2	ND	1	9	ND	ND	0.003	ND	ND
73-SGS-66W	0.1	0.3	ND	ND	0.8	ND	ND	ND	ND	ND
73-SGS-67W	9	0.9	ND	2	30	ND	ND	ND	ND	ND
73-SGS-68W	0.4	0.4	ND	ND	2	ND	ND	0.002	ND	ND
73-SGS-69W	4	0.9	ND	1	6	ND	ND	0.003	ND	ND
73-SGS-70W	4	0.6	ND	6	24	ND	ND	0.002	ND	ND
73-SGS-71W	0.4	0.4	ND	ND	2	ND	ND	ND	ND	ND
73-SGS-72W	0.6	0.7	ND	0.9	2	ND	ND	0.004	ND	ND
73-SGS-73W	ND	ND	ND	1	3	ND	ND	ND	0.008	ND
73-SGS-74W	2	1	ND	ND	2	ND	ND	0.005	ND	ND
73-SGS-76W	ND	1	ND	ND	1	ND	ND	0.004	ND	ND
73-SGS-77W	ND	ND	ND	ND	1800	680	ND	ND	0.4	0.06
73-SGS-78W	ND	0.5	ND	ND	1	ND	ND	0.006	ND	ND
73-SGS-79W	ND	ND	ND	42	320	ND	ND	ND	ND	ND

TABLE 1-2 (Continued)

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene µg/L	Toluene µg/L	Ethyl Benzene µg/L	Xylenes µg/L	C_4-C_9 TVHC µg/L	C_{10}-C_x TVHC µg/L	CH_2CL_2 µg/L	TCA µg/L	TCE µg/L	PCE µg/L
73-SGS-80W	ND	2	ND	ND	3	0.5	0.5	0.009	ND	0.008
73-SGS-81W	0.8	1	ND	2	4	ND	ND	0.004	ND	ND
73-SGS-82W	ND	1	ND	ND	1	ND	ND	0.009	ND	0.008
73-SGS-83W	ND	ND	ND	ND	34	5	ND	0.002	0.01	0.005
73-SGS-84W	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-85W	1	3	ND	1	16	ND	ND	0.002	ND	ND
73-SGS-86W	13	1	ND	ND	ND	ND	ND	0.003	ND	ND
73-SGS-87W	ND	1	ND	8	34	ND	ND	ND	ND	ND
73-SGS-88W	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND
73-SGS-89W	3	0.6	ND	ND	7	ND	ND	0.002	0.07	ND
73-SGS-90W	0.08	0.4	ND	ND	1	ND	ND	0.004	ND	ND
73-SGS-91W	ND	0.7	ND	ND	1	ND	ND	ND	ND	ND
73-SGS-92W	ND	2	ND	2	27	ND	ND	0.003	ND	ND
73-SGS-93W	0.2	1	ND	0.6	2	ND	ND	0.004	ND	ND
73-SGS-94W	0.2	0.4	ND	ND	8	ND	ND	0.002	ND	ND
73-SGS-95W	ND	0.3	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-96W	ND	0.8	ND	2	14	ND	ND	0.004	ND	ND
73-SGS-97W	0.4	0.9	ND	ND	2	ND	ND	0.006	ND	ND

TABLE 1-2 (Continued)

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene µg/L	Toluene µg/L	Ethyl Benzene µg/L	Xylenes µg/L	C_4-C_9 TVHC µg/L	C_{10}-C_x TVHC µg/L	CH_2CL_2 µg/L	TCA µg/L	TCE µg/L	PCE µg/L
73-SGS-98W	0.2	0.4	ND	ND	0.6	ND	ND	0.003	ND	ND
73-SGS-99W	0.2	0.6	ND	ND	0.8	ND	ND	0.006	ND	ND
73-SGS-100W	ND	1	ND	2	54	ND	ND	ND	ND	ND
73-SGS-101W	0.3	0.6	ND	ND	4	ND	ND	ND	ND	ND
73-SGS-102W	0.2	2	ND	ND	4	ND	ND	0.01	0.008	0.008
73-SGS-103W	0.3	1	ND	1	3	ND	ND	0.008	ND	0.004
73-SGS-104W	0.2	0.6	ND	ND	1	ND	ND	0.003	ND	0.008
73-SGS-105W	ND	2	ND	1	12	ND	ND	0.002	ND	0.004
73-SGS-106W	ND	0.9	ND	0.5	1	ND	ND	0.002	ND	0.004
73-SGS-107W	ND	0.5	ND	1	6	ND	ND	0.002	ND	ND
73-SGS-108W	ND	1	ND	1	9	ND	ND	0.004	ND	0.005
73-SGS-109W	0.2	0.8	ND	1	2	ND	ND	0.002	ND	ND
73-SGS-110W	0.2	0.8	ND	ND	8	ND	ND	ND	ND	ND
73-SGS-111W	0.3	1	ND	1	3	ND	ND	ND	ND	ND
73-SGS-112W	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
73-SGS-113W	ND	0.7	ND	1	2	ND	ND	0.002	ND	ND
73-SGS-114W	0.2	0.8	ND	1	2	ND	ND	ND	ND	ND
73-SGS-115W	0.08	0.6	ND	ND	12	ND	ND	ND	ND	ND

TABLE 1-2 (Continued)

ANALYTICAL RESULTS FROM GROUNDWATER SAMPLE SCREENING
SITE 73 - AMPHIBIOUS VEHICLE MAINTENACE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample	Benzene µg/L	Toluene µg/L	Ethyl Benzene µg/L	Xylenes µg/L	C_4-C_9 TVHC µg/L	C_{10}-C_x TVHC µg/L	CH_2CL_2 µg/L	TCA µg/L	TCE µg/L	PCE µg/L
73-SGS-116W	0.2	0.6	ND	2	2	ND	ND	ND	ND	ND
73-SGS-117W	0.2	0.7	ND	ND	0.9	ND	ND	0.002	ND	ND
73-SGS-118W	0.2	0.8	ND	1	2	ND	ND	0.003	ND	ND
73-SGS-119W	0.2	0.6	ND	ND	0.7	ND	ND	ND	ND	ND
73-SGS-120W	0.08	0.4	ND	0.5	0.5	ND	ND	0.001	ND	ND
AIR - max[ ]	0.2	3	<0.3	0.5	4	<0.5	0.4	0.002	<0.007	<0.001
AIR - min [ ]	<0.08	<0.1	<0.2	<0.4	<0.4	<0.4	<0.07	0.0003	<0.0009	<0.0002

Notes:

TVHC = Total Volatile HydroCarbons
TCA = 1,1,2-Trichloroethane
TCE = Trichoroethene

PCE = Tetrachloroethene
µg/L = Micrograms Per Liter
ND = Not Detected Above Detection Limits

INT = Interference

TABLE 1-3

REMEDIAL INVESTIGATION OBJECTIVES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Site 73 - Soil	1a. Assess the extent of soil contamination at the Courthouse Bay Liquids Disposal Area, including all UST locations (former and present).	Characterize contaminant levels in surface and subsurface soils at the Courthouse Bay Liquids Disposal Area and UST locations.	Drill soil borings and obtain surface and subsurface soil samples.
	1b. Assess human health and ecological risks associated with exposure to surface soils at the site.	Characterize contaminant levels in surface and subsurface soils at the site.	Obtain surface soil samples. Conduct human health and ecological risk assessment.
	1c. Evaluate treatment alternatives.	Characterize areas of concern above action levels. Evaluate effectiveness and implementability of treatment technologies.	Analyze selected soil samples for engineering parameters. Evaluate alternatives under FS. Conduct treatability study, if needed.
2. Site 73 - Groundwater	2a. Determine whether contamination from soils is migrating to groundwater.	Characterize shallow groundwater quality in the area.	Install shallow groundwater wells.
	2b. Assess the extent of shallow and intermediate zone groundwater contamination across the site, and at each known UST location (former and current).	Determine the horizontal and vertical extent of shallow groundwater contamination; determine if shallow contamination has migrated vertically to a lower zone; determine the presence or absence of petroleum product or constituents in groundwater at each UST location.	Install shallow and intermediate zone groundwater wells.
	2c. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow and intermediate aquifers (flow direction, transmissivity, permeability, etc.).	Perform field aquifer tests.
	2d. Assess health risks posed by potential future usage of the shallow and intermediate zone groundwater.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Conduct human health risk assessment.

TABLE 1-3 (Continued)

REMEDIAL INVESTIGATION OBJECTIVES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
3. Site 73 - Sediment	3a. Assess human health and ecological risks associated with exposure to sediments in the unnamed creeks and Courthouse Bay.	Characterize nature and extent of contamination in sediment.	Obtain sediment samples from unnamed creeks and Courthouse Bay. Conduct a risk assessment.
	3b. Assess potential ecological impacts posed by contaminated sediments in the unnamed creeks and Courthouse Bay.	Qualitatively evaluate stress to benthic, crab, and fish communities.	Obtain fish, crab, and benthic samples from the unnamed creeks and Courthouse Bay. Conduct an ecological risk assessment.
4. Site 73 - Surface Water	4a. Assess the presence or absence of surface water contamination in the unnamed creeks and Courthouse Bay.	Characterize surface water quality.	Obtain surface water samples from the unnamed creeks and Courthouse Bay

2.0 STUDY AREA INVESTIGATION

The field program at Site 73 was initiated to characterize potential environmental impacts and threats to human health, ecology and the environment resulting from previous activities. Investigations conducted at the site were initiated in an attempt to define potential impacts to surface and subsurfaces soils, groundwater, sediments and surface waters. Specifically, this study was designed to provide:

- Data regarding the nature and extent of environmental impact on aquatic and benthic species in the two unnamed creeks located east and west of the site as well as Courthouse Bay.
- Additional soil and groundwater data to support a quantitative, site-wide environmental risk assessment.
- Sufficient data to characterize the nature and extent of soil and groundwater contamination (if any) resulting from leaks and/or spills associated with six UST locations within the site boundaries.
- Soil and groundwater data sufficient to afford an evaluation of source, nature, and extent (if any) of shallow, intermediate and deep groundwater contamination and evaluate the groundwater flow patterns in the area.

The RI field activities at Site 73 were conducted in two phases. The first phase of work was intent on detailing the extent of soil and groundwater contamination based on historical information and previous investigations. At the completion of the initial phase, the analytical data was evaluated to determine whether the extent of soil and groundwater contamination had been delineated. With the concurrence of LANTDIV, USEPA, NC DEHNR, and MCB Camp Lejeune, it was concluded that an additional phase of field work was necessary to further define the vertical and horizontal extent of soil and groundwater contamination detected at the site.

The first phase was initiated April 3 and concluded May 25, 1995. Additional work associated with the first phase (primarily IDW management, surveying, and groundwater elevation measurements) was conducted between May 26 and August 21, 1995. The second phase commenced on February 16, and concluded March 27, 1996. Investigative derived waste (IDW) management, groundwater elevation measurements and a geophysical survey associated with the second phase of field work was conducted between May13 and 16, 1996. The field programs consisted of: soil investigations; groundwater investigations; a surface water and sediment investigation; an ecological investigation; a site survey; and IDW handling. All field activities were performed in accordance with the Project Plans submitted March, 1995 and the amendments to the plans submitted January 1996. A summary of these activities, as well as details of any modifications to the plans, are discussed in the following sections.

2.1 Soil Investigation

A soil investigation was conducted at Site 73 to assess the nature and extent of previously detected contamination resulting from past disposal practices and site activities as well as any contamination associated with the UST systems within the site boundary. Additionally, the investigation was conducted to assess human health, ecological, and environmental risks associated with contact, inhalation and possible ingestion of surface and subsurface soil particles. The following subsections describe the drilling procedures, sample locations, sample methods and analytical program for the site.

Baker supervised a total of seventy-six (76) soil borings (73-SB01 through 73-SB14, 73-MW01 through 73-MW37, 73-MW01B, -MW02B, -MW06B, -MW11B, -MW15B, 73-DW01 through 73-DW13, 73-TW01, 73-RW02, and 73-GW01 through 73-GW05) during the two phases of field work. Fifty-five (55) soil borings were advanced during the first phase and 21 during the second for the purpose of sample collection, geologic identification and description, and monitoring well installation. Drilling activities were conducted using a truck-mounted drill rig supplied and operated by Parrott Wolff, Inc. of Syracuse, New York. Soil cuttings obtained during both drilling programs were contained and handled in accordance with procedures outlined in Section 2.5. Drilling and sampling activities were preformed using Level D personal protection and operations were continuously monitored with a photoionization detector (PID) and LEL/O2 meter. All soil boring/monitoring well locations are shown on Figure 2-1.

The soil borings were advanced to three ranges of depth for different purposes. Procedures varied depending upon the type of soil boring needed at each location. Fourteen (14) borings were advanced for soil classification and sample collection purposes only and were terminated at the water table. These borings were designed for collection of information pertaining to soil contamination in areas where additional groundwater monitoring wells were not practical or where information was needed concerning soils only.

Baker supervised the completion of 37 soil borings as shallow groundwater monitoring wells extending approximately 5 to 15 feet below the water table. These borings were terminated at approximately 9 to 21 feet below ground surface (bgs) using 6.25-inch inside diameter (ID) hollow stem augers and, in some, cases were not logged by the site geologist due to the close horizontal proximity of an adjacent deeper boring. These borings were designed to allow construction of monitoring wells with screens that intersect the water table (Figure 2-2).

A total of five borings were completed as shallow-intermediate wells extending approximately 10 to 20 feet below a clay layer that separated the shallow aquifer into two zones across a large portion of the site (see Section 3.4.2). These wells were terminated approximately 32 to 46 feet bgs. Upon placement of the surficial casing, these borings were advanced to the termination depth using fluid (bentonite slurry) rotary drilling methods. These wells were designed to allow the portion of the surficial aquifer that lies between the clay unit and the semi-confining unit of the Castle Hayne Aquifer to be monitored and sampled (Figure 2-3).

Baker supervised the advancement and completion of 13 soil borings for the purpose of installing intermediate groundwater monitoring wells. The monitoring wells were extended 10 to 15 feet into the Castle Hayne Aquifer terminating at approximately 51 to 71 feet bgs. The borings were advanced using fluid (bentonite slurry) rotary drilling methods. These borings were designed in a manner allowing construction of wells that monitor and provide samples from the upper-most portion of the Castle Hayne Aquifer, thus determining whether contamination observed in the surficial aquifer is migrating through the semi-confining unit (Figure 2-4).

Additionally, Baker designed and supervised the advancement of five deep borings to a depth of 150 feet bgs for the purpose of further defining the vertical extent of groundwater contamination associated with the site. Similar to the intermediate borings, they were advanced using fluid (bentonite slurry) rotary drilling methods (Figure 2-5).

Each boring was advanced using 4.25- or 3.25-inch ID hollow stem augers to the appropriate completion depth (shallow borings/monitoring wells) or to the top of a stratigraphic segregating layer (shallow-intermediate, intermediate and deep wells). Those borings designated for shallow well completion were later reamed with 6.25-inch ID augers. Shallow well construction was performed through the larger augers. During the advancement of the shallow-intermediate borings, a 8.25-inch ID hollow stem augers were used as temporary casing sealing off the upper portion of the surficial aquifer from the lower portion. In the deeper borings (intermediate and deep), 10- or 8- inch ID steel casing was installed in the boring to seal off the surficial aquifer from the underlying Castle Hayne aquifer. In each case, the augers and/or steel casing was seated approximately two feet into the less permeable soil units.

All borings were continuously sampled to the water table (located approximately 1.5 to 6.5 feet bgs) and every five feet thereafter until termination of the boring. Soil samples were obtained via a split spoon following methods outlined in ASTM 1586-84 and FSAP (Baker 1995). The sampling protocols were modified in some cases where the site geologist needed more information about a particular soil type, if the boring was in close horizontal proximity to a deeper boring or if the formation appeared to be unstable at a particular interval. Soils were considered unstable if problems occurred during drilling that were indicative of borehole collapse. When these conditions prevailed, samples were not collected until the borehole was advanced beyond the problem interval.

Each split-spoon soil sample was classified by the site geologist. Soils were classified and field screened with a PID, recorded in the field logbook, and later transposed onto boring log records. Classification included characterization of soil type, grain size, color, moisture content, relative density (from Standard Penetration Test "blow counts"), plasticity and other pertinent information such as indications of contamination. Lithologic descriptions of site soils are provided on the Test Boring and Well Construction Records in Appendix B.

2.1.1 Surface and Subsurface Soils

Soil samples were collected from soil boring locations across the site to delineate the vertical and horizontal extent of contamination and provide data for human health and ecological risk assessments. Selection of soil boring/monitoring well locations were based on Camp LeJeune historical records, previous site investigations and existing boring analytics. A summary of the sample numbers and analytical parameters is provided in Appendix C.

Surface soil samples were collected from 52 borings as shown on Figure 2-1, using stainless steel spoons and aluminum pie plates. Samples were collected from zero to 12 inches bgs after the first few inches of top soil and matted roots were removed. The VOC samples were placed directly into the appropriate laboratory supplied containers immediately after collection. The remaining samples were composited in a aluminum pie pan and mixed to homogenize the sample, then placed into the appropriate sample containers. All samples were temporarily stored in ice-filled coolers until shipment to Quanterra Environmental Services in Knoxville, Tennessee, for analyses. The stainless steel spoons were decontaminated prior to sample collection according to the procedures outlined in the FSAP (Baker, 1995).

Soil sampling protocols specified in the FSAP called for two soil samples to be collected from each boring/well cluster location where less than six feet of unsaturated conditions were encountered. These samples were to be collected at the ground surface and directly above the soil/groundwater interface. If greater than six feet of saturated soil conditions were encountered, three samples were to be collected, with the third sample interval to be based on visual observations, field screening using a PID or midway between the surface and the water table. However, the protocols were modified in the field. It was determined that 10 feet of unsaturated soil conditions would better warrant additional samples being collected. This modification was incorporated into the plans in order to reduce the possibilities of collecting an overabundance of unnecessary samples from shallow soil borings.

A single vadose zone, subsurface soil sample was collected from directly above the water table in each boring. The samples were collected via a 2- or 3-inch, split-spoon sampler. Analytical samples were collected in the same manner as surface soil samples.

2.1.3 Analytical Program for Soils

The analytical program for the soil investigation at Site 73 focused on the suspected contaminants of concern based on previous disposal practices, site activities and findings of previous investigations. In general, soils at the site were analyzed for Target Compound List (TCL) organics, Target Analyte List (TAL) metals and Total Petroleum Hydrocarbons (TPH) (EPA Method 8015). Soil samples collected in the vicinity of the UST systems within the site had multiple analytical methods for volatile analyses as required by NC DEHNR regulations governing UST investigations. Additionally, USTs which contain or have contained waste oil required that soil samples be analyzed for oil and grease (EPA Method 9071) and TCLP for organics and metals (EPA Method 1311). In addition to the environmental samples collected at the site, a single soil sample was collected from soil boring 73-MW13 and submitted for engineering parameters analyses. The analyses included fluoride, chloride, total phosphorous, Total Organic Carbon (TOC), alkalinity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), microbial count, Total Kjeldahl Nitrogen (TKN), atterburg limits, and particle-size distribution. The engineering parameters were obtained to assist in selecting potential applicable remediation technologies under the FS.

All soil samples retained for analysis were prepared and handled according to USEPA Region IV Standard Operating Procedures (SOPs) as outlined in the Project Plans (Baker, 1995 and 1996). Chain-of-Custody documentation, which includes information such as sample numbers, date, time of sampling, and sampling party accompanied the samples to the laboratory and is provided in Appendix D. Samples were shipped overnight via overnight courier to the off-site laboratory.

2.2 Groundwater Investigation

The groundwater investigation at Site 73 consisted of several activities including construction of shallow, shallow-intermediate, intermediate and deep monitoring wells, well development, groundwater sampling, static water measurement, tidal study and aquifer testing. The intent of the investigation was to confirm the presence or absence of groundwater contamination in the shallow and Castle Hayne aquifers, evaluate the horizontal and vertical extent of potentially impacted groundwater, and evaluate groundwater flow patterns across the site.

The field procedures and sampling methods employed for this study were implemented in accordance with USEPA Region IV SOPs. Specific sampling procedures are detailed in the RI Project Plans (Baker 1995 and 1996).

2.2.1 Monitoring Well Construction Details

Shallow, shallow-intermediate, intermediate and deep wells were constructed of 2-inch nominal diameter, schedule 40, flush-jointed and threaded, polyvinyl chloride (PVC) casing with 0.010

slotted screen. The only exceptions to the previously stated construction details were the temporary well 73-TW01 and recovery/pumping well 73-RW02. The temporary well was construction of 1-inch nominal diameter, schedule 40, flush-jointed and threaded, PVC casing with 0.010 slotted screen and the recovery/pumping well was construction of 4-inch nominal diameter, schedule 40, flush-jointed and threaded, PVC casing with 0.010 slot, continuous wrap screen. The shallow wells were constructed with a 15-foot section of screen; the shallow-intermediate and intermediate wells were constructed with a 7-to 10-foot section of screen; and the deep wells were constructed with a five-foot section of screen. The shallow-intermediate, intermediate and deep wells required either temporary or permanent casing to seal off the upper water bearing zone from the zone to be monitored. Typically, a 10-, 8-, or 6-inch ID, 3/16-inch thick steel casing was seated into the laterally discontinuous clay unit that separates the surficial aquifer. An 8 or 6-inch ID, 3/16-inch thick steel casing was installed from the surface to the semi-confining unit separating the surficial and Castle Hayne aquifers.

A fine-grained sand pack (#1 sand) was placed in the annulus between the screen and the borehole wall extending above the screen interval about two feet. The shallow wells were installed with a sodium bentonite seal approximately two feet thick placed on top of the sand pack to prohibit intrusion of grout or surface runoff into the sand pack. If shallow groundwater conditions were encountered (i.e., the water table within three feet of the surface), the thickness of the sand pack and bentonite seal may have been reduced to allow for the completion of the well. The shallow-intermediate and intermediate wells had a sodium bentonite seal placed on top of the sand pack continuing two to three feet inside the protective casing to prohibit intrusion of grout into the sand pack or into the aquifer; or surficial ground water into the Castle Hayne aquifer. Likewise, the deep wells had a bentonite seal that continues approximately 10 to 15 feet inside the protective casing for the same reasons as the shallow-intermediate and intermediate wells. Since the column of grout placed in the deep wells is much larger and consequently heavier than the columns used in the shallow-intermediate and intermediate wells, extra bentonite was used to ensure that the grout could not enter the sand pack surrounding the well screen.

The remaining annular space between the bentonite seal and the surface was filled with cement/bentonite grout. A locking protective cover and well pad complete the construction of each well and protected the well from damage and tampering. Cement-filled bollards were used as additional protection for wells not completed flash with the ground surface (i.e., wells placed in high traffic areas). Well tags containing information pertaining to well construction and the notation "Caution Not Potable Water" were affixed to the wells. Well construction details are summarized on Tables 2-1, 2-2, 2-3, 2-4, and 2-5 for pre-existing wells and newly installed shallow, shallow-intermediate, intermediate and deep monitoring wells.

Baker installed 37 Type II groundwater monitoring wells (wells without casing sealing off a confining layer) and one Type II recovery well during the two phases of field work. Thirty (30) wells were installed during the first phase and seven during the second (see Figure 2-1). These wells were installed into the water table aquifer to determine the horizontal and vertical extent of contamination existing within the aquifer, and evaluate the shallow groundwater flow patterns. The shallow wells were constructed allowing the screened portion of the well to intercept the water table yet compensate for seasonal fluctuation. They were constructed in accordance with the Project Plans (Baker 1995 and 1996) and USEPA Region IV SOPs. Well construction details can be found on Table 2-2.

One of the Type II monitoring wells that was installed during the first phase of the investigation was designed and constructed to be used as a recovery/pumping well for use in a scheduled pump test. The pump test was designed to determine a pumping rate and radius of influence for the eventual removal of suspected POL contamination (based on historical data). However, data from the first phase of work indicated that the surficial aquifer did not have as much contamination as originally suspected and may not warrant large scale remediation. Therefore, the pump test was postponed until further information could be gathered during the second phase of field work. The pumping well (73-RW02) was never developed or sampled.

Baker installed a total of 24 Type III groundwater monitoring wells (wells installed with an outer casing to seal off the confining layer), one in each of the shallow-intermediate, intermediate and deep soil borings as well as a temporary deep well. These wells were designed to evaluate the vertical and horizontal extent of contamination (if any) residing in the lower portion of the surficial and the Castle Hayne aquifers; to determine if the laterally discontinuous clay bed is locally impeding the vertical migration of water from the upper portion of the surficial to the lower portion; to determine if the marker bed between the surficial sediments and the Belgrade Formation (commonly referred to as the semi-confining unit separating the surficial and Castle Hayne aquifers) is confining, semi-confining or not confining; and to evaluate the groundwater flow patterns in the upper and the mid to lower portions of the Castle Hayne Aquifer.

The temporary well referenced in the previous paragraph (73-TW01) was installed during the second phase of work. The well was positioned in an area where TCE had been detected in high concentrations during the first phase of work. It was designed to provide data regarding the vertical delineation of TCE contamination in the Castle Hayne aquifer. This data would then be used to establish the depth of all other deep wells at the site. This well was installed in a similar manner to the other deep wells with a few exceptions. The composition of the surface casing was changed from steel to PVC and the diameter was reduced. Additionally the diameter of the riser pipe and slotted screen was reduced to one inch. Upon completion of sampling activities, the well was abandoned according to protocols established by NC DEHNR (North Carolina Administration Code, Title 15A, Subchapter 2C, Section .0100, Well Construction Standards).

Upon completion and curing of the grout, each newly installed well was developed to remove fine-grained sediment from the screen and to establish hydraulic communication between the well and the formation. A minimum of three to five well volumes were removed from each well until the groundwater was essentially sediment-free. Groundwater recovered during development was contained and handled in accordance with procedures outlined in Section 2.5. The wells were developed by a combination of surging and pumping techniques. Hoses used for development were dedicated to each well and discarded upon completion, minimizing the potential for cross contamination. Measurements of pH, turbidity, conductivity and temperature were recorded to assist in evaluating well stabilization. The wells were considered stable when three consecutive measurements of ph, conductivity and temperature were within 10% of the previous measurements. Turbidity stabilization was established when a measurement was under 10 Nephelometric Turbidity Units (NTUs). If the well did not stabilize with in three hours, it was considered developed. Well development forms summarizing the information are provided in Appendix E.

A total of five rounds of water levels were taken at Site 73 to establish groundwater flow direction in both the shallow and Castle Hayne aquifers. Measurements were collected on May 9 and 20, 1995, February 25, March 25, and May 14, 1996, for selected newly installed and existing wells at the site. All groundwater measurements were recorded from the top of the PVC casing using an electronic measuring tape to the nearest 0.01 foot. Measurements were collected within a four-hour time period during each event and can be found on Tables 2-6, 2-7, and 2-8.

Slug testing was conducted on eight shallow and three shallow-intermediate wells at Site 73 during the field programs. Monitoring wells 73-MW01A, 73-MW03, 73-MW11A, 73-MW13, 73-MW20, 73-MW21, 73-MW22, 73-MW23, 73-MW01B, 73-MW11B and 72-MW15B were tested on May 22 and 23, 1995 and February 26, 1996 in order to determine shallow groundwater characteristics. Details regarding the results of these tests are discussed in Section 3 of this report.

A tidal test was conducted at the site during the first phase to determine if or how much of the site is affected by the tides. The test was conducted between the dates of April 12 and May 2, 1995 and involved measurements from a staff gauge located at the edge of Courthouse Bay and monitoring wells A47/3-11, A47/3-22, RW-1, DW-4, MW-8, and MW-7. Monitoring wells A47/3-11 and A47/3-22 are located near Courthouse Bay and were expected to experience some affects associated with tides. The remaining wells were installed by Baker and ATEC during the investigation of UST SA-21 and are located north of Building A47. Data for the test was gathered using Hermit 2000C Data Logger and pressure transducers. Details regarding the results of this test are provided in Section 3 of this report.

2.2.2 Groundwater Sampling

Groundwater samples were collected from 40 newly installed wells and 15 existing wells during the first phase, and 25 newly installed wells and 24 existing wells, one active supply well (BB-44) and one temporary well during the second phase to confirm the presence or absence of contamination in the surficial and Castle Hayne aquifers. Prior to collecting the samples, the wells were purged of three to five well volumes of water using low-flow techniques. Groundwater recovered during the groundwater sampling program was contained and handled in the same manner as the development water. Temperature, conductivity, turbidity and pH were collected after each well volume was removed to determine that the groundwater had stabilized prior to sampling. The definition of stabilization is the same for development and purging. Tables 2-9 and 2-10 summarize the results of pH, temp, specific conductance and turbidity obtained during purging activities. The only notable difference between purging and development was turbidity values less than 10 NTUs were obtained much quicker during purging than during development. Prior to sampling supply well BB-44, the pump was activated and allowed to run for 15-20 minutes prior to sampling.

Samples were collected using a peristaltic pump and Teflon tubing. Flow rates were about 1/4 gallon per minute to establish low flow conditions. This method of purging allows less disturbance within the water column therefore, fewer sediments are captured during sampling creating a false impression of high inorganics in groundwater and the potential of organic compound volatilization is decreased. The tubing was decontaminated prior to sampling and was discarded after sampling any well suspected of being contaminated and at the end of each day's sampling event.

Groundwater samples were introduced directly from the tubing into the appropriate laboratory supplied sample container and stored on ice in a cooler. Preparation of the samples for shipment to the laboratory incorporated similar procedures as to those described for soil samples and are outlined in the Project Plans (Baker 1995 and 1996). Chain-of-Custody documentation (provided in Appendix D) accompanied the samples to the analytical laboratory. Samples were shipped overnight via overnight courier to Quanterra Environmental Laboratory in Knoxville, Tennessee.

2.2.3 Analytical Program for Groundwater Samples

A single round of samples were collected during the first phase of field work at the site. The analytical parameters selected for each sample were dependant upon the objectives associated with the well. Samples collected from monitoring wells designed to investigate USTs which contain or have contained low boiling point fuels (i.e., gasoline or jet fuel) were analyzed via Method 601/602, MTBE, EDB, and isopropyl ether. Groundwater samples collected from wells designed to investigate USTs which contain or have contained high boiling point fuels (i.e., diesel) were analyzed via Methods 602 and 625 (plus the ten largest peaks). Samples originating from monitoring wells designed to investigate USTs which contain or have contained used/waste oil were analyzed via Methods 524.2 and 625 (with ten largest peaks identified). All other monitoring wells were analyzed for volatiles via Method 601/602, and TCL semivolatiles, pesticides and PCBs via CLP protocols. In addition, all monitoring wells were analyzed for TSS and TAL metals (total metals plus five percent of the samples for dissolved metals) via CLP protocols, and an additional sample was collected from monitoring wells 73-MW13 and A47\3-08 and analyzed for BOD, COD, TOC, total Kjeldahl nitrogen (TKN), TDS, total phosphorus, microbial count, and alkalinity.

An additional round of groundwater samples were collected during the second phase of field work. Samples collected during this phase were analyzed for TCL volatiles via CLP protocols, only. In addition, a sample was collected from monitoring well 73-GW01 for engineering parameters, specifically TSS, TDS, BOD, COD, TOC, TKN, alkalinity, microbial count and total phosphorus. The engineering parameters were intended to assist in selecting potentially applicable remedial technologies. A summary of the sample numbers and parameters analyzed are provided in Appendix C.

2.3 Geophysical Investigation

GEO-CENTERS, INC, of Newton, Massachusetts, under contract to Baker, conducted a geophycical survey using electromagnetic induction at Site 73 for the purpose of locating UST A47-1. MCB Camp Lejeune has conflicting reports as to the state of this UST and a geophysical survey was conducted to determine if the UST in question had been removed or abandoned in place. The investigation was conducted on May 14 and 15, 1996, and consisted of surveying two areas on a concrete pad of approximately 6 acres used by the U.S. Marine Corps for parking AMTRACS. The original scope of work was to survey the entire pad, however the scope was amended due to the presence of approximately 40 AMTRACS.

The survey was conducted with a Geonics, Ltd. model EM61 pulsed electromagnetic induction sensor. The system consists of two one-meter square antennas mounted to a well assembly in a top and bottom configuration. The antennas are connected to a battery and an electronic unit mounted in a backpack, which provided power and pulse control. In addition, the antennas are connected to a hand-held recorder.

The basic physical principle of the EM61 system is an electronic pulse which is transmitted at a 75 Hz rate, i.e., 75 pulses per second. Each individual pulse decays rapidly. If ferrous or nonferrous metal objects are present in the ground, eddy currents are induced in these objects, which in turn generate a secondary electromagnetic field. The recorder then samples this secondary field after the initial pulse is transmitted, allowing for the primary field to decay and assuring that any recorded electromagnetic field is due to the secondary field. In actuality, the system uses the principle of stacking to enhance signal-to-noise ratio. This involves summing the secondary fields from 25 consecutive cycles, thereby canceling-out any incoherent noise present in the data. Thus the actual sampling rate is 3 Hz.

At the Site-73 survey, the unit was employed in wheel mode, where the sampling of the electromagnetic field was triggered by an encoder mounted in the wheel assembly, so that the field is actually sampled along a constant interval along the line of survey. This interval is calibrated to be 0.193 m, but it can vary due to several factors, including varying air pressure in the tires of the wheel assembly, deviation of the survey track from a straight line, and deviation of the survey track due to elevation changes along the survey line.

The standard data outputs of the EM61 system are in 4 different channels: the top antenna output, the bottom antenna output, the difference between top and bottom, given by:

$$(\text{difference}) = (\text{top}) - (\text{bottom}),$$

and a channel which attempts to reduce the noise, which is given by the formula:

$$(\text{reduced noise channel}) = (\text{bottom channel}) - 0.28^{*}\,(\text{top channel}).$$

The results of this investigation are included in Appendix F.

2.4 Surface Water/Sediment Investigation

Baker collected surface water and sediment samples from Courthouse Bay and two streams located along the eastern and western portions of the site to assess possible impacts from the site and assist in human health and ecological risk assessments. The surface water/sediment investigation was conducted between May 7 and 23, 1995. A total of 12 sampling locations were proposed in the FSAP (Baker 1995), however, only 11 were accessible during field activities. The remaining station 73SW/SD-10 was too marshy to access by foot and too shallow for boat. The exact sampling locations were determined in the field and corresponded roughly with the aquatic/ecological sampling locations (Figure 2-1). One surface water and two sediment samples (0 to 6 inches and 6 to 12 inches below the sediment surface) were collected from each location.

2.4.1 Surface Water Sample Collection

Baker collected the surface water samples from the approximate mid-vertical point in Courthouse Bay by using a subsurface grab sampler (if the water was greater than two feet deep) or by dipping an unpreserved sample jar into the water by hand (if the water was less than two feet deep). If the water was less than one-foot deep, care was taken while collecting the sample to ensure that the sampler did not contact and/or stir up the sediments, while still being relatively close to the sediment-water interface.

For water greater than two-feet deep, a clean laboratory-supplied 1-liter amber sample bottle was attached to the subsurface grab sampler via a clamp. Baker sampling personnel lowered the bottle to the mid-vertical point, twisted off the lid with a suction cup attachment, and allowed the bottle to fill with water. After the bottle was filled, the lid was secured and the bottle was removed from the water. The contents of the bottle were transferred into the remaining sample bottles in accordance with the FSAP (Baker 1995).

When samples were collected in the streams (typically less than two feet in depth), samples at the furthest downstream station were collected first, with subsequent samples taken at the next upstream stations(s). Due to the influence of tides on the streams, samples were not collected during periods of high tide because stream flow would reverse potentially carrying contaminants upstream. Sediment samples were collected after the surface water samples to minimize sediment disturbance and suspension. If surface water samples were collected after the sediment samples, potentially contaminated sediments could be captured within the surface water sample and could potentially affect the results of the sample analyses.

Care was taken when collecting samples for analysis of volatile organic compounds (VOCs) to avoid excessive agitation that could result in loss of VOCs. VOC samples were collected prior to the collection of other parameters. The sample bottles were filled by pouring down the side until the container was completely filled leaving no headspace. Each filled bottle was checked for bubbles and rejected if encountered.

Each sampling location was marked by placing a wooden stake and bright colored flagging at the nearest bank. The sampling location was marked with indelible ink on the stake. In addition, the distance from the bank and the approximate location of the sample was estimated and recorded in the field log book of one of the Baker personnel. Photographs were taken to document the physical and biological characteristics of the sampling location.

2.4.2 Sediment Sample Collection

At each sediment sampling station, samples were collected at a depth of 0 to 6 inches and 6 to 12 inches. The samples were collected using a decontaminated stainless steel sediment corer fitted with a new disposable plastic liner, eggshell catch, and a decontaminated plastic nosecone or just a plastic liner. In shallow water conditions, it was not necessary to use a coring device but instead, a liner without the cover was sufficient.

Sampling personnel pushed the sediment corer using the necessary extension rods, between 15 and 20 inches into the sediment. The sediment corer was then withdrawn and the plastic liner was removed from the corer. Sediment deeper than 12 inches was extruded from the liner and the 0 to 6 and 6 to 12 inch sediment intervals were placed into separate clean aluminum pie pans.

For shallow water conditions, the plastic liner (sometimes with an eggshell catch) was pushed into 15 to 20 inches into the sediment and withdrawn. The same protocols were applied for the removal and segregation of the samples.

Baker collected the samples for the VOC analysis with a clean stainless steel spoon. The remaining sediment was homogenized and transferred into their respective sample jars. This process was repeated until enough sediment was obtained to fill all the sample jars.

2.4.3 Surface Water/Sediment Sample Analysis

Surface water/sediment samples were analyzed for TCL organics, TAL metals and TOC. In addition, the 0- to 6-inch sample for each location was analyzed for grain-size distribution. A summary of the sample numbers and parameters analyzed are provided in Appendix C. The samples were prepared and handled in accordance with the FSAP (Baker 1995) and USEPA Region IV SOPs.

2.4.4 Ecological Investigation

Baker conducted an ecological investigation at Site 73. Biological samples collected as part of this investigation included fish, crab and benthic macroinvertebrates. The biological samples were collected to obtain population statistics for fish, crab and benthic macro invertebrates and to obtain fish and crab tissue samples for chemical analysis.

2.4.5 Fish Sample Collection

Baker personnel collected fish and crabs in Courthouse Bay (sample number 73FS-01, -02, and -03) using gill nets, trawling, and/or crabpots. The gill nets were constructed of monofilament line and were approximately 50 to 100 feet in length, eight-feet deep and had a stretch mesh size ranging from three to four inches. The nets were deployed with the ends secured with weights and with two yellow buoys marked with Baker's name and scientific collection permit number attached. Most of the nets were deployed along the shore adjacent to the site, however, one net for each station was deployed along the southeastern edge of the bay. The nets were originally proposed to be deployed in the central portion of the bay by the positioning of the nets were modified because of the high degree of boat traffic. Baker deployed gill nets either in the morning or evening, and they were checked within 12 hours of deployment. Fish that were dead for an extended period of time (i.e., bloating, brown gills, etc.) or had been partially eaten were not used for tissue analysis. The reason for exclusion of these fish as samples was decomposition may potentially allow leaching of contaminants from the organs into the edible portions of the fish. In addition, partially eaten fish would allow exposure of tissue to potentially contaminated water.

Baker used a trawl to collect fish at Site 73. The trawl width was 16 feet, with a body netting stretch mesh size of 1-3/8 inches, and 30-inch by 15-inch boards. The net had tickle chains to keep the net on the bottom of the bay. The trawl was deployed off the side of the boat and dragged between five and ten minutes at a time. After the net was brought back on board with the fish then were measured, weighed and released. None of the fish that were collected with the trawl were large enough for tissue analysis. However, several large crabs were collected and retained for tissue analysis.

In addition to the trawl, Baker used crabpots to collect blue crabs at each of the sampling stations. They were either baited with chicken necks or dead fish obtained during the fish sampling, checked daily and re-baited if necessary. The crabpots were constructed of chicken wire with one inch openings. A yellow buoy was attached to each crabpot with Baker's name and scientific collection permit number.

All fish and crabs that were retained for tissue analysis were placed on ice in a cooler lined with a clean plastic bag. Baker measured and weighed the fish and crabs at the site trailer, taking care not to contaminant the samples. The samples then were wrapped in aluminum foil and placed into a plastic bag with a tag identifying the sample number. The wrapped samples were then placed into a freezer.

2.4.6 Fish and Crab Tissue Sample Analysis

Fish and crab tissue samples were collected from the fish and crabs and analyzed for TCL organics and TAL metals. The samples were sent to the laboratory in coolers with dry ice. The samples were prepared in accordance with USEPA Region IV protocols by the laboratory.

2.4.7 Benthic Macroinvertebrate Sample Collection

Baker collected benthic macroinvertebrates in the same proximity as their respective adjacent sediment/surface water sampling locations. Samples were collected from Courthouse Bay and the streams on the eastern and western portions of the site. The samples were collected from a boat using a standard ponar grab in accordance with the FSAP (Baker 1995) or a petite ponar grab sampler. The dimensions of the standard ponar are 0.229 x 0.229 meters (m) [9 x 9 inches (in)] for a sampling area of 0.0523 m^2). The dimensions of the petite ponar are 15.2 x 15.2 centimeters (cm) [6 x 6 in.] for a sampling area of 232 cm^2 (36 in^2). The sampling area of the ponar is used to calculate the species density in individuals per m^2.

The petite ponar was used to collect samples 73BN-01 and -02. These samples were collected down an embankment and it was safer to carry the 25-pound petite ponar than the 60-pound standard ponar. Baker used the standard ponar to collect the remaining samples.

2.5 Investigation Derived Waste

Investigation derived wastes (IDW) were generated during the both field programs at Site 73. The IDW generated includes soil and mud cuttings, purge and development groundwater, personal protective equipment (PPE) , and spent decontamination fluids. The following paragraphs describe the procedures for IDW management for Site 73.

Soil cuttings (and drilling mud) generated during soil boring and monitoring well installations were either placed back into the boring in the same order in which it was taken out, spread out on the ground surface when wells were constructed in the borehole, or placed in a rolloff box if the boring was advanced in a manicured area of the site. In the initial two cases, the philosophy was contaminated soil cuttings would be remedied with the remaining soils during site remediation (if necessary). If the soil cuttings were deemed "clean" then returning them to their place of origin would cause no harm to the environment.

However, in some cases the soils were not spread out near the boring but rather containerized in a roll-off box. Containerization of the soils occurred if site esthetics or conditions (i.e., concrete or asphalt surfaces) did not allow for soils to be disposed in the manner previously described. The soils contained within the roll-off box were sampled and analyzed for Toxicity Characteristic Leaching Procedure (TCLP) (full range), TCL PCBs, and RCRA hazardous waste characteristics. The analytical results of the soils and recommendations for disposal are included in a correspondence letter contained in Appendix G of this report.

During the first phase of field work, spent decontamination fluids and groundwater generated during well development and purging were combined with groundwater from Site 65 and temporarily contained in two 5,000 gallon stainless steel tankers and a 1,000 gallon poly tank. Decontamination fluids and groundwater from the second phase of work was temporarily stored in a single 5,000 gallon tanker pending analytical results. A sample was collected from each of the storage containers and analyzed for TCL organics, TAL metals, and RCRA hazardous waste characteristics. A correspondence letter is included in Appendix H which discusses the results of the analyses and the fate of groundwater contained in each one of the storage tankers.

PPE (e.g., nitrile gloves, tyvek, etc.) were double bagged, labeled and disposed as solid waste in an on site refuse container which eventually was emptied at a sanitary landfill. If the PPE would have been exposed to potentially hazardous substances or excessively contaminated soil or groundwater, the equipment would have been placed in a drum and disposed in a solid waste landfill (Subtitle D).

2.6 References

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NC DEHNR, 1993. North Carolina Department of Environment, Health, and Natural Resources. North Carolina Administrative Code; Title ISA, Subchapter 2C, Section .0100, Well Construction Standards. February 1993.

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SECTION 2.0 TABLES

TABLE 2-1

SUMMARY OF PRE-EXISTING GROUNDWATER MONITORING WELL CONSTRUCTION DETAILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Consultant Supervising Well Installation	Top of PVC Casing Elevation (feet, above msl)(1)	Ground Surface Elevation (feet, above msl)	Stick-Up (feet, above ground surface)	Boring Depth (feet, bgs)(2)	Well Depth (feet, bgs)	Depth of 6" PVC Casing (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)
73GW2(3)	1984	ESE	13.13	10.7	2.7	22.5	22.5	--	7.5-22.5	--	--
73GW3(3)	1984	ESE	11.04	10.2	0.8	--	--	--	--	--	--
73GW5(3)	1986/87	ESE	10.25	7.9	2.4	26.7	26.7	--	11.7-26.7	--	--
DW-2	5-3-92	Baker	18.00	14.2	3.8	30.0	30.0	20.0	24.79-29.61	22.0	20.0
MW-9	4-30-92	Baker	14.92	15.2	-0.3(4)	16.0	14.0	N/A	4.2-13.5	2.0	1.0
MW-13	5-2-92	Baker	12.37	12.3	0.1	13.48	12.0	N/A	2.43-11.2	2.0	1.0
MW-18	1-17-93	Baker	14.18	11.6	2.6	14.0	14.0	N/A	4.25-13.25	2.5	1.0
MW-8	8-22-91	ATEC	12.98	10.0	3.0	15.0	15.0	N/A	2.5-5.0	1.5	1.0
MW-16	1-17-93	Baker	12.15	9.3	2.9	20.0	11.5	N/A	1.79-10.82	1.0	0.5
A47/3-8	10-21-93	Catlin & Assoc.	6.87	7.5	-0.6(4)	17.0	17.0	N/A	2.0-17.0	1.0	0.5
A47/3-9	10-21-93	Catlin & Assoc.	7.15	7.8	-0.6(4)	17.0	17.0	N/A	2.0-17.0	1.0	0.5
A47/3-11	10-21-93	Catlin & Assoc.	8.10	6.5	1.6	17.0	17.0	N/A	2.0-17.0	1.0	0.5
A47/3-13	10-28-93	Catlin & Assoc.	8.54	8.7	-0.2(4)	17.0	15.0	N/A	2.0-15.0	1.5	1.0
A47/3-16	11-1-93	Catlin & Assoc.	7.75	6.3	1.5	16.0	15.5	N/A	2.5-15.5	2.0	1.0
A47/3-22	10-25-93	Catlin & Assoc.	10.45	8.6	1.9	20.0	18.5	15.0	15.5-18.5	16.5	16.0

Notes:

(1) MSL = mean sea level
(2) bgs = below ground surface
(3) Information regarding wells installed by ESE, Inc. during the Confirmation Study is not available. Therefore, information provided within has been estimated based on information provided within the Site Summary Report
(4) Negative values indicate that wells were installed in high traffic areas and the protective casing is flush with the ground surface

TABLE 2-2

SUMMARY OF SHALLOW WELL CONSTRUCTION DETAILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Consultant Supervising Well Installation	Top of PVC Casing Elevation (feet, above msl)(1)	Ground Surface Elevation (feet, above msl)	Stick-Up (feet, above ground surface)	Boring Depth (feet, bgs)(2)	Well Depth (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)
73-MW01	4-8-95	Baker	15.35	13.4	1.9	19.0	18.0	3.0-18.0	2.5	2.0
73-MW02	4-7-95	Baker	14.66	12.8	1.9	19.0	18.0	3.0-18.0	2.5	2.0
73-MW03	4-7-95	Baker	13.70	11.9	1.8	19.0	18.0	3.0-18.0	2.5	2.0
73-MW04	4-20-95	Baker	12.86	13.2	-0.3(3)	11.5	11.5	2.0-11.5	1.5	0.5
73-MW05	4-7-95	Baker	15.78	13.9	1.9	19.0	18.0	3.0-18.0	2.5	2.0
73-MW06	4-6-95	Baker	7.32	5.4	1.9	12.0	10.0	3.0-10.0	2.5	2.0
73-MW07	4-6-95	Baker	13.94	11.8	2.1	19.0	17.0	4.0-17.0	3.0	2.0
73-MW08	4-19-95	Baker	10.98	9.0	2.0	11.5	11.5	2.0-11.5	1.0	0.0
73-MW09	4-20-95	Baker	6.94	7.1	-0.2	12.0	11.0	3.0-11.0	2.0	1.0
73-MW10	4-19-95	Baker	6.54	6.8	-0.3	11.0	11.0	2.0-11.0	1.5	0.5
73-MW11	4-17-95	Baker	13.14	11.3	1.8	19.0	18.0	3.0-18.0	2.5	2.0
73-MW12	5-5-95	Baker	9.76	10.1	-0.3	17.0	15.0	3.0-15.0	2.0	1.5
73-MW13	5-4-95	Baker	8.43	8.80	-0.4	19.0	18.0	3.0-18.0	2.0	1.5
73-MW14	4-21-95	Baker	8.48	8.80	-0.3	19.0	18.0	3.0-18.0	1.5	1.0
73-MW15	4-19-95	Baker	5.00	3.3	1.7	11.0	10.0	3.0-10.0	2.5	2.0
73-MW16	4-22-95	Baker	11.13	11.4	-0.3	15.0	15.0	2.0-15.0	1.5	1.0
73-MW17	5-5-95	Baker	10.69	11.8	-0.3	19.0	18.0	3.0-15.0	2.0	1.5
73-MW18	4-5-95	Baker	12.19	10.2	2.0	18.0	17.0	3.0-17.0	2.5	2.0
73-MW19	4-5-95	Baker	12.73	10.9	1.8	19.0	18.0	3.0-18.0	2.5	2.0
73-MW20	4-9-95	Baker	7.70	5.7	2.0	19.0	18.0	3.0-18.0	2.5	2.0
73-MW21	4-5-95	Baker	7.26	5.2	2.1	21.0	20.0	5.0-20.0	4.0	2.0
73-MW22	4-6-95	Baker	10.11	8.1	2.0	12.0	10.5	3.0-10.0	2.5	2.0
73-MW23	4-6-95	Baker	11.67	9.8	1.9	19.0	18.0	3.0-18.0	2.5	2.0
73-MW24	4-4-95	Baker	6.59	4.8	1.8	19.0	18.0	3.0-18.0	2.5	2.0

TABLE 2-2 (Continued)

SUMMARY OF SHALLOW WELL CONSTRUCTION DETAILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Consultant Supervising Well Installation	Top of PVC Casing Elevation (feet, above msl)[1]	Ground Surface Elevation (feet, above msl)	Stick-Up (feet, above ground surface)	Boring Depth (feet, bgs)[2]	Well Depth (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)
73-MW25	4-19-95	Baker	11.09	8.4	2.7	9.0	9.0	2.0-9.0	1.0	0.0
73-MW26	4-18-95	Baker	16.04	14.1	1.9	18.0	16.0	3.0-16.0	2.5	2.0
73-MW27	4-23-95	Baker	9.52	9.9	-0.4[3]	19.0	18.0	3.0-18.0	2.0	1.5
73-MW28	4-19-95	Baker	11.45	9.3	2.2	11.0	11.0	2.0-11.0	1.0	0.0
73-MW29	4-23-95	Baker	8.76	9.2	-0.4	19.0	18.0	3.0-18.0	2.0	1.5
73-MW30	5-3-95	Baker	9.13	7.4	1.73	19.0	18.0	3.0-15.0	2.5	2.0
73-MW31	2-21-96	Baker	12.06	9.9	2.2	12.0	12.0	2.0-12.0	1.5	0.5
73-MW32	2-23-96	Baker	6.73	4.2	2.5	10.0	9.0	2.0-9.0	1.5	0.5
73-MW33	2-21-96	Baker	14.32	11.6	2.7	12.0	12.0	2.0-12.0	1.5	0.5
73-MW34	2-22-96	Baker	12.90	10.1	2.8	17.0	17.0	2.0-17.0	1.5	0.5
73-MW35	2-23-96	Baker	12.89	10.5	2.4	18.0	18.0	3.0-18.0	2.0	1.0
73-MW36	3-21-96	Baker	8.40	5.8	2.6	11.0	11.0	11.0-2.5	2.0	0.5
73-MW37	3-10-96	Baker	11.12	11.22	-0.1	18.0	18.0	3.0-18.0	2.0	1.0
73-RW2	5-6-95	Baker	13.21	11.3	1.91	16.0	15.0	5.0-15.0	3.0	2.0

Notes:

[1] msl = mean sea level
[2] bgs = below ground surface
[3] Negative values indicate that wells were installed in high traffic areas and the protective casing is flush with the ground surface.

TABLE 2-3

SUMMARY OF SHALLOW - INTERMEDIATE WELL CONSTRUCTION DETAILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Consultant Supervising Well Installation	Top of PVC Casing Elevation (feet, above msl)(1)	Ground Surface Elevation (feet, above msl)	Stick-Up (feet, above ground surface)	Boring Depth (feet, bgs)(2)	Well Depth (feet, bgs)	Depth of 6" Steel Casing (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)
73-MW01B	4-10-95	Baker	15.86	13.80	2.06	38.0	35.0	18.0	25.0-35.0	24.0	16.0
73-MW02B	5-2-95	Baker	14.39	12.50	1.89	32.0	30.0	16.0	20.0-30.0	18.0	14.5
73-MW06B	5-2-95	Baker	6.86	4.88	1.98	43.0	42.0	12.0	32.0-42.0	30.0	10.0
73-MW11B	5-3-95	Baker	13.00	11.20	1.8	38.0	37.0	16.0	27.0-37.0	25.0	14.0
73-MW15B	4-25-95	Baker	4.68	3.20	1.48	46.0	44.0	10.0	34.0-44.0	32.0	8.0

Notes:

(1) msl = mean sea level
(2) bgs = below ground surface

TABLE 2-4

SUMMARY OF INTERMEDIATE WELL CONSTRUCTION DETAILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Consultant Supervising Well Installation	Top of PVC Casing Elevation (feet, above msl)(1)	Ground Surface Elevation (feet, above msl)	Stick-Up (feet, above ground surface)	Boring Depth (feet, bgs)(2)	Well Depth (feet, bgs)	Depth of 8" Steel Casing (feet, bgs)	Depth of 6" Steel Casing (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)
73-DW01	4-19-95	Baker	15.92	14.30	1.62	58.0	57.0	(4)	37.0	47.0-57.0	45.0	34.0
73-DW02	4-21-95	Baker	6.74	7.10	-0.36(3)	63.0	62.0	(4)	45.0	52.0-62.0	49.0	42.5
73-DW03	4-24-95	Baker	8.28	8.80	-0.52	71.0	70.0	(4)	55.0	60.0-70.0	58.0	52.0
73-DW04	4-26-95	Baker	4.68	3.20	1.48	61.0	60.0	(4)	46.6	50.0-60.0	48.0	45.0
73-DW05	4-11-95	Baker	7.32	5.80	1.52	54.0	53.0	(4)	34.0	43.0-53.0	41.0	732.0
73-DW06	3-8-96	Baker	11.85	9.6	2.3	71.0	70.0	13.0	55.0	60.0-70-0	58.0	50.0
73-DW07	3-10-96	Baker	6.85	4.1	2.8	52.0	51.0	10.0	35.0	41.0-51.0	37.0	32.0
73-DW08	3-9-96	Baker	14.33	11.7	2.6	57.0	56.0	13.0	38.0	46.0-56.0	43.0	33.0
73-DW09	3-8-96	Baker	12.57	9.9	2.7	62.0	61.0	18.0	45.0	51.0-61.0	48.0	41.0
73-DW10	3-7-96	Baker	13.29	10.6	2.7	62.0	61.0	--	42.0	51.0-61.0	48.0	35.0
73-DW11	3-8-96	Baker	16.15	14.2	2.0	57.0	55.0	16.0	39.0	45.0-55.0	43.0	35.5
73-DW12	3-9-96	Baker	6.94	4.3	2.6	75.0	74.0	20.0	58.0	64.0-74.0	61.0	55.0
73-DW13	3-12-96	Baker	8.67	6.2	2.5	46.0	45.0	11.0	30.0	35.0-45.0	32.0	29.0

Notes:

(1) msl = mean sea level
(2) bgs = below ground surface
(3) Negative values indicate that the wells were installed in high traffic areas and the protective casing is flush with the ground surface
(4) 8¼" hollow-stem augers were used as temporary casing during the first phase of work at Site 73

TABLE 2-5

SUMMARY OF DEEP WELL CONSTRUCTION DETAILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Consultant Supervising Well Installation	Top of PVC Casing Elevation (feet, above msl)(1)	Ground Surface Elevation (feet, above msl)	Stick-Up (feet, above ground surface)	Boring Depth (feet, bgs)(2)	Well Depth (feet, bgs)	Depth of 10" Steel Casing (feet, bgs)	Depth of 8" Steel Casing (feet, bgs)	Depth of 6" Steel Casing (feet, bgs)	Screen Interval Depth (feet, bgs)	Depth to Sand Pack (feet, bgs)	Depth to Bentonite (feet, bgs)
73-GW01	3-10-96	Baker	15.83	13.8	2.0	152.0	150.0	16.0	39.0	98.0	145.0-150.0	142.7	81.0
73-GW02	3-6-96	Baker	6.69	7.13	-0.4(3)	152.0	150.0	13.0	45.0	100.0	145.0-150.0	143.0	88.0
73-GW03	3-26-96	Baker	5.75	3.1	2.6	151.5	150.0	13.0	33.0	100.0	145.0-150.0	142.5	87.7
73-GW04	3-19-96	Baker	6.55	4.0	2.6	153.0	150.0	17.0	60.0	100.0	145.0-150.0	141.5	59.5
73-GW05	3-21-96	Baker	8.40	5.8	2.6	153.0	150.0	11.0	30.0	104.0	145.0-150.0	142.0	67.0

Notes:

(1) msl = mean sea level
(2) bgs = below ground surface
(3) Negative values indicate that wells were installed in high traffic areas and the protective casing is flush with the ground surface

TABLE 2-6

SUMMARY OF SHALLOW GROUNDWATER LEVEL MEASUREMENTS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Top of PVC Casing Elevation (feet, above msl)	Depth to Groundwater (feet, below top of Casing) February 25, 1996	Groundwater Elevation (feet, above msl) February 25, 1996	Depth to Groundwater (feet, below top of casing) March 25, 1996	Groundwater Elevation (feet, above msl) March 25, 1996	Depth of Groundwater (feet, below top of casing) May 14, 1996	Groundwater Elevation (feet, above msl) May 14, 1996
73-MW01	15.35	5.79	9.56	5.30	10.05	6.60	8.75
73-MW01B	15.86	12.88	2.98	12.79	3.07	13.80	2.06
73-MW02	14.66	5.27	9.39	5.18	9.48	5.84	8.82
73-MW02B	14.39	11.75	2.64	11.68	2.71	12.00	2.39
73-MW03	13.70	4.18	9.52	4.09	9.61	4.58	9.12
73-MW04	12.86	2.76	10.10	2.51	10.35	3.26	9.60
73-MW05	15.78	5.86	9.92	5.41	10.37	6.50	9.28
73-MW06	7.32	6.32	1.00	6.36	0.96	7.72	-0.40
73-MW06B	6.86	4.99	1.87	4.91	1.95	5.02	1.84
73-MW07	13.94	8.14	5.80	7.77	6.17	8.90	5.04
73-MW08	10.98	4.74	6.24	4.55	6.43	5.08	5.90
73-MW09	6.94	4.26	2.68	3.17	3.77	3.28	3.66
73-MW10	6.54	2.97	3.57	2.89	3.65	2.97	3.57
73-MW11	13.14	4.21	8.93	3.92	9.22	4.74	8.40
73-MW11B	13.00	10.33	2.67	10.27	2.73	10.58	2.42
73-MW14	16.15	3.79	12.36	3.74	12.41	3.87	12.28
73-MW15	5.00	3.54	1.46	3.85	1.15	3.91	1.09
73-MW15B	4.68	2.39	2.29	2.37	2.31	2.62	2.06
73-MW16	11.13	2.84	8.29	2.60	8.53	3.06	8.07
73-MW17	10.69	7.79	2.90	5.76	4.93	5.92	4.77
73-MW18	12.19	3.70	8.49	---	---	4.82	7.37
73-MW19	12.73	5.92	6.81	5.74	6.99	7.28	5.45
73-MW20	7.70	2.46	5.24	2.39	5.31	3.60	4.10
73-MW21	7.26	3.58	3.68	3.49	3.77	4.40	2.86
73-MW23	11.67	4.05	7.62	3.89	7.78	4.72	6.95
73-MW24	6.59	2.94	3.65	2.93	3.66	---	---
73-MW25	11.09	4.36	6.73	4.22	6.87	4.70	6.39

TABLE 2-6 (Continued)

SUMMARY OF SHALLOW GROUNDWATER LEVEL MEASUREMENTS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Top of PVC Casing Elevation (feet, above msl)	Depth to Groundwater (feet, below top of Casing) February 25, 1996	Groundwater Elevation (feet, above msl) February 25, 1996	Depth to Groundwater (feet, below top of casing) March 25, 1996	Groundwater Elevation (feet, above msl) March 25, 1996	Depth of Groundwater (feet, below top of casing) May 14, 1996	Groundwater Elevation (feet, above msl) May 14, 1996
73-MW26	16.04	7.02	9.02	6.69	9.35	7.34	8.70
73-MW27	9.52	3.92	5.60	3.82	5.70	4.02	5.50
73-MW28	11.45	6.03	5.42	5.84	5.61	6.25	5.20
73-MW29	8.76	3.08	5.68	3.06	5.70	3.15	5.61
73-MW30	9.13	2.67	6.46	2.65	6.48	3.80	5.33
73-MW31	12.06	---	---	9.69	2.37	10.51	1.55
73-MW32	6.73	---	---	3.98	2.75	5.20	1.53
73-MW33	14.32	---	---	5.70	8.62	7.02	7.30
73-MW34	12.90	---	---	6.25	6.65	7.50	5.40
73-MW35	12.89	---	---	7.60	5.29	8.78	4.11
73-MW36	8.40	---	---	5.35	3.05	7.04	1.36
73-MW37	11.12	---	---	5.89	5.23	6.01	5.11
A47/3-11	8.10	7.06	1.04	7.09	1.01	7.12	0.98
A47/3-13	8.54	4.94	3.60	4.87	3.67	4.88	3.66
A47/3-8	6.87	4.64	2.23	4.61	2.26	4.72	2.15
MW-08	12.98	5.96	7.02	4.76	8.22	7.54	5.44
MW-09	14.92	5.34	9.58	4.96	9.96	4.72	10.20
MW-16	12.15	5.58	6.57	5.41	6.74	6.67	5.48

Notes:

msl = mean sea level

TABLE 2-7

SUMMARY OF GROUNDWATER MEASUREMENTS COLLECTED FROM UPPER PORTION OF CASTLE HAYNE AQUIFER
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Top of PVC Casing Elevation (feet, above msl)	Depth to Groundwater (feet, below top of Casing) February 25, 1996	Groundwater Elevation (feet, above msl) February 25, 1996	Depth to Groundwater (feet, below top of casing) March 25, 1996	Groundwater Elevation (feet, above msl) March 25, 1996	Depth of Groundwater (feet, below top of casing) May 14, 1996	Groundwater Elevation (feet, above msl) May 14, 1996
73-DW01	15.92	12.96	2.96	12.89	3.03	13.66	2.26
73-DW02	6.74	4.84	1.90	4.77	1.97	4.94	1.80
73-DW03	8.28	5.66	2.62	5.62	2.66	5.89	2.39
73-DW04	4.68	2.42	2.26	2.39	2.29	3.64	1.04
73-DW05	7.32	4.42	2.90	4.37	2.95	4.76	2.56
73-DW06	11.85	---	---	9.73	2.12	9.87	1.98
73-DW07	6.85	---	---	4.16	2.69	4.56	2.29
73-DW08	14.33	---	---	11.26	3.07	11.68	2.65
73-DW09	12.57	---	---	9.51	3.06	9.92	2.65
73-DW10	13.29	---	---	10.50	2.79	10.46	2.83
73-DW11	16.15	---	---	13.34	2.81	13.37	2.78
73-DW12	6.94	---	---	4.11	2.83	4.52	2.42
73-DW13	8.67	---	---	6.32	2.35	8.20	0.47
DW-02	18.00	12.28	5.72	---	---	10.60	7.40

Notes:

msl = mean sea level

TABLE 2-8

SUMMARY OF GROUNDWATER MEASUREMENTS FROM MID TO LOWER PORTION OF CASTLE HAYNE AQUIFER
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Top of PVC Casing Elevation (feet, above msl)	Depth to Groundwater (feet, below top of Casing) February 25, 1996	Groundwater Elevation (feet, above msl) February 25, 1996	Depth to Groundwater (feet, below top of casing) March 25, 1996	Groundwater Elevation (feet, above msl) March 25, 1996	Depth of Groundwater (feet, below top of casing) May 14, 1996	Groundwater Elevation (feet, above msl) May 14, 1996
73-GW01	15.83	---	---	13.01	2.82	13.37	2.46
73-GW02	6.69	---	---	4.66	2.03	4.60	2.09
73-GW03	5.75	---	---	3.12	2.63	3.39	2.36
73-GW04	6.55	---	---	3.39	3.16	3.70	2.85
73-GW05	8.40	---	---	5.58	2.82	5.36	3.04

Notes:

msl = mean sea level

TABLE 2-9

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
73-MW01	5/4/95	19.94	2.0	0	65	4.60	19.0	16.5	5.6
				1	65	4.73	19.0	15.2	6.4
				2	65	4.61	19.0	15.1	6.4
				3	***65***	***4.82***	***18.5***	***16.0***	***6.2***
73-MW02	5/4/95	19.93	2.2	0	165	5.72	18.5	15.8	2.0
				1	155	5.60	18.0	16.2	2.4
				2	155	5.38	18.0	15.7	1.4
				3	***140***	***5.43***	***18.0***	***15.4***	***1.1***
73-MW03	5/4/95	20.12	2.4	0	195	5.73	18.5	15.9	4.5
				1	210	5.75	19.0	17.0	4.2
				2	215	5.68	19.0	15.5	4.4
				3	***210***	***5.57***	***19.0***	***15.8***	***4.7***
73-MW04	5/6/95	11.16	1.3	0	175	6.72	14.7	--(7)	4.4
				1	148	6.97	14.6	--(7)	1.7
				2	147	7.12	14.7	--(7)	1.0
				3	***147***	***7.26***	***14.9***	--(7)	***0.7***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)$^{(1)}$	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)$^{(2)}$	pH (SU)$^{(3)}$	Cond. Temp (deg. C)$^{(4)}$	Ph Temp. (deg. C)$^{(5)}$	Turbidity (NTU)$^{(6)}$
73-MW04	5/21/95	11.16	1.3	0	130	5.60	25.0	22	16.8
				1	170	5.58	25.0	22	16.9
				2	195	5.61	25.5	22	15.7
				3	175	5.66	25.5	22	14.1
				4	180	5.44	24.5	22	13.2
				5	175	5.54	24.5	22	10.8
				7	***180***	***5.56***	***24.0***	***22***	***9.1***
73-MW05	5/4/95	20.00	2.1	0	200	5.75	19.5	16.4	4.9
				1	200	5.67	18.0	16.1	2.0
				2	195	5.67	18.5	16.1	2.2
				3	***195***	***5.71***	***19.0***	***16.4***	***2.2***
73-MW06	5/4/95	11.02	0.7	1	470	5.80	18.5	16.2	1.8
				2	430	5.97	18.5	16.5	1.6
				3	***430***	***5.93***	***18.5***	***16.3***	***1.1***
73-MW07	5/4/95	19.02	1.2	0	160	4.66	17.5	13.5	9.9
				1	170	4.75	16.0	14.4	3.3
				2	170	4.87	17.0	16.9	1.8
				3	***170***	***4.78***	***17.0***	***14.8***	***1.2***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)[1]	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)[2]	pH (SU)[3]	Cond. Temp (deg. C)[4]	Ph Temp. (deg. C)[5]	Turbidity (NTU)[6]
73-MW08	5/7/95	13.03	1.2	0	170	5.80	23.5	20.0	4.1
				1	175	5.78	23.0	21.0	7.6
				2	170	5.65	22.0	20.0	6.5
				3	***170***	***5.72***	***21.5***	***20.0***	***6.4***
73-MW09	5/8/95	10.13	1.1	0	270	6.14	22.0	21.0	18.4
				1	285	7.35	23.0	22.0	182.0
				2	280	7.11	23.0	22.0	89.3
				3	285	7.08	24.0	22.0	77.0
				4	***280***	***6.74***	***23.0***	***22.0***	***113.0***
73-MW10	5/7/95	10.38	1.2	0	320	5.98	25.0	24.0	3.2
				1	335	5.89	26.0	24.0	1.7
				2	335	5.90	24.0	23.0	1.4
				3	***325***	***5.94***	***24.0***	***23.0***	***1.5***
73-MW11	5/16/95	20.23	2.6	1	161	6.63	18.2	19.7	3.0
				2	164	6.71	17.9	19.2	2.8
				3	***168***	***6.76***	***17.9***	***18.9***	***2.4***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
73-MW12	5/17/95	14.72	1.8	0	251	6.44	23.8	23.6	1.8
				1	257	6.49	24.0	24.2	1.9
				2	259	6.53	23.9	23.6	2.4
				3	262	6.57	23.9	24.1	2.8
				4	***258***	***6.57***	***23.8***	***24.1***	***2.5***
73-MW13	5/18/95	17.77	2.4	1	378	5.73	23.0	23.4	1.6
				2	382	5.77	24.0	24.2	7.4
				3	***370***	***5.80***	***23.0***	***23.7***	***6.3***
73-MW14	4/25/95	16.95	2.1	0	755	5.73	22.9	26.6	7.6
				1	664	6.42	21.5	23.2	2.7
				2	633	6.36	21.3	22.1	2.5
				3	***638***	***6.33***	***21.3***	***23.6***	***2.3***
73-MW15	5/16/95	11.81	1.4	0	1,467	7.51	20.0	19.6	4.6
				1	1,416	7.60	19.6	20.5	2.1
				2	1,446	7.62	20.4	19.0	1.1
				3	1,448	7.66	20.5	18.9	0.7
				4	***1,446***	***7.65***	***20.5***	***19.1***	***0.6***
73-MW16	5/7/95	13.95	1.7	0	520	6.25	24.0	22.0	8.0
				1	510	6.17	24.0	23.0	4.6
				2	500	6.15	24.0	22.0	4.9
				3	***492***	***6.12***	***24.0***	***22.0***	***4.8***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
73-MW17	5/17/95	17.92	2.0	0	646	6.73	21.2	21.3	3.7
				1	644	6.73	21.0	21.1	1.8
				2	644	6.72	21.2	21.0	2.1
				3	***645***	***6.75***	***21.1***	***21.0***	***1.8***
73-MW18	5/5/95	18.9	2.2	0	120	5.09	19.0	18.0	4.4
				1	125	5.13	18.0	18.0	13.0
				2	115	5.48	20.0	18.0	4.0
				3	***110***	***5.37***	***18.0***	***18.0***	***1.3***
73-MW19	5/5/95	19.99	2.0	0	340	5.67	19.0	19.0	6.4
				1	280	5.85	19.0	18.0	4.0
				2	295	5.74	19.0	20.0	3.1
				3	***300***	***5.72***	***19.0***	***19.0***	***2.5***
73-MW20	5/5/95	20.02	2.6	0	80	4.31	19.0	18.0	0.5
				1	72	4.30	20.0	17.2	0.6
				2	72	4.72	20.0	18.0	0.4
				3	***72***	***4.66***	***20.0***	***18.0***	***0.3***
73-MW21	5/6/95	21.92	2.8	0	280	4.24	16.5	15.0	2.0
				1	285	4.34	17.0	16.0	1.9
				2	285	4.38	17.0	15.0	1.1
				3	***285***	***4.36***	***17.0***	***16.0***	***0.9***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
73-MW22	5/4/95	11.79	1.3	0	200	5.74	19.0	17.4	13.1
				1	190	5.57	19.0	17.2	1.9
				2	200	5.47	20.0	17.9	0.9
				3	***198***	***5.45***	***20.0***	***17.7***	***0.7***
73-MW23	5/6/95	19.99	2.4	0	60	4.14	18.5	16.5	9.5
				1	100	4.15	18.5	16.5	5.8
				2	98	4.30	18.5	16.0	7.7
				3	***98***	***4.05***	***18.5***	***17.0***	***4.1***
73-MW24	5/6/95	19.82	2.5	0	65	4.18	17.0	16.0	6.3
				1	70	4.34	17.0	15.5	4.0
				2	72	4.26	17.0	16.0	3.6
				3	***72***	***4.30***	***17.0***	***16.0***	***3.8***
73-MW25	5/8/95	10.2	0.8	3	185.3	6.31	19.6	20.1	>200
				15	166	6.50	22.6	23.1	>200
				30	168	6.51	23.8	24.6	40.0
				45	171	6.52	25.0	25.6	29.0
				60	173	6.55	25.7	25.4	13.2
				75	***173***	***6.55***	***25.7***	***25.4***	***10.8***
73-MW26	5/7/95	17.82	1.6	0	395	6.32	23.0	20.5	3.4
				1	385	6.36	22.0	22.0	2.3
				2	385	6.40	23.0	20.0	1.3
				3	***375***	***6.45***	***22.5***	***21.5***	***1.0***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)[(1)]	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)[(2)]	pH (SU)[(3)]	Cond. Temp (deg. C)[(4)]	Ph Temp. (deg. C)[(5)]	Turbidity (NTU)[(6)]
73-MW27	5/18/95	15.93	2.0	0	493	6.01	25.4	26.9	2.1
				1	362	5.92	24.6	25.8	0.8
				2	380	5.98	24.6	25.2	0.7
				3	380	5.99	24.8	24.9	0.6
				4	***378***	***6.00***	***24.5***	***25.2***	***0.7***
73-MW28	5/7/95	13.04	1.1	0	215	6.07	23.0	21.0	5.6
				1	230	6.01	23.5	21.0	3.1
				2	235	6.02	23.5	20.0	2.6
				3	***230***	***6.04***	***23.0***	***20.0***	***2.4***
73-MW29	5/18/95	17.61	2.5	0	436	5.87	22.4	22.0	16.1
				1	426	5.96	23.3	23.1	8.9
				2	426	5.94	23.0	22.6	8.1
				3	***430***	***5.91***	***23.2***	***22.4***	***6.3***
73-MW30	5/16/95	20.08	2.8	1	136	4.52	17.3	18.0	4.5
				2	143	4.54	17.2	17.8	3.8
				3	***149***	***4.56***	***18.7***	***19.6***	***3.5***
73-MW01B	5/4/95	36.98	3.8	0	155	5.47	18.0	16.7	4.0
				1	142	5.75	18.0	17.4	2.7
				2	150	5.80	18.5	17.0	2.3
				3	***148***	***5.79***	***19.0***	***16.9***	***2.0***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

				Field Parameters					
Well Number	Sampling Date	Well Depth (ft)[1]	Purge Volume (gal)	Well Volume	Specific Conductance (umhos/cm)[2]	pH (SU)[3]	Cond. Temp (deg. C)[4]	Ph Temp. (deg. C)[5]	Turbidity (NTU)[6]
73-MW02B	5/16/95	31.52	3.3	1	148	6.22	19.0	19.7	11.1
				2	160	6.43	18.8	19.8	43.6
				3	164	6.54	18.9	20.0	18.9
				3.5	163	6.55	18.3	19.1	13.4
				4	165	6.60	18.5	19.1	8.5
73-MW06B	5/19/95	43.23	5.5	0	318	7.32	19.8	20.4	66.4
				1	308	7.35	20.0	20.8	40.2
				2	294	7.40	19.9	20.6	4.5
				3	293	7.45	20.4	20.3	2.5
				4	***289***	***7.44***	***19.9***	***20.9***	***2.0***
73-MW11B	5/17/95	38.65	4.6	1	308	7.22	20.5	21.0	7.7
				2	304	7.29	19.6	20.6	2.0
				3	***306***	***7.58***	***19.8***	***20.7***	***1.6***
73-MW15B	5/17/95	45.16	7.3	0	355	7.38	20.9	21.3	38.2
				1	352	7.39	20.7	21.8	4.6
				2	353	7.40	21.0	21.2	1.2
				3	***353***	***7.38***	***21.1***	***21.4***	***1.4***
73-DW01	5/5/95	58.98	7.3	0	280	6.52	18.0	17.5	31.8
				1	280	6.25	18.5	17.2	33.6
				2	275	6.35	19.5	18.0	4.1
				3	***275***	***6.41***	***19.0***	***18.0***	2.1

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
73-DW02	5/8/95	61.40	9.0	0	950	11.85	21.5	20.0	21.5
				1	1.950	11.95	21.5	20.0	2.4
				2	1,750	12.25	23.5	21.0	*1.8*
				3	***1,750***	***12.29***	***23.0***	***21.0***	***1.6***
73-DW03	5/18/95	68.70	10.5	1	581	7.51	22.1	23.5	28.3
				2	598	7.39	22.2	24.4	5.6
				3	***598***	***7.51***	***24.4***	***24.4***	***5.3***
73-DW04	5/17/95	60.70	9.9	0	430	8.95	21.4	21.8	>200
				1	380	7.72	22.0	22.0	83.1
				2	360	7.58	20.7	21.1	31.8
				3	357	7.55	20.5	20.8	25.4
				4	357	7.57	20.5	20.8	15.1
				5	***357***	***7.55***	***20.5***	***20.7***	***9.7***
73-DW05	5/5/95	54.91	8.1	0	170	9.48	19.5	18.1	43.2
				1	230	9.87	19.5	17.8	8.4
				2	250	9.53	21.0	19.0	2.6
				2.5	245	9.68	20.0	18.5	2.1
				3	240	9.62	19.5	18.5	1.9
				4	***230***	***9.56***	***19.5***	***18.5***	***1.9***
73-GW02	5/16/95	20.92	2.7	1	145	6.16	18.7	19.2	7.2
				2	143	6.14	18.4	18.8	3.9
				3	***142***	***6.19***	***18.2***	***18.9***	***2.9***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
73-GW03	5/19/95	22.86	2.5	0	460	6.58	19.3	20.4	33.0
				1	449	6.55	19.5	19.9	80.5
				2	461	6.50	19.8	20.3	7.4
				3	***456***	***6.49***	***19.4***	***20.0***	***4.1***
73-GW05	5/2/95	27.53	3.6	0	47	5.72	15.1	17.3	2.3
				1	49	5.76	15.0	16.8	0.4
				2	47	5.73	15.0	17.1	0.2
				3	***48***	***5.75***	***14.8***	***16.6***	***0.3***
MW-08	5/2/95	17.01	4.3	0	367	5.86	18.8	20.2	2.7
				1	334	5.76	18.5	21.4	2.6
				2	329	5.77	18.5	21.5	2.6
				3	***328***	***5.74***	***18.9***	***22.3***	***1.9***
MW-09	5/2/95	12.83	1.2	0	260	6.79	21.1	22.4	25.6
				1	268	6.74	20.8	21.8	9.5
				2	268	6.74	20.4	20.9	5.0
				3	***262***	***6.76***	***20.3***	***20.5***	***3.5***
MW-13	5/2/95	12.56	1.3	0	506	6.28	18.8	18.7	2.5
				1	507	6.25	19.0	19.4	4.7
				2	457	6.20	19.5	19.5	6.3
				3	440	6.20	20.2	19.5	3.0
				4	***439***	***6.20***	***19.8***	***19.5***	***1.4***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
MW-16	5/1/95	13.7	1.0	0	287	6.64	19.2	20.2	6.5
				1	299	6.59	17.7	20.2	5.6
				3	333	6.53	18.7	19.5	4.9
				4	343	6.48	18.5	21.1	2.3
				5	***337***	***6.47***	***18.5***	***21.4***	***1.9***
MW-18	5/2/95	15.87	1.3	0	230	5.89	20.2	22.3	6.7
				1	202	5.82	17.6	20.1	4.6
				2	208	5.87	17.6	21.2	3.2
				3	***208***	***5.84***	***17.5***	***20.8***	***2.7***
DW-02	5/6/95	31.98	3.0	0	180	6.23	22.0	21.0	192
				1	175	6.37	22.0	24.0	111
				2	135	6.16	22.0	24.0	32.2
				3	140	6.09	22.0	22.0	8.2
				4	***125***	***6.08***	***24.0***	***21.0***	***4.0***
A47\3-8	5/17/95	16.86	2.0	1	508	5.72	22.5	23.9	0.8
				2	509	5.76	23.8	24.0	5.3
				3	***552***	***5.87***	***26.5***	***27.3***	***5.0***
A47\3-9	5/17/95	16.70	2.1	0	164	5.33	22.3	22.7	1.2
				1	161	5.33	21.1	22.7	1.0
				2	160	5.34	21.4	22.2	0.7
				3	***164***	***5.34***	***21.5***	***23.2***	***5.7***

TABLE 2-9 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE I)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters					
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Cond. Temp (deg. C)(4)	Ph Temp. (deg. C)(5)	Turbidity (NTU)(6)
A47\3-11	5/7/95	18.94	2.0	0	--(8)	5.58	--(8)	--(8)	--(8)
				1	--(8)	5.63	--(8)	--(8)	--(8)
				2	--(8)	--(8)	--(8)	--(8)	--(8)
				3	--(8)	--(8)	--(8)	--(8)	--(8)
A47\3-13	5/17/95	16.25	1.9	***0.5(8)***	***1,426***	***7.21***	***21.3***	***21.9***	***5.5***
A47\3-16	5/7/95	18.54	2.0	0	600	5.81	19.0	17.0	2.7
				1	600	5.75	18.5	17.0	2.5
				2	600	5.74	18.5	17.0	2.1
				3	***600***	***5.70***	***18.5***	***17.0***	***1.5***
A47\3-22	5/8/95	20.35	2.0	0	1,450	5.89	18.5	17.0	6.3
				1	1,250	5.96	23.0	22.0	25.8
				2	***1,200***	***5.65***	***18.5***	***20.0***	***17.2***

Notes:

(1) Measured from top of PVC casing
(2) Specific Conductance at 25°C
(3) SU - Standard Units
(4) Temperature Measured with Cond. meter
(5) Temperature Measured with pH meter
(6) NTU - Nephelometric Turbidity Units
(7) Readings were not collected due to instrument malfunction
(8) Well did not recover sufficiently to provide enough sample to be measured

The bold and italicized results were collected immediately prior to sampling the well.

TABLE 2-10

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Temp (deg. C)	Turbidity (NTU)(4)
73MW-01	2/22/96	19.94	2.31	0	579	4.34	13.8	42.0
				1	565	3.86	13.3	4.2
				2	461	4.10	13.6	1.3
				3	***425***	***4.17***	***13.4***	***0.5***
73MW-02	2/22/96	19.88	2.42	0	295	7.16	15.4	10.0
				1	221	6.75	13.5	9.0
				2	207	6.66	13.8	1.7
				3	***191***	***6.84***	***13.6***	***0.8***
73MW-09	2/23/96	10.12	1.13	0	334	7.90	16.0	180
				1	303	7.63	14.3	79
				2	299	7.54	14.2	30
				3	299	7.52	14.3	16
				4	302	7.49	14.2	22
				5	301	7.41	14.3	24
				7	304	8.05	14.4	50
				10	***293***	***7.55***	***14.5***	***60***
73MW-11	2/23/96	20.02	2.61	0	175	6.72	14.7	4.4
				1	148	6.97	14.6	1.7
				2	147	7.12	14.7	1.0
				3	***147***	***7.26***	***14.9***	***0.7***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

				Field Parameters				
Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Temp (deg. C)	Turbidity (NTU)(4)
73MW-13	2/21/96	17.78	2.33	0	375	6.33	16.4	9.8
				1	357	6.15	17.9	3.8
				2	350	6.07	18.2	2.2
				3	***328***	***6.06***	***19.4***	***1.3***
73MW-14	2/24/96	17.0	2.17	0	608	7.02	16.2	7.8
				1	575	6.81	16.1	8.3
				2	561	6.76	16.0	1.5
				3	***556***	***6.85***	***16.0***	***1.1***
73MW-15	2/27/96	11.80	1.33	0	2,583	6.91	14.0	0.1
				1	1,309	7.08	12.9	0.1
				2	1,246	7.19	13.0	0.1
				3	***1,222***	***7.15***	***13.0***	***0.1***
73MW-19	2/21/96	20.0	2.34	0	391	8.33	14.8	76.0
				1	404	7.39	13.8	66.0
				2	397	6.92	14.1	16.0
				3	***392***	***6.83***	***14.4***	***10.0***
73MW-20	2/23/96	19.96	2.86	0	64	5.85	15.1	1.8
				1	60	5.55	14.7	1.5
				2	65	5.83	14.8	0.9
				3	***61***	***5.57***	***14.8***	***1.0***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

				Field Parameters				
Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Temp (deg. C)	Turbidity (NTU)(4)
73MW-26	2/20/96	18.82	1.91	0	351	7.54	15.8	79.0
				1	345	7.51	14.7	20.0
				2	343	7.53	14.5	11.0
				3	***342***	***7.55***	***14.6***	***3.5***
73MW-27	2/20/96	16.0	1.95	0	350	6.24	17.3	0.7
				1	340	6.17	17.0	0.8
				2	339	6.23	17.5	1.9
				3	***337***	***6.22***	***17.8***	***0.3***
73MW-30	2/22/96	20.06	2.89	0	65	5.13	12.8	17.0
				1	80	4.90	12.3	1.5
				2	86	4.72	12.1	1.0
				3	***90***	***4.73***	***12.1***	***0.9***
73MW-31	3/20/96	13.05	0.68	0	345	6.41	12.2	>200
				1	318	6.73	13.6	3.6
				2	313	6.59	13.5	6.1
				3	331	6.68	13.8	8.6
				5	***326***	***6.59***	***14.2***	***2.5***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Temp (deg. C)	Turbidity (NTU)(4)
73MW-32	3/21/96	11.8	0.68	0	113	7.13	13.2	49.0
				1	96	6.88	13.3	35.0
				2	95	6.86	13.1	36.0
				4	103	7.20	14.1	49.0
				6	95	7.03	13.6	54.0
				9	96	6.92	13.7	52.0
				15	105	7.22	13.2	57.0
				20	***104***	***7.08***	***13.4***	***57.0***
73MW-33	3/20/96	14.35	1.5	0	90	8.45	13.6	16.4
				1	114	8.58	13.6	15.2
				2	117	7.97	13.8	12.0
				3	124	7.64	13.8	10.2
				4	***129***	***7.65***	***13.8***	***9.8***
73MW-34	3/20/96	19.45	2.2	0	61	8.33	12.3	20
				1	59	7.80	11.6	17
				2	61	7.70	12.1	14
				3	59	7.63	11.9	16
				4	60	7.53	11.8	15
				5	60	7.31	12.0	15
				6	61	7.34	11.9	15
				7	60	7.30	11.4	14
				8	***60***	***7.38***	***11.2***	***14***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)$^{(1)}$	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)$^{(2)}$	pH (SU)$^{(3)}$	Temp (deg. C)	Turbidity (NTU)$^{(4)}$
73MW-35	3/18/96	20.95	2.22	0	--	--	--	18.6
				1	116	5.85	13.2	9.7
				2	88	5.30	13.3	3.1
				3	111	5.67	13.6	3.1
				4	85	5.49	13.5	2.2
				5	86	5.43	13.4	1.9
				6	***87***	***5.39***	***13.4***	***1.8***
73MW-36	3/24/96	13.33	1.30	0	285	6.57	15.1	10.1
				1	282	6.57	13.7	4.3
				2	281	6.57	13.6	3.9
				3	281	6.57	13.7	3.8
				4	***286***	***6.60***	***13.6***	***3.8***
73MW-37	3/22/96	17.83	1.68	0	212	7.05	16.6	43.9
				1	302	6.86	17.3	31.0
				2	327	6.79	17.0	14.5
				3	262	6.69	17.2	6.8
				4	***260***	***6.71***	***17.2***	***5.1***
73MW-01B	2/22/96	36.94	3.94	0	146	6.66	16.3	12.0
				1	145	6.53	16.6	3.9
				2	137	6.39	16.8	2.6
				3	***136***	***64.8***	***17.0***	***1.5***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)$^{(1)}$	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)$^{(2)}$	pH (SU)$^{(3)}$	Temp (deg. C)	Turbidity (NTU)$^{(4)}$
73MW-02B	2/22/96	31.54	3.25	0	124	6.46	17.9	112
				1	136	6.45	17.8	16
				2	134	6.51	17.9	7.8
				3	***137***	***6.60***	***18.2***	***3.6***
73MW-11B	2/23/96	38.68	4.66	0	151	6.82	17.9	7.0
				1	223	7.07	18.2	2.3
				2	233	7.19	18.3	1.9
				3	***218***	***7.25***	***18.1***	***4.6***
73MW-15B	2/27/96	45.15	6.80	0	330	7.58	18.3	0.0
				1	321	7.66	18.6	0.2
				2	325	7.83	19.8	0.2
				3	***327***	***7.86***	***19.4***	***0.2***
73DW-01	2/22/96	58.92	7.51	0	259	7.51	16.8	4.5
				1	283	7.39	17.6	5.9
				2	286	7.84	17.9	1.9
				3	***288***	***7.87***	***18.2***	***3.3***
73DW-02	2/23/96	61.10	9.22	0	1,213	11.81	20.6	4.1
				1	493	11.67	20.0	0.9
				2	470	11.39	19.8	2.3
				3	***426***	***11.27***	***19.8***	***1.1***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

				Field Parameters				
Well Number	Sampling Date	Well Depth (ft)[(1)]	Purge Volume (gal)	Well Volume	Specific Conductance (umhos/cm)[(2)]	pH (SU)[(3)]	Temp (deg. C)	Turbidity (NTU)[(4)]
73DW-03	2/21/96	68.5	10.27	0	511	7.72	20.9	21.0
				1	523	7.66	20.5	8.0
				2	560	7.49	19.6	5.0
				3	***571***	***7.59***	***19.1***	***4.5***
73DW-04	2/27/96	60.68	9.46	0	307	7.98	18.6	0.1
				1	336	7.93	19.2	0.1
				2	339	7.80	19.2	0.1
				3	***340***	***7.89***	***19.3***	***0.1***
73DW-05	2/23/96	54.84	8.20	0	144	8.81	17.1	3.8
				1	252	7.51	18.2	0.9
				2	255	7.37	17.8	0.7
				3	***270***	***7.50***	***18.3***	***0.9***
73DW-06	3/20/96	73.05	10.34	0	1,810	11.73	16.5	10.6
				1	3,839	10.69	17.1	6.9
				2	3,204	10.04	16.5	4.7
				3	***3,063***	***9.75***	***16.6***	***5.3***
73DW-07	3/21/96	54.10	7.68	0	2,220	12.24	16.0	9.8
				1	2,168	12.38	15.5	5.8
				2	2,341	12.22	16.7	4.0
				3	***2,197***	***12.12***	***16.4***	***2.7***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Temp (deg. C)	Turbidity (NTU)(4)
73DW-08	8/21/96	60.19	7.70	0	2,203	12.56	16.5	12.3
				1	1,714	12.82	17.4	2.7
				2	1,298	12.76	17.7	2.0
				3	992	12.62	17.4	1.5
				4	916	12.55	17.6	1.5
				5	740	12.45	17.4	1.3
				6	712	12.44	17.2	1.3
				7	***712***	***12.44***	***17.4***	***1.5***
73DW-09	3/20/96	64.90	9.06	0	2,905	12.08	17.1	2.9
				1	745	11.64	16.6	40
				2	409	11.19	16.5	10.1
				3	328	10.97	15.2	6.8
				4	260	10.33	15.6	4.7
				5	***250***	***10.14***	***15.7***	***4.8***
73DW-10	3/18/96	63.54	8.76	0	2,215	11.82	16.1	10.6
				1	2,300	12.03	16.4	1.5
				2	2,382	11.82	16.5	0.8
				3	***2,257***	***11.96***	***16.9***	***1.5***
73DW-11	3/21/96	57.85	7.28	0	305	9.26	16.3	157
				1	290	8.40	18.1	20.0
				2	288	8.09	17.9	11.0
				3	***301***	***8.44***	***19.1***	***7.1***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)$^{(1)}$	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)$^{(2)}$	pH (SU)$^{(3)}$	Temp (deg. C)	Turbidity (NTU)$^{(4)}$
73DW-12	3/22/96	76.22	11.77	0	251	10.05	16.9	17.1
				1	230	10.01	15.8	23.0
				2	231	9.74	16.9	23.0
				3	229	10.22	17.6	7.4
				4	***230***	***9.94***	***17.9***	***5.4***
73DW-13	3/24/96	47.58	6.71	0	194	9.14	16.6	63.7
				1	180	9.37	17.7	24.6
				2	184	9.29	17.8	21.7
				3	185	9.22	17.5	18.0
				4	189	9.15	18.0	13.0
				5	190	9.11	17.7	12.9
				6	191	9.01	17.8	11.1
				7	194	8.96	18.4	12.1
				8	197	8.95	18.5	10.6
				9	***195***	***8.92***	***18.3***	***8.8***
73GW-01	3/22/96	150.5	22.29	0	1,169	11.76	16.8	14.0
				1	1,850	11.62	18.3	6.4
				2	1,604	11.21	18.1	4.9
				3	***1,519***	***10.59***	***17.6***	***5.5***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)(1)	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)(2)	pH (SU)(3)	Temp (deg. C)	Turbidity (NTU)(4)
73GW-02	3/19/96	150.4	23.7	0	744	9.90	18.9	200
				1	2,860	9.17	18.8	122
				2	2,996	8.50	18.9	50.0
				3	***3,008***	***8.03***	***18.6***	***47.0***
76GW-03	3/19/96	153.3	24.5	0	1,171	9.82	17.7	5.1
				1	1,946	8.65	18.7	5.2
				2	2,049	7.84	19.6	5.2
				3	***2,050***	***7.77***	***19.2***	***5.2***
73GW-04	3/24/96	153.6	24.13	0	506	11.78	17.7	81.0
				1	423	9.75	19.4	40.0
				1.5	456	9.43	19.6	9.0
				2	469	9.30	20.3	7.9
				2.5	469	9.18	19.3	8.9
				3	***469***	***9.20***	***19.2***	***6.9***
73GW-05	3/24/96	152.1	23.9	0	832	11.70	18.2	3.4
				1	185	9.99	19.8	>100
				2	236	9.05	18.8	86.5
				3	***270***	***8.94***	***18.3***	***38.5***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well Number	Sampling Date	Well Depth (ft)[1]	Purge Volume (gal)	Field Parameters				
				Well Volume	Specific Conductance (umhos/cm)[2]	pH (SU)[3]	Temp (deg. C)	Turbidity (NTU)[4]
73TW-01	2/21/96	147.1	5.46	0	715	9.12	18.6	>200
				1	619	8.29	20.5	>200
				2	1,404	7.71	20.3	>200
				3	1,901	7.65	20.7	>200
				4	2,076	7.57	19.8	>200
				5	2,145	7.59	20.3	>200
				6	2,173	7.63	20.0	>200
				7	2,143	7.61	19.6	>200
				8	2,112	7.61	18.0	170
				9	2,141	7.65	17.8	104
				10	2,128	7.59	18.0	148
				11	***2,135***	***7.56***	***17.7***	***125***
A47/3-8	2/24/96	17.62	2.12	0	537	6.25	21.3	1.4
				1	505	6.10	21.8	0.8
				2	495	6.13	21.3	0.7
				3	***511***	***6.15***	***21.8***	***1.0***
A47/3-19	2/24/96	19.12	2.18	0	717	6.76	17.5	39.0
				1	710	6.70	17.4	17.3
				2	733	6.72	18.7	12.6
				3	***720***	***6.67***	***17.8***	***6.9***

TABLE 2-10 (Continued)

SUMMARY OF GROUNDWATER SAMPLING FIELD PARAMETERS (PHASE II)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Notes:

(1) Measured from top of PVC casing
(2) Specific Conductance at 25°C
(3) SU - Standard Units
(4) NTU - Nephelometric Turbidity Units

The bold and italicized results were collected immediately prior to sampling the well.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section presents a discussion of the physical characteristics of site surface features, climatology and meteorology, hydrology, geology (regional and site), soils, hydrogeology (regional and site), land usage, ecology (regional and site), and a water supply well inventory of the area. This information was obtained from available literature pertaining to MCB Camp Lejeune and from the RI field activities.

3.1 Topography and Surface Features

The generally flat topography of MCB Camp Lejeune is typical of the North Carolina Coastal Plain. Elevations on the base vary from sea level to 72 feet above mean sea level (msl); however, the elevation of most of Camp Lejeune is between 20 and 40 feet msl.

Drainage at Camp Lejeune is generally toward the New River, except in areas near the coast which drain through the Intracoastal Waterway. In developed areas, natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of Camp Lejeune is in broad, flat interstream areas. Drainage is poor in these areas and the soils are often wet (WAR, 1983).

The U.S. Army, Corps of Engineers has mapped the limits of 100-year floodplain at Camp Lejeune at 7.0 feet above msl in the upper reaches of the New River increasing downstream to 11 feet above msl near the coastal area (WAR, 1983). A large portion of Site 73 lies within the 100-year floodplain of the New River based on elevations acquired during the site survey.

The surface of Site 73 is covered with a mix of vegetation (grasses and heavily wooded areas), asphalt, concrete and structures. The outer perimeter of the site is heavily wooded whereas the central portion of the site is covered with asphalt roads and parking areas (for personal vehicles), concrete parking areas (for heavy equipment), five warehouses, numerous wash basins, six oil/water separators, two hazardous materials storage shelters, a flammable materials storage shed, two maintenance buildings, four ASTs, a water tower, and numerous smaller facilities/shelters. The central portion is well manicured and the wooded areas on the perimeter of the site are bisected by numerous tank trails and contain several areas used for troop maneuvers/training.

The topography of Site 73 ranges from approximately 3 to 16 feet above msl. The topographical high resides in the area of the water tower (well cluster 73-MW26, -DW11, -GW01) and slopes in all directions (radially). The topographical low is located in the vicinity of the concrete ramp used for entrance and exit from Courthouse Bay (well cluster 73-MW15, -MW15B, -DW04, -GW03). The site has numerous areas where the natural topography has been modified by man-made, stormwater collection systems, concrete and paved parking lots, and various structures located on the site. The rain water collected in the stormwater system travels through one of the six oil/water separators and is eventually transported via underground piping and discharged along the northwestern edge of Courthouse Bay. Infiltration rates are expected to be fairly low in the vicinity of the buildings and parking areas; however, high rates of infiltration are expected in the grassy areas (Figure 3-11).

The wooded areas along the perimeter of the site primarily experience natural drainage patterns, however some areas have been modified by the removal and redistribution of earth materials. Infiltration is high within these areas with the exception of the occasional low lying area.

3.2 Surface Water Hydrology

The following summary of surface water hydrology was originally presented in the IAS report (WAR, 1983). The dominant surface water body at MCB Camp Lejeune is the New River. It receives drainage from most of the base. The river is short, with a course of approximately 50 miles on the central Coastal Plain of North Carolina. Over most of its course, the New River is confined to a relatively narrow channel entrenched in Eocene and Oligocene limestones. South of Jacksonville, the river widens as it flows across less resistant sands, clays, and marls. At MCB Camp Lejeune, the New River flows in a southerly direction into the Atlantic Ocean through the New River Inlet. Several small coastal creeks drain into the area of MCB Camp Lejeune not associated with the New River and its tributaries. The New River, the Intracoastal Waterway and the Atlantic Ocean converge at the New River Inlet.

Water quality criteria for surface waters in North Carolina have been published under Title 15 of the North Carolina Administration Code. The following classifications were assigned to the New River and Courthouse Bay.

At MCB Camp Lejeune, the New River falls into two classifications: estuarine waters not suited for body-contact sports or commercial shell fishing (SC) and; estuarine water suited for commercial shell fishing, primary recreation, aquatic life propagation and survival, fishing, wildlife, and secondary recreation (SA). The portion of the river that is nearest to the site, as well as Courthouse Bay and its tributaries, are classified as Class SA.

Surface water in the vicinity of the site is tidally influenced and, as such, the direction of flow is heavily dependent on tidal oscillations. During high tide, surface water flows into the bay and begins to flow up the tributaries feeding the bay. However, the predominant flow at the site is toward Courthouse Bay and eventually the New River.

3.3 Geology and Soil

3.3.1 Regional

MCB Camp Lejeune is situated within the Tidewater region of the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist mostly of interbedded sands, silts, clays, calcareous clays, shell beds, sandstone and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast to a combined thickness of approximately 1,500 feet. These sediments were deposited in marine or near-shore environments and range in age from early Cretaceous to Quaternary time. Regionally, they comprise 10 aquifers and 9 confining units which overlie igneous and metamorphic basement rocks of the pre-Cretaceous age. Seven of these aquifers and their associated confining units are present in the MCB, Camp Lejeune area (Cardinell, et al., 1993). Table 3-1 presents a generalized stratigraphic column for Jones and Onslow Counties, North Carolina, and geologic cross-sections of the MCB Camp Lejeune area are presented on Figures 3-1 and 3-2.

According to Cardinell, et al. (1993) and Harned, et al. (1989), the surficial aquifer is comprised of undifferentiated deposits of silt, sand and clay of Quaternary age. The group of soils has been referred to as the "undifferentiated deposits." The Castle Hayne confining unit is composed of silt and sandy clay averaging 9 feet thick where present. The Castle Hayne aquifer is composed of 60 to 90 percent sand and limestone with clay and silt beds. Studies have determined that the aquifer ranges from 156 to 400 feet thick.

3.3.2 Site-Specific

Information regarding surface soil classifications was obtained from a study entitled Soil Survey, Camp Lejeune, North Carolina (Barnhill, 1984). The soils at the site are categorized into one of four soil complexes mapped at MCB Camp Lejeune including: Wando fine sand (WaB), Urban land (Ur), Muckalee loam (Mk) or Bohicket silty clay loam (Bo).

Surface soils in the area of the A-47 complex, located in the central portion of Site 73, are classified as urban land according to the Soil Conservation Service (SCS). This classification is reserved for soils in areas that are more than 85 percent covered by buildings, streets, parking lots, and other urban uses. Because of the extensive amount of development, the natural soil has been altered and the topography and original landscape have been changed. Nearly all of the precipitation results in runoff which can increase the flood hazard in adjacent low-lying areas.

An area of the site positioned between the A-47 complex and North Carolina State Route 172, and the unnamed tributary to Courthouse Bay located on the western edge of the site, has been classified as the Wando fine sand soil complex according to the SCS. This soil is mapped over the majority of the site. This soil complex is typically found in areas located near the coast and range from 10 to 25 feet above sea level. Most of the acreage is woodland with some unsurfaced roads for tactical vehicle maneuvers. Infiltration and permeability is rapid, surface runoff is slow, and available water capacity is very low. In absence of ground cover, this soil is subject to erosion.

Surface soils adjacent to the unnamed tributary located west of the site have been classified into two distinctly different complexes. Soils located adjacent to the northern-most portion of the tributary were classified as the Muckalee loam complex. This nearly-level, poorly-drained soil is typically located in floodplains and tends to be mapped as long, narrow areas. Infiltration is moderate and surface runoff is very slow. Permeability is moderate and available water capacity is medium. This soil typically experiences flooding for brief periods of time and water ponds in low-lying areas on the wider flood plains for long periods during the winter.

The other complex that comprises the soils adjacent to the unnamed tributary has been classified as the Bohicket silty clay loam. This very poorly drained soil is primarily mapped on tidal flats at elevations less than three feet msl. The areas where this soil type is found are commonly broad and dissected by shallow, narrow waterways. The areas are generally inaccessible and are used by marine and wetland wildlife. Drainage is very slow and shrink/swell potential is high.

Subsurface soils encountered during drilling at Site 73 are representative of undifferentiated, Belgrade and River Bend Formations. Geologic cross sections are presented on Figures 3-3, 3-4, and 3-5.

Numerous borings were advanced within the study area during the RI field investigations conducted by Baker. Subsurface soil descriptions are provided in the Test Boring and Well Construction Records in Appendix B. Additional information regarding the soils were obtained from the previous investigations. The following provides a detailed description of the stratigraphy underlying the study area.

Soil conditions are generally uniform throughout the study area. Typically, the shallow soils consist of unconsolidated deposits of sand and silty sand separated by a discontinuous clay layer that thickens and thins across the site. These soils represent the Quaternary age "undifferentiated" deposits which overlay the Belgrade and River Bend Formations. Sands are fine to medium grained and contain varied amounts of silt and clay. Results of the standard penetration tests indicate that the sands have a relative density of very loose to medium dense. Based on field observations, the sands classify as silty sand (SM) and/or poorly graded sand (SP) according to the Unified Soil Classification System (USCS).

The clay, also originating during the Quaternary age, was described in the field as containing varied amounts of silt, sand and wood fragments. The relative density ranges from very soft to soft. Two feet of the material was collected in a shelby tube, sent to a geotechnical laboratory and analyzed for grain size distribution and vertical hydraulic conductivity. The laboratory determined that approximately 50 percent of the material was clay, 34 percent silt and 16 percent fine sand. The vertical permeability was measured to be 2.6×10^{-7} cm/sec ($7.4\mathrm{x}10^{-4}$ ft/day).

Underlying soils are loose to very dense, greenish-gray, fine sand containing varying amounts of silt and shell fragments, trace (0-10%) clay and cemented sand nodules. This soil unit constitutes the Belgrade Formation typically referred to as the semi-confining unit separating the surficial and Castle Hayne aquifers; however, it appears that this unit is not acting as a confining or semi-confining unit at Site 73. Based on hydraulic head differentials, it does not appear that this unit is restricting flow from the surficial to the Castle Hayne aquifer. This unit appears to be approximately 3 to 15 feet thick, except in the vicinity of monitoring wells 73-DW12/73-GW04 where this unit has been eroded. Cross-sections indicate that a much larger tributary (i.e., a paleochannel) had existed on the eastern edge of the site during deposition of the Quaternary sands which may have connected the New River and Courthouse Bay. The evidence for this theory are: the highly angular, geologically younger sands (typical of Quaternary sands) encountered at depths more typical of the River Bend Formation; the Belgrade and upper units of the River Bend Formations are missing; and topographical maps provided by the USGS (Sneads Ferry, NC and New River Inlet, NC) indicate that wetlands/marshlands located on the north of NC State Route 172 have the same surficial topography as the area in the vicinity of 73-DW12/73-GW04 and the unnamed tributary on the western side of the site (Figure 3-7).

Evidence of paleochannels that cut through the Belgrade formation (Castle Hayne confining unit) has been documented by Cardinell (1993) and Harned (1989). Paleostream channels linking the Castle Hayne aquifer with estuaries and/or the surficial aquifer provide a hydraulic conduit for vertical and lateral migration of contaminated surface water or groundwater.

Beneath the Belgrade resides the River Bend Formation. Thirteen borings were advanced between 10 and 15 feet into this formation and six borings were advanced 100 to 120 feet into this formation. Although the upper portion of the River Bend Formation had been throughly investigated during the RI, knowledge of specific details regarding the condition of the mid to lower portions is limited. Soils comprising the River Bend Formation are partially cemented, white to gray, fine to coarse grained sand with varying amounts of shell fragments intermixed with beds of white to gray, fossiliferous limestone fragments containing varying amounts of cemented sand nodules and shell fragments.

Geologic cross-sections were constructed to illustrate subsurface soil beneath the study area. As shown on Figure 3-3, the site was traversed to provide a cross-sectional view of the study area. The following paragraphs discuss each of the four cross-sections that traverse the site.

Cross-section A-A' depicts subsurface soils to an elevation of -60.4 feet below msl from the southern to the northwestern portion of the site. As illustrated on Figure 3-4, the soil underlying this portion of the study area consists of the forementioned fine to medium sands with varying amounts of silt and clay. The clay unit, which separates the surficial aquifer, thickens and thins across the sections and appears to be continuous along A-A' traverse. It ranges from approximately 2 to 21 feet thick with the upper and lower portions of this unit illustrating irregularity. Fine to medium sands with varying amounts of clay and silt are encountered again beneath the clay with the only exception being the area near 73-MW31/73-DW06. At this location, the clay is positioned on top of the Belgrade Formation (Castle Hayne semi-confining unit).

The semi-confining unit separating the surficial and Castle Hayne aquifers was encountered at an approximate depth 35 feet bgs and appears to imitate the topography across the traverse. The thickness of the unit appears to range from 8 to 12 feet in thickness.

Beneath the Belgrade resides the River Bend Formation in which the Castle Hayne aquifer resides. However, only the upper portion of this formation was investigated along this traverse.

Cross-section B-B' depicts the subsurface soil conditions to an elevation of -146 feet below msl from the northwestern to the eastern portions of the site (Figure 3-4). Overall, the soil types were consistent; however, the erosion of the semi-confining unit is apparent. As noted in previous text, in the area of borings 73-DW12/73-GW04 the Quaternary aged sands extend well below the depth at which the River Bend Formation was expected to have been encountered. In addition, the clay unit appears to be more uniform in thickness and not as irregular in shape and size as previously noted in the A-A' traverse. The clay unit is discontinuous across the traverse and appears to have been eroded away near Courthouse Bay.

The River Bend Formation was investigated to much greater depths along this traverse when compared to the A-A' traverse. A single bed of fossiliferous limestone fragments were encountered at a depth of -101 feet below msl and was approximately 10 feet thick.

Cross-section C-C' illustrates the subsurface soil conditions from the southern to eastern portion of the study area to an elevation of approximately -147 feet below msl (Figure 3-5). The soil types were consistent with soils encountered along cross-sections A-A' and B-B'. The clay unit within the surficial aquifer is much thicker than previously noted. The thickness of this unit ranges from 19 to 30 feet along this traverse thinning and eventually discontinues in the eastern portion of the site.

The thickness of the semi-confining unit increases toward the eastern portion with the maximum thickness detected in the vicinity of monitoring wells 73-MW15, -MW15B, -DW04 and -GW03. East of this cluster, the unit is not detected and is suspected to have been eroded during more recent geologic time. The River Bend Formation appears to be consistent with the types of soils encountered in the previously described traverses.

Cross-section D-D' traverses the site from the western to the eastern portion of the site to an elevation of approximately -147 feet below msl (Figure 3-5). Again, overall the soils did not differ substantially from those previously described. The discontinuous clay unit thickens and thins across the site similar to cross-section A-A'. The only noticeable difference between cross-section D-D' and the previously discussed cross-sections, is the two distinct beds of fossiliferous limestone fragments encountered in the borings verses one bed in the previous cross-sections.

As mentioned previously, evidence of paleochannels (or paleostream channels) which cut through the confining unit separating the Castle Hayne aquifer from the surficial aquifer has been documented.

The erosional event documented on the eastern portion of the site is suspected to be a paleochannel which connected the New River to Courthouse Bay and may act as a conduit for the migration of contaminated surficial groundwater into the Castle Hayne aquifer.

In summary, the soils encountered during investigations within the study area are fairly consistent throughout. Note that within the study area, the clay unit within the surficial aquifer thickens and thins irregularly across the site until it reaches the eastern portion of the site at which it discontinues. The semi-confining unit for the Castle Hayne aquifer also behaves in the same manner as the clay unit as it thickens and thins, eventually discontinuing in the eastern portion of the site. There has clearly been an erosional event that affected the eastern portion of the site and removed a portion of the semi-confining unit and approximately 20 feet of the upper-most portion of the River Bend Formation. The location of the semi-confining unit separating the surficial from the Castle Hayne aquifer was encountered approximately 41 feet bgs. This is consistent with the range reported by the USGS, but exceeds the reported average of 25 feet bgs (Cardinell et al., 1993).

3.4 Hydrogeology

3.4.1 Regional

The following sections discuss the regional and site-specific hydrogeologic conditions. The information presented on the regional hydrogeology is from literature (Harned, et al., 1989 and Cardinell, et al., 1993). Site-specific, hydrogeologic information presented is from data collected during field investigations. Additional information was collected from a technical memorandum prepared by Baker which summarizes groundwater data and aquifer characteristics for MCB Camp Lejeune (see Appendix I).

United States Geological Survey (USGS) studies at MCB Camp Lejeune indicate that the area is underlain by sand and limestone aquifers separated by confining units of silt and clay. These aquifers include the surficial (water table), Castle Hayne, Beaufort, Peedee, Black Creek, and upper and lower Cape Fear. Less permeable clay and silt beds function as confining units or semi-confining units which separate the aquifers and impede the flow of groundwater between aquifers.

The surficial aquifer consist of interfingering beds of sand, clay, sandy clay and silt that contain some peat and shells of Quaternary and Miocene age. These sediments commonly extend to depths of 50 to 100 feet bgs. Thickness of the surficial aquifer in the MCB Camp Lejeune area ranges from 0 to 73 feet, and typically average 25 feet (Cardinell, et al., 1993). The aquifer is generally thickest in the interstream divide areas and may be absent where it is cut by the New River and its tributaries. The clay, sandy clay, and silt beds that occur in the surficial aquifer are thin and discontinuous throughout. A semi-confining unit is found in the surficial aquifer within some portions of MCB Camp Lejeune.

Recharge to the surficial aquifer is by rainfall. The aquifer receives more recharge in the winter than in the summer when much of the water evaporates or is transpired by plants before it can reach the water table. Most of the surficial groundwater is discharged to local streams, but some water passes through the underlying semi-confining unit. Recharge for the surficial aquifer is based on an average rainfall of 52 inches per year and an average recharge of 30 percent, or an annual recharge of approximately 16 inches per year (Table 3-2). The remaining 70 percent of the rainfall is lost as surface runoff or evapotranspiration. Sixteen inches of recharge equates to 7,600,000 gallons per day (gpd) per square mile or approximately 114,000,000 gpd for all of MCB Camp Lejeune (based on 150 square miles of recharge area). Water levels in the wells tapping the surficial aquifer vary seasonally. The water table is generally highest in the winter and spring, and lowest in the summer and early fall. The estimated lateral hydraulic conductivity for the surficial aquifer is 50 feet per day (ft/d) and is based on a general composition of fine sand mixed with some silt and clay (Cardinal, et al., 1993).

Although the aquifer is classified as GA (i.e., existing or potential source of drinking water supply for humans), it is not used as a potable water source at MCB Camp Lejeune because of its low yielding production rates (typically less than three gpm).

The Castle Hayne semi-confining unit in the MCB Camp Lejeune area is characterized as less permeability beds overlying the Castle Hayne aquifer that have been partly eroded or incised in places. This unit is composed of clay, silt, and sandy clay, with vertical hydraulic conductivity estimates of 1.4×10^{-3} to 0.41 feet/day. The range in vertical hydraulic conductivity of the semi-confining layers determines the degree to which the semi-confining unit transmits flow. The thickness of the semi-confining unit ranges from zero to 26 feet and averages about nine feet where present.

The principal water supply aquifer for MCB Camp Lejeune is the Castle Hayne aquifer. This aquifer primarily resides within the River Bend Formation which consists of sand, cemented shells and limestone. The upper portion of the aquifer is primarily comprised of calcareous sands with some thin clay and silt beds. The sand becomes increasingly more limy with depth. The lower portion of the aquifer is comprised of partially unconsolidated limestone and sandy limestone interbedded with clay and sand. Also, buried paleostream channels containing various deposits exist within the aquifer. The top of the aquifer ranges from 10 feet above sea level to 70 feet below sea level and is irregular over most of the northern portion of MCB Camp Lejeune. The aquifer is more regular in areas southeast of the New River, where it slopes southeastward. The Castle Hayne thickens to the east, from 160 feet in the Camp Geiger area to over 400 feet at the eastern boundary of MCB Camp Lejeune.

Estimated transmissivity, hydraulic conductivity and storage coefficient values for the Castle Hayne aquifer range from 6,100 to 183,300 gpd/ft, 14 to 91 feet/day and $2\text{x}10^{-4}$ to $1.9\text{x}10^{-3}$, respectively. An aquifer pump test conducted by ESE (1988) in the Hadnot Point Industrial Area, using an existing water supply well (HP-642), indicates an average transmissivity and storage coefficient of 9,600 gpd/ft and $8.8\text{x}10^{-4}$, respectively (ESE, 1988). Table 3-3 summarizes the previously stated information.

Recharge of the Castle Hayne aquifer at MCB Camp Lejeune is primarily received from the surficial aquifer. Natural discharge is to the New River and its major tributaries. The Castle Hayne aquifer provides roughly seven million gallons of water to MCB Camp Lejeune. Groundwater pumping has not significantly affected natural head gradients in the aquifer.

MCB Camp Lejeune lies in an area where the upper part of the Castle Hayne aquifer contains freshwater. Saltwater is found in the bottom of the aquifer in the region and in the New River estuary; both are of concern in managing water withdrawals from the aquifer. Over pumping the deeper parts of the aquifer or in areas hydraulically connected to estuarine streams could cause saltwater intrusions. The aquifer underlying most of the area contains water having less than 120 milligrams per liter (mg/L) of chloride.

3.4.2 Site-Specific

The following sections describe the site hydrogeologic conditions for the surficial (water table) and Castle Hayne aquifers underlying Site 73. Hydrogeologic characteristics in the vicinity of the site were evaluated by reviewing existing information and installing a network of shallow, shallow-intermediate, intermediate, and deep monitoring wells.

Groundwater was encountered at varying depths during the drilling programs. The variation was primarily attributed to topographical changes. In general, the groundwater was encountered between 1.0 and 6.5 feet bgs during field activities.

As previously described in Section 2.2.1, two rounds of groundwater measurements were collected during the first phase (May 9 and 20, 1995) and three rounds were collected during the second phase (February 25, March 25, and May 14, 1996). The water levels were collected from selected shallow, shallow-intermediate, intermediate, and deep monitoring wells within the study area. The measurements are recorded on Tables 2-6, 2-7 and 2-8 and groundwater contours for the surficial and Castle Hayne aquifers are depicted on Figures 3-6, 3-7, and 3-8.

Shallow groundwater elevations exhibited some fluctuation between February 25 and May 14, 1996. The water table decreased an average of 0.24 feet in elevation between February 25 and March 25, 1996. Although most of the monitoring wells demonstrated a decrease in head ranging from 0.01 to 2.03 feet, three wells showed an increase in head ranging from 0.03 to 0.31 feet. Conversely, between March 25 and May 14, 1996, the water table increased an average of 0.94 feet in elevation. The majority of the monitoring wells surveyed on May 14, 1996 demonstrated an increase in head; however, one shallow well (MW-09) showed a decrease in elevation (0.24 feet).

Typically at MCB Camp Lejeune, a higher water table is observed in the winter and spring and a lower water table is noted in the summer and fall. According to historical rainfall data provided by the Naval Oceanography Command Detachment, rainfall increases throughout the summer with July recording the largest quantity per year on average. A decrease in amount of rain is usually observed in August; however, the month of August historically records the second highest quantity of rain for the entire year with the month of June recording the third highest amount (see Table 3-2). During the spring and summer of 1995, the following quantities of rain were recorded by Headquarters and Headquarters Squadron Station Weather (H and HSSW) located at the Marine Corps Air Station (MCAS), New River:

- April - 0.14 inches
- May - 3.66 inches
- June - 9.54 inches
- July - 2.37 inches
- August - 7.49 inches

These actual quantities were well below the historical average for these months. Winter and spring seasons provided the following quantities of precipitation as recorded by H and HSSW at MCAS, New River:

- January - 4.53 inches
- February - 1.47 inches
- March - 4.77 inches

- April - 3.06 inches
- May - 2.94 inches

The quantities reported for February and May are below the historical average. However, January and April recorded average precipitation and March was well above average. Appendix H contains the Weather Service Reports obtained from H and HSSW.

Shallow groundwater elevations and flow patterns observed on March 25, 1995 as well as gradient calculations are depicted on Figure 3-6. The data indicates that the surficial groundwater flow is radial with an average gradient of 1.32×10^{-2} ft/ft. The groundwater contours appear to somewhat parallel the topography of the site with the highest groundwater elevations corresponding to the highest surface elevations. Shallow groundwater is suspected to discharge to Courthouse Bay (south), the eastern and western unnamed tributaries, and the New River (north). The steepest gradient observed at the site appears to be in the vicinity of monitoring wells 73-MW06, 73-MW06B, 73-MW07, 73-MW09 and 73-MW25 toward the east. This area corresponds to a relatively steep decline in surficial elevation as well as a discharge area for surficial groundwater into Courthouse Bay. The concrete pad and wall located south of Buildings A-1 and A-2, provide very little chance for groundwater to discharge into the bay, hence the higher groundwater elevations in the wells in this area as opposed to the elevations recorded in wells 73-MW06 and 73-MW15.

Groundwater elevations collected in the area north of Building A-47, specifically MW-08, indicate that localized surficial groundwater recharge occurs in this area. During most of the spring months, the area near monitoring wells 73-MW24, 73-MW19, MW-16, 73-MW20 and MW-08 typically contains ponded water. The surficial runoff from the marsh lands located north of State Route 172 travels under the state route via stormwater culverts and dumps into the area near 73-MW24. This water adds to the water already collecting in the area to create a large, shallow pond that dissipates slowly over numerous weeks.

Additionally, groundwater elevations collected from monitoring wells 73-MW17, 73-MW37, 73-MW27, 73-MW14, A47/3-08 and A47/3-13 indicate that a lesser surficial groundwater recharge area exists in this area. The surface of the area is covered with concrete and surface water is collected in stormwater collection systems. The only feasible source for groundwater recharge is a cracked or broken stormwater collection line. This would not provide the amount of recharge evident in the vicinity of MW-08; however, it would provide enough water to disturb the natural groundwater flow.

Hydraulic conductivity tests were performed at the site on May 22 and 23, 1995 and February 26, 1996. The log normal average conductivity recorded for the upper portion of the surficial aquifer was 1.3 ft/day (4.6×10^{-4} cm/sec) and the log normal average for the lower portion was 3.6 ft/day (1.3×10^{-3} cm/sec). These values were calculated using the Geraghty and Miller, Aquifer Test Solver (AQTESOLV) program which uses the Bouwer and Rice (1976) method for unconfined aquifers. The average values are consistent with expected values of hydraulic conductivity for the well sorted fine sands observed at the site (Fetter, 1980). The copies of the AQTESOLV printouts are located in Appendix I and the results are summarized on Tables 3-4 and 3-5.

A study of data from other aquifer tests (pump tests) performed at MCB Camp Lejeune was conducted by Baker to further evaluate aquifer characteristics and production capacities. The technical memorandum is provided in Appendix J. The information contained in this memorandum pertains primarily to the surficial aquifer. Average pumping rates range from 0.5 to 3 gpm. Transmissivity ranges from 7.1 to 7,100 ft^2/day; storativity ranges from 1.5×10^{-3} to 7.5×10^{-2}; and hydraulic conductivity ranged from 0.5 to 1.4 ft/day.

A tidal study was conducted during the first phase of field work conducted at between April 12 and May 2, 1995. As expected, the monitoring wells located near Courthouse Bay (A47/3-11 and A47/3-22) demonstrated changes in head that correspond to the tidal oscillations occurring in the bay but at a lesser magnitude. The wells located north of Building A-47 did not demonstrate changes in head corresponding to the tides (see data in Appendix K). A theoretical zone of tidal influence was calculated to determine the horizontal distance at which the tides should no longer effect the groundwater flow. To calculate this, the following formula was used:

- $H_x = H_o \exp(-x\, S/t_o T)$ (Fetter, 1988)

Where:

H_o = Amplitude of tidal change
t_o = Tidal period
x = Some distance inland from the bay
H_x = Amplitude of tidal fluctuation at some distance x
S = Storativity
T = Transmissivity

Based on the above referenced formula, monitoring wells located at a distance of 56 feet from the bay should not experience significant tidal influence (greater than 0.01 feet).

Fluctuation of the groundwater elevations within the intermediate and deep wells completed within the Castle Hayne aquifer were observed over three and one-half months; however, the fluctuations was not as significant as observed in the shallow wells. An average decrease of 0.05 feet was observed between February 25 and March 25, and a increase of 0.40 feet in the groundwater elevation March 25 and May 14, 1996.

Groundwater elevations and flow patterns for the upper portion of the Castle Hayne aquifer are depicted on Figure 3-7. Groundwater appears to flow in a southeastern direction over most of the site at an average gradient of 7.58×10^{-4} ft/ft; however, the northern portion of the site appears to have a gradient divide that parallels State Route 172. The groundwater elevations indicate that the gradient changes direction north of the divide to a northeastern direction. It should be noted that monitoring wells 73-DW09 and 73-DW10 are the only wells located north of State Route 172 that are constructed in a manner that allows monitoring the upper portion of the Castle Hayne aquifer. Note that the groundwater elevation of monitoring well 73-DW13 (located across Courthouse Bay, southeast of the site) is higher than the elevation of the wells located on the downgradient portion of the site indicating that groundwater is not flowing in the direction of the supply well BB44 (located east of 73-DW13).

Figure 3-8 depicts the groundwater elevations and flow patterns for the middle to lower portions of the Castle Hayne aquifer. Given the limited number of points, groundwater flow direction and gradient is estimated to flow in a southern direction with a gradient of 1.0×10^{-3} ft/ft. The northern portion of the site is not represented in Figure 3-8 because no wells were constructed in this portion that would allow monitoring of the middle to lower portions of the Castle Hayne aquifer. The elevation of the groundwater in the area of 73-GW05 is equal to the elevation observed in monitoring well 73-GW01. This indicates that groundwater flow in this portion of the aquifer is not toward supply well BB44.

3.4.3 Site 73 Groundwater Flow Model Summary

The regional groundwater discharge areas around Site 73 are the New River and all of its tributaries (including swamps, wetlands, and streams), many of which lie very nearly at sea level. The Base-Wide groundwater flow model (Baker, 1996) simulated the three-dimensional pattern of groundwater flow within the surficial units and the Castle Hayne aquifer. The model demonstrated that discharge to the New River is the controlling factor on flow directions in the Castle Hayne aquifer in the regional vicinity of Camp Lejeune.

The Site 73 groundwater model describes the three-dimensional pattern of groundwater flow in and between the surficial unit and Castle Hayne aquifer. The flow portion of the groundwater model has been calibrated to match measured head values at Site 73. The simulated water table contours in the surficial unit (Appendix L, Figure A) look very much like those contoured from the measured values (Figure 3-6). The simulated piezometric surface in the upper Castle Hayne aquifer (Appendix L, Figure B) also closely resembles the measured surface in the DW-series intermediate wells (shown in Figure 3-7). Appendix L, Figure C shows the simulated piezometric surface in the lower Castle Hayne aquifer and is very similar to the contours in the GW-series deep wells (Figure 3-8).

Most of the area surrounding Site 73 is a recharge area. The elevation of the upper Castle Hayne aquifer is below that of the water table everywhere except very near to Courthouse Bay. This indicates that there is a very strong downward component of flow over most of the site which becomes critical in understanding groundwater flow.

According to pathline analysis, done as part of the overall modeling effort, groundwater in the surficial aquifer moves in accordance with the contours in Appendix L, Figure A for a relatively short distance until it can make its way downward into the Castle Hayne aquifer. The areas where there is no confining unit provide the shortest path. To illustrate such movement, a particle of groundwater recharging the water table near the suspected location of UST A47/1 would move northeast and then north into the area just northeast of Building A-47 before it reaches the bottom of the surficial unit and then moves into the upper Castle Hayne (there is no clay unit in this area). The particle would then start to flow south, southwest toward Courthouse Bay in accordance with the contours on Appendix L, Figure B. At some point the movement of the particle would change from downward to upward as it enters the discharge area. Appendix L, Figure D is a south to north cross-section from the pathline analysis which shows how the flow is mostly downward in the north and changes to upward flow in the south.

3.5 Land Use and Demographics

MCB Camp Lejeune presently covers an area of approximately 236 square miles. Currently, the military population of MCB Camp Lejeune is approximately 41,000 active duty personnel. The military dependent community is in excess of 32,000 civilian employees perform facilities management and support functions. The population of Onslow County has grown from 17,738 in 1940, prior to the formation of the base, to its present population of 121,350.

During World War II, MCB Camp Lejeune was used as a training area to prepare Marines for combat. This has been a continuing function of the facility during the Korean and Vietnam Conflicts and the recent Gulf War (i.e., Desert Storm). Toward the end of World War II, the base was designated as home for the Second Marine Division. Since that time, Fleet Marine Forces units also have been stationed here as tenant commands.

The existing land use patterns in the various geographic areas within the MCB are described in this section and listed, per geographic area, on Table 3-6. In addition, the number of acres comprising each land use category has been estimated and provided on the table. The areas described below are depicted on Figure 1-2.

Site 73 (the Amphibious Vehicle Maintenance Facility) refers to a 81 acre parcel of land centered around Building A47 located in the Courthouse Bay section of MCB, Camp Lejeune. Courthouse Bay is located on the south side of state road 172 along the eastern shore of the New River. It is one of a series of small bays which are formed by the New River.

The Amphibious Vehicle Maintenance Facility has a primary function of servicing and storing amphibious vehicles stationed at the base. Wash basins are positioned along the southeastern edge of the fence encompassing the compound and are used to clean the AMTRACs upon return from field operations and pre/post maintenance. The primary maintenance facility is Building A47, however some truck maintenance is preformed in Building A-2. Additionally, supplies for servicing are stored in the five warehouses (A-1, A-8, A-9, A-10 and A-11). Several wide, cleared trails for tanks and AMTRACs bisect the wooded portions of the site. Some areas within the woods are designated for troop training and maneuvers.

3.6 Climatology and Meteorology

Although coastal North Carolina lacks distinct wet and dry seasons, there is some seasonal variation in average precipitation (See Table 3-2). July tends to receive the most precipitation and rainfall amounts during summer are generally the greatest. Daily showers during the summer are not uncommon, nor are periods of one or two weeks without rain. Convective showers and thunderstorms contribute to the variability of precipitation during the summer months. October tends to receive the least amount of precipitation, on average. Throughout the winter and spring months precipitation occurs primarily in the form of migratory low pressure storms. MCB Camp Lejeune's average yearly rainfall is approximately 52 inches. Table 3-2 presents a climatic summary of data collected during 35 years (January 1955 to December 1990) of observations at Marine Corps Air Station New River.

Coastal plain temperatures are moderated by the proximity of the Atlantic Ocean. The ocean effectively reduces the average daily fluctuation of temperature. Lying 50 miles offshore at its nearest point, the Gulf Stream tends to have little direct effect on coastal temperatures. The southern reaches of the cold Labrador Current offsets any warming effect the Gulf Stream might otherwise provide.

MCB Camp Lejeune experiences hot and humid summers, however ocean breezes frequently produce a cooling effect. The winter months tend to be mild, with occasional brief cold spells. Average daily temperatures range from 38°F to 58°F in January and 72°F to 86°F in July. The average relative humidity, between 75 and 85 percent, does not vary greatly from season to season.

Observations of sky conditions indicate yearly averages of approximately 112 days clear, 105 partly cloudy, and 148 cloudy. Measurable amounts of rainfall occur 120 days per year, on the average. Prevailing winds are generally from the south-southwest 10 months of the year, and from the north-northwest during September and October at an average speed of 6.9 miles per hour.

3.7 Water Supply

Potable water for MCB Camp Lejeune is supplied entirely by groundwater. The Base has no formally established groundwater preservation areas; however, because the Base controls more than 110,000 acres of land, and because much of this land has remained undeveloped, the undeveloped areas serve the function of groundwater preserves. Groundwater usage is roughly seven million gallons per day (Cardinell, et al., 1993). Groundwater is pumped from approximately 77 of 90 water supply wells located within the boundaries of MCB Camp Lejeune. According to base personnel, groundwater is treated at five plants located at Hadnot Point, Holcomb Boulevard, Marine Corps Air Station, Courthouse Bay and Onslow Beach having a total capacity of 15.8 million gallons per day.

All of the water supply wells utilize the Castle Hayne aquifer. The Castle Hayne aquifer is highly permeable, semi-confined aquifer that is capable of yielding several hundred to 1,000 gpm in municipal and industrial wells in the MCB Camp Lejeune area. The water supply wells at the Base average 162 feet in depth; eight inches in diameter (casing); and yield 174 gpm (Harned, et al., 1989). The water is typically a hard, calcium bicarbonate type. Table 3-7 provides a summary of the supply wells within a one-mile radius of Site 73. The locations of these supply wells are depicted in Figure 3-9. Information pertaining to the supply wells was gathered from the Wellhead Management Program Engineering Study 91-36 (Geophex, 1991), the Preliminary Draft Report Wellhead Monitoring Study 92-34 (Greenhorne and O'Mara, Inc., 1992), and interviews with base personnel.

Three active wells are located within a one-mile radius of Site 73 (BB-44, BB-47, and BB-220) and two active wells are located just beyond a mile (BB-218 and BB-221). Production well BB44 is located approximately 4,225 feet from the site. The total depth of this well is 62 feet bgs and is screened from 32 to 62 feet bgs. This well is suspected to have been impacted by surficial groundwater infiltration due to its relatively shallow screen. Additionally, contamination was detected in samples collected from this well during the study conducted by Greenhorne and O'Mara in 1992. Trichloroethane (TCE) was detected in the sample from supply well BB-44 at a concentration of 1 µg/L. Site 73 was listed as one of the possible sources for the TCE contamination. Therefore, the supply well was resampled during the second phase of field work.

Production wells BB47, BB218, BB220, and BB221 have total depths of 150, 185, 150, and 200 feet, respectively. The screen intervals for the wells (measured in feet bgs) are as follows:

- BB 47 - 40-53 feet; and 102-125 feet
- BB 218 - 64-94 feet; and 148-168 feet
- BB 220 - 55-70 feet; 85-95 feet; and 130-145 feet
- BB 221 - 60-80 feet; and 135-155 feet

3.8 Ecological Characteristics

3.8.1 Regional Ecology

Camp Lejeune covers approximately 108,800 acres, 84 percent of which is forested (USMC, 1987). Approximately 45 percent of this is pine forest, 22 percent is mixed pine/hardwood forest, and 17 percent is hardwood forest. Nine percent of the base, a total of 3,587 acres, is wetland and includes pure pond pine stands, mixed pond pine/hardwood stands, marshes, pocosins, and wooded swamps. The base also contains 80 miles of tidal streams, 21 miles of marine shoreline, and 12 freshwater ponds.

MCB Camp Lejeune drains primarily to the New River or its tributaries. These tributaries include Northeast Creek, Southwest Creek, Wallace Creek, French's Creek, Bear Head Creek, and Duck Creek.

Because of the natural resources on the base, forested areas are actively managed for timber. Game species are also managed for hunting, and ponds are maintained for fishing. Game species managed include wild turkey, white-tailed deer, black bear, grey and fox squirrels, bobwhite quail, eastern cottontail and marsh rabbits, racoons, and wood ducks.

A number of natural communities are present in the coastal plain. Subcommunities and variations of these major community types are also present and alterations of natural communities have occurred in response to disturbance and intervention (i.e., forest cleared to become pasture). The natural communities found in the Camp Lejeune area are summarized as follows:

- Loblolly Pine Forest - One of the dominant forest types at Camp Lejeune. Pine forest often has a dense hardwood subcanopy and shrub understory as a result of clear-cutting and/or fire suppression. Dense shading results in a sparse ground layer of vegetation with little probability or rare species occurring (LeBlond et. al., 1994).

- Hardwood Forest - Found primarily in stream floodplains and on slopes and terraces adjacent to stream valleys and estuarine features. Stream floodplain communities include cypress - gum swamp and coastal plain small stream swamp. Very few rare species are found in hardwood forests, but the communities themselves can be quite rare (Le Blond et. al., 1994).

- Loblolly Pine/Hardwoods Community - The predominant forest type at Camp Lejeune. Second growth forest that includes loblolly pine with a mix of hardwoods - oak, hickory, sweetgum, sour gum, red maple, and holly (oak is the predominant hardwood). These forests have a low probability for rare species because of the lack of herbaceous development and overall plant diversity (Le Blond et. al., 1994).

- Longleaf Pine Forest and Longleaf Pine/Hardwood Forests - Contain critical, fire maintained natural communities: Pine Savanna, Wet Pine Flatwoods, Mesic Pine Flatwoods, Pine/Scrub Oak Sanhill, and Zeric Sanhill Scrub. Some longleaf pine forests have developed in old fields and cut-over areas. The Federal endangered red-cockaded woodpecker (Picoides Borealis) is essentially restricted to opened, burned longleaf pine forests. The pine savannas and wet pine flatwood communities are particularly important habitats for several rare species (Le Blond et. al., 1994).

- Maritime Forest - Develop on the lee side of stable sands and dunes protected from the ocean. Live oak is an indicator species with pine, cedar, yaupon, holly, and laurel oak. Deciduous hardwoods may be present where forest is mature (USMC, 1987).

- Pond Pine Forest - These forests are primarily found in pocosins and are classified by Schafale and Wealkey (1990) as the Pond Pine Woodland natural community. Red bay, sweet bay, and loblolly bay are important components of this community. These forests frequently produce areas of high plant diversity and support several rare species. The Federal endangered loosestrife (Lysimachia asperulifolia) is found in this community (LeBlond et. al., 1994).

- Freshwater Marsh - Occurs upstream from tidal marshes and downstream from non-tidal freshwater wetlands. Cattails, sedges, and rushes are present. ON the coast of North Carolina, swamps are more common than marshes (USMC, 1987).

- Salt Marsh - These areas occur in saline tidal areas protected from tidal action by barrier beach features. The barrier islands fronting the Atlantic Ocean support Brackish Marsh, Upper Beach, Dune Grass, and Martitime Wet and Dry Grassland communities. Regularly flooded, tidally influenced areas dominated by salt-tolerant grasses. Saltwater cordgrass is a characteristic species. Tidal mud flats may be present during low tide. These dynamic communities are critical to such Federal endangered species as the piping plover (Charadrius Melodus) and the Federal threatened American loggerhead turtle (Caretta caretta) and the green turtle (Chelonia Mydas) (LeBlond et. al., 1994).

- Salt Shrub Thicket - High areas of salt marshes and beach areas behind dunes. Subjected to salt spray and periodic saltwater flooding. Dominated by salt resistant shrubs.

- Dunes/Beaches - Zones from the ocean shore to the maritime forest. Subjected to sand, salt, wind, and water.

- Ponds and Lakes - Low depressional areas where water table reaches the surface or where ground is impermeable. In ponds rooted plants can grow across the bottom, Fish populations managed in these ponds include redear, bluegill, largemouth bass, and channel catfish (USMC, 1987).

- Open Water - Marine and estuarine waters as well as all underlying bottoms below the intertidal zone.

3.8.2 Site-Specific Ecology

During May 15 to 24, 1995, Baker conducted a qualitative habitat evaluation of the terrestrial and aquatic environment at Site 73. Site 73 is characterized by mixed forest, marsh, buildings, and paved areas. Courthouse Bay which opens into the New River is present on the southern edge of Site 73. A large amphibious vehicle maintenance area with a maintenance building is located in the center of the site. Mixed forest areas composed of pine and deciduous trees, are present to the west, north, and east of the site. Marsh areas are present on both the extreme eastern and western edges of the site. Snags are scattered throughout the marsh area. Topography is primarily broad and flat with gentle downward slopes to the west and south, and upward slopes to the east and north.

Eight habitat types are present at Site 73. As displayed on Figure 3-10, these eight habitats include three forest areas, four marsh areas, and Courthouse Bay. Each area is demarcated by an abbreviation (i.e., the first forest area is identified as F1). In addition, a large industrial area is present in the center of the site.

Areas identified by F1, encompass the majority of land at Site 73. These areas are found primarily to the west and northwest of Site 73. The following is a listing of the tree and shrub species identified within the F1 area:

- Loblolly Pine-Pinus taeda
- Sweetgum-Liquidambar styraciflua
- Water Oak-Quercus nigra
- Eastern Red Cedar-Juniperus virginiana
- Southern (Wax) Myrtle-Myrica cerifera
- Wild Grape-Vitis sp.

Because of the large wooded area present to the west of Site 73, the following birds were observed or expected to occur at Site 73:

- Robin-Turdus migratorious
- Northern Mockingbird-Mimus polyglottas
- Carolina Wren-Thryrothorus ludovicianus
- Common Grackle-Quiscalus quiscula
- Red-Winged Blackbird-Agelaius phoeniceus
- Red-bellied Woodpecker-Melanerpes carolinus
- House Sparrow-Passer domesticus

Five mammal Species were identified at Site 73 based upon field signs, and are listed below:

- Raccoon-Procyon lotor
- Whitetail Deer-Odocoileus virginianus
- Gray Squirrel-Sciurus carolinensis
- Opossum-Didelphis marsupialis
- Marsh Rabbit-Sylvilagus palustris

Areas identified by F2 are found primarily to the east and northeast of Site 73. The following is a listing of the tree and shrub species identified within the F2 area:

- Loblolly Pine-Pinus taeda
- Black Willow-Salix nigra
- Red Maple-Acer rubrum
- Southern (Wax) Myrtle-Myrica cerifera
- Wild Grape-Vitis sp.
- Trumpet Creeper-Campsis radicans

The area identified by F3 is located approximately 300 feet due south from the southwest corner of Figure 3-10. Area F3 is found to the south and southwest of Site 73. The following is a listing of the tree and shrub species identified within the F3 area:

- Eastern Red Cedar-Juniperus virginiana
- Green Ash-Fraxinus pennsylvanica
- Sweetgum-Liquidambar styraciflua
- Loblolly Pine-Pinus taeda
- Water Oak-Quercus nigra
- Virginia Creeper-Parthenocissus quinquefolia
- Southern (Wax) Myrtle-Myrica cerifera
- Rushes-Juncus spp.

- Marsh Cordgrass-Spartina sp.
- American Beachgrass-Ammophila breviligulata

Four marsh areas were identified in the surrounding areas of Site 73. As depicted on Figure 3-10, the first marsh area (M1), is located on the western edge of Site 73 and is surrounded by F1 forest. The following is a list of dominant species identified within area M1:

- American Beachgrass-Ammophila breviligulata
- Cattail-Typha sp.
- Marsh Cordgrass-Spartina sp.
- Rush (various)-Juncus spp.

Marsh area M2 is located on the eastern edge of Site 73. The following is a list of dominant species identified within area M2:

- Switch Cane-Arundaria tecta
- Black Willow-Salix nigra
- Sweetgum-Liquidambar styraciflua
- Virginia Creeper-Parthenocissus quinquefolia

Marsh area M3 is located to the southeast of Site 73, with Site 73 being located to the northwest and Courthouse Bay bordering M3 on its southern edge. Area M3 is provided on Figure 3-10. The following is a list of the dominant species identified within area M3:

- Bulrush-Scirpus americanus
- Rush (various)-Juncus spp.
- American Beachgrass-Ammophila breviligulata
- Marsh Elder-Iva frutescens
- Southern (Wax) Myrtle-Myrica cerifera

The last marsh identified at Site 73 is M4. Area M4 is located to the east of Site 73 and is also located 200 feet to the east of M3. In addition, Courthouse Bay borders M4 on the southeastern edge, and an unnamed tributary to Courthouse Bay travels through M4 on the northwestern edge. Area M4 is provided on Figure 3-10. The following is a list of the dominant species identified within area M4:

- Bulrush-Scirpus americanus
- Rush (various)-Juncus spp.
- American Beachgrass-Ammophila breviligulata
- Southern (Wax) Myrtle-Myrica cerifera

The last habitat type identified during the habitat evaluation was Courthouse Bay (See Figure 3-10. Courthouse Bay borders Site 73 on the southern edge, with the bay primarily running east to west. A surface water, sediment, fish and crab investigation was conducted at several locations within Courthouse Bay. From this investigation, four species of shore and sea birds were identified:

- Brown pelican-Pelecanus occidentalis
- Unidentified Gulls-Laridae
- Killdeer-Charadrius vociferus
- Great egret-Casmerodius albus

During the fish and crab investigation, gill nets and a trolling net were used to collect fish. Crab pots were used to collect blue crabs. From this investigation, several fish species, one specie of crab, two species of shrimp, and one specie of squid were captured, and are listed below:

- Pinfish-Lagodon rhomboides
- Spot-Leiostomus xanthurus
- Atlantic croaker-Microgonias undulatus
- Southern flounder-Paralichthys lethostigma
- Butterfish-Peprilus triacanthus
- Spotted sea trout-Cynoscion nebulosus
- Bluefish-Pomatomus saltatrix
- Pigfish-Orthopristis chrysoptera
- Bay anchovy-Anchoa mitchilli
- Yellowfin menhaden-Brevoortia smithi
- Atlantic menhaden-Brevoortia tyrannus
- Spanish mackeral-Scomberomorus maculatus
- Striped mullet-Mugil cephalus
- Banded rudderfish-Seriola zonata
- Pink shrimp-Panaeus duorarum
- Mantis shrimp-Squilla empusa
- Brief squid-Lolliguncula brevis
- Blue crab-Callinectes sapidus
- Unidentified (skate or ray)-Elasmobranch

Sensitive Environments

This section describes the sensitive environments that were evaluated at Site 73. These sensitive environments include wetlands, threatened and endangered species, and other potentially sensitive environments.

3.8.3 Wetlands

The NC DEHNR's Division of Environmental Management (DEM) has developed guidance pertaining to activities that may impact wetlands (NC DEHNR, 1992). In addition, certain activities affecting wetlands also are regulated by the U.S. Corps of Engineers. The U.S. Fish and Wildlife Service has prepared NWI maps for the Camp Lejeune, North Carolina area by stereoscopic analysis of high altitude aerial photographs (USDI, 1982).

The study area consists of Courthouse Bay an inlet from the New River and two unnamed tributaries to Courthouse Bay. Courthouse Bay is surrounded by wetland areas classified by NWI as "E2EM1N" (Estuarine, intertidal, emergent, persistent, regularly flooded). One of the unnamed tributaries is classified as "E2M1N" and the other unnamed tributary is classified as "E2EM1P" (Estuarine, intertidal, emergent, irregularly flooded). Information from the NWI maps was transferred to a site-specific biohabitat map (Figure 3-10).

3.8.4 Other Sensitive Environments

In addition to wetlands and protected species, other sensitive environments, including those listed in 40 CFR Part 300, were evaluated during Hazard Ranking System evaluations. These sensitive environments and their presence or absence at Site 73 are discussed below.

- Marine Sanctuary - Site 73 is not located within a Marine Sanctuary (NCMFC, 1994).
- National Park - Site 73 is not located within a National Park (NPS, 1993a).
- Designated Federal Wilderness Area - Site 73 is not located within a Designated Federal Wilderness Area (WS, 1989, 1993).
- Areas Identified under the Coastal Zone Management Act - The North Carolina Coastal Area Management Act (CAMA) regulates various types of Areas of Environmental Concern including estuarine waters, coastal wetlands, public trust areas, and estuarine shoreline through the establishment of unified policies, criteria, standards, methods, and processes (CAMA, 1974).
- Sensitive Areas Identified under the National Estuary Program (NEP) or Near Coastal Waters Program (NCWP) - Site 73 is not located within a Sensitive Area identified under the NEP or NCWP (NCMFC, 1994).
- Critical Areas Identified under the Clean Lakes Program - Site 73 is not located within a Critical Area identified under the Clean Lakes Program (NPS, 1993).
- National Monument - Site 73 is not located near a National Monument (NPS, 1993).
- National Seashore Recreational Area - Site 73 is not located within a National Seashore Recreational Area (NPS, 1993).
- National Lakeshore Recreational Area - Site 73 is not located within a National Lakeshore Recreational Area (NPS, 1993).
- National Preserve - Site 73 is not located within a National Preserve (NPS, 1991).
- National or State Wildlife Refuge - Site 73 is not located within a National or State Wildlife Refuge (NCWRC, 1992).
- Unit of the Coastal Barrier Resource Program - Site 73 is not located within a unit of the Coastal Barrier Resource Program (USDI, 1993).
- Administratively Proposed Federal Wilderness Area - Site 73 is not located within an Administratively Proposed Federal Wilderness Area (WS, 1989, 1993).
- Spawning Areas Critical for the maintenance of fish/shellfish species within river, lake, or coastal tidal waters (USMC, 1993).

- State land designated for wildlife or game management - Site 73 is not located within a State game land (NCWRC, 1992).

- State designated Natural Area - Site 73 is not located within a State designated Natural Area or Area of Significant Value (LeBlond, 1991).

- State designated areas for protection or maintenance of aquatic life - No areas within the boundaries of Site 73 are designated as primary nursery areas or are unique or special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses (NC DEHNR, 1994).

- Areas of Significant Value - Site 73 is not located within a State Area of Significant Value (LeBlond, 1991).

- State Registered Natural Resource Area - Site 73 is not located within a State Registered Natural Resource Area (LeBlond, 1991).

3.8.5 Threatened and Endangered Species

Certain species have been granted protection by the FWS under the Federal Endangered Species Act (16 U.S.C. 1531-1543), and/or by the North Carolina Wildlife Resources Commission, under the North Carolina Endangered Species Act (G.S. 113-331 to 113-337). The protected species fall into one of the following status classifications: Federal or State endangered, threatened, or candidate species; State special concern; State significantly rare; or State watch list. While only the Federal or State threatened or endangered and State special concern species are protected from certain actions, the other classified species have the potential for protection in the future.

Surveys have been conducted to identify threatened or endangered species at Camp Lejeune and several programs are underway to manage and protect them. Table 3-8 lists protected species present at the base and their protected classifications. Of these species, the red-cockaded woodpecker, American alligator, and sea turtles are covered by specific protection programs.

The red-cockaded woodpecker is classified as state endangered. This species requires a specific habitat in mature longleaf or loblolly pine trees. The birds exist in family groups and young are raised cooperatively. At Camp Lejeune, 2,512 acres of habitat have been identified and marked for protection. Research on the bird at Camp Lejeune began in 1985 and information has been collected to determine home ranges, population size and composition, reproductive success, and habitat use. An annual roost survey is conducted and 36 colonies of birds have been located.

The American alligator is considered threatened in the northernmost part of its range, which includes North Carolina. The alligator is found in freshwater, estuarine, and saltwater wetlands in Camp Lejeune. Base wetlands are maintained and protected for the alligator. Signs have been erected where alligators are known to live. Annual surveys of Wallace, Southwest, French, Duck, Mill, and Stone Creeks have been conducted since 1977 to identify alligators and their habitats on base.

Two protected sea turtles, the Atlantic loggerhead and Atlantic green turtle, nest on Onslow Beach at Camp Lejeune and are both classified as threatened species. The green turtle was found nesting in 1980; the sighting was the first time the species was observed nesting north of Georgia. The turtle returned to nest in 1985. Turtle nests on the beach are surveyed and protected, turtles are tagged, and annual turtle status reports are issued.

Four bird species (black skimmer, piping plover, Bachman's sparrow, and peregrine falcon) have also been identified during surveys at Camp Lejeune. The piping plover and peregrine falcon are classified as threatened species. The black skimmer and Bachman's sparrow are classified as special concern (state). The black skimmer and piping plover are sea and shore birds respectively. Skimmers nest on low sandy islands and sand bars along the coast and piping plovers prefer beaches with broad open sandy flats above the high tide line. Skimmers feed above open water and piping plovers feed along the edge of incoming waves. Like the black skimmer and piping plover, Bachman's sparrows are very specific in their habitat requirements. They live in open stretches of pines with grasses and scattered shrubs for ground cover. Bachman's sparrows were observed at numerous locations throughout the southern portion of Camp Lejeune.

In addition to the protected species that breed or forage at Camp Lejeune, several protected whales migrate through the coastal waters off the base during the spring and fall. These include the Atlantic right whale, finback whale, sei whale, and sperm whale. Before artillery or bombing practice is conducted in the area, aerial surveys are made to assure that whales are not present in the impact areas.

A natural heritage resources survey was conducted at Camp Lejeune (LeBlond, 1991) to identify threatened or endangered plants and areas of significant natural interest. From this list, the rough-leaf loosestrife was the only specie that is both Federal and State endangered. Also, several State endangered/threatened and Federal and State candidate species were found on the base.

3.9 References

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SECTION 3.0 TABLES

TABLE 3-1

GEOLOGIC AND HYDROGEOLOGIC UNITS IN THE COASTAL PLAIN OF NORTH CAROLINA
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

GEOLOGIC UNITS			HYDROGEOLOGIC UNITS
System	Series	Formation	Aquifer and Confining Unit
Quaternary	Holocene/Pleistocene	Undifferentiated	Surficial Aquifer
Tertiary	Pliocene	Yorktown Formation(1)	Yorktown Confining Unit
			Yorktown Aquifer
	Miocene	Eastover Formation(1)	Pungo River Confining Unit
		Pungo River Formation(1)	Pungo River Aquifer
		Belgrade Formation(2)	Castle Hayne Confining Unit
	Oligocene	River Bend Formation	Castle Hayne Aquifer
	Eocene	Castle Hayne Formation	Beaufort Confining Unit(3)
	Palocene	Beaufort Formation	Beaufort Aquifer
Cretaceous	Upper Cretaceous	Peedee Formation	Peedee Confining Unit
			Peedee Aquifer
		Black Creek and Middendorf Formations	Black Creek Confining Unit
			Black Creek Aquifer
		Cape Fear Formation	Upper Cape Fear Confining Unit
			Upper Cape Fear Aquifer
			Lower Cape Fear Confining Unit
			Lower Cape Fear Aquifer
	Lower Cretaceous(1)	Unnamed Deposits(1)	Lower Cretaceous Confining Unit
			Lower Cretaceous Aquifer(1)
Pre-Cretaceous Basement Rocks		--	--

Notes:

(1) Geologic and hydrologic units not present beneath Camp Lejeune.
(2) Constitutes part of the surficial aquifer and Castle Hayne confining unit in the study area.
(3) Estimated to be confined to deposits of Paleocene age in the study area.
Source: Cardinell, et al., 1993

TABLE 3-2

CLIMATIC DATA SUMMARY
MARINE CORPS AIR STATION, NEW RIVER
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Precipitation (Inches)			Relative Humidity (Percent)	Temperature (Fahrenheit)			Mean Number of Days With				
								Precipitation		Temperature		
	Maximum	Minimum	Average		Maximum	Minimum	Average	>=0.01"	>=0.5"	>=90F	>=75F	<=32F
January	7.5	1.4	4.0	79	54	34	44	11	2	0	1	16
February	9.1	.9	3.9	78	57	36	47	10	3	0	2	11
March	8	.8	3.9	80	64	43	54	10	3	*	5	5
April	8.8	.5	3.1	79	73	51	62	8	2	1	13	*
May	8.4	.6	4.0	83	80	60	70	10	3	2	25	0
June	11.8	2.2	5.2	84	86	67	77	10	4	7	29	0
July	14.3	4.0	7.7	86	89	72	80	14	5	13	31	0
August	12.6	1.7	6.2	89	88	71	80	12	4	11	31	0
September	12.8	.8	4.6	89	83	66	75	9	3	4	27	0
October	8.9	.6	2.9	86	75	54	65	7	2	*	17	*
November	6.7	.6	3.2	83	67	45	56	8	2	0	7	3
December	6.6	.4	3.7	81	58	37	48	9	2	0	2	12
Annual	65.9	38.2	52.4	83	73	53	63	118	35	39	189	48

Notes:

* = Mean no. of days less than 0.5 days
Source: Naval Oceanography Command Detachment, Asheville, North Carolina. Measurements obtained from January 1955 to December 1990.

TABLE 3-3

HYDRAULIC PROPERTY ESTIMATES OF THE CASTLE HAYNE AQUIFER AND CONFINING UNIT
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Hydraulic Properties	USGS Phase I Study(1)	USGS Aquifer Test(2)	ESE, Inc. (3)	DEHNR Aquifer Test(4)	RASA Estimate(5)
Aquifer transmissivity (cubic foot per day per square foot times foot of aquifer thickness)	4,300 to 24,500 average 9,500	1,140 to 1,325	820 to 1,740 average 1,280	900	10,140 to 26,000
Aquifer hydraulic conductivity (foot per day)	14 to 82 average 35	20 to 60	--	18 to 91 average 54	45 to 80 average 65
Aquifer storage coefficient (dimensionless)	--	2.0×10^{-4} to 2.2×10^{-4}	5.0×10^{-4} to 1.0×10^{-3} average 8.0×10^{-4}	1.9×10^{-3}	--
Confining-unit vertical hydraulic conductivity (foot per day)	--	3.0×10^{-2} to 4.1×10^{-1}	1.4×10^{-3} to 5.1×10^{-2} average 3.5×10^{-3}	--	--

Notes:

(1) Analysis of specific capacity data from Harned and others (1989).
(2) Aquifer test at well HP-708.
(3) Aquifer test at Hadnot Point well HP-462 from Environmental Sciences and Engineering, Inc. (1988).
(4) Unpublished aquifer test data at well X24s2x, from DEHNR well records (1985).
(5) Transmissivities based on range of aquifer thickness and average hydraulic conductivity from Winner and Coble (1989).

Source: Cardinell, et al., 1993.

TABLE 3-4

SUMMARY OF HYDRAULIC CONDUCTIVITY TESTS FOR SHALLOW MONITORING WELLS SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY REMEDIAL INVESTIGATION, CTO-0312 MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Hydraulic Conductivity Failing Head Test		Hydraulic Conductivity Rising Head Test	
	ft/day	cm/sec	ft/day	cm/sec
73MW-01A	0.1	4.9×10^{-5}	0.2	6.3×10^{-5}
73MW-03	4.9	1.7×10^{-3}	4.9	1.7×10^{-3}
73MW-11A	1.1	3.9×10^{-4}	1.1	3.7×10^{-4}
73MW-13	0.5	1.8×10^{-4}	0.3	1.2×10^{-4}
73MW-20	1.1	3.9×10^{-4}	1.1	3.8×10^{-4}
73MW-21	--	--	3.9	1.4×10^{-3}
73MW-22	1.8	6.5×10^{-4}	1.6	5.5×10^{-4}
73MW-23	--	--	4.1	1.4×10^{-3}

Notes:

Average Hydraulic Conductivity for shallow wells:

Entire Site: 7.6×10^{-4} cm/sec (2.3 ft/day)

Log Normal Average Hydraulic Conductivity:

Entire Site: 4.6×10^{-4} cm/sec (1.3 ft/day)

Hydraulic conductivity test results were analyzed using Bouwer and Rice method as presented in the Geraghty and Miller "AQTESOLV" program, versions 1.10 and 2.01.

Hydraulic conductivity tests were conducted on May 22 and 23, 1995 and February 26, 1996, using an In-Situ Environmental Data Logger (Model SE-2000C) and pressure transducer.

The following formulas were used for calculations and conversions:

- To change ft/min to ft/day, the results were multiplied by 1440 min/day.
- To convert ft/day to cm/sec, the results were multiplied by 3.53×10^{-4}.

TABLE 3-5

SUMMARY OF HYDRAULIC CONDUCTIVITY TESTS
FOR SHALLOW-INTERMEDIATE MONITORING WELLS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	Hydraulic Conductivity Failing Head Test		Hydraulic Conductivity Rising Head Test	
	ft/day	cm/sec	ft/day	cm/sec
73MW-01B	10.3	3.6×10^{-3}	6.2	2.2×10^{-3}
73MW-11B	8.5	3.0×10^{-3}	4.5	1.6×10^{-3}
73MW-15B	0.8	2.8×10^{-4}	1.2	4.1×10^{-4}

Notes:

Average Hydraulic Conductivity for shallow wells:

Entire Site: 3.7×10^{-3} cm/sec (5.3 ft/day)

Log Normal Average Hydraulic Conductivity for shallow-intermediate wells:

Entire Site: 1.28×10^{-3} cm/sec (3.61 ft/day)

Hydraulic conductivity test results were analyzed using Bouwer and Rice method as presented in the Geraghty and Miller "AQTESOLV" program, version 1.10.

Hydraulic conductivity tests were conducted on May 22 and 23, 1995, using an In-Situ Environmental Data Logger (Model SE-2000C) and pressure transducer.

The following formulas were used for calculations and conversions:

- To change ft/min to ft/day, the results were multiplied by 1440 min/day.
- To convert ft/day to cm/sec, the results were multiplied by 3.53×10^{-4}.

TABLE 3-6

LAND UTILIZATION: DEVELOPED AREAS LAND USE[1]
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Geographic Area	Oper.	Training (Instruc.)	Maint.	Supply/ Storage	Medical	Admin.	Family Housing	Troop Housing	CM	CO	Recreat.	Utility	Total
Hadnot Point	31 (2.9)	15 (1.4)	154 (14.3)	157 (14.4)	10 (0.9)	122 (11.3)	22 (2.0)	196 (18.1)	115 (10.7)	36 (3.3)	182 (16.9)	40 (3.7)	1,080 (100)
Paradise Point	1 (0)		3 (0.4)	1 (0)			343 (34)	19 (1.9)	31 (3.1)		610 (60.4)	2 (0.2)	1,010 (100)
Berkeley Manor/ Watkins Village							406 (80)		41 (8.1)	1 (0.2)	57 (11.2)	2 (0.5)	507 (100)
Midway Park		1 (0.4)		2 (0.7)		2 (0.7)	248 (92.2)		8 (3.0)	3 (1.1)	4 (1.5)	1 (0.4)	269 (100)
Tarawa Terrace I and II			3 (0.5)			1 (0.3)	428 (77.4)		55 (9.9)	11 (2.0)	47 (8.5)	8 (1.4)	553 (100)
Knox Trailer							57 (100)						57 (100)
French Creek	8 (1.4)	1 (0.2)	74 (12.7)	266 (45.6)	3 (0.5)	7 (1.2)		122 (20.9)	22 (3.8)	6 (1.0)	74 (12.7)		583 (100)
Courthouse Bay		73 (28.6)	28 (10.9)	14 (5.5)		12 (4.7)	12 (4.7)	43 (16.9)	15 (5.9)	4 (1.6)	43 (16.9)	11 (4.3)	255 (100)
Onslow Beach	6 (9.8)	1 (1.6)	3 (4.8)	2 (3.2)	1 (1.6)	2 (3.2)		2 (3.2)	12 (19.3)		25 (40.3)	8 (13.0)	62 (100)
Rifle Range		1 (1.3)	1 (1.3)	7 (8.8)	1 (1.3)	5 (6.3)	7 (8.8)	30 (37.5)	5 (6.3)	1 (1.3)	9 (11.3)	13 (16.3)	80 (100)
Camp Geiger	4 (1.9)	15 (6.9)	19 (8.8)	50 (23.1)		23 (10.6)		54 (25.0)	27 (12.5)	2 (1.0)	16 (7.4)	6 (2.8)	216 (100)
Montford Point	6 (2.6)	48 (20.5)	2 (0.9)	4 (1.7)	2 (0.9)	9 (3.9)		82 (35.2)	20 (8.6)	1 (0.4)	49 (21.0)	10 (4.3)	233 (100)
Base-Wide Misc.	1 (0.8)			87 (68.0)		3 (2.3)			19 (14.8)			18 (14.1)	128 (100)
TOTAL	**57 (1.1)**	**155 (3.1)**	**287 (5.7)**	**590 (11.7)**	**17 (0.38)**	**186 (3.7)**	**1,523 (30.2)**	**548 (10.8)**	**370 (7.4)**	**65 (1.3)**	**1,116 (22.2)**	**119 (2.4)**	**5,033 (100)**

Note:

[1] Upper number is acres, lower number is overall percent.

TABLE 3-7

SUMMARY OF SUPPLY WELLS IN THE VICINITY OF SITE 73
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Well No.	USGS I.D. No.	Approximate Distance/Direction Site to Well	Year Drilled	Depth (feet)	Driller	Screen Interval (feet below surface)	Well Diameter (inches)	Static Water Level (feet below land surface)	Status
BB-44	3435040772143.1	3,960 feet southeast	1942	62	Layne Atlantic Company	32 - 62	8	13.4	active
BB-47	3434560772148.1	4,752 feet southeast	1982(1)	150	East Coast Construction Company	40 - 55 102 - 125	8(1)	10.1	active
BB-218	3500010772049.1	9,240 feet southeast	1985	185	Carolina Well and Pump Company	64 - 94 148 - 168	10	55	active
BB-220	3435140772136.1	4,119 feet east	1975	150	Carolina Well and Pump Company	55 - 70 85 - 95 130 - 145	8(1)	10.2	active
BB-221	3435220772122.1	5,280 feet southeast	1974	200	Carolina Well and Pump Company	60 - 80 135 - 155	8(1)	33.5	active

Note:

(1) As per conservations with Mac Farzelle, General Forman, Water Treatment, MCB, Camp Lejeune.

TABLE 3-8

PROTECTED SPECIES WITHIN MCB, CAMP LEJEUNE
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Species	Protected Classification
Animals: American alligator (Alligator mississippienis)	SC
Bachmans sparrow (Aimophilia aestivalis)	FCan, SC
Green (Atlantic) turtle (Chelonia m. mydas)	T(f), T(s)
Loggerhead turtle (Caretta caretta)	T(f), T(s)
Peregrine falcon (Falco peregrinus)	E(f), E(s)
Piping plover (Charadrius melodus)	T(f), T(s)
Red-cockaded woodpecker (Picoides borealis)	E(f), E(s)
Southern Hognose Snake (Heterodon simus)	FCan, SR
Diamondback Terrapin (Malaclemys terrapin)	FCan, SC
Carolina Gopher Frog (Rana capito capito)	FCan, SC
Cooper's Hawk (Accipiter cooperii)	SC
Eastern Diamondback Rattlesnake (Crotalus adamanteus)	SR
Eastern Coral Snake (Micrurus fulvius)	SR
Pigmy Rattlesnake (Sistrurus miliarius)	SR
Black Bear (Ursus americanus)	SR
Plants: Rough-leaf loosestrife (Lysimachia asperulifolia)	E(f), E(s)
Seabeach Amaranth (Amaranthus pumilus)	T(f), T(s)
Chapman's Sedge (Carex chapmanii)	FCan
Hirst's Witchgrass (Dichanthelium sp.)	FCan
Pondspice (Litsea aestivalis)	FCan
Boykin's Lobelia (Lobelia boykinii)	FCan
Loose Watermilfoil (Myriophyllum laxum)	FCan,T(s)
Awned Meadowbeauty (Rhexia aristosa)	FCan,T(s)
Carolina Goldenrod (Solidago pulchra)	FCan, E(s)
Carolina Asphodel (Tofieldia glabra)	FCan
Venus Flytrap (Dionaea muscipula)	FCan
Flaxleaf Gerardia (Agalinis linifolia)	SR
Pinebarrens Goober Grass (Amphicarpum purshii)	SR
Longleaf Three-awn (Aristida palustris)	SR
Pinebarrens Sandreed (Calamovilfa brevipilis)	E(s)
Warty Sedge (Carex verrucosa)	SR
Smooth Sawgrass (Cladium mariscoides)	SR
Leconte's Flatsedge (Cyperus lecontei)	SR

TABLE 3-8 (Continued)

PROTECTED SPECIES WITHIN MCB, CAMP LEJEUNE
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Species	Protected Classification
Erectleaf Witchgrass (Dichanthelium erectifolium)	SR
Horsetail Spikerush (Eleocharis equisetoides)	SR
Sand Spikerush (Eleocharis montevidensis)	SR
Flaxleaf Seedbox (Ludwigia linifolia)	SR
Torrey's Muhley (Muhlenbergia torreyana)	E(s)
Southeastern Panic Grass (Panicum tenerum)	SR
Spoonflower (Peltandra sagittifolia)	SR
Shadow-witch (Ponthieva racemosa)	SR
West Indies Meadowbeauty (Rhexia cubensis)	SR
Pale Beakrush (Rhynchospora pallida)	SR
Longbeak Baldsedge (Rhynchospora scirpoides)	SR
Tracy's Beakrush (Rhynchospora tracyi)	SR
Canby's Bulrush (Scirpus etuberculatus)	SR
Slender Nutrush (Scleria minor)	SR
Lejeune Goldenrod (Solidago sp.)	SR
Dwarf Bladderwort (Utricularia olivacea)	T(s)
Elliott's Yellow-eyed Grass (Xyris elliottii)	SR
Carolina Dropseed (Sporobolus sp.)	T(s)

Legend:

E(f) = Federal Endangered
T(f) = Federal Threatened
Fcan = Candidate for Federal Listing
E(s) = State Endangered
T(s) = State Threatened
SC = State Special Concern
SR = State Rare

Source: LeBlond, 1994

4.0 NATURE AND EXTENT OF CONTAMINATION

The objective of this section is to describe the nature and extent of contamination at the site. The characterization in all media sampled was accomplished through environmental sample collection and laboratory analysis of soil, groundwater, biota, surface water and sediments. The analytical results (only detected contaminants) are summarized on tables and figures, which are located at this end of the section.

Analytical parameters can be segregated into two broad categories: organics and inorganics. The organic compounds included in the analytical program do not occur naturally. Therefore, any organics detected in the samples collected from the site can be attributed to either site or sampling/laboratory contamination. However, many of the inorganic compounds included in the analytical program do exist naturally. In order to accurately present the nature and extent of contamination, detected parameters that are either common laboratory contaminants (organics) or are naturally occurring (inorganics) must be segregated from those that can be attributed to on- site or off-site activities.

4.1 Data Management and Tracking

Analytical data generated during the RI was submitted for third-party validation to Heartland Environmental Services, Inc (Heartland), of St. Charles, Missouri. Procedures established by the National Functional Guidelines for Organic (USEPA, 1991) and Inorganic (USEPA, 1988) Analyses were followed during the validation process. Validation of the analytical data through established procedures served to reduce the inherent uncertainties associated with its usability. Data qualified as "J" were retained as estimated. Estimated analytical results within a data set are common and considered usable by the USEPA. Data may be qualified as estimated for several reasons including: an exceedance of holding times; high or low surrogate recovery; intra-sample variability; or the reported value is below the Contract Required Detection Limit (CRDL) or the Contract Required Quantitation Limit (CRQL).

Additional data qualifiers were employed during the validation of data. The "NJ" qualifier denotes that a compound was tentatively identified, but the reported value may not be accurate or precise. Compounds which were not detected and had inaccurate or imprecise quantitation limits were assigned the "UJ" qualifier. The "B" qualifier identifies a compound that was detected in the method blank associated with the sample. If the sample result has serious deficiencies with regard to the ability to analyze the sample and meet quality control criteria, the compound is assigned the "R" qualifier and the data is rejected. A small percentage of the data collected during this RI was rejected, however it is not expected to affect the overall assessment of the site.

The management and tracking of data from the time of field collection to receipt of the validated electronic analytical results is of primary importance and reflects the overall quality of the analytical results. Field samples and their corresponding analytical tests were recorded on the chain-of-custody sheets, included as Appendix D. The chain-of-custody forms were checked against the Field Sampling and Analysis Plan (Baker, 1994) to determine if all designated samples were collected for the appropriate parameters. Similarly, the validated information was compared to laboratory information as a final check. In summary, the tracking information was used to identify the following items:

- Identify sample discrepancies between the analysis plan and the field investigation
- Verify that the laboratory received all samples, and analyzed for the correct parameters
- Verify that the data validator received a complete data set
- Ensure that a complete data set was available for each media of concern prior to entering results into the database

4.2 Non-Site Related Analytical Results

Many of the organic and inorganic constituents detected in soil, groundwater, surface water and sediments at Site 73 are attributable to non-site related conditions or activities. Two primary sources of non-site related results include laboratory contaminants and naturally-occurring inorganic elements. In addition, non-site related operational activities and conditions may contribute to "on-site" contamination. A discussion of non-site related analytical results for the site is provided in the following subsections.

4.2.1 Laboratory Contaminants

Blank samples (i.e., rinsate, field, trip) provide a measure of contamination that has been introduced into a sample set during the collection, transportation, preparation and/or analysis of samples. To prevent the inclusion of non-site related contaminants from further assessment, the concentrations for chemicals in blanks are compared with analytical results from the site.

Common laboratory contaminants (i.e., acetone, 2-butanone, chloroform, methylene chloride, toluene, and phthalate esters) were considered as positive results only when observed concentrations exceeded ten times the maximum concentration detected in any blank. If the concentration of a common laboratory contaminant was less than ten times the maximum blank concentration, then it was concluded that the chemical was not detected in that particular sample (USEPA, 1989a). Organic constituents contained in blanks that were not considered common laboratory contaminants were considered as positive results only when observed concentrations exceeded five times the maximum concentration detected in any blank (USEPA, 1989b). All TCL compounds less than five times the maximum level of contamination noted in any blank were considered to be not detected in that sample. Refer to Table 4-1 for a summary of organic compounds and associated maximum concentration detected in QA/QC blanks by media.

When assessing soil concentrations, the CRQL and percent moisture were accounted for in order to correlate solid and aqueous quantitation limits. For example, when assessing semivolatile contaminants the CRQL for solid samples is 33 to 66 times (depending on the contaminant) that of aqueous samples. In order to assess contaminant levels in soil samples using an aqueous blank concentration, the concentration must be multiplied by 5 or 10 (noncommon or common lab contaminant) and then multiplied by 33 or 66 to correct for the variance in the CRQL. This value is then divided by the percent moisture determined for the sample.

A limited number of sediment samples that exhibited high concentrations of tentatively identified compounds (TICs) underwent an additional sample preparation. Medium level sample preparation provides a corrected CRQL based on the volume of sample used for analysis. The corrected CRQL produces higher detection limits than the low-level sample preparation. A comparison to laboratory blanks used in the medium-level preparation was used to evaluate the relative amount of contamination within these samples.

4.2.2 Naturally-Occurring Inorganic Elements

In order to differentiate inorganic contamination due to site operations from naturally-occurring inorganic elements in site media, the results of the sample analyses were compared to information regarding background conditions at Camp Lejeune. The following guidelines were used for each media:

• Soil:	MCB, Camp Lejeune Background Soil Samples
• Groundwater:	MCB, Camp Lejeune Background Groundwater Samples
• Surface Water:	Off-Base Reference Stations (White Oak River Basin)
• Sediment:	Off-Base Reference Stations (White Oak River Basin)

Site specific background groundwater, sediment and surface water samples were not obtained at Site 73 because of the availability of other data sources.

The following subsections address the various comparison criteria used to evaluate the analytical results from soil, groundwater, surface water and sediment samples collected at Site 73.

4.2.2.1 Soil

In general, chemical-specific standards and criteria are not available for soil. As a result, base-specific background concentrations have been compiled from a number of locations throughout Camp Lejeune to evaluate background levels of inorganic elements in the surface and subsurface soil. Organic contaminants, unlike inorganic elements, do not occur naturally. Therefore, it is probable that all organic contaminants detected in the surface and subsurface soil are attributable to activities which have then or are currently taking place within or surrounding the study area.

Site background and base background concentration values for inorganic elements in surface and subsurface soil at Camp Lejeune are presented in Tables 4-2 and 4-3, respectively. The background ranges are based on analytical results of background samples collected in areas not known to have been impacted by site operations or disposal activities at Camp Lejeune. In subsequent sections, which discuss the analytical results of samples collected during the soil investigation, only those inorganic parameters with concentrations exceeding these ranges will be considered. Appendix M contains the summary of the base soil background database for inorganics.

4.2.2.2 Groundwater

Background groundwater monitoring wells are installed to assess the natural state and quality of groundwater. Natural in this sense implies that the groundwater has not been altered due to human activity. In some cases, these monitoring wells provide data that is representative of naturally occurring conditions. In other cases, these wells may not be representative of naturally occurring conditions, if other base-related activities have altered the natural state of groundwater. In the latter case, the well samples would be classified as "control" samples. Control samples are samples which may not represent background conditions, but represent the current state of groundwater quality upgradient of the site. During the past few years, a number of background wells have been installed throughout the base as part of individual site investigations. Most of these wells provide control samples. Data collected from these wells are representative of "base-wide" groundwater quality.

Chemical-specific standards and criteria are available for evaluation of groundwater analytical results. In the subsequent sections, which address the analytical results of samples collected during the groundwater investigation, only those inorganic parameters with concentrations exceeding applicable Federal and/or State regulations will be discussed. In order to supplement comparison criteria, a number of base-specific background (i.e., upgradient) samples were compiled as part of a study to evaluate levels of inorganic elements in groundwater at Camp Lejeune. Appendix N presents Baker's Draft Report Evaluation of Metals in Groundwater, June 1994, prepared for the DON, Atlantic Division Naval Facilities Engineering Command.

Groundwater samples were analyzed for total and dissolved metals parameters during the first phase of field work conducted at the site. Of the 54 samples analyzed for total metals (unfiltered), six were also analyzed for dissolved metals. The concentrations for the dissolved metals were generally found to be similar to the total metals in the uppermost portion of the surficial aquifer. The only exception were the results from monitoring well 73-MW09, in which the filtered sample results were typically much less than the unfiltered sample results. A 0.45-micron filter was used in the field to remove small particles of silt and clay that would otherwise be dissolved during sample preservation. During purging and development of monitoring well 73-MW09, sediment concentrations less than 10 NTUs could not be acquired indicating a higher percentage of sediment was present in the unfiltered sample from this well than any of the other samples. The sediment captured during sampling activities increases the chance that small particles of silt and clay dissolved during sample preservation would generate an unrealistically high value of metals in the sample. In a situation where sediment is captured with the groundwater, the unfiltered sample reflects a combination of the concentrations of inorganics in the natural lithology and dissolved in the groundwater and the filtered sample would only reflect the concentrations of inorganics in groundwater. Elements illustrating the largest difference in concentration between filtered and unfiltered samples collected from well 73-MW09 are aluminum, iron and magnesium which are typically associated with clays.

A single sample was collected from the lower portion of the surficial aquifer and analyzed for total and dissolved metals. When the results were compared, the concentrations for the dissolved metals were generally higher than total metals except for barium and zinc. Samples collected from the uppermost portion of the Castle Hayne aquifer exhibited similar results with the only exception being iron. In both cases, the results for each element were similar.

USEPA Region IV requires that unfiltered inorganic concentrations be used in evaluating ARARs and risk to human health and the environment. In the subsequent sections, which discuss the groundwater sample analytical results, both total and dissolved inorganics (which exceed applicable federal and/or state standards) will be presented and discussed.

Groundwater in the Camp Lejeune area is naturally rich in iron and manganese often exceeding the federal MCLs and NCWQS of 300 and 50 µg/L, respectively. Elevated levels of iron and manganese, at concentrations above the MCL and NCWQS were reported in samples collected from a number of base potable water supply wells which were installed at depths greater than 162 feet bgs (Greenehorne and O'Mara, 1992). Iron and manganese concentrations in several monitoring wells at Site 73 exceeded the MCL and NCWQS but fell within the range of concentrations for samples collected elsewhere at the base. In lieu of this fact, it is assumed that these two compounds are naturally-occurring inorganic elements in groundwater, and their presence is not attributable to site operations.

4.2.2.3 Surface Water and Sediment

Offsite surface water and sediment samples were collected from three tributaries of the White Oak River as a part of a background investigation, White Oak River Basin Reference Study. These tributaries were generally located between Swansboro and the Croatan national Forest and were believed not to be impacted by previous activities that were conducted at current Base IR sites. As a part of this study a total of ten surface water and 20 sediment samples were collected from nine reference stations and analyzed for TAL metals. A summary of metals results for surface water and sediment are included in Appendix N. Reference stations were located in the following areas of the White Oak River Basin:

- Webb Creek - two reference stations
- Hadnot Creek - four reference stations
- Holland Mill Creek - three reference stations

4.3 State and Federal Criteria and Standards

Contaminant concentrations can be compared to contaminant-specific established federal and state criteria and standards such as federal MCLs or NCWQS.

The only enforceable federal regulatory standards for water are the MCLs. In addition to the federal standards, North Carolina developed the NCWQS for groundwater and surface water. Samples collected at the site with contaminant concentrations exceeding federal MCLs and/or NC DEHNR Standards would likely be considered contaminated by either the EPA or NC DEHNR.

NC DEHNR and EPA Region III has established pre-calculated risk-based contaminant concentrations based on the potential for soil contaminants to leach into groundwater. These soil concentrations protect resulting groundwater contamination from exceeding the target groundwater concentrations.

Regulatory guidelines were used for comparative purposes to infer the potential health risks and environmental impacts when necessary. Relevant regulatory guidelines include federal Ambient Water Quality Criteria (AWQC) and Health Advisories.

NC DEHNR and EPA Region III has established pre-calculated risk based contaminant concentrations based on the potential for soil contaminants to leach into groundwater. These soil concentrations protect resulting groundwater contamination from exceeding the target groundwater concentrations. In addition, base-specific background concentrations were compiled to evaluate background levels of inorganic constituents in the surface and subsurface soil. Organic contaminants were not detected in the base-specific background samples. Therefore, it is likely that all organic contaminants detected in the surface and subsurface soil, within OU No. 9, Site 73, are attributable to the practices which have taken or are currently taking place within the areas of concern.

A brief explanation of the criteria and standards used for the comparison of site analytical results is presented below.

North Carolina Water Quality Standards (Groundwater) - NCWQSs are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the state, which may be tolerated without creating a threat to human health or which otherwise render the groundwater unsuitable for its intended purpose.

Maximum Contaminant Levels - MCLs are enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply.

North Carolina Water Quality Standards (Surface Water) - The NCWQSs for surface water are the standard concentrations, that either alone or in combination with other wastes, in surface waters that will not render waters injurious to aquatic life or wildlife, recreational activities, public health, or impair waters for any designated use.

USEPA Water Quality Screening Values (WQSV) - WQSVs are non-enforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic systems. WQSVs are provided for both freshwater and saltwater aquatic systems, and are reported as acute and/or chronic values (USEPA, 1995a, b). Most of the WQSVs are the same as the USEPA Ambient Water Quality Criteria (AWQC); however, some of the WQSVs are based on more current studies.

Sediment Screening Levels - Sediment Screening Levels (SSLs) have been compiled to evaluate the potential for contaminants in sediments to cause adverse biological effects (Long, et al., 1995; Long and Morgan 1991; and USEPA, 1995). The lower ten percentile (Effects Range-Low [ER-L]) and the median percentile (Effects Range-Median [ER-M]) of biological effects have been developed for several contaminants. The concentration below the ER-L represents a minimal-effects range (adverse effects would be rarely observed). The concentration above the ER-L but below the ER-M represents a possible-effects range (adverse effects would occasionally occur). Finally, the concentration above the ER-M represents a probable-effects range (adverse effects would probably occur).

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

4.4 Analytical Results

The analytical results of the surface soil, subsurface soil, groundwater, surface water, sediment, and fish sampling performed at Site 73 are presented in the following sections. A summary of site contamination by media is provided in Tables 4-4, 4-5, 4-6 and 4-7. The Data Frequency Summaries for all media at Site 73 are presented in Appendix O.

All samples collected for the RI organic compounds including volaitles were analyzed for one or more of the following: TCL organic compounds including volatiles, semivolatiles and pesticides/PCBs, volatiles via EPA Method 601/602, and TAL inorganics (excluding cyanide), using CLP protocols and Level IV data quality.

4.4.1 Soil Investigation

Unique sample notations were employed to identify soil samples and sample depths at Site 73. Soil samples designated with the prefix "MW", "DW", or "GW" were collected from monitoring well pilot test borings. The "SB" designation denotes samples collected from soil borings. The following suffix designations refer to the depth at which a sample was obtained:

- 00 - ground surface to 12 inches below ground surface (i.e., surface soil)
- 01 - 1 to 3 feet below ground surface
- 02 - 3 to 5 feet below ground surface
- 03 - 5 to 7 feet below ground surface
- 04 - 7 to 9 feet below ground surface
- 05 - 9 to 11 feet below ground surface

4.4.1.1 Surface Soil

A total of 52 surface soil samples were collected from various locations across Site 73. Seventeen of the samples were collected for the purpose of assessing conditions near UST locations throughout the site. The remaining samples were collected from other locations potentially impacted by non-UST related activities such as vehicle maintenance. Surface soil sample detection summaries for organic compounds and inorganic elements analyzed for the purpose of the RI are presented in Tables 4-8, 4-9, 4-10, and 4-11. The locations and analytical results of these samples are shown on Figures 4-1 and 4-2. Additional detection summaries for compounds analyzed for the assessment of USTs are included in Appendix A of this report.

Eleven volatile organic compounds (VOCs) were detected in the surface soil samples (Table 4-4). Acetone, 2-butanone and toluene were detected, however the concentrations of these compounds did not exceed ten times the maximum blank concentration for soils. Toluene was detected in one of 35 samples collected from the surface soils at a concentration of 1 J µg/kg. The sample was collected from soil boring 73-DW01 located in the northwestern portion of the site. This detection was considered as a possible laboratory contaminant due to its low concentration and the detection of this compound in a trip blank. The concentration of toluene in the trip blank was determined to be 29 µg/kg. As previously discussed, if the concentration of a common laboratory contaminant was less than ten times the maximum blank concentration its presence among the sample set was attributed to laboratory contamination and excluded from further evaluation. Xylene was observed in 10 samples collected throughout the site at concentrations ranging from 1J to 4J µg/kg. The detections may be attributed to small leaks and/or spills related to the maintenance and operation of the large number of vehicles at the site. The remaining VOCs ranged in concentration from 1J to 8J µg/kg. None of the VOCs were detected at concentrations exceeding the USEPA Region III Soil Screening Levels for Protection of Groundwater (USEPA, 1994). The detection of 1,2-dichloroethane in soil boring 73-SB07 (2J µg/kg) exceeded the NC DEHNR Soil Target Concentration of 1.84 µg/kg.

Fifteen semi-volatile organic compounds (SVOCs) were detected in the surface soil samples (see Table 4-4). Bis(2-ethylhexyl)phthalate was not detected at concentrations in excess of ten times the maximum blank concentration. Di-n-butyl phthalate was detected a total of eleven times, but only five times did the sample concentration exceed ten times the maximum blank concentration. However, they did not exceed USEPA Region III Soil Screening Levels for Protection of Groundwater. The surface soil sample collected from monitoring well borehole 73-MW07 exhibited the following semivolatile compounds: acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, phenanthrene, pyrene, chrysene and fluoranthene. Monitoring well 73-MW07 was positioned near an area where evidence of dumping was reported and in the vicinity of the surface seep.

2,4-Dinitrophenol was detected a total of four times at concentrations ranging from 56J to 200J µg/kg. Of the four detections, two exceeded the USEPA Region III Soil Screening Levels for Protection of Groundwater (USEPA, 1994). Some of the common uses for this compound are pesticide application, herbicide application, the use of chemical indicators and/or the use of explosives (i.e., the use of blank ammunition during training exercises). None of the remaining SVOCs detected at the site exceeded the USEPA Region III Soil Screening Levels protective of groundwater.

Pesticides were detected in nine of the 29 samples submitted for laboratory analysis. None of the compounds exceeded the Soil Screening Levels protective of groundwater. As indicated on Table 4-4, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT and gamma-chlordane were the most prevalent of the six pesticides detected. 4,4'-DDD and 4,4'-DDE were detected in seven and three of the surface soil samples, respectively. 4,4'-DDT and gamma-chlordane were each detected only twice among surface samples. The maximum concentration for 4,4'-DDD was detected in the middle of the concrete parking area adjacent to Building A-47 (boring 73-MW14). The maximum concentrations for the other five pesticides were detected in samples collected from either 73-SB09 or 73-MW20 which are in close proximity to each other. Both samples were collected north of Building A-47 in an area of the site that is wooded and bisected with tank trails.

Aroclor-1060 and aroclor-1260 were detected at low levels in the surface sample from 73-MW20 and were the only PCBs detected in the surface soils at the site. The area near 73-MW20 is suspected to be an area where battery acid and POL were reportedly disposed. Aroclor-1060 and aroclor-1260 were detected at concentrations of 140NJ and 170J, respectively.

A total of 12 metals were detected in the surface soil samples collected across Site 73. The elements include: aluminum, barium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, vanadium and zinc. Aluminum, barium, iron, lead, magnesium and manganese were the most often detected elements, observed in each of the 35 surface samples. USEPA Region III has published Soil Screening Levels (USEPA, 1994) for the protection of groundwater for three of the elements (barium, cadmium and zinc) and NC DEHNR has published Soil Target Concentrations for eight elements (barium, cadmium, chromium, copper, iron, lead, manganese, and zinc) detected in samples collected from Site 73. Barium exceeded the criteria established by the USEPA four times and Iron exceeded NC DEHNR Soil Target concentrations in each of the 35 samples collected at the site. All of the metals detected in the surface samples exceeded twice the average base-specific (i.e., Camp Lejeune) background concentrations at least once (refer to Table 4-4 and Appendix M for base-specific inorganic background concentrations). The elements which exceeded twice the average base-specific background concentrations the most often were as follows: zinc (16), magnesium (10), chromium (8) and lead (7).

4.4.1.2 Subsurface Soil

A total of 30 subsurface soil samples were collected for the purpose of determining if soils beneath the ground surface are contaminated from the past activities at the site. Additionally, analysis of the soils in conjunction with groundwater will help determine if a source of groundwater contamination exists at the site. Twenty-two (22) sample locations were obtained from areas where the groundwater level was at or near the surface (i.e., within one foot of the surface). Subsurface soil sample detection summaries for organic compounds and inorganic elements are presented in Tables 4-12, 4-13, 4-14, and 4-15 and the locations of these samples are shown on Figures 4-3 and 4-4. Additional detection summaries for compounds analyzed for the assessment of USTs are included in Appendix A of this report.

Eleven (11) VOCs were detected in the samples collected during the RI (see Table 4-4). Two of the compounds (i.e., 2-butanone and acetone) were detected at concentrations less than ten times the maximum blank concentration and for reasons discussed in Section 4.4.1.1 will not be further evaluated. Total xylenes, o-xylene, and ethylbenzene were the compounds most often detected in the samples at a frequency of five, two and two detections, respectively. The remaining VOCs were detected in only one sample each. None of the VOCs were detected at concentrations that exceeded the USEPA Region III Soil Screening Levels for Protection of Groundwater.

Analysis of the subsurface samples detected a total of 14 SVOCs including two which were determined to be common laboratory contaminants. Bis(2-ethylhexyl)phthalate, detected a total of 11 times at concentrations ranging from 62J to 360J µg/kg, is well below the concentration accepted as laboratory contributed contamination. The other common laboratory contaminant detected in the subsurface samples was di-n-butyl phthalate, which was detected a total of 10 times at concentrations ranging from 110J to 430 µg/kg. The concentration determined as being attributed to laboratory contamination was 330 µg/kg. Four of the 10 samples containing di-n-butyl phthalate possessed levels exceeding concentrations established as laboratory contributed contamination. However, the contamination detected in these samples is suspected to have originated from field practices and sample handling within the laboratory.

Only two of the 14 compounds exceeded the Soil Screening Levels for Protection of Groundwater and/or NC DEHNR Soil Target Concentrations. 2,4-Dinitrophenol and benzo(a)anthracene were each detected in two subsurface samples and exceeded the Soil Screening Levels twice and once, respectively. Benzo(a)antracene concentrations exceeded NC DEHNR Soil Target Concentrations of 343 µg/kg once. As stated in an earlier paragraph, 2,4-dinitrophenol is a compound used in the manufacturing of pesticides, herbicides, chemical indicators and explosives, all of which may have been used at the site and benzo(a)anthracene is a common coal tar component.

A total of seven pesticides were detected in the subsurface samples collected across the site, two of which exceeded Soil Screening Levels established by the USEPA for the Protection of Groundwater (USEPA, 1994). Dieldrin and 4,4'-DDD each exceeded the Soil Screening Levels in one sample. Dieldrin had only been detected in the subsurface sample collected from soil boring 73-SB07; however, 4,4'-DDD had been detected in nine samples with the highest concentration detected in the sample collected from boring 73-MW28. In addition to dieldrin, the subsurface sample from soil boring 73-SB07 contained the only detections of 4,4'-DDT, alpha-chlordane and endosulfan I. Additionally, endrin aldehyde, 4,4'-DDD and 4,4'-DDE were detected in the sample from 73-SB07 as well as samples from other locations throughout the site. Soil boring 73-SB07 was advanced in the vicinity of oil/water separator SA-42 which is in a manicured portion of the site. At this juncture, it is not known why so many pesticide compounds were detected in a sample collected in this portion of the site and not along the tree line or wooded areas.

A single PCB compound (aroclor-1254) was detected in subsurface samples from borings 73-SB07 and 73-MW14. The maximum concentration was detected in the sample from 73-SB07. The source of the PCBs is suspected to be improper disposal of POL in the central and eastern portions of the site.

Twelve metals were detected in subsurface samples collected across the site. Although reported concentrations for barium, cadmium and zinc did not exceed the USEPA Soil Screening Levels for Protection of Groundwater, every element exceeded twice the average base-specific background levels at least once. Chromium, zinc and magnesium exceeded these levels ten, nine and eight times, respectively. Nine of the 12 metals were detected in at least 20 of the 29 samples that were analyzed for inorganics. No element was detected at a concentration exceeding one order of magnitude higher than base background levels. Only two elements exceeded the NC DEHNR Soil Target Concentrations. Chromium exceeded this criteria one time and iron exceeded the soil target concentration in each of the 29 samples collected and analyzed for inorganics.

4.4.1.3 Extent of Contamination

Positive detections of organic and inorganic compounds in both the surface and subsurface soil samples at Site 73 are depicted on Figures 4-1 through 4-4. Figures 4-1 and 4-3 depict the distribution of organic contamination while Figures 4-2 and 4-4 depict the distribution of inorganic analytes with concentrations exceeding two times base specific background levels.

No VOCs exceeded the USEPA Region III Soil Screening Levels for protection of groundwater and only one compound exceeded NC DEHNR's Soil Target Concentration. Nearly all of the VOCs in the soils were detected at very low concentrations with the exception of acetone. In addition, the distribution of contaminants in the surface and subsurface soils followed no discernible pattern; therefore, the contamination suggests that past spills or disposal events have not resulted in long-term impacts to soil. The low levels of VOCs may reflect the lack of significant spills involving solvents. It is also possible that the VOCs have volatilized, migrated to the water table and dispersed, or naturally attenuated.

The presence of SVOCs in soil is most likely the result of general site operations, incidental maneuvers and training. Typically, the compounds were detected at low concentrations with the exception of one surface and three subsurface samples. As previously stated in Section 4.4.1.1, the surface soil sample from 73-MW07 was collected from an area where evidence of waste disposal had been observed during field operations. The remaining two subsurface samples that contained high SVOCs were collected in an area of the site that had previously been investigated by Law-Catlin for hydrocarbon contamination and are likely to be associated with this contamination. High SVOC concentrations were detected in samples collected from borings 73-MW14, 78-MW15B, 73-SB01, and 73-SB06.

With respect to pesticides, the scattered detections across the site and the relatively low concentrations observed in the surface soils provide evidence that the contamination is probably the result of former pest control applications rather than disposal. Historical information did not indicate pesticide storage and presently pesticides are not stored at the site thus indicating that contamination observed is most likely the result of pest control.

The only exception to the previous statement is the detection of 4,4'-DDD in a subsurface sample from 73-MW28. The concentration observed in this sample (9,000 μg/Kg) indicates that it was not the result of surface application, but probably a result of a small spill.

Low levels of PCBs were detected in a limited number of surface and subsurface soils. PCB detections were correlated with an area of the site where POL spills and releases have been reported. The site history does not indicate large-scale PCB or transmitter storage; however, these PCBs were used as part of oils and lubricants that may have been disposed at Site 73 in the past.

The distribution of inorganic analytes in both surface and subsurface followed no pattern that would suggest a spill or disposal area since the contaminants were observed throughout the study area at concentrations both above and below background levels.

4.4.2 Groundwater Investigation

Groundwater samples were collected from selected existing wells, all newly installed monitoring wells, a temporary well and a water supply well during both phases of the RI (refer to Section 2.2.2). During the first phase of field work, samples originating from wells designed to provide information pertaining to the RI were analyzed for volatiles via EPA Method 601/602 and TCL semivolatiles, pesticides and PCBs via CLP protocols. In addition, all monitoring wells were analyzed for TSS and TAL metals via CLP protocols. In the second phase of work at the site, the samples were analyzed for TCL volatiles via CLP protocols, only. The use of both methods allowed confirmation of contamination during the second phase and a more precise contaminant concentration. EPA method 601/602 requires that a sample be analyzed by a gas chromatograph and therefore the contaminants are identified by only their retention time. Hence with EPA Method 601/602 false positive results may occur and quantification may not be exact, however lower detection limits are able to be acquired and compounds can be detected at much lower concentrations. TCL volatiles via CLP protocols requires that a sample be analyzed by gas chromatograph and mass spectrometer, hence identifying the contaminant by retention time and ion pattern. TCL volatiles can provide false negatives by not detecting compounds that are present at relatively low concentrations due to the method's higher detection limits.

Groundwater samples were collected from four separate zones across the site including: the upper portion of the surficial aquifer; the lower portion of the surficial aquifer; the uppermost portion of the Castle Hayne Aquifer; and the mid to lower portion of the Castle Hayne Aquifer. The analytical results for each of the groundwater zones will be discussed independently and compared to North Carolina Water Quality Standards (NCWQS) and federal Maximum Contaminant Levels (MCLs). A summary of groundwater contamination is provided on Table 4-5.

4.4.2.1 Upper Portion of the Surficial Aquifer

A total of 38 samples were collected for the purpose of determining if the surficial aquifer has been contaminated from past activities at the site. Groundwater sample detection summaries for organic compounds and inorganic elements analyzed under the RI are presented in Tables 4-16, 4-17, 4-18, 4-19 and 4-20. The distribution of organics and inorganics is shown on Figures 4-5, 4-6 and 4-7. Additional detection summaries for compounds analyzed for the assessment of USTs are included in Appendix A of this report.

Organic contamination in the upper surficial aquifer was primarily limited to VOCs. The VOCs consisted of contaminants that are associated with fuel (benzene, ethylbenzene, and xylene) as well as contaminants related to solvents such as TCE. Toluene was detected in only one of 38 groundwater samples collected from the uppermost portion of the surficial aquifer (A47/3-08) at a concentration of 3.1 J µg/L. Because this contaminant was not detected frequently and had such a low concentration, it is assumed that this compound's detection is the result of laboratory introduced contamination and not the result of site-related activities. The concentration of toluene detected in the trip blank (3.6 µg/L) was slightly higher than the level detected in the groundwater monitoring well.

Ten VOCs were detected in samples collected during the first phase of the RI (see Table 4-5). Two compounds (chloroform and toluene) are common laboratory contaminants and were detected at concentrations less than ten times the maximum blank concentration. A third compound (1,2-dichloroethene), that is not a common laboratory contaminant, was detected at a level less than 5 times the maximum blank concentration. As a result, these three compounds did not undergo further evaluation.

Of the remaining seven compounds, ethylbenzene, trans-1,2-dichloroethene and xylenes (total) were the only ones that did not exceed either the NCWQS or the federal MCL.

Benzene contamination (i.e., concentrations exceeding NCWQS and/or federal MCLs) was detected in samples collected from monitoring wells A47/3-09, A47/3-08, A47/3-11, 73-MW27, 73-MW29, 73-MW14 and 73-MW13. Groundwater contamination defined by these wells is present in the central to eastern portion of the site, southeast of Building A-47. This contamination is believed to have originated from spills and/or releases associated with a former UST located in the central portion of the A-47 complex. The sample collected from well A47/3-08 contained the highest concentration of benzene (18J µg/L) detected in the surficial aquifer.

Trichloroethene (TCE) contamination was detected at various locations across the site. A total of 13 samples contained detectable levels of TCE, six exceeded the standard established by the state of North Carolina for the protection of groundwater (NCWQS) and four exceeded the federal MCL. Contaminant concentrations exceeding the previously mentioned standards and/or levels were detected in samples from monitoring wells 73-MW01, 73-MW11, 73-MW14, 73-MW19, 73-MW23 and 73-MW27. The highest concentration was detected in a sample collected from monitoring well 73-MW27 at a concentration of 24 µg/L. The source for the TCE contamination in the shallow groundwater is not known; however, it is the likely result of past operations conducted at Building A-3 (eventually replaced by Building A-47) and improper disposal of used solvents.

TCE was a common solvent used in the degreasing and cleaning of parts associated with various pieces of equipment used throughout Camp Lejeune. Although it has since been replaced by other types of cleaners and solvents, the disposal of spent solvents was, for many years, directly to the ground surface. A 1983 aerial photograph depicts stained soils around the western and southwestern parameter of the concrete apron surrounding Building A-3 (the maintenance facility in 1983). This corresponds roughly with the highest concentrations of TCE in the shallow groundwater. The contamination detected in samples collected from groundwater monitoring wells 73-MW19, 73-MW23 and 73-MW01 is suspected to have been the result of past disposal practices for spent solvents used at the facility. Given the relatively low concentrations detected in these samples, it is not assumed that a continuing source exists at the site or that the contamination is migrating from an off-site source.

Vinyl chloride and cis-1,2-dichloroethene were detected in three and nine samples, respectively. Of the three detections of vinyl chloride, all exceeded the NCWQS and two exceeded the federal MCL. The highest concentration was recorded in the sample collected from monitoring well A47/3-08, installed by Law-Catlin during a UST investigation. Cis-1,2-dichloroethene (cis-1,2-DCE) was detected at concentrations in exceedence of the NCWQS and the federal MCL two times each. The maximum concentration of cis-1,2-DCE was detected in a sample from monitoring well 73-MW13 located near the center of the site. Both of these compounds are degradation products resulting from the dechlorination (i.e., the replacement of chlorine by hydrogen) of TCE. Therefore, the source for the vinyl chloride and cis-1,2-dichloroethene contamination detected in the shallow groundwater is suspected to be the TCE.

VOCs detected in the samples collected during the second phase of field work included vinyl chloride, acetone, 1,2-dichloroethene (total), trichloroethene, benzene, and toluene. Acetone and toluene were detected at concentrations less than ten times the maximum blank concentration and will not be further evaluated. The concentration of toluene detected in the groundwater sample was 2J µg/L. This concentration is below the level detected in the trip blank (3.6 µg/L). Vinyl chloride was detected in two samples, each exceeding the NCWQS and the federal MCL than previously identified in Phase I (Phase I = 23J, Phase II = 43J). TCE was detected in only three samples exceeding the NCWQS twice and the federal MCL once. The highest concentration was again detected in well 73-MW27. Benzene was detected a total of three times, four less than the first phase, exceeding the NCWQS in each case and the federal MCL only once.

The biggest difference between the VOCs detected in the first and second phases is that fewer detections were noted from samples collected and analyzed in the second phase when compared to those collected in the first phase. However, it is not believed that this is an indication that contamination is degrading, but rather a result of the different methods used to analyze the samples (as previously noted). Monitoring wells whose samples collected in the first phase contained the highest detections of benzene, vinyl chloride and TCE contamination were sampled in the second phase and again contained the highest detections of these same contaminants.

The only semivolatile detected in the groundwater samples that exceeded the NCWQS and the federal MCL was bis(2-ethylhexyl)phthalate. This compound is used in plasticizing a variety of polymeric materials such as natural rubber, synthetic rubber, polyvinyl chloride resins (PVC), component of dielectric fluids in electrical capacitators, erasable ink, inert ingredient in pesticide formulations and widely used in insect repellant formulations, cosmetics, rubbing alcohol, liquid soap, detergents, munitions, and lubricating oils. Bis(2-ethylhexyl)phthalate released to soil will neither evaporate nor leach into groundwater. If released to water systems, the compound will biodegrade fairly rapidly (half-life is two to three weeks) following a period of acclimation. However, the concentrations detected in the three samples were all below ten times the maximum blank concentration and is therefore considered to be laboratory related contamination. In addition, no pesticides or PCBs were detected in the samples submitted for analysis.

A total of 13 metals were detected in the groundwater samples collected from the uppermost portion of the surficial aquifer. Of the 13, only four (antimony, iron, manganese and thallium) were detected in excess of the NCWQS and none were detected at concentrations exceeding the federal MCLs. The two elements with the highest number of exceedences were iron (43) and manganese (14) which are commonly detected at concentrations exceeding the NCWQS throughout Camp Lejeune. It is not believed that the occurrence of these elements is the result of waste disposal, but rather these elements naturally exist at levels that exceed the NCWQS.

4.4.2.2 Lowermost Portion of the Surficial Aquifer

Samples were collected from six monitoring wells that were designed to determine if contamination was present beneath the clay bed that divides the surficial aquifer under the western portion in the site. The following wells were sampled: 73-MW01B, 73-MW02B, 73-MW06B, 73-MW11B, 73-MW15B and DW-02 (installed by Baker during an investigation of UST SA-21). Groundwater sample detection summaries for organic compounds and inorganic elements analyzed were the RI are presented in Tables 4-21, 4-22, 4-23, 4-24, and 4-25. The locations of these samples are shown on Figures 4-8, 4-9 and 4-10. Additional detection summaries for compounds analyzed for the assessment of USTs are included in Appendix A of this report.

Six VOCs were detected in samples collected during the first phase of field work. Only three compounds (1,2-dichloroethane, chloroform and trichloroethene) exceeded either the NCWQS or the federal MCL. 1,2-Dichloroethane and chloroform were detected at concentrations below ten times the maximum blank concentration and are considered to be laboratory-related contamination. TCE was detected in three of the five samples exceeding the NCWQS and the federal MCL twice. These exceedences occurred in samples collected from monitoring wells 73-MW11B and 73-MW01B.

During the second phase of field work, samples were collected from four wells (DW-02 and 73-MW06B were not resampled). 1,2-Dichloroethene and TCE were detected in two of the four samples submitted for analysis. TCE concentrations exceeded the NCWQS and the federal MCL in each sample and the highest concentration was detected in the sample from well 73-MW11B. Detections of TCE in the lower portion of the surficial aquifer is evidence of downward migration from the upper portion of the surficial aquifer based on a comparison of data from both locations.

The only SVOCs detected in groundwater were 1,2,4-trichlorobenzene and naphthalene. 1,2,4-Trichlorobenzene is used as a chemical intermediate and to a lesser extent as a solvent. Neither compound exceeded the NCWQS or the federal MCL. No pesticides or PCBs were detected in any of the groundwater samples.

Only seven metals were detected in samples collected from the site. Aluminum, barium, cobalt, iron, magnesium, manganese and zinc were detected in the samples at frequencies ranging from one out of six to six out of six. The only elements that exceeded the NCWQS was iron and manganese which as described in an earlier paragraph is not considered to be the result of waste disposal.

4.4.2.3 Uppermost Portion of the Castle Hayne Aquifer

Five groundwater samples were collected during the first phase of the RI and 14 were collected from the second phase to determine if the uppermost portion of the Castle Hayne aquifer had been contaminated by past activities at the site. Groundwater sample detection summaries for organic compounds and inorganic elements are presented in Tables 4-26, 4-27, 4-28, 4-29, and 4-30. The locations of these samples are shown on Figures 4-11, 4-12 and 4-13.

Analysis of the groundwater samples submitted to the laboratory during the first phase of work identified six VOCs (see Table 4-5). Four of these compounds (1,2-dichloroethane, benzene, chloroform and trichloroethene) either exceeded the NCWQS or the federal MCL, or both. 1,2-Dichloroethane and chloroform was detected at a concentration below ten times the maximum blank concentration and, therefore is considered to be laboratory-related contamination and will be dropped from further evaluation.

TCE was detected in each of the five samples collected in the first phase of the RI at concentrations above the NCWQS; three detections exceeded the federal MCL. The highest concentration, detected in the sample collected from groundwater monitoring well 73-DW03 (110 µg/L), was an order of magnitude higher than the federal MCL. The concentration of TCE detected in this well was the highest observed during the first phase of the RI. Based on results in the upper and lower portions of the surficial aquifer in this area, it is evident that TCE has migrated downward into the Castle Hayne aquifer. At the conclusion of the Phase I RI, it was evident that the vertical and horizontal extent of groundwater contamination at Site 73 had not been determined.

Fourteen samples from the upper portion of the Castle Hayne aquifer were submitted to the laboratory for VOC analysis during the second phase of the RI. A total of five compounds were detected, four exceeded either NCWQS and/or federal MCLs. One of the compounds that exceeded the NCWQS was chloroform. Its concentration in each of the four samples was below ten times the maximum blank concentration and is considered laboratory-related. The remaining contaminants were all detected in the sample collected from monitoring well 73-DW03. TCE was detected at a concentration of 320 µg/L, one order of magnitude higher than the federal MCL and two orders of magnitude higher than the NCWQS. However, the lesser concentrations of TCE that were detected in other samples collected during the first phase were not detected during the second phase. This may be an example of the varied results derived from the different analytical methods used in Phase I versus Phase II.

The vinyl chloride and 1,2-dichloroethene concentrations detected in monitoring well 73-DW03 are suspected to be degradation products associated with the dechlorination of TCE. Vinyl chloride exceeded both the NCWQS and the federal MCL once and 1,2-dichloroethene exceeded the federal MCL.

Two SVOCs were detected in the samples collected during the first phase of field work. Neither compound exceeded either the NCWQS or the federal MCLs. In addition, no pesticides or PCBs were detected.

Eight of the 15 metals detected in the groundwater samples collected from the uppermost portion of the Castle Hayne aquifer exceeded the NCWQS and/or the federal MCLs. The elements detected at concentrations was in excess of the standards were: antimony, barium, beryllium, cadmium, chromium, iron, manganese, nickel and silver. The only elements that exceeded either standard more than once were iron and manganese. As discussed previously, these elements are ubiquitous in the groundwater at Camp Lejeune and; therefore are not considered to be the product of waste disposal. The highest detected concentration for each of the elements was observed in the sample collected from 73-DW01. This monitoring well was constructed in an area previously occupied by a supply well (A5) abandoned prior to 1992. No evidence of groundwater contamination was documented from this well.

4.4.2.4 Combined Lowermost Portions of the Surficial Aquifer and Uppermost Portion of the Castle Hayne Aquifer

Sections 4.4.2.2 and 4.4.2.3 present data obtained from the lower portion of the surficial aquifer and the upper portion of the Castle Hayne aquifer. This section examines the combined data sets from these two zones because data gathered during the RI indicated that substantial hydraulic communication occurs between the aquifers. To best present the combined data, Figure 4-17 was developed to depict the estimated horizontal limits of VOC contamination. To provide a comparison of results from the upper portion of the surficial aquifer and the combined data set, Figure 4-18 was developed.

The horizontal limits of VOC detections shown in Figure 4-17 represent an estimated 1 ppm isoconcentration line. When the combined data sets are considered there are four areas where VOC detections were identified. The easternmost plume appears to be centered in the vicinity of monitoring well 73-DW03. The detections of vinyl chloride, 1,2-dichloroethene, and trichloroethene observed in this location exceeded established standards.

A small centrally located plume consisting of 1,2 dichloroethene, and trichloroethene was defined by monitoring wells 73-MW11B and 75-DW11. However, only the detections of trichloroethene exceeded acceptable standards at this location.

A third plume was located on the eastern side of the site. This plume consisted of 1,2-dichlorothene, and trichloroethene and was defined by monitoring wells 73-MW11B and 75-DW11. However, only the detections of trichloroethene exceeded acceptable standards at this location.

A fourth plume was located on the northeastern eastern side of the site. This plume consisted of trichloroethene and was defined by monitoring wells 73-MW01B and 75-DW08. Trichloroethene detections exceeded acceptable standards at this location.

4.4.2.5 Mid to Lower Portions of the Castle Hayne Aquifer

Six groundwater samples were collected from monitoring wells designed to determine the vertical extent of contamination previously identified in the mid to lower portions of the Castle Hayne aquifer. These wells were installed and sampled during the second phase of field work conducted at the site. The samples were analyzed for VOCs only and only two compounds were detected (acetone and chloroform). Both compounds are common laboratory contaminants and were detected at concentrations below ten times the maximum blank concentration for each. Therefore, both were considered to be laboratory-related contamination and not related to practices at the site. TCE was not detected in any of the samples submitted for analysis including a sample collected in the vicinity of monitoring well 73-DW03. Table 4-31 summarizes detected volatiles in the mid to lower portions of the Castle Hayne aquifer.

4.4.2.6 Extent of Groundwater Contamination

Benzene contamination detected in the surficial aquifer was defined horizontally by monitoring wells A47/3-09, A47/3-11, 73-MW27 and 73-MW29. As previously stated, former UST A47/3 was located in the general vicinity of these wells and is the suspected source of this contamination. The contamination is believed to be restricted to the shallow aquifer because of the natural tendency of benzene to reside in the upper portions of any water-bearing zone due to specific gravity. Low levels of benzene were detected in monitoring well 73-DW03 (installed to approximately 70 feet, bgs); however, it is possible that this contamination may have been introduced during monitoring well installation. Analysis of samples collected from 73-MW15B (installed to approximately 43 ft, bgs) did not detect benzene, indicating that contamination did not migrate through the lower portion of the surficial aquifer to the uppermost portions of the Castle Hayne aquifer.

Chlorinated organic contamination residing in the uppermost portion of the surficial aquifer consists of TCE and its degradation byproducts vinyl chloride and cis-1,2-DCE. Although TCE was detected in a number of samples collected across the site, the concentrations are relatively low compared to samples collected from deeper wells. The highest concentration of TCE was detected in deep well 73-DW03, located in the central portion of the Building A-47 complex. Horizontally, the extent of contamination is defined by monitoring wells 73-DW06, -DW07, and 73-DW08 to the west, wells 73-DW09 and 73-DW10 to the north, well 73-DW13 to the east, and Courthouse Bay to the south. The vertical extent lies between 63 and 146.5 feet msl. No VOCs were detected in the mid to lower portions of the Castle Hayne aquifer. This is further supported by the groundwater flow model (discussed in Section 3.4.3) which concludes that groundwater in the vicinity of Site 73 travels downward from the surficial aquifer into the upper portion of the Castle Hayne aquifer. Groundwater continues its downward progression as it heads toward Courthouse Bay until at some depth it begins to travel upward and discharges into the bay. The point at which groundwater begins its upward flow defines the vertical extent of contamination. Detections of TCE observed north and west of the Building A-47 complex may be the result of singular events of deposition and the compound may have been dispersed further by shallow groundwater flow patterns. The detections of chlorinated compounds along the southeastern and southern edges of the site may be due to the upward migration and eventual recharge of Courthouse Bay by deeper groundwaters at the site.

The absence of vinyl chloride and 1,2-DCE in the deeper portions of the Castle Hayne indicates that the dechlorination is occurring in the shallow aquifer further lending evidence that the TCE contamination originated at the surface and did not migrate into the deeper zones until much later. The lack of dechlorination products in deep groundwater samples is evident that the contamination occurred relatively recently and substantiates the suspicion that the disposal of spend solvents (suspected in the 1983 aerial photograph) may be the source of the contamination.

Inorganic contamination is not perceived to be a concern at Site 73. The most commonly detected analytes were iron and manganese which are typical to the groundwaters within Camp Lejeune and coastal North Carolina. These compounds are not considered to be the result of waste disposal, but are commonly detected throughout Camp Lejeune at concentrations exceeding NCWQS values. According to the U.S. Air Force <u>Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater</u>, these elements should be monitored and mapped to assist in evaluating the biodegradation of chlorinated solvents. Therefore, the elevated levels of these metals may be due to the degradation of the chlorinated solvents at the site. Additional analytes were detected in a sample collected from 73-DW01. However, without corroborating evidence the results obtained from this sample are not considered indicative of inorganic contamination at the site, rather a localized incident in the vicinity of the well.

4.4.3 Surface Water/Sediment Investigation

A total of 12 sampling stations were establish at Site 73 for the intention of collecting surface water/sediment samples. As previously described in Section 2.4, one of the stations was not accessible and, therefore was not sampled. A total of 11 surface water and 22 sediment samples were collected from Courthouse Bay and two unnamed tributaries located east and west of the site. A single sample (73-SW13-01) was collected from a seep observed on the southwestern portion of the site. Surface water/sediment and the seep samples were analyzed for TCL organics, TAL metals and TOC. In addition, the zero to 6-inch sediment surface sample obtained at each location was analyzed for grain-size distribution. Summaries of surface water and sediment contamination are provided on Tables 4-6 and 4-7, respectively.

4.4.3.1 Sediment Investigation

Two samples were collected at each sampling station from zero to 6 and 6 to 12 inches below the sediment surface. A comparison of contamination detected in sediment samples to NOAA ER-L (Effects - Range Low Screening Values) and ER-M (Effects - Range Medium Screening Values) is provided on Table 4-6. Detections of organic compounds and inorganic elements are summarized on Tables 4-32, 4-33, 4-34, 4-35 and 4-36 and depicted on Figures 4-14 and 4-15.

Acetone and 2-butanone were detected in seven and two samples, respectively. In each case, the concentrations of the compounds were below ten times the maximum blank concentration. Other common laboratory contaminants that were not detected in blank samples were methylene chloride and toluene. Due to their relatively low concentrations, it is believed that these compounds may not be related to site conditions, but rather be the result of laboratory-introduced contamination.

Carbon disulfide contamination was detected in 13 samples collected from the eastern and western tributaries and Courthouse Bay. It is used in the manufacturing of various products including such items as carbon tetrachloride, paints and paint removers and as a solvent for such items as wax, phosphorus, sulfur, resins, lacquers and cold vulcanized rubber. The relatively low concentrations observed in the sediments and the lack of its presence in soil and groundwater samples, affords suspicion that the compound is the result of decaying organic matter within the sediments and not contamination from the site.

Xylene was only detected in sample 73-SD11 collected from the western tributary at a concentration of 9J µg/L. The presence of this contaminant is suspected to be the result of a spill or leak from all the training vehicles used on the tank trails and in Courthouse Bay. The concentration is not high enough to indicate that a persistent problem exists. Groundwater and soil samples in the vicinity of this sample location do not contain detections of xylene thus indicating that the contamination is not originating from the site.

Semivolatiles such as bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, fluoranthene, phenanthrene, phenol and pyrene were detected in samples collected during the RI. Bis(2-ethylhexyl)phthalate and di-n-butyl phthalate are common laboratory contaminants and, even though they were not detected in the blanks associated with the sediment samples, they were detected in blanks associated with other media. It is suspected that these compounds may be laboratory-related contamination.

Fluoranthene, phenanthrene and pyrene are PAHs that may be the result of the degradation of organic material, the incomplete combustion of organic material (i.e., forest fires) and the combustion of fossil fuels. Based on activities at the base (controlled burning, training exercises in the bay) and the high degree of organic content in the swampy areas along the bay, it is believed that the presence of these compounds are not related to site contamination, but a function of base and site activities.

The remaining SVOC detected at the site is phenol. This highly soluble compound is used in a number of products including resins, dyes and plastics. It was only detected once in the sediments collected from Courthouse Bay and at fairly low concentrations. The ER-M was not exceeded and no value has been established as the ER-L by NOAA.

Three pesticides were detected in the sediments collected from the eastern tributary and Courthouse Bay. 4,4'-DDD was detected in six samples in which each sample exceeded the ER-L but only one exceeded the ER-M. Five samples contained detectable concentrations of 4,4'-DDE exceeding the

ER-L, but not the ER-M. Both samples that contained detectable concentrations of endrin exceeded the ER-L value, but not the ER-M. Additionally, a single detection of aroclor-1260 was observed in the 6- to 12-inch sample collected from 73-SD06 located in Courthouse Bay. It exceeded the ER-L value, only.

Three (arsenic, iron and lead) of the 14 metals detected in the sediment samples exceeded the ER-L. Lead and iron was detected in each of the 22 samples collected at the site but were in excess of the ER-L only one time each. Arsenic was detected in nine samples, exceeding the ER-L twice. The sample from sampling station 73-SD09 contained the highest detections of 11 of the 14 metals.

4.4.3.2 Surface Water Investigation

A comparison of contamination detected in surface water samples to NCWQS for Class SC waters and average reference station concentrations collected from the White Oak River Basin is provided on Table 4-7. Surface water sample summaries for organic compounds and inorganic elements are presented on Tables 4-37 and 4-38 and illustrated on Figure 4-16.

Acetone, chloroform and toluene were the only VOCs detected in the surface water samples collected during the RI. Three samples contained detectable concentrations of acetone but all were below ten times the maximum blank concentration and not considered to be site related contamination. Chloroform and toluene were each detected in a single sample and exceeded the average reference station concentration in each case. Although these compounds were not detected in the blank samples, they are common laboratory contaminants and are suspected to have originated in the laboratory and not related to site conditions.

Seven of the eight metals detected in the samples exceeded the NCWQS and/or the average reference station concentration. The metals that exceeded these standards were aluminum, antimony, iron, magnesium, manganese, silver and zinc. Elements most frequently detected at concentrations exceeding the Average Reference Station Concentration were antimony, iron, magnesium, manganese and zinc. Additionally, silver and zinc exceeded the NCWQS standard for each element once.

4.4.3.3 Seep Sample Analytical Results

A single sample was collected from a seep that originated on the southeastern portion oft he site and flowed into Courthouse Bay. The bay is located approximately 100 feet south of the northernmost portion of the seep (Figure 4-16). Analytical results from the seep sample were compared to NCWQC for Class SC waters and average reference station concentrations collected from the White Oak River Basin (see Table 4-6). The results were compared to surface water criteria since the bay is the receptor for the contaminants observed in the seep sample.

1,2-Dichloroethane, toluene and 2-butanone were the only VOCs detected in the sample. The concentrations of 1,2-dichloroethane and 2-butanone were below ten times the maximum blank concentration and are not considered to be site-related contamination. Toluene was not discovered in any blanks associated with surface water samples; however, is low concentration (6 J µg/L) and detection in blanks from other media provide evidence that it may have originated in the laboratory and not be site-related. There are no NCWQS for toluene; however, it does exceed the average reference station concentration (ND).

The only SVOC detected in the seep sample was 4-methylphenol at a concentration of 4 J µg/L. The state of North Carolina has not established a NCWQS for this compound and it was not detected during the White Oak River Basin study. Phenols are typically used as soap and at this concentration, soap may be the source for this compound.

Metals detected in the seep sample include aluminum, barium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, vanadium, and zinc. Seven elements (cadmium, chromium, copper, lead, mercury, nickel, and zinc) were detected at concentrations which exceeded the NCWQS and all of the elements were detected in the sample at concentrations exceeding the average reference station concentration.

4.4.3.4 Extent of Surface Water and Sediment Contamination

Volatiles detected in the surface water samples were suspected to be laboratory-related contamination. No chlorinated compounds were observed in the samples, even though Courthouse Bay is the local groundwater discharge area. Analyte concentrations were similar to the levels detected in groundwater samples, as expected. It is evident that Courthouse Bay is not affected by the volatiles detected in the groundwaters at the site.

PAHs were detected in the sample collected from the sediments at sampling station 73-SD04. All of the compounds were detected in the zero to 6-inch sample indicating that they might result from the combustion of fossil fuel. The sampling station is located in the area where water craft used for training and maneuvers are typically docked.

The pesticides were detected in most of the samples collected from the sediments. There is no pattern of distribution which suggests that the compounds are the result of erosion and possible aerial application. The level of pesticides observed at Site 73 is typical for MCB Camp Lejeune.

A single detection of aroclor-1260 was observed in the sediments collected from 73-SD06. This detection may be the result of past POL spills and/or release at the site.

Detected metals were evenly distributed across sediments in Courthouse Bay and the two unnamed tributaries. The only metals that exceeded the ER-L was arsenic, iron and lead. All three of the metals that exceeded the ER-L were detected in samples collected from sampling stations 73-SD09 and 73-SD06. These analytes may be attributed to activities conducted at the site.

4.4.4 Ecological Investigation

A total of 13 fish samples were collected from the three sampling stations located in Courthouse Bay and the junction of the western tributary and the bay. Five of the samples were collected for whole body and eight for fillet analysis. In addition, six Blue Crab samples were submitted to the laboratory for analysis of the edible portions. Positive organic and metal results are presented in Tables 4-39 through 4-47.

4.4.4.1 Blue Crab Samples

Three VOCs (methylene chloride, acetone, and toluene) were detected in Blue Crab samples at levels that exceeded concentrations detected in other media by at least two orders of magnitude. These VOCs are common laboratory contaminants, and are probably the result of sample preparation. It is believed that these compounds are not related to contamination detected at the site for two reasons. The concentrations of VOCs detected in the surface water and sediment samples were very low and detected infrequently. Additionally, they do not bioconcentrate in fish and crab tissues as noted in the relatively low bioconcentration factors (acetone - 0.69; methylene chloride = 3.75; and toluene = 10.7). Therefore, it is more likely that these VOC detections were introduced to the laboratory; however, the exact procedure for introduction cannot be determined.

In addition to the VOCs, di-n-butyl phthalate (another common laboratory contaminant) was the only detected semi-volatile in the samples. It is suspected that detection of this compound in the sample is also the result of poor sample preparation. No pesticides or PCBs were detected in any of the samples.

A total of 11 metals were detected in the samples. The metals were arsenic, barium, copper, iron, lead, magnesium, manganese, mercury, selenium, silver and zinc. Mercury and selenium, as stated previously, were not detected in any other media and are not considered contamination related to Site 73.

4.4.4.2 Fish Samples

Three VOCs (methylene chloride, acetone, and toluene) were detected in Blue Crab samples at levels that exceeded concentrations detected in other media by at least two orders of magnitude. As mentioned previously, these VOCs are common laboratory contaminants, and are probably the result of sample preparation. The concentrations of the compounds detected in the surface water and sediment samples were very low and detected infrequently and do not bioconcentrate in fish and crab tissues as noted in the relatively low bioconcentration factors (acetone - 0.69; methylene chloride = 3.75; and toluene = 10.7). Therefore, it is more likely that these VOC detections were introduced to the laboratory; however, the exact procedure for introduction cannot be determined.

A single VOC (acetone) was detected in whole body samples, and three VOCs (methylene chloride, acetone, and toluene) were detected in fillet samples. These VOC detections are suspected to be laboratory related and not site related for the reasons mentioned previously.

The only semivolatile detected in either the whole body or fillet samples is di-n-butyl phthalate. The compound was detected in sample 73-FS03-AC01F, a fillet sample from sampling station F/C-03. Di-n-butyl phthalate is a common laboratory contaminant, like the previously mentioned volatiles is suspected to have been introduced during sample preparation.

Endrin was detected in sample 73-FS02-SS01F, a fillet sample collected from sampling station F/C-02. This compound was detected in the sediments collected from sampling stations SW/SD-04 and SW/SD-06 as well as the surface and subsurface soil samples collected from the site. This contaminant is suspected to have originated from site related activities. Groundwater and surface water samples confirm that the contaminant is not being transported via groundwater and discharging to the bay. Therefore it is believed that erosion and transportation of on site soils may be the transport mechanism by which this compound is accumulating in the sediments and biota in the bay.

A total of 15 metals were detected in the whole body samples collected from the site. Mercury, selenium and molybdenum were detected in the samples but not detected in any other media sampled at the site. These elements are suspected to have been acquired by the fish elsewhere and not associated with the site.

Ten metals were detected in the fillet samples submitted for analyses. Like the previously described samples, mercury and selenium were detected in the samples but not detected in any other media. The fish are likely to have ingested these elements elsewhere and not at the site.

4.5 Engineering Results

A total of sixteen samples were collected for engineering parameters during the RI. A subsurface soil sample (73-AC1-MW13), four groundwater samples (73-AC1-MW13-01, 73-A47/3-8-01, 73-AC5-MW20-01 and 73-GW04GW-01), and 11 sediment samples (one from each station) were analyzed. The results are included in Appendix P.

4.6 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) samples were collected during the soil, groundwater, surface water and sediment investigations. These samples include trip blanks, field blanks, equipment rinsate blanks and duplicate samples. Analytical results of the field duplicates are provided in Appendix Q and the other field QA/QC results are provided in Appendix R.

Organic compounds detected within the blank samples include methylene chloride, acetone, 1,2-dichloroethane, 2-butanone, chloroform, bromodichloromethane, di-n-butylphthalate, bis(2-ethylhexyl) phthalate, dibromochloromethane, toluene, 2-hexanone and 4-chloroaniline. The trip blanks used for the Site 73 RI were prepared by the laboratory, shipped to the field and then returned to the laboratory with the samples. Methylene chloride, toluene, chloroform, and 1,2-dichloroethane were detected in the trip blanks at low concentrations. This would tend to indicate that these contaminants either originated from the laboratory or had been introduced during shipping.

The equipment rinsate blanks were collected in the field from sampling equipment that had recently been cleaned. 4-Chloroaniline, di-n-butyl phthalate, bis(2-ethylhexyl)phthalate, methylene chloride, acetone, 2-butanone, 1,2-dichloroethane and 2-hexanone were detected in the rinsate blanks. With the exception of acetone, the other contaminants were detected at relatively low concentrations. The origin of di-n-butyl phthalate, bis(2-ethylhexyl)phthalate, 2-hexanone, methylene chloride, 1,2-dichloroethane, and 2-butanone contamination may be related to the laboratory, the deionized water used for the blanks or from the field decontamination process or cross contamination. The methylene chloride and 1,2-dichloroethane was detected in the trip blanks at similar concentrations and, therefore are suspected to be laboratory-related contamination. Di-n-butyl phthalate, bis(2-ethylhexyl)phthalate, 2-hexanone and 2-butanone were not detected in the trip blanks but are common laboratory contaminants and, therefore are suspected of originating in the laboratory. 4-Chloroaniline was not detected in any of the samples collected at the site and is suspected to be laboratory related contamination.

Acetone was detected at its highest concentration in sample numbers 73-RB-19, 73-RB-20 and 73-RS-27. Possible sources for the acetone contamination detected in the blanks include field decontamination and laboratory cleaning/extraction procedures. Acetone is commonly used in laboratories for cleaning glassware and contaminant extractions. However, due to the sharp increase in the concentration of acetone in the equipment rinsate blanks, the suspected source of the contamination is small amounts of isopropanol (which has acetone as a component) that are in scratches, grooves and have not completely dried prior to sampling.

In addition to the organic contamination observed in the blank equipment rinsate blanks, eight metals and three salts were detected. These analytes include aluminum, barium, cadmium, cobalt, calcium, iron, manganese, potassium, magnesium, sodium and zinc. The origin of these elements is most likely site related.

Field blanks were collected from the three sources of water used at the site. Samples 73-FB-01 (phase I) and 73-FB-202 (phase II) were collected from the distilled water used for equipment decontamination (i.e., stainless steel spoons, split spoons, bowls, etc.); samples 73-FB-02 (phase I) and 73-FB-201 (phase II) were collected from the deionized water supplied by the laboratory for use in collection of equipment rinsate blanks; and samples 73-FB-03 (phase I) and 73-FB203 (phase II) were collected from the potable water used for decontamination of heavy equipment (i.e., steam cleaning). Sample 73-FB-01 contained acetone, di-n-butylphthalate and bis(2-ethylhexyl) phthalate as contaminants. Sample 73-FB-202 contained acetone contamination. The water was packaged in plastic bags contained within cardboard boxes and the plastic bags may be the source of the phthalate contamination. The acetone contamination is again suspected to be laboratory related contamination.

Sample 73-FB-02 contained methylene chloride and both 73-FB-02 and 73-FB-201 contained acetone contamination. The methylene chloride contamination is suspected to have originated in the laboratory; however the acetone is suspected to have had two sources of contamination. Since acetone was detected in the trip blanks, the equipment blanks and the deionized water, it is suspected that the contamination originated from the laboratory (i.e., contaminated deionized water and/or equipment) and the field decontamination procedures (i.e., not allowing the equipment to completely dry prior to use). This would explain the sharp increase in concentration in the rinsate blanks and the high concentration observed in field blank sample 73-FB-02.

Sample 73-FB-03 contained contaminants acetone, chloroform, bromodichloromethane and dibromochloromethane. Sample 73-FB-203 contained detectable concentrations of chloroform, bromodichloromethane and dibromochloromethane. With the exception of acetone and chloroform, these contaminants are suspected to exist within the potable water supply. The suspected origin of acetone contamination has been discussed in previous paragraphs. Chloroform contamination can come from the use of chlorinated water in the laboratory or if the potable water is chlorinated during its treatment, if any.

Ten of the 23 TAL Inorganics were detected in the field blanks. The analytes include aluminum, barium, calcium, copper, iron, lead, magnesium, potassium, sodium and zinc.

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SECTION 4.0 TABLES

TABLE 4-1

SUMMARY OF BLANK CONTAMINANT RESULTS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Constituent	Maximum Concentration Detected in Blank (μg/L)	Medium Associated with Maximum Concentration Detected in Blank	Type of Blank with Maximum Detected Value	Concentration for Comparison(1) (Aqueous - μg/L)	Concentration for Comparison(2) (Solid - μg/kg)
Volatiles Methylene Chloride	9.4	Soil	Rinsate	94	94
Acetone	69J	Soil	Rinsate	690	690
Chloroform	33	Soil	Field	165	165
2-Butanone	4.7J	Soil	Rinsate	47	47
Bromodichloromethane	13	Soil	Field	65	65
Dibromochloromethane	3J	Soil	Field	15	15
Toluene	2.9J	Soil	Trip	29	29
Semivolatiles 4-Chrloroaniline	2J	Soil	Rinsate	10	330(3)
Di-n-butylphthalate	1J	Soil	Field	10	330(3)
Bis(2-ethylhexyl)phthalate	2J	Soil	Field	20	630(3)
Volatiles - Phase I Methylene Chloride	5.2J	Groundwater	Rinsate	52	NA
Chloroform	0.8J	Groundwater	Trip	8	NA
1,2-Dichloroethane	3.6J	Groundwater	Trip	18	NA
Toluene	3.6	Groundwater	Trip	36	NA
Volatiles - Phase 11 Methylene Chloride	1J	Groundwater	Trip	10	NA
Acetone	19	Groundwater	Rinsate	190	NA
Chloroform	33	Groundwater	Field	330	NA
Bromodichloromethane	13	Groundwater	Field	65	NA
Dibromochloromethane	3J	Groundwater	Field	15	NA
Volatiles Acetone	170	Surface Water/Sediment	Rinsate	1,700	1,700
1,2-Dichloroethane	1J	Surface Water/Sediment	Rinsate	5	5
2-Butanone	22	Surface Water/Sediment	Rinsate	220	220
2-Hexanone	7J	Surface Water/Sediment	Rinsate	35	35

Notes:

(1) Concentration is five or ten times (for common laboratory blank contaminants) the maximum detected concentration in a blank.

(2) Concentration is five or ten times the maximum detected concentration in a blank; converted to μg/kg.

NA - Not applicable

TABLE 4-1

SUMMARY OF BLANK CONTAMINANT RESULTS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Constituent	Maximum Concentration Detected in Blank (μg/L)	Medium Associated with Maximum Concentration Detected in Blank	Type of Blank with Maximum Detected Value	Concentration for Comparison(1) (Aqueous - μg/L)	Concentration for Comparison(2) (Solid - μg/kg)
Volatiles					
Methylene Chloride	9.4	Soil	Rinsate	94	94
Acetone	69J	Soil	Rinsate	690	690
Chloroform	33	Soil	Field	165	165
2-Butanone	4.7J	Soil	Rinsate	47	47
Bromodichloromethane	13	Soil	Field	65	65
Dibromochloromethane	3J	Soil	Field	15	15
Toluene	2.9J	Soil	Trip	29	29
Semivolatiles					
4-Chrloroaniline	2J	Soil	Rinsate	10	330(3)
Di-n-butylphthalate	1J	Soil	Field	10	330(3)
Bis(2-ethylhexyl)phthalate	2J	Soil	Field	20	630(3)
Volatiles - Phase I					
Methylene Chloride	5.2J	Groundwater	Rinsate	52	NA
Chloroform	0.8J	Groundwater	Trip	8	NA
1,2-Dichloroethane	3.6J	Groundwater	Trip	18	NA
Toluene	3.6	Groundwater	Trip	36	NA
Volatiles - Phase 11					
Methylene Chloride	1J	Groundwater	Trip	10	NA
Acetone	19	Groundwater	Rinsate	190	NA
Chloroform	33	Groundwater	Field	330	NA
Bromodichloromethane	13	Groundwater	Field	65	NA
Dibromochloromethane	3J	Groundwater	Field	15	NA
Volatiles					
Acetone	170	Surface Water/Sediment	Rinsate	1,700	1,700
1,2-Dichloroethane	1J	Surface Water/Sediment	Rinsate	5	5
2-Butanone	22	Surface Water/Sediment	Rinsate	220	220
2-Hexanone	7J	Surface Water/Sediment	Rinsate	35	35

Notes:

(1) Concentration is five or ten times (for common laboratory blank contaminants) the maximum detected concentration in a blank.

(2) Concentration is five or ten times the maximum detected concentration in a blank; converted to μg/kg.

NA - Not applicable

TABLE 4-2

COMPARISON OF SITE BACKGROUND CONCENTRATIONS TO BASE BACKGROUND LEVELS IN SURFACE SOILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Site Background (mg/kg)	Base Background (mg/kg)
Aluminum	1,080	17.7 - 9,570
Antimony	ND	0.33 - 8
Arsenic	ND	0.065 - 3.9
Barium	2.3	0.65 - 20.8
Beryllium	ND	0.02 - 0.26
Cadmium	ND	0.04 - 1.0
Calcium	70.2	4.25 - 10,700
Chromium	ND	0.33 - 12.5
Cobalt	ND	0.185 - 4.15
Copper	ND	0.5 - 87.2
Iron	572	69.7 - 9,640
Lead	3.7	0.47 - 142
Magnesium	23	2.55 - 610
Manganese	0.97	0.87 - 66
Mercury	ND	0.01 - 0.13
Nickel	ND	0.45 - 7.2
Potassium	ND	1 - 416
Selenium	ND	0.075 - 1.3
Silver	ND	0.0435 - 4.3
Sodium	ND	4.7 - 126
Thallium	ND	0.055 - 1.2
Vanadium	ND	0.305 - 48.6
Zinc	6	0.3 - 28.3

Note:

ND = Not Detected

TABLE 4-3

COMPARISON OF SITE BACKGROUND CONCENTRATIONS TO BASE BACKGROUND LEVELS IN SUBSURFACE SOILS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Site Background (mg/kg)	Base Background (mg/kg)
Aluminum	1,360	16.9 - 11,000
Antimony	ND	0.355 - 6.9
Arsenic	ND	0.033 - 15.4
Barium	3.6	0.65 - 22.6
Beryllium	ND	0.01 - 0.31
Cadmium	ND	0.155 - 1.2
Calcium	113	4.75 - 4,410
Chromium	ND	0.65 - 66.4
Cobalt	ND	0.175 - 7
Copper	ND	0.16 - 9.5
Iron	703	63.3 - 90,500
Lead	1.5	0.465 - 21.4
Magnesium	3.5	2.85 - 852
Manganese	1.8	0.395 - 19.9
Mercury	ND	0.01 - 0.68
Nickel	ND	0.45 - 9.2
Potassium	ND	1.05 - 1,250
Selenium	ND	0.085 - 2.4
Silver	ND	0.175 - 1
Sodium	ND	2.2 - 141
Thallium	ND	0.055 - 2.7
Vanadium	ND	0.34 - 69.4
Zinc	3.8	0.32 - 26.6

Note:

ND = Not Detected

TABLE 4-4

SUMMARY OF SOIL CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria			Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above			Distribution of Positive Detections
			Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background					Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background	
Surface Soil	Volatile (µg/kg)	1,1,1-Trichloroethane	900	1,668	NA	2 J	2 J	73-DW09	1/35	0	0	NA	north, N.C. HWY 172
		1,2-Dichloroethane	10	1.84	NA	2 J	2 J	73-SB07	1/27	0	1	NA	adjacent to SA-42
		1,2-Dichloropropane	20	2.88	NA	1 J	1 J	73-SB07	1/35	0	0	NA	adjacent to SA-42
		2-Butanone	NE	692	NA	2 J	4.2 J	73-DW03	4/35	NA	0	NA	north and east
		Acetone	8,000	2,810	NA	24	29 J	73-MW20	2/35	0	0	NA	north
		Chlorobenzene	600	438	NA	1 J	1 J	73-MW14	1/35	0	0	NA	adjacent to 73-DW03
		Ethylbenzene	5,000	241	NA	8 J	8 J	73-MW20	1/35	0	0	NA	adjacent to 73-DW05
		Styrene	2,000	2,242	NA	2 J	2 J	73-MW18	1/35	0	0	NA	near Courthouse Road
		Toluene	5,000	7,275	NA	1 J	1 J	73-DW01	1/35	0	0	NA	north, near 73-MW01
		Trichloroethene	20	18.30	NA	2 J	2 J	73-MW05	1/35	0	0	NA	near Building A8
		Xylenes (total)	74,000	4,958	NA	1 J	4 J	73-MW36	10/30	0	0	NA	scattered
	Semivolatile (µg/kg)	2,4-Dinitrophenol	100	NE	NA	56 J	200 J	73-MW23	4/34	2	NA	NA	scattered
		4-Chloro-3-Methylphenol	NE	NE	NA	36 J	36 J	73-SB09	1/35	NA	NA	NA	near 73-MW37
		Acenaphthene	200,000	8,160	NA	40 J	40 J	73-MW07	1/35	0	0	NA	south, near 73-MW06
		Anthracene	4,300,000	995,000	NA	50 J	50 J	73-MW07	1/35	0	0	NA	south, near 73-MW06
		Benzo(a)anthracene	700	343	NA	220 J	220 J	73-MW07	1/35	0	0	NA	south, near 73-MW06
		Benzo(a)pyrene	4,000	NE	NA	160 J	160 J	73-MW07	1/35	0	NA	NA	south, near 73-MW06
		Benzo(b)fluoranthene	4,000	NE	NA	260 J	330 J	73-SB07	2/35	0	NA	NA	east and south
		Benzo (g,h,i)perylene	NE	6,720,000	NA	140 J	140 J	73-SB04	1/35	NA	0	NA	southeast, near 73-MW15
		Bis(2-ethylhexyl)phthalate	11,000	NE	NA	42 J	84 J	73-SB12	9/35	0	NA	NA	scattered, north and west
		Butyl Benzyl Phthalate	68,000	27,800	NA	110 J	110 J	73-SB11	1/35	0	0	NA	northwest, near 73-MW21
		Chrysene	1,000	38,150	NA	60 J	190 J	73-MW07	3/35	0	0	NA	scattered
		Di-n-butyl Phthalate	120,000	24,800	NA	110 J	510	73-MW05	11/35	0	0	NA	north, west and east
		Fluoranthene	980,000	276,080	NA	42 J	380 J	73-MW07	4/35	0	0	NA	scattered
		Phenanthrene	NE	59,640	NA	260 J	260 J	73-MW07	1/35	NA	0	NA	west, near 73-MW06
		Pyrene	1,400,000	286,440	NA	41 J	450	73-MW07	5/35	0	0	NA	southwest and east
	Pesticide (µg/kg)	4,4'-DDD	700	NE	NA	7	82	73-MW14	7/29	0	NA	NA	scattered
		4,4'-DDE	500	NE	NA	3.9 NJ	11 J	73-MW20	3/29	0	NA	NA	scattered
		4,4'-DDT	1,000	NE	NA	2.8 NJ	15 J	73-MW20	2/29	0	NA	NA	north and east
		Alpha-Chlordane	NE	NE	NA	2.5 NJ	2.5 NJ	73-SB09	1/29	NA	NA	NA	near 73-MW37
		Endrin Ketone	NE	NE	NA	7 NJ	7 NJ	73-MW20	1/29	NA	NA	NA	near 73-DW05
		Gamma-Chlordane	NE	NE	NA	3.3 J	6.8 J	73-SB09	2/29	NA	NA	NA	north and east
	PCB (µg/kg)	Aroclor-1060	NE	NE	NA	140 NJ	140 NJ	73-MW20	1/29	NA	NA	NA	near 73-DW05
		Aroclor-1260	NE	NE	NA	170 J	170 J	73-MW20	1/29	NA	NA	NA	near 73-DW05

TABLE 4-4

SUMMARY OF SOIL CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria			Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above			Distribution of Positive Detections
			Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background					Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background	
Surface Soil (continued)	TPH (mg/kg)	Diesel Range Organics	NE	NE	NA	11	160	73-MW12	28/46	NA	NA	NA	scattered
		Gasoline Range Organics	NE	NE	NA	16	16	73-SB02	1/49	NA	NA	NA	adjacent to 73-MW08
		HBPH, as motor oil	NE	NE	NA	130	160	73-MW19	3/3	NA	NA	NA	northeast, southwest
		Oil and Grease	NE	NE	NA	860	13,800	73-MW28	8/26	NA	NA	NA	west, south and southeast
	Metal (1) (mg/kg)	Aluminum	NE	NE	5,856.1	147	10,600	73-SB03	35/35	NA	NA	1	scattered
		Barium	32	848	17.3	2.3	46.3	73-MW20	35/35	4	0	1	scattered
		Cadmium	6	2.72	0.7	1.1	1.9	73-MW14	5/35	0	0	5	scattered
		Chromium	NE	27.20	6.6	2.3	13.5 J	73-SB05	27/35	NA	0	8	scattered
		Cobalt	NE	NE	2	4.4	7.2	73-MW29	4/35	NA	NA	4	central and southeast
		Copper	NE	704	7.1	2.4	9.2	73-MW28	15/35	NA	0	2	scattered
		Iron	NE	151.20	3,702	174	8,310 J	73-SB05	35/35	NA	35	3	scattered
		Lead	NE	270.06	23.4	1.2	38.2	73-MW07	35/35	NA	0	7	scattered
		Magnesium	NE	NE	203	14	789	73-SB05	35/35	NA	NA	10	scattered
		Manganese	NE	65.20	18.5	0.97	38.8	73-SB05	35/35	NA	0	1	scattered
		Vanadium	NE	NE	11.4	2.6	14.8	73-SB03	21/35	NA	NA	1	scattered
		Zinc	42,000	1100.40	13.8	2.9 J	197	73-MW12	30/35	0	0	16	scattered
Subsurface Soil	Volatile (µg/kg)	1,1,1-Tricloroethane	900	1,668	NA	21	21	73-DW09	1/28	0	0	NA	north, N.C. HWY 172
		2-Butanone	NE	692	NA	2 J	9 J	73-SB07	7/27	NA	0	NA	scattered
		4-Methyl-2-Pentanone	NE	220,000 (4)	NA	11	11	73-SB07	1/28	NA	0	NA	adjacent to SA-42
		Acetone	8,000	2,810	NA	22 J	530	73-DW10	13/28	0	0	NA	scattered
		Carbon Disulfide	14,000	4,940	NA	2 J	2 J	73-DW09	1/28	0	0	NA	north, N.C. HWY 172
		Ethylbenzene	5,000	241	NA	1 J	1 J	73-MW37	2/28	0	0	NA	north and northeast
		M-Xylene & P-Xylene	240,000	4,958	NA	1.8 J	1.8 J	73-DW03	1/2	0	0	NA	central, near 73-MW13
		O-Xylene	150,000	4,958	NA	0.89 J	3 J	73-MW14	2/3	0	0	NA	central
		Tetrachloroethene	40	7.40	NA	1 J	1 J	73-SB01	1/28	0	0	NA	west, near 73-MW02
		Tricloroethene	20	18.30	NA	6 J	6 J	73-MW23	1/28	0	0	NA	west, near 73-MW30
		Xylenes (Total)	74,000	4,958	NA	1 J	11 J	73-SB13	5/25	0	0	NA	scattered
	Semivolatile (µg/kg)	2-Methylnaphthalene	NE	NE	NA	250 J	9,400	73-SB01	2/27	NA	NA	NA	west and central
		2,4-Dinitrophenol	100	NE	NA	140 J	180 J	73-MW23	2/26	2	NA	NA	west and northeast
		Acenaphthene	200,000	8,160	NA	51 J	830 J	73-SB01	3/27	0	0	NA	scattered
		Anthracene	4,300,000	995,000	NA	2000 J	2000 J	73-MW15B	1/27	0	0	NA	southeast, near 73-DW04
		Benzo(a)antracene	700	343	NA	120 J	880 J	73-MW15B	2/27	1	1	NA	southeast
		Benzo(a)pyrene	4,000	NE	NA	140 J	140 J	73-SB06	1/27	0	NA	NA	southeast, near 73-MW15
		Benzo(b)fluoranthene	4,000	NE	NA	230 J	690 J	73-MW15B	2/27	0	NA	NA	southeast
		Bis(2-ethylhexyl)phthalate	11,000	NE	NA	62 J	360 J	73-MW14	11/27	0	NA	NA	scattered
		Chrysene	1,000	38,150	NA	120 J	930 J	73-MW15B	2/27	0	0	NA	southeast

TABLE 4-4

SUMMARY OF SOIL CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria			Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above			Distribution of Positive Detections
			Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background					Soil Screening Levels (3)	Soil Target Concentrations (4)	Base Background	
Subsurface Soil (continued)	Semivolatile (µg/kg) (continued)	Di-n-butyl Phthalate	120,000	24,800	NA	110 J	430	73-MW02	10/27	0	0	NA	scattered
		Fluoranthene	980,000	276,080	NA	44 J	4000	73-MW15	3/27	0	0	NA	southeast and central
		Fluorene	160,000	44,297	NA	100 J	1200 J	73-SB01	2/27	0	0	NA	west and central
		Phenanthrene	NE	59,640	NA	140 J	1600 J	73-SB01	3/27	NA	0	NA	scattered
		Pyrene	1,400,000	286,440	NA	100 J	3100 J	73-MW15B	3/27	0	0	NA	southeast and central
	Pesticide (µg/kg)	Dieldrin	1	NE	NA	6.6 J	6.6 J	73-SB07	1/27	1	NA	NA	east, adjacent to SA-42
		4,4'-DDE	500	NE	NA	4.8 J	50	73-MW15	5/27	0	NA	NA	scattered
		4,4'-DDD	700	NE	NA	6.5 J	9100	73-MW28	9/27	1	NA	NA	south, west and southeast
		4,4'-DDT	1,000	NE	NA	17 J	17 J	73-SB07	1/27	0	NA	NA	east, adjacent to SA-42
		Alpha-Chlordane	NE	NE	NA	2.4 J	2.4 J	73-SB07	1/27	NA	NA	NA	east, adjacent to SA-42
		Endosulfan I	3,000	NE	NA	4.1 J	4.1 J	73-SB07	1/27	0	NA	NA	east, adjacent to SA-42
		Endrin Aldehyde	NE	NE	NA	3.9	3.9	73-MW15B	1/27	NA	NA	NA	south, near 73-DW04
	PCB (µg/kg)	Aroclor-1254	NE	NE	NA	35 J	56 NJ	73-SB07	2/27	NA	NA	NA	central and southeast
	TPH (mg/kg)	Diesel Range Organics	NE	NE	NA	13	1,000	73-MW28	12/35	NA	NA	NA	scattered
		HBPH, as motor oil	NE	NE	NA	27	10,000	73-MW28	4/4	NA	NA	NA	scattered
		Oil and Grease	NE	NE	NA	730	7200	73-MW28	8/31	NA	NA	NA	scattered
	Metal (1) (mg/kg)	Aluminum	NE	NE	5,856.1	141	17,200	73-MW21	29/29	NA	NA	2	scattered
		Barium	32	848	17.3	2	26.3	73-MW21	28/29	0	0	5	scattered
		Cadmium	6	2.72	0.7	1.3	1.6	73-SB07	2/29	0	0	2	south and southeast
		Chromium	NE	27.20	6.6	2.3	28.7	73-MW21	23/29	NA	1	10	scattered
		Cobalt	NE	NE	2	4.9	5.3	73-MW28	3/29	NA	NA	3	south and southeast
		Copper	NE	704	7.1	2.7	9.5	73-MW06	7/29	NA	0	1	south, central and east
		Iron	NE	151.20	3,702	200	9,620	73-MW21	29/29	NA	29	3	scattered
		Lead	NE	270.06	23.4	0.91	71.8	73-MW06	29/29	NA	0	3	scattered
		Magnesium	NE	NE	203	16.6	1090	73-MW21	29/29	NA	NA	8	scattered
		Manganese	NE	65.20	18.5	0.65	20 J	73-SB06	29/29	NA	0	1	scattered
		Vanadium	NE	NE	11.4	2.5	30.1	73-MW21	20/29	NA	NA	2	scattered
		Zinc	42,000	1100.40	13.8	1.4 J	87.7	73-MW12	24/29	0	0	9	scattered

Notes:

(1) Metals in both surface and subsurface soils were compared to twice the average base background positive concentrations for aluminum, barium, iron, manganese cadmium, chromium, cobalt, copper, lead, magnesium, vandium and zinc.

(2) Soil Screening Level - USEPA Region III Soil Screening Levels for Protection of Groundwater, established by the Office of Solid Waste Emergency Response: R.L. Smith (October 4, 1995).

(3) Soil Target Concentrations - North Carolina Risk Analysis Framework methods for determining contaminant target concentrations in soil and groundwater, Method I, S3: G-1.

(4) No concentration was provided under S3: G-1 classification therefore the concentration for the S3: G-2 classification was used for comparison.

- Concentrations are presented µg/kg for organics (parts per billion), metal concentrations for soils are presented in mg/kg (parts per million).

NE - Not Established

NA - Not applicable

TABLE 4-5

SUMMARY OF GROUNDWATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Aquifer System	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS	Federal MCLs					NCWQS	Federal MCLs	
Uppermost Portion of the Surficial Aquifer	Volatiles via EPA Method 601/602 (µg/l) (Phase I)	1,2-Dichloroethane	0.38	5	0.3	0.7 J	A47/3-08	9/38	7	0	scattered
		Benzene	1	5	2.2 J	18 J	A47/3-08	7/38	7	3	central and east
		Chloroform	0.19	100	0.7	0.7	73-MW07	1/38	1	0	south, near 73-MW06
		Cis-1,2-Dichloroethene	70	70	1.3	74	73-MW13	9/38	2	2	central, east and south
		Ethylbenzene	29	700	3.1	3.1	MW-13	1/38	0	0	north, near DW-02
		Toluene	1000	1000	3.1 J	3.1 J	A47/3-08	1/38	0	0	east, near A47/3-09
		Trans-1,2,-Dichloroethene	100	70	1.7	4.5 J	A47/3-09	4/38	0	0	central and east
		Trichloroethene	2.8	5	1.4	24	73-MW27	13/38	6	4	scattered
		Vinyl Chloride	0.015	2	1.8 J	23 J	A47/3-08	3/38	3	2	central, east and south
		Xylenes (total)	530	10,000	1.2	5.5	MW-13	4/37	0	0	central and north
	Volatiles via CLP Method (µg/l) (Phase II)	Vinyl Chloride	0.015	2	22	43 J	A47/3-08	2/20	2	2	east
		Acetone	700	NE	2 J	2 J	73-MW27	1/20	0	NA	central, near Building A-47
		1,2-Dichloroethene (total)	NE	70	2 J	44	A47/3-08	5/20	NA	0	central, east and west
		Trichloroethene	2.8	5	1 J	46	73-MW27	3/20	2	1	central and northwest
		Benzene	1	5	3 J	27	A47/3-08	3/20	3	1	central and southeast
		Toluene	1000	1000	2 J	2 J	A47/3-08	1/20	0	0	east, near SA-42
	Semivolatile (µg/l) (Phase I)	Phenol	300	NE	2 J	2 J	A47/3-22	1/42	0	NA	east, near SA-42
		Bis(2-Ethylhexyl)phthalate	3	6	1 J	50	73GW-03	3/43	1	1	scattered
		Acenaphthene	800	NE	2 J	4 J	73-MW15	2/43	0	NA	south and southeast
		Di-n-butyl Phathalate	700	NE	1 J	6 J	73-MW25	10/43	0	NA	scattered
		Fluorene	280	NE	1 J	1 J	73-MW15	1/43	0	NA	southeast, near 73-DW04
		Naphthalene	21	NE	6 J	6 J	73-MW29	1/43	0	NA	central, within parking area
	Pesticide (µg/l)	ND	--	--	--	--	--	--	--	--	--
	PCB (µg/l)	ND	--	--	--	--	--	--	--	--	--
	Metals (mg/l)	Aluminum	NE	NE	49.9	29,700 J	73-MW09	37/44	NA	NA	scattered
		Antimony	6	NE	55.8	55.8	73-MW30	1/44	1	NA	west, near 73-MW02
		Barium	2,000	2,000	10.2	116	A47/3-22	44/44	0	0	scattered
		Chromium	50	100	10.6	39.7	73-MW09	3/44	0	0	central
		Cobalt	NE	NE	26.1	53.4	A47/3-22	9/44	NA	NA	scattered
		Copper	1,000	1,300	13.8	14.3	73-MW09	2/44	0	0	south and central
		Iron	300	NE	171	38,800	A47/3-22	44/44	43	NA	scattered
		Lead	15	15	3.6	14.9	73-MW09	3/44	0	0	scattered
		Magnesium	NE	NE	629	25,900	73-MW15	44/44	NA	NA	scattered
		Manganese	50	NE	4.8	310	A47/3-13	43/44	14	NA	scattered
		Thallium	2	NE	10.8	10.8	A47/3-22	1/44	1	NA	east, near SA-42

TABLE 4-5

SUMMARY OF GROUNDWATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Aquifer System	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS	Federal MCLs					NCWQS	Federal MCLs	
Upper Surficial (continued)	Metals (mg/l) (continued)	Vanadium	NE	NE	10.7	10.7	73-MW09	2/44	NA	NA	east and south
		Zinc	2,100	NE	8.6	186	73-MW29	38/44	0	NA	scattered
Lower Surficial Aquifer	Volatiles via EPA Method 601/602 (µg/l) (Phase I)	1,2-Dichloroethane	0.38	5	0.4	0.4	73-MW15B	1/5	1	0	southeast, near 73-DW04
		Chloroform	0.19	100	0.6	0.7	73-MW11B	2/5	2	0	central and south
		Cis-1,2-Dichloroethene	70	70	11	11	73-MW11B	1/5	0	0	central, near 73-MW16
		Ethylbenzene	29	700	1.3 J	1.3 J	73-MW15B	1/5	0	0	southeast, near 73-DW04
		Trichloroethene	2.8	5	1.4	31	73-MW11B	3/5	2	2	scattered
		Xylenes (total)	530	10,000	1.4	31	73-MW15B	1/5	0	0	southeast, near 73-DW04
	Volatiles via CLP (µg/l) (Phase II)	1,2-Dichloroethene (total)	70	NE	3 J	35	73-MW02B	2/4	0	0	west and central
		Trichloroethene	2.8	5	9 J	9 J	73-MW01B	2/4	2	2	central and north
	Semivolatile (µg/l) (Phase I)	1,2,4-Trichlorobenzene	NE	70	1 J	1 J	73-MW01B	1/6	NA	0	north
		Naphthalene	21	NE	2 J	3 J	73-MW15B	2/6	0	NA	north and southeast
	Pesticide (µg/l)	ND	--	--	--	--	--	--	--	--	--
	PCB (µg/l)	ND	--	--	--	--	--	--	--	--	--
	Metals (mg/l) (Phase I)	Aluminum	NE	NE	67.6 J	192	73-MW02B	3/6	NA	NA	
		Barium	2,000	2,000	6.3	23.8	73-MW02B	6/6	0	0	scattered
		Cobalt	NE	NE	26.8	26.8	DW-02	1/6	NA	NA	north, near 73-MW18
		Iron	300	NE	766	2010	73-MW02B	6/6	6	NA	scattered
		Magnesium	NE	NE	687	2230	73-MW11B	5/6	NA	NA	scattered
		Manganese	50	NE	13.8	356	73-MW02B	6/6	3	NA	scattered
		Zinc	2,100	NE	11.6	46.8	73-MW15B	5/6	0	NA	scattered
Uppermost Portion of the Castle Hayne Aquifer	Volatiles via EPA Method 601/602 (µg/l) (Phase I)	1,2-Dichloroethane	0.38	5	0.6	0.7	73-DW03	2/5	2	0	
		Benzene	1	5	2.4	2.4	73-DW03	1/5	1	0	central, near 73-MW13
		Chloroform	0.19	100	1 J	5.5 J	73-DW04	3/5	3	0	
		Cis-1,2-Dichloroethene	70	70	67	67	73-DW03	1/5	0	0	central, near 73-MW13
		Trans-1,2,-Dichloroethene	100	70	1.8	1.8	73-DW03	1/5	0	0	central, near 73-MW13
		Trichloroethene	2.8	5	3.2	110	73-DW03	5/5	5	3	scattered
	Volatiles via CLP Method (µg/l) (Phase II)	Vinyl Chloride	0.015	2	4 J	4 J	73-DW03	1/14	1	1	central, near 73-MW13
		Chloroethane	NE	NE	3 J	3 J	73-DW03	1/14	NA	NA	central, near 73-MW13
		1,2-Dichloroethene (total)	NE	70	120	120	73-DW03	1/14	NA	1	central, near 73-MW13
		Chloroform	0.19	100	1 J	2 J	73-DW11	4/14	4	0	
		Trichloroethene	2.8	5	320	320	73-DW03	1/14	1	1	central, near 73-MW13
	Semivolatile (µg/l) (Phase I)	1,2,4-Trichlorobenzene	NE	70	2 J	5 J	73-DW02	2/5	NA	0	south and north
		Di-n-Butyl Phthalate	700	NE	2 J	2 J	73-DW02	1/5	0	NA	south
	Pesticide (µg/l)	ND	--	--	--	--	--	--	--	--	--

TABLE 4-5

SUMMARY OF GROUNDWATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Aquifer System	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS	Federal MCLs					NCWQS	Federal MCLs	
Uppermost Portion of the Castle Hayne Aquifer (continued)	PCB (µg/l)	ND	--	--	--	--	--	--	--	--	--
	Metals (mg/l) (Phase I)	Aluminum	NE	NE	52.1	2240	73-DW01	4/5	NA	NA	scattered
		Antimony	6	NE	457	457	73-DW01	1/5	1	NA	north, near 73-MW01
		Barium	2,000	2,000	11.2	2050	73-DW01	5/5	1	1	scattered
		Beryllium	NE	4	52.3	52.3	73-DW01	1/5	NA	1	north, near 73-MW01
		Cadmium	5	5	50.7	50.7	73-DW01	1/5	1	1	north, near 73-MW01
		Chromium	50	100	210	210	73-DW01	1/5	1	1	north, near 73-MW01
		Cobalt	NE	NE	530	530	73-DW01	1/5	NA	NA	north, near 73-MW01
		Copper	1,000	1,300	269	269	73-DW01	1/5	0	0	north, near 73-MW01
		Iron	300	NE	74.4	2070	73-DW01	4/5	3	NA	scattered
		Magnesium	NE	NE	64.3	4190	73-DW01	5/5	NA	NA	scattered
		Manganese	50	NE	2.2	534	73-DW01	4/5	2	NA	scattered
		Nickel	100	100	520	520	73-DW01	1/5	1	1	north, near 73-MW01
		Silver	18	NE	54.2	54.2	73-DW01	1/5	1	NA	north, near 73-MW01
		Vanadium	NE	NE	518	518	73-DW01	1/5	NA	NA	north, near 73-MW01
		Zinc	2,100	NE	11.4 J	541	73-DW01	5/5	0	NA	scattered
Mid/Lower Portions of Castle Hayne Aquifer	Volatiles via CLP (µg/l) (Phase II)	Acetone	700	NE	2 J	2 J	73-GW05	1/6	0	NA	across Courthouse Bay
		Chloroform	0.19	100	2 J	2 J	73-GW01	1/6	1	0	central, near 73-DW11
	Semivolatile (µg/l)	Not Requested	--	--	--	--	--	--	--	--	--
	Pesticide (µg/l)	Not Requested	--	--	--	--	--	--	--	--	--
	PCB (µg/l)	Not Requested	--	--	--	--	--	--	--	--	--
	Metals (mg/l)	Not Requested	--	--	--	--	--	--	--	--	--

Notes:
- Organic concentrations are presented µg/l for liquids (parts per billion), metal concentrations for liquids are presented in mg/l (parts per million).
- Positively detected compounds were compared to North Carolina Water Quality Standards (NCWQS) and the Federal Maximum Contaminant Levels (MCLs) established by the

NE - Not Established

NA - Not applicable

TABLE 4-6

SUMMARY OF SURFACE WATER CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above		Distribution of Positive Detections
			NCWQS (2)	Average Reference Station Conc.					NCWQS	Average Reference Station Conc.	
Surface Water	Volatiles via CLP Method (µg/l)	Acetone	NE	ND	2 J	5 J	73-SW01	3/11	NA	3	scattered
		Chloroform	NE	ND	50	50	73-SW01	1/11	NA	1	east trib.
		Toluene	NE	ND	3 J	3 J	73-SW06	1/11	NA	1	Courthouse Bay
	Metal (1) (mg/l)	Aluminum	NE	ND	74.6	500	73-SW11	4/11	NA	4	scattered
		Antimony	NE	ND	116	216	73-SW06	10/11	NA	10	scattered
		Barium	NE	24.3	6.7	10.5	73-SW01	10/11	NA	0	scattered
		Iron	NE	317.8	245	4,540	73-SW01	11/11	NA	9	scattered
		Magnesium	NE	511,200	1550	1,390,000	73-SW06	11/11	NA	10	scattered
		Manganese	NE	ND	5.8	37.7	73-SW02	11/11	NA	11	scattered
		Silver	0.1	19.1	6.4	6.4	73-SW06	1/11	1	0	Courthouse Bay
		Zinc	86	ND	12	103	73-SW04	10/11	1	10	scattered

Notes:
- Organic concentrations are presented in µg/l (parts per billion), metal concentrations are presented in mg/l (parts per million).

(1) Metals were compared to North Carolina Water Quality Standards and Average Reference Station Concentrations for aluminum, antimony, barium, iron, mangesium manganese, silver and zinc.

(2) NC DEHNR, 1994 (North Carolina Water Quality Standards)

NE - Not Established
ND - Not Detected
NA - Not applicable

TABLE 4-7

SUMMARY OF SEDIMENT CONTAMINATION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction (units)	Detected Contaminants or Analytes	Comparison Criteria		Min.	Max.	Location of Maximum Detection	Depth (inches)	Detection Frequency	Detections Above		Distribution of Positive Detections
			ER-L (2)	ER-M (3)						ER-L (1)	ER-M (2)	
Sediment	Volatile (µg/kg)	Methylene Chloride	NE	NE	7 J	7 J	73-SD11	6-12	1/22	NA	NA	west trib.
		Acetone	NE	NE	5 J	280	73-SD09	0-6	7/22	NA	NA	scattered
		Carbon Disulfide	NE	NE	2 J	75	73-SD09	6-12	13/22	NA	NA	scattered
		2-Butanone	NE	NE	4 J	13 J	73-SD01	6-12	2/22	NA	NA	east trib. & Courthouse Bay
		Toluene	NE	NE	1 J	12 J	73-SD11	6-12	2/22	NA	NA	west trib. & Courthouse Bay
		Xylenes (total)	NE	NE	9 J	9 J	73-SD11	6-12	1/22	NA	NA	west trib.
	Semivolatile (µg/kg)	Bis(2-ethylhexyl)phthalate	1,300	NE	51 J	1900 J	73-SD06	6-12	8/22	1	NA	scattered
		Di-n-butyl Phthalate	1,400	NE	240 J	680 J	73-SD11	0-6	11/22	0	NA	scattered
		Fluoranthene	600	5100	1000 J	1000 J	73-SD04	0-6	1/22	1	0	Courthouse Bay
		Phenanthrene	240	1500	940 J	940 J	73-SD04	0-6	1/22	1	0	Courthouse Bay
		Phenol	NE	420	150 J	150 J	73-SD07	6-12	1/22	NA	0	Courthouse Bay
		Pyrene	665	2600	880 J	880 J	73-SD04	0-6	1/22	1	0	Courthouse Bay
	Pesticide (µg/kg)	4,4'-DDD	2	20	4.2 J	28	73-SD01	0-6	6/22	6	1	east trib. & Courthouse Bay
		4,4'-DDE	2	27	5.6 J	17 J	73-SD06	6-12	5/22	5	0	east trib. & Courthouse Bay
		Endrin	0.02	45	4.7	7.5 J	73-SD06	0-6	2/22	2	0	east trib. & Courthouse Bay
	PCB (µg/kg)	Aroclor-1260	22.7	180	120 J	120 J	73-SD06	6-12	1/22	1	0	Courthouse Bay
	Metal (1) (mg/kg)	Aluminum	NE	NE	431	28,100	73-SD09	6-12	21/22	NA	NA	scattered
		Arsenic	8.2	70	3.3	14.1	73-SD09	0-6	9/22	2	0	scattered
		Barium	500	NE	1.3	27.8	73-SD09	6-12	21/22	0	NA	scattered
		Cadmium	1.2	9.6	2.7 J	6.1 J	73-SD06	6-12	2/22	2	0	Courthouse Bay
		Chromium	81	370	3.3	55.9	73-SD09	6-12	17/22	0	0	scattered
		Cobalt	NE	NE	7.68	11.5	73-SD08	0-6	3/22	NA	NA	Courthouse Bay
		Copper	34	270	3.2	20.5	73-SD09	0-6	14/22	0	0	scattered
		Iron	27,000	NE	3.7	27,400	73-SD09	0-6	22/22	1	NA	scattered
		Lead	46.7	218	3.3	47.7 J	73-SD06	6-12	22/22	1	0	scattered
		Magnesium	NE	NE	140	9430	73-SD09	0-6	21/22	NA	NA	scattered
		Manganese	230	NE	3.4	137	73-SD09	0-6	21/22	0	NA	scattered
		Nickel	20.9	51.6	6	19.7	73-SD09	6-12	5/22	0	0	scattered
		Vanadium	NE	NE	2.6	50.8	73-SD09	6-12	16/22	NA	NA	scattered
		Zinc	150	410	8	100	73-SD09	6-12	21/22	0	0	scattered

Notes: - Organic concentrations are presented in µg/kg (parts per billion), metal concentrations for sediments are presented in mg/kg (parts per million).

(1) Metals in both surface and subsurface soils were compared to twice the average base background positive concentrations for aluminum, cobalt, barium, arsenic, cadmium, chromium, copper, lead, iron, manganese, magnesium, nickel, vanadium, zinc.

(2) NOAA ER-L - USEPA Region IV Sediment Effects-Range Low Screening Values, established by the National Oceanic and Atmospheric Administration.

(3) NOAA ER-M - USEPA Region IV Sediment Effects-Range Medium Screening Values, established by the National Oceanic and Atmospheric Administration.

NE - Not established

NA - Not applicable

ND - Not detected

5.0 CONTAMINANT FATE AND TRANSPORT

The potential for a contaminant to migrate and persist in an environmental medium is critical when evaluating the potential for a chemical to elicit an adverse human health or ecological effect. The environmental mobility of a chemical is influenced by its physical and chemical properties, the physical characteristics of the site, and the site chemistry. This section presents a discussion of the various physical and chemical properties of contaminants detected at OU No. 9, Site 73, that impact the fate and transport of the contaminants in the environment. The basis for this discussion of contaminant fate and transport is presented in Section 4.0, Nature and Extent of Contamination.

5.1 Chemical and Physical Properties Impacting Fate and Transport

Table 5-1 presents the physical and chemical properties associated with a representative group of organic contaminants detected at the site which determine inherent environmental mobility and fate. These properties include:

- Vapor pressure
- Water solubility
- Octanol/water partition coefficient
- Organic carbon partition coefficient
- Specific gravity
- Henry's Law constant
- Mobility index

A discussion of the environmental significance of each of these properties follows.

Vapor pressure provides an indication of the rate at which a chemical may volatilize. It is of primary significance at environmental interfaces such as surface soil/air and surface water/air. Volatilization is not as important when evaluating groundwater and subsurface soils. Vapor pressure for monocyclic aromatics are generally higher than vapor pressures for PAHs. Contaminants with higher vapor pressures will enter the atmosphere at a quicker rate than the contaminants with low vapor pressures.

The rate at which a contaminant is leached from soil by infiltrating precipitation is proportional to its water solubility. More soluble contaminants are usually more readily leached than less soluble contaminants. The water solubilities indicate that the volatile organic contaminants, including monocyclic aromatics, are usually several orders-of-magnitude more soluble than PAHs.

Vapor pressure and water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. These two parameters can be used to estimate an equilibrium concentration of a contaminant in the water phase and in the air directly above the water. This can be expressed as Henry's Law Constant.

The octanol/water partition coefficient (K_{ow}) is a measure of the equilibrium partitioning of contaminants between octanol and water. A linear relationship between octanol/water partition coefficient and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor - BCF) has been established (Lyman et al., 1982). The coefficient is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available.

The organic carbon partition coefficient (K_{oc}) indicates the tendency of an organic chemical to adhere to soil particles. Contaminants with high soil/sediment partition coefficients generally have low water solubilities and vice versa. For example, contaminants such as PAHs are relatively immobile in the environment and are preferentially bound to the soil. The compounds are not subject to aqueous transport to the extent of compounds with higher water solubilities. Erosional properties of surface soils may; however, enhance the mobility of these bound soils contaminants.

Specific gravity is the ratio of the weight of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a contaminant will have a tendency to float or sink (as an immiscible liquid) in water, if it exceeds its corresponding water solubility.

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

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

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

Relative MI	Mobility Description
> 5	extremely mobile
0 to 5	very mobile
-5 to 0	slightly mobile
-10 to -5	immobile
< -10	very immobile

5.2 Contaminant Transport Pathways

Based on the evaluation of existing conditions at Site 73, the following potential contaminant transport pathways have been identified:

- Erosion of contaminated soils and transportation of the soils to surface water and sediment.
- Off-site atmospheric deposition of windblown dust.
- Leaching of sediment contaminants to surface water.
- Leaching of soil contaminants to groundwater.
- Migration of groundwater contaminants off site.
- Groundwater infiltration from the shallow aquifer to the deep aquifer.
- Groundwater discharge to surface water.

Contaminants released to the environment could also undergo the following during transportation:

- Physical transformations: volatilization, precipitation
- Chemical transformations: photolysis, hydrolysis, oxidation, reduction
- Biological transformation: biodegradation
- Accumulation in one or more media

The following paragraphs describe the potential transport pathways listed above.

5.2.1 Erosion of Contaminated Soils and Transportation to Surface Water and Sediment

Surface water run-off can transport contaminated surface soils from the site to a surface water body, contaminating the surface water and/or sediment. This is influenced by the velocity of the surface water run-off; vegetation; grain size of the soils; solubility of the contaminants; distance to the water body and the proximity of the contaminated soils to the water body.

The majority of Site 73 is covered with concrete, asphalt or vegetation. The only exceptions are the tank trails and a few dirt pathways which have shown signs of erosion. The areas covered by vegetation are in some cases only sparsely covered and susceptible to erosion. Erosion occurring at the site has the possibility to transport potential contaminants to Courthouse Bay or other portions of the site. Although surface and subsurface soils are primarily sands with high infiltration rates, analytical results indicate that erosion of surface soils at the site has transported some contamination to Courthouse Bay.

5.2.2 Off-Site Deposition of Windblown Dust

Wind can act as a contaminant transport pathway agent by eroding exposed soil and exposed sediment and blowing it across or even off site. This is influenced by: wind velocity, moisture, the grain size/density of the soil/sediment particles and the amount of vegetative cover over the soil or sediment.

The majority of Site 73 is covered and would not be susceptible to much wind erosion. However, the tank trails, vehicle pathways and sparsely vegetated areas would be susceptible and could be considered a source of any airborne contaminant carried by dust particles.

5.2.3 Contaminant Transfer Between Sediments and Surface Water

When in contact with surface water, contaminants attached to sediment particles can disassociate from the sediment particle into surface water or vise versa. This is primarily influenced by the physical and chemical properties of the contaminant, (i.e., water solubility, K_{oc}) and the physical and chemical properties of the sediment particle (i.e., grain size, f_{oc}).

Surface water sample analytical results indicate that there has not been significant leaching of sediment contaminants into surface water (Section 4.0), based on the infrequent occurrence and level of contamination. However, the concentrations of elemental contamination observed in the sediments may have originated by evaporation of surface water causing precipitation of the elements into the sediments.

5.2.4 Leaching of Soil Contaminants to Groundwater

Contaminants that adhere to soil particles or have accumulated in soil pore spaces can leach and migrate vertically to the groundwater. This is influenced by the depth to the water table, precipitation, infiltration, physical and chemical properties of the soil, and physical and chemical properties of the contaminant.

Groundwater samples were collected from shallow, shallow-intermediate, intermediate and deep monitoring wells at Site 73. The groundwater results can be compared to soil sample analytical results to determine if contaminants detected in soil have migrated or may migrate in the future, to underlying groundwater.

Soil contamination does not appear significant at Site 73, however an aerial photograph from 1983 depicts stained soils around the perimeter of Building A-3 (recently replaced by Building A-47). Although contamination was not detected in the soils collected in this area, shallow and deep groundwater contamination was observed. The suspected contamination observed in the form of stained soils appears to have leached into shallow groundwater, eventually migrating into deeper groundwater zones.

5.2.5 Migration of Groundwater Contaminants

Contaminants leaching from soils to underlying groundwater can migrate as dissolved constituents in groundwater in the direction of groundwater flow. Three general processes govern the migration of dissolved contaminants caused by the flow of water: (1) advection - movement caused by flow of groundwater; (2) dispersion - movement caused by irregular mixing of waters during advection; and (3) retardation - principally chemical mechanisms which occur during advection. Subsurface transport of the immiscible contaminants is governed by a set of factors different from those of dissolved contaminants. The potential movement of immiscible organic liquids (non-aqueous phase liquids) will not be discussed in this section.

Advection is the process which most strongly influences the migration of dissolved organic solutes. Groundwater, under water table aquifer conditions (i.e., unconfined aquifer), generally flows from regions of the subsurface where the water table is under a higher head (i.e., recharge areas) to regions where the water table is under a lower head (i.e., discharge areas). Hydraulic gradient is the term used to describe the magnitude of this force (i.e., the slope of the water table). In general, the gradient usually follows the topography for shallow, uniform sandy aquifers which are commonly found in coastal regions. In general, groundwater flow velocities, in sandy aquifers under natural gradient conditions, are probably between 10 meters/year to 100 meters/year (Lyman, et al., 1982).

The average seepage velocity of groundwater flow at Site 73 for both the shallow and deep water-bearing zones can be estimated using a variation of Darcy's Equation:

$$V_x = \frac{Ki}{N_e} \qquad (Fetter, 1988)$$

Where:
V_x = average seepage velocity
K = hydraulic conductivity (cm/sec)
i = hydraulic gradient
N_e = effective porosity

Thus, when monitoring wells or potable supply wells in sandy aquifers are located hundreds of meters downgradient of a contaminant source, the average travel time for the groundwater to flow from the source to the well point is typically on the order of years. In the zone of influence created by a high capacity production well or well field; however, the artificially increased gradient could substantially increase the local velocity, and the average travel times for groundwater flow are increased.

Dispersion results from two basic processes, molecular diffusion and mechanical mixing. The kinetic activity of dissolved solutes result in diffusion of solutes from a zone of high concentration to a lower concentration. Dispersion and spreading during transport result in the dilution of contaminants (maximum concentration of contaminant decreases with distance from the plume). For simple hydrogeological systems, the spreading is reported to be proportional to the flow rate. Furthermore, dispersion in the direction of flow is often observed to be markedly greater than dispersion in the directions transverse (perpendicular) to the flow. In the absence of detailed studies to determine dispersive characteristics at Site 73, longitudinal and transverse dispersivities are estimated based on similar hydrogeological systems (Mackay, et al., 1985).

Some dissolved contaminants may interact with the aquifer solids encountered along the flow path through adsorption, partitioning, ion exchange, and other processes. The interactions result in the contaminant distribution between aqueous phase and aquifer solids, diminution of concentrations in the aqueous phase, and retardation of the movement of the contaminant relative to groundwater flow. The higher the fraction of the contaminant sorbed, the more retarded its transport. Certain halogenated organic solvents sorption is affected by hydrophobility (antipathy for dissolving in water) and the fraction of solid organic matter in the aquifer solids (organic carbon content). If the aquifer below Site 73 is homogeneous, sorption of hydrophobic organic solute should be constant in space and time. If the sorptive interaction is at equilibrium and completely reversible, the solute should move at a constant average velocity equal to the average velocity of the groundwater divided by the retardation factor.

Organic contaminants can be transformed into other organic compounds by a complex set of chemical and biological mechanisms. The principal classes of chemical reactions that can affect organic contaminants in water are hydrolysis and oxidation. However, it is believed that most chemical reactions occurring in the groundwater zone are likely to be slow compared with transformations mediated by microorganisms. Certain organic groundwater contaminants can be biologically transformed by microorganisms attached to solid surfaces within the aquifer. Factors which affect the rates of biotransformation of organic compounds include: water temperature and pH, the number of species of microorganisms present, the concentration of substrate, and presence of microbial toxicants and nutrients, and the availability of electron acceptors. Transformation of a toxic organic solute is no assurance that it has been converted to harmless or even less harmless hazardous products. Biotransformation of common groundwater contaminants, such as trichloroethene and tetrachloroethene, can result in the formation of such intermediates as vinyl chloride (Mackay, et al., 1985).

The interaction of non-ionic organic compounds with solid phases can also be used to predict the fate of the highly nonpolar organic contaminants (i.e., 4,4'-DDT, PCBs). Sorptive binding is proportional to the organic content of the sorbent. Sorption of non-ionic organic pesticides can be attributed to an active fraction of the soil organic matter (Lyman et al., 1982). The uptake of neutral organics by soils results from their partitioning to the solutes aqueous solubility and to its liquid-liquid (e.g., octanol-water) partition coefficient. Currently, information is available on the interrelation of soil organic properties to the binding of pesticides, herbicides, and high molecular weight pollutants such as PCBs. However, data is lacking for the non-ionic components of solvents and fuels. Organic matrices in natural systems that have varying origins, degrees of humification, and degrees of association with inorganic matrices exhibit dissimilarities in their ability to sorb non-ionic organic contaminants.

The soils and sediments formed or deposited on the land surface can act as a reservoir for inorganic contaminants. Soils contain surface-active mineral and humic constituents involved in reactions that affect metal retention. The surfaces of fine-grained soil particles are very active chemically; surface sites are negatively or positively charged or they are electronically neutral. Oppositely charged metallic counterions from solutions in soils (i.e., groundwater) are attracted to these charged surfaces. The relative proportions of ions attracted to these various sites depends on the degree of acidity or alkalinity of the soil, on its mineralogical composition, and on its content of organic matter. The extent of adsorption depends on either the respective charges on the adsorbing surface and the metallic cation. In addition to these adsorption reactions, precipitation of new mineral phases also may occur if the chemical composition of the soil solution becomes supersaturated with respect to the insoluble precipitates. Of the probable precipitates, the most important of these phases are hydroxides, carbonates, and sulfides. The precipitation of hydroxide minerals is important for metals such as iron and aluminum. The precipitation of carbonate minerals is significant for calcium and barium; and the precipitation of sulfide minerals dominates the soil chemistry of zinc, cadmium, and mercury. A number of precipitates may form if metals are added to soils. The concentration of metal in solution, will be controlled, at equilibrium, by the solid phase that results in the lowest value of the activity of the metallic ion in solution (Evans, 1989).

5.2.6 Groundwater Discharge to Surface Water

Groundwater discharge to Courthouse Bay is evident according to groundwater elevations collected at the site during the investigation and the results of the site model. Groundwater can transport contamination to the bay, however it is dependent on the solubility of the contamination. Like groundwater flow, three general processes govern the flow of the water: advection, dispersion and retardation. These three processes are described in detail in section 5.2.5.

The G-3 Groundwater Contaminant Transport Model (G3CTM) will be used during the Feasibility Study to determine the target concentrations for groundwater discharging to Courthouse Bay. This is the same model used in the NC DEHNR Risk Analysis Framework, November 1996. The methodology employed in this model starts with the surface water quality standard for a particular chemical, then works backwards through the various mixing and transport processes to arrive at a groundwater calculated source concentration. This concentration is the maximum contaminant concentration that may exist in groundwater without exceeding surface water quality standards and is used in determining the target concentration.

The model is comprised of two parts. Step 1 calculates the transport of the groundwater contaminant plume from some defined position and time to some future point in time in order to predict the maximum contaminant concentrations in the groundwater at the surface water boundary. This step assumes no lateral dispersion, that the contaminant plume is uniformly spread throughout the depth of the aquifer, and that at time=0 the contaminant plume is initially uniformly spread throughout the areal extent of the plume size at the calculated source concentration.

Step 2 considers the mixing effect of groundwater and surface water. The model uses a mixing formula to calculate the mixing of a groundwater contaminant with surface water to produce a surface water contaminant concentration. The mixing formula assumes that the entire surficial groundwater aquifer discharges into the surface water body, and that the groundwater discharging into the surface water body completely mixes with the 7Q10 flow at the point of contact. The 7Q10 flow is the low-flow characteristic of the surface water body.

5.2.7 Groundwater Infiltration from the Shallow to the Deep Aquifer

Vertical movement of groundwater from one aquifer system to another, through a semi-confining unit is dependent on a number of factors including: intrinsic permeability of all involved units; density of the fluid (i.e., water and/or contaminant); viscosity of the fluid; hydraulic head; unit thickness; effective porosity; and bulk density of the soil comprising the semi-confining unit. At Site 73, the vertical hydraulic gradient was calculated using the intermediate wells (completed below the confining unit) and adjacent shallow-intermediate wells (screened at the bottom of the shallow aquifer). According to pathline analysis performed as part of the groundwater model, a potential for downward movement through the semi-confining unit exists in the northern portion of the site. As the groundwater flows from the shallow to the deeper zones, its course changes and it begins to head toward Courthouse Bay. As it nears the bay, the vertical gradient changes the deeper groundwater begins its ascent eventually recharging the bay.

5.3 Fate and Transport Summary

The following paragraphs summarize the contaminant group fate and transport data for contaminants detected in media collected at Site 73.

5.3.1 Volatile Organic Compounds

VOCs tend to be mobile in environmental media as indicated by their presence in groundwater and their corresponding values. Their environmental mobility is a function of high water solubilities, high vapor pressures, low K_{ow} and K_{oc} values, and high mobility indices (see Table 5-1). Without a continuing source, VOCs do not generally tend to persist in environmental media because photolysis, oxidation, and biodegradation figure significantly in their removal.

5.3.2 Polynuclear Aromatic Hydrocarbons

Low water solubilities, high K_{ow} and K_{oc} indicate a strong tendency for PAHs to adsorb to soils. Of the PAHs, fluoranthene, is probably the best marker compound, since it is consistently the most abundant of the PAHs measured and provides the strongest correlation with total PAH values. Benzo(g, h, i) perylene is usually the most abundant compound in soils with low PAH values, but becomes less important with increasing total PAH values. Other PAHs are benzo(a)anthracene, chrysene, pyrene, benzo(g,h,i) perylene, benzo(b)fluoranthene and phenanthrene. Their mobility indices indicate that they are relatively immobile from a physical-chemical standpoint. An exception is naphthalene, which is considered only slightly immobile because of somewhat higher water solubility (Jones, et al., 1989).

PAHs generally lack adequate vapor pressures to be transmitted via vaporization and subsequent airborne transport. However, surface and shallow surface soil particles containing PAHs could potentially be subject to airborne transport and subsequent deposition, especially during mechanical disturbances such as vehicle traffic or digging (Jones, et al., 1989).

PAHs are somewhat persistent in the environment. In general, their persistence increases with increasing aromatic ring numbers. Photolysis and oxidation may be important removal mechanisms in surface waters and surficial soils, while biodegradation could be an important fate process in groundwater, surface soils or deeper soils. PAHs are ubiquitous in nature. The presence of PAHs in the soil may be the result of aerially deposited material, and the chemical and biological conditions in the soil which result in selective microbial degradation/breakdown.

5.3.3 Pesticides/PCBs

Pesticides/PCBs are persistent and immobile contaminants in environmental media. Pesticides travel at varying rates through soil, mainly due to their affinity for soil surfaces. The soil sorption coefficient (K_d) is the distribution of a pesticide between soil and water. In general, the K_d values are higher for high organic carbon soil than for low organic carbon soils. Therefore, soils with high K_d values will retain pesticides (i.e., 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD). As evidenced by the ubiquitous nature of 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, volatilization is an important transport process from soils and waters. PCBs have low vapor pressures, low water solubilities, and high K_{oc} and K_{ow} values. Adsorption of these contaminants to soil and sediment is the major fate of these contaminants in the environment.

5.3.4 Inorganics

Inorganics can be found as solid complexes at ambient temperature and pressure in soils at the site. Inorganic ions exist in pure solutions as hydrated ions. Groundwater, as opposed to a pure solution, is a highly complex chemical system which is heavily influenced by the mineralogy of the substrate. Factors affecting the transport of inorganics in saturated soils are interactive and far more complex and numerous than those affecting the transport of organic contaminants.

The most complicated pathway for inorganic contaminants is migration in subsurface soils and groundwaters, where oxidation reduction potential (Eh) and pH play critical roles. Table 5-2 presents and assessment of relative inorganic environmental mobilities as a function of Eh and pH. Soils at MCB, Camp Lejeune are relatively neutral; therefore, inorganics in the subsurface soil should be relatively immobile.

Transport of inorganic species in groundwater is mainly a function of the inorganic's solubility in solution under the chemical conditions of the soil-solution matrix. The inorganic must be dissolved (i.e., in solution) for leaching and transport by advection with the groundwater to occur. Generally, dynamic and reversible processes control solubility and transport of the dissolved metal ions. Such processes include precipitation/dissolution, adsorption/desorption, and ion exchange.

Inorganics could be sorbed onto colloidal materials, theoretically increasing their inherent mobility in saturated porous media. It is important to note; however, that colloids themselves are not mobile in most soil/water systems.

Inorganics, such as arsenic and chromium, depend upon speciation to influence their mobility. Speciation varies with the chemistry of the environmental medium and temporal factors. These variables make the site-specific mobility of an inorganic constituent difficult to assess. As stated in Section 4.4.2.5, the metals that exceeded state and/or federal standards in groundwater at the site were iron and manganese. These elements occur historically at elevated levels throughout MCB, Camp Lejeune.

5.4 <u>References</u>

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SECTION 5.0 TABLES

TABLE 5-1

PHYSICAL AND CHEMICAL PROPERTIES OF ORGANIC COMPOUNDS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log K_{ow}	Log K_{oc}	Specific Gravity (g/cm^3)	Henry's Law Constant (atm-m^3/mole)	Mobility Index
Volatile Organic Compounds							
1,2-Dichloroethane	61	8.69x10^{03}	1.48	1.52	1.250	--	4.2
Benzene	76	1.78x10^{03}	2.13	1.92	0.879	5.55x10^{-03}	3.2
Cis-1,2-dichloroethane	--	--	--	--	--	--	--
Chloroform	160	3.0x10^{03}	1.97	1.59	1.48	3.39x10^{-03}	4.5
Trichloroethene	60	1.1x10^{03}	2.29	2.09	1.46	11.7x10^{-03}	2.7
Vinyl Chloride	2,660	1.1x10^{03}	0.60	1.91	0.9121	--	4.6
Acetone	270	6x10^{05}	-0.24	-0.45/1.25	0.791	3.43x10^{-05}	6.9/8.7
Toluene	22	5.15x10^{02}	2.69	2.54	0.867	5.9x10^{-03}	1.5
Semivolatile Organic Compounds							
2,4-Dimethylphenol	9.8 x 10^{-02}	6.2 x 10^{03}	2.30	1.98	NA	6.30 x 10^{-07}	NA
Benzo(a)anthracene	2.2 x 10^{-08}	5.7 x 10^{-03}	5.61	5.34	NA	7.34 x 10^{-07}	-15.2
Bis(2-ethylhexyl)phthalate	9.8 x 10^{-06}	0.34	5.11	8.73	0.99	1.5 x 10^{-05}	-14.2
Fluoranthene	5.0 x 10^{-06}	0.265	5.33	4.64	NA	5.12 x 10^{-06}	-10.5
Phenanthrene	9.6 x 10^{-04}	1.29	4.46	4.2	1.025	2.25 x 10^{-04}	-7.2
Pyrene	2.5 x 10^{-06}	0.14	5.32	4.91	1.271	5.10 x 10^{-06}	-11.90
Pesticides/PCBS							
4,4'-DDD	1.0 x 10^{-06}	0.16	6.2	5.9	NA	4 x 10^{-06}	-12.7
Dieldrin	1.87x10^{-07}	0.1	5.6	5.31	1.75	--	-12.0

TABLE 5-1 (Continued)

PHYSICAL AND CHEMICAL PROPERTIES OF ORGANIC COMPOUNDS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-312
MCB, CAMP LEJEUNE, NORTH CAROLINA

COPCs	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log K_{ow}	Log K_{oc}	Specific Gravity (g/cm^3)	Henry's Law Constant (atm-m^3/mole)	Mobility Index
Endrin	$2x10^{-07}$	0.26	5.6	4.06	NA	--	-11.0
Aroclor 1260	$4.1x10^{-05}$	0.003	6.11	4.87	1.58	--	-12.0
Aroclor 1254	$7.7x10^{-05}$	0.03	6.03	4.59	1.50	--	-10.0

Notes:

NA = Not Available

References:

ATSDR, 1989
Clement, 1985
Howard, 1989-1991
Montgomery, 1990
Sax and Lewis, 1987
SCDM, 1991, 1992
SPHEM, 1986
USEPA, 1986
USEPA, 1986a
Verscheuren, 1983

TABLE 5-2

RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh, pH)
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILTY
REMEDIAL INVESTIGATION CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

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

Notes:

Se = Selenium
Zn = Zinc
Cu = Copper
Ni = Nickel
Hg = Mercury
Ag = Silver
As = Arsenic
Cd = Cadmium
Ba = Barium
Pb = Lead
Fe = Iron
Cr = Chromium
Be = Beryllium

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

6.0 BASELINE RISK ASSESSMENT

6.1 Introduction

This Baseline Risk Assessment (BRA) evaluates the projected impact of contaminants of potential concern (COPCs) on human health and/or the environment, now and in the future, in a "no further remedial action scenario". The BRA process examines the data generated during the sampling and analytical phase of the RI and identifies areas of concern (AOCs) and COPCs with respect to geographical, demographic, physical and biological characteristics of the study area. These factors are combined with an understanding of physical and chemical properties of site-associated contaminants, (relative to environmental fate and transport processes) and are then used to estimate contaminant concentrations at logical exposure pathway endpoints. Finally, contaminant intake levels are calculated for hypothetical receptors. Toxicological properties are applied in order to estimate potential public health threats posed by detected contaminants.

The BRA for Operable Unit (OU) No. 9, Site 73, has been conducted in accordance with current USEPA Risk Assessment Guidance (USEPA, 1989a and USEPA, 1991a) and USEPA Region IV Supplemental Risk Guidance (USEPA, 1991b).

The components of the BRA include:

- Hazard Identification
- The exposure assessment
- The toxicity assessment
- Risk characterization
- Uncertainty analysis
- Conclusions of the BRA and potential site risk

The BRA is divided into eight sections beginning with the introduction. Section 6.2 presents the Hazard Identification, which presents criteria for selecting COPCs. COPCs are chosen, for each environmental medium at each site, from an overall list of detected contaminants. Section 6.3 presents the Exposure Assessment, which lists site characteristics, identifies potential exposure pathways, and describes current and future exposure scenarios. In section 6.4, the Toxicity Assessment, advisory criteria for evaluating human health risk is presented. Section 6.5 is the risk characterization. Section 6.6 addresses sources of uncertainty in the BRA. Section 6.7 provides conclusions regarding potential human health impacts, in terms of total site risk. Section 6.8 lists references sited in the BRA text. Referenced tables and figures are presented after the text portion of this section.

6.2 Hazard Identification

Data generated during the remedial investigation and previous studies at the site were used to draw conclusions and to identify data gaps in the BRA. The data were evaluated to assess which data were of sufficient quality to include in the risk assessment. The objective when selecting data to include in the risk assessment was to provide accurate and precise data to characterize contamination and evaluate exposure pathways.

6.2.1 Data Evaluation and Reduction

The initial hazard identification step entailed the validation and evaluation of the site data to determine its usability in the risk assessment. This process resulted in the identification of COPCs for the site. During this validation and evaluation, data that would result in inaccurate conclusions (e.g., data that were rejected or attributed to blank contamination, as qualified by the validator) were reduced within the data set. Data reduction entailed the removal of unreliable data from the original data set based on the guidelines established by USEPA. A summary of the data quality was presented in Section 4.0.

6.2.2 Identification of Data Suitable for Use in a Quantitative Risk Assessment

To provide for accurate conclusions to be drawn from sampling results, analytical data were reviewed and evaluated. This section presents the criteria that were used to review, reduce, and summarize the analytical data. These criteria are consistent with USEPA guidance for data reduction.

Six environmental media were investigated at the site during this RI: surface soils (0 to 12 inches below ground surface [bgs]), subsurface soils (one to seven feet bgs), groundwater, surface water, sediment, and aquatic biota. For Site 73, these media were assessed for potential risk to human receptors. Surface water and sediment samples were collected from Courthouse Bay and unnamed tributaries to Courthouse Bay. For a more detailed discussion on sampling procedure, refer to Section 3.0.

Although shallow groundwater is not utilized as a potable source at Site 73, the shallow and deep groundwater at the site were evaluated as a single exposure source since it has been shown that there is a potential interconnection between the shallow and deep aquifers (see Section 3.0). Consequently, exposure to both sources of groundwater combined were evaluated. It should be noted that development of the shallow aquifer for potable use is unlikely because of the general water quality in the shallow zone and poor flow rates. However, there remains the possibility that upon closure of this facility, residential housing could be constructed and shallow groundwater used for potable purposes in the future. Therefore, in accordance with USEPA guidance, groundwater exposure was conservatively evaluated for future residential receptors.

For current receptors (military personnel, military dependents, and civilian base personnel), potable water is supplied by the base treatment facilities via water supply wells that are set in the lower reaches of the Castle Hayne aquifer. Current operating wells are periodically monitored for control purposes. Hence, assessing current risks to contaminants detected in the shallow aquifer for current receptors is unnecessary and, if estimated, may present an unlikely risk. Therefore, groundwater exposure to current receptors was not estimated for this investigation.

The groundwater investigation for Site 73 was separated into two phases. In Phase I, groundwater was sampled during the first field investigation in May, 1995. The first round of sampling was to evaluate the nature and extent of groundwater contamination at Site 73. These samples were analyzed for VOCs, SVOCs, pesticides/PCBs, and metals. In Phase II, groundwater was sampled during the second field investigation in February and March, 1996. The second round of groundwater samples were taken to delineate the VOC contamination and were analyzed for VOCs only.

In this BRA, Phase I and Phase II groundwater data were evaluated separately. This is because the data points were not the same for the two phases. Sampling points from the second phase of groundwater sampling were chosen based on their prior detected concentrations. Such data points, when used in the risk assessment, could bias the calculations. Furthermore, additional wells were installed and sampled during Phase II. Therefore, two separate risk scenarios exist. Based on this reasoning, VOC data from the second phase was combined with the SVOC, pesticide/PCB, and metals data from the first phase in the quantitative risk assessment. In this way, two complete groundwater exposure scenarios are presented. Phase I data presents a more conservative estimate of risk, while Phase II data presents a more plausible estimate of the risk from exposure to groundwater at Site 73.

Information relating to the nature and extent of contamination at the site is provided in Section 4.0 of this report. The discussion provided in Section 4.0 also was utilized in the selection of COPCs at the site. The reduced data sets for all media of concern at the site are provided in Appendix O of this report.

6.2.3 Criteria for Selecting Contaminants of Potential Concern

Criteria used in selecting COPCs from constituents detected during the field sampling and analytical phase of the investigation are:

- Comparison to USEPA Region III Risk-Based Concentrations (RBCs)
- Historical information
- Comparison to field and laboratory blank data
- Prevalence

In addition, the criteria used in the qualitative analysis of COPCs selected from the media investigated during this RI include:

- Persistence
- Mobility
- Comparison to anthropogenic levels
- Toxicity
- Comparison to background or naturally occurring levels
- State and federal standards and criteria

USEPA's Risk Assessment Guidance for Superfund provides the criteria used to establish COPCs (USEPA, 1989a). COPC selection also involves comparing detection levels to additional contaminant-specific criteria. A brief description of the selection criteria used in choosing final COPCs is presented below. A contaminant must not necessarily fit into all of these categories to be retained as a COPC.

6.2.3.1 USEPA Region III RBCs

RBC values are derived using conservative USEPA promulgated default values and the most recent toxicological criteria available. The RBCs for potentially carcinogenic chemicals are based on a target ICR of $1x10^{-6}$. The RBCs for noncarcinogens are based on a target hazard quotient of 1.0. In order to account for cumulative risk from multiple chemicals in a medium, it is necessary to derive the RBCs based on a target hazard quotient of 0.1. Re-derivation of the noncarcinogenic

RBCs based on a target hazard quotient of 0.1, while using the most recent toxicological criteria available, results in a set of values that can be used as screening values. In order to provide the accurate screening values, the noncarcinogenic RBCs were divided by a factor of ten. For potential carcinogens, the toxicity criteria applicable to the derivation of RBC values are oral and inhalation cancer slope factors (CSFs); for noncarcinogens, they are chronic oral and inhalation reference doses (RfDs). These toxicity criteria are subject to change as more updated information and results from the most recent toxicological/epidemiological studies become available. Therefore, the use of toxicity criteria in the derivation of RBC values requires that the screening concentrations be updated periodically to reflect changes in the toxicity criteria. The RBC table is issued on a semi-annual basis. It should be noted that the most recent update was published in March of 1997.

6.2.3.2 Historical Information

Using historical information to associate contaminants with site activities, when combined with the following selection procedures, helps determine contaminant retention for, or elimination from, evaluation in the BRA.

6.2.3.3 Contaminant Concentrations in Blanks

Associating contaminants detected in field related QA/QC samples (i.e., trip blanks, equipment rinsates and/or field blanks) or laboratory method blanks with the same contaminants detected in analytical samples can eliminate non-site-related contaminants from the list of COPCs. Blank data should be compared to sample results with which the blanks are associated; however, due to the comprehensive nature of data sets, it is difficult to associate specific blanks with specific environmental samples. Thus, in order to evaluate contaminant levels, maximum contaminant concentrations reported in a given set of blanks are applied to an entire data set for a given medium.

In accordance with the National Functional Guidelines for Organics, common laboratory contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) should be regarded as a direct result of site activities only when sample concentrations exceed 10 times the maximum blank concentration. For other contaminants not considered common in a laboratory, concentrations exceeding five times the maximum blank concentration indicate contamination resulting from site activities (USEPA, 1991).

When evaluating contaminant concentrations in soil, Contract Required Quantitation Limits (CRQLs) and percent moisture are employed, in order to correlate solid and aqueous quantitation limits. The CRQL for semivolatiles (SVOCs) in soil is 33 to 66 times that of aqueous samples, depending on the contaminant. In order to assess SVOC contaminant levels in soil using aqueous blanks, blank concentrations must be multiplied by 33 or 66 to account for variances in the CRQL. The final value is divided by the sample percent moisture, in order to account for the aqueous-to-solid blank medium adjustment.

Eliminating a sample result correlates directly to a reduction in the contaminant prevalence in that medium. Consequently, if elimination due to blank concentration reduces the prevalence of a contaminant to less than five percent, a contaminant that may have been included according to its prevalence is eliminated as a COPC. Maximum concentrations of common laboratory contaminants detected in blanks are presented in Table 6-1.

Blanks containing organic constituents that are not considered common laboratory contaminants (i.e., all other TCL compounds) are regarded as positive results only when observed concentrations exceed five times the maximum concentration detected in any blank (USEPA, 1989b). All TCL compounds at concentrations less than five times the maximum level of contamination noted in any blank are considered to be attributed to blank contamination. Maximum concentrations of other contaminants detected in blanks are presented in Table 6-1. QA/QC data summaries are presented in Appendix R.

6.2.3.4 Prevalence

The frequency of positive detections in sample sets and the level at which a contaminant is detected in a given medium are factors that determine a chemical's prevalence. The judicious use of data sets limits for including infrequently detected contaminants. Chemical occurrence must be evaluated with respect to the number of samples taken in order to determine frequency criteria warranting the inclusion of a chemical as a COPC. Contaminants that are infrequently detected, (i.e., less than five percent when at least 20 samples of a medium are available) do not necessarily indicate contamination. Such detections may result from certain sampling or analytical practices.

A contaminant may not be retained for quantitative evaluation in the BRA if: (1) it is detected infrequently in an environmental medium; (2) it is absent or detected at low concentrations in other media; or (3) site history does not provide evidence to suggest that the contaminant should be present.

6.2.3.5 Persistence

Contaminant persistence in the environment varies in accordance with factors such as microbial content in soil and water, organic carbon content, contaminant concentration, climate and potential for microbes to degrade a contaminant under site conditions. In addition, chemical degradation, (i.e., hydrolysis) photochemical degradation and certain fate processes such as absorption may contribute to the elimination or retention of a particular compound in a given medium.

6.2.3.6 Mobility

A contaminant's physical and chemical properties are responsible for its transport in the environment. These properties, in conjunction with site conditions, determine whether a contaminant will have a greater tendency to volatilize into the air, out of surface soils or surface waters, or to relocate via advection or diffusion through soils, groundwaters, and surface waters. Physical and chemical properties also determine tendency for contaminant adsorption onto soil/sediment particles. In summary, environmental mobility factors can increase or decrease contaminant effects on human health and/or the environment.

6.2.3.7 Anthropogenic Levels

Ubiquitous anthropogenic background concentrations result from sources of contamination not related to the site, such as combustion of fossil fuels (i.e., automobiles), plant synthesis, natural fires and factories. Polynuclear aromatic hydrocarbons (PAHs) are examples of ubiquitous, anthropogenic chemicals. Sometimes it is difficult to determine whether contamination is actually site-incurred, or caused by contaminant-producing activities that are not site-related (i.e., anthropogenic). It then follows that systematically omitting anthropogenic background chemicals from the risk assessment may produce false negative results. For this reason, anthropogenic chemicals are typically not eliminated as COPCs without considering other selection criteria.

6.2.3.8 Toxicity

Contaminant toxicity assessment must be incorporated when selecting COPCs with respect to human health risk. Toxic properties to be considered in COPC selection include weight-of-evidence classification, carcinogenicity, mutagenicity, teratogenicity, systemic effects and reproductive toxicity. Bioaccumulation and bioconcentration properties may affect the severity of toxic response in an organism and/or subsequent receptors; these additional properties are evaluated if relevant data exist.

Despite their inherent toxicity, certain inorganic contaminants are essential nutrients (e.g., calcium, sodium). As such, these contaminants need not be considered in a quantitative risk assessment, if one of the following conditions applies: (1) they are detected at relatively low concentrations, (i.e., below two times average base-specific background levels or slightly elevated above naturally occurring levels) or (2) the contaminant is toxic at doses much higher than those which can be assimilated through exposures at the site.

6.2.3.9 Background or Naturally Occurring Levels

Naturally occurring levels of chemicals are present under ambient conditions. Generally, a comparison to naturally occurring levels applies only to inorganic analytes, because the majority of organic contaminants are not naturally occurring. Background samples are collected from areas that are known to be uninfluenced by site contamination. Sample concentrations for surface and subsurface soil were compared to base-specific (i.e., twice the base-wide average concentration) background levels. Sample concentrations for surface water and sediment were compared to average base-specific concentrations. It should be noted that background data was used for qualitative analysis of COPCs only. COPCs were not chosen based on comparison to background data. Background soil data is presented in Appendix M. Background surface water and sediment data is presented in Appendix W.

6.2.3.10 State and Federal Criteria and Standards

Contaminant concentrations in aqueous media can be compared to contaminant-specific state and federal criteria. This risk assessment utilizes North Carolina Water Quality Standards (NCWQS) for groundwater and surface water. The only enforceable federal regulatory standards for water are Federal Maximum Contaminant Levels (MCLs).

Regulatory guidelines are used, when necessary, to infer potential health risks and environmental impacts. Health Advisories (HA) are relevant regulatory guidelines. An explanation of the federal and state criteria and standards used for qualitative evaluation of contaminants is presented below. It should be emphasized that COPCs were not chosen based on comparison to state and federal criteria. However, these standards and criteria were used for a qualitative analysis of the COPCs.

North Carolina Water Quality Standards (NCWQSs) - Groundwater - NCWQSs are the maximum allowable concentrations resulting from any discharge of contaminants to the land or waters of the state, which may be tolerated without creating a threat to human health or which otherwise render the groundwater unsuitable for its intended purpose.

Maximum Contaminant Levels (MCLs) - Federal Groundwater Standards - 40 CFR 161 - MCLs are enforceable standards for public water supplies promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiological studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with a lifetime exposure (70-year lifetime) of an average adult (70 kg) consuming 2 liters of water per day. MCLs also consider the technical feasibility of removing the contaminant from the public water supply.

Health Advisories (HAs) - HAs are guidelines developed by the USEPA Office of Drinking Water for nonregulated constituents in drinking water. These guidelines are designed to consider both acute and chronic toxic effects in children (assumed body weight 10 kg) who consume 1 liter of water per day or in adults (assumed body weight 70 kg) who consume 2 liters of water per day. HAs are generally available for acute (1 day), subchronic (10 days), and chronic (longer-term) exposure scenarios. These guidelines are designed to consider only threshold effects and, as such, are not used to set acceptable levels of potential human carcinogens.

North Carolina Water Quality Standards (Surface Water) - The NCWQSs for surface water are the standard concentrations that, either alone or in conjunction with other wastes in surface waters, will neither render waters injurious to aquatic life, wildlife, or public health, nor impair the waters for any designated use.

Ambient Water Quality Criteria - AWQCs are non-enforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic systems. They may also be used for identifying the potential for human health risks. AWQCs consider acute and chronic effects in both freshwater and saltwater aquatic life, and potential carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day), or from ingestion of water alone (2 liters/day). The human health AWQCs for potential carcinogenic substances are based on the USEPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 10,000,000 to 100,000 (i.e., the 10^{-7} to 10^{-5} range).

As stated previously, COPCs in all media of concern at the site were compared with these aforementioned criteria. The results of the standards/criteria/TBC comparison for the site are presented in Tables 6-2 through 6-11.

6.2.4 Selection of Contaminants of Potential Concern

The following sections present an overview of the analytical data obtained for each environmental medium during the RI and the subsequent retention or elimination of COPCs using the aforementioned selection criteria. The primary criterion used in selecting a chemical as a COPC at each site was comparing the maximum detected sample concentration to the USEPA Region III RBCs (USEPA, 1996). In conjunction with the concentration comparisons to the USEPA Region III RBCs, evaluation of laboratory contaminants, chemical prevalence, and site history was conducted. Furthermore, calcium, magnesium, potassium, and sodium were detected in almost every sample, regardless of the medium; however, these constituents were considered to be essential nutrients (USEPA, 1995) and were therefore, not retained as COPCs in any medium under investigation at Site 73.

Tables 6-2 through 6-11 present the selection of COPCs for each environmental medium based on a comparison of the maximum detected concentration with the USEPA Region III COC values, and other applicable criteria. Information is presented in these tables only for those constituents detected at least once, in the medium of interest. Other statistical information is presented in Appendix S.

6.2.4.1 Surface Soil

A maximum of 35 surface soil samples were analyzed for volatile organic contaminants (VOCs). The following VOCs were detected at maximum concentrations less than their respective residential soil RBCs: 1,1,1-trichloroethane, 1,2-dichloroethane, 1,2-dichloropropane, 2-butanone, acetone, chlorobenzene, ethylbenzene, styrene, toluene, trichloroethene, and total xylenes. For this reason, these VOCs were not retained as COPCs.

A maximum of 35 surface soil samples were analyzed for semivolatile organic compounds (SVOCs). 2,4-Dinitrophenol, acenaphthene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, butyl benzyl phthalate, chrysene, di-n-butylphthalate, bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene were detected at maximum concentrations less than their respective residential soil RBCs. These compounds were not retained as surface soil COPCs. 4-Chloro-3-methylphenol was detected in 1 out of 35 surface soil samples. Although there is no risk-based criteria for comparison, this SVOC is not retained as a COPC due to its low frequency of detection (2.9%). Benzo(a)pyrene was detected in 1 out of 35 samples at a concentration that exceeded its residential soil RBC. Although benzo(a)pyrene was detected at a low frequency of detection (2.9%), it was retained as a COPC due to its toxicity.

Twenty-nine surface soil samples were analyzed for pesticides/PCBs. 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT, alpha-chlordane, Aroclor-1016, Aroclor-1260, endrin ketone, and gamma-chlordane were detected at concentrations less than respective residential soil RBCs. Although it was detected as a low frequency of detection (3.4%), it was re-included as a COPC based on its toxicity. Therefore, Aroclor was retained as a surface soil COPC. Site 73 surface soil organic data summary and COPC selection results are presented in Table 6-2.

Thirty-five surface soil samples were analyzed for inorganic contaminants. Barium, cadmium, chromium, cobalt, copper, manganese, vanadium and zinc were detected at maximum concentrations less than respective residential soil RBCs. Lead was detected in 35 of 35 samples at a maximum concentration of 38.2 mg/kg, which is less than the USEPA lead action level for soil of 400 mg/kg. Therefore, these inorganics were not retained as COPCs.

Aluminum and iron were detected in all surface soil samples. Their respective maximum concentrations exceed their respective background levels and residential soil RBCs. Consequently, aluminum and iron are retained as surface soil COPCs. Site 73 surface soil inorganic data summary and COPC selection results are presented in Table 6-3.

6.2.4.2 Subsurface Soil

A maximum of 28 subsurface soil samples were analyzed for VOCs. 1,1,1-Trichloroethane, 2-butanone, acetone, carbon disulfide, ethylbenzene, m-xylene, o-xylene, tetrachloroethene, trichloroethene, and total xylenes were detected at maximum concentrations less than their respective residential soil RBCs. 4-Methyl-2-pentanone was detected in 1 out of 28 subsurface soil samples. Although there is no risk-based criteria for this compound, it was not retained as a COPC based on its low frequency of detection (3.6%). p-Xylene was detected in 1 out of 2 samples. Although there is no risk-based criteria for this compound, it was determined not to be a human health concern based on comparison to the residential soil RBCs for m-xylene, o-xylene, and total xylenes. Hence, none of the VOCs detected are retained as COPCs.

A maximum of 27 subsurface soil samples were analyzed for SVOCs. The following SVOCs were not retained as COPCs because they were detected at maximum concentrations that did not exceed respective residential soil RBCs: 2-methylnaphthalene, 2,4-dinitrophenol, acenaphthene, anthracene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, di-n-butylphthalate, fluoranthene, fluorene, phenanthrene, and pyrene. Benzo(a)anthracene was detected in 2 out of 27 samples at a maximum concentration equal to its residential soil RBC and was retained as a COPC. Benzo(a)pyrene and was detected in 1 out of 27 subsurface soil samples at a concentration that exceeded its residential soil RBC. Although it was detected at a low frequency of detection (3.7%), it was re-included as a COPC due to its toxicity. Consequently, benzo(a)pyrene was retained as a subsurface soil COPC.

Twenty-seven subsurface soil samples were analyzed for pesticides/PCBs. The following pesticides/PCBs were not retained as COPCs because they were detected at maximum concentrations less than respective residential soil RBCs: dieldrin, 4,4'-DDE, 4,4'-DDT, alpha-chlordane, Aroclor-1254, endosulfan I, and endrin aldehyde.

4,4'-DDD was detected frequently (33%) and at a maximum concentration that exceeded it residential soil RBC. Therefore, it was retained as a subsurface soil COPC. Site 73 subsurface soil organic data summary and COPC selection results are presented in Table 6-4.

Twenty-nine subsurface soil samples were analyzed for inorganic contaminants. The following inorganics were not retained as COPCs because they were detected at concentrations less than respective residential soil RBCs: barium, cadmium, chromium, cobalt, copper, manganese, vanadium and zinc. Lead was detected in all subsurface soil samples at concentrations less than the lead action level for residential soils. Therefore, lead was not retained as a COPC.

Aluminum and iron were detected in all 29 subsurface soil samples. The maximum concentrations for these analytes exceeded background levels as well as the corresponding RBCs for residential soil. For this reason, aluminum and iron were retained as subsurface soil COPCs. Site 73 subsurface soil inorganic data summary and COPC selection results are presented in Table 6-5.

6.2.4.3 Groundwater

Site 73 groundwater data was separated into two phases for evaluation under this BRA. Phase I groundwater was sampled during the first field investigation in May, 1995. The first round of sampling was to evaluate the nature and extent of groundwater contamination at Site 73. These samples were analyzed for VOCs, SVOCs, pesticides/PCBs, and metals. Phase II groundwater was sampled during the second field investigation in February and March, 1996. The second round of groundwater samples were taken to delineate the VOC contamination and were analyzed for VOCs only.

Phase I

A maximum of 48 Phase I groundwater samples were analyzed for VOCs. Ethylbenzene, toluene, total xylenes, trans-1,2-dichloroethene were detected at maximum concentrations less than their respective tap water RBCs. Thus, these VOCs were not retained as Phase I groundwater COPCs.

1,2-Dichloroethane, cis-1,2-dichloroethene, benzene, vinyl chloride, and trichloroethene were detected in Phase I groundwater samples at maximum concentrations that exceeded their respective tap water RBCs. Consequently, these VOCs were retained as Phase I groundwater COPCs. In addition, although 1,2-dichloroethane was detected in blanks at a concentration of 3.6 µg/L, it was re-included as a COPC based on known site activities that have potentially contributed to VOC contamination. Chloroform was detected in 6 out of 48 samples at a maximum concentration that exceeded its tap water RBC. However, chloroform was also detected in the blanks at a concentration of 0.8 µg/L. Therefore, chloroform was not retained as a Phase I groundwater COPC.

Fifty-four Phase I groundwater samples were analyzed for SVOCs. Phenol, 1,2,4-trichlorobenzene, acenaphthene, di-n-butyl phthalate, fluorene, and naphthalene were detected at maximum concentrations less than respective tap water RBCs. For this reason, these SVOCs were not retained as COPCs. Bis(2-ethylhexyl)phthalate was detected in blanks at 25 µg/L. Because bis(2-ethylhexyl)phthalate is a common lab contaminant, this concentration is multiplied by 10 to yield a blank concentration of 250 µg/L. Bis(2-ethylhexyl)phthalate was detected at a maximum concentration of 50 µg/L. Because the sample concentration is less than the comparison concentration in blanks, bis(2-ethylhexyl)phthalate is not retained as a COPC.

No pesticides or PCBs were detected in the Phase I groundwater samples.

Fifty-five Phase I groundwater samples were analyzed for inorganic contaminants. Zinc was detected at a maximum concentration less than its tap water RBC and was not retained as a COPC. Beryllium, cadmium, nickel, silver, and thallium were each detected in 1 out of 55 samples (1.8%). Antimony was detected in 2 out of 55 samples (3.6%). Due to the low frequencies of detection (less than 5%), these analytes were not retained as COPCs. Lead was detected at a maximum concentration less than the lead action level for groundwater. Therefore, it was not retained as a COPC.

Aluminum, barium, chromium, cobalt, copper, iron, manganese, and vanadium were detected at concentrations that exceeded their respective tapwater RBCs. Therefore, these analytes were retained as Phase I groundwater COPCs. Table 6-6 presents these results.

Phase II

Forty-four groundwater samples were analyzed for VOCs only under the second phase of the Site 73 RI. Chloroethane, toluene, and acetone were detected at maximum concentrations well below their respective tap water RBCs. Therefore, these compounds were not retained as Phase II groundwater COPCs. In addition, chloroform was detected in 5 out of 44 samples at a maximum concentration that exceeded its tap water RBC. However, chloroform was also detected in the blanks at a concentration of 33 µg/L. Since the concentrations in the environmental samples were below the maximum detection in the blanks, chloroform was not retained as a Phase II groundwater COPC.

1,2-Dichloroethene (total), benzene, vinyl chloride, and trichloroethene were detected at concentrations that exceeded their respective tap water RBCs. Therefore, these VOCs were retained as Phase II groundwater COPCs. Table 6-7 presents the Phase II groundwater data and COPC selection summary.

6.2.4.4 Surface Water

Eleven surface water samples were analyzed for VOCs. Acetone, a common laboratory contaminant, was detected in one of eleven samples at a maximum concentration of 50 µg/L. It was also detected in the blanks at a concentration of 170 µg/L. For this reason, acetone was not retained as a surface water COPC. Toluene and chloroform were also detected in Site 73 surface water samples. However, both VOCs were detected at maximum concentrations less than their respective NWQS values. Therefore, toluene and chloroform were not retained as surface water COPCs.

No SVOCs, pesticides, or PCBs were detected in Site 73 surface water samples.

Eleven surface water samples were analyzed for inorganic contaminants. Barium and manganese and were detected at maximum concentrations less than their respective NCWQSs. Therefore, these analytes were not retained as surface water COPCs.

Aluminum, antimony, iron, silver, and zinc were detected in surface water samples. The maximum detected concentrations of aluminum and zinc exceed background levels and NCWQSs. Thus, aluminum and zinc are retained as surface water COPCs. Antimony and iron were detected at concentrations exceeding their respective NWQS values. For this reason, these analytes are also retained as surface water COPCs. These results are presented in Table 6-8.

6.2.4.5 Sediment

Twenty-two sediment samples were analyzed for VOCs. Methylene chloride, acetone, carbon disulfide, 2-butanone, toluene, and total xylenes were detected at maximum concentrations less than their respective residential soil RBCs. Therefore, these VOCs were not retained as sediment COPCs.

Twenty-two sediment samples were analyzed for SVOCs. Phenol, phenanthrene, di-n-butyl phthalate, fluoranthene, pyrene, and bis(2-ethylhexyl)phthalate were detected at maximum concentrations less than their respective residential soil RBCs. Therefore, these SVOCs were not retained as sediment COPCs.

Twenty-two sediment samples were analyzed for pesticides/PCBs. 4,4'-DDE, endrin, and 4,4'-DDD were detected at maximum concentrations less than their respective residential soil RBCs. Therefore, these pesticides were not retained as sediment COPCs. Aroclor-1260 was the only PCB detected in sediment samples. It was detected at a maximum concentration less than its residential soil RBC. Therefore, no PCBs were retained as sediment COPCs.

Twenty-two sediment samples were analyzed for inorganic contaminants. Barium, cobalt, copper, manganese, nickel, vanadium, and zinc were detected in sediment samples at maximum concentrations less than their respective residential soil RBCs. Therefore, these analytes were not retained as sediment COPCs. Lead was detected at a maximum concentration less than the lead action level for soil. For this reason, lead was not retained as a COPC.

Aluminum, arsenic, cadmium, chromium, and iron were detected at maximum concentrations exceeding their respective residential soil RBCs. Consequently, these analytes were retained as sediment COPCs. Table 6-9 presents the sediment data and COPC selection summary.

6.2.4.6 Aquatic Biota

Fish Tissue (Fillet Portion)

Eight fillet fish tissue samples were analyzed for VOCs. Toluene was detected at a maximum concentration less than its fish tissue RBC. Therefore, toluene was not retained as a COPC.

Acetone and methylene chloride were detected at maximum concentrations exceeding their respective fish tissue RBCs. However, since acetone is a normal metabolic component and unlikely to be site related, it was not retained as a COPC. Therefore, only methylene chloride was retained as a fish tissue COPC.

Eight fillet fish tissue samples were analyzed for SVOCs. Di-n-butyl phthalate was detected in 1 out of 8 samples at a concentration less than its fish tissue RBC. Therefore, it was not retained as a fish tissue COPC.

Eight fillet fish tissue samples were analyzed for pesticides/PCBs. Endrin was detected in 1 out of 8 samples at a concentration of 9.8 µg/kg. This concentration is less than the fish RBC for endrin. Therefore, endrin was not retained as a fish tissue COPC.

Eight fillet fish tissue samples were analyzed for inorganic contaminants. Barium, copper, iron, manganese, selenium, and zinc were detected at high frequencies, but, in each case, maximum concentrations were less than the fish tissue RBCs. Therefore, these analytes were not retained as fish tissue COPCs.

Arsenic and mercury were detected at maximum concentrations exceeding their respective RBCs. Arsenic was not retained as a fish tissue COPC since it is naturally occurring in marine animals. Lead was detected in 1 out of 8 fish fillet samples at a concentration of 0.07 µg/kg. However, there is no fish tissue RBC for lead. Therefore, mercury and lead were retained as fish tissue COPCs. Table 6-10 presents these results.

Crab Tissue (Edible Portion)

Six crab tissue samples were analyzed for VOCs. Toluene was detected at a maximum concentration less than its fish tissue RBC. Therefore, toluene was not retained as a COPC.

Acetone and methylene chloride were detected at maximum concentrations exceeding their respective fish tissue RBCs. However, since acetone is a normal metabolic component and unlikely to be site related, it was not retained as a COPC. Therefore, only methylene chloride was retained as a crab tissue COPC.

Six crab tissue samples were analyzed for SVOCs. Di-n-butyl phthalate was detected in 2 out of 6 samples at concentrations less than the fish tissue RBC. Therefore, it was not retained as a crab tissue COPC.

There were no pesticides/PCBs detected in crab tissue samples.

Six crab tissue samples were analyzed for inorganic contaminants. Barium, iron, manganese, selenium, silver, and zinc were detected at maximum concentrations less than their respective fish tissue RBCs. Therefore, these analytes were not retained as crab tissue COPCs. Although arsenic was detected at a maximum concentration exceeding its fish tissue RBC, it was not retained as a crab tissue COPC since it is naturally occurring in marine animals.

Copper and mercury were detected at maximum concentrations exceeding their respective fish tissue RBCs. Lead was detected in 1 out of 6 crab tissue samples at a concentration of 0.08 µg/kg. However, there is no fish tissue RBC for lead. Therefore, copper, mercury, and lead were retained as crab tissue COPCs. Table 6-11 presents these results.

6.2.4.7 Summary of COPCs

Table 6-12 presents a detailed summary of COPCs identified in each environmental medium sampled at Site 73.

6.3 Exposure Assessment

This section addresses potential human exposure pathways at Site 73 and presents the rationale for their evaluation. Potential source areas and potential migration routes, in conjunction with contaminant fate and transport information, are combined to produce a site conceptual model. Exposure pathways to be retained for quantitative evaluation are subsequently selected, based on the conceptual site model.

6.3.1 Conceptual Site Model of Potential Exposure

A conceptual site model of potential sources, migration pathways and human receptors is developed to encompass all current and future routes for potential exposure at Site 73. Figure 6-1 presents the Site 73 conceptual model. Inputs to the conceptual model include qualitative descriptions of current and future land use patterns in the vicinity of Site 73. The following list of receptors is developed for a quantitative health risk analysis:

- Future on-site residents (child [1-6 years] and adult)
- Current military personnel
- Current trespasser (adolescent [7-16 years] and adult)
- Current adult subsistence fisherman
- Child (1-6 years) receptor - fish/crab tissue ingestion
- Future construction worker

Contaminants detected in surface and subsurface soils are discussed in Section 4.0 (Nature and Extent of Contamination) and in section 6.2.2, selection of COPCs. Migration of COPCs from these sources can occur in the following ways:

- Vertical migration of contaminants from surface soil to subsurface soil.
- Leaching of contaminants from subsurface soil to water-bearing zones.
- Vertical migration from shallow water-bearing zones to deeper flow systems.
- Horizontal migration in groundwater in the direction of groundwater flow.

- Groundwater discharge into local streams.
- Wind erosion and subsequent deposition of windblown dust.

The potential for a contaminant to migrate spatially and persist in environmental media is important in estimating exposure.

Current and Future Scenarios

The Amphibious Vehicle Maintenance Facility (Site 73) is located in the Courthouse Bay Area of MCB, Camp Lejeune. Site 73 is roughly bounded by State Route 172 to the north, Courthouse Bay to the south, and unnamed tributaries to Courthouse Bay to the east and west. The study area consists of numerous buildings, aboveground storage tanks (ASTs), underground storage tanks (USTs), vehicle wash racks, and oil/water separators. Site 73 is used for maintenance and storage of large vehicles. The area includes a wharf and a vehicle loading ramp.

Current receptors are on-site military personnel, trespassers, and off-site fishermen. Military personnel maintain large vehicles at Site 73. Potential exposure pathways are surface soil incidental ingestion, dermal contact, and inhalation of fugitive dust. In addition, military personnel drive amphibious vehicles into Courthouse Bay to conduct training maneuvers. Consequently, ingestion and dermal contact of surface water and sediment are also assessed as potential exposure pathways. Under a worst case scenario, an individual working at Site 73 and conducting maneuvers in Courthouse Bay would be exposed to these three media. In accordance with USEPA guidance and to maintain a conservative approach, the worst case exposure scenario was evaluated for the military personnel.

Access to Site 73 is not restricted between 6:00 AM to 5:00 PM. Also, members of the public are allowed unlimited access to Courthouse Bay for recreational purposes. Therefore, current adult and adolescent trespassers were assessed for potential exposure to surface soil, surface water, and sediment. Potential exposure pathways are surface soil incidental ingestion, dermal contact, and inhalation of fugitive dusts and surface water and sediment incidental ingestion and dermal contact. Presently, the groundwater at the site is not used for potable purposes. Consequently, exposure to groundwater was not considered to be applicable for current receptors at the site.

Fishing and crabbing are allowed in Courthouse Bay. To be conservative, surface water and sediment exposure to an adult fisherman receptor was assessed. Potential exposure pathways are surface water and sediment incidental ingestion and dermal contact. Ingestion of fish (fillet portion) and crab tissue (edible portion) was also evaluated for the adult fisherman receptor based on a subsistence scenario. In order to maintain a conservative approach, a child receptor was also assessed for exposure to aquatic biota through ingestion. Most of the fishing done in Courthouse Bay is of a commercial nature. Based on professional opinion, it was assumed that the adult and child receptor received ten percent of the fish and crab in their diet from Courthouse Bay.

It is unlikely that this site will be developed for residential use in the future. However, to be conservative groundwater exposure to a child and adult residential receptor was assessed. It assumed that a private well could be installed on-site in the future case. The potential exposure pathways were ingestion, dermal contact, and inhalation of VOCs while showering. The future adult resident only was evaluated for inhalation of VOCs while showering.

Similarly, it is anticipated that a residential child and adult may become exposed to surface soil. As a result, surface soil exposure via ingestion, dermal contact and inhalation was evaluated for the future residential child and adult receptor. While it is doubtful that surface water recreational facilities may be expanded in the future, a conservative exposure scenario was examined for a future residential population. The potential exposure pathways are ingestion and dermal contact of surface water and sediment.

Finally, surface and subsurface soil exposure resulting from future excavation and construction activities was assessed. A future construction worker was evaluated for surface and subsurface soil ingestion, dermal contact, and inhalation.

6.3.2 Exposure Pathways

This section presents exposure pathways, shown in Figure 6-1, associated with each environmental medium and each human receptor group. It then qualitatively evaluates each pathway for further consideration in the quantitative risk analysis. Table 6-13 presents the matrix of human exposure at Site 73.

6.3.2.1 Surface Soil

Potential exposure to surface soil (0 to 12 inches bgs) may occur by incidental soil ingestion, contaminant absorption through the skin and inhalation of airborne particulates. Surface soil exposure is evaluated for current military personnel, current trespassers, future residential children and adults, and future construction workers .

6.3.2.2 Subsurface Soil

Subsurface soil (one to seven feet bgs) is available for contact only during excavation activities, so potential exposure to subsurface soil is limited to future construction workers. Exposure pathways involving ingestion, dermal contact, and inhalation of airborne particulates are evaluated for future construction workers only.

6.3.2.3 Groundwater

Currently, shallow groundwater at Site 73 is not used as a potable supply for residents or base personnel. However, it will be conservatively assumed that in the future, (albeit unlikely due to poor transmissivity and insufficient flow) shallow groundwater may be tapped for potable water. In this scenario, potential exposure pathways are ingestion, dermal contact and inhalation of volatile contaminants while showering. Groundwater exposure is evaluated for future residential children and adults. The future adult resident only was evaluated for inhalation of VOCs while showering.

6.3.2.4 Surface Water/Sediment

Access to surface water at Site 73 is limited to Courthouse Bay. Military personnel drive amphibious vehicles into the bay (via Site 73) to conduct training maneuvers. Members of the public have access to Courthouse Bay for recreational purposes. In addition, it is known that individuals fish and crab in the bay. In a current scenario, swimming is unlikely due to the murky quality of the water. However, based on known activities in or around Courthouse Bay, a wading scenario is considered a conservative estimation of potential exposure. In a future scenario, it is possible that surface water recreational facilities may be expanded for residents (although this is a conservative assumption). Surface water and sediment exposure pathways include ingestion and dermal contact. Exposure is evaluated for current military personnel, current adolescent and adult trespassers, current fisherman, and future residential children and adults.

6.3.2.5 Aquatic Biota

The potential release sources to be considered in evaluating exposure via fish and crab consumption are contaminated surface water and sediments. Fish and crab can uptake contaminants present in these media by bioaccumulation and biomagnification. The exposure pathway for human receptors is fish and crab tissue ingestion. Exposure based on a subsistence scenario is evaluated for current adult fisherman, as well as a child receptor.

6.3.3 Quantification of Exposure

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

To quantify exposure, analytical data must be evaluated to determine its distributional nature. In general, two types of distributions are applied to environmental data; these are the normal and log-normal distributions. For example, most large data sets from soil sampling are log-normally distributed rather than normally distributed. The geometric mean is the best estimator of central tendency for a log-normal data set (USEPA, 1992c). However, most Agency health criteria are based on the long-term average exposure which is expressed as the sum of all daily intakes divided by the total number of days in the averaging period. The geometric mean of a set of sampling results may not adequately represent random exposure and the cumulative intake that would result from long-term contact with site contaminants.

Potential exposure to soil, surface water, and sediment at Site 73, regardless of location, is considered as having an equal probability of occurrence as an individual moves randomly across the site. Therefore, for these media, the exposure point concentration for a constituent in the intake equation can be reasonably estimated as the arithmetic average concentration of site sampling data. USEPA supplemental risk assessment guidance (USEPA, 1992c) states that the average concentration is an appropriate estimator of the exposure concentration for two reasons: 1) carcinogenic and chronic noncarcinogenic toxicity criteria are based on lifetime average exposures; and 2) the average concentration is most representative of the concentration that would be contacted over time. However, uncertainty is inherent in the estimation of the true average constituent concentration at the site.

In order to account for this uncertainty and to be health protective, USEPA risk assessment guidance (USEPA, 1989a) requires that an upper bound estimate of the arithmetic mean concentration, be used to calculate CDI. This estimate, which should be in the high end of the concentration frequency distribution, is called the RME concentration. The RME concentration is defined as the highest concentration that could reasonably be expected to be contacted via a given pathway over a long-term exposure period.

Assuming all data sets originate from a skewed underlying distribution, lognormal distribution is used to represent all relevant media. This ensures conservative CDI calculations. Ninety-five percent upper confidence levels, (95 percent UCL) derived for lognormal data sets, produce concentrations in excess of the 95 percent confidence interval derived assuming normality. The 95 percent UCL for lognormal distribution is used for each contaminant in a given data set, in order to quantify conservative exposure values. For exposure areas with limited amounts of data or extreme variability in measured data, the 95 percent UCL can be greater than the maximum measured concentration; therefore, in cases where the 95 percent UCL for a contaminant exceeds the maximum detected value in a given data set, the maximum result was used in the estimate of exposure. However, the true mean may still be higher than this maximum value (i.e., the 95 percent UCL indicates a higher mean is possible), especially if the most contaminated portion of the site has not been sampled (USEPA, 1992c). Statistical summaries are presented in Appendix S.

The 95 percent UCL of the lognormal distribution was calculated using the following equation (USEPA, 1992c):

$$\mathit{Lognormal}\ 95\%\ \mathit{UCL} = e^{(\bar{x} + 0.5s^2 + sH/\sqrt{n}-1)}$$

where:

UCL = upper confidence limit
e = constant (base of the natural log, equal to 2.718)
$\bar{x}$ = mean of the transformed data
s = standard deviation of the transformed data
H = H-statistic (Gilbert, 1987)
n = number of samples

In addition to the RME risk descriptor, which is represented by the maximum and/or 95% UCL concentration for the selected COPC, the central tendency (CT) risk descriptor was also used for data sets when the RME concentration term showed a potential risk to human health, specifically, to future on-site residents. The CT concentration term utilized was the lognormal 95% UCL or the arithmetic mean (if the UCL was greater than the arithmetic mean) (USEPA, 1993). The CT concentrations were then utilized to calculate chemical intakes for the CT-case scenarios. The results of the CT calculations are presented in Section 6.6.7.

The human health risk assessment for future groundwater use incorporates groundwater data collected from all monitoring wells at a given site. In this BRA, two separate scenarios were presented for groundwater exposure based on two sets of concentrations. The first scenario presents the maximum groundwater exposure and used the maximum detected concentrations of the COPCs in the CDI calculations. The second scenario presents a more plausible groundwater exposure and used the RME concentrations of the COPCs in the CDI calculations. In this manner, the worst case scenario is presented as well as a range of potential chemical intakes from plausible to maximum.

6.3.4 Calculation of Chronic Daily Intakes (CDI)

In order to numerically calculate risks for current and future human receptors at Site 73, a CDI must be computed for each COPC, in each relevant exposure pathway. Appendix U contains CDI equations for specific exposure scenarios (USEPA, 1989a).

The following paragraphs present the general equations and input parameters used to calculate CDIs. USEPA promulgated exposure factors are used in conjunction with USEPA standard default exposure factors for both the CT and RME exposure scenarios; however, the CT exposure scenario was utilized only for future residential receptors. Furthermore, when USEPA exposure factors are not available, best professional judgement and site-specific information are used to derive a conservative and defensible value. Tables 6-14 through 6-17 present the exposure factors used in the estimation of potential CDIs for COPCs retained for each receptor. The following paragraphs present the rationale for the RME assumptions for each receptor group evaluated in the baseline RA. The CT assumptions, though not discussed below, are presented in the tables in parentheses.

Carcinogenic risk is calculated as an incremental lifetime risk, and thereby involves exposure duration (years) over the course of a lifetime (70 years, or 25,550 days).

Noncarcinogenic risk, on the other hand, involves average annual exposure. Exposure time and frequency represent the number of hours of exposure per day, and days of exposure per year, respectively. Generally, noncarcinogenic risk for certain exposure routes (e.g., soil ingestion) is greater for children, as the combination of a lower body weight and an exposure frequency equal to that of an adult increases their ingestion rates.

Future residential exposure scenarios address 1 to 6-year old children weighing 15 kg and adults weighing 70 kg, on average. Current trespasser exposure scenarios address 7 to 16-year old adolescents weighing 37 kg and adults. An exposure duration of 4 years is used to estimate military standard tour of duty. A one year duration is used for future construction workers.

6.3.4.1 Incidental Ingestion of Soil

The equation for CDI, calculated for all human receptors potentially experiencing incidental soil ingestion, is as follows:

$$CDI = \frac{C \text{ x } IR \text{ x } CF \text{ x } Fi \text{ x } EF \text{ x } ED}{BW \text{ x } AT_c \text{ or } AT_{nc}}$$

Where:

C = Contaminant concentration in soil (mg/kg)
IR = Ingestion rate (mg/day)
CF = Conversion factor (1E-6 kg/mg)
Fi = Fraction ingested from source (dimensionless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)

AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in incidental soil ingestion. In each exposure scenario, the Fi value, indicating the portion of ingested soils that originated from Site 73 versus other sources.

Military Personnel

Military personnel may be exposed to COPCs by ingesting surface soil during the course of vehicle maintenance activities conducted at Site 73.

The IR for military personnel exposed to surficial soils is assumed to be 100 mg/day (USEPA, 1989a). An EF of 260 days per year is used in conjunction with a 4-year ED. The EF value represents the reasonable worst case scenario of an individual present 5 days/week for 52 weeks over the course of a year.

Carcinogenic compounds have an AT 25,550 days (70 years x 365 days/year), and the AT for noncarcinogenic compounds is 1,460 days (4 years ED x 365 days/year). Adult average body weight (BW) is 70 kg (USEPA, 1989a).

Current Trespassers

Current adolescent and adult trespassers may be exposed to surface soil in the event they were to gain access to Site 73.

The IR for both adolescent and adult trespassers exposed to surficial soils is assumed to be 100 mg/day (USEPA, 1989a). An EF of 48 days per year is used in conjunction with a 9-year ED for adolescents and 30-year ED for adults. The EF value represents a site-specific, professional judgement, where exposure to surface water is estimated at 8 days/month for 6 months/year.

An AT of 25,550 days is used for carcinogenic compounds, and the AT for noncarcinogenic compounds is 3,285 days (9 years ED x 365 days/year) for the adolescents and 10,950 days for adults. The average BW for adolescents is 37 kg, and the BW for adults is 70 kg.

Future On-Site Residents

Future on-site residents may be exposed to COPCs in surface soil, during outdoor activities around their homes. In addition, children and adults may be exposed to COPCs by incidental ingestion of surface soil through hand-to-mouth contact.

Ingestion rates (IR) for adults and children in this scenario are assumed to be 100 mg/day and 200 mg/day, respectively. The EF for both receptor groups is 350 days per year. Residential exposure duration (ED) is divided into two parts. First, a six-year ED, used for young children, represents the period of highest soil ingestion (200 mg/day). Second, a 30-year ED, used for adults, represents a period of lower soil ingestion (100 mg/day) (USEPA, 1991a). The BW of future residential children (age 1 to 6 years) is assumed to be 15 kg, and 70 kg is used as the BW for future residential adults.

AT values of 25,550 days (70 years x 365 days/year) and 10,950 days (30 years x 365 days/year) are assigned to potentially carcinogenic and noncarcinogenic constituents, respectively, to estimate adult CDIs. The AT used for children exposed to noncarcinogens is 2,190 days (6 years x 365 days/year).

Future Construction Worker

Construction workers may be exposed to COPCs through incidental ingestion of surface and subsurface soil, during the course of excavation activities.

An IR of 480 mg/day is assigned to future construction workers. A 90-day per year EF is used in conjunction with a 1-year ED, representing the estimated length of a typical construction job (USEPA, 1991a). AT_{nc} is 365 days (USEPA, 1989a). CF, Fi, BW and AT_c values are the same as those used for adults in the residential exposure scenarios.

6.3.4.2 Dermal Contact with Soil

The equation for CDI, calculated for all human receptors potentially experiencing dermal contact with soil, is as follows:

$$CDI = \frac{C \ x \ CF \ x \ SA \ x \ AF \ x \ ABS \ x \ EF \ x \ ED}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration in soil (mg/kg)
CF = Conversion factor (kg/mg)
SA = Skin surface available for contact (cm^2)
AF = Soil to skin adherence factor (mg/cm^2)
ABS = Absorption factor (dimensionless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in dermal contact with soil.

Military Personnel

Base personnel may be exposed to COPCs through dermal contact with surface soil, during the course of work-related activities.

It is assumed that military personnel taking part in vehicle maintenance at Site 73 wear military issue work clothes consisting of a short-sleeved shirt, fatigue trousers (long pants), and boots. Exposed body parts include the hands (840 cm^2), head (1,180 cm^2), and arms (2,280 cm^2) (USEPA, 1992a). The total SA for the military trainee is 4,300 cm^2.

USEPA Region IV default values of 0.01 for organics and 0.001 for metals were used for the dermal absorption factor (ABS) (USEPA, 1992b). Data on AF is limited. A value of 1.0 mg/cm^2 is used in this assessment (USEPA, 1995).

The ED, EF, BW and AT values are the same as those used in the incidental soil ingestion scenario. A summary of these values is presented in Table 6-14.

Current Trespassers

Adolescent and adult trespassers may be exposed to COPCs through dermal contact with Site 73 surface soil.

It is assumed that adolescent trespassers involved in recreational activities have approximately 3,480 cm^2 of skin surface (SA) available for contact with COPCs (USEPA, 1992a). The SA for adult trespassers is assumed to be 5,800 cm^2 (USEPA, 1992a). These values represent individuals wearing a short-sleeved shirt, shorts, and shoes. Exposed body parts include the head, hands, forearms, and lower legs, and represent 25 percent of total body surface area.

USEPA Region IV default values of 0.01 for organics and 0.001 for metals were used for the ABS. A value of 1.0 mg/cm^2 was used in this assessment for the AF.

The ED, EF, BW and AT values are the same as those used in the incidental soil ingestion scenario. A summary of these values is presented in Table 6-15.

Future On-Site Residents

Future on-site residents may be exposed to COPCs through dermal contact with surface soil during outdoor activities near their homes.

The SA values represent reasonable worst case scenarios for an individual wearing a short-sleeved shirt, shorts, and shoes. The exposed skin surface area is limited to the head, hands, forearms and lower legs. Twenty-five percent of the upper-bound total body surface area yields a default SA of 5,800 cm^2 for adults. The exposed skin surface for a child (2,400 cm^2) is estimated using an average of the 50th (0.866 m^2) and the 95th (1.06 m^2) percentile body surface for a six year old child, multiplied by 25 percent (USEPA, 1992a).

ED, EF, BW and AT values are the same as those used in the incidental soil ingestion scenario.

A value of 1.0 mg/cm^2 was used in this assessment for the AF. USEPA Region IV default values of 0.01 for organics and 0.001 for metals were used for the ABS. A summary of these values is presented in Table 6-16.

Future Construction Worker

Construction workers may be exposed to COPCs through dermal contact with subsurface soil, experienced during excavation activities.

It is assumed that a construction worker wears a short-sleeved shirt, long pants and boots. Exposed skin surface area is then limited to the head, (1,180 cm^2) arms (2,280 cm^2) and hands (840 cm^2) (USEPA, 1992a). Total SA for the construction worker is 4,300 cm^2.

ED and EF values are the same as those used in the incidental soil ingestion scenario.

Data on AF is limited. A value of 1.0 mg/cm^2 is used in this assessment. USEPA Region IV default values of 0.01 for organics and 0.001 for metals were used for the ABS. A summary of these values is presented in Table 6-17.

6.3.4.3 Inhalation of Fugitive Particulates

The equation for CDI, calculated for future residents and base personnel potentially inhaling particulates, is as follows:

$$CDI = \frac{C \ x \ IR \ x \ ET \ x \ EF \ x \ ED \ x \ 1/PEF}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration in soil (mg/kg)
IR = Inhalation rate (m^3/hr)
ET = Exposure time (hr/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
1/PEF = Particulate emission factor (m^3/kg)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

PEF relates contaminant concentrations in soil to concentrations of respirable particles in air, from surface soil fugitive dust emissions. A default PEF is used in this assessment (USEPA, 1989b). Particulate emissions at contaminated sites occur vis-a-vis wind erosion, and thereby vary according to irritability of the surface material. The PEF is $1.32x10^9$ m^3/kg for all receptors in this scenario (Cowherd et al., 1985).

The following paragraphs explain the exposure assumptions used to evaluate COPC impact in particulate inhalation.

Military Personnel

During work related activities, military personnel may inhale COPCs emitted as fugitive dust from surface and subsurface soil. An inhalation rate of 20 m^3/day is used in this scenario (USEPA 1991a). ED, EF, BW and AT values are the same as those used in the incidental soil ingestion scenario. A summary of these values is presented in Table 6-14.

Current Trespassers

During recreational activities, adolescent and adult trespassers may inhale COPCs emitted as fugitive dust. An inhalation rate of 20 m^3/day is used for both adolescents and adults in this scenario

(USEPA 1991a). ED, EF, BW and AT values are the same as those used in the incidental soil ingestion scenario. A summary of these values is presented in Table 6-15.

Future On-Site Residents

Future on-site residents may be exposed to COPCs by inhaling fugitive dust during outdoor activities near their homes. The adult IR for residential exposure scenarios is 20 m^3/day (USEPA 1989a) and 15 m^3/day (USEPA, 1995) is used for children. ED, EF, BW and AT values are the same as those used the incidental soil ingestion scenario. A summary of these values is presented in Table 6-16.

Future Construction Worker

Construction workers may be exposed to COPCs through inhalation of fugitive particulates in surface and subsurface soil during excavation activities. The IR is 20 m^3/day (USEPA 1991a). ED, EF, BW and AT values are the same as those used in the incidental soil ingestion scenario. A summary of these values is presented in Table 6-17.

6.3.4.4 Ingestion of Groundwater

Currently at Site 73, deep groundwater provides the potable water supply. Due to the generally low water quality and poor flow rates in the shallow aquifer, it is not likely that the shallow aquifer will be developed as a potable water supply. However, should residential housing be constructed in the future, shallow groundwater may be used to provide potable supplies. Currently, there are three supply wells within a one mile radius of this site. These supply wells utilize the Castle Hayne aquifer. If well contamination is reported, the wells are no longer used as potable water supplies.

The equation for CDI, calculated for all human receptors potentially ingesting groundwater, is as follows:

$$CDI = \frac{C \ x \ IR \ x \ EF \ x \ ED}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration is groundwater (mg/L)
IR = Ingestion rate (L/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to calculate the impact of COPCs in groundwater ingestion.

Future On-Site Residents

Exposure to COPCs by groundwater ingestion is a possible future exposure pathway for children and adults.

A 6-year-old child weighing 15kg has an IR of 1.0 L/day. This rate provides a conservative exposure estimate, in terms of systemic health effects. This value assumes that children obtain all the tap water they drink from the same source, for 350 days/year (EF). AT is 2,190 days (6 years x 365 days/year) for noncarcinogenic compound exposure.

The IR for adults is 2 L/day (USEPA 1989a). The ED is 30 years, the national upper-bound (90th percentile) time spent at one residence (USEPA 1989b). The AT for noncarcinogens is 10,950 days. An AT of 25,550 days (70 years x 365 days/year) is used to evaluate exposure to potential carcinogenic compounds, for children and adults. A summary of groundwater ingestion exposure assessment input parameters is presented in Table 6-16.

6.3.4.5 Dermal Contact with Groundwater

The equation for CDI, calculated for all human receptors potentially experiencing dermal contact with groundwater, is as follows:

$$CDI = \frac{C \ x \ SA \ x \ PC \ x \ ET \ x \ EF \ x \ ED \ x \ CF}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration is groundwater (mg/L)
SA = Surface area available for contact (cm^2)
PC = Dermal permeability constant (cm/hr)
ET = Exposure time (hour/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
CF = Conversion factor (1 L/1000 cm^3)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in dermal contact with groundwater.

Future On-Site Residents

Children and adults may be exposed to COPCs through dermal contact with groundwater while bathing or showering. It is assumed that bathing takes place 350 days/year (EF). The SA available for dermal absorption is estimated at 10,000 cm^2 for children and 23,000 cm^2 for adults (USEPA, 1992c). The ET for bathing or showering is 0.25 hours/day (USEPA, 1989a), a conservative estimate. The ED, BW and AT values are the same as those used in the groundwater ingestion scenario.

The PC indicates the movement of a chemical through the skin and into the blood stream. The permeability of a chemical is an important property in evaluating actual absorbed dose; however, many compounds do not have published PC values. The permeability constants for these compounds (Appendix T) are calculated according to USEPA guidance (USEPA, 1992a). A summary of dermal contact with groundwater exposure assessment input parameters is presented in Table 6-16.

6.3.4.6 Inhalation of Volatile Organics

The Foster and Chrostowski (Foster et al., 1987) inhalation model is applied in a quantitative assessment of inhaling volatile organics released from shower water. Contaminant (VOC) concentrations in air while showering are estimated by determining the following: the rate of chemical releases into air, (generation rate) the buildup of VOCs in the shower room air when the shower is on, the decay of VOCs in the shower room after the shower is turned off and the quantity of airborne VOCs inhaled while the shower is on and off.

The equation for CDI, calculated for all human receptors potentially inhaling volatile organics while showering, is as follows:

$$CDI = \frac{C \ x \ IR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hr)
ET = Exposure time (hr/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

Future On-Site Residents

The potential to inhale vaporized volatile organic COPCs while showering is considered for adults only. Based on professional opinion, it is considered unlikely that children under the age of six take showers. It is assumed that showering takes place 350 days/year (EF). IR for adults is 0.6 m^3/hr. The ET is 0.25 hrs/day (USEPA, 1989a). ED, BW and AT values are the same as those used in the groundwater ingestion scenario. A summary of groundwater inhalation exposure assessment input parameters is presented in Table 6-16.

6.3.4.7 Incidental Ingestion of Surface Water

The equation for CDI, calculated for all human receptors potentially ingesting surface water, is as follows:

$$CDI = \frac{C \ x \ IR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration in surface water (mg/L)
IR = Ingestion rate (L/hr)
ET = Exposure time (hrs/event)
EF = Exposure frequency (events/year)

ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in surface water ingestion.

Military Personnel

Current military personnel who work at Site 73 may be exposed to COPCs through surface water incidental ingestion. These individuals may be involved in maneuvers that require the amphibious vehicles to be driven into Courthouse Bay. Although exposure to surface water via swimming is considered unlikely due to the murky nature of the water, surface water exposure via wading is possible. However, a surface water ingestion scenario based on potential exposure while swimming is included based on conservative professional judgement.

The IR for military personnel is 0.05 L/hr (USEPA, 1989a). ET is 2.6 hr/day (USEPA, 1992a). EF is 100 days/yr. This EF value represents a site-specific, professional judgement, according to which exposure to surface water is estimated at approximately half the time spent working at Site 73 during a regular work year. ED, BW, and AT values are the same as those used in soil exposure scenarios. These values are presented in Table 6-14.

Current Trespassers and Adult Fishermen

Trespassers have access to Courthouse Bay. Trespassers and individuals known to fish and crab from Courthouse Bay may be exposed to COPCs through surface water ingestion. Although exposure to surface water via recreational swimming is considered unlikely due to the murky nature of the water, surface water exposure via wading is possible. However, a surface water ingestion scenario based on potential exposure while swimming is included based on conservative professional judgement.

The IR, ET and EF values used for trespassers apply to both adolescents and adults. The IR is 0.05 L/hr (USEPA, 1989a). The ET is 2.6 hr/day (USEPA, 1992a). The EF is 48 days/yr. This value represents a site-specific, professional judgement, according to which exposure to surface water is estimated at 8 days/month, for 6 months/year. The ED, BW and AT values are the same as those given for trespassers under the soil ingestion scenario. A summary of surface water ingestion exposure assessment input parameters is presented in Table 6-15.

Future On-Site Residents

The IR, ET and EF values used for future residents apply to both children and adults. The IR is 0.05 L/hr (USEPA, 1989a). The ET is 2.6 hr/day (USEPA, 1992a). The EF is 48 days/yr. This value represents a site-specific, professional judgement, according to which exposure to surface water is estimated at 8 days/month, for 6 months/year.

ED values represent lifetime residential exposure durations. They are the same as those used for future children and adult residents in the groundwater exposure scenarios. BW and AT values are also the same as those used in groundwater exposure scenarios. These values are presented in Table 6-16.

6.3.4.8 Dermal Contact with Surface Water

The equation for CDI, for all residents potentially experiencing dermal contact with surface water, is as follows:

$$CDI = \frac{C \ x \ CF \ x \ SA \ x \ PC \ x \ EF \ x \ ED \ x \ ET}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:

C = Contaminant concentration in surface water (mg/L)
CF = Conversion factor (L/cm^3)
PC = Permeability constant (cm/hour)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
ET = Exposure time (hours/day)
BW = Body weight (kg)
AT_c = Averaging time carcinogen (days)
AT_{nc} = Averaging time noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in dermal contact with surface water.

Military Personnel

The total SA for the military trainee is 4,300 cm^2. The ED, EF, BW and AT values are the same as those used in the surface water ingestion scenario. PC values are chemical-specific (USEPA, 1992a). They are provided on the CDI spreadsheets in Appendix U. A summary of these values is presented in Table 6-14.

Current Trespassers and Adult Fishermen

Although unlikely, an exposure scenario for individuals who may trespass onto Site 73 and/or fish/crab in Courthouse Bay is presented to evaluate the impact of COPCs in dermal contact with surface water.

Values of 5,800 cm^2 for adults and 3,480 cm^2 for adolescents are used for the surface area exposed for contact with surface water. ET, EF, ED, BW and AT values are the same as those used in the surface water ingestion exposure scenario.

PC values are chemical-specific (USEPA, 1992a). They are provided on the CDI spreadsheets in Appendix U. A summary of surface water dermal contact exposure assessment input parameters is presented in Table 6-15.

Future On-Site Residents

SA values represent dermal surface area of hands, forearms and lower extremities exposed for contact with surface water. SA is 2,400 cm^2 for children and 5,800 cm^2 for adults (USEPA, 1992a).

ET, EF, ED, BW and AT values are the same as those used for future children and adult residents in the groundwater ingestion exposure scenario. These values are presented in Table 6-16.

6.3.4.9 Incidental Ingestion of Sediment

The equation for CDI, for all receptors potentially experiencing incidental ingestion of sediment, is as follows:

$$CDI = \frac{C \text{ x } IR \text{ x } CF \text{ X } EF \text{ x } ED}{BW \text{ x } AT_c \text{ or } AT_{nc}}$$

Where:

C = Contaminant concentration in sediment (mg/kg)
IR = Ingestion rate (mg/day)
CF = Conversion factor for kg to mg (mg/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in sediment ingestion.

Military Personnel

Due to the nature of the work-related activities at Site 73, exposure to sediment via ingestion is possible. A sediment ingestion scenario is included based on conservative professional judgement.

IR is 100 mg/day for adult military personnel (USEPA, 1989a). EF, ED, BW and AT values are the same as those used for military personnel in the surface water exposure scenarios. These values are presented in Table 6-14.

Current Trespassers and Adult Fishermen

Contact with sediment by individuals who may trespass onto Site 73 and/or fish/crab from Courthouse Bay is considered unlikely for the same reasons given in the surface water ingestion section. However, a conservative exposure scenario is presented in the event that exposure to sediment were to occur.

IR for an adult and an adolescent is 200 mg/day. EF, ED, BW and AT values are the same as those for the trespassers and adult fishermen in the surface water exposure scenario. The CF is $1 \text{x} 10^{-6}$ kg/mg (USEPA, 1989a). It is applied to sediment exposure analyses for both adolescents and adults. A summary of sediment ingestion exposure assessment input parameters is presented in Table 6-15.

Future On-Site Residents

The IR is 200 mg/day for children and 100 mg/day for adults (USEPA, 1989a). EF, ED, BW and AT values are the same as those used for future children and adult residents in the surface water exposure scenarios. These values are presented in Table 6-16.

6.3.4.11 Dermal Contact with Sediment

The equation for CDI, for all receptors potentially experiencing dermal contact with sediment, is as follows:

$$CDI = \frac{C \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT_c \text{ or } AT_{nc}}$$

Where:

C = Concentration of contaminant in sediment (mg/kg)
CF = Conversion factor (kg/mg)
SA = Exposed skin surface area (cm^2)
AF = Sediment to skin adherence factor ($mg/cm^{2)}$
ABS = Fraction absorbed (unitless)
EF = Exposure frequency (events/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

The following paragraphs explain the exposure assumptions used to evaluate the impact of COPCs in dermal contact with sediment.

Military Personnel

Due to the nature of the work-related activities at Site 73, exposure to sediment via dermal contact is possible. This scenario is included based on conservative professional judgement. The total SA for the military personnel is 4,300 cm^2. The ED, EF, BW and AT values are the same as those used in the surface water ingestion scenario. A summary of these values is presented in Table 6-14.

Current Trespassers and Adult Fishermen

The SA values are the same as those used for the adults (trespasser and fisherman) and adolescents (trespasser) in the dermal contact with surface water exposure scenario. The EF, ED, BW, AT and CF values are the same as those used in the sediment ingestion exposure scenario. A summary of sediment dermal contact exposure assessment input parameters is presented in Table 6-15.

Future On-Site Residents

The SA values are the same as those used for future residential children and adults in the dermal contact with surface water exposure scenario. The AF is 1.0 mg/cm^2. It is used to evaluate dermal contact with sediment for both children and adults. The ABS is 1.0 percent for organics and

0.1 percent for inorganics (USEPA, 1991b). The EF, ED, BW, AT and CF values are the same as those used in the sediment ingestion exposure scenario. These values are presented in Table 6-16.

6.3.4.10 Ingestion of Fish/Crab Tissue

The equation for CDI, for those individuals potentially ingesting edible fish/crab tissue, is as follows:

$$CDI = \frac{C \ x \ IR \ x \ Fi \ x \ EF \ x \ ED}{BW \ x \ AT_c \ or \ AT_{nc}}$$

Where:
CF = Concentration of contaminant in fish/crab (mg/kg)
IR = Ingestion rate (kg/day)
Fi = Fraction ingested from source (dimensionless)
EF = Exposure frequency (days/yr)
ED = Exposure duration (years)
BW = Body weight (kg)
AT_c = Averaging time, carcinogen (days)
AT_{nc} = Averaging time, noncarcinogen (days)

Fishermen

The IR and EF values used for the adult fisherman and the child receptor are based on a recreational fishing/crabbing scenario. The IR is 0.054 kg/day and EF is 350 days/year (USEPA, 1995). The ED, BW, and AT values are the same as those used for adult trespassers in the sediment ingestion exposure scenario. The Fi value, indicating the portion of exposure from fish/crab tissue actually originating from Courthouse Bay versus other sources, is 10 percent. This is based on the professional opinion that most fishing from Courthouse Bay is commercial, and fisherman and their families get most of their fish or crab from other sources. These values are presented in Table 6-15.

Appendix U contains CDI calculation spreadsheets for specific exposure scenarios (USEPA 1989a).

6.4 Toxicity Assessment

This section reviews toxicological information available for COPCs identified in Section 6.2.

6.4.1 Toxicological Evaluation

Toxicological evaluation addresses the inherent toxicity of chemical compounds. It consists of the review of scientific data to determine the nature and extent of the potential human health and environmental effects associated with exposure to various contaminants.

Because of uncertainties in exposure estimates and inherent difficulties in determining causal relationships established by epidemiological studies, human data from occupational exposures are often insufficient for determining quantitative indices of toxicity. For this reason, animal bioassays are conducted under controlled conditions, and results are extrapolated to humans. There are several stages in this extrapolation. First, to account for species differences, conversion factors are used to apply test animal data to human studies. Second, high dosage administered to test animals must be translated into lower dosage, more typical of human exposure. When developing acceptable human doses of noncarcinogenic contaminants, safety factors and modifying factors are applied to animal test results. When studying carcinogens, mathematical models are used to convert high dosage effects to effects at lower dosages. Epidemiological data can then be used to determine credibility of these experimentally derived indices.

An RfD is an experimentally derived exposure index for noncarcinogenic contaminants, and a CSF is an experimentally derived exposure index for carcinogens. These values are addressed, within the context of dose-response evaluation, in the next section.

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

6.4.2 Dose-Response Evaluation

An important component in risk assessment is the relationship between the dose of a compound and the potential for adverse health effects resulting from the exposure to that dose. Dose-response relationships provide a means by which potential public health impacts may be evaluated. The published information on doses and responses is used in conjunction with information on the nature and magnitude of exposure to develop an estimate of risk.

6.4.2.1 Carcinogenic Slope Factor

CSFs are used to estimate upper-bound lifetime probability of developing cancer as a result of exposure to a particular dose of a potential carcinogen (USEPA, 1989a). This factor is generally reported in $(mg/kg/day)^{-1}$ CSF is derived by converting high dose-response values produced by animal studies to low dose-response values, and by using an assumed low-dosage linear multistage model. The value used in reporting the slope factor is the upper 95th percent confidence limit.

USEPA weight of evidence (WOE) classifications accompany CSFs. They provide the WOE according to which particular contaminants are defined as potential human carcinogens.

The USEPA's Human Health Assessment Group (HHAG) classifies carcinogenic potential by placing chemicals into one of the following groups, according to WOE from epidemiological and animal studies:

Group A - Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B - Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans based on epidemiological studies; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)

Group C	-	Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
Group D	-	Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)
Group E	-	Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

6.4.2.2 Reference Dose

RfDs are developed for chronic and/or subchronic chemical exposure and is based solely on noncarcinogenic effects of chemical substances. It is defined as an estimate of the daily exposure level for a human population that is not likely to produce an appreciable risk of adverse effects during a lifetime. The RfD is usually expressed as dose (mg) per unit body weight (kg) per unit time (day). It is generally derived by dividing a no-observed-(adverse)-effect-level (NOAEL or NOEL) or a lowest observed-adverse-effect-level (LOAEL) for the critical toxic effect, by the appropriate "uncertainty factor (UF)". Effect levels are determined by laboratory or epidemiological studies. The UF is based on the availability of toxicity data.

UFs usually consist of multiples of 10, where each factor represents a specific area of uncertainty naturally present in the extrapolation process. These UFs are presented below and were taken from the Risk Assessment Guidance Document for Superfund, Volume I, Human Health Evaluation Manual (Part A) (USEPA, 1989a):

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

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

- An MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default for the MF is 1.

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

Toxicity factors and the USEPA WOE classifications are presented in Table 6-18. The hierarchy for choosing these values is as follows (USEPA, 1989a):

- Integrated Risk Information System (IRIS)
- Health Effects Assessment Summary Table (HEAST)
- USEPA National Center for Environmental Assessment Office (EPA-NCEA)

The IRIS database is updated monthly and contains both verified CSFs and RfDs. The USEPA has formed the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Workgroup to review and to validate toxicity values used in developing CSFs. Once the slope factors have been verified with extensive peer review, they appear in the IRIS database. Like the Crave Workgroup, an RfD Workgroup has been formed by the USEPA to review existing data used to derive RfDs. Once RfDs have been verified, they also appear in IRIS.

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

6.5 Risk Characterization

This section presents estimated incremental lifetime cancer risks (ICRs) and hazard indices (HIs) for identified receptor groups possibly exposed to COPCs by the exposure pathways presented in Section 6.3.

Quantitative risk calculations for carcinogenic compounds estimate ICR levels for individuals in a given population. An ICR of $1x10^{-6}$, for example, indicates that, within a lifetime of exposure to site-specific contamination, one additional case of cancer may occur per one million exposed individuals.

The following represents an individual's total ICR:

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

where CDI_i is the chronic daily intake (mg/kg/day) for compound i, and CSF_i is the compound's carcinogenic slope factor $[(mg/kg/day)^{-1}]$. The CSF is defined as an upper 95th percentile confidence limit of the probability of a carcinogenic response, based on experimental animal data. The CDI defines exposure, expressed as a mass of a substance contracted per unit body weight per unit time, averaged over a period of time (i.e., six years to a lifetime). The above equation is derived assuming that cancer is a non-threshold process and that the potential excess risk level is proportional to the cumulative intake over a lifetime.

Quantitative noncarcinogenic risk calculations assume that noncarcinogenic compounds have threshold values for toxicological effects. Noncarcinogenic effect weighs CDI against threshold levels (RfDs). Noncarcinogenic effect is estimated by calculating the hazard index (HI), defined by the following equation:

$$HI = HQ_1 + HQ_2 + \ldots HQ_n$$

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

$$\text{where } HQ_i = CDI_i / RfD_i$$

where HQi is the hazard quotient for contaminant i, CDI_i is chronic daily intake (mg/kg/day) and RfD_i is the reference dose (mg/kg/day) for contaminant i, over a prolonged period of exposure.

6.5.1 Human Health Risks

ICR and HI values associated with exposure to environmental media at Site 73 (soil, groundwater, surface water/sediment, and fish and crab tissue) are presented in Tables 6-19 through 6-25, respectively. Total carcinogenic and noncarcinogenic risks, per medium, for all relevant receptor groups, are provided in these tables. ICR and HI are also broken down to show risks from specific exposure pathways: ingestion, dermal contact and inhalation (where applicable).

A cancer risk range of $1\text{x}10^{-6}$ to $1\text{x}10^{-4}$ is used to evaluate calculated ICR levels. Any ICR value within this range is considered "acceptable"; an ICR greater than $1\text{x}10^{-4}$ denotes an existing cancer risk. A noncarcinogenic risk of 1.0 is used as an upper limit to which calculated HI values are compared. Any HI exceeding 1.0 indicates an existing noncarcinogenic risk (USEPA 1989a).

6.5.1.1 Current Military Personnel

The current military receptor was evaluated for potential noncarcinogenic and carcinogenic risk from exposure to the surface soil, surface water, and sediment. The noncarcinogenic and carcinogenic risks for surface soil (i.e., HI=0.01 and ICR=$1.3\text{x}10^{-7}$), surface water (i.e., HI=0.4), and sediment (i.e., HI=0.07 and ICR=$2.7\text{x}10^{-7}$) were within the acceptable risk levels (i.e., HI<1 and $1\text{x}10^{-6}<\text{ICR}<1\text{x}10^{-4}$). There were no carcinogens retained as COPCs in surface water. Hence, ICR values were not calculated for this media. These results are presented in Table 6-19.

6.5.1.2 Current Adolescent Trespasser

In the current scenario, an adolescent trespasser receptor was evaluated for potential risk from exposure to site surface soils, surface water, and sediment. The potential noncarcinogenic and carcinogenic risks from exposure to the surface soil (i.e., HI<0.01 and ICR=$9.5\text{x}10^{-8}$), the surface water (i.e., HI=0.3), and sediment (i.e., HI=0.07 and ICR=$5.4\text{x}10^{-7}$) were within acceptable risk levels (i.e., HI<1 and $1\text{x}10^{-6}<\text{ICR}<1\text{x}10^{-4}$). There were no carcinogens retained as COPCs in surface water. Hence, there were no ICR values calculated for this media. These results are presented in Table 6-20.

6.5.1.3 Current Adult Trespasser

In the current scenario, an adult trespasser was evaluated for potential risk from exposure to site surface soils (i.e., HI<0.01 and ICR=$2.1\text{x}10^{-7}$), surface water (i.e., HI=0.2), and sediment (i.e., HI=0.04 and ICR=$1.1\text{x}10^{-6}$). The potential noncarcinogenic and carcinogenic risks from exposure to these media were within acceptable risk levels (i.e., HI<1 and $1x10^{-6}$<ICR<$1x10^{-4}$). These results are provided in Table 6-21.

6.5.1.3 Current Adult Fisherman

In the current scenario, an adult fisherman was evaluated for potential risk from exposure to site surface water (i.e., HI=0.2) and sediment (i.e., HI=0.04 and ICR=$1.1x10^{-6}$). The potential noncarcinogenic and carcinogenic risks from exposure to these media were within acceptable risk levels (i.e., HI<1 and $1x10^{-6}$<ICR<$1x10^{-4}$).

The adult fisherman was also evaluated for potential risks from ingestion of fish tissue (i.e., HI=0.05 and ICR=$2.6x10^{-7}$) and crab tissue (i.e., HI=0.05 and ICR=$4.0x10^{-6}$). The potential noncarcinogenic and carcinogenic risks from exposure to these media were within acceptable risk levels (i.e., HI<1 and $1x10^{-6}$<ICR<$1x10^{-4}$). These results are provided in Table 6-22.

6.5.1.4 Child Receptor - Aquatic Biota Ingestion

A child receptor was evaluated for potential risk from exposure to biota (i.e., fish fillet and crab tissue) through ingestion. The total noncarcinogenic risks from fish tissue (HI=0.2) and crab tissue (HI=0.2) did not exceed the acceptable risk level of one. In addition, the total carcinogenic risks from fish tissue (ICR=$2.4x10^{-7}$) and crab tissue (ICR=$3.8x10^{-6}$) did not exceed the upper bound of USEPA's acceptable risk range. These results are provided in Table 6-23.

6.5.1.5 Future Residential Child

The child receptor was evaluated for potential risk from exposure to surface soil and groundwater (Phase I and Phase II) in the future scenario. It was assumed that current exposure to surface water and sediment also would occur in the future case.

The potential noncarcinogenic and carcinogenic risks from exposure to the surface soil (i.e., HI=0.2 and ICR=$1.6x10^{-6}$), the surface water (i.e., HI=0.8) and sediment (i.e., HI=0.3 and ICR=$1.6x10^{-6}$) were within acceptable risk levels (i.e., HI<1 and $1x10^{-6}$<ICR<$1x10^{-4}$). There were no carcinogens retained as COPCs in surface water. Hence, ICR values were not calculated for this media. The results are summarized in Table 6-22.

Phase I Groundwater

In Phase I groundwater maximum and plausible exposure scenarios, there are potential noncarcinogenic risks from ingestion for the child receptor. The total noncarcinogenic risk levels for the maximum and plausible scenarios were 24 and 2.0, respectively. This was due primarily to the groundwater ingestion pathway. This value exceeded the acceptable risk level of one for noncarcinogenic risks. Primarily, iron and manganese in groundwater contributed to this risk.

The total carcinogenic risk from Phase I groundwater plausible exposure scenario (i.e., ICR=$1.6x10^{-5}$) was within USEPA's acceptable risk range. The total carcinogenic risk from the maximum exposure scenario (i.e., ICR=$2.6x10^{-4}$) exceeded USEPA's acceptable risk range. This was due primarily to the groundwater ingestion pathway. Vinyl chloride contributed approximately 94 percent of this elevated carcinogenic risk. The risk results are presented in Table 6-24.

Phase II Groundwater

It should be re-emphasized that during Phase II only VOC analyses were requested for the groundwater samples and that these VOC results were combined with the SVOC, pesticide/PCB, and metals results from Phase I. In Phase II groundwater maximum and plausible exposure scenarios, there are potential noncarcinogenic risks from ingestion for the child receptor. The total noncarcinogenic risk levels of 27 and 2.1 for maximum and plausible exposure scenarios, respectively, were due primarily to the groundwater ingestion pathway. Iron and manganese from the ingestion pathway contributed to these risks.

The total carcinogenic risk from Phase II groundwater plausible exposure scenario (i.e., ICR=7.1×10^{-5}) was within USEPA's acceptable risk range. The total carcinogenic risk from the maximum exposure scenario (i.e., ICR=4.8×10^{-4}) exceeded USEPA's acceptable risk range. This was due primarily to the groundwater ingestion pathway. Vinyl chloride contributed 95 percent of this elevated carcinogenic risk. The risk results are presented in Table 6-24.

6.5.1.6 Future Residential Adult

The adult receptor was evaluated for potential risk from exposure to surface soil and groundwater (Phase I and Phase II) in the future scenario. Similar to the child receptor, it was assumed that current exposure to the surface water and sediment also would occur in the future case.

In surface soil (i.e., HI=0.02 and ICR=1.6×10^{-6}), surface water (i.e., HI=0.2), and sediment (i.e., HI=0.04 and ICR=1.1×10^{-6}), the potential noncarcinogenic and carcinogenic risks from exposure to these media were within acceptable levels (i.e., HI<1 and $1 \times 10^{-4} < \text{ICR} < 1 \times 10^{-6}$). Table 6-25 summarizes these results.

Phase I Groundwater

The potential noncarcinogenic (i.e., HI=0.87) and carcinogenic (i.e., ICR=3.7×10^{-5}) risks for the adult from exposure to Phase I groundwater plausible exposure scenario were within acceptable levels (i.e., HI<1 and $1 \times 10^{-4} < \text{ICR} < 1 \times 10^{-6}$). The potential noncarcinogenic (i.e., HI=10) and carcinogenic (i.e., ICR=5.5×10^{-4}) risks for the adult from exposure to Phase I groundwater maximum exposure scenario exceeded acceptable levels. The ingestion pathway was the primary contributor to these elevated risks. Iron and vanadium contributed approximately 50 percent of the HI, while vinyl chloride contributed approximately 96 percent to the ICR. Table 6-25 summarizes these results.

Phase II Groundwater

It should be re-emphasized that during Phase II only VOC analyses were requested for the groundwater samples and that these VOC results were combined with the SVOC, pesticide/PCB, and metals results from Phase I. In the Phase II groundwater plausible exposure scenario, there is a potential noncarcinogenic risk from ingestion for the adult receptor. The total noncarcinogenic risk level of 1.0 was due primarily to the groundwater ingestion (HI=0.86) pathway. Primarily, iron and manganese contributed to this risk. It should be noted that no individual HQ exceeded unity. In the Phase II groundwater maximum exposure scenario, there is a potential noncarcinogenic risk from ingestion for the adult receptor. Similarly, iron and manganese contributed to the risk.

The total carcinogenic risk from Phase II groundwater maximum and plausible exposure scenarios (i.e., ICR=1.0×10^{-3} and ICR=1.6×10^{-4}) slightly exceeded USEPA's acceptable risk range. This exceedence was due primarily to the groundwater ingestion pathway (ICR=1.0×10^{-3} and 1.5×10^{-4}, respectively). Vinyl chloride was the primary contributor to this elevated ICR. The risk results are presented in Table 6-25.

6.5.1.7 Construction Worker

The construction worker was evaluated for potential noncarcinogenic and carcinogenic risk from exposure to surface soil and subsurface soil in the future case. The noncarcinogenic and carcinogenic risks (i.e., HI=0.02 and ICR=3.4×10^{-8}) from exposure to surface soil and the noncarcinogenic and carcinogenic risks from exposure to subsurface soil (i.e., HI=0.02 and ICR=6.7×10^{-8}) fell below the acceptable risk levels (i.e., HI<1 and $1 \times 10^{-4} < ICR < 1 \times 10^{-6}$). Table 6-26 presents these results.

6.5.2 Lead Uptake/Biokinetic (UBK) Model Results

Lead was detected in fish and crab tissue at maximum detected concentrations of 0.07 mg/kg and 0.08 mg/kg, respectively. The USEPA lead UBK model was used to determine if exposure to site media would result in unacceptable levels in younger children upon exposure to fish fillet and/or crab tissue from Courthouse Bay, which is adjacent to Site 73. Blood lead levels are considered unacceptable when a greater than five percent probability exists that the blood lead levels will exceed 10 µg/dl.

The maximum concentrations of lead found in the fish and crab tissue were used in the model. The remaining model parameters used were the default factors supplied in the model. These maximum concentrations did not result in a greater than five percent probability of the blood lead levels exceeding 10 µg/dl, which is within acceptable levels. Figure 6-2 illustrates these results.

6.6 Sources of Uncertainty

Uncertainties may arise during the risk assessment process. This section presents site-specific sources of uncertainty in the risk assessment:

- Sampling strategy
- Analytical data
- Exposure Assessment
- Toxicity Assessment
- Iron
- Phase I and Phase II Groundwater
- CT-Case Scenarios

6.6.1 Sampling Strategy

As an environmental medium, soil is available for direct contact exposure, and it is often the main source of contamination released to other media. Soil sampling intervals should be appropriate for the exposure pathways and contaminant transport routes of concern. Surface soil exposure assessment is based on samples collected from the shallowest depth, zero to one foot below the ground surface. Subsurface soil samples are necessary to generate data for exposure assessment when soil excavation is possible, or if leaching of chemicals to groundwater is likely. Subsurface soil samples are collected at depths greater than one foot below the ground surface.

6.6.2 Analytical Data

The credibility of the BRA relies on the quality of the analytical data available to the risk assessor. Analytical data are limited by the precision and accuracy of the analytical method of analysis. In addition, the statistical methods used to compile and analyze data (mean concentration, standard deviation, and detection frequencies) are subject to uncertainty in the ability to acquire data.

Data validation serves to reduce some of the inherent uncertainty associated with analytical data by establishing the usability of the data to the risk assessor who may or may not choose to include the data point in risk estimation. Data can be qualified as "J" (estimated) for many reasons, including a slight exceedance of holding times, high or low surrogate recovery, or intra-sample variability. Data qualified with "J" were retained for risk assessment. Organic data qualified with "B" (detected in blank) or "R" (rejected/unreliable) were not applied to risk analysis. Dismissing data points qualified with "B" or "R" did not significantly increase uncertainty in the risk assessment.

6.6.3 Exposure Assessment

When performing exposure assessments, uncertainties can arise from two main sources. First, the chemical concentration to which a receptor may be exposed must be estimated for every medium of interest. Second, uncertainties can arise in estimating contaminant intakes resulting from contact with a particular medium.

Estimating the contaminant concentration in a given medium to which a human receptor may be exposed can be as simple as deriving the 95th percent upper confidence limit of the mean for a given data set. More complex methods for deriving contaminant concentration are necessary when exposure to COPCs in a given medium occurs subsequent to contaminant release from another medium, or when analytical data are not available to characterize the release. In this case, modeling is usually employed to estimate potential human exposure.

Potential inhalation of fugitive dusts from affected soils is estimated by using USEPA's Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination (Cowherd et al., 1985). The Cowherd model employs the use of a site-specific PEF for wind erosion based on source area and vegetative cover.

Groundwater samples were analyzed for total (unfiltered) and dissolved (filtered) inorganic contaminants. These samples were obtained from wells which were constructed using USEPA Region IV monitoring well design specifications. Groundwater taken from monitoring wells is not truly representative of groundwater that is obtained from a domestic well at the tap. The use of total inorganic analytical results overestimates the potential human health risks associated with potable use scenarios. However, in order to produce the most conservative risk estimates, total organic results were used to calculate the potential intake associated with groundwater use.

As stated previously, the shallow groundwater at Camp Lejeune is currently not used as a potable source because of the general water quality in the shallow zone and poor flow rates. Current receptors are only exposed to groundwater drawn from the deep zone. For this reason, exposure to shallow groundwater is not evaluated for current receptors. Groundwater exposure is evaluated for future residents only, as there is a possibility that shallow groundwater may be tapped someday. In addition, it has been shown that there is a hydraulic connection between the shallow and deep aquifer. The soil unit typically referred to as the semi-confining unit (Belgrade Formation) is not acting as a confining or semi-confining unit at Site 73. Based on hydraulic head differentials, it does not appear that this unit is restricting flow from the surficial to the Castle Hayne aquifer. Therefore, future groundwater exposure to contaminants in the deeper groundwater could be as a result of migration from the shallow aquifer. For a more detailed description of the study area, refer to Section 3.0.

To estimate receptor intake, certain assumptions must be made about exposure events, exposure durations and the corresponding assimilation of contaminants by the receptor. Exposure factors have been created from a range of values generated by studies conducted by the scientific community, and have been reviewed by the USEPA. Conservative assumption for daily intakes are employed throughout the BRA when values are not available; they are designed to produce low error, to protect human health and to yield reasonable clean-up goals. In all instances, the values, conservative scientific judgments and conservative assumptions used in the risk assessment concur with USEPA guidelines.

6.6.4 Toxicity Assessment

In making quantitative estimates about the toxicity of varying chemical doses, uncertainties arise from two sources. First, existing data usually provide insufficient information about toxic exposure and subsequent effects. Human exposure data display inherent temporal variability and often lack adequate concentration estimates. Animal studies are often used to subsidize available human data. In the process of extrapolating animal results to humans; however, more uncertainties can arise. Second, in order to obtain visible toxic effects in experimental animals, high chemical doses are employed over short periods of time. Doses typical of human exposure, however, are much lower, relative to those doses administered to experimental animals. In order to apply animal test results to human exposure assessments, then, data must be adjusted to extrapolate from high dose effects to low dose effects.

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

- Studies are preferred in which the animal closely mimics human pharmacokinetics
- Studies are preferred in which dose intake most closely mimics intake route and duration for humans
- Studies are preferred in which the most sensitive responses to the compound in question is demonstrated

In order to evaluate compounds that cause threshold effects, (i.e., noncarcinogens) safety factors are taken into account when experimental results are extrapolated from animals to humans, and from high to low doses.

Employing conservative assumptions yields quantitative toxicity indices that are not expected to underestimate potential toxic effects, but may overestimate these effects by some magnitude.

6.6.5 Iron

Recently, the element iron was given a RBC value and toxicity values with which to evaluate potential human health risks. However, iron is still considered an essential nutrient. Also, the studies that prompted the addition of a RBC value for iron are provisional only and have not undergone formal review by the USEPA. For these reasons, the selection of iron as a COPC for evaluation in human health risk assessments is associated with some uncertainty. However, by evaluating iron in the risk assessment, a conservative approach is taken and potential toxic effects are not expected to be underestimated.

6.6.6 Phase I vs. Phase II Groundwater

The groundwater investigation under this RI was separated into two phases. The first round of sampling was to determine the nature and extent of potential groundwater contamination at Site 73. Once it was determined that VOC contamination existed at Site 73, a second round of groundwater sampling was done to delineate the VOC contamination vertically and horizontally. Thus, the data points from the second phase of groundwater sampling were chosen based on their prior detected concentrations. Such data points used in the risk assessment could bias the calculations. However, Phase II groundwater was evaluated quantitatively to support the risk calculations based on the Phase I groundwater data, as well as to be protective of human health.

6.6.7 CT-Case Scenarios

The CT risk descriptor was used for data sets when the RME concentration term showed a potential risk to human health, specifically, to future on-site residents. The CT concentration term utilized was the lognormal 95% UCL or the arithmetic mean (if the UCL was greater than the arithmetic mean) (USEPA, 1993). In addition, USEPA standard default exposure factors for central tendency were used in the CDI calculations. The results of the CT calculations are summarized below.

As shown in Table 6-24, under the CT-case scenario there was an unacceptable noncarcinogenic risk to the future child resident from groundwater in both Phase I (HI=1.3) and Phase II (HI=1.4). These elevated HI values are primarily from the ingestion pathway. Iron and manganese contributed predominantly to this risk. The total site ICRs calculated under the CT-case scenario for both Phase I and Phase II were within USEPA's acceptable risk range. As shown in Table 6-25, under the CT-case scenario the total site noncarcinogenic and carcinogenic risks to the future adult resident fell below the acceptable risk levels (i.e., HI<1 and $1x10^{-4}$<ICR<$1x10^{-6}$).

6.7 BRA Conclusions

The BRA highlights the media of interest from the human health standpoint at Site 73 by identifying areas with risk values greater than acceptable levels. Current and future potential receptors at the site included current military personnel, current trespassers (i.e., adolescents and adults), current adult fishermen, child receptor for aquatic biota ingestion, future residents (i.e., children and adults),and future construction workers. The total risk from the site for these receptors was estimated by logically summing the multiple pathways likely to affect the receptor during a given activity. Exposure to surface soil, surface water and sediment was assessed for the current receptors. Ingestion of fish and crab tissue was assessed for the adult fisherman. Ingestion of fish and crab tissue was assessed for the child receptor. Surface soil, groundwater, surface water, and sediment exposure were evaluated for the future residents. Surface and subsurface soil exposure was evaluated for the future construction worker. Total site risks are summarized in Table 6-28.

6.7.1 Current Scenario

In the current case, the following receptors were assessed: military personnel, adult and adolescent trespassers, and adult fishermen. Receptor exposure to surface soil, surface water, and sediment at Site 73 was examined. In addition, the adult fisherman and child receptor were evaluated for potential risks due to the ingestion of fish and crab tissue. The risks calculated for all exposure pathways for military personnel, adult and adolescent trespassers, and adult and child fishermen were within acceptable risk ranges.

6.7.2 Future Scenario

In the future case, child and adult residents were assessed for potential exposure to groundwater, surface soil, surface water, and sediment. A construction worker was evaluated for surface and subsurface soil exposure. The potential noncarcinogenic and carcinogenic risks for the construction worker at Site 73 were within acceptable levels. The site total carcinogenic risk to the future residential child and adult under the Phase I groundwater plausible exposure scenario was within the USEPA's acceptable risk range. Also, the site total carcinogenic risk to the future residential child under the Phase II groundwater plausible exposure scenario was within the USEPA's acceptable risk range.

Under the Phase I and Phase II groundwater maximum exposure scenarios, there is a potential carcinogenic risk from groundwater to the future residential adult and child. These elevated ICRs (refer to Tables 6-24 and 6-25) for the maximum exposure scenario are driven by the ingestion of vinyl chloride. The maximum exposure scenarios represent the worst case scenario for Site 73 groundwater exposure. Under the Phase II groundwater plausible exposure scenario, there is a potential carcinogenic risk from groundwater ingestion to the future residential adult. The ICR from Phase II groundwater plausible exposure scenario was 1.6×10^{-4} for the future adult. Vinyl chloride was the primary contributor to this elevated risk value. Vinyl chloride is a break down product of trichloroethene, which is present at Site 73.

Under the Phase I groundwater maximum and plausible exposure scenarios, the total site noncarcinogenic risks exceeded unity for the adult and child residents. The total site HI was 10 under the maximum exposure scenario and 1.1 under the plausible exposure scenario for the future residential adult. The total site HI under the maximum exposure scenario was driven by the groundwater ingestion pathway. Iron (35%) and vanadium (20%) contributed predominantly to the groundwater ingestion HI of 10. However, for the adult receptor, the individual media HI values were below one under the plausible exposure scenario. Therefore, it is unlikely that adverse systemic health effects would result from the Phase I groundwater plausible exposure scenario for the adult receptor. The total site HI was 25 under the maximum exposure scenario and 3.3 under the plausible exposure scenario for the future residential child. The groundwater ingestion HI of 2.0 in the plausible exposure scenario was due primarily to the presence of iron (61%) and manganese (17%) in the groundwater. In the maximum exposure scenario, iron (35%) and vanadium (20%) contributed predominantly to the groundwater ingestion HI of 24.

Under the Phase II groundwater maximum and plausible exposure scenarios, the total site noncarcinogenic risks exceeded unity for the adult and child residents. The total site HI was

12 under the maximum exposure scenario and 1.3 under the plausible exposure scenario for the future residential adult. The total site HI under the maximum exposure scenario was driven by the groundwater ingestion pathway. Iron (35%), vanadium (18%), and trichloroethene (13%) contributed predominantly to the groundwater ingestion HI of 12. However, for the adult receptor, the individual exposure pathway HI values were below one under the plausible exposure scenario. Therefore, it is unlikely that adverse systemic health effects would result from the Phase II groundwater plausible exposure scenario for the adult receptor. The total site HI was 28 under the maximum exposure scenario and 3.4 under the plausible exposure scenario for the future residential child. The groundwater ingestion HI of 2.1 in the plausible exposure scenario was due primarily to the presence of iron (60%) and manganese (16%) in the groundwater. In the maximum exposure scenario, iron (35%), vanadium (18%), and trichloroethene (13%) contributed predominantly to the groundwater ingestion HI of 26.

Upon examination of the target organs for the analytes listed above, it can be shown these elevated total site HIs may overestimate the risk. This may be the case if the individual HQs are less than one and each contributing analyte targets a different organ. Iron has been found to target the liver, heart, and endocrine glands. Manganese has been found to target the central nervous system and lung. Information on the target organ and/or system of vanadium was not available. For example, in Phase I and Phase II total site HIs for the future adult resident under the plausible exposure scenario, the analytes contributing to the risk target different organs and their individual HQs were less than one.

As noted in Section 6.6.5, iron is a naturally occurring element that is also considered an essential nutrient. The studies that prompted the addition of toxicity criteria for iron have yet to be reviewed by the USEPA. If iron were removed from the risk calculations under Phase I and II groundwater ingestion exposure pathways, both HI values would fall below the acceptable risk level of 1.0.

Finally, there is a notable increase in the ICR and HI values between the Phase I and the Phase II groundwater exposure scenarios. This is due in part to the difference in sampling strategies during the first and second phases of the groundwater investigation under this RI. The first round of sampling was conducted to determine the nature and extent of potential groundwater contamination at Site 73. Once it was determined that VOC contamination existed at Site 73, a second round of groundwater sampling was performed to delineate the VOC contamination vertically and horizontally. Thus, the data points from the second phase of groundwater sampling were chosen based on prior detected concentrations from Phase I. Such data points, when used in the risk assessment, could bias the calculations. Also, as a result of the two sampling strategies, different analytical methods were used for the two phases. The method used in Phase II had higher detection limits than the method used in Phase I. Thus, the positively detected concentrations incorporated into the statistical calculations would be higher in the Phase II analytical results than in Phase I. These reasons could explain in part the increase in the risk calculations from Phase I to Phase II.

6.8 References

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SECTION 6.0 TABLES

TABLE 6-1

SUMMARY OF ORGANIC BLANK CONTAMINANT RESULTS
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Constituent	Maximum Concentration Detected in Blank (μg/L)	Medium Associated with Maximum Concentration Detected in Blank	Type of Blank with Maximum Detected Value	Concentration for Comparison(1) (Aqueous -μg/L)	Concentration for Comparison(2) (Solid - μg/kg)
Volatiles					
Methylene Chloride	9.4	Soil	Rinsate	94	94
Acetone	69J	Soil	Rinsate	690	690
Chloroform	33	Soil	Field	165	165
2-Butanone	4.7J	Soil	Rinsate	47	47
Bromodichloromethane	13	Soil	Field	65	65
Dibromochloromethane	3J	Soil	Field	15	15
Toluene	2.9J	Soil	Trip	29	29
Semivolatiles					
4-Chloroaniline	2J	Soil	Rinsate	10	330(3)
Di-n-butyl phthalate	1J	Soil	Field	10	330(3)
Bis(2-ethylhexyl)phthalate	2J	Soil	Field	20	660(3)
Volatiles-Phase I					
Methylene Chloride	5.2J	Groundwater	Rinsate	52	NA
Chloroform	0.8J	Groundwater	Trip	8	NA
1,2-Dichloroethane	3.6J	Groundwater	Trip	18	NA
Toluene	3.6	Groundwater	Trip	36	NA
Semivolatiles					
Bis(2-ethylhexyl)phthalate	25	Groundwater	Rinsate	250	NA
Volatiles-Phase II					
Methylene Chloride	1J	Groundwater	Trip	10	NA
Acetone	19	Groundwater	Rinsate	190	NA
Chloroform	33	Groundwater	Field	330	NA
Bromodichloromethane	13	Groundwater	Field	65	NA
Dibromochloromethane	3J	Groundwater	Field	15	NA
Volatiles					
Acetone	170	Surface Water/ Sediment	Rinsate	1,700	1,700
1,2-Dichloroethane	1J	Surface Water/ Sediment	Rinsate	5	5

TABLE 6-1 (Continued)

SUMMARY OF ORGANIC BLANK CONTAMINANT RESULTS
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Constituent	Maximum Concentration Detected in Blank (µg/L)	Medium Associated with Maximum Concentration Detected in Blank	Type of Blank with Maximum Detected Value	Concentration for Comparison(1) (Aqueous -µg/L)	Concentration for Comparison(2) (Solid - µg/kg)
2-Butanone	22	Surface Water/ Sediment	Rinsate	220	220
2-Hexanone	7J	Surface Water/ Sediment	Rinsate	35	35

Notes:

(1) Concentration is five or ten times (for common laboratory blank contaminants) the maximum detected concentration in a blank.
(2) Concentration is five or ten times the maximum detected concentration in a blank; converted to µg/kg.
(3) Semivolatile blank concentrations are multiplied by 33 or 66 to account for matrix difference.

NA = Not applicable

TABLE 6-2

DATA AND COPC SELECTION SUMMARY
ORGANICS IN SURFACE SOIL
SITE 73-AMPHIBIOUS VEHICLE MAINTAINENCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Range/Frequency		Region III Criteria	Comprison to Criteria	
Parameter	Range of Positive Detections (µg/kg)	No. of Positive Detects/ No. of Samples	Residential RBC Value (µg/kg)	Positive Detects Above Residential RBC Value	COPC Selection(1)/ Basis(2)
Volatiles					
1,1,1-Trichloroethane	2J	1/35	270,000	0	No /A
1,2-Dichloroethane	2J	1/27	7,000	0	No/A
1,2-Dichloropropane	1J	1/35	9,400	0	No/A
2-Butanone	2J - 4.2J	4/35	4,700,000	0	No/A
Acetone	24 - 29J	2/35	780,000	0	No/A
Chlorobenzene	1J	1/35	160,000	0	No/A
Ethylbenzene	8J	1/35	780,000	0	No/A
Styrene	2J	1/35	1,600,000	0	No/A
Toluene	1J	1/35	1,600,000	0	No/A
Trichloroethene	2J	1/35	58,000	0	No/A
Total Xylenes	1J - 4J	10/30	16,000,000	0	No/A
Semivolatiles					
2,4-Dinitrophenol	56J - 200J	4/34	16,000	0	No/A
4-Chloro-3-methylphenol	36J	1/35	NE	NA	No/C
Acenaphthene	40J	1/35	470,000	0	No/A
Anthracene	50J	1/35	2,300,000	0	No/A
Benzo(a)anthracene	220J	1/35	880	0	No/A
Benzo(a)pyrene	160J	1/35	88	1	Yes/D
Benzo(b)fluoranthene	260J - 330J	2/35	880	0	No/A
Benzo(g,h,i)perylene	140J	1/35	230,000(3)	0	No/A
Butyl benzyl phthalate	110J	1/35	1,600,000	0	No/A
Chrysene	60J - 190J	3/35	88,000	0	No/A
Di-n-butylphthalate	110J - 510	11/35	780,000	0	No/A

TABLE 6-2 (Continued)

DATA AND COPC SELECTION SUMMARY
ORGANICS IN SURFACE SOIL
SITE 73-AMPHIBIOUS VEHICLE MAINTAINENCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Range/Frequency		Region III Criteria	Comprison to Criteria	
Parameter	Range of Positive Detections (µg/kg)	No. of Positive Detects/ No. of Samples	Residential RBC Value (µg/kg)	Positive Detects Above Residential RBC Value	COPC Selection(1)/ Basis(2)
bis(2-Ethylhexyl)phthalate	42J - 84J	9/35	46,000	0	No/A
Fluoranthene	42J - 380J	4/35	310,000	0	No/A
Phenanthrene	260J	1/35	230,000(3)	0	No/A
Pyrene	41J - 450	5/35	230,000	0	No/A
Pesticides/PCBs					
4,4'-DDE	3.9NJ - 11J	3/29	1,900	0	No/A
4,4'-DDD	7 - 82	7/29	2,700	0	No/A
4,4'-DDT	2.8NJ - 15J	2/29	1,900	0	No/A
Alpha-chlordane	2.5NJ	1/29	490(4)	0	No/A
Aroclor-1016	140NJ	1/29	550	0	No/A
Aroclor-1260	170J	1/29	319	0	No/A
Endrin ketone	7NJ	1/29	2,300	0	No/A
Gamma-chlordane	3.3J - 6.8J	2/29	490(4)	0	No/A

Notes:

(1) COPC = Chemical of potential concern for human health risk assessment (yes/no).
(2) A = <RBC value and/or Action Level.
C = Frequency of detection less than 5%.
D = Although frequency of detection is less than 5%, constituent re-included based on toxicity.
(3) USEPA Region III RBC Value for pyrene used as a surrogate.
(4) USEPA Region III RBC Value for chlordane used as a surrogate.

NE = Not established
NA = Not applicable
J = Estimated value
N = Tentative identification. Consider present.

TABLE 6-3

SUMMARY OF DATA AND COPC SELECTION
METALS IN SURFACE SOIL
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Range/Frequency		Comparison to Criteria				
Analyte	Range of Positive Detections (mg/kg)	No. of Positive Detects/ No. of Samples	Twice the Average Base Specific Background(1) Concentration (mg/kg)	No. of Times Exceeded Twice the Average Background Concentration	Residential RBC Value (mg/kg)	Positive Detects Above Residential RBC Value	COPC Selection(1)/ Basis(2)
Aluminum	147 - 10,600	35/35	5,856.1	1	7,800	1	Yes/A
Barium	2.3 - 46.3	35/35	17.3	4	550	0	No/B
Cadmium	1.1 - 1.9	5/35	0.7	5	3.9	0	No/B
Calcium	69.3 - 40,200	35/35	1,373	18	NE	NA	No/E
Chromium	2.3 - 13.5J	27/35	6.6	8	39	0	No/B
Cobalt	4.4 - 7.2	4/35	2.1	4	470	0	No/B
Copper	2.4 - 9.2	15/35	7.1	2	310	0	No/B
Iron	174 - 8,310J	35/35	3,702.4	3	2,300	6	Yes/A
Lead	1.2 - 38.2	35/35	23.4	7	400(4)	0	No/B
Magnesium	14 - 789	35/35	203	10	NE	NA	No/E
Manganese	0.97 - 38.8J	35/35	18.5	1	180	0	No/B
Potassium	215 - 473	7/35	200.1	7	NE	NA	No/E
Sodium	44 - 297	18/35	59	11	NE	NA	No/E
Vanadium	2.6 - 14.8	21/35	11.4	1	55	0	No/B
Zinc	2.9J - 197	30/35	13.8	16	2,300	0	No/B

Notes:

(1) Soil background concentrations are based on reference background soil samples collected from MCB Camp Lejeune investigations.
(2) COPC = Chemical of Potentail Concern for human health risk assessment (yes/no).
(3) A = >RBC value and/or Action Level.
B = <RBC value and/or Action Level.
E = Essential nutrient; professional judgement used before the analyte was eliminated as a COPC.
(4) Action Level for residential soils (USEPA, 1994).

NE = Not established
NA = Not applicable
J = Estimated Value

TABLE 6-4

SUMMARY OF DATA AND COPC SELECTION
ORGANICS IN SUBSURFACE SOIL
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Contaminant Range/Frequency		Region III Criteria	Comparison to Criteria	
	Range of Positive Detections (µg/kg)	No. of Positive Detects/ No. of Samples	Residential RBC Value (µg/kg)	Positive Detects Above Residential RBC Value	COPC Selection$^{(1)}$/ Basis$^{(2)}$
Volatiles					
1,1,1-Trichloroethane	21	1/28	270,000	0	No/A
2-Butanone	2J - 9J	7/27	4,700,000	0	No/A
4-Methyl-2-pentanone	11	1/28	NE	NA	No/C
Acetone	22J - 530	13/28	780,000	0	No/A
Carbon disulfide	2J	1/28	780,000	0	No/A
Ethylbenzene	1J	2/28	780,000	0	No/A
m-Xylene	1.8J	1/2	16,000,000	0	No/A
o-Xylene	0.89J - 3J	2/3	16,000,000	0	No/A
p-Xylene	1.8J	1/2	NE	NA	No/F
Tetrachloroethene	1J	1/28	12,000	0	No/A
Trichloroethene	6J	1/28	58,000	0	No/A
Total Xylenes	1J - 11J	5/25	16,000,000	0	No/A
Semivolatiles					
2-Methylnaphthalene	250J - 9,400	2/27	310,000$^{(3)}$	0	No/A
2,4-Dinitrophenol	140J - 180J	2/26	16,000	0	No/A
Acenaphthene	51J - 830J	3/27	470,000	0	No/A
Anthracene	2,000J	1/27	2,300,000	0	No/A
Benzo(a)anthracene	120J - 880J	2/27	880	1	Yes/B

TABLE 6-4 (continued)

SUMMARY OF DATA AND COPC SELECTION
ORGANICS IN SUBSURFACE SOIL
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Range/Frequency		Region III Criteria	Comparison to Criteria	
Parameter	Range of Positive Detections (µg/kg)	No. of Positive Detects/ No. of Samples	Residential RBC Value (µg/kg)	Positive Detects Above Residential RBC Value	COPC Selection$^{(1)}$/ Basis$^{(2)}$
Benzo(a)pyrene	140J	1/27	88	1	Yes/D
Benzo(b)fluoranthene	230J - 690J	2/27	880	0	No/A
bis(2-Ethylhexyl)phthalate	62J - 360J	11/27	46,000	0	No/A
Chrysene	120J - 930J	2/27	88,000	0	No/A
Di-n-butyl phthalate	110J - 430	10/27	780,000	0	No/A
Fluoranthene	44J - 4,000	3/27	310,000	0	No/A
Fluorene	100J - 1,200J	2/27	310,000	0	No/A
Phenanthrene	140 - 1,600	3/27	230,000$^{(4)}$	0	No/A
Pyrene	100J - 3,100	3/27	230,000	0	No/A
Pesticide/PCBs					
Dieldrin	6.6J	1/27	40	0	No/A
4,4'-DDE	4.8NJ - 50	5/27	1,900	0	No/A
4,4'-DDD	6.5J - 9,100	9/27	2,700	1	Yes/B
4,4'-DDT	17J	1/27	1,900	0	No/A
Alpha-chlordane	2.4J	1/27	490$^{(5)}$	0	No/A

TABLE 6-4 (continued)

SUMMARY OF DATA AND COPC SELECTION
ORGANICS IN SUBSURFACE SOIL
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Range/Frequency		Region III Criteria	Comparison to Criteria	
Parameter	Range of Positive Detections (µg/kg)	No. of Positive Detects/ No. of Samples	Residential RBC Value (µg/kg)	Positive Detects Above Residential RBC Value	COPC Selection(1)/ Basis(2)
Aroclor-1254	35J - 56NJ	2/27	160	0	No/A
Endosulfan I	4.1J	1/27	47,000	0	No/A
Endrin aldehyde	3.9	1/27	2,300(6)	0	No/A

Notes:

(1) COPC = Chemical of Potential Concern for human health risk assessment(yes/no).

(2) A = <RBC value and/or Action Level.
B = >RBC value and/or Action Level.
C = Frequency of detection less than 5%.
D = Although frequency of detection is less than 5%, constituent re-included as COPC based on toxicity.
F = No RBC screening value available to quantify risk; other data indicate chemical is not a human health concern.

(3) USEPA Region III RBC Screening Value for naphthalene used as a surrogate.

(4) USEPA Region III RBC Screening Value for pyrene used as a surrogate.

(5) USEPA Region III RBC Screening Value for chlordane used as a surrogate.

(6) USEPA Region III RBC Screening Value for endrin used as a surrogate.

NA - Not applicable
J - Estimated value.
N - Tentative identification. Consider present.
NE - Not established

TABLE 6-5

SUMMARY OF DATA AND COPC SELECTION
METALS IN SUBSURFACE SOIL
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Analyte	Range/Frequency		Comparison to Criteria				COPC Selection[2]/ Basis[3]
	Range of Positive Detections (mg/kg)	No. of Positive Detects/ No. of Samples	Twice the Average Base Specific Background[1] Concentration (mg/kg)	No. of Times Exceeded Twice the Average Background Concentration	Region III Residential RBC Value (mg/kg)	Positive Detects Above Residential RBC Value	
Aluminum	141 - 17,200	29/29	7,413.2	2	7,800	2	Yes/B
Barium	2 - 26.3	28/29	14.4	5	550	0	No/A
Cadmium	1.3 - 1.6	2/29	0.72	2	3.9	0	No/A
Calcium	61.8 - 36,300	29/29	387.8	18	NE	NA	No/E
Chromium	2.3 - 28.7	23/29	12.5	1	39	0	No/A
Cobalt	4.9 - 5.3	3/29	1.6	3	470	0	No/A
Copper	2.7 - 9.5	7/29	2.4	7	310	0	No/A
Iron	200 - 9,620	29/29	7,134.6	1	2,300	5	Yes/B
Lead	0.91 - 71.8	29/29	8.3	8	400[4]	0	No/A
Magnesium	16.6 - 1,090	29/29	263.4	8	NE	NA	No/E
Manganese	0.65 - 20J	29/29	8	9	180	0	No/A
Potassium	247 - 992	4/29	344.3	2	NE	NA	No/E
Sodium	44.2 - 234	13/29	54.6	9	NE	NA	No/E
Vanadium	2.5 - 30.1	20/29	13.3	2	55	0	No/A
Zinc	1.4J - 87.7	24/29	6.7	13	2,300	0	No/A

Notes:

[1] Soil background concentrations are based on reference background soil samples collected from MCB, Camp Lejeune investigations.

[2] COPC = Chemical of Potential Concern for human health risk assessment (yes/no).

[3] A = <RBC value and/or Action Level.
B = >RBC value and/or Action Level.
E = Essential nutrient; professional judgement used before the analyte was eliminated as a COPC.

[4] Action Level for residential soils (USEPA, 1994).

NE = Not established
NA = Not applicable
J = Estimated value

TABLE 6-6

SUMMARY OF DATA AND COPC SELECTION
ORGANICS AND METALS IN GROUNDWATER (PHASE I)
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Groundwater Criteria					Frequency/Range		Comparison to Criteria					
				Federal Health Advisories[3] (µg/L)							Positive Detects Above Health Advisories		
Parameter	NCWQS[1] (µg/L)	MCL[2] (µg/L)	Region III Tap Water RBC Value (µg/L)	10 kg Child	70 kg Adult	No. of Positive Detects/ No. of Samples	Concentration Range (µg/L)	Positive Detects Above NCWQS	Positive Detects Above MCL	Positive Detects Above RBC Value	10 kg Child	70 kg Adult	COPC Selection[4] / Basis[5]
Volatiles													
Ethylbenzene	29	700	130	1,000	3,000	2/48	1.3J - 3.1	0	0	0	0	0	No/A
1,2-Dichloroethane	0.38	5	0.12	700	2,600	12/48	0.3 - 0.7J	10	0	12	0	0	Yes/B
Toluene	1,000	1,000	75	2,000	7,000	1/48	3.1J	0	0	0	0	0	No/A
Xylenes (total)	530	10,000	1,200	40,000	100,000	5/47	1.2 - 5.5	0	0	0	0	0	No/A
cis-1,2-Dichloroethene	70	70	6.1	3,000	11,000	11/47	1.3 - 74	2	2	6	0	0	Yes/B
trans-1,2-Dichloroethene	100	100	12	2,000	6,000	5/48	1.7 - 4.5J	0	0	0	0	0	No/A
Chloroform	0.19	100	0.15	100	400	6/48	0.6 - 5.5J	6	0	6	0	0	No/G
Benzene	1	5	0.36	NE	NE	8/48	2.2J - 18J	8	3	8	NA	NA	Yes/B
Vinyl chloride	0.015	2	0.019	10	50	3/48	1.8J - 23J	3	2	3	2	0	Yes/B
Trichloroethene	2.8	5	1.6	NE	NE	21/48	1.4 - 110	13	9	18	NA	NA	Yes/B
Semivolatiles													
Phenol	300	NE	2,200	6,000	20,000	1/53	2J	0	NA	0	0	0	No/A
Bis(2-ethylhexyl)phthalate	3	6	4.8	NE	NE	3/54	1J - 50	1	1	1	NA	NA	No/G
1,2,4-Trichlorobenzene	NE	70	19	100	500	3/54	1J - 5J	NA	0	0	0	0	No/A
Acenaphthene	80	NE	220	NE	NE	2/54	2J - 4J	0	NA	0	NA	NA	No/A
Di-n-butyl phthalate	700	NE	370	NE	NE	11/54	1J - 6J	0	NA	0	NA	NA	No/A
Fluorene	280	NE	150	NE	NE	1/54	1J	0	NA	0	NA	NA	No/A
Naphthalene	21	NE	150	400	1,000	3/54	2J - 6J	0	NA	0	0	0	No/A
Metals													
Aluminum	NE	50/200[6]	3,700	NE	NE	44/55	49.9 - 29,700J	NA	43/18	1	NA	NA	Yes/B
Antimony	NE	6	1.5	10	15	2/55	55.8 - 457	NA	2	2	2	2	No/C
Barium	2,000	2,000	260	NE	NE	55/55	6.3 - 2,050	1	1	1	NA	NA	Yes/B
Beryllium	NE	4	0.016	4,000	20,000	1/55	52.3	NA	1	1	0	0	No/C
Cadmium	5	5	1.8	5	20	1/55	50.7	1	1	1	1	1	No/C
Calcium	NE	NE	NE	NE	NE	55/55	2,700-148,000	NA	NA	NA	NA	NA	No/E

TABLE 6-6 (Continued)

CHEMICALS OF POTENTIAL CONCERN
ORGANICS AND METALS IN GROUNDWATER (PHASE I)
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Groundwater Criteria					Frequency/Range		Comparison to Criteria					COPC Selection[4] / Basis[5]
	NCWQS[1] (µg/L)	MCL[2] (µg/L)	Region III Tap Water RBC Value (µg/L)	Federal Health Advisories[3] (µg/L) 10 kg Child	Federal Health Advisories[3] (µg/L) 70 kg Adult	No. of Positive Detects/ No. of Samples	Concentration Range (µg/L)	Positive Detects Above NCWQS	Positive Detects Above MCL	Positive Detects Above RBC Value	Positive Detects Above Health Advisories 10 kg Child	Positive Detects Above Health Advisories 70 kg Adult	
Chromium	50	100	18	200	800	4/55	10.6 - 210	1	1	2	1	0	Yes/B
Cobalt	NE	NE	220	NE	NE	11/55	26.1 - 530	NA	NA	1	NA	NA	Yes/B
Copper	1,000	1,300	150	NE	NE	3/55	13.8 - 269	0	0	1	NA	NA	Yes/B
Iron	300	300[6]	1,100	NE	NE	54/55	74.4 - 38,800	52	NA	33	NA	NA	Yes/B
Lead	15	15[7]	NE	NE	NE	3/55	3.6 - 14.9	0	0	NA	NA	NA	No/A
Magnesium	NE	NE	NE	NE	NE	54/55	64.3 - 25,900	NA	NA	NA	NA	NA	No/E
Manganese	50	50[6]	84	NE	NE	53/55	2.2 - 534	19	19	9	NA	NA	Yes/B
Nickel	100	100[8]	73	500	1,700	1/55	520	1	1	1	0	0	No/C
Potassium	NE	NE	NE	NE	NE	36/55	1,070 - 15,400	NA	NA	NA	NA	NA	No/E
Silver	18	NE	18	200	200	1/55	54.2	1	NA	1	0	0	No/C
Sodium	NE	NE	NE	NE	NE	55/55	2,450 - 149,000	NA	NA	NA	NA	NA	No/E
Thallium	NE	2	0.29[9]	7	20	1/55	10.8	NA	1	1	1	0	No/C
Vanadium	NE	NE	26	NE	NE	3/55	10.7 - 518	NA	NA	2	NA	NA	Yes/B
Zinc	2,100	5,000[6]	1,100	3,000	10,000	48/55	8.6 - 541	0	0	0	0	0	No/A

Notes:

[1] NCWQS = North Carolina Water Quality Standards for Groundwater (October, 1994).
[2] MCL = Safe Drinking Water Act Maximum Contaminant Level (October, 1996).
[3] Longer Term Health Advisories for a 10 kg Child and 70 kg Adult.
[4] COPC = Chemical of potential concern for human health risk assessment (yes/no).
[5] A = < RBC value and/or Action Level.
B = >RBC value and/or Action Level.
C = Frequency of detection less than 5%.
E = Essential nutrient; professional judgement used before analyte was eliminated as a COPC.
G = Blank contamination.

[6] SMCL = Secondary Maximum Contaminant Level.
[7] Action Level for drinking water.
[8] Value being remanded.
[9] Value for thallium carbonate, sulfate, etc.
NE - Not established.
NA - Not Applicable.
J - Estimated Value.

TABLE 6-7

SUMMARY OF DATA AND COPC SELECTION
ORGANICS IN GROUNDWATER (PHASE II)
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Groundwater Criteria					Frequency/Range		Comparison to Criteria					COPC Selection(4) / Basis(5)
	NCWQS(1) (µg/L)	MCL(2) (µg/L)	Region III Tap Water RBC Value (µg/L)	Federal Health Advisories(3) (µg/L)		No. of Positive Detects/ No. of Samples	Concentration Range (µg/L)	No. of Detects Above NCWQS	No. of Detects Above MCL	No. of Detects Above RBC Value	No. of Detects Above Health Advisories		
				10 kg Child	70 kg Adult						10 kg Child	70 kg Adult	
Volatiles													
Chloroethane	NE	NE	860	NE	NE	1/44	3J	NA	NA	0	NA	NA	No/A
Toluene	1,000	1,000	75	2,000	7,000	1/44	2J	0	0	0	0	0	No/A
Acetone	700	NE	370	NE	NE	2/44	2J	0	NA	0	0	0	No/A
1,2-Dichloroethene (total)	NE	70	5.5	3,000	11,000	8/44	2J - 120	NA	1	5	0	0	Yes/B
Chloroform	0.19	100	0.15	100	400	5/44	1J - 2J	5	0	5	0	0	No/G
Benzene	1	5	0.36	NE	NE	3/44	3J - 27	3	1	3	NA	NA	Yes/B
Vinyl chloride	0.015	2	0.019	10	50	3/44	4J - 43J	3	3	3	2	0	Yes/B
Trichloroethene	2.8	5	1.6	NE	NE	6/44	1J - 320	5	4	5	NA	NA	Yes/B

Notes:

(1) NCWQS = North Carolina Water Quality Standards for Groundwater (October, 1994)
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level (October, 1996)
(3) Longer Term Health Advisories for a 10 kg Child and 70 kg Adult
(4) COPC = Chemical of potential concern (yes/no)
(5) A = <RBC value and/or Action Level.
B = >RBC value and/or Action Level.
G = Blank contamination

NE = No Criteria Established
NA = Not Applicable
J = Estimated Value

TABLE 6-8

SUMMARY OF DATA AND COPC SELECTION
ORGANICS AND METALS IN SURFACE WATER
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Surface Water Criteria			Average Background	Contaminant Frequency/Range		Comparison to Criteria			COPC Selection(3)/ Basis(4)
	NCWQS(1) (µg/L)	Federal Health AWQCs(2)					Positive Detects Above NCWQS	Positive Detects Above AWQC		
		Water & Organisms (µg/L)	Organisms Only (µg/L)		No. of Positive Detects/ No. of Samples	Contaminant Range (µg/L)		Water & Organisms	Organisms Only	
Volatiles										
Acetone	500	NE	NE	ND	1/11	50	0	NA	NA	No/G
Toluene	200,000	6,800	200,000	ND	3/11	2J - 5J	0	0	0	No/H
Chloroform	470	5.7	470	ND	1/11	3J	0	0	0	No/H
Inorganics										
Aluminum	87	NE	NE	ND	4/11	74.6 - 500	1	NA	NA	Yes/I
Antimony	4,300	14	4,300	ND	10/11	116 - 216	0	10	0	Yes/I
Barium	1,400	1,000	NE	24.25	10/11	6.7 - 10.5	0	0	NA	No/H
Calcium	NE	NE	NE	134,025	11/11	9,410 - 283,000	NA	NA	NA	No/E
Iron	300	300	NE	317.75	11/11	245 - 4,540	9	9	NA	Yes/I
Magnesium	NE	NE	NE	511,200	11/11	1,550 - 1,390,000	NA	NA	NA	No/E
Manganese	100	50	100	ND	11/11	5.8 - 37.7	0	0	0	No/H
Potassium	NE	NE	NE	207,250	10/11	293,000-388,000	NA	NA	NA	No/E
Silver	0.1	50	NE	19.13	1/11	6.4	1	0	NA	Yes/I
Sodium	NE	NE	NE	3,073,750	11/11	10,100-11,100,000	NA	NA	NA	No/E
Zinc	86	NE	NE	ND	10/11	12 - 103	1	NA	NA	Yes/I

Notes:

(1) NCWQS = North Carolina Water Quality Standards for Surface Water (October, 1996).
(2) AWQC = Ambient Water Quality Standard (May, 1991).
(3) COPC = Chemical of Potential Concern for human health risk assessment (yes/no).
(4) E = Essential nutrient; professional judgement used before the analyte was eliminated as a COPC.
G = Blank contamination.
H = <NCWQS and/or average background.
I = >NCWQS and/or average background.

NE = Not Established
ND = Not Detected
NA = Not Applicable
J = Estimated value

TABLE 6-9

SUMMARY OF DATA AND COPC SELECTION
ORGANICS AND METALS IN SEDIMENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Region III Residential Soil RBC Screening Value	Average Background	Range/Frequency		Positive Detects Above Residential Soil RBC Value	COPC Selection[(1)]/ Basis[(2)]
			Range of Positive Detections	No. of Positive Detects/ No. of Samples		
Volatiles (µg/kg)						
Methylene chloride	85,000	ND	7J	1/22	0	No/A
Acetone	780,000	ND	5J - 280	7/22	0	No/A
Carbon disulfide	780,000	ND	2J - 75	13/22	0	No/A
2-Butanone	4,700,000	ND	4J - 13J	2/22	0	No/A
Toluene	1,600,000	ND	1J - 12J	2/22	0	No/A
Xylenes (total)	16,000,000	ND	9J	1/22	0	No/A
Semivolatiles (µg/kg)						
Phenol	4,700,000	ND	150J	1/22	0	No/A
Phenanthrene	230,000	ND	940J	1/22	0	No/A
Di-n-butyl phthalate	780,000	ND	240J - 680J	11/22	0	No/A
Fluoranthene	310,000	ND	1,000J	1/22	0	No/A
Pyrene	230,000	ND	880J	1/22	0	No/A
Bis(2-ethylhexyl)phthalate	46,000	ND	51J - 1,900J	8/22	0	No/A
Pesticides/PCBs (µg/kg)						
4,4'-DDE	1,900	ND	5.6J - 17J	5/22	0	No/A
Endrin	2,300	ND	4.7 - 7.5J	2/22	0	No/A
4,4'-DDD	2,700	3.38	4.2J - 28	6/22	0	No/A
Aroclor-1260	319	ND	120J	1/22	0	No/A
Inorganics (mg/kg)						
Aluminum	7,800	9,864.29	431 - 28,100	21/22	8	Yes/B
Arsenic	0.43	ND	3.3 - 14.1	9/22	9	Yes/B
Barium	550	12.44	1.3 - 27.8	21/22	0	No/A
Cadmium	3.9	ND	2.7J - 6.1J	2/22	1	Yes/B

TABLE 6-9 (Continued)

SUMMARY OF DATA AND COPC SELECTION
ORGANICS AND METALS IN SEDIMENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Region III Residential Soil RBC Screening Value	Average Background	Range/Frequency		Positive Detects Above Residential Soil RBC Value	COPC Selection(1)/ Basis(2)
			Range of Positive Detections	No. of Positive Detects/ No. of Samples		
Calcium	NE	2,932.86	483 - 27,800	21/22	NA	No/E
Chromium	39	30.87	3.3 - 55.9	17/22	2	Yes/B
Cobalt	470	3.2	7.68 - 11.5	3/22	0	No/A
Copper	310	ND	3.2 - 20.5	14/22	0	No/A
Iron	2,300	12,868.57	3.7 - 27,400	22/22	14	Yes/B
Lead	400(3)	5.75	3.3 - 47.7J	22/22	0	No/A
Magnesium	NE	5,081.43	140 - 9,430	21/22	NA	No/E
Manganese	180	45.66	3.4 - 137	21/22	0	No/A
Nickel	160	10.21	6 - 19.7	5/22	0	No/A
Potassium	NE	1,570	305 - 4,390	15/22	NA	No/E
Sodium	NE	ND	74.8 - 28,500	21/22	NA	No/E
Vanadium	55	26.59	2.6 - 50.8	16/22	0	No/A
Zinc	2,300	30.66	8 - 100	21/22	0	No/A

Notes:

(1) Chemical of potential concern for human health risk assessment (yes/no).

(2) A = <RBC value and/or Action Level.
B = >RBC value and/or Action Level.
C = Frequency of detection less than 5%.
D = Although frequency of detection is less than 5%, constituent re-included as a COPC based on toxicity.
E = Essential nutrient; professional judgement was used before eliminating analyte as a COPC.

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

NE = Not Established
ND = Not Detected
NA = Not Applicable
J = Estimated value

TABLE 6-10

DATA AND COPC SELECTION SUMMARY
ORGANICS AND METALS IN FISH TISSUE (FILLET)
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Frequency/Range		Region III Criteria	Comprison to Criteria	
Contaminant	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Fish RBC Value	Positive Detects Above Fish RBC Value	COPC Selection(1)/ Basis(2)
Volatiles (µg/kg)					
Acetone	6,400 - 140,000	8/8	14,000	7	No/K
Methylene Chloride	1,100J	1/8	420	1	Yes/B
Toluene	520J - 580J	2/8	27,000	0	No/A
Semivolatiles (µg/kg)					
Di-n-butylphthalate	4,400	1/8	14,000	0	No/A
Pesticide/PCBs (µg/kg)					
Endrin	9.8J	1/8	41	0	No/A
Inorganics (mg/kg)					
Arsenic	0.17J - 3.3J	8/8	2.1	5	No/K
Barium	0.04	1/8	9.5	0	No/A
Calcium	183J - 4,540J	8/8	ND	NA	No/E
Copper	0.43 - 1.1	6/8	5.4	0	No/A
Iron	4.4J - 9J	5/8	41	0	No/A
Lead	0.07	1/8	ND	NA	Yes/J
Magnesium	243J - 424J	8/8	ND	NA	No/E
Manganese	0.08J - 0.82J	8/8	3.1	0	No/A
Mercury	0.063J - 0.18J	4/8	0.041	4	Yes/B
Potassium	3,060J - 4,790J	8/8	ND	NA	No/E
Selenium	0.23 - 0.59	7/8	0.68	0	No/A

TABLE 6-10 (Continued)

DATA AND COPC SELECTION SUMMARY
ORGANICS AND METALS IN FISH TISSUE (FILLET)
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Contaminant Frequency/Range		Region III Criteria	Comprison to Criteria	COPC Selection[1]/ Basis[2]
	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Fish RBC Value	Positive Detects Above Fish RBC Value	
Sodium	544 - 1,030	8/8	ND	NA	No/E
Zinc	4.2J - 12.4J	8/8	41	0	No/A

Notes:

(1) COPC = Chemical of potential concern for human health risk assessment (yes/no).
(2) A = <Fish tissue RBC value.
B = >Fish tissue RBC value.
E = Essential nutrient; professional judgement was used before elimination as a COPC.
J = No RBC value availble to quantify risk.
K = Not selected since constituent is naturally occurring in organism.

ND = Not determined
NA = Not applicable
J = Estimated value

TABLE 6-11

DATA AND COPC SELECTION SUMMARY
ORGANICS AND METALS IN CRAB TISSUE (EDIBLE PORTION)
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Frequency/Range		Region III Criteria	Comprison to Criteria	
Contaminant	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Fish RBC Value	Positive Detects Above Fish RBC Value	COPC Selection(1)/ Basis(2)
Volatiles (µg/kg)					
Acetone	2,500J - 290,000	5/6	14,000	4	No/K
Methylene Chloride	1,300J - 17,000J	2/6	420	2	Yes/B
Toluene	580J	1/6	27,000	0	No/A
Semivolatiles (µg/kg)					
Di-n-butylphthalate	2,000 - 2,200	2/6	14,000	0	No/A
Inorganics (mg/kg)					
Arsenic	2.9J - 4.6J	6/6	2.1	6	No/K
Barium	0.054J - 0.094J	2/6	9.5	0	No/A
Calcium	549J - 1,820J	6/6	ND	NA	No/E
Copper	4.4 - 6.6	6/6	5.4	2	Yes/B
Iron	4.5J - 7.1J	6/6	41	0	No/A
Lead	0.08	1/6	ND	NA	Yes/J
Magnesium	378J - 456J	6/6	ND	NA	No/E
Manganese	0.15J - 0.46J	6/6	3.1	0	No/A
Mercury	0.042J - 0.05J	3/6	0.041	3	Yes/B
Potassium	2,130J - 3,090J	6/6	ND	NA	No/E
Selenium	0.28 - 0.44	6/6	0.68	0	No/A
Silver	0.12 - 0.25	5/6	0.68	0	No/A

TABLE 6-11 (Continued)

DATA AND COPC SELECTION SUMMARY
ORGANICS AND METALS IN CRAB TISSUE (EDIBLE PORTION)
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Frequency/Range		Region III Criteria	Comprison to Criteria	
Contaminant	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Fish RBC Value	Positive Detects Above Fish RBC Value	COPC Selection[1]/ Basis[2]
Sodium	3,400 - 4,860	6/6	ND	NA	No/E
Zinc	23.6J - 39.1J	6/6	41	0	No/A

Notes:

[1] COPC = Chemical of potential concern for human health risk assessment (yes/no).
[2] A = <Fish tissue RBC value.
B = >Fish tissue RBC value.
E = Essential nutrient; professional judgement was used before elimination as a COPC.
J = No fish tissue RBC value available to quantify risk.
K = Not selected since constituent is naturally occurring in organism.

ND = Not determined
NA = Not applicable
J - Estimated value

TABLE 6-12

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water		Sediment		Fish Tissue		Crab Tissue	
Volatiles																
Methylene Chloride											●		●	X	●	X
Acetone	●		●				●		●		●		●		●	
Carbon disulfide			●								●					
Chloroform					●		●		●							
1,2-Dichloroethane	●				●	X										
cis-1,2-Dichloroethene					●	X										
trans-1,2-Dichloroethene					●											
1,2-Dichloroethene (total)							●	X								
2-Butanone	●		●								●					
Vinyl Chloride					●	X	●	X								
Trichloroethene	●		●		●	X	●	X								
Tetrachloroethene			●													
Toluene	●				●		●		●		●		●		●	
Benzene					●	X	●	X								
Ethylbenzene	●		●		●											
1,1,1-Trichloroethane	●		●													
1,2-Dichloropropane	●															
Chloroethane							●									
Chlorobenzene	●															
Styrene	●															
4-Methyl-2-pentanone			●													
m-Xylene			●													
o-Xylene			●													
p-Xylene			●													
Xylenes (total)	●		●		●						●					

TABLE 6-12 (Continued)

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN
SITE 73-AMPHIBIOUS VEHICLE DUMP
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water		Sediment		Fish Tissue		Crab Tissue	
Semivolatiles																
Phenol					●						●					
1,2,4-Trichlorobenzene					●											
2-Methylnaphthalene			●													
Naphthalene					●											
Acenaphthene	●		●		●											
2,4-Dinitrophenol	●		●													
4-Chloro-3-methylphenol	●															
Fluorene			●		●											
Phenanthrene	●		●								●					
Anthracene	●		●													
Butly benzyl phthalate	●															
Di-n-butylphthalate	●		●		●						●		●		●	
Fluoranthene	●		●								●					
Pyrene	●		●								●					
Benzo(a)anthracene	●		●	X												
Chrysene	●		●													
bis(2-Ethylhexyl)phthalate	●		●		●						●					
Benzo(b)fluoranthene	●		●													
Benzo(a)pyrene	●	X	●	X												
Benzo(g,h,i)perylene	●															
Pesticides/PCBs																
Endosulfan I			●													
Dieldrin			●													
4,4'-DDE	●		●								●					
Endrin											●		●			

TABLE 6-12 (Continued)

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN
SITE 73-AMPHIBIOUS VEHICLE DUMP
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water		Sediment		Fish Tissue		Crab Tissue	
4,4'-DDD	●		●	X							●					
4,4'-DDT	●		●													
Endrin Aldehyde			●													
Alpha Chlordane	●		●													
Gamma Chlordane	●															
Endrin Ketone	●															
Aroclor-1016	●															
Aroclor-1254			●													
Aroclor-1260	●										●					
Metals																
Aluminum	●	X	●	X	●	X			●	X	●	X				
Antimony					●				●	X						
Arsenic											●	X	●		●	
Barium	●		●		●	X			●		●		●		●	
Beryllium					●											
Cadmium	●		●		●						●	X				
Calcium	●		●		●				●		●		●		●	
Chromium	●		●		●	X					●	X				
Cobalt	●		●		●	X					●					
Copper	●		●		●	X					●		●		●	X
Iron	●	X	●	X	●	X			●	X	●	X	●		●	
Lead	●		●		●						●		●	X	●	X
Magnesium	●		●		●				●		●		●		●	
Manganese	●		●		●	X			●		●		●		●	
Mercury													●	X	●	X
Nickel					●						●					

TABLE 6-12 (Continued)

SUMMARY OF COPCs IN ENVIRONMENTAL MEDIA OF CONCERN
SITE 73-AMPHIBIOUS VEHICLE DUMP
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water		Sediment		Fish Tissue		Crab Tissue	
Potassium	●		●		●				●		●		●		●	
Selenium													●		●	
Silver					●				●	X					●	
Sodium	●		●		●				●		●		●		●	
Thallium					●											
Vanadium	●		●		●	X					●					
Zinc	●		●		●				●	X	●		●		●	

Notes:

● = Detected in media; compared to relevant criteria and standards.
X = Selected as a COPC for human health risk assessment.

TABLE 6-13

MATRIX OF POTENTIAL HUMAN EXPOSURE
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB CAMP LEJEUNE, NORTH CAROLINA

Exposure Medium/ Exposure Route	Current Military Personnel	Current Trespassers	Current Fisherman	Future Residential Population	Future Construction Worker
Surface Soil Incidental Ingestion	M	A,T	NA	A,C	W
Dermal Contact	M	A,T	NA	A,C	W
Subsurface Soil Incidental Ingestion	NA	NA	NA	NA	W
Dermal Contact	NA	NA	NA	NA	W
Groundwater Ingestion	NA	NA	NA	A,C	NA
Dermal Contact	NA	NA	NA	A,C	NA
Surface Water Ingestion	M	A,T	A	A,C	NA
Dermal Contact	M	A,T	A	A,C	NA
Sediment Incidental Ingestion	M	A,T	A	A,C	NA
Dermal Contact	M	A,T	A	A,C	NA
Fish Tissue Incidental Ingestion	NA	NA	A,C	NA	NA
Crab Tissue Incidental Ingestion	NA	NA	A,C	NA	NA
Air Inhalation of Vapor Phase Chemicals Indoor	NA	NA	NA	A	NA
Inhalation of Particulates Outdoor	M	A,T	NA	A,C	W

Notes:

A = Lifetime exposure - adults
C = Exposure - children
T = Exposure - adolescents
M = Military exposure during tour of duty
W = Construction duration exposure
NA = Not applicable to receptor group

TABLE 6-14

EXPOSURE INPUT PARAMETERS
CURRENT MILITARY PERSONNEL
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Media	Units	Military Personnel	Comments/ References
Exposure Duration, ED	All media	year	4	Professional Judgement
Exposure Frequency, EF	Soil	days/year	260	USEPA, 1991a Professional Judgment
	Surface Water/Sediment	days/year	100	
Exposure Time, ET	Surface Water	hr/day	2.6	USEPA, 1989a
Ingestion Rate, IR	Soil/Sediment	mg/day	100	USEPA, 1989a
	Surface Water	L/hr	0.05	USEPA, 1989a
Surface Area, SA	All Media	cm^2	4,300	USEPA, 1992a
Respiration Rate, RR	Soil	m^3/day	20	USEPA, 1991a
Fraction Ingested, FI	All Media	unitless	1	Professional Judgment
Absorption Factor, ABS	Soil/Sediment	unitless	Chemical Specific(1)	USEPA, 1995
Adherence Factor, AF	Soil/Sediment	mg/cm^2	1	USEPA, 1992a
Body Weight, BW	All Media	kg	70	USEPA, 1989a
Permeability Constant, PC	Surface Water	cm/hr	Chemical Specific(2)	USEPA, 1992a
Averaging Time, AT noncarcinogens, AT_{nc}	All Media	day	1,460	USEPA, 1989a
carcinogens, AT_c	All Media	day	25,550	USEPA, 1989a

Notes:

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

USEPA Region IV Defaults (USEPA, 1995): organics - 0.01
inorganics - 0.001

(2) Permeability constant calcultations found in Appendix T.

TABLE 6-15

EXPOSURE INPUT PARAMETERS
CURRENT ADULT AND ADOLESCENT TRESPASSERS,
ADULT FISHERMAN, CHILD RECEPTOR
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Media	Units	Current Receptor			Comments/ References
			Adolescent (7-16 years)	Adult	Child	
Exposure Duration, ED	All media	year	9	30	6	USEPA, 1992b
Exposure Frequency, EF	Soil, Surface Water, Sediment	days/year	48	48	NA	Professional Judgment USEPA, 1991a
	Fish/Crab Tissue	days/year	NA	350	350	
Exposure Time, ET	Surface Water	hr/day	2.6	2.6	NA	USEPA, 1989a
Ingestion Rate, IR	Soil, Sediment	mg/day	100	100	NA	USEPA, 1989a
	Surface Water	L/hr	0.05	0.05	NA	USEPA, 1989a
	Fish/Crab Tissue	kg/day	NA	0.054	0.054	USEPA, 1995
Surface Area, SA	Soil, Surface Water, Sediment	cm^2	3,480	5,800	NA	USEPA, 1992a
Respiration Rate, RR	Soil	m^3/day	20	20	NA	USEPA, 1991a
Fraction Ingested, FI	Soil, Surface Water, Sediment	unitless	1	1	NA	Professional Judgment
	Fish/Crab Tissue	unitless	NA	0.1	0.1	
Absorption Factor, ABS	Soil/Sediment	unitless	Chemical Specific(1)	Chemical Specific(1)	NA	USEPA, 1995
Adherence Factor, AF	Soil/Sediment	mg/cm^2	1	1	NA	USEPA, 1992a
Body Weight, BW	All Media	kg	37	70	15	USEPA, 1989a
Permeability Constant, PC	Surface Water	cm/hr	Chemical Specific(2)	Chemical Specific(2)	NA	USEPA, 1992a
Averaging Time, AT noncarcinogens, AT_{nc}	All Media	day	3,285	10,950	2,190	USEPA, 1989a
carcinogens, AT_c	All Media	day	25,550	25,550	25,550	USEPA, 1989a

Notes:

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

USEPA Region IV Defaults (USEPA, 1995): organics - 0.01
inorganics - 0.001

(2) Permeability constant calculations found in Appendix T.

NA = Not applicable

TABLE 6-16

REASONABLE MAXIMUM (RME) AND CENTRAL TENDENCY (CT)
EXPOSURE INPUT PARAMETERS
FUTURE RESIDENTIAL CHILDREN AND ADULTS
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter(1)	Media	Units	Future Receptor		Comments/ References
			Child (1 to 6 years)	Adult	
Exposure Duration, ED	All media	years	6 (NA)	30 (9)	USEPA, 1991a (USEPA, 1993)
Exposure Frequency, EF	Soil/Groundwater	days/year	350 (234)	350 (234)	USEPA, 1991a (USEPA, 1993)
	Sediment/ Surface Water	days/year	48 (NA)	48 (NA)	Professional Judgment
Exposure Time, ET	Surface Water	hrs/day	2.6 (NA)	2.6 (NA)	USEPA, 1989a
	Groundwater	hrs/day	0.25 (NA)	0.25 (NA)	USEPA, 1989a
Ingestion Rate, IR	Groundwater	L/day	1 (NA)	2 (1.4)	USEPA, 1991a
	Soil/Sediment	mg/day	200 (100)	100 (50)	USEPA, 1989a (USEPA, 1993)
	Surface Water	L/day	0.05 (NA)	0.05 (NA)	USEPA, 1989a
Surface Area, SA	Groundwater	cm^2	10,000 (6,978)	23,000 (23,000)	USEPA, 1992a (USEPA, 1992a)
	Soil/Sediment/ Surface Water	cm^2	2,400 (1,745)(2)	5,800 (5,000)(2)	USEPA, 1992a (USEPA, 1992a)
Respiration Rate, RR	Soil	m^3/day	15 (NA)	20 (NA)	USEPA, 1995/1991a
	Groundwater	m^3/hr	NA (NA)	0.6 (NA)	USEPA 1989a
Fraction Ingested, FI	Soil/Sediment	unitless	1.0 (NA)	1.0 (NA)	Professional Judgment
Absorbance Factor, ABS	Soil/Sediment	unitless	Chemical Specific(3)	Chemical Specific(3)	USEPA, 1995
Adherence Factor, AF	Soil/Sediment	mg/cm^2	1 (0.2)	1 (0.2)	USEPA, 1992b (USEPA, 1992a)
Body Weight, BW	All Media	kg	15 (NA)	70 (NA)	USEPA, 1989a
Permeability Constant, PC	Groundwater/ Surface Water	cm/hr	Chemical-Specific(4)	Chemical-Specific(4)	USEPA, 1992a

TABLE 6-16 (Continued)
REASONABLE MAXIMUM (RME) AND CENTRAL TENDENCY (CT)
EXPOSURE INPUT PARAMETERS
FUTURE RESIDENTIAL CHILDREN AND ADULTS
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter[1]	Media	Units	Future Receptor		Comments/ References
			Child (1 to 6 years)	Adult	
Averaging Time, AT noncarcinogens, AT_{nc}	All Media	day	2,190 (NA)	10,950 (3,285)	USEPA, 1989a (USEPA, 1993)
carcinogens, AT_c	All Media	day	25,550	25,550	USEPA, 1989a

Notes:

[1] CT exposure input parameters are presented in parentheses.

[2] Represents 25% of the total body surface area at the 50th percentile value.

[3] The following absorbance factors will be applied to estimate dermal intake of COPCs:

USEPA Region IV Defaults (USEPA, 1995): organics - 0.01
inorganics - 0.001

[4] Permeability constant calculations found in Appendix T.

NA = Not applicable

TABLE 6-17

EXPOSURE INPUT PARAMETERS
FUTURE ADULT CONSTRUCTION WORKERS
SITE 73-AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Future Receptor	Comments/ References
		Adult Construction Worker	
Exposure Duration, ED	years	1	USEPA, 1991a
Exposure Frequency, EF	days/year	90	USEPA, 1991a
Ingestion Rate, IR	mg/day	480	USEPA, 1991a
Exposed Surface Area, SA	cm^2/day	4,300	USEPA, 1992a
Respiration Rate, RR	m^3/day	20	USEPA, 1991a
Fraction Ingested, FI	unitless	1.0	Professional Judgment
Dermal Absorption Factor, ABS	unitless	Chemical-specific(1)	USEPA, 1995a
Adherence Factor, AF	mg/cm^2	1	USEPA, 1992a
Body Weight, BW	kg	70	USEPA, 1989a
Averaging Times, AT noncarcinogens, AT_{nc}	days	365	USEPA, 1989a
carcinogens, AT_c	days	25,550	USEPA, 1989a

Notes:

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

USEPA Region IV Defaults (USEPA, 1995): organics - 0.01
inorganics - 0.001

(2) Permeability constant calculations found in Appendix T.

TABLE 6-18

TOXICITY FACTORS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	RfD	Dermally Adjusted* RfD	RfDi	CSF	Dermally Adjusted * CSF	CSFi	Oral Absorption Factors[1]	WOE	Reference
Volatiles: 1,2-Dichloroethene (total)	9.0E-03	7.2E-03	NE	NE	NE	NE	80%	C	HEAST
cis-1,2-Dichloroethene	1.0E-02	8.0E-03	NE	NE	NE	NE	80%	D	HEAST
1,2-Dichloroethane	NE	NE	2.86E-03	9.1E-02	1.1E-01	9.1E-02	80%	B2	IRIS
Benzene	NE	NE	1.71E-03	2.9E-02	3.6E-02	2.9E-02	80%	A	IRIS, EPA-NCEA-provisional
Vinyl Chloride	NE	NE	NE	1.9E+00	2.4E+00	3.0E-01	80%	A	HEAST, EPA-NCEA
Trichloroethene	6.0E-03	4.8E-03	NE	1.1E-02	1.4E-02	6.0E-03	80%	B2	EPA-NCEA[2]
Methylene Chloride	6.0E-02	4.8E-02	8.75E-01	7.5E-03	9.4E-03	1.64E-03	80%	B2	IRIS, HEAST
Semivolatiles: Benzo(a)anthracene	NE	NE	NE	7.3E-01	1.46E+00	6.1E-01	50%	B2	EPA-NCEA
Benzo(a)pyrene	NE	NE	NE	7.3E+00	1.46E+01	6.1E+00[2]	50%	B2	IRIS
Pesticides: 4,4'-DDD	NE	NE	NE	2.4E-01	4.8E-01	NE	50%	B2	IRIS
Inorganics: Aluminum	1.0E+00	2.0E-01	NE	NE	NE	NE	20%	ND	EPA-NCEA
Antimony	4.0E-04	8.0E-05	NE	NE	NE	NE	20%	D	IRIS
Arsenic	3.0E-04	6.0E-05	NE	1.5	7.5	15.1	20%	A	IRIS
Barium	7.0E-02	1.4E-02	1.43E-04	NE	NE	NE	20%	D	IRIS, HEAST-alternate
Cadmium (soil)	1.0E-03	2.0E-04	NE	NE	NE	6.3E+00	20%	D	IRIS
Chromium (VI)	5.0E-03	1.0E-03	NE	NE	NE	4.2E+01	20%	D	IRIS
Cobalt	6.0E-02	1.2E-02	NE	NE	NE	NE	20%	D	EPA-NCEA
Copper	4.0E-02	8.0E-03	NE	NE	NE	NE	20%	D	EPA-NCEA
Iron	3.0E-01	6.0E-2	NE	NE	NE	NE	20%	ND	EPA-NCEA
Lead	NE	NE	NE	NE	NE	NE	20%	D	IRIS
Manganese	2.3E-02	4.6E-03	1.43E-05	NE	NE	NE	20%	D	IRIS

TABLE 6-18 (Continued)

TOXICITY FACTORS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	RfD	Dermally Adjusted* RfD	RfDi	CSF	Dermally Adjusted * CSF	CSFi	Oral Absorption Factors(1)	WOE	Reference
Mercury	3.0E-04	6.0E-05	8.75E-05	NE	NE	NE	20%	D	HEAST
Silver	5.0E-03	1.0E-03	NE	NE	NE	NE	20%	D	IRIS
Vanadium	7.0E-03	1.4E-03	NE	NE	NE	NE	20%	D	HEAST
Zinc	3.0E-01	6.0E-02	NE	NE	NE	NE	20%	D	IRIS

Notes:		
	RfD	Oral Reference Dose (mg/kg - day)
	RfDi	Inhalation Reference Dose (mg/kg - day)
	CSF	Oral Cancer Slope Factor $(\text{mg/kg-day})^{-1}$
	CSFi	Inhalation Cancer Slope Factor $(\text{mg/kg-day})^{-1}$
	WOE	Weight of Evidence
	IRIS	Integrated Risk Information System
	HEAST	Health Effects Assessment Summary Tables
	EPA-NCEA	Environmental Protection Agency - National Center for Environmental Assessment
	ND	Not Determined
	A	Human Carcinogen
	B1	Probable Human Carcinogen - Limited Evidence
	B2	Probable Human Carcinogen - Sufficient Evidence
	C	Possible Human Carcinogen
	D	Not Classifiable as to Human Carcinogenicity

* Only oral toxicity values were dermally adjusted; inhalation toxicity values were not adjusted.
Dermally-adjusted RfD = oral RfD*oral absorption factor
Dermally-adjusted CSF = oral CSF/oral absorption factor

(1) Region IV recommended values (i.e., 80% for VOCs, 50% for SVOCs/Pesticides, and 20% for Inorganics).
(2) CSF withdrawn.

TABLE 6-19

SUMMARY OF RISKS
CURRENT MILITARY PERSONNEL
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Surface Soil		
Ingestion	0.01	6.8E-08
Dermal Contact	<0.01	5.8E-08
Inhalation	NA	8.6E-12
total	0.01	1.3E-07
Surface Water		
Ingestion	0.3	NA
Dermal Contact	0.1	NA
total	0.4	NA
Sediment		
Ingestion	0.06	2.2E-07
Dermal Contact	0.01	4.8E-08
total	0.07	2.7E-07
Total Risk	0.5	4.0E-07

Notes:

NA - Not applicable. No carcinogenic and/or noncarcinogenic COPCs selected.

TABLE 6-20

SUMMARY OF RISKS
CURRENT ADOLESCENT TRESPASSER
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Surface Soil		
Ingestion	<0.01	5.3E-08
Dermal Contact	<0.01	3.7E-08
Inhalation	NA	6.8E-12
total	<0.01	9.3E-08
Surface Water		
Ingestion	0.25	NA
Dermal Contact	0.09	NA
total	0.34	NA
Sediment		
Ingestion	0.06	4.5E-07
Dermal Contact	0.01	7.9E-08
total	0.07	5.3E-07
Current Risk	0.4	6.2E-07

Notes:

NA = Not applicable. No carcinogenic and/or noncarcinogenic COPCs selected.

TABLE 6-21

SUMMARY OF RISKS
CURRENT ADULT TRESPASSER
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Surface Soil		
Ingestion	<0.01	9.4E-08
Dermal Contact	<0.01	1.1E-07
Inhalation	NA	1.2E-11
total	<0.01	2.0E-07
Surface Water		
Ingestion	0.13	NA
Dermal Contact	0.08	NA
total	0.21	NA
Sediment		
Ingestion	0.03	8.0E-07
Dermal Contact	0.01	2.3E-07
total	0.04	1.0E-06
Current Risk	0.3	1.3E-06

Notes:

NA = Not applicable. No carcinogenic and/or noncarcinogenic COPCs selected.

TABLE 6-22

SUMMARY OF RISKS
CURRENT ADULT FISHERMAN
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Surface Water		
Ingestion	0.13	NA
Dermal Contact	0.08	NA
total	0.21	NA
Sediment		
Ingestion	0.03	8.0E-07
Dermal Contact	0.01	2.3E-07
total	0.04	1.0E-06
Fillet Fish Tissue		
Ingestion	0.05	2.6E-07
Crab Tissue		
Ingestion	0.05	4.0E-06
Current Risk	0.35	5.5E-06

Notes:

NA = Not applicable. No carcinogenic COPCs selected.

TABLE 6-23

SUMMARY OF RISKS
CHILD RECEPTOR - BIOTA INGESTION
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Fillet Fish Tissue Ingestion	0.2	2.4E-07
Crab Tissue Ingestion	0.2	3.8E-06
Total Risk	0.4	4.0E-06

TABLE 6-24

SUMMARY OF RISKS
FUTURE CHILD RESIDENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Noncarcinogenic Risk		Carcinogenic Risk	
Exposure Pathway	RME	CT	RME	CT
Surface Soil				
Ingestion	0.2	0.05	1.3E-06	4.3E-07
Dermal Contact	0.01	<0.01	2.9E-07	3.0E-08
Inhalation	NA	NA	6.1E-11	4.1E-11
total	0.21	0.05	1.6E-06	4.6E-07
Phase I Groundwater (Maximum Exposure)				
Ingestion	24	1.3	2.5E-04	1.1E-05
Dermal Contact	0.3	0.01	6.0E-06	1.8E-07
total	24	1.3	2.6E-04	1.1E-05
Phase I Groundwater (Plausible Exposure)				
Ingestion	2.0	1.3	1.6E-05	1.1E-05
Dermal Contact	0.03	0.01	4.0E-07	1.8E-07
total	2.0	1.3	1.6E-05	1.1E-05
Phase II Groundwater (Maximum Exposure)				
Ingestion	26.2	1.4	4.7E-04	4.6E-05
Dermal Contact	0.47	0.01	1.1E-05	7.6E-07
total	27	1.4	4.8E-04	4.7E-05
Phase II Groundwater (Plausible Exposure)				
Ingestion	2.1	1.4	6.9E-05	4.6E-05
Dermal Contact	0.03	0.01	1.6E-06	7.6E-07
total	2.1	1.4	7.1E-05	4.7E-05
Surface Water				
Ingestion	0.62	0.44	NA	NA
Dermal Contact	0.14	0.08	NA	NA
total	0.8	0.5	NA	NA
Sediment				
Ingestion	0.27	0.06	1.5E-06	7.5E-07
Dermal Contact	0.02	<0.01	8.6E-08	1.3E-08
total	0.3	0.06	1.6E-06	7.6E-07
Future Risk - Maximum Phase I Groundwater	25	1.9	2.6E-04	1.2E-05
Future Risk - Plausible Phase I Groundwater	3.3	1.9	1.9E-05	1.2E-05
Future Risk - Maximum Phase II Groundwater	28	2.0	4.8E-04	4.8E-05
Future Risk - Plausible Phase II Groundwater	3.4	2.0	7.4E-05	4.8E-05

Notes:

NA = Not Applicable. No carcinogenic and/or noncarcinogenic COPCs selected.

TABLE 6-25

SUMMARY OF RISKS
FUTURE ADULT RESIDENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk		Carcinogenic Risk	
	RME	CT	RME	CT
Surface Soil				
Ingestion	0.02	0.01	6.9E-07	6.9E-08
Dermal Contact	<0.01	<0.01	8.0E-07	2.8E-08
Inhalation	NA	NA	8.7E-11	1.7E-11
total	0.02	0.01	1.5E-06	1.0E-07
Phase I Groundwater (Maximum Exposure)				
Ingestion	10.1	0.4	5.3E-04	4.9E-06
Dermal Contact	0.2	0.01	1.5E-05	2.0E-07
Inhalation	0.03	<0.01	1.1E-05	1.5E-07
total	10	0.4	5.5E-04	5.3E-06
Phase I Groundwater (Plausible Exposure)				
Ingestion	0.86	0.4	3.5E-05	4.9E-06
Dermal Contact	0.01	0.01	9.7E-07	2.0E-07
Inhalation	<0.01	<0.01	7.5E-07	1.5E-07
total	0.87	0.4	3.7E-05	5.3E-06
Phase II Groundwater (Maximum Exposure)				
Ingestion	11.2	0.4	1.0E-03	2.1E-05
Dermal Contact	0.23	0.01	2.8E-05	8.1E-07
Inhalation	0.05	0.01	2.1E-05	6.0E-07
total	12	0.4	1.0E-03	2.2E-05
Phase II Groundwater (Plausible Exposure)				
Ingestion	0.88	0.4	1.5E-04	2.1E-05
Dermal Contact	0.02	0.01	4.0E-06	8.1E-07
Inhalation	0.01	0.01	3.0E-06	6.0E-07
	1.0	0.4	1.6E-04	2.2E-05
Surface Water				
Ingestion	0.13	0.09	NA	NA
Dermal Contact	0.08	0.05	NA	NA
total	0.21	0.14	NA	NA
Sediment				
Ingestion	0.03	0.01	8.0E-07	1.2E-07
Dermal Contact	0.01	<0.01	2.3E-07	1.2E-08
total	0.04	0.01	1.0E-06	1.3E-07

TABLE 6-25 (continued)

SUMMARY OF RISKS
FUTURE ADULT RESIDENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk		Carcinogenic Risk	
	RME	CT	RME	CT
Future Risk - Maximum Phase I Groundwater	10	0.6	5.5E-04	5.5E-06
Future Risk - Plausible Phase I Groundwater	1.1	0.6	4.0E-05	5.5E-06
Future Risk - Maximum Phase II Groundwater	12	0.6	1.0E-03	2.2E-05
Future Risk - Plausible Phase II Groundwater	1.3	0.6	1.6E-04	2.2E-05

Notes:

NA = Not Applicable. No carcinogenic and/or noncarcinogenic COPCs selected.

TABLE 6-26

SUMMARY OF RISKS
FUTURE CONTSTRUCTION WORKER
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Surface Soil		
Ingestion	0.02	2.8E-08
Dermal Contact	<0.01	5.1E-09
Inhalation	NA	7.4E-13
total	0.02	3.3E-08
Subsurface Soil		
Ingestion	0.02	5.7E-08
Dermal Contact	<0.01	1.0E-08
Inhalation	NA	1.1E-12
total	0.02	6.7E-08
Future Risk	0.04	1.0E-07

Notes:

NA = Not Applicable. No carcinogenic and/or noncarcinogenic COPCs selected.

TABLE 6-27

SUMMARY OF UNCERTAINTIES IN THE RESULTS
HUMAN HEALTH RISK ASSESSMENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Potential Magnitude for Over-Estimation of Risks	Potential Magnitude for Under-Estimation of Risks	Potential Magnitude for Over or Under-Estimation of Risks
Environmental Sampling and Analysis Sufficient samples may not have been taken to characterize the media being evaluated.			Low
Systematic or random errors in the chemical analysis may yield erroneous data.			Low
Selection of COPCs The use of USEPA Region III COPC screening concentrations in selecting COPCs in soil and groundwater.			Low
Exposure Assessment The standard assumptions regarding body weight, exposure period, life expectancy, population characteristics, and lifestyle may not be representative of the actual exposure situations.			Moderate
The use of the 95th percentile upper confidence level data of the lognormal distribution in the estimation of the RME.			Low
Assessing future residential property use when the likelihood of residential development is low.	High		
The amount of media intake is assumed to be constant and representative of any actual exposure.			Low
Toxicological Assessment Toxicological indices derived from high dose animal studies, extrapolated to low dose human exposure.	Moderate		
Lack of promulgated toxicological indices for inhalation pathway.		Low	
Risk Characterization Assumption of additivity in the quantitation of cancer risks without consideration of synergism, antagonism, promotion and initiation.			Moderate

TABLE 6-27 (Continued)

SUMMARY OF UNCERTAINTIES IN THE RESULTS
HUMAN HEALTH RISK ASSESSMENT
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE AREA
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Potential Magnitude for Over-Estimation of Risks	Potential Magnitude for Under-Estimation of Risks	Potential Magnitude for Over or Under-Estimation of Risks
Assumption of additivity in the estimation of systemic health effects without consideration of synergism, antagonism, etc.			Moderate
Additivity of risks by individual exposure pathways (dermal and ingestion and inhalation).			Low

Notes:

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

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

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

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

TABLE 6-28

TOTAL SITE RISK
SITE 73, AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Receptors	Surface Soil		Subsurface Soil		Phase I Groundwater		Phase II Groundwater		Surface Water/Sediment		Fish/Crab Tissue		Total (Phase I Groundwater)		Total (Phase II Groundwater)	
	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI	ICR	HI
Current Military Personnel	1.3E-07	0.01	NA	NA	NA	NA	NA	NA	2.7E-07	0.5	NA	NA	4.0E-07	0.5	4.0E-07	0.5
Current Adolescent Trespasser	9.3E-08	<0.01	NA	NA	NA	NA	NA	NA	5.3E-07	0.4	NA	NA	6.2E-07	0.4	6.2E-07	0.4
Current Adult Trespasser	2.0E-07	<0.01	NA	NA	NA	NA	NA	NA	1.0E-06	0.3	NA	NA	1.3E-06	0.3	1.3E-06	0.3
Current Adult Fisherman	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-06	0.3	4.3E-06	0.1	5.5E-06	0.35	5.5E-06	0.35
Biota Ingestion-Child Receptor	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.0E-06	0.4	4.0E-06	0.4	3.5E-04	0.4
Future Child Resident (RME)	1.6E-06	0.2	NA	NA	1.6E-05	2.0	7.1E-05	2.1	1.6E-06	1.1	NA	NA	1.9E-05	3.3	7.4E-05	3.4
Future Adult Resident (RME)	1.6E-06	0.02	NA	NA	3.7E-05	0.87	1.6E-04	1.0	1.1E-06	0.3	NA	NA	4.0E-05	1.1	1.6E-04	1.3
Future Construction Worker	3.4E-08	0.02	6.7E-08	0.02	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-07	0.04	1.0E-07	0.04

Notes:

ICR = Incremental Lifetime Cancer Risk
HI = Hazard Index
Total = Soil + Groundwater + Surface Water/Sediment + Fish/Crab Tissue
NA = Not Applicable

7.0 ECOLOGICAL RISK ASSESSMENT

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, directs the United States Environmental Protection Agency (USEPA) to protect human health and the environment with respect to releases or potential releases of contaminants from abandoned hazardous waste sites (USEPA, 1989a). This section of the report presents the ecological risk assessment (ERA) conducted at Operable Unit No. 9 (Site 73) that assesses the potential impacts to ecological receptors from contaminants detected at this site.

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

The objective of this ERA is to determine whether past site operations at Site 73 have adversely impacted the terrestrial and aquatic communities on, or adjacent to, the site. This assessment also evaluates the potential effects of contaminants related to Site 73 on sensitive environments including wetlands, protected species, and fish nursery areas. The conclusions of the ERA are used in conjunction with the human health risk assessment to evaluate the appropriate remedial action for this site for the overall protection of public health and the environment.

This ERA evaluates and analyzes the results from the Remedial Investigation (RI) including chemical analysis of the soil, surface water, and sediment. In addition, fish and crabs were collected and chemically analyzed and benthic macroinvertebrate samples were collected and identified. Information used to evaluate sensitive environments is obtained from historical data and previous studies obtained in the literature, or through conversations with appropriate state, federal, and local personnel. If potential risks are characterized for the ecological receptors, further ecological evaluation of the site and surrounding areas may be warranted.

The risk assessment methodologies used in this evaluation are consistent with those outlined in the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA, 1994) and Framework for Ecological Risk Assessment (USEPA, 1992). In addition, information found in the following documents was used to supplement the USEPA guidance document:

- Supplemental Guidance to Risk Assessment Guidance for Superfund: Region IV Bulletins Ecological Risk Assessment (USEPA, 1995a)
- USEPA Supplemental Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (USEPA, 1989b)
- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989c)
- Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters (USEPA, 1990)
- Fish Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters (USEPA, 1993a)

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

7.2 Problem Formulation

Problem formulation is the first step of an ERA and includes a preliminary characterization of exposure and effects (USEPA, 1992). The problem formulation of this ERA includes Sections 7.3 through 7.7 of this report. Chemical analyses were performed on samples collected from the soil, surface water, sediment, fish, and crabs to evaluate the presence, concentrations, and variabilities of the contaminants. Ecological surveys and a habitat characterization also were conducted as part of the field activities. Based on these observations, potential ecological receptors were identified. Finally, toxicological information for the contaminants detected in the media was obtained from available references and literature and used to evaluate the potential adverse ecological effects to the ecological receptors.

The components of the problem formulation include identifying the stressors and their potential ecological effects, identifying the ecosystems potentially at risk, defining ecological endpoints, and presenting a conceptual model. The following sections discuss each of these components and how they are evaluated in this ERA.

7.3 Contaminants of Potential Concern

One of the initial steps in the problem formulation stage of an ERA is identifying the stressors and their potential ecological effects. For this ERA, the stressors that are evaluated include contaminants detected in the surface soil, surface water, sediment, fish, and crabs.

Contaminants in the subsurface soil and groundwater are not evaluated in this ERA. Some terrestrial species burrow in the subsurface soil, and microorganisms most likely exist in the groundwater. However, current guidance does not provide sufficient information to evaluate risk to these receptors for the baseline ERA.

The nature and extent of contaminants detected in the environmental media at Site 73 are presented in Section 4.0 of this report. Sample locations are based on available historical site information and a site visit to evaluate potential ecosystems and ecological receptors.

7.3.1 Criteria for Selecting Contaminants of Potential Concern

The data set of all the positively identified contaminants was reduced to a list of contaminants of potential concern (COPCs). COPCs are site-related contaminants used to estimate ecological exposures and associated potential adverse effects.

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

- Historical information
- Prevalence
- Toxicity
- Comparison to established screening values
- Comparison to investigation associated field and laboratory blank data
- Comparison to background or naturally occurring levels

Each of these criteria is discussed in the following subsections.

7.3.1.1 Historical Information

Historical information combined with the following selection procedures assists in the identification of the COPCs. The historical information for Site 73 is presented in Section 1.0 of this report. To be conservative, contaminants detected in the surface soil, surface water, and sediment that may not have been historically used at the site were retained as COPCs to evaluate risk, but may have been eliminated in the ecological significance section as not being site-related. Contaminants detected in the tissue samples that are not detected in any of the surface water or sediment samples are not retained as COPCs.

7.3.1.2 Prevalence

The frequencies of positive detections in sample sets and the level at which a contaminant is detected in a given medium are factors that determine a chemical's prevalence. Contaminants that were detected Infrequently (approximately in five-percent or fewer of the samples) were not retained as COPCs. The prevalence of contaminants is discussed in further detail in Section 6.2.3.5.

7.3.1.3 Toxicity

The potential toxicity of a contaminant is an important consideration when selecting COPCs for further evaluation in the ERA. Several of the contaminants detected in the media at Site 73 are prevalent. However, the inherent toxicity of some of the contaminants to ecological receptors is low (e.g., calcium, magnesium, potassium, and sodium); therefore, they were not retained as COPCs. In addition, several contaminants have not been adequately studied to develop published toxicity values, or even accepted toxicological data with which to assess the contaminants. Contaminants that fell into this category were retained as COPCs (if they were not eliminated due to other criteria), however, they are not quantitatively evaluated in the ERA.

7.3.1.4 Comparison to Established Screening Values

Surface soil screening values (SSSVs) from the Dutch Soil Cleanup Act (Richardson, 1987) and constituents that were not provided in the Dutch Soil Cleanup Act, were evaluated against Oak Ridge National Laboratory (ORNL) (Will and Suter, 1994a, b) and USEPA Region III (USEPA, 1995a). The Dutch soil criteria were developed to evaluate the severity of contamination at sites. The Dutch background soil criteria were used in this ERA to determine if the soil concentraitons appeared to be elevated. ORNL has developed benchmark screening values for plants, invertebrates, earthworms, microorganisms, and microbial processes. The USEPA Region III Biological Technical Assistance

Group (BTAG) has developed SSSVs for the protection of flora and fauna. Most of the inorganic SSSVs used in this ERA were developed by ORNL, while most of the organic SSSVs were developed by USEPA Region III. There are no state or federal soil screening values that can be used to evaluate potential ecological risks to terrestrial receptors (other than plants or invertebrates). Therefore, the SSSVs are not used as criteria for retaining COPCs.

Water Quality Standards (WQS) for surface water have been developed for North Carolina (NC DEHNR, 1996). These are the only enforceable surface water standards. In addition to the WQS, Water Quality Screening Values (WQSVs) have been developed by USEPA Region IV (USEPA, 1995b), USEPA Region III (USEPA, 1995c), and Oak Ridge National Laboratory (ORNL) (Suter and Mabrey, 1994). The WQS and WQSVs will be herein referred to as Surface Water Screening Values (SWSVs).

Sediment quality standards have not been developed for North Carolina. However, Sediment Screening Values (SSVs) are available for many contaminants. These SSVs include the following: screening levels developed by Long et. al. (1995), Long and Morgan (1991), and the USEPA Region III (1995c), calculated sediment quality criteria (SQC) (USEPA, 1993b), Apparent Effect Threshold values (AET) (Tetra-Tech, Inc., 1986), and the Wisconsin Department of Natural Resources interim guidance criteria for in-water disposal of dredged sediments (Sullivan, et al., 1985).

The SWSVs and SSVs are used for comparative purposes to infer potential ecological risks. Contaminants that were detected at concentrations less than these screening values were not retained as COPCs for aquatic receptors since contaminants detected at concentrations less than these values are not expected to pose a significant risk to the aquatic receptor population. Contaminants in the surface water below SWSVs may still be retained as COPCs for the terrestrial receptors. None of the contaminants detected in the sediment were retained as COPCs for the terrestrial receptors because current guidance does not exist to evaluate this pathway for this baseline ERA.

There are no state or federal biota tissue screening values that can be used to evaluate potential ecological risks to aquatic receptors such as fish and crabs.

A brief explanation of the standards, criteria, and screening values used for the evaluation of the COPCs is presented below.

North Carolina Water Quality Standards (Surface Water) - WQSs are the concentrations of toxic substances that will not result in chronic toxicity to aquatic life (NC DEHNR, 1996). WQSs are provided for both freshwater and saltwater aquatic systems.

USEPA Water Quality Screening Values - WQSVs are non-enforceable regulatory guidelines and are of primary utility in assessing acute and chronic toxic effects in aquatic systems. WQSVs are provided for both freshwater and saltwater aquatic systems, and are reported as acute and/or chronic values (USEPA, 1995b,c). Most of the WQSVs are the same as the USEPA Ambient Water Quality Criteria (AWQC), however, some of the WQSVs are based on more current studies.

Oak Ridge National Laboratory Aquatic Benchmarks - ORNL Aquatic Benchmarks are developed for many contaminants, including those that do not have WQS of WQSVs (Suter and Mabrey, 1994). The ORNL aquatic benchmarks include secondary acute values and secondary chronic values that are calculated using the Tier II method described in the EPA's Proposed Water Quality Guidance for the Great Lakes System (USEPA, 1993c). Tier II values are developed so that aquatic benchmarks could be established with fewer data than are required for the USEPA AWQC. The benchmarks are limited to contaminants in freshwater.

Sediment Screening Values - Sediment screening values have been compiled to evaluate the potential for contaminants in sediments to cause adverse biological effects (Long, et al, 1995; Long and Morgan 1991; and, USEPA, 1995c). The lower ten percentile (Effects Range-Low [ER-L]) and the median percentile (Effects Range-Median [ER-M]) of biological effects have been developed for several contaminants. The concentration below the ER-L represents a minimal-effects range (adverse effects would be rarely observed). The concentration above the ER-L, but below the ER-M represents a possible-effects range (adverse effects would occasionally occur). The concentration above the ER-M represents a probable-effects range (adverse effects would probably occur). The SSVs developed by the Region III BTAG are primarily ER-L values, with the exception of AET values, which are considered ER-M values.

In addition to the SSVs, Apparent Effects Threshold (AET) Sediment Quality Values have been developed by Tetra Tech Inc., (1986) for the Puget Sound. ABETS are the concentrations of contaminants above which statistically significant biological effects would always be expected. Finally, the Wisconsin Department of Natural Resources has developed interim criteria for in-water disposal of dredged sediments (Sullivan, et al., 1985). These criteria are established using background data and are not based on aquatic toxicity. AET values are used as ER-Ms and the interim criteria are used as ER-Ls.

Sediment Quality Criteria - Currently, promulgated sediment quality criteria (SQC) only exist for a few contaminants. However, SQC for nonionic organic compounds can be calculated using the procedures in the <u>Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by using Equilibrium Partitioning</u> (USEPA, 1993b) as follows:

SQC = (Foc)(Koc)(FCV)/1,000,000

Where:

SQC = sediment quality criteria (µg/kg)
Foc = sediment organic carbon content (mg/kg)
Koc = chemical organic carbon partition coefficient (mL/g)
FCV = final chronic water quality value (µg/L)

7.3.1.5 Comparison to Field and Laboratory Blank Data

Associating contaminants detected in field related blanks (i.e., trip blanks, equipment rinsates and/or field blanks) or laboratory method blanks with the same contaminants detected in analytical samples can eliminate non-site-related contaminants from the list of COPCs. Blank data should be compared to sample results with which the blanks are associated. However, for this data set it is difficult to associate specific blanks with specific environmental samples. Thus, in order to evaluate detection levels, maximum contaminant concentrations reported in a given set of blanks are applied to a corresponding set of samples.

In accordance with the National Functional Guidelines for Organics, common lab contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene, and phthalate esters) should be regarded as a direct result of site activities only when sample concentrations exceed 10 times the maximum blank concentration. For other contaminants not considered common in a lab, concentrations exceeding five times the maximum blank concentration indicates contamination resulting from site activities (USEPA, 1991a).

Contract Required Quantitation Limits (CRQLs) and percent moisture are employed when evaluating contaminant concentrations in soil, in order to correlate solid and aqueous detection limits. For example, the CRQL for semivolatiles in soil is 33 to 66 times that of aqueous samples, depending on the contaminant. In order to assess semivolatile contaminant levels in soil using aqueous blanks, the blank concentration must then also be multiplied by 33 or 66 to account for variance from the CRQL (common lab contaminants must first be multiplied by five or ten, as explained in the paragraph above). The final value is divided by the sample percent moisture.

Eliminating a sample result correlates directly to a reduction in the contaminant prevalence in that medium. Consequently, if elimination due to blank concentration reduces the prevalence of a contaminant to less than 5 percent, a contaminant that may have been included according to its prevalence is eliminated as a COPC.

Maximum concentrations of common laboratory contaminants detected in blanks are presented in Section 6.0, Table 6-1. Blanks containing organic constituents that are not considered common laboratory contaminants (i.e., all other TCL compounds) are regarded as positive results only when observed concentrations exceed five times the maximum concentration detected in any blank (USEPA, 1989a). All TCL compounds at less than five times the maximum level of contamination noted in any blank are considered not detected in that sample.

7.3.1.6 Comparison to Background or Naturally Occurring Levels

Naturally occurring compounds common to the region were taken into consideration when selecting COPCs. Analytical data collected from ecologically comparable background stations were used to eliminate contaminants from consideration as COPCs. Background surface water, sediment, and biota were collected off-site in tidal freshwater habitats in the White Oak River Basin during a background study (see Appendix W). Background surface soil data used in this assessment were collected Base-wide. Contaminants that were detected in the surface soil at concentrations less than two-times the average background concentrations were not retained as COPCs. Contaminants that were detected in the surface water and sediment at concentrations less than the average background concentrations were not retained as COPCs.

7.3.2 Selection of Contaminants of Potential Concern

The following sections present an overview of the analytical data obtained for each medium during the RI and the subsequent retention or elimination of COPCs using the aforementioned selection criteria. Once this task has been completed, a final list of media-specific COPCs will be selected based on the remaining criteria. Contaminants that were not eliminated due to the above criteria were retained as COPCs. The primary reasons for retaining contaminants as COPCs include, but may not be limited to the following: (1) frequently detected, (2) detected at concentrations above the screening values (if available) and/or (3) detected at concentrations above background (if available). In addition, some common laboratory contaminants (i.e., phthalates, acetone, 2-butanone) are retained as COPCs because they were detected frequently and were not detected in the blank samples. Calcium, magnesium, potassium, and sodium are not retained as COPCs in any of the media because they are common naturally occurring chemicals, are not related to the site, and no published toxicity data was identified to assess potential impacts to aquatic or terrestrial life.

Table 7-1 presents the selection of the surface soil COPCs based on frequency of detection and comparison to twice the Base-background concentrations. Table 7-2 compares surface water contaminant concentrations to SWSVs and the average off-site background concentrations. Table 7-3 presents the comparison of the sediment contaminant concentrations to applicable SSVs and the average off-site background concentrations. Table 7-4 presents the contaminant concentrations detections detected in the biota tissue samples. A summary of the COPCs identified in each medium is presented in Table 7-5.

7.3.2.1 Surface Soil

As depicted on Table 7-1, thirty-five surface soil samples were collected at Site 73. All 35 samples were analyzed for TCL VOCs, TCL SVOCs, and TAL inorganics and 29 samples were analyzed for TCL pesticides/PCBs. One VOC (xylenes), six SVOCs [benzo(b)fluoranthene, chrysene, di-n-butylphthalate, 2,4-dinitrophenol, fluoranthene, and pyrene], four pesticides (gamma-chlordane, DDD, DDE, and DDT), and eleven inorganics (aluminum, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, vanadium, and zinc) were retained as surface soil COPCs because they were detected above twice the average background concentrations.

7.3.2.2 Surface Water

As depicted on Table 7-2, eleven surface water samples were collected in Courthouse Bay and two unnamed tributaries to Courthouse Bay at Site 73. All the surface water samples were analyzed for TCL VOCs, SVOCs, and pesticides/PCBs, and TAL inorganics. Because the sample locations are tidally influenced, the contaminant concentrations in the surface water and sediment are compared to the estuarine screening values.

Two VOCs (chloroform and toluene) were retained as only terrestrial COPCs. Three total inorganics (iron, manganese, and zinc) were retained as both aquatic and terrestrial COPCs and two total inorganics (aluminum and antimony) were retained only as terrestrial COPCs.

7.3.2.3 Sediment

As shown on Table 7-3, twenty-two sediment samples were collected at Site 73. At each station, sediment samples were collected from two depths, 0 to 6 inches and 6 to 12 inches. The sediment samples were analyzed for TCL VOCs, SVOCs, pesticides/PCBs, TAL inorganics, and total organic carbon (TOC). The lowest TOC concentration (26.1 mg/kg) was used to calculate the SQC since the lowest values produce the most conservative criteria. Appendix X presents the SQC calculations.

Two VOCs (carbon disulfide and toluene), two SVOCs [bis(2-ethylhexyl)phthalate and di-n-butylphthalate], three pesticides (DDD, DDE, and endrin), and ten inorganics (aluminum, arsenic, cadmium, chromium, copper, cobalt, iron, lead, nickel, and vanadium) were as COPCs because they were detected above background concentrations and/or SSVs.

7.3.2.4 Tissue Samples

As depicted on Table 7-4, eight fish fillet samples, five fish whole body samples, and six crab (edible portions) samples were collected from Courthouse Bay and from a tributary to the Bay east of Site 73. Contaminants detected in the tissue samples that were not detected in any of the surface water or sediment samples were not retained as COPCs in the tissue samples. However, due to the dilution required in the sediment samples because of matrix interferences created by the presence of elevated fuel constituents, the quantitation limits for the sediment SVOCs were high (see Section 7.11). Therefore, all SVOCs detected in the fish tissue samples were retained as COPCs.

Fish Whole Body Samples

All five whole body samples were analyzed for TCL organics and TAL inorganics. Ten inorganic analytes (aluminum, arsenic, barium, chromium, copper, iron, lead, manganese, vanadium, and zinc) were retained as whole body COPCs because concentrations were detected in the surface water and/or sediment samples collected from Site 73.

Fish Fillet Samples

All eight fillet samples were analyzed for TCL organics, pesticides/PCBs, and TAL inorganics. Two VOCs (methylene chloride and toluene), one SVOC (di-n-butylphthalate), one pesticide (endrin), and seven inorganics (arsenic, barium, copper, iron, lead, manganese, and zinc) were retained as fillet COPCs because concentrations were detected in the surface water and/or sediment samples collected from Site 73.

Crab Samples

All six samples were analyzed for TCL organics and TAL inorganics. Two VOCs (methylene chloride and toluene) one SVOC (di-n-butyl phthalate) and eight inorganics (arsenic, barium, copper, iron, lead, manganese, silver, and zinc) were retained as crab tissue COPCs because concentrations were detected in the surface water and/or sediment samples collected from Site 73.

7.3.3 Physical/Chemical Characteristics of COPCs

Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include bioconcentration factors (BCFs), organic carbon partition coefficient (Koc), octanol water partition coefficient (Kow), and biotransfer factors (Bv, Bb, Br). Table 7-6 summarizes these values for the COPCs detected in the surface water, sediment, tissue and surface soil samples. Information from these tables is used to assess the fate and transport of the constituents and the potential risks to the environmental receptors at each site.

Bioconcentration factors measure the tendency for a chemical to partition from the water column or sediment and concentrate in aquatic organisms. Bioconcentration factors are important for ecological receptors because chemicals with high BCFs could accumulate in lower-order species and subsequently accumulate to toxic levels in species higher up the food chain. The BCF is the concentration of the chemical in the organism at equilibrium divided by the concentration of the chemical in the water. The BCF is used to determine if a contaminant has a high potential to bioaccumulate in aquatic or terrestrial organisms.

The organic carbon partition coefficient (Koc) measures the tendency for a chemical to partition between soil and sediment particles containing organic carbon and water. This coefficient is important in the ecological environment because it determines how strongly an organic chemical will be bound to the organics in the sediments. The Koc is used to calculate sediment quality criteria.

The octanol/water partition coefficient (Kow) is the ratio of a chemical concentration in octanol divided by the concentration in water. The octanol/water partition coefficient has been shown to correlate well with bioconcentration factors in aquatic organisms and with adsorption to soil or sediment. The Kow is used to calculate the plant biotransfer factors that are used to estimate the COPC concentration in plants that would potentially be ingested by the terrestrial receptors in the intake model.

The plant biotransfer factors (Bv or Br) measure the potential for a chemical to accumulate in a plant. These factors are used to calculate the concentration of the COPCs in either the leafy part of the plant (Bv) or the fruit of the plant (Br). The factors for inorganics are obtained from Baes et al. (1984), while the factors for organics are calculated according to Travis and Arms (1988). The Bv and Br values for the organics are assumed to be same value.

Finally, the beef biotransfer factors (Bb) measure the potential for a chemical to accumulate in an animal. This factor is used to calculate the COPC concentration in the small mammal that is ingested by the red fox. The factors for inorganics are obtained from Baes et al. (1984), while the factors for organics are calculated according to Travis and Arms (1988).

7.4 Ecosystems Potentially at Risk

Ecological receptors that might be potentially at risk from contaminants at Site 73 were identified during the field investigations and the habitat evaluation. The regional and site-specific ecologies are presented in Section 3.8 of this report. Based on the results of the field investigations and the habitat evaluation, potential receptors of contaminants in surface water and sediment include the following: fish, benthic macroinvertebrates, other aquatic flora and fauna and some terrestrial faunal species. Potential receptors of contaminants in soil include the following: deer, rabbits, foxes, raccoons, birds and other terrestrial flora and fauna.

7.5 Ecological Endpoints

The information compiled during the first stage of problem formulation (stressor characteristics and ecosystems potentially at risk) is used to select the ecological endpoints for this ERA. The following section presents the ecological endpoints selected for this ERA, and the reasons they are selected.

There are two primary types of ecological endpoints: assessment endpoints and measurement endpoints. Assessment endpoints are explicit expressions of the actual environmental values that are to be protected (USEPA, 1994). Measurement endpoints are measurable responses to a stressor that are related to the valued characteristics chosen as the assessment endpoints (USEPA, 1994). Measurement endpoints may be identical to assessment endpoints (e.g., measurement of abundance of fish), or they may be used as surrogates for assessment endpoints (e.g., toxicity test endpoints).

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

7.5.1 Aquatic Endpoints

The assessment endpoints for the aquatic portion of this ERA are differences (compared to background) in the structure (i.e., density, diversity) of benthic macroinvertebrate communities attributable to site-related contaminants and the protection of benthic macroinvertebrates and fish due to exposure of site-related contaminants in the surface water and sediment. Measurement endpoints for the first aquatic assessment endpoint include the following: 1) lower benthic macroinvertebrate species diversity and richness when compared to an ecologically similar background location; 2) elevated levels of contaminants in the biota tissue samples as compared to tissue samples collected at off-site background stations or in the literature; and, 3) contaminant levels in the tissue samples that exceed toxicity values in the literature (where available). The measurement endpoints for the second aquatic assessment endpoint include exceedances of contaminant-specific surface water and sediment effect concentrations (i.e., SWSVs, and SSVs).

Species diversity, richness, and change in species dominance are evaluated by comparing the type of species, the species diversity, and community similarity of the benthic macroinvertebrates collected at Site 73 to the appropriate off-site background stations.

7.5.1.1 Species Diversity

The benthic macroinvertebrate community was examined using a mathematical expression of community structure called a diversity index. Diversity data are useful because they condense a substantial amount of data into a single value. The Shannon-Wiener diversity index and Brillouin diversity index both were calculated for the benthic macroinvertebrate species.

The Shannon-Wiener (H') function is one of the more commonly used formulas for calculating species diversity. Species diversity was calculated in logarithmic base 10 using the following equation (Brower and Zar, 1977):

$$H' = \sum (p_i * \log(p_i)).$$

H' = mean species diversity
p_i = proportion of the total number of individuals occurring in species i.

Brillouin's diversity (H) is used if a data set is not considered to be a random sample. This situation arises when data comprising an entire population are available or for data that are from a sample obtained non-randomly from a population. Brillouin's diversity is calculated using the following equation (Brower and Zar, 1977):

$$H = \frac{(\log n! - \sum(\log(f_i!))}{n}.$$

H = species diversity
n = the sample size
f = the number of observations in a category i

The operative assumption in the interpretation of diversity values is that relatively undisturbed environments tend to support communities that consist of a large number of species with no single species present in overwhelming abundance. Many forms of stress tend to reduce diversity by producing an environment that is less desirable for some taxa and, therefore, giving a competitive advantage to other taxa. In addition, unsuitable habitats in some tidally influenced streams, due to natural salinity fluctuations, will cause the diversity of the benthic macroinvertebrate population to be less than one (Tenore, 1971).

7.5.1.2 Community Similarity

Community similarity between benthic macroinvertebrate stations was measured using two qualitative indices of community similarity, the Jaccard coefficient (S_J) and the SΦrenson index (S_S). The indices use two possible attributes of the ecosystem, which is whether a species was or was not present in the collected sample. Because these coefficients are based on the number of species collected and not the number of individuals, a few organisms from several taxa could significantly change the similarity value, whereas there may not be an overall significant difference between the communities.

The S_J is better than the S_S at discriminating between highly similar collections and has been used widely in stream pollution investigations. The S_J ranges from 0.0 (dissimilar) to 1.0 (similar) and is calculated using the following equation (Brower and Zar, 1977):

$$S_j = \frac{a}{a + b + c}$$

a = number of species common to both collections
b = number of species in the first collection but not the second
c = number of species in the second collection but not in the first

The S_S places more emphasis on common attributes, and is better than the S_J at discriminating between highly dissimilar collections. The S_S ranges from 0.0 (dissimilar) to 1.0 (similar) and is calculated using the following equation (Brower and Zar, 1977):

$$S_s = \frac{2a}{2\,a + b + c}$$

Where a, b, and c are as described above.

These indices are used to detect changes in the community structure. Stressed communities presumably have different species than relatively non-stressed communities, given that all other factors are equal. Several factors determine the type of benthic population that will inhabit an area including salinity fluctuations, sediment type, size of water body, and time of collection. Although the community similarity indices will give some indication as to the similarities of the communities, more weight will be placed on the types of species that were collected, the relative densities, and the species diversities of the site stations as compared to the reference stations.

7.5.2 Terrestrial Endpoints

The assessment endpoint for the terrestrial receptors are as follows: 1) The protection of terrestrial herbivore and carnivore mammals from ingesting plants, soil, surface water, fish, and/or small mammals that contain site-related contaminants; 2) The protection of terrestrial herbivore avian species from ingesting plants, soil, and surface water that contain site-related contaminants; and, 3) The protection of terrestrial plants and invertebrates from direct exposure to site-related contaminants in the soil.

The measurement endpoints for the terrestrial ERA include exceedances of contaminant-specific soil effect screening values (i.e., SSSVs) and contaminant-specific effect doses (TRVs).

7.6 Conceptional Model

This section of the ERA presents each potential exposure pathway via soil, groundwater, surface water, sediment, and air, and the likelihood that an exposure will occur through these pathways. Figure 7-1 presents the flowchart of potential exposure pathways and ecological receptors.

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

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

7.6.1 Soil Exposure Pathway

Potential release sources to be considered in evaluating the soil pathway are surface or buried wastes and contaminated soil. The release mechanisms to be considered are fugitive dust, leaching, tracking, and surface runoff. The transport medium is the soil. The potential routes to be considered for ecological exposure to the contaminated soil are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the soil. COPCs were detected in the surface soil demonstrating a release from a source to the surface soil. Potential receptors that may be exposed to contaminants in surface soil at/or around surface soil in the areas of detected COPCs include the following: deer, fox, raccoon, rabbits, birds, plants, and other terrestrial life.

Terrestrial receptors potentially are exposed to contaminants in the soil through ingestion, dermal contact, and/or direct uptake (for flora). The magnitude of the exposure depends on their feeding habits and the amount of time they reside in the contaminated soil. In addition, terrestrial species may ingest organisms that have bioconcentrated contaminates from the soil. This exposure pathway is likely to occur at Site 73 and will be retained for further analysis.

7.6.2 Groundwater Exposure Pathway

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

Sub-surface biota (i.e., microorganisms) are the only ecological receptors expected to be directly exposed to groundwater. Potential impacts to these biota are accounted for in the surface water section of the ERA, since the receptors of concern are not directly exposed to groundwater at Site 73.

7.6.3 Surface Water and Sediment Exposure Pathway

Potential release sources to be considered in evaluating the surface water and sediment pathways are contaminated surface soil and groundwater. The release mechanisms to be considered are groundwater seepage and surface runoff. The potential routes to be considered for ecological exposure to the contaminated surface water/sediment are ingestion and dermal contact. Potential exposure points for ecological receptors include species living in, or coming in contact with, the surface water/sediment on-site or downgradient of the site. COPCs were detected in the surface water and sediment demonstrating a release from a source to the surface water or sediment transport medium. Potential receptors that may be exposed to contaminants in surface water and sediment include the following: fish, benthic macroinvertebrates, deer, birds, and other aquatic and terrestrial life.

Aquatic receptors are exposed to contaminants in the surface water and sediment by ingesting water while feeding and by direct contact while feeding or swimming. This exposure pathway is likely to occur at Site 73 and will be evaluated in the ERA. In addition, aquatic organisms may ingest other aquatic flora and fauna that have bioaccumulated chemicals from the surface water and sediment. This potential exposure pathway will not be evaluated in the ERA because current guidance does not provide sufficient information to evaluate risk.

Terrestrial faunal receptors potentially are exposed to contaminants in the surface water and sediment through ingestion and dermal contact. The magnitude of the exposure depends on their feeding habits and the amount of time they reside in the contaminated waters. In addition, terrestrial species may ingest organisms (e.g., fish, small mammals, invertebrates, and plants) that have bioconcentrated contaminates from the surface water and sediment. These exposure pathways are likely to occur at Site 73. However, only the surface water and surface soil ingestion pathway will be evaluated in the ERA. Current guidance does not exist to evaluate the sediment pathway, sub-surface soil pathway, or dermal contact pathway for terrestrial receptors for this baseline ERA.

7.6.4 Air Exposure Pathway

There are two potential release mechanisms to be considered in evaluating the atmospheric pathway: release of contaminated particulates and volatilization from surface soil, groundwater and surface water. The potential exposure points for receptors are areas on or adjacent to the site. The air exposure pathway is not evaluated in this ERA because air sampling was not conducted, and current guidance does not provide sufficient information to evaluate risk

7.7 Exposure Assessment

The exposure assessment evaluates the interaction of stressors (COPCs) with the ecological receptors. The RI included collecting samples for analytical analysis from five media; soil, groundwater, surface water, sediment, and tissue (fish and crabs). Contaminants in the subsurface soil and groundwater were not evaluated in this ERA. The analytical results for the data used in ERA are presented in Section 4.0 of this report.

The regional ecology, site ecology, and habitat characterization in the areas surrounding Site 73 are presented in Section 3.0 of this report. Information on sensitive environments and endangered species also is included in this section.

Exposure of terrestrial flora and fauna (invertebrates and microorganisms) to contaminants in the surface soil was assumed to be equal to the contaminant concentration in the surface soil. It is noted in the uncertainty section of this ERA that all the contaminants detected in the surface soil may not be bioavailable to the terrestrial flora or fauna. Exposure of aquatic receptors to contaminants in the surface water and sediment were assumed to be equal to the contaminant concentration detected in the surface water and sediment. Exposure of other terrestrial fauna (mammals, birds) to contaminants in the surface soil and surface water was estimated using the chronic daily intake models presented in the next section of this ERA.

The following sections present the results of the ecosystem characterization including the surface water, sediment, abiotic habitat, and biotic habitat.

7.7.1 Surface Water, Sediment, and Biological Sampling

Biological samples collected at Site 73 included fish and crabs to obtain tissue samples and benthic macroinvertebrates to obtain population statistics. Water quality measurements were collected during the sampling event prior to the surface water and sediment sample collection. These measurements consisted of temperature, pH, specific conductance, salinity, and dissolved oxygen. Site-specific descriptions, and field water quality measurements were recorded on field data sheets (see Appendix Y). The station locations and sampling procedures for collecting each of the environmental media are presented in Section 2.0 of this report.

7.7.1.1 Abiotic Habitat

The abiotic habitat consists of the description of the stations with regard to size of the creek, depth of the water, substrate type, water chemistry and other such non-biological descriptors. The following sections present the abiotic habitat for the sampling stations at Site 73.

The three water bodies sampled at Site 73 were Courthouse Bay and two unnamed tributaries to Courthouse Bay (east and west of the Bay). The samples were collected in high polyhaline (>25 ppt) tidally influenced zones, except one headwater station had zero to 0.5 ppt salinity (tidal freshwater).

Table 7-7 presents the sampling station characterization summary that includes the stream width and depth, canopy cover, sediment type, and sediment odor of the Site 73 stations. The width of the tributary to the west to Courthouse Bay ranged from three to one hundred feet (at the mouth of the tributary) and the width of the tributary to the east of the bay ranged from three to five feet. The width of Courthouse Bay was not measured due to the large size of the bay. The stream depth was approximately one foot deep in the tributary west of the bay, 0.4 to one foot deep in the tributary east of the bay, and one to eight feet deep in Court House Bay. The canopy cover ranged from partly open to open. Finally, the sediment was primarily a sandy-silt with organic material in several samples, with odors including normal, anaerobic and one station in the northeast portion of the bay had a petroleum odor. Oil sheens were observed in several of the sediment samples.

Table 7-8 presents the results of the field chemistry including the temperature, pH, dissolved oxygen concentration, conductivity, and salinity. The temperature ranged from 19.5 to 29.6 °C, the pH ranged from 6.06 to 8.48 S.U., the dissolved oxygen ranged from 1.2 to 9.4 mg/L, the conductivity ranged from 145 to 48,000 umhos/cm, and the salinity ranged from 0 to 33 ppt. With the exception of the DO values, the field chemistry at these stations appear to be typical of surface waters at MCB Camp Lejeune based on previous sampling experience. The low DO value (1.2) may be due to the DO probe being immersed in the sediment.

7.7.1.2 Biotic Habitat

The biotic habitat consists of the description of the stations with regard to the biological community. The following sections present the results of the benthic macroinvertebrate community for the sampling stations at Site 73. Benthic macroinvertebrates were collected from Courthouse Bay and two tributary streams to Courthouse Bay. Fish were collected from two stations in Courthouse Bay adjacent to Site 73 and one station in the tributary to the west of Courthouse Bay. All of the sampling locations are tidally-influenced. It is noted that one upstream station (73-SW/SD01) is a tidal freshwater salinity zone with pHs ranging from 0 to 0.5.

Fish Community

Table 7-9 presents a summary of the fish and non-fish aquatic species collected at Site 73. The fish distribution and characterization summary is presented in Table 7-10. Appendix AA presents the lengths and weights of the individual fish collected at each station. No external tumors, lesions, or other abnormalities were visually observed on any of the fish collected at the site.

Trawling, followed by gill nets was the most successful fish collection method used at Site 73. Pinfish was the most abundant fish collected via trawling (175 individuals), followed by spot (26 individuals). Other fish collected by trawling include Atlantic croaker, banded rudderfish, bay anchovy, butterfish, pigfish, southern flounder, and yellowfin menhaden.

Yellowfin menhaden and southern flounder were the only fish species collected at all three site stations, using gill nets. The southern flounder was the most abundant fish collected at each station. Other fish collected at Site 73 in the gill nets include: Atlantic croaker, Atlantic menhaden, bluefish, pinfish, Spanish mackerel, spotted seatrout, and stripped mullet. One unidentified skate or ray was collected at 73-FS02. Blue crabs were collected at all three stations.

Benthic Macroinvertebrate Community

Table 7-11 presents the benthic macroinvertebrates collected from the Site 73 stations in Courthouse Bay and the tributaries to Courthouse Bay. Appendix Z presents the benthic macroinvertebrate raw data tables and laboratory bench sheets for the Site 73 stations. Appendix W presents the benthic macroinvertebrates collected from ecologically similar, off-site, reference stations (HC03 and HM03). Table 7-12 presents the tolerance values of each species to organic pollution, and metals, and the

North Carolina Biotic Index. Table 7-13 presents the benthic station summary statistics. Finally, Table 7-14 presents the community similarity for the benthic macroinvertebrates between the Site 73 stations and between the Site 73 stations and the off-site reference stations.

A total of 23 species consisting of 1,197 individuals was collected at the eleven Site 73 stations. At the off-site reference stations, nine species consisting of 341 individuals were collected. The majority of the individuals collected were the annelids Capitella capitata and Streblospio benedicti. The arthropods Corophium Lacuatre and Leptochelia rapox and the mollusc Macoma tenta comprised the majority of the individuals collected at the off-site reference stations.

The species similarities were highest between the site stations. The highest Sj was calculated between 73-BN03 and 73-BN05 (0.60) and 73-BN03 and 73-BN06 (0.67). The highest Ss values were also calculated between 73-BN06 and 73-BN05 (0.92) and 73-BN03 and 73-BN06 (0.80). The highest Sj values calculated between the site and background stations were between 73-BN06 and HM03 (0.30), between 73-BN07 and HM03 (0.25), and between 73-BN12 and HM03 (0.85). The highest Ss values calculated with background were between 73-BN06 and HM03 (0.31) and between 73-BN07 and HM03 (0.32).

For the Brilliouin's index, species diversities were within or above background (0.50 and 0.68) at stations 73-BN03 (0.61), 73-BN05 (0.70), 73-BN06 (0.52), 73-BN07 (0.71), and 73-BN08 (0.51). For the Shgannon-Weiner index, species diversities were within or above background (0.54 and 0.68) at Stations 73-BN03 (0.65), 73-BN05 (0.67), 73-BN07 (0.74), and 73-BN08 (0.55). Diversities were calculated at zero for Stations 73-BN04 and 73-BN11, where only one type of specie was collected.

7.8 Ecological Effects Characterization

The ecological effects data that were used to assess potential risks to aquatic and/or terrestrial receptors in this ERA include aquatic and terrestrial screening values as presented in Section 7.3.1.4. The following sections present a summary of the ecological effects comparison.

7.8.1 Surface Water

Contaminant concentrations detected in the surface water at Site 73 were compared to estuarine SWSVs to determine if there were any exceedances of the published values (see Table 7-2). In summary, manganese, silver, and zinc were retained as surface water COPCs because they exceeded the SWSVs. Chloroform, toluene, aluminum, and antimony concentrations were below their corresponding SWSVs, but were retained as a terrestrial COPCs. There were no SWSVs available to evaluate surface water concentrations of iron.

The source for the SWSV for manganese of 10 µg/L is not known. However, the Aquatic Information Retrieval Database (AQUIRE) reports that 10 µg/L caused decreased growth in the pacific oyster (Crassostrea gigas). This study, which did not meet the criteria for reliability, may be the data source for the Region III value. Other toxicity values for manganese obtained from AQUIRE listed adverse effects at 20,000 µg/L which is higher than the maximum sample concentration collected at Site 73 (37.7 µg/L)). These AQUIRE studies also were conducted with mollusk species.

The maximum concentrations of iron (4,540 µg/L) in the surface water is within the range of concentrations that caused adverse impacts to aquatic life of some of the studies obtained from the AQUIRE (100 to 330,000 µg/L). However, the majority of the effect concentrations from the studies on AQUIRE are several orders of magnitude above the maximum iron concentration detected in the surface water. Most of the studies on iron in AQUIRE were conducted with various marine phytoplankton cultures.

7.8.2 Sediment

Contaminant concentrations detected in the sediment at Site 73 were compared to SSVs to determine if there were any exceedances of the published values (see Tables 7-3). Toluene, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, 4,4'-DDD, 4,4'-DDE, endrin, arsenic, cadmium, iron, and lead were selected as sediment COPCs because they exceeded the SSVs. No SSVs were available for carbon disulfide, aluminum, cobalt, or vanadium. Of the inorganics, arsenic, cadmium, and lead exceeded ER-L values and iron exceeded the ER-M value. The iron SSV is an apparent effects threshold value (Tetra Tech, Inc., 1986). There were no ER-L values located for iron.

7.8.3 Fish Tissue

The following sections discuss the chemical concentrations detected in the tissue samples collected from Site 73. The fish tissue samples were divided into two groups for discussion: fillet and whole body. Crab tissue samples were grouped separately from the fish samples. Table 7-15 presents a summary of the fish sent to the laboratory for analysis along with their trophic level.

The individuals in each sample that were retained for chemical analysis are presented in Appendix AA. The appendix lists the length and weight of all the individuals in each composite, along with the new sample number, and how the sample should be prepared for analysis (i.e., fillet, whole body, or edible portions for crabs). In accordance with the Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories, Volume I, Fish Sampling and Analysis (USEPA, 1993d), the smallest fish in a composite should be no less than 75 percent of the total length of the largest individual. As presented in Appendix AA, the minimum to maximum ratio is greater than 75 percent in all but one sample. Fish tissue sample 73-FS02-PF01 had a ratio of 65 percent.

Table 7-16 presents the COPCs for the tissue samples collected at Site 73. The positive detection tables are presented in Section 4 and the statistical summaries for these samples are presented in Appendix S.

The fish fillet and crab tissue concentrations were compared to the tissue contaminant concentrations in an off-site tissue study Baker conducted in the White Oak River Basin in 1993 (Baker, 1994a). This background study was limited to the fillet portion of the fish and the edible portion of crabs (see Appendix W). Site 73 whole body fish tissue contaminant concentrations were compared to the tissue contaminant concentrations in a fish survey conducted in Albermarl and Pamlico Sounds in North Carolina (NC Study) (Benkert, 1992). This background study was limited to the whole body portion of the fish. Table 7-16 presents these comparisons.

7.8.3.1 Fish Tissue Organics

Two VOCs (methylene chloride and toluene) were retained as COPCs in the fish fillet and crab samples. Methylene chloride was detected at low concentrations in the fillet and crab samples collected for the Baker background study while toluene was not detected in background fillet and crab samples. One SVOC (di-n-butyphthalate) was retained as a fillet and crab COPC. Di-n-butylphthalate was not detected in the tissue collected from the Baker background study. One pesticide (endrin) was retained as a fish fillet COPC. Endrin was not detected in the background investigation. Toxicity data could not be located for methylene chloride, toluene, or di-n-butylphthalate. The state of New York has proposed an endrin fish tissue criterion for the diet of piscivorous wildlife at 250 µg/kg for non-carcinogenic risk based on the mallard duck (Newell et al., 1987). This proposed criterion value is greater than the detected endrin concentrations at Site 73 (9.8J µg/kg).

7.8.3.2 Fish Tissue Inorganics

The whole body concentrations of chromium, copper, lead, and zinc collected from Site 73 were below the concentrations detected in the NC Study. In addition, crab tissue concentrations of barium, copper, and manganese collected from Site 73 were below background concentrations. The remaining inorganics in the fish and crab samples retained as COPCs were detected in higher concentrations in the Site 73 samples than the background or NC study samples.

Toxicity data were located for arsenic, chromium, lead, and zinc. Therefore, toxicological impacts to aquatic and piscivorous wildlife only are evaluated for these COPCs. The following paragraphs present the available toxicity data.

Arsenic

Diminished growth and survival have been reported in immature bluegills Lepomis macrochirus when total arsenic residues in muscle was greater than 1.3 mg/kg fresh weight, or greater than five mg/kg in adults (Eisler, 1988). Depending on the chemical form of arsenic, certain marine teleosts may be unaffected at muscle total arsenic residues of 40 mg/kg (Eisler, 1988). Arsenic was detected at a maximum concentration of 3.3 mg/kg in the summer flounder fillet sample. Therefore, arsenic concentrations in the fillet fish tissue samples were less than the five mg/kg reported to cause diminished growth and survival in adult fish. Arsenic concentrations in the Site 73 fillet samples were within the range of the off-site background concentrations. However, the Site 73 crab tissue concentration of arsenic was greater than the background crab tissue concentrations.

Chromium

It has been suggested that organs and tissues of fish and wildlife that contain greater than four mg/kg total chromium should be viewed as presumptive of chromium contamination (Eisler, 1986). The maximum chromium tissue concentration in Site 73 samples (0.71 mg/kg) is below the concentration considered to be indicative of contamination. In addition, chromium was detected at a concentration within the range of the concentrations detected in the NC Study.

Lead

Lead concentrations tend to be high in marine water near bridges, industrial disposal areas, sewage areas, dredging sites, and at mining sites. No significant biomagnification of lead occurs in aquatic food chains. Lead concentrations in aquatic vertebrates tend to be directly correlated with the age of the organisms. Lead tends to localize in hard tissues such as bone and teeth (Eisler, 1988). The whole body concentrations of lead detected at Site 73 were below the concentrations in the NC Study. Lead was not detected in the fillet and crab collected during the background study.

Zinc

Bird diets should contain 93 to 120 mg/kg of zinc for adequate optimal growth, and it should be less than 178 mg/kg to prevent marginal sublethal effects (Eisler, 1993). The maximum zinc concentration in Site 73 fish tissue samples (26.6 mg/kg) is below this concentration. In addition, the concentrations detected in the whole body samples collected from Site 73 are below concentrations detected in the NC Study. The concentrations of zinc in all of the fillet and crab samples are higher than the zinc concentrations in the off-site background fish and crab samples.

7.8.4 Surface Soil

Although promulgated standards do not exist, SSSVs that may be used to evaluate potential ecological risks to terrestrial flora and fauna have been developed by the Dutch (Richardson, 1987), USEPA Region III (USEPA, 1995a) and ORNL (Will and Suter, 1994a, 1994b, and 1995). The contaminant concentrations in the surface soils are compared to the SSSVs to determine if potential impacts to terrestrial flora and fauna invertebrates may be expected.

As presented on Table 7-17, only three SVOCs exceeded the Dutch background levels while five SVOCs exceeded the other toxicity values. The SVOC toxicity values that were exceeded were developed by the USEPA Region III. The toxicity values were based on a mice study that caused stomach tumors when treated with 100 μg/kg of benzo(a)pyrene. Since, ingestion of contaminants by small mammals is addressed in the chronic daily intake models presented later in this ERA, these screening values do not address potential effects on soil invertebrates and plants.

A literature search was conducted to determine potential impacts to soil flora and fauna from SVOCs in the surface soil. Toxicity data to plants and/or soil invertebrates for one of the SVOCs (fluoranthene) was located in the literature. The No Observed Effects Concentration (i.e., the concentration at which no adverse effects were observed) ranged from 267,000 μg/kg to 1,214,000 μg/kg for isopods and worms (Brummelen et al., 1996 and Achazi et al., 1995) which are well above the concentrations detected in the surface soil collected at Site 73.

Two inorganics exceeded the Dutch background levels while six inorganics also exceeded after toxicity values. The inorganics with the highest number of exceedances were aluminum (35/35), chromium (27/27), iron (35/35), and vanadium (21/21). The concentrations of VOCs and pesticides detected in the surface soil were below the benchmark toxicity values, indicating no risk is expected from these contaminants.

7.8.5 Terrestrial Chronic Daily Intake Model

In addition to comparing the soil concentrations to toxicity values for terrestrial invertebrates and plants, a terrestrial Chronic Daily Intake (CDI) model is used to estimate the exposure of the COPCs to terrestrial receptors. The following describes the procedures used to evaluate the potential soil exposure to terrestrial fauna at Site 73 by both direct and indirect exposure to COPCs via surface water, soil, and foodchain transfer.

Based on the regional ecology and potential habitat at the site, the indicator species used in this analysis were white tail deer, cottontail rabbit, red fox, the bobwhite quail and the raccoon. It is realized that all the terrestrial species may not exist at the site, and that other species may exist at the site. The species were chosen based on the most likely exposure scenarios and the availability of exposure data (i.e., ingestion rates, body weights). The white tail deer represents a large mammal ingesting vegetation. The cottontail rabbit represents a small mammal ingesting vegetation. The red fox represents a small mammal ingesting vegetation and other small mammals. The bobwhite quail represents a bird ingesting vegetation. The raccoon represents a small mammal ingesting vegetation and fish. The exposure points for these receptors were the surface soil and biota transfers. The routes for terrestrial exposure to the COPCs in the soil were incidental soil ingestion, vegetation (leafy plants, seeds and berries) ingestion, and ingestion of small mammals.

7.8.5.1 Derivation of Terrestrial Reference Value

Total exposure of the terrestrial receptors to the COPCs in the soil and surface waters is determined by estimating the CDI dose and comparing this dose to Terrestrial Reference Values (TRVs) representing acceptable daily doses in mg/kg/day. The TRVs were developed from No-Observed-Adverse-Effect-Levels (NOAELs) or Lowest-Observed-Adverse-Effect-Levels (LOAELs) obtained from the Integrated Risk Information System (IRIS), Agency for Toxic Substances and Disease Registry Toxicological Profiles, mineral tolerance levels of domestic animals (NAS, 1992) or other toxicological data in the literature. Appendix AB presents the methodology used in deriving the TRVs and the animals that were used to derive each TRV.

7.8.5.2 Calculation of Chronic Daily Intake

Potential impacts of the terrestrial receptors to the COPCs in the soil and surface water are determined by estimating the CDI dose and comparing this dose to TRVs representing acceptable daily doses in mg/kg/day. The CDI equations were adapted from those used in Scarano et al., (1993). The estimated CDI doses of the bobwhite quail, cottontail rabbit, white-tailed deer and small mammal, to soil, surface water, and vegetation are determined using the following equation:

$$CDI = \frac{(Cw)(Iw) + [(Cs)(Bv)(Iv) + (Cs)(Is)][H]}{BW}$$

Where:

CDI = Chronic Daily Intake, mg/kg/d
Cw = Contaminant concentration in the surface water, mg/L
Iw = Rate of drinking water ingestion, L/d
Cs = Contaminant concentration in soil, mg/kg
Bv = Soil to plant transfer coefficient (leaves, stems, straw, etc.), unitless
Iv = Rate of vegetation ingestion, kg/d
Is = Incidental soil ingestion, kg/d
H = Contaminated area/Home range area ratio, unitless
BW = Body weight, kg

To calculate the contaminant concentration in the small mammal (meadow vole), the resulting CDI from the above equation is multiplied by the biotransfer factor for beef (Bb) for organics (Travis and Arms, 1988) and metals (Baes, et al., 1984).

The estimated CDI dose of the raccoon is determined using the following equation.

$$CDI = \frac{(Cw)(Iw) + (Cf)(If) + [(Cs)(Br)(Iv) + (Cs)(Is)][H]}{BW}$$

Where:

CDI = Chronic Daily Intake, mg/kg/d
Cw = Contaminant concentration in the surface water, mg/L
Iw = Rate of drinking water ingestion, L/d
Cf = Contaminant concentration in the fish, mg/kg
If = Rate of fish ingestion, kg/d
Cs = Contaminant concentration in soil, mg/kg
Br = Soil to plant transfer coefficient (fruit, seeds, tubers, etc.), unitless
Iv = Rate of vegetation ingestion, kg/d
Is = Incidental soil ingestion, kg/d
H = Contaminated area/Home range area ratio, unitless
BW = Body weight, kg

The contaminant concentration in the fish is the whole body fish concentration from the samples collected at Site 73.

The estimated CDI dose of the red fox is determined using the following equation:

$$CDI = \frac{(Cw)(Iw) + [(Cs)(Bv)(Iv) + (Cs)(Is) + (Cm)(Im)][H]}{BW}$$

Where:

CDI = Chronic Daily Intake, mg/kg/d
Cw = Contaminant concentration in the surface water, mg/L
Iw = Rate of drinking water ingestion, L/d
Cs = Contaminant concentration in soil, mg/kg
Bv = Soil to plant transfer coefficient (leaves, stems, straw, etc.), unitless
Iv = Rate of vegetation ingestion, kg/d
Is = Incidental soil ingestion, kg/d
Cm = Contaminant concentrations in small mammals, mg/kg
Im = Rate of small mammal ingestion, kg/d
H = Contaminated area/Home range area ratio, unitless
BW = Body weight, kg

Bioconcentration of the COPCs to plants is calculated using the soil to plant transfer coefficient (Bv or Br) for organics (Travis and Arms, 1988) and metals (Baes et al., 1984). The concentrations of the COPCs used in the models were the lower of the log normal 95 percent upper confidence limit (UCL) or the maximum concentration detected of each COPC. The exposure parameters used in the CDI calculations are presented in Table 7-18. It is noted that the area of Site 73 is estimated to be 81 acres. Approximately half of the site is industrial areas with buildings, pavement, and concrete. Therefore, 40.5 acres was used as an input in the chronic daily intake models to represent the acreage of contaminated area available to terrestrial receptors.

7.9 Risk Characterization

The risk characterization is the final phase of a risk assessment. It is at this phase that the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. This section evaluates the potential decrease in aquatic and terrestrial populations at Site 73 from contaminants identified at the site.

A Quotient Index (QI) approach is used to characterize the risk to aquatic receptors from exposure to surface water and sediments and terrestrial receptors from exposure to surface soil, surface water, and biota. This approach characterizes the potential effects by comparing exposure levels of COPCs in the surface water and sediments to the aquatic reference values presented in Section 7.8, Ecological Effects Characterization. The QI is calculated as follows:

$$QI = \frac{(EC,\ CDI)}{(SWSV,\ SSV,\ TRV)}$$

Where: Quotient Index
EC = Exposure Concentration, μg/L, μg/kg or mg/kg
CDI = Chronic Daily Intake, mg/kg/day
SWSV = Surface Water Screening Value, μg/L
SSV = Sediment Screening Value, μg/kg or mg/kg
TRV = Terrestrial Reference Value, mg/kg/day

A QI greater than "unity" is considered to be indicative of potential risk. Such values do not necessarily indicate that an effect will occur but only that a lower threshold has been exceeded. However, it is important to determine which contaminants are posing the highest risks, in order to evaluate the significance of those contaminants to the site. Therefore, the evaluation of the significance of the QI has been judged as follows: (Menzie et al., 1993)

- QI exceeds "1" but less than "10": some small potential for environmental effects
- QI exceeds "10": significant potential that greater exposures could result in effects based on experimental evidence
- QI exceeds "100": effects may be expected since this represents an exposure level at which effects have been observed in other species

The risks characterized above provide insight into general effects upon animals and plants in the local population. However, depending on the endpoint selected, they may not indicate if population-level effects will occur.

7.9.1 Surface Water

Table 7-19 presents the surface water QIs calculated per station. This table only presents the COPCs with QIs greater than one. Table 7-20 presents the surface water QIs calculated per COPC and the cumulative QI values for Site 73, using the log normal UCL. The actual QI calculations for Site 73 are located in Appendix X. Figure 7-2 graphically displays the QIs that exceeded one. Manganese and zinc are the only COPCs detected in the surface water that have QIs greater than one. Surface water concentrations of manganese slightly exceeded chronic SWSVs at stations in the northern portion of Courthouse Bay and in the tributaries to the bay. Finally, zinc at one station in the southern portion of Courthouse Bay slightly exceeded screening levels.

The surface water conditions at Site 73 have a low potential to impact the aquatic community as indicated by a cumulative surface water QI values of 1.13 for the NC WQS, 1.02 for the acute SWSV, and 3.05 for the chronic SWSV. Based on other studies, the concentrations of manganese in the surface water is not expected to adversely impact the aquatic community. In addition, zinc only exceeded the SWSV in one samples and does not appear to be site-related. The surface water at Site 73 is not expected to adversely impact the receptors at the site.

7.9.2 Sediment

Table 7-21 presents the sediment QIs calculated per station at Site 73. This table only presents the COPCs with QIs greater than one. Table 7-22 presents the sediment QIs calculated per COPC and cumulative QI values for the site, using UCL concentrations. Figure 7-2 graphically displays the QIs that exceeded one. Appendix X presents the SQC and the sediment QI calculations. A TOC value of 26.1 mg/kg was used to calculate the SQC values used in the COPC selection process. The value 26.1 mg/kg was used in the SQC calculation to be conservative because this was the lowest TOC value calculated at Site 73. TOC values at the site ranged from 26.1 mg/kg to 229,000 mg/kg. The wide range of TOCs at the site is due to the different substrata between stations, especially between Courthouse Bay and the small tributaries to the bay. Higher TOC values existed in the tributary to the west of Courthouse Bay, where the sediment was a fine silt. The station-specific QI values were calculated using the TOC value for that particular station.

Of the organics, concentrations of bis(2-ethylhexyl)phthalate, di-n-butylphthalate, 4,4'-DDD, 4,4'-DDE, and endrin detected in the sediment had QIs greater than one. Several of the organics did not exceed the SSVs when station-specific SQCs were calculated. Bis(2-ethylhexyl)phthalate slightly exceeded an ER-M value at one station (73-SD06-612). Di-n-butylphthalate concentrations were more than five times the SQC values at two stations in the middle of Courthouse Bay (73-SD07-06/612 and 73-SD08-06/612).

High ER-L and SQC values were calculated for the pesticides detected in the sediment. Only 4,4'-DDD at one station (73-SD01-06) in the eastern tributary to Courthouse Bay slightly exceeded the ER-M value and exceeded the ER-L value by a magnitude of ten. High pesticide QIs for the ER-L and SQC were calculated at several stations in Courthouse Bay. Based on the high ER-L and SQC QIs values, there is a moderate potential for pesticides detected in the sediment collected at Site 73 to cause a decrease in the aquatic receptor population.

Of the inorganics, ER-L QIs were calculated between one and five for arsenic, cadmium, copper, lead, and nickel at several stations. The ER-M QI for iron was slightly greater than one. There is no significant potential for inorganics detected in the sediment to cause a decrease in the aquatic receptor population.

Overall, there is a potential for COPCs detected in the sediment collected at Site 73 to adversely impact the aquatic receptors in the bay as indicated by the high cumulative QIs calculated (ER-L =

261.34, ER-M = 4.74, and SQC = 1,830.99). The primary contributors to the high QIs were the pesticides detected in the sediments.

7.9.3 Terrestrial Chronic Daily Intake Model

Table 7-23 presents the QIs for the terrestrial CDI model and Appendix AB contains the actual models. QIs calculated for red fox, bobwhite quail, cottontail rabbit, and white-tail deer were between one and ten. The QI for the red fox (1.38) was driven by antimony concentrations in the surface water. The QI for the quail (2.82) was driven by aluminum concentrations in the surface water and surface soil and the QI for the rabbit (6.58) was driven by aluminum concentrations in the surface water and surface soil and cadmium in the surface soil. The cumulative QI calculated for the deer (1.38) was greater than one, but none of the individual QIs exceeded one. Antimony and cadmium in the deer model produced the highest QI values. The QI for the raccoon was calculated between ten and one hundred. The QI for the raccoon (20.40) was driven primarily by the aluminum detected in the surface water, surface soil, and fish tissue. Also, the risk in the raccoon model was secondarily driven by concentrations of antimony in the surface water and concentrations of arsenic in the fish tissue.

7.10 Ecological Significance

This section summarizes the overall risks to the ecology at the site. It addresses impacts to the ecological integrity at Site 73 from the COPCs detected in the media, and determines which COPCs are impacting the site to the greatest degree, and what site-related contaminants are "significant." This information, to be used in conjunction with the human health risk assessment, supports the selection of remedial action(s) for Site 73 that are protective of public health and the environment.

7.10.1 Aquatic Receptors

Based on the risk characterization, there is a slight potential for inorganics in the surface water and sediment and pesticides in the sediment to adversely impact the aquatic ecosystem at Site 73. Manganese and zinc were the only COPCs detected in the surface water at concentrations above the SWSVs. As presented earlier in the ERA, manganese and zinc have a low potential to adversely impact the aquatic receptor population at Site 73.

Also, the inorganics detected in the sediment did not produce in any significant risk to the aquatic environment. Pesticides were detected in the sediment collected from the main body of Courthouse Bay. The pesticides produce the greatest risk to the aquatic environment at Site 73 as indicated by the high QI values. It does not appear that the pesticides detected in the sediment are significantly bioaccumulating in the fish inhabiting the site, as indicated by the detection of only one pesticide (endrin) in one fillet sample collected from the site.

Several inorganics detected in the fish tissue are elevated above the NC Study and the background studies. Based on the relatively abundant and diverse fish population in Courthouse Bay, these contaminants do not appear to be significantly impacting the fish community in terms of population effects. It should be noted that the fish may be impacted in other ways that are not readily visibly (i.e., internal pathologies, decreased reproduction, decreased growth, etc.).

In the whole body fish samples, arsenic and chromium were detected below the concentrations that appear to cause adverse impacts to fish or be indicative of contamination. No toxicological information was located for aluminum, barium, copper, iron, lead, manganese, silver, vanadium, or zinc in fish tissue. The NC Study did not analyze the fish samples for aluminum, barium, iron, manganese, silver, or vanadium; therefore, no comparisons could be made for these contaminants. Copper, lead, and zinc were detected at concentrations below the range of concentrations in the NC Study and do not appear to be elevated.

In the fillet fish samples, arsenic was detected at concentrations below the rage of concentrations in the background study and do not appear to be elevated. Toluene, di-n-butylphthalate, endrin, barium, copper, iron, lead, manganese, and zinc were detected at concentrations above those in the background study, but no toxicological information was located to determine potential impacts to fish from the detected concentrations in the tissue.

In the crab samples, barium, copper, and manganese were detected at concentrations below the range of concentrations in the background study and do not appear to be elevated. Concentrations of toluene, di-n-butylphthalate, arsenic, iron, lead, silver, and zinc were detected above concentrations detected in the background study, but no toxicological information was located to determine potential impacts to fish from the detected concentrations in the tissue.

Overall, the benthic community in the tributaries to the west and east of Courthouse Bay had lower numbers of species, individuals, densities, and diversities than the comparative background stations. It is noted that there were not a significant number of contaminants detected in the sediment collected from the tributary stations. However, there were low oxygen levels detected in the tributary located to the east of the bay.

Overall, the benthic community within Courthouse Bay was similar to the background stations with the exception of 73-BN02 (which has a lower number of species and diversities than background) and 73-BN04 (which has a lower number of species, individuals, densities, and diversities than background). It is noted that sediment concentrations of pesticides at 73-BN04 were relatively high; however, there were no significant contaminants detected in the sediment collected from 73-BN02.

A study conducted in the Pamlico River Estuary, North Carolina, indicated that the Shannon-Weiner species diversity in the oligohaline zone was 0.69, and the species density was 375/m^2 (Tenore, 1971). In addition, the oligohaline zone is dominated by <u>Rangia</u> <u>cuneata</u> and <u>Neanthes</u> <u>succinea</u> (Tenore, 1971). The species diversities at the Site 73 stations (0.00 to 0.74) were below the 0.69 diversity, except at one station (73-BN07). The species densities were higher at all of the Site 73 stations, with the exception of stations 73-BN04 and 73BN11.

7.10.2 Terrestrial Receptors

Several contaminants were detected in the surface soil at concentrations that exceed the SSSVs. Therefore, there is the potential for a decrease in the population of terrestrial plants and invertebrates at Site 73. No visible signs of stressed or dead vegetation in these areas were observed during the field investigations. In addition, Site 73 is very industrial and the majority of the soil samples were collected from landscape areas (i.e., mowed grass, shrubs, etc.).

All the QI values for the terrestrial CDI model are greater than one. The QIs for the red fox, bobwhite quail, eastern cottontail rabbit, and white-tail deer ranged from 2.00 to 9.22, indicating a slight potential for adverse risk to these species. The QI for the raccoon was 28.00, indicating a significant potential of risk to the raccoon inhabiting Site 73. Aluminum was the primary contributor of risk in the raccoon model. The risk is driven by aluminum concentrations in the surface soil, surface water, and fish collected from Site 73. Aluminum has a relatively high BCF value that is contributing to the high QI.

7.10.3 Threatened and Endangered Species

The American alligator is the only threatened or endangered species known to occur at Site 73. Due to elevated levels of some of the COPCs in the surface water and sediment, there is the potential for the alligator to be impacted by these contaminants. However, no toxicological data was located in the literature to quantitatively evaluate risk to the alligator.

7.10.4 Wetlands

Wetlands have been identified at Site 73. Several contaminants in the surface soil, some of which were in topography low areas that may be wetlands, did exceed plant SSSVs. In addition, samples were collected in the surface water and sediment in the water bodies adjacent to the wetlands and some COPCs exceeded SWSVs and SSVs. Therefore, potential impacts to aquatic and terrestrial receptors associated with these wetlands are evaluated in other sections of this ERA.

7.11 Uncertainty Analysis

The procedures used in this evaluation to assess risks to ecological receptors, as in all such assessments, are subject to uncertainties. The following subsections discuss some of the uncertainty in this ERA associated with the sampling methods, benthic macroinvertebrate interpretation, screening values, sediment quantitation limits, and terrestrial models.

7.11.1 Sampling Method

The ecological investigation consisted on one sampling effort. The results of this sampling only will provide a "snapshot in time" of the ecological environment. Because the biotic community can have a high amount of natural variability, the "snapshot" may not be an accurate representation of actual site conditions.

The chemical sampling program at Site 73 consisted of eleven surface water samples. Because there were less than 20 samples, contaminants could be eliminated because of infrequency. Therefore, contaminants not related to the site may have been retained as surface water COPCs and thus carried through the ERA.

There is uncertainty in the sampling method used to collect the benthic macroinvertebrates. A petite Ponar bottom grab sampler was used to collect these samples. The effectiveness of the Ponar depends upon the sediment type. The Ponar is less effective in hard, rocky sediment, or sediment containing organic debris that may prevent the Ponar from completely closing, than in soft muck sediment. Because the sediment types varied among stations, the effectiveness of the Ponar also would have varied.

7.11.2 Benthic Macroinvertebrate Interpretation

There is uncertainty in the interpretation of benthic macroinvertebrate data in attributing differences in species density, diversity, and similarities between stations and specific hazards. These differences may be the result of natural causes or qualities of the natural environment, such as stream velocity and sediment type, as well as tidal cycles that leave sediment exposed at low tides. In addition, not all of the species identified had adequate life history information available to classify them as opportunistic or equilibrium.

7.11.3 Screening Values

Potential adverse impacts to terrestrial flora and fauna were evaluated by comparing the COPC concentrations to surface soil benchmark values obtained in the literature. There is uncertainty assessing the terrestrial environment using these benchmark values. Most of these studies do not take into account the soil type, which may have a great influence on the toxicity of the contaminants. For example, soil with high organic carbon content will tend to absorb many of the organic COPCs, thus making them less bioavailable to terrestrial receptors. Also, various inorganic compounds in surface soil tend to have high degrees of variability. The variability of the inorganic concentrations in surface soil in turn magnifies the uncertainty associated with using the literature toxicity values to assess the risk posed to the terrestrial environment.

The majority of the organic surface soil flora and fauna benchmark values are USEPA BTAG screening levels. The reference studies for the BTAG screening levels for SVOCs do not apply to soil flora and fauna. In addition, the benchmark values established by ORNL are based on both field and growth chamber studies; therefore, the reported toxic concentrations are not always equivalent to actual field conditions. The majority of the benchmark values used for comparison purposes had low levels of confidence assigned to the values based on the low number of studies performed (less than ten studies) and the lack of diversity of species tested.

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

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

There is uncertainty in comparing tissue concentrations to fish collected at Site 73 to fish collected in other studies. In many cases, the fish that were collected at Site 73 were different species than the fish collected in the other studies. Many contaminants bioaccumulate differently in different species. Therefore, comparisons of contaminant concentrations of different fish may be misleading. Finally, there is limited data in the literature to assess potential impacts to fish from contaminants in their tissue.

The toxicity of chemical mixtures is not well understood. All the toxicity information used in the ERA for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals due to synergistic or antagonistic effects. In addition, the species that were used to develop the toxicity data may not be present at the site, or have the potential to exist at the site. Depending on the sensitivity of the tested species to the species at the site, use of the toxicity values may overestimate or underestimate risk. Many chemicals are not acutely toxic; however, they have the potential to bioaccumulate in ecological receptors through food chain transfer. This bioaccumulation potential typically is not taken into account when comparing contaminant concentrations to screening values.

Finally, toxicological data for several of the COPCs were limited or did not exist. Therefore, there is uncertainty in any conclusions involving the potential impacts to ecological receptors from contaminants.

7.11.4 Quantitation Limits

There is uncertainty associated with the quantitation limits reported for the SVOCs in the sediment samples. The high quantitation limits are a result of matrix interference created due to the elevated concentrations of fuel constituents (i.e., high molecular hydrocarbons) present in the sediment. The presence of these high molecular weight compounds, which were reported as tentatively identified compounds, resulted in the "masking" of target SVOC contaminants. Attempts to reduce the interference by performing reanalysis at elevated dilutions resulted in nondetects being reported at elevated quantitation limits for the SVOCs. Because of the elevated levels of fuel constituents, alternative methods for sample preparation or analysis would not result in significantly increasing the ability to resolve the target compound identification. Therefore, there is uncertainty in the actual presence of, and concentrations of SVOCs in the sediment collected from Site 73.

7.11.5 Terrestrial Models

There are some differences of opinion found in the literature as to the effectiveness of using models to predict concentrations of contaminants found in terrestrial species. According to one source, the food chain models currently used incorporate simplistic assumptions that may not represent conditions at the site, bioavailability of contaminants, or site-specific behavior of the receptors. Simple food chain models can provide an effective means of initial characterization of risk; however, residue analyses, toxicity tests, and the use of biomarkers provide a better approach for assessing exposure (Menzie et al., 1993).

There are several sources of uncertainty when using these models. First, most of the TRVs are based on toxicity data from another species, which is then extrapolated to the species of concern using a body-size scaling equation. Since the toxicity of all contaminants may not be proportional to body size, the calculated TRVs may not accurately predict risk to the species of concern. Another source of uncertainty with the models is that many of the input parameters are based on default values (i.e., ingestion rates) that may or may not adequately represent the actual values of the parameters. In addition, there is uncertainty in the level to which the indicator species will represent other species potentially exposed to COPCs at the site. There is uncertainty in the use of bioconcentration and biotransfer factors. Bioconcentration and biotransfer factors can vary widely from species to species. The species used in the calculation of the bioconcentration and biotransfer factors are different from the species that actually inhabit the site. Therefore, the use of the factors will tend to either overestimate or underestimate actual bioaccumulation of contaminants. Terrestrial species also will be exposed to contaminants by ingesting fauna that have accumulated contaminants. The modeling biomagnification within a food web compounds the uncertainty associated with a single species model. Finally, terrestrial species also will be exposed to contaminants in the sediments. However, currently, there is no guidance in the literature that can be used to evaluate this potential exposure pathway.

7.12 Conclusions

Overall, conditions at Site 73 potentially may adversely impact the aquatic and terrestrial ecosystems at the site. The following subsections provide an overview of potential risk to the ecological environment identified in this ERA.

7.12.1 Aquatic Ecosystem

As presented earlier in the ERA, the assessment endpoints for the aquatic receptors are differences (as compared to background) in the structure of benthic macroinvertebrate communities attributable to site-related contaminants and the potential reduction of an aquatic receptor population or subpopulation that is attributable to site-related contaminants. These assessment endpoints were evaluated using a series of measurement endpoints. This section of the ERA examines each of the measurement endpoints to determine if the assessment endpoints are impacted.

The first measurement endpoint is lower benthic macroinvertebrate species diversity and richness in the Site 73 stations when compared to an ecologically similar background location. The benthic species at the stations located in the tributaries to Courthouse Bay (73-BN01, 73-BN11, and 73-BN12) and several stations within the bay (73-BN02, 73-BN04, and 73-BN09) had lower indices than the background stations. This indicates that the benthic community at these stations may be adversely impacted by contaminants detected in the sediment. However, the shallow nature and tidal conditions of the tributary stations may also contribute a significant stress to the benthic community. In particular, the tributaries had no significant levels of contaminants detected in the sediment collected, indicating other stresses are contributing to poor benthic community. Of the stations within Courthouse Bay, only station 73-BN04 had high levels of pesticides detected in the sediment that may impact the benthic communities.

The second measurement endpoint is determining if the contaminant levels in the Site 73 biota tissue samples are elevated when compared to tissue samples collected at off-site background stations or in the literature. Several of the contaminants detected in the fish and crab tissues appeared to be slightly elevated above background studies and the NC Study. However, based on the relatively abundant and diverse fish population at Site 73, these contaminants do not appear to be significantly impacting the fish community from the visual observations. Other non-visual impacts (i.e., decrease in reproduction and growth) were not evaluated in this ERA.

The third measurement endpoint is determining if the contaminant levels in the Site 73 fish tissue samples exceed toxicity values in the literature. Tissue concentrations of arsenic, chromium, lead, and zinc were below toxicity concentrations located in the literature for aquatic and piscivorous wildlife. However, there are several inorganics detected in the fish tissue that there are no toxicological data available to evaluate the detected concentrations.

The last measurement endpoint is determining if the contaminant concentrations in the surface water and sediment exceed the contaminant-specific surface water and sediment effect concentrations (i.e., SWSVs, and SSVs). The inorganics in the surface water and sediment appear to have a low potential to adversely impact the aquatic receptor population.

The significant risk posed by the sediment is from pesticides detected at several stations within Courthouse Bay. The pesticides are not considered to site-related contaminants, but they are most likely remnants of past Base-wide pesticide application.

7.12.2 Terrestrial Ecosystem

As presented earlier in the ERA, the assessment endpoint for the terrestrial receptors is the potential reduction of a receptor population or subpopulation that is attributable to site-related contaminants. This section evaluates this assessment endpoint using the measurement endpoints.

The first measurement endpoint is determining if there are exceedances of contaminant-specific soil effect concentrations (i.e., SSSVs). Several inorganics (aluminum, chromium, iron, and vanadium) in the surface soil collected at Site 73 exceeded soil toxicity benchmark values. Most of the values exceeded were plant benchmark values. However, the flora community did not appear to be adversely impacted based on visual observations during the site investigations (i.e., stressed vegetation). However, the flora may be impacted in ways that are not visually apparent (i.e., reduced growth).

The second measurement endpoint is determining if the terrestrial CDI exceeds the TRVs. The CDI exceeds the TRV for the all five terrestrial species. However, the risk is higher for the raccoon. The risks in the terrestrial models were driven by aluminum, antimony, arsenic, and cadmium.

Overall, some potential impacts to soil invertebrates and plants may occur as a result of site-related contaminants. It should be noted that there is much uncertainty in the SSSVs. There is a slight potential for decrease in the terrestrial vertebrate population from site-related contaminants based on the terrestrial intake model. It is noted that aluminum concentrations detected in the surface soil exceed flora and fauna values, as well as contribute to risks in terrestrial models.

7.13 References

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SECTION 7.0 TABLES

TABLE 7-1

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO SURFACE SOIL BACKGROUND VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Twice the Average Background Surface Soil Concentration	Contaminant Frequency/Range		Ecological COPC?	Comments
		No. of Positive Detects/No. of Samples	Range of Positive Detections		
Volatiles (µg/kg):					
Acetone	NZ	2/35	24-29J	No	Lab. Contaminant
2-Butanone	NZ	4/35	2J-4.2J	No	Lab. Contaminant
Chlorobenzene	NZ	1/35	1J	No	Infrequently Detected
1,2-Dichloroethane	NZ	1/27	2J	No	Infrequently Detected
1,2-Dichloropropane	NZ	1/35	1J	No	Infrequently Detected
Ethylbenzene	NZ	1/35	8J	No	Infrequently Detected
Styrene	NZ	1/35	2J	No	Infrequently Detected
Toluene	NZ	1/35	1J	No	Infrequently Detected/ Lab. Contaminant
1,1,1-Trichloroethane	NZ	1/35	2J	No	Infrequently Detected
Trichloroethene	NZ	1/35	2J	No	Infrequently Detected
Xylenes (total)	NZ	10/30	1J-4J	Yes	
Semivolatiles (µg/kg):					
Acenaphthene	NZ	1/35	40J	No	Infrequently Detected
Anthracene	NZ	1/35	50J	No	Infrequently Detected
Benzo(a)anthracene	NZ	1/35	220J	No	Infrequently Detected
Benzo(a)pyrene	NZ	1/35	160J	No	Infrequently Detected
Benzo(b)fluoranthene	NZ	2/35	260J-330J	Yes	
Benzo(g,h,i)perylene	NZ	1/35	140J	No	Infrequently Detected
Bis(2-ethylhexyl)phthalate	NZ	9/35	42J-84J	No	Lab. Contaminant
Butylbenzylphthalate	NZ	1/35	110J	No	Infrequently Detected
4-Chloro-3-Methylphenol	NZ	1/35	36J	No	Infrequently Detected
Chrysene	NZ	3/35	60J-190J	Yes	
Di-n-butylphthalate	NZ	11/35	110J-510	Yes	
2,4-Dinitrophenol	NZ	4/34	56J-200J	Yes	
Fluoranthene	NZ	4/35	42J-380J	Yes	
Phenanthrene	NZ	1/35	260J	No	Infrequently Detected
Pyrene	NZ	5/35	41J-450	Yes	

TABLE 7-1

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO SURFACE SOIL BACKGROUND VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Twice the Average Background Surface Soil Concentration	Contaminant Frequency/Range		Ecological COPC?	Comments
		No. of Positive Detects/No. of Samples	Range of Positive Detections		
Volatiles (µg/kg):					
Acetone	NZ	2/35	24-29J	No	Lab. Contaminant
2-Butanone	NZ	4/35	2J-4.2J	No	Lab. Contaminant
Chlorobenzene	NZ	1/35	1J	No	Infrequently Detected
1,2-Dichloroethane	NZ	1/27	2J	No	Infrequently Detected
1,2-Dichloropropane	NZ	1/35	1J	No	Infrequently Detected
Ethylbenzene	NZ	1/35	8J	No	Infrequently Detected
Styrene	NZ	1/35	2J	No	Infrequently Detected
Toluene	NZ	1/35	1J	No	Infrequently Detected/ Lab. Contaminant
1,1,1-Trichloroethane	NZ	1/35	2J	No	Infrequently Detected
Trichloroethene	NZ	1/35	2J	No	Infrequently Detected
Xylenes (total)	NZ	10/30	1J-4J	Yes	
Semivolatiles (µg/kg):					
Acenaphthene	NZ	1/35	40J	No	Infrequently Detected
Anthracene	NZ	1/35	50J	No	Infrequently Detected
Benzo(a)anthracene	NZ	1/35	220J	No	Infrequently Detected
Benzo(a)pyrene	NZ	1/35	160J	No	Infrequently Detected
Benzo(b)fluoranthene	NZ	2/35	260J-330J	Yes	
Benzo(g,h,i)perylene	NZ	1/35	140J	No	Infrequently Detected
Bis(2-ethylhexyl)phthalate	NZ	9/35	42J-84J	No	Lab. Contaminant
Butylbenzylphthalate	NZ	1/35	110J	No	Infrequently Detected
4-Chloro-3-Methylphenol	NZ	1/35	36J	No	Infrequently Detected
Chrysene	NZ	3/35	60J-190J	Yes	
Di-n-butylphthalate	NZ	11/35	110J-510	Yes	
2,4-Dinitrophenol	NZ	4/34	56J-200J	Yes	
Fluoranthene	NZ	4/35	42J-380J	Yes	
Phenanthrene	NZ	1/35	260J	No	Infrequently Detected
Pyrene	NZ	5/35	41J-450	Yes	

TABLE 7-1 (Continued)

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS
COMPARED TO SURFACE SOIL BACKGROUND VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Twice the Average Background Surface Soil Concentration	Contaminant Frequency/Range		Ecological COPC?	Comments
		No. of Positive Detects/No. of Samples	Range of Positive Detections		
Pesticides/PCBs (µg/kg):					
alpha-Chlordane	NZ	1/29	2.5J	No	Infrequently Detected
gamma-Chlordane	NZ	2/29	3.3J-6.8J	Yes	
4,4'- DDD	NZ	7/29	7-82	Yes	
4,4'-DDE	NZ	3/29	3.9NJ-11J	Yes	
4,4'-DDT	NZ	2/29	2.8NJ-15J	Yes	
Endrin Ketone	NZ	1/29	7NJ	No	Infrequently Detected
Aroclor-1016	NZ	1/29	140NJ	No	Infrequently Detected
Aroclor-1260	NZ	1/29	170J	No	Infrequently Detected
Inorganics (mg/kg):					
Aluminum	5,941	35/35	147-10,600	Yes	
Barium	17.36	35/35	2.3-46.3	Yes	
Cadmium	0.69	5/35	1.1-1.9	Yes	
Calcium	1,397	35/35	69.3-40,200	No	Low Toxicity
Chromium	6.69	27/35	2.3-13.5J	Yes	
Cobalt	1.92	4/35	4.4-7.2	Yes	
Copper	7.20	15/35	2.4-9.2	Yes	
Iron	3,755	35/35	174-8,310J	Yes	
Lead	23.75	35/35	1.2-38.2	Yes	
Magnesium	205.75	35/35	14-789	No	Low Toxicity
Manganese	18.50	35/35	0.97-38.8J	Yes	
Potassium	199.6	7/35	215-473	No	Low Toxicity
Sodium	59.30	18/35	44-297	No	Low Toxicity
Vanadium	11.63	21/35	2.6-14.8	Yes	
Zinc	13.88	30/35	2.9J-197	Yes	

Notes:

NZ = Not Analyzed

TABLE 7-2

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO ESTUARINE SURFACE WATER SCREENING VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Surface Water Screening Values (SWSV)				Contaminant Frequency/Range					
		USEPA Region IV Water Quality Screening Values (WQSV)(2)								
Contaminant	North Carolina Water Quality Standards (WQS)(1)	Acute	Chronic	Average Reference Station Concentration	No. of Positive Detects/ No. of Samples	Range of Positive Detection	No. of Positive Detects Above Lowest SWSV	No. of Positive Detects Above the Average Reference Station Concentration	Ecological Contaminant of Concern?	Comments
Organics (µg/L):										
Acetone	500	NE	NE	ND	1/11	50	0	1	No	Below SWSL Lab. Contaminant
Chloroform	815	NE	NE	ND	1/11	3J	0	1	Yes	Terrestrial Concern
Toluene	37	NE	NE	ND	3/11	2J-5J	0	3	Yes	Terrestrial Concern
Inorganics (µg/L):										
Aluminum	NE	1,050(3)	5,000(4)	ND	4/11	74.6-500	0	0	Yes	Terrestrial Concern
Antimony	NE	1,050(5)	500(3)	ND	10/11	116-216	0	10	Yes	Terrestrial Concern
Barium	1,400	10,000(3)	NE	24	10/11	6.7-10.5	0	0	No	Below SWSL/ Below Background
Calcium	NE	NE	NE	134,025	11/11	9,410-283,000	NA	10	No	Low Toxicity
Iron	NE	NE	NE	317.8	11/11	245-4,540	NA	9	Yes	
Magnesium	NE	NE	NE	511,200	11/11	1,550-1,390,000	NA	9	No	Low Toxicity
Manganese	NE	NE	10(3)	ND	11/11	5.8-37.7	5	11	Yes	
Potassium	NE	NE	NE	207,250	10/11	293,000-388,000	NA	10	No	Low Toxicity

TABLE 7-2 (Continued)

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO ESTUARINE SURFACE WATER SCREENING VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Surface Water Screening Values (SWSV) North Carolina Water Quality Standards (WQS)$^{(1)}$	USEPA Region IV Water Quality Screening Values (WQSV)$^{(2)}$ Acute	Chronic	Average Reference Station Concentration	Contaminant Frequency/Range No. of Positive Detects/ No. of Samples	Range of Positive Detection	No. of Positive Detects Above Lowest SWSV	No. of Positive Detects Above the Average Reference Station Concentration	Ecological Contaminant of Concern?	Comments
Inorganics (µg/L) (continued):										
Silver	0.1	2.3	NE	19.1	1/11	6.4	1	0	No	Below Background
Sodium	NE	NE	NE	3,073,750	11/11	10,100-11,100,000	NA	10	No	Low Toxicity
Zinc	86	95	86	ND	10/11	12-103	1	10	Yes	

Notes:

NE = Not Established
NA = Not Applicable
ND = Not Detected
(1) NC DEHNR, 1994 (North Carolina Water Quality Standards)
(2) USEPA, 1995a (Region IV Toxic Substance Spreadsheet)
(3) USEPA, 1995b (Region III BTAG Screening Levels)
(4) USEPA, 1991 (Wall Chart) Lowest Observed Level
(5) USEPA, 1991 (Wall Chart) Lowest Proposed Value

TABLE 7-3

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO ESTUARINE SEDIMENT SCREENING VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Sediment Screening Values (SSV)			Average Reference Station Concentration	Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSV	No. of Positive Detect Above the Average Reference Concentration	Ecological Contaminant of Concern?	Comments
	ER-L[(4)]	ER-M[(1)]	SQC[(2)]		No. of Positive Detects/ No. of Samples	Range of Positive Detections				
Volatiles (μg/kg):										
Acetone	NE	NE	NE	ND	7/22	5J-280	NA	7	No	Lab. Contaminant
2-Butanone	NE	NE	NE	ND	2/22	4J-13J	NA	2	No	Lab. Contaminant
Carbon Disulfide	NE	NE	NE	ND	13/22	2J-75	NA	13	Yes	
Methylene Chloride	NE	NE	NE	ND	1/22	7J	NA	1	No	Infreq. Detected
Toluene	NE	NE	8.2	ND	2/22	1J-12J	1	2	Yes	
Xylenes (total)	NE	40[(3)]	38	ND	1/22	9J	0	1	No	Below SSV/ Infreq. Detected
Semivolatiles (μg/kg):										
Bis(2-ethylhexyl)phthalate	182	1,300[(3)]	940	ND	8/22	51J-1,900J	3	8	Yes	
Di-n-butylphthalate	NE	1,400[(3)]	15	ND	11/22	240J-680J	11	11	Yes	
Fluoranthene	113	5,100	7.7	ND	1/22	1,000J	1	1	No	Infreq. Detected
Phenanthrene	86.7	1,500	6.2	ND	1/22	940J	1	1	No	Infreq. Detected
Phenol	NE	420[(3)]	2.2	ND	1/22	150J	1	1	No	Infreq. Detected
Pyrene	153	2,600	298	ND	1/22	880J	1	1	No	Infreq. Detected

TABLE 7-3 (Continued)

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO ESTUARINE SEDIMENT SCREENING VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Sediment Screening Values (SSV)			Average Reference Station Concentration	Contaminant Frequency/Range		No. of Positive Detects Above Lowest SSV	No. of Positive Detect Above the Average Reference Concentration	Ecological Contaminant of Concern?	Comments
	ER-L(4)	ER-M(1)	SQC(2)		No. of Positive Detects/ No. of Samples	Range of Positive Detections				
Pesticides/PCBs (µg/kg):										
4,4'-DDD	2(4)	20(4)	0.02	3.4	6/22	4.2J-28	6	6	Yes	
4,4'-DDE	2.2(1)	27	0.11	ND	5/22	5.6J-17J	5	5	Yes	
Endrin	0.02	45(4)	0.004	ND	2/22	4.7-7.5J	2	2	Yes	
Aroclor-1260	22.7(5)	180(5)	0.01	ND	1/22	120J	1	1	No	Infreq. Detected
Inorganics (mg/kg):										
Aluminum	NE	NE	NE	9,864.3	21/22	431-28,100	NA	5	Yes	
Arsenic	7.24	70	NE	ND	9/22	3.3-14.1	2	9	Yes	
Barium	500(6)	NE	NE	12.4	21/22	1.3-27.8	0	5	No	Below SSV
Cadmium	0.676	9.6	NE	0.1	2/22	2.7J-6.1J	2	2	Yes	
Calcium	NE	NE	NE	2,932.9	21/22	483-27,800	NA	11	No	Low Toxicity
Chromium	52.3	370	NE	30.9	17/22	3.3-55.9	1	4	Yes	
Cobalt	NE	NE	NE	3.20	3/22	7.68-11.5	NA	3	Yes	
Copper	18.7	270	NE	ND	14/22	3.2-20.5	2	14	Yes	
Iron	27,000(7)	NE	NE	12,868.6	22/22	3.7-27,400	1	6	Yes	

TABLE 7-3 (Continued)

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS COMPARED TO ESTUARINE SEDIMENT SCREENING VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Sediment Screening Values (SSV)				Contaminant Frequency/Range					
Contaminant	ER-L(4)	ER-M(1)	SQC(2)	Average Reference Station Concentration	No. of Positive Detects/ No. of Samples	Range of Positive Detections	No. of Positive Detects Above Lowest SSV	No. of Positive Detect Above the Average Reference Concentration	Ecological Contaminant of Concern?	Comments
Inorganics (mg/kg) (continued):										
Lead	30.2	218	NE	5.8	22/22	3.3-47.7J	8	18	Yes	
Magnesium	NE	NE	NE	5,081.4	21/22	140-9,430	NA	4	No	Low Toxicity
Manganese	230(7)	NE	NE	45.7	21/22	3.4-137	0	6	No	Below SSV
Nickel	15.9	51.6	NE	10.2	5/22	6-19.7	2	4	Yes	
Potassium	NE	NE	NE	1,570.0	15/22	305-4,390	NA	6	No	Low Toxicity
Sodium	NE	NE	NE	ND	21/22	74.8-28,500	NA	21	No	Low Toxicity
Vanadium	NE	NE	NE	26.6	16/22	2.6-50.8	NA	4	Yes	
Zinc	124	410	NE	30.7	21/22	8-100	0	10	No	Below SSV

Notes:

NE = Not Established
ER-L - Effects Range Low
ER-M - Effects Range Median
SQC = Sediment Quality Criteria
NA = Not Applicable
(1) Long et.al., 1995

(3) USEPA, 1995c (Region III BTAG Screening Levels)
(4) USEPA, 1995a - (Region IV Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessments), unless otherwise noted
(5) Used Total PCB Value
(6) Sulliven et.al., 1985
(7) Tetra Tech Inc., 1986 (Apparent Effects Threshold Sediment Quality Values)

(2) Values were calculated using the following equation: SQC = Foc*Koc*FCV/1,000,000
Where:
Foc = Fraction of organic carbon in the sediments (used 26.1 mg/kg)
Koc = Organic carbon partition coefficient (chemical specific)
FCV = Final water chronic value (chemical specific)

TABLE 7-4

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS IN TISSUE SAMPLES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Contaminant Frequency/Range							
	Whole Body Samples		Fillet Samples		Crab Samples			
Contaminant	No. of Positive Detects/No. of Samples	Range of Positive Detections	No. of Positive Detects/No. of Samples	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Range of Positive Detections	Ecological COPC?	Comments
Volatiles (µg/kg):								
Acetone	4/5	11,000-540,000	8/8	6,400-140,000	5/6	2,500J-290,000	No	Lab. Contaminant
Methylene Chloride	NA	ND	1/8	1,100J	2/6	1,300J-17,000J	Yes	
Toluene	NA	ND	2/8	520J-580J	1/6	580J	Yes	
Semivolatiles (µg/kg):								
Di-n-Butylphthalate	NA	ND	1/8	4,400	2/6	2,000-2,200	Yes	
Pesticides (µg/kg):								
Endrin	NA	ND	1/8	9.8J	NA	ND	Yes	
Inorganics (mg/kg):								
Aluminum	2/5	9.2J-119J	NA	ND	NA	ND	Yes	
Arsenic	5/5	0.4J-2.4J	8/8	0.17J-3.3J	6/6	2.9J-4.6J	Yes	
Barium	3/5	0.34J-1.5J	1/8	0.04	2/6	0.054J-0.094J	Yes	
Calcium	5/5	334J-18,300J	8/8	183J-4,540J	6/6	549J-1,820J	No	Low Toxicity
Chromium	2/5	0.011-0.71	NA	ND	NA	ND	Yes	
Copper	2/5	1.1-1.3	6/8	0.43-1.1	6/6	4.4-6.6	Yes	
Iron	4/5	9.5J-137J	5/8	4.4J-9J	6/6	4.5J-7.1J	Yes	
Lead	2/5	0.27	1/8	0.07	1/6	0.08	Yes	
Magnesium	5/5	10.1J-550J	8/8	243J-424J	6/6	378J-456J	No	Low Toxicity
Manganese	5/5	0.15J-4.6J	8/8	0.08J-0.82J	6/6	0.15J-0.46J	Yes	

TABLE 7-4 (Continued)

FREQUENCY AND RANGE OF CONTAMINANT DETECTIONS IN TISSUE SAMPLES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Contaminant Frequency/Range						Ecological COPC?	Comments
	Whole Body Samples		Fillet Samples		Crab Samples			
	No. of Positive Detects/No. of Samples	Range of Positive Detections	No. of Positive Detects/No. of Samples	Range of Positive Detections	No. of Positive Detects/ No. of Samples	Range of Positive Detections		
Inorganics (mg/kg) (continued):								
Mercury	1/5	0.044J	4/8	0.063J-0.18J	3/6	0.042J-0.05J	No	Not detected in SW/ SD
Molybednum	2/5	0.15-0.22	NA	ND	NA	ND	No	Not detected in SW/SD
Potassium	NA	ND	8/8	3,060J-4,790J	6/6	2,130J-3,090J	No	Low Toxicity
Selenium	5/5	0.34-0.69	7/8	0.23-0.59	6/6	0.28-0.44	No	Not detected in SW/SD
Silver	NA	ND	NA	ND	5/6	0.12-0.25	Yes	
Sodium	NA	ND	8/8	544-1,030	6/6	3,400-4,860	No	Low Toxicity
Thallium	1/5	0.12	NA	ND	NA	ND	No	Not detected in SW/SD
Vanadium	2/5	0.022-2.3	NA	ND	NA	ND	Yes	
Zinc	5/5	0.51J-26.6J	8/8	4.2J-12.4J	6/6	23.6J-39.1J	Yes	

Notes:

NA = Not Applicable
ND = Not Detected
SW = Surface Water
SD = Sediment

TABLE 7-5

CONTAMINANTS OF POTENTIAL CONCERN IN EACH MEDIA
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

	Surface Water				Fish Samples		
Contaminant	Aquatic Receptor	Terrestrial Receptor	Sediment	Surface Soil	Fillet	Whole Body	Crab Samples
Volatiles: Carbon Disulfide			X				
Chloroform		X					
Methylene Chloride					X		X
Toluene		X	X		X		X
Xylenes (total)				X			
Semivolatiles: Benzo(b)fluoranthene				X			
Bis(2-ethylhexyl)phthalate			X				
Chrysene				X			
Di-n-Butylphthalate			X	X	X		X
2,4-Dinitrophenol				X			
Fluoranthene				X			
Pyrene				X			
Pesticides/PCBs: gamma-Chlordane				X			
4,4'-DDD			X	X			
4,4'-DDE			X	X			
4,4'-DDT				X			
Endrin			X		X		
Inorganics: Aluminum	X	X	X	X		X	
Antimony		X					
Arsenic			X		X	X	X
Barium				X	X	X	X
Cadmium			X	X			
Chromium			X	X		X	
Cobalt			X	X			
Copper			X	X	X	X	X
Iron	X	X	X	X	X	X	X
Lead			X	X	X	X	X
Manganese	X	X		X	X	X	X
Nickel			X				
Silver							X
Vanadium			X	X		X	
Zinc	X	X		X	X	X	X

TABLE 7-6

PHYSICAL/CHEMICAL CHARACTERISTICS OF THE COPCS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Potential Concern	BCF	Organic Carbon Partition Coefficient (mL/g)	Log Octanol/ Water Coefficient	Biotransfer Factors		
				B_v(1)(2)	B_r(1)(2)	B_b(1)(2)
Volatiles:						
Carbon Disulfide	ND	54(5)	2.0(6)	2.70+00	2.70+00	2.51e-06
Chloroform	3.75(3)	31(5)	1.9(6)	3.09e+00	3.09e+00	2.00-06
Toluene	10.70(3)	300(5)	2.8(6)	9.32e-01	9.32e-01	1.58e-05
Xylenes (total)	2.20(4)	240(5)	3.2(6)	5.48e-01	5.48e-01	3.98e-05
Semivolatiles:						
Benzo(b)fluoranthene	30(3)	550,000(5)	6.2(6)	1.01e-02	1.01e-02	3.98e-02
Bis(2-ethylhexyl)phthalate	130(3)	100,000(7)	7.3(6)	2.34e-03	2.34e-03	5.01e-01
Chrysene	30(3)	200,000(5)	5.7(6)	1.97e-02	1.97e-02	1.26e-02
Di-n-butylphthalate	89(3)	170,000(5)	4.6(6)	8.50e-02	8.50e-02	1.00e-03
2,4-Dinitrophenol	1.5(3)	16.6(5)	1.6(6)	4.60e+00	4.60e+00	1.00e-06
Fluoranthene	1,150(3)	100,000(8)	5.1(8)	4.40e-02	4.40e-02	3.90e-03
Pyrene	30(3)	38,000(5)	5.1(6)	4.37e-02	4.37e-02	3.16e-03
Pesticides/PCBs:						
gamma-Chlordane	14,100(3)	140,000(5)	6.4(6)	7.74e-03	7.74e-03	6.31e-02
4,4'-DDD	53,600(3)	770,000(5)	6.1(6)	1.15e-02	1.15e-02	3.16e-02
4,4'-DDE	53,600(3)	4,400,000(5)	6.8(6)	4.55e-02	4.55e-02	1.26e-02
4,4'-DDT	53,600(3)	243,000(5)	6.5(6)	6.78e-03	6.78e-03	7.94e-02
Endrin	3,970(3)	69,183(9)	5.1(6)	4.37e-02	4.37e-02	3.16e-03
Inorganics:						
Aluminum	231(4)	ND	ND	4.00e-03	6.50e-04	1.50e-03
Antimony	1(3)	ND	ND	2.00e-01	3.00e-02	1.00e-03
Arsenic	44(3)	ND	ND	4.00e-02	6.00e-03	2.00e-03
Barium	8(4)	ND	ND	1.50e-01	1.50e-02	1.50e-04
Cadmium	64(3)	ND	ND	5.50e-01	1.50e-01	5.50e-04
Chromium	16(3)	ND	ND	7.50e-03	4.50e-03	5.50e-03
Cobalt	40(4)	ND	ND	2.00e-02	7.00e-03	2.00e-02
Copper	36(3)	ND	ND	4.00e-01	2.50e-01	1.00e-02
Iron	ND	ND	ND	4.00e-03	1.00e-03	2.00e-02
Lead	49(3)	ND	ND	4.50e-02	9.00e-03	3.00e-04

TABLE 7-6 (Continued)

PHYSICAL/CHEMICAL CHARACTERISTICS OF THE COPCS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Potential Concern	BCF	Organic Carbon Partition Coefficient (mL/g)	Log Octanol/ Water Coefficient	Biotransfer Factors		
				B_v (1)(2)	B_r (1)(2)	B_b (1)(2)
Inorganics (continued):						
Manganese	35(4)	ND	ND	2.50e-01	5.00e-02	4.00e-04
Silver	0.5(3)	ND	ND	4.00e-01	1.00e-01	3.00e-03
Vanadium	ND	ND	ND	5.50e-03	3.00e-03	2.50e-03
Zinc	47(3)	ND	ND	1.50e+00	9.00e-01	1.00e-01

Notes:

(1) Baes et.al., 1984 for the inorganics
(2) The organics were calculated using Travis, 1988
(3) USEPA, 1995b (Region IV)
(4) USEPA, 1995c (Region III)
(5) USEPA, 1986.
(6) SCDM, 1996. (Accessed from the Internet November 1997)
(7) Montgomery and Welkon, 1990.
(8) USEPA, 1993e (Sediment Quality Criteria for Fluoranthene)
(9) USEPA, 1993h (Sediment Quality Criteria for Endrin)

BCF	Bioconcentration Factor
ND	No Data
B_v	Biotransfer factor for vegetation (stems, leaves)
B_r	Biotransfer factor for vegetation (berries, fruits)
B_b	Biotransfer factor for beef

TABLE 7-7

SAMPLING STATION CHARACTERIZATION SUMMARY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Station	Stream Width (ft)	Stream Depth (ft)	Canopy Cover	Sediment Description	Sediment Odor
73-SW/SD/BN01	5	1	Partly Open	Brown/gray silty sand with much organic material, very slight oil sheen	Normal
73-SWSD/BN02	3-5	0.4	Partly Open	Gray/brown/black fine silty/sand, slight oil sheen	Petroleum
73-SWSD/BN03	NM	1	Open	Silty/fine sand and some organic material	Normal
73-SWSD/BN04	NM	3	Open	Mostly fine sand with some coarse sand/gravel	Anaerobic
73-SWSD/BN05	NM	1	Open	Mostly fine sand with some medium/coarse sand, slight oils	Anaerobic
73-SWSD/BN06	NM	1	Open	Fine sand with some shell fragments	Petroleum
73-SWSD/BN07	NM	1	Open	Fine sand with some shell fragments	Anaerobic
73-SWSD/BN08	NM	7	Open	Fine silty sand with some gravel and shell fragments, very slight oil sheen	Anaerobic
73-SWSD/BN09	NM	8	Open	Very fine silt	Anaerobic
73-SWSD/BN11	3-4	1	Open	Silty with much organic material (roots, plants)	Anaerobic
73-SWSD/BN12	100	1	Open	Very fine brown silt/sand	Anaerobic

Notes:

NM = Not measured due to large size of the Courthouse Bay
SW = Surface water sample
SD = Sediment sample
BN = Benthic macroinvertebrate sample

TABLE 7-8

FIELD CHEMISTRY DATA
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Station	Temperature (°C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Conductivity (umhos/cm)	Salinity (ppt)
73-SW/SD01	23	6.06	3.8	145	0
73-SW/SD02	19.5	6.91	7.4	36,000	28.5
73-SW/SD03	24.7-28.5	8.04-8.36	8.8-9.1	46,000-48,000	31.8-32
73-SW/SD04	23.1-26	7.92-8.34	8.1-9.4	40,500-45,500	29-31.1
73-SW/SD05	22.9-27.2	8.03-8.48	8.9-9.4	44,000	30-31
73-SW/SD06	22.7-24.8	7.9-8.17	8.5-9.1	43,500-45,000	31-31.8
73-SW/SD07	21.7-29.6	7.98-8.23	8.2-8.8	43,500-47,900	32-33
73-SW/SD08	22.2-24.9	7.41-8.42	1.6-8.7	43,500-46,600	30.5-31
73-SW/SD09	21.6-25.6	7.85-8.47	1.2-9.1	44,000-46,000	31-32
73-SW/SD11	25.4	8.0	6.9	46,000	32
73-SW/SD12	25.4	8.13	9.0	45,500	31

Notes:

°C = Degrees Centigrade
mg/L = Miligrams per Liter
S.U. = Standard Units
umhos/cm = Micromhos per centimeter
ppt = Parts Per Thousand

TABLE 7-9

AQUATIC ORGANISM COLLECTION SUMMARY
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Fish Species	Number of Aquatic Organisms per Station			
	Trawling	73-FS01	73-FS02	73-FS03
Atlantic Croaker	4		1	1
Atlantic Menhaden		2	2	
Banded Rudderfish	1			
Bay Anchovy	8			
Bluefish		2	1	
Butterfish	1			
Pigfish	1			
Pinfish	175	6	3	
Southern Flounder	2	6	10	5
Spanish Mackeral			2	
Spot	26			
Spotted Seatrout			1	
Stripped Mullet				2
Yellowfin Menhaden	1	1	5	1
Non-Fish Species				
Blue Crab	8	22	21	19
Pink Shrimp	5-10			
Mantis Shrimp	5-10			
Brief Squid	approximately 30			
Unidentified Elasmobranch (skate or ray)			1	

TABLE 7-10

FISH DISTRIBUTION AND CHARACTERIZATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Common Name	Scientific Name	Length range (cm)	Water Type	Habitat	Tolerance	Family	Sources
Atlantic Croaker	Micorpogonias undulatus	to 61	Estuaries, brackish or maine	Cool water migrant	NA	Scianidae	1,2,5
Atlantic Menhaden	Brevoortia tyrannus	to 46	Brackish or marine, enters freshwater	Rivers, streams	Intermediate	Clupeidae	1,2,3,4
Banded Rudderfish	Seriola zonata	to 60	Marine	Coastal waters	NA	Carangidae	5
Bay Anchovy	Anchoa mitchilli	to 15	Marine	Shallow coastal waters	NA	Engraulidae	2
Bluefish	Pomatomus saltatrix	to 1,100	Marine	Surface waters, near shore and off-shore	NA	Pomatomidae	2
Butterfish	Peprilus triacanthus	to 30	Marine	Surface waters, near shore and off-shore	NA	Stromateidae	2
Pigfish	Orthopristis chrysoptera	to 38	Marine	Bays, coastal waters	NA	Haemulidae	5
Pinfish	Lagodon rhomboides	to 38	Marine, seldom enters freshwater	Shallow waters	NA	Sparidae	1,2
Southern Flounder	Paralichthys lethostigma	to 91	Marine, enters freshwater	Over mud in estuaries and coastal waters	NA	Bothidae	2,5
Spanish Mackeral	Scomberomorus maculatus	to 97	Marine	Near shore in bays and estuaries	NA	Scombridae	3
Spot	Leiostomas xanthurus	NA	Brackish or marine, enters freshwater	NA	NA	Sciaenidae	1

TABLE 7-10 (Continued)

FISH DISTRIBUTION AND CHARACTERIZATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Common Name	Scientific Name	Length range (cm)	Water Type	Habitat	Tolerance	Family	Sources
Spotted Seatrout	Cynoscion nebulosus	to 71	Marine	Juveniles in estuaries, tidal mud flats, grass beds, and salt marshes, larger specimens in shallow coastal waters over sand	NA	Scianidae	3
Stripped Mullet	Mugil cephalus	23-35	Brackish or marine, enters freshwater	Rivers	NA	Mugilidae	1,2
Yellowfin Menhaden	Brevoortia smithi	to 33	Brackish or marine, enters freshwater	Rivers, streams	NA	Clupeidae	5

Notes:

1 Menhinick, 1992.
2 Boschung et.al., 1983
3 USEPA, 1989d.
4 Raasch, 1991.
5 Robbins and Ray, 1986

NA - Not Available

TABLE 7-11

NUMBER AND PERCENTAGE OF BENTHIC MACROINVERTEBRATE SPECIES PER STATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Taxon	73-BN01	73-BN02	73-BN03	73-BN04	73-BN05	73-BN06	73-BN07	73-BN08	73-BN09	73-BN11	73-BN12
Nemertinea			1(0.8)								
Anopla											
Heteronemertea											
Lineidae											
Micrura leidyi								3(1.4)			1(1.4)
Annelida											
Oligochaeta											
Tubificida											
Tubificidae											
Limnodrilus hoffmeisteri	9(13.6)										
Polychaeta											
Phyllodocida											
Goniadidae											
Glycinde solitaria							5(2.3)	1(0.5)	5(8.2)		
Hesionidae											
Gyptis vittata								1(0.5)			
Nereidae											
Ceratonereis tridentata		13(7.5)	64(48.5)		58(38.7)	37(34.9)	54(24.8)				
Neanthes succinea					1(0.7)						
Phyllodocidae											
Eteone lactea			3(2.3)								
Capitellida											
Capitellidae											
Capitella capitata	3(4.5)	151(86.8)	18(13.6)		28(18.7)	57(53.8)	14(6.4)	48(22.7)	1(1.6)	5(100)	67(90.5)
Heteromastus filiformis			1(0.8)		6(4.0)	8(7.5)	9(4.1)	1(0.5)			
Spionida											
Spionidae											
Polydora cornuta		10(5.7)	1(0.8)				1(0.5)				

TABLE 7-11 (Continued)

NUMBER AND PERCENTAGE OF BENTHIC MACROINVERTEBRATE SPECIES PER STATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Taxon	73-BN01	73-BN02	73-BN03	73-BN04	73-BN05	73-BN06	73-BN07	73-BN08	73-BN09	73-BN11	73-BN12
Streblospio benedicti			26(19.7)		18(12.0)	1(0.9)	57(26.1)	127(60.2)	49(80.3)		
Ariciida											
Orbiniidae											
Leitoscoloplos fragilis			10(7.6)		4(2.7)	1(0.9)	1(0.5)	4(1.9)	6(9.8)		6(8.1)
Cirratulida											
Cirratulidae											
Tharyx setigera			8(6.1)		35(23.3)	2(1.9)	65(29.8)	4(1.9)			
Paraonidae											
Aricidea (acmira) catherinae								1(0.5)			
Eunicida											
Arabellidae											
Drilonereis longa							1(0.5)				
Dorvilleidae											
Stauronereis ruldolphi								1(0.5)			
Lumbrinereidae											
Scoletoma sp.							1(0.5)				
Arthropoda											
Insecta											
Diptera											
Chaoboridae											
Chaoborus sp.	51(77.3)										
Chironomidae											
Chironomus sp.	3(4.5)										

TABLE 7-11 (Continued)

NUMBER AND PERCENTAGE OF BENTHIC MACROINVERTEBRATE SPECIES PER STATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Taxon	73-BN01	73-BN02	73-BN03	73-BN04	73-BN05	73-BN06	73-BN07	73-BN08	73-BN09	73-BN11	73-BN12
Hemichordata											
Enteropneusta											
Harrimaniidae											
Saccoglossus kowalewskii							8(3.7)	17(8.1)			
Mollusca											
Bivalvia											
Veneroida								1(0.5)			
Mactridae											
Mulinia lateralis							1(0.5)				
Tellinidae											
Tellina agilis								1(0.5)			
Veneridae											
Gemma gemma				1(100)			1(0.5)	1(0.5)			

TABLE 7-12

TOLERANCE VALUES OF BENTHIC MACROINVERTEBRATE SPECIES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Taxon	USEPA Tolerance Values(1)		NCDEHNR Biotic Index(2)
	Metals	Organic Waste	
Nemertinea			
Anopla			
Heteronemertea			
Lineidae			
Micrura leidyi	NA	NA	NA
Annelida			
Oligochaeta			
Tubificida			
Tubificidae			
Limnodrilus hoffmeisteri	NA	5	9.4
Polychaeta			
Phyllodocida			
Goniadidae			
Glycinde solitaria	NA	NA	NA
Hesionidae			
Gyptis vittata	NA	NA	NA
Nereidae			
Ceratonereis tridentata	NA	NA	NA
Neanthes succinea	NA	NA	NA
Phyllodocidae			
Eteone lactea	NA	NA	NA
Capitellida			
Capitellidae			
Capitella capitata	NA	NA	NA
Heteromastus filiformis	NA	NA	NA
Spionida			
Spionidae			
Polydora cornuta	NA	NA	NA
Streblospio benedicti	NA	NA	NA
Ariciida			
Orbiniidae			
Leitoscoloplos fragilis	NA	NA	NA
Cirratulida			
Cirratulidae			
Tharyx setigera	NA	NA	NA
Paraonidae			
Aricidea (acmira) catherinae	NA	NA	NA
Eunicida			

TABLE 7-12 (Continued)

TOLERANCE VALUES OF BENTHIC MACROINVERTEBRATE SPECIES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Taxon	USEPA Tolerance Values(1)		NCDEHNR Biotic Index(2)
	Metals	Organic Waste	
Arabellidae			
Drilonereis longa	NA	NA	NA
Dorvilleidae			
Stauronereis ruldolphi	NA	NA	NA
Lumbrinereidae			
Scoletoma sp.	NA	NA	NA
Arthropoda			
Insecta			
Diptera			
Chaoboridae			
Chaoborus sp.	NA	NA	NA
Chironomidae			
Chironomus sp.	NA	NA	9.6
Hemichordata			
Enteropneusta			
Harrimaniidae			
Saccoglossus kowalewskii	NA	NA	NA
Mollusca			
Bivalvia			
Veneroida			
Mactridae			
Mulinia lateralis	NA	NA	NA
Tellinidae			
Tellina agilis	NA	NA	NA
Veneridae			
Gemma gemma	NA	NA	NA

Notes:

(1) - USEPA, 1990
(2) - Lenat, 1993
NA = Not Available
Organic Ranking = 0 to 5 with 0 being the least tolerant to organic wastes

TABLE 7-13

SUMMARY STATISTICS OF BENTHIC MACROINVERTEBRATE SPECIES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Station	Number of Species	Number of Individuals	Species Density (#/m^2)	Brillouin's Species Diversity	Shannon-Wiener Species Diversity	Macroinvertebrate Biotic Index
Site 73 Stations:						
73-BN01	4	66	947	0.29	0.33	NC
73-BN02	3	174	2,497	0.20	0.21	NC
73-BN03	9	132	842	0.61	0.65	NC
73-BN04	1	1	6	0.00	0.00	NC
73-BN05	7	150	957	0.70	0.67	NC
73-BN06	6	106	676	0.52	0.46	NC
73-BN07	13	217	1,384	0.71	0.74	NC
73-BN08	14	211	1,346	0.51	0.55	NC
73-BN09	4	61	389	0.26	0.29	NC
73-BN11	1	5	32	0.00	0.00	NC
73-BN12	3	74	472	0.14	0.15	NC
Off-Site Background Station:						
HM03	7	97	618	0.50	0.54	9.6
HC03	8	244	1,555	0.68	0.68	NC

Notes:

#/m^2 = Total number of individuals per square meter
NC = MBI was not calculated since most of the species do not have biotic index values

TABLE 7-14

RESULTS OF THE JACCARD COEFFICIENT (S_J) AND THE SΦRENSON INDEX (S_S) FOR COMMUNITY SIMILARITY BETWEEN SITE STATIONS AND BACKGROUND STATIONS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJUENE, NORTH CAROLINA

S_J

S_S

Stations	73-BN01	73-BN02	73-BN03	73-BN04	73-BN05	73-BN06	73-BN07	73-BN08	73-BN09	73-BN11	73-BN12	HC03	HM03
73-BN01	NA	0.17	0.08	0.00	0.10	0.11	0.06	0.06	0.14	0.25	0.17	0.00	0.10
73-BN02	0.29	NA	0.33	0.00	0.25	0.29	0.23	0.06	0.17	0.33	0.20	0.00	0.00
73-BN03	0.15	0.50	NA	0.00	0.60	0.67	0.47	0.28	0.30	0.11	0.20	0.08	0.14
73-BN04	0.00	0.00	0.00	NA	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.00	0.00
73-BN05	0.18	0.40	0.75	0.00	NA	0.86	0.43	0.31	0.38	0.14	0.25	0.15	0.27
73-BN06	0.20	0.44	0.80	0.00	0.92	NA	0.46	0.33	0.43	0.17	0.29	0.08	0.30
73-BN07	0.12	0.38	0.64	0.14	0.60	0.63	NA	0.42	0.31	0.08	0.14	0.05	0.25
73-BN08	0.11	0.12	0.43	0.13	0.48	0.50	0.59	NA	0.29	0.07	0.21	0.15	0.22
73-BN09	0.25	0.29	0.46	0.00	0.55	0.60	0.47	0.44	NA	0.25	0.40	0.00	0.22
73-BN11	0.40	0.50	0.20	0.00	0.25	0.29	0.14	0.13	0.40	NA	0.33	0.00	0.00
73-BN12	0.29	0.33	0.33	0.00	0.40	0.44	0.25	0.35	0.57	0.50	NA	0.10	0.25
HC03	0.00	0.00	0.12	0.00	0.29	0.14	0.10	0.17	0.00	0.00	0.18	NA	0.25
HM03	0.18	0.00	0.25	0.00	0.29	0.31	0.32	0.27	0.18	0.00	0.00	0.40	NA

Notes:

BN = Benthic Macroinvertebrate Sample
NA = Not Applicable
Values presented above "NA" are S_j values
Values presented below "NA" are S_s values

TABLE 7-15

SUMMARY OF BIOTA SAMPLES SENT TO LABORATORY FOR CHEMICAL ANALYSIS
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Sample Number	Species	Sample Analysis	Trophic Level
73-FS01-BC01F	Blue Crab	Edible Portion	Omnivore
73-FS01-BC02F	Blue Crab	Edible Portion	Omnivore
73-FS01-BF01F	Bluefish	Fillet	Piscivore
73-FS01-SF01W	Southern Flounder	Whole Body	Piscivore
73-FS01-SF01F	Southern Flounder	Fillet	Piscivore
73-FS02-BC01F	Blue Crab	Edible Portion	Omnivore
73-FS02-BC02F	Blue Crab	Edible Portion	Omnivore
73-FS02-YM01W	Yellowfin Menhaden	Whole Body	Plantivore
73-FS02-SF01W	Southern Flounder	Whole Body	Piscivore
73-FS02-SF01F	Southern Flounder	Fillet	Piscivore
73-FS02-SS01F	Spotted Sea Trout	Fillet	Piscivore
73-FS02-SPM01F	Spanish Mackeral	Fillet	Piscivore
73-FS02-PF01W	Pinfish	Whole Body	Omnivore
73-FS03-BC01F	Blue Crab	Edible Portion	Omnivore
73-FS03-BC02F	Blue Crab	Edible Portion	Omnivore
73-FS03-AC01F	Atlantic Croaker	Fillet	Omnivore
73-FS03-SF01F	Southern Flounder	Fillet	Piscivore
73-FS03-SM01F	Stripped Mullet	Fillet	Plantivore
73-FS03-YM01W	Yellowfin Menhaden	Whole Body	Plantivore

TABLE 7-16

COMPARISON OF CONTAMINANT LEVELS IN SITE 73 TISSUE SAMPLES
TO CONTAMINANT LEVELS IN TISSUE COLLECTED IN OTHER STUDIES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Site 73 Fish Whole Body Concentrations(1)	NC Study Fish Whole Body Concentrations(2)	Site 73 Fish Fillet Concentration(1)	Off-Site Background Fish Fillet Concentrations	Site 73 Crab Tissue Concentrations	Off-Site Background Crab Tissue Concentrations
Volatiles (µg/kg):						
Methylene Chloride	ND	NA	1,100J(AC)	3J-41	1,300J-17,000J	110J-220J
Toluene	ND	NA	520J-580J(AC)	ND	580J	ND
Semivolatiles (µg/kg):						
Di-n-Butylphthalate	ND	NA	4,400(AC)	ND	2,000-2,200	ND
Pesticides (µg/kg):						
Endrin	ND	ND	9.8J(SS)	ND	ND	ND
Inorganics (mg/kg):						
Aluminum	9.2J-119J(YM)	NA	ND	36.5	ND	ND
Arsenic	0.4J-2.4J(YM)	NA	0.17J-3.3J(SF)	0.34L-3.9L	2.9J-4.6J	0.39-0.68
Barium	0.34J-1.5J(YM)	NA	0.04(SM)	ND	0.054J-0.094J	10.1
Chromium	0.011-0.71(YM)	0.45-9.73	ND	0.21L-0.68L	ND	0.52L
Copper	1.1-1.3(YM)	1.43-5.33	0.43-1.1(SPM)	0.18J-0.46J	4.4-6.6	5.8-7.9
Iron	9.5J-137J(YM)	NA	4.4J-9J(SPM)	ND	4.5J-7.1J	ND
Lead	0.27(YM)	0.04-1.15	0.07(BF)	ND	0.08	ND
Manganese	0.15J-4.6J(YM)	NA	0.08J-0.82J(SS)	0.08J-0.38	0.15J-0.46J	1.8-13.6

TABLE 7-16 (Continued)

COMPARISON OF CONTAMINANT LEVELS IN SITE 73 TISSUE SAMPLES TO CONTAMINANT LEVELS IN TISSUE COLLECTED IN OTHER STUDIES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Site 73 Fish Whole Body Concentrations[1]	NC Study Fish Whole Body Concentrations[2]	Site 73 Fish Fillet Concentration[1]	Off-Site Background Fish Fillet Concentrations	Site 73 Crab Tissue Concentrations	Off-Site Background Crab Tissue Concentrations
Inorganics (mg/kg) (continued):						
Silver	ND	NA	ND	ND	0.12-0.25	ND
Vanadium	0.022-2.3(YM)	NA	ND	ND	ND	ND
Zinc	0.51J-26.6J(PF)	44.9-67.7	4.2J-12.4J(BF)	3.9-6.5	23.6J-39.1J	17.9-25

Notes:

[1] Species in parenthesis is sample with the highest detection
[2] Pamlico Sound Study (Benkert, 1992)

AC = Atlantic Croaker
BF = Bluefish
PF = Pinfish
SF = Summer Flounder
SPM = Spanish Mackeral
SS = Spotted Seatrout
YM = Yellowfin Menhaden
NA = Not Analyzed
ND = Not Detected

TABLE 7-17

CONTAMINANT DETECTIONS COMPARED TO SOIL FLORA AND FAUNA TOXICITY VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Background Dutch Soil Values(3)	Soil Flora and Fauna Toxicity Values(1)				No. of Exceedences of Dutch Values/No. of Detects	No. of Exceedances of Other Toxicity Values/No. of Detects	Range of Positive Detections	UCL
		Plant	Earthworm	Invertebrate	Microorganisms and Microbial Processes				
Volatiles (µg/kg):									
Xylenes (total)	50	NE	<100(2)	<100(2)	NE	NA	0/10	1J-4J	4*
Semivolatiles (µg/kg):									
Benzo(b)fluoranthene	NE	NE	100(2)	100(2)	NE	NA	2/2	260J-330J	330*
Chrysene	NE	NE	100(2)	100(2)	NE	NA	1/3	60J-190J	190*
Di-n-butylphthalate	NE	200,000	NE	NE	NE	NA	0/11	110J-510	510*
2,4-Dinitrophenol	20(4)	20,000	100(2)	100(2)	NE	4/4	2/4	56J-200J	200*
Fluoranthene	100	NE	100(2)	100(2)	NE	3/4	3/4	42J-380J	380*
Pyrene	100	NE	100(2)	100(2)	NE	3/5	3/5	41J-450	450*
Pesticides/PCBs (µg/kg):									
gamma-chlordane	100(5)	NE	<100(2)	<100(2)	NE	0/2	0/2	3.3J-6.8J	1.43
4,4'-DDD	100(5)	NE	<100(2)	<100(2)	NE	0/7	0/7	7-82	10.93
4,4'-DDE	100(5)	NE	<100(2)	<100(2)	NE	0/3	0/3	3.9NJ-11J	2.74
4,4'-DDT	100(5)	NE	<100(2)	<100(2)	NE	0/2	0/2	2.8NJ-15J	2.59
Inorganics (mg/kg):									
Aluminum	20	50	NE	NE	600	35/35	35/35	147-10,600	3,492.83
Barium	200	500	440(2)	440(2)	3,000	0/35	0/35	2.3-46.3	12.03
Cadmium	1	3	20	3	20	5/5	0/5	1.1-1.9	0.80
Chromium	100	1	0.4	NE	10	0/27	27/27	2.3-13.5J	6.96
Cobalt	20	20	200(2)	200(2)	1,000	0/4	0/4	4.4-7.2	3.11
Inorganics (mg/kg) (continued):									
Copper	50	100	50	20	100	0/15	0/15	2.4-9.2	2.98
Iron	NE	3,260(2)	NE	3,515	200	NA	32/35	174-8,310J	2,675.75

TABLE 7-17 (Continued)

CONTAMINANT DETECTIONS COMPARED TO SOIL FLORA AND FAUNA TOXICITY VALUES
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Background Dutch Soil Values[3]	Soil Flora and Fauna Toxicity Values[1]				No. of Exceedences of Dutch Values/No. of Detects	No. of Exceedances of Other Toxicity Values/No. of Detects	Range of Positive Detections	UCL
		Plant	Earthworm	Invertebrate	Microorganisms and Microbial Processes				
Lead	50	50	500	300	900	0/35	0/35	1.2-38.2	17.71
Manganese	NE	500	330[2]	330[2]	100	NA	0/35	0.97-38.8J	11.24
Vanadium	NE	2	58[2]	58[2]	20	NA	21/21	2.6-14.8	4.37
Zinc	200	50	200	500	100	0/30	3/30	2.9J-197	34.5

Notes:

UCL = 95% Upper Confidence Level
NE = Not established
* = Maximum value (UCL was higher than the maximum value)
µg/kg = micrograms per kilogram
mg/kg = milligrams per kilogram

[1] Will and Suter, 1994a 1994b, and 1995 unless indicated otherwise (Values presented for plants, earthworms, microorganisms and microbial processes are benchmarks below which adverse impacts to these species are not expected values for invertebrates are no observed effects concentrations, they are based on less data than the benchmarks)

[2] USEPA, 1995c (Soil Screening Values for Soil Fauna)

[3] Richardson, 1987 (Dutch Soil Criteria)

[4] Value for phenols

[5] Value for total pesticides

TABLE 7-18

EXPOSURE PARAMETERS FOR CHRONIC DAILY INTAKE MODEL
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Exposure Parameter	Units	White-Tailed Deer	Eastern Cottontail Rabbit	Bobwhite Quail	Red Fox	Raccoon	Small Mammal (Meadow Vole)
Food Source Ingestion	NA	Vegetation 100%	Vegetation 100%	Vegetation 100%	Small Mammals 80% Vegetation 20%	Vegetation 40% Fish 60%	Vegetation 100%
Feeding Rate	kg/day	1.6$^{(2)}$	0.237$^{(4)}$	0.0135$^{(3)}$	0.601$^{(3)}$	0.214$^{(6)}$	0.112$^{(3)}$
Incident Soil Ingestion	kg/day	0.0185$^{(1)}$	0.0057$^{(5)}$	0.0011$^{(5)}$	0.0168$^{(5)}$	0.0201$^{(5)}$	0.00269$^{(5)}$
Rate of Drinking Water Ingestion	L/day	1.1$^{(2)}$	0.119$^{(3)}$	0.0191$^{(3)}$	0.385$^{(3)}$	0.422$^{(3)}$	0.0652$^{(3)}$
Rate of Vegetation Ingestion	kg/day	1.6	0.237	0.0135	0.12	0.086	0.112
Body Weight	kg	45.4$^{(2)}$	1.229$^{(3)}$	0.174$^{(3)}$	4.54$^{(3)}$	5.12$^{(3)}$	0.3725$^{(3)}$
Rate of Small Mammal Ingestion	kg/day	NA	NA	NA	0.48	NA	NA
Rate of Fish Ingestion	kg/day	NA	NA	NA	NA	0.128	NA
Home Range Size	acres	454$^{(2)}$	9.30$^{(3)}$	26.24$^{(3)}$	1,245$^{(3)}$	257$^{(3)}$	0.032$^{(3)}$

Notes:

(1) Arthur and Alldridge, 1979
(2) Dee, 1991
(3 USEPA, 1993c
(4) Opresko, *et.al.*, 1994
(5) Beyer, 1993
(6) Nagy, 1987
NA - Not Applicable

TABLE 7-19

SURFACE WATER QUOTIENT INDICIES PER STATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Station	Concentration (µg/L)	Quotient Indicies		
			North Carolina WQS	USEPA SWSV	
				Acute	Chronic
Total Inorganics (µg/L):					
Manganese	73-SW01-01	25.3	NA	NA	2.53
	73-SW02-01	37.7	NA	NA	3.77
	73-SW06-01	10.7	NA	NA	1.07
	73-SW11-01	11.3	NA	NA	1.13
	73-SW12-01	10.7	NA	NA	1.07
Zinc	73-SW04-01	103	1.20	1.08	1.20

Notes:

Shaded boxes are Quotient Indices that exceed "1".

SW = Surface Water
WQS = Water Quality Standard
SWSV = Surface Water Screening Value
µg/L = micrograms per liter
NA = Not Applicable

TABLE 7-20

SURFACE WATER QUOTIENT INDICIES PER CONTAMINANT OF POTENTIAL CONCERN
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION, CTO-312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Log Normal UCL Concentration (µg/L)	UCL Quotient Index		
		North Carolina WQS	USEPA SWSV	
			Acute	Chronic
Total Inorganics (µg/L):				
Manganese	19.24	NA	NA	1.92
Zinc	97.29	1.13	1.02	1.13
Total QI		1.13	2.02	3.05

Notes:

Shaded boxes are Quotient Indices that exceed "1"

SW = Surface Water
WQS = Water Quality Standard
SWSV = Surface Water Screening Value
UCL = Upper Confidence Level
µg/L = micrograms per liter
NA = Not Applicable

TABLE 7-21

SEDIMENT QUOTIENT INDICES PER STATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Station	Sample Concentration	Quotient Index		
			ER-L	ER-M	SQC(1)
Semivolatiles (µg/kg):					
Bis(2-ethylhexyl)phthalate	73-SD06-612	1,900J	10.44	1.46	0.71
	73-SD08-06	250J	1.37	0.19	0.27
	73-SD11-612	190J	1.04	0.15	0.20
Di-n-butylphthalate	73-SD07-06	350J	NA	0.25	7.80
	73-SD07-612	430	NA	0.31	9.45
	73-SD08-06	590	NA	0.42	14.26
	73-SD08-612	420J	NA	0.30	11.32
Pesticides (µg/kg):					
4,4'-DDD	73-SD01-06	28	14.00	1.40	1.96
	73-SD02-612	6.8J	3.40	0.34	0.74
	73-SD03-612	4.2J	2.10	0.21	70.00
	73-SD04-612	7.8J	3.90	0.39	195.00
	73-SD06-612	18J	9.00	0.90	300.00
	73-SD08-612	12J	6.00	0.60	240.00
4,4'-DDE	73-SD01-06	17J	7.73	0.63	0.21
	73-SD04-06	6J	2.73	0.22	31.58
	73-SD04-612	9.8J	4.45	0.36	44.55
	73-SD06-612	17J	7.73	0.63	51.52
	73-SD08-612	5.6J	2.55	0.21	20.00
Endrin	73-SD04-06	4.7	235.00	0.10	470.00
	73-SD06-612	7.5J	375.00	0.17	750.00
Inorganics (mg/kg):					
Arsenic	73-SD09-06	14.1	1.95	0.20	NA
	73-SD09-612	11.9	1.64	0.17	NA
Cadmium	73-SD06-06	2.7J	3.99	0.28	NA
	73-SD06-612	6.1J	9.02	0.64	NA
Copper	73-SD04-612	18.8	1.01	0.07	NA
	73-SD09-06	20.5	1.10	0.08	NA
Chromium	73-SD09-612	55.9	1.07	0.15	NA
Iron	73-SD09-06	27400	NA	1.01	NA

TABLE 7-21 (Continued)

SEDIMENT QUOTIENT INDICES PER STATION
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Station	Sample Concentration	Quotient Index		
			ER-L	ER-M	SQC[1]
Lead	73-SD06-612	47.7J	1.58	0.22	NA
	73-SD04-06	30.7	1.02	0.14	NA
	73-SD04-612	33.6	1.11	0.15	NA
	73-SD08-06	41.4	1.37	0.19	NA
	73-SD09-06	37	1.23	0.17	NA
	73-SD09-612	39.6	1.31	0.18	NA
	73-SD11-06	41.6	1.38	0.19	NA
	73-SD11-612	36.8	1.22	0.17	NA
Nickel	73-SD09-06	18.1	1.14	0.35	NA
	73-SD09-612	19.7	1.24	0.38	NA

Notes:

Shaded boxes are Quotient Indices that exceed "1".

(1) Station-specific total organic carbon concentrations used to calculate SQC

SD - Sediment
ER-L - Effects Range - Low
ER-M - Effects Range - Median
µg/kg - Microgram Per Kilogram
mg/kg - Milligram Per Kilogram
SQC - Sediment Quality Criteria
NA - Not Applicable

TABLE 7-22

SEDIMENT QUOTIENT INDICES PER CONTAMINANT OF POTENTIAL CONCERN
SITE 73 - AMPHIBIOUS VEHICLE MAINTENANCE FACILITY
REMEDIAL INVESTIGATION CTO-0312
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Log Normal UCL Concentration	Quotient Index		
		ER-L	ER-M	SQC
Volatiles (µg/kg):				
Toluene	12*	NA	NA	1.46
Semivolatiles (µg/kg):				
Bis(2-ethylhexyl)phthalate	1,900*	NA	1.46	2.02
Di-n-butylphthalate	680*	NA	0.49	45.33
Pesticides (µg/kg):				
4,4'-DDD	9.65	4.80	0.50	482.5
4,4'-DDE	7.94	3.60	0.30	72.18
Endrin	4.91	245.50	0.10	1,227.5
Inorganics (mg/kg):				
Arsenic	6.63	0.92	0.10	NA
Cadmium	1.9	2.81	0.20	NA
Chromium	55.75	1.07	0.15	NA
Copper	16.74	0.90	0.06	NA
Iron	27,400*	NA	1.01	NA
Lead	36.18	1.20	0.20	NA
Nickel	8.58	0.54	0.17	NA
Total QI		261.34	4.74	1,830.99

Notes:

Shaded boxes are Quotient Indices that exceed "1".
*Maximum value (UCL was higher than the maximum value)

SD = Sediment
ER-L = Effects Range - Low
ER-M = Effects Range - Median
SQC = Sediment Quality Criteria
µg/kg = Microgram Per Kilogram
mg/kg = Milligram Per Kilogram
NA = Not Applicable
UCL = Upper Confidence Level

8.0 SUMMARY AND CONCLUSIONS

This section presents a summary of the findings obtained during the RI and conclusions derived from data collected at Site 73.

8.1 Summary

A summary based on an evaluation of data obtained at Site 73 is presented by media in the following sections. In addition to media, the results of the human health and ecological risks are summarized separately.

8.1.1 Media

The following summary are presented by media including soils, groundwater, surface water/sediment, and biota.

8.1.1.1 Soils

- The subsurface soils at the site consist of unconsolidated deposits of sand and silty sand separated by a discontinuous clay layer that thickens and thins across the site. The sands are fine to medium grained and contain varied amounts of silt and clay.

- Underlying the sands described in the previous paragraph is a loose to very dense, greenish-gray, fine sand containing varying amounts of silt and shell fragments, trace clay and cemented sand nodules. This soil unit constitutes the Belgrade Formation typically referred to as the semi-confining unit separating the surficial and Castle Hayne aquifers. It appears that this unit is not acting as a confining or semi-confining unit at Site 73. Based on hydraulic head differentials, it does not appear that this unit is restricting flow from the surficial to the Castle Hayne aquifer.

- Cross-sections indicate that a much larger tributary existed where the eastern unnamed tributary presently exists. This tributary (i.e., paleochannel) may have connected the New River, north of the site, with Courthouse Bay. The evidence for this theory is the highly angular, geologically younger sands encountered at depths more typical of the River Bend Formation; the surficial clay mentioned in the first paragraph) and the Belgrade and upper units of the River Bend Formations are missing; and topographical maps provided by the USGS indicate that wetlands/marshlands located north of NC State Route 172 have the same surficial topography as the area surrounding the unnamed tributary on the eastern portion of the site. The significance of this observation is that chlorinated contamination has a potential pathway into deeper groundwater zones without impediment by less permeable geologic units on the eastern portion of the site.

- Eleven VOCs were detected in surface and subsurface soils collected at Site 73, however, none of the compounds exceeded the EPA's Soil Screening Levels protective of groundwater.

- High concentrations of SVOCs were detected in surface soil sample 73-AC2-MW07-00, and in subsurface soil samples collected from soil boring locations 73-MW15B, 73-MW14, 73-SB01 and 73-SB06. Soil sample 73-AC2-MW07-00 was collected from an area where evidence of waste disposal had been observed during field operations. Soil borings 73-MW15B, 73-MW14, 73-SB01 and 73-SB06 were drilled in areas located near to USTs or oil/water separators which may be the source of the elevated SVOCs. 2,4-Dinitrophenol and benzo(a)anthracene were detected in the soils at concentrations exceeding applicable soil screening levels for groundwater protection.

- Pesticides were detected in the surface and subsurface soils throughout the site. The most commonly detected compound was 4,4'-DDD. An equal number of compounds were detected in both the surface and subsurface samples. Pesticides detected in the subsurface soils were observed in areas where the soils have been either disturbed by excavation, construction, or training exercises and the reworked soil may have contained pesticide contamination. The scattered detections of pesticides and the relatively low concentrations observed in the samples provide evidence that the contamination is probably the result of surface pesticide application rather than disposal.

- PCBs were detected in the surface and subsurface soils. Detections were observed in a surface sample collected from 73-MW20 and a subsurface soil sample from boring 73-SB07. The frequency, location and concentration of PCB detections suggest that the contamination is the result of POL spills and releases.

- The distribution of inorganic analytes among both the surface and subsurface soils followed no pattern that would be characteristic of a spill. Inorganics were observed throughout the site at varying concentrations, suggesting that the former and current site operations have not resulted in noticeable inorganic contamination.

8.1.1.2 Groundwater

- Shallow groundwater flow is radial from a topographical high centered near Buildings A-8 through A-11. Flow patterns in the eastern portion of the site are influenced by the underlying clay. The absence of the clay on the eastern portion of the site allows the surficial groundwater to combine with the underlying groundwater zones causing change in the direction of groundwater flow. In addition, a paleochannel exists on the eastern portion of Site 73 which acts as a vertical conduit for contaminated groundwater from the surficial aquifer to mix with the deeper Castle Hayne aquifer.

- Groundwater flow in the upper portion of the Castle Hayne aquifer is influenced by Courthouse Bay. A groundwater divide is present north of the site in the area of State Route 172. Flow direction in the mid to lower portion of the Castle Hayne aquifer is influenced by the New River.

- Groundwater elevations collected from the monitoring wells indicate that groundwater located on the southeastern side of the bay flows toward Courthouse Bay as does groundwater on the northwestern side.

- A pathline analysis was conducted as part of an overall modeling effort conducted at the site. The analysis indicated that as groundwater in the shallow aquifer begins to descend it changes course heading toward Courthouse Bay, however continuing its decent. As groundwater nears the bay, the vertical gradient reverses and groundwater begins to recharge Courthouse Bay.

- Benzene contamination was detected in the shallow groundwater within the A-47 complex. It was defined horizontally by monitoring wells A47/3-09, A47/3-11, 73-MW27 and 73-MW29. A former UST, reportedly located in the vicinity of the A-47 complex, is the suspected source of this contamination. The contamination is, for the most part, restricted to the surficial aquifer which is consistent with the contaminants natural tendency to reside in the upper portions of any water-bearing zone.

- The highest concentration of TCE was detected in intermediate monitoring well 73-DW03 unscreened from approximately -51.7 to -61.7 feet msl), located in the central portion of the Building A-47 complex. The horizontal extent of contamination is defined by monitoring wells 73-DW06, -DW07, and 73-DW08 to the west, 73-DW09 and -DW10 to the north, 73-DW13 to the east and Courthouse Bay to the south. The vertical extent lies between 63 feet and 146.5 feet msl based on the lack of VOCs detected in the mid to lower portions of the Castle Hayne aquifer.

- Inorganic contamination in the groundwater mainly consisted of iron and manganese; however, these analytes are commonly detected groundwater at Camp Lejeune at levels exceeding the NCWQS values. Therefore, these inorganic constituents are not considered to be the result of past waste disposal practices at Site 73.

- No evidence of contamination was detected in the groundwater samples collected from monitoring wells 73-MW36, -DW13 or -GW05 or supply well BB-44.

8.1.1.3 Surface Water/Sediment

- PAHs detected in the sediments are suspected as the result of fossil fuel combustion due to the high amount of boat and amphibious traffic occurring in the bay on a daily basis.

- The concentrations and distribution of pesticides in sediments sampled in Courthouse Bay indicate that the occurrence of these compounds is probably the result of erosion and possible aerial pesticide application, and not from spills or disposal events.

8.1.1.4 Biota

- VOCs detected in the fish and crab samples were restricted to common laboratory contaminants and are suspected to be the result of sample preparation.

- Endrin (a pesticide) was detected in a fillet sample collected from sampling station F/C-02 located in Courthouse Bay. This same compound was detected in sediments and surface and subsurface soils and is suspected to have originated from Base-wide aerial application. Pesticides have also been detected in fillet samples at other surface water bodies suggesting that the source may be related to widespread pest control activities and not from site operations or disposal practices.

- A number of metals were detected in the fish and crab samples collected from Courthouse Bay. Three of the metals detected (mercury, molybdenum and selenium) were not detected in any other media sampled at the site and are not considered to be related to past waste disposal activities at Site 73. Mercury has been detected in ecological samples at other surface water bodies indicating that the source may be related to base-wide or regional influences and not from site operations.

8.1.2 Human Health Risk Assessment

The following sections present a summary of the human health risk assessment (current and future scenarios.

8.1.2.1 Current Scenario

- Carcinogenic and noncarcinogenic risk values for the adult fisherman and child receptor exceeded USEPA's acceptable risk range for ingestion of both fish and crab tissue. The elevated ICR and HI values are due primarily to the presence of arsenic. The risk, in this instance, may not be site related because sediment was the only other media in which arsenic was detected and because the fish and crab are migratory by nature.

8.1.2.2 Future Scenario

- The Phase I groundwater exposure scenario (assuming that the area is converted to residential dwellings) indicated that the overall site noncarcinogenic risk exceeded unity for the adult and child residents. However, for the adult receptor, the individual media HI values were below unity (i.e., 1.0), therefore making it unlikely that adverse systemic health effects would result in future adult receptors.

- Under the Phase II groundwater exposure scenario, the total site noncarcinogenic risk exceeded unity for the adult and child residents. Adverse systemic health effects are unlikely for the adult receptor since the exposure pathway HI values were below unity. The total site HI was 4 for the child receptor. The risk was again driven primarily by the ingestion of iron and manganese in the groundwater at the site.

- The Phase II groundwater exposure scenario indicated that a potential carcinogenic risk in excess of EPA's acceptable range from groundwater ingestion to the future residential child and adult. Vinyl chloride was the primary contributor to these elevated risk values.

8.1.3 Ecological Risk Assessment

The following sections present a summary of the ecological risk assessment (aquatic and terrestrial ecosystems).

8.1.3.1 Aquatic Ecosystem

- The benthic species at the sampling stations located in the tributaries to Courthouse Bay and several stations within the bay had lower indices than the background stations. This indicates that the benthic community at these locations may be adversely impacted by contaminants detected in the sediment. However, the shallow nature and tidal conditions of the tributary stations may also contribute a significant stress to the community. In particular, the tributaries had no significant levels or contaminates detected in the sediment indicating other stresses are contributing to poor numbers within the community.

- Several of the contaminants detected in the fish and crab tissues appeared to be elevated above background studies. Based on the relatively abundant and diverse fish population at the site, these contaminants do not appear to be significantly impacting the fish community.

- Tissue concentrations of arsenic, chromium, lead and zinc were below toxicity concentrations located in the literature for aquatic and piscivorous wildlife.

- The inorganics detected in the surface water and sediment appear to have a low potential to adversely impact the aquatic receptor population.

- The risk posed by the sediment is from pesticides detected at several stations within the bay. The compounds are not considered to be site-related contaminants, but they are most likely remnants of past Base-wide pesticide application.

8.1.3.2 Terrestrial Ecosystem

- Several inorganics such as aluminum, chromium, iron and vanadium detected in samples collected from the surface soils exceeded soil toxicity benchmark values. Most of the benchmark values exceeded were plant benchmark values, however, the flora community did not appear to be impacted.

- The CDI exceeded the TRV for all five terrestrial species evaluated at the site. The risks were driven by aluminum, antimony, arsenic and cadmium.

- Some potential impacts to soil invertebrates and plants may occur as a result of site-related contaminants. In addition, there is a potential for decrease in the terrestrial vertebrate population from site-related contaminants based on the terrestrial intake model. Aluminum concentrations in the surface soils exceed flora and fauna values, as well as contribute to risks in terrestrial models. QIs calculated for red fox, bobwhite quail, cottontail rabbit, and white-tail deer were between one and ten. The QI for the red fox (1.38) was driven by antimony concentrations in the surface water. The QI for the quail (2.82) was driven by aluminum concentrations in the surface water and surface soil and the QI for the rabbit (6.58) was driven by aluminum concentrations in the surface water and surface soil and cadmium in the surface soil. The cumulative QI calculated for the deer (1.38) was greater than one, but none of the individual QIs exceeded one. Antimony and cadmium in the deer model produced the highest QI values. The QI for the raccoon was calculated between ten and one hundred. The QI for the raccoon (20.40) was driven primarily by the aluminum detected in the surface water, surface soil, and fish tissue. Also, the risk in the raccoon model was secondarily driven by concentrations of antimony in the surface water and concentrations of arsenic in the fish tissue.

8.2 Conclusions

This section presents conclusions based on an evaluation of the data obtained at Site 73.

- The scope of the RI focused on nine Areas of Concern (AOCs). At the outset of the RI, the AOCs that appeared to be the most significant, based on available information, were AOCs 1, 5, and 6. Data obtained under the RI indicates the vertical and horizontal extent of contamination has been defined to within the vicinity of Site 73. There appears no surface or subsurface soil contamination that presents a significant human health risk. However, some potential impacts to soil invertebrates and plants may occur as a result of site related contaminants. The most significant contamination was encountered in groundwater at AOCs 1 and 6.

- AOC 1 comprises the main portion of the site which includes the majority of the Building A-47 complex. Historical information indicated that 400,000 gallons of POL may have been disposed along with an undetermined volume of solvents. Few surface soil samples collected in this AOC possessed concentrations of metals in excess of base background. Less than 5 percent of the subsurface samples collected within AOC 1 contained organic or inorganic concentrations in excess of comparison criteria. Groundwater results indicate that most of the compounds whose concentration exceed NCWQS and/or federal MCLs were collected from wells installed inside the boundaries of AOC 1. The results of the RI indicated the presence of a BTEX plume in this area. However, the source of this plume is most likely to be a nearby former UST reportedly located in the A-47 complex rather than the reported POL disposed at AOC 1. Data obtained for UST investigations at the site (see Appendix A) indicates the presence of elevated levels of total petroleum hydrocarbons (TPH) and oil and grease south of Building A-47 which could be remnants of the POL disposal in this area. Solvent contamination was also encountered in AOC 1 consistent with historical data. The detected levels of TCE , DCE, and vinyl chloride in AOC 1 were the highest encountered during the RI at 320 μg/L, 120 μg/L, and 43 J μg/L, respectively. Groundwater modeling performed by Baker indicated that the natural tendencies of groundwater at the site is to recharge Courthouse Bay and limit the downward migration potential of the contamination. Vertically, the extent of contamination is defined to exist between 63 and 146.5 feet msl as evident by analytical results received from samples collected from deep monitoring wells.

- AOC 6 is adjacent to the eastern border of AOC 5 and is the site of a former 30,000-gallon UST used to store diesel fuel (UST A47/3). Although soil sample results from this portion of the site indicate very few compounds exceeded comparison criteria, groundwater possessed contaminant concentrations exceeding NCWQS and/or MCLs. The results of the RI confirmed the results of previous studies indicating the presence of fuel and solvent-related groundwater contamination. The solvent contamination is likely related to the historical disposal activities that reportedly occurred at AOC 1.

- AOC 5 is the general area north of Building A-47 where 20,000 gallons of waste battery acid and an undetermined volume of waste oil may have been disposed. The results of the investigation in this area did not yield levels of inorganics indicative of a large volume of waste battery acid disposal. Evidence of waste oil disposal was primarily limited to two detections of PCBs in soil samples obtained at 73MW-20 (140 NJ and 170 J µg/kg). Soil Screening levels for the protection of Groundwater were not established for PCBs; therefore, neither concentration is in excess of screening criteria. Neither TPH or oil and grease were detected in soil samples obtained from this area.

- Based on the results of surface water and sediment sampling in Courthouse Bay and the unnamed tributaries located to the east and west of Site 73, it appears that volatile organic contamination present in the groundwater is not impacting Courthouse Bay.

- The results of the human health risk assessment indicated that current site conditions do not present an adverse risk to military personnel engaged in daily activities at the Amphibious Vehicle Maintenance Facility.

- Adverse human health risks at this site are associated primarily with organic and inorganic contaminants in the groundwater and inorganic contaminants identified in fish and crab tissue. However, only the organic contaminants are clearly associated with past site activities.

- The ecological risks associated with the terrestrial and aquatic ecosystems were primarily associated with inorganic contaminants in the surface soils, sediment and surface waters at the site.